Green Buildings – A holistic approach

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C-USE

Centre for Urban Science & Engineering
Indian Institute of Technology, Bombay

Guest Lecture CS 620

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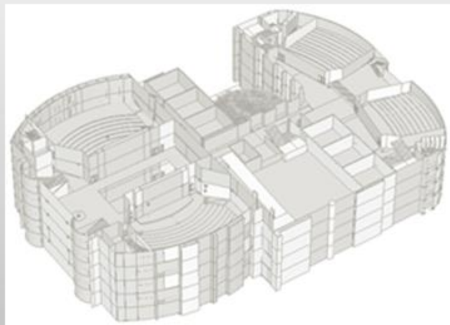
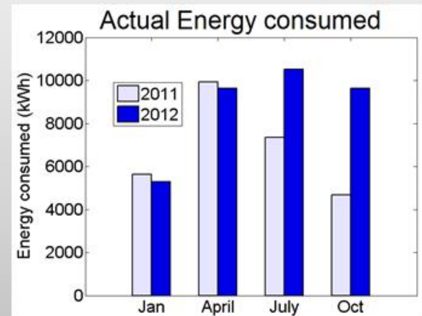
Goal: Closing the Design-Technology-Policy gap



Design



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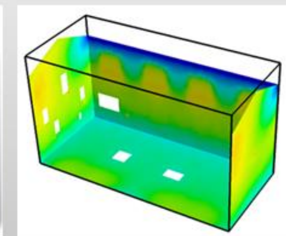


Sensing/Analytics

Simulation image, courtesy IBM

Design Improvements

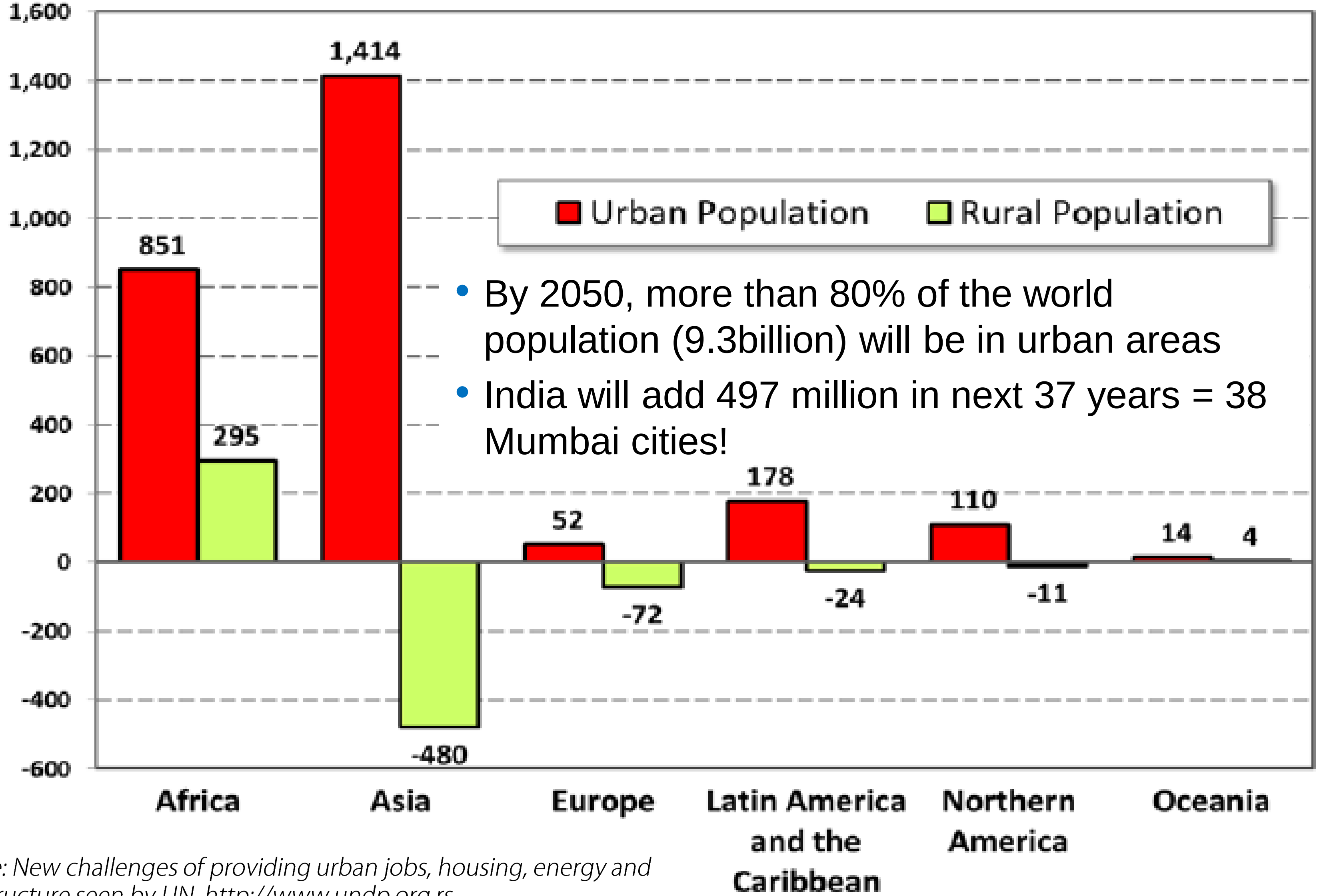
Efficient Operations

Policy Changes

Overview

- Introduction to Green Buildings
- IIT B Campus as Living Lab
- Campus Water Case Studies
- Beyond Buildings
- Policy Implications

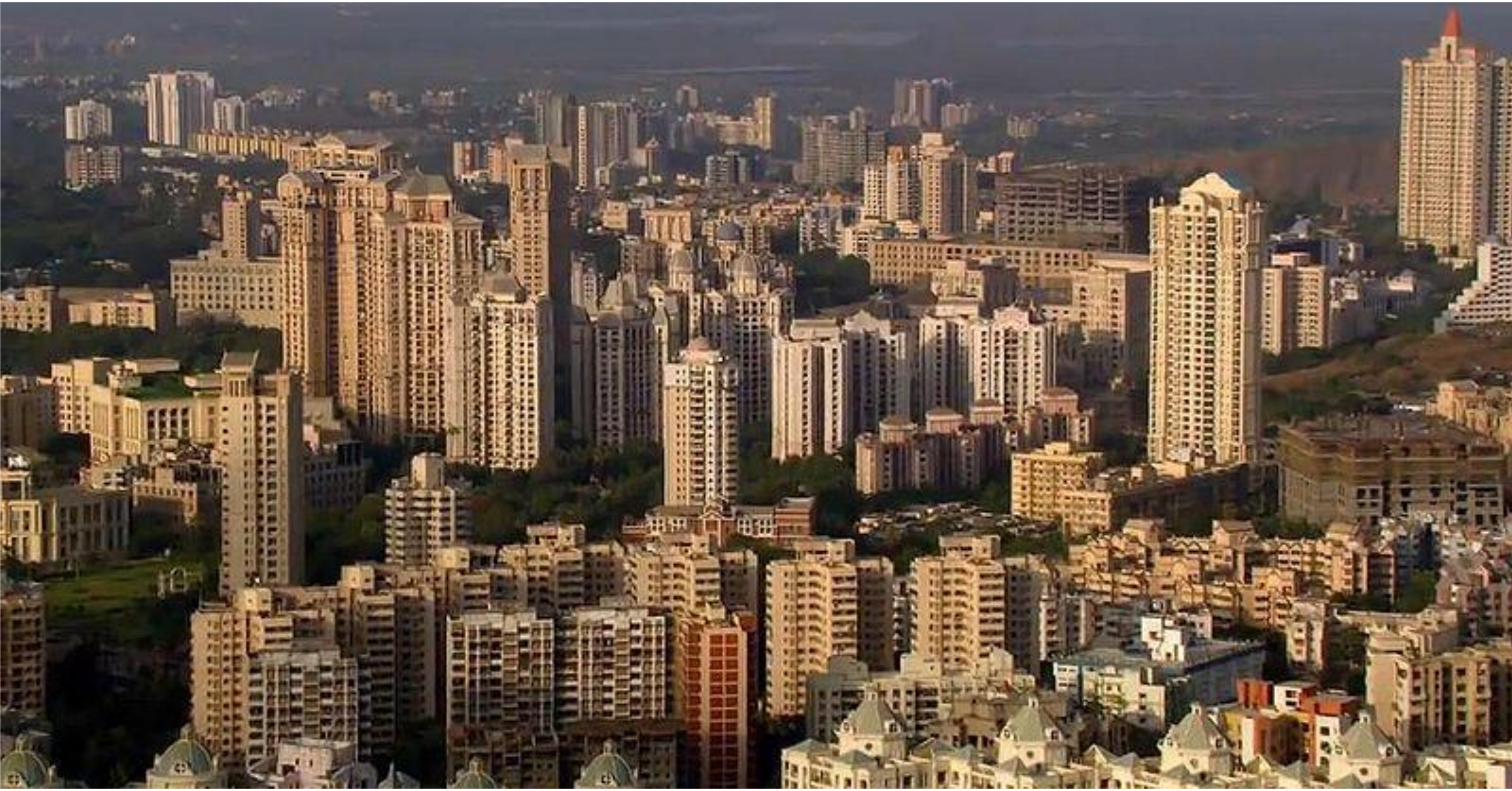
Urbanizing India



- By 2050, more than 80% of the world population (9.3billion) will be in urban areas
- India will add 497 million in next 37 years = 38 Mumbai cities!

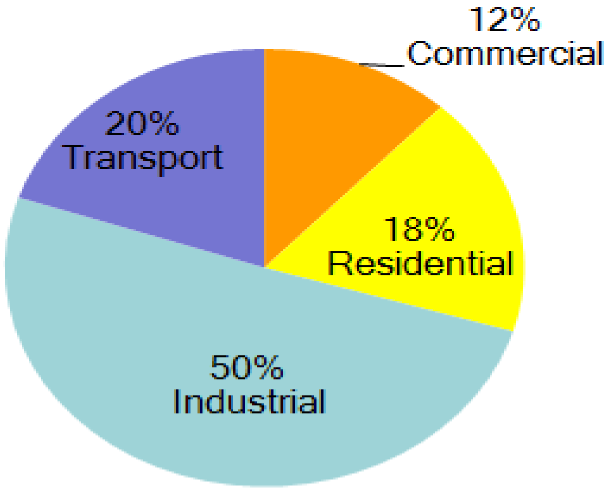
Source: New challenges of providing urban jobs, housing, energy and infrastructure seen by UN. http://www.undp.org.rs

Why Buildings?



http://getaway2india.files.wordpress.com/2009/09/mumbai-skyline2.jpg

Building Energy Efficiency



Source: http://www.eia.gov

Building sector contributes to 30% of world energy cost

Our buildings does not pay attention to climate and context

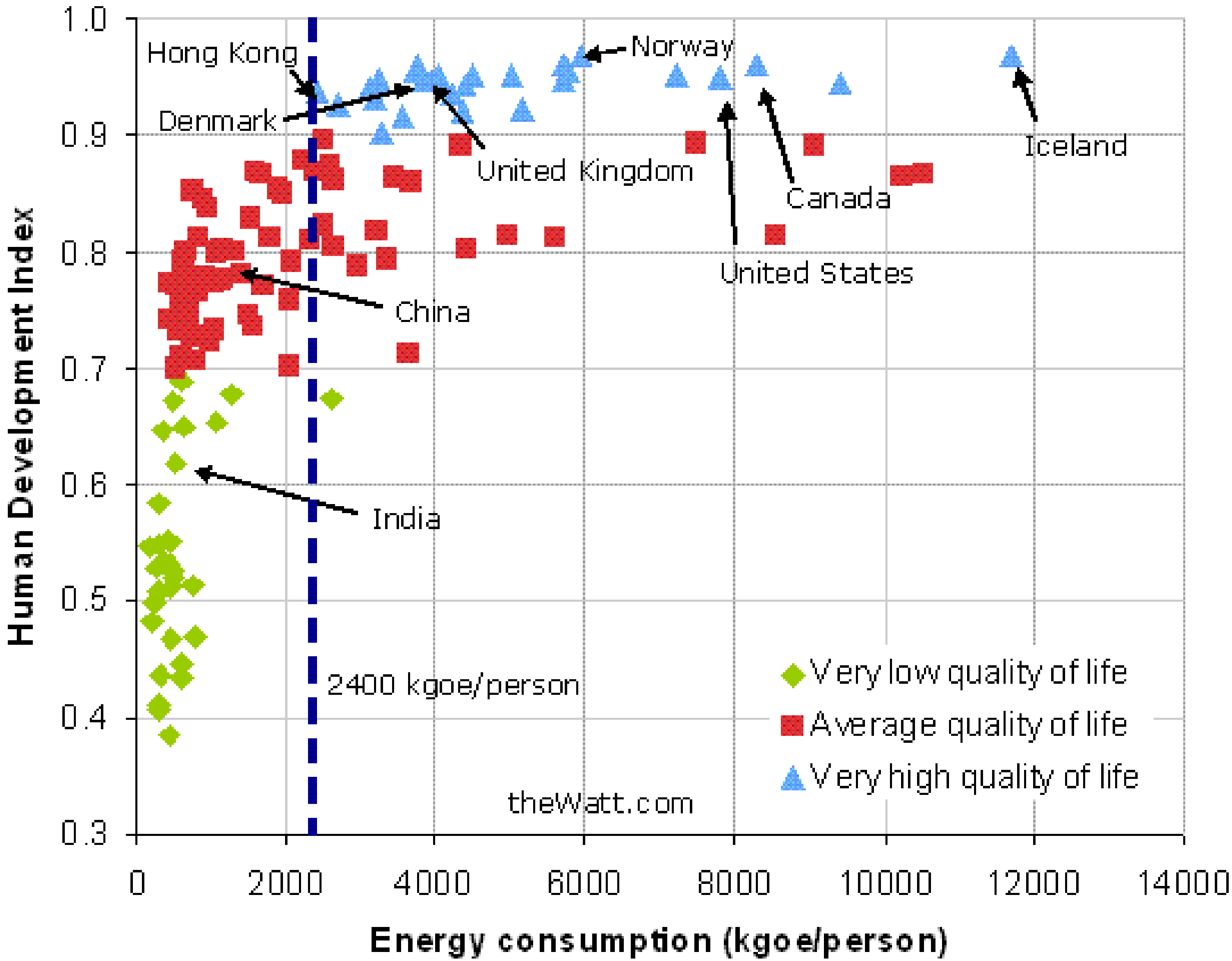
- 45% of total global energy is used in heating, cooling and lighting of buildings
- 5% in building construction

