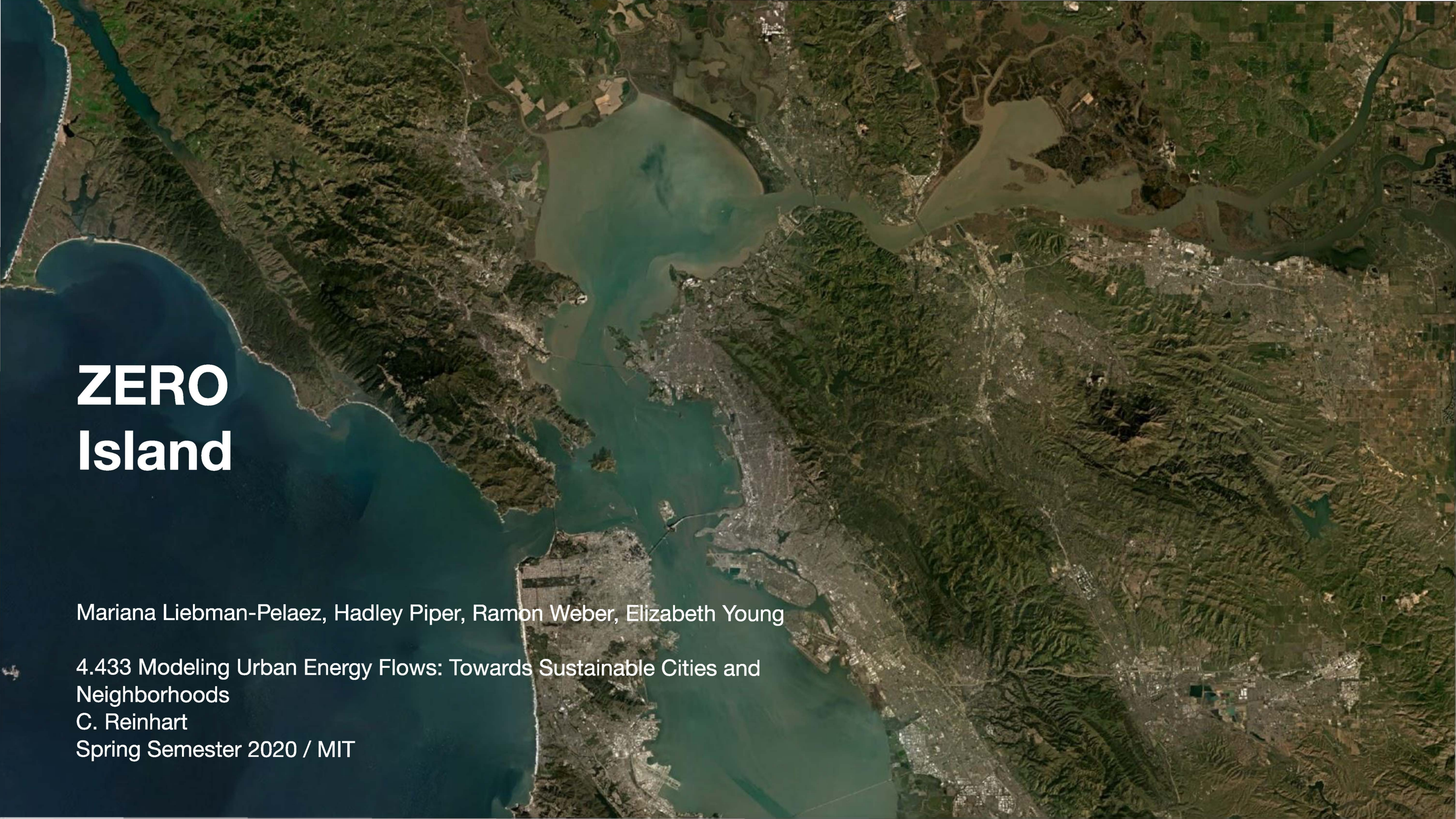


ZERO Island

Mariana Liebman-Pelaez, Hadley Piper, Ramon Weber, Elizabeth Young

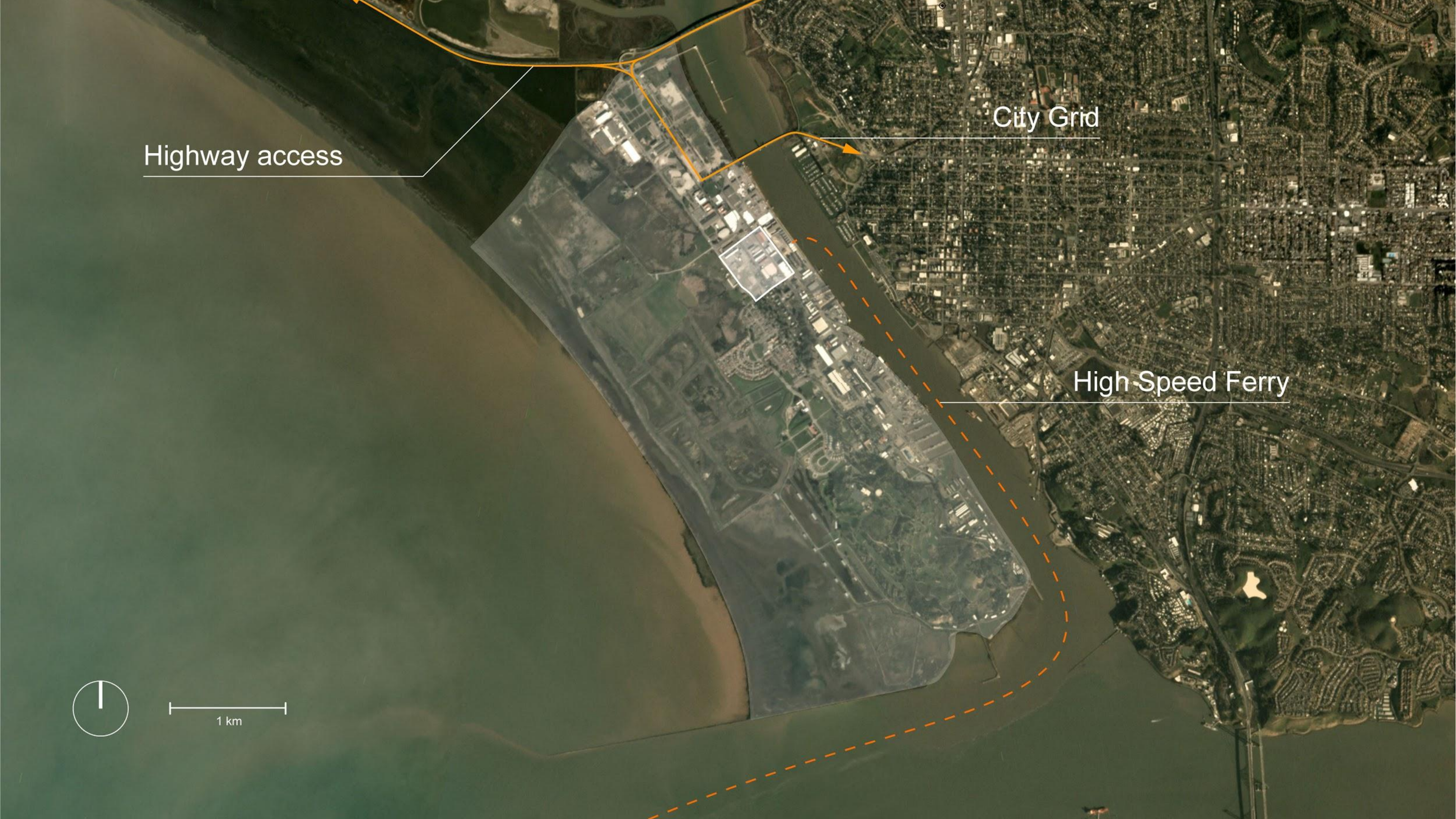
4.433 Modeling Urban Energy Flows: Towards Sustainable Cities and Neighborhoods
C. Reinhart
Spring Semester 2020 / MIT


Mare Island
Vallejo
Richmond
Oakland
San Francisco

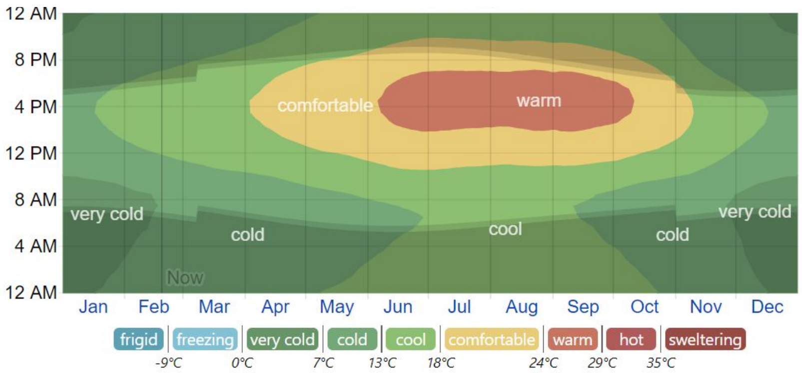

Mare Island
1 km


Site
1 km

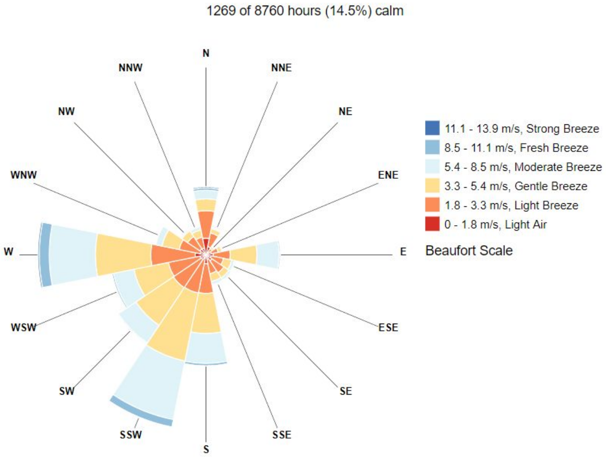

Nature
Park and Wetland
Waterfront
Old warehouses
and factories
1 km


City Grid
Highway access
High Speed Ferry
1 km

Today's Climate

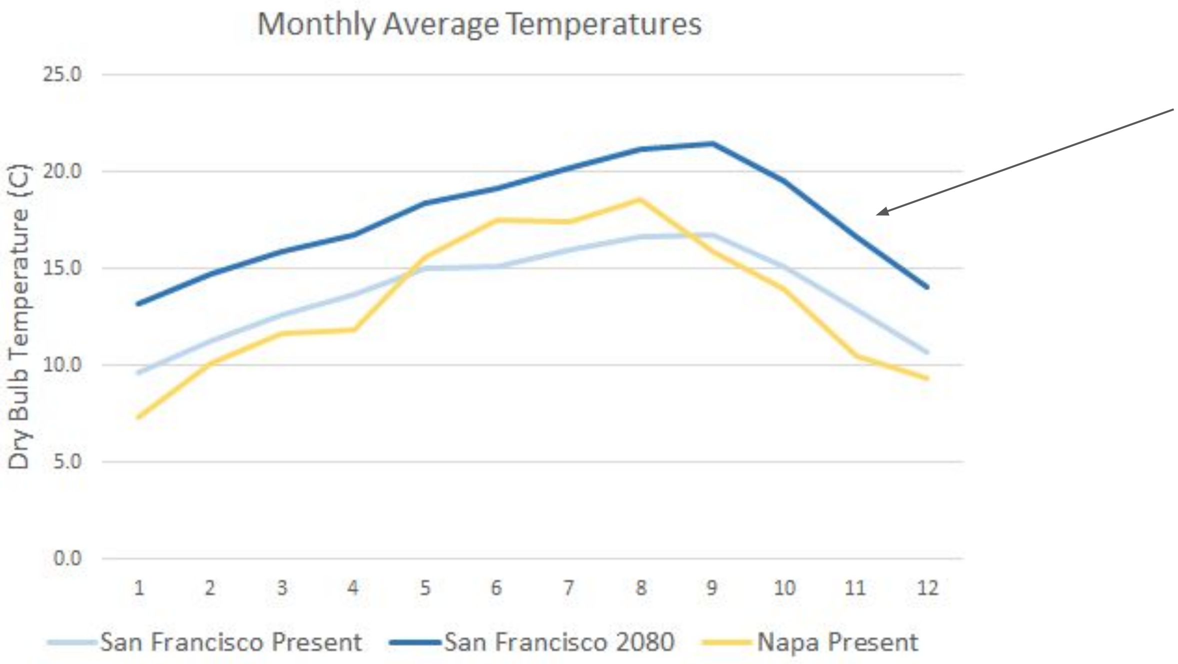


Average hourly temperature



Wind rose

Design for the Future



Can we design a **low carbon** community with

resilient energy supply and human-powered **mobility**?

Building Energy

EUI [kWh/m²/year]

$kgCO_2/m^2$

Can we design a **low carbon** community with **resilient energy** supply and human-powered **mobility**?

Building Energy

EUI [kWh/m²/year]

$kgCO_2/m^2$

Can we design a **low carbon** community with **resilient energy** supply and human-powered **mobility**?

Urban grid layout

% of year

thermally comfortable

Building Energy

EUI [kWh/m²/year]

$kgCO_2/m^2$

Can we design a **low carbon** community with **resilient energy** supply and human-powered **mobility**?

On-site PV

% demand met during a heat wave

Urban grid layout

% of year thermally comfortable

1. Building Energy
2. Urban Layout + Mobility
3. Grid-independence

1. Building Energy
2. Urban Layout + Mobility
3. Grid-independence

-

EUI
kWh/m²/year

-

kgCO2/m2

-

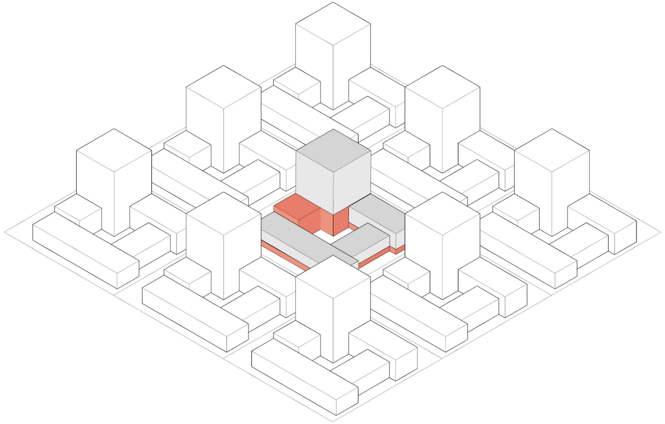
% demand met by PV during heat wave

-

of year Thermally Comfortable

Baseline Scenario

High-Density San Francisco
Neighborhood



70% Residential
30% Commercial

-
EUI
kWh/m^2/year

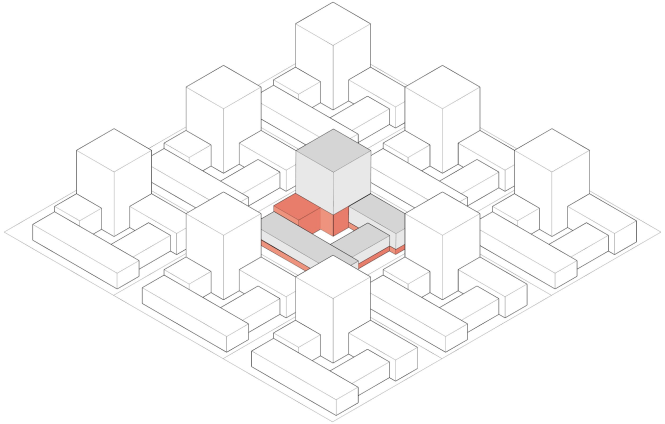
-
kgCO2/m2

-
% demand met by PV during heat wave

-
of year Thermally Comfortable

Baseline Scenario

High-Density San Francisco Neighborhood



70% Residential
30% Commercial

82

EUI
kWh/m²/year

18.4

kgCO2/m2

-

% demand met by PV during heat wave

-

of year Thermally Comfortable

1. Building Energy
2. Urban Layout + Mobility
3. Grid-independence

82
EUI
$kWh/m^2/year$

18.4
kgCO2/m2

-
% demand met by PV during heat wave

-
of year Thermally Comfortable

1. Building Energy

Building Massing

High performance upgrades

82

EUI
kWh/m^2/year

18.4

kgCO2/m2

-

% demand met by PV during heat wave

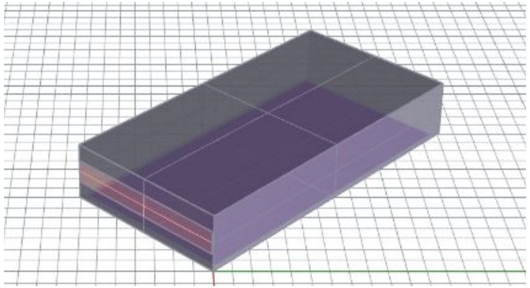
-

of year Thermally Comfortable

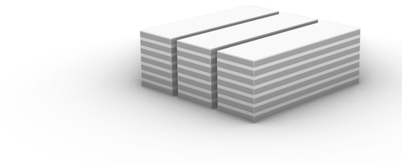
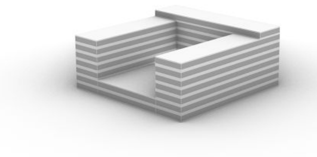
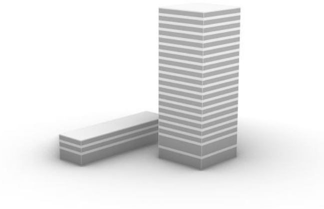
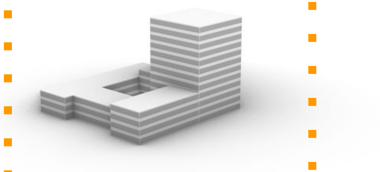
Building Energy | Massing Design

Parametric Analysis

- Window Wall Ratio
- Depth
- Orientation



Protoblocks

Name	Reference	A	B	**C**
sDA	35.10%	74.20%	91.00%	**100.00%**
Floor Area (m2)	13,448	14,760	15,120	**12,540**
Walkability	**high**	**high**	low	**high**
Occupancy Ratio	92.23%	100.00%	**45.68%**	71.60%
Courtyard Area	0	**1620**	1584	828
FAR	4.6	5.1	5.2	4.3

Building Energy

Baseline vs.

