A BETTER CITY

CARBON FREE BOSTON

SUSTAINABLE BUILDINGS INITIATIVE

THURSDAY, JULY 12, 2018

THE CARBON FREE BOSTON PROJECT

ALISON BRIZIUS

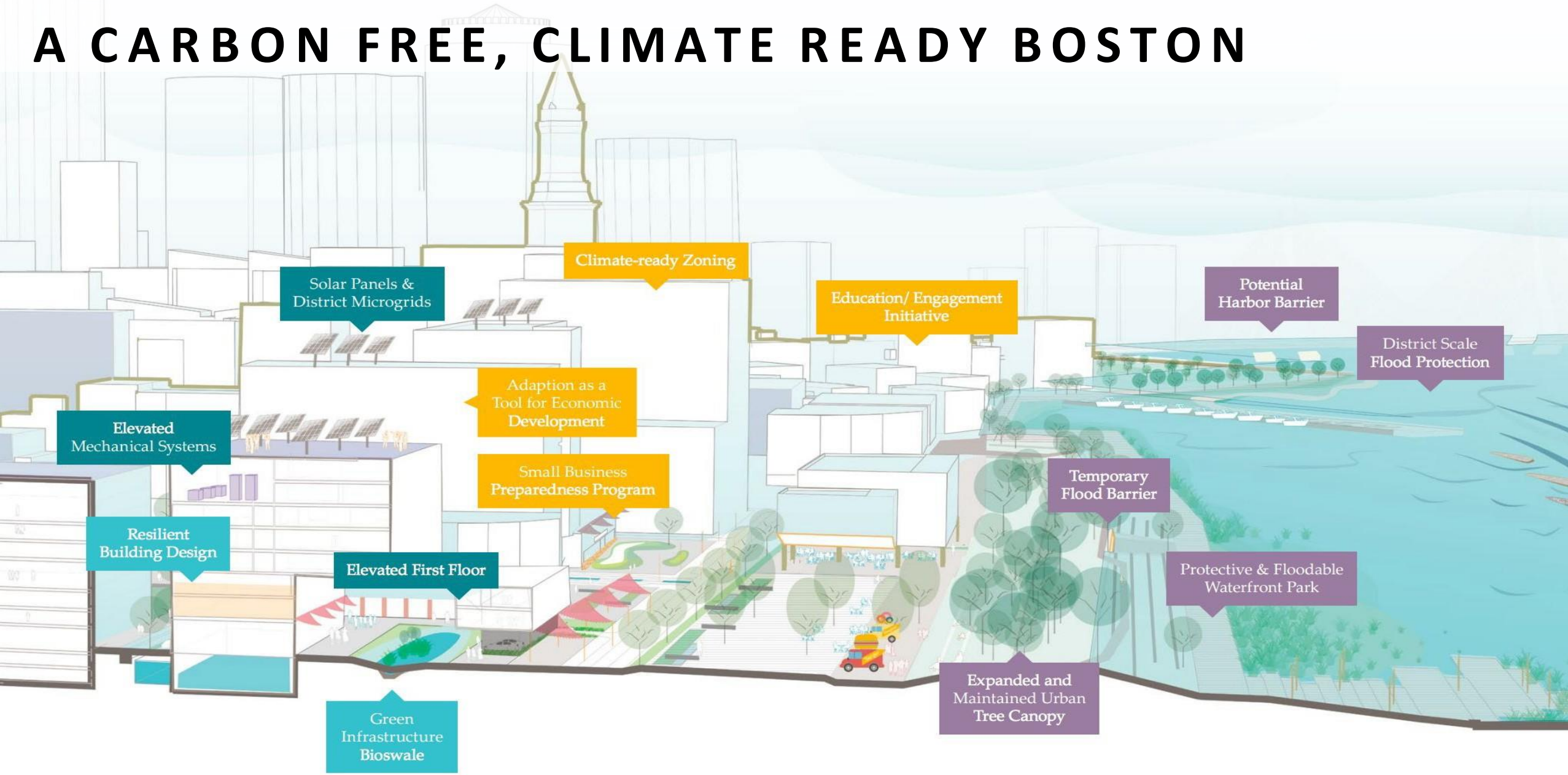
DIRECTOR OF CLIMATE AND ENVIRONMENTAL PLANNING

CITY OF BOSTON

CARBON FREE BOSTON

Alison Brizius
Director of Climate and Environmental Planning
July 12, 2018

A CARBON FREE, CLIMATE READY BOSTON



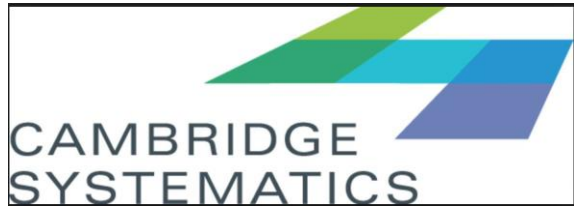
*"We are America's climate champion, with a target date of 2050 for going 100% **carbon-neutral**."*

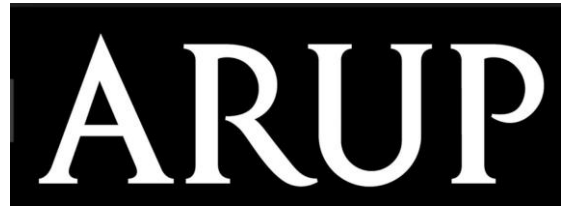
– Mayor Martin J. Walsh, State of the City 2017

CARBON FREE BOSTON

Carbon Free Boston is the City's initiative to analyze the likely effectiveness, cost and benefits of the technology and policy options for deep decarbonization.

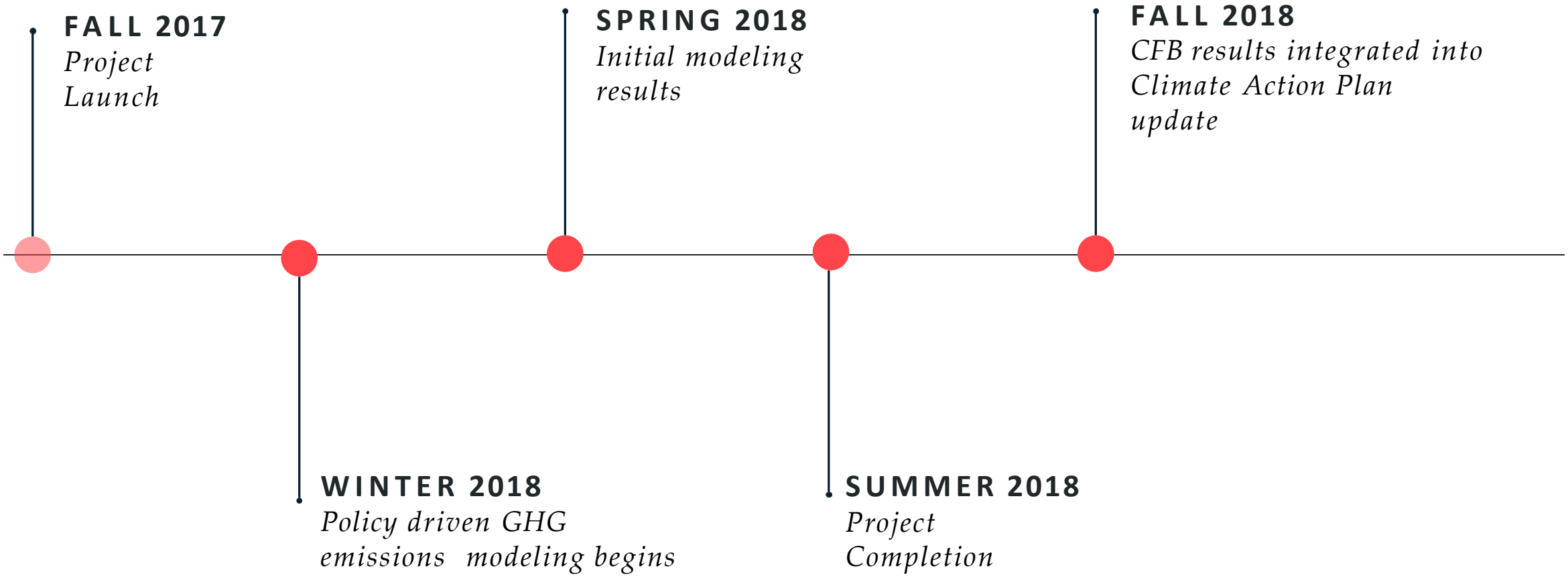
Institute for Sustainable Energy



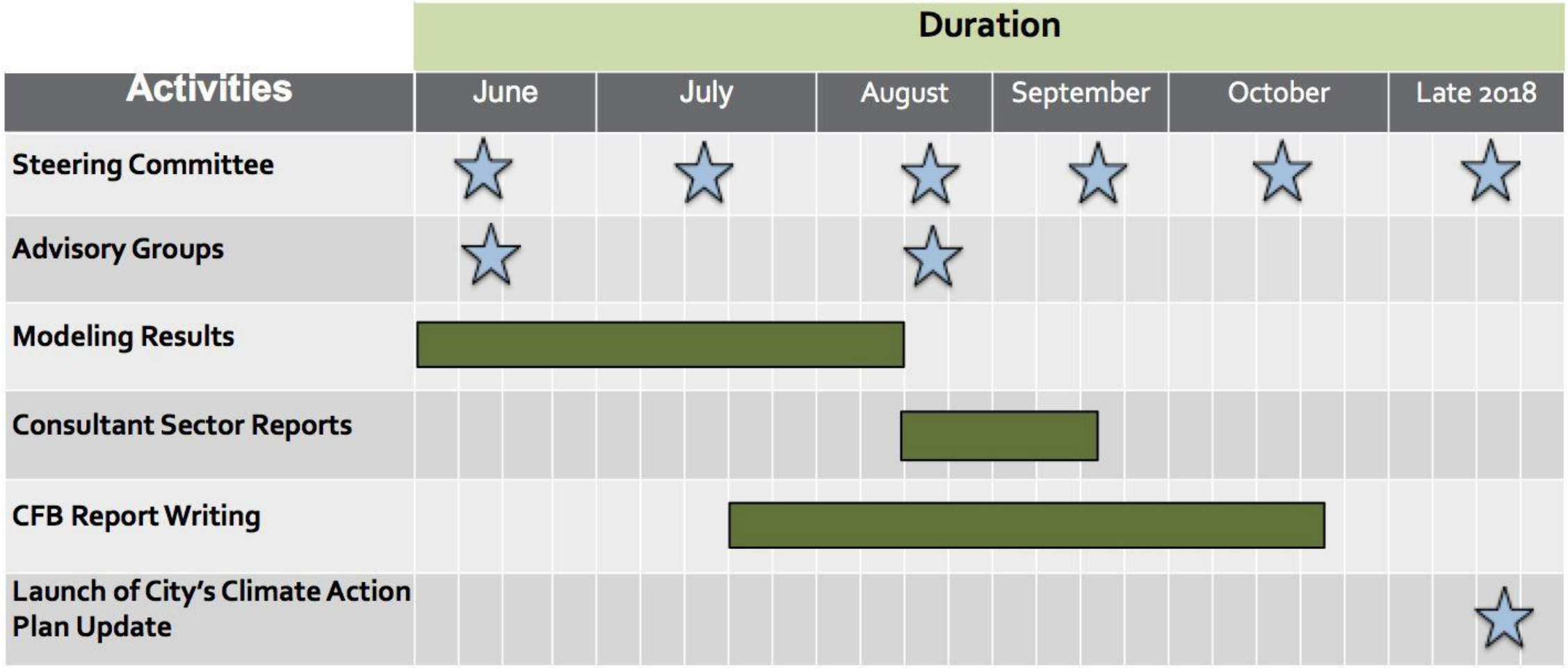


The results will inform the City's next update of its Climate Action Plan.

