Assessing Low-Carbon Performance of Urban Blocks Under Future Climate

Through Microclimate Simulation

Presenter: Yilei Li

Authors: Yilei Li · Teng Fei · Jiayue Yu · Jingyi Liu · Pengqi Sun

Harbin Institute of Technology, China · WCDH 2026

Presenter

Yilei Li

Ph.D. candidate · School of Architecture and Design

Research focus

Urban microclimate / Climate-responsive urban design

Building energy performance / Severe-cold residential districts

Warming changes the seasonal energy balance

Harbin: a heating-dominated city

112.13

Current heating EUI

9.15

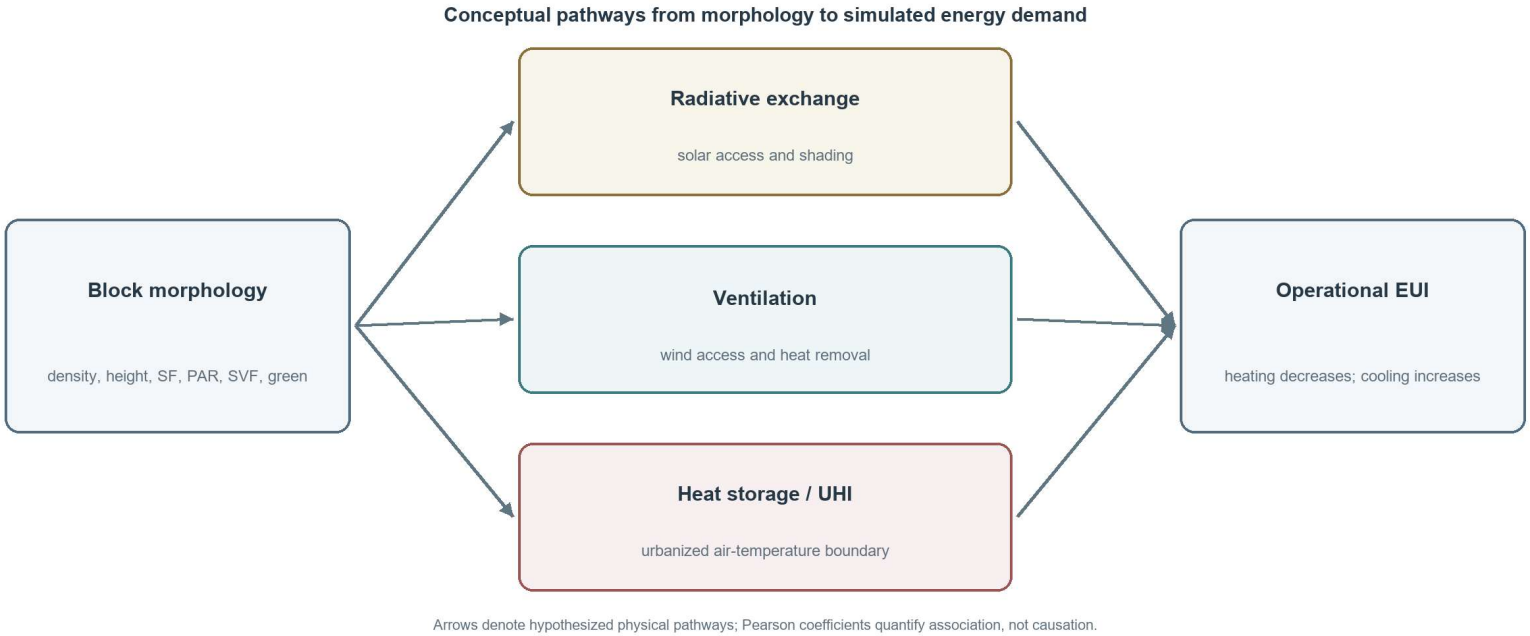
Current cooling EUI

The planning problem

A lower annual total can hide rapid growth in summer cooling.

Both end uses need separate evaluation under future and urbanized weather.

Block form acts through several linked pathways



Solar access and shading **Wind access and heat removal** **Heat storage and UHI**

These are plausible physical routes. Correlations later in the talk do not isolate them.