High Performance

Baseline	High Performance
82 EUI $kWh/m^2/year$	**61** EUI $kWh/m^2/year$
18.4 kgCO2/m2	**14.35** kgCO2/m2
- % demand met by PV during heat wave	**-** % demand met by PV during heat wave
- of year Thermally Comfortable	**-** of year Thermally Comfortable

Building Energy

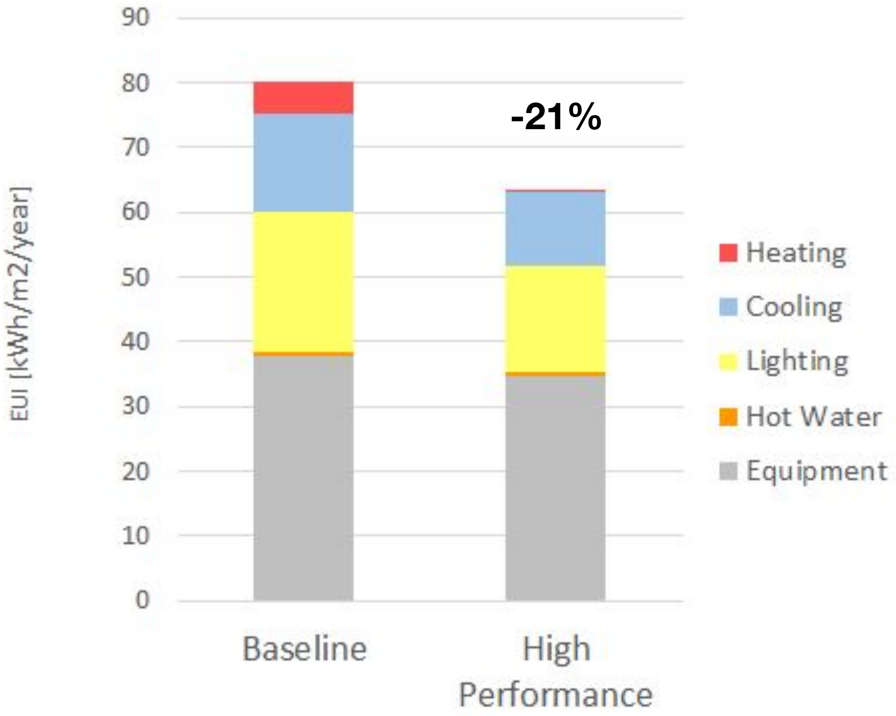
Baseline vs.

High Performance

- Insulation
- Cooling System Efficiency
- Natural Ventilation

Baseline	High Performance
82 EUI $kWh/m^2/year$	**61** EUI $kWh/m^2/year$
18.4 kgCO2/m2	**14.35** kgCO2/m2
- % demand met by PV during heat wave	- % demand met by PV during heat wave
- of year Thermally Comfortable	- of year Thermally Comfortable

Building Energy: Baseline Vs High Performance



61
EUI
kWh/m²/year

14.35
kgCO2/m2

-
% demand met by PV during heat wave

-
of year Thermally Comfortable

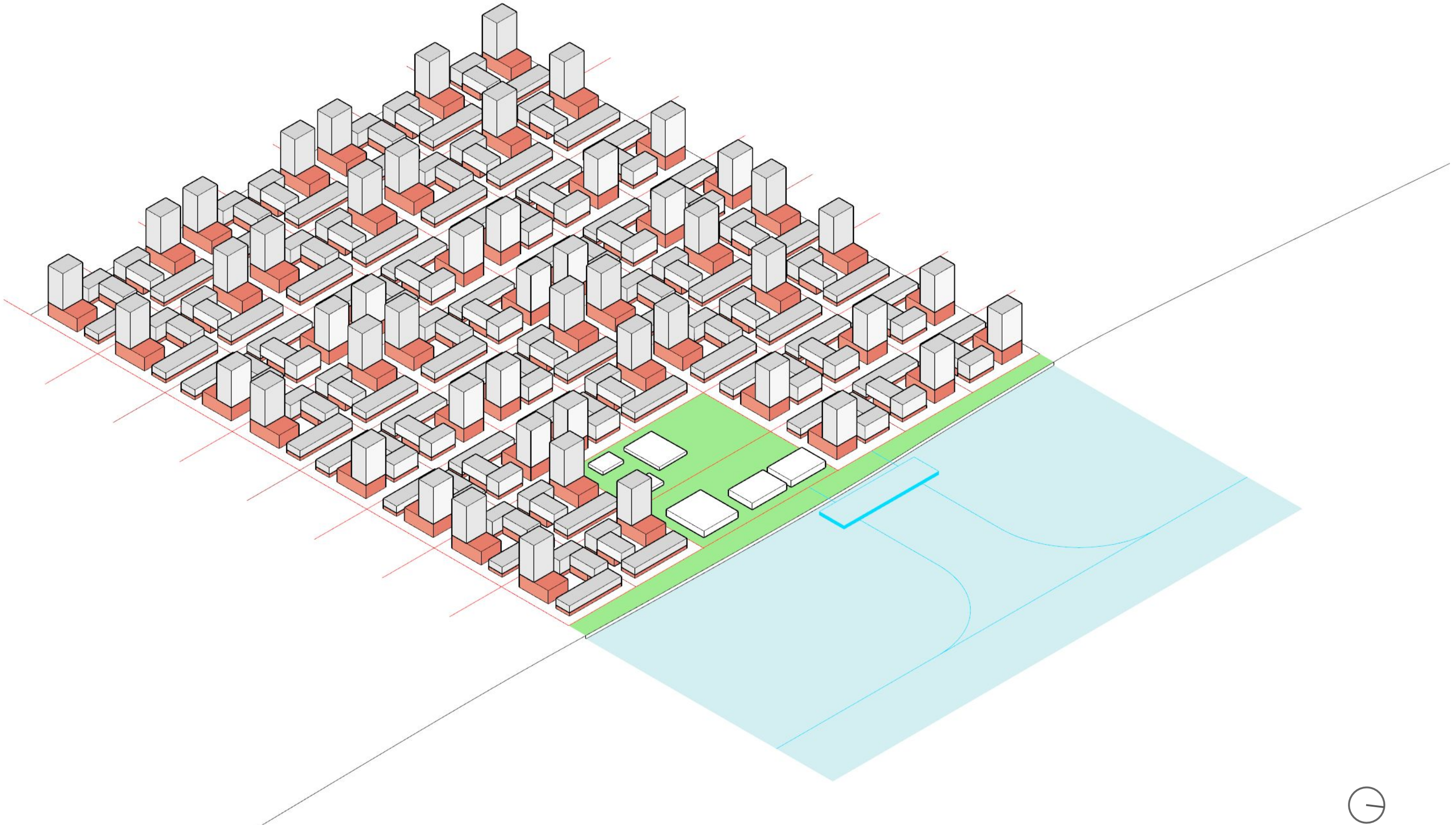
1. Building Energy
2. Urban Layout + Mobility
3. Grid-independence

