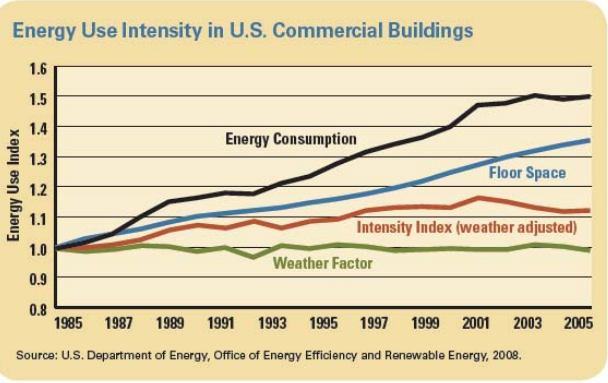

THE IMPACTS OF URBAN FORM ON ENERGY USE IN BUILDINGS
large footprint
TAREK
RAHKA
COREY
WOWK
TRAVIS
SHEEHAN

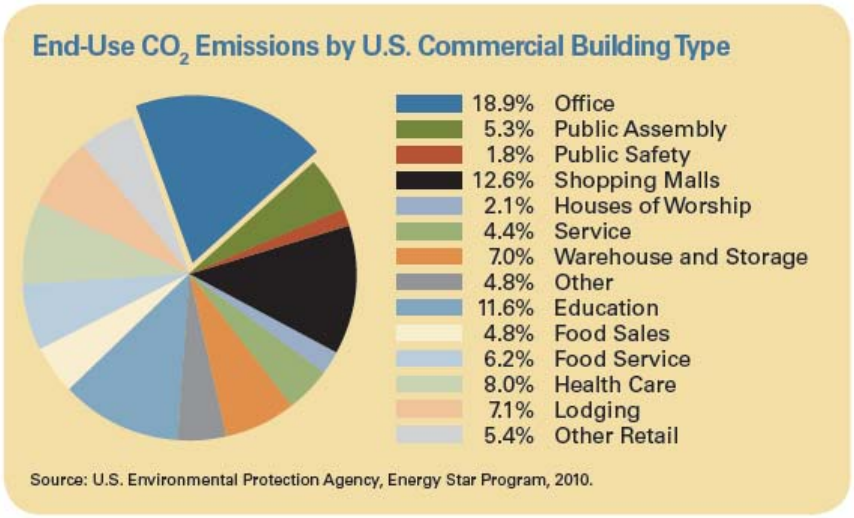
Why large footprint buildings?

THE EXISTING BUILDING STOCK AND ASSOCIATED CARBON EMISSIONS

Sector	Number of Buildings	Total Building Area	% of Total U.S. GHG Emissions
Commercial	**4.9 million**	**72 billion gsf**	**18.2%**
Smaller 50,000 gsf	4.6 million (93%)	36 billion gsf (50%)	–
Larger 50,000 gsf	255,000 (7%)	36 billion gsf (50%)	–
Built before 1990	3.6 million (73%)	51 billion gsf (68%)	–
Residential	**111 million**	**256 billion gsf**	**20.8%**
Single Family	87 million (78%)	233 billion gsf (91%)	–
Multi-Unit	24 million (22%)	23 billion gsf (9%)	–
Built before 1990	84 million (76%)	180 billion gsf (70%)	–

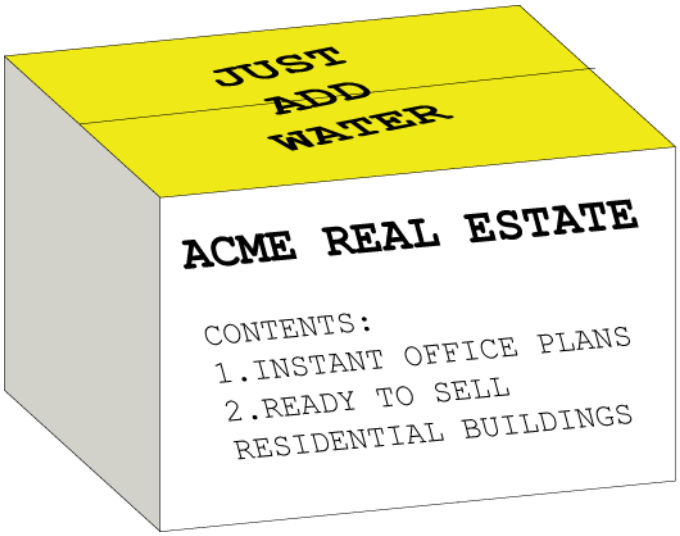
Sources: U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey, 2003; U.S. Energy Information Administration, Residential Energy Consumption Survey, 2005.





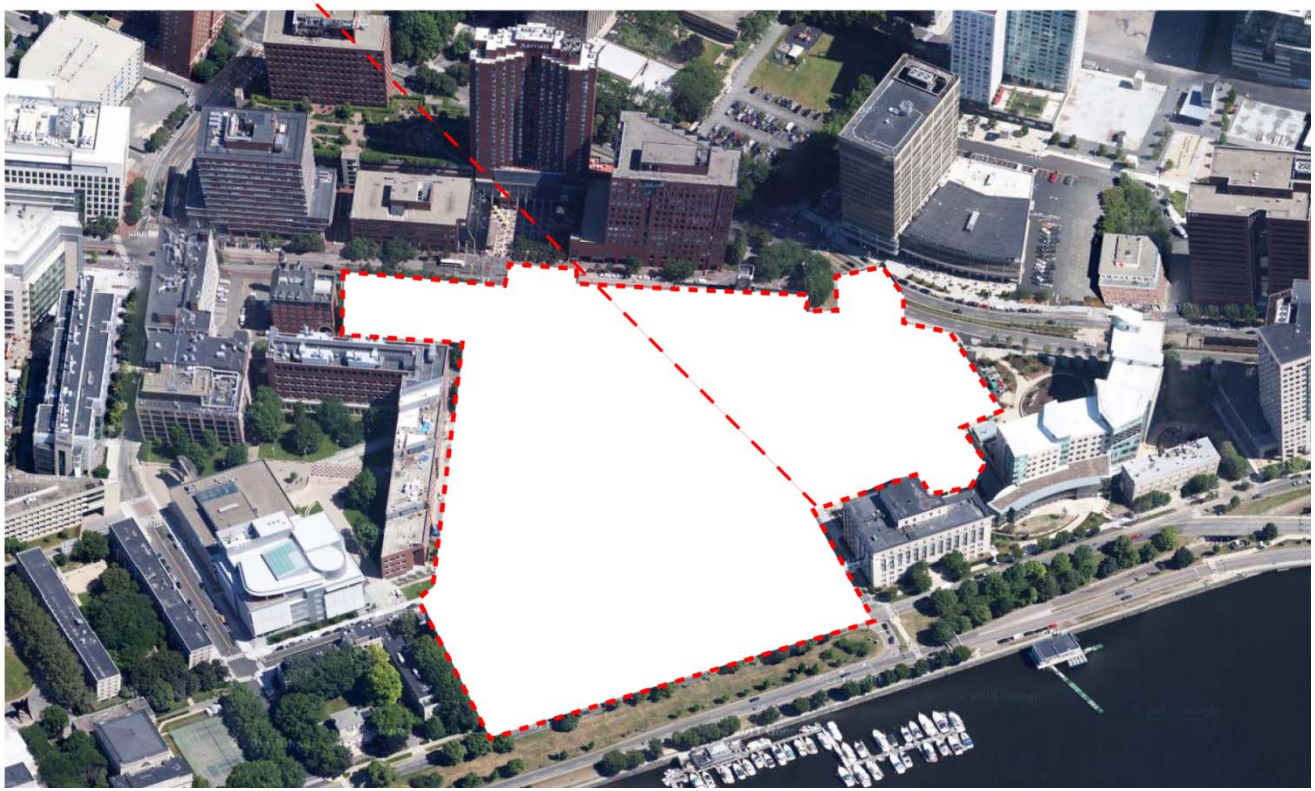
SOURCE: "CLIMATE CHANGE, LAND USE AND ENERGY, URBAN LAND INSTITUTE, 2010

