

Spring 2014: 4.433 [Modelling Urban Energy Flows]
Towards Sustainable Cities and Neighborhoods

MIT

net-zero growth

a case for the future
of the campus and kendall square

Instructors

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Team Members

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the vision

Kendall Square Area

sustainable development

MIT Campus

building-scale retrofits



4 phases: 2014 - 2020 - 2030 - 2040 - 2050

the project goal

'net-zero growth'

DEFINITION

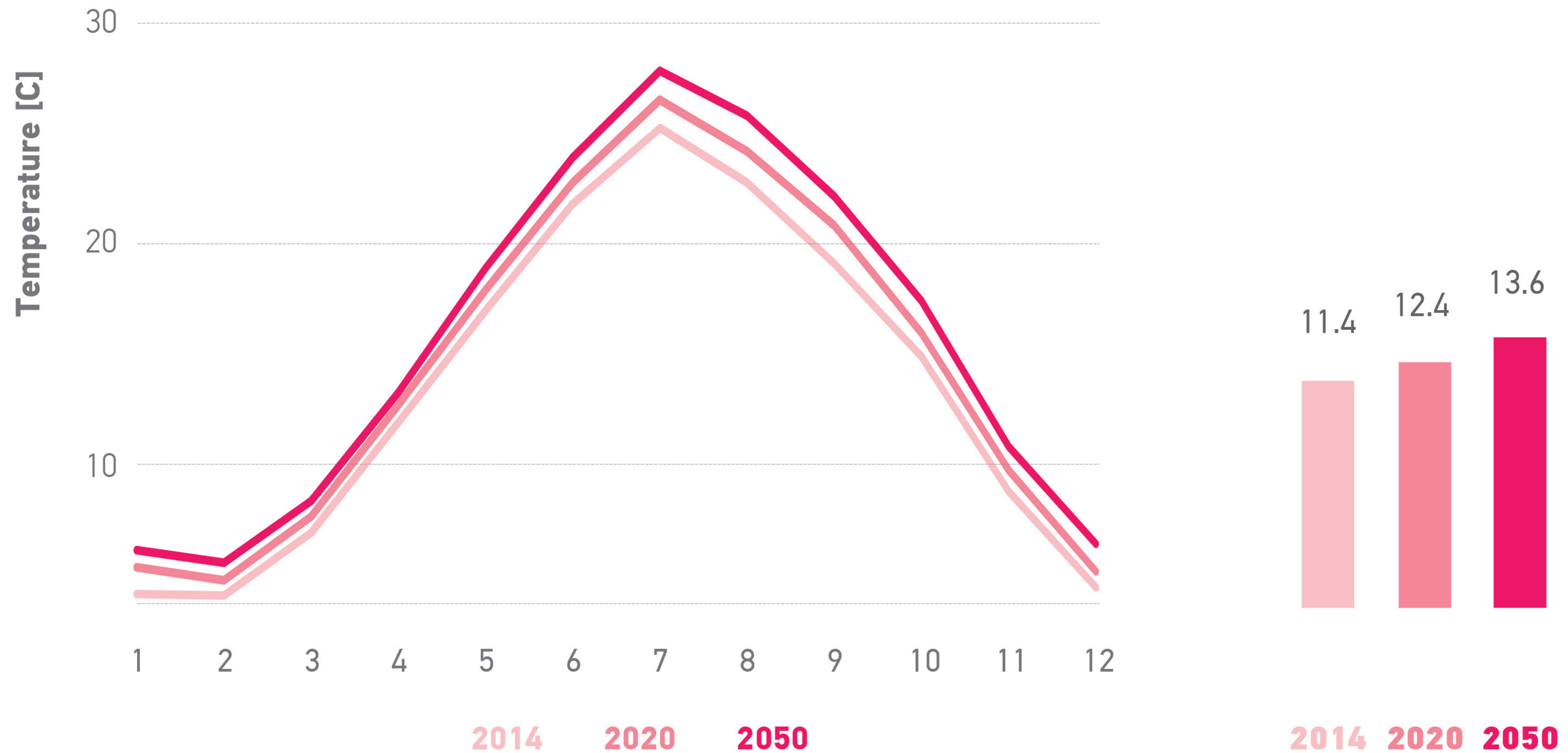
using **CARBON EMISSIONS** as metric

considering the campus as **ONE** entity

NO off-site energy generation

considering current and future expansion **PRESSURES**

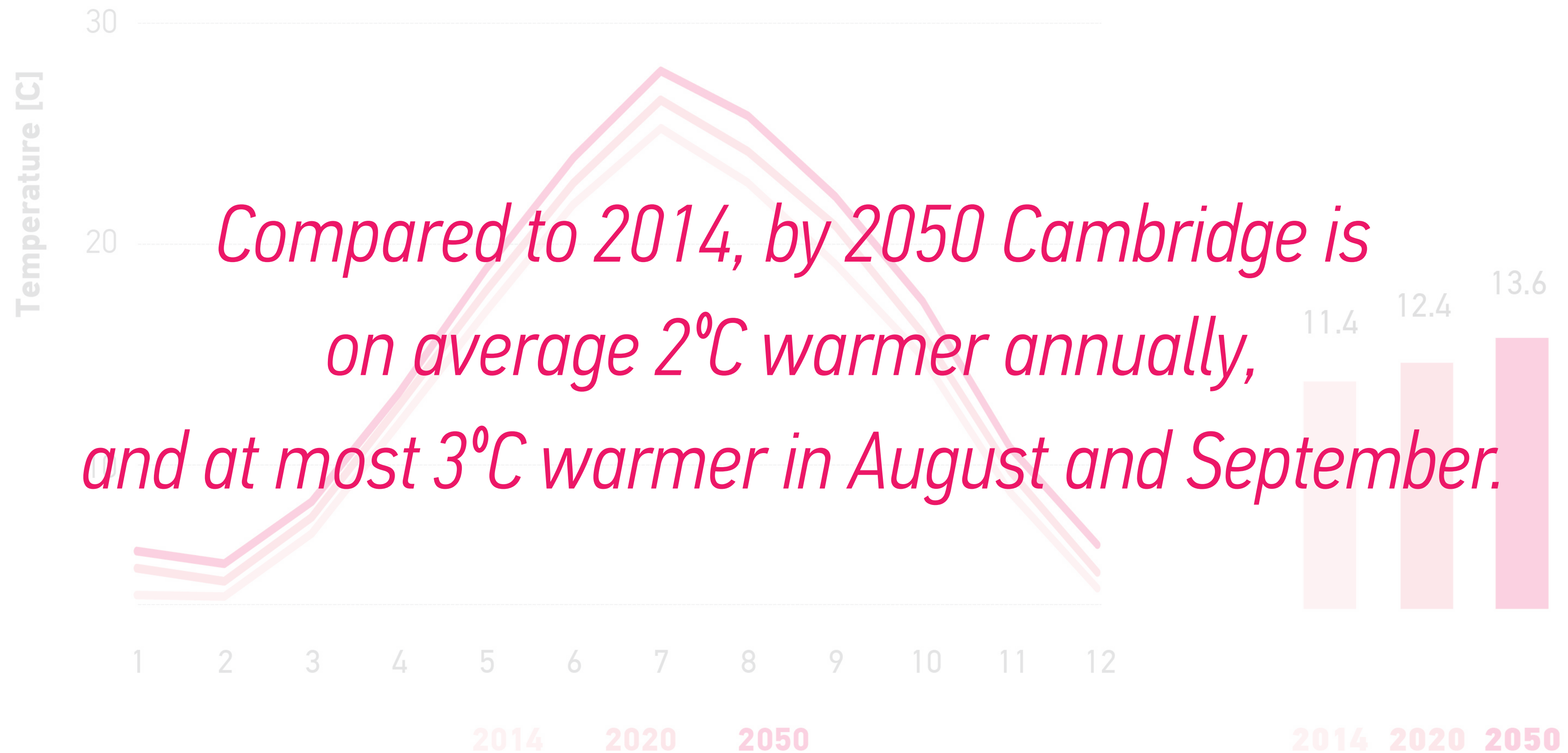
climate change effect on average temperature



Source: Belcher SE, Hacker JN, Powell DS. Constructing design weather data for future climates. Building Services Engineering Research and Technology 2005; 26 (1): 49-61.

HadCM3 (Hadley Centre Coupled Model, version 3) takes average of A2a, A2b and A2c experiments for the four grid points closest to the chosen weather station

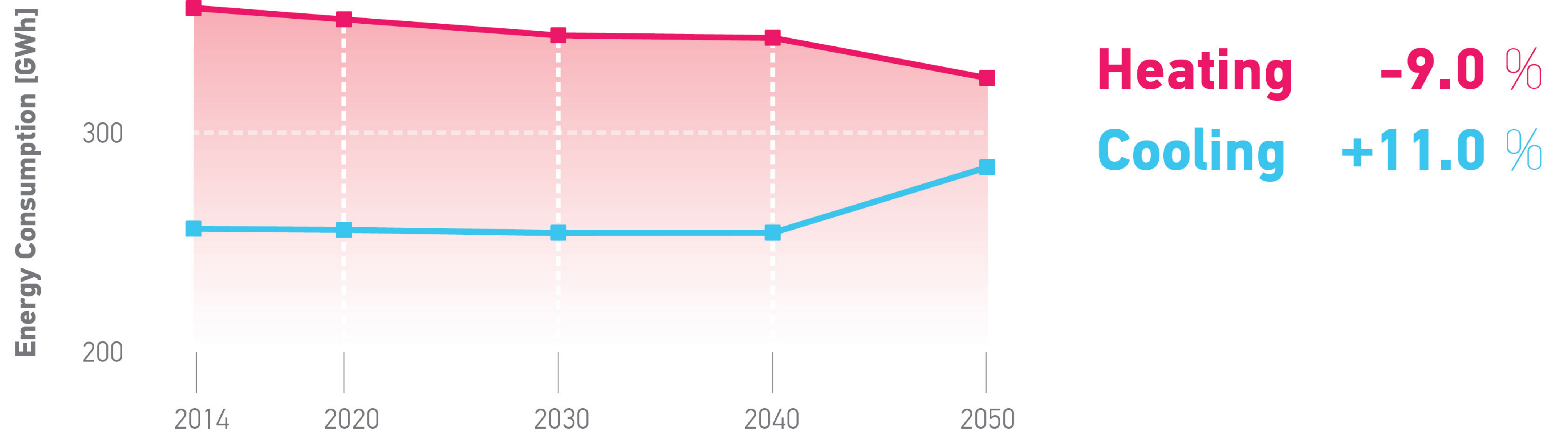
climate change effect on average temperature



