KUWAIT NEIGHBORHOOD PROPOSAL

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4.433 Urban Energy Modeling

May 3, 2016

Team Introduction

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Executive, Accenture Smart Buildings
S.M. Building Technology | MIT
HVAC Certificate Core | University of California, Berkeley
B.S. Mechanical Engineering | University of Illinois, Urbana-Champaign

HOLLY JACOBSON

Master of City Planning | MIT
B.S. Biology and Environmental Studies | Bowdoin College

Guiding Principles

1 **Minimize Energy Intensity**
Focus on reducing the energy consumption per floor area

2 **Create Comfortable, Healthy Spaces**
Improving access to daylight and outdoor thermal comfort

3 **Improve Resource-efficiency**
Decrease water consumption

Methodology

Completed several studies to determine the relationship between several variables and EUI and average daylight autonomy.

Parametric Studies

1. WWR
2. Dimming
3. Building Height
4. Building Spacing
5. Internal Mass
6. Infiltration Rate
7. Cooling CoP

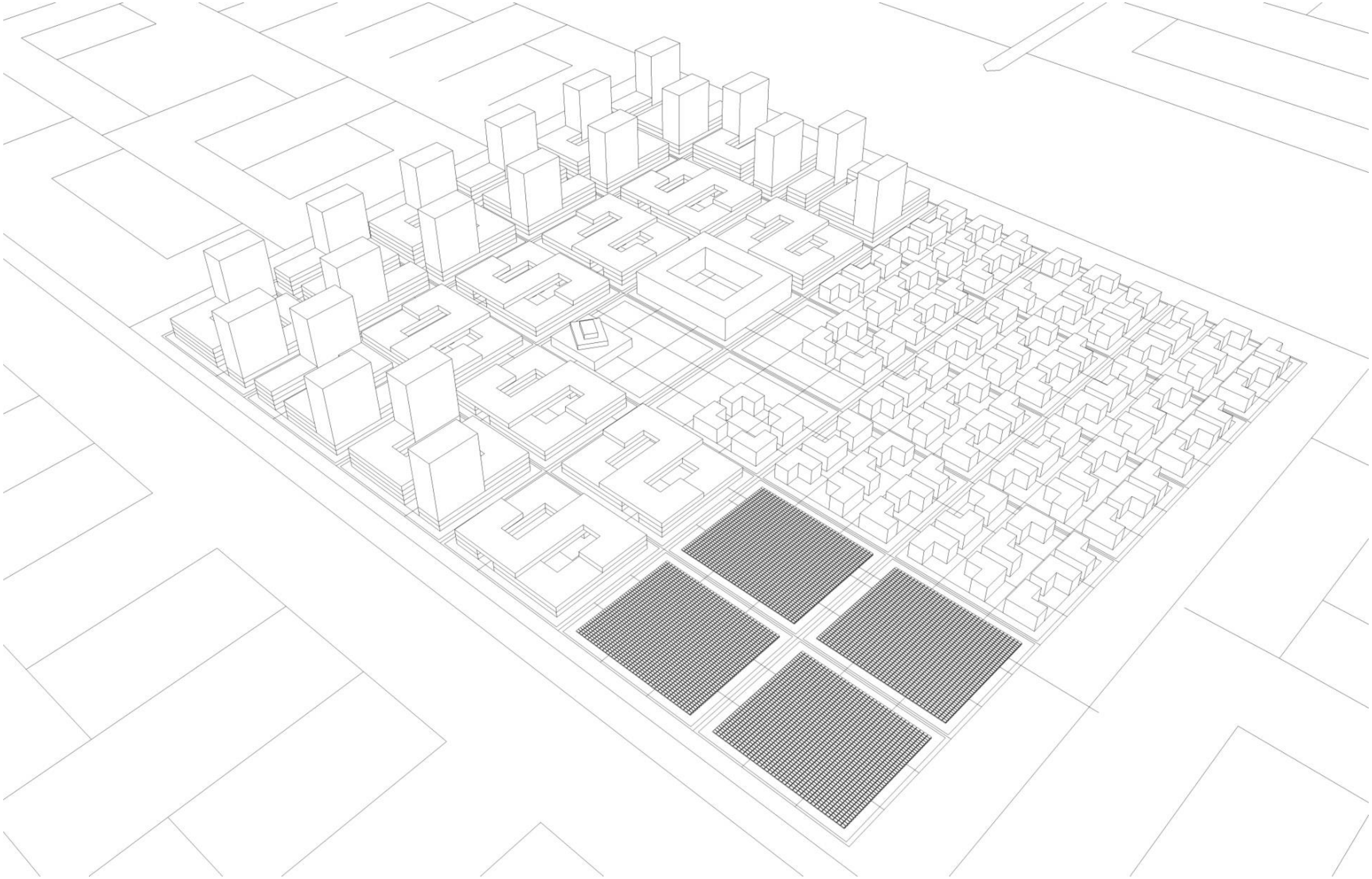
Energy Supply

1. Single cycle natural gas turbine
2. Combined Cycle Gas Turbine with a Secondary Steam Turbine
3. Combined Cooling, Heat, and Power Plant with a natural gas turbine

Thermal Comfort Analyses

- Conducted initial evaluation of outdoor thermal comfort
- Attempted to model photovoltaic panels and trees for use as shading materials
- Lack of time allowed full investigation

NEIGHBORHOOD DEVELOPMENT



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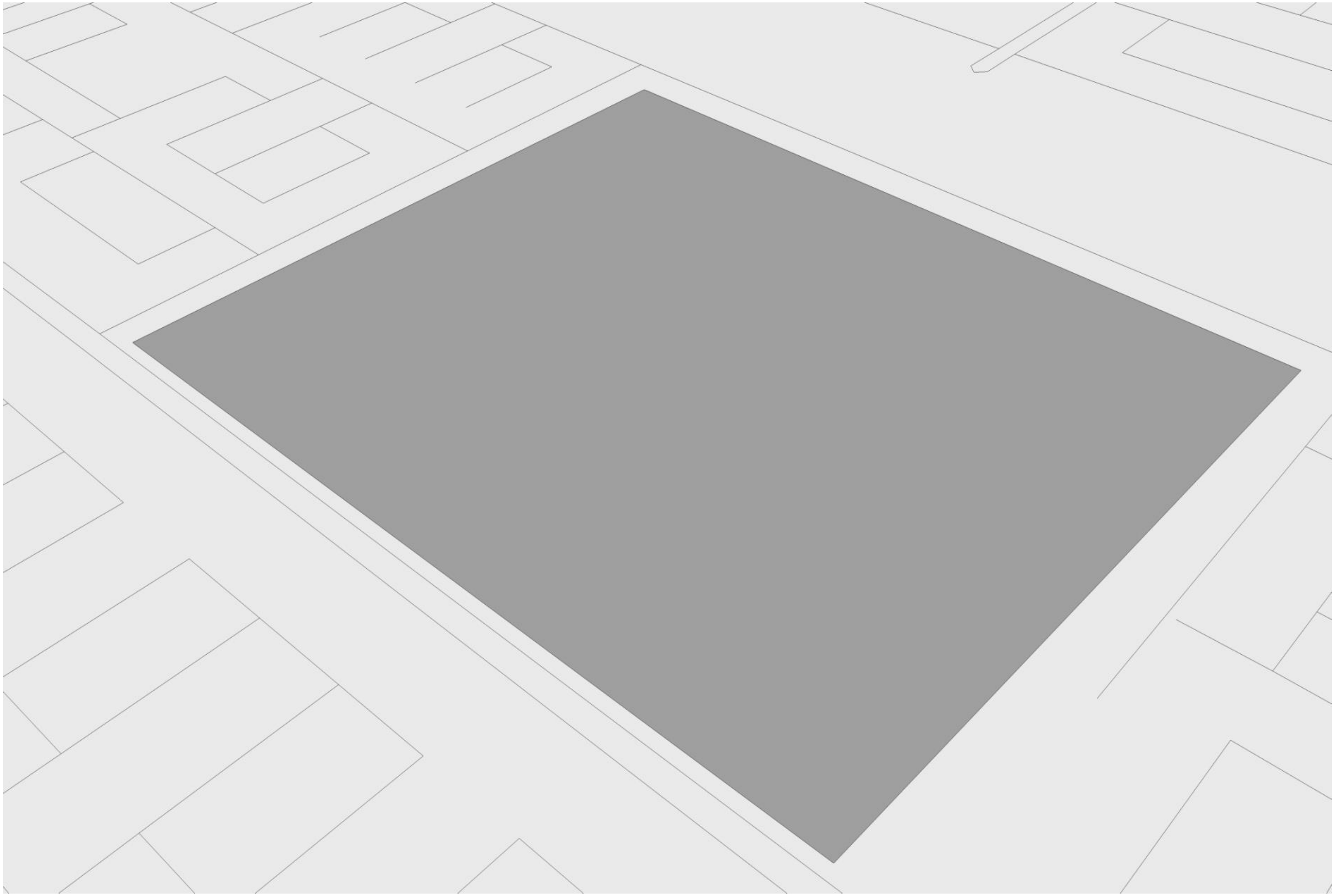
SITE



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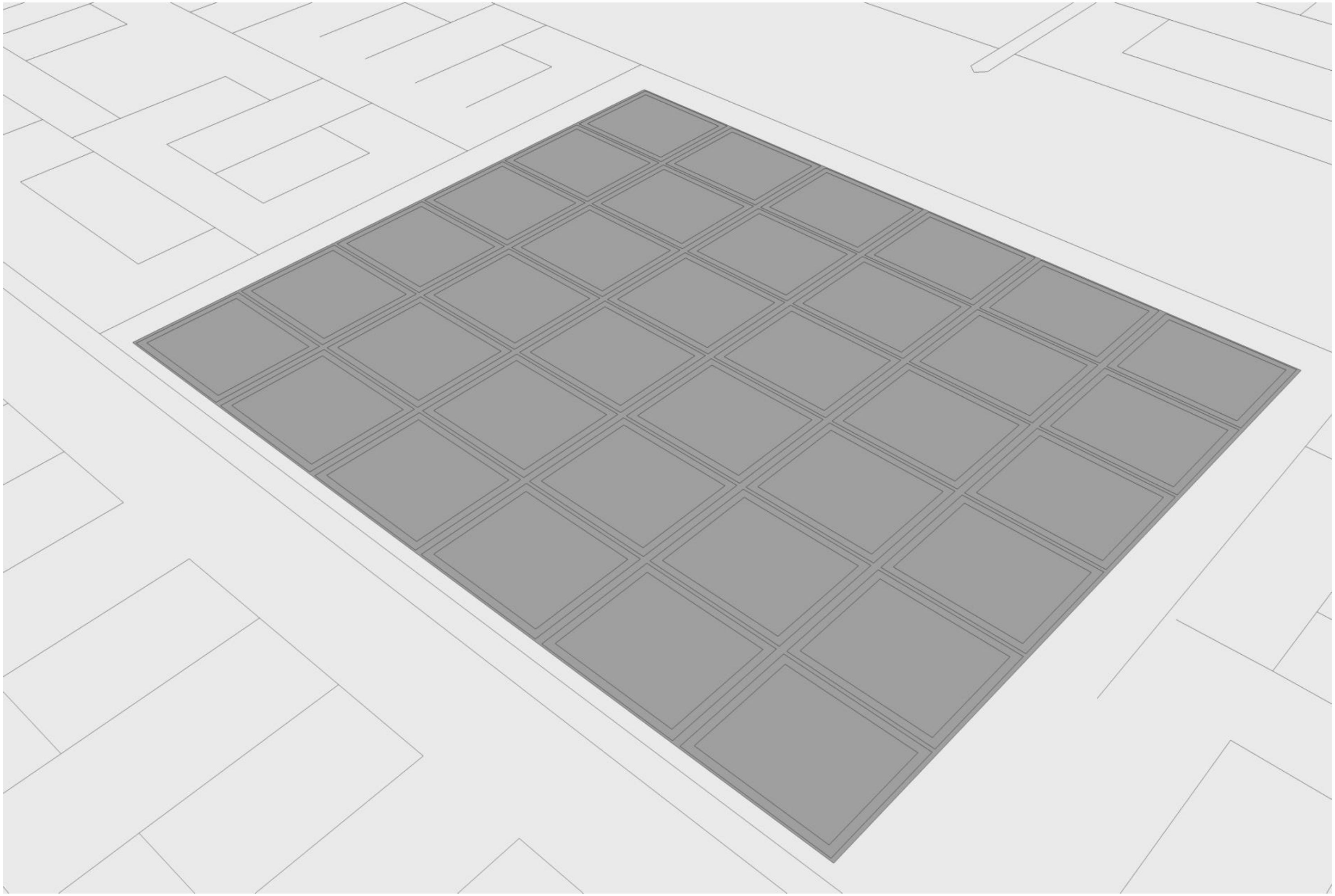
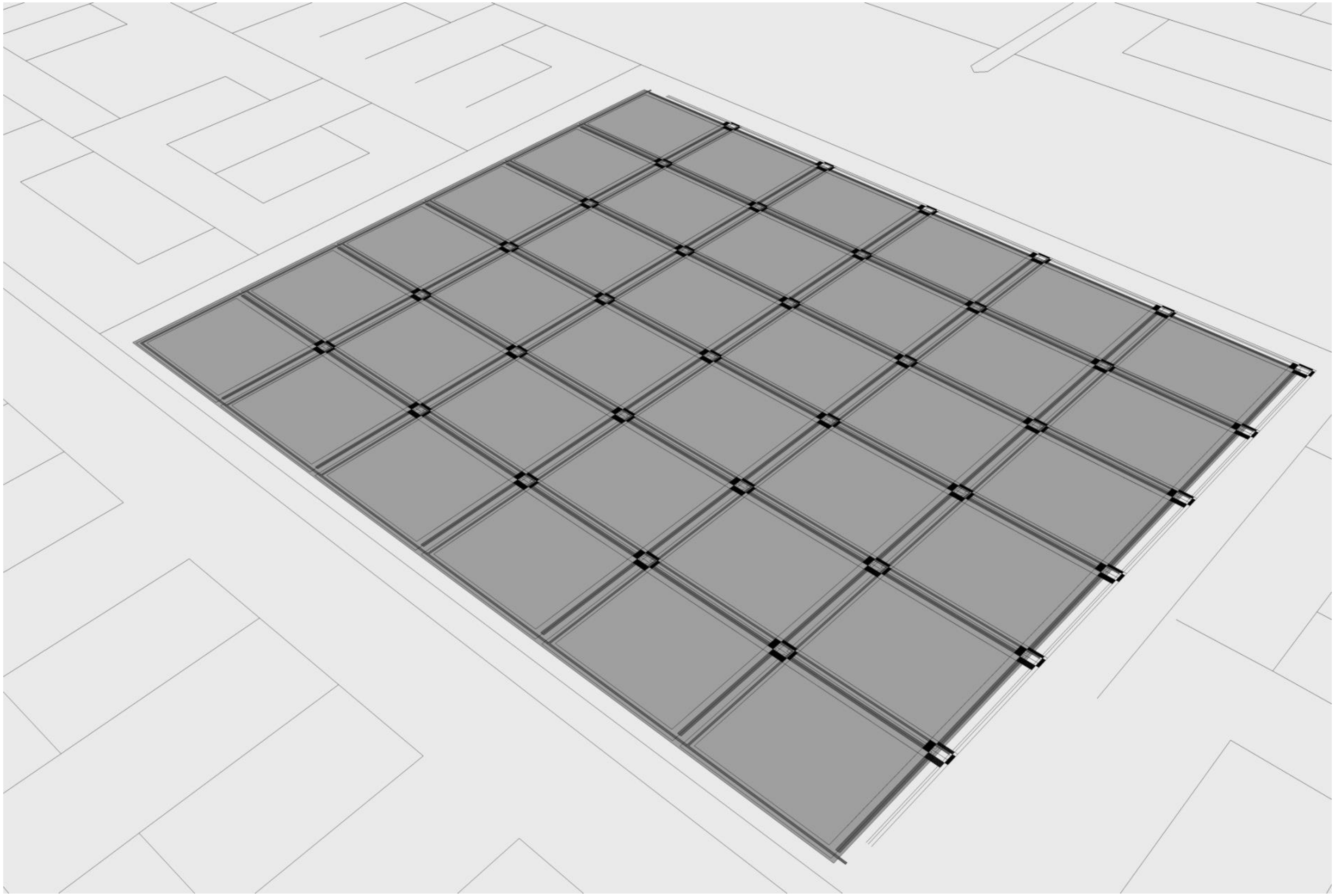
PROTOBLOCK GRID



