The Boston Community Energy Study

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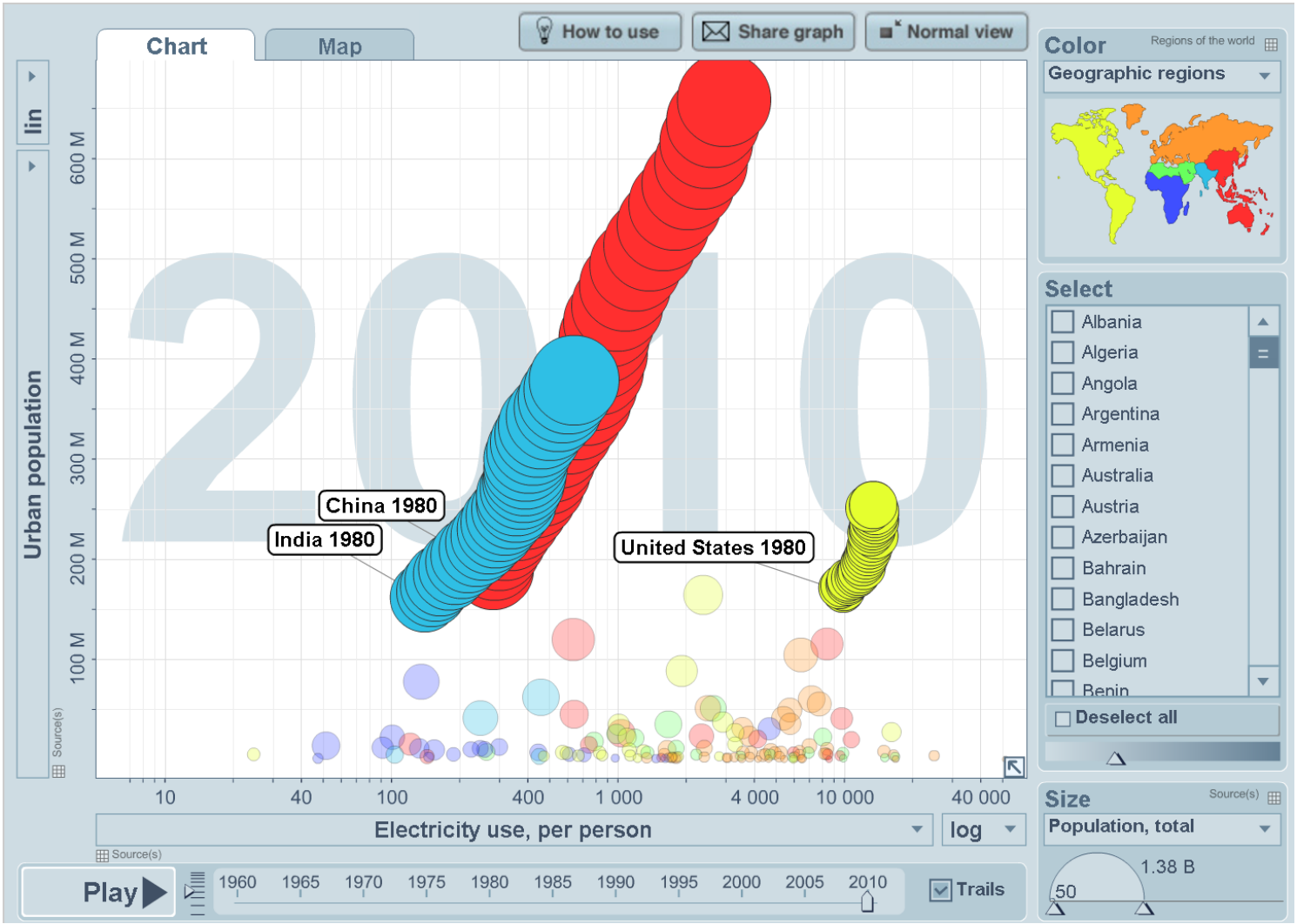
World Urban Population and Electricity



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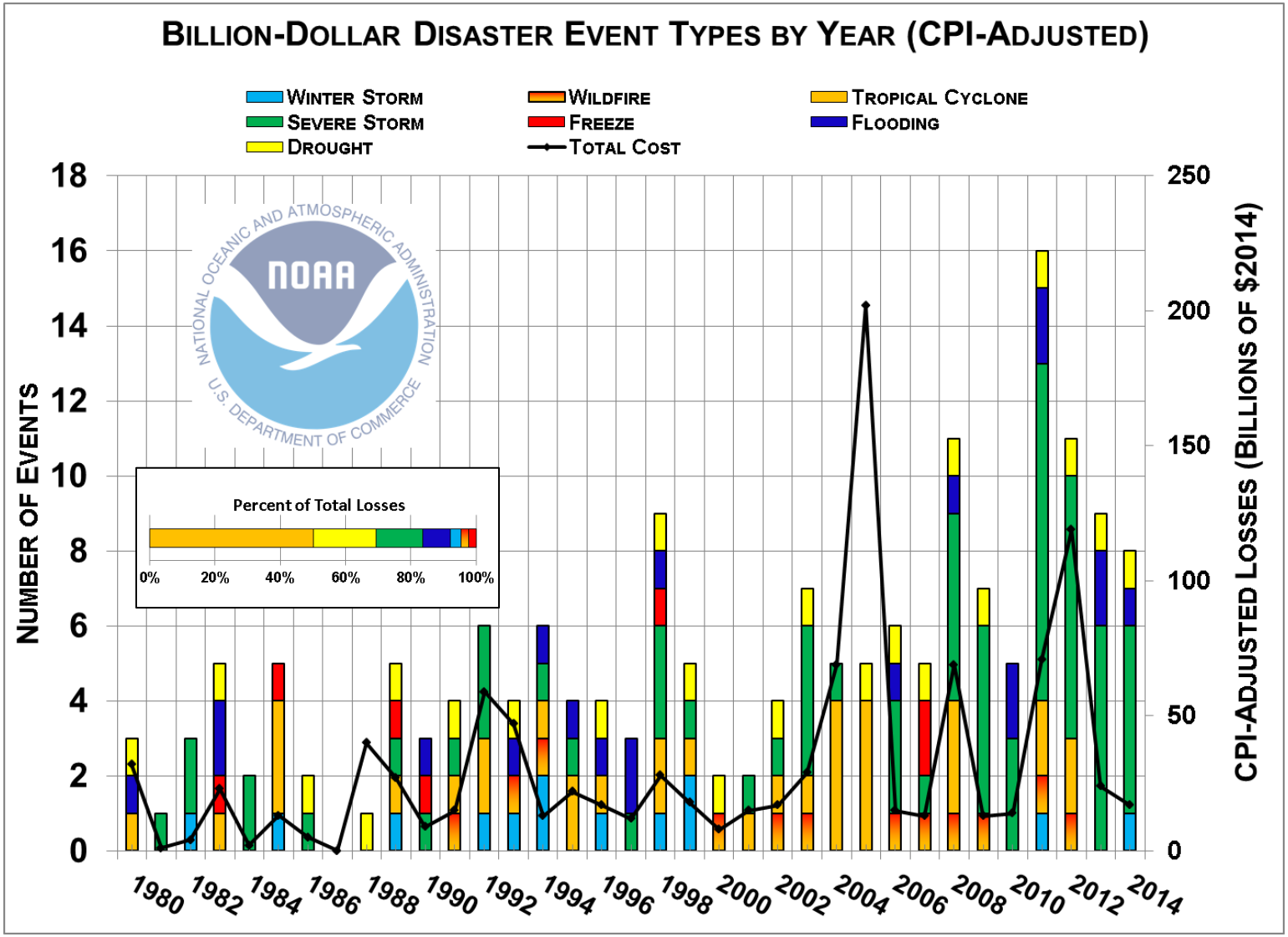
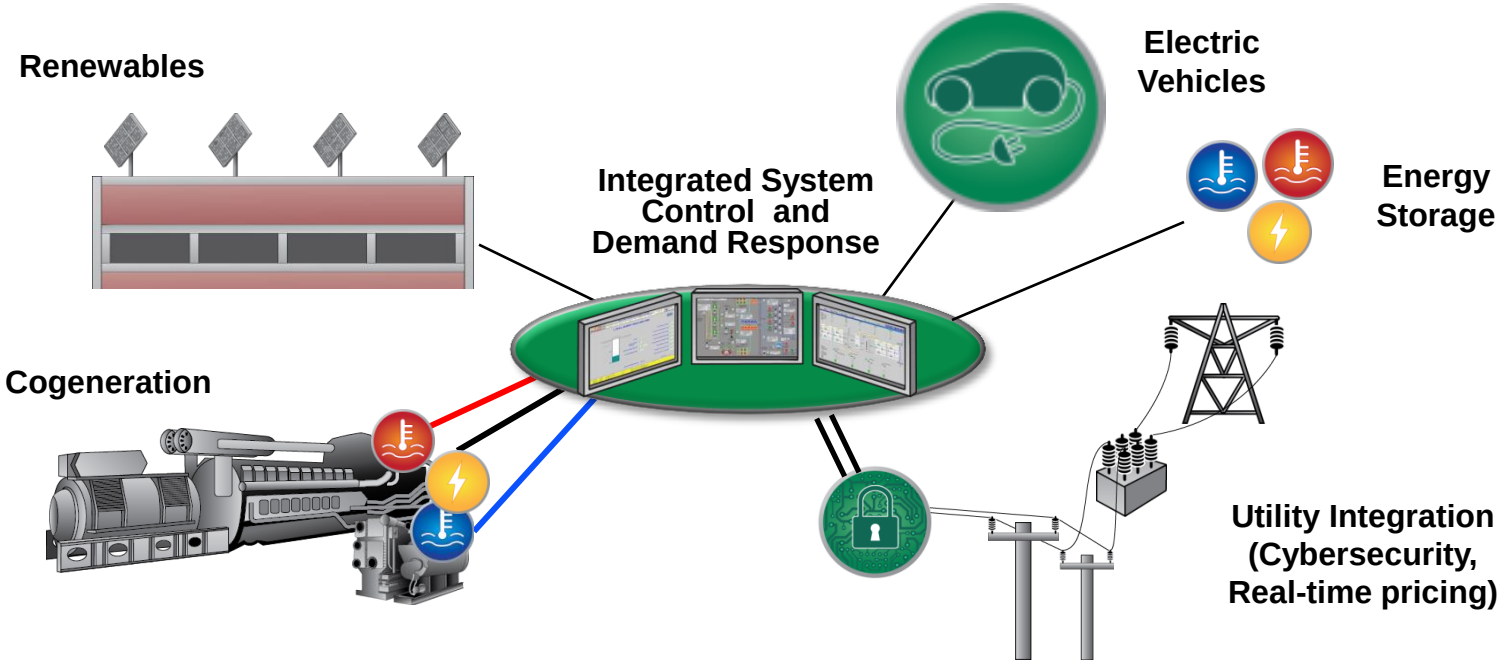
US Billion Dollar Disaster Events



Introduction to Microgrids

Microgrid: ***A set of interconnected loads and energy resources that acts as a single integrated entity with respect to the grid and can operate in both grid-tied and island mode.***

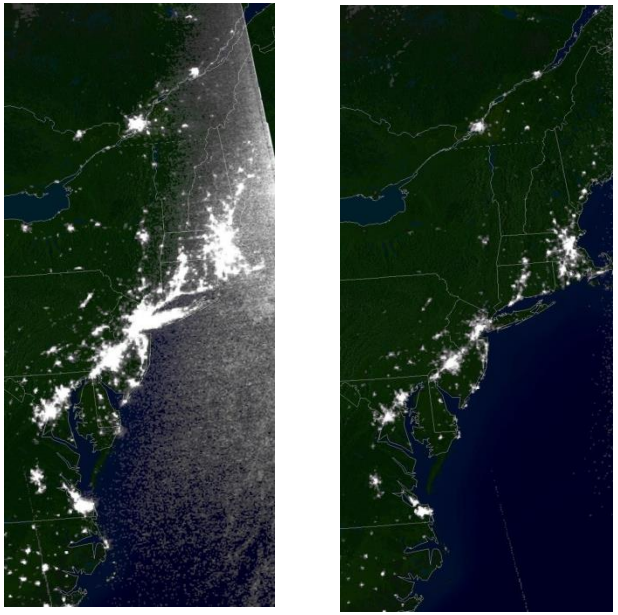


- **Microgrids can improve energy…**
  - Security, grid stability and resilience in the face of outages and demand variability
  - Cost-effectiveness and efficiency through demand response and distributed generation
  - Sustainability through enabling the incorporation of intermittent renewables
- **System integration challenges are significant**

Microgrids and Resiliency

- During Superstorm Sandy, all microgrids in NYC and the surrounding area performed without incident
  - Eleven facilities, 145 MW of power
  - Hospitals, places of refuge, municipal entities
- During the 2003 blackout, ½ of NYC's hospital backup gensets failed

Superstorm Sandy



2003 Blackout

Boston Key Statistics

- **Home to 655,000 people**
- **Covers 48 square miles**
- **Contains 84,345 parcels of land**
  - **92,000 buildings**
- **Globally, the equivalent of 3 Bostons/week are moving into cities**

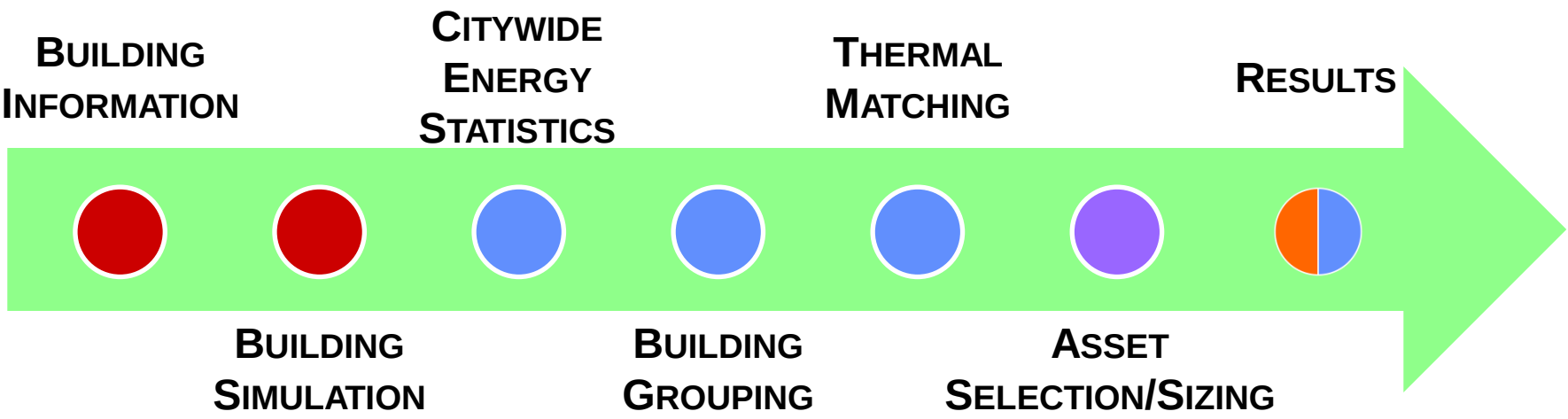
Citywide Energy Study Objectives

- Analyze regions in Boston where microgrids and distributed energy resources:
  - Make economic sense
  - Support critical loads
  - Serve vulnerable populations
  - Reduce GHG emissions
- Develop an approach that can be implemented in many other cities and regions
- Foster relationships between Boston's government, utility stakeholders, and the public
- Assess necessary information for large-scale energy transitions

Outline

- Study approach
- Overview of building modelling
  - MIT Sustainable Design Lab data set
  - Boston's simulated energy use
- Distributed Energy Resources Customer Adoption Model (DER-CAM) primer
- CHP search algorithm using GIS and building data
- Results & way ahead