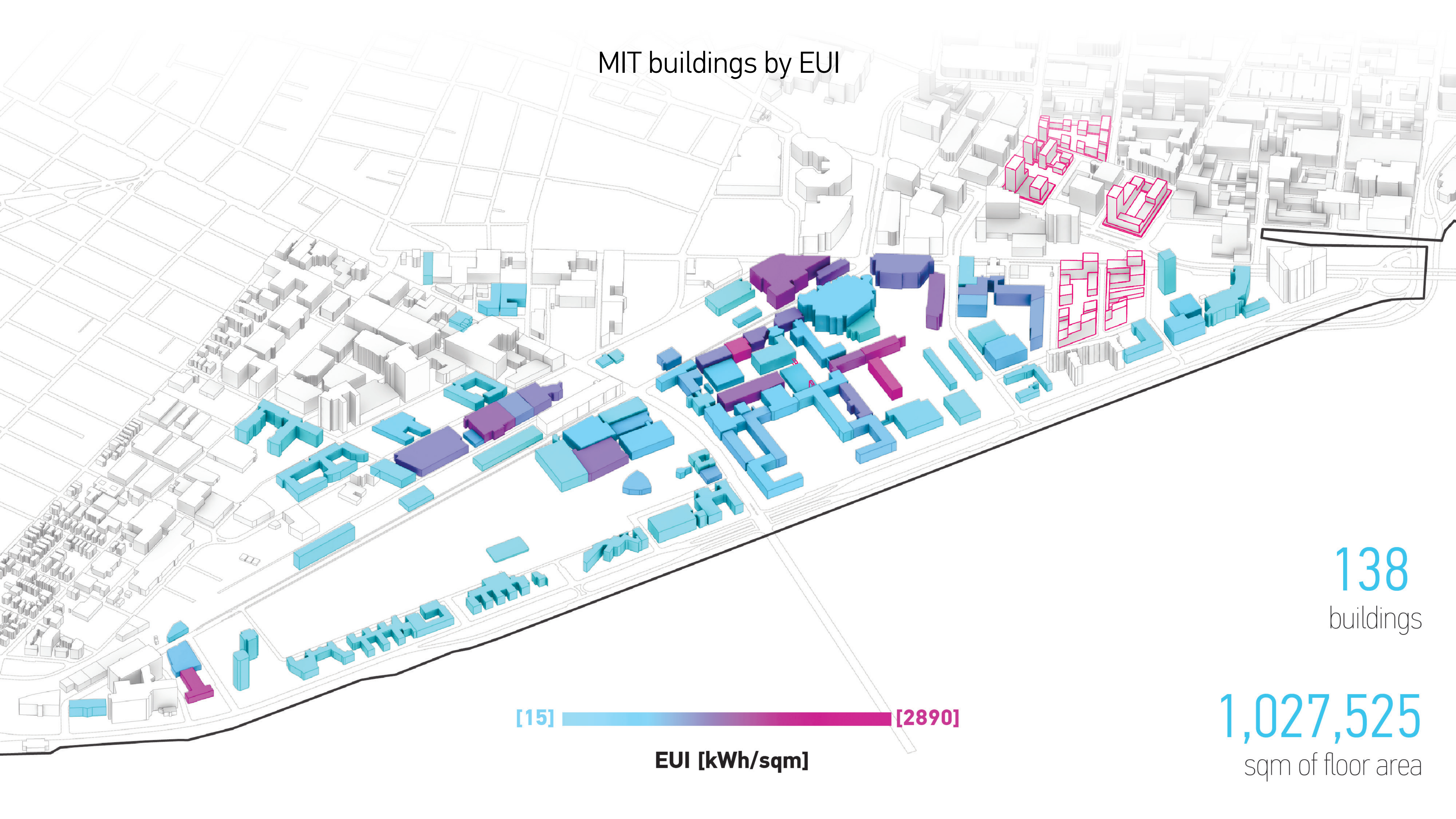
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HadCM3 (Hadley Centre Coupled Model, version 3) takes average of A2a, A2b and A2c experiments for the four grid points closest to the chosen weather station

climate change effect on MIT heating and cooling loads



MIT buildings by EUI



138
buildings

1,027,525
sqm of floor area

[15] [2890]

EUI [kWh/sqm]

MIT buildings by EUI

*To what extent certain retrofits would **reduce** campus energy consumption in order to **enable** campus expansion on a net-zero basis*

138
buildings

1,027,525
sqm of floor area

[15] [2890]

EUI [kWh/sqm]

methodology

01

DATA SOURCES

floor plans
architectural drawings
building automation systems
building audits
measured use for
2012-2013 weather data

02

MODEL INPUTS

3D Geometry
construction materials
temperature setpoints
internal loads
local weather file for 2013

03

DETAILED MODELS

highly detailed analysis
of selected buildings
with thermal zoning;
calibration to
measured data

04

GROUPING

grouping buildings by
similar usage types and
envelope constructions
into templates
group calibration

05

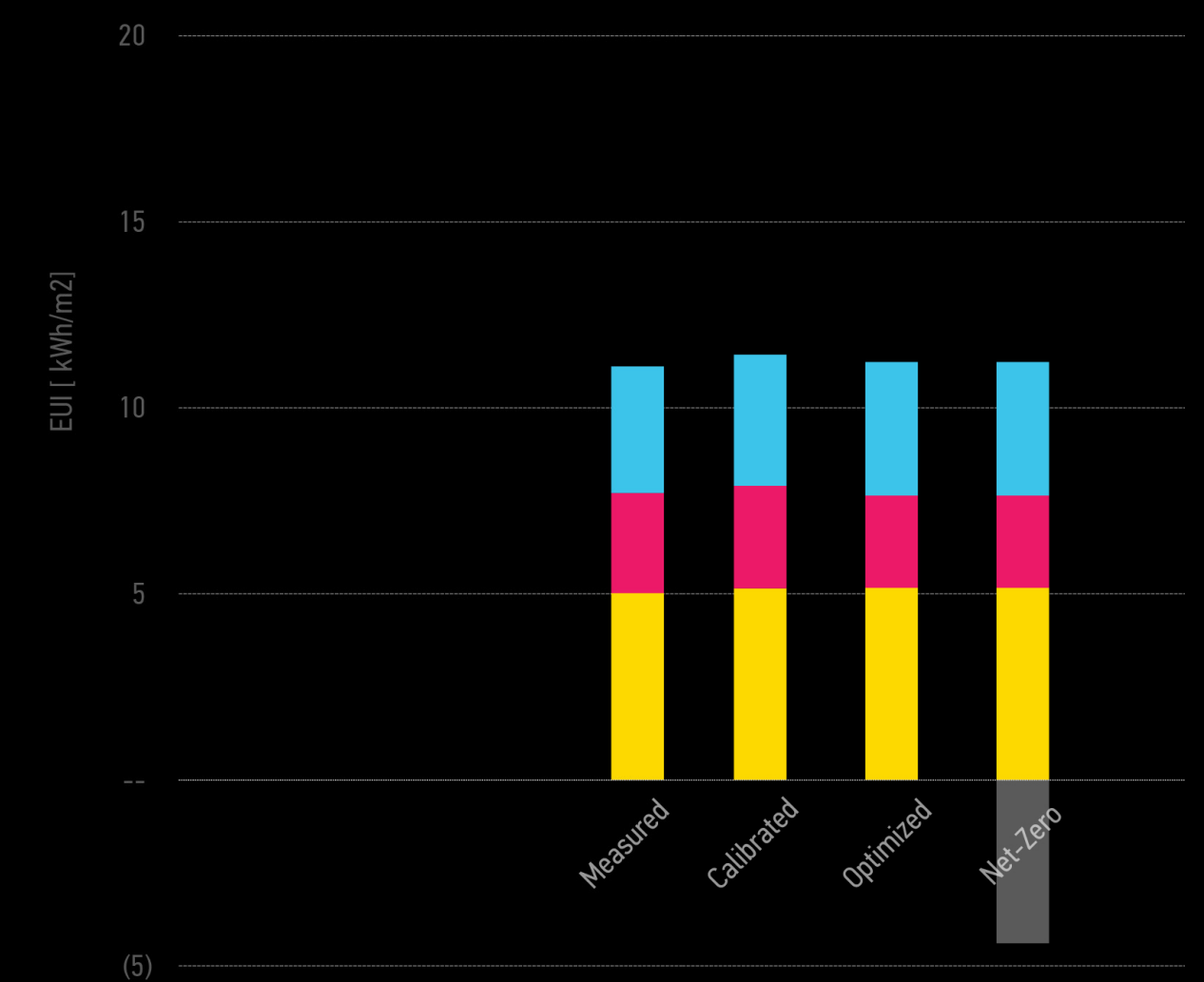
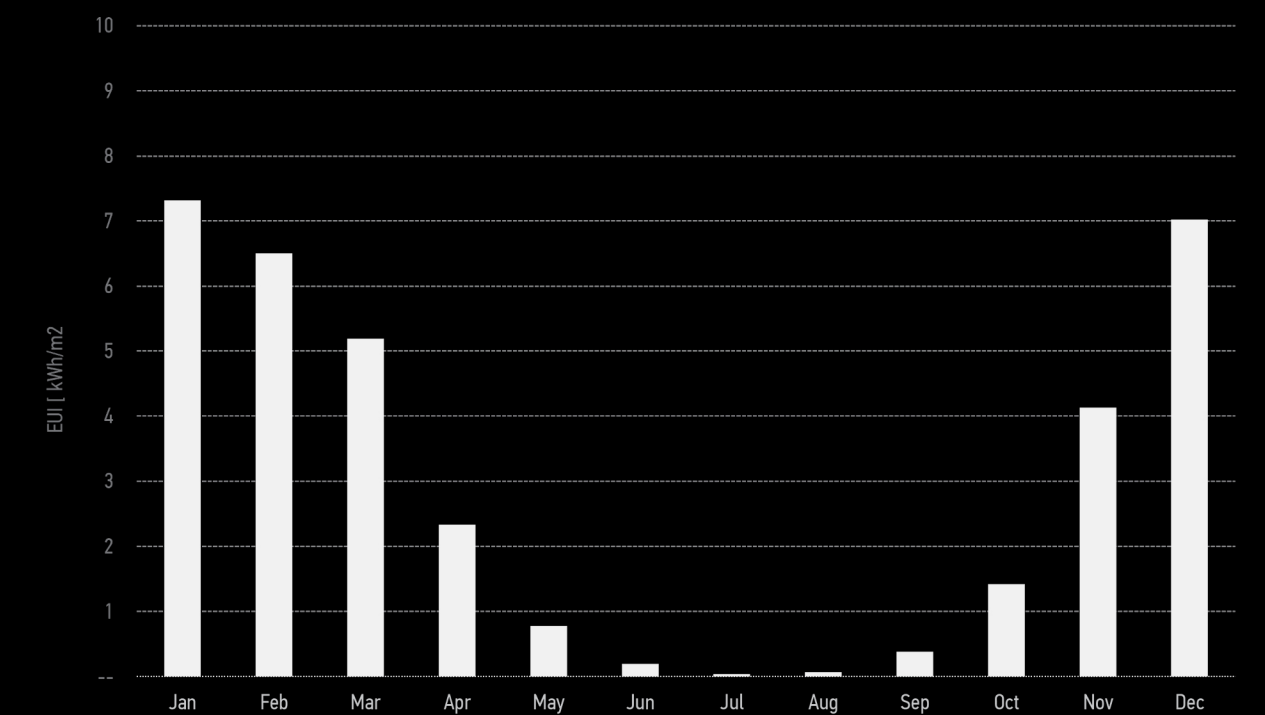
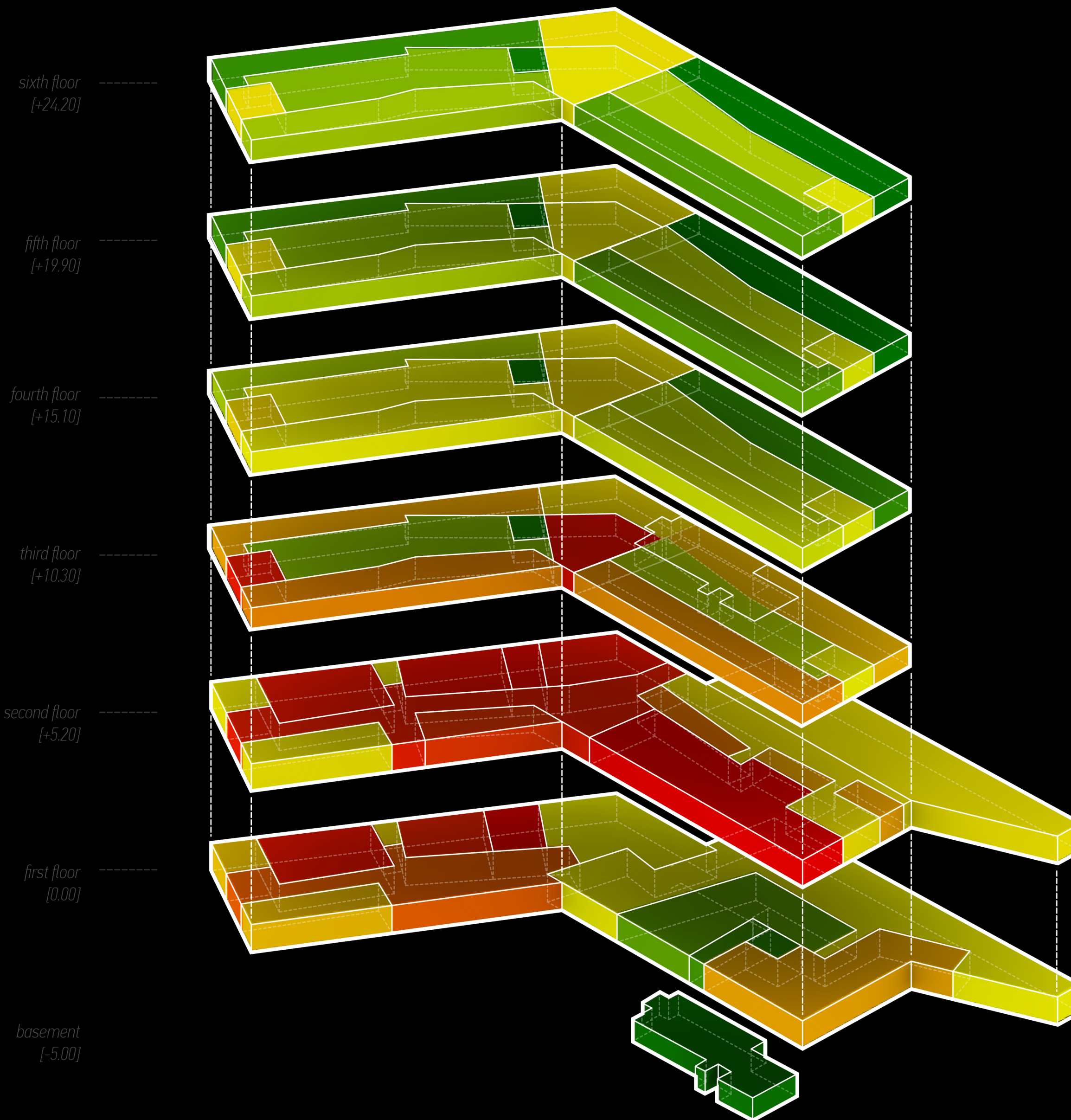
CAMPUS SCALE