STREET GRID



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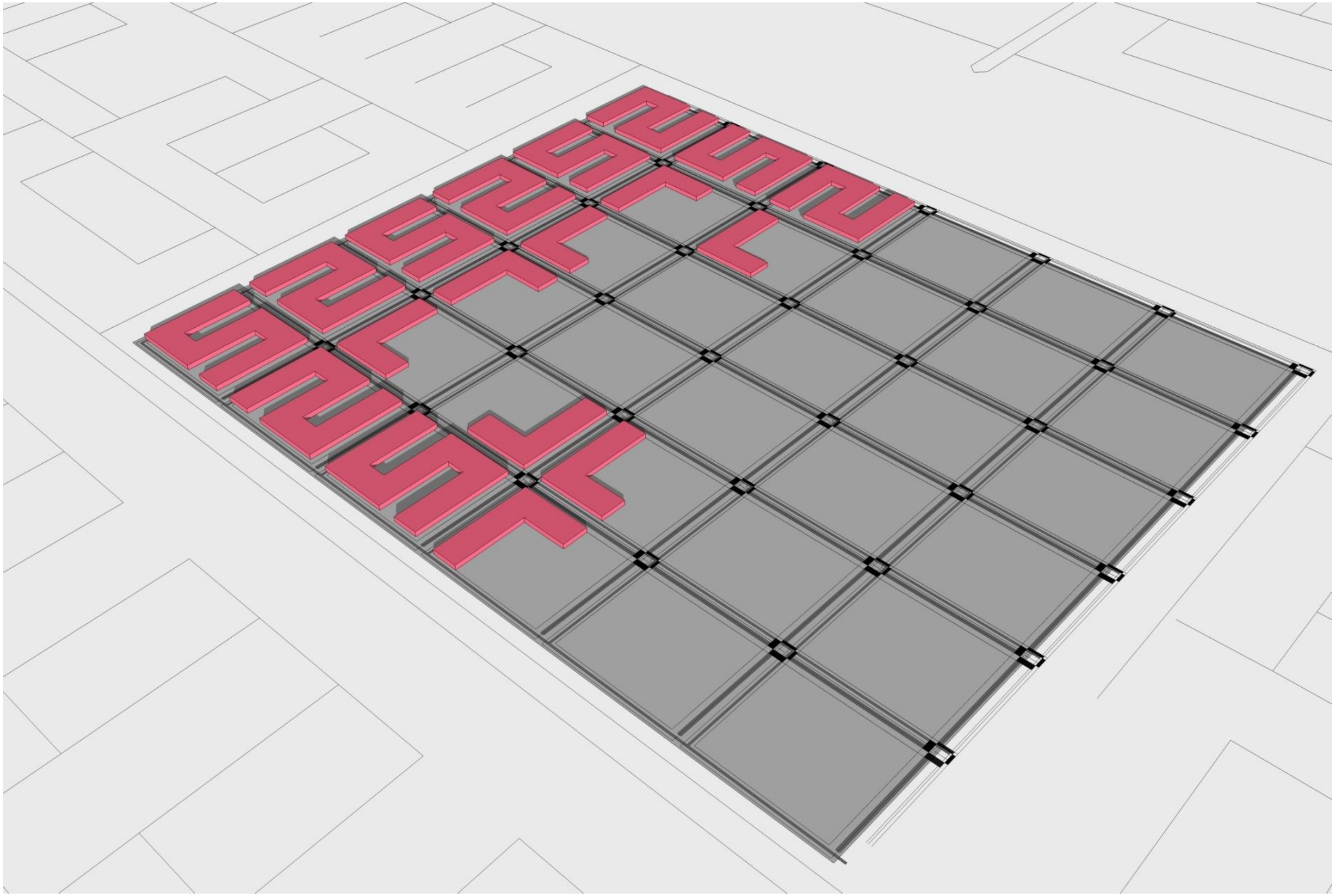
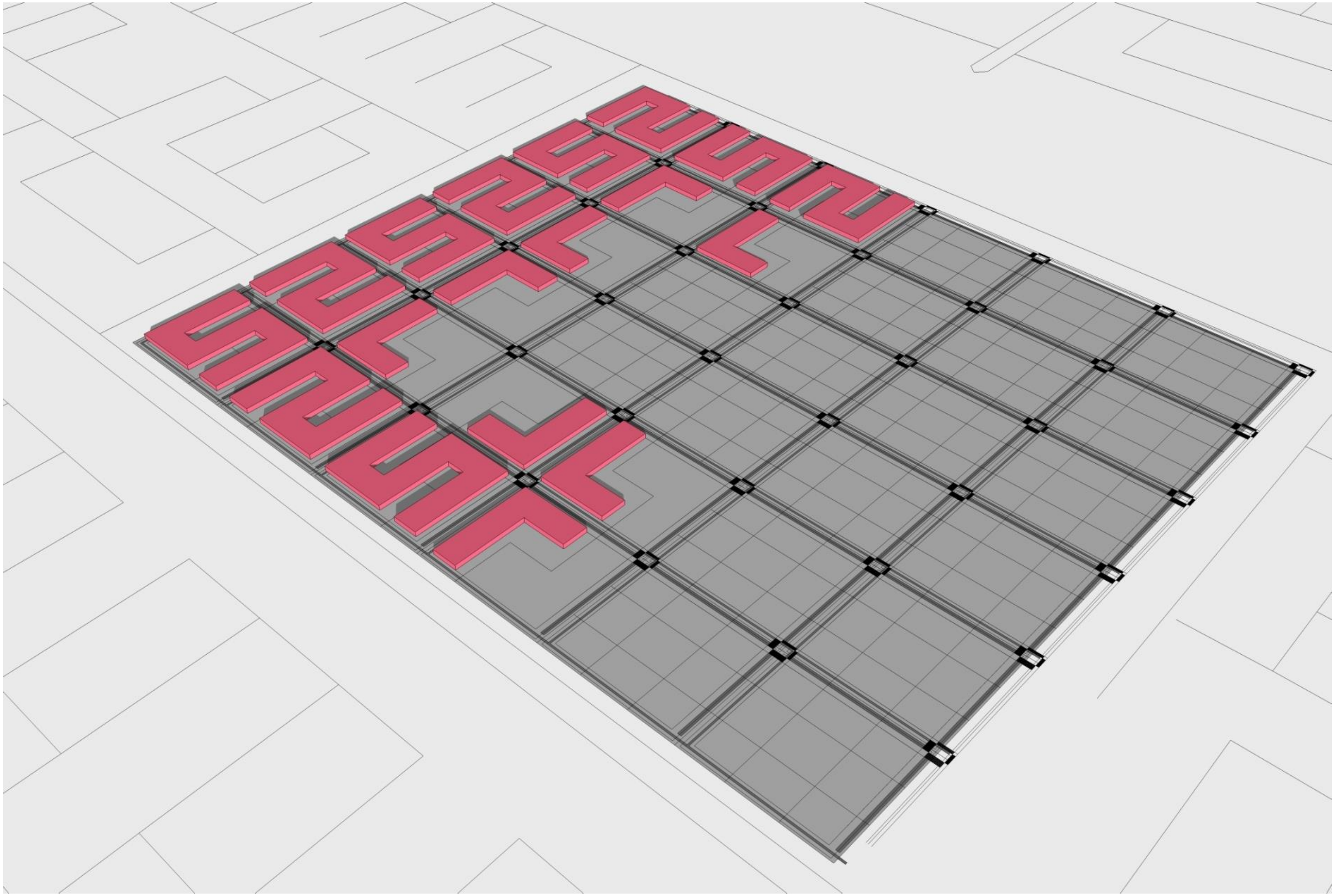
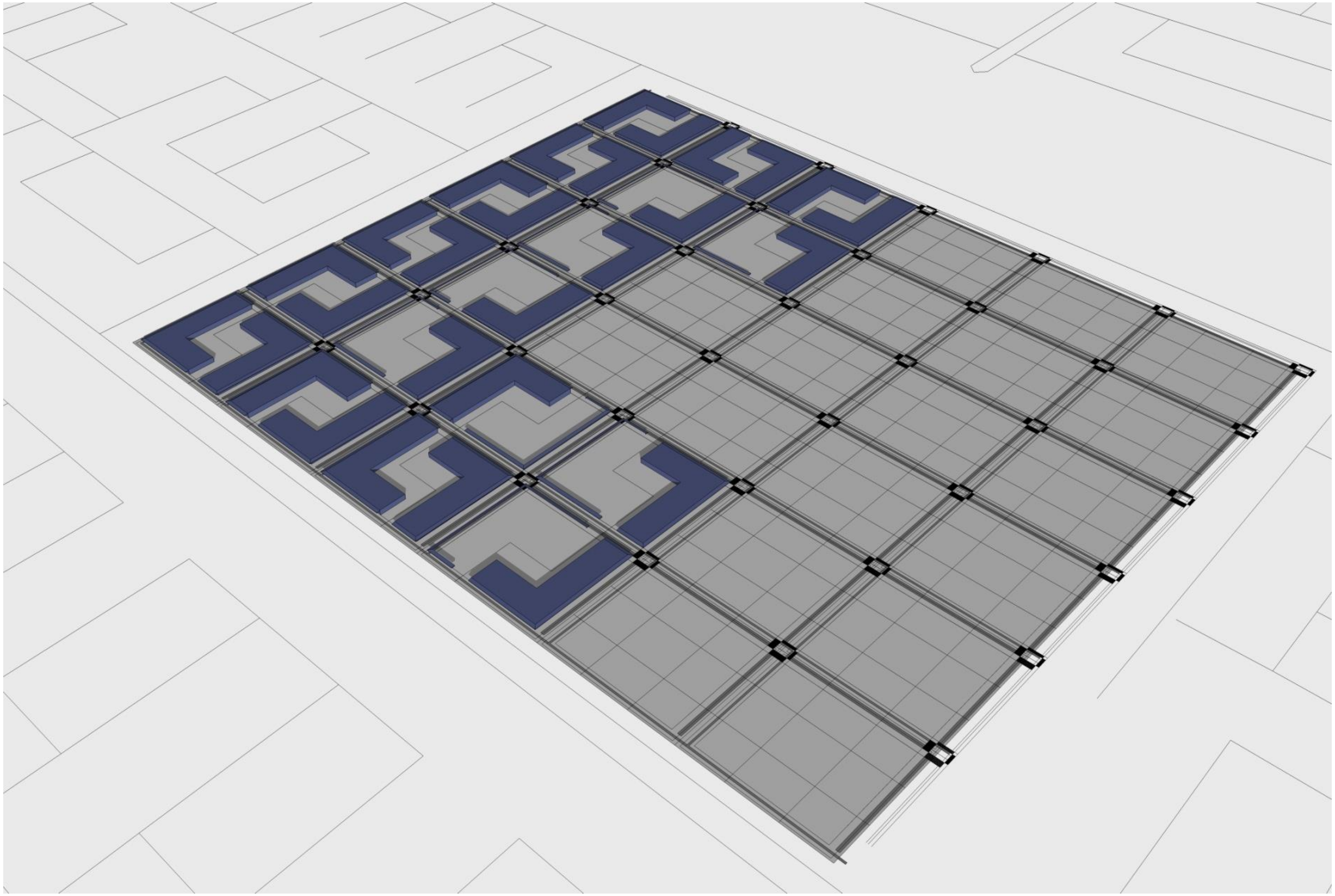
OFFICE SPACES