ACME REAL ESTATE

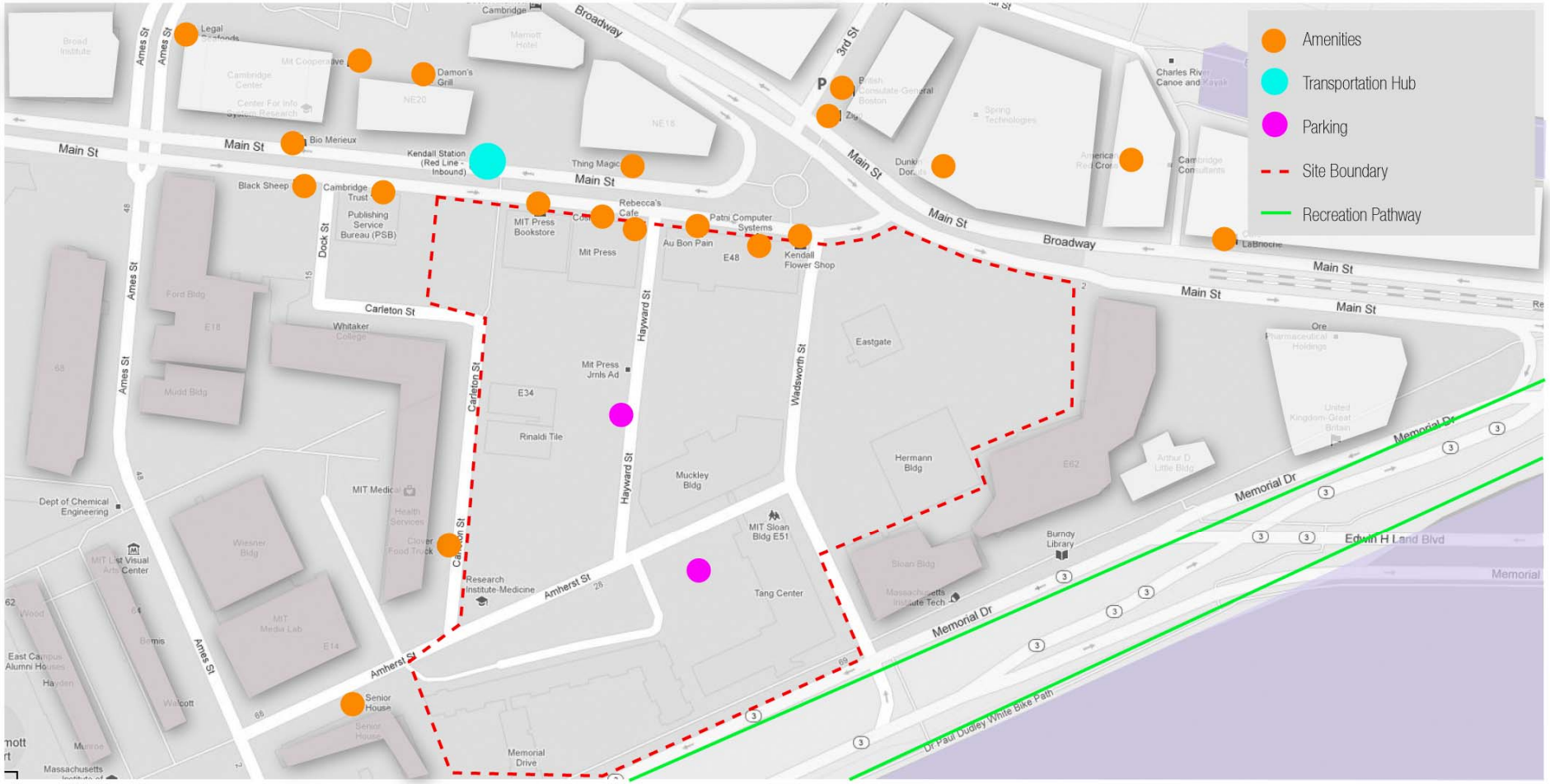


SITE REDEVELOPMENT

KENDALL SQUARE
CAMBRIDGE, MA



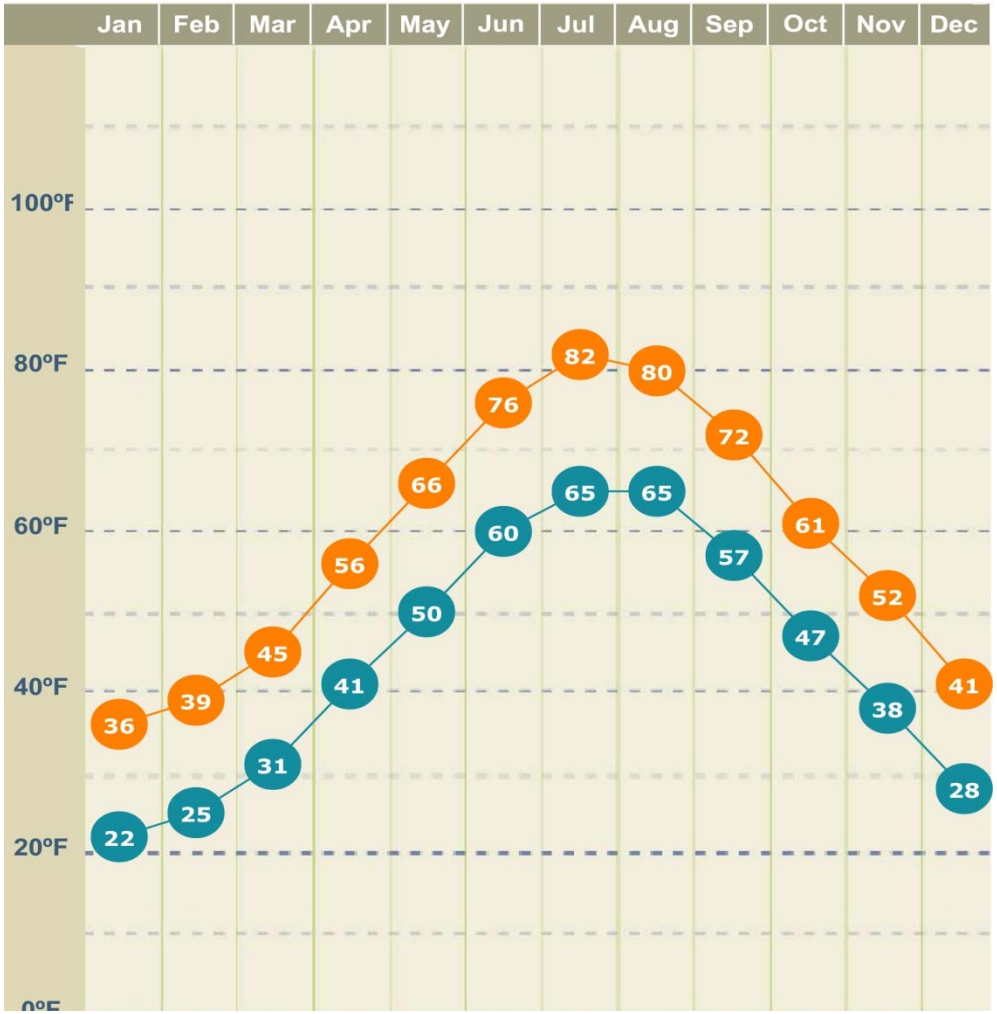
SITE AMENITIES

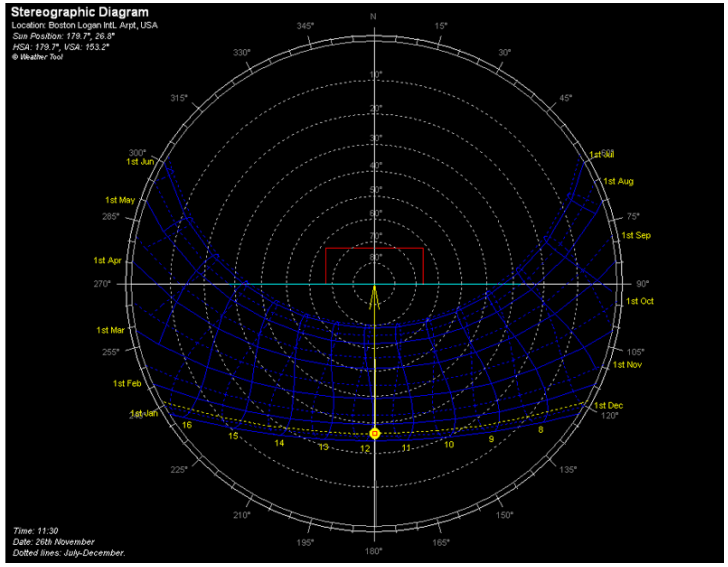


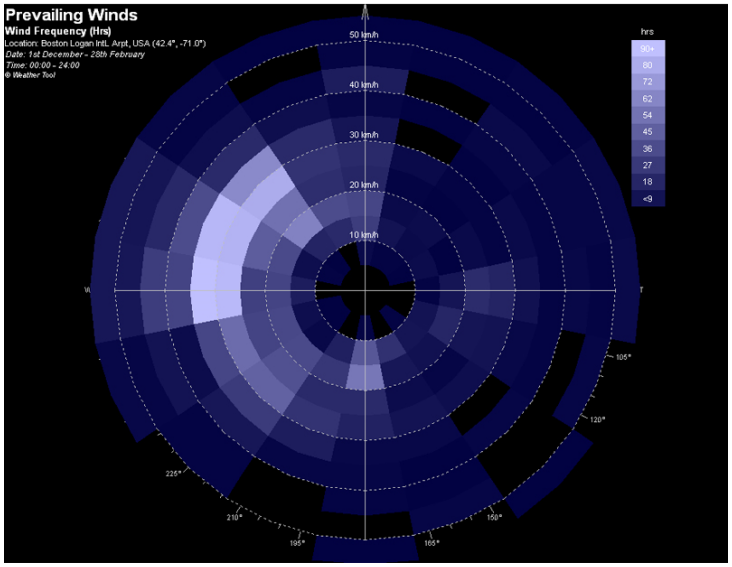
Cambridge Average Walkscore: 93%

Walkscore Around Kendal: 78% (Could be better)