Source: Prof. S. C. Kaushik, IIT Delhi

- More than half of the world's new construction is taking place in China and India alone

Source: *Building Energy Efficiency Why Green Buildings Are Key to Asia's Future*

Energy and Quality of Life

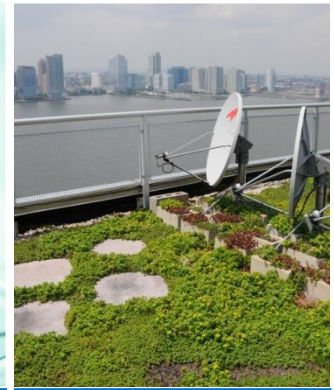


Ingredients & Benefits of Green Buildings

Save energy

Produce energy

Save water



Capture rainwater

Create open space

Produce local food

Building insulation or thermal mass leads to energy and cost **savings**

Improved/water quality, open spaces and fresh local food promotes **health**

Reduces burden on City's electrical grid and sewer **infrastructure**

Reduced pollution & increased biodiversity connects people to **nature**

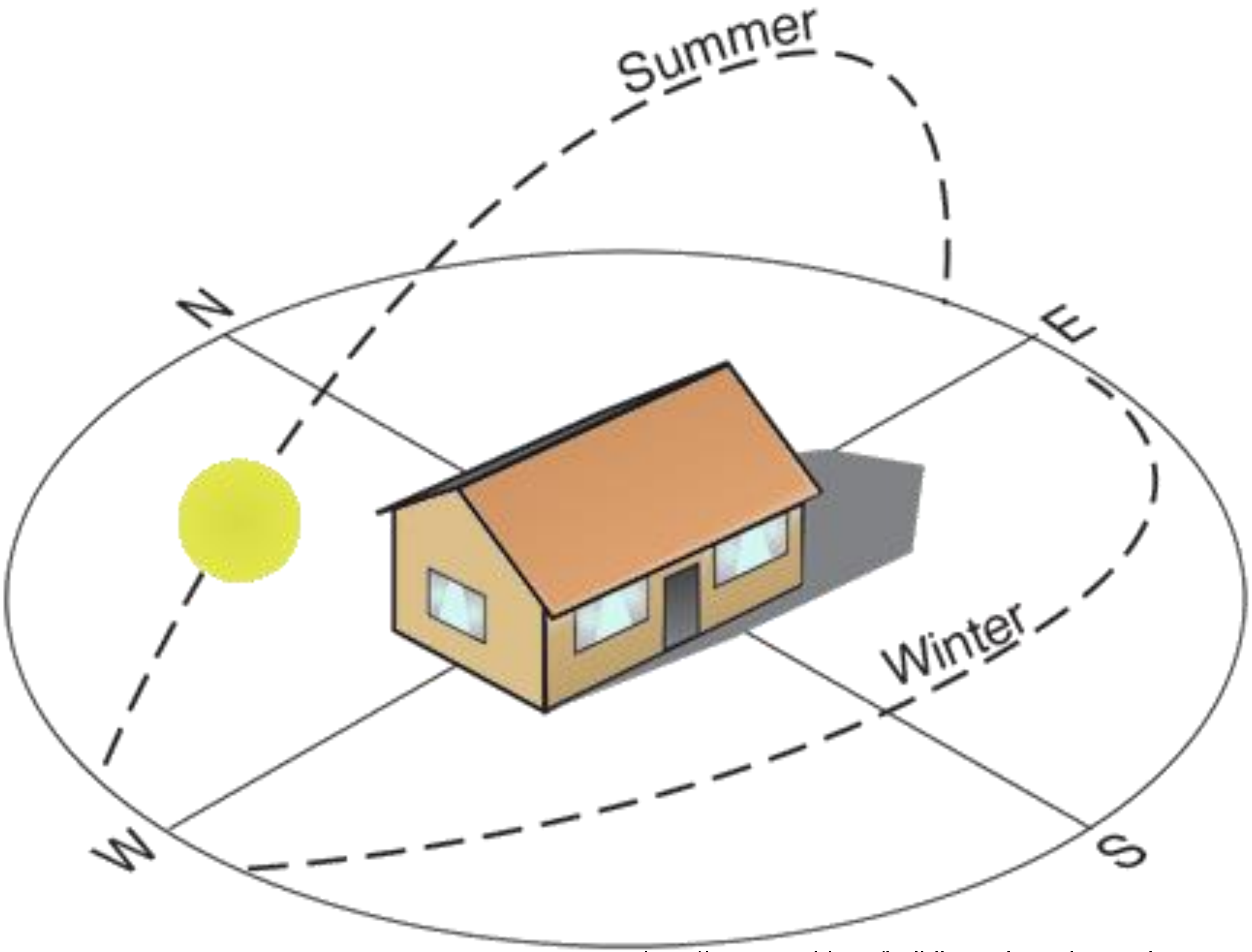
Factors affecting energy efficiency

- Environmental parameters
  - Sun (temperature, humidity, wind)
  - Geography / microclimate
- Building design
  - Building orientation
  - Building envelope
- Building operations
  - Usage profile (occupancy)
  - Load balancing
  - Types of appliances

Convention Centre, IIT Bombay

Efficient building operations is key

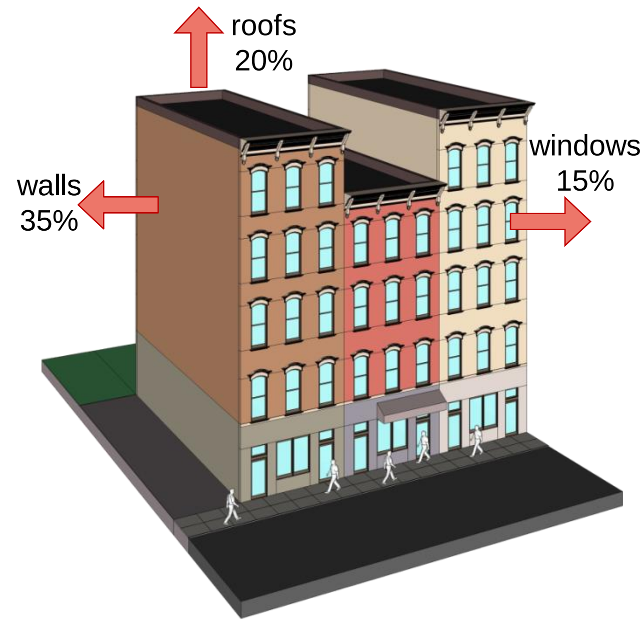
Building and Sun

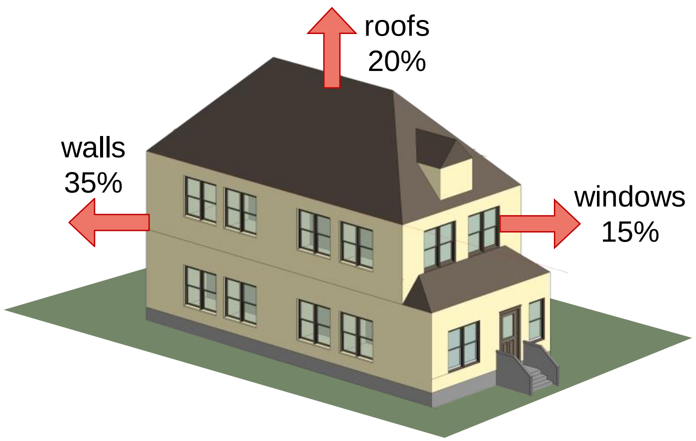


http://www.nachi.org/building-orientation-optimum-energy.htm

Building Envelope

- Building shell that separates outside from inside
  - External walls
  - Windows & Skylights
  - External doors
  - Roof
  - Floor
  - Foundation systems
  - Any other openings in external surfaces





GOAL: Maintain comfortable temperature, humidity, ventilation, lighting levels passively or with help of artificial building systems with the aim of energy conservation

Thermal resistance (R)

- Property of material to resist the flow of heat per unit time

$$\Delta T \propto \frac{\dot{Q}L}{A} \qquad \Delta T = R\frac{\dot{Q}L}{A}$$

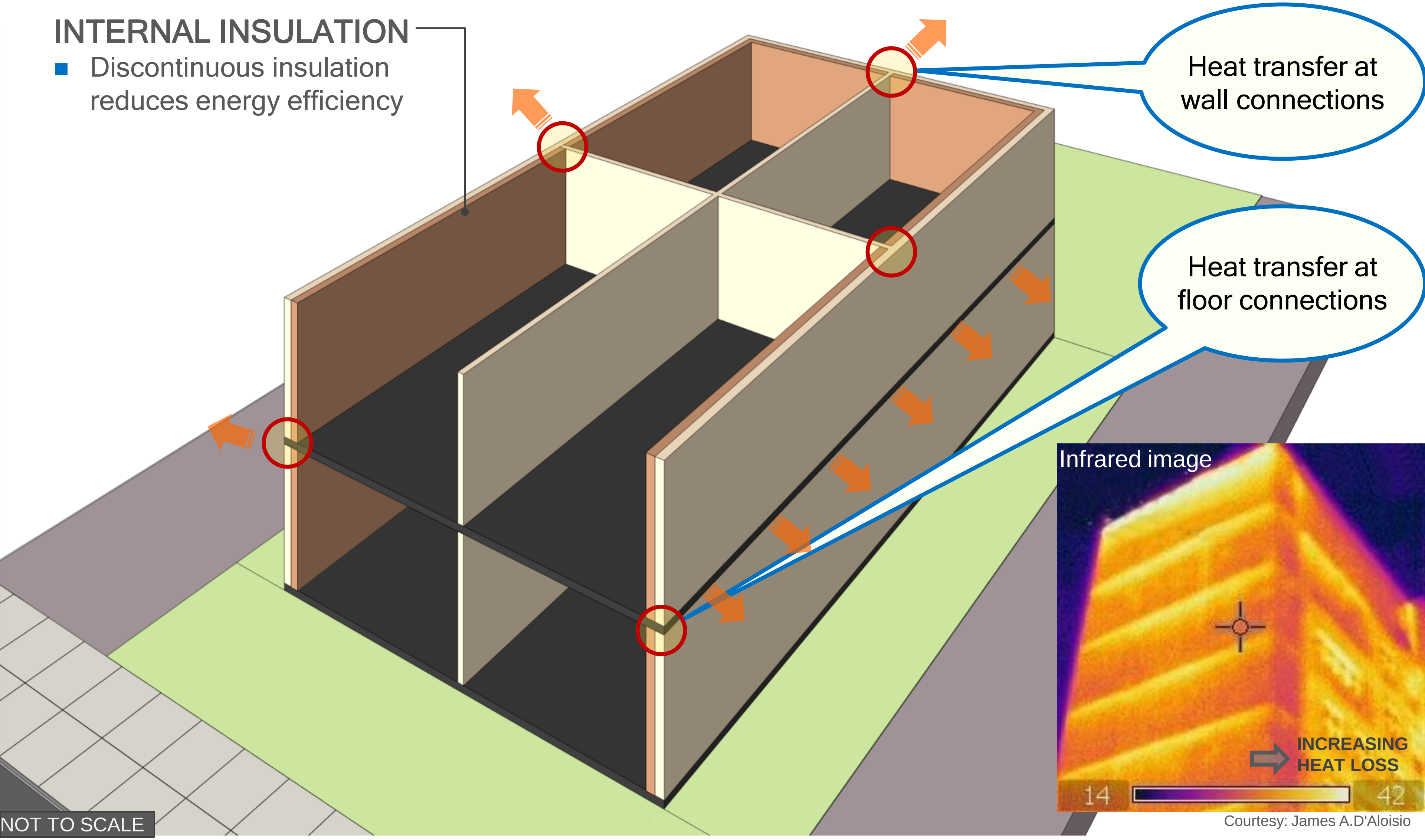
- R is measured in
  - m^{2}K/(W-inch)
  - ft$^{2\circ}$ Fhour/(BTU-inch)