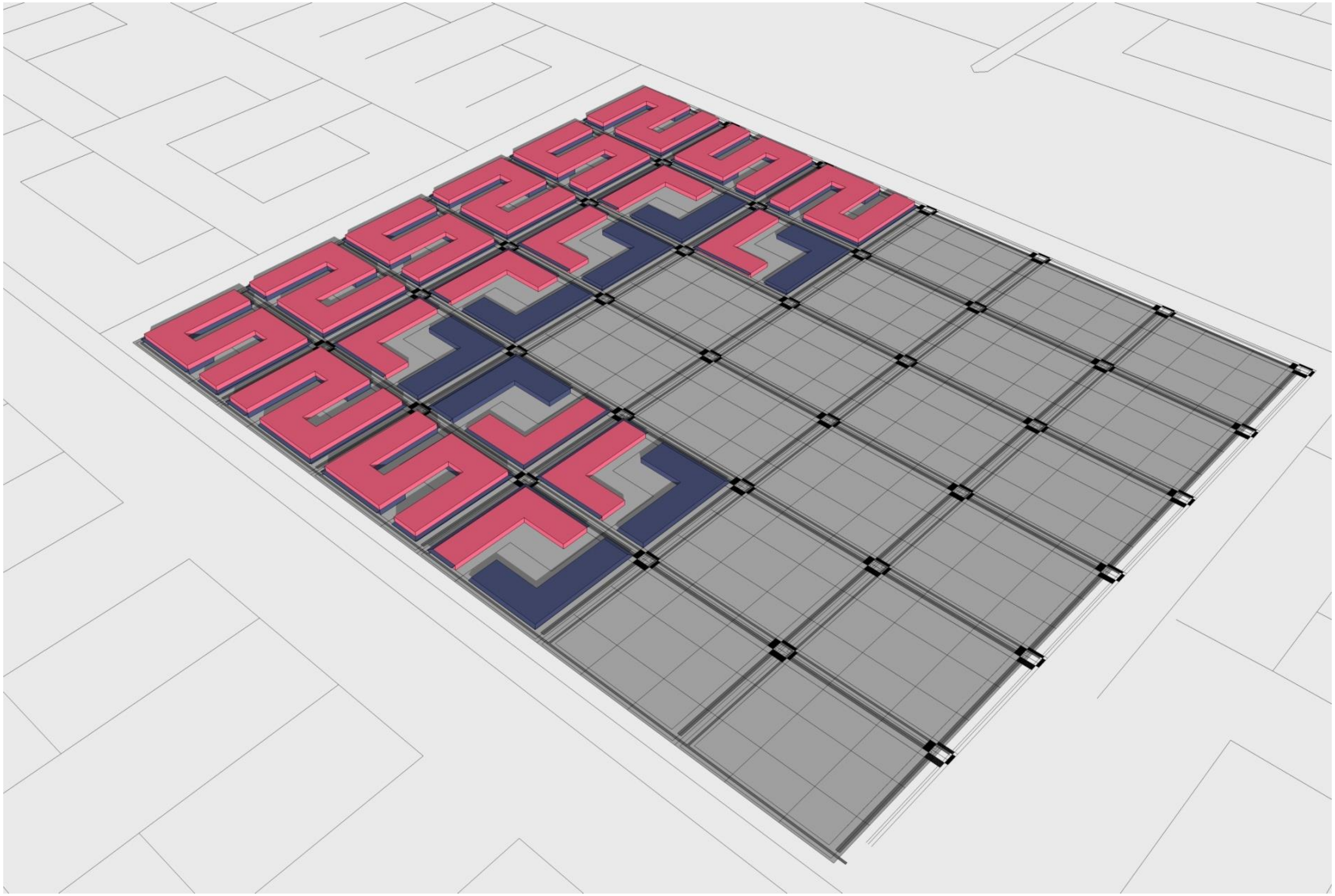
WALKING PATHS



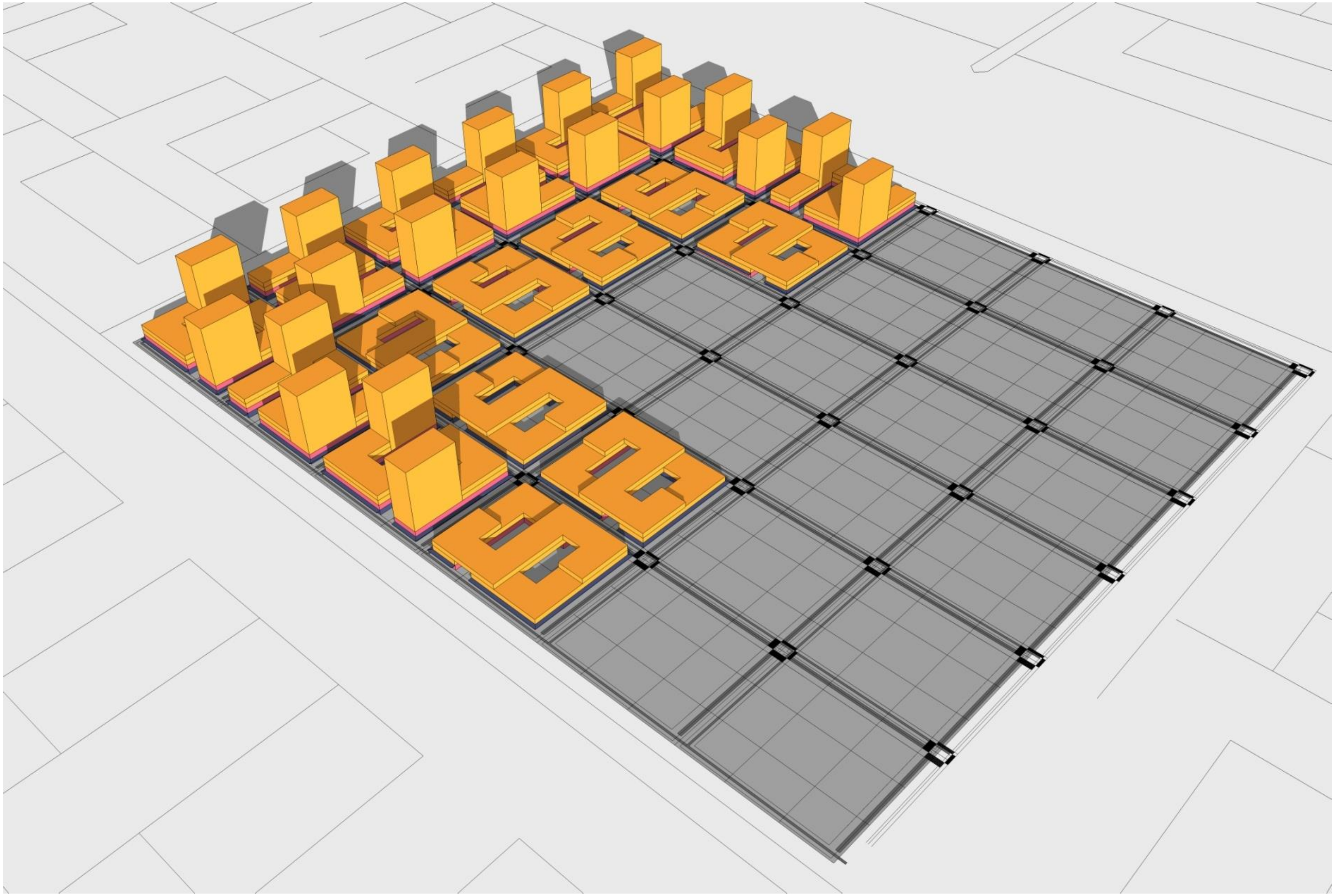
RETAIL SPACES



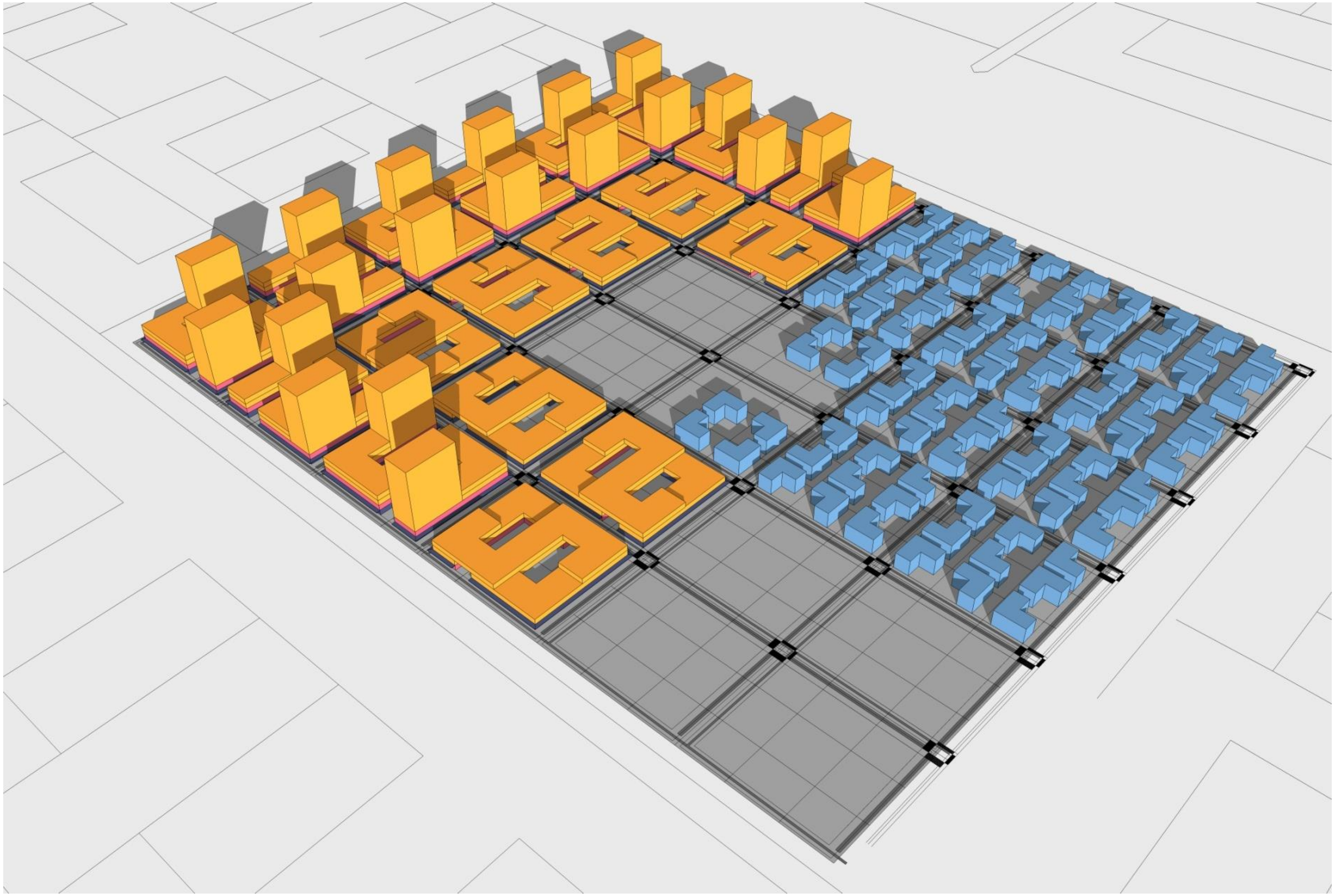
OFFICE + RETAIL STACK



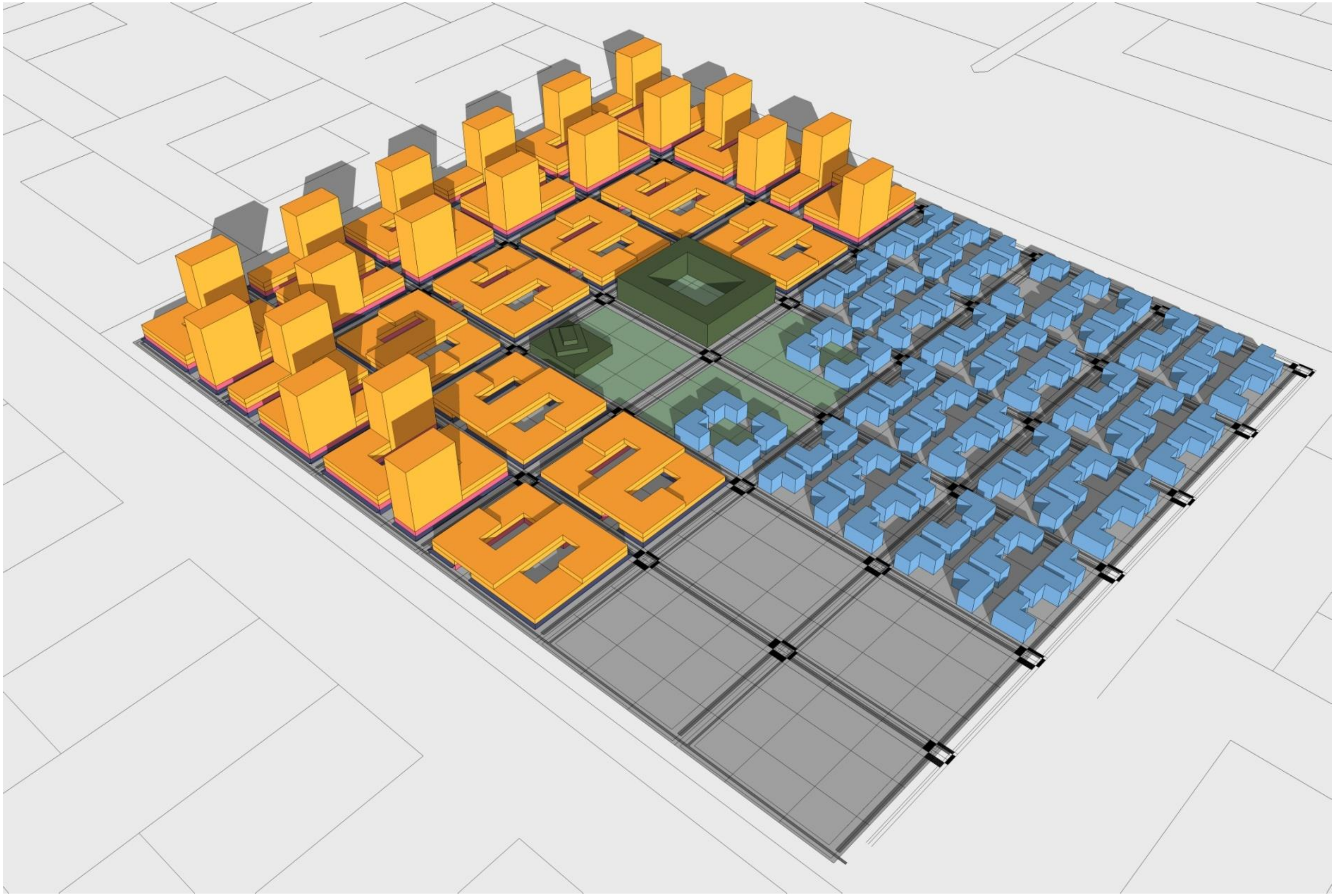
APARTMENT BLOCKS



INDEPENDENT VILLAS



RECLAIM GREEN



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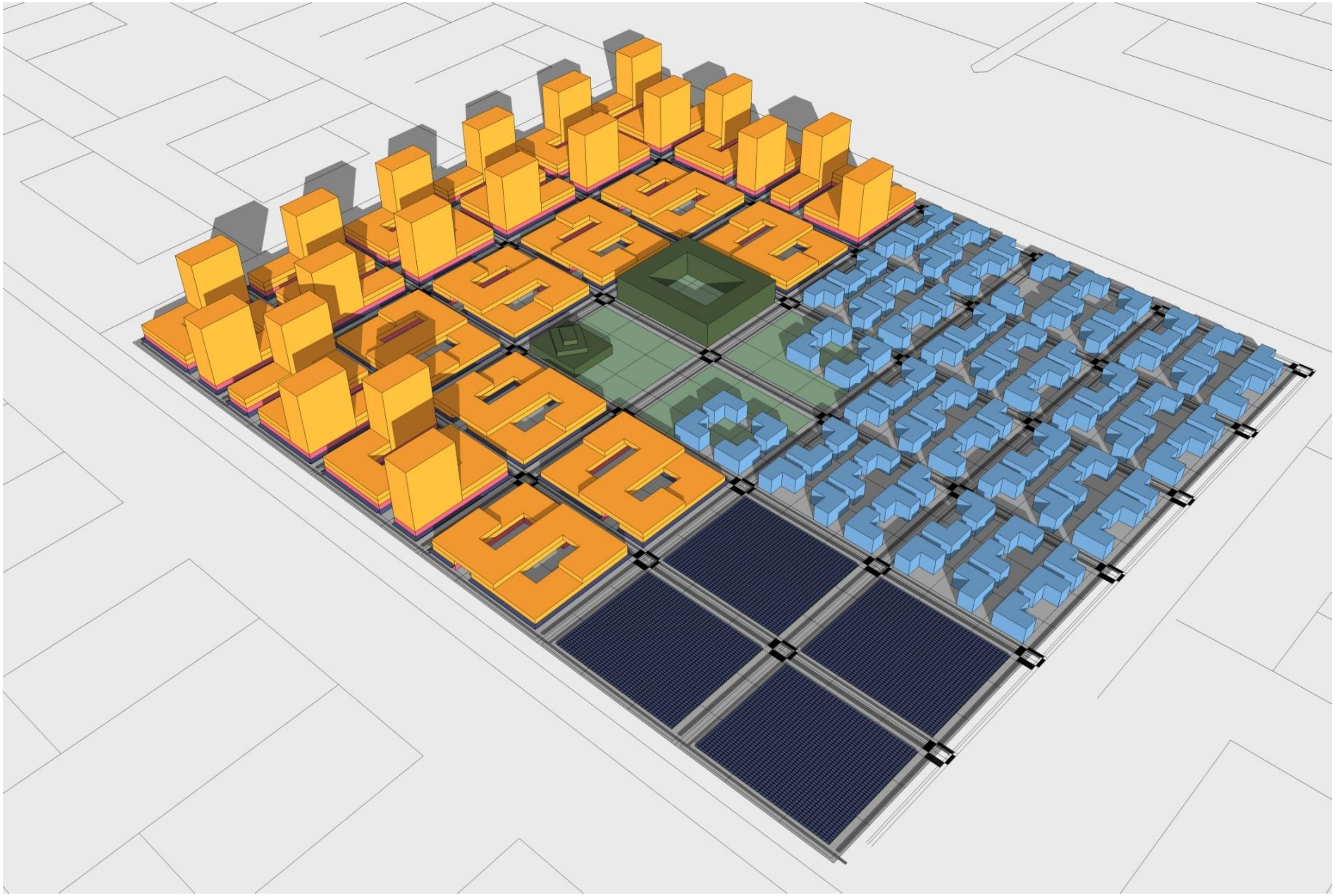
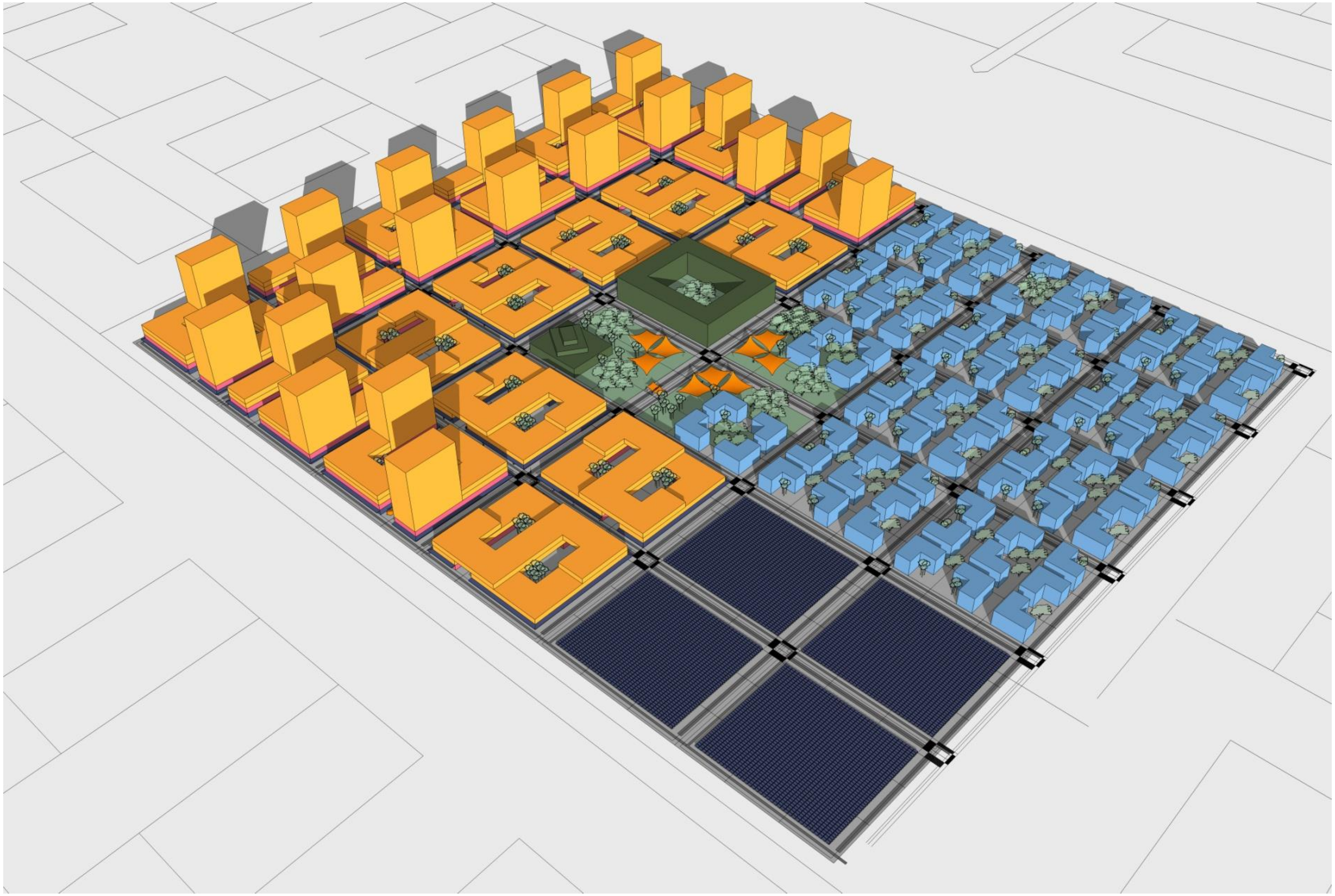
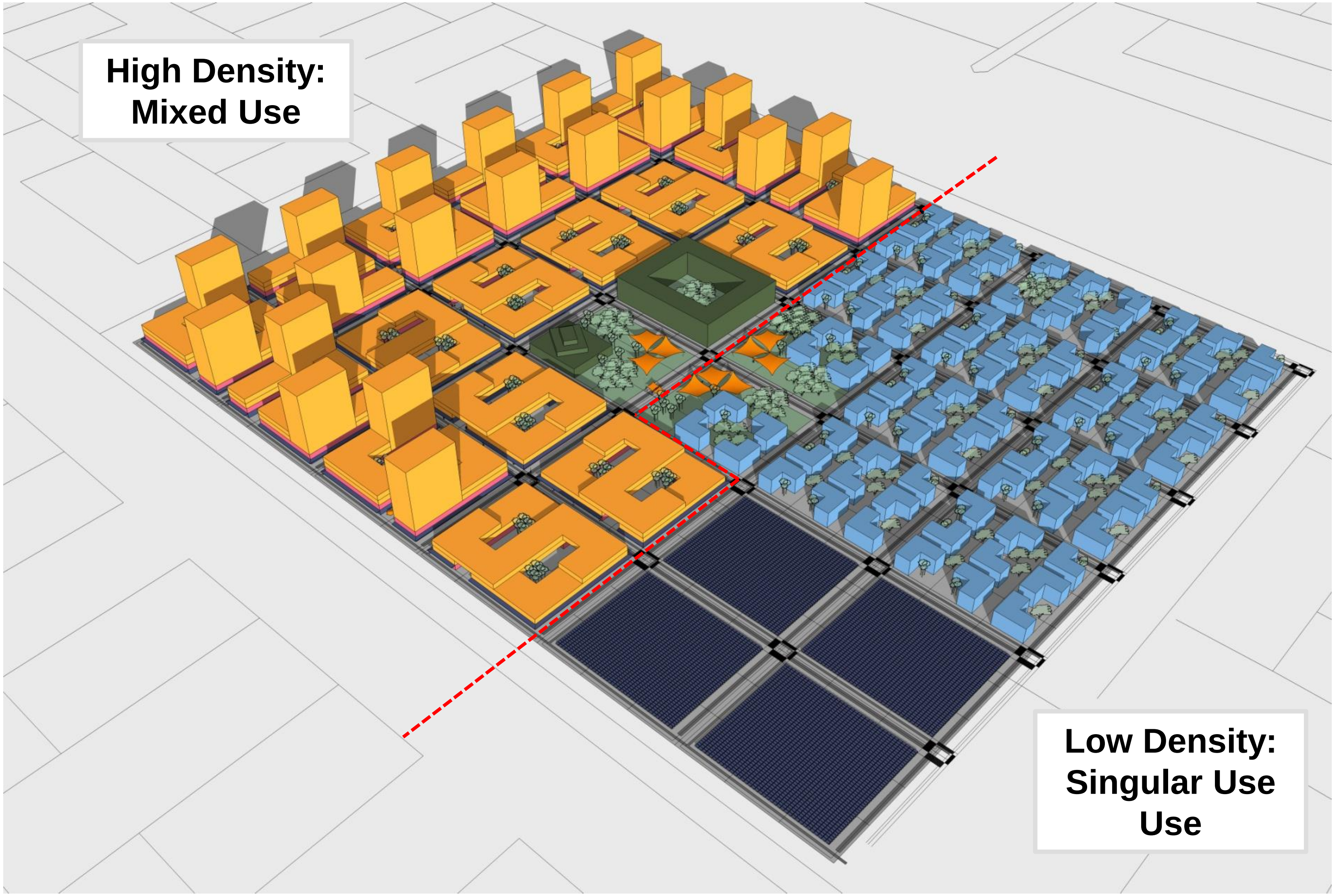
SOLAR FARM



