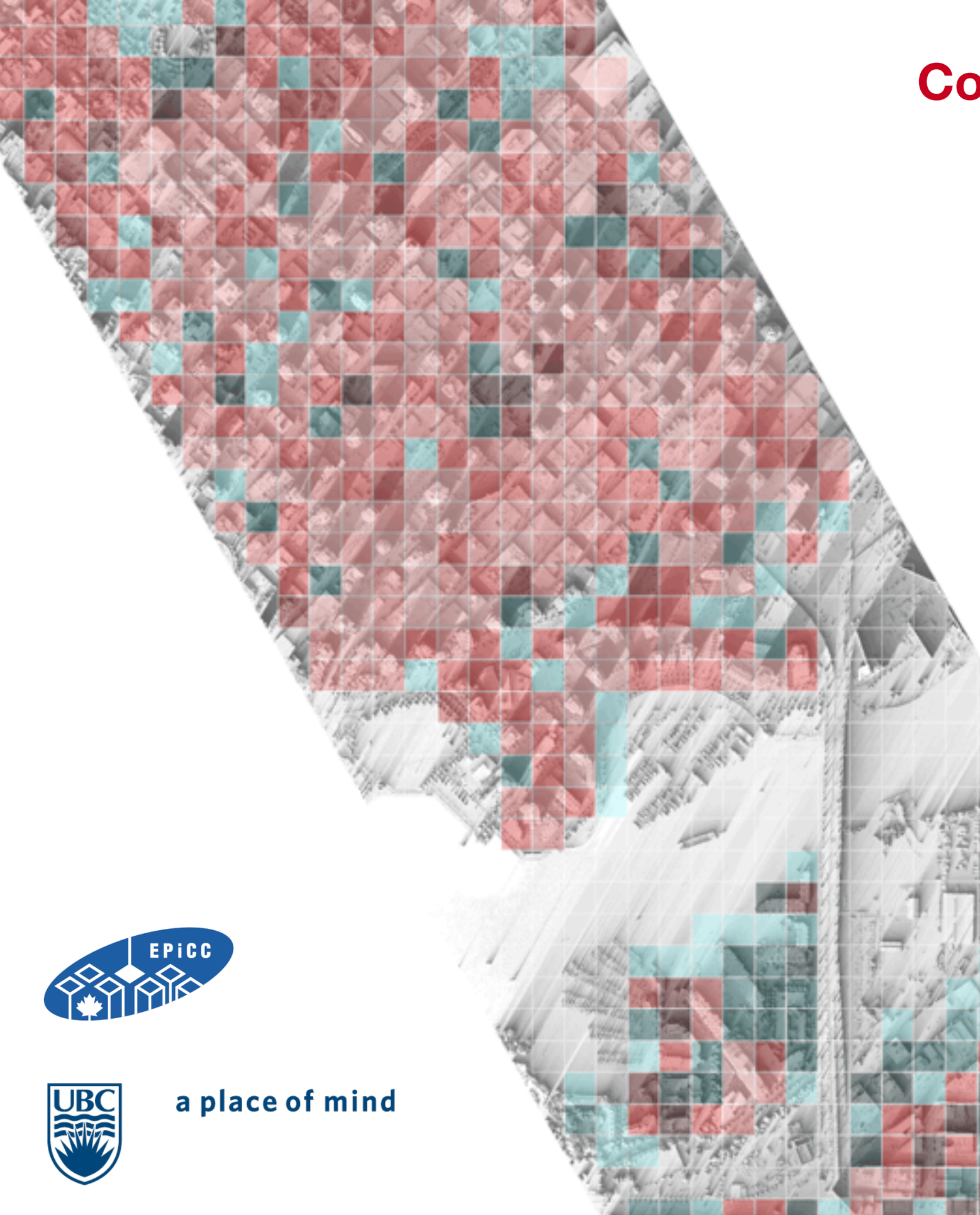

Context sensitive scaling of energy use simulations

From individual buildings to cities

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EPiCC

UBC a place of mind

Energy use and emissions estimates for entire cities rely mostly on **inventory data**, which is typically only available at aggregate space and time scales.

At the building-scale, sophisticated building energy models (BEM) exist, but require detailed knowledge about the building and its environment.

Vancouver, Canada

Very **few inventories** of energy demand are **at the intermediate neighborhood-scale** though this is where many development decisions are made, and information is required for atmospheric models.

This is in large part due to the difficulties in scaling and the effort needed to characterize **urban form.**

Vancouver, Canada

Factors influencing energy demand
Potential for automated inputs

Form-based input

Typology input

Population

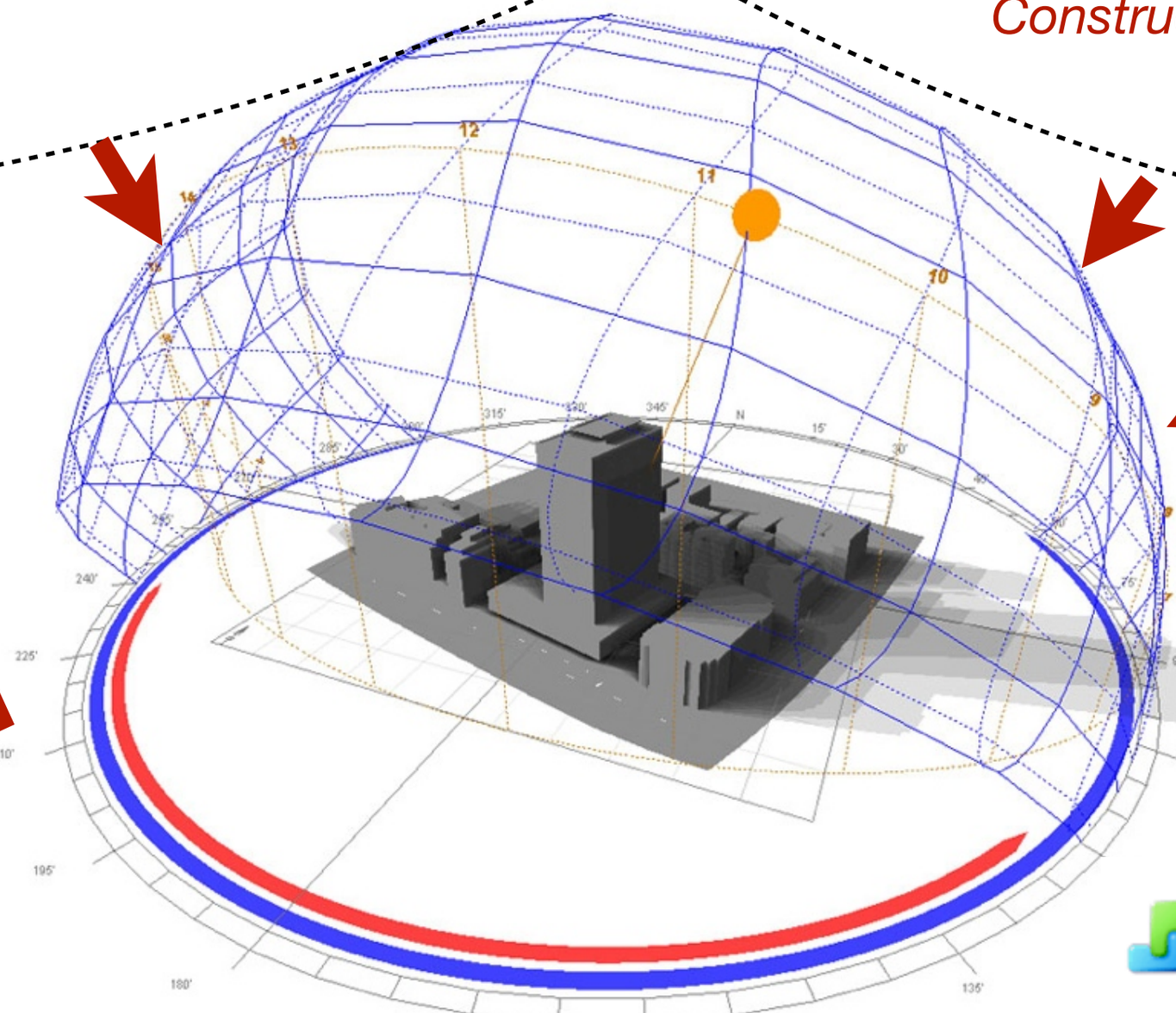
Building use

Building Morphology

Construction

Urban Morphology

Systems



Weather

Hourly Energy Estimates

a place of mind

DesignBuilder SOFTWARE

7 km long and 1 km wide LIDAR scan in Vancouver, Canada
with about 11’000 individual buildings

Central business district
mostly high rises

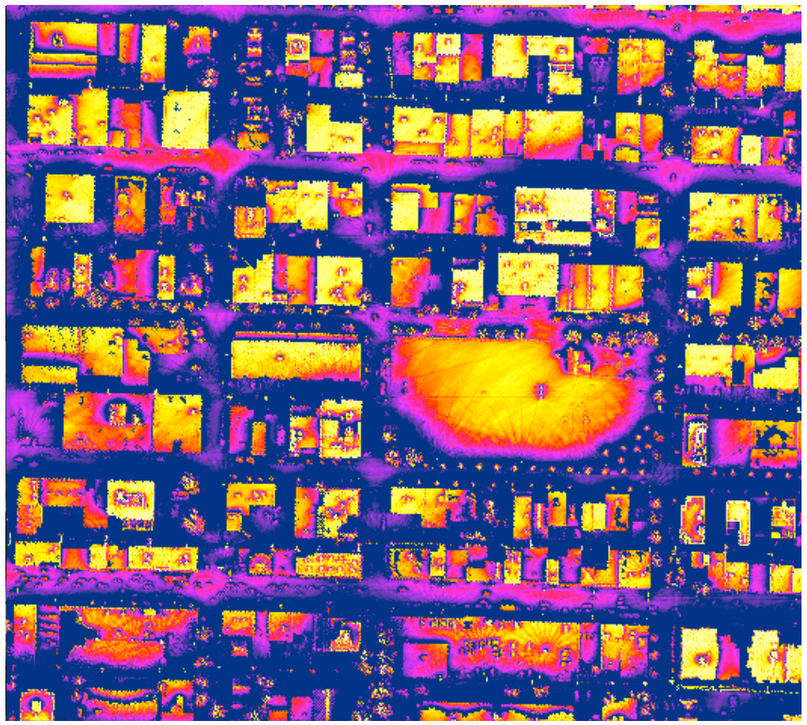
Suburban
mostly detached dwellings

Gridded lidar data products

3D morphometrty of buildings and trees at 1 x 1 m

Intersection of Knight and 49th in Vancouver (Goodwin and Coops, UBC, 2008)

What can we derive/inform from LiDAR that is important to building energy use?