Climate Analysis







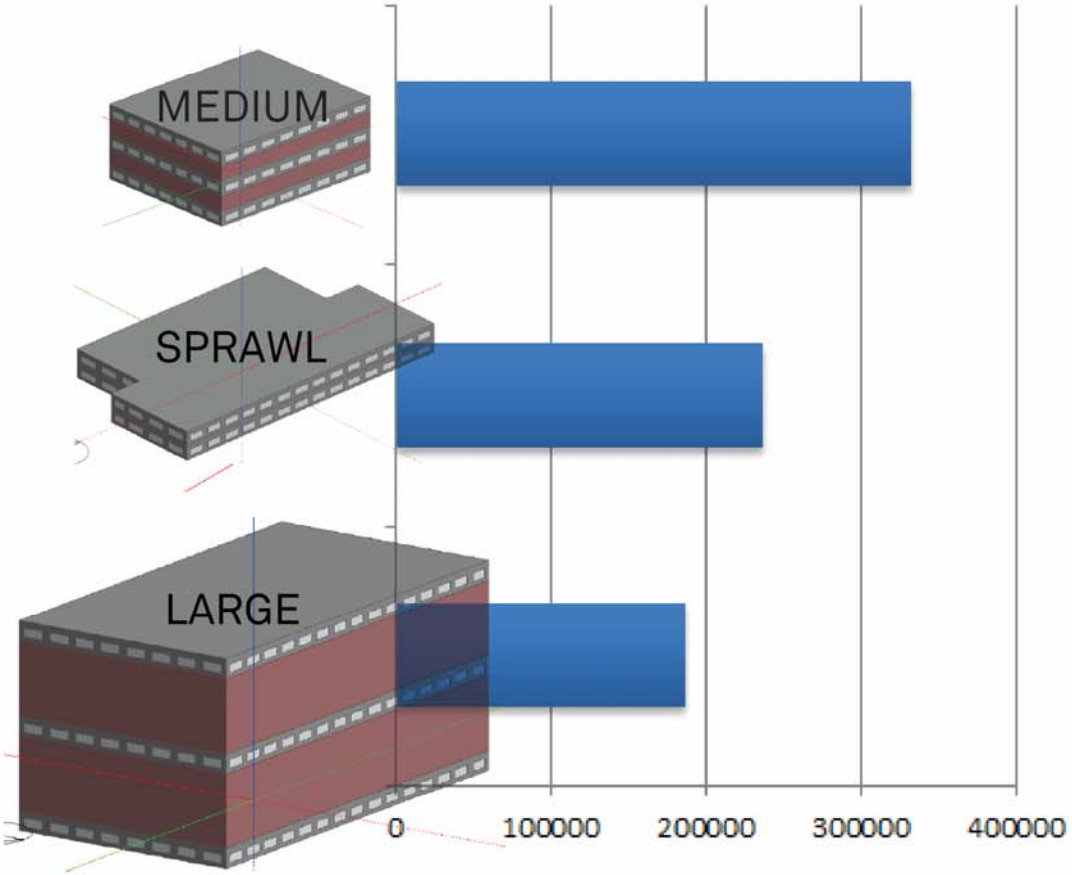
Heating Degree Days: 5641
Cooling Degree Days: 678

Sustainable Goals

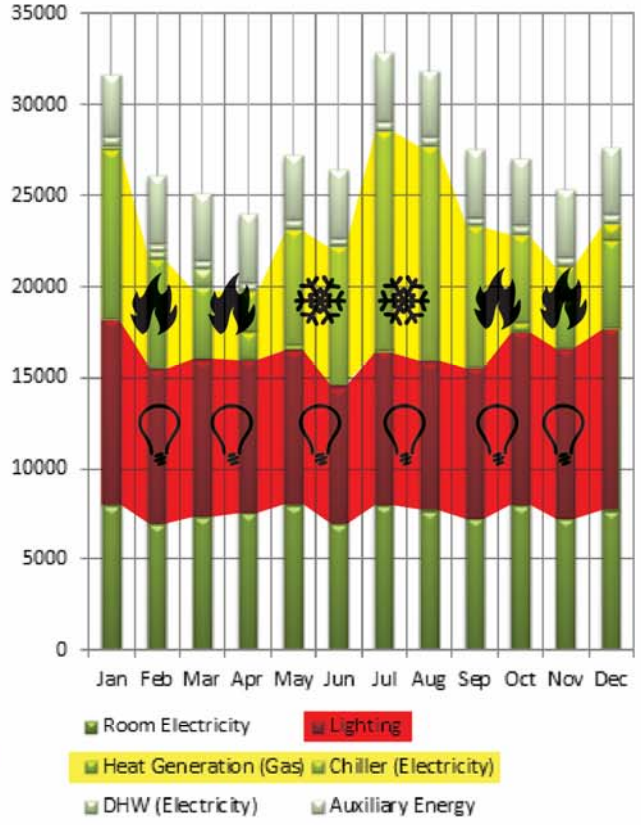
- **Minimize Energy Use Intensity with Mixed Used Configurations** (Business as Usual Typologies)
  - Optimize Building Envelope and Utilize High Performance Skins
    - Energy Plus Parametric Investigations
  - Optimize Skin / Volume Ratio
    - UMI (Urban Energy Modeling)
  - Maximize Solar Access Potential (Thermal & Daylighting)
    - DIVA – Daylighting Availability
- **Maintain Walkable Streetscape and Plan for Thermal Comfort**
  - Minimize pedestrian discomfort through blocking prevailing Winter wind.
    - Flow Designer CFD Modeling
  - Solar Access in Main Streets
    - DIVA – Radiation (Nodes)

OFFICE STUDY

ANNUAL FUEL TOTAL- W/m^2

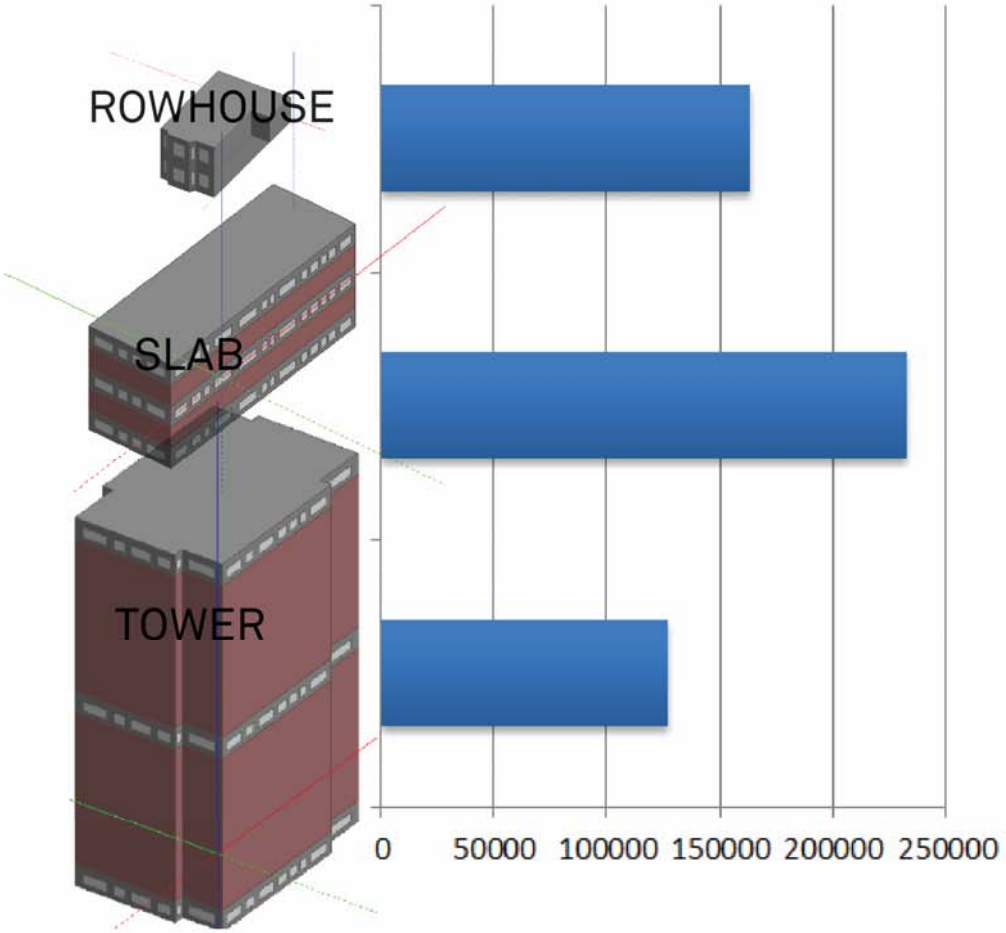


MONTHLY FUEL BREAKDOWN- W/m^2
('medium' office example)