Study Approach



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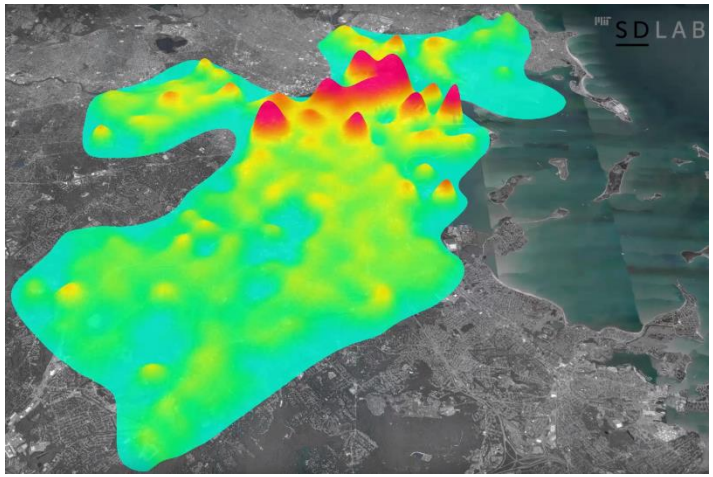
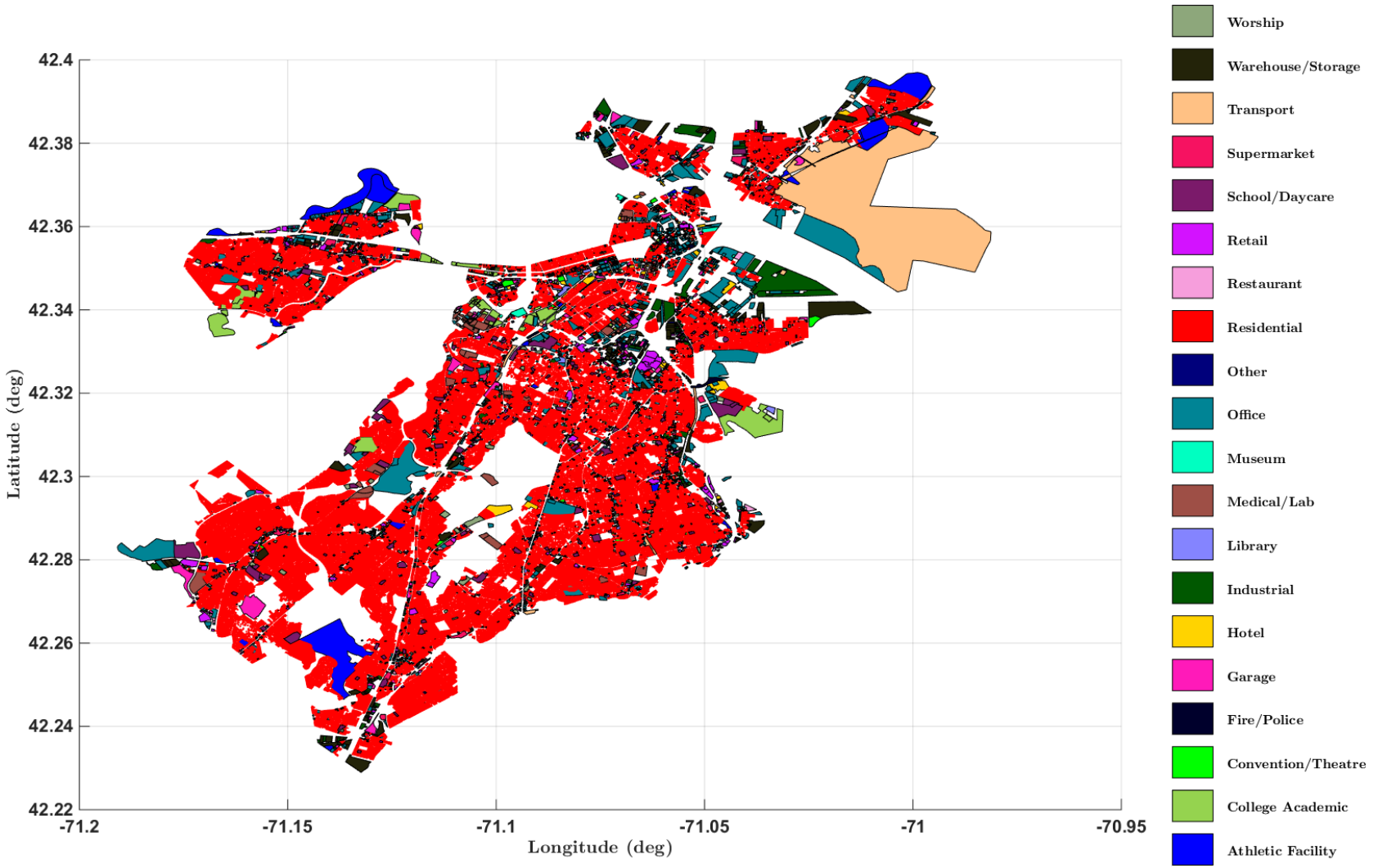
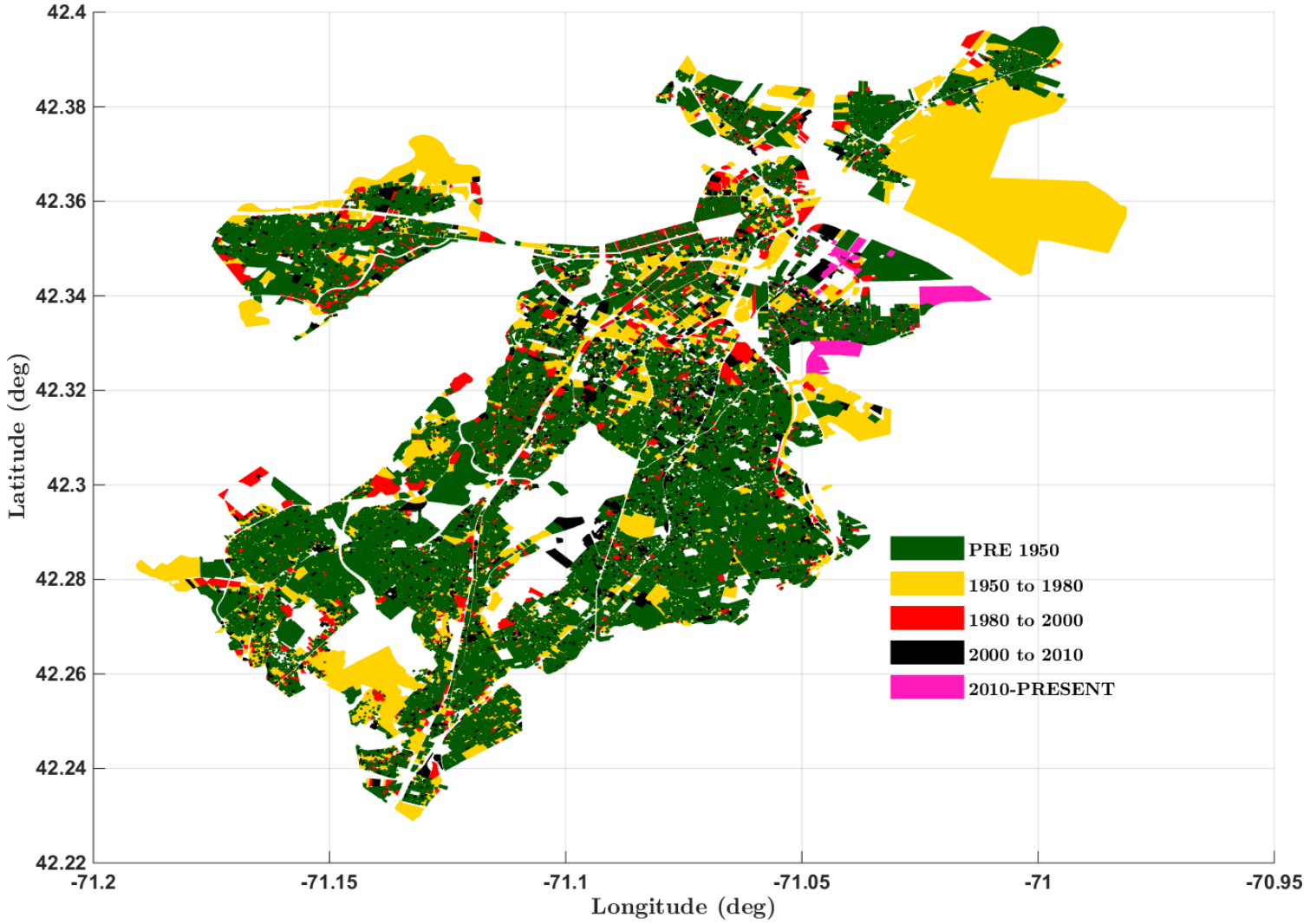


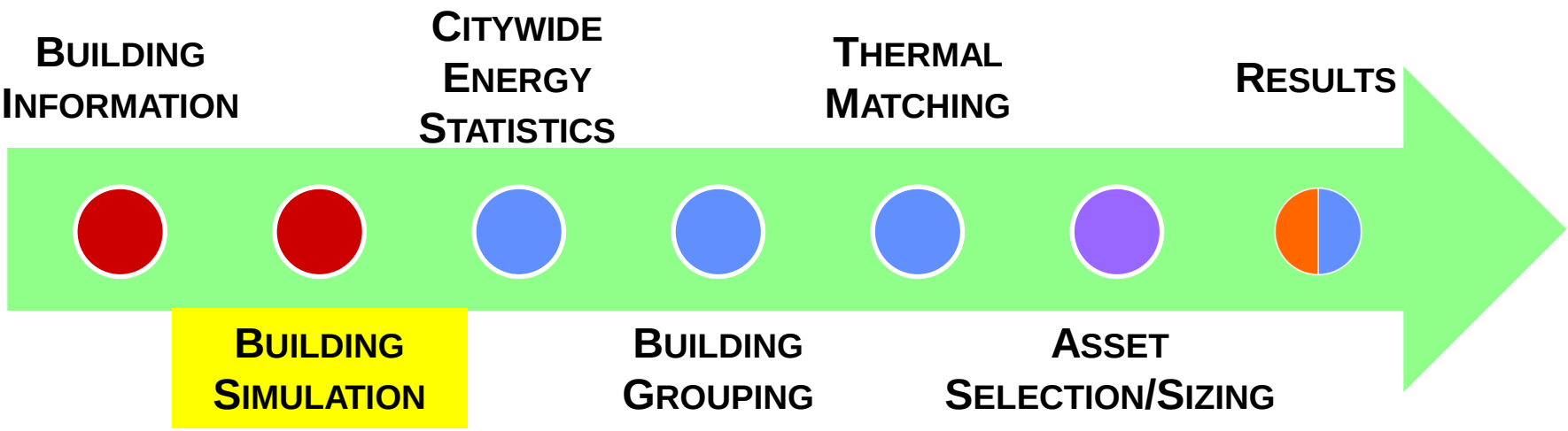
Boston's Building Types



Boston Building Vintages



Study Approach



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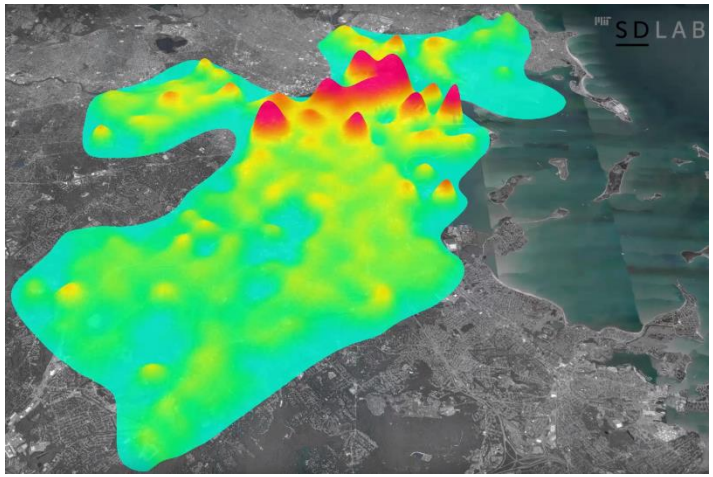
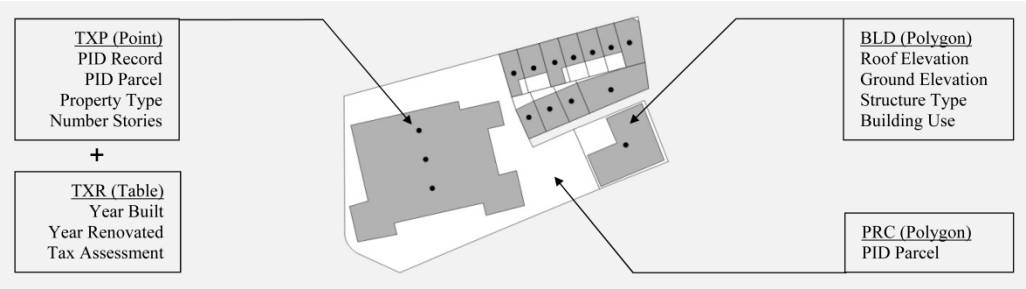