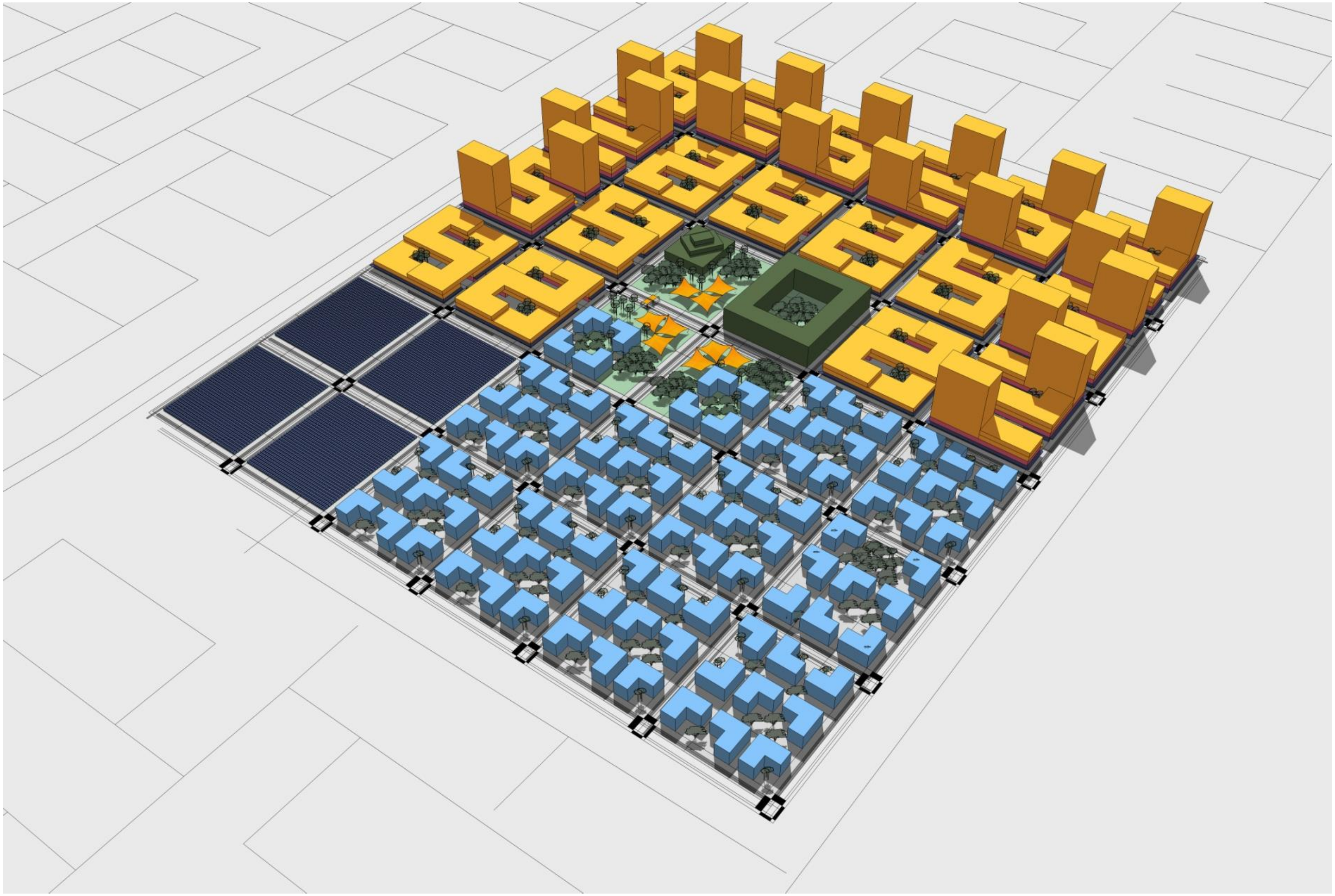
PROPOSED NEIGHBORHOOD



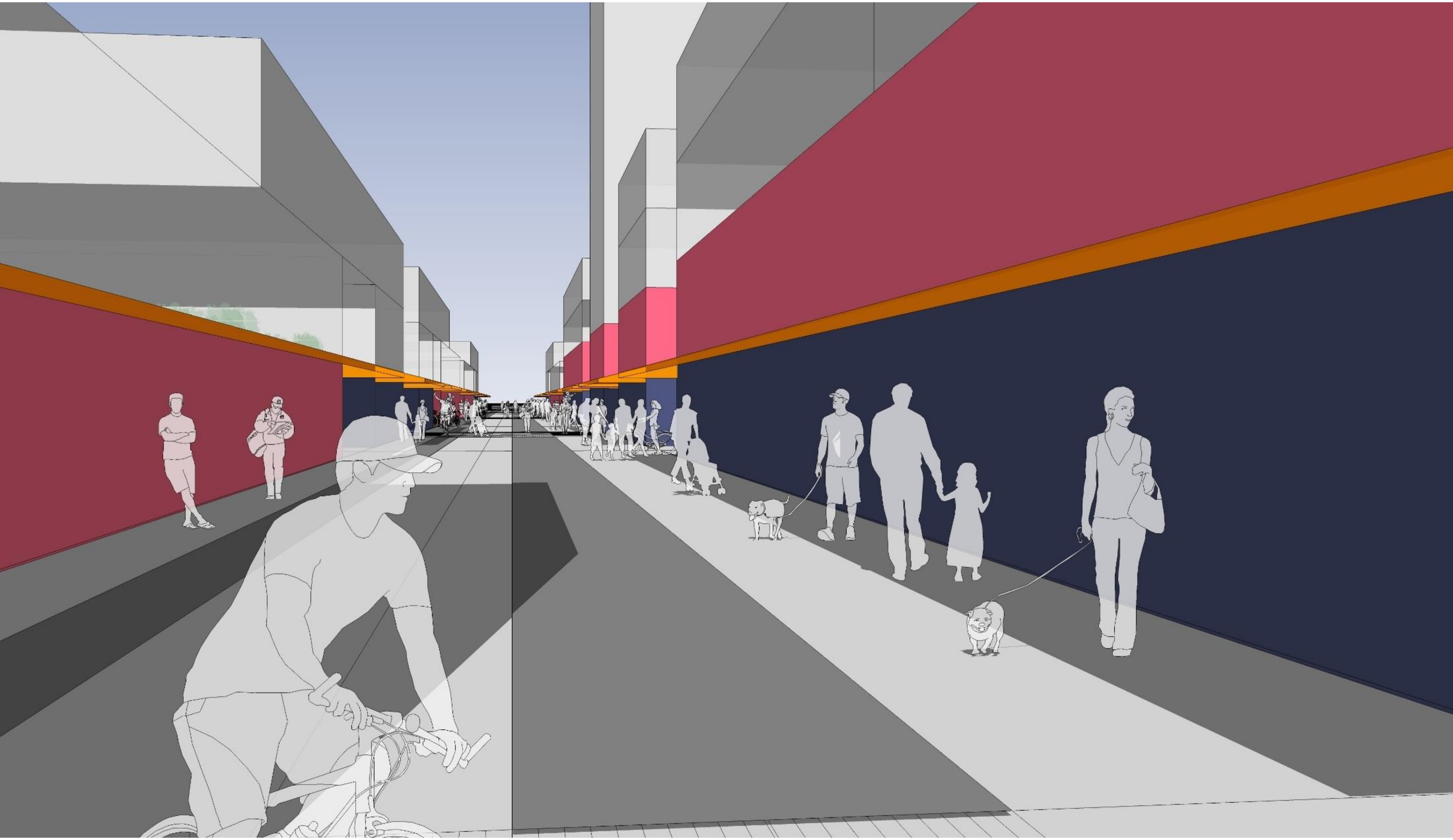
NEIGHBORHOOD DENSITY



PROPOSED NEIGHBORHOOD



INSIDE THE CANYONS



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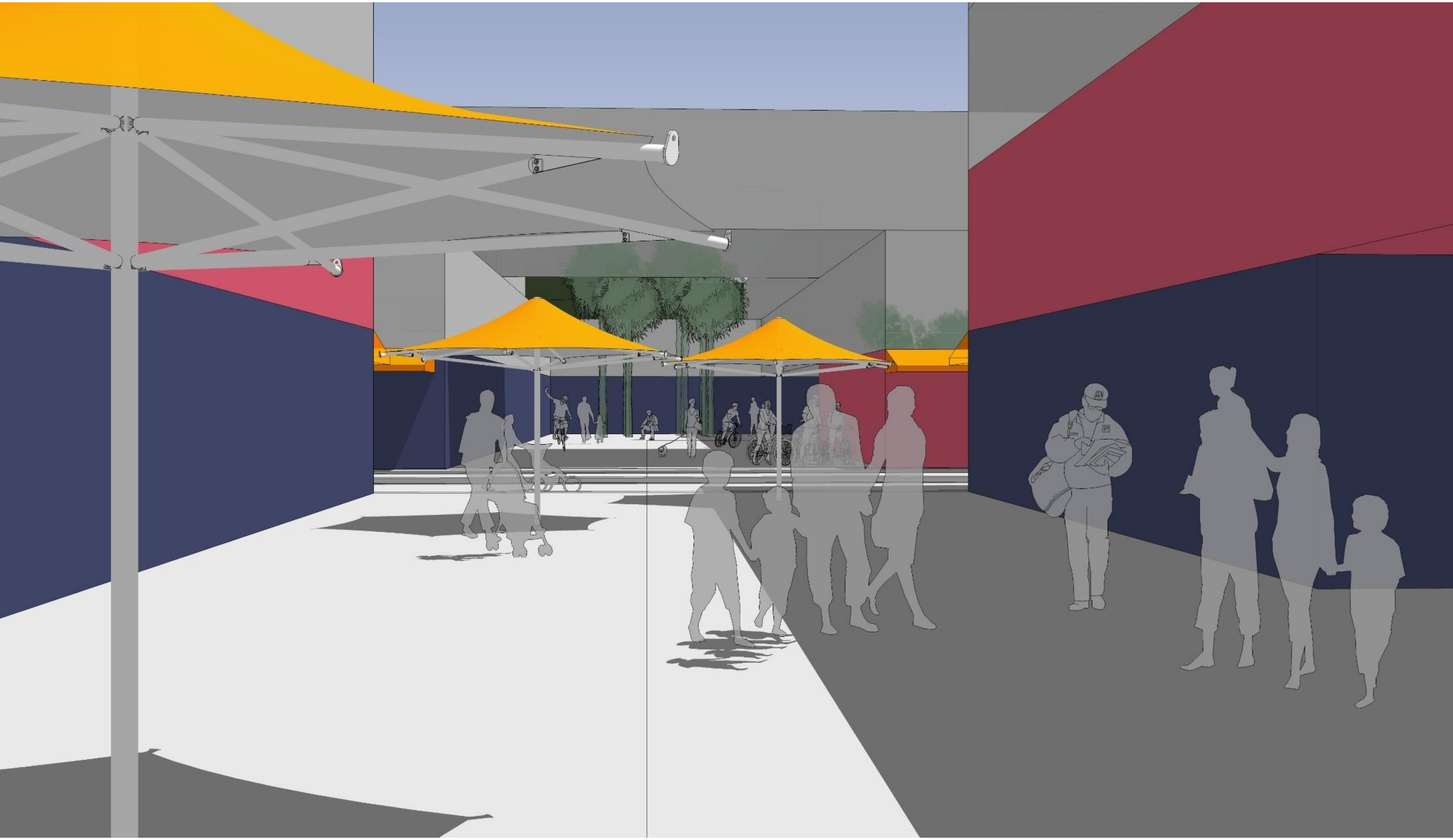
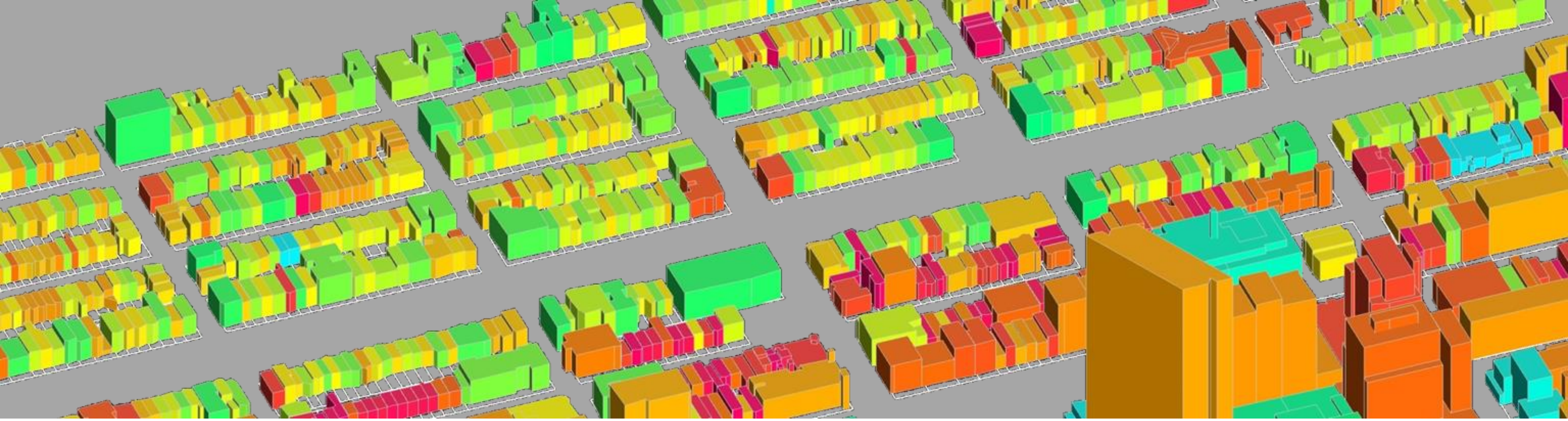
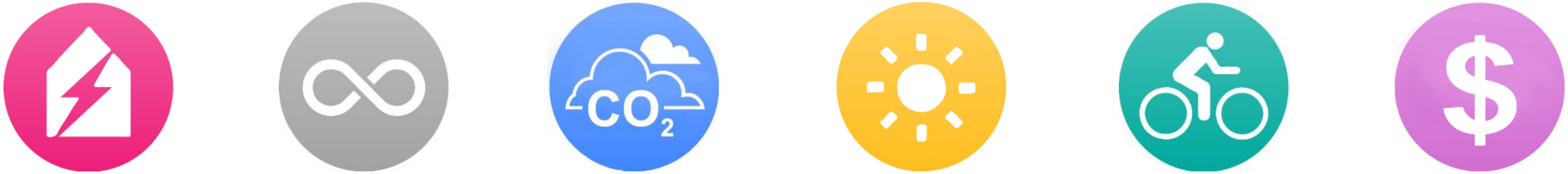




Kuwait City

Land area (m^2)	188,178
Building area (m^2)	312,536
Residents (pp/m^2 land)	0.032
Workers (pp/m^2 land)	0.056

141	2,100	8,500	72	74	16
kWh/m^2y	**kWh/m^2**	**kgCO2/m^2**	**% DA**	**% WS**	**% ROI**
OPERATION ENERGY	EMBODIED ENERGY (50y)	BUILDING GHG EMISSIONS (50y)	DAYLIGHT AREA	WALKABILITY SCORE	FINANCIAL RETURN (1y)