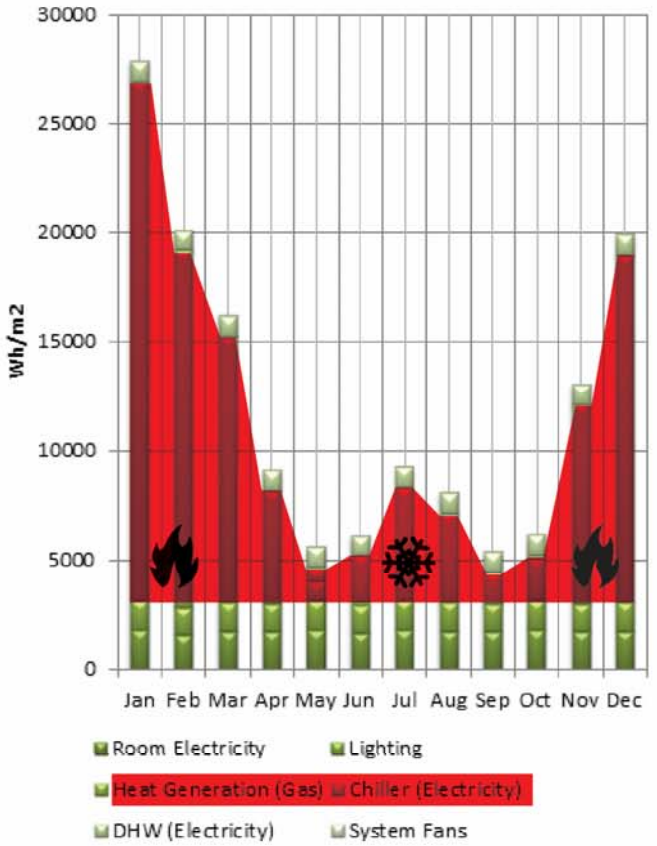


RESIDENTIAL STUDY

ANNUAL FUEL TOTAL-W/m2



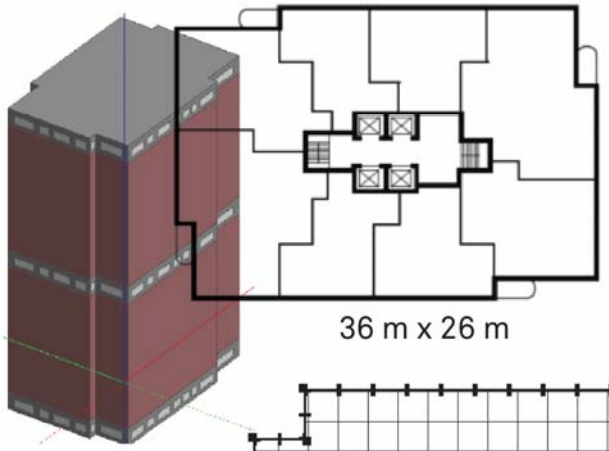
MONTHLY FUEL BREAKDOWN-W/m2
(example of 'slab' residential)