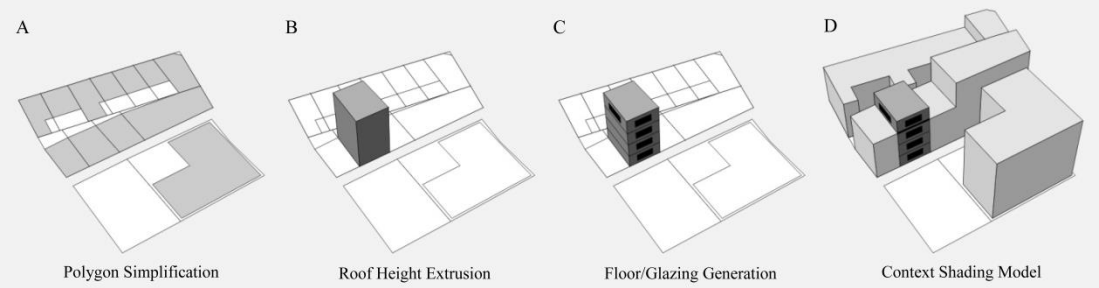
Modelling Energy Use in Buildings

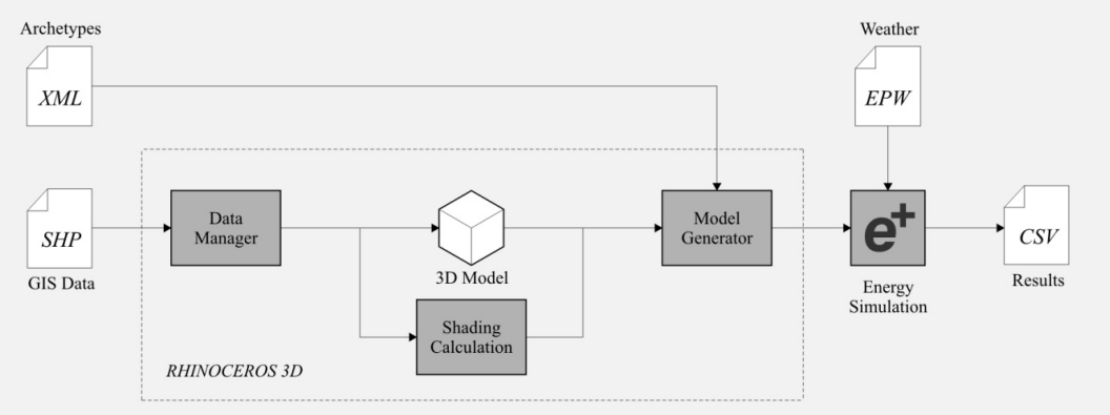
Data from BRA

Building Geometry

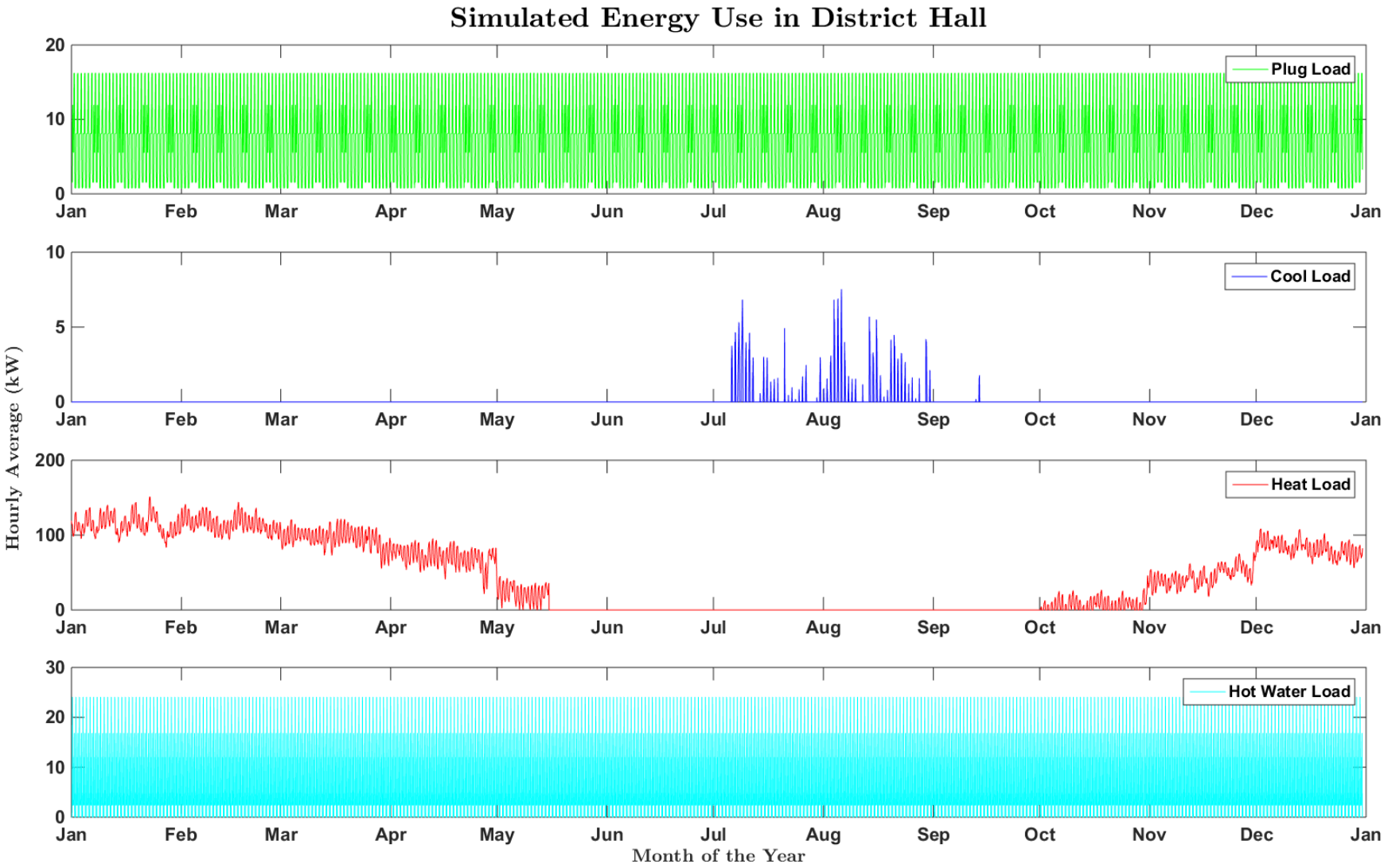
Building Energy



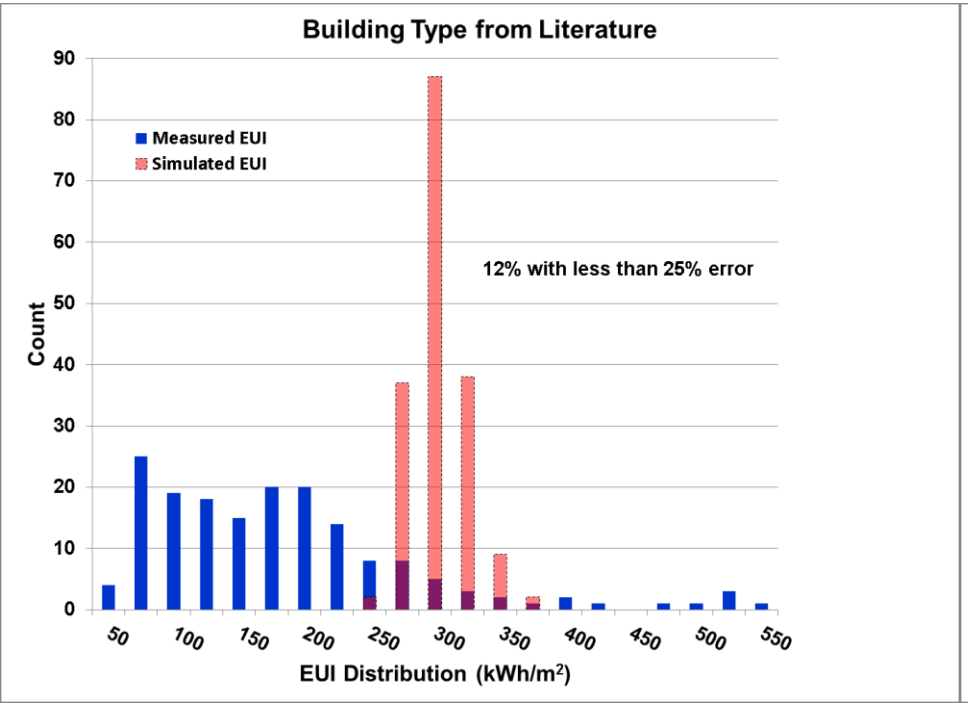


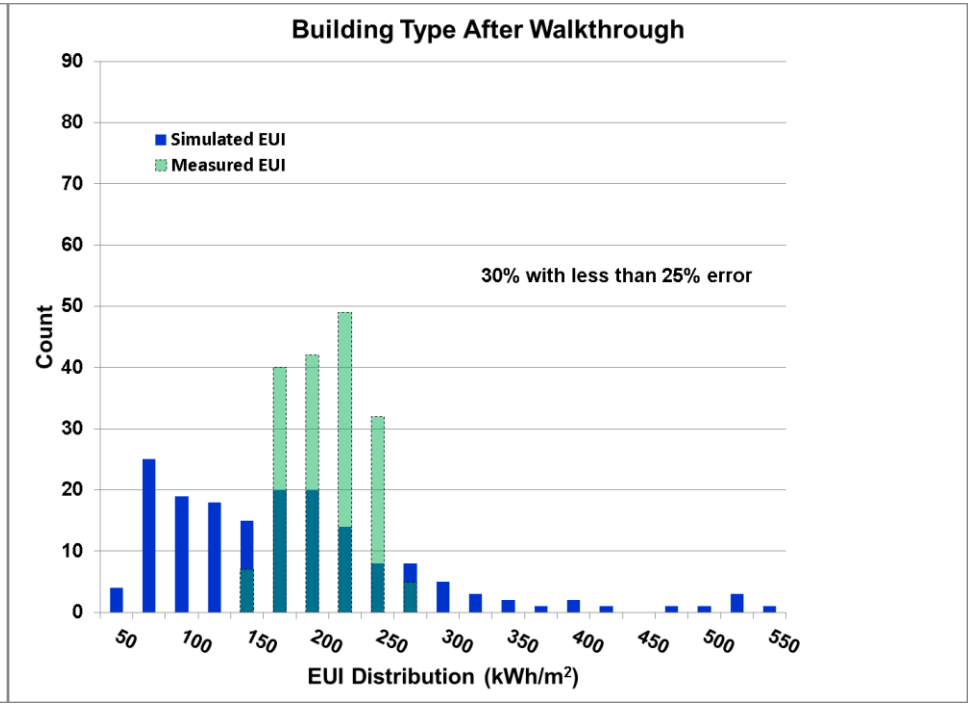


Resulting MIT SDL Dataset



Kuwait Case Study

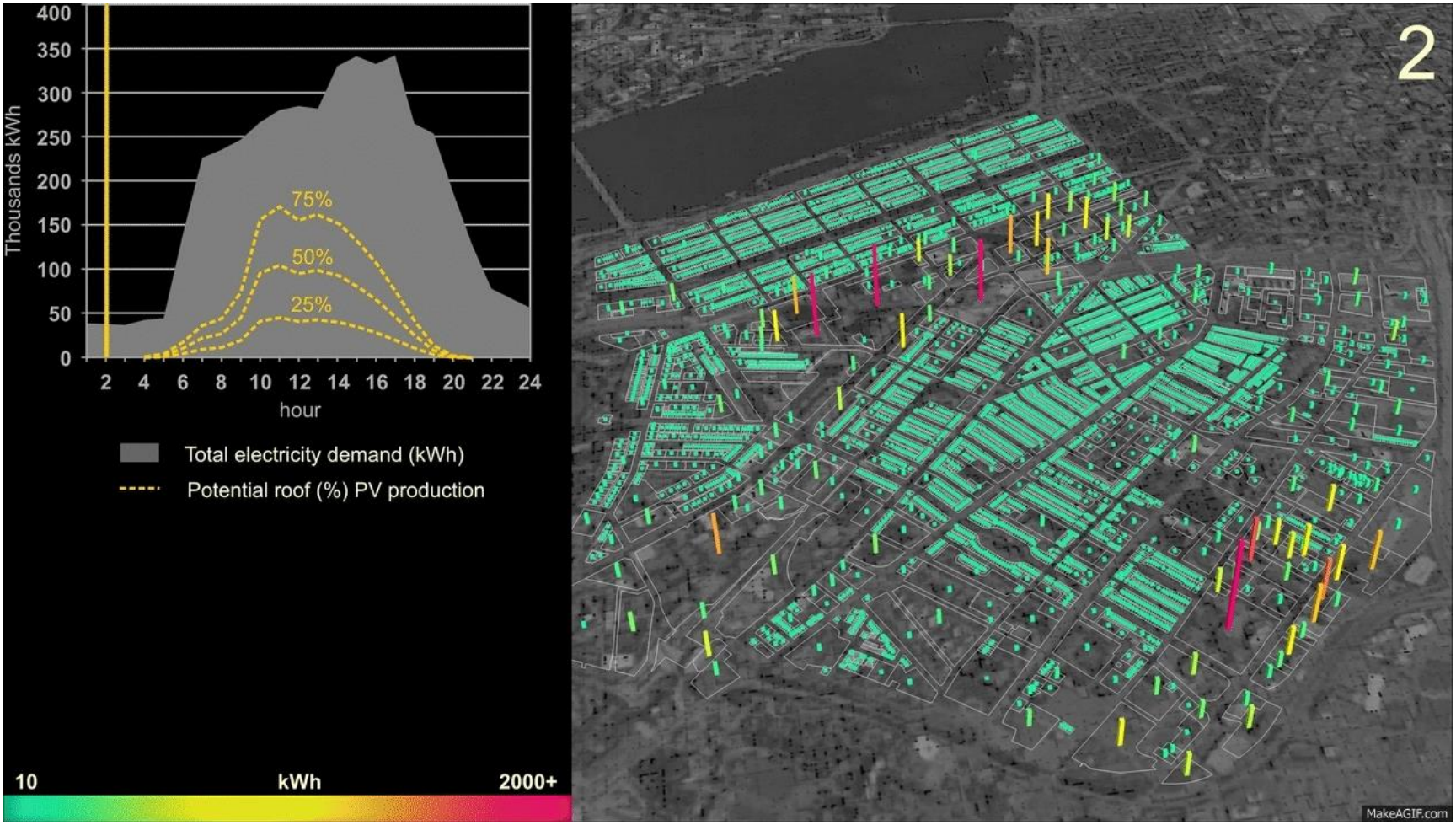




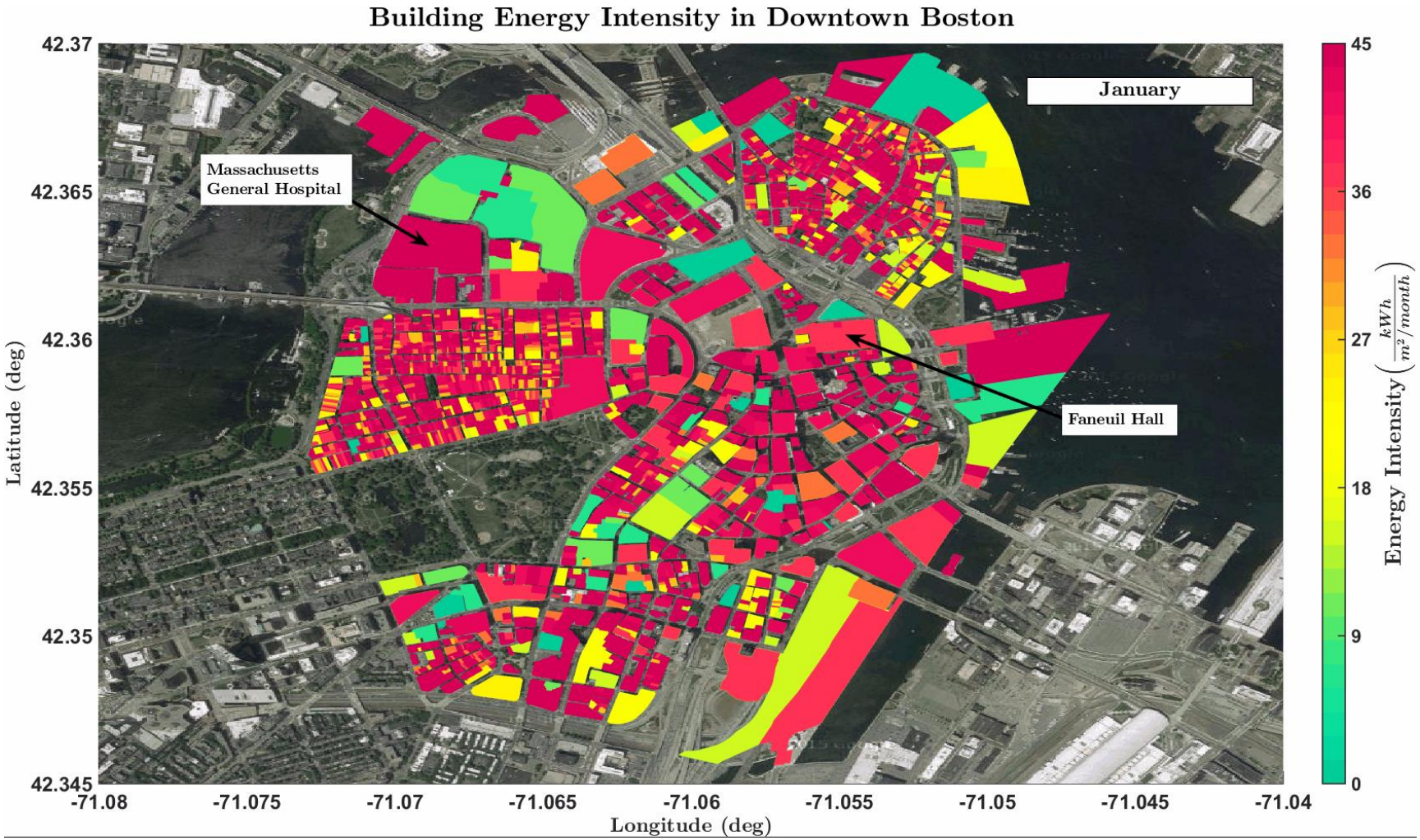
Average MES = 175 kWh/m²
Average SIM = 290 kWh/m²