RESIST HEAT GAIN
RESIST HEAT LOSS

Material	R/ Inch
Insulation Materials	
Fiberglass Batt	3.14
Fiberglass Blown (attic)	2.20
Fiberglass Blown (wall)	3.20
Rock Wool Batt	3.14
Rock Wool Blown (attic)	3.10
Rock Wool Blown (wall)	3.03
Cellulose Blown (attic)	3.13
Cellulose Blown (wall)	3.70
Vermiculite	2.13
Air-entrained Concrete	3.90
Urea terpolymer foam	4.48
Rigid Fiberglass (> 4lb/ft3)	4.00
Expanded Polystyrene (beadboard)	4.00
Extruded Polystyrene	5.00
Polyurethane (foamed-in-place)	6.25
Polyisocyanurate (foil-faced)	7.20

www.allwallsystem.com/design/**RValueTable**.html

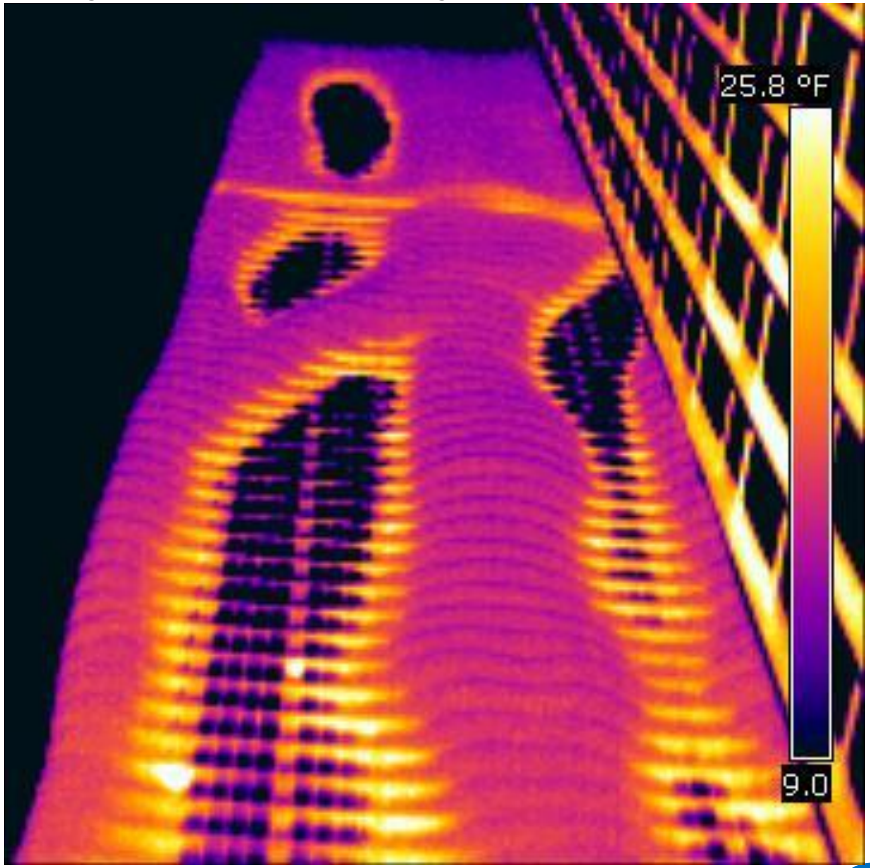
Thermal resistance: Insulation



Thermal bridging

- When insulation or a single material is interrupted by another more conductive material or creates a leak.

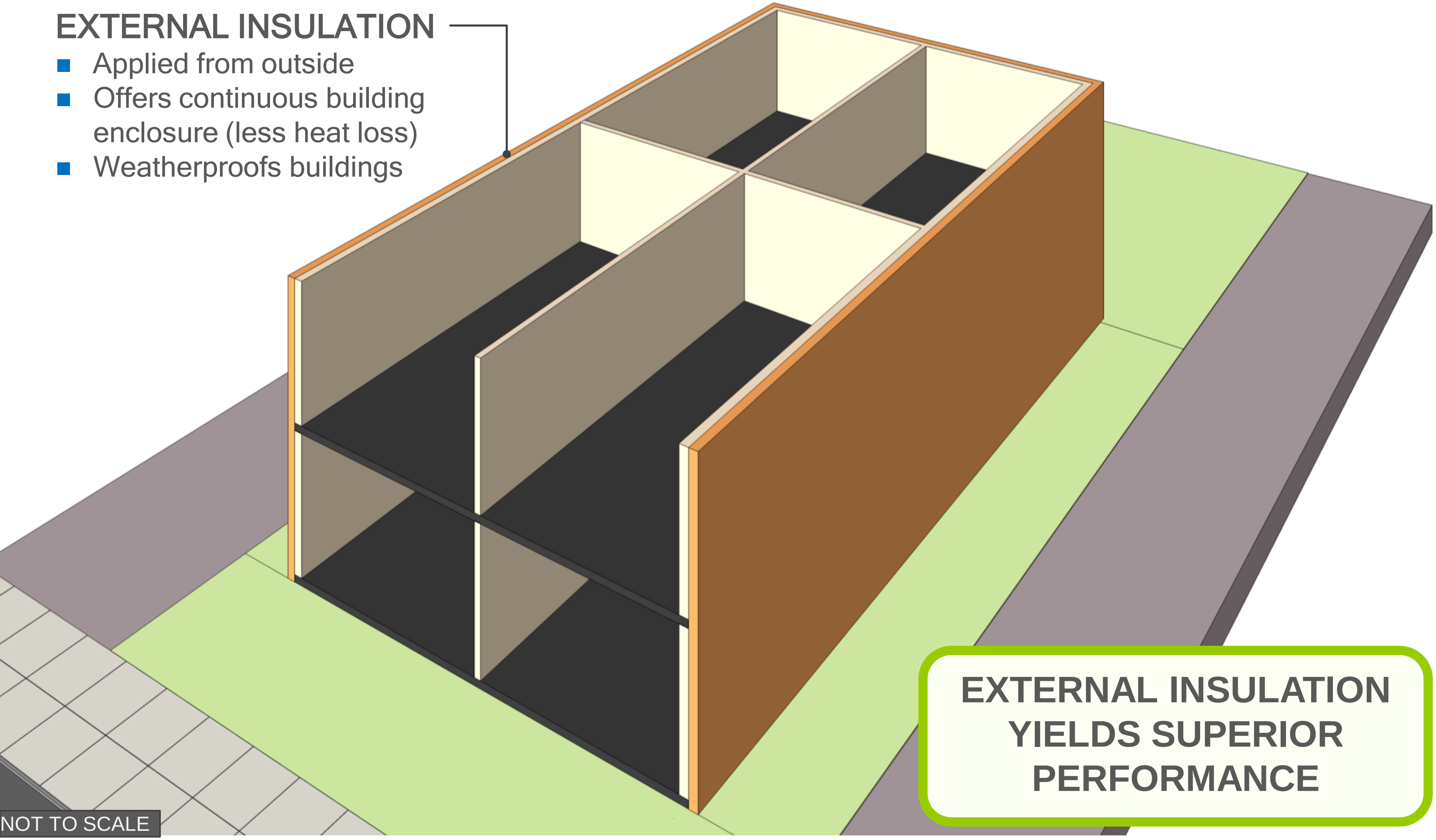
Thermal Image of Aqua Tower, Chicago, IL USA. Source: Wikimedia



Thermal resistance: Insulation

EXTERNAL INSULATION

- Applied from outside
- Offers continuous building enclosure (less heat loss)
- Weatherproofs buildings

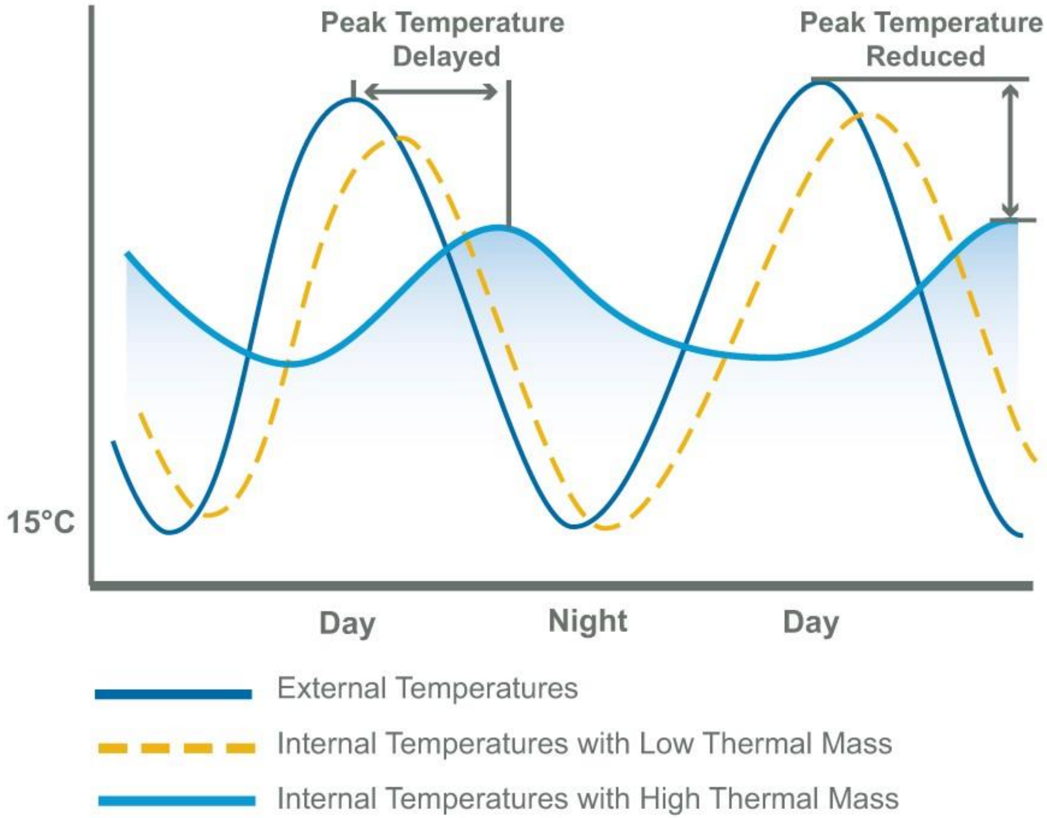


EXTERNAL INSULATION YIELDS SUPERIOR PERFORMANCE

Thermal capacity = Thermal mass

- how the mass of the building provides "inertia" against temperature fluctuations

$$C = \frac{Q}{m\Delta T}$$

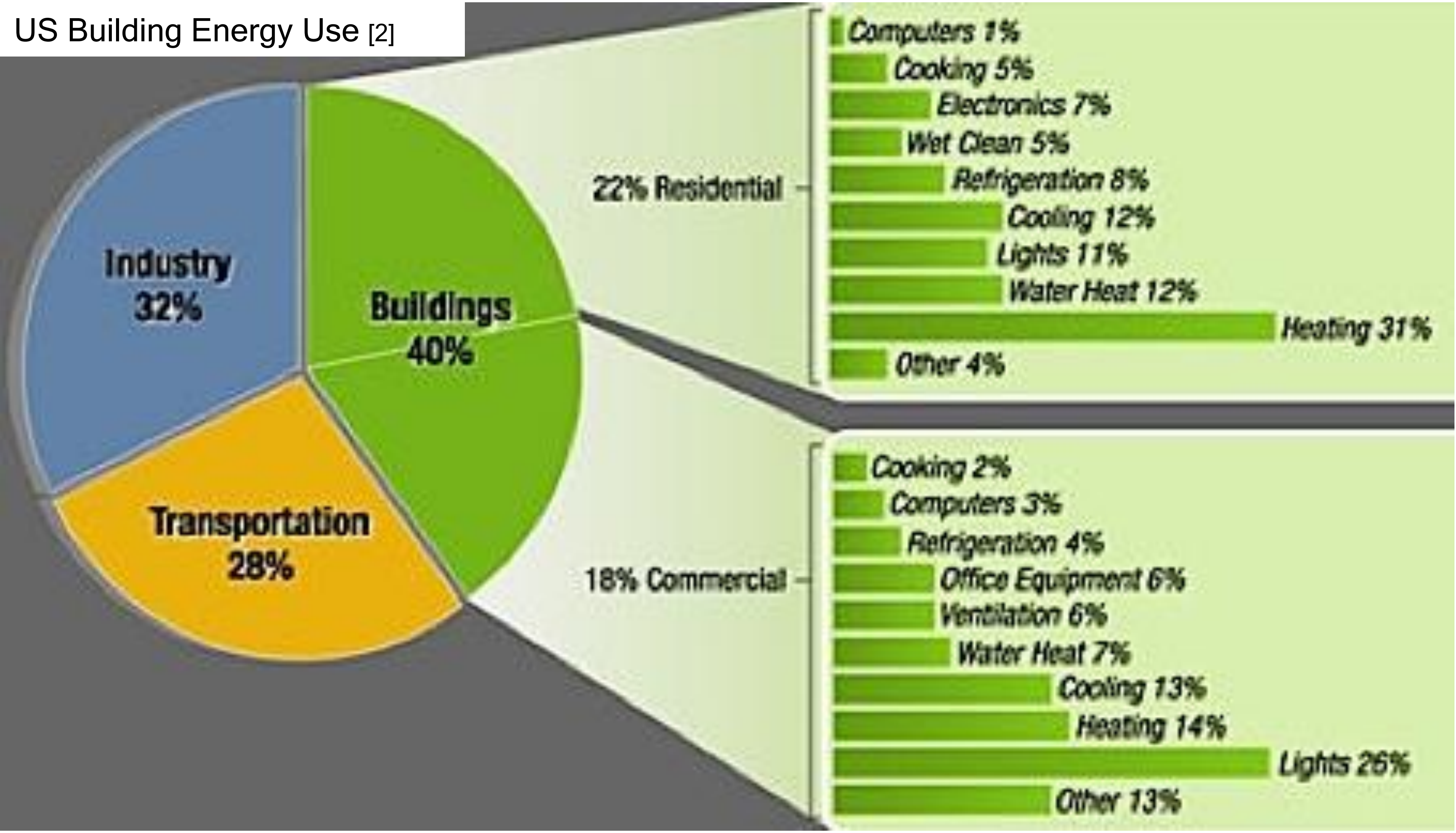


http://www.new4old.eu/guidelines/D3_Part2_H2.html

Novel building material: Phase Change Material has a very high thermal capacity

Building Operations

US Building Energy Use [2]



[1] http://ies.lbl.gov/iespubs/india_energy_outlook.pdf

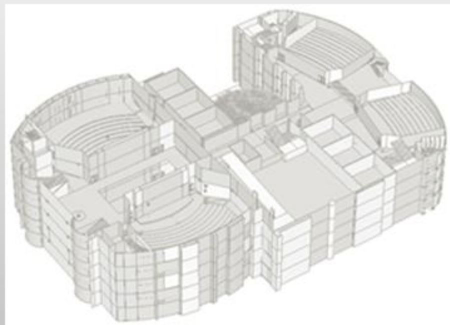
[2] http://www.jetsongreen.com/2009/08/breaking-down-building-energy-use.html