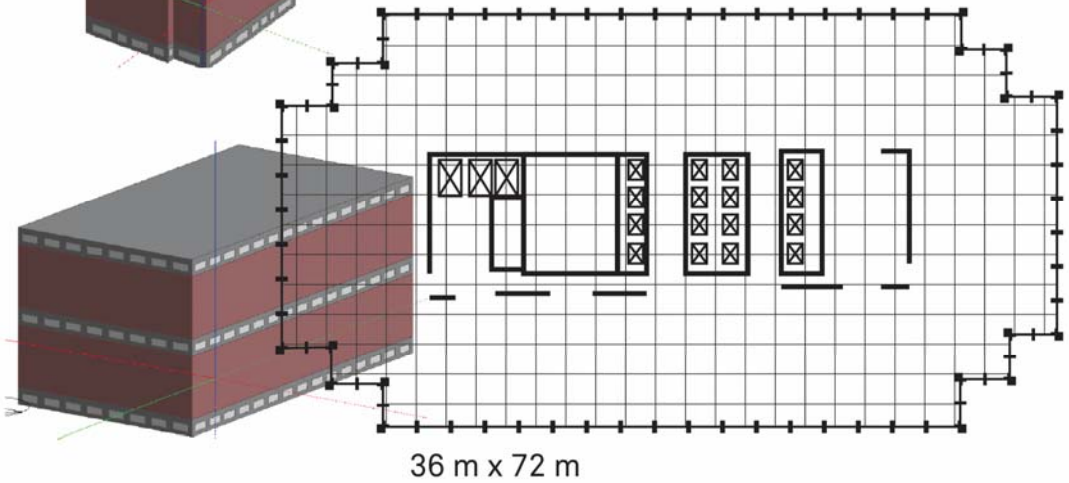
ACME PROTOBLOCKS

Residential
EUI: 61 kWh/m2
WWR- 40%

Office Profile
EUI: 109 kWh/m2
WWR- 40%



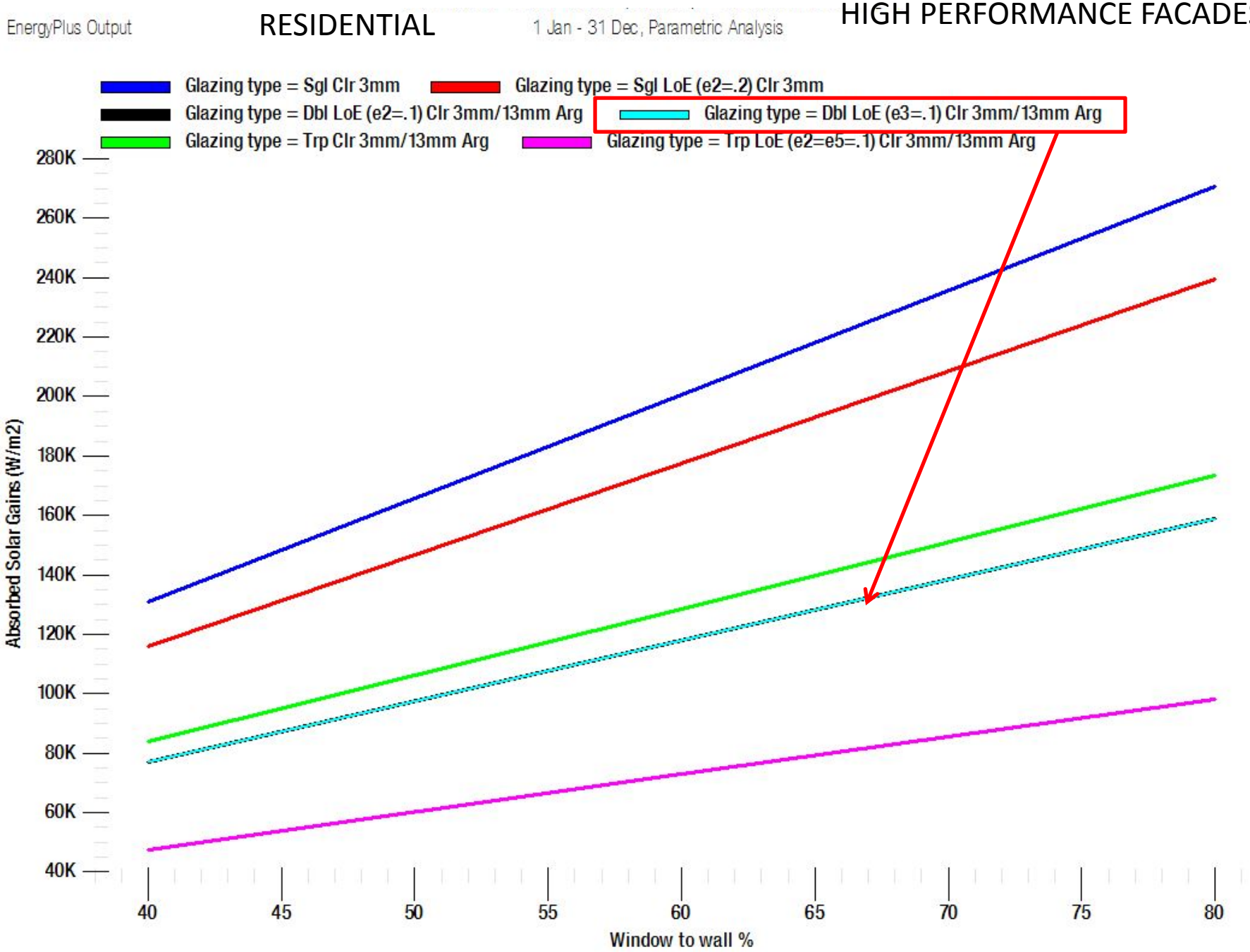
36 m x 26 m

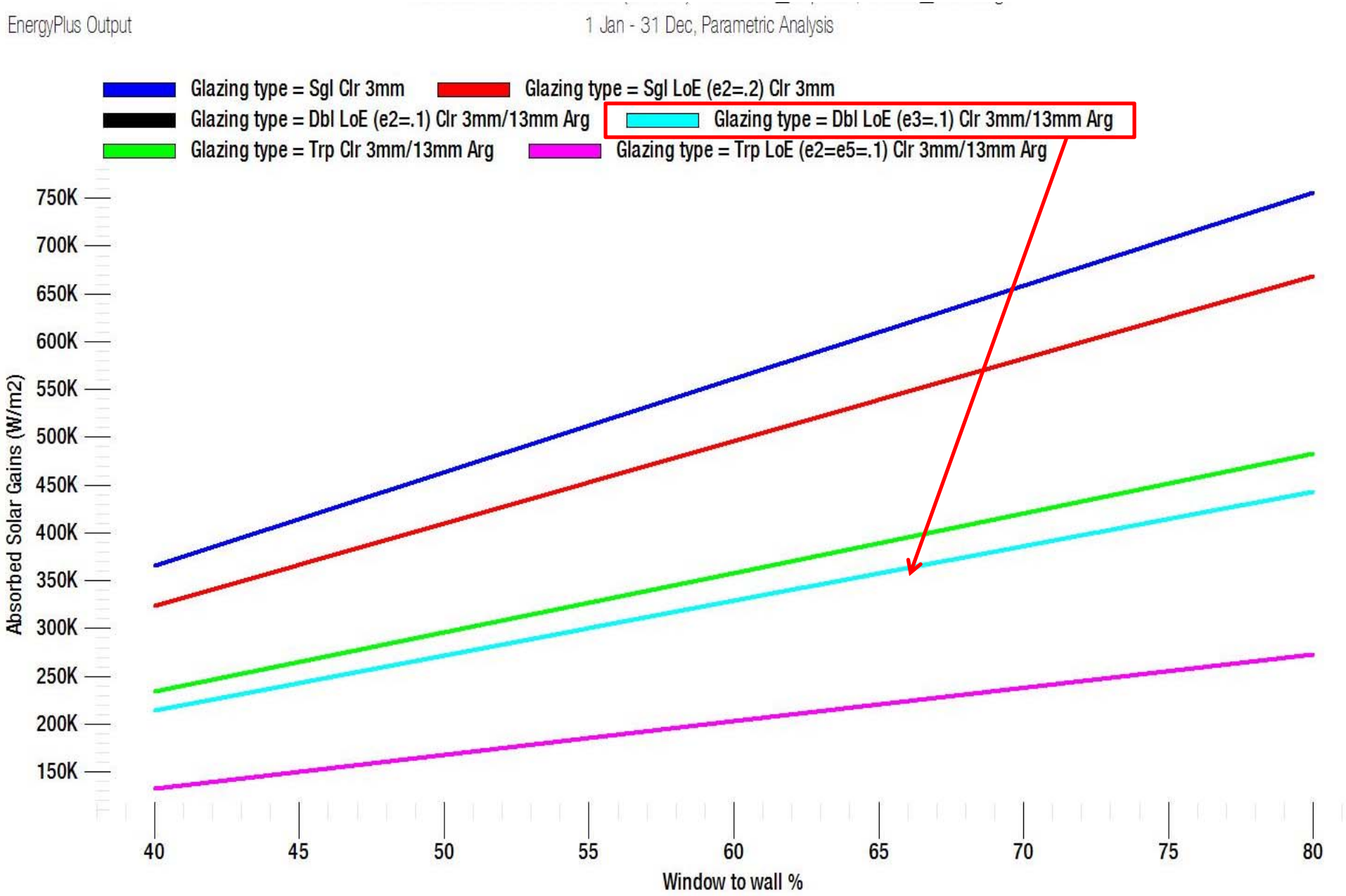


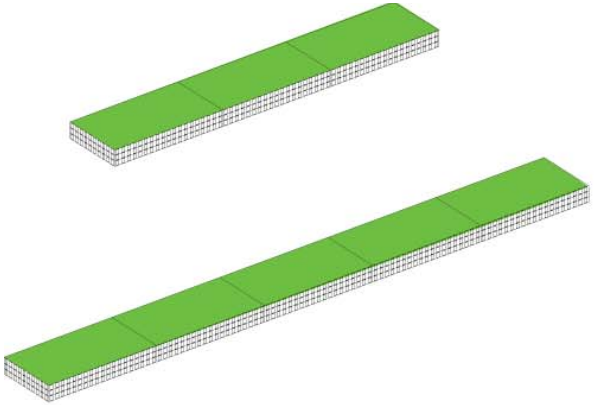
36 m x 72 m

Inner surface	
Convective heat transfer coef...	2.152
Radiative heat transfer coeffi...	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coef...	19.870
Radiative heat transfer coeffi...	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (...	0.261
R-Value (m2-K/W)	4.000
U-Value (W/m2-K)	0.250
With Bridging (BS EN ISO 6946)	
Upper resistance limit (m2-K/W)	3.979
Lower resistance limit (m2-K/W)	3.979
U-Value surface to surface (...	0.261

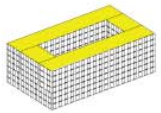
RESIDENTIAL



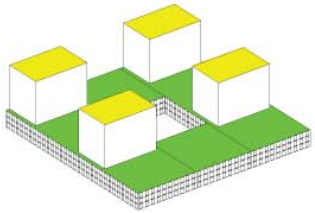

EnergyPlus Output
1 Jan - 31 Dec, Parametric Analysis
Glazing type = Sgl Clr 3mm
Glazing type = Sgl LoE (e2=.2) Clr 3mm
Glazing type = Dbl LoE (e2=.1) Clr 3mm/13mm Arg
Glazing type = Dbl LoE (e3=.1) Clr 3mm/13mm Arg
Glazing type = Trp Clr 3mm/13mm Arg
Glazing type = Trp LoE (e2=e5=.1) Clr 3mm/13mm Arg
Absorbed Solar Gains (W/m2)
750K
700K
650K
600K
550K
500K
450K
400K
350K
300K
250K
200K
150K
40
45
50
55
60
65
70
75
80
Window to wall %