Average MES = 175 kWh/m²
Average SIM = 190 kWh/m²

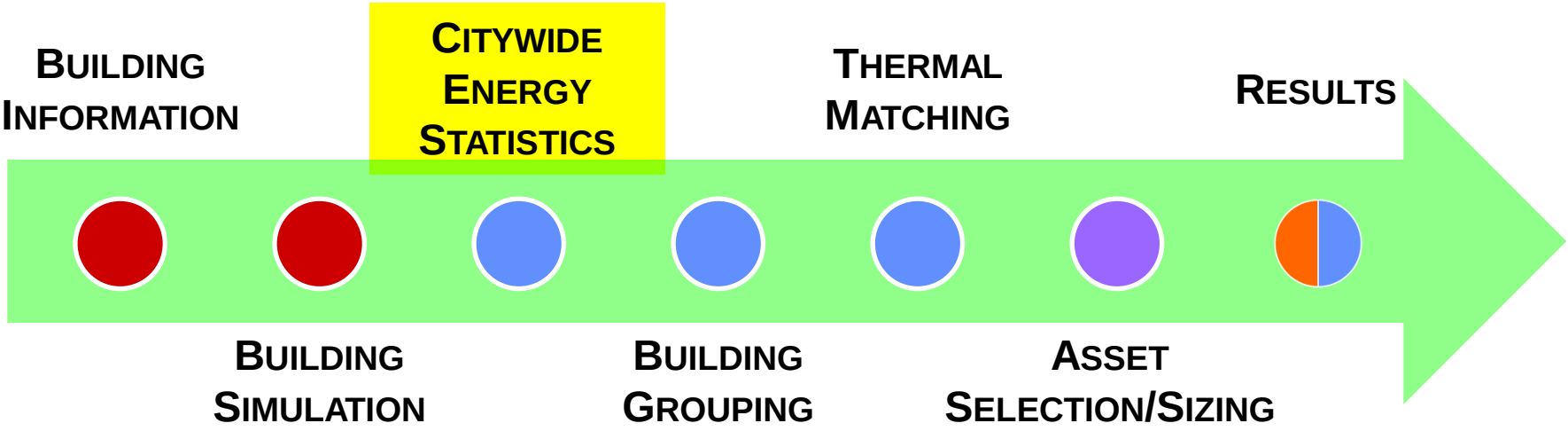
Back Bay Electricity



Downtown Monthly Energy Intensity



Study Approach



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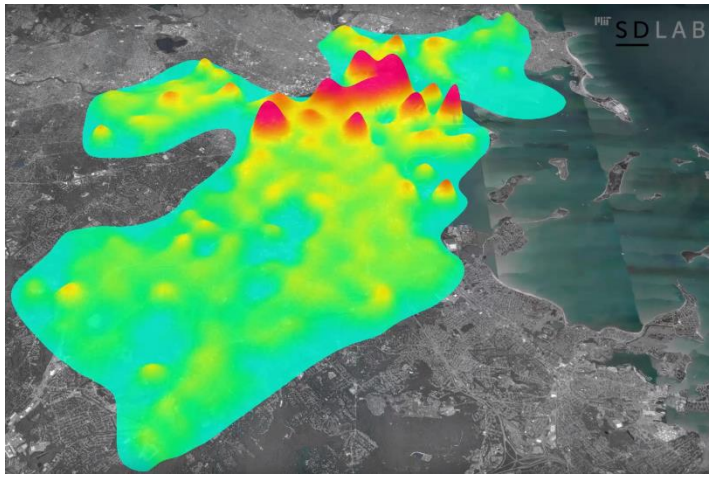
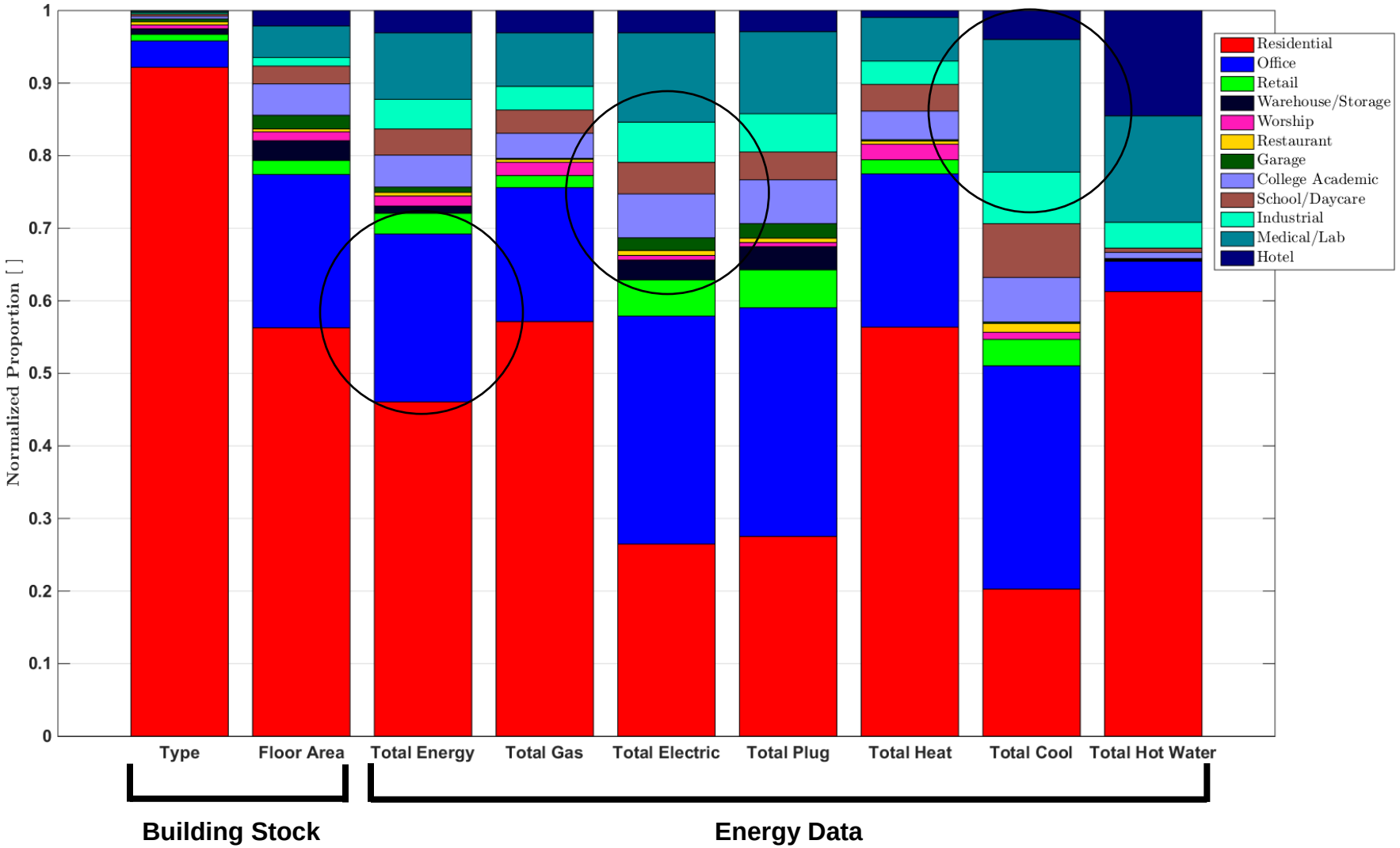
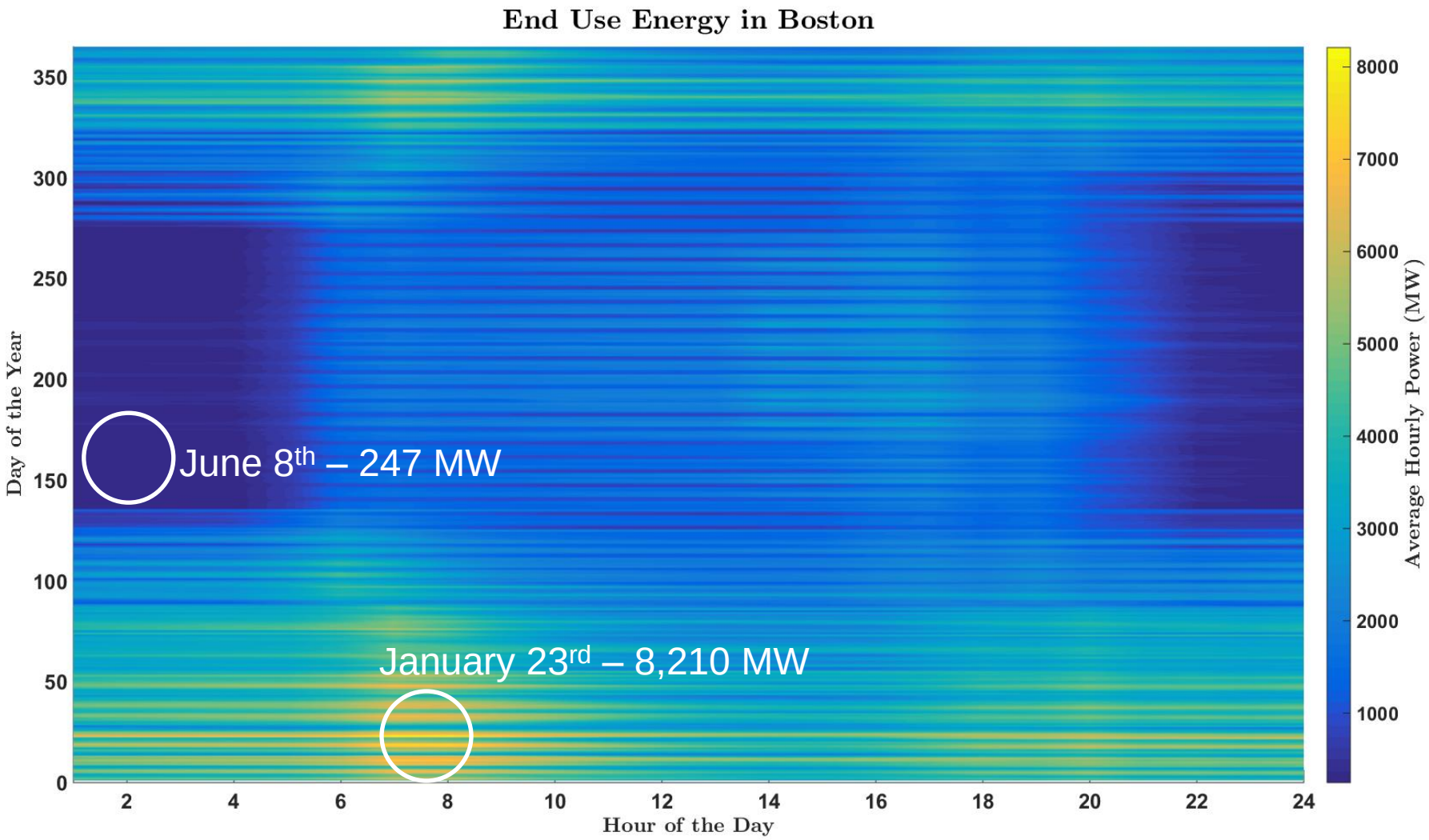


Boston's Building Stock & Energy Statistics



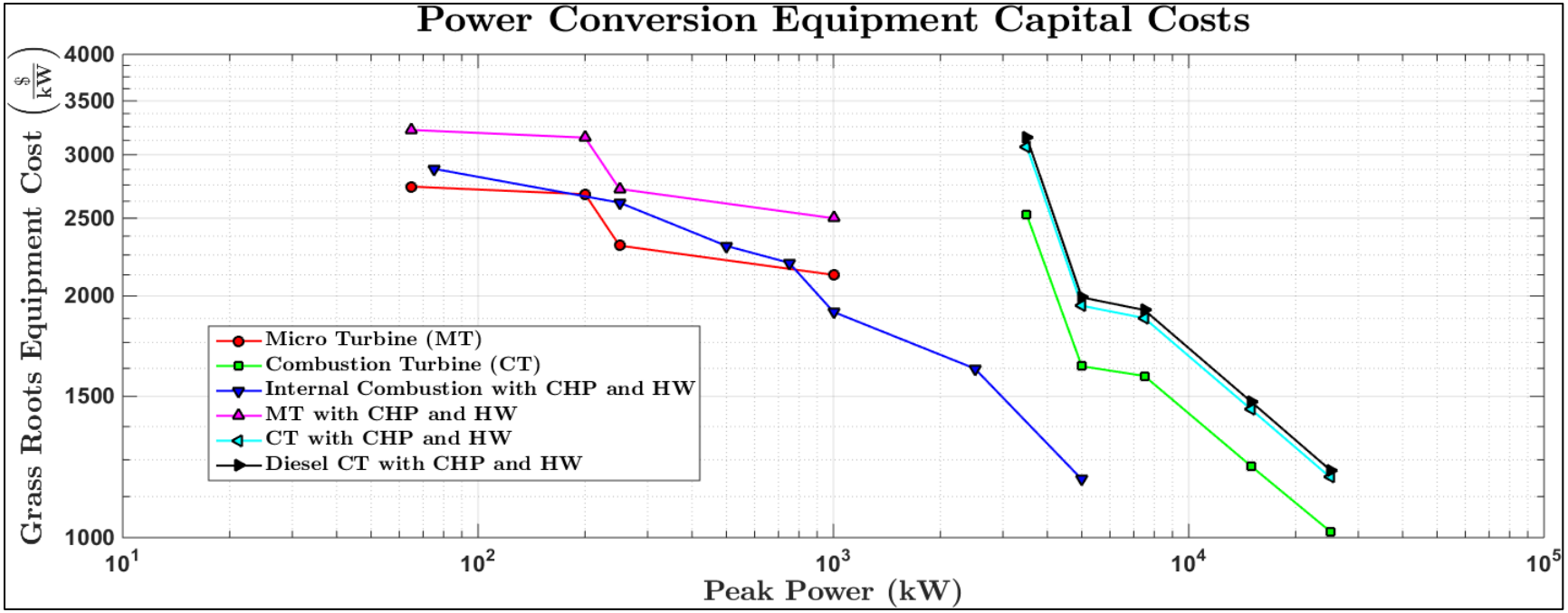
Boston Simulated Energy Heat Map



DER-CAM Overview

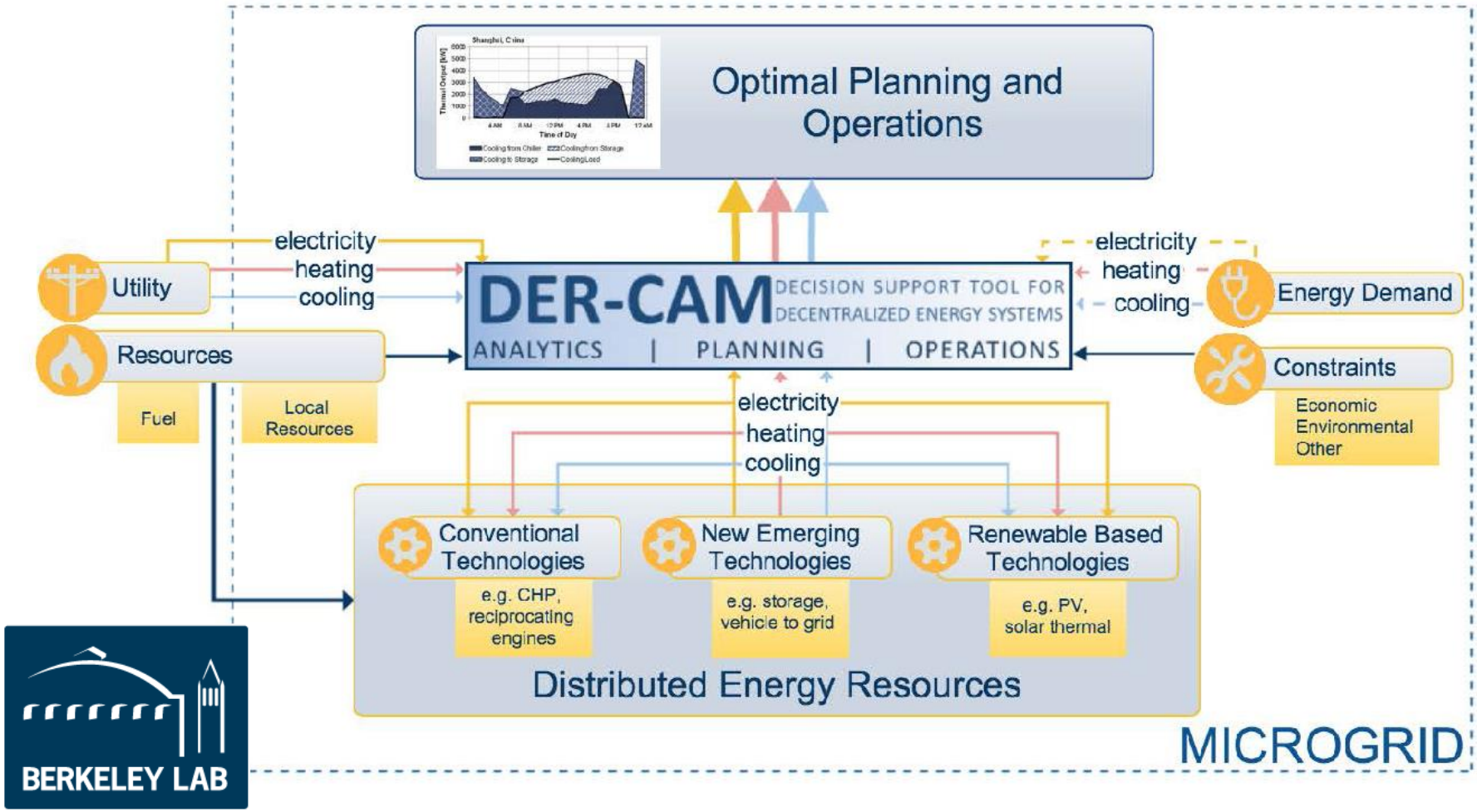
- DER-CAM (Distributed Energy Resources Customer Adoption Model)
- Mixed integer linear program (MILP)
- Optimal DER asset selection while minimizing:
  - total energy costs
  - carbon dioxide (CO_2) emissions
  - weighted objective that simultaneously considers both criteria
- Input building data for optimization
  - Heating loads
  - Electric loads
  - Hot water
  - Cooling