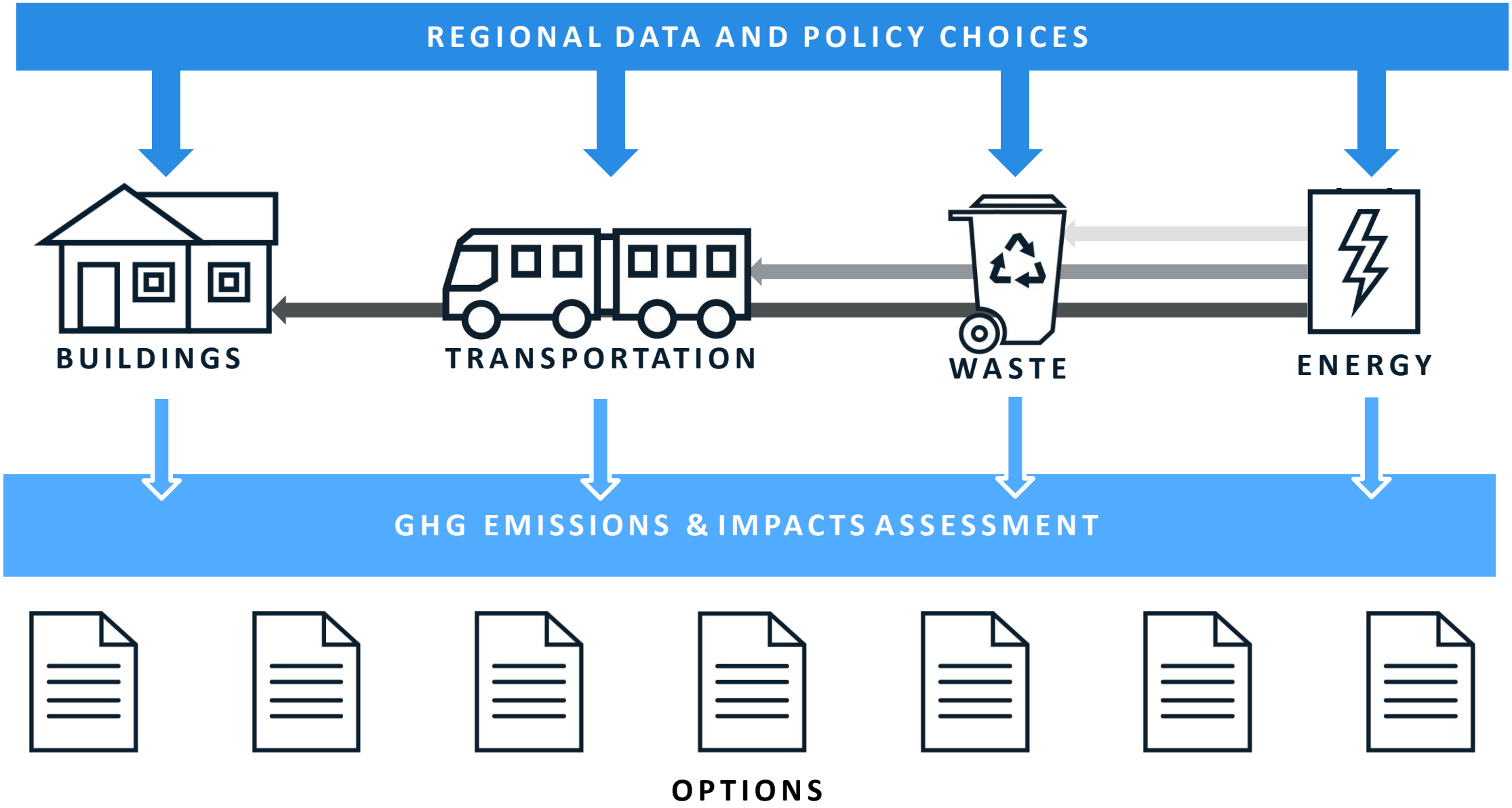
CARBON FREE BOSTON TIMELINE



PROJECT TIMELINE



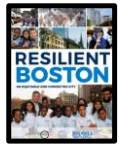
CARBON FREE BOSTON



CLIMATE ACTION PLAN UPDATE

IMAGINE BOSTON

GO BOSTON



RESILIENT BOSTON

CLIMATE READY BOSTON

ZERO WASTE BOSTON

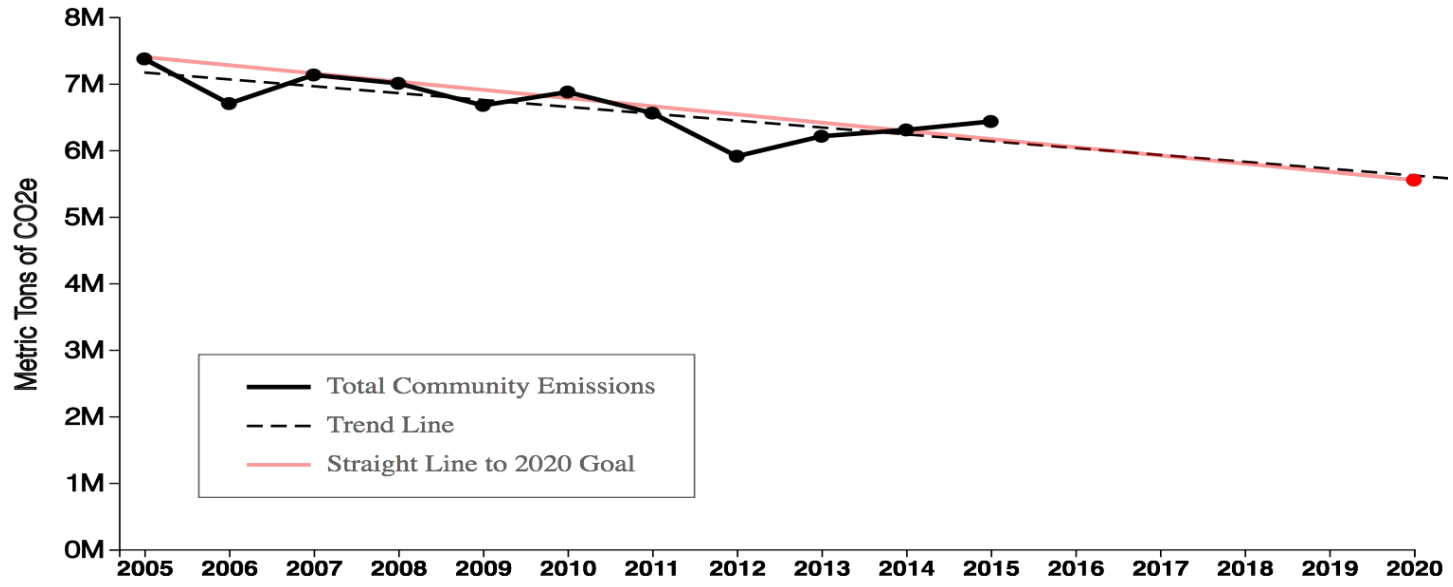
CARBON FREE BOSTON

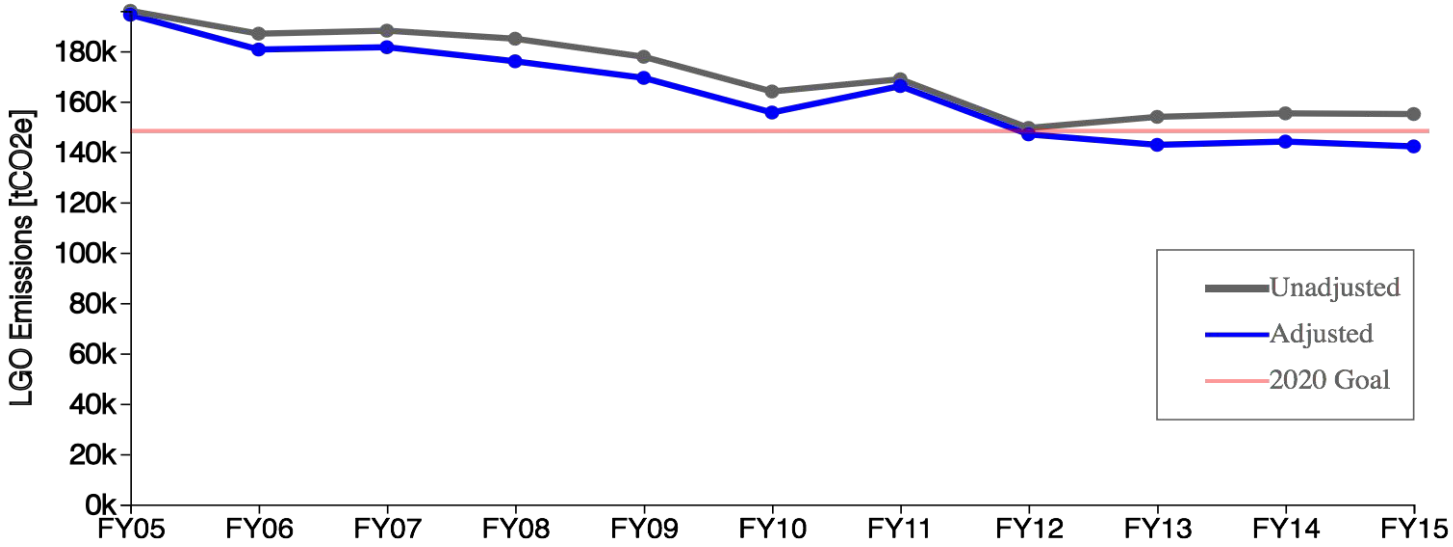
CLIMATE ACTION PLAN UPDATE = CARBON FREE & CLIMATE READY

CARBON NEUTRALITY

BOSTON GREENHOUSE GAS INVENTORY

COMMUNITY GHG EMISSIONS





LOCAL GOVERNMENT OPERATIONS

BOSTON CAN GROW AND REDUCE EMISSIONS

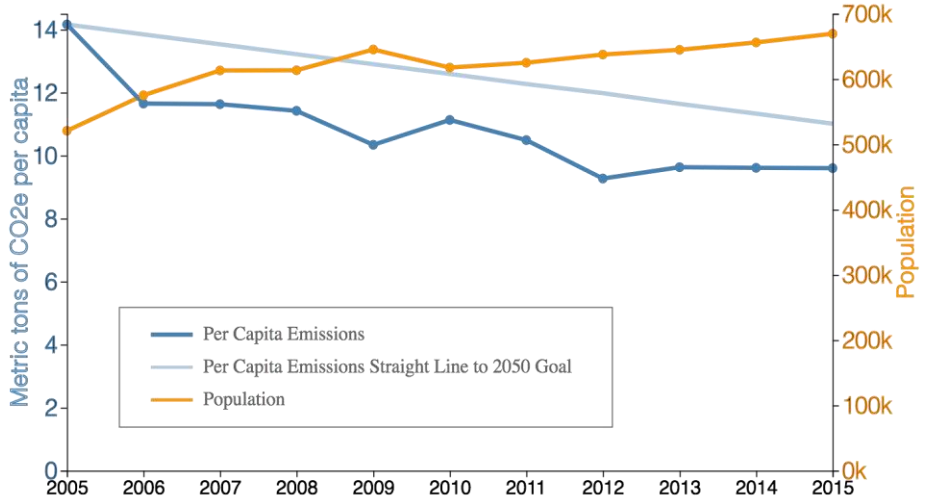
2005 to 2015:

GROSS CITY PRODUCT
2005: $91B
2015: $105B

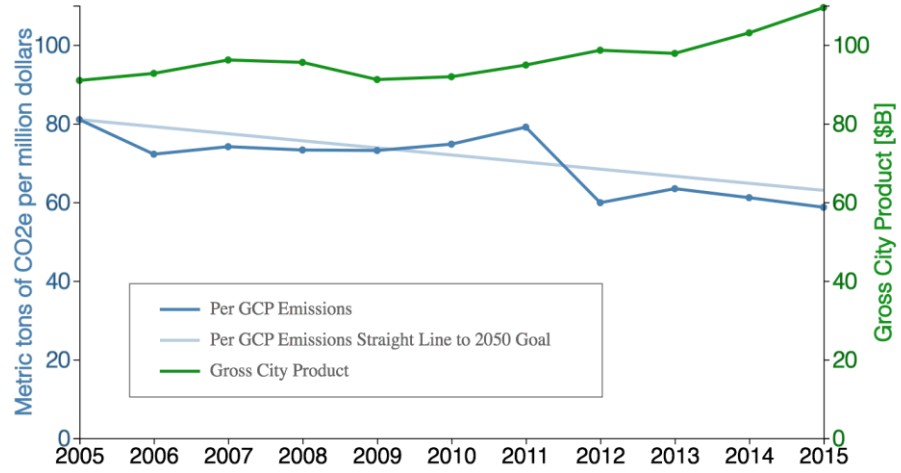
POPULATION
2005: 520,000
2015: 670,000

EMISSIONS REDUCED BY:
PER CAPITA: 32%
PER GCP: 27%
TOTAL: 13%

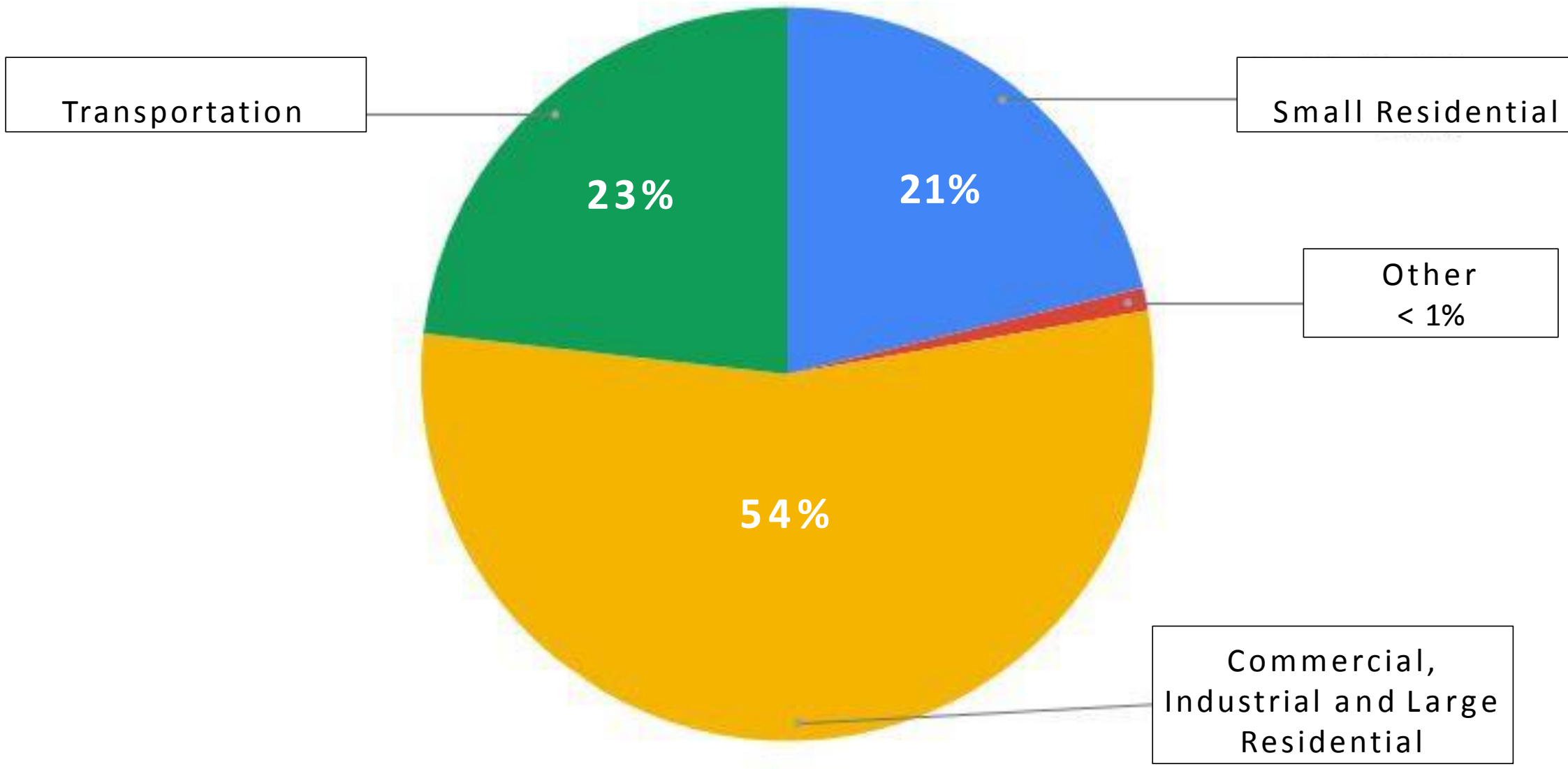
PER CAPITA EMISSIONS



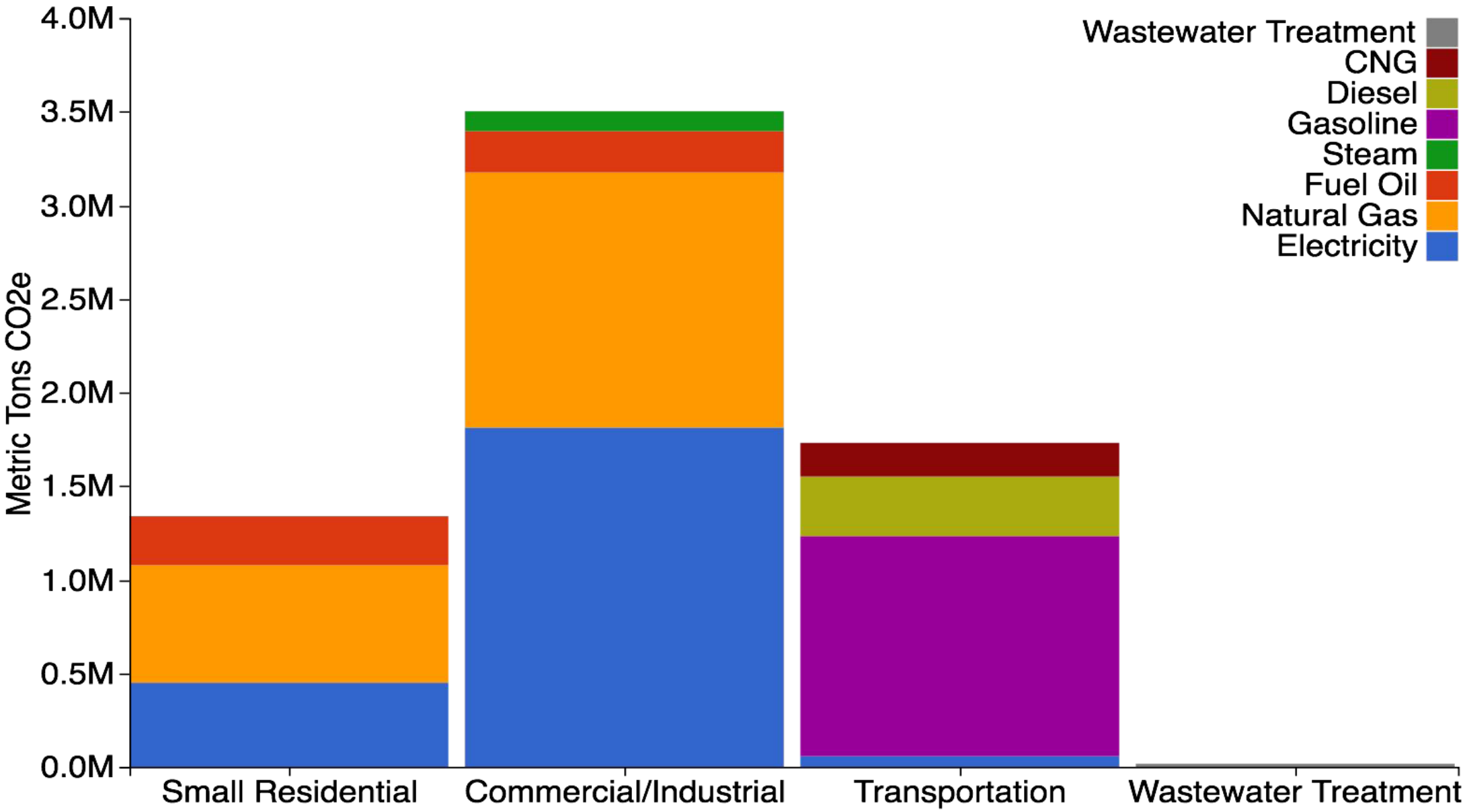
EMISSIONS PER GROSS CITY PRODUCT



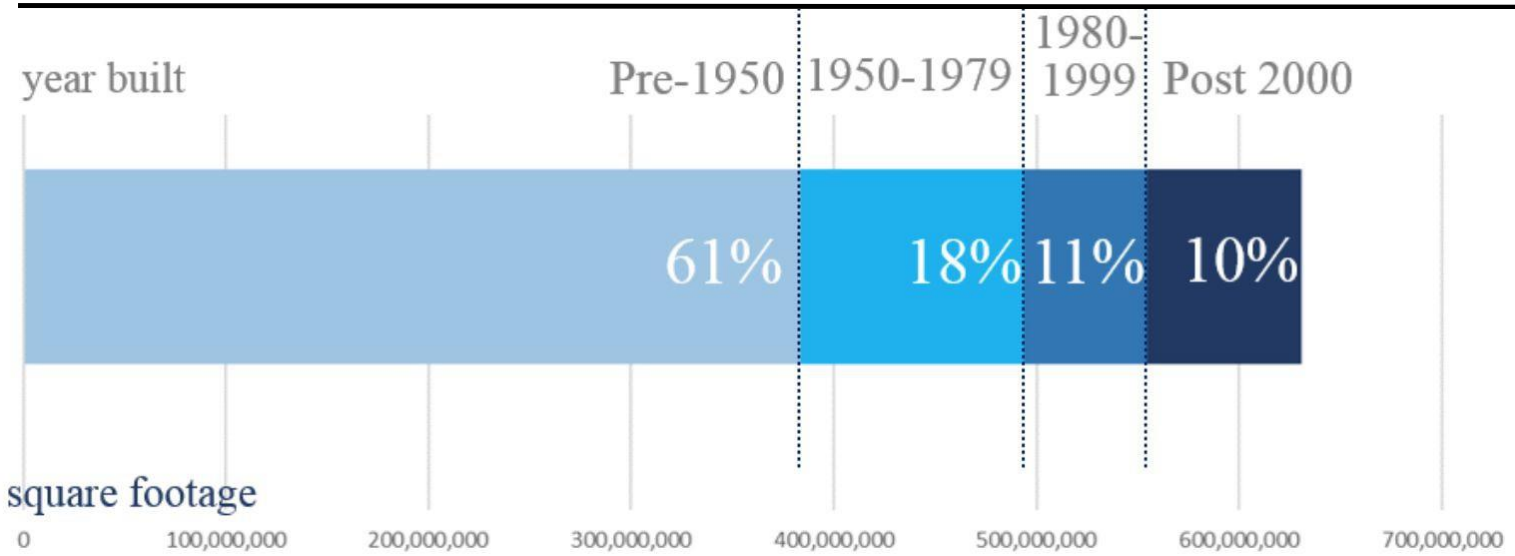
BUILDINGS ARE BOSTON'S LARGEST SOURCE OF GHG EMISSIONS