Urban morphology
Shading and sheltering

Building morphology
Archetype and form

	LiDAR Volume	avg M3 / capita
Residential Detached (1900-1964)	626	166
Residential Detached (1965-1990)	736	166
Residential Detached (1991-2009)	663	166
Residential Duplex	836	195
Residential Multiplex	983	200
Residential Rowhouse	1205	209
Residential Lowrise/Midrise	2812	206
Residential Midrise/Highrise	36693	223
Mixed-use	1631	772

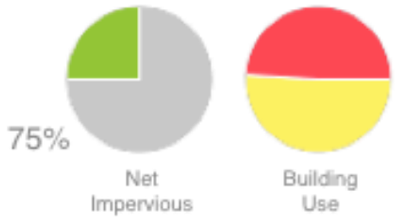
Population distribution
Hot water demand

Modelling 10’000s of buildings
An archetype approach

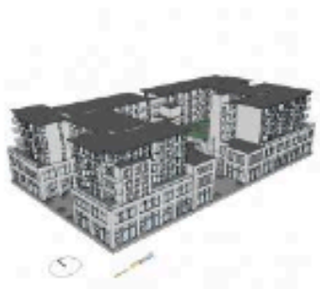
elements db
BETA

Dalhousie Mixed-use Mid-rise

Apartment housing with exterior circulation above two stories of retail



Case # 33006-00



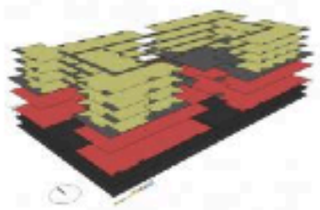
OCCUPIED STORIES
6

DWELLINGS
80

COMMERCIAL UNITS
26

APERTURE % of EXTERIOR WALL
0 %

RATIO OF ENVELOPE TO CONDITIONED FLOOR
0.55



RESIDENTIAL FLOOR AREA
7730 m²

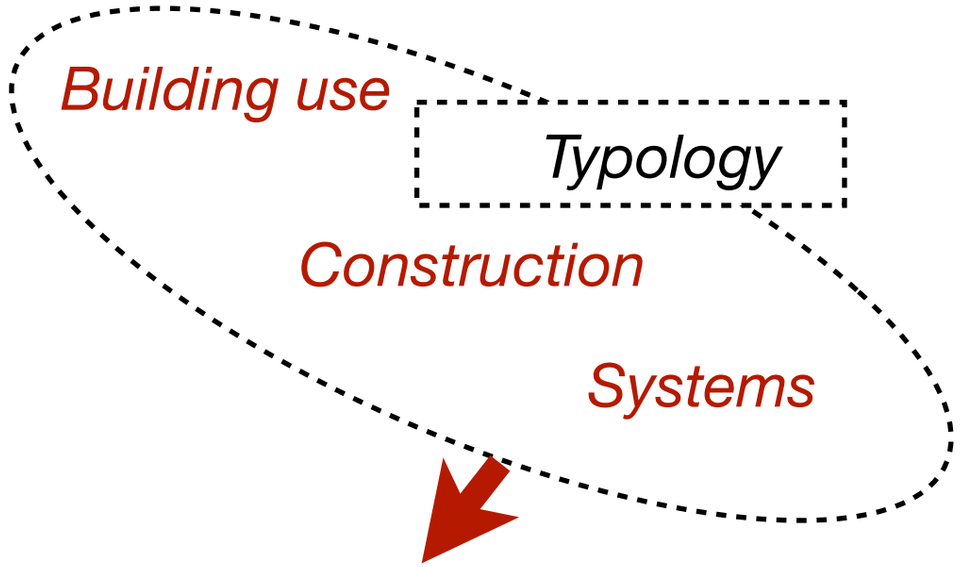
COMMERCIAL FLOOR AREA
7412 m²

TOTAL CONDITIONED
15142 m²

TOTAL PARKING
9875 m²

INDUSTRIAL FLOOR AREA
0 m²

CIVIC FLOOR AREA
0 m²



*Assumes archetypes are **scalable** and **replicable***

***12 Archetypes** chosen based an assumed correlation between building use, form, period of construction and energy performance*

UBC a place of mind

simulating
12 archetypes
with
5 different building volumes
5 different shading factors
5 different population inputs

are

180 simulations in BEM

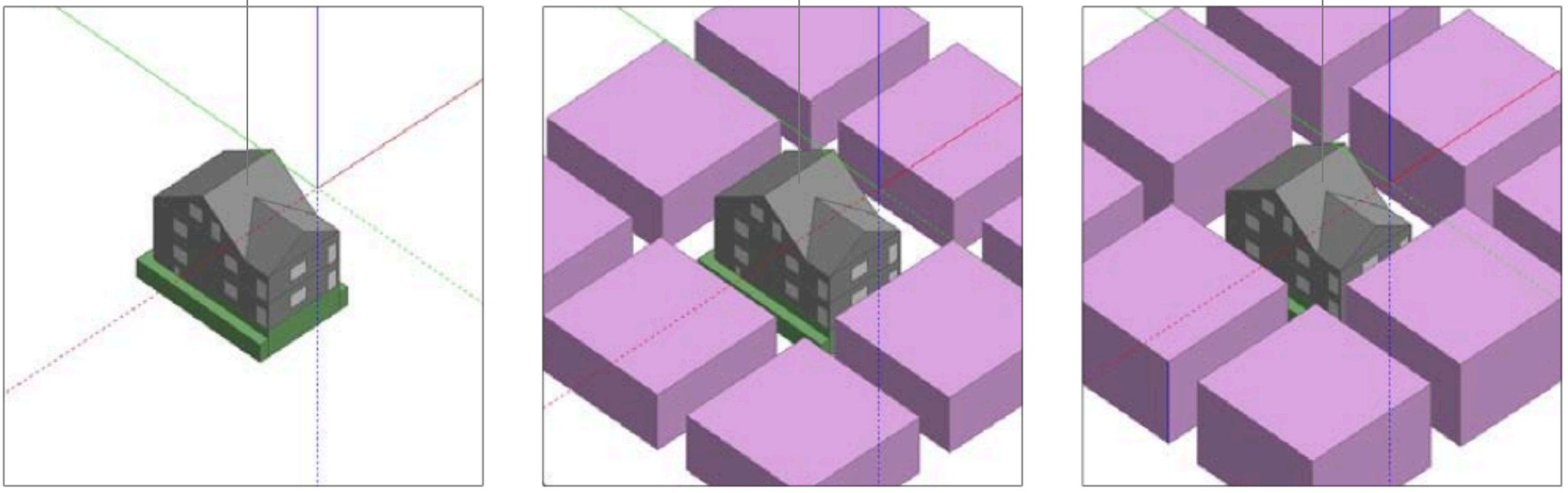
simulating
11’000 buildings individually