61
EUI
$kWh/m^2/year$

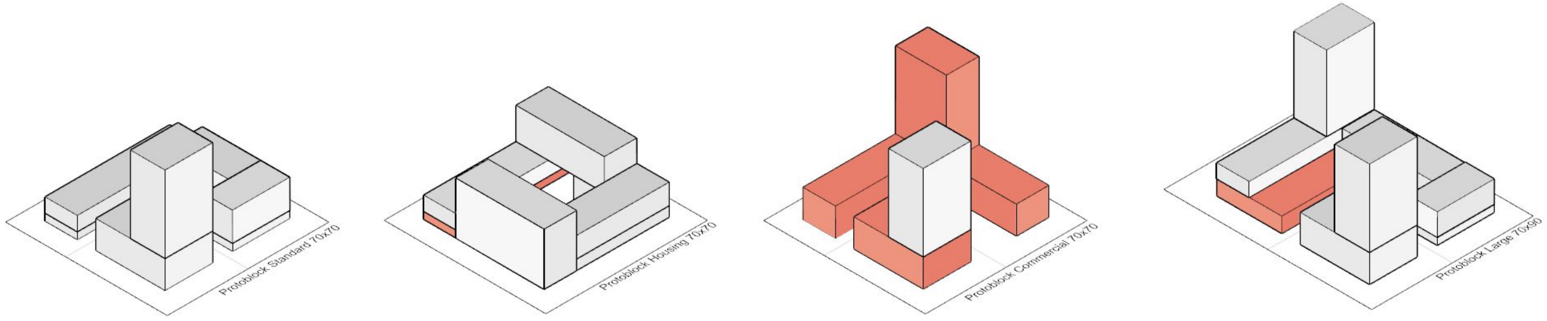
14.35
kgCO2/m2

-
% demand met by PV during heat wave

-
of year Thermally Comfortable

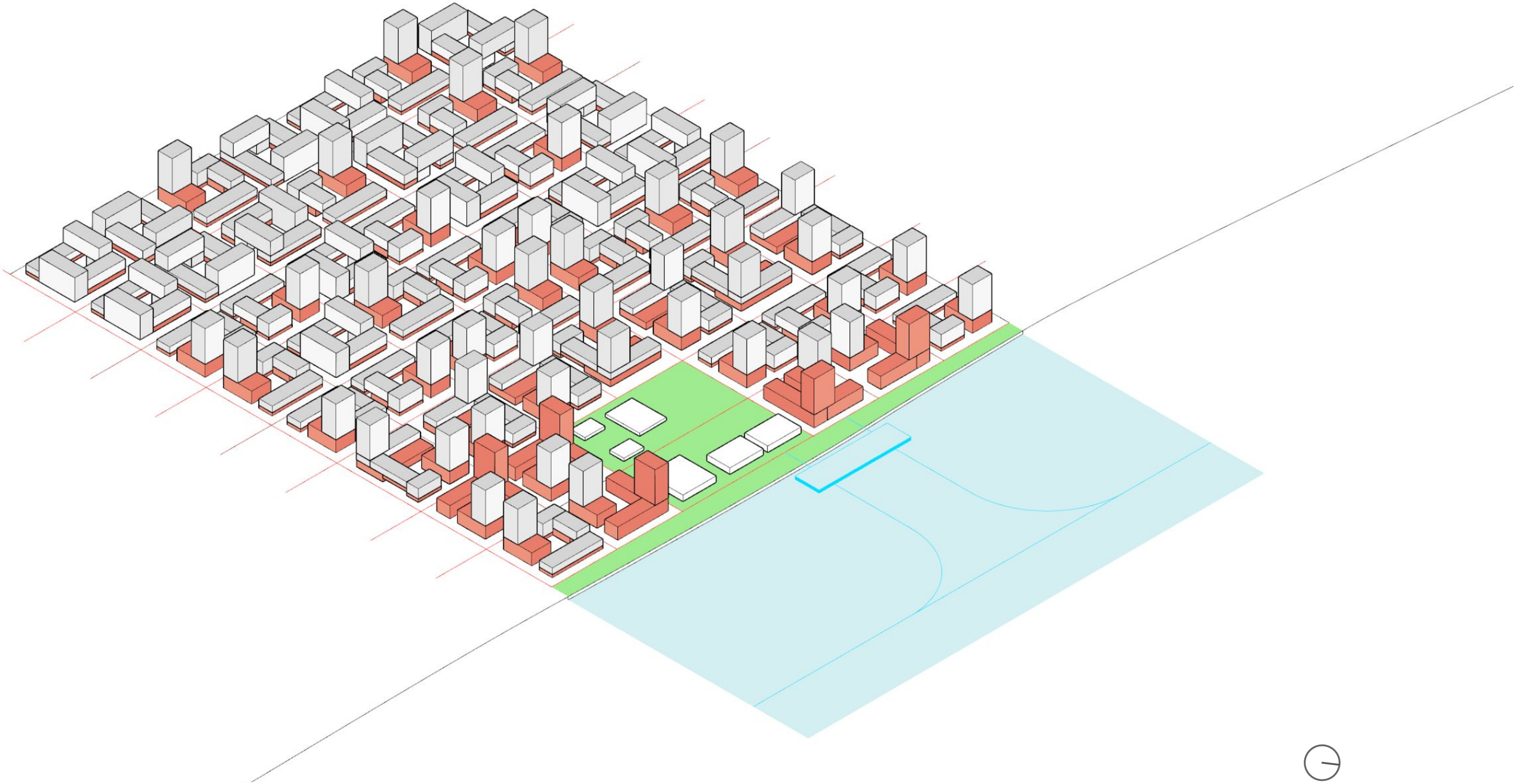


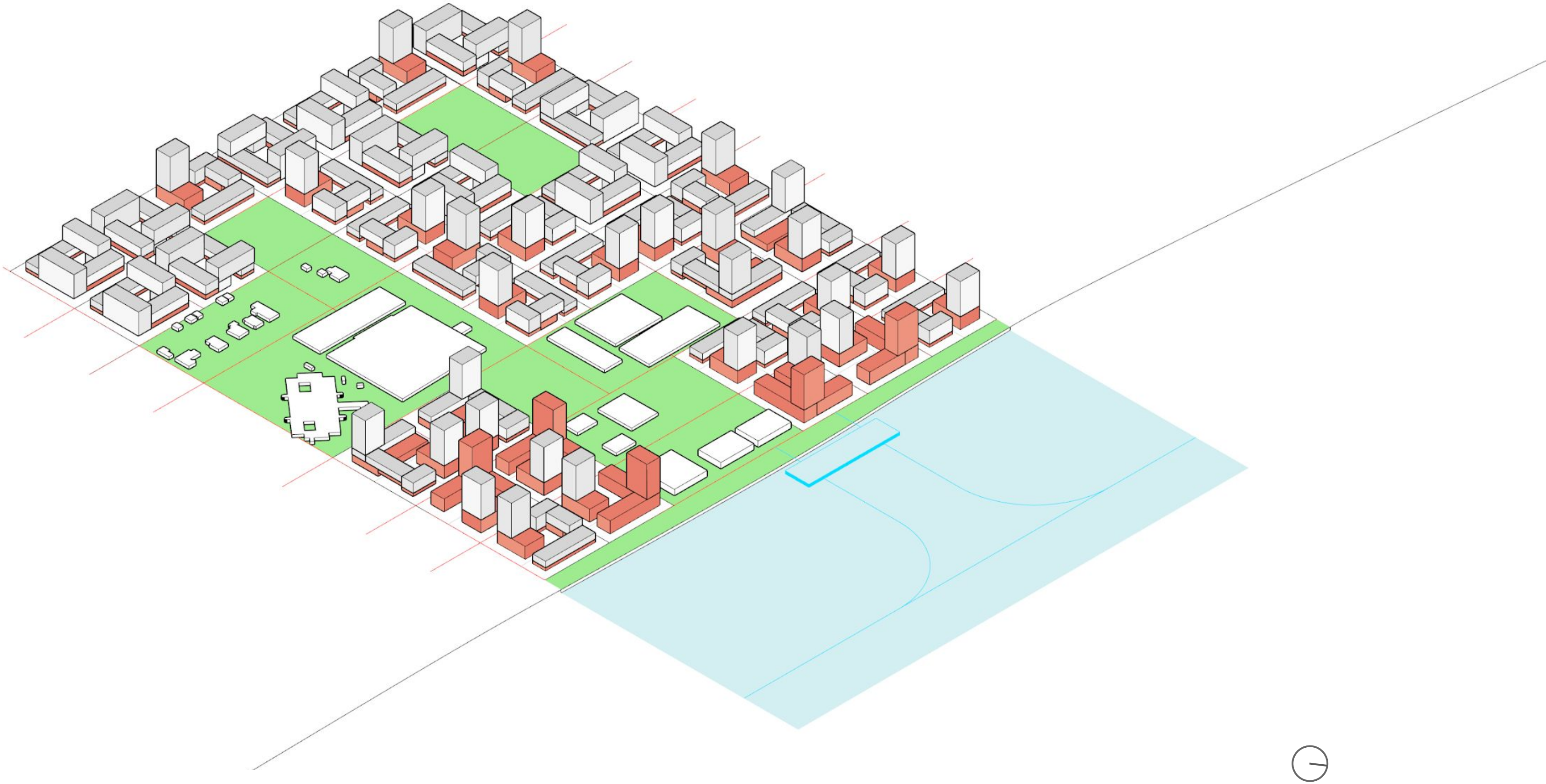
Protoblock Variations

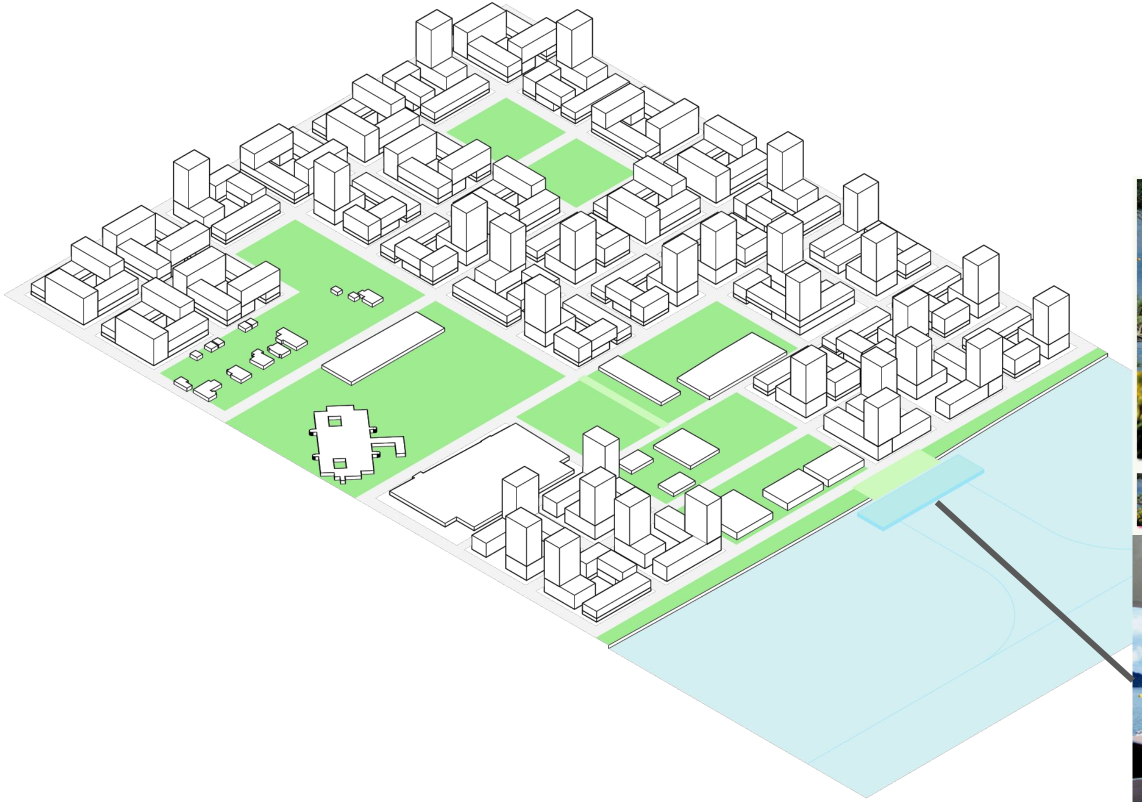


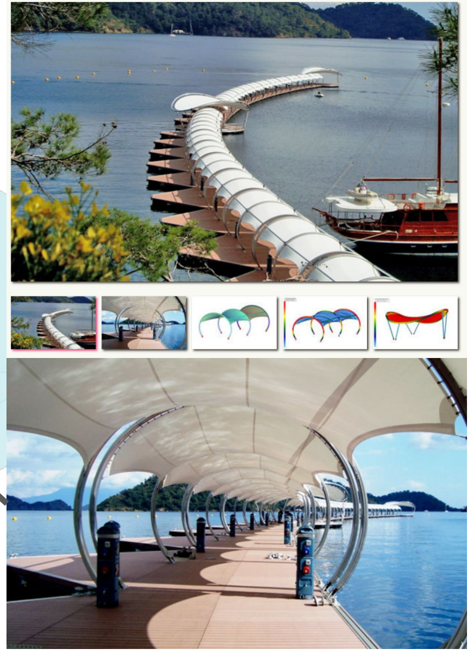
Label this

Commercial Space indicated in Red



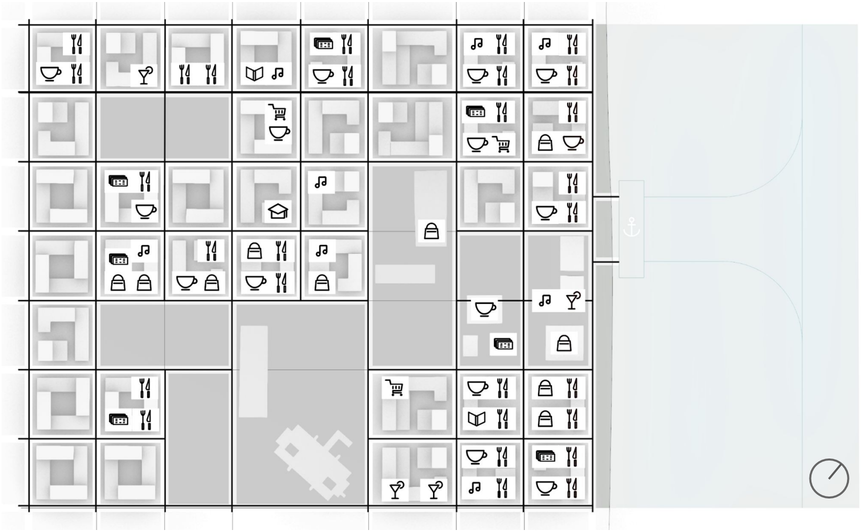




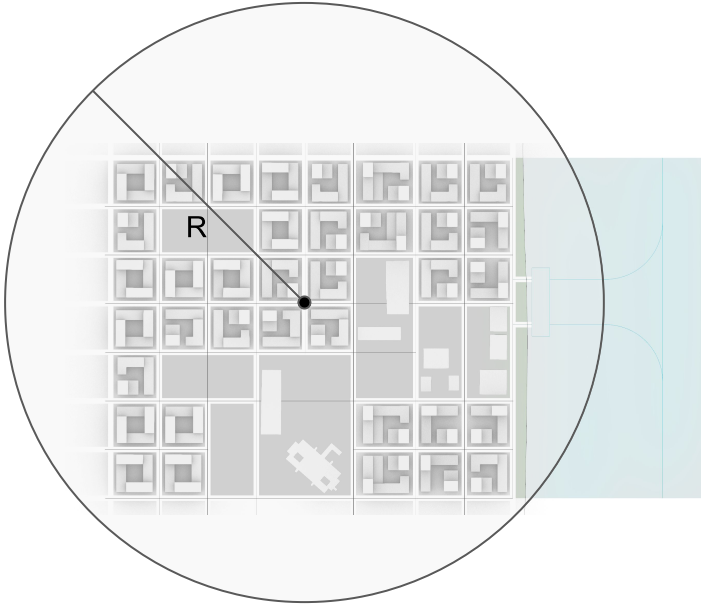


Ferry terminal

Mobility

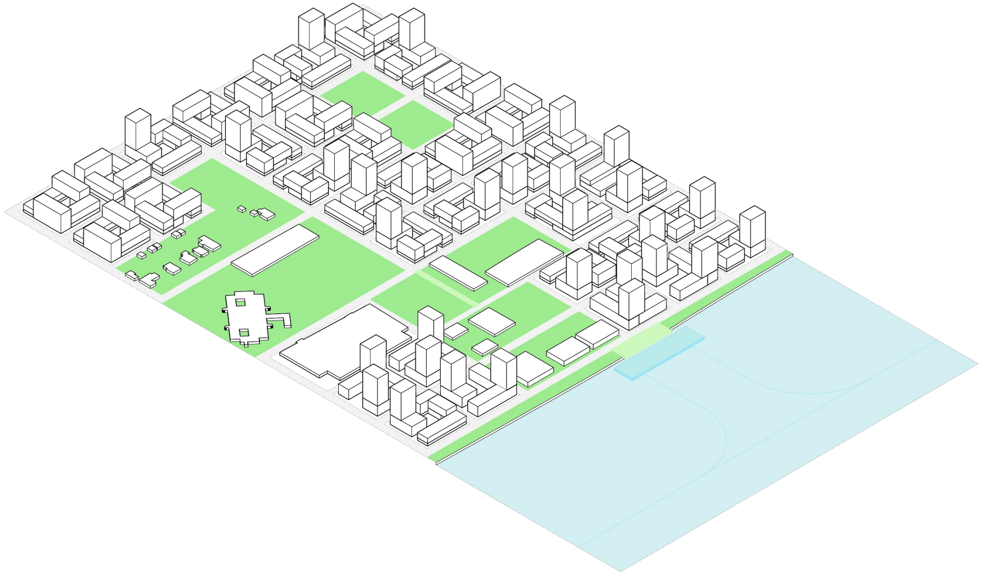


Walk Score of 94: High due to small site area

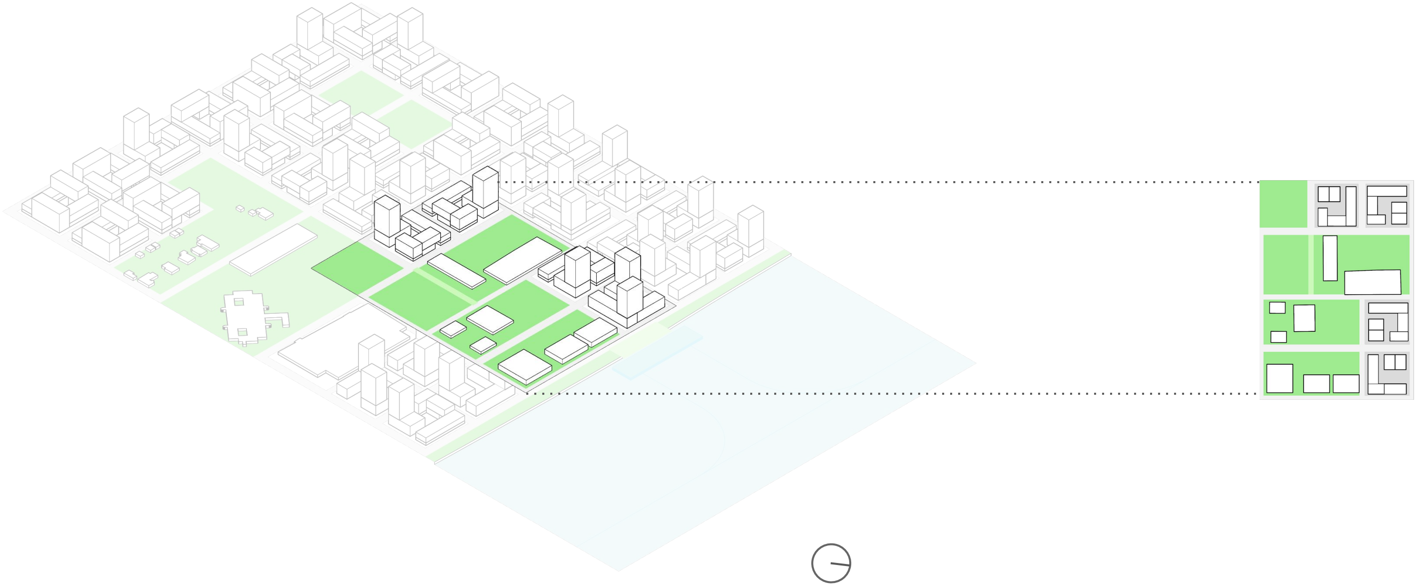


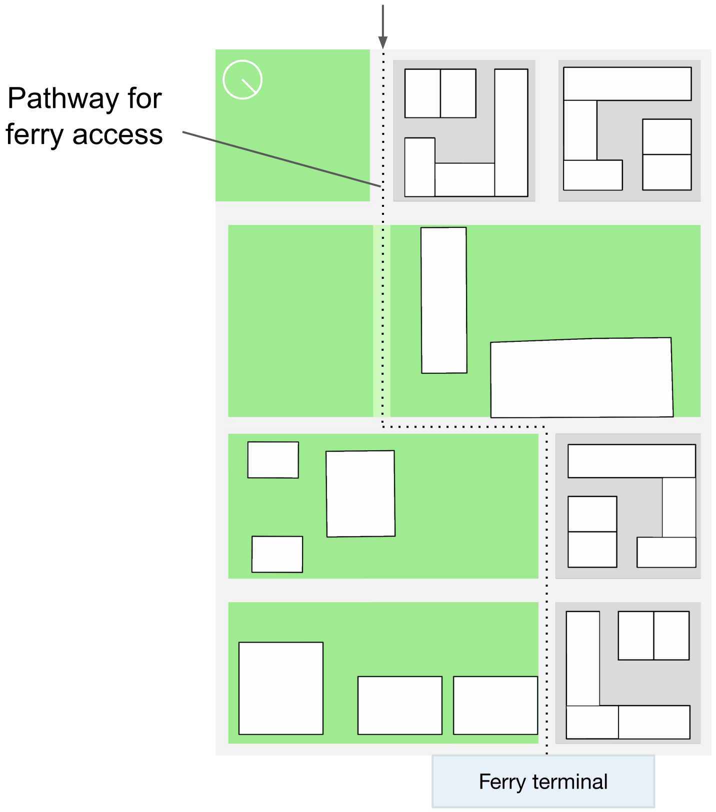
R = 400 m ~ 5 minute Walk

Enabling Mobility through Outdoor Comfort

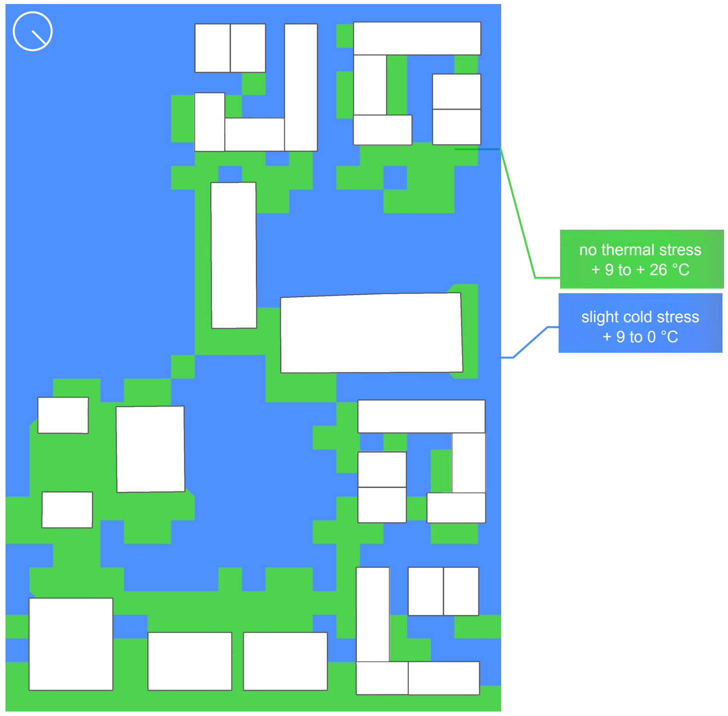


Targeted UTCI Analysis



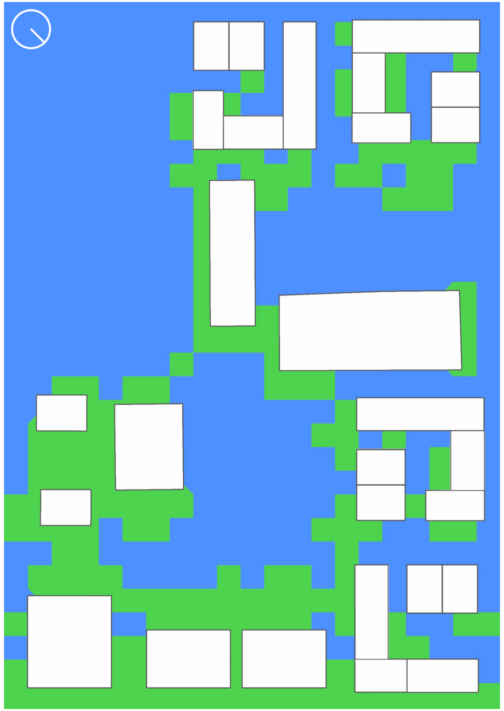


Plan



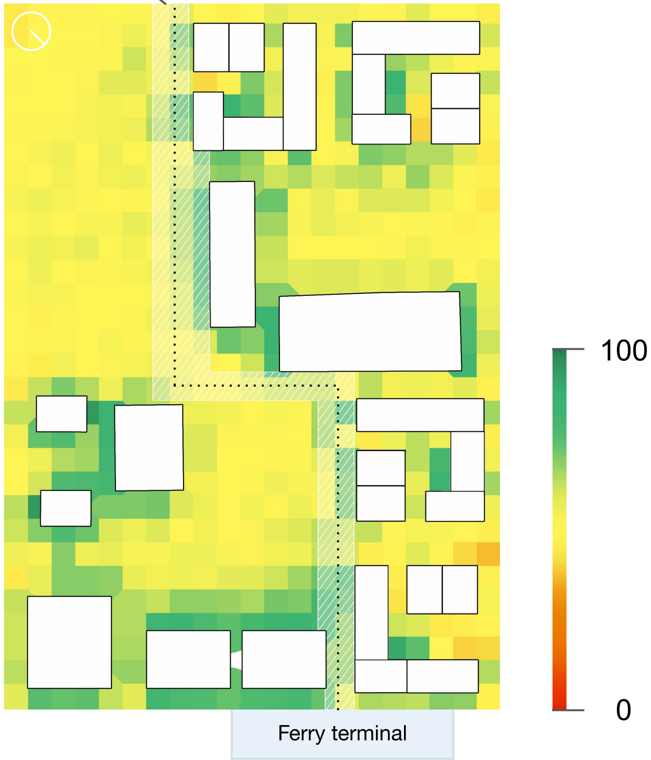
UTCI distribution today May 7 at 9am

Pathway is comfortable at 9am for 55% of year without shading



UTCI distribution today May 7 at 9am

365 Day Evaluation



Annual comfortable hours [%]

61

EUI

kWh/m²/year

14.35

kgCO2/m2

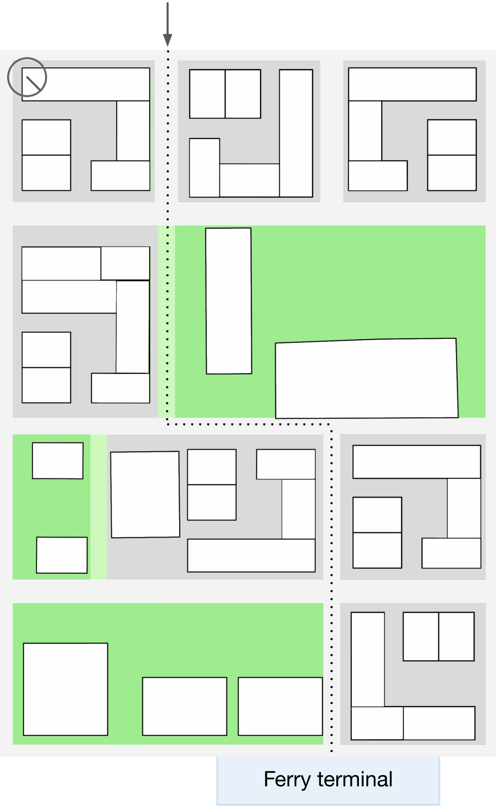
-

% demand met by PV during heat wave

55%

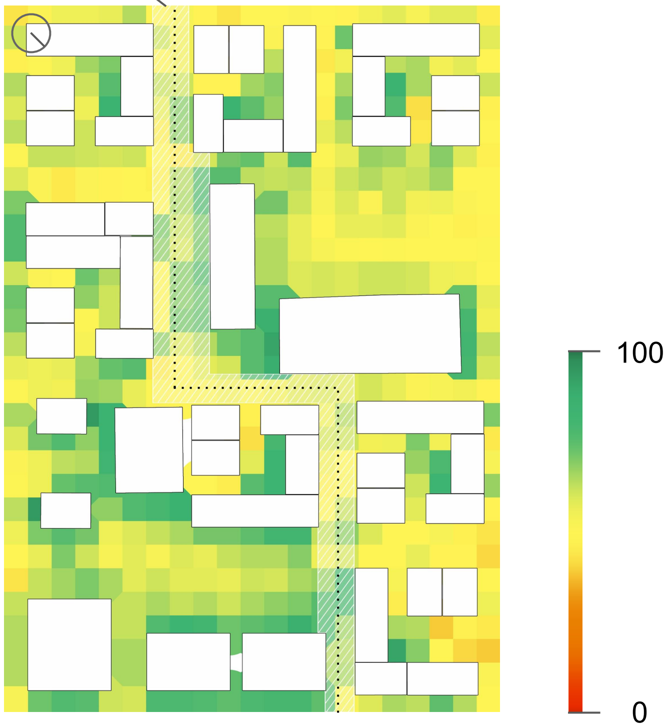
of year Thermally Comfortable

Pathway is comfortable at 9am for 51% of year without shading



Plan with increased density

365 Day Evaluation



Annual comfortable hours [%]