EMISSIONS BY SECTOR AND SOURCE

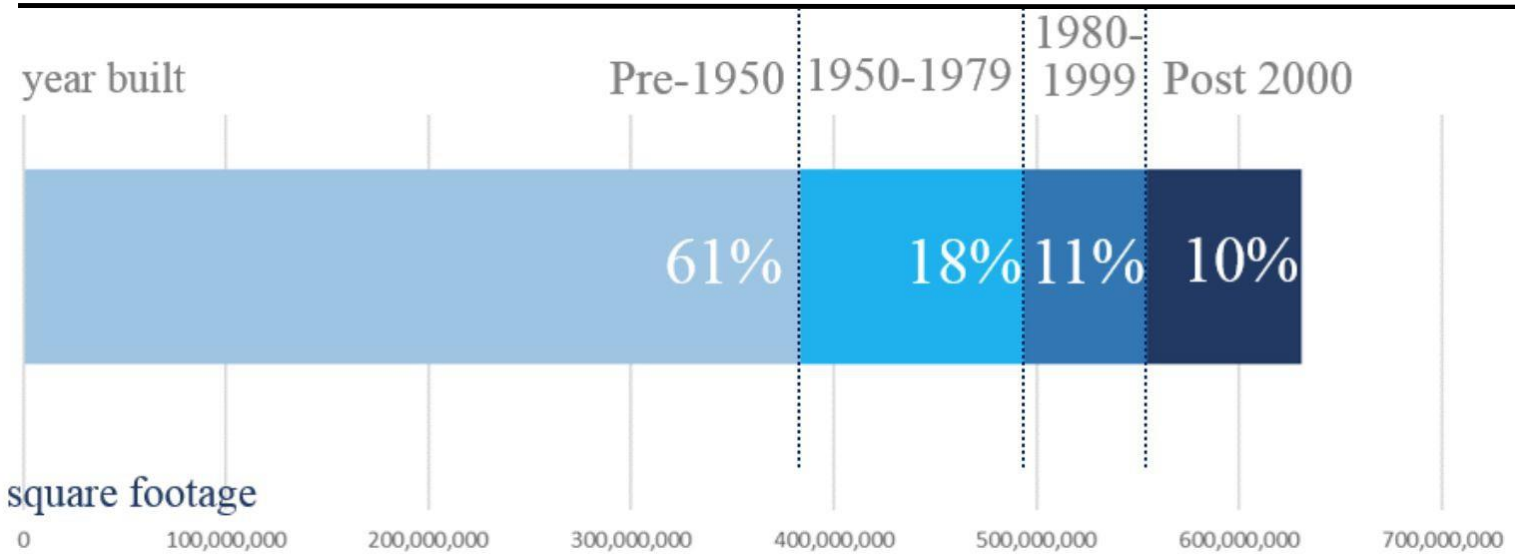


BOSTON'S BUILDINGS STOCK

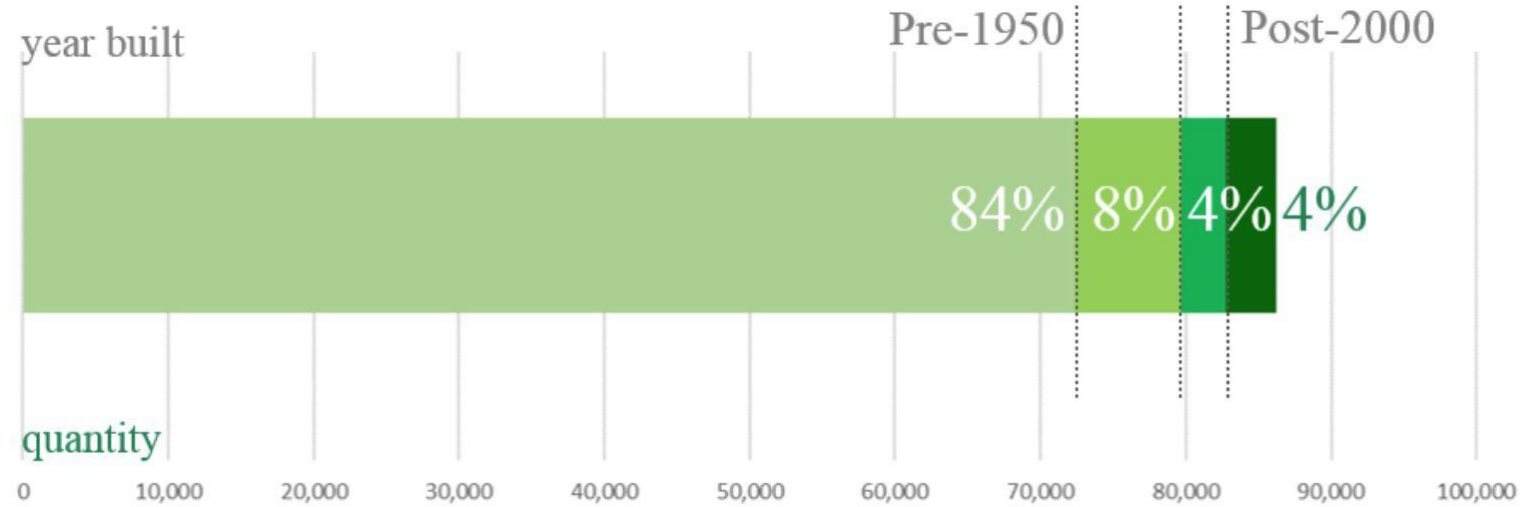


= 633,000,000 SF

BOSTON'S BUILDINGS STOCK



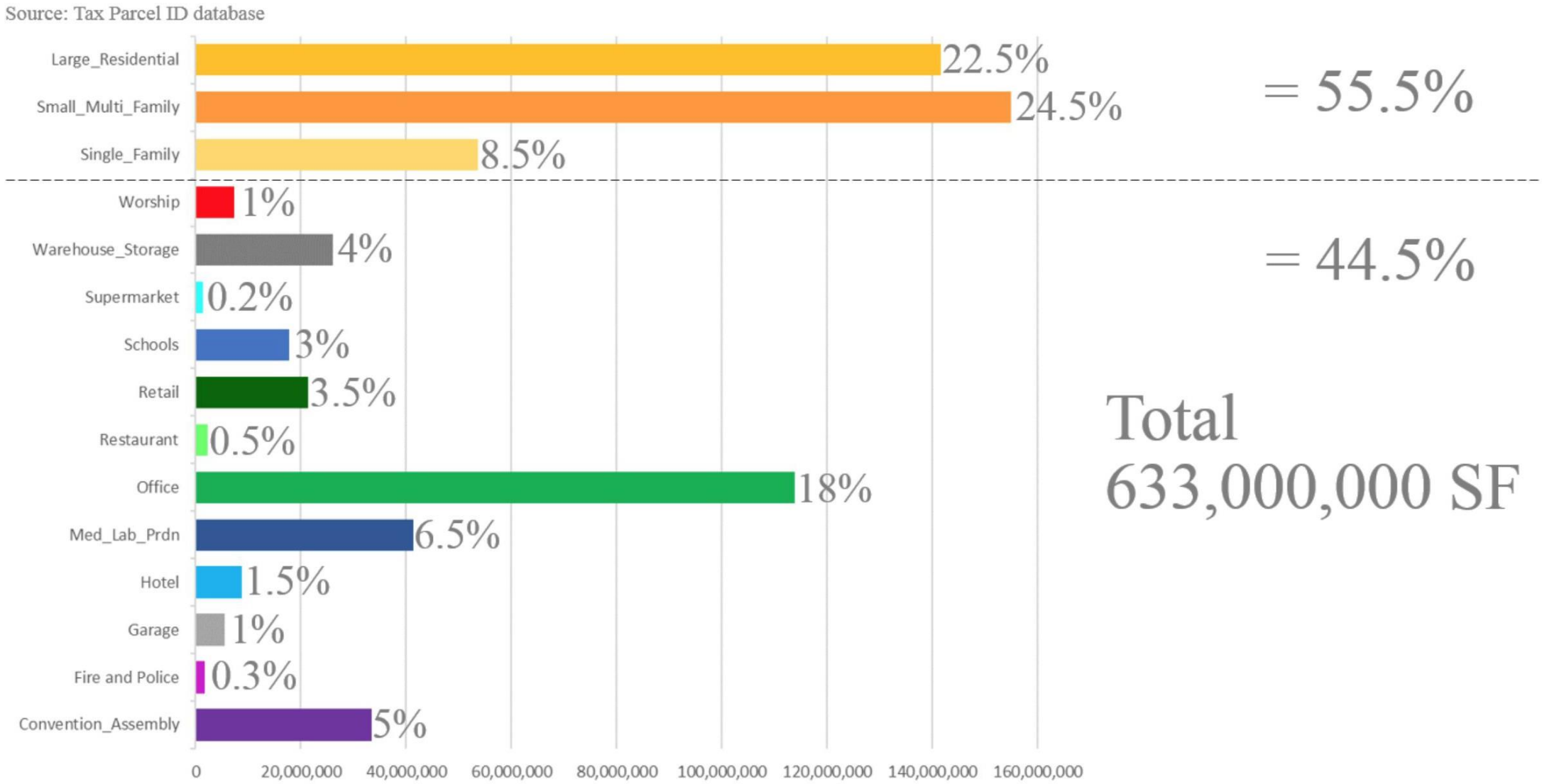
= 633,000,000 SF



= 86,565 buildings

BU ARUP

BOSTON'S BUILDINGS STOCK BY TYPE



CARBON FREE BOSTON AND THE BUILDING SECTOR

MICHAEL WALSH

SENIOR RESEARCH SCIENTIST

BOSTON UNIVERSITY'S INSTITUTE FOR SUSTAINABLE ENERGY

Carbon Free Boston

July 12, 2018

BU Institute for Sustainable Energy

BOSTON Green Ribbon COMMISSION

GREENOVATE
Carbon Free Boston

Carbon Free Boston: Project Overview

Multi-sector, Data-driven Analysis

Buildings

- Energy efficiency
- Heating and cooling with clean energy

Transportation

- Mode shifts
- Electric vehicles

Energy

- Clean grid
- Clean energy procurements
- Offsets

Waste & Services

- Zero waste
- Public sector services

Project Outcomes

- Assessment of alternative strategies that enable City to be carbon-neutral by 2050
- Inform upcoming Climate Action Plan update
- Detailed spatial evaluation of:
  - Greenhouse gas emissions
  - Equity impacts
  - Health impacts of air pollution