are

11’000 simulations in BEM with
individual inputs

Solar access and sheltering
Scaling of urban morphology

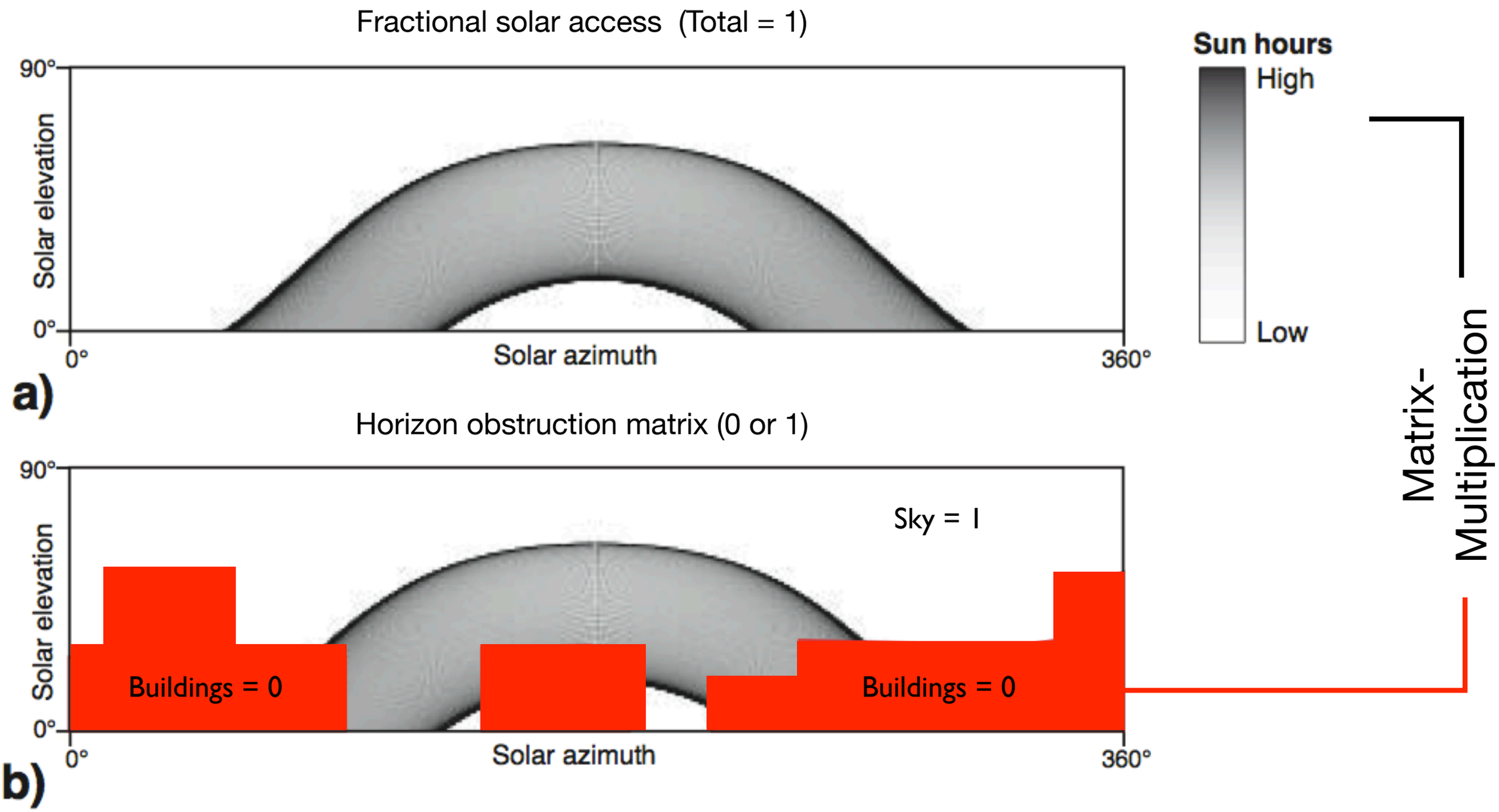
Same building archetype



Reference BEM run in unobstructed terrain

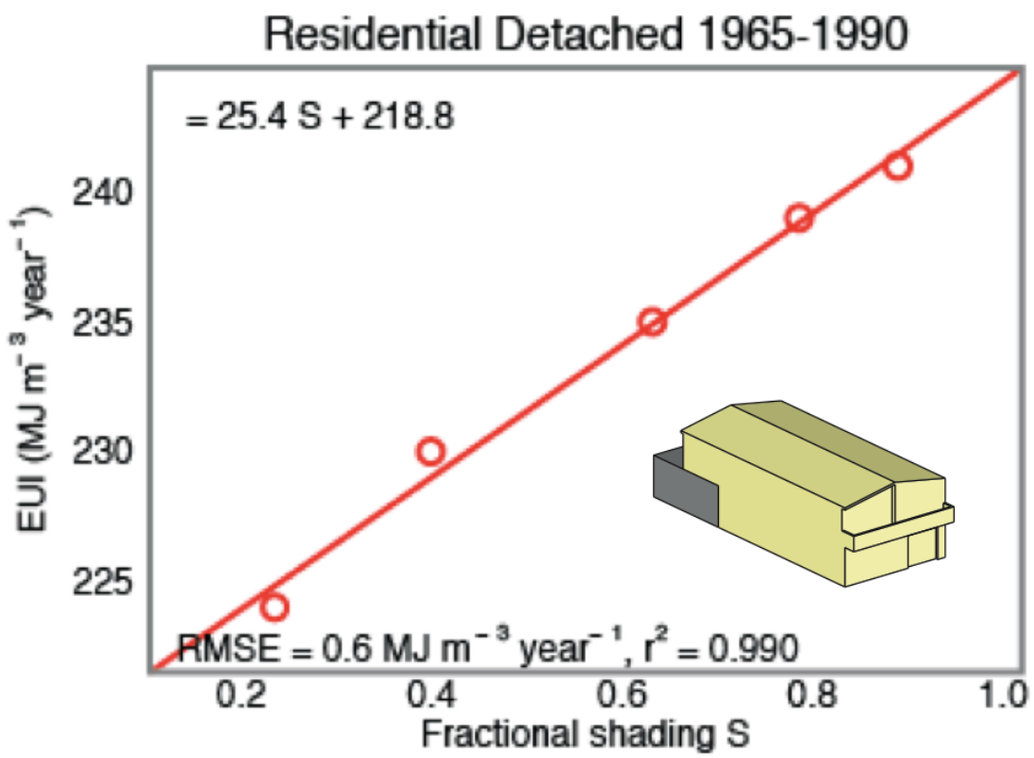
4 BEM runs with increasing obstruction

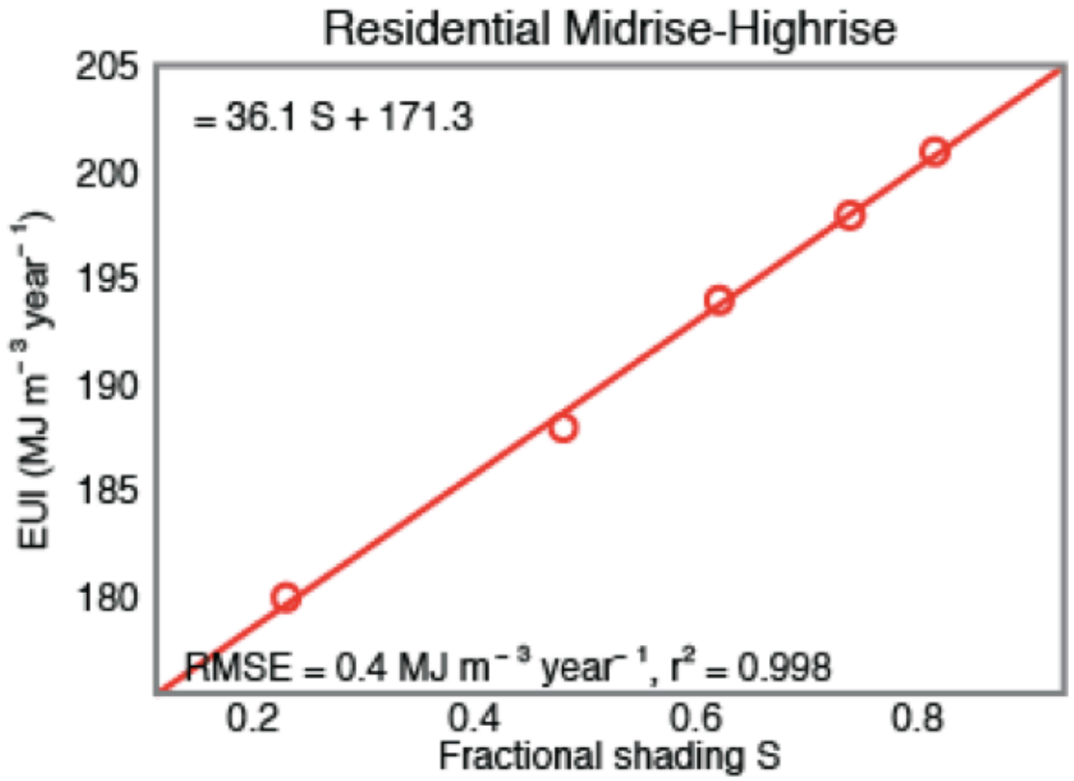
Fractional shading
Rapid calculation of potential direct sunlight