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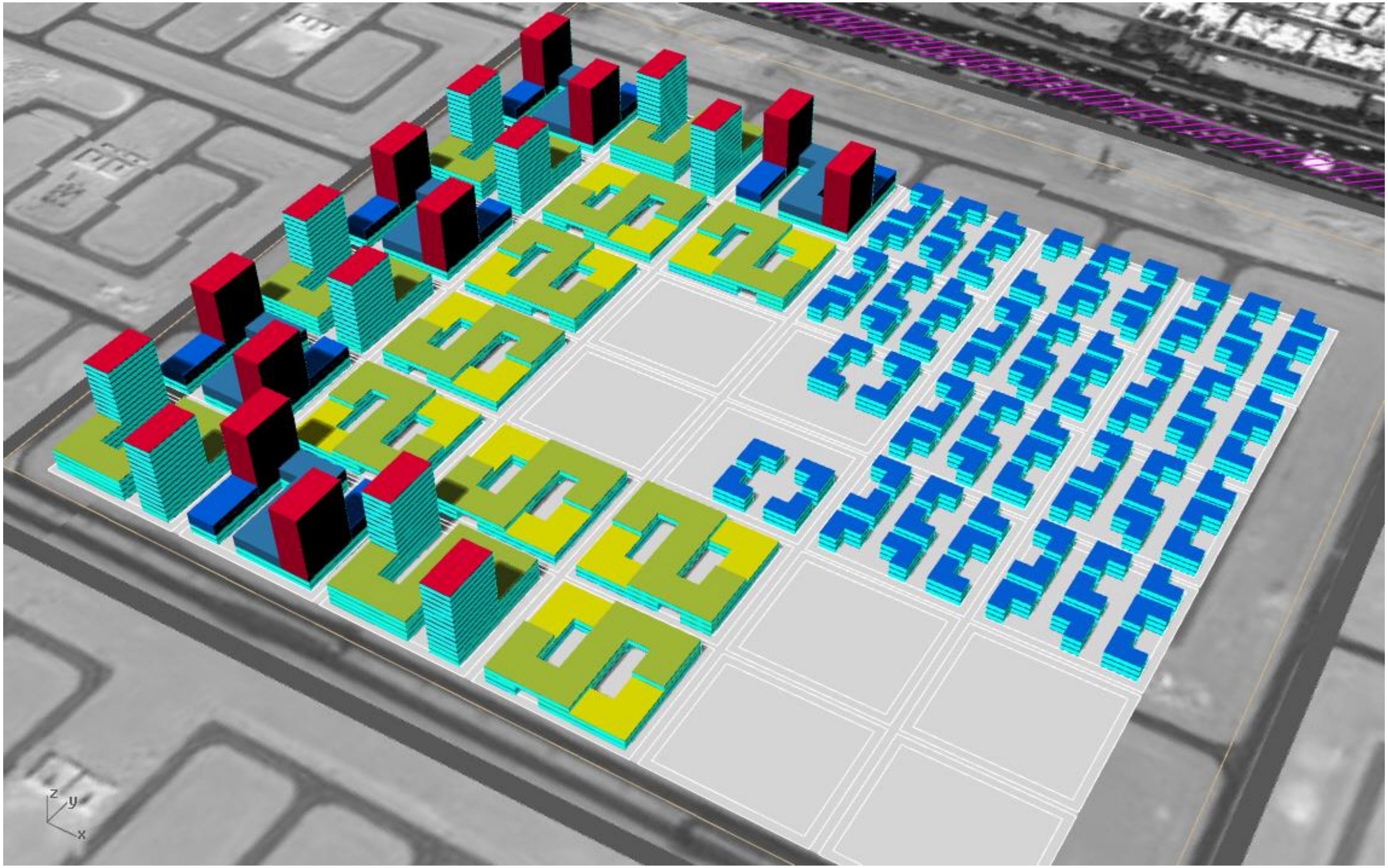
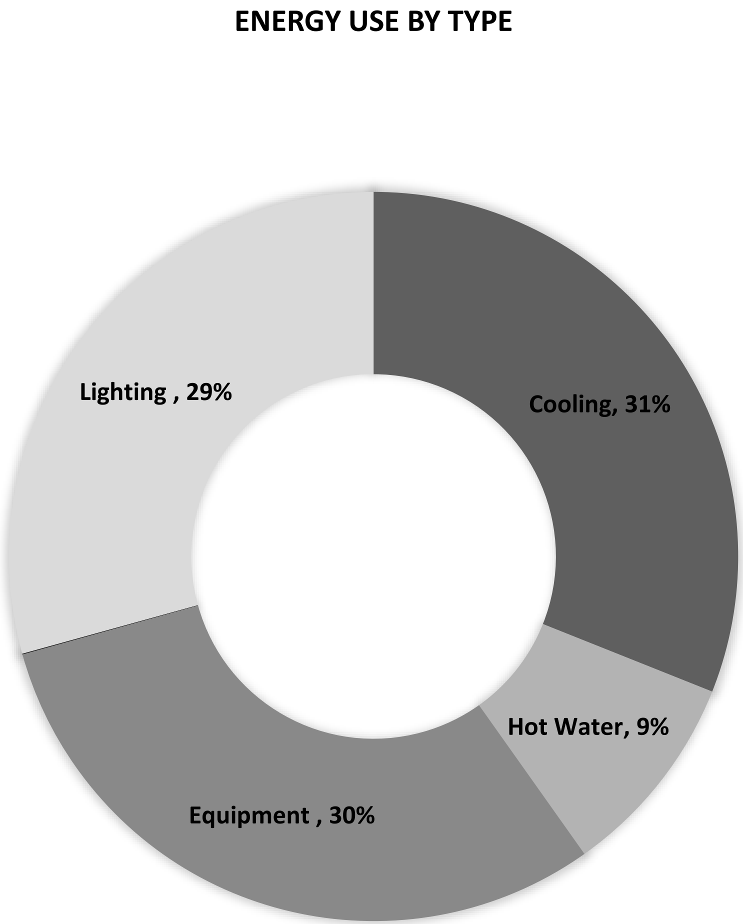
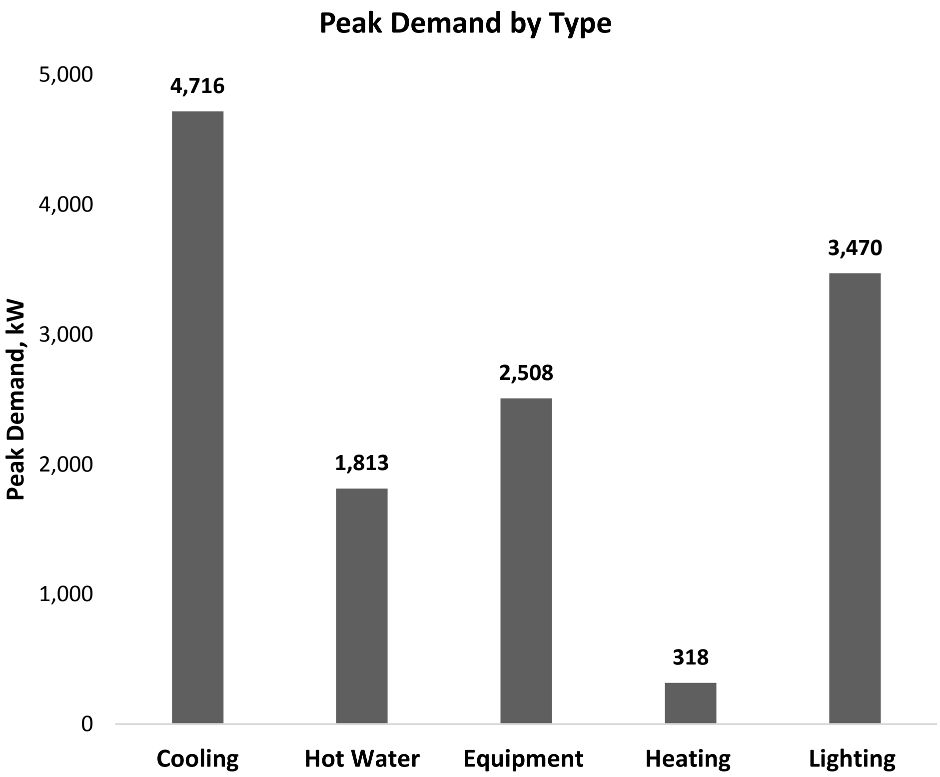
Energy Usage Color Map



Energy Consumption Details



11 MW Peak Demand

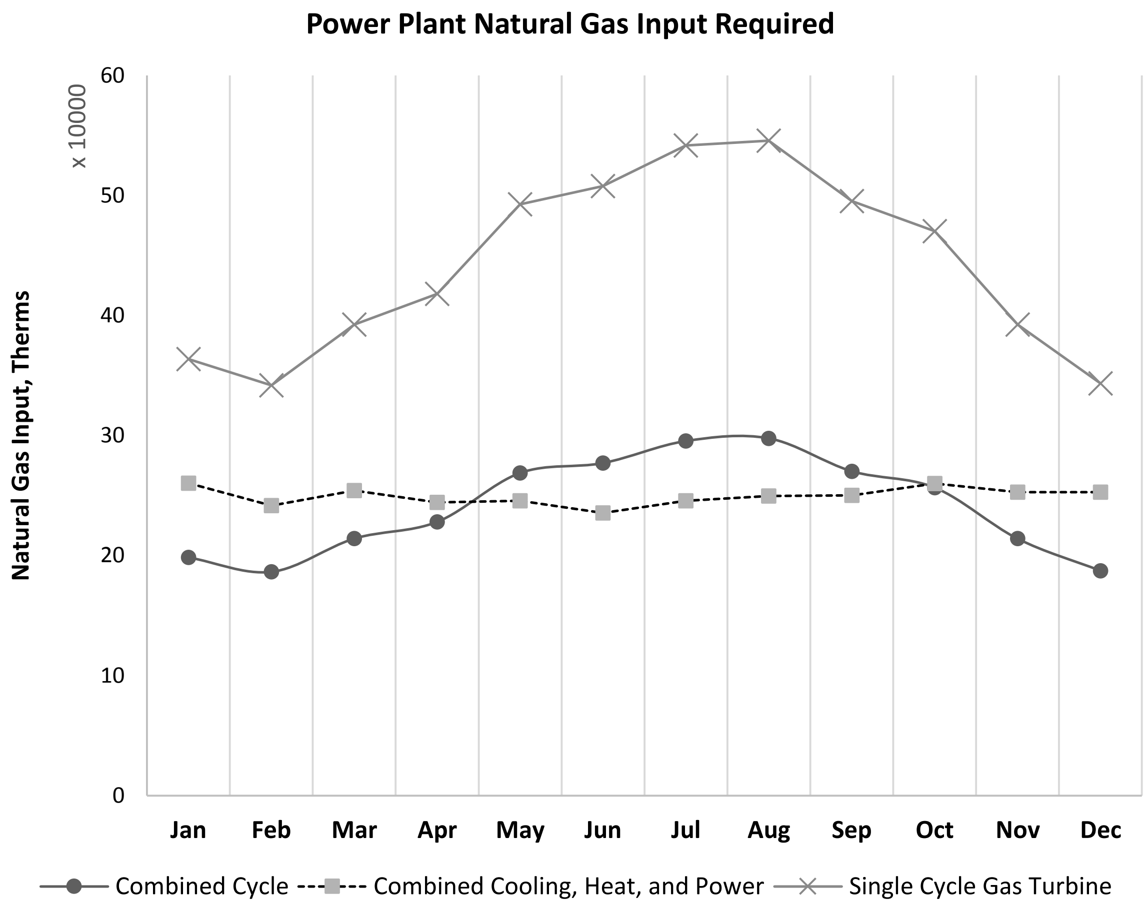


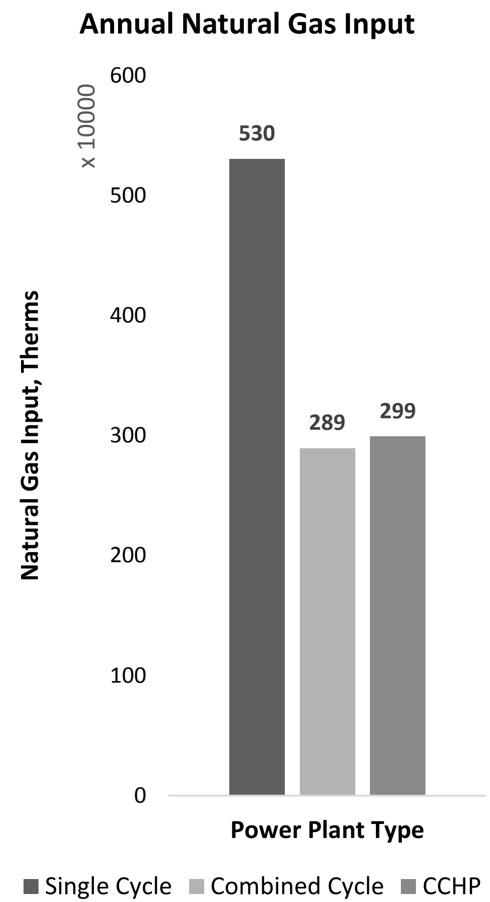
Energy Supply Strategies

Annual Metrics	**Single Cycle Gas Turbine Plant**	**Combined Cycle GT + ST Plant**	**Combined Cooling, Heat, and Power**
NG Input Therms	**5.3M**	**2.9M**	**3.0M**
Fuel Cost	**$9.0M**	**$4.9M**	**$5.1M**
CO_2 Metric Tons	**28.1k**	**15.3k**	**15.9k**

Natural Gas Input Required

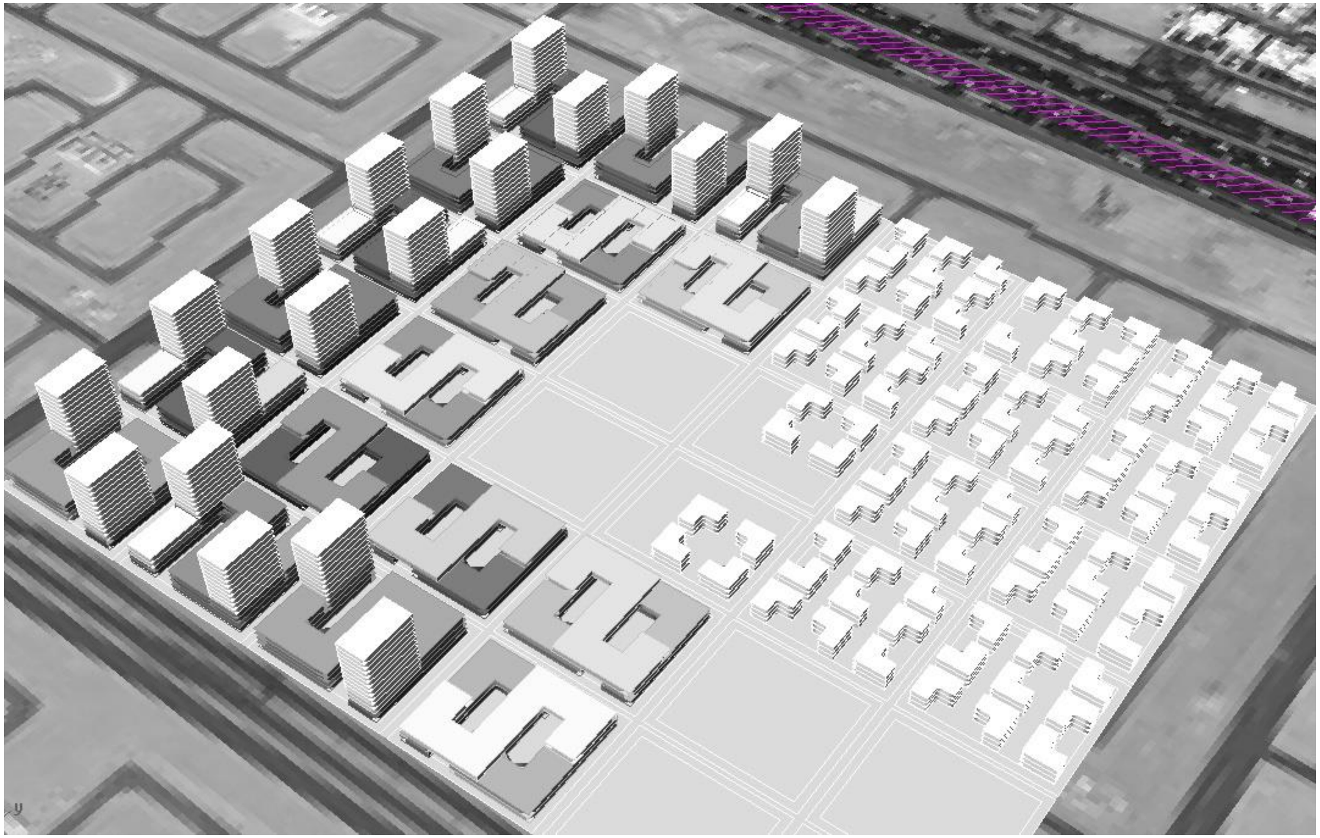
Combined Cycle and CCHP plants' predicted energy consumption are ~45% of a standard, single cycle natural gas turbine plant.





72% Daylight Autonomy

Primary drivers of high access to daylight were (1) large 80% WWRs and (2) use of short residential villas



Next Steps

1. Include financial analysis of power plant options

2. Determine feasibility of using a Rankine power cycle in Kuwait

3. Combine photovoltaic potential analysis with the previously shown power plant models

4. Apply power plant models to larger areas

APPENDIX

URBAN RULE | PERFORMATIVE

DESIGN SIDE: Maximum EUI

RETAIL

175 kWh / sq.m.

OFFICE

75 kWh / sq.m.

RESIDENTIAL

115 kWh / sq.m.

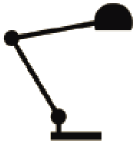
OCCUPANT SIDE: pricing

Building owners pay
4 fils (0.01 USD) per kWh
for all energy consumed
under the threshold

Building owners pay
60 fils (0.15 USD) per kWh
for all energy consumed
above the threshold

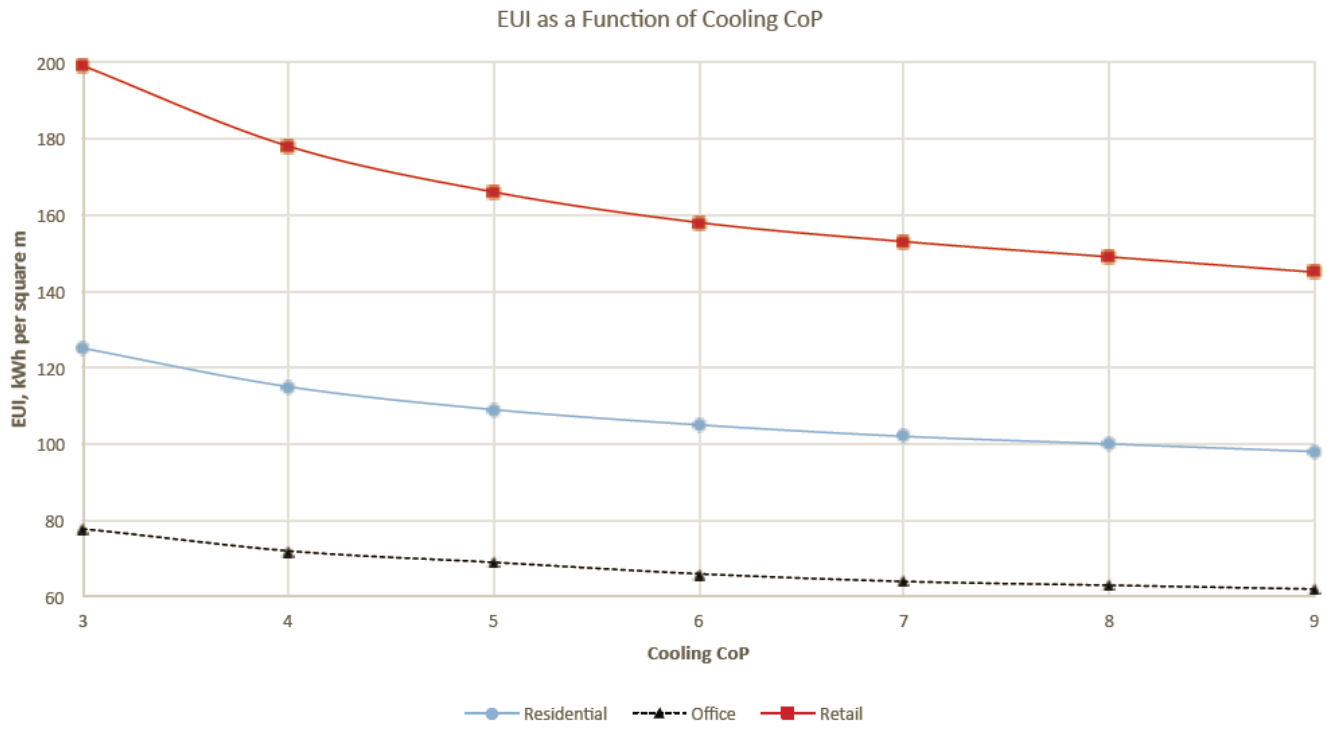
icons by: Dennis Nicolai Andersen, Ralf Schmitzer, chiccabubble