HARBIN INSTITUTE OF TECHNOLOGY

Study design

PART 01

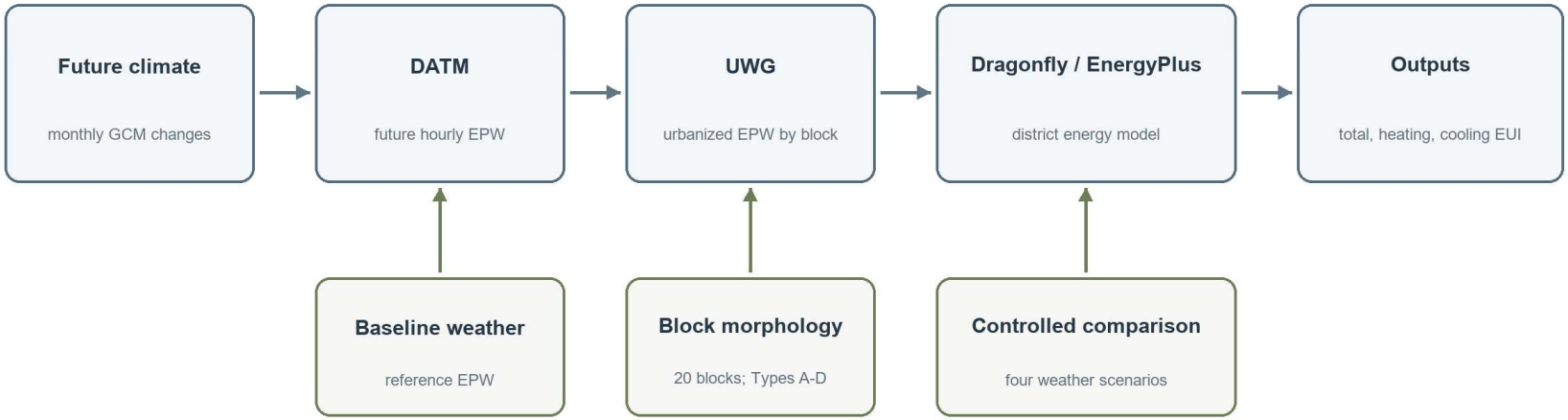
Harbin blocks, future weather and district energy models

Twenty residential blocks represent four LCZ types

Type	Urban form	Mean FAR	Mean height (m)
A / LCZ 1	Compact high-rise	3.84	69.9
B / LCZ 2	Compact mid-rise	2.63	32.4
C / LCZ 4	Open high-rise	2.18	34.0
D / LCZ 5	Open mid-rise	1.36	17.8

Shape factor: Type A 0.170; Type D 0.234. Five blocks represent each type.

One workflow connects future weather to block energy

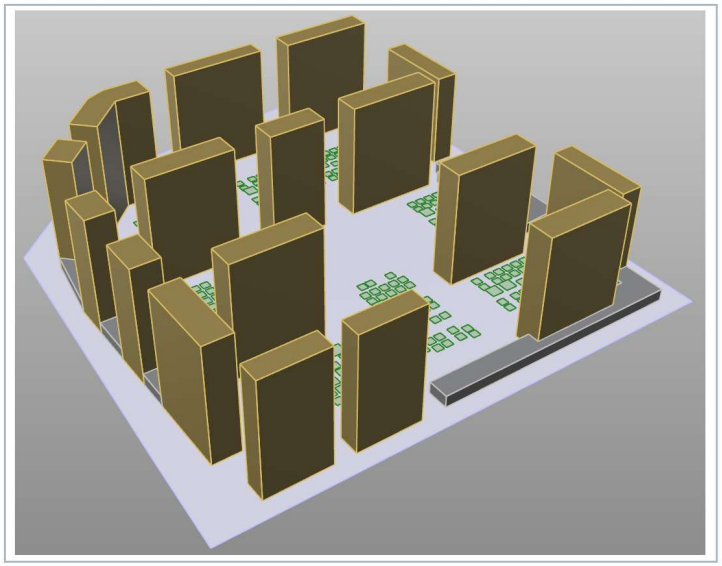


DATM: SSP2-4.5 hourly EPW **UWG: block-specific urban EPW** **EnergyPlus: total/heating/cooling EUI**