reflecting measured
energy use by building
type on a monthly basis

03

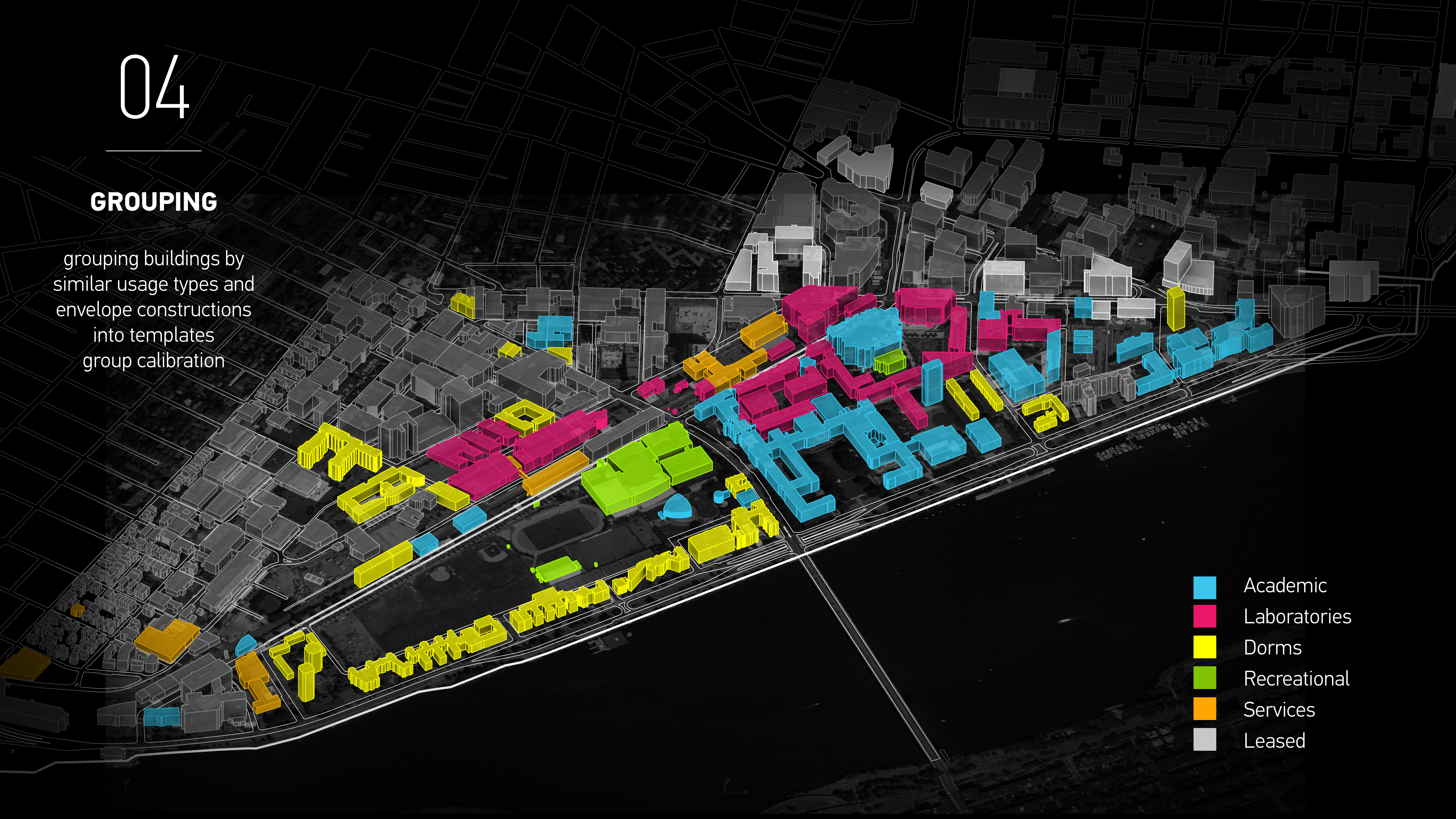
DETAILED MODELS

highly detailed analysis
of selected buildings
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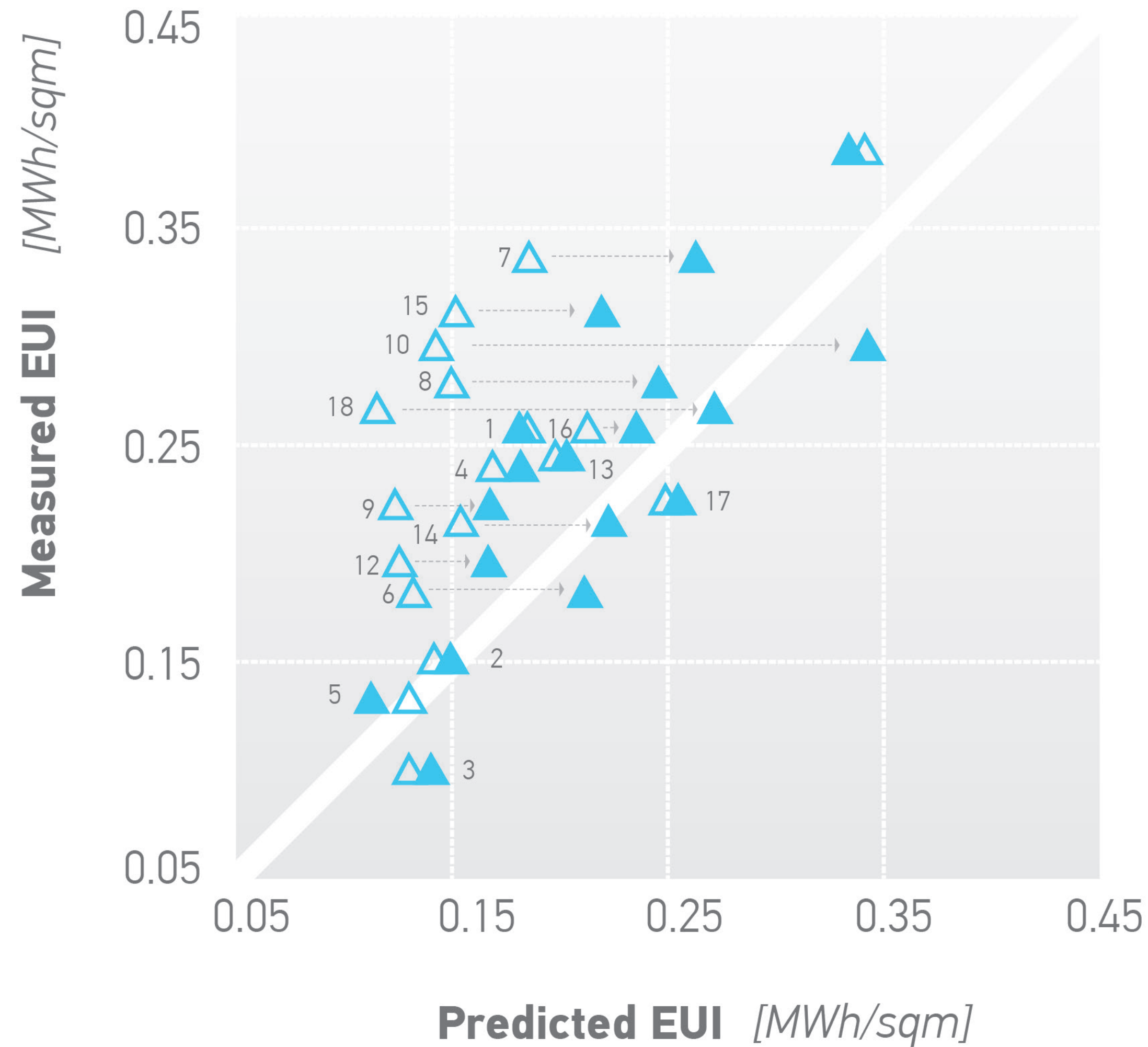
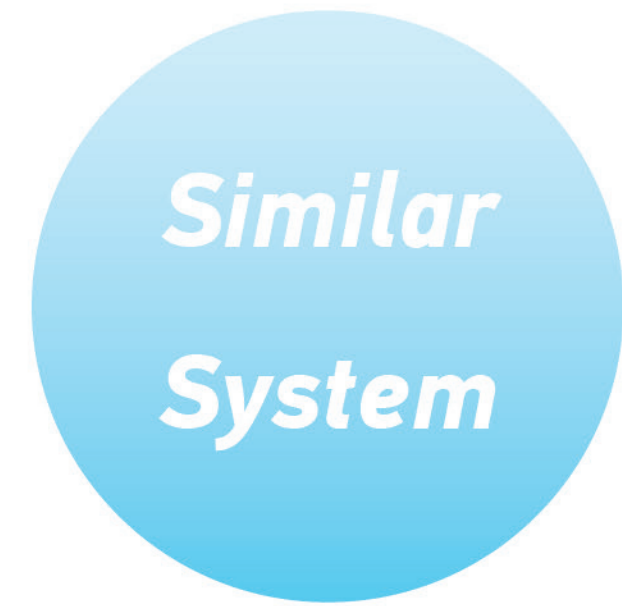
GROUPING

grouping buildings by
similar usage types and
envelope constructions
into templates
group calibration