DER-CAM Technology Lists

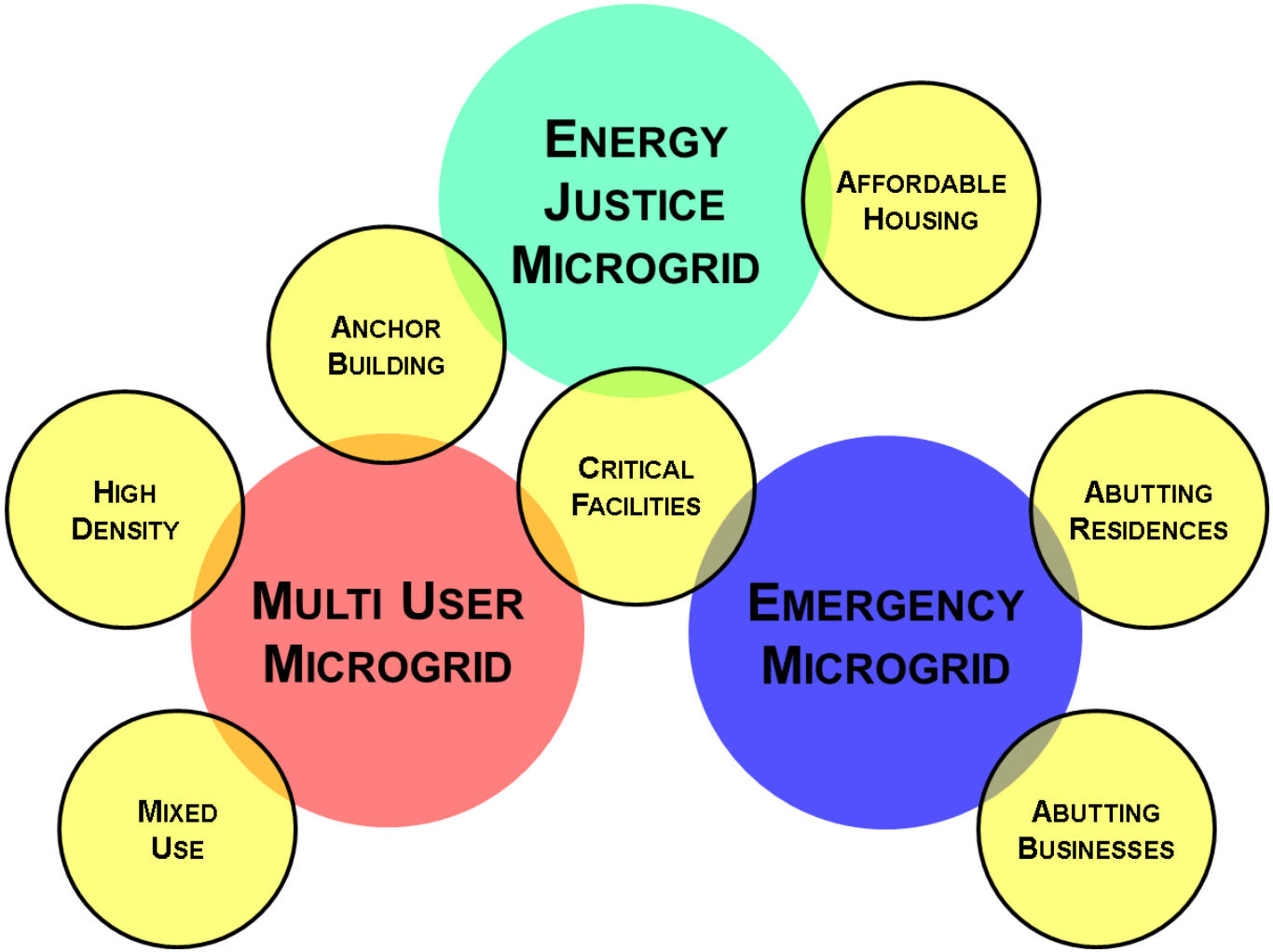


Technology	Upfront Cost ($)	Capital Cost ($/kW or $/kWh)	Lifetime (years)	O&M (%/year)
Heat Storage	10,000	50	17	0
Cold Storage	10,000	50	17	0
Battery	295	193	5	0
Absorption Chiller	93,900	685	20	1.88
Refrigeration	93,900	753	20	2.07
Photovoltaic	3,850	3,240	30	0.25
Solar Thermal	0	500	15	0.5
Air Source Heat Pump	0	70	10	0.52
Ground Source Heat Pump	0	80	10	0.32

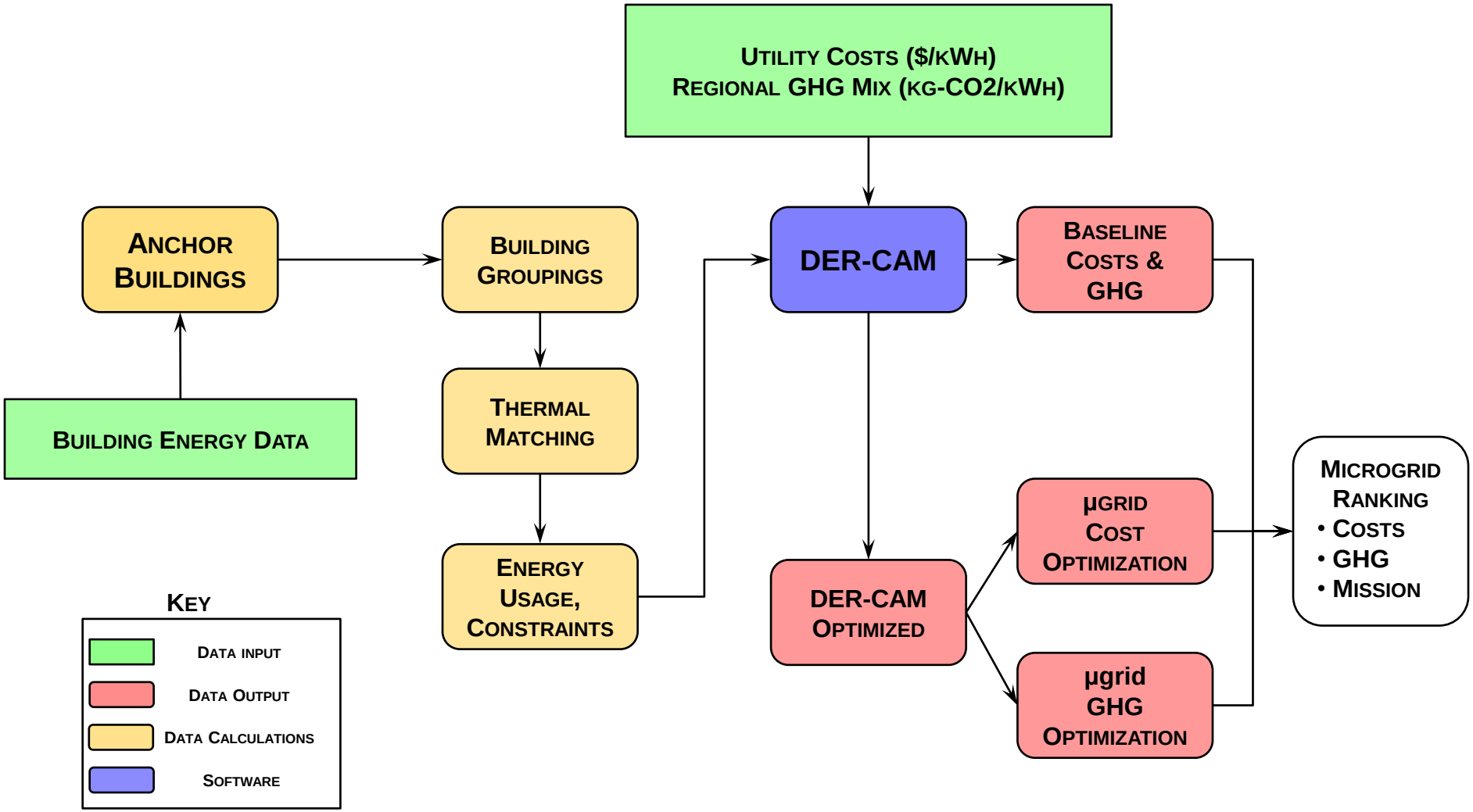
DER-CAM Flow Chart



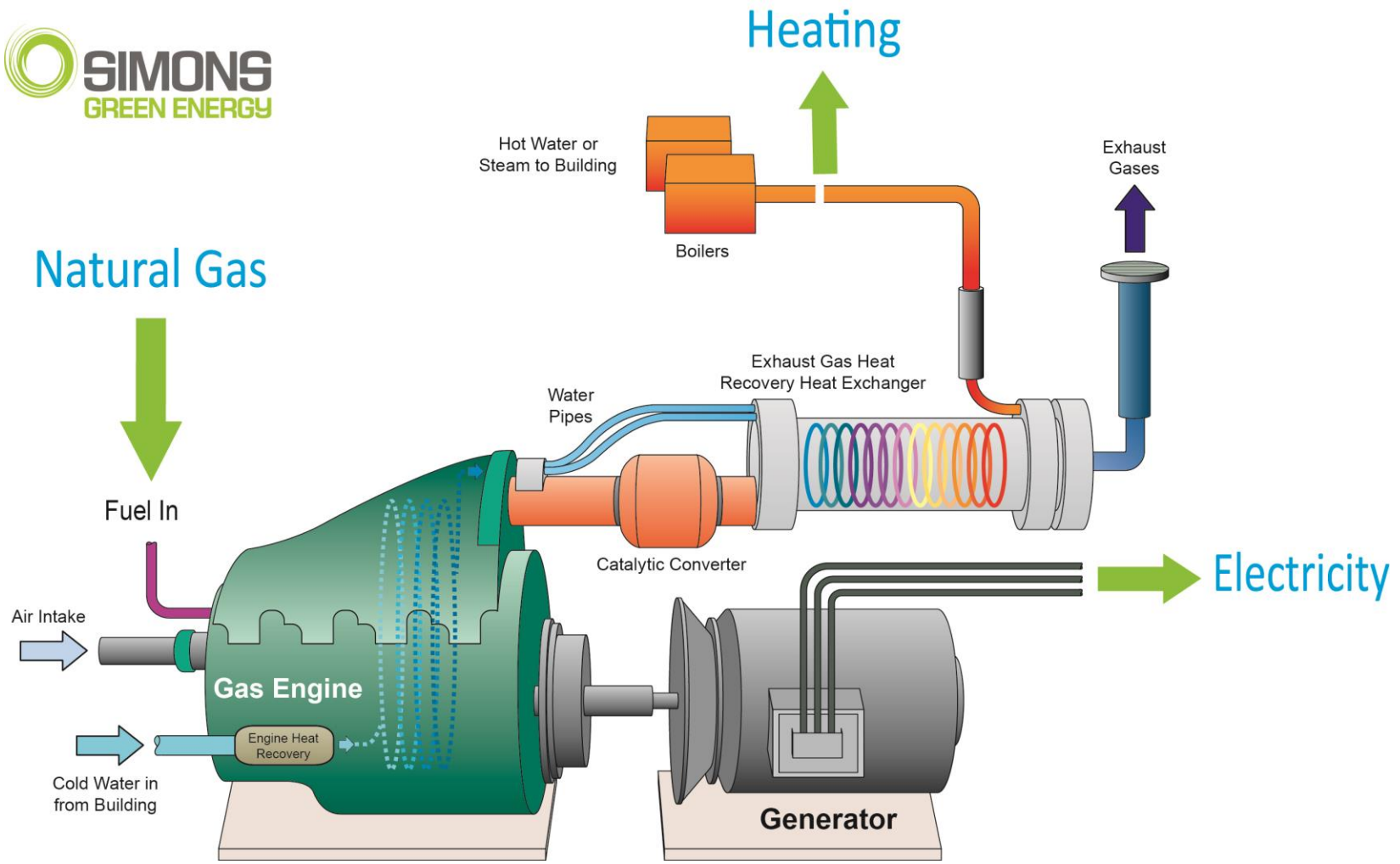
Three Microgrid Types



Microgrid Analysis Methodology



Combined Heat and Power



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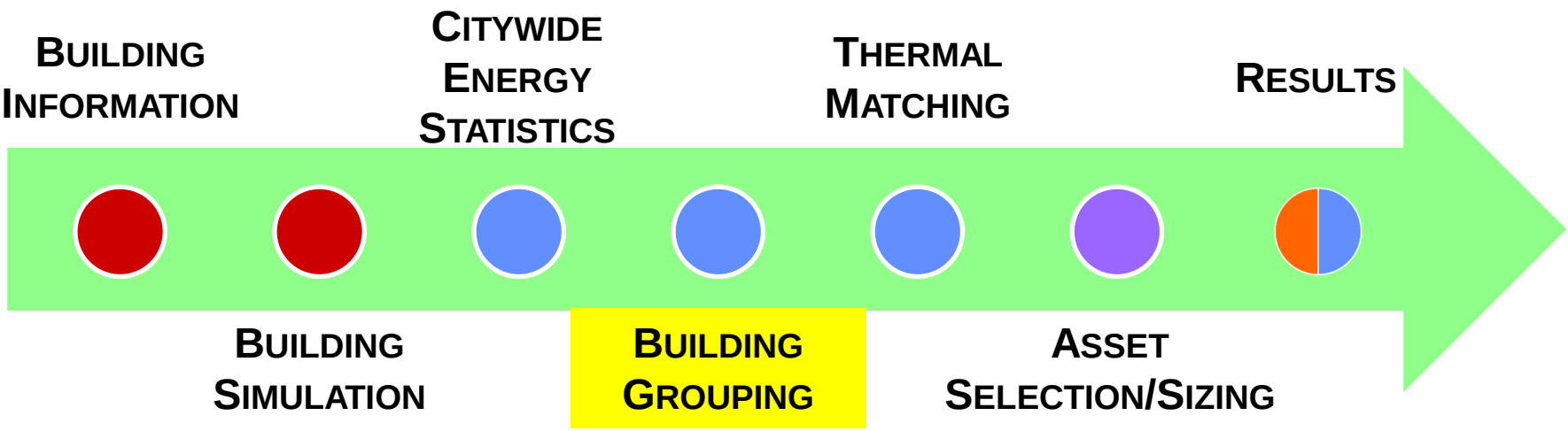