IIT BOMBAY AS LIVING LAB

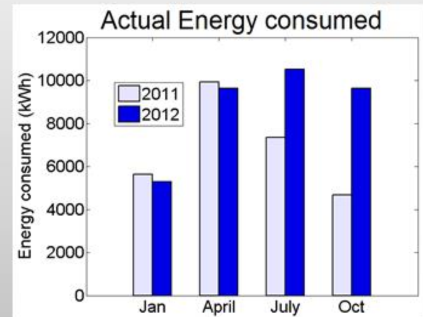
IIT Bombay Campus

- 500 acres, 18,000 population
- Buildings representative of various uses/occupancies
  - Academic Area
    - Convention Center, Lecture Hall Complexes, Nano Lab, new and old buildings
  - Residential Area
    - Housing, hospital, school, market, restaurants
- Open spaces
  - Lakes, wooded land
- Transportation (public & private)

Goal: Closing the Design-Technology-Policy gap



Design



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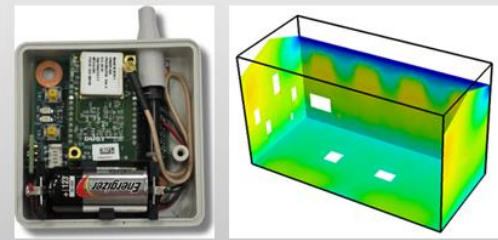


Sensing/Analytics

Simulation image, courtesy IBM

Design Improvements

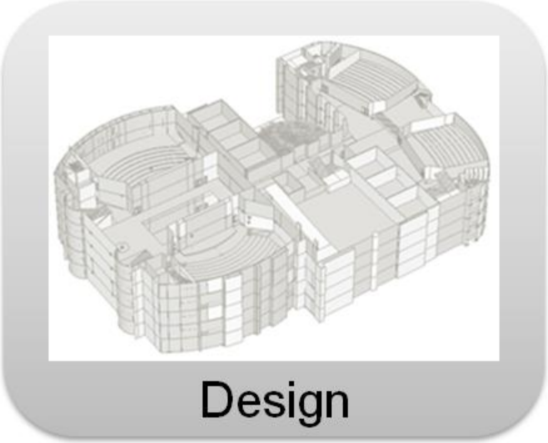
Efficient Operations

Policy Changes

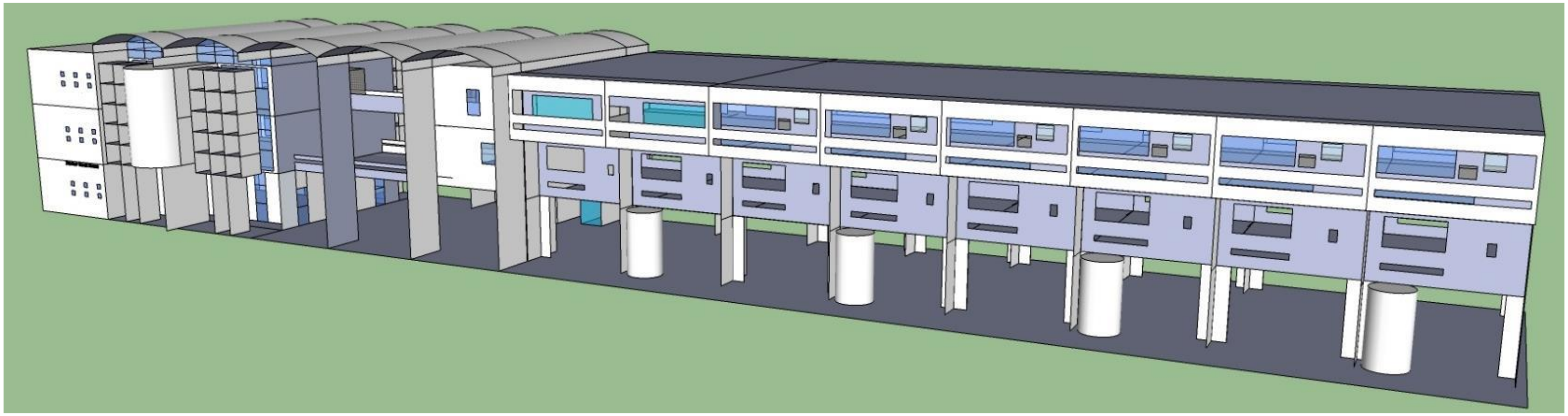
Example: Jal Vihar Guest House

Process: Analyse the Design

- Building Area, Height
- Building orientation
- Building Material
- Function and Use
- Building operations
  - Occupancy
  - Appliances



Tool Set: Physical Survey, Sketchup, AutoCAD, BIM



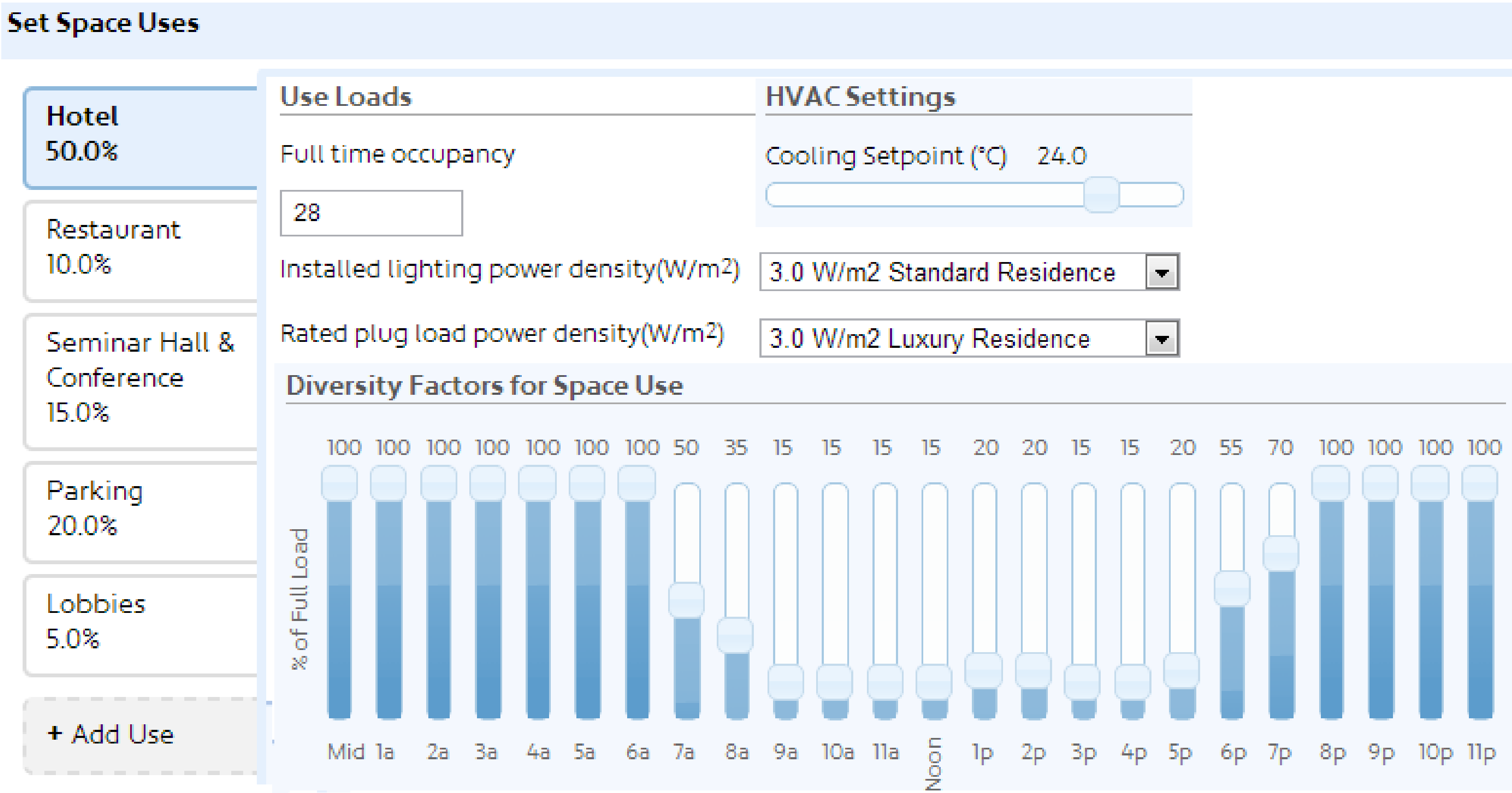
Space Use Mix

Space	Floor Area (%)	Total Occupancy	Lighting Power Density (W/m2)	Rated Plug load Power Density (W/m2)
Hotel Rooms	50	40	3	3
Restaurant	10	25	3	6
Conference Hall	15	15	9	6
Parking	20	2	2	1
Lobby Space	5	12	4	1

Data Collection

Parameter	Description	Property	Value
Façade Glazing	Single glazed, coated windows	U-value	6 W/m^2-K
		SHGC	0.55
Walls, floor and roof	Brick + concrete	U-value	2.0 W/m^2-K
Leakage	Standard assumption	Leakage rate	4.8 m^2/m^2-h
HVAC system	Spilt AC	Cooling COP	3.0
Water fixtures	Measurements of actual flow rates along with daily estimates from interviews and surveys	Faucet Flow rate	4.8L/min

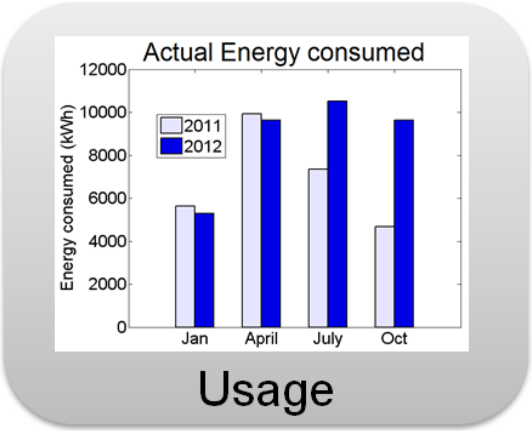
Sefaira: Space Use Mix + Occupancy



Sefaira.com

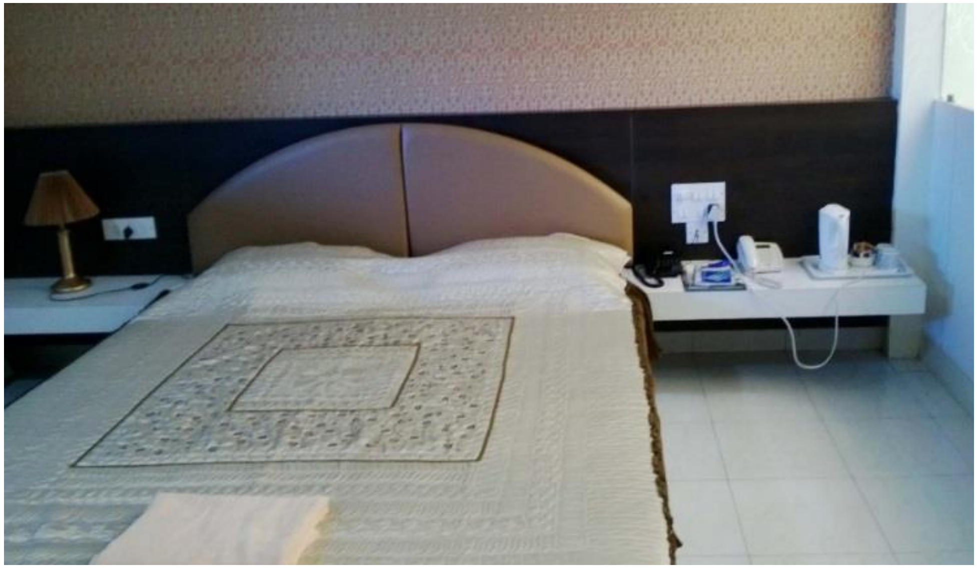
Process: Modeling

- Model the Usage
- Verify/validate the models
- Evaluate Energy efficiency strategies