- Academic
- Laboratories
- Dorms
- Recreational
- Services
- Leased

measured vs. partially calibrated buildings EUI

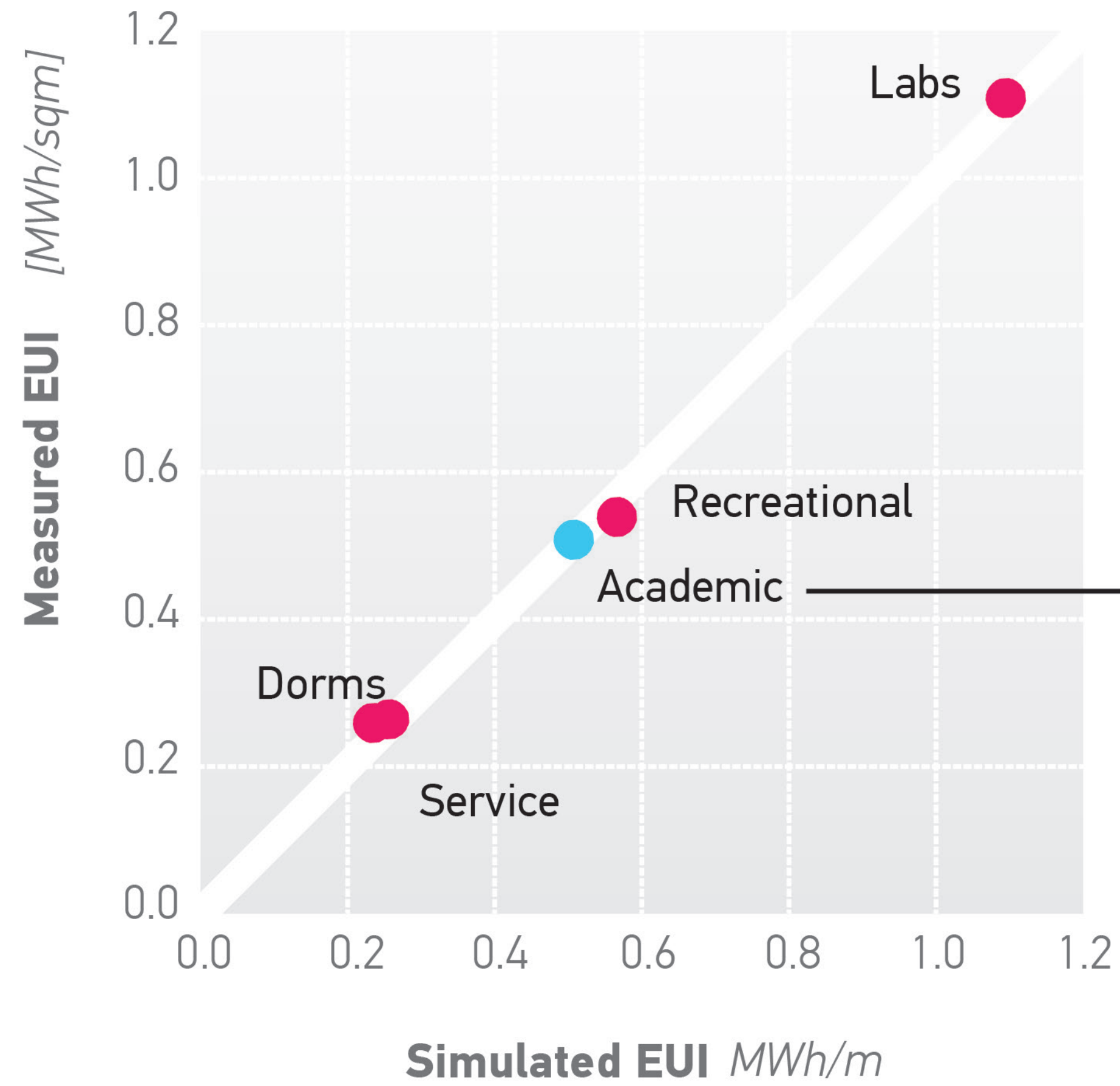


- △ Design-Phase Models
- ▲ Final Partially-Calibrated Models
- # Building Number

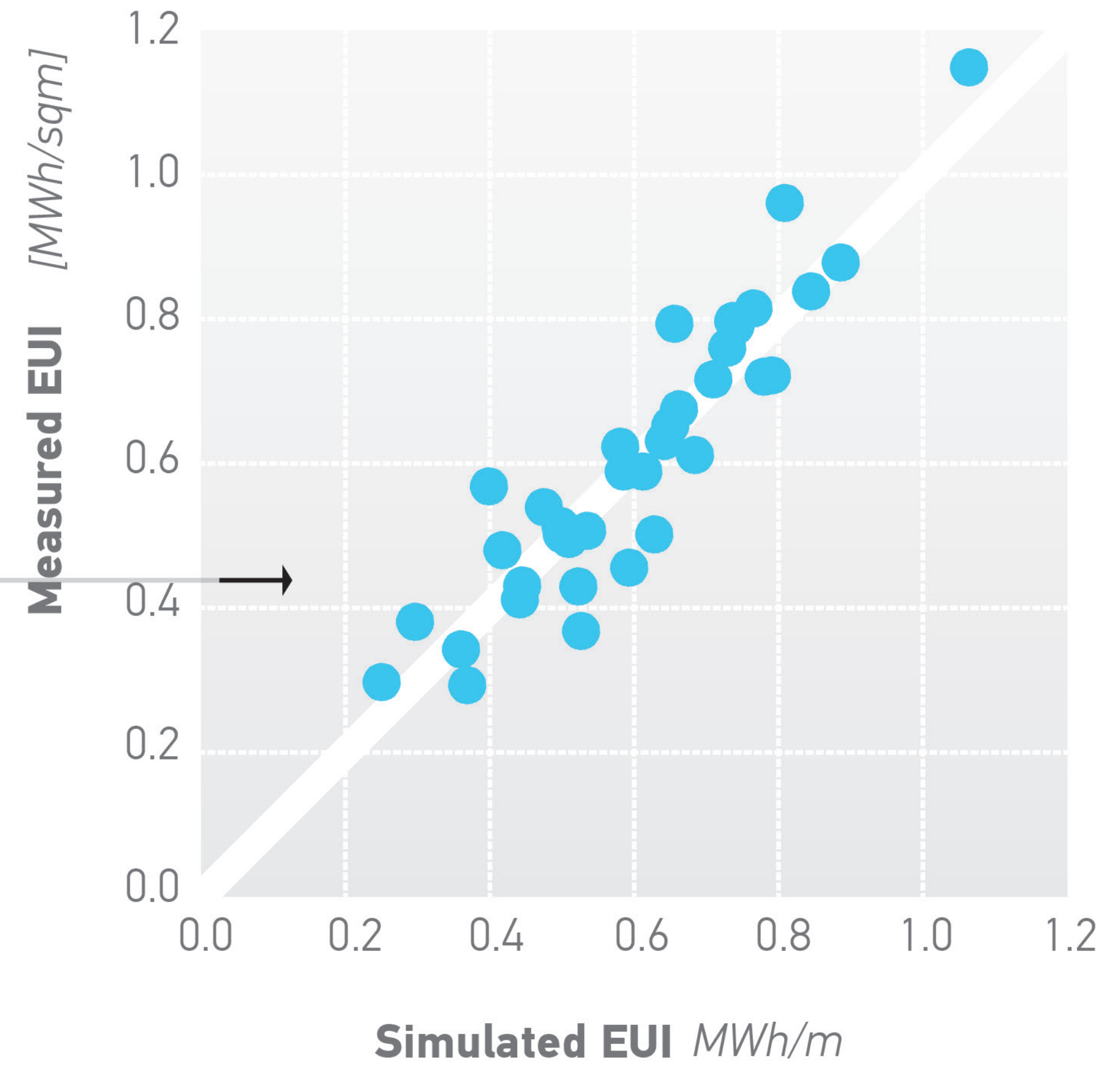
Paper: H W Samuelson, A Ghorayshib & C F Reinhart,
'Analysis of a Simplified Building Energy Model
Calibration Procedure for 18 Real-World Case Studies,
SimBuild 2014, Atlanta, September 2-14