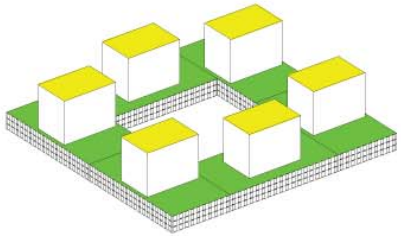


ADIABATIC WALLS

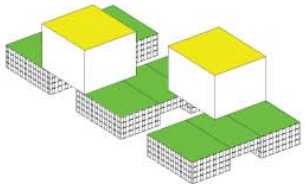


THE DONUT



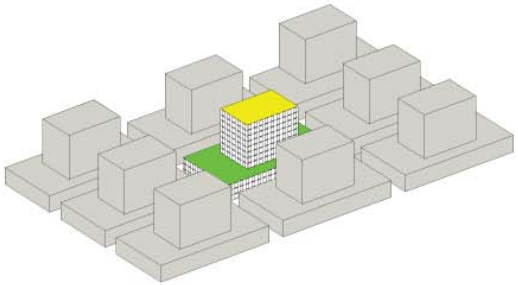


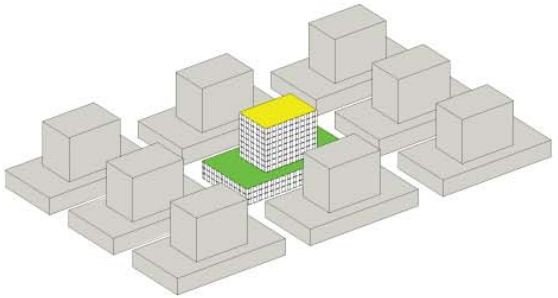
THE COURT YARD

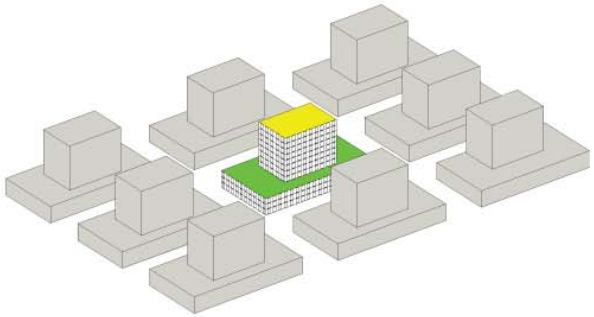


THE SNAKE

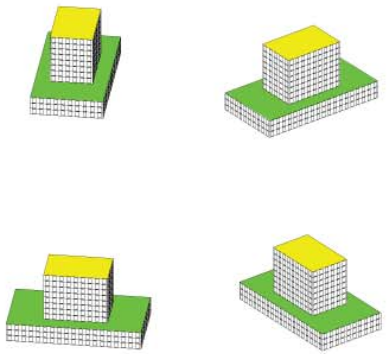
STREET LAYOUT

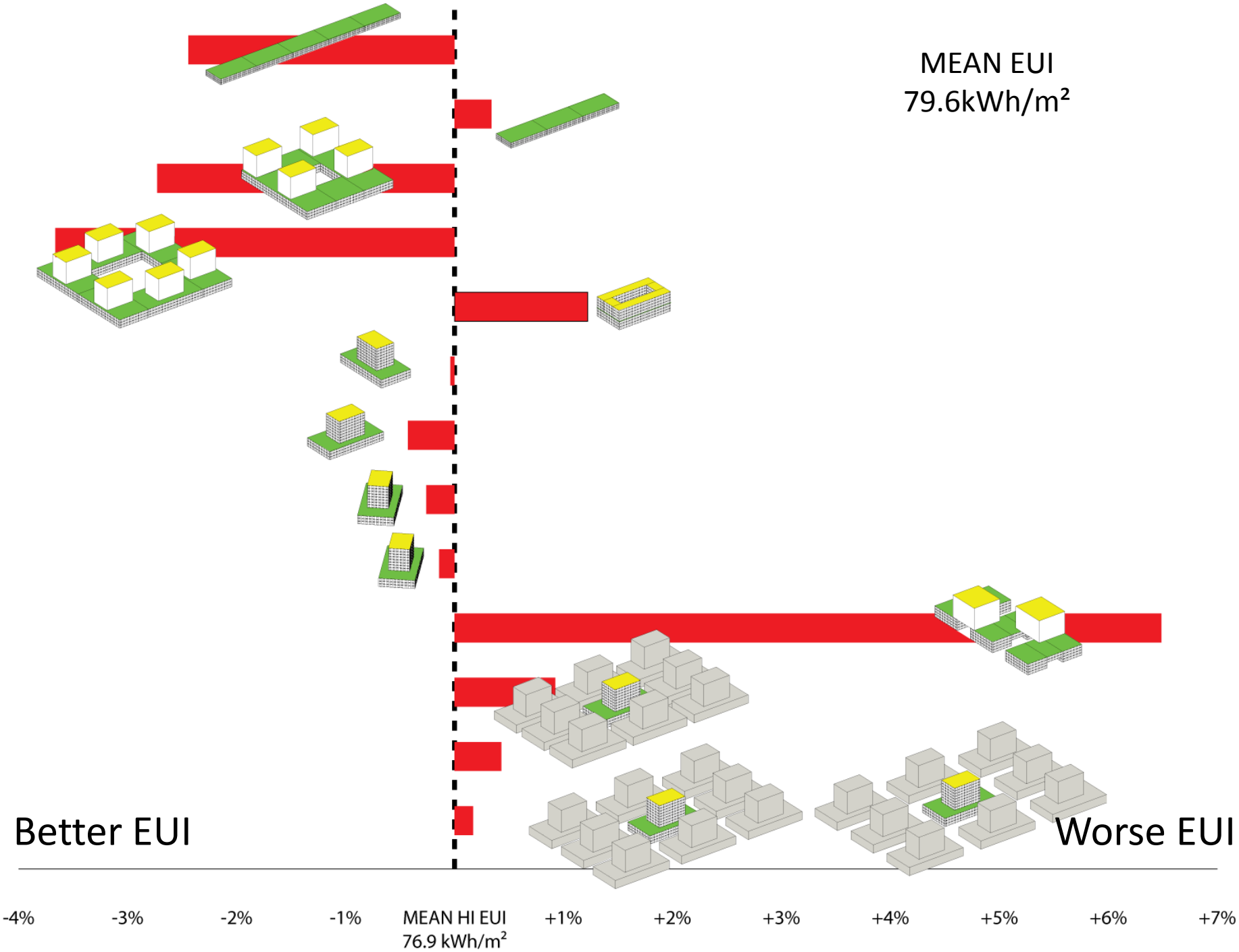


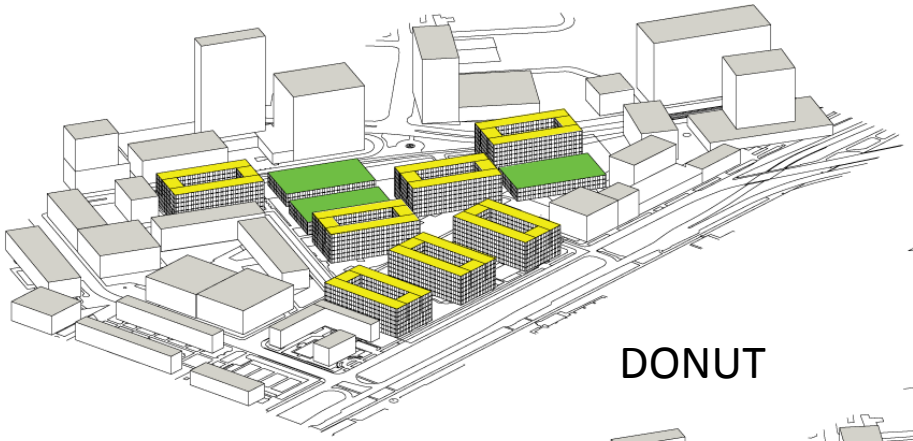




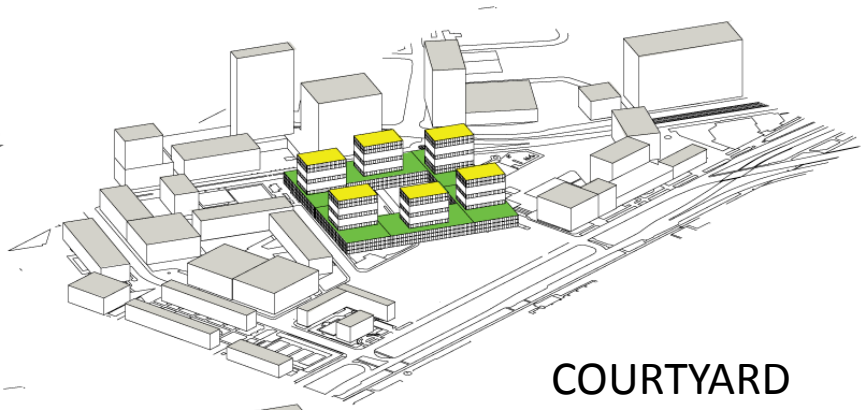
ROTATION



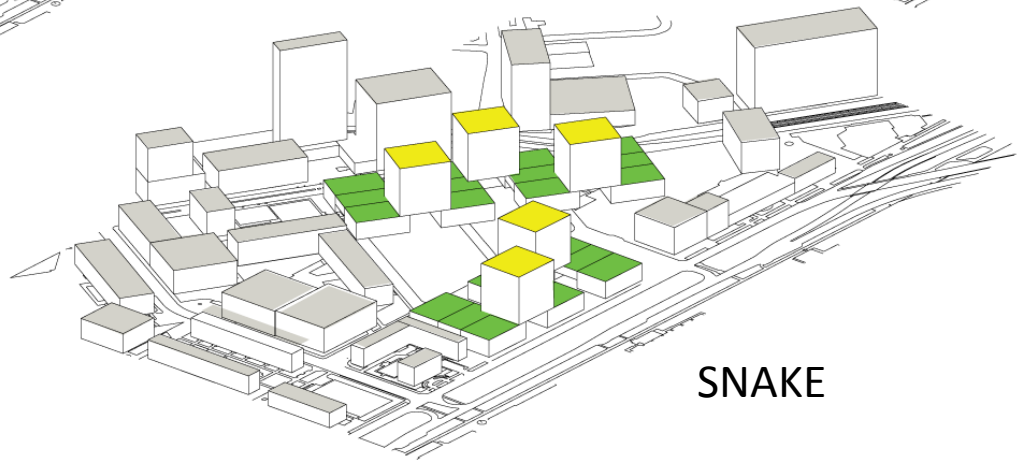

MEAN EUI
79.6kWh/m²
Better EUI
Worse EUI
-4%
-3%
-2%
-1%
MEAN HI EUI
76.9 kWh/m²
+1%
+2%
+3%
+4%
+5%
+6%
+7%