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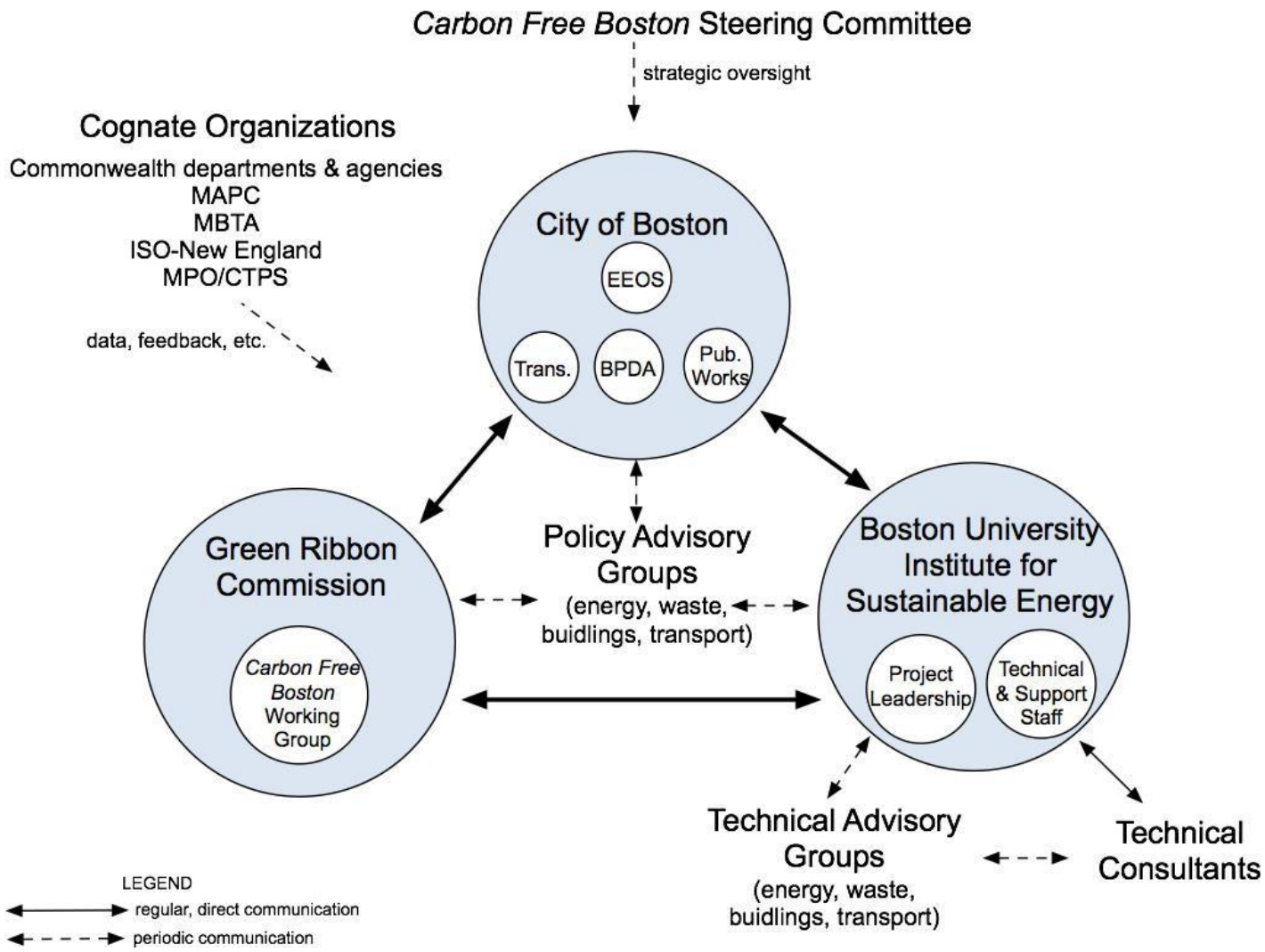
Greenovate Carbon Free Boston

Carbon Free Boston Ecosystem



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GREENOVATE *Carbon Free Boston*

FUNDING

Barr Foundation

Leventhal Foundation

Kendall Foundation

Hewlett Foundation

Grantham Foundation

Microsoft

C40

Commonwealth of Massachusetts

City of Boston

Eversource

National Grid

Bank of America

CFB Team

- **Boston University**
  - Cutler Cleveland
  - Peter Fox-Penner
  - Michael Walsh
  - Adam Pollack
  - Kevin Zheng
  - Taylor Perez
  - Joshua Castigliego
- **Green Ribbon Commission**
  - Amy Longsworth
  - John Cleveland
- **City of Boston**
  - Allison Brizius
  - Katherine Eshel
- **Arup**
  - Brian Sweet
  - Rebecca Hatchadorian
  - Rob Best
  - Katie Wholey
  - Erica Levine
- **Cambridge Systematics**
  - Chris Porter
  - Marty Milkovits
  - XiaoYun Chang

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GREENOVATE Carbon Free Boston

Outputs

A data-driven framework & platform for evaluating carbon mitigation pathways for cities

Scenarios

- Sector-specific models for buildings, transportation, energy supply, and waste
- Integrating module that ties together sector models

Direct Benefits/Costs

- Emissions reductions
- Sector-specific benefits, e.g., changes in congestion and commuting time
- $ value of benefits and costs associated with specific policy/technology combinations

Co-benefits

- Public health
- Social equity
- Technical innovation
- Employment

Modeling Philosophy

Reduce the cost of urban climate action planning, improve knowledge of city ecosystems, increase transparency

Analysis Design

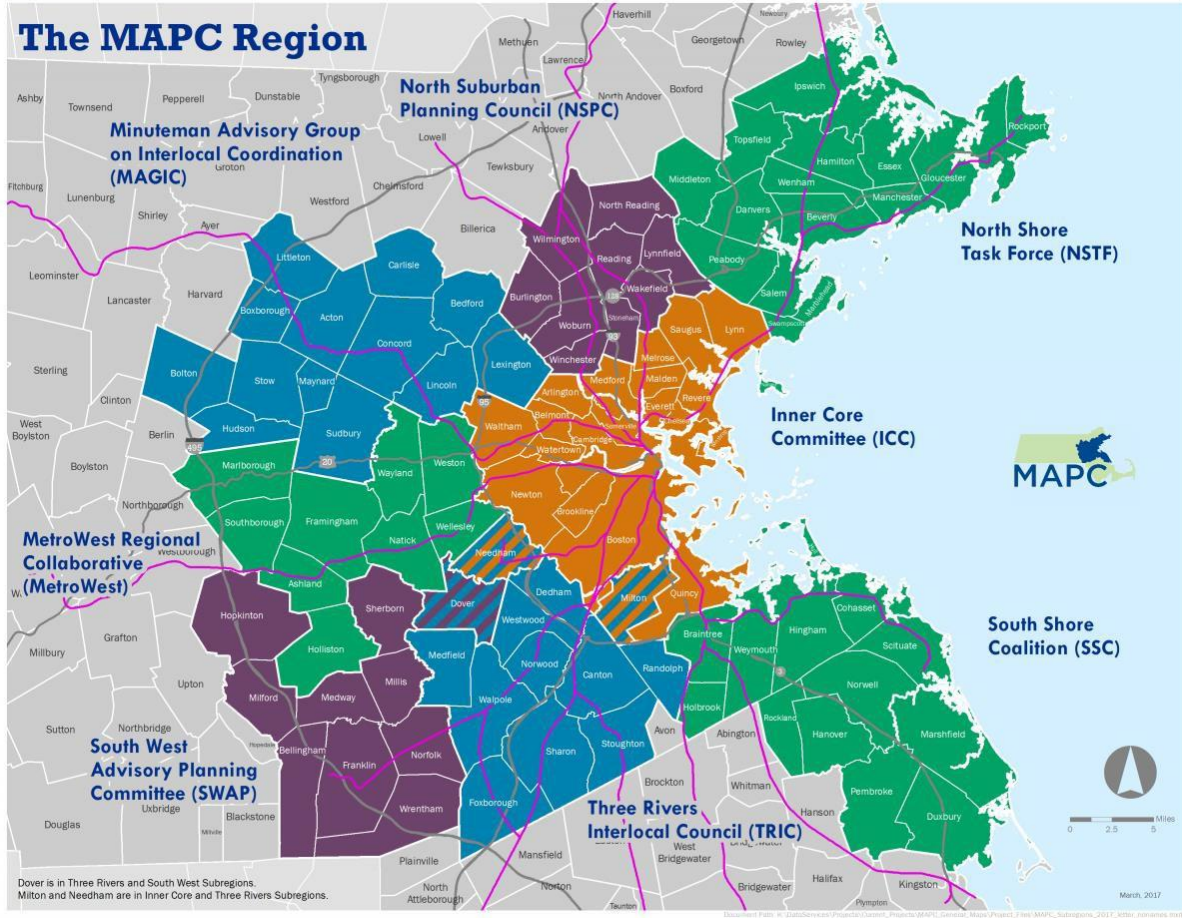
- Bottom-up, sector-based approach
- Spatially Explicit (Boston)
  - Limited by geographic boundary
- Compatible with existing frameworks (e.g. GPC)
- Use scenario narratives to contextualize uncertainty

(Ideal) Software Principals

- Open Source
- Modular, Extensible, Scalable
- Cloud-based
- Python 3 + associated models
- Aim for Continuous Integration

Long-term Goals

- Scale Approach
  - Partner with Metropolitan Area Planning Council in regional plan update
  - Identify other cities
  - Integrate water planning
- Standardize Platform
  - Cloud based container for easy spin up
- Identify Partners
  - C40
  - National Labs/JGCRI/EPA/DOE