URBAN RULE | PRESCRIPTIVE

	MINIMUM COOLING CoP	DIMMING REQUIREMENTS	MAXIMUM INFILTRATION
 RETAIL	6	continuous	0.08 ACH
 OFFICE	6	continuous	0.03 ACH
 RESIDENTIAL	6	continuous	0.03 ACH

icons by: Dennis Nicolai Andersen, Ralf Schmitzer, chiccabubble

PARAMETRIC ANALYSES | cooling CoP



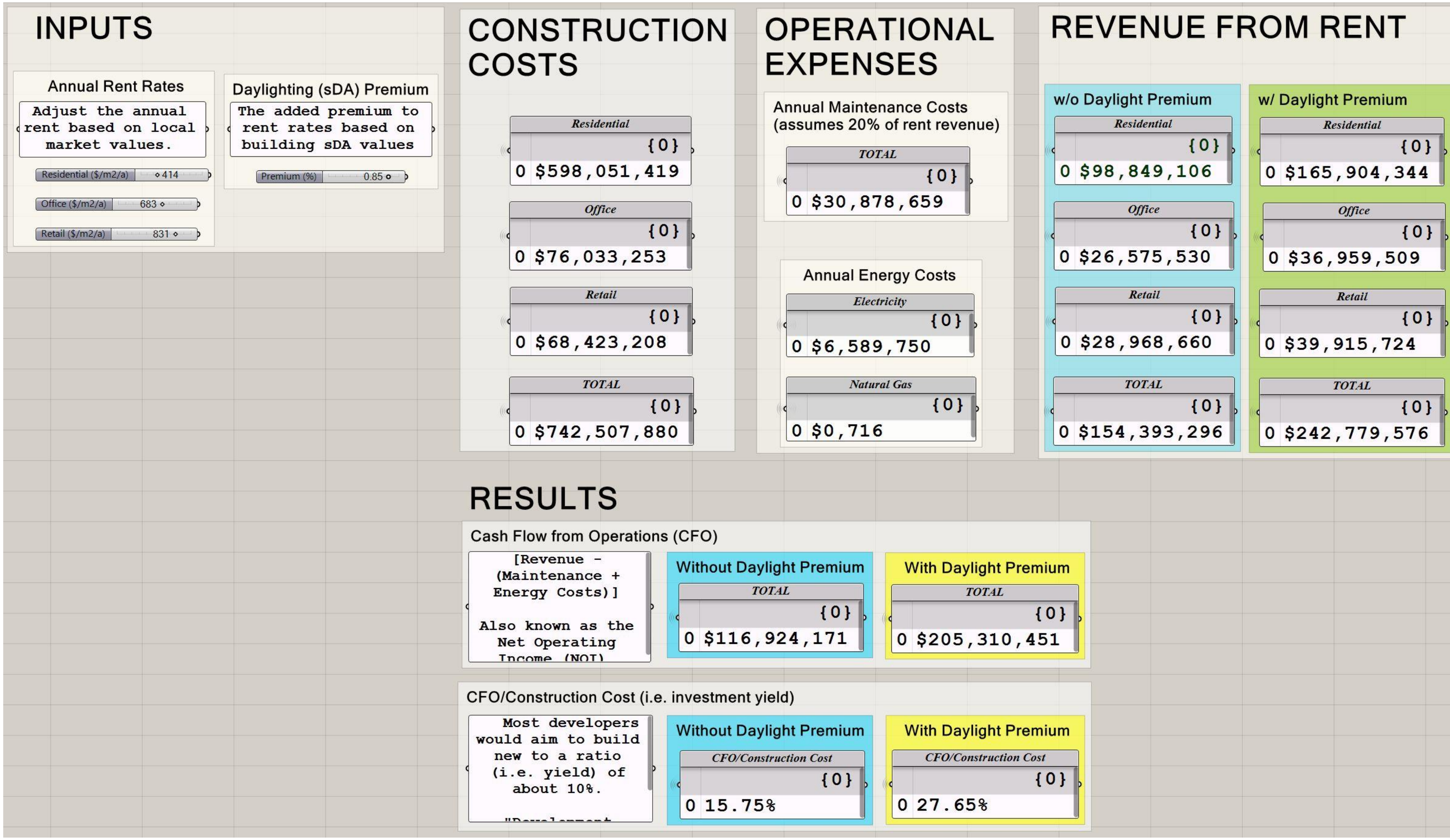
PARAMETRIC ANALYSES | cooling CoP percent change in EUI

Residential							
Cooling COP	3	4	5	6	7	8	9
EUI	125	115	109	105	102	100	98
% Change		-8.0%	-5.2%	-3.7%	-2.9%	-2.0%	-2.0%

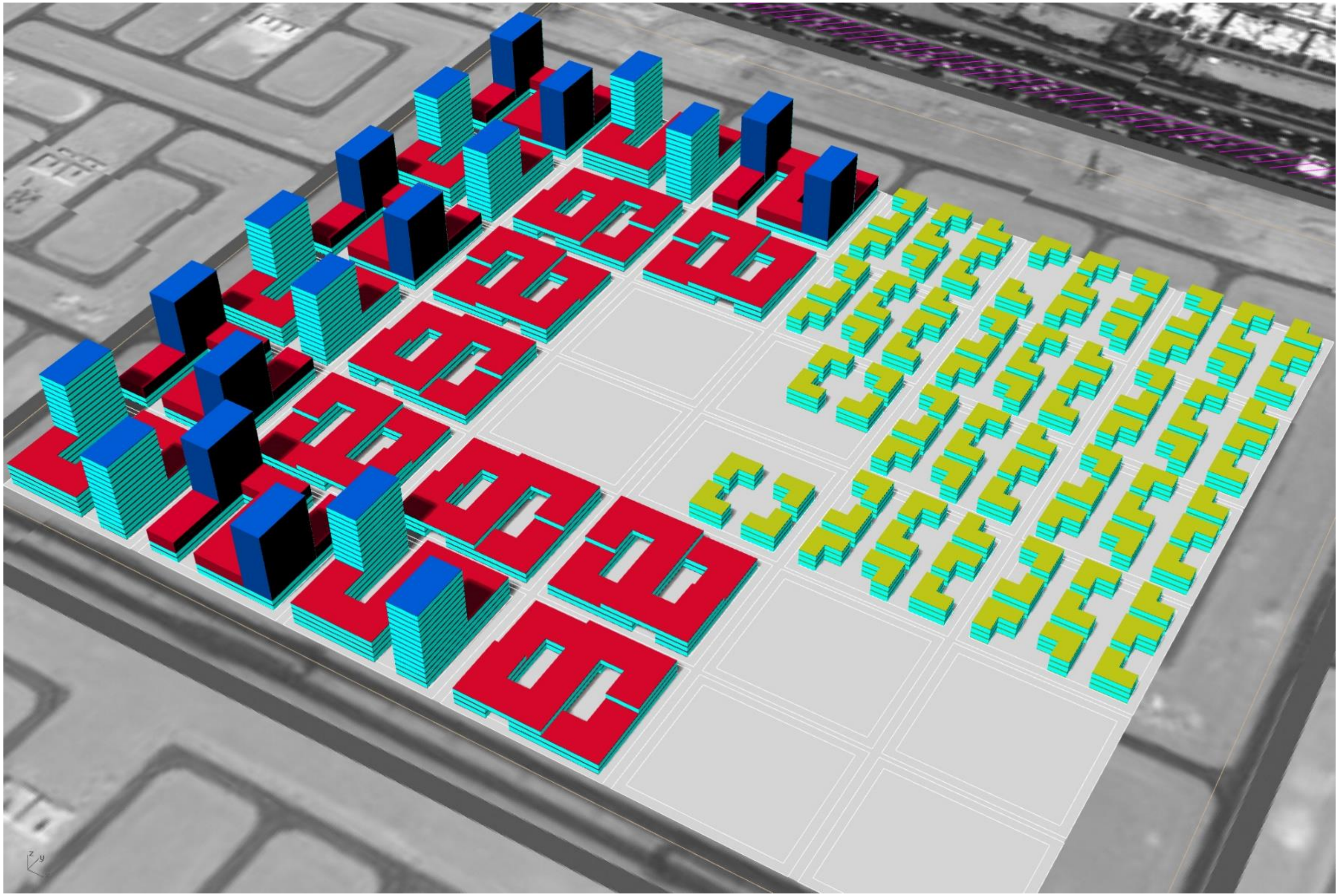
Office							
Cooling COP	3	4	5	6	7	8	9
EUI	78	72	69	66	64	63	62
% Change		-7.7%	-4.2%	-4.3%	-3.0%	-1.6%	-1.6%

Retail							
Cooling COP	3	4	5	6	7	8	9
EUI	199	178	166	158	153	149	145
% Change		-10.6%	-6.7%	-4.8%	-3.2%	-2.6%	-2.7%

Financial Results

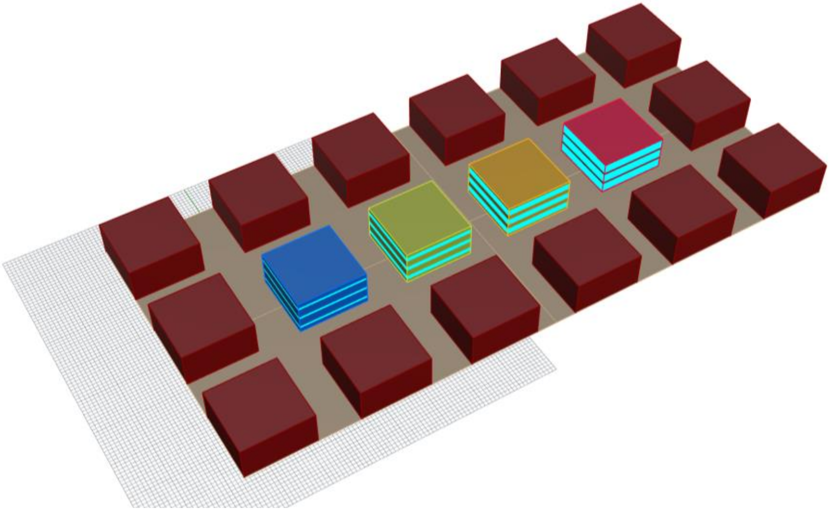


Embodied Energy Falsecolor



Energy Parametric Studies

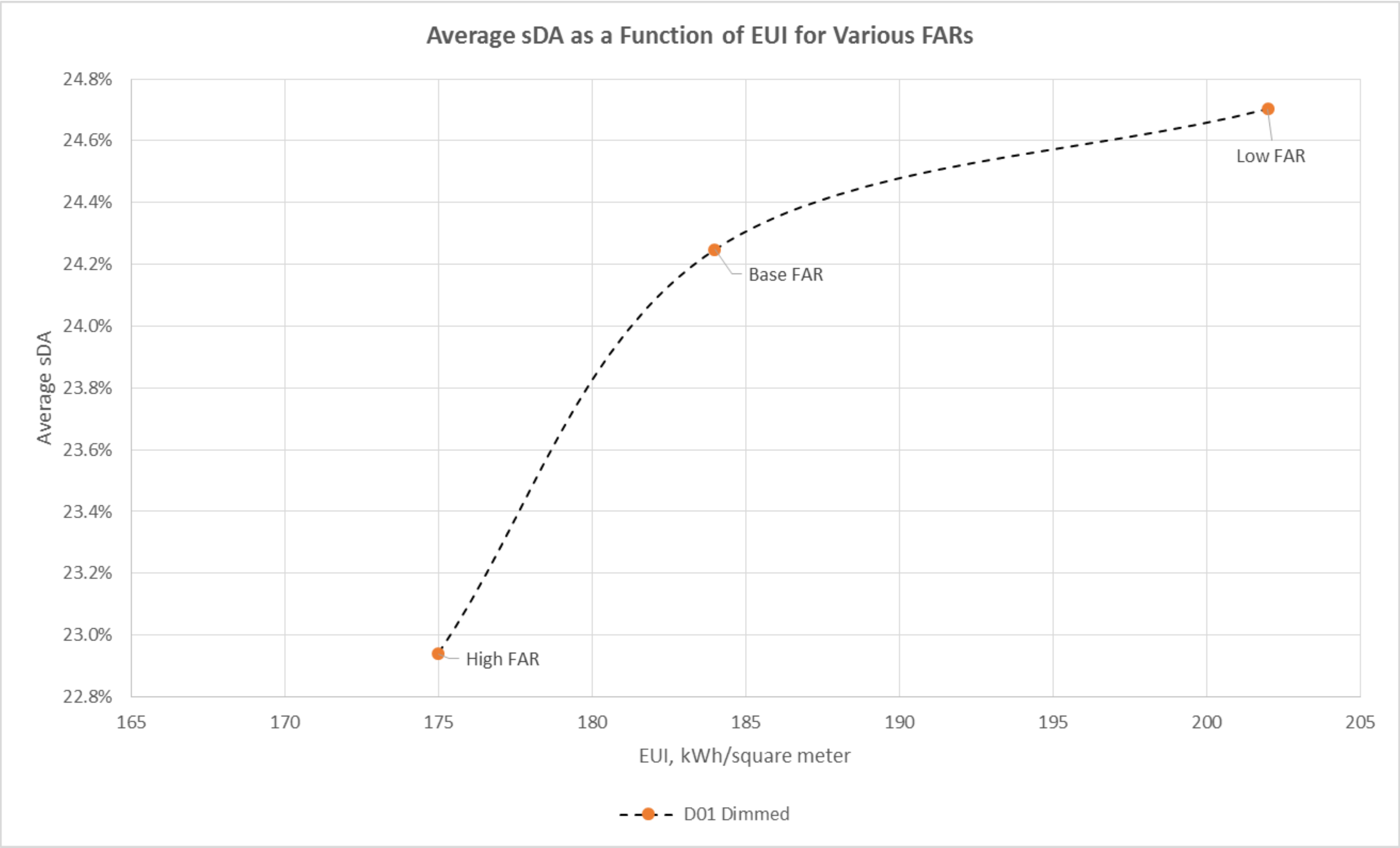
Approach: We used the simplified blocks below to determine the impact of 6 different parameters on EUI.



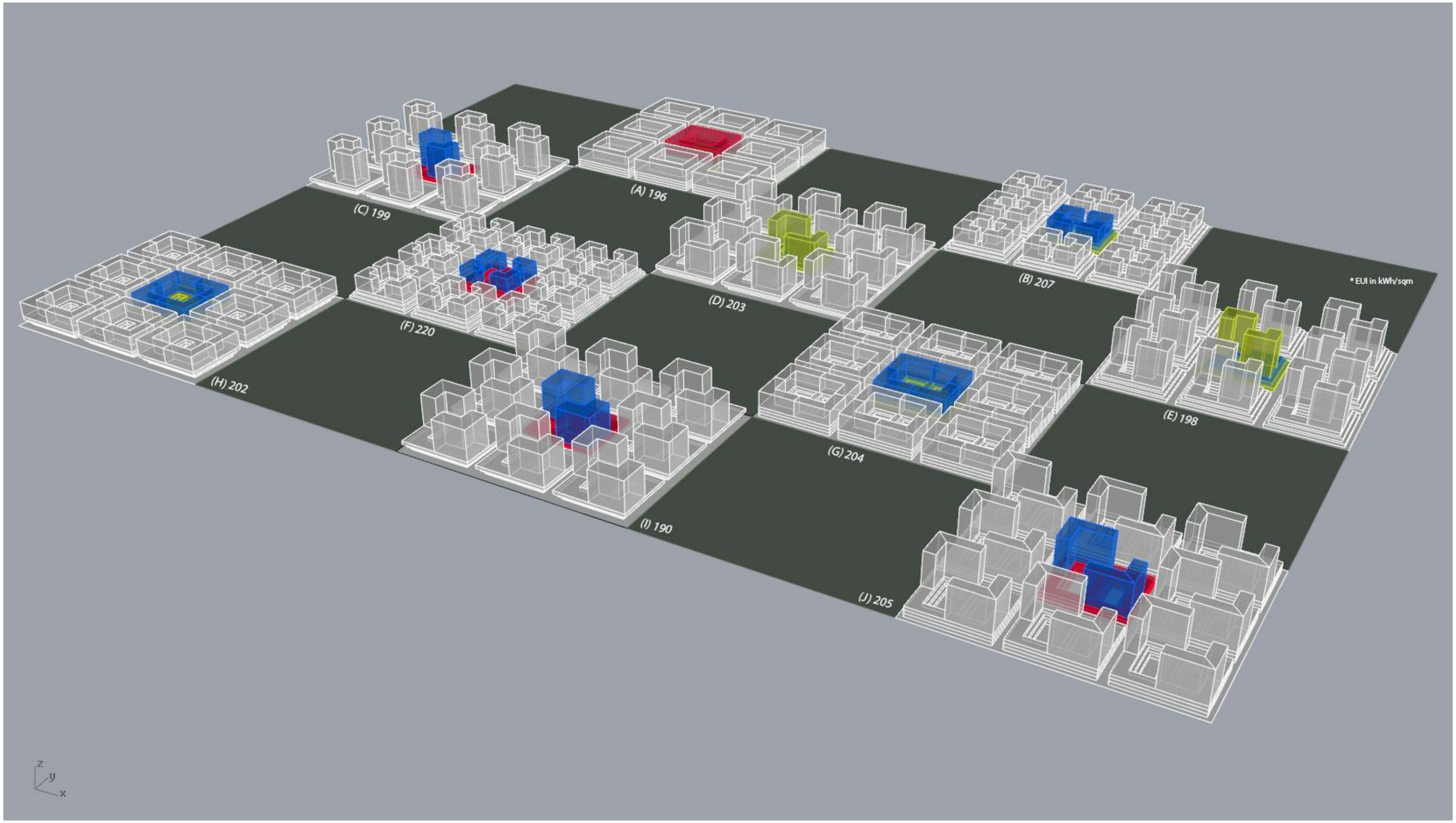
Tested Parameters

1. **WWR** Higher WWRs increased EUI
2. **Dimming** decreased EUI
3. **Internal Mass** had no impact
4. **Infiltration** Higher rates increased EUI
5. **Building Height** Taller buildings decreased EUI
6. **Building Spacing** Greater distance between buildings decreased EUI