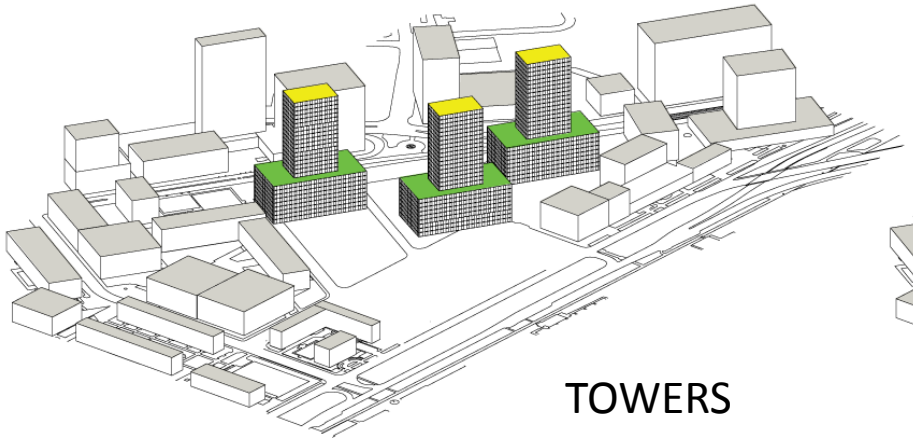
DONUT



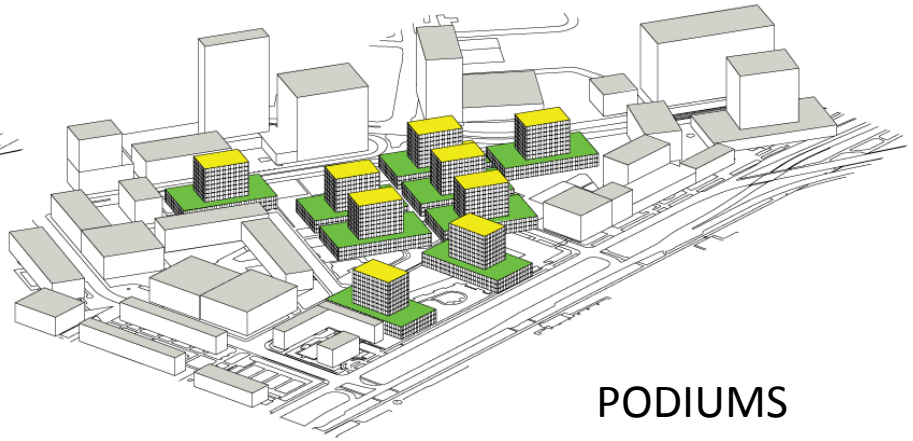
COURTYARD



SNAKE

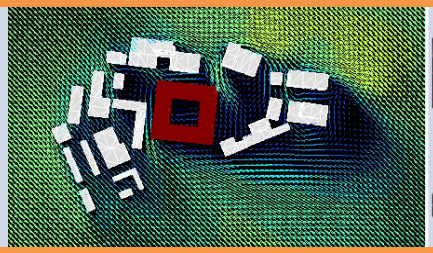
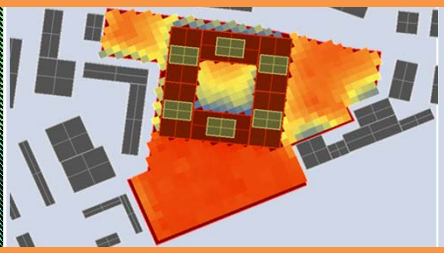
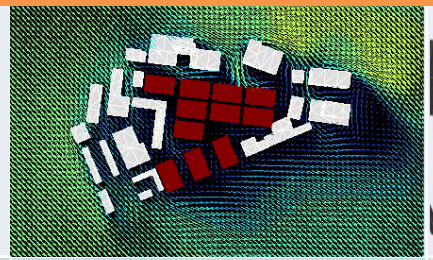
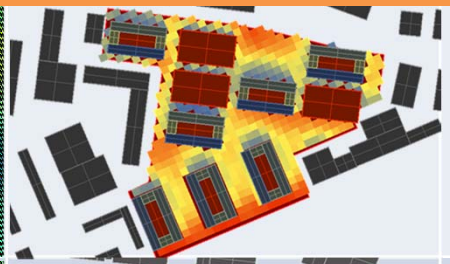
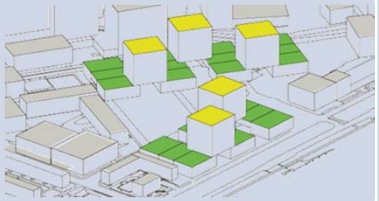
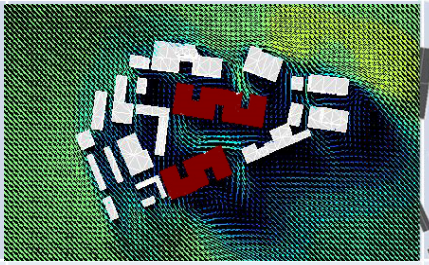
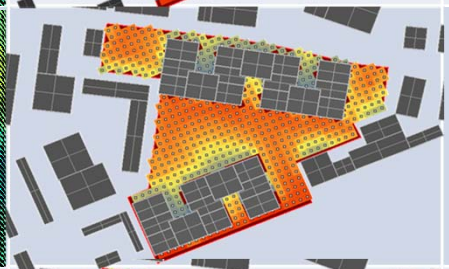
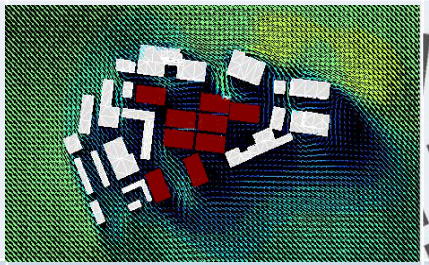
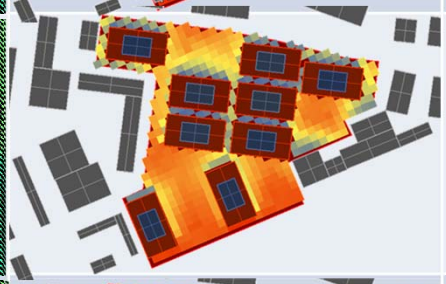
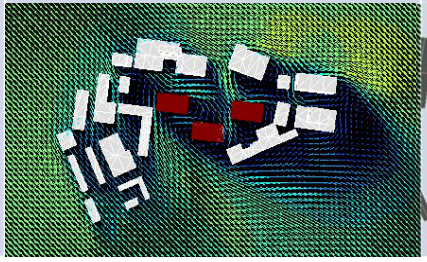
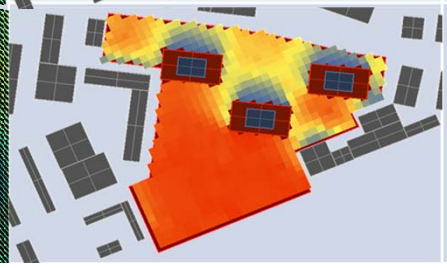


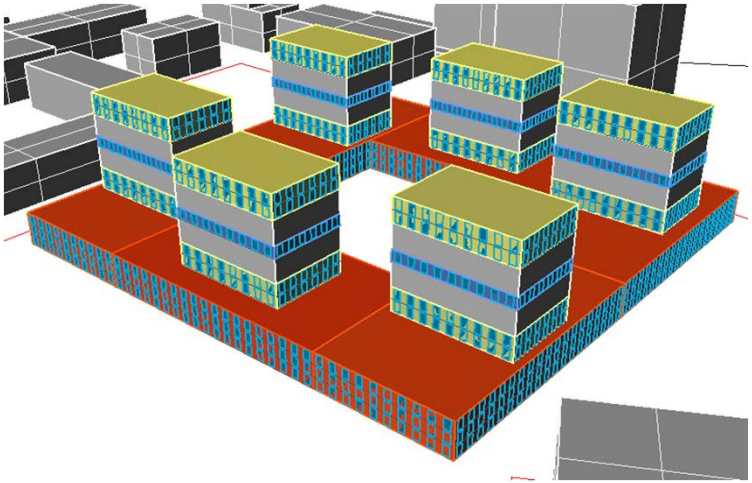
TOWERS

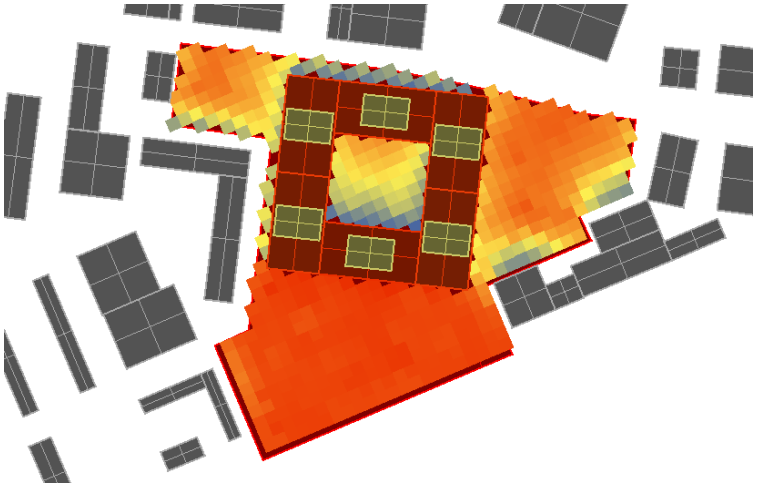


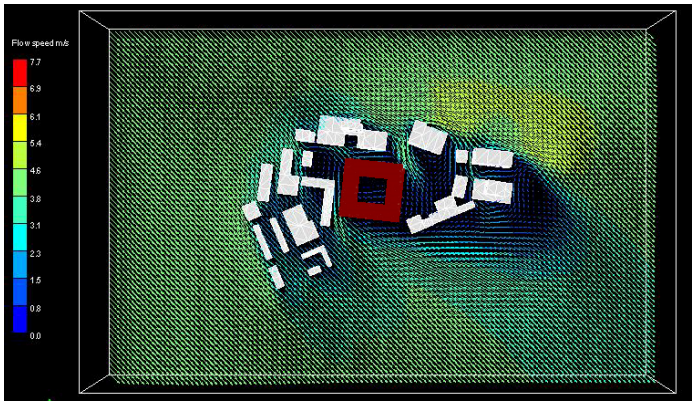
PODIUMS

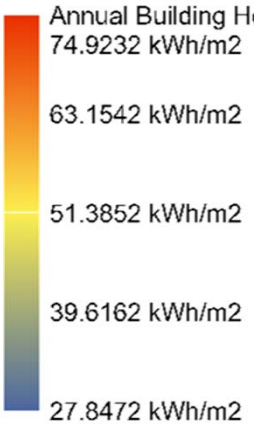
Site Design Alternatives

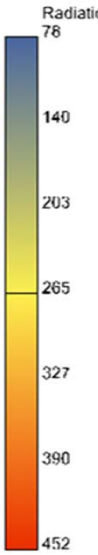
	Urban EUI (kWh/m2)	Winter Wind Patterns	Mean Radiation (Solar Access kWh/m2)		Daylighting Availability
Courtyard 	Hi: 74.9 Lo: 27.9			300	16 to 22%
Donut 	Hi: 77.7 Lo: 37.4			265	14%
Snake 	Hi: 80.9			248	18 to 26%
Podium 	Hi: 78.0 Lo: 42.5			298	24%
Tower 	Hi: 77.8 L: 33.9			340	33%