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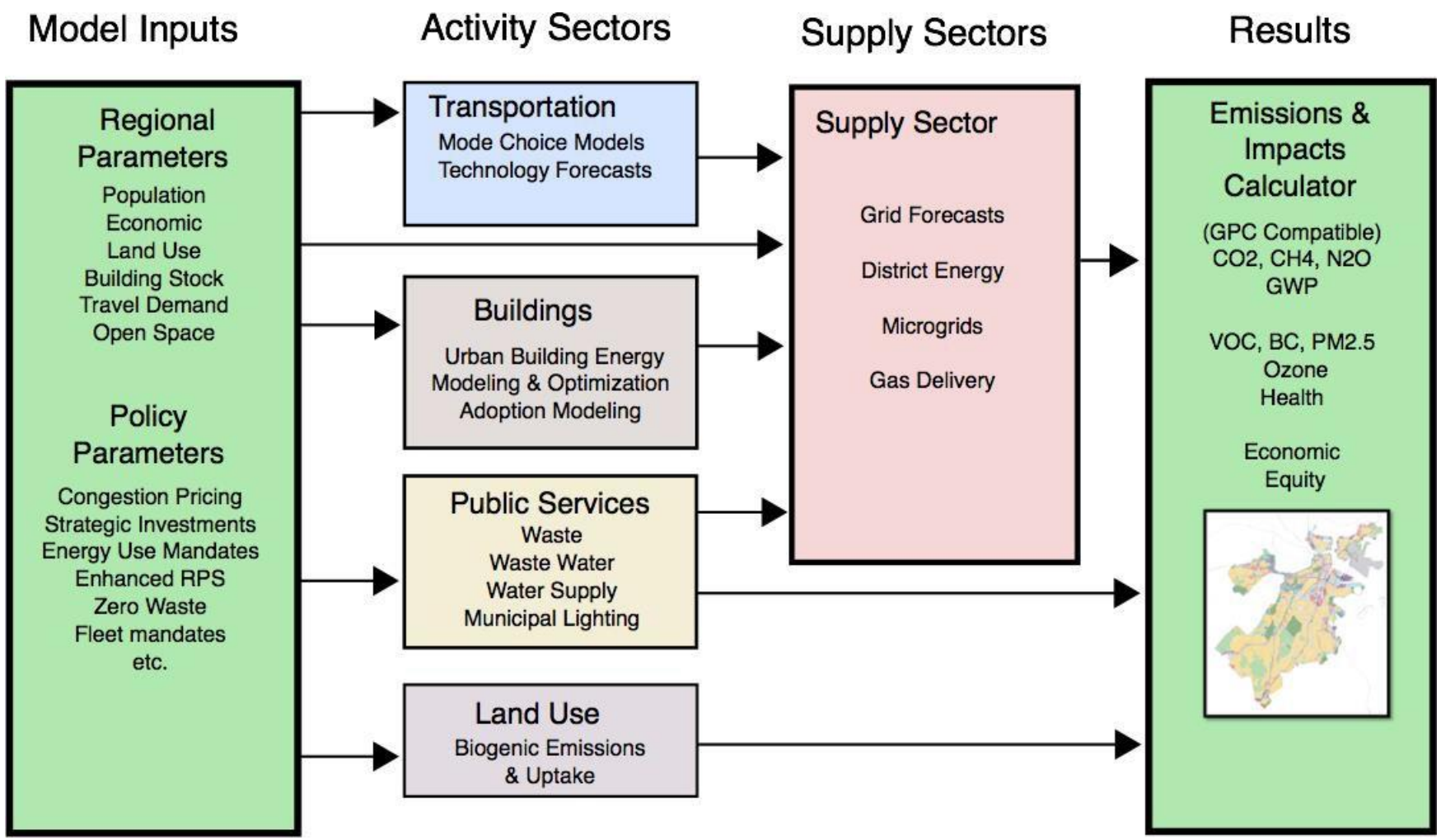
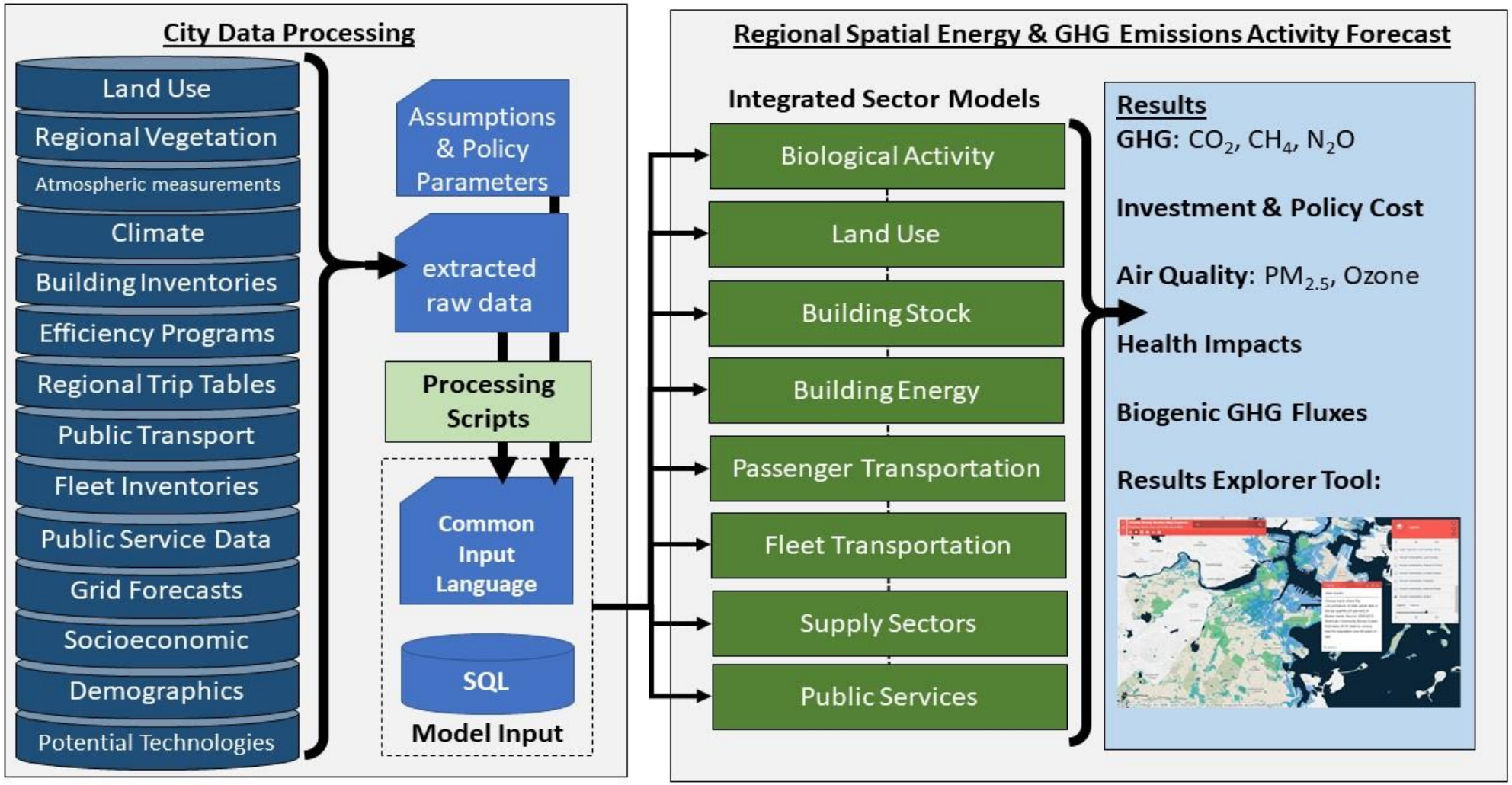
GREENOVATE Carbon Free Boston

Conceptual Framework



Integrated City Climate Mitigation Planning



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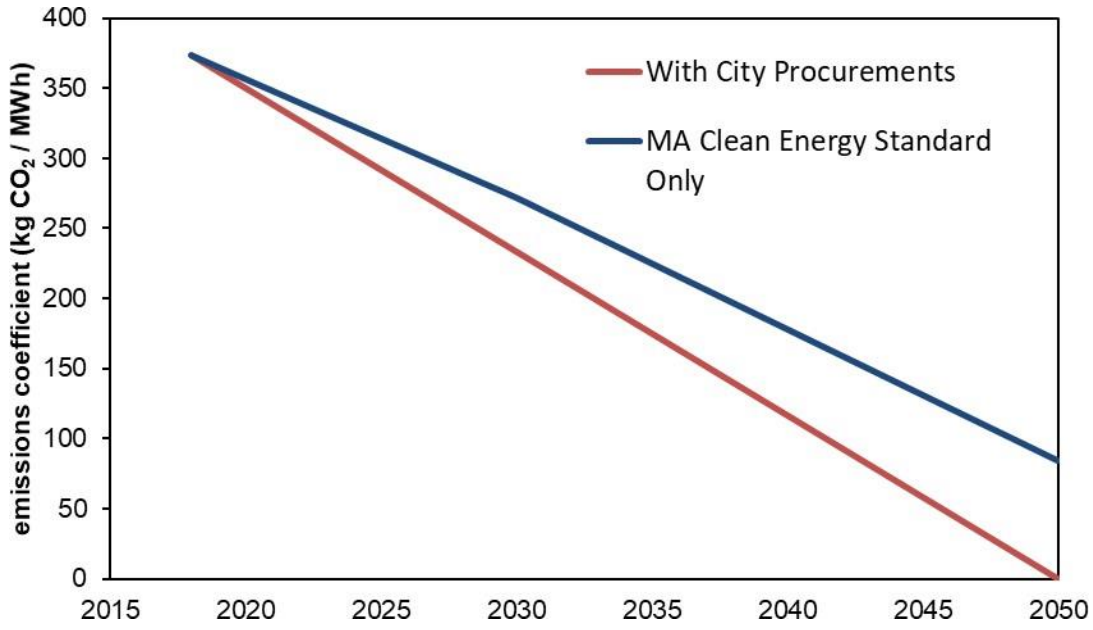
ELECTRICITY SUPPLY

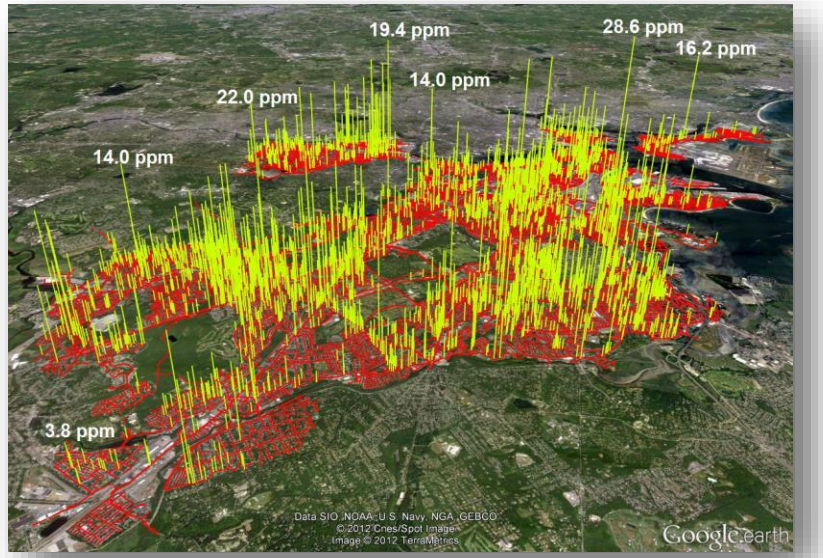


- MA GWSA and Clean Energy Standard will result in an cleaner (80% renewable) grid by 2050

- Additional city procurements will be necessary to achieve zero carbon electricity

- CFB is not explicitly modeling the electricity supply but will derive insights from transportation and buildings sectors

Natural Gas Lock-in?