measured vs. simulated EUI

MIT Building Groups

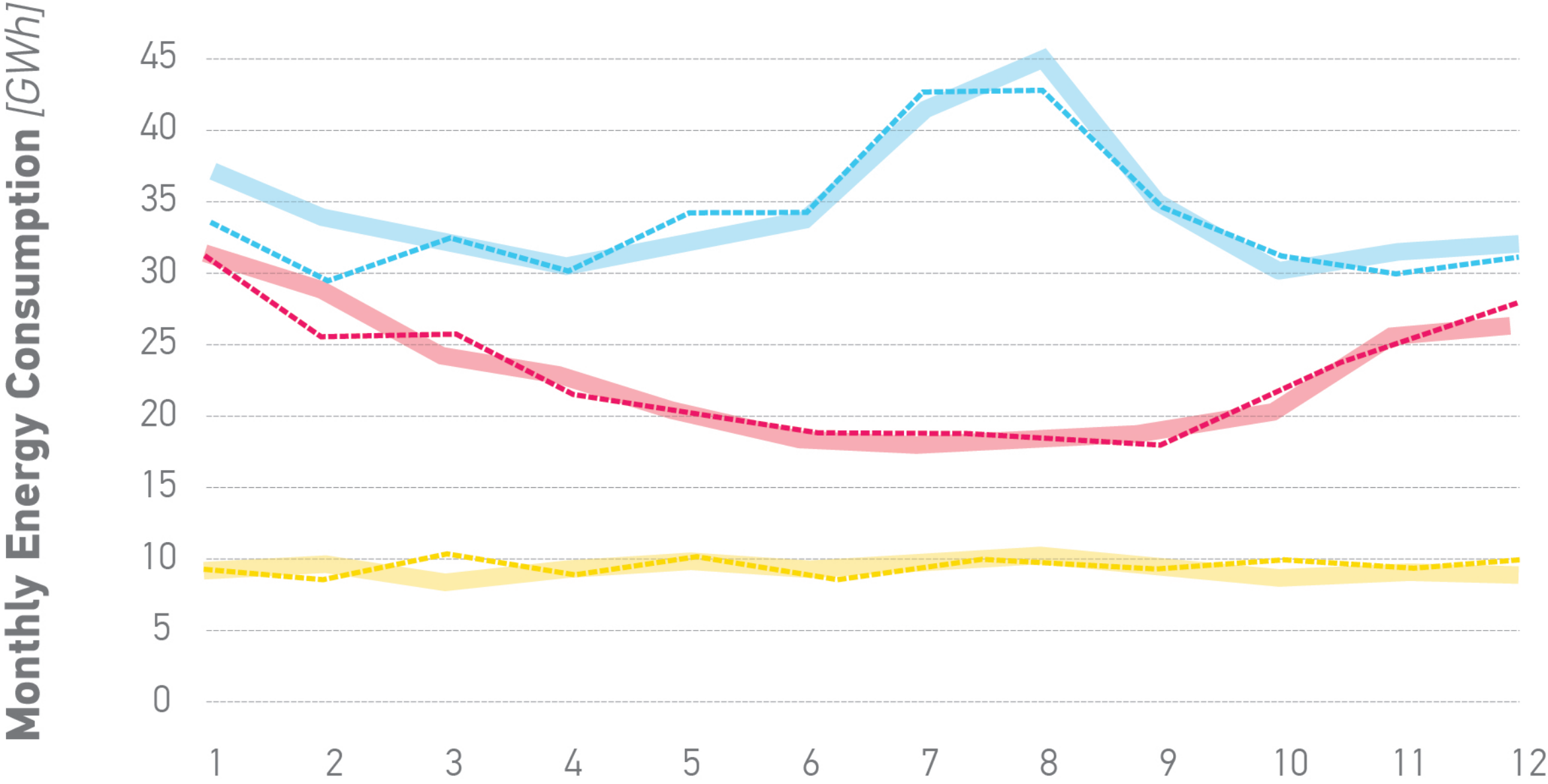


Academic Buildings

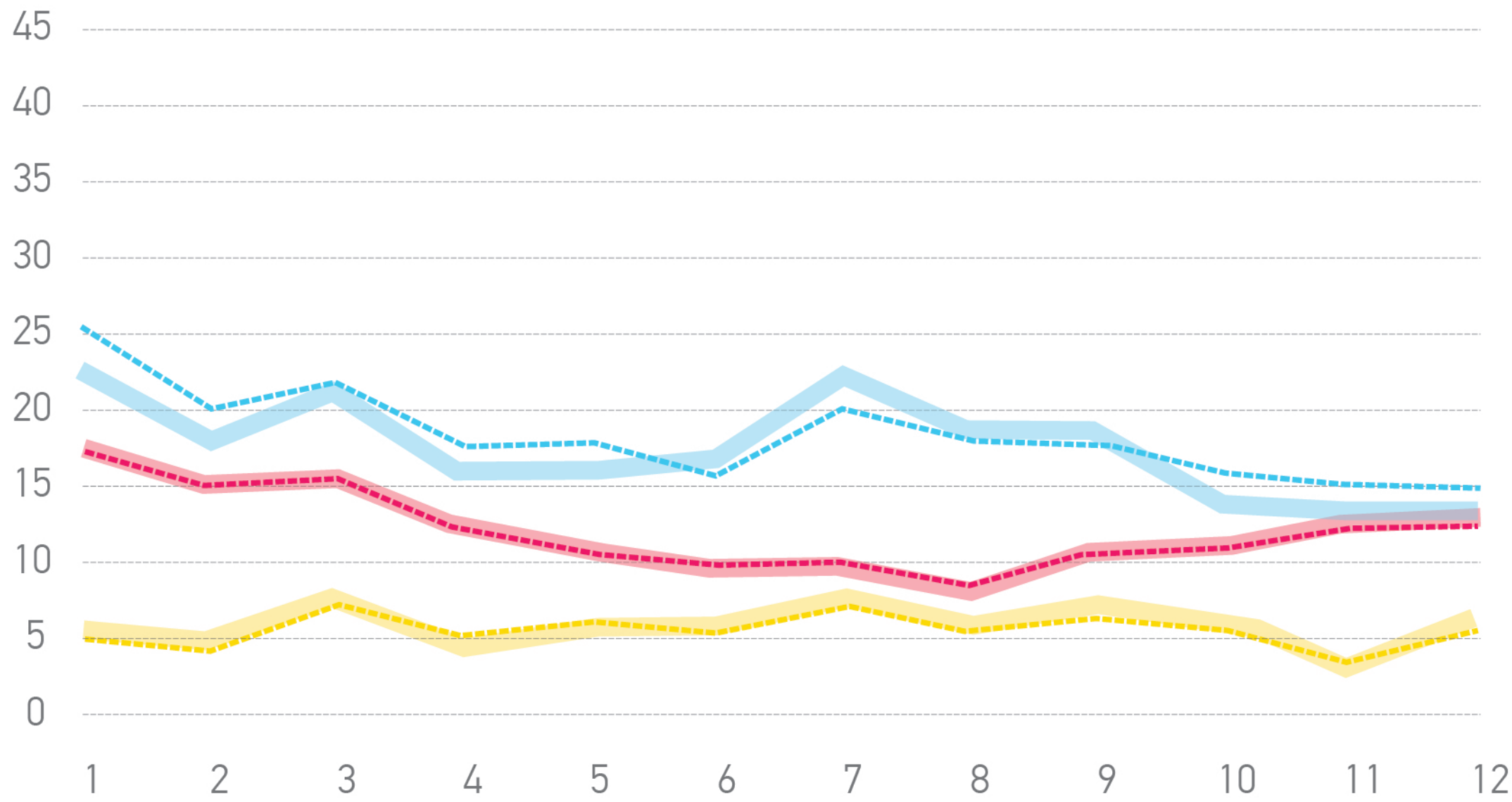


measured vs. simulated EUI

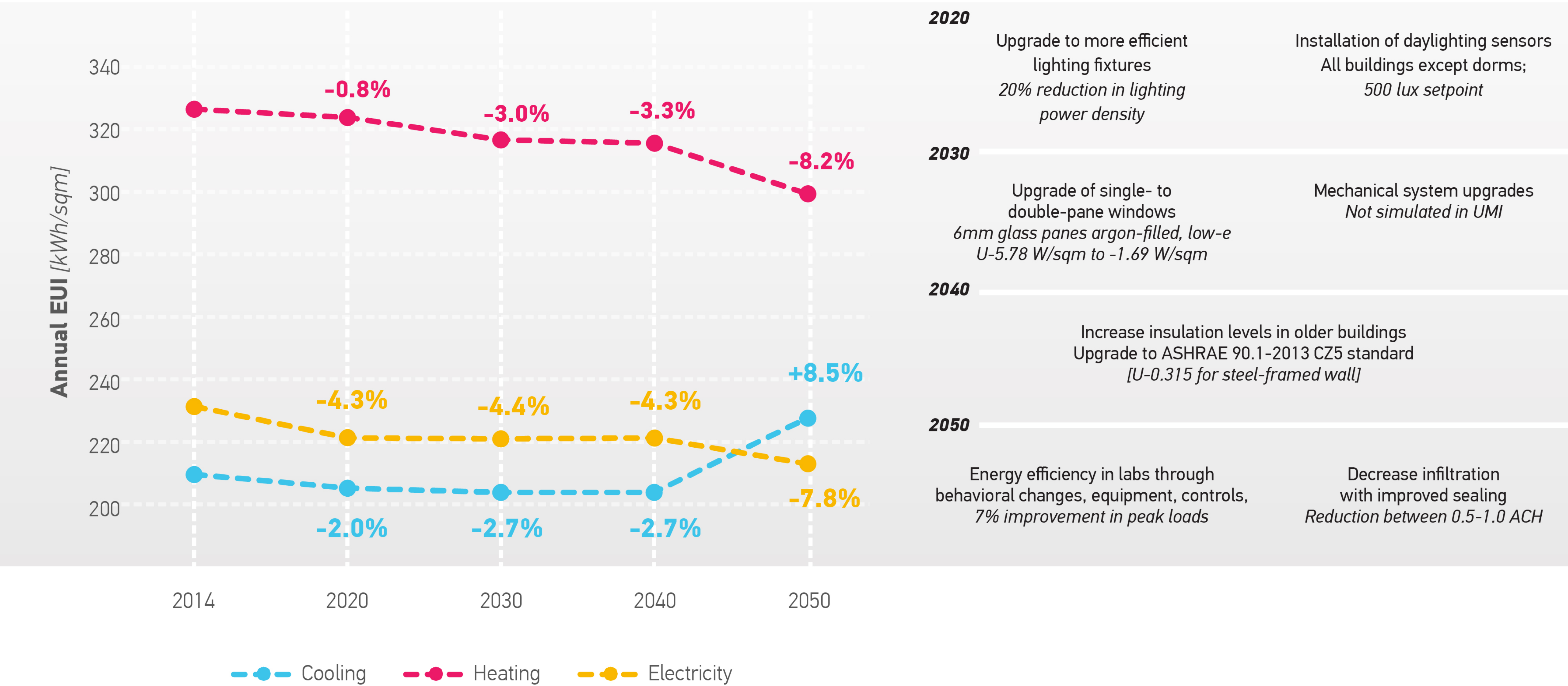
Laboratories



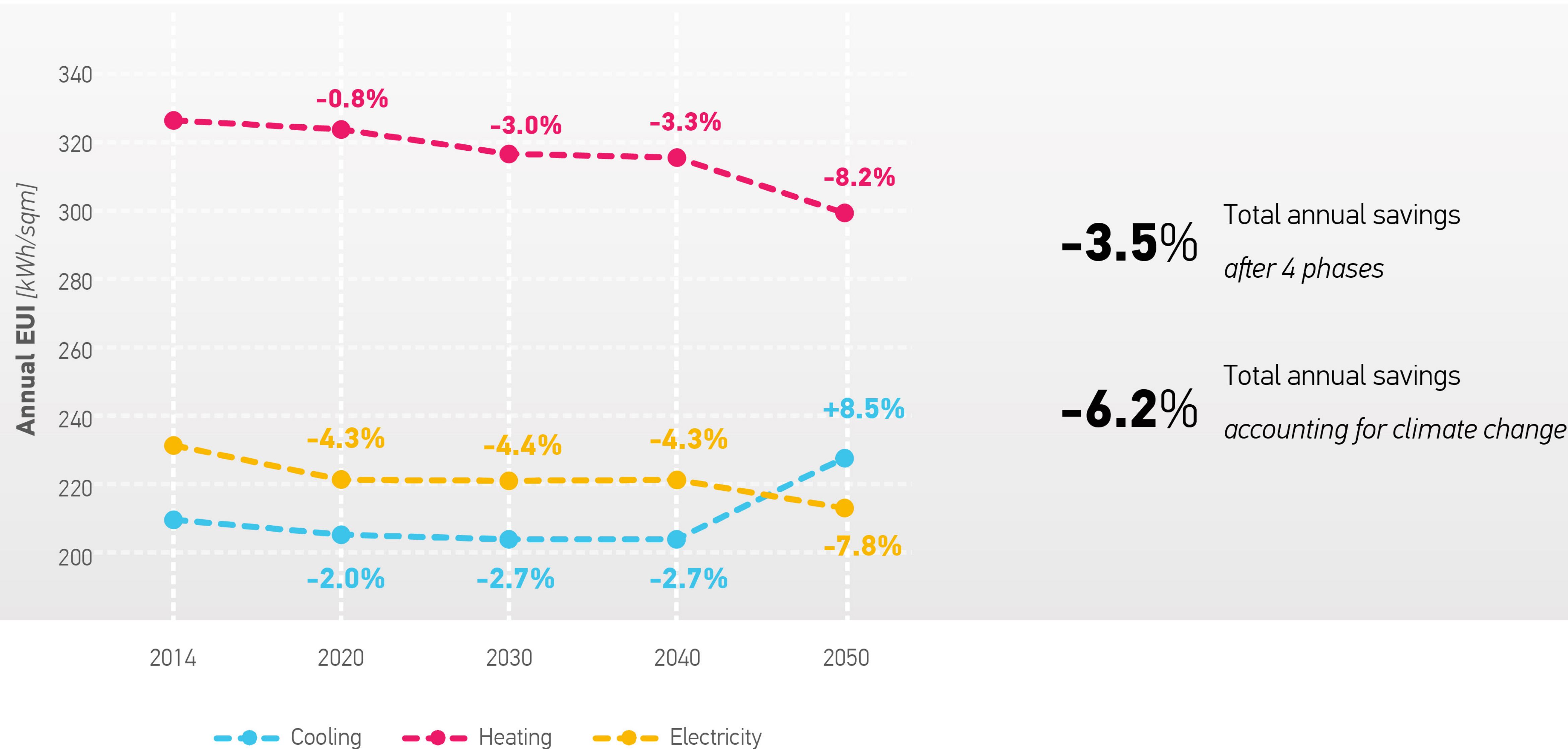
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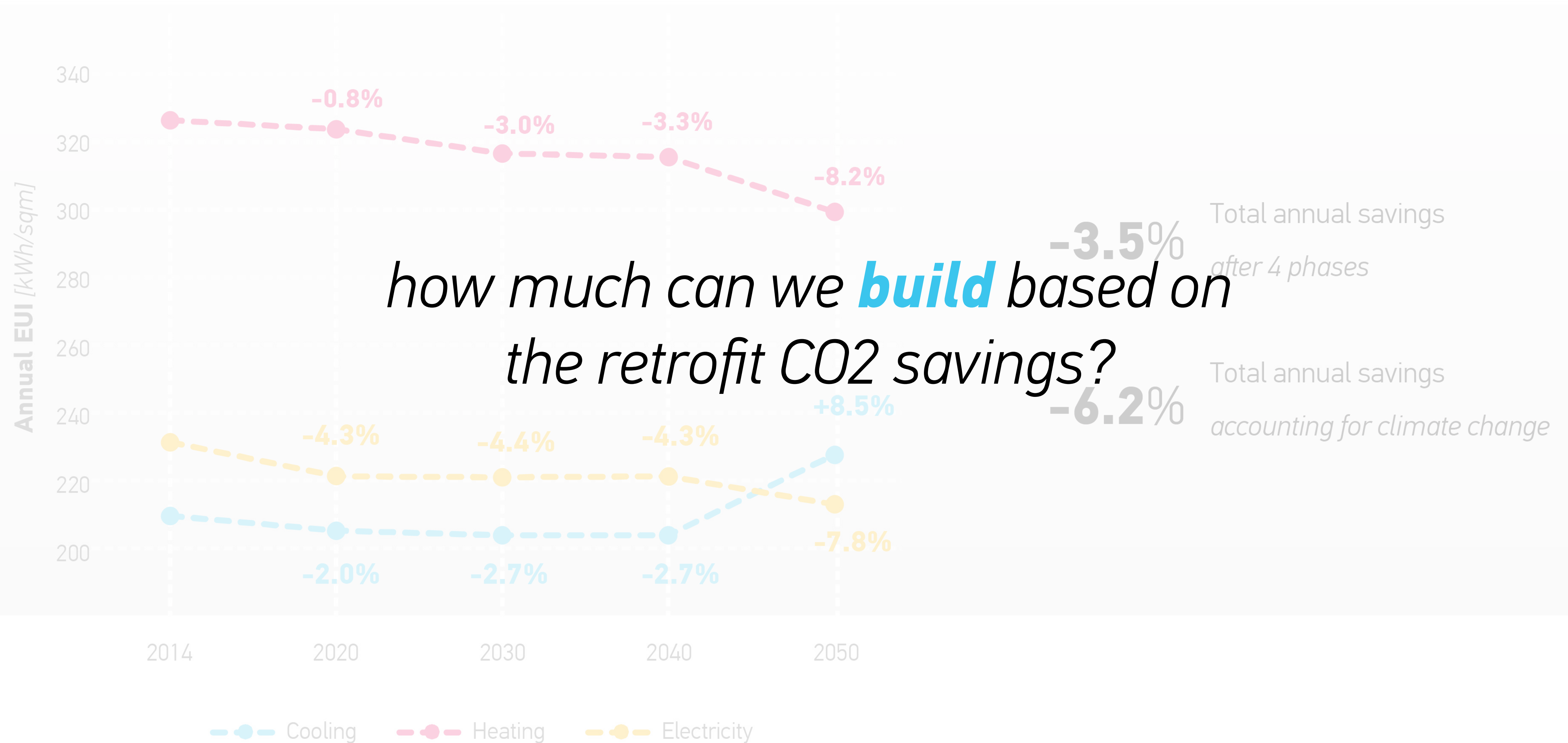