61

EUI kWh/m^2/year

14.35

kgCO2/m2

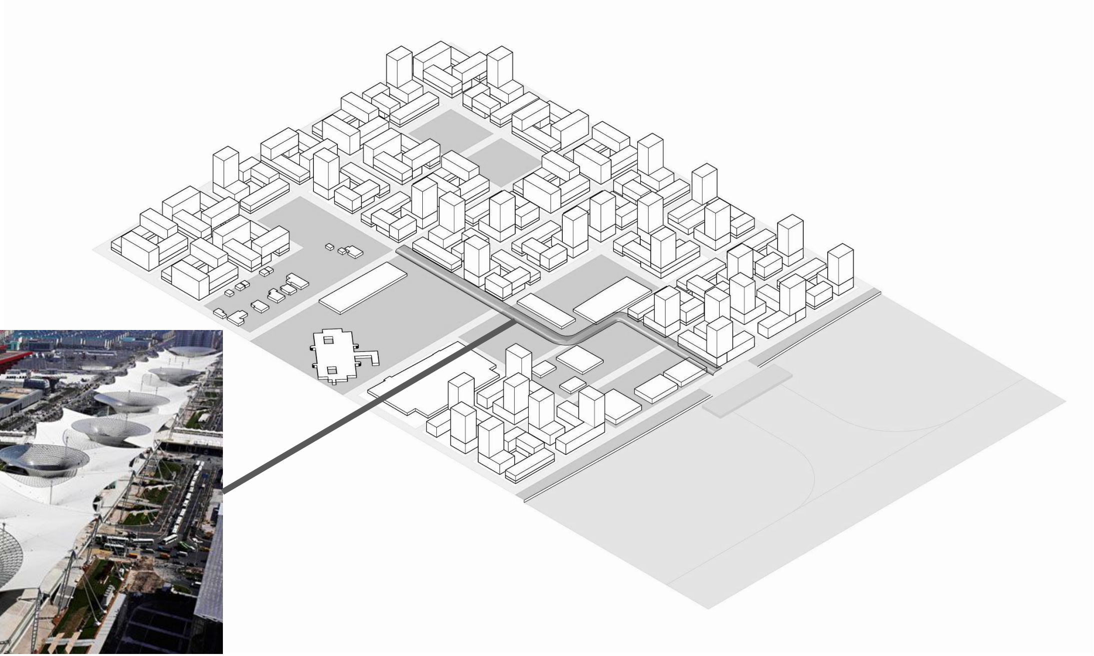
-

% demand met by PV during heat wave

55%

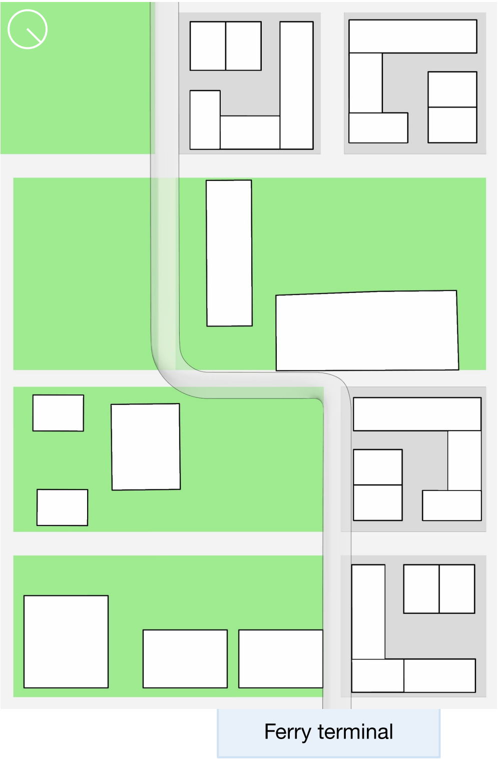
of year Thermally Comfortable

Architectural Intervention



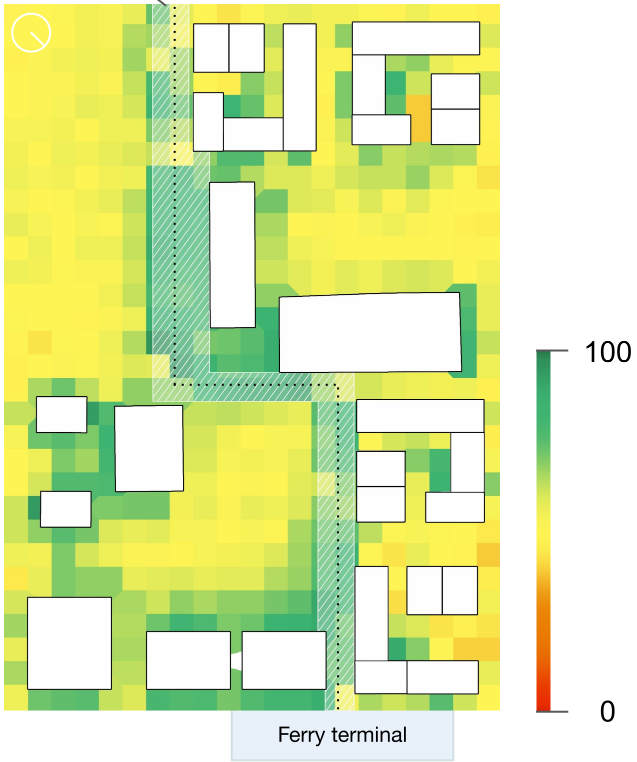
Covered area in Park

Pathway is comfortable at 9am for 70% of year
with shading, a 54 day increase!



Plan with sun and wind shaded pathway

365 Day Evaluation



Annual comfortable hours [%]