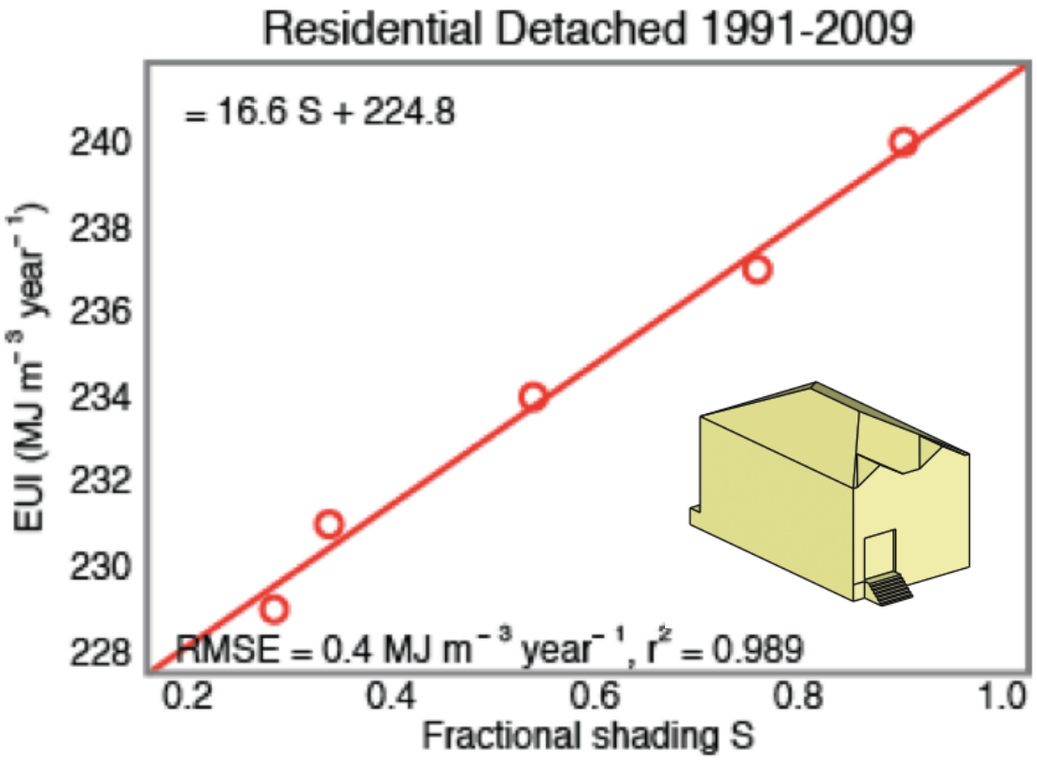


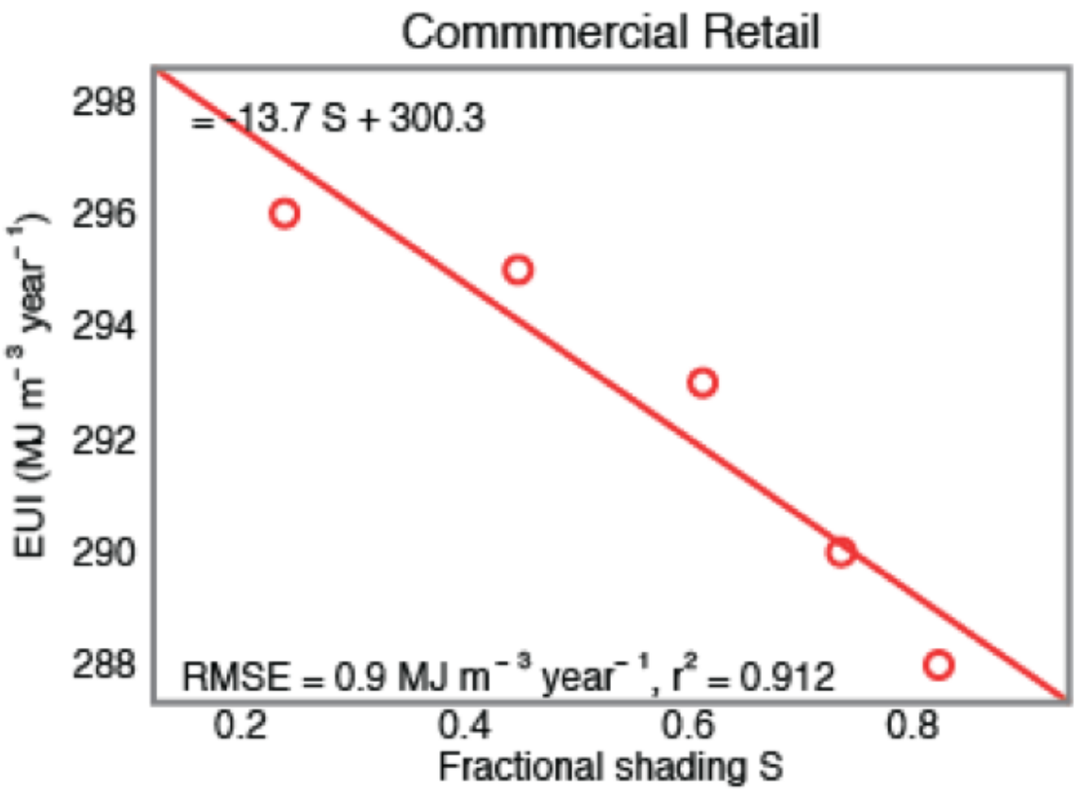
Fractional shading calculated for for each building based on gridded LIDAR dataset

Fractional shading
Impact on Energy Use Intensity (MJ m^{-3} $year^{-1}$)