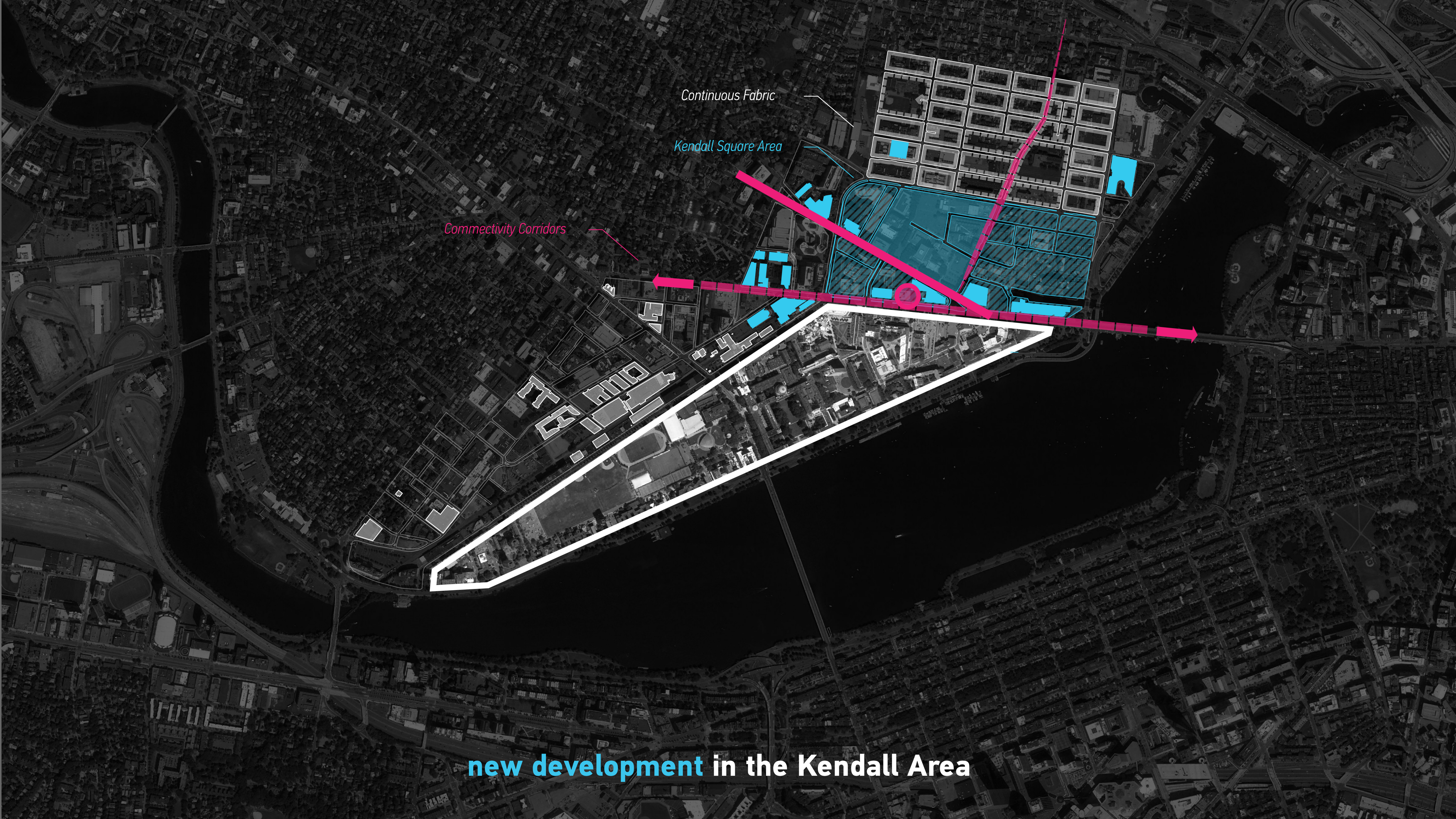
predicted annual EUI **with retrofits** [breakdown]



predicted annual EUI **with retrofits** [cumulative]