Tool Set: Sefaira, Energy Plus, Design Builder, Radiance

Guest house rooms

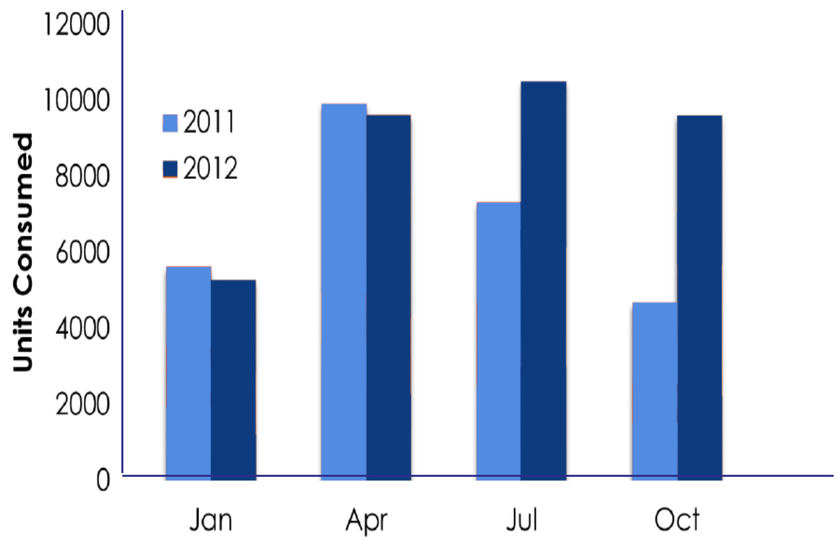


Common Areas

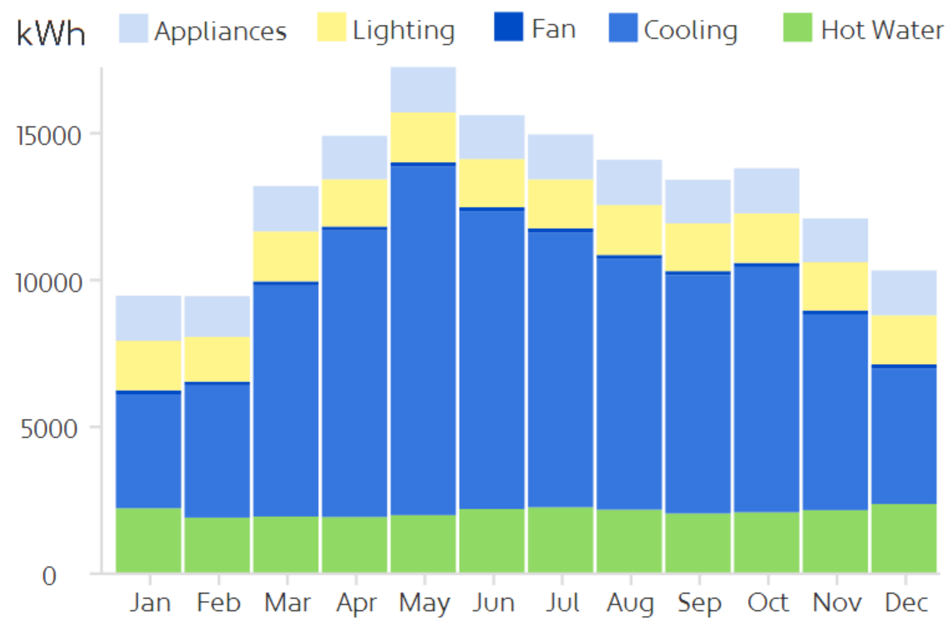
Category	Load
Air-conditioning	31 ton
Water Heating	54.5 kW
Lighting Load	4.52 kW
Appliance Load (TV, Fridge, Fan in each room)	14.4 kW

Validation of model

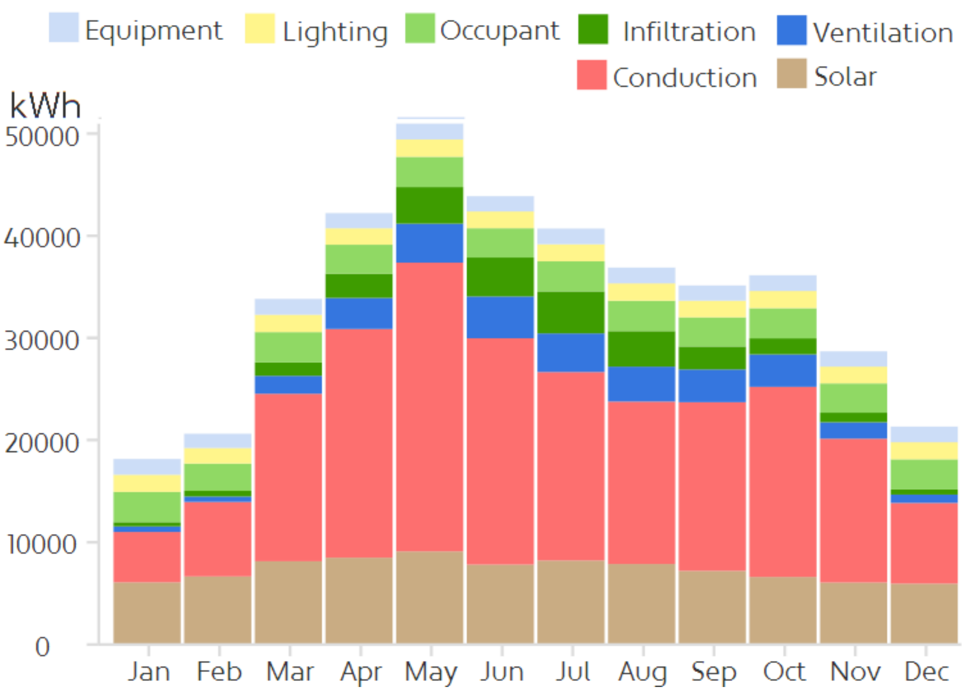
Actual Energy Usage



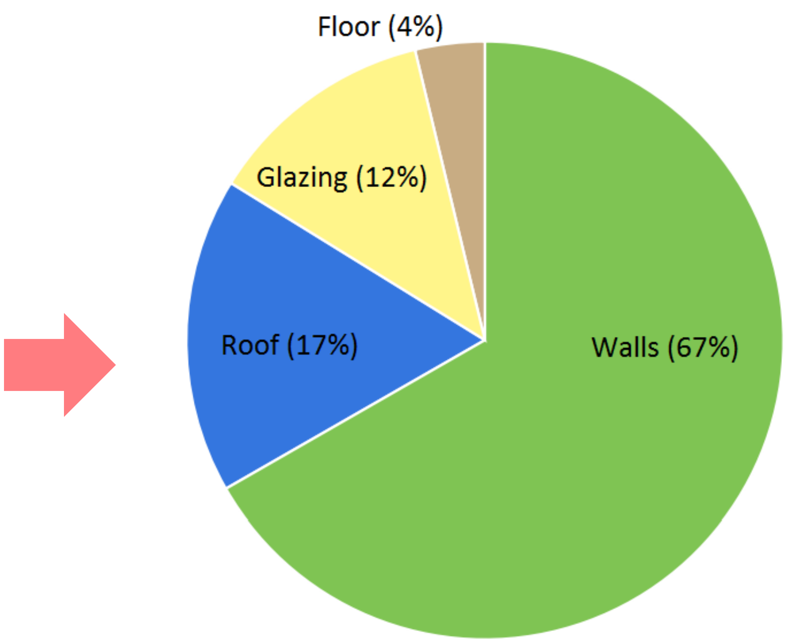
Modeled Energy Usage



Jal Vihar Guest House

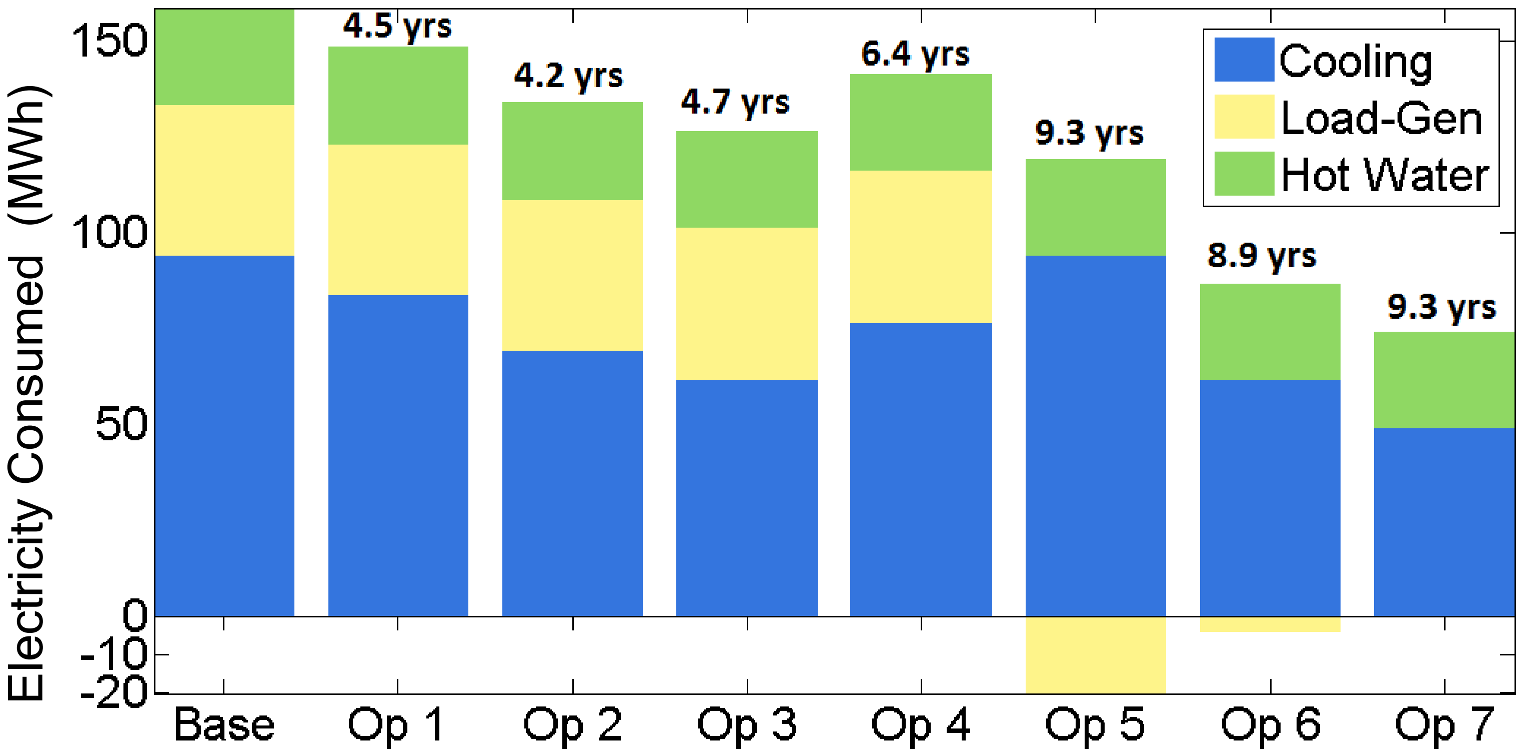


Heat Gain



Fabric Conduction Gain

Evaluating Retrofit Strategies

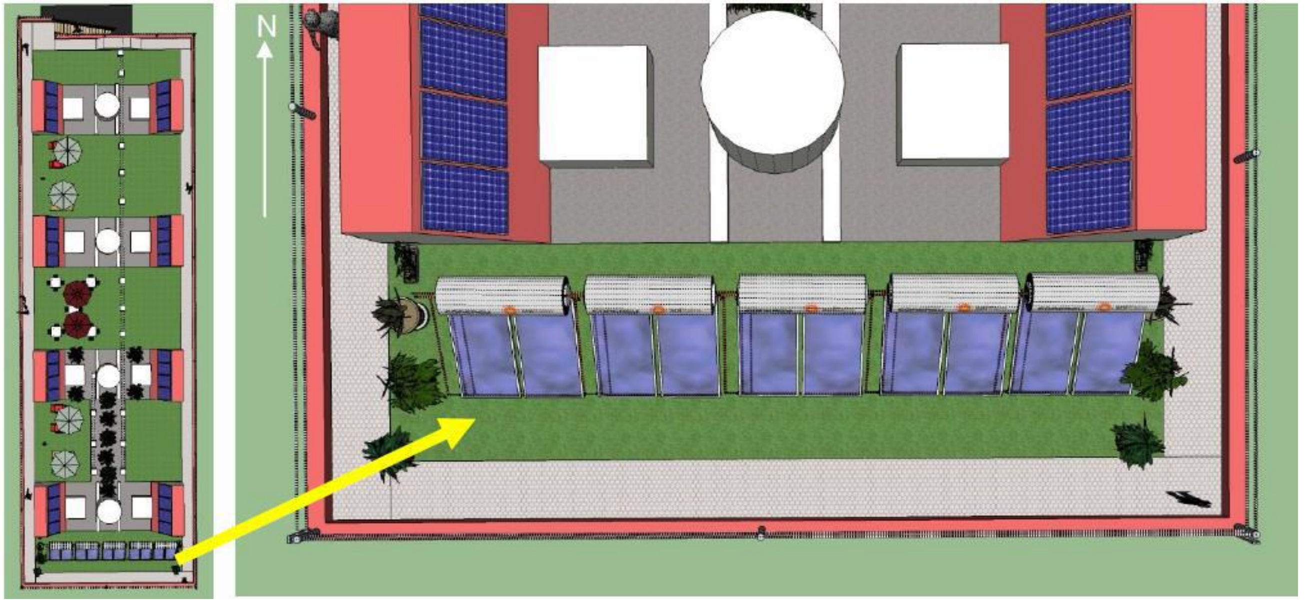


Op 1: Improved windows (11% cooling load redn)
Op 2: Improved Air-Conditioners (26%)
Op 3: Improved windows and AC (35%)
Op 4: Improved insulation only (19%)

Op 5: Solar PV only (45% gen)
Op 6: 1+2+3+5 (57%)
Op 7: All of the above (64%)

Jalvihar Guest house roof

- Solar PV and Solar Thermal installation
- Green roof and seating areas created for view