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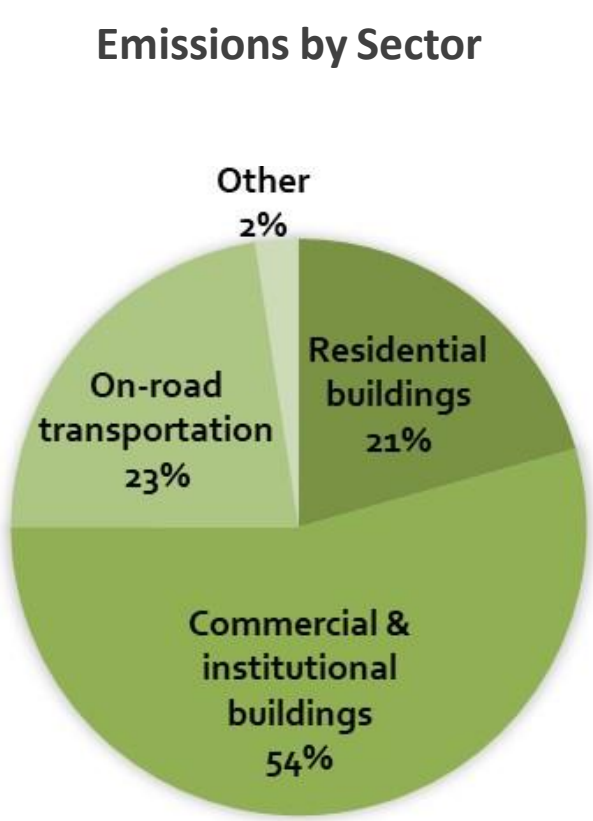
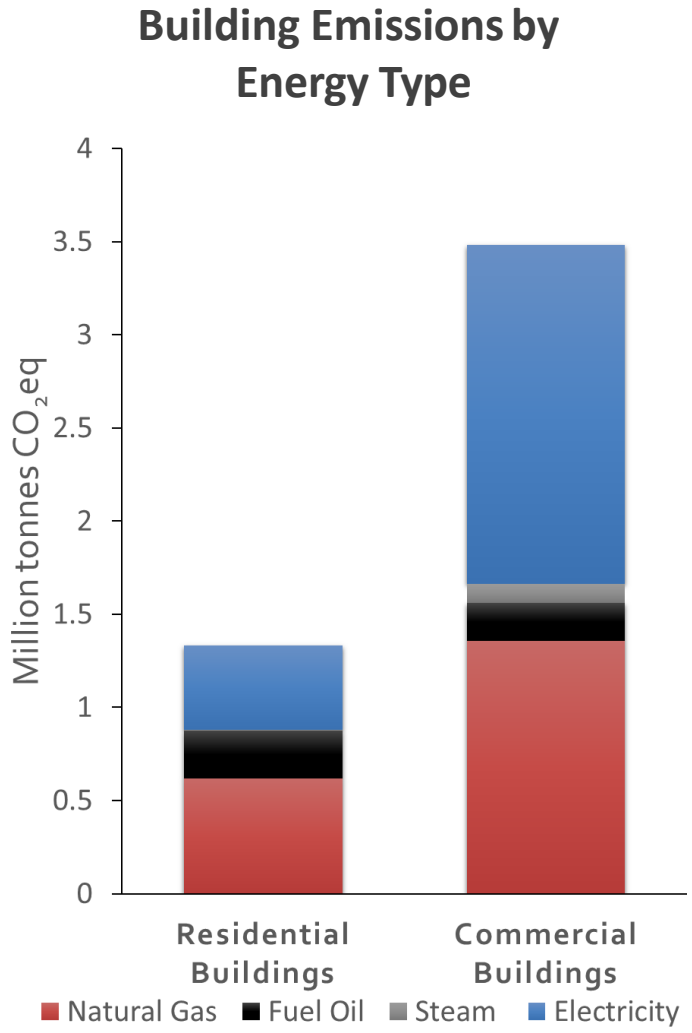
Can Renewable Gas Save Us?

Buildings are Boston's Largest Source of GHG





- State policy (GWSA): 80% renewable grid by 2050
- City policy: eliminate on-site fossil fuel use in buildings by 2050

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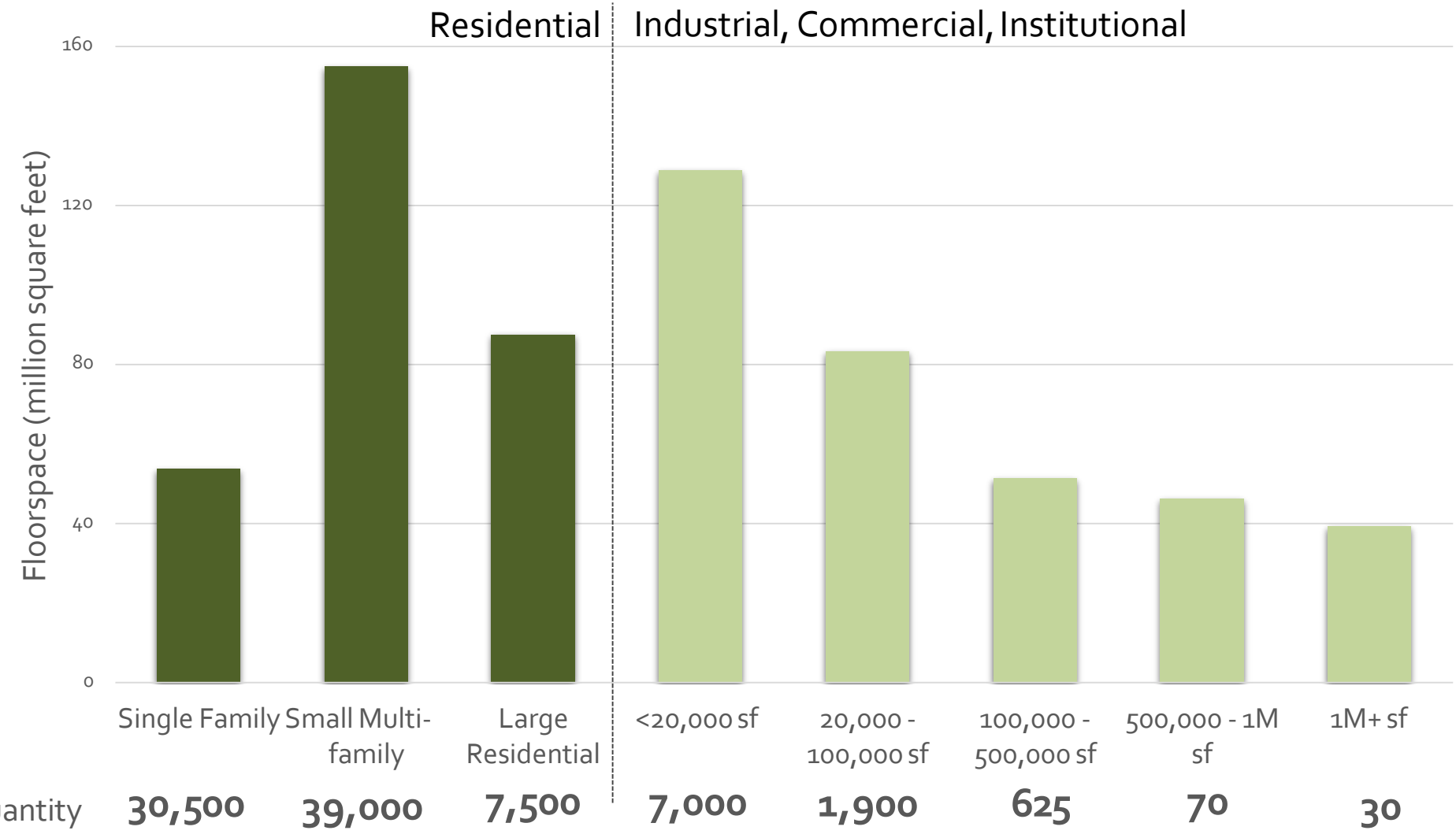
Greenovate Carbon Free Boston

BOSTON'S BUILDINGS VARY IN SIZE



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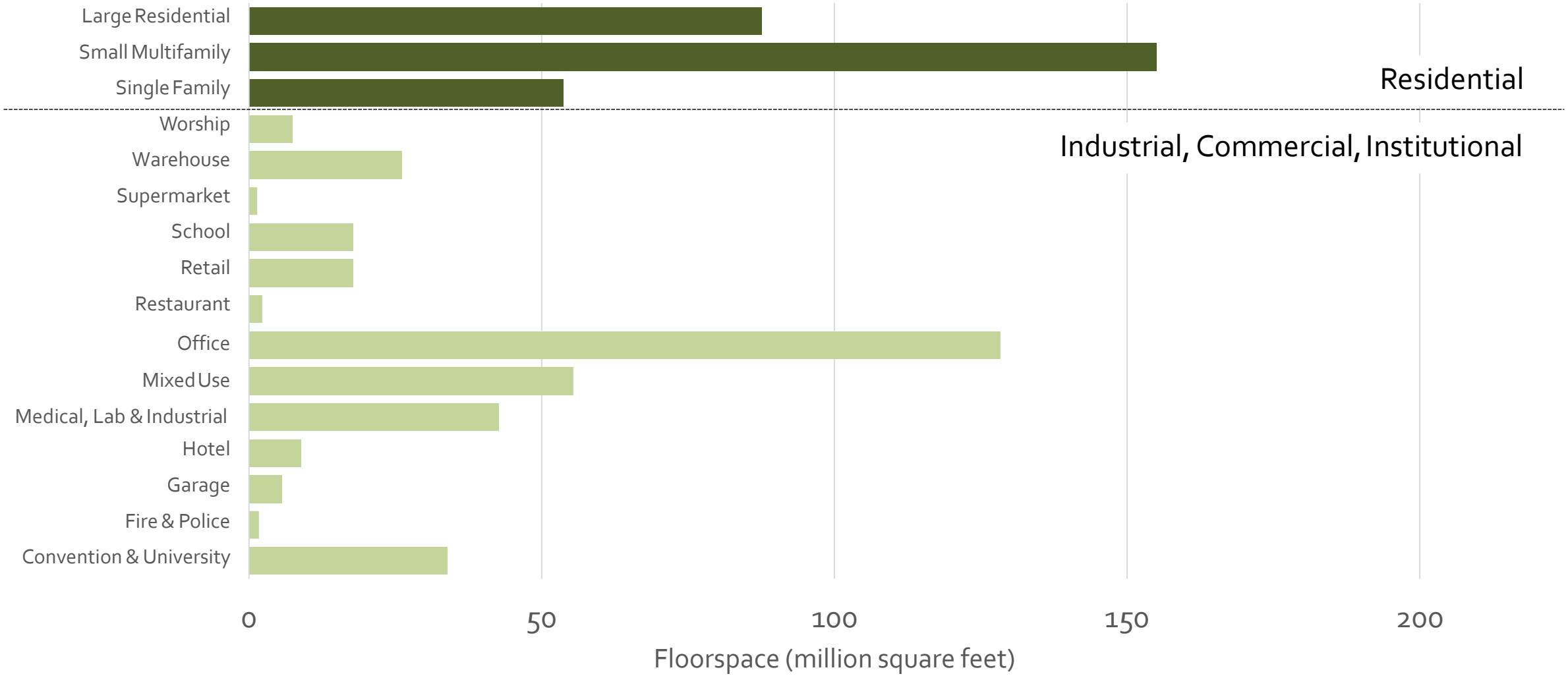
Boston's Building Use is Diverse