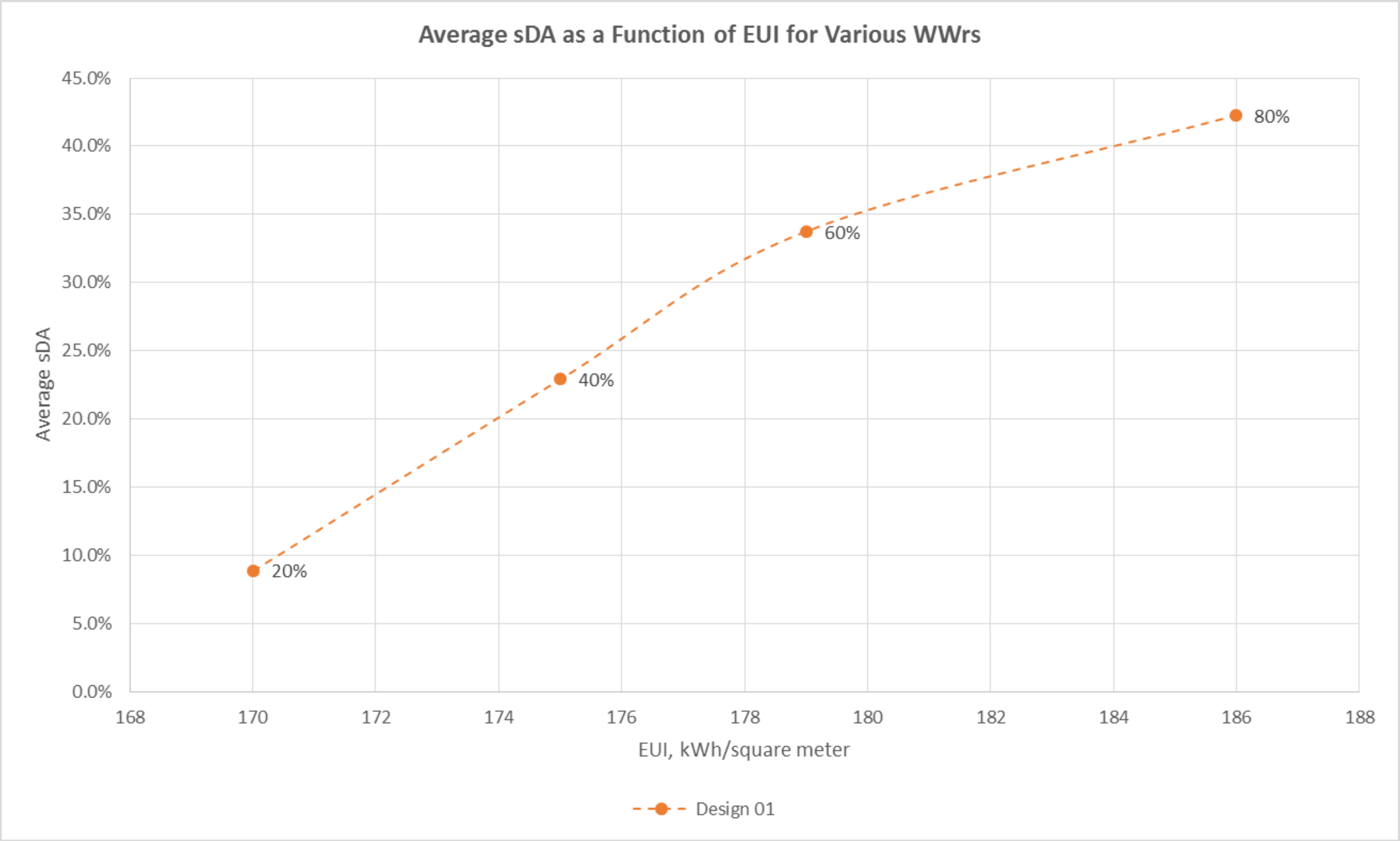
Daylight Parametric Studies



Other Tested Building Typologies

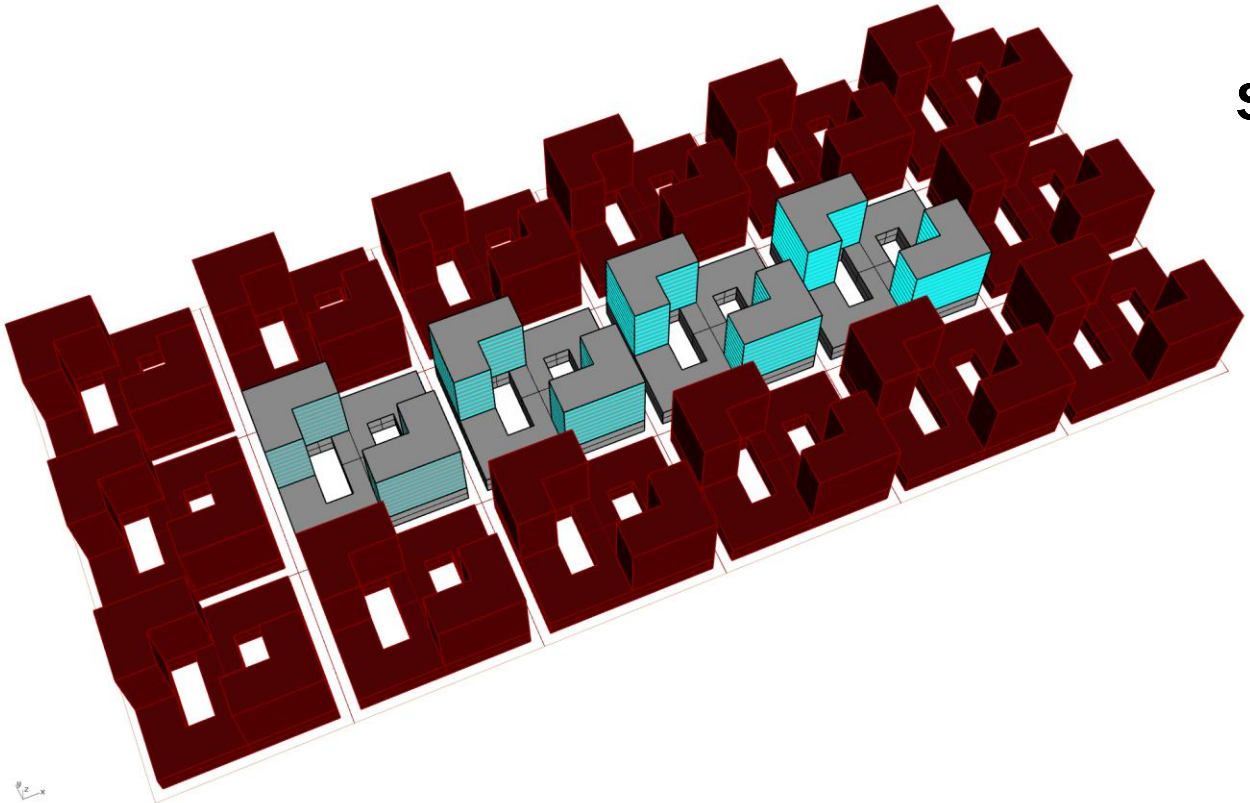


Daylight Parametric Studies



Reference Block

Our proposed reference block consisted of two residential towers with three floors of retail space below.

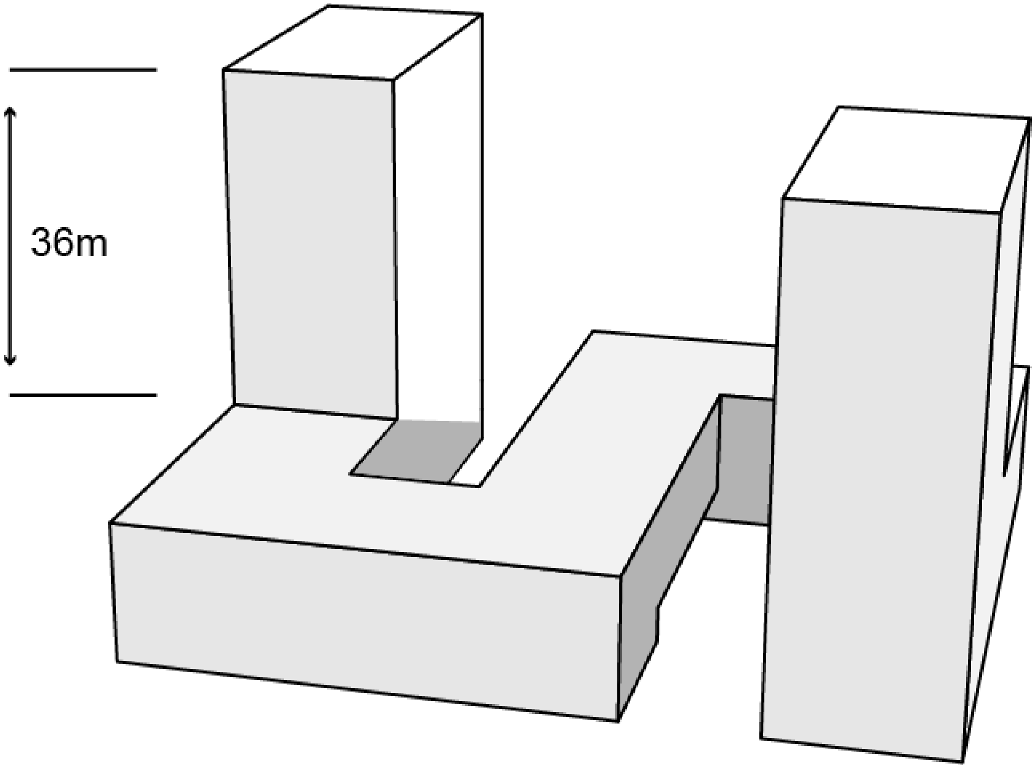


Select Characteristics

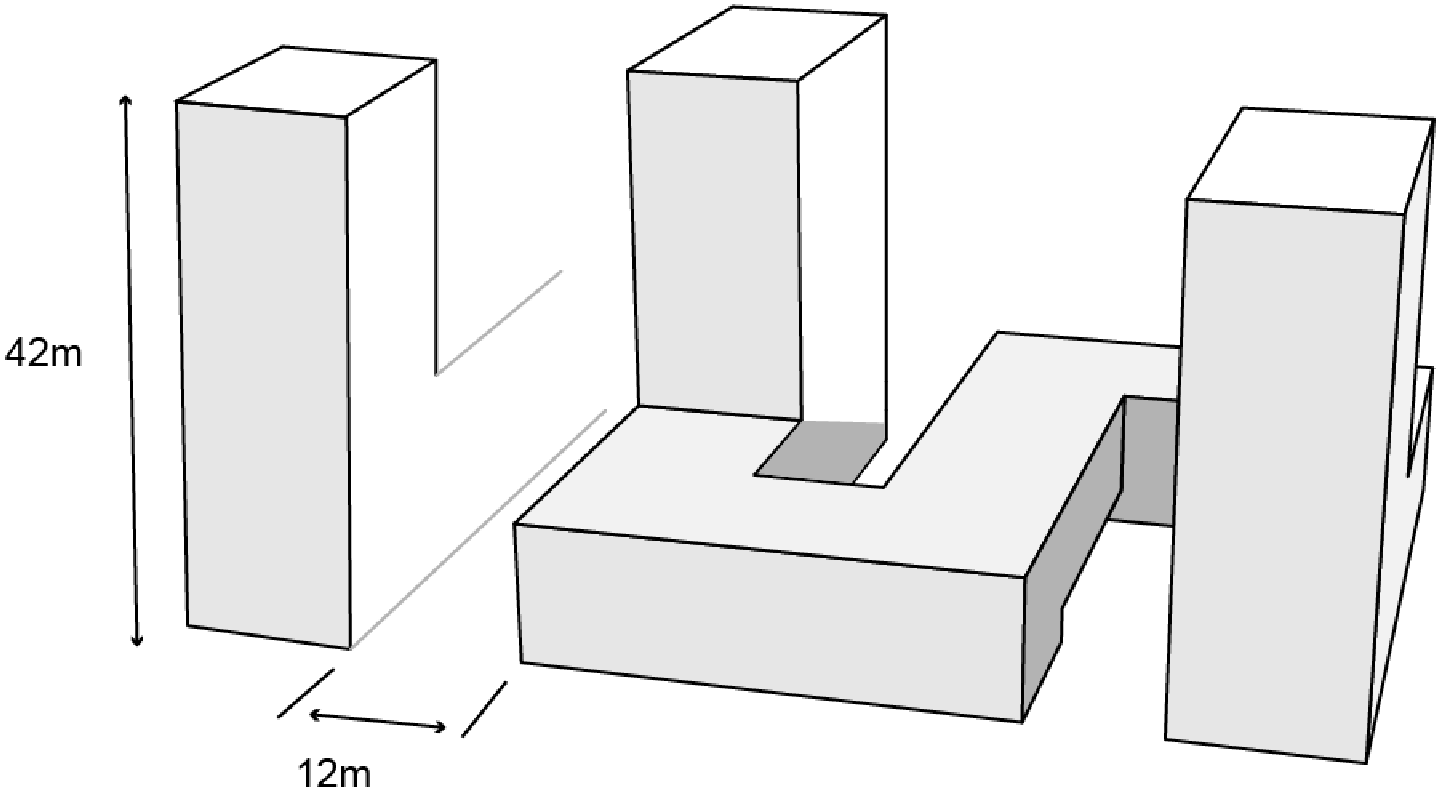
- FAR: 3.4
- Floors: 8
- WWR: 20%
- EUI: 211
- Average sDA: 25%

OPTIMIZING THE BLOCK TYPOLOGY

simulation results: larger tower height decreased EUI

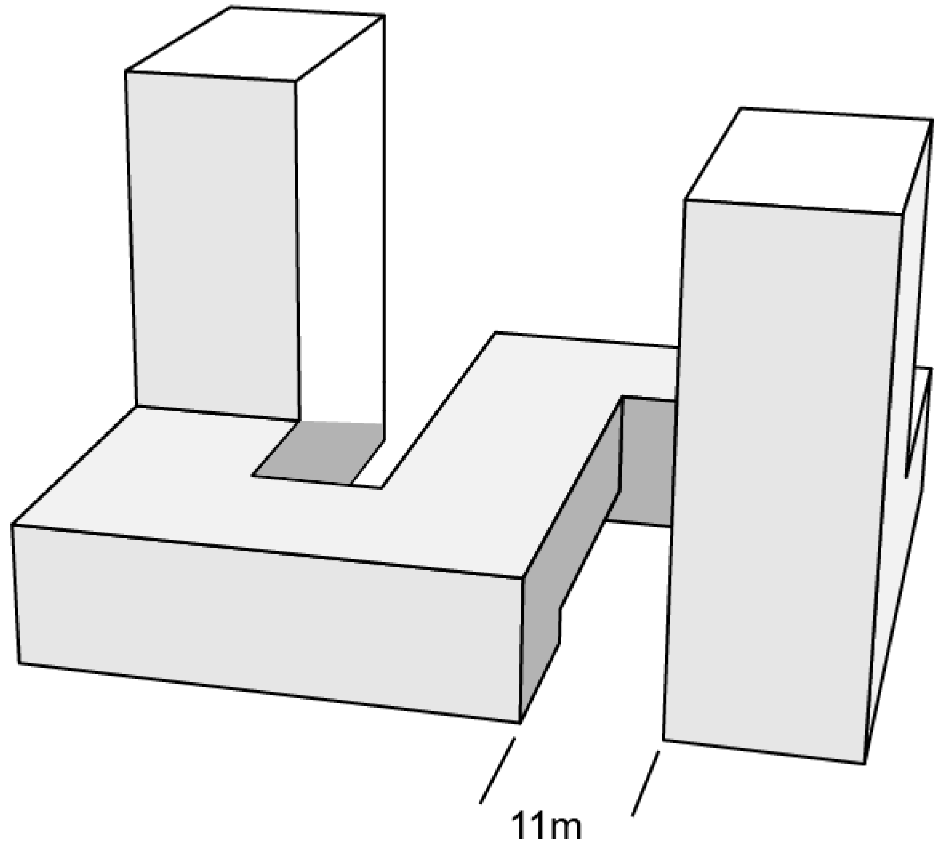


OPTIMIZING THE BLOCK TYPOLOGY



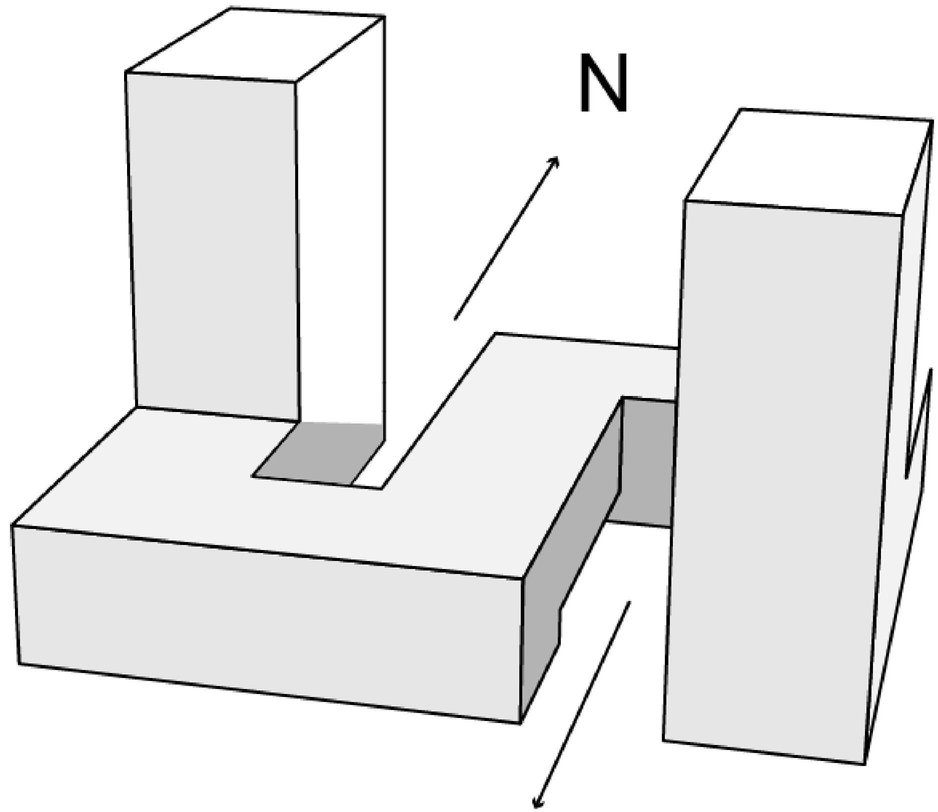
"**deep street canyons** in hot, dry climates experience
a considerably lower daytime air temperature
than shallow canyons" (Jamei et al., 2016)