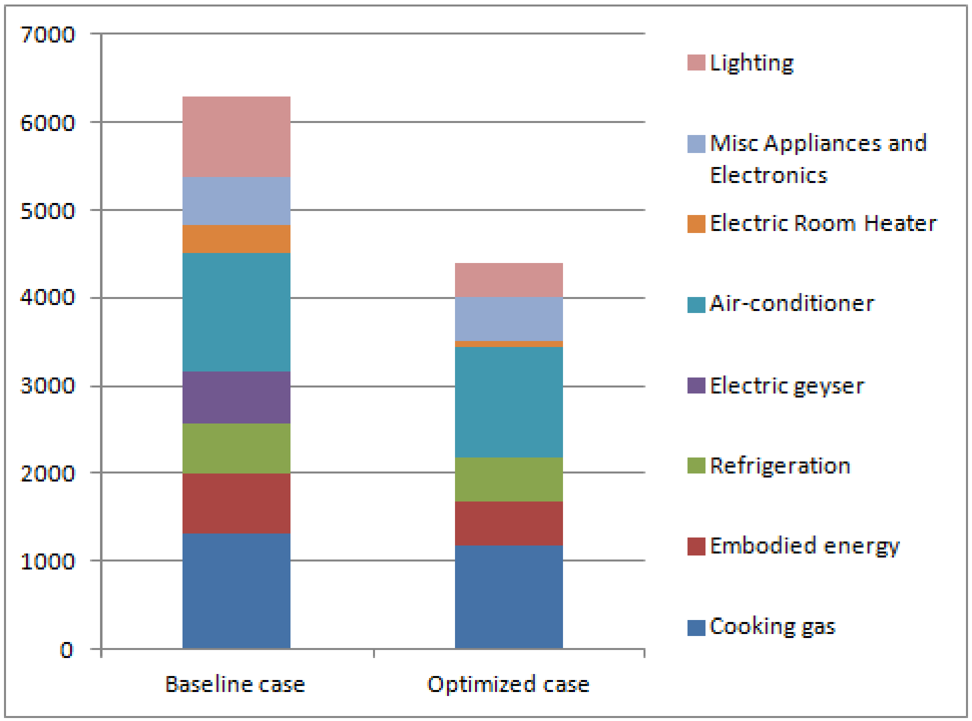


Analysis of Existing Buildings on campus

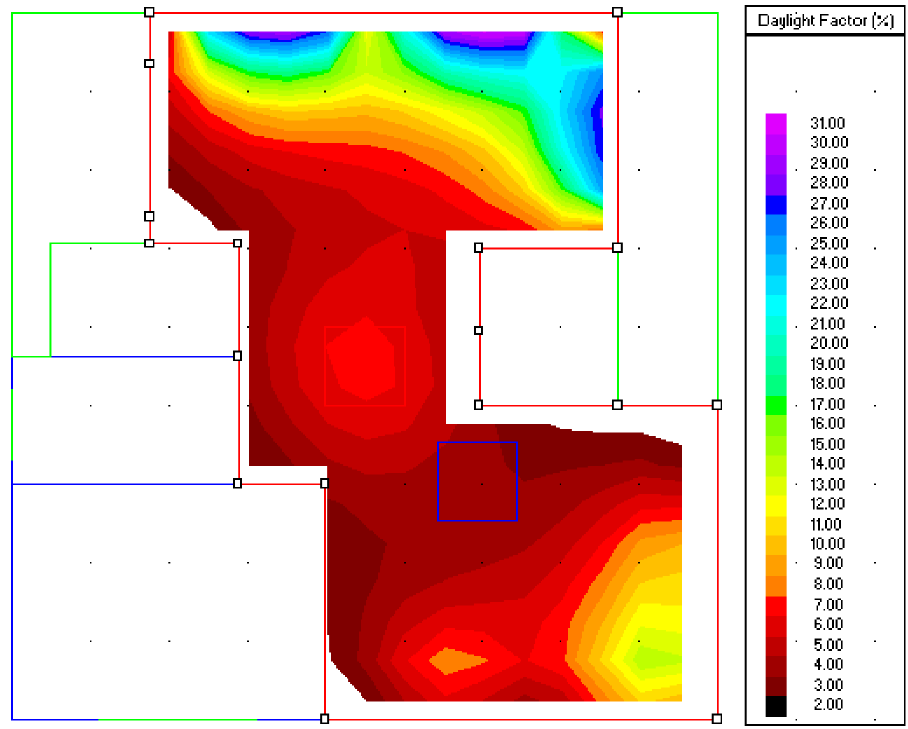
1. Hostel 13
2. Jal Vihar Guest House
3. KreSIT Building (CSE)
4. B 24 Faculty Housing
5. Lecture Hall Complex
6. Nano Electronics
7. Convention Centre
8. Mechanical Engineering
9. Main Building

Simulations to optimize design

Life cycle energy (in kWh/year)



Daylighting design optimization



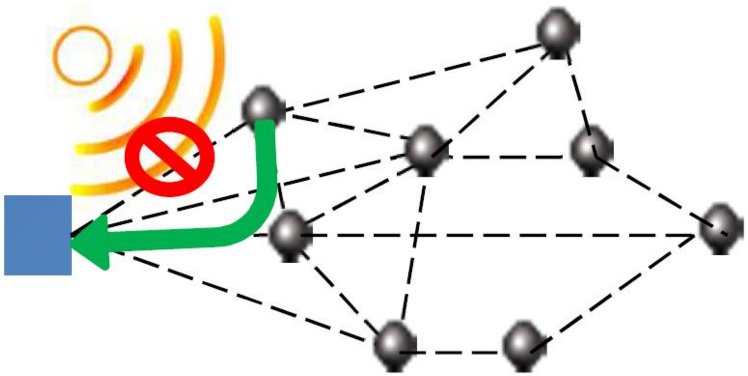
Team Shunya's H-Naught

Modeling limitations

- Difficult to model trees and effects of topography
- Micro-climate is different from weather file
- Internal walls and room sizes have an impact on the energy consumption but the Sefaira model does not consider it's impact

Next Steps: Real time sensing & analytics

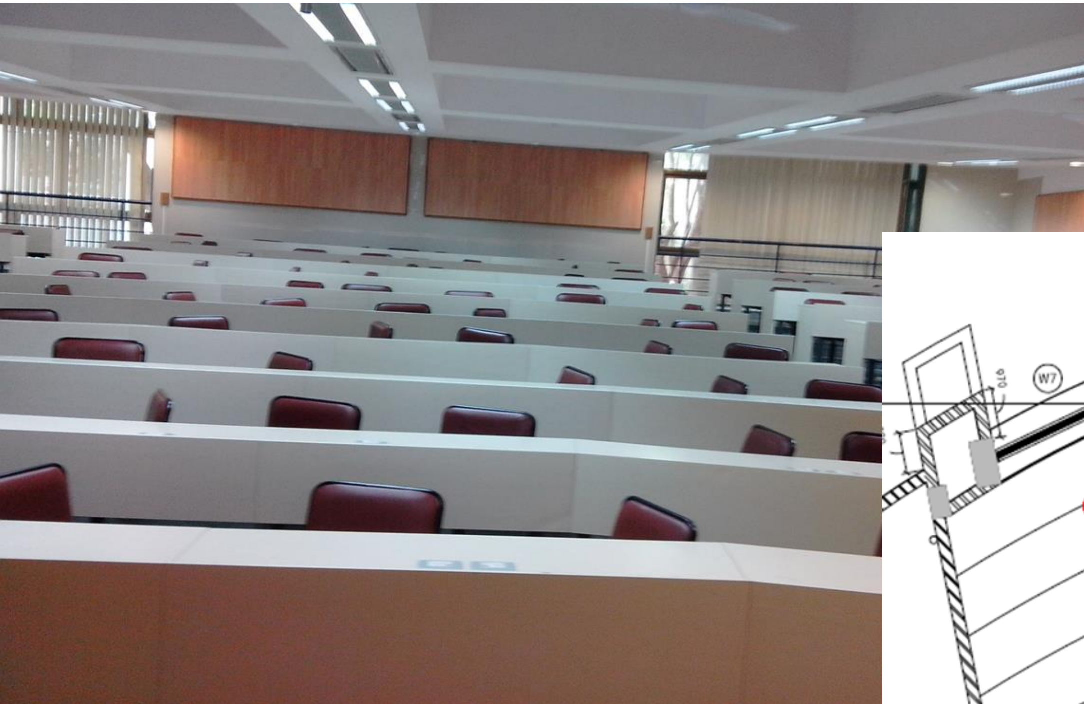
Create wireless sensor networks to measure real time environmental variables

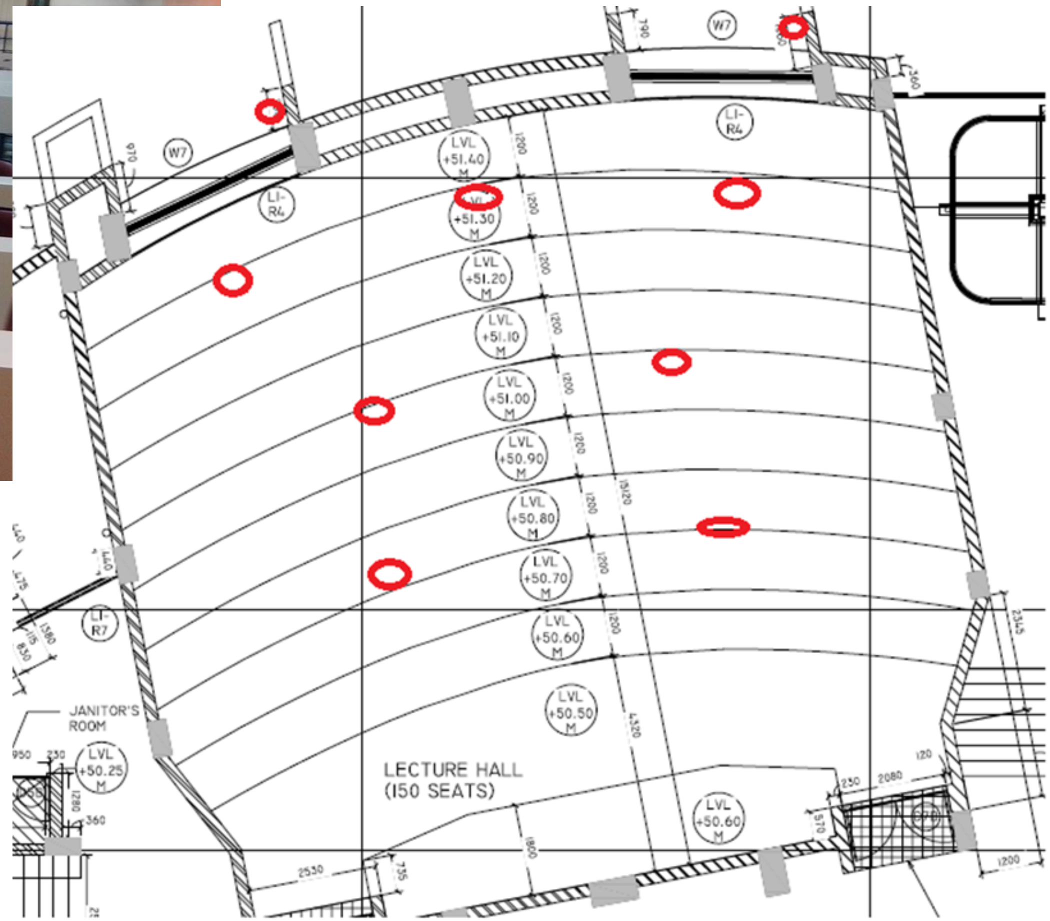


Calibrate modeling software with real time data and use the calibrated model for analytics