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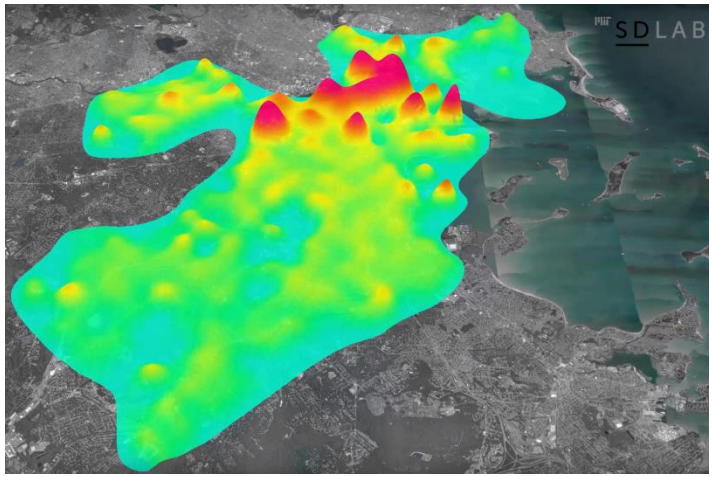
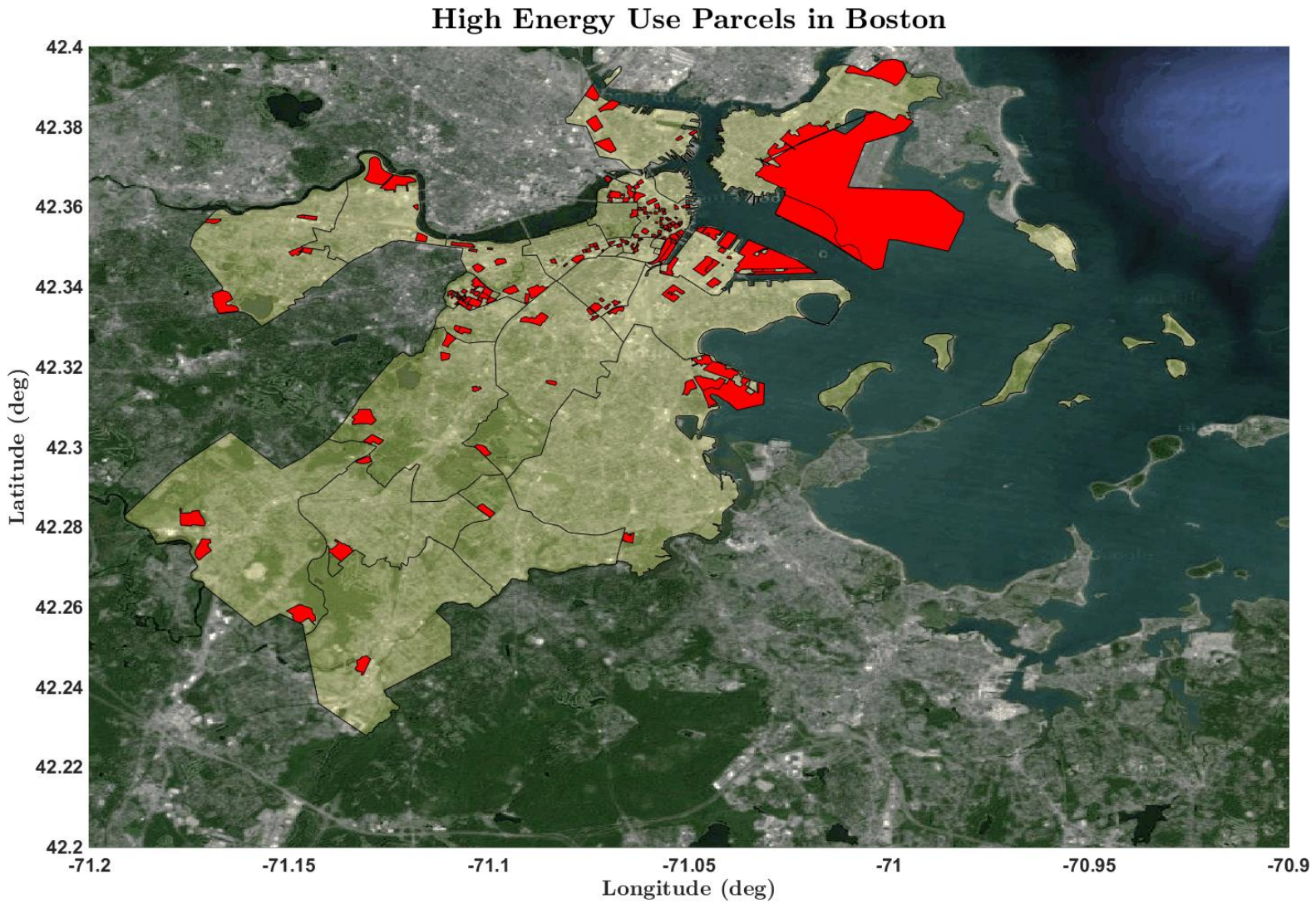
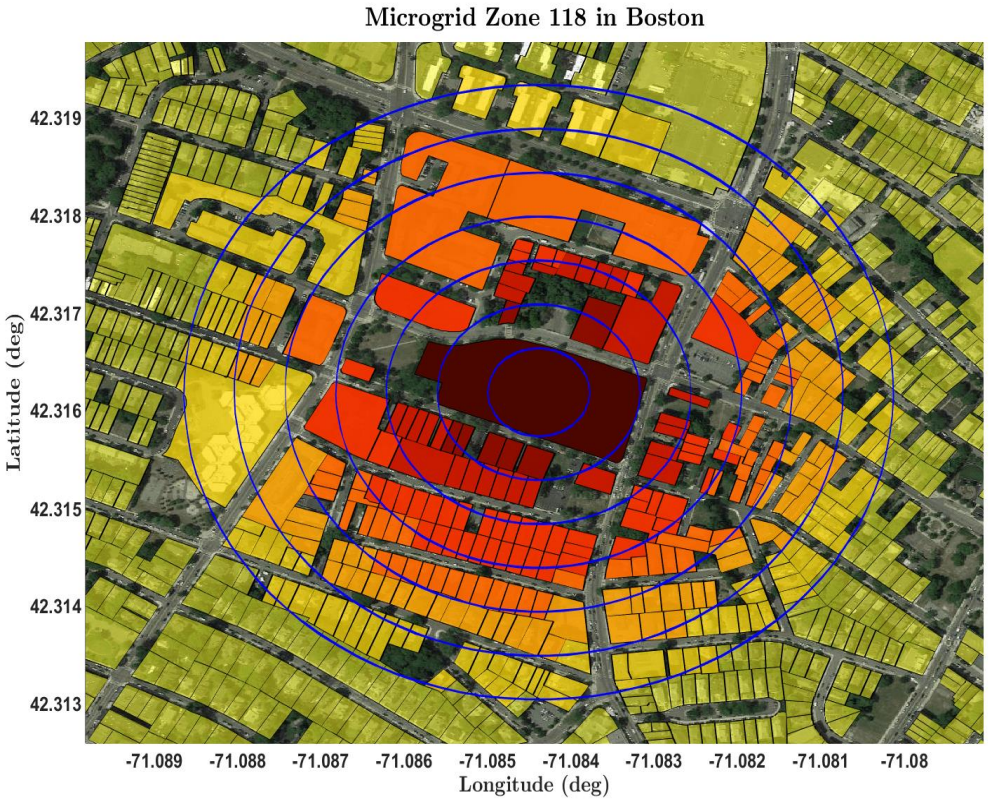


Top 0.2% By Energy Use



Multi-User Microgrid Screening Algorithm

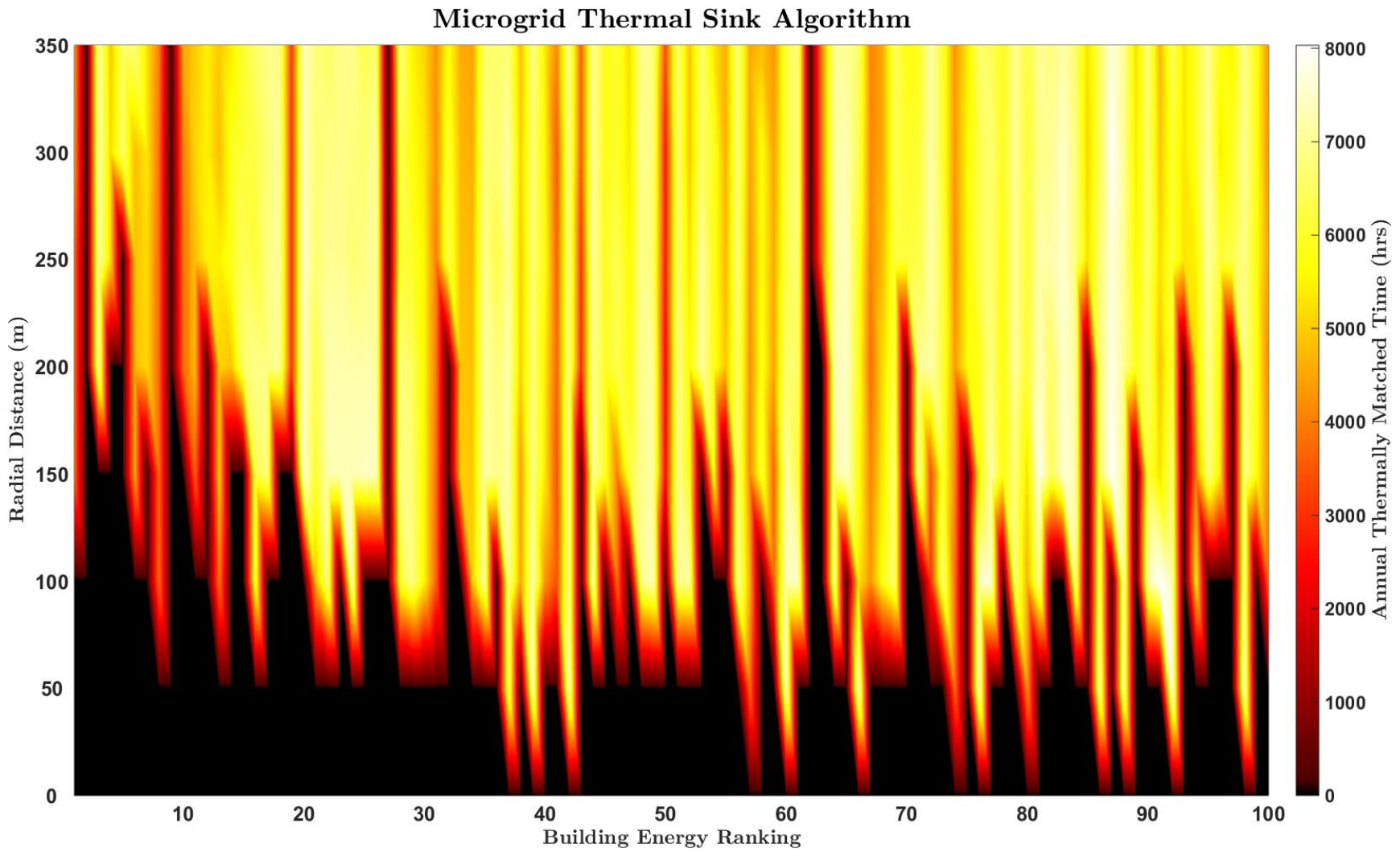
- Search around the anchor for other buildings in concentric rings
  - Size CHP plant for 60% of peak electric
  - Assume 40% electric generation efficiency
  - "Spark spread" ≈ $70/MWh
- For each ring continuous thermal sinks are identified
- Assume that electricity can always be bought from the utility grid
  - Not sold to the utility grid



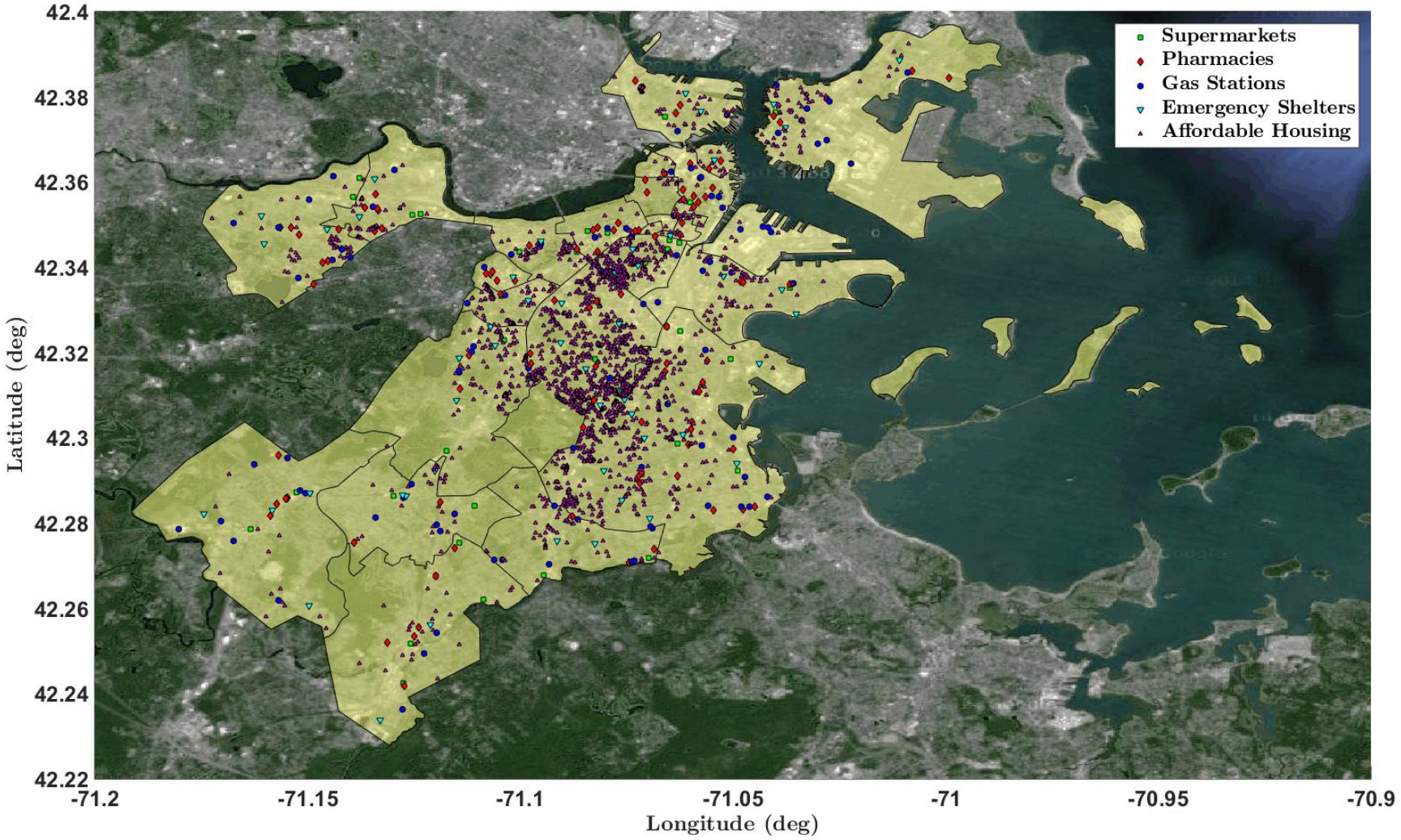
$$CHP\ Design, Sizing: \frac{\left(max(Elec) \times \frac{3}{5}\right)}{\frac{2}{5}} = \frac{3}{2}\left(max(Elec)\right)$$