61

EUI kWh/m^2/year

14.35

kgCO2/m2

-

% demand met by PV during heat wave

70%

of year Thermally Comfortable

1. Building Energy Demand
2. Urban Grid Layout
3. Grid-independence

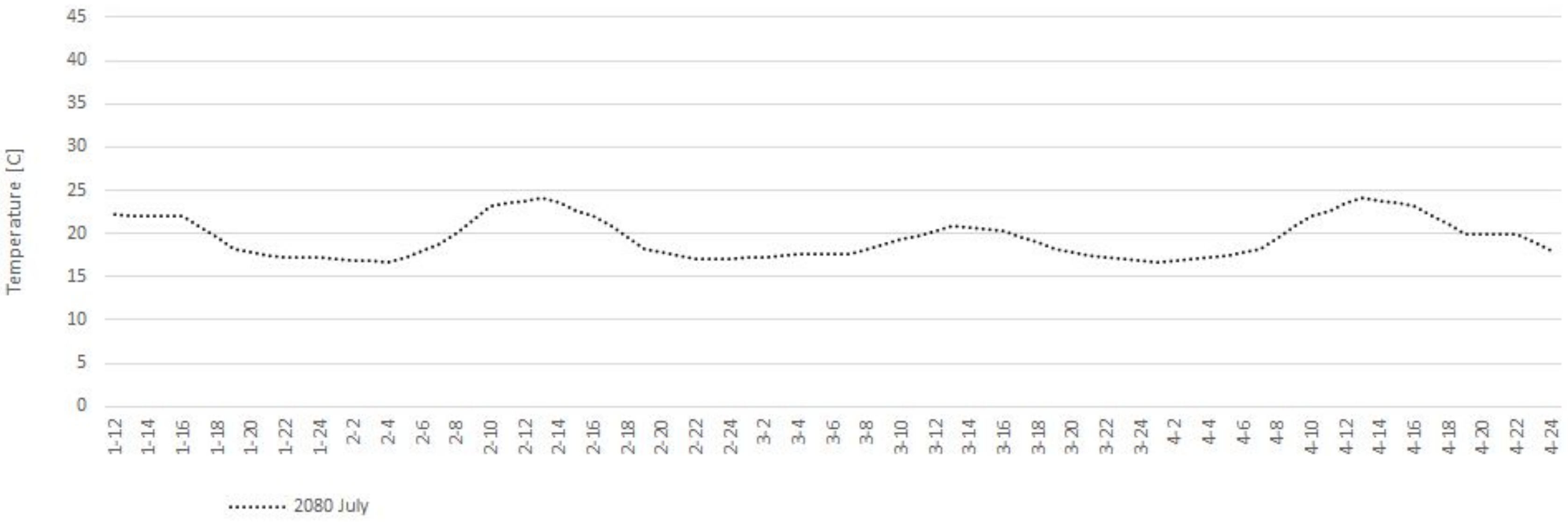
61
EUI
kWh/m²/year

14.35
$kgCO_2/m^2$

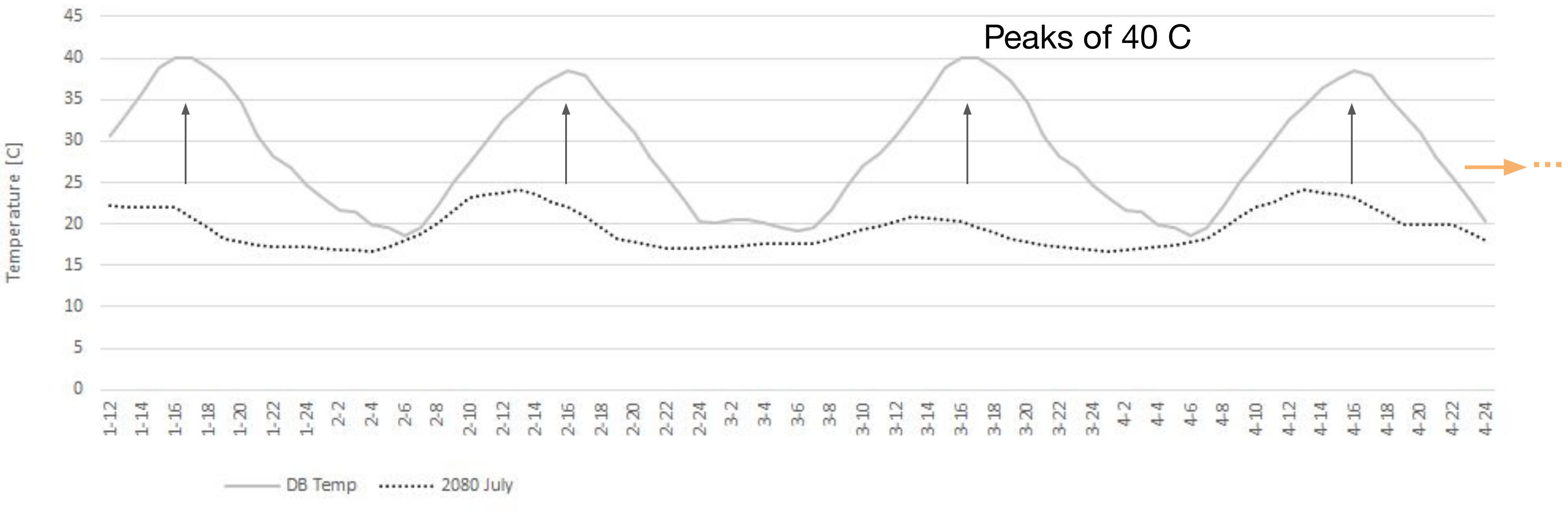
-
% demand met by PV during heat wave

70%
of year Thermally Comfortable

Heat Waves | CA July, 2006

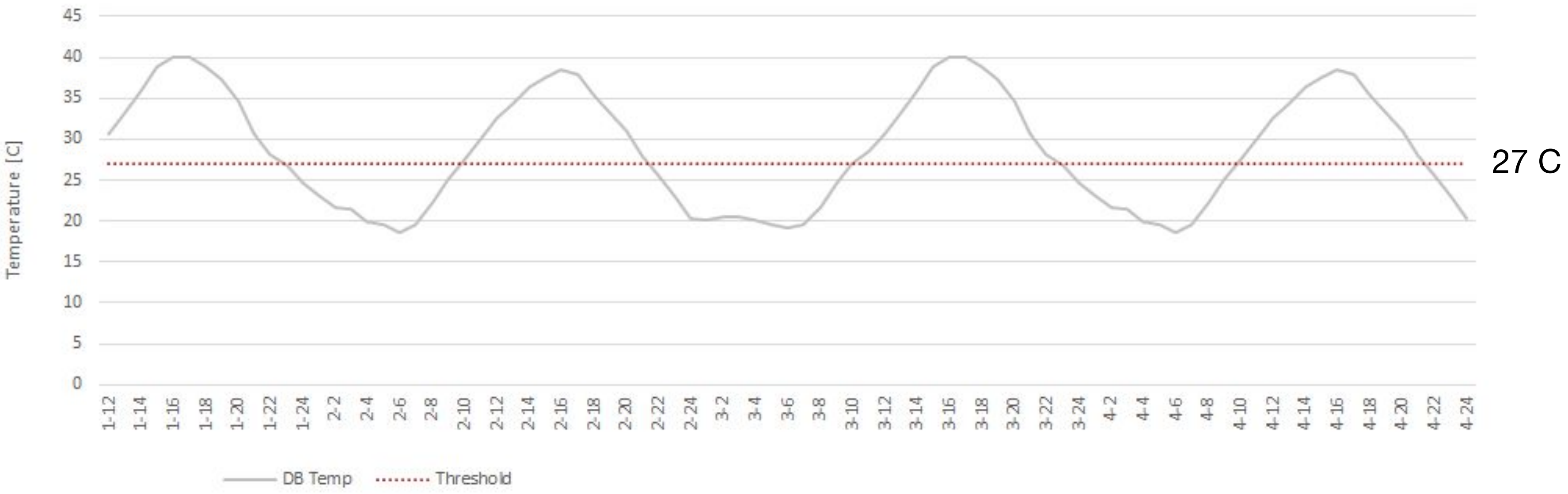


Heat Waves | CA July, 2006

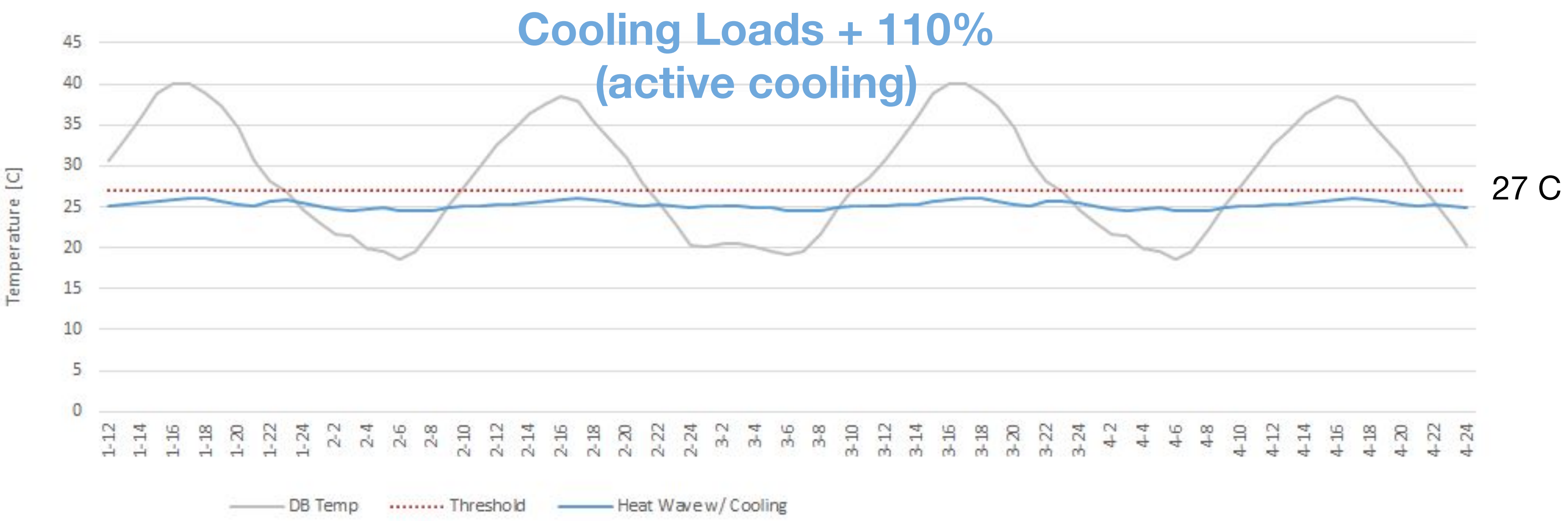


... continues to total 7 days

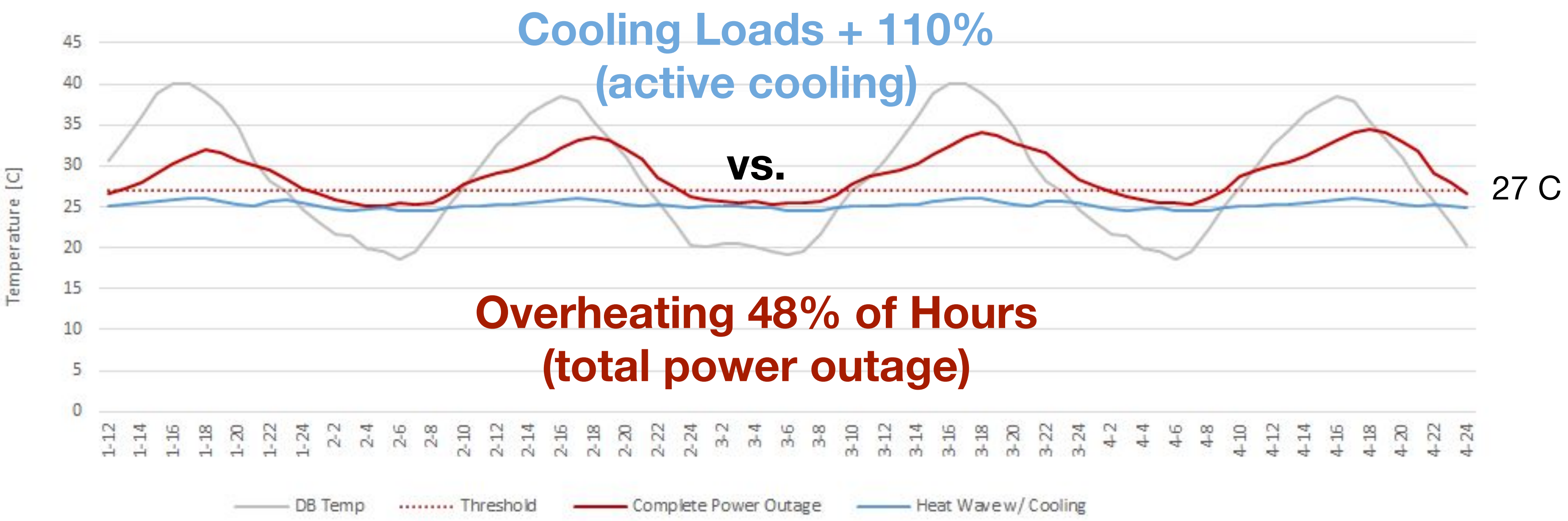
Heat Waves | Safe Indoor Temperatures



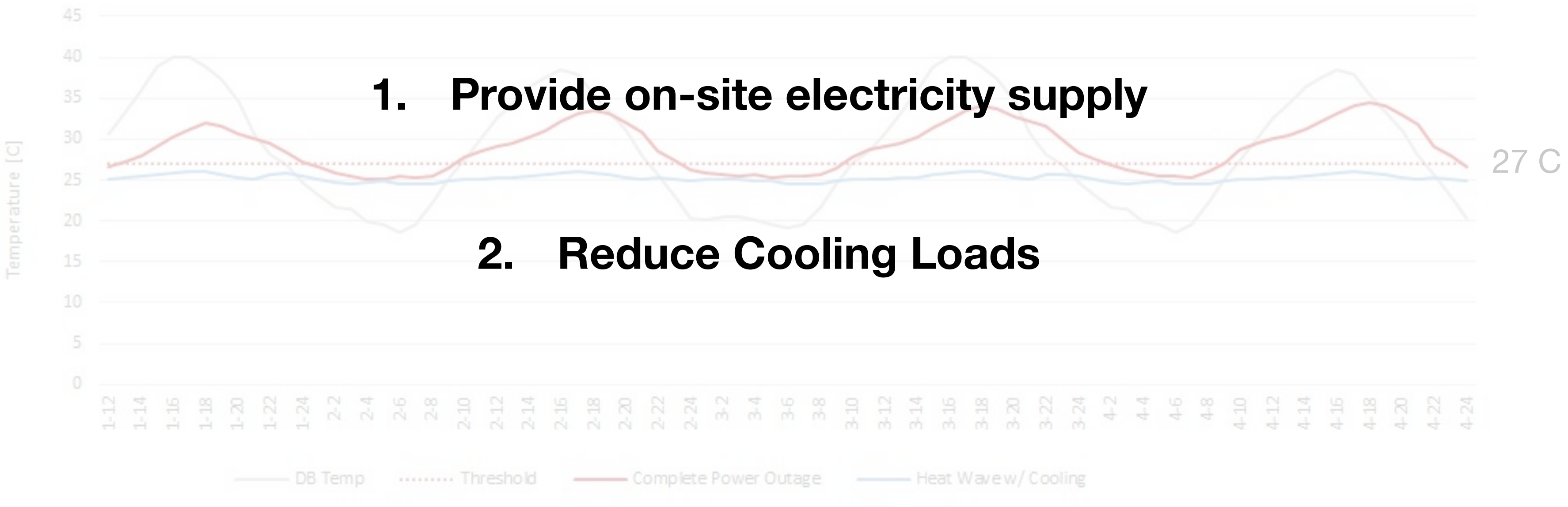
Heat Waves | Safe Indoor Temperatures



Heat Waves | Safe Indoor Temperatures

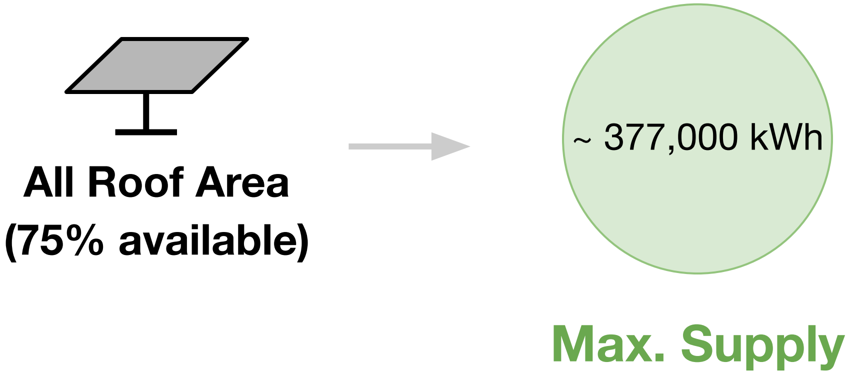


Heat Waves | Achieving Grid Independence

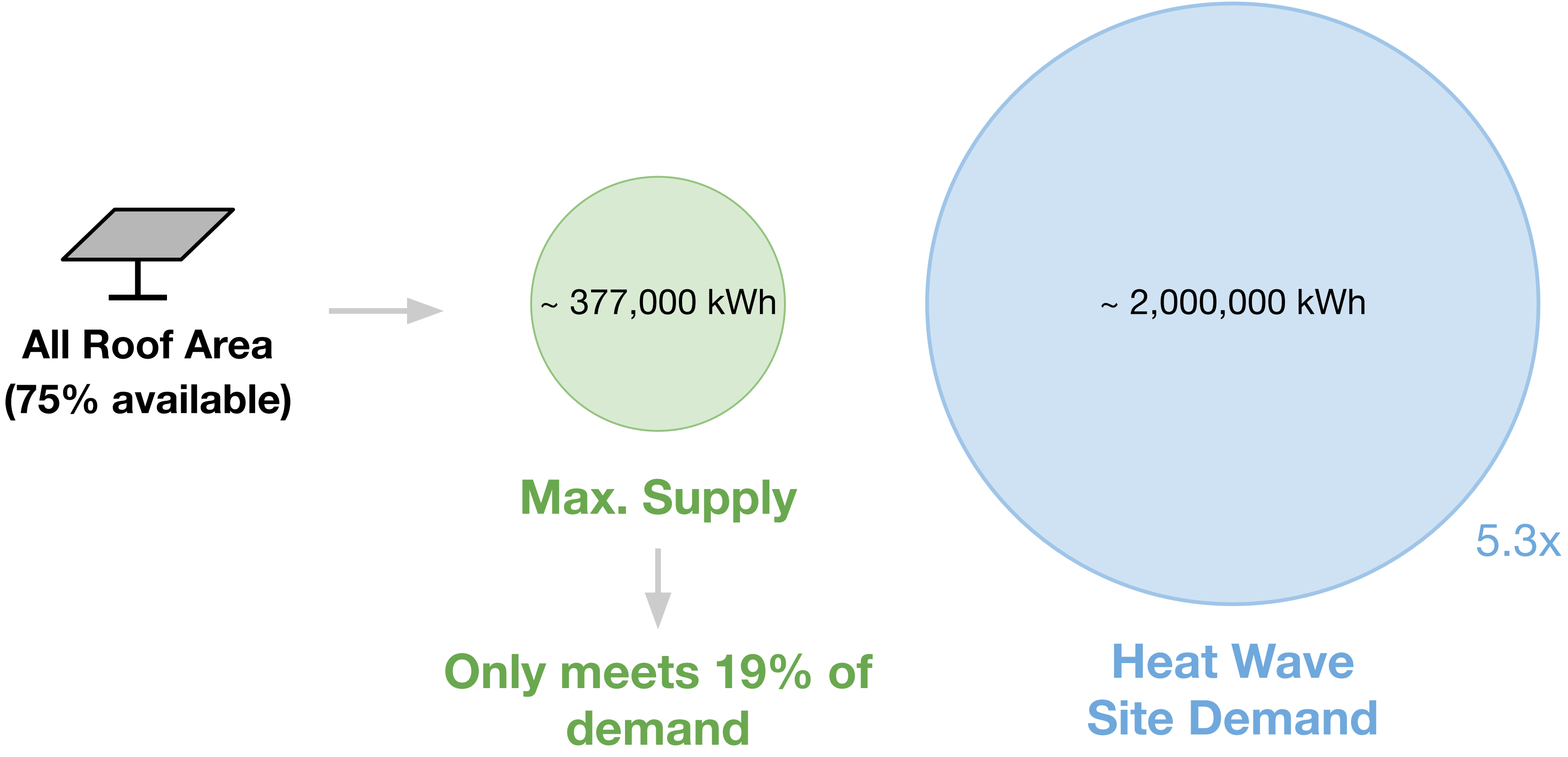


1. **Provide on-site electricity supply**
2. **Reduce Cooling Loads**

On-site Electricity Supply | Rooftop PV + Batteries

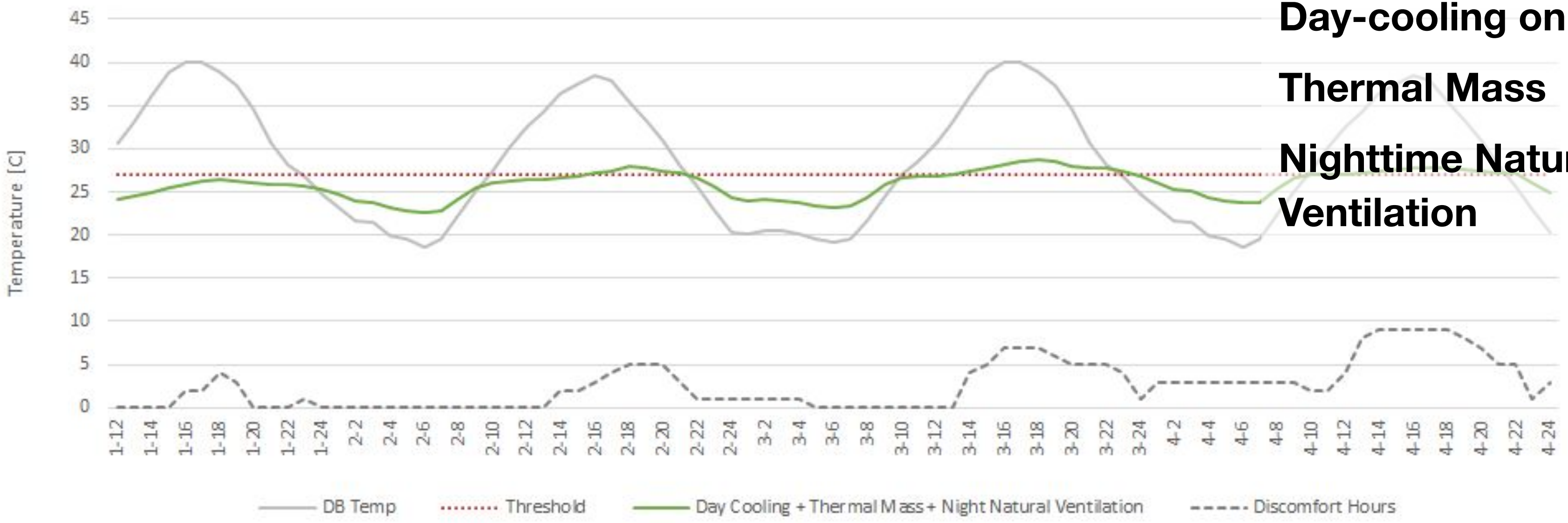


On-site Electricity Supply | Rooftop PV + Batteries



Load Reduction + Low Discomfort Hours

Load Reduction + Low Discomfort Hours



Day-cooling only

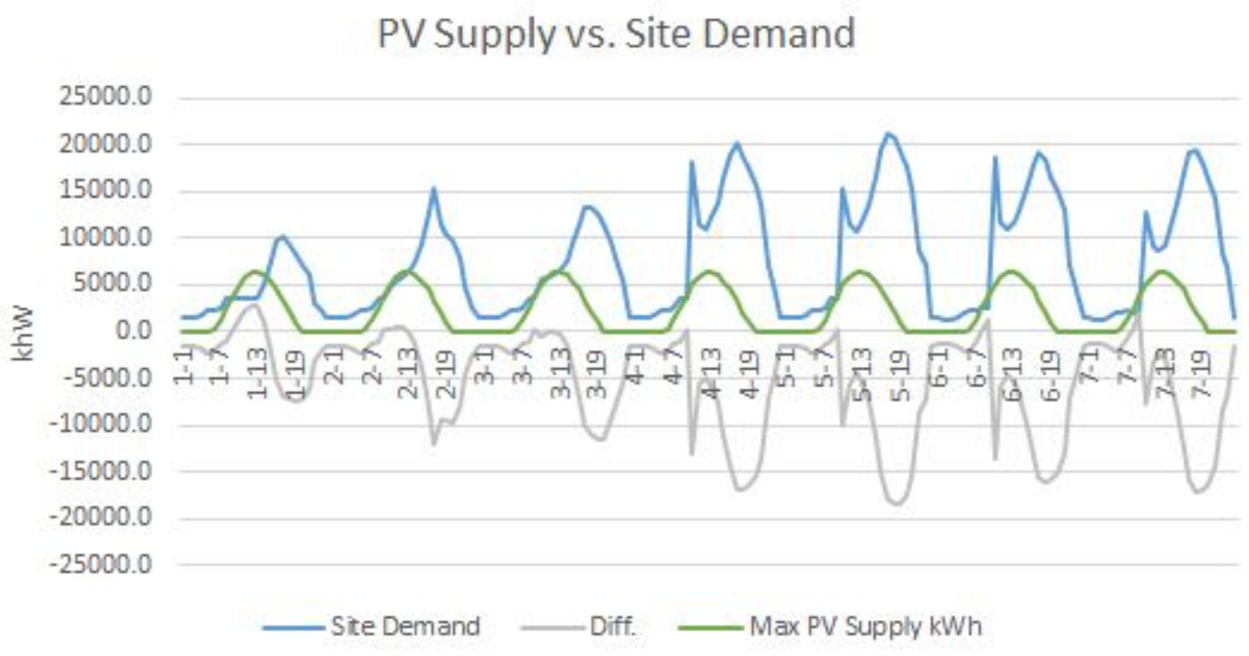
Thermal Mass

Nighttime Natural Ventilation

Discomfort Hours : **1%**

% of energy demand : **30 % vs. 19 %**

Load Reduction + Low Discomfort Hours



Day-cooling only

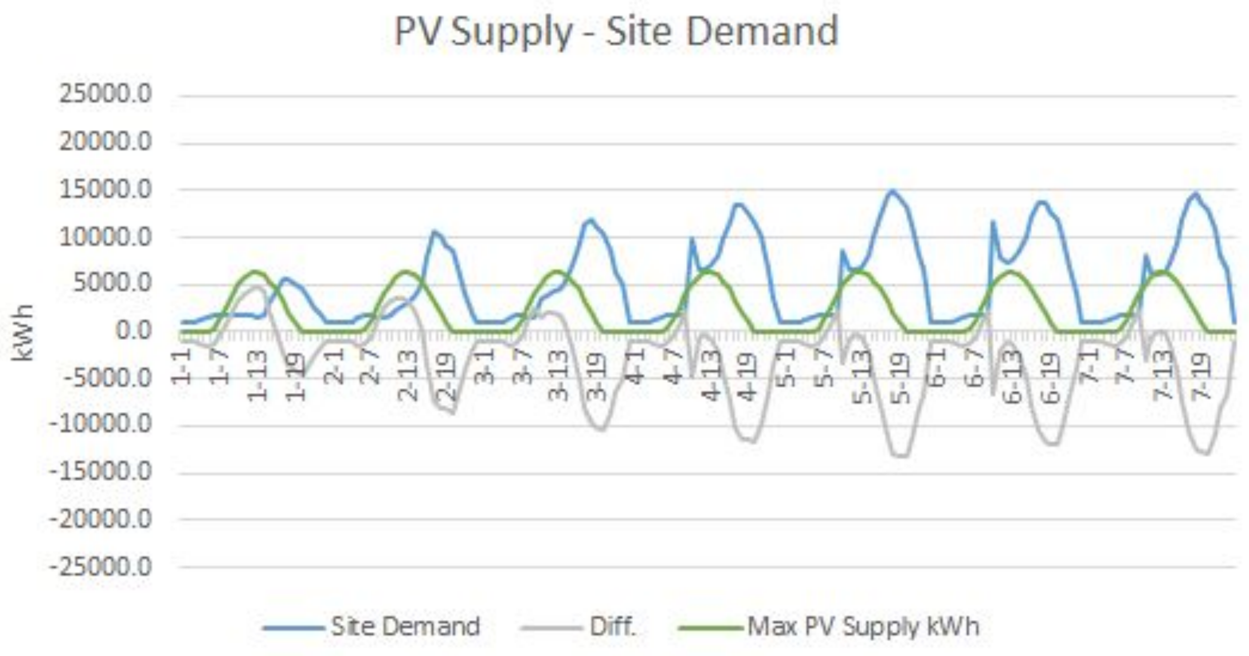
Thermal Mass

Nighttime Natural Ventilation

energy demand met:

30 %

Further Load Reduction

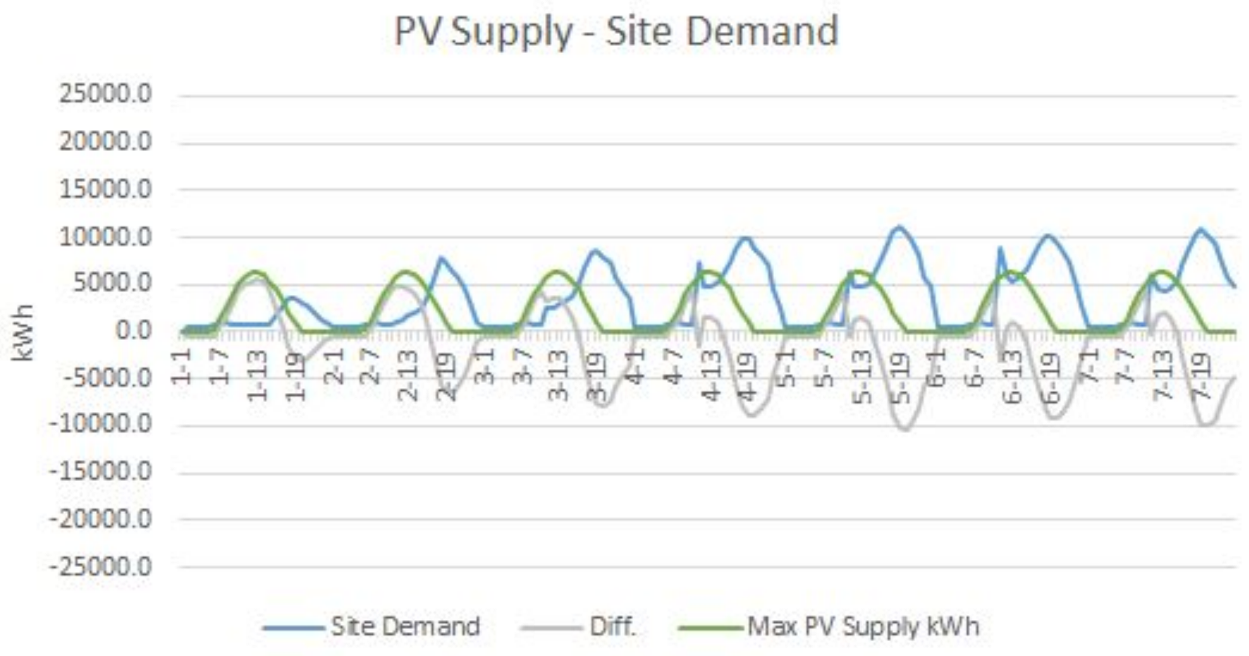


- 20% of most energy intensive commercial space

energy demand met:

43 %

Further Load Reduction



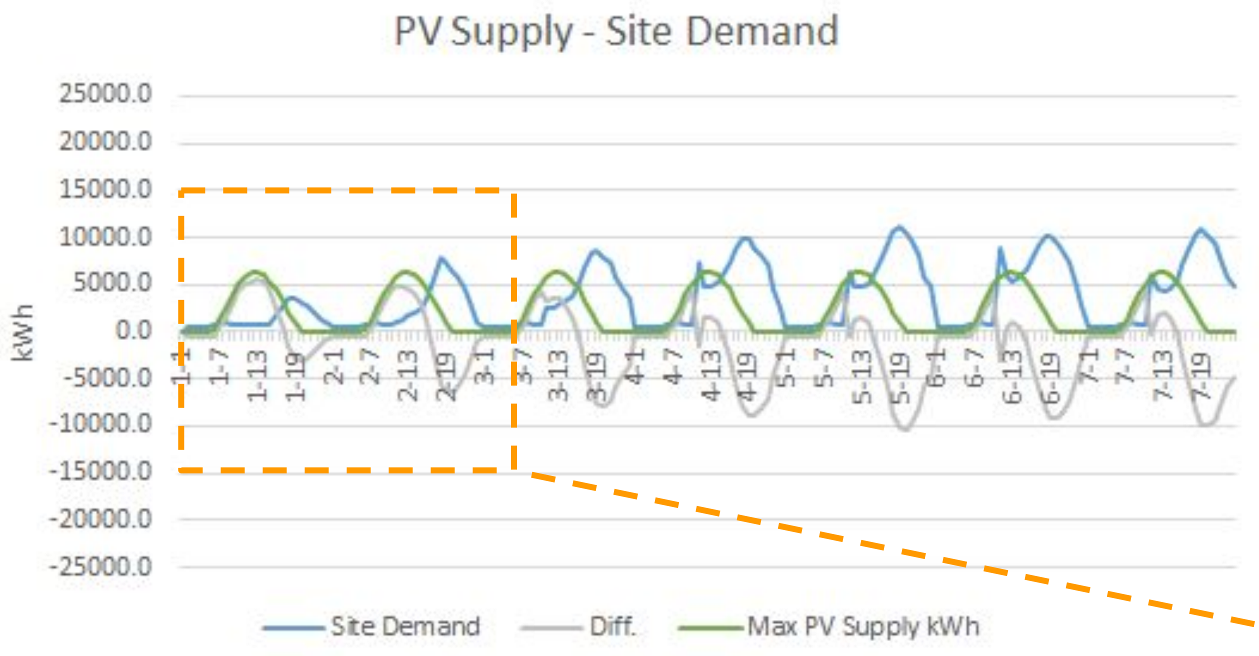
- 20% of most energy intensive commercial space

Reduced lighting and equipment loads 50%

energy demand met:

63 %

Further Load Reduction



- 20% of most energy intensive commercial space

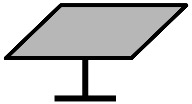
Reduced lighting and equipment loads 50%

energy demand met:

63 %

116%

PV Effects of Annual Energy Supply



All Roof Area
(75% available)

Upgrades to Energy Supply

Business As Usual

Net Zero + 7 days of battery storage

	Business as Usual	Net Zero	
tCO2eq	5,839	1,932	
tCO2eq / ppl	**0.40**	**0.13**	-67%
kgCO2eq / m2	14.35	4.75	

61

EUI
kWh/m^2/year

4.75

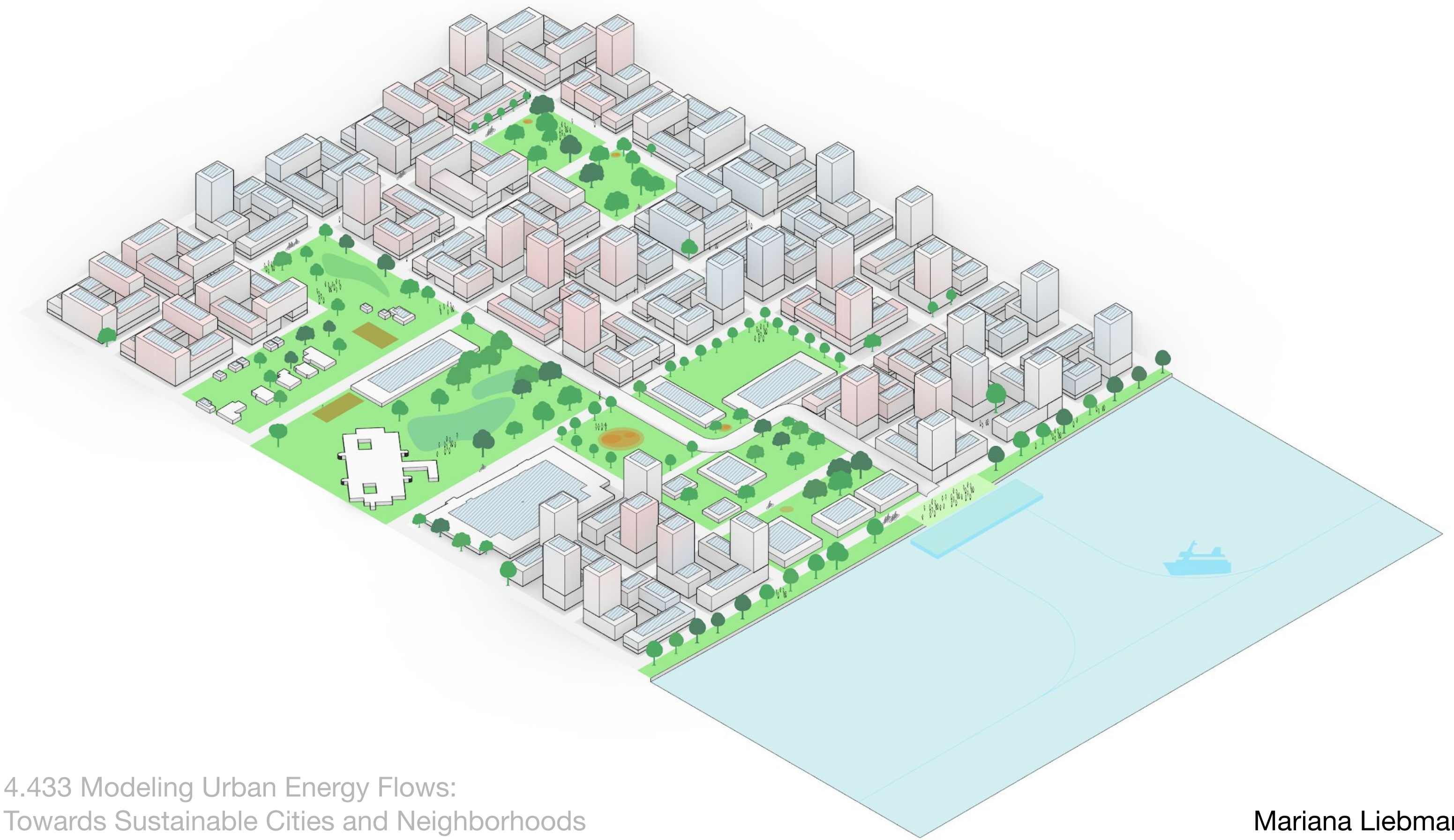
kgCO2/m2

116

% demand met by PV during heat wave

70%

of year Thermally Comfortable



ZERO Island

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Towards Sustainable Cities and Neighborhoods
C. Reinhart / Spring Semester 2020 / MIT

Mariana Liebman-Pelaez, Hadley Piper,
Ramon Weber, Elizabeth Young

Upgrades to Energy Supply

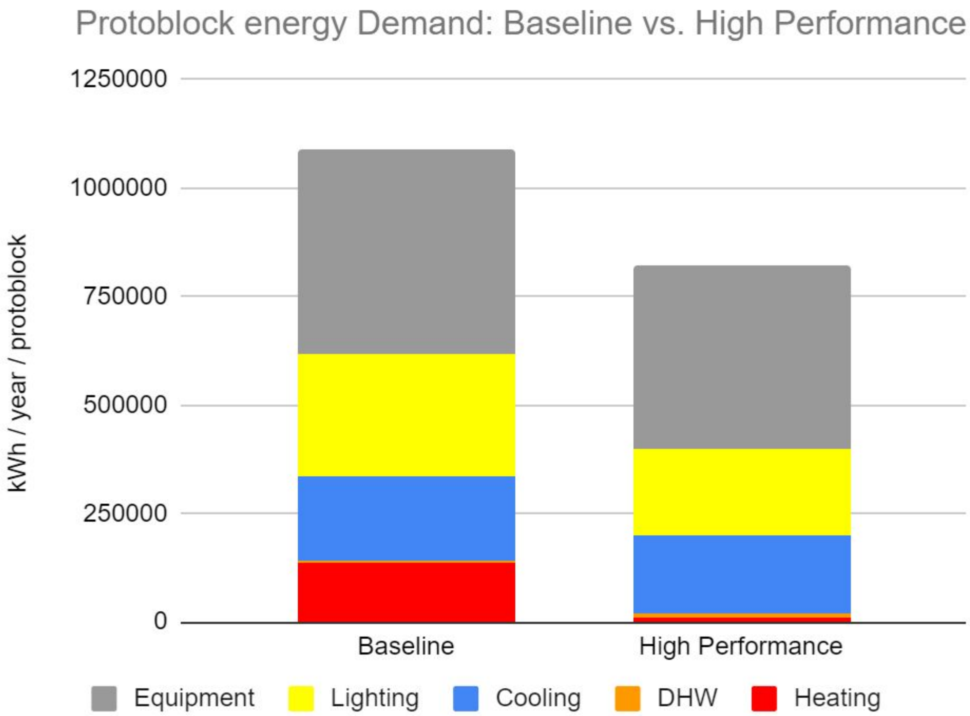
[Placeholder: visual for existing scenario vs. upgrades to all electric grid]

Energy Model Templates [rcp 8.5]

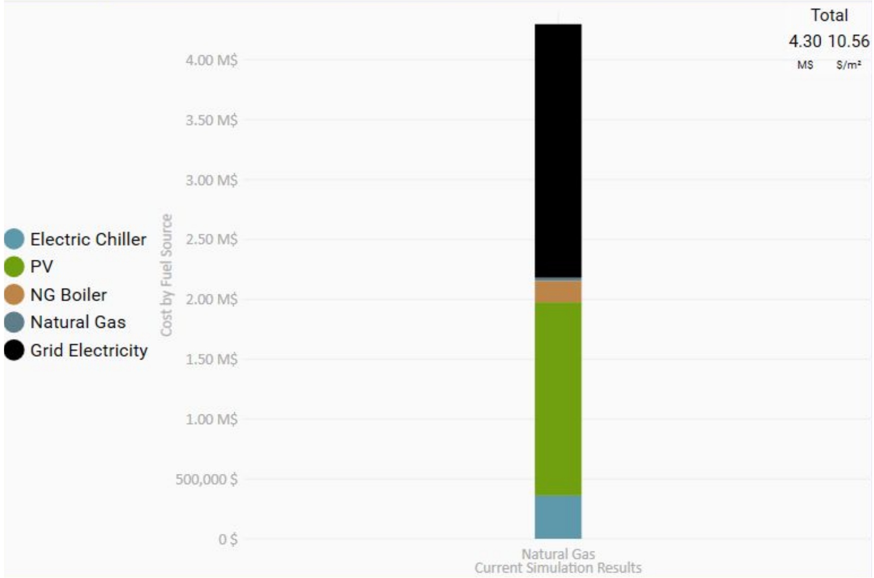
		Residential - Base	Commercial - Base	Residential - HP	Commercial - HP
Internal Loads	Equipment Power Density (w/m2)	5.38	10.76	5.38	**8.608**
	Lighting Power Density (W/m2)	5.38	10.76	5.38	**8.608**
	Illuminance target [lux]	500	500	**300**	**300**
	Dimming type (on/off)	off	off	**continuous**	**continuous**
Cooling + Ventilation	Cooling COP	3.66	3.66	**5**	**5**
	Natural Ventilation	off	off	**on**	**on**
	Nat. Vent. Setpoint (C)	--	--	23	23
	Nat. Vent. min outdoor air temp (C)	--	--	21.1	21
	Mech. Vent. Heat Recovery	--	--	**sensible**	**sensible**
Construction	Infiltration (ACH)	0.42	0.1	**0.2**	0.1
	Roof R-Value (IP)	R-15	R-15	**R-40**	**R-40**
	Facade R-Value (IP)	R-10	R-10	**R-30**	**R-30**
	Window Type	single pane	single pane	**double pane Low E2**	**double pane Low E2**
	EUI (kWh/m2/year)	**177**	**155**	**103**	**92**

60% WWR, Shading Used | 70% Residential, 30% Commercial

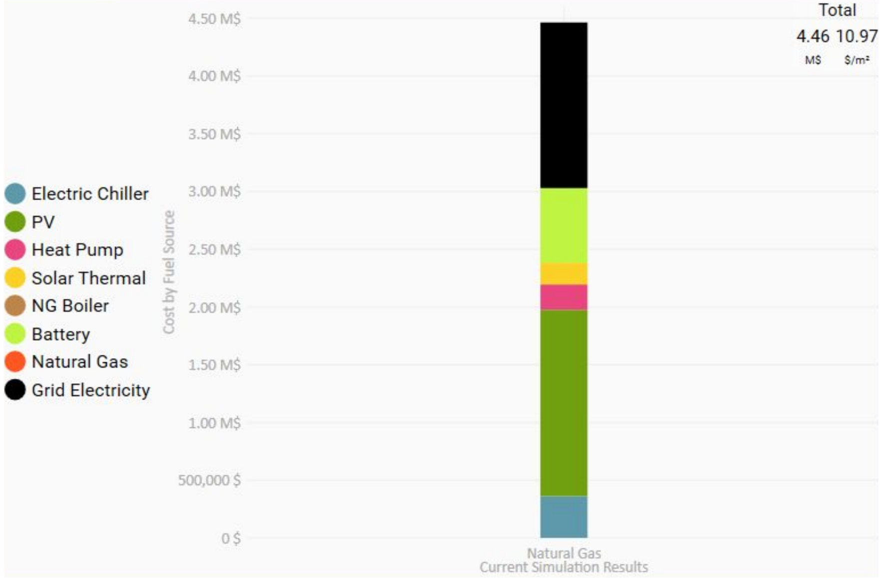
Present Climate Energy Demand Comparison