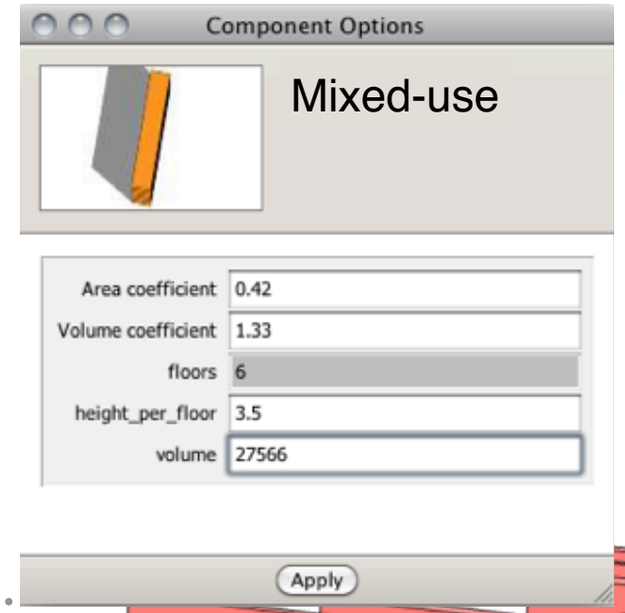


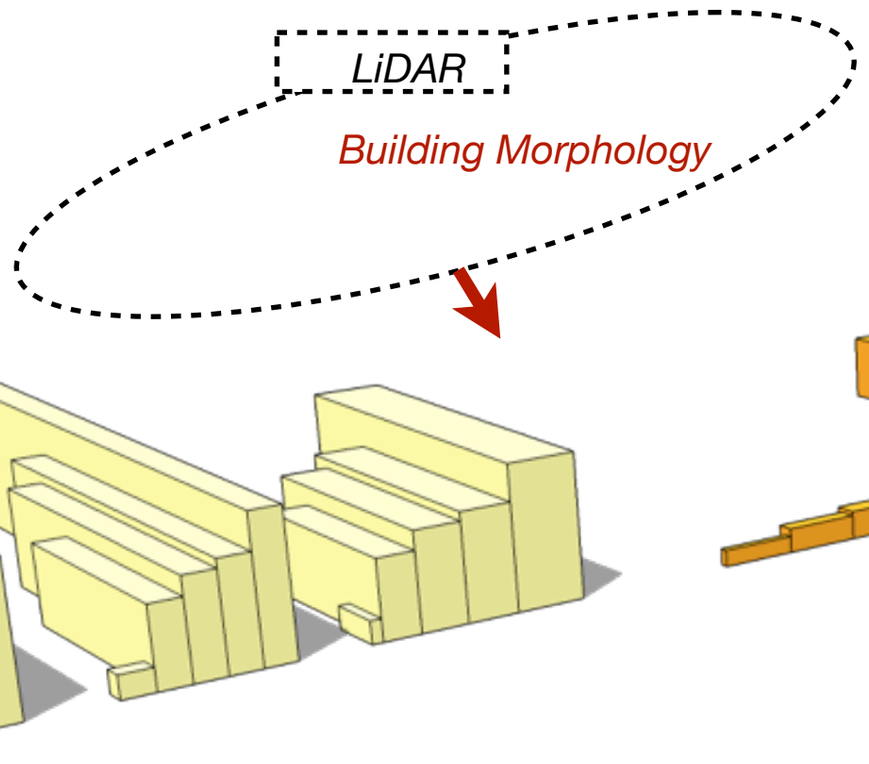


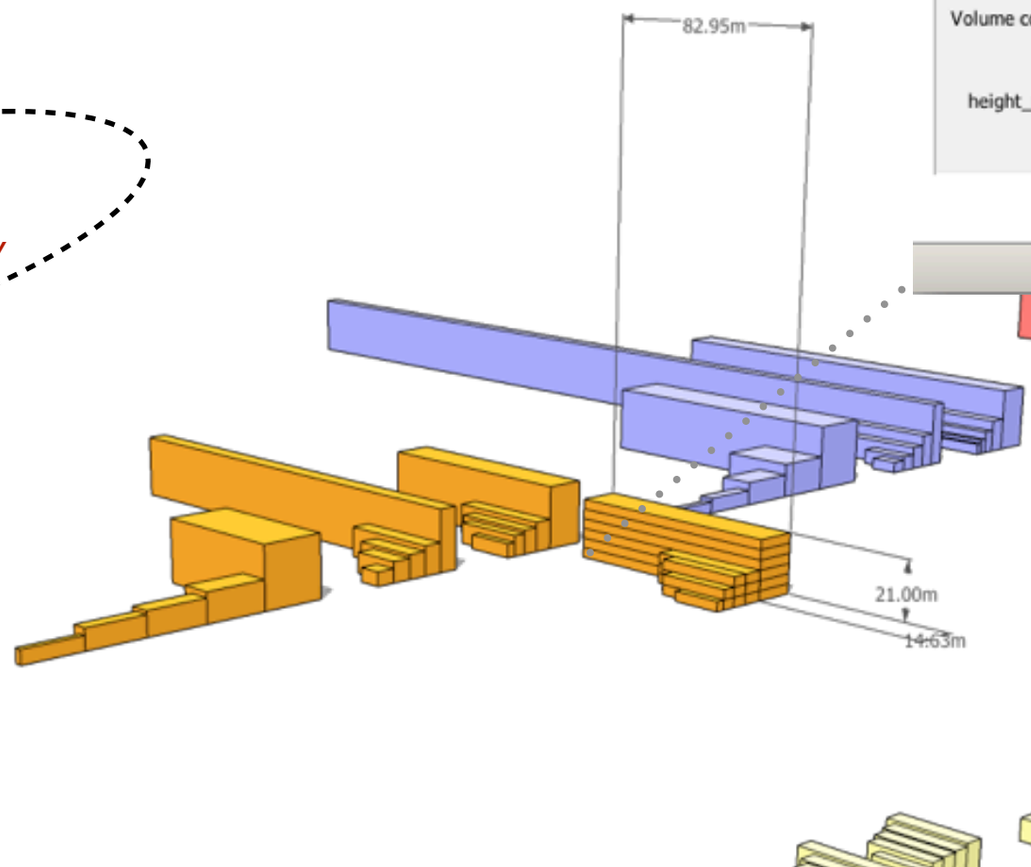


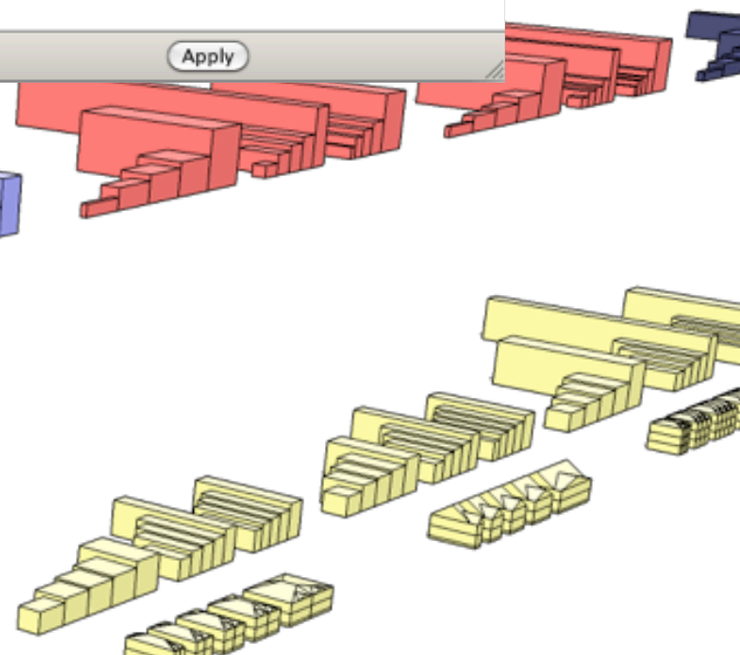
Building allometry

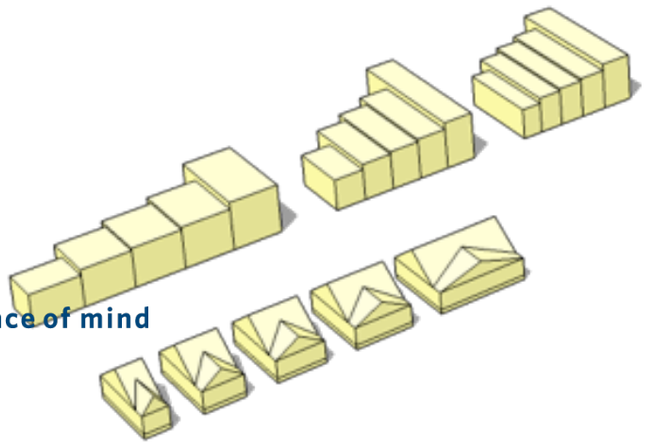
Lidar-informed scaling of building morphology