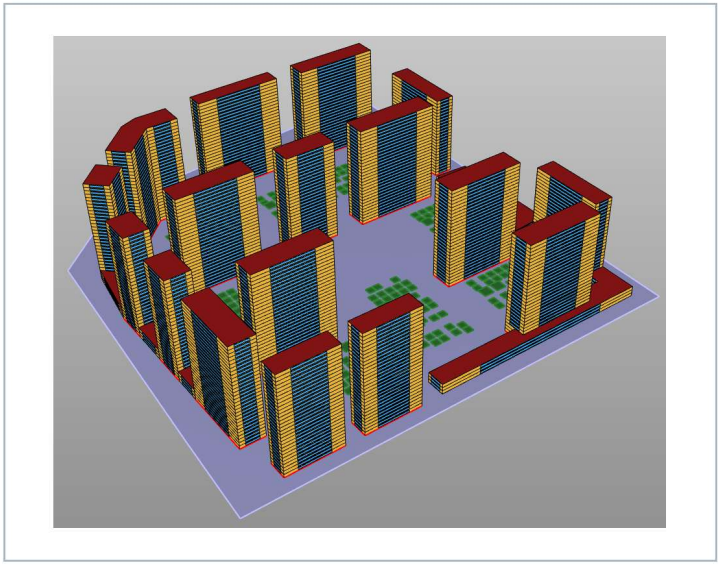
UWG supplies an air-temperature boundary; it does not resolve outdoor thermal comfort.

The same block is modeled for weather and energy

(a) UWG urban-canopy model



(b) Dragonfly/EnergyPlus energy model



Left: urban canopy parameters used to modify weather.

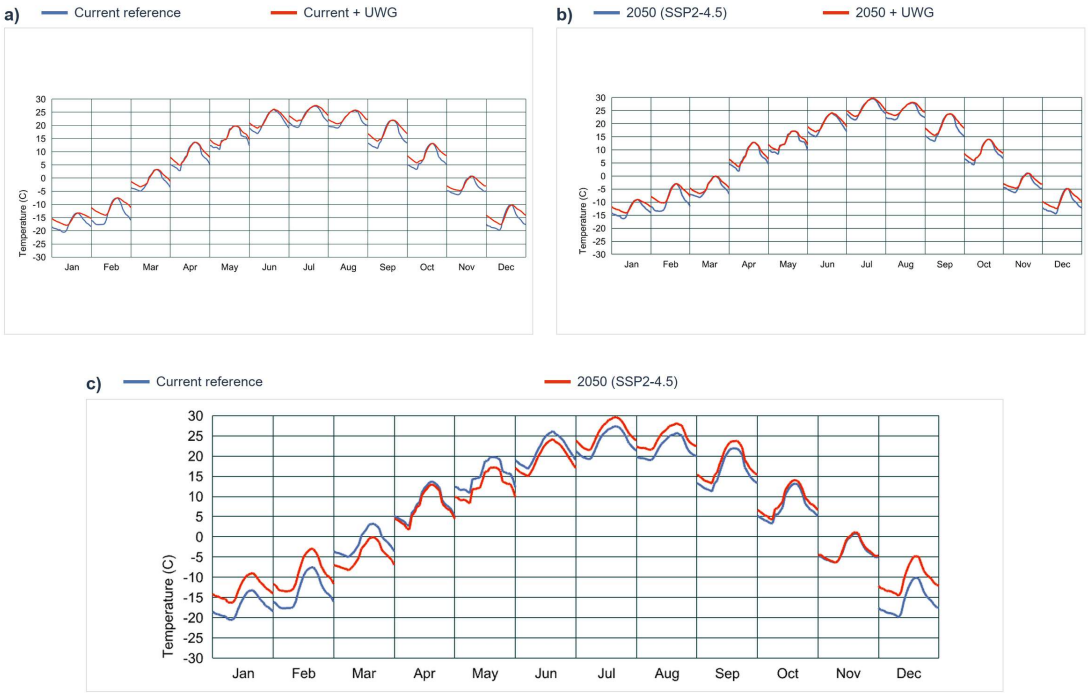
Right: building geometry used in the energy model.

Four scenarios separate future climate and UHI

	Reference weather	UWG urbanized weather
CURRENT	**Current** 2026 reference EPW	**Current + UHI** UWG-adjusted 2026 EPW
2050	**2050** DATM 2050 EPW	**2050 + UHI** DATM + UWG 2050 EPW

Horizontal: UHI adjustment at one period. Vertical: future-climate difference.

The weather files differ across seasons and urban settings



UWG raises the representative urban air-temperature profile.

DATM changes the hourly weather profile across the year.