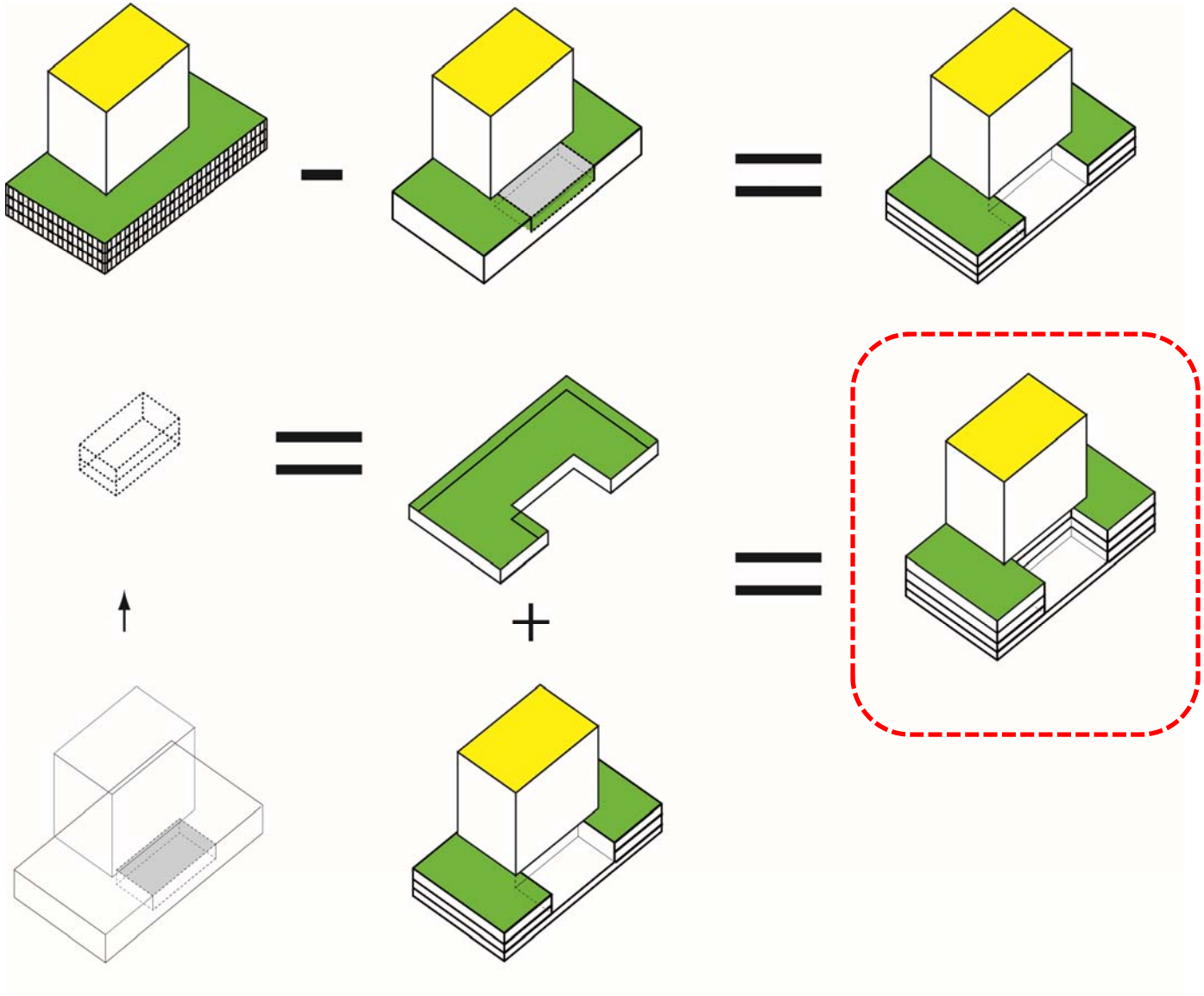






- EUI
  - Office Buildings Shares Volume
  - Minimal Residential Shading, Maximum Solar Exposure
  - Increase in Daylighting due to Courtyard
- Walkalbility
  - Enhanced Access to Solar Radiation
  - Minimal Winter Wind Inside the Courtyard
  - Increase in Wind Speed around the Building Complex
  - Reduce Human Scale Qualities of the Urban Form

CUT THE FAT

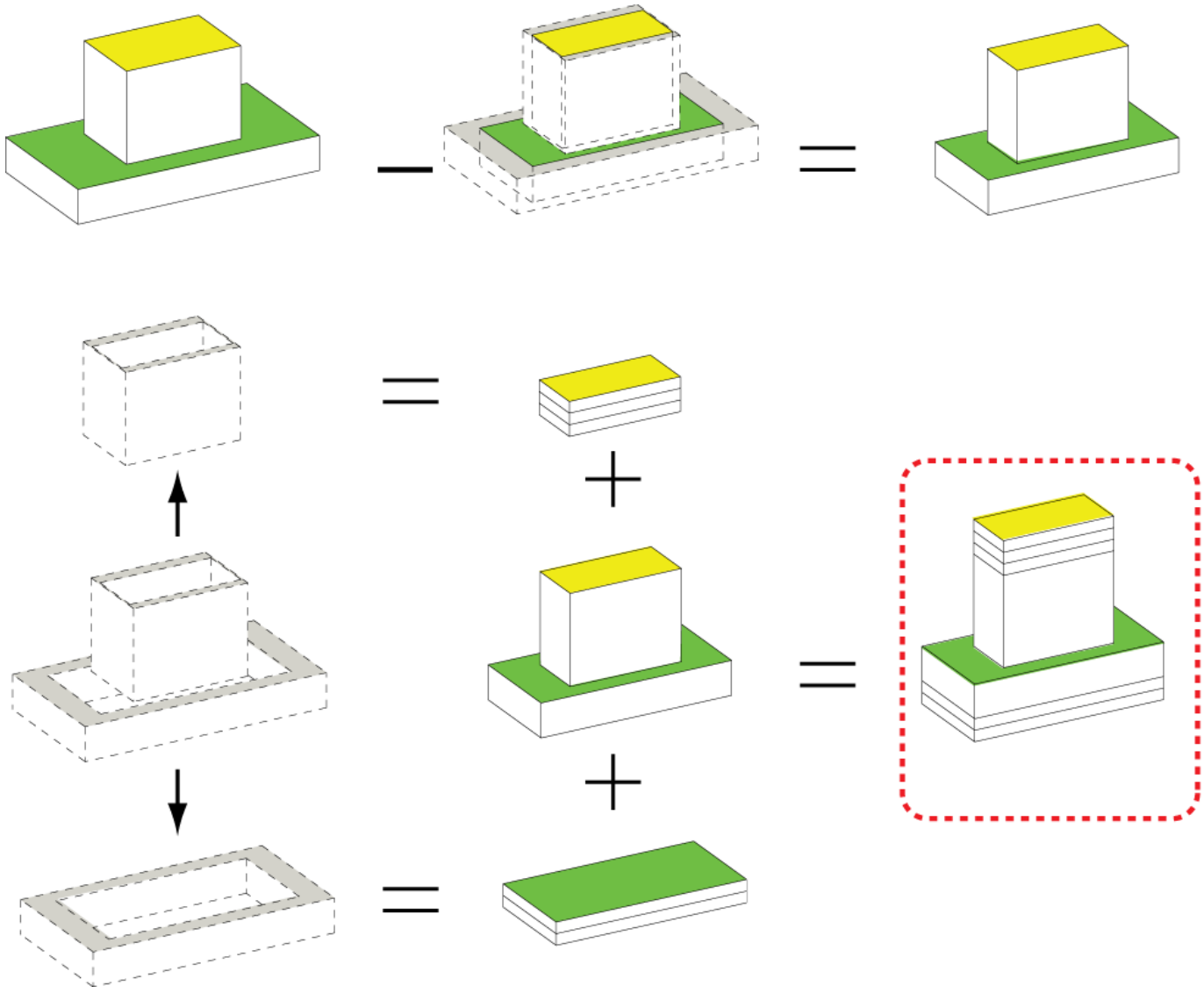


Total Cutout Space
2000 m^2

Additional
Floorplate
2000 m^2

EUI : 80.9 kWh/m^2

CUT THE FAT



Office Floor Plate
30m x 60m

Res. Floor Plate
17m x 35m

EUI : 109 kWh/m^2

SO WHAT NEXT?

- Find the tipping point for targeted parameters
  - Thinning the footprint – to what a extent?
  - Creating Courtyards – how big?
  - Blocking wind – but allowing for radiation
- The prototype that performed best is the Courtyard
  - Best EUI
  - Negative Impact on Walkability
- A Tool for Parametric Volume Investigations for Energy Efficiency