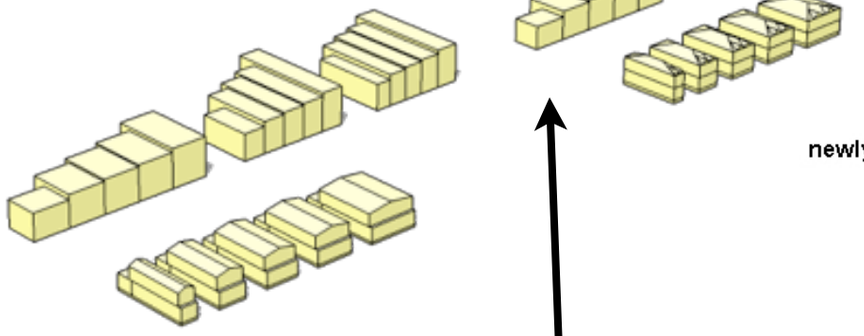


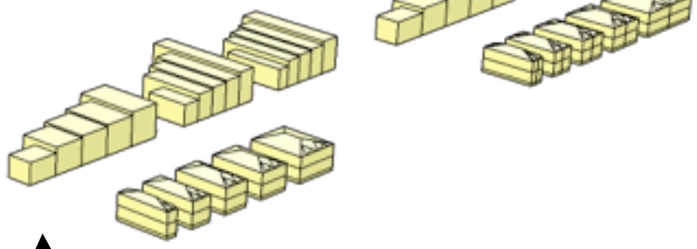


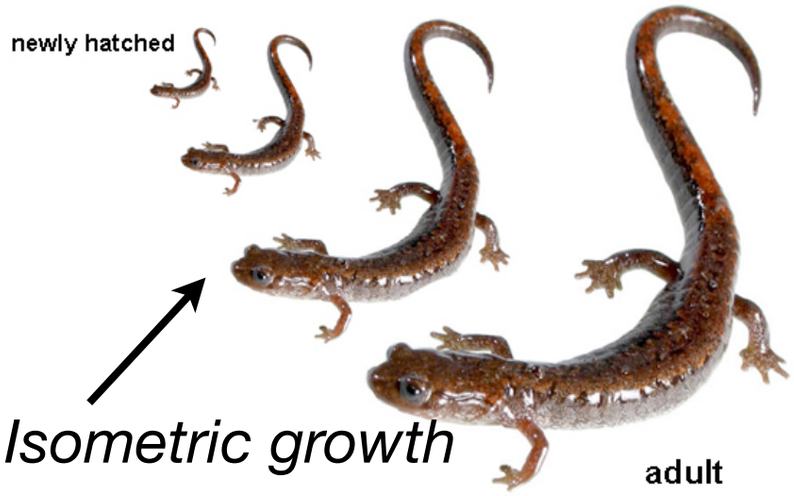






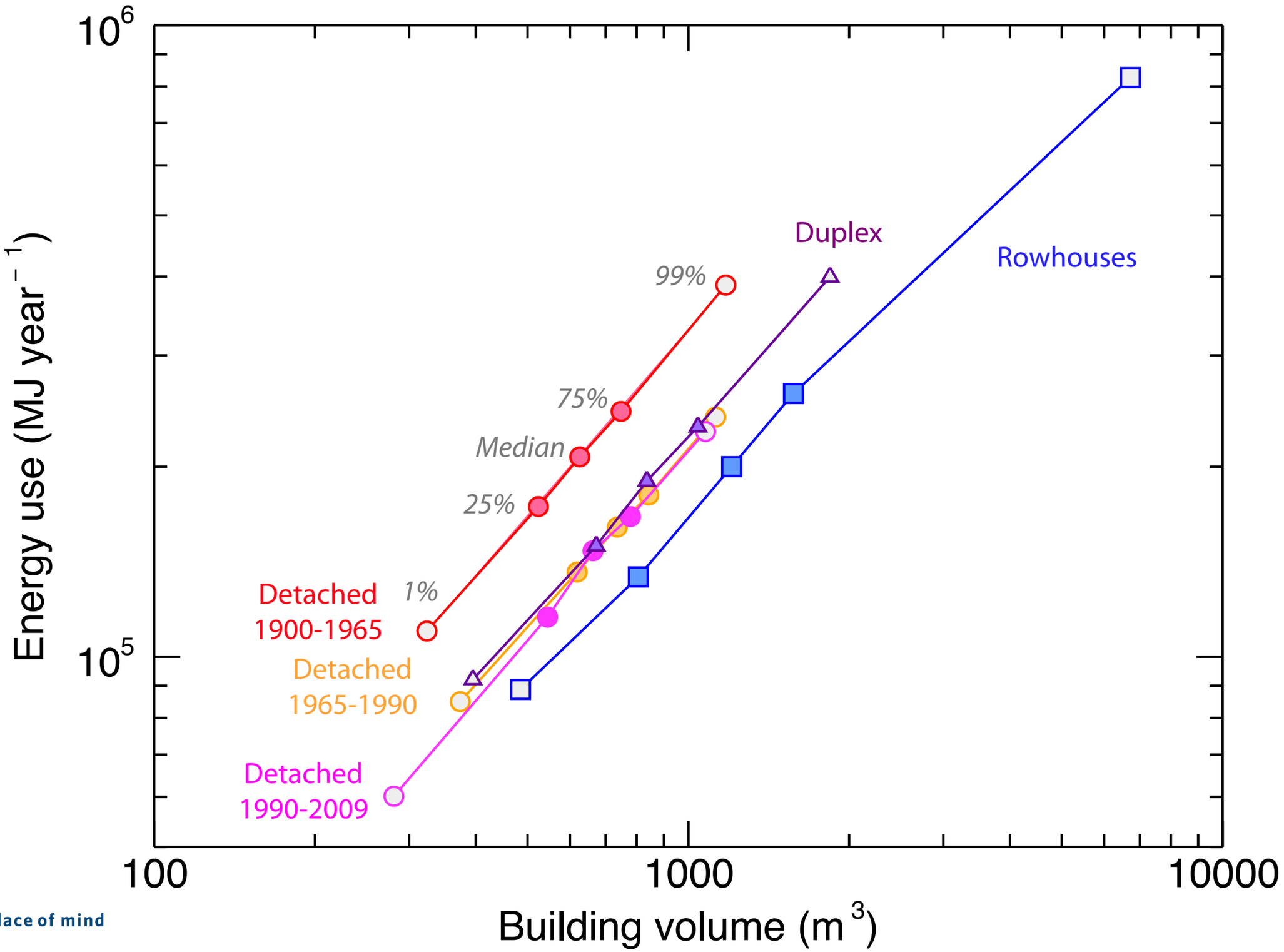




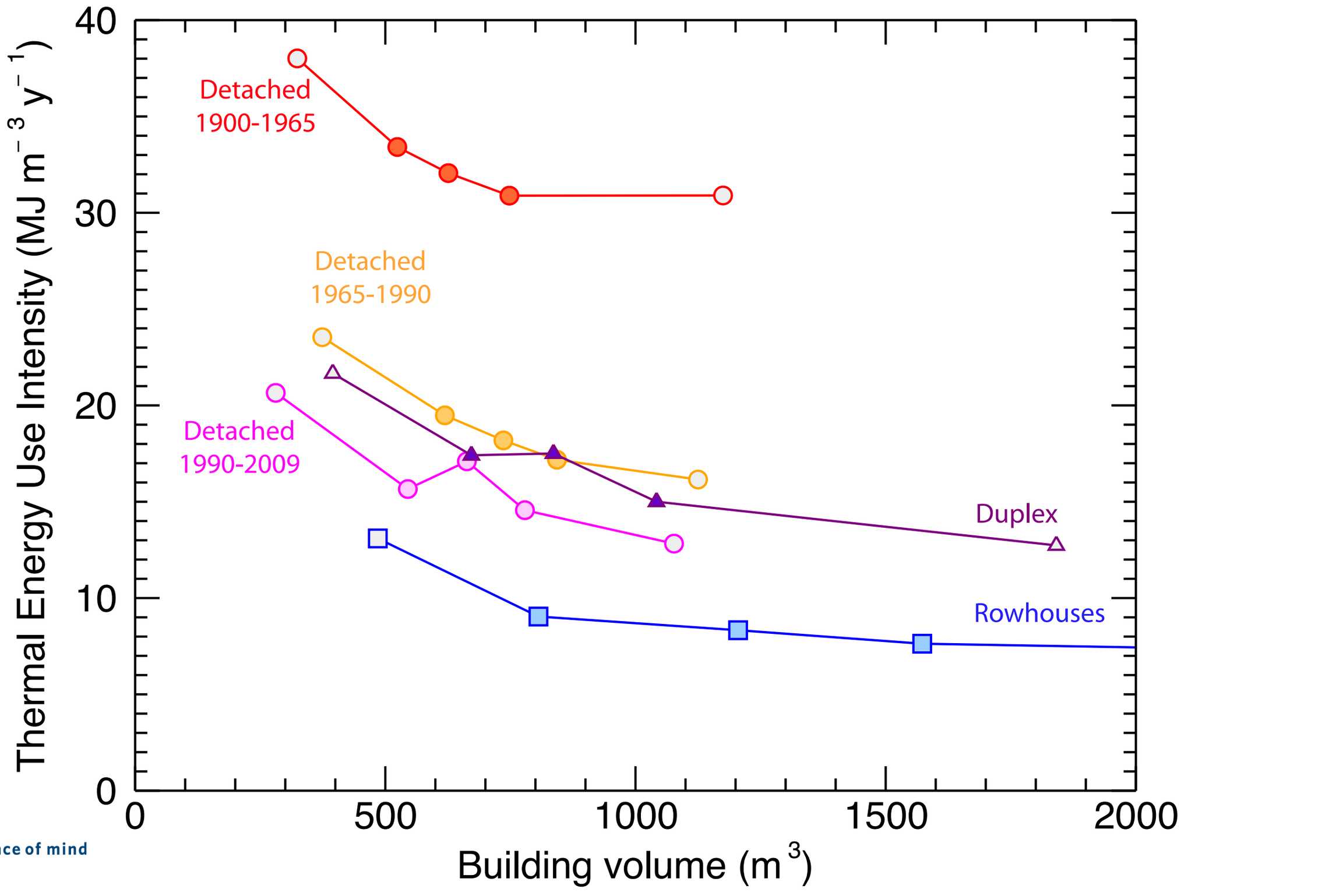


Allometric vs Isometric growth

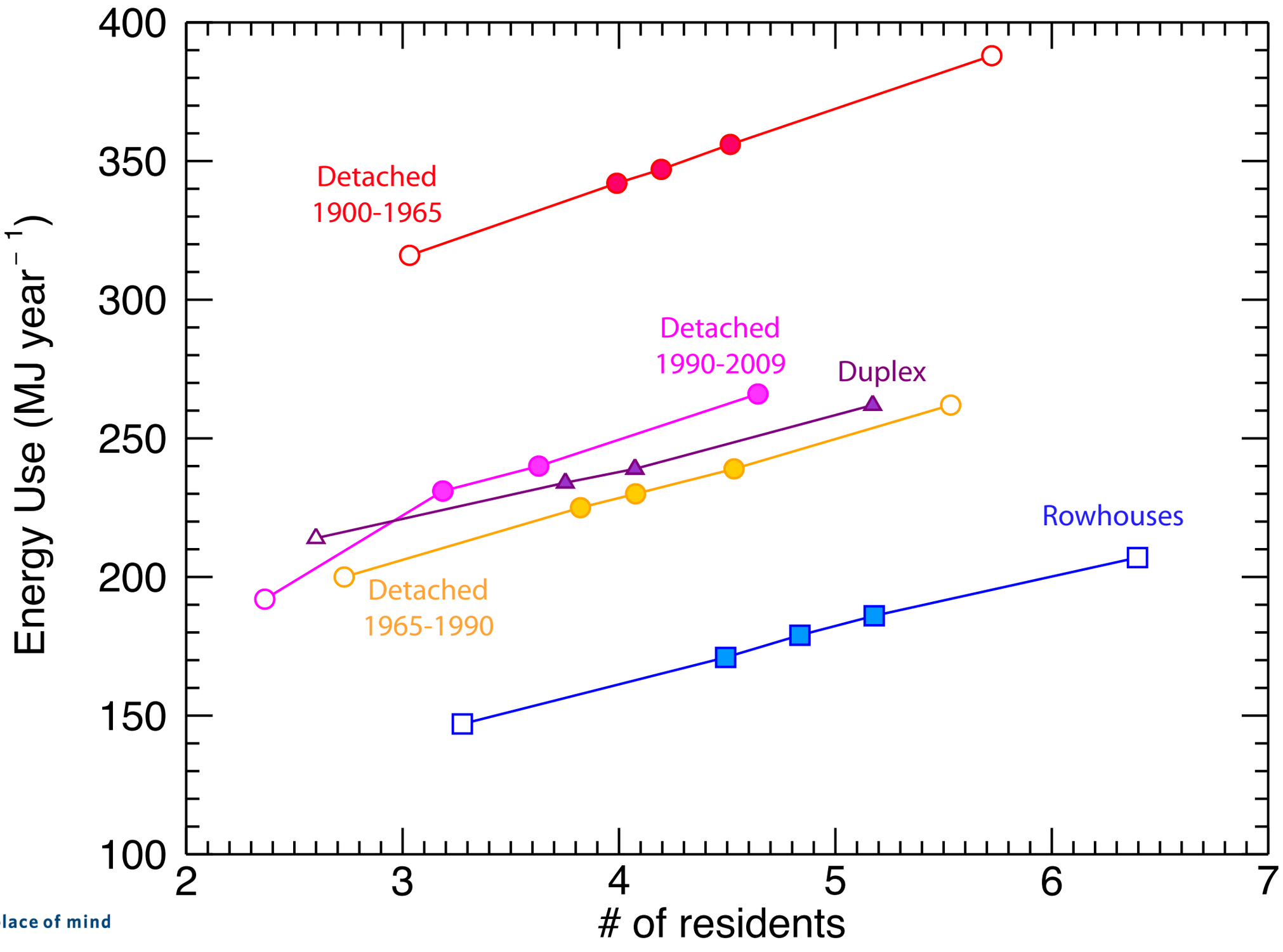
Total building energy use
increases with volume