The analysis screens morphology against four energy outcomes

20 indicators described

8 selected for correlation tests

2050 heating EUI

2050 cooling EUI

Absolute heating reduction

Absolute cooling increase

8 indicators × 4 outcomes = 32 Pearson tests

Benjamini–Hochberg adjustment controls the false discovery rate; $q < 0.05$ is marked.

Results

PART 02

Seasonal energy shifts and morphology sensitivity

Heating EUI decreases under both future comparisons

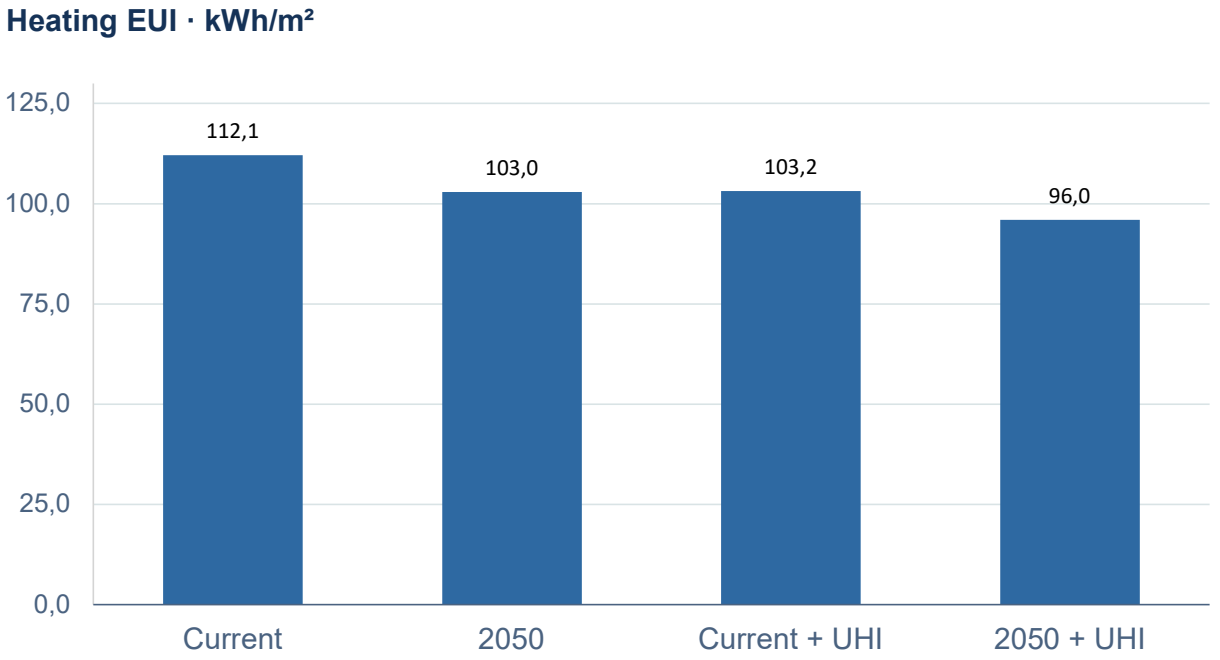
Heating remains the dominant annual end use.

−8.18%

Current → 2050

With UHI: −7.00%

Absolute change without UHI: −9.17 kWh/m².