OPTIMIZING THE BLOCK TYPOLOGY



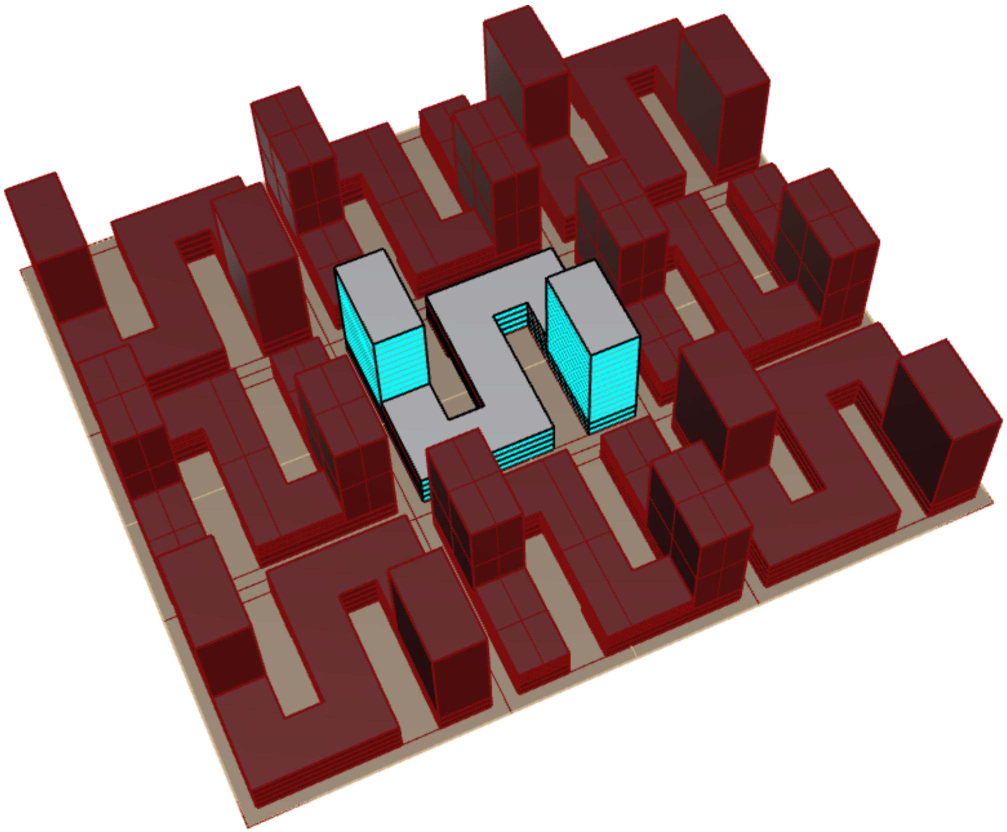
“the **small courtyard** is an excellent thermal regulator... if the courtyard’s size is kept small enough to achieve **shade during the day**, it will allow more heat dissipation from surrounding indoor spaces” (Heidari, 2010)

OPTIMIZING THE BLOCK TYPOLOGY



"**E–W oriented streets suffer** from a prolonged period of solar exposure during the summer compared with N–S oriented streets." (Jamei et al., 2016)

Current Block Design

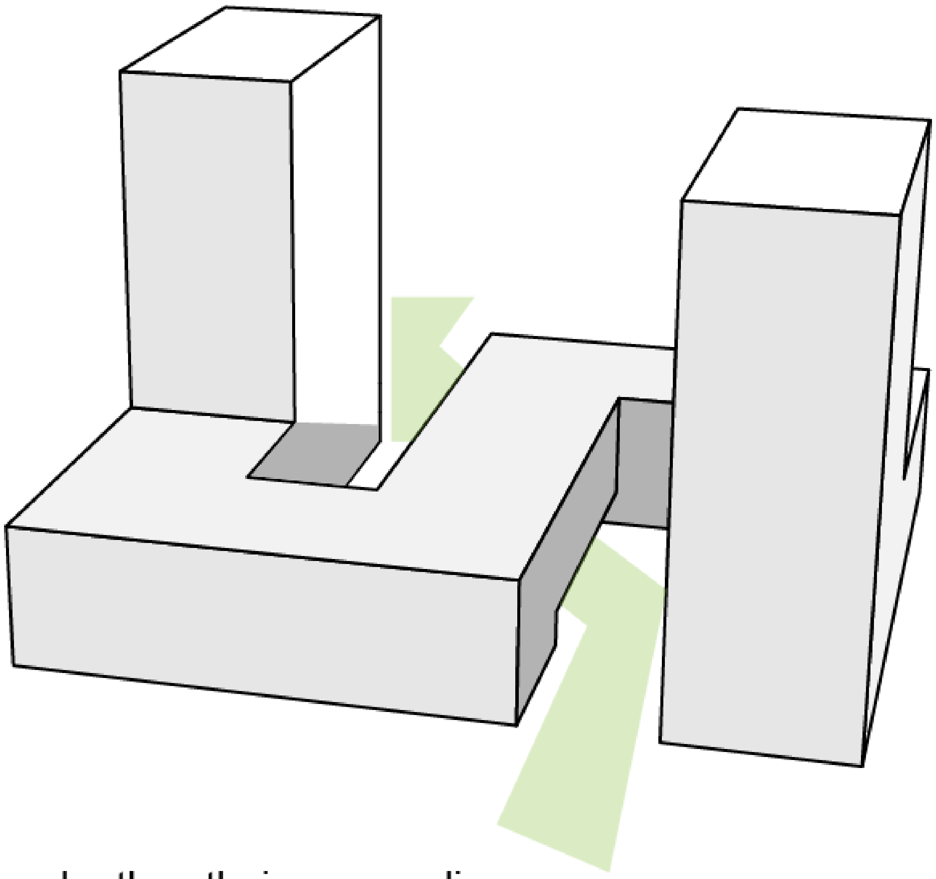


Select Characteristics

- FAR: 4.1
- Floors: 14
- WWR: 80%
- EUI: 124 vs. 211
- Average sDA: 51% vs. 25%

- NV estimated to reduce cooling load by 7%
- Max PV supplies ~35% of annual electric needs

OPTIMIZING THE BLOCK TYPOLOGY



“green areas are usually cooler than their surrounding built up areas, leading to a temperature difference of up to 1 to 7 degrees C” (Jamei, 2016)

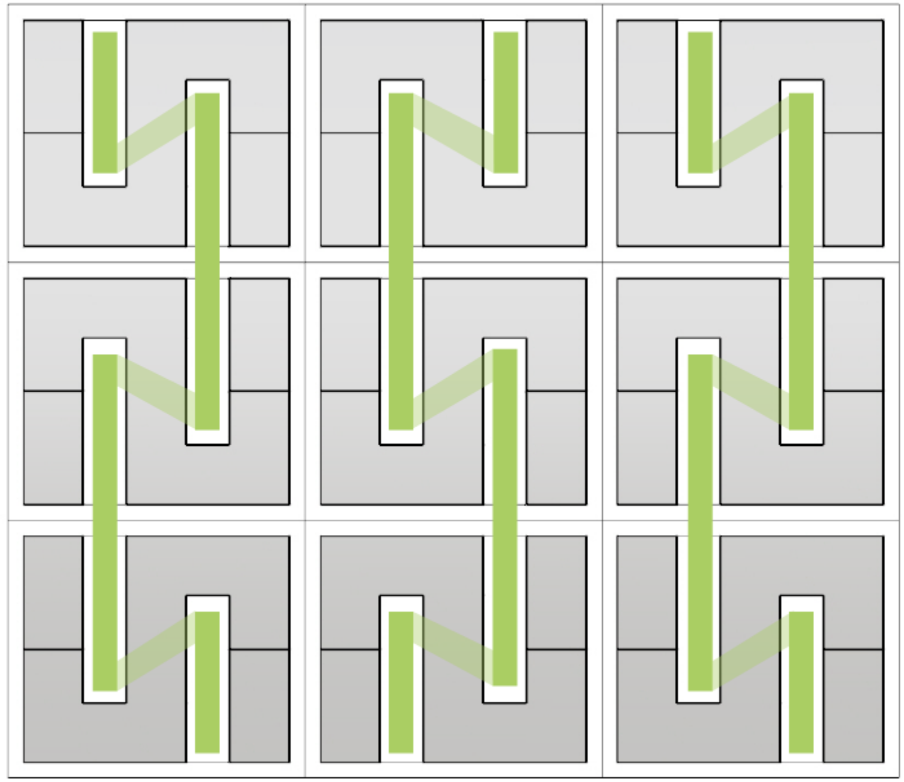
ADAPTIVE GREEN SPACE

- high water (and energy) intensity
- consumed 44.8 MM m^3/yr (2002)(only 12 MM m^3/yr was recycled)
- water table has risen 5m (2001)

- low water (and energy) intensity
- as population grows, so will wastewater quantities; as of 2002, 74 MM m^3/yr wastewater was not being re-used

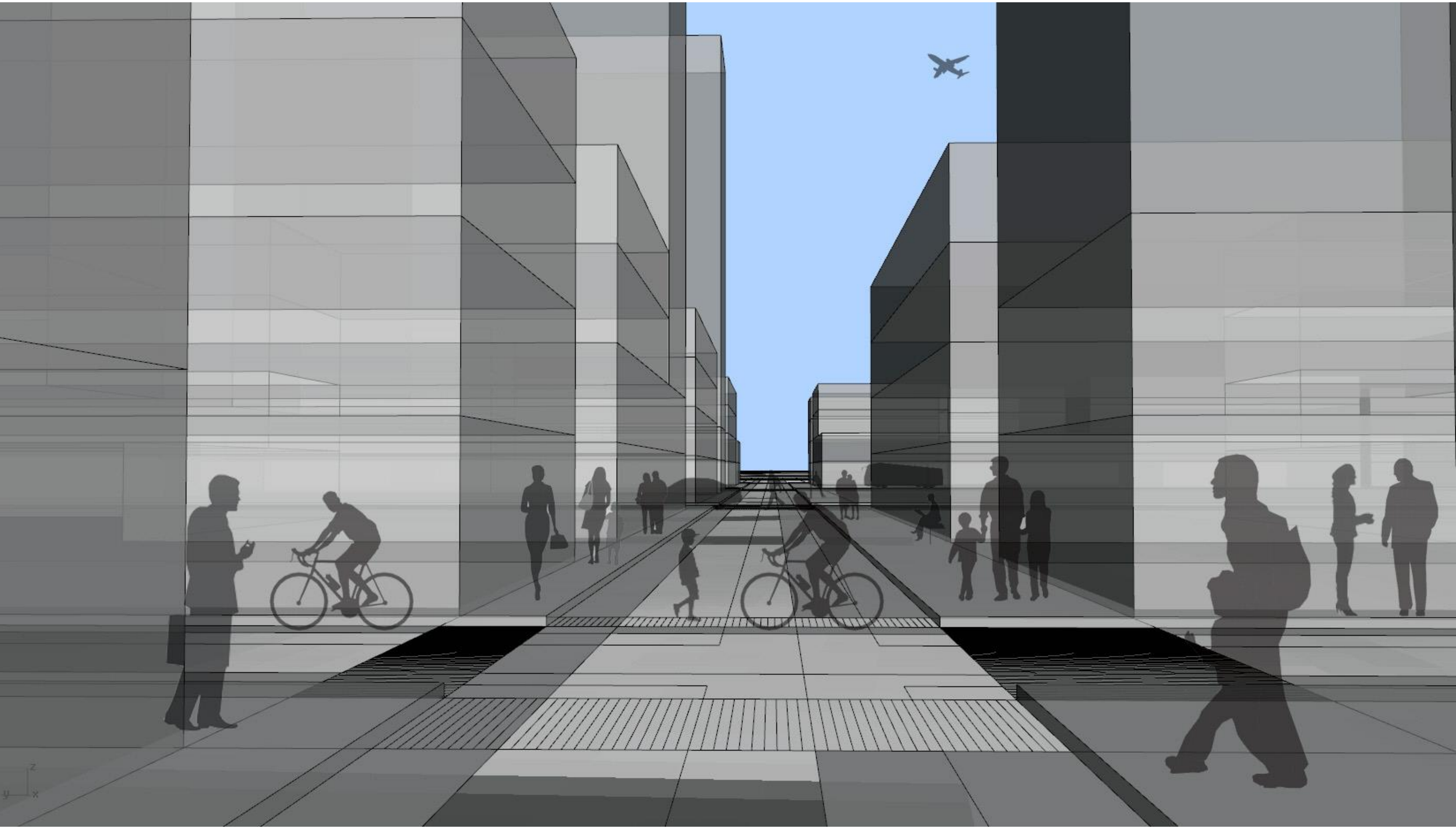
Images from: http://goo.gl/1D45AQ; https://goo.gl/mhr3nh; http://goo.gl/re0iiE

Greenspace Corridors

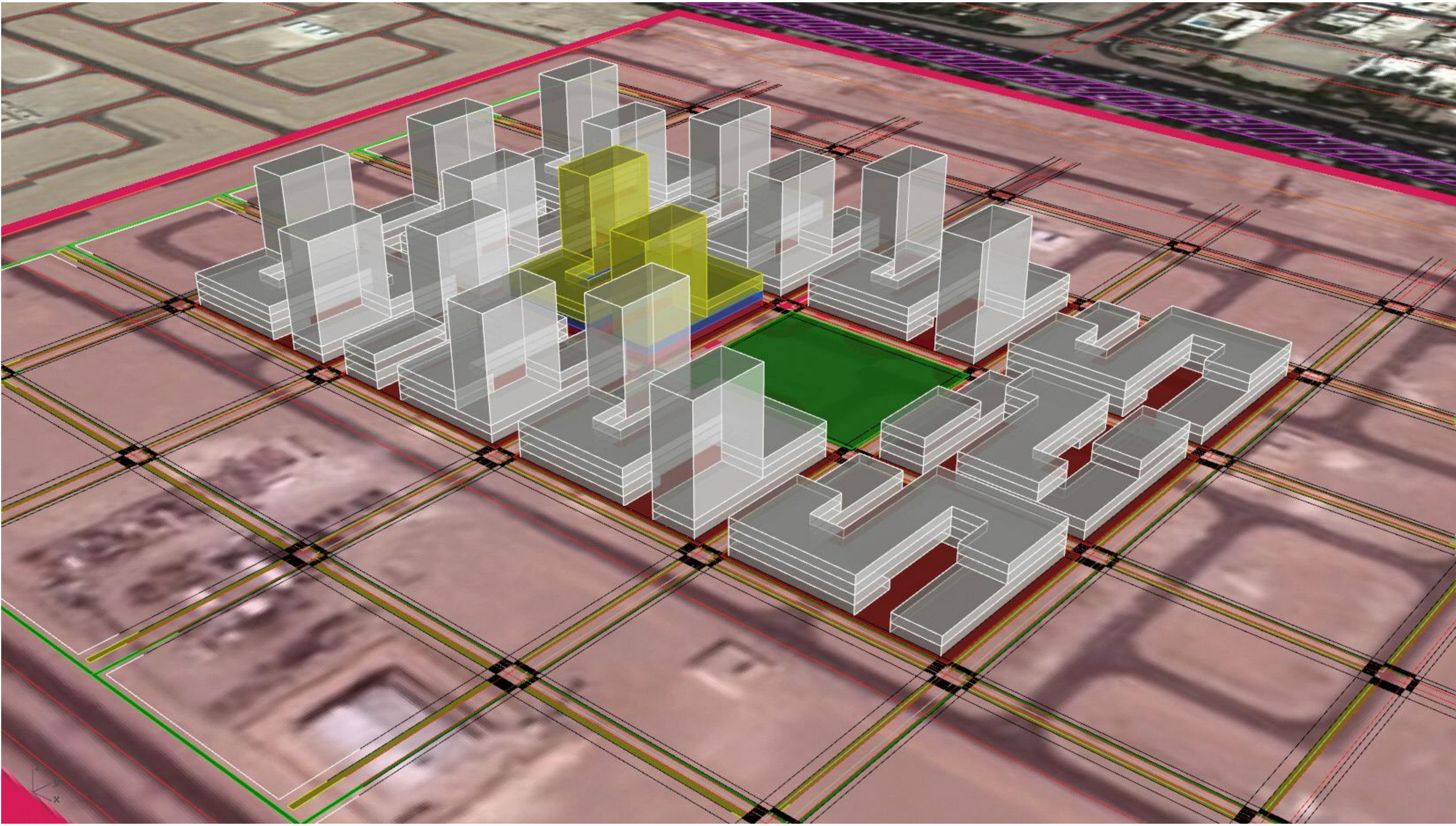


Courtyard

Streetview



Neighborhood



Reference vs. Current Design Comparison

METRIC	REFERENCE CASE	CURRENT DESIGN
Block dimensions	75m x 65m	75m x 65m
Street width	8m	10m E/W 12m for N/S
FAR	3.4	4.1
OD/m^2 w/res.	0.06	0.06
OD/m^2 w/o res.	0.3	0.3
# of stories	8	14
WWR	20%	80%
PV area	3,225m	2,895m
PV/floor area	36.5 kWh/m^2	47.3 kWh/m^2
EUI	211	124
EUO	1,180 kWh per person/year	2,275 kWh per person/year
Average sDA	25%	51%

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