$$CHP\ Score: \sum_{t=1}^{8760} max(Elec) - HeatLoad(t) > 0$$

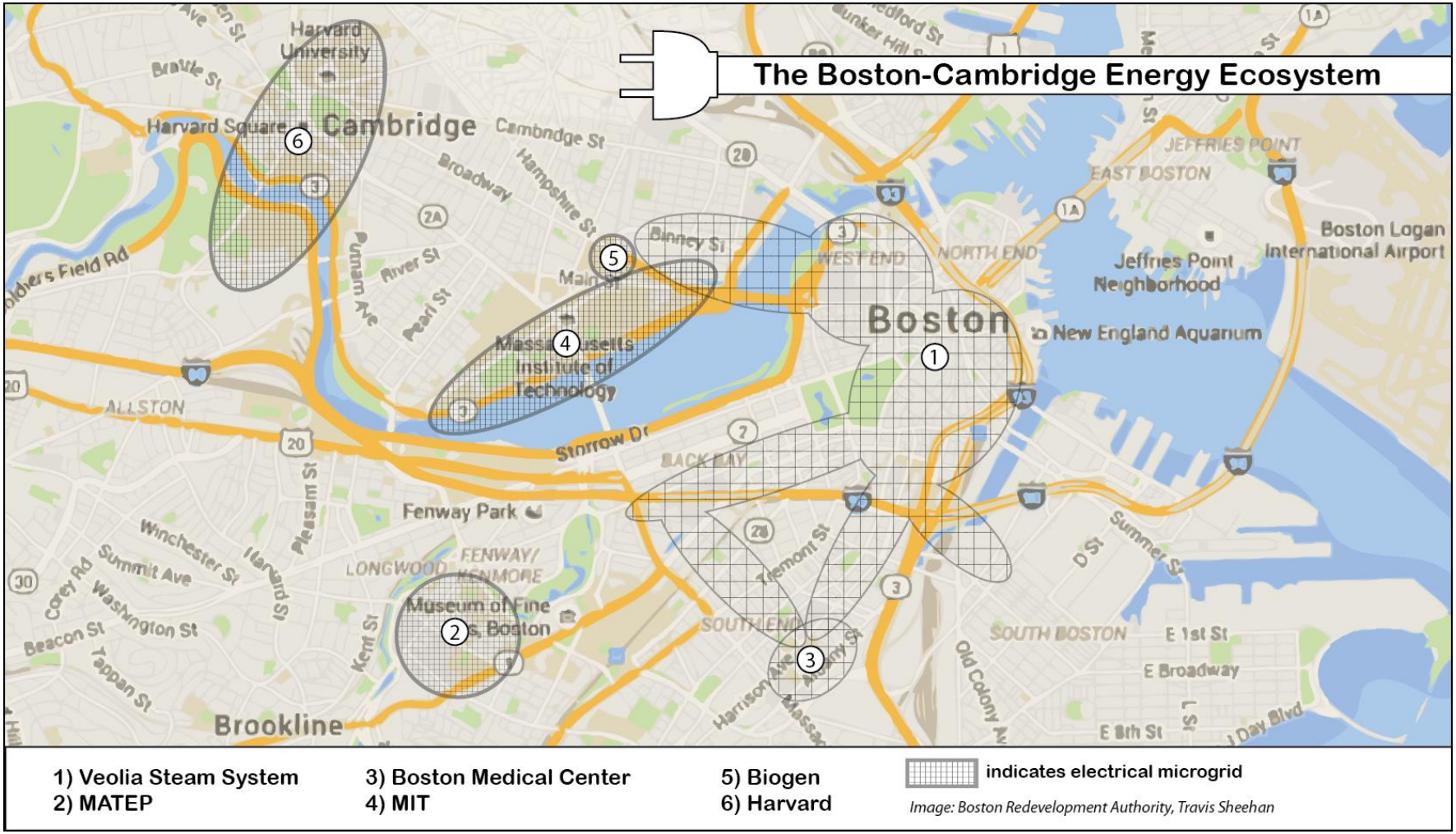
Thermal Sink Analysis



Critical Facilities & Affordable Housing in Boston



Other Constraints



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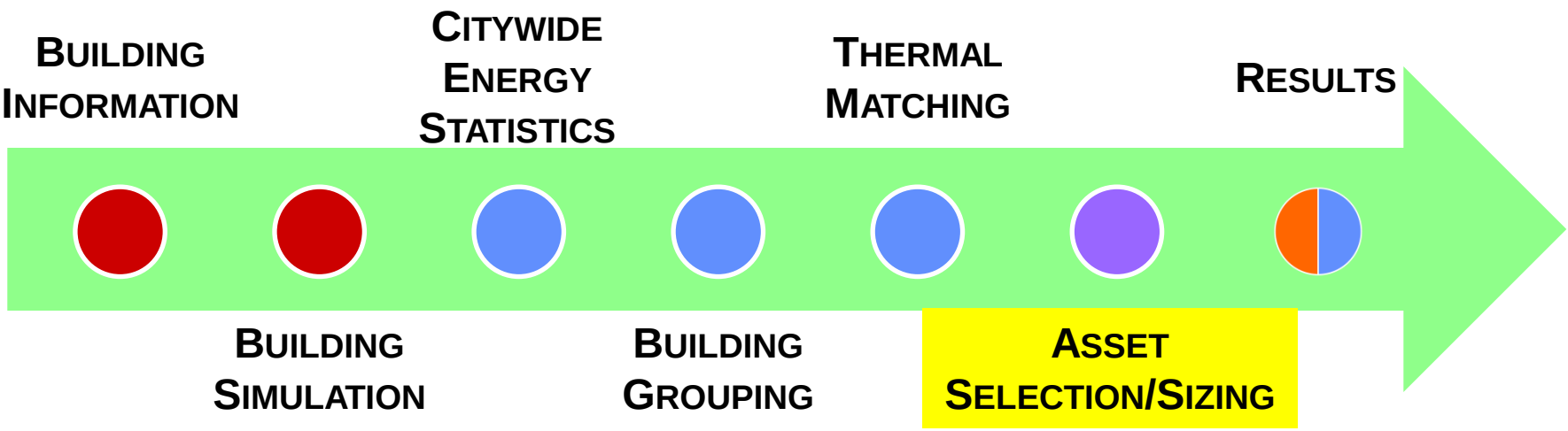

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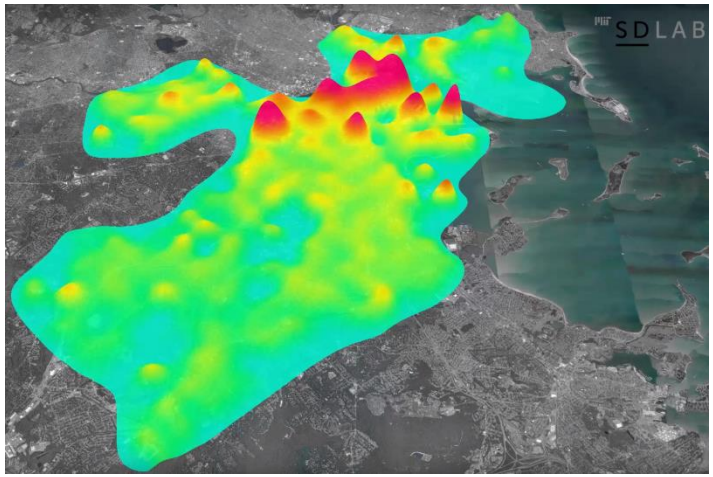
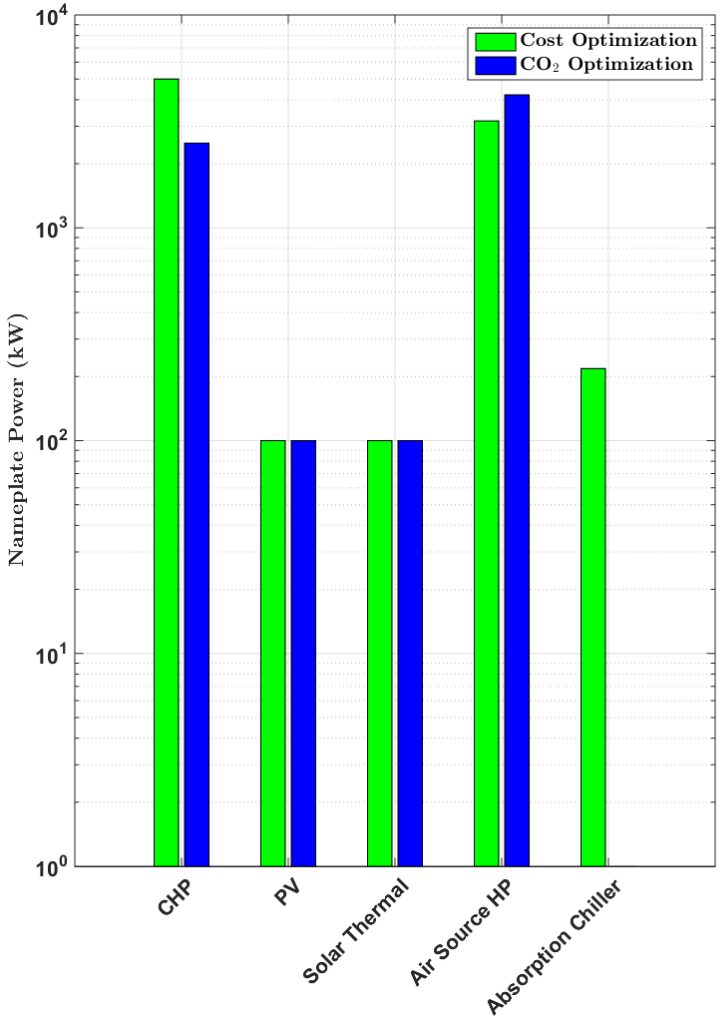
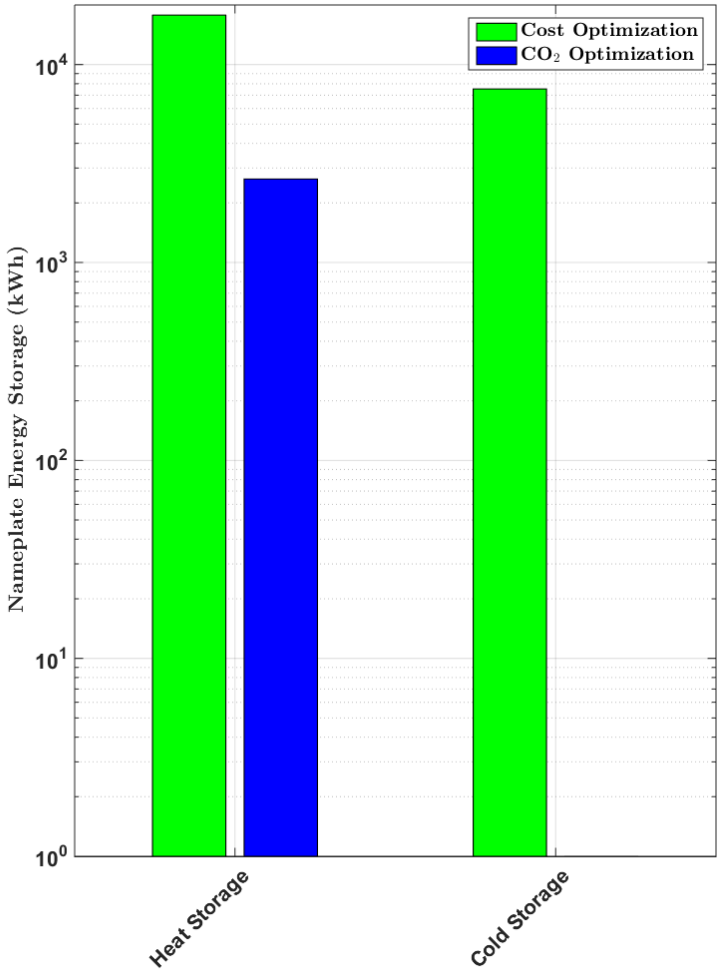
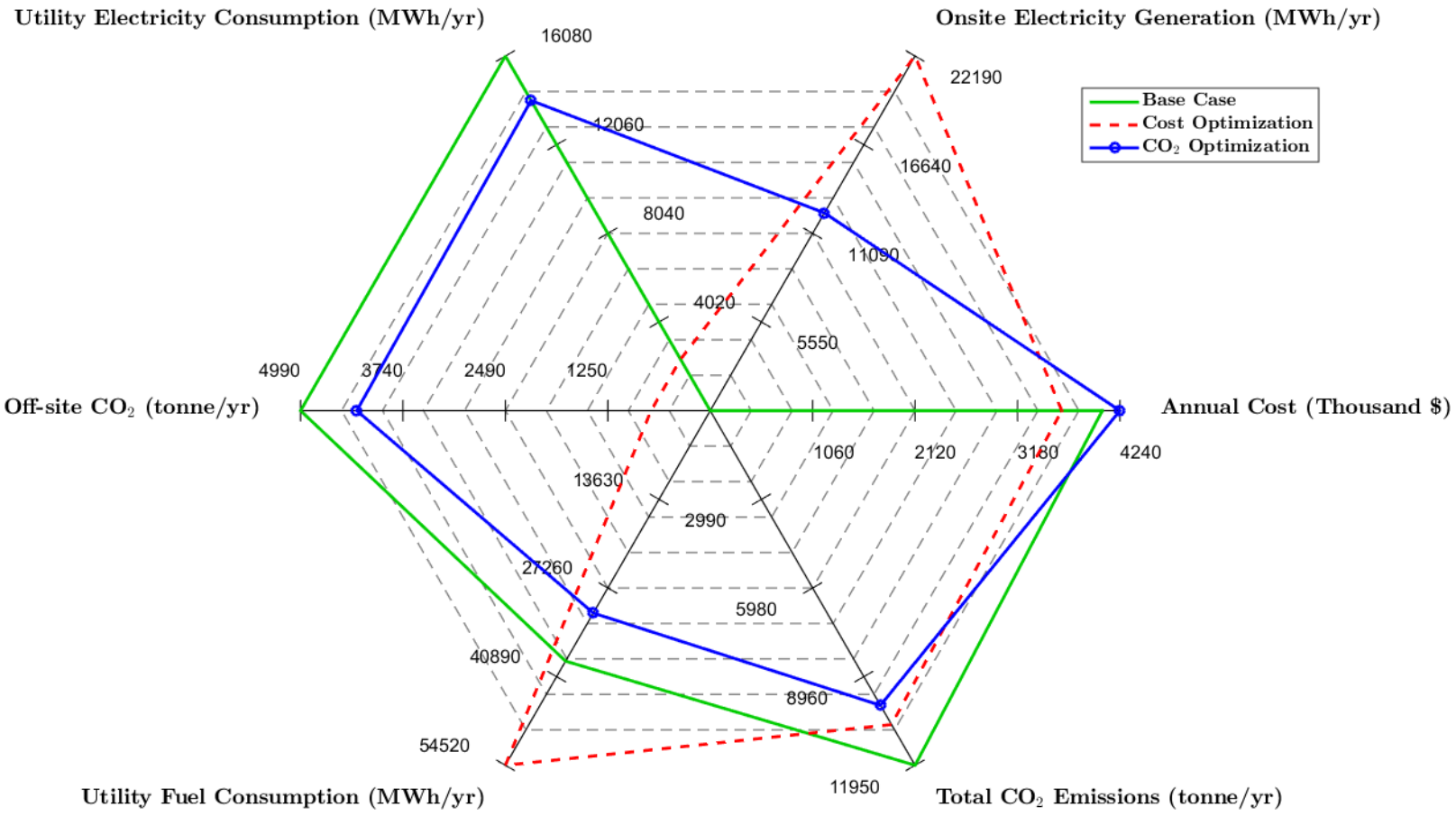