Cooling EUI rises by about one quarter by 2050

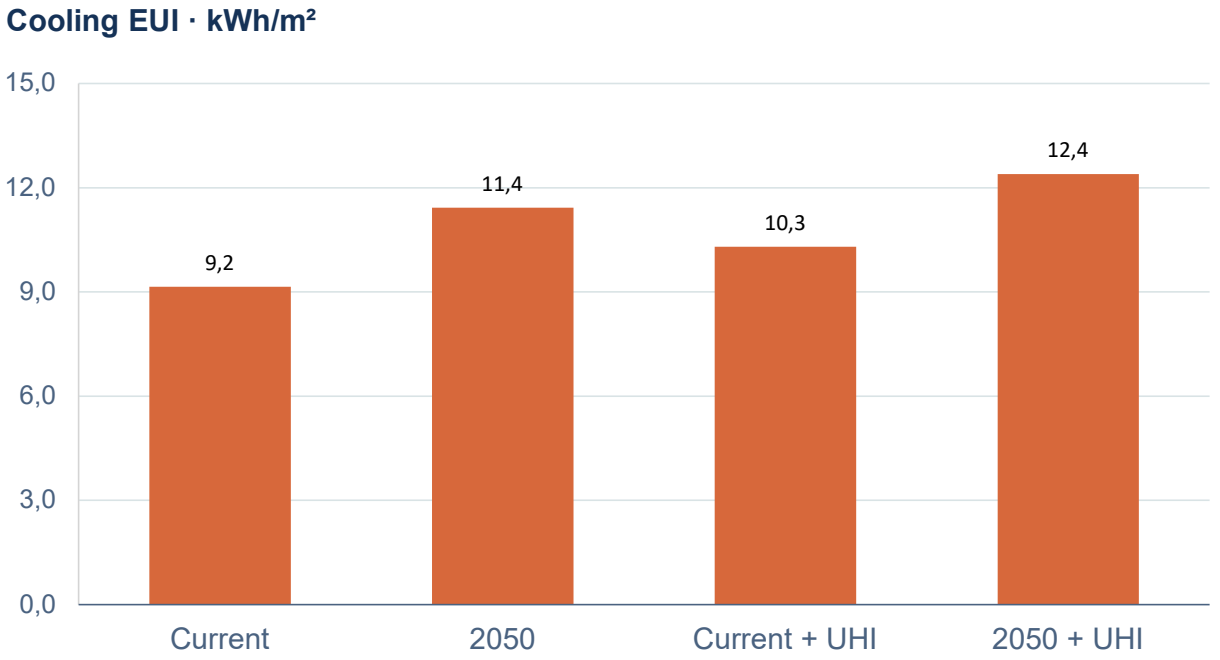
Relative growth is large despite the smaller absolute load.

+24.90%

Current → 2050

With UHI: +20.28%

Absolute change without UHI: +2.28 kWh/m².



Annual total EUI decreases as heating savings dominate

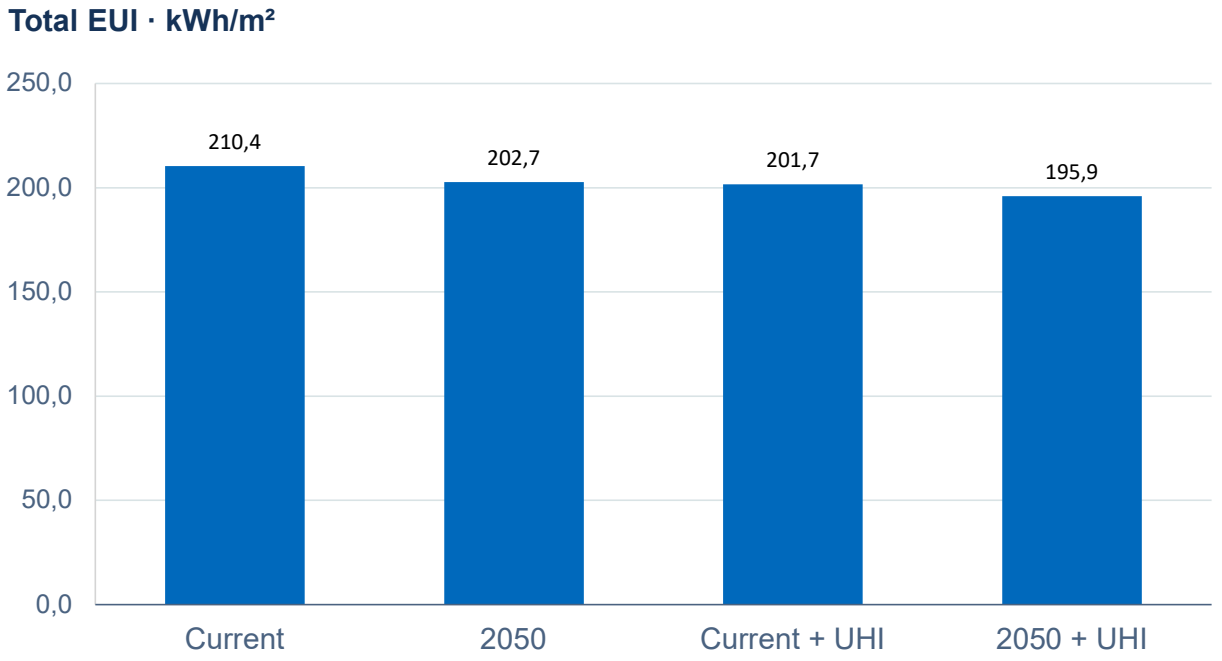
The larger heating saving outweighs the cooling increase.