Energy intensity (m^{-3}) for space heating
decreases with increasing volume



Population
driven primarily by hot water demand



Urban Morphology

Building Morphology

Population

Base-load

$$EUI = \alpha_s\, S + \alpha_v\, V + \alpha_p\,(P - \overline{P}) + \beta_v$$

Sensitivity to shading

★ **Fractional shading factor**

Sensitivity to volume

★ **Building volume**

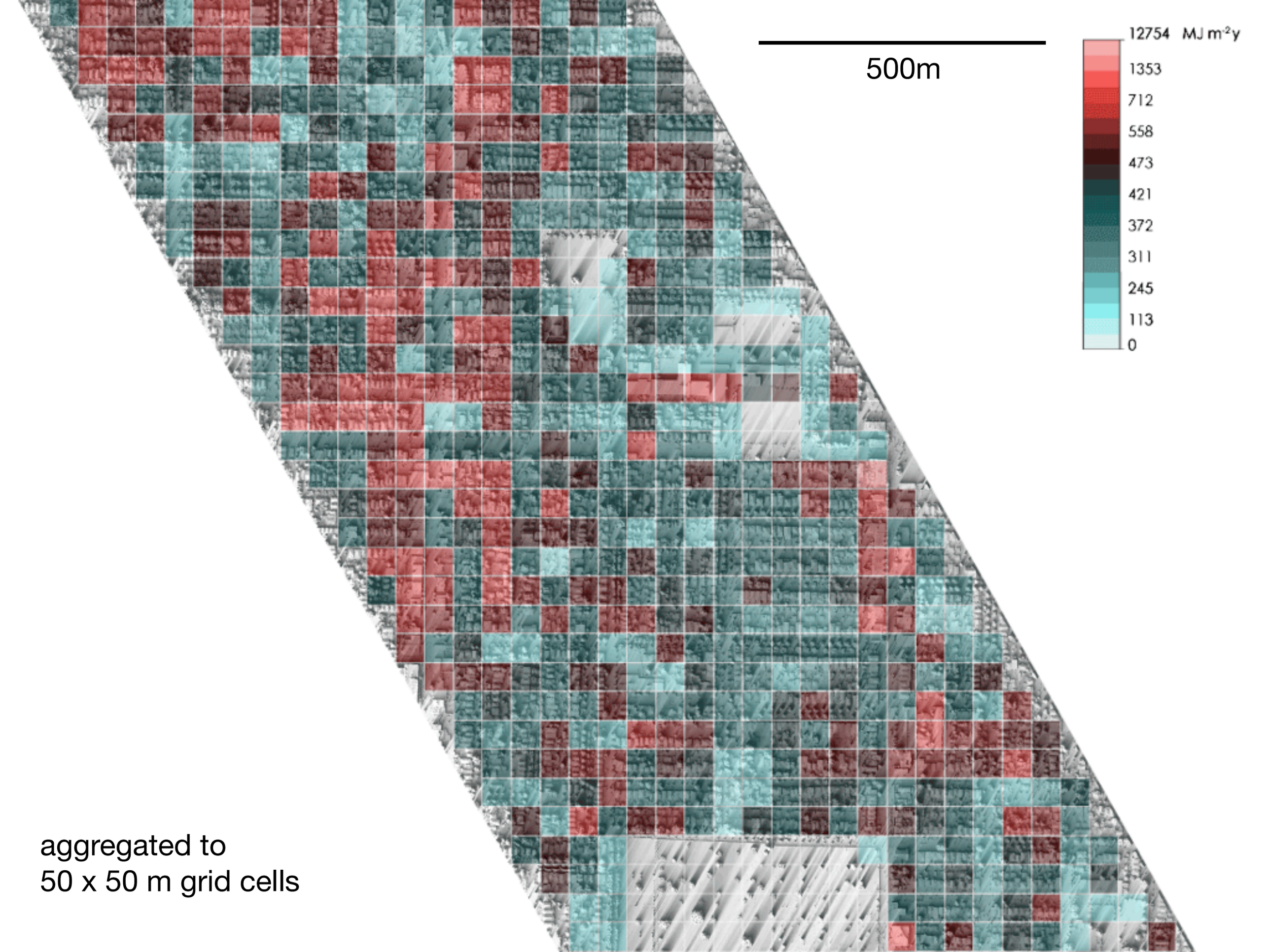
Sensitivity to population

★ **Population**

Average population of archetype

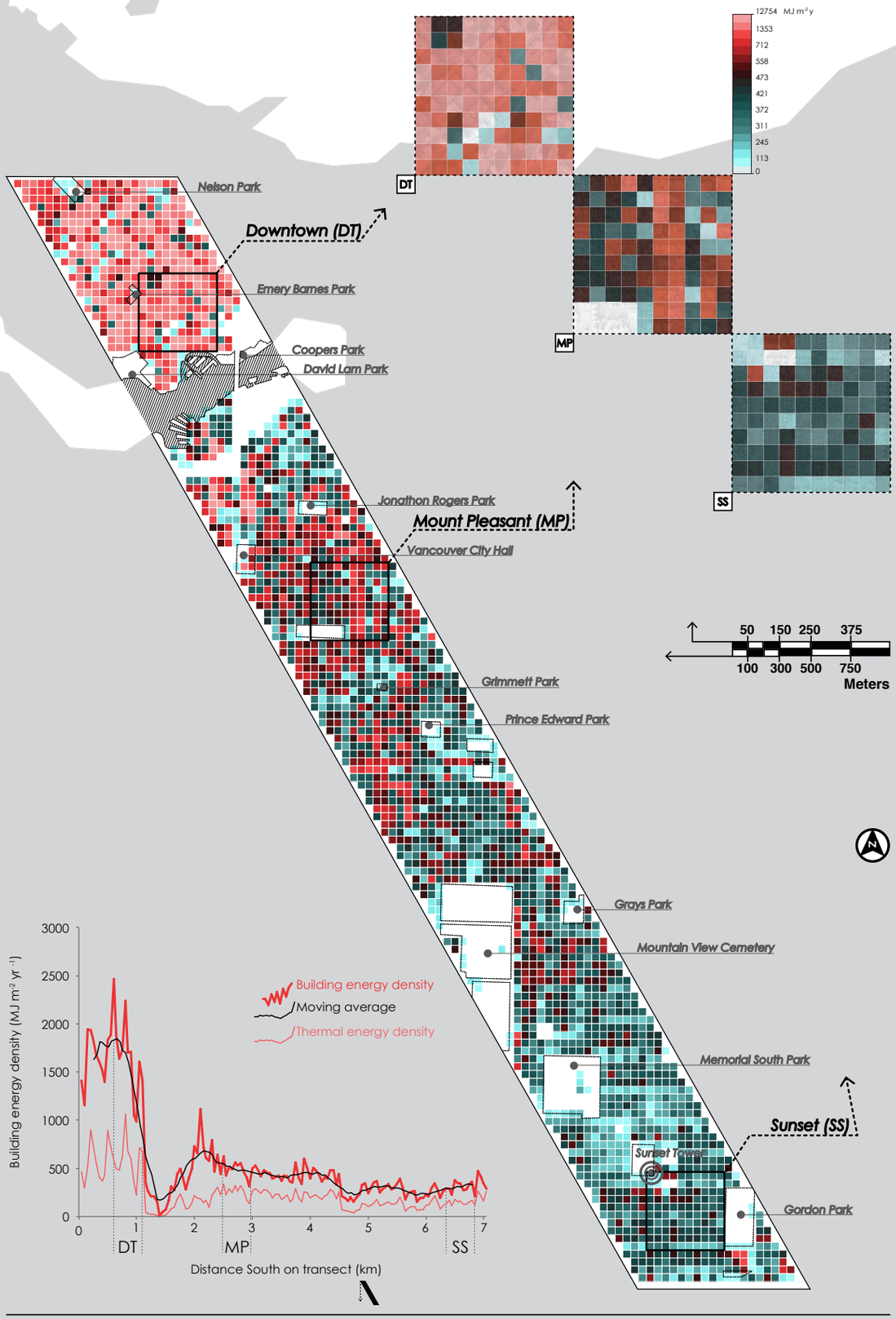
a place of mind

★ = derived using LIDAR for each individual building



aggregated to
50 x 50 m grid cells

Building Energy Use



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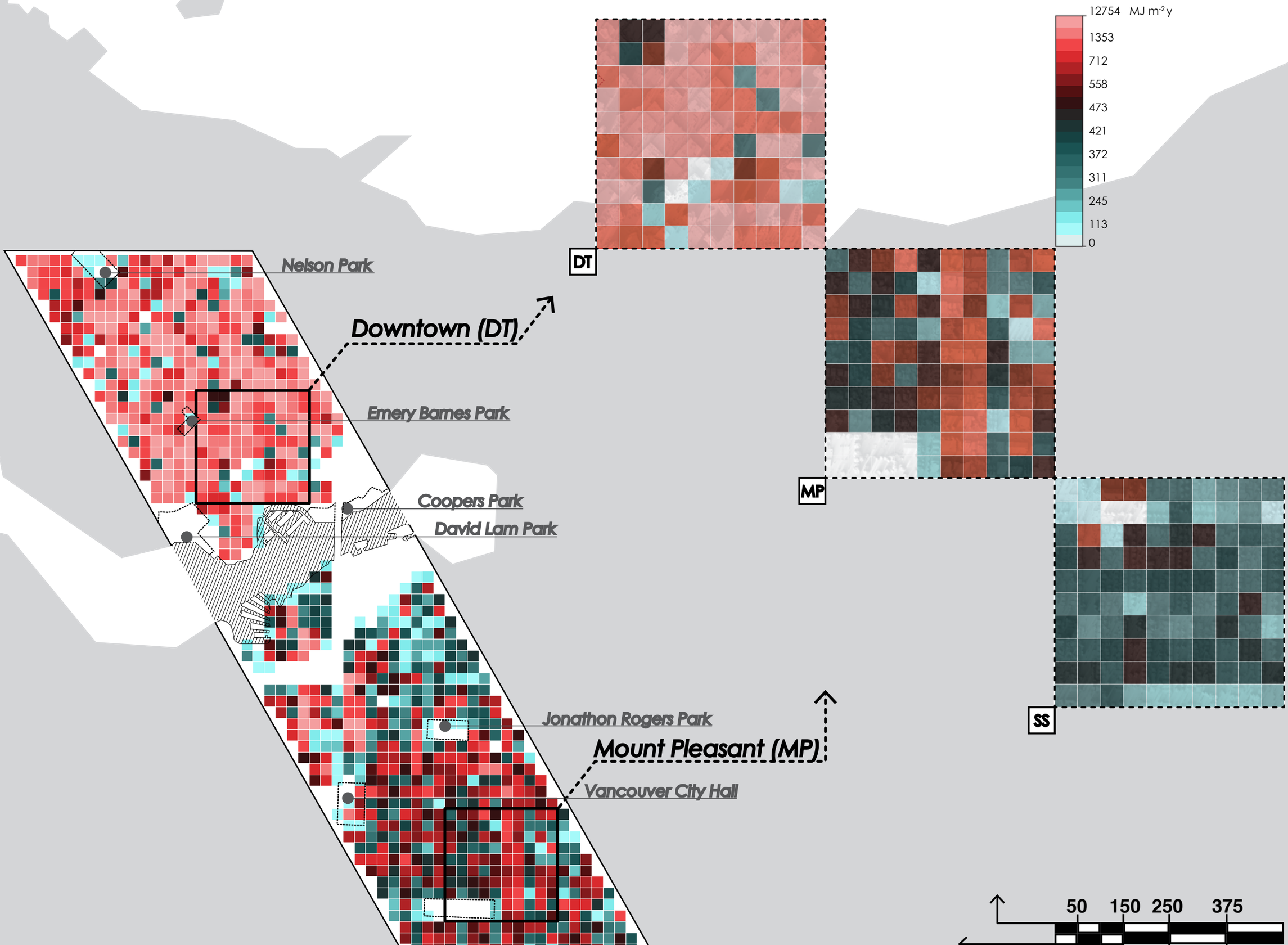
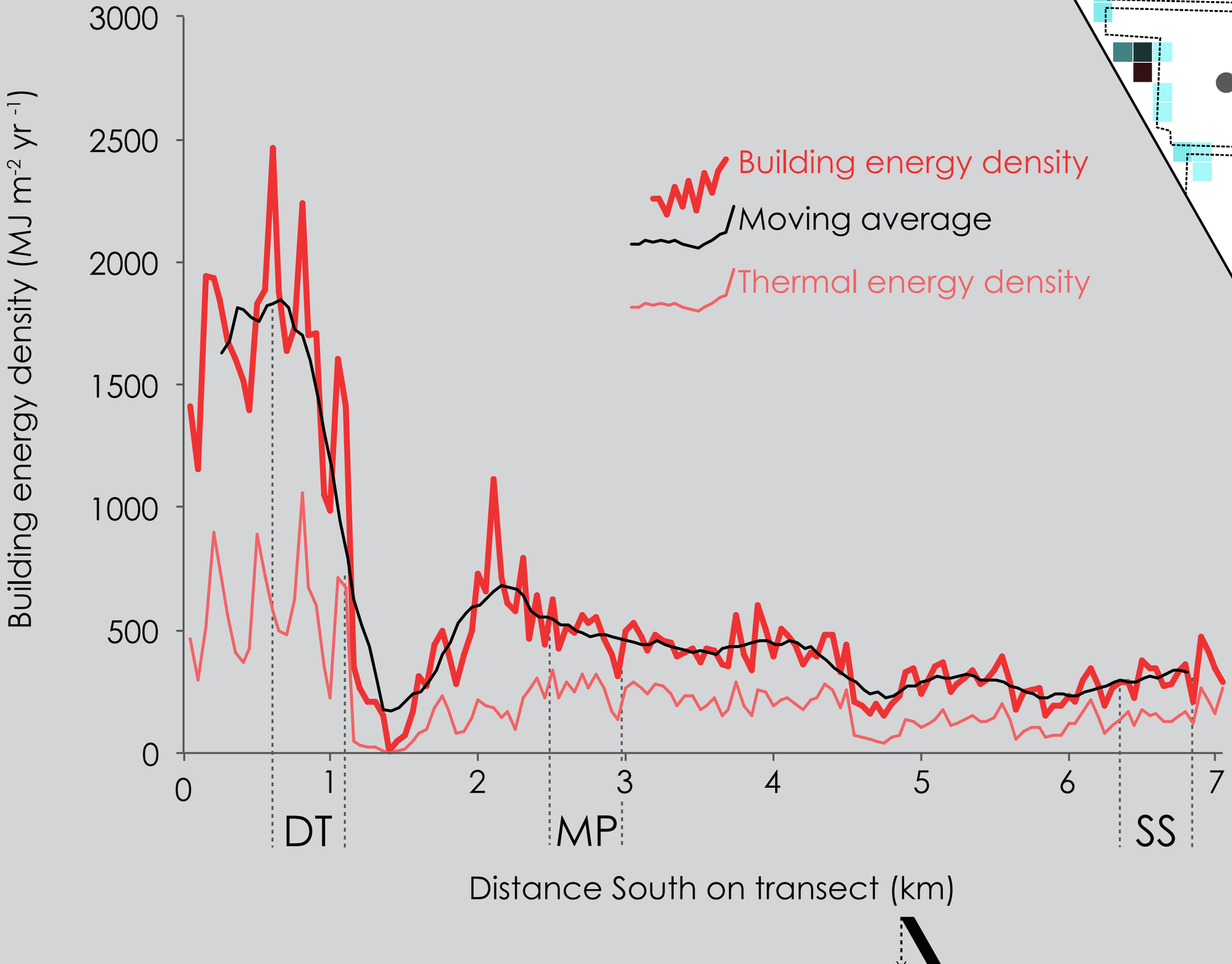
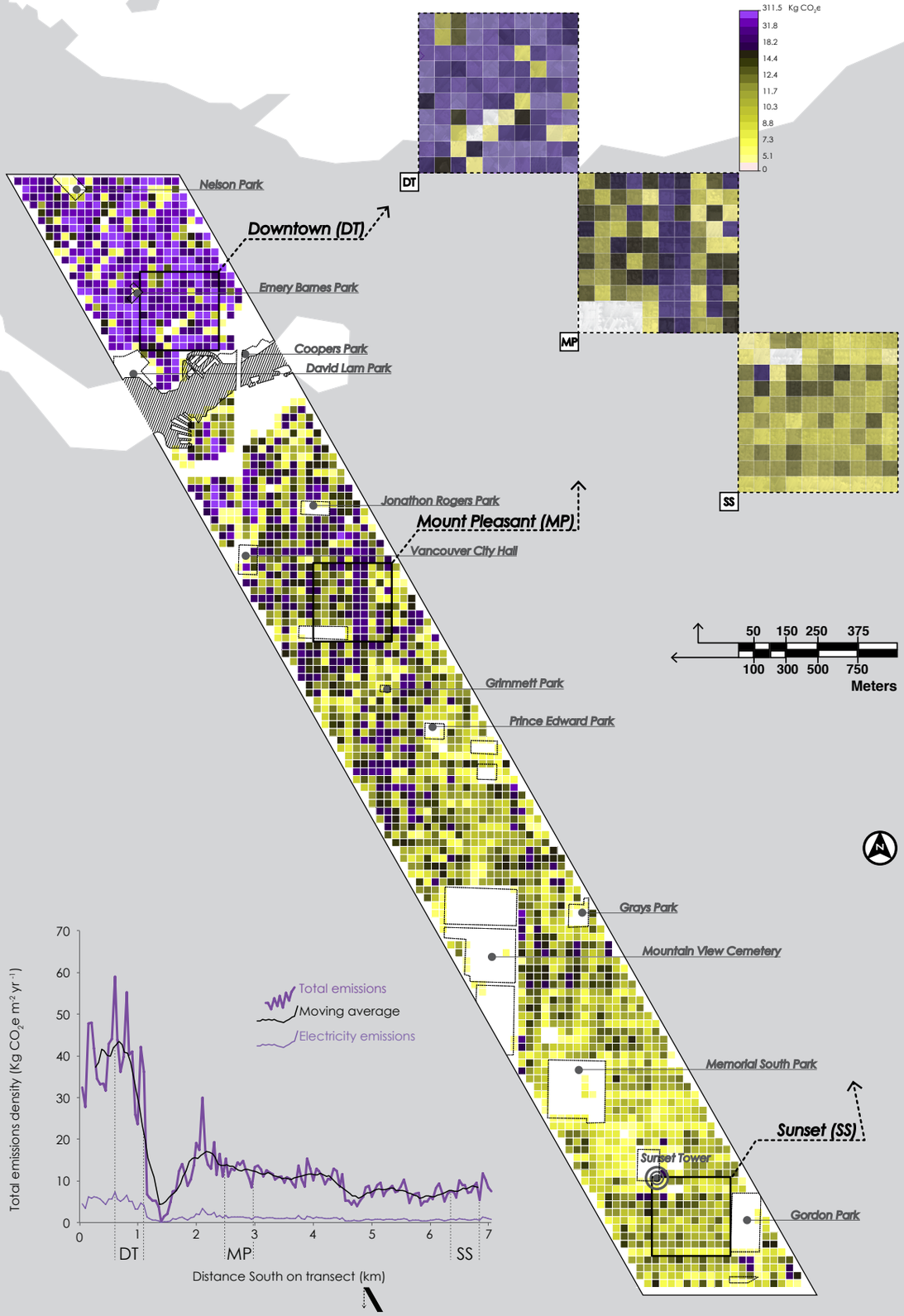
Building Energy Use




Building energy density (MJ m-2 yr-1)
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
DT
MP
SS
Distance South on transect (km)
Building energy density
Moving average
Thermal energy density

CO_2e Emissions



Conclusions and Summary

- Building energy demand has been **scaled using a multiple linear regression** model based on parameters derived from a **limited number of generic runs in a BEM**.

- Settings of the generic BEM runs were informed by **form data extracted from LIDAR**, and an **archetype database** that incorporates actual buildings and energy audits.

- Inputs to linear regression equation for each individual building were efficiently extracted from gridded LIDAR and land-use data.

- Approach enables data-products on **city or neighborhood-scale**, usable for urban planning, load forecasting, emission reduction and atmospheric models (emissions, anthropogenic heat flux).