Costs



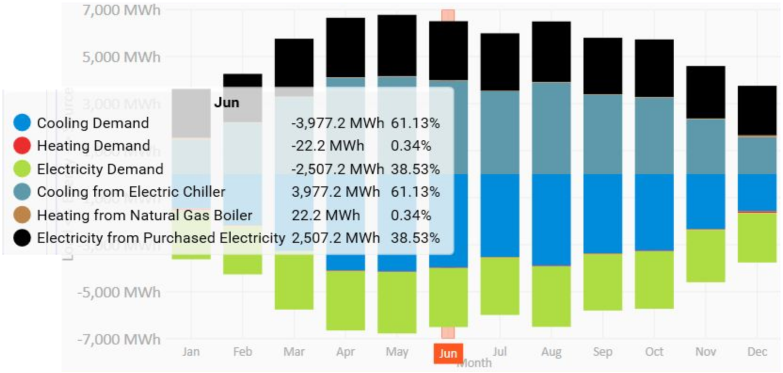
Business As Usual



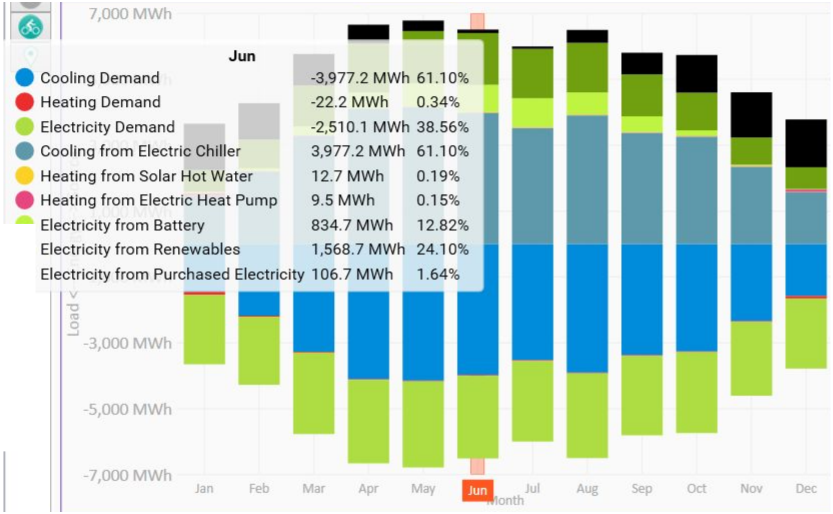
Net Zero + 7 days of battery storage

Preliminary District Energy Results

Business As Usual

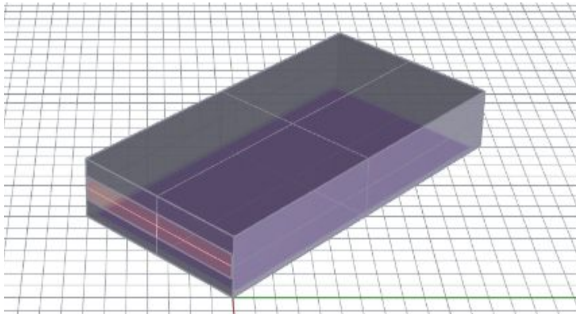


Net Zero + 7 days of battery storage

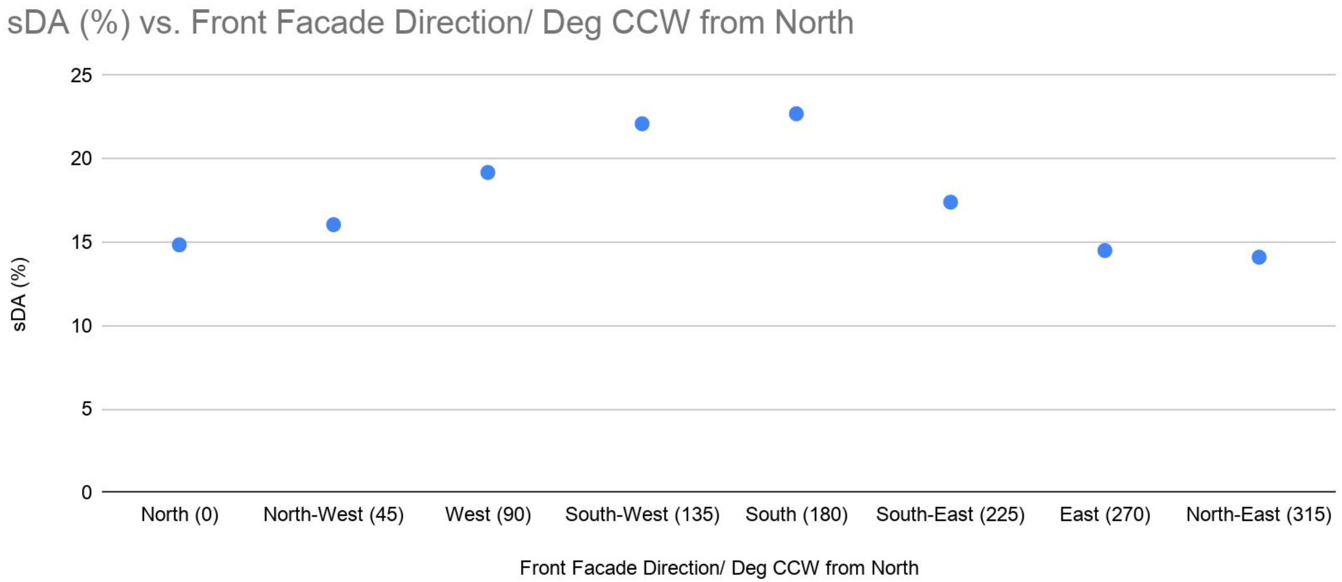


Building Primitive Assumptions

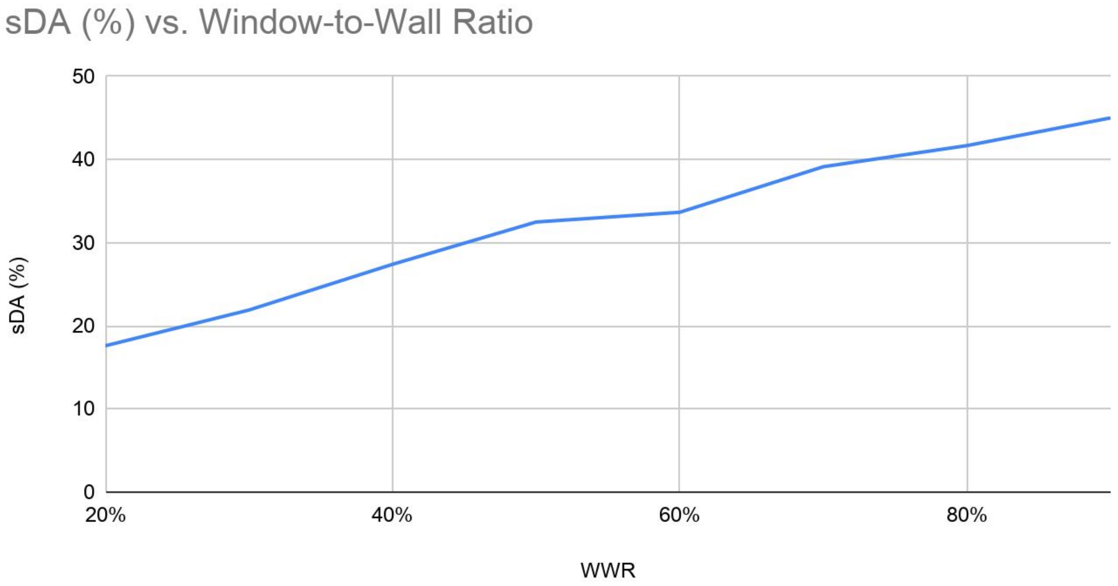
room height	3m
workplane offset	0.6m
sensor spacing	0.76m
Occupancy	8am - 6pm with DST
floor material	Floor LM83
room material	Wall LM83
window material	Double IGU Clear Tvis 39%



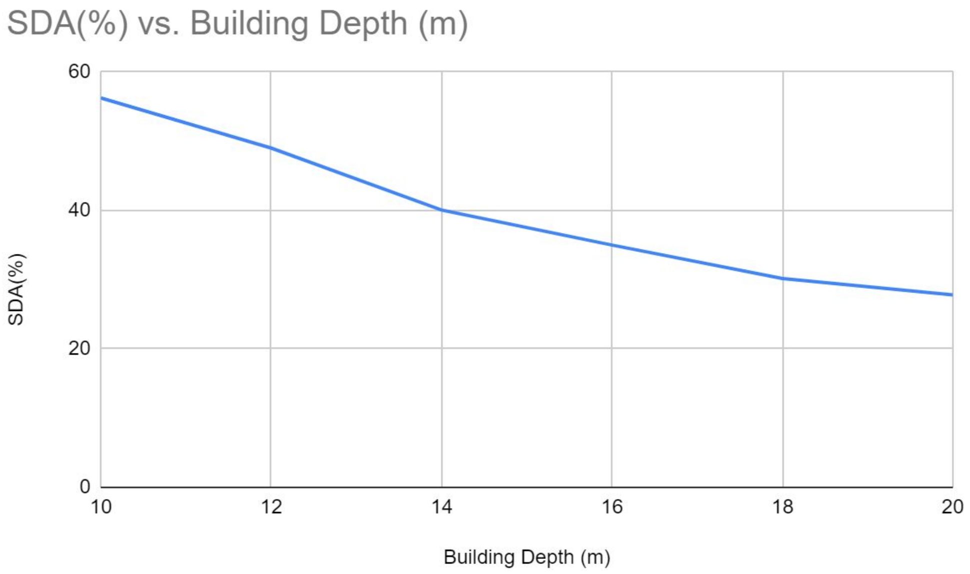
Building Primitive Orientation



Building Primitive WWR



Building Primitive Building Depth



Street Grid

Site Boundary

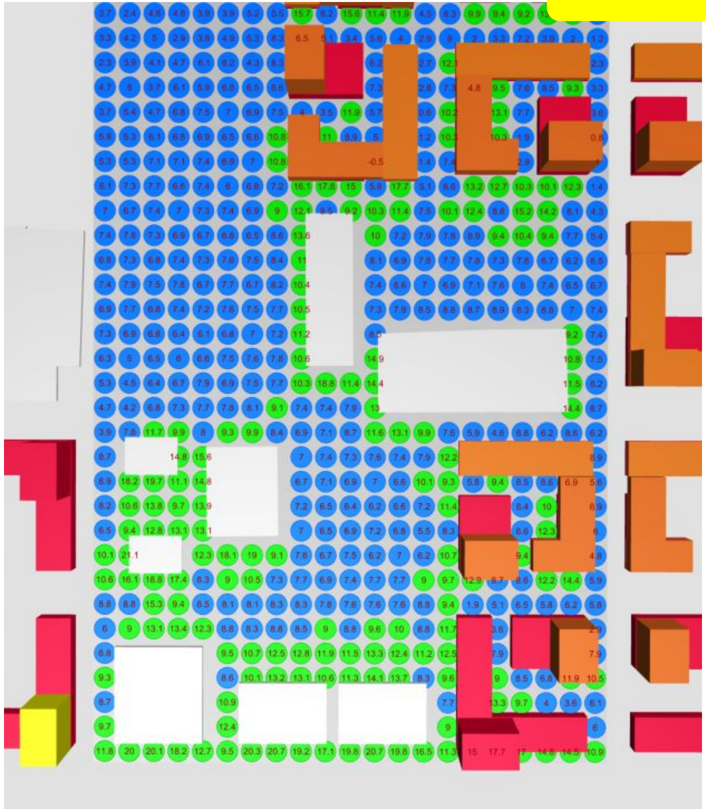
Existing Street Grid

Proposed Street Grid

Mobility from Thermal Comfort

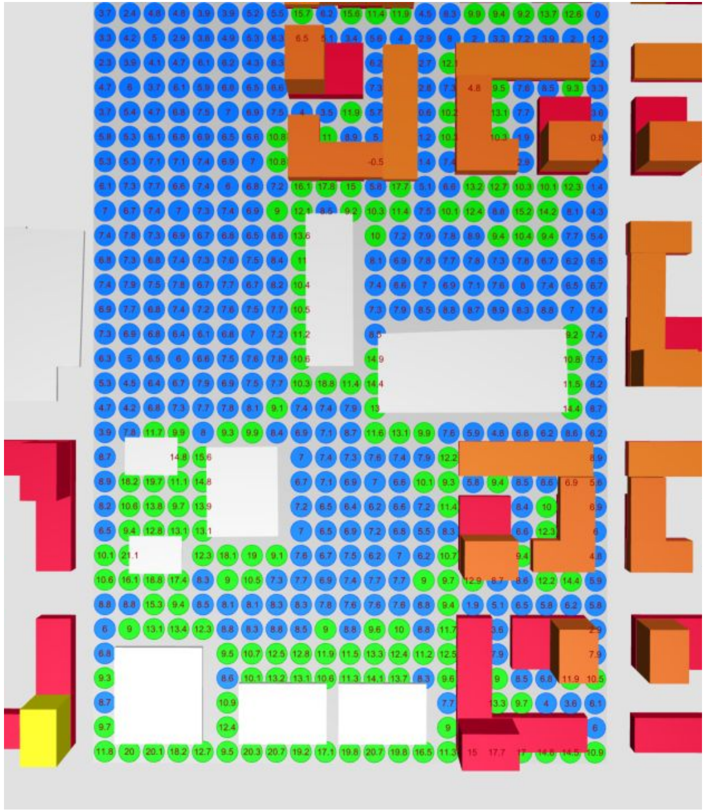
UTCI distribution today May 7 at 9am

Screenshot 1



Mobility from Thermal Comfort

UTCI distribution today May 7 at 9am



Screenshot 2

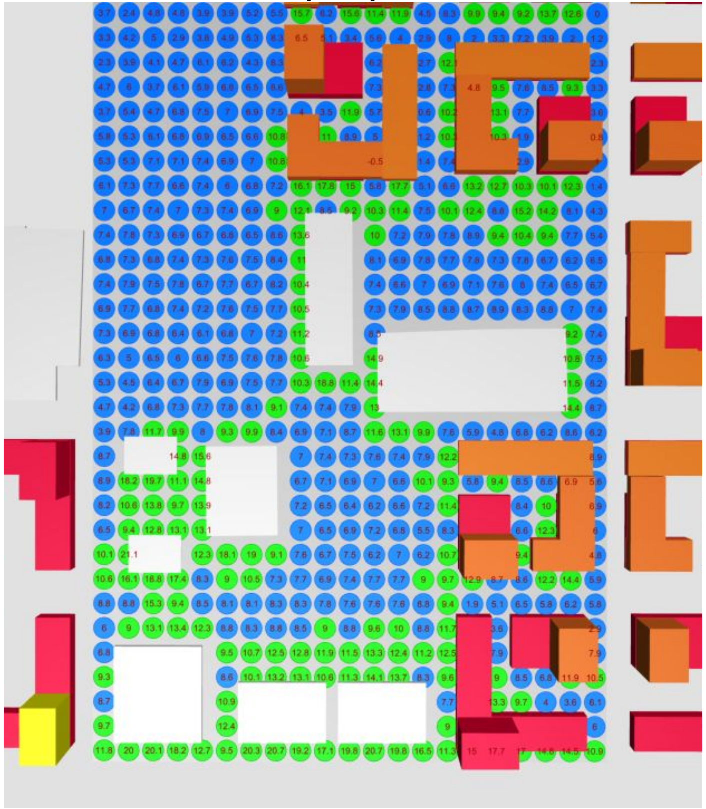
Evaluate comfort at
9am for 365 days

Percent of comfort hours at 9am for the whole year

Mobility from Thermal Comfort

Pathway is comfortable at 9am for 55% of year **without shading**

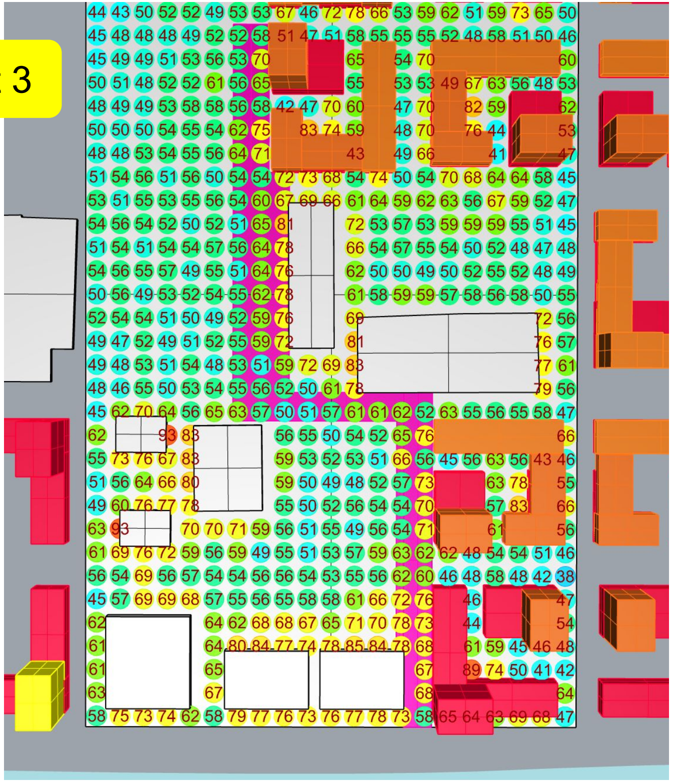
UTCI distribution today May 7 at 9am



Screenshot 3

Evaluate comfort at 9am for 365 days

Percent of comfort hours at 9am for the whole year



Mobility from Thermal Comfort

Pathway is comfortable at 9am for 51% of year

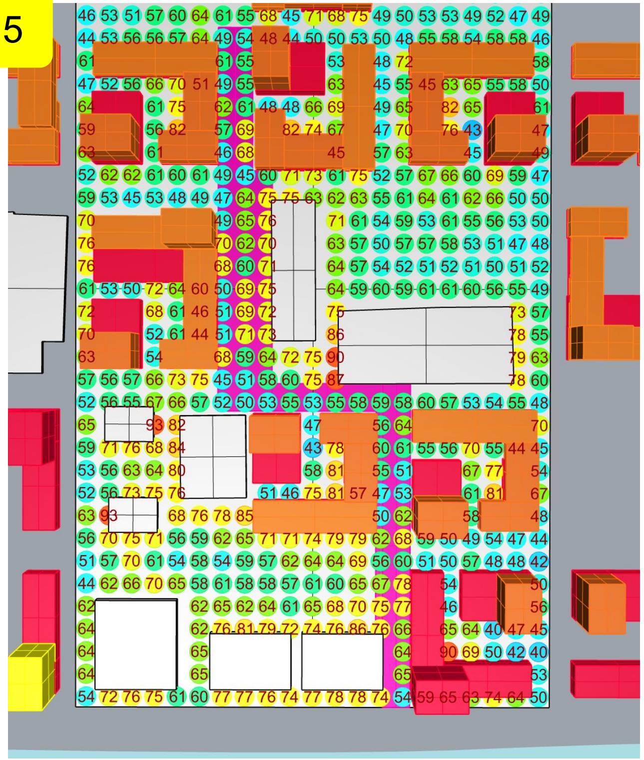
Modification 1: Redistributing park space