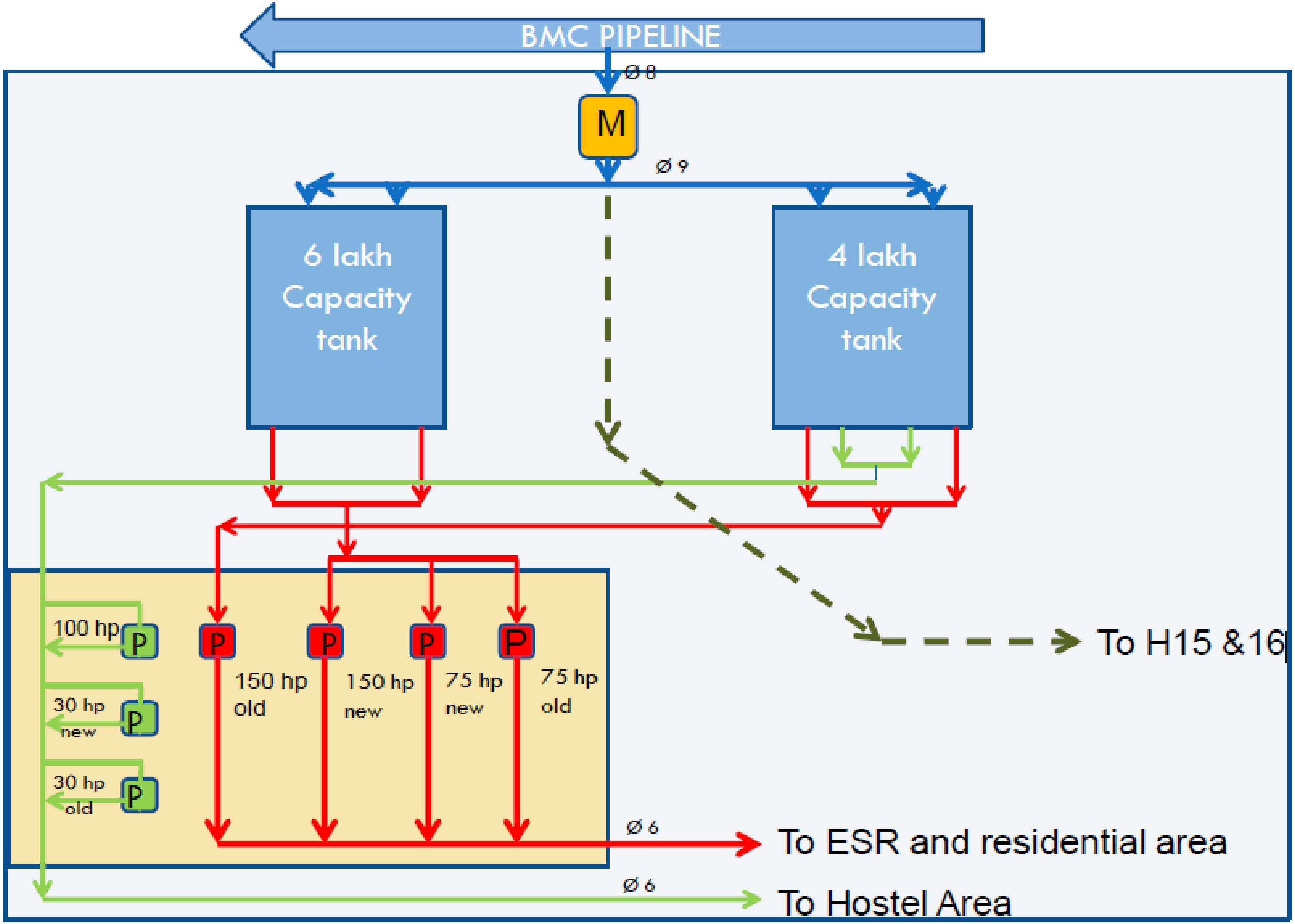
Photo by Monika Jain

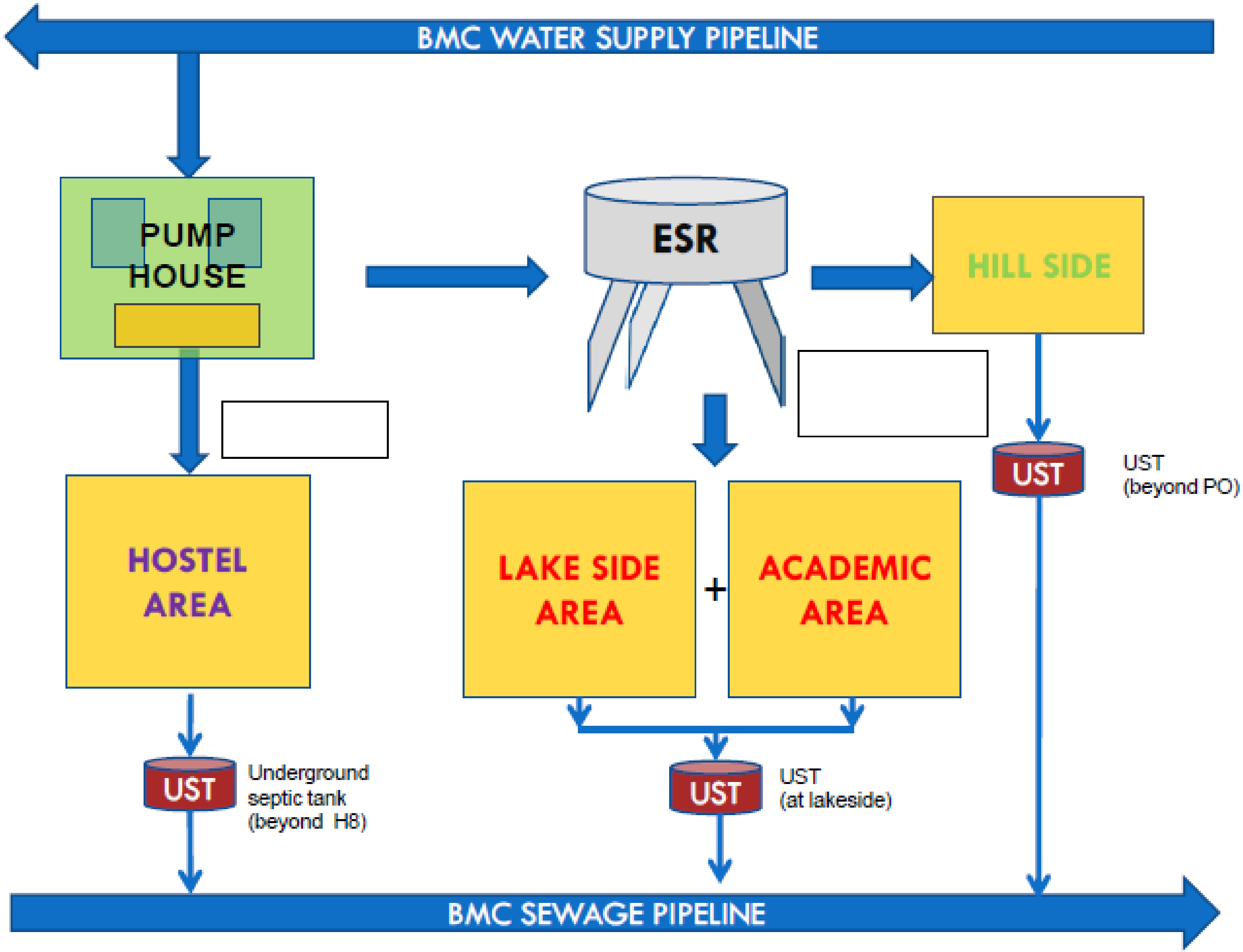
Pilot Project: LCC 32





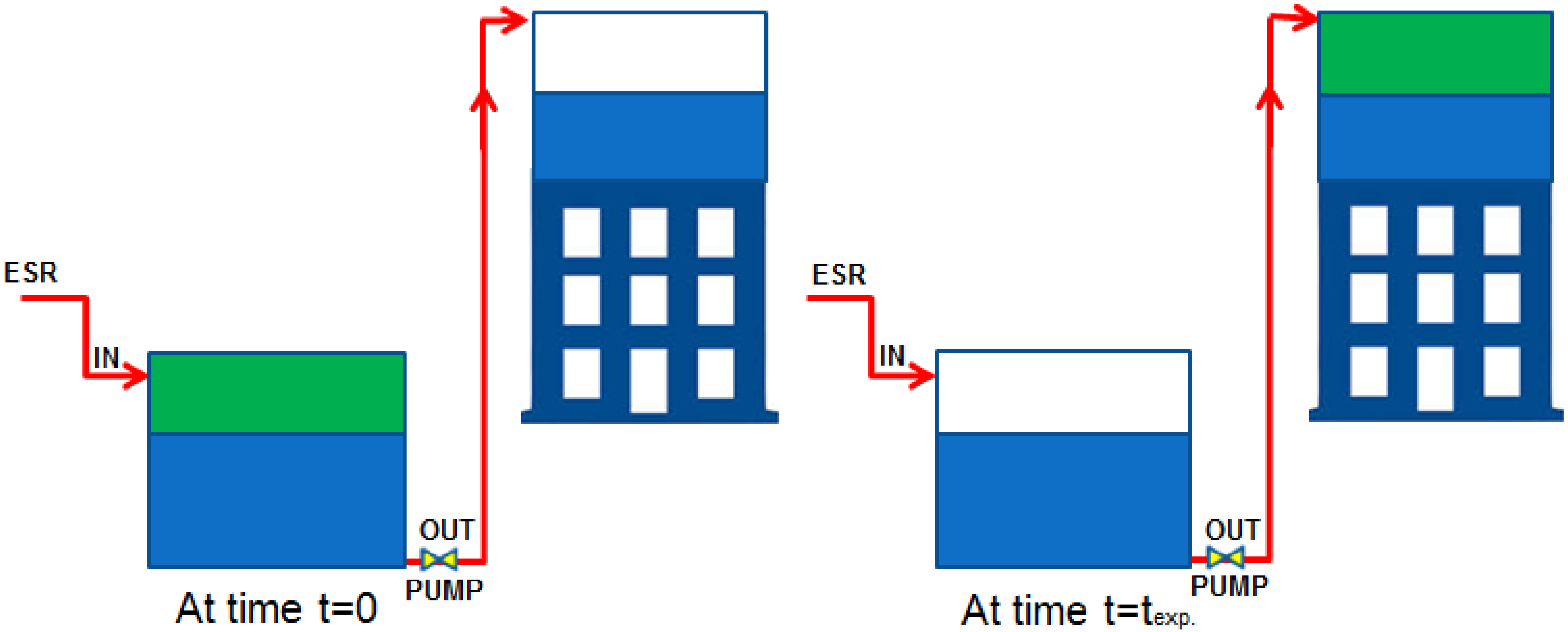
CAMPUS WATER


BMC PIPELINE
Ø 8
M
Ø 9
6 lakh Capacity tank
4 lakh Capacity tank
To H15 &16
100 hp
P
30 hp new
P
30 hp old
P
P
150 hp old
P
150 hp new
P
75 hp new
P
75 hp old
Ø 6
To ESR and residential area
Ø 6
To Hostel Area


BMC WATER SUPPLY PIPELINE
PUMP HOUSE
ESR
HILL SIDE
UST
UST
(beyond PO)
HOSTEL AREA
LAKE SIDE AREA
+
ACADEMIC AREA
UST
Underground septic tank (beyond H8)
UST
UST
(at lakeside)
BMC SEWAGE PIPELINE

Experiments

- to calculate per capita water consumption



- Ananta faculty housing; Hostel 12, 13, 14; Main Building

Water consumption in IITB

- Total LPCD of IIT Bombay= Average consumption per day / Total population
- = 1,82,770,500/ (17,019*30)
- = 357.97 liters per person per day

- Ananta (Residential): **513 lpcd**
- Hostel 12, 13, 14 (Hostel): **362 lpcd**
- Main Building (Office): **57 lpcd**

Norms as per CPEEHO

Residential: 150 lpcd
Office: 45 lpcd

Question: How to do such measurements for buildings without pumping of water from underground tank to overhead tank?

BEYOND BUILDINGS

Campus Transportation

- Vehicle-free academic area & main gate road– is it possible?

- Monitor vehicular traffic in real time.

- Create an air pollution map of campus roads, and do real-time 'what if' case-studies?

- Improve campus air quality by implementing an optimized traffic management system

Demonstration of Electric vehicle

- Solar powered electrical vehicle demonstration
- For commuting within campus
- For utility vehicles
- Pilot to be implemented in Colaba island (Clean Air Island)


http://venturebeat.com/2012/03/13/local-motion-funky-electric-golf-cart/


EV Two tractors for waste. Source: Clean Air Island


EV Taxi. Source: Clean Air Island

Transportation: Bike Share program

- Hundreds of bikes are discarded every year
- Bike share program with smart technology and security
- Operations and maintenance structure
- Safe and properly designed bike paths

Air Quality: Indoor air quality

- Are students sleeping in classes due to poor air quality? ☺
- Monitor indoor air quality as a function of occupancy levels.
- Predictive control of temperature, humidity and air flow based on events.

Air Quality: Outdoor Dust and Pollution

- Identify/quantify sources of dust and pollution
- How to manage construction dust and debris?
- Create policies for campus cleaning and construction management

Water: Conservation & leakage detection

- Can we predict water leakage incidents?
- Leaks are currently detected by human eye/ear.
- Currently, only one water meter for the entire campus.
- Use smart water meters in the supply network to enable
  - Leak detection
  - Water management
  - Differential pricing

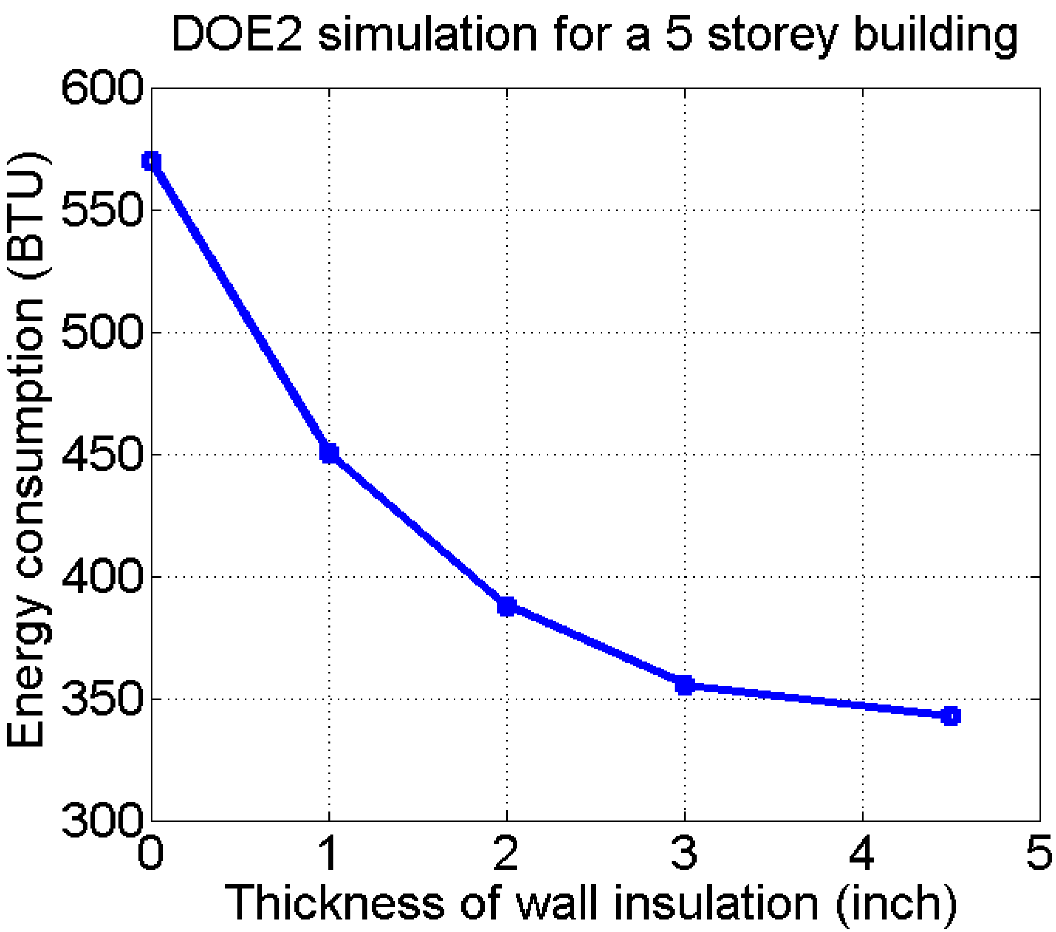
Main Gate Road as showcase project

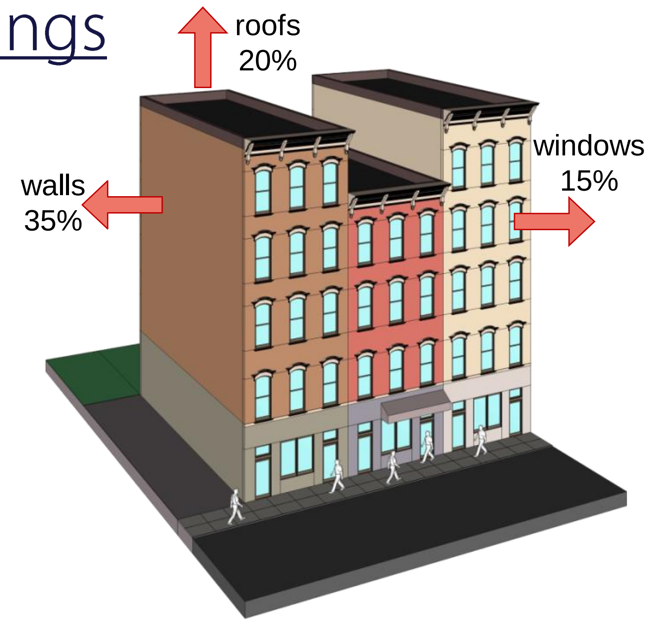
- Main gate road forms the main spine of campus
- Waste water recycling from buildings along the main road
- Rain water harvesting through rain gardens
- Streetlighting, seating, signage and pedestrian & bike friendly main road