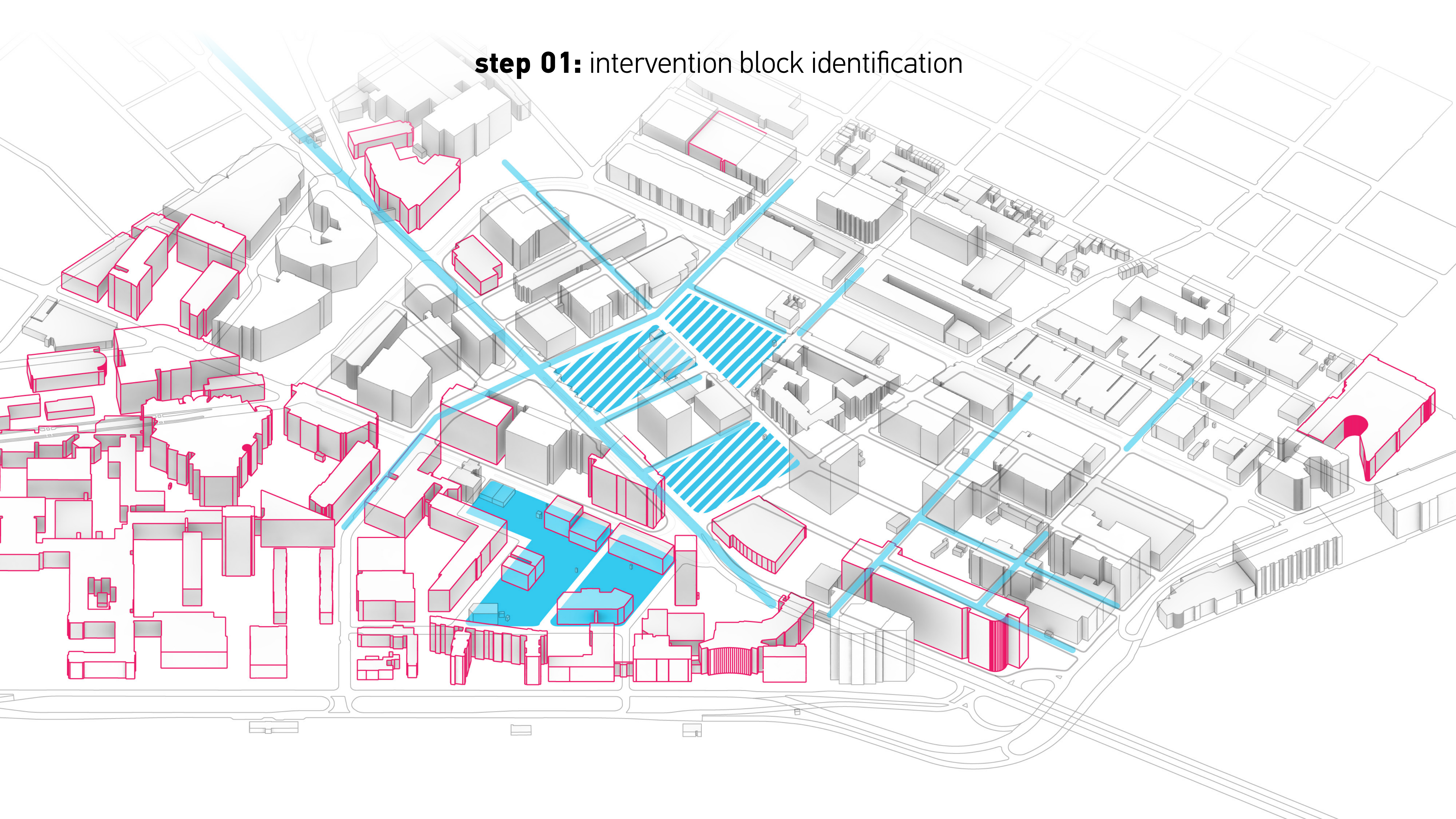
Continuous Fabric

Kendall Square Area

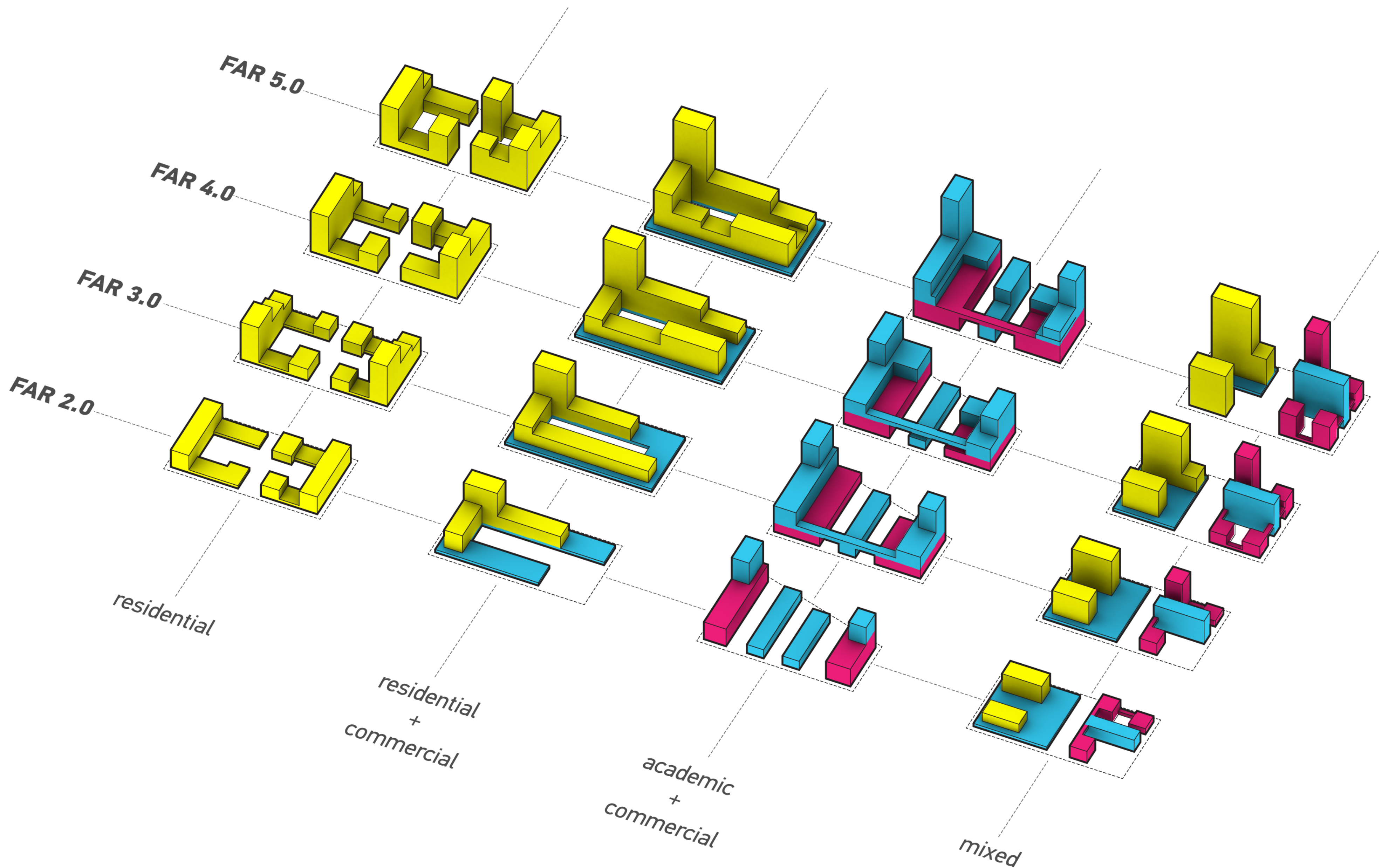
Connectivity Corridors

new development in the Kendall Area

step 01: intervention block identification

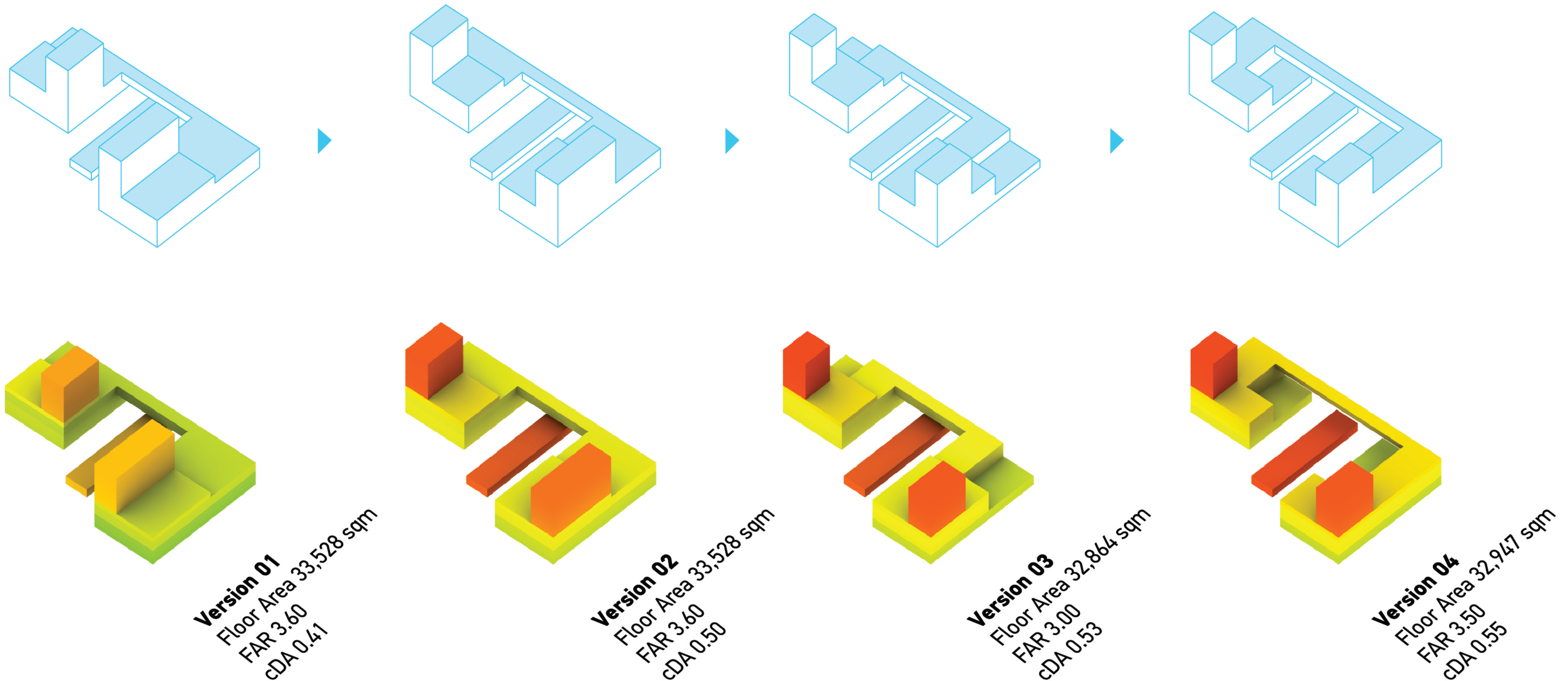


step 02: new block typologies

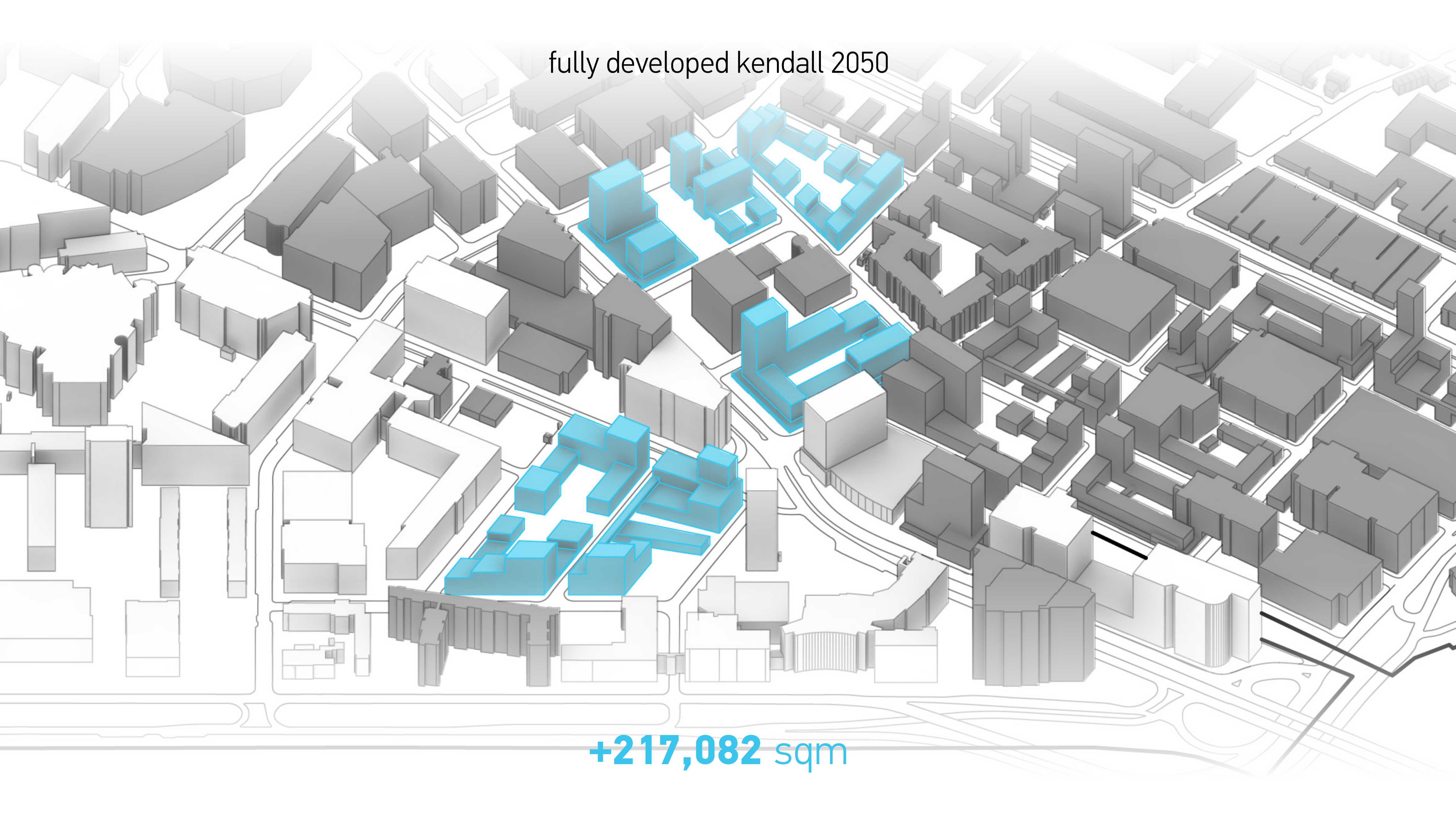


step 03: massing optimization based on daylighting performance

Built Area -1.7% ↓ Daylighting Performance +25% ↑



fully developed kendall 2050



+217,082 sqm

NEW DEVELOPMENT

RETROFITS

New Development CO2 Emissions

Retrofit CO2 Savings

CO2 Emissions from Annual
Energy Use (million kg)

80
70
60
50
40
30
20
10

New
Development

2020 [phase 01]

MIT Nanotechnology Building
643 New Dorm Units [60 sqm per unit]

+48,442 sqm
at FAR 4.2 & 59.3 % Coverage

2030 [phase 02]

New Office Spaces [+21,125 sqm]
New Academic Spaces [+15,935 sqm]

+37,060 sqm
at FAR 4.4 & 67.0% Coverage

2040 [phase 03]

New Office Spaces [+7,784 sqm]
948 New Dorm Units [60 sqm per unit]

+88,976 sqm
FAR 5.6 & 75.0% Coverage

2050 [phase 04]

New Office Spaces [+9,372 sqm]
New Academic Spaces [+11,077 sqm]
296 New Dorm Units [60 sqm per unit]

+42,604 sqm
FAR 4.4 & 61.5% Coverage

NEW DEVELOPMENT

RETROFITS

New Development CO2 Emissions

Retrofit CO2 Savings

CO2 Emissions from Annual
Energy Use (million kg)