Asset Selection Example





Example Microgrid Operation



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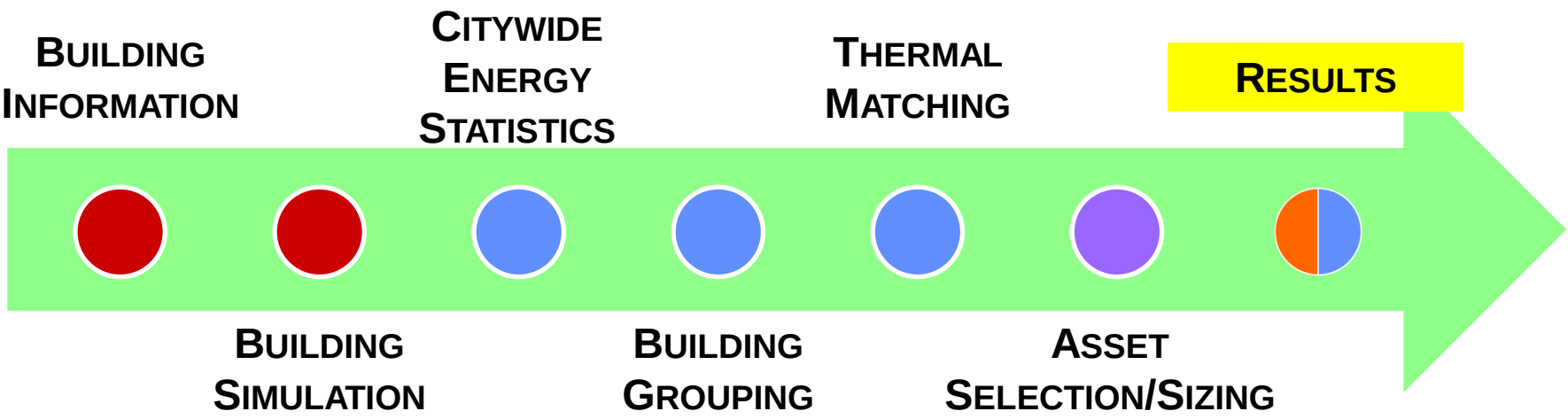

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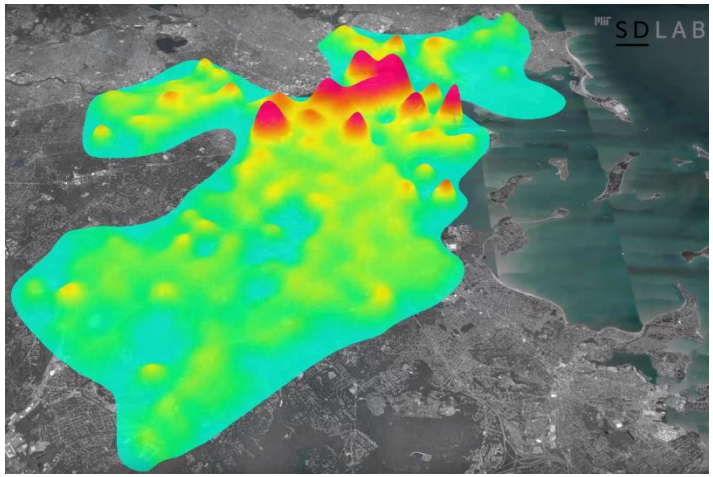
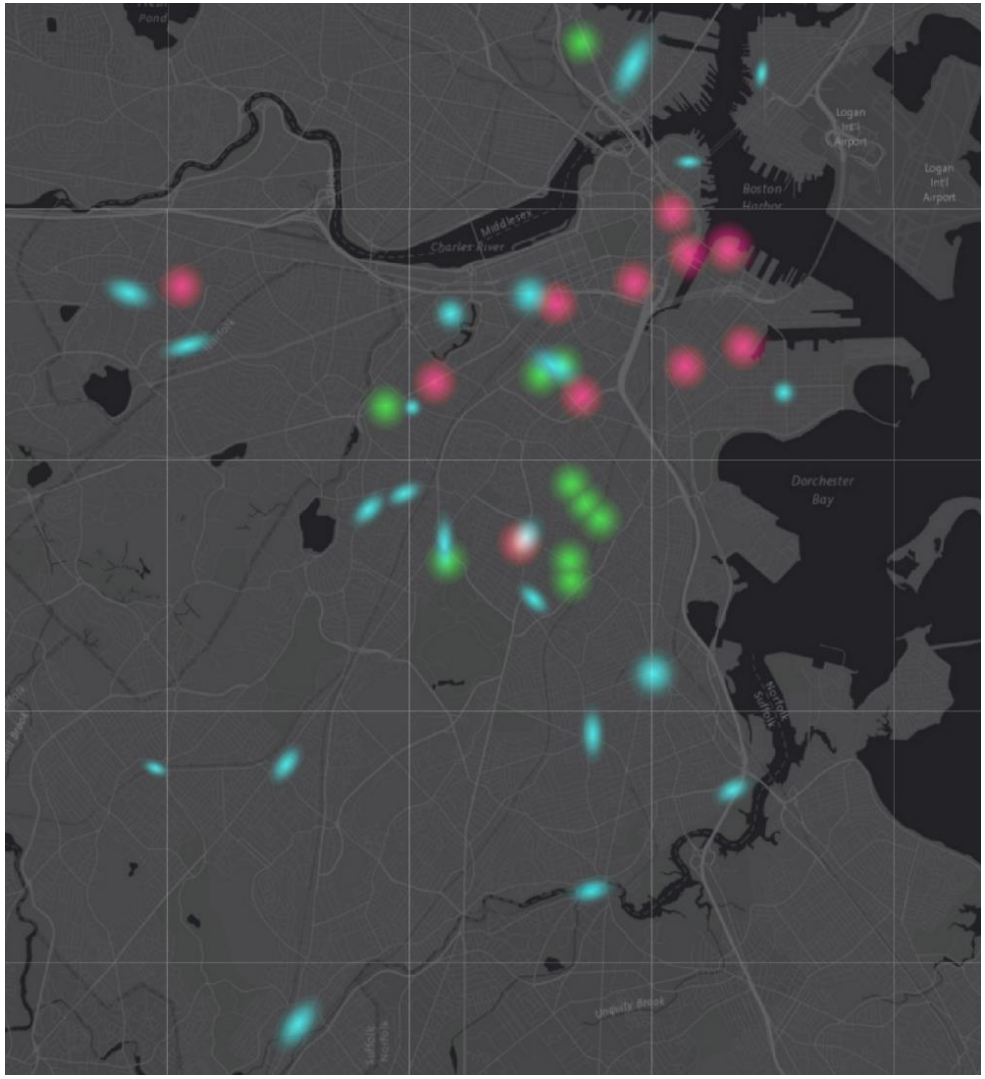


Microgrid Placement

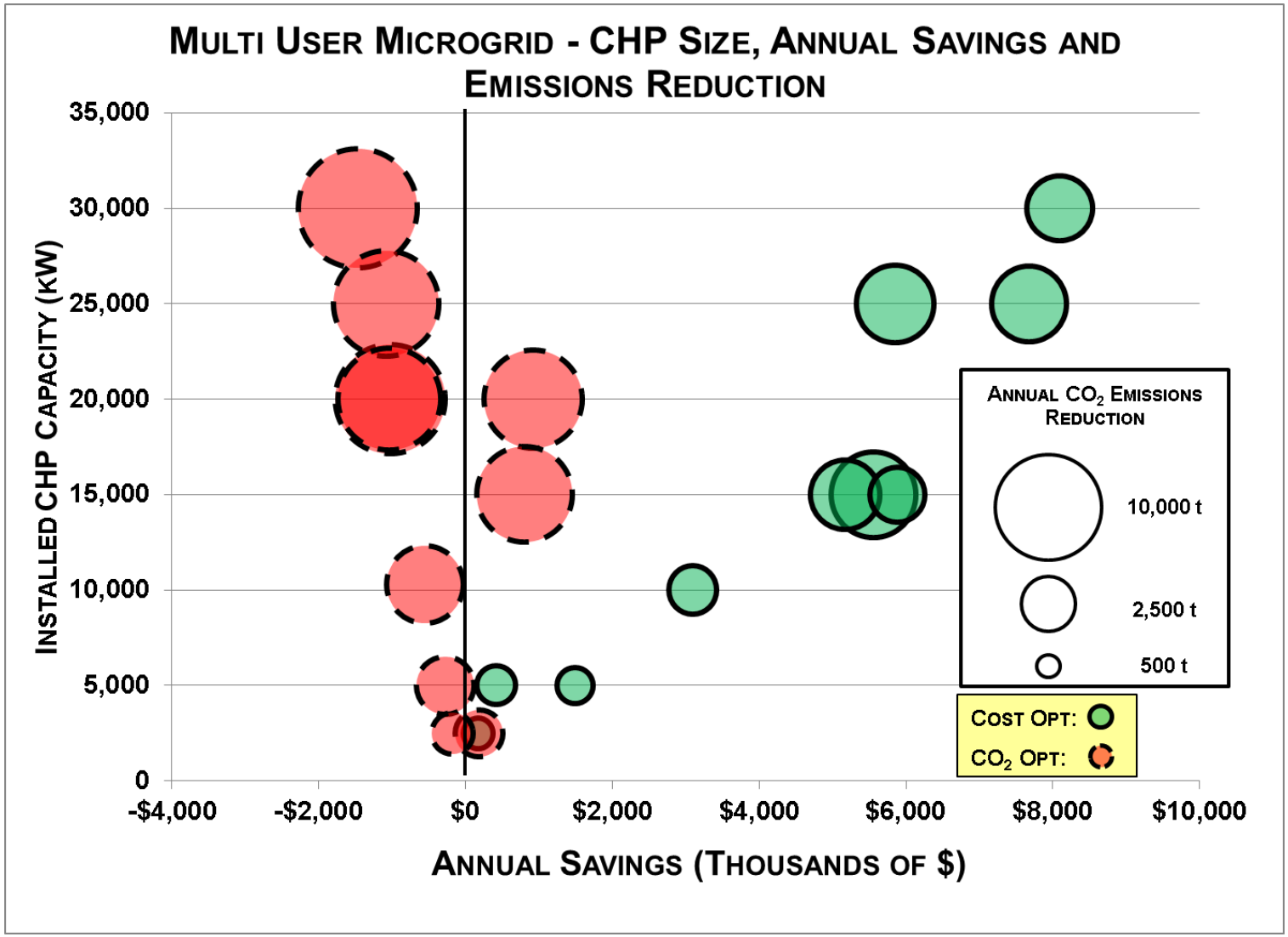


Energy load suitability (Multi-User Microgrids)

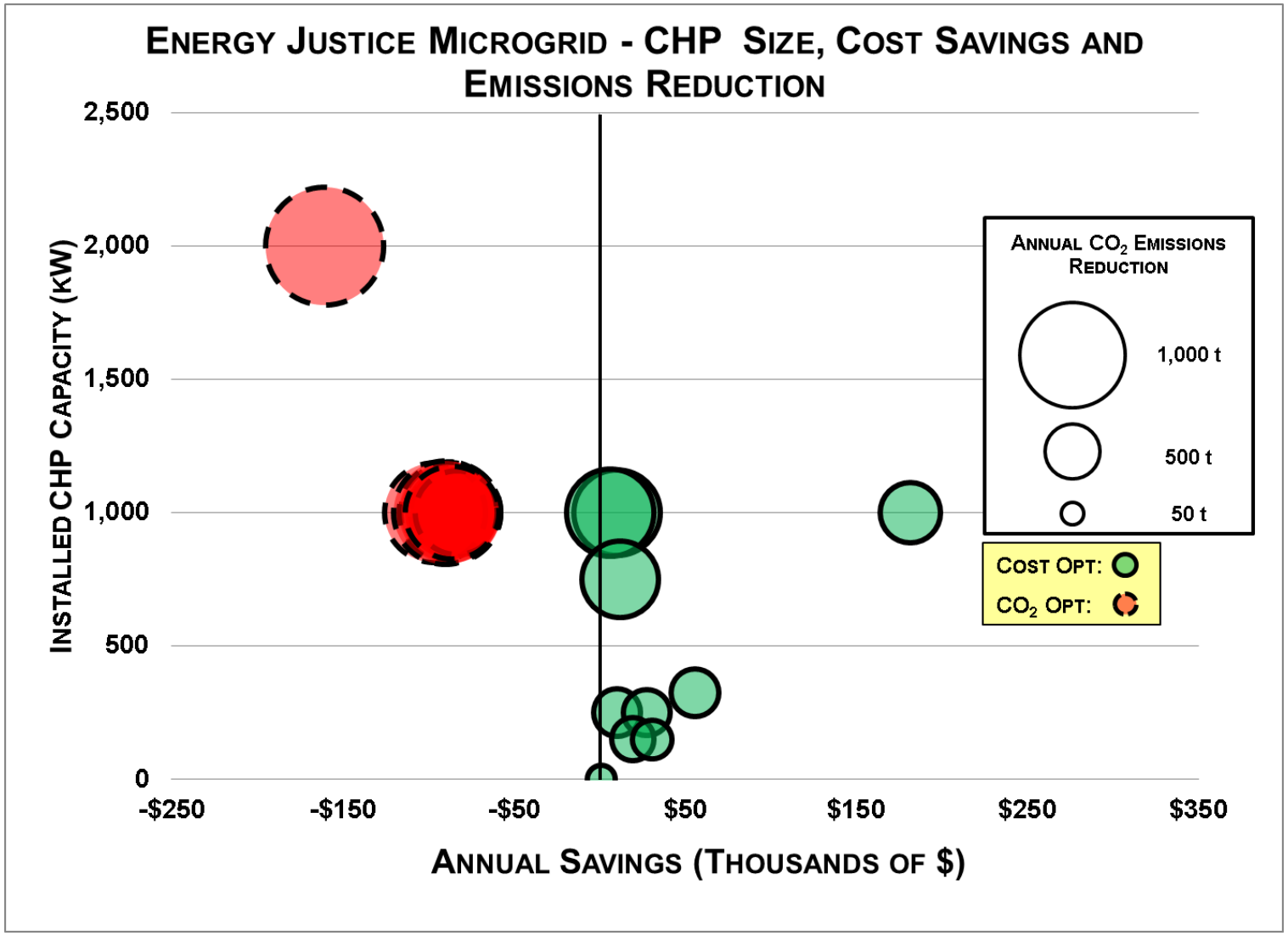
Affordable housing (Energy Justice Microgrids)

Clustering of critical facilities (Emergency Microgrids)

Multi-User Microgrid Outputs



Energy Justice Microgrids – Savings and Emissions Reductions



Way Ahead

- **Integrate additional GIS information**
  - **Substation locations and loads**
  - **Electric line data**
  - **Natural gas pipeline networks**
  - **District steam lines**
- **Criticality and vulnerability analysis using GIS data**
- **Run similar analysis on calibrated building data**

Summary

- Pioneered a city-scale energy assessment
  - Identified 22 sites with $1.7b in potential savings over 25 years
  - Established a framework that is applicable to other regions
  - Identified data needs and stakeholder impacts for faster execution
- Fostered relationships between the public, the utilities, and Boston
- Demonstrated that microgrids are economically and environmentally viable in Boston

Partners

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY DELIVERY & ENERGY RELIABILITY

Homeland Security
Science and Technology

MASSACHUSETTS CLEAN ENERGY CENTER

BERKELEY LAB

BOSTON REDEVELOPMENT AUTHORITY

MIT SUSTAINABLE DESIGN LAB

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  - Vicki Dydek
  - Bill Ross
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  - Jamie Bemis
  - Carlos Davila
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  - Travis Sheehan
  - Brad Swing
  - Jon Lee
- MassCEC
  - Galen Nelson