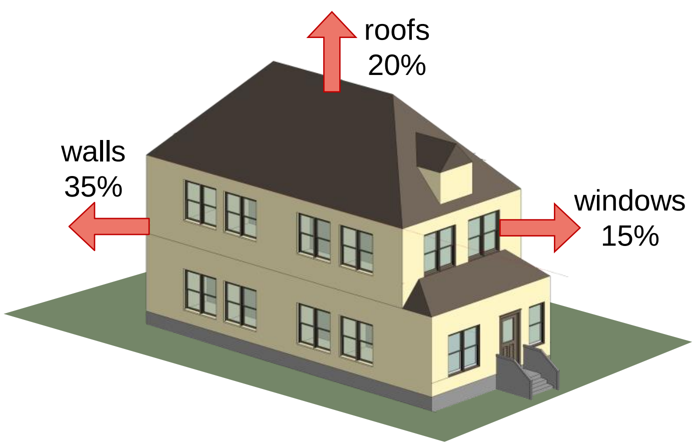
POLICY LEVEL IMPLICATIONS

Zone Green: NYC Regulations

GOAL: Promote insulation of existing buildings



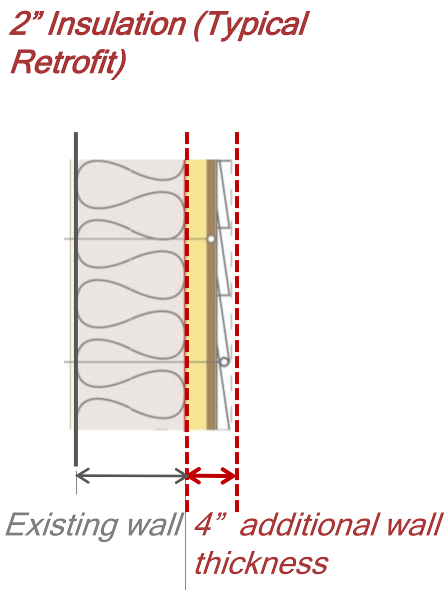


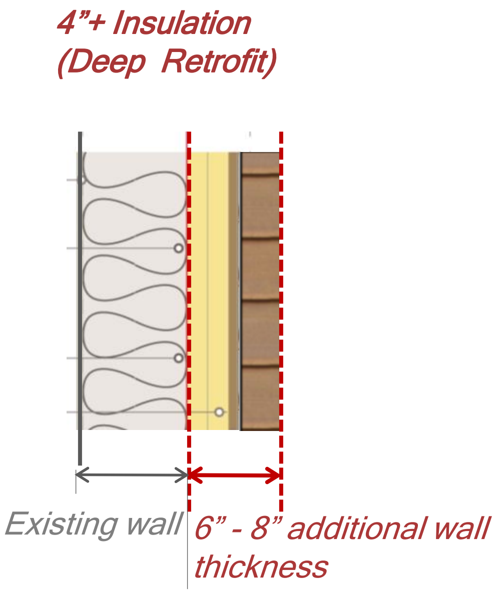


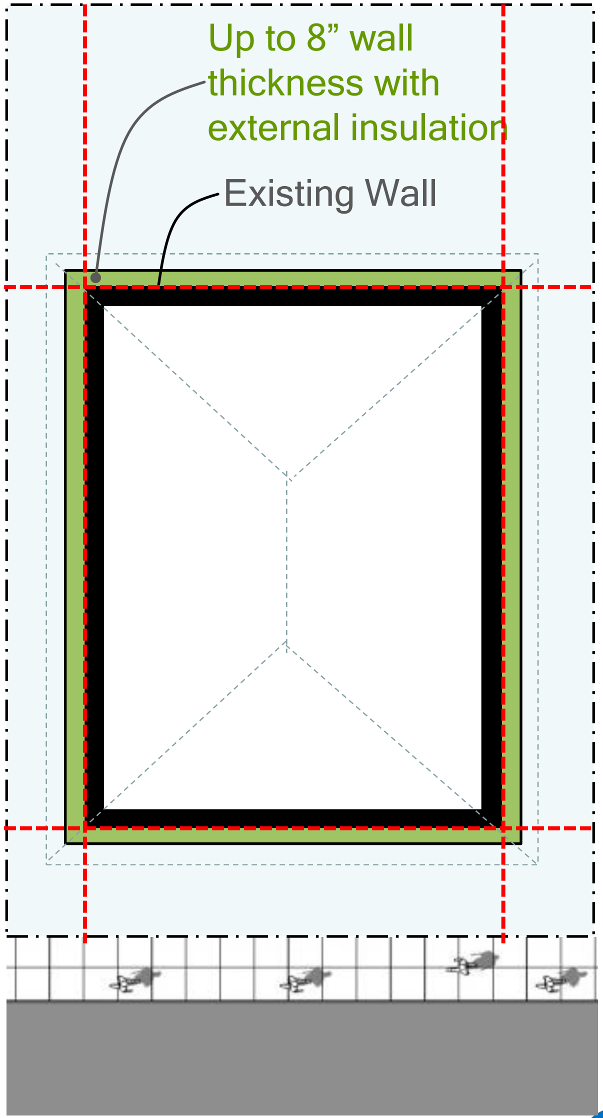
Zone Green: NYC Regulations

GOAL: Promote insulation of existing buildings

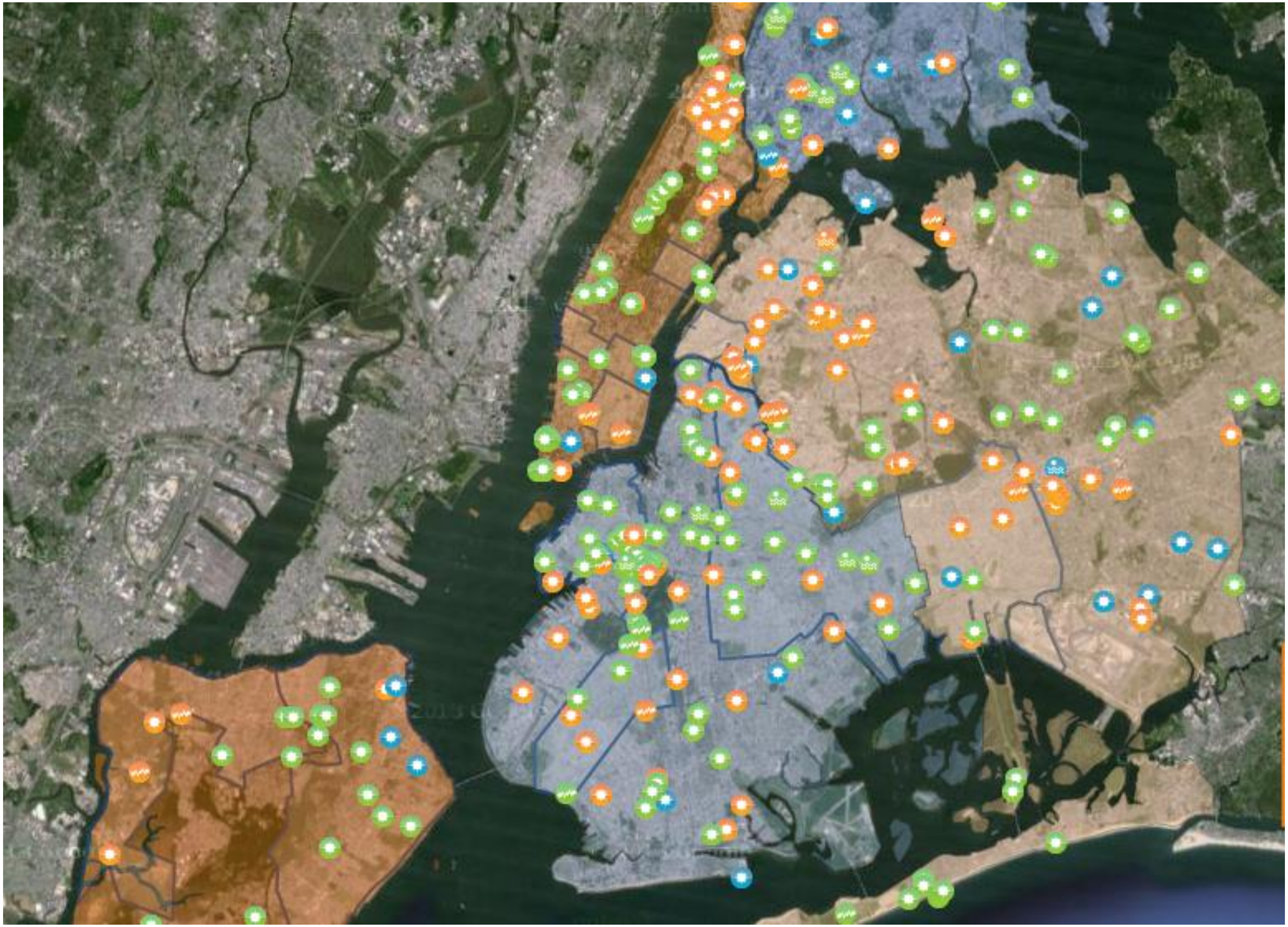
Up to 8 inches of wall thickness may project into a required yard, open space or setback area and not count toward floor area or lot coverage



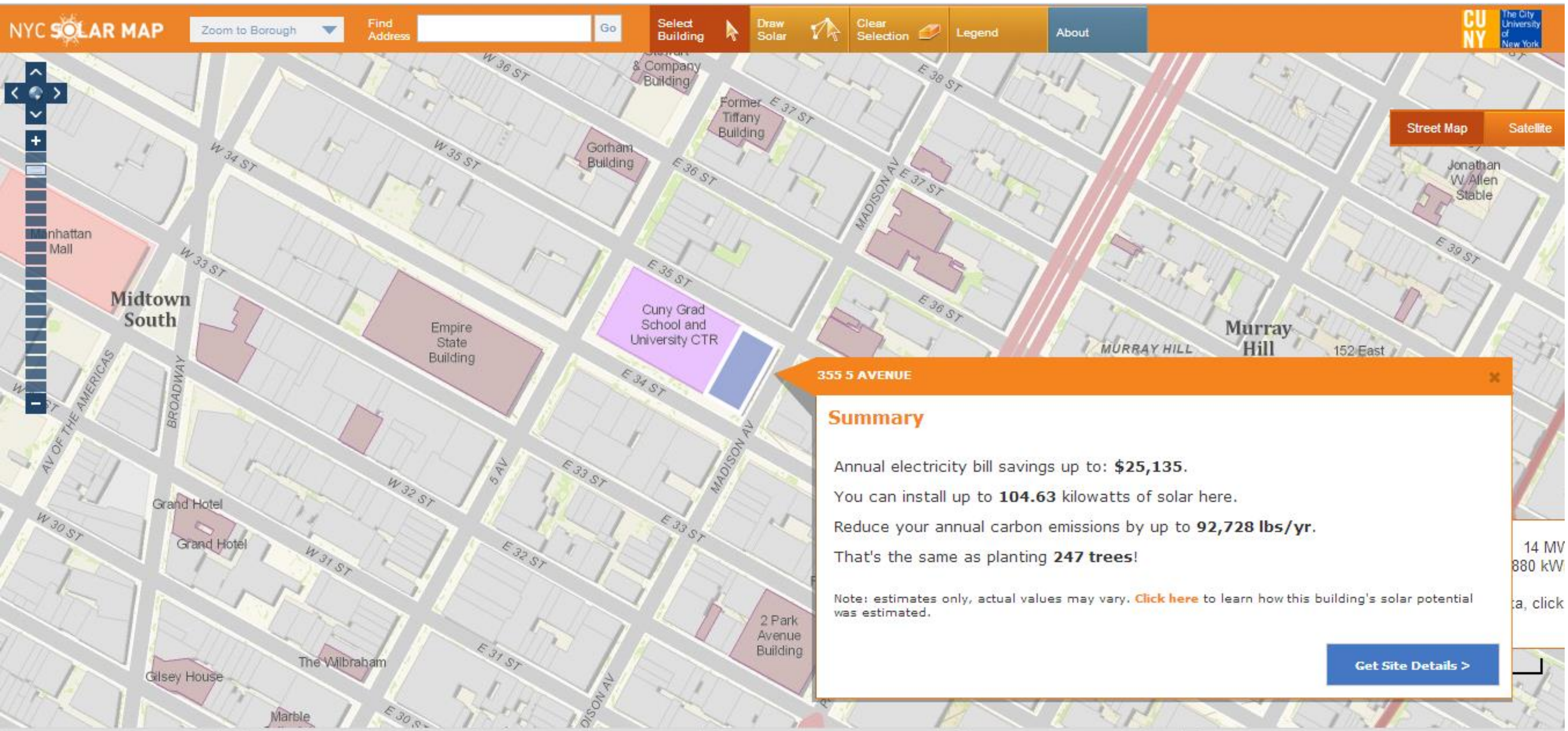




NYC SOLAR MAP



NYC SOLAR MAP



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Thank you!

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