−3.67%

Current → 2050

With UHI: −2.85%

Cooling still rises, so annual total alone is incomplete.

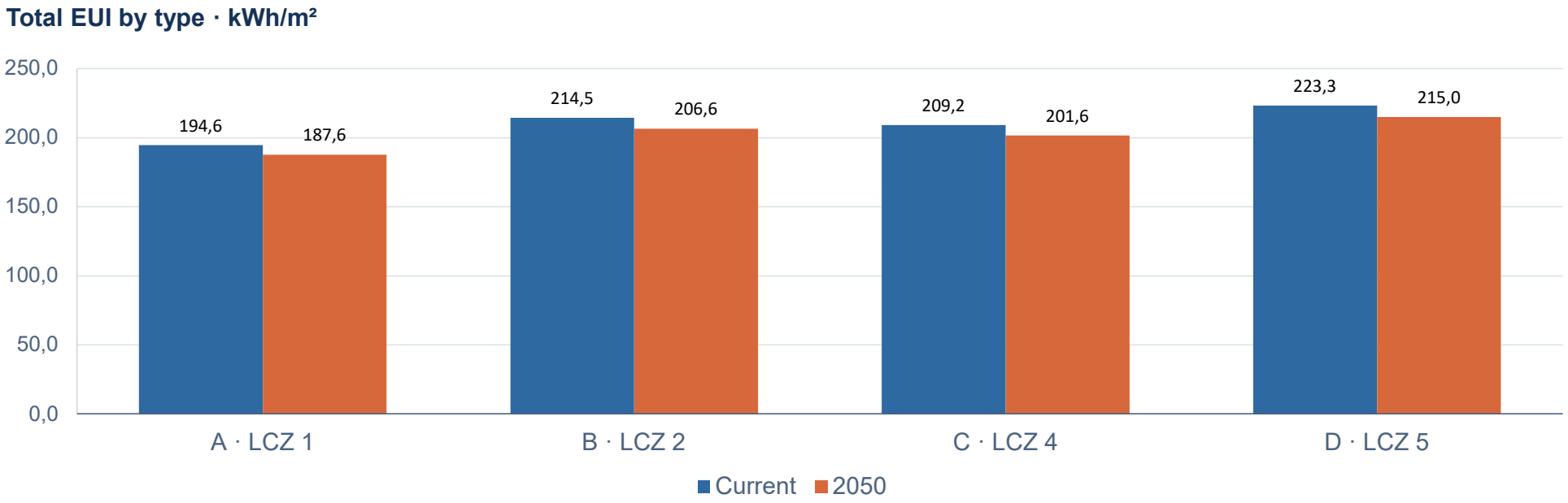


The UHI adjustment shifts heating and cooling oppositely

	Current vs current + UHI	2050 vs 2050 + UHI
Heating	−8.95	−7.00
Cooling	+1.16	+0.97
Total	−8.73	−6.76

Difference in mean EUI, kWh/m². Other simulated end uses are included in total EUI.