Screenshot 4

Insert nice screenshot of variant 3 with split park

Percent of comfort hours at 9am for the whole year

Screenshot 5

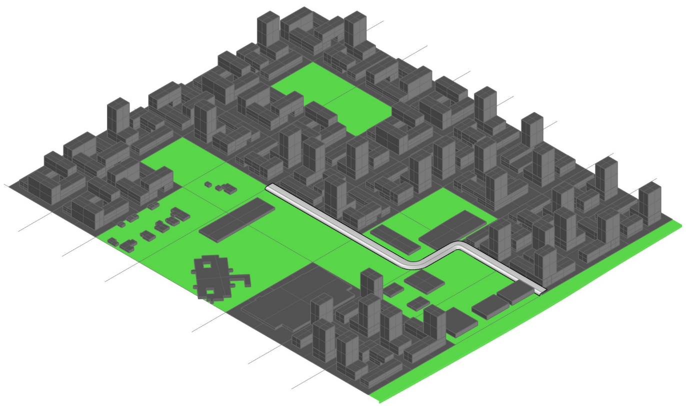


Mobility from Thermal Comfort

Pathway is comfortable at 9am for 70% of year **with shading => 54 days increase!**

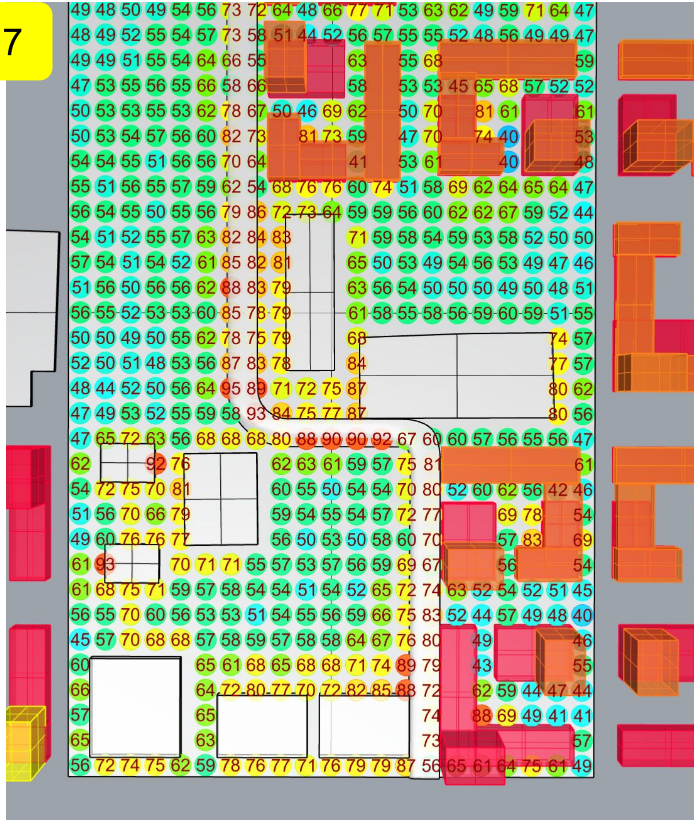
Proposed Shaded Pathway

Screenshot 6

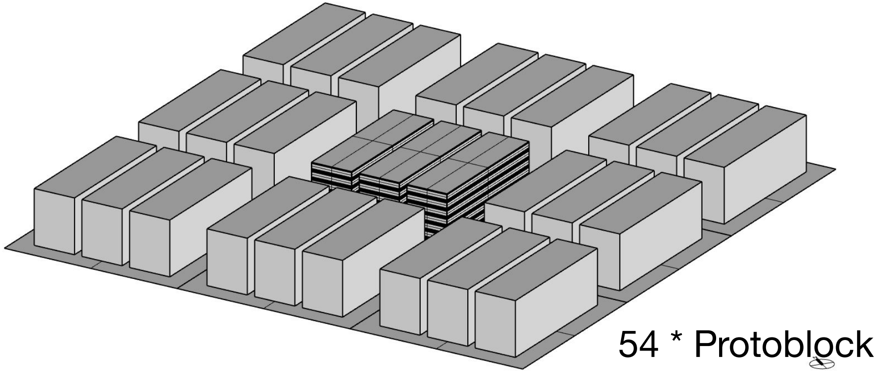


Percent of comfort hours at 9am for the whole year

Screenshot 7



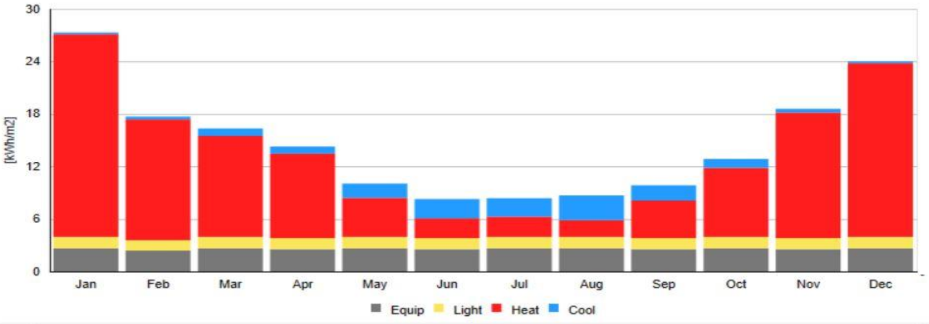
Baseline Scenario

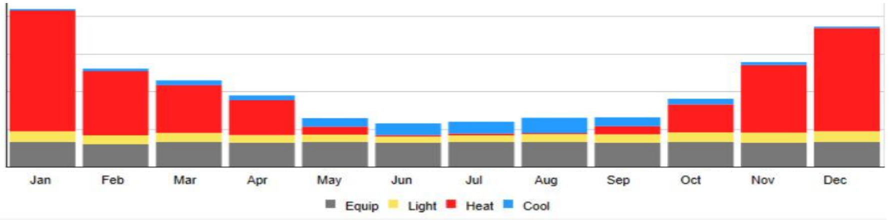


Category	Factor		Notes
Heating	0.1888	[1,2]	60% natural gas, 20% electricity, 20% other (assume oil)
DHW	0.1888	[1,2]	assume same as heating
Cooling	0.202	[2]	assume all electric
Lighting	0.202	[2]	all electric
Equipment	0.202	[2]	all electric

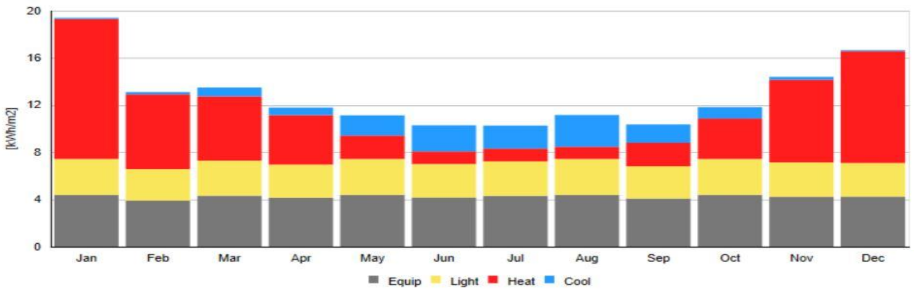
Building Energy: Baseline Vs High Performance

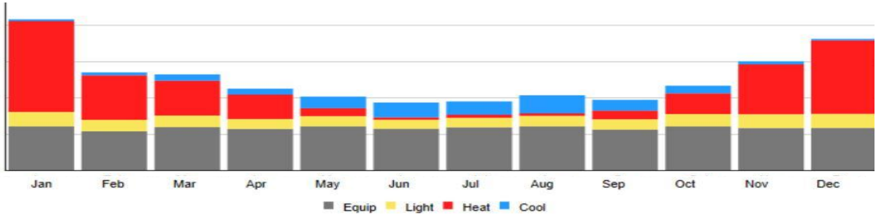
Residential



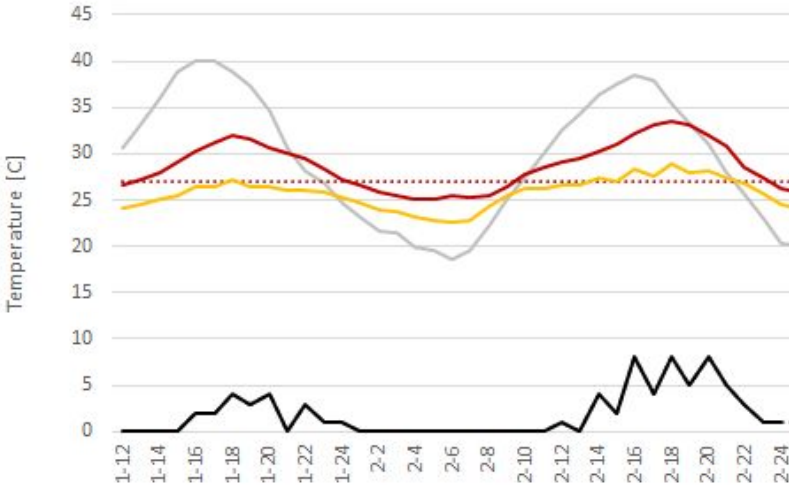


Commercial





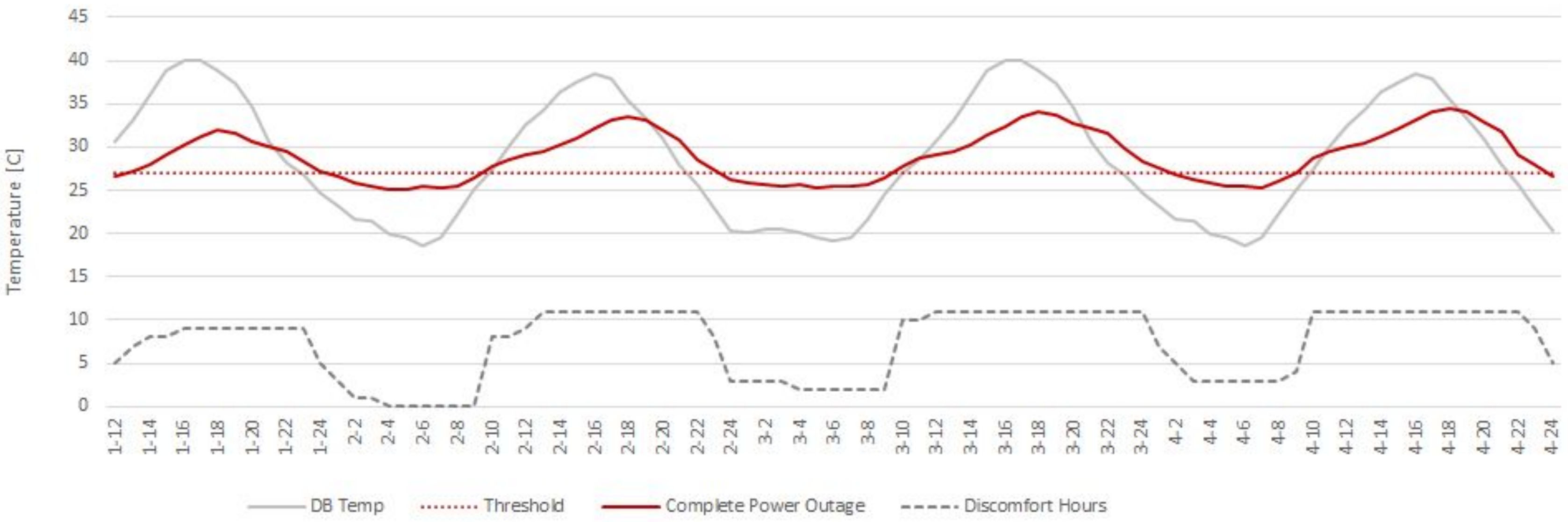
Intermittent-cooling + Thermal Mass + Nighttime Natural Ventilation



Discomfort Hours : **0%**

% of PV Supply : **156%**

Cooling Load Reduction



Discomfort Hours : **48%**

PV Area : **0**

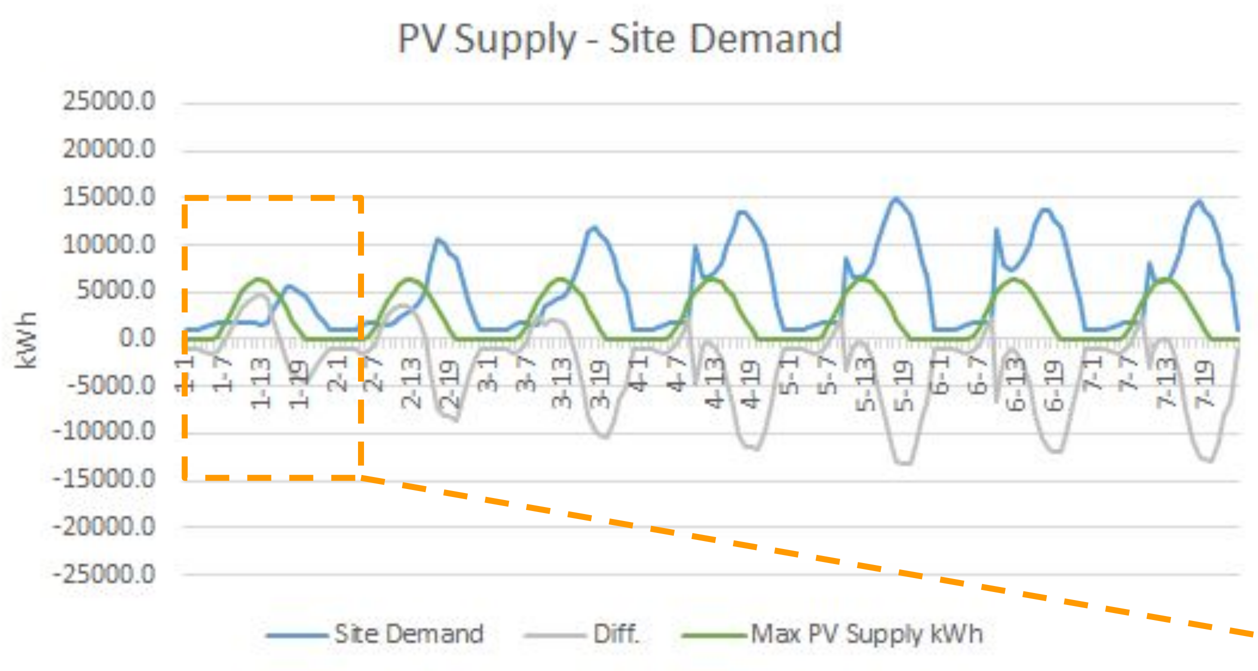
Building Energy
EUI [$kWh/m^2/year$]
$kgCO_2/m^2$

Can we design a **low carbon** community with **resilient energy** supply and human-powered **mobility**?

On-site PV
number of grid independent days during a heat wave

Urban grid layout
% of year thermally comfortable

Further Load Reduction



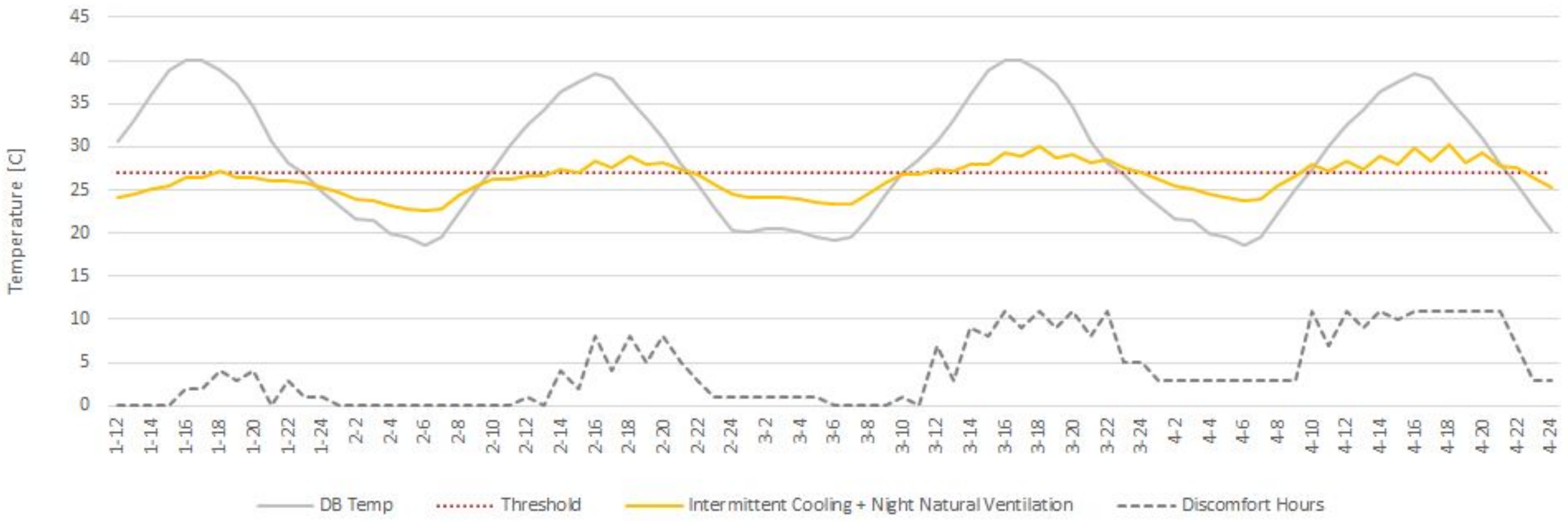
- 20% of most energy intensive commercial space

energy demand met:

43 %

93%

Intermittent-cooling +
Thermal Mass + Nighttime Natural Ventilation



Discomfort Hours : **32%**

% of PV Supply : **240%**

*Thermal mass reduced cooling energy by ~20%