NEW DEVELOPMENT = RETROFITS + **RENEWABLES**

New
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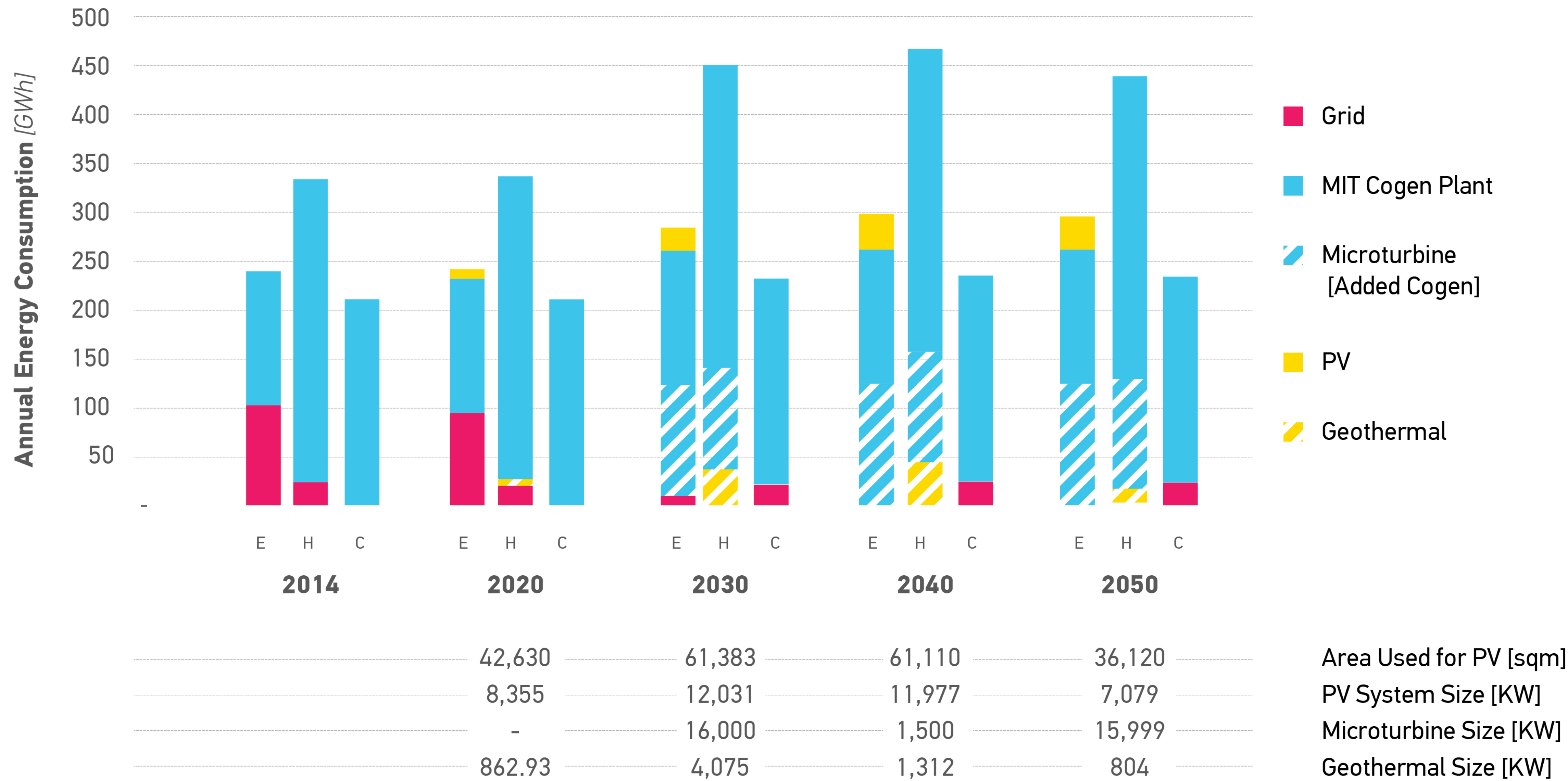
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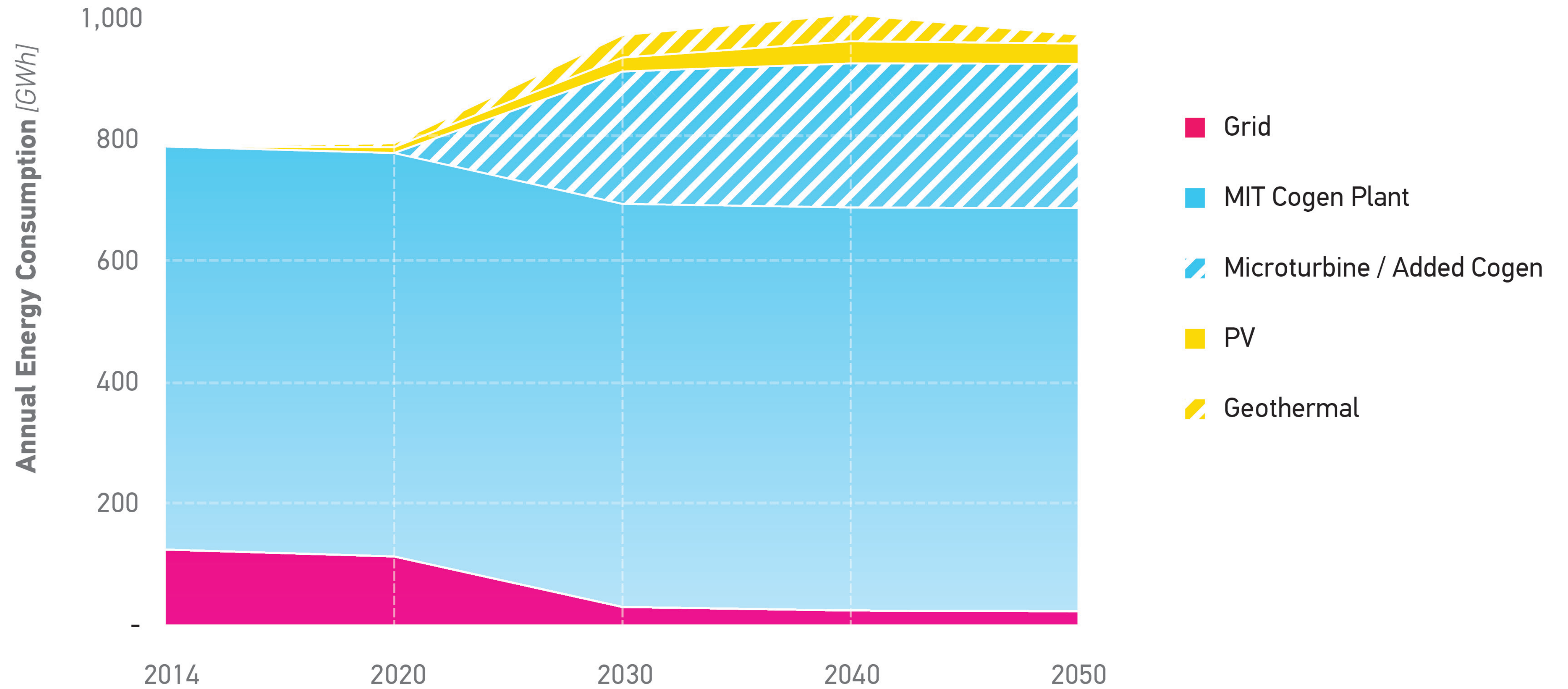
renewable energy model

Technologies Considered	Carbon Footprint Assumptions	Installation Cost Assumptions
Solar PV	N/A	\$4.20 / Watt
Geothermal Heat Pumps	N/A	\$3.20 / Watt
Microturbines	0.21 kg/kWh	\$1.50 / Watt
MIT Co-Gen	0.21 kg/kWh	N/A
Electricity from the Grid	0.64 kg/kWh	N/A
Gas from NSTAR	0.23 kg/kWh	N/A
Model Goal		
Minimize Cost		
Model Constraints		
60% Rooftop Area Availability for PV		
New Development Site Area Availability for Geothermal		
Max CO2 Emissions per year: 216,168,811 Kg		

energy mix per category over time *[breakdown]*

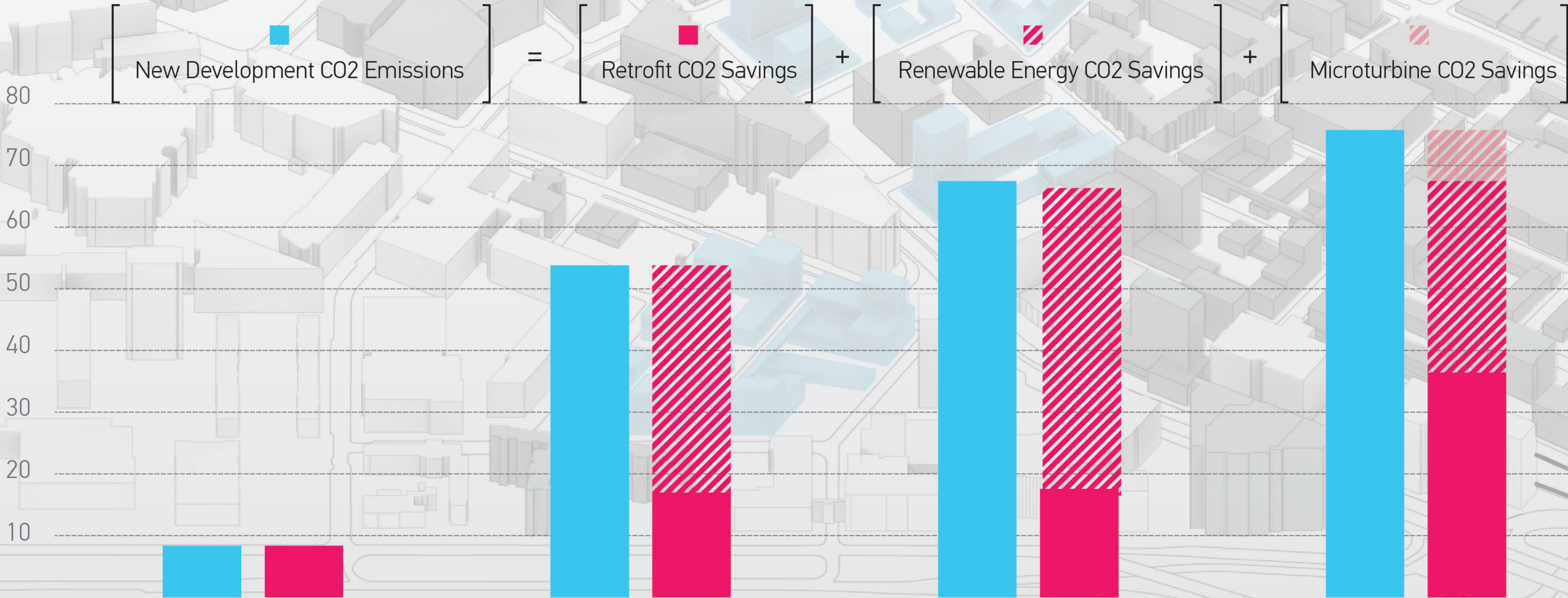


energy mix per category over time *[cumulative]*



NEW DEVELOPMENT = RETROFITS + RENEWABLES

C02 Emissions from Annual
Energy Use (million kg)



2020 [phase 01]

2030 [phase 02]

2040 [phase 03]

2050 [phase 04]

Area Used for PV [sqm]

42,630

61,383

61,110

36,120

PV System Size [KW]

8,355

12,031

11,977

7,079

Microturbine Size [KW]

-

16,000

1,500

15,999

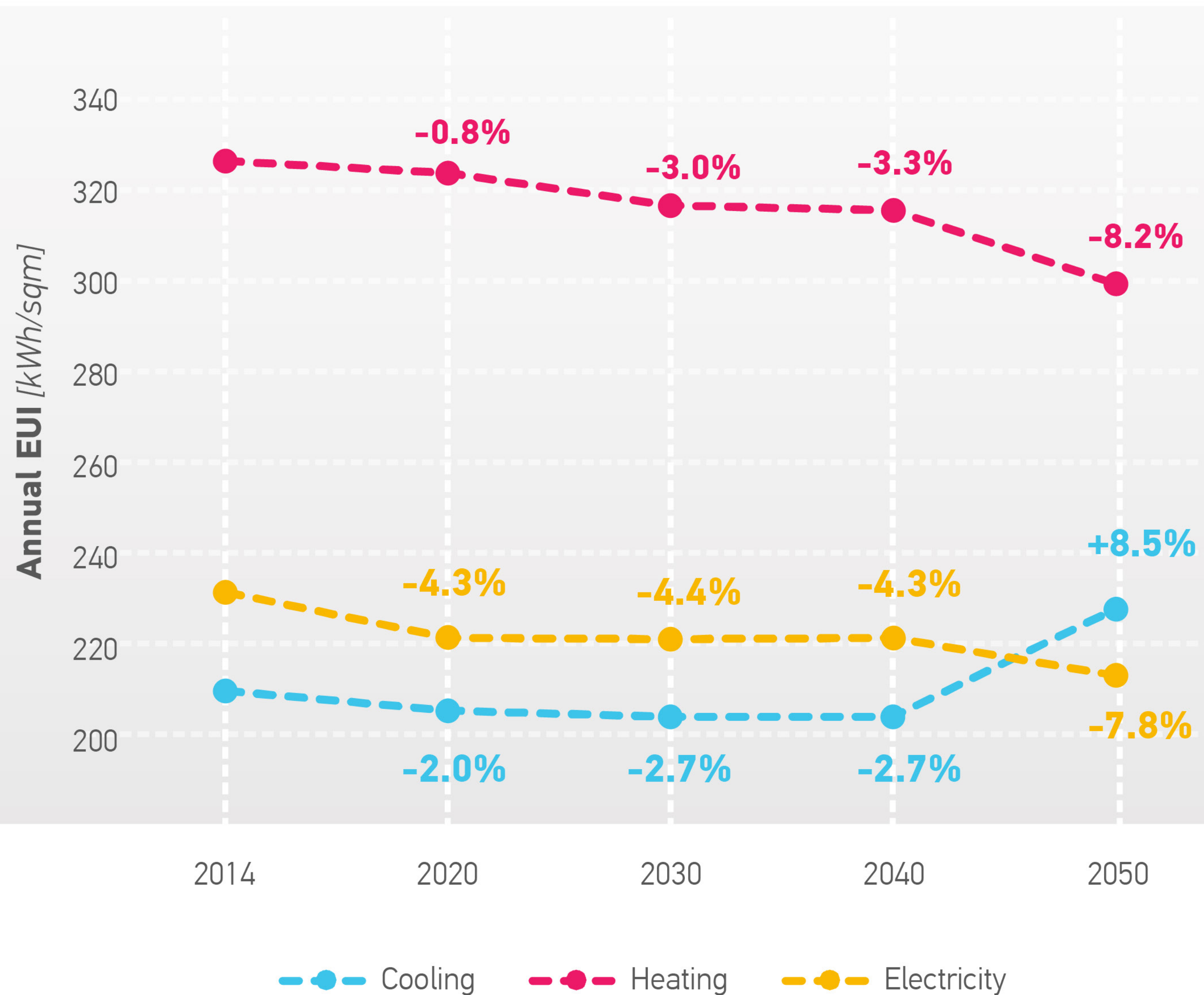
Geothermal Size [KW]

862.93

4,075

1,312

804



-3.5%

Total annual savings
after 4 phases

-6.2%

Total annual savings
accounting for climate change