Compact high-rise blocks have lower mean total EUI

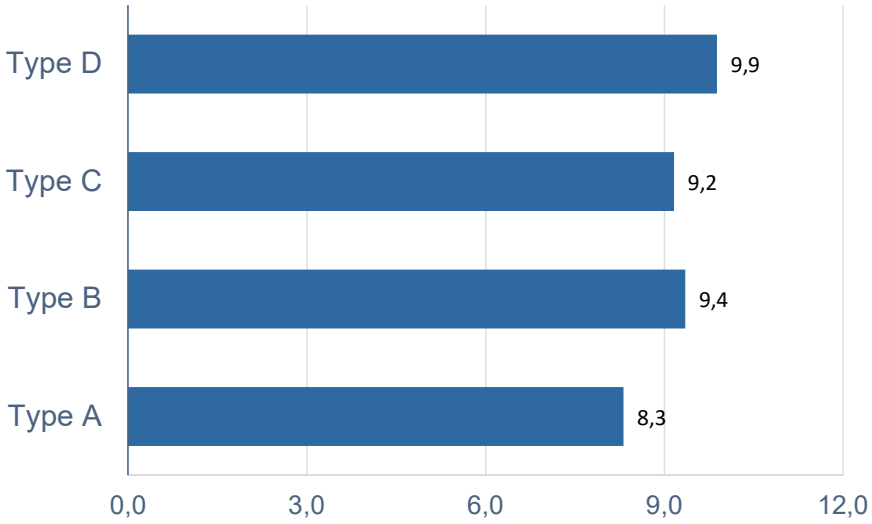


Current gap between Type D and A: 28.74 kWh/m²

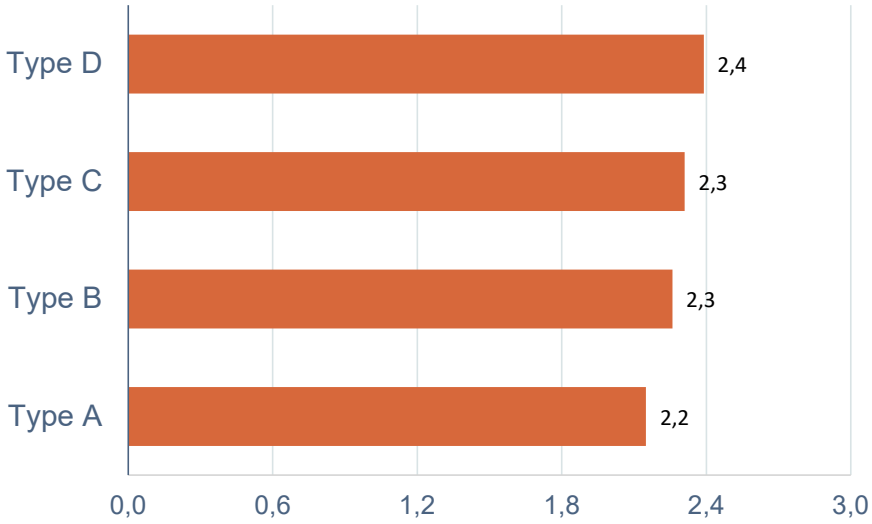
Five blocks per type. LCZ labels combine density, height, exposed envelope and context.

Open mid-rise blocks have the largest absolute changes

Heating reduction · kWh/m²



Cooling increase · kWh/m²



Type D: largest heating reduction (9.88) and cooling increase (2.39)

Type labels are bundles of correlated attributes; the comparison does not isolate cause.

Shape factor and perimeter ratio stand out

	2050 heating	2050 cooling	Heating reduction	Cooling increase
FAR	-0.62*	-0.12	-0.56*	-0.37
BCR	0.61*	0.23	0.58*	0.39
ABH	-0.73*	-0.17	-0.66*	-0.43
MBH	-0.79*	-0.27	-0.73*	-0.56*
SF	0.99*	0.70*	0.98*	0.88*
PAR	0.91*	0.84*	0.92*	0.94*
SVF	-0.02	-0.19	-0.03	-0.09
Green	-0.58*	-0.67*	-0.64*	-0.66*

SF and PAR: positive associations with all four outcomes

* Benjamini–Hochberg adjusted q < 0.05 across 32 tests

Exposed form tracks both heating and cooling changes

Pearson r with absolute current-to-2050 change

	Heating reduction	Cooling increase
Shape factor	0.977	0.882
Perimeter-area ratio	0.922	0.944

Interpretation: exposed building surface and perimeter may signal climate sensitivity.

All four $q < 0.01$. Bivariate correlations; no independent causal effect is established.

Morphology correlations do not isolate causes

01	**Twenty blocks**	Five cases in each LCZ group limit generalization.
02	**Co-varying form**	Height, envelope exposure and construction age differ.
03	**Unmeasured factors**	Envelope and equipment may contribute to observed EUI.
04	**Fixed operation**	Occupant schedules and adaptation were not varied.

Correlations screen indicators; they do not establish causal thresholds.

Test design alternatives against both seasons

Envelope exposure	Reduce unnecessary fragmentation, then check winter losses.
Solar and shading	Protect useful winter sun while reducing summer gains.
Open space and green	Test placement for shade, ventilation and cold-wind exposure.

Use the same four weather scenarios to compare candidate layouts; report heating and cooling separately.

Conclusions

−8.18%	Heating EUI under 2050 reference weather
+24.90%	Cooling EUI under 2050 reference weather
SF + PAR	Strongest morphology correlates in this sample

KEY LESSON

Global warming and urban heat islands can raise summer cooling in hot regions, yet ease winter heating in severe-cold areas. Assess energy by season and climate.