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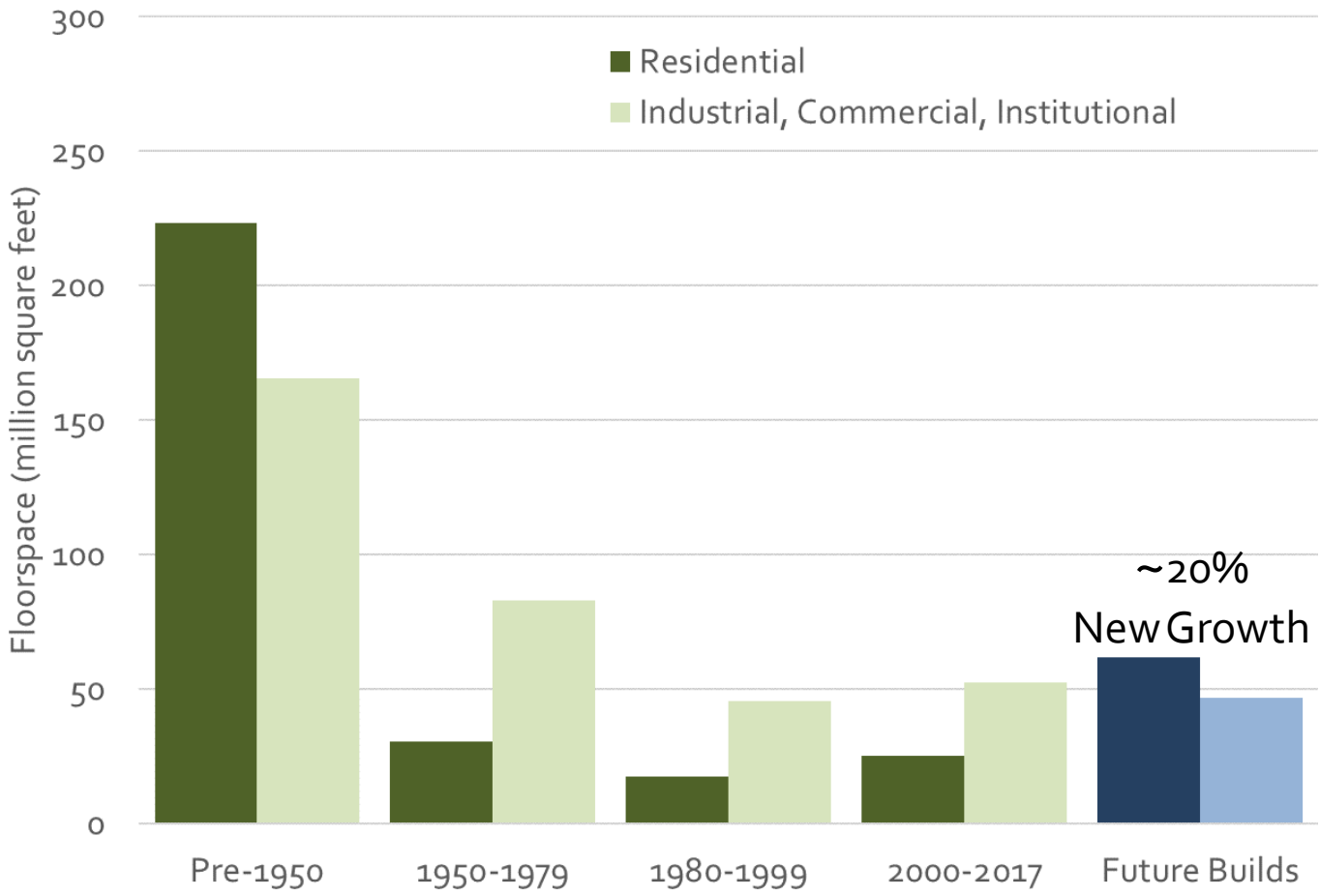
Boston's Building Stock Is Old



- Net zero building strategies are essential
- Retrofits and clean energy for existing stock are largest challenges

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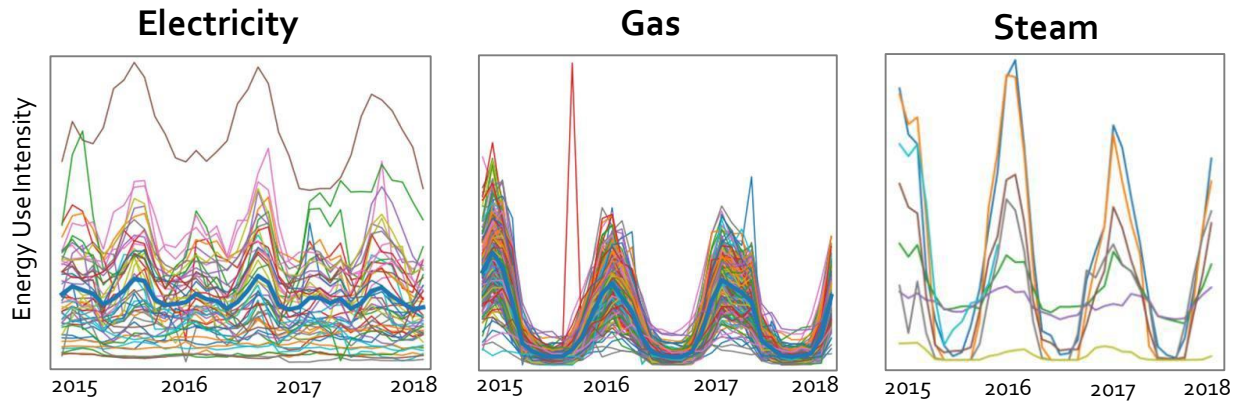
CFB Buildings Sector Modeling Approach

Data

- 15 Building classes
- 4 Age categories
- Boston parcel database
- Meter samples
- "First mover" initiatives



Methods

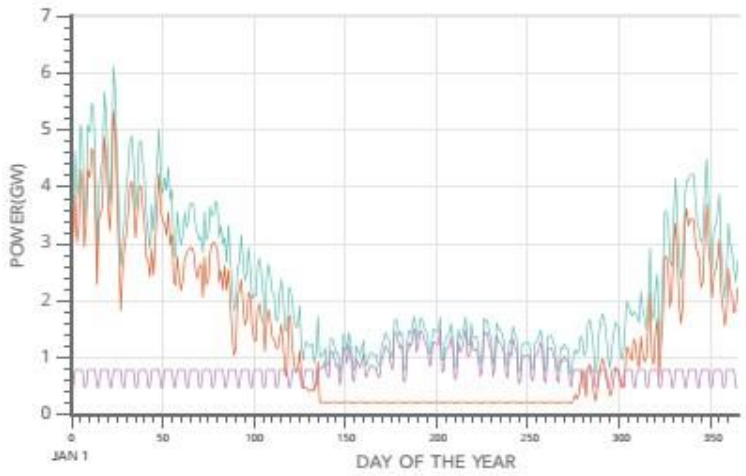
Building Energy Modeling

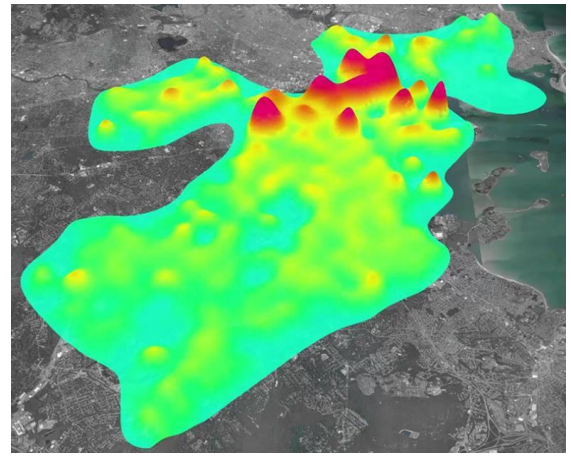
Policy-interpretive Adoption Modeling

Spatial Disaggregation

Output

- Most effective strategies
- Policy design
- Energy pulse of the City





2016 Boston Community Energy Study

Building Typologies

1. Single family residential
2. Small multi-family (triple decker)
3. Multifamily residential
4. Office
5. Fire/police
6. Convention/Assembly
7. Hotel
8. Medical/Lab/Production
9. Restaurant
10. Retail
11. School
12. Supermarket
13. Warehouse
14. Worship
15. Garage

Age ranges:

Pre-1950; 1950 – 1979; 1980-1999; Post-2000

Data Sources

Commercial Building Energy Consumption Survey (CBECS)

DOE-led survey conducted (3 years) examining energy performance, appliances, building characteristics

Residential Energy Consumption Survey (RECS)

DOE-led survey evaluating single- and multi-family energy performance, appliances, building characteristics

ResStock

NREL program to better detail single family home characteristics by vintage; uses RECS data supplemented by surveys of homes from National Association of Home Builders

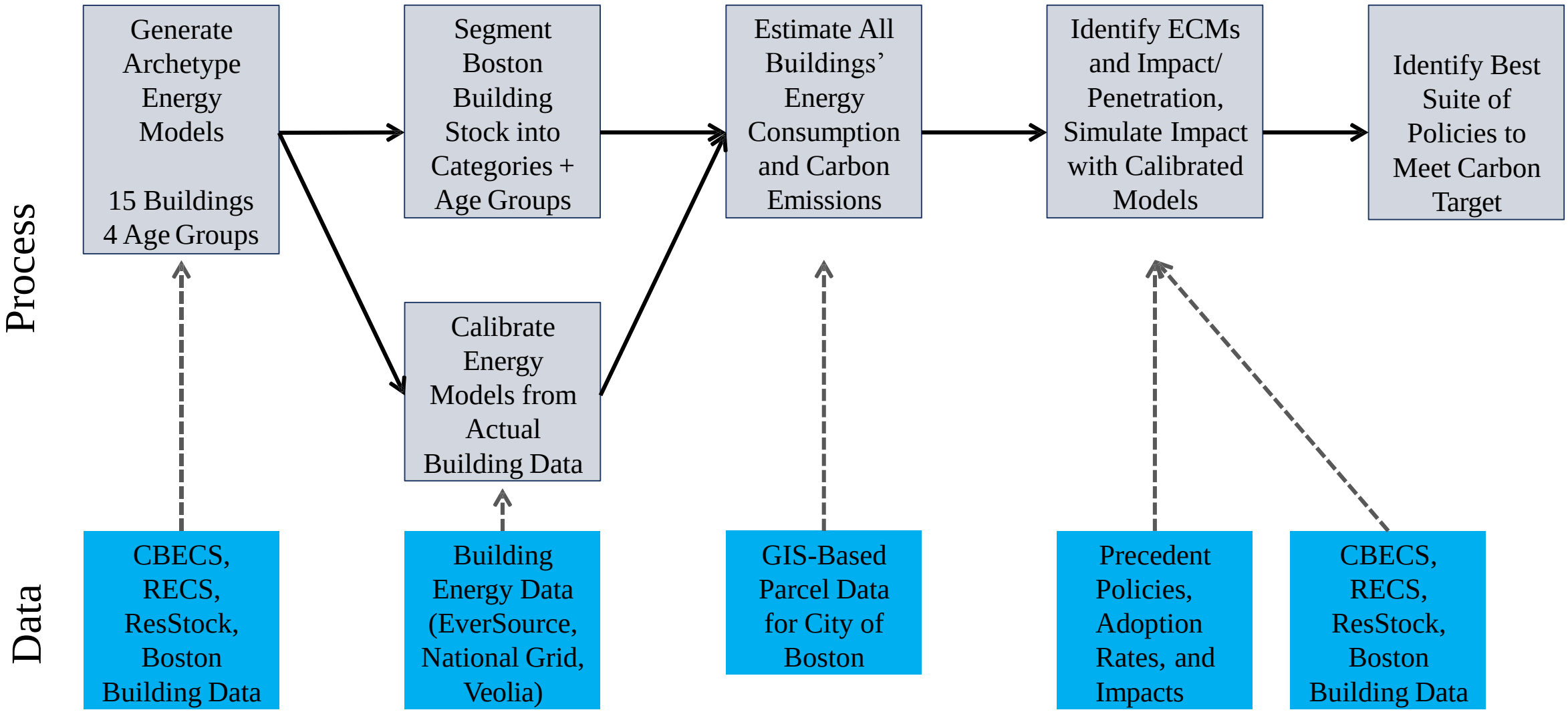
ASHRAE 90.1

Typical consumption patterns for new buildings and typical use schedules; can be reviewed for older buildings (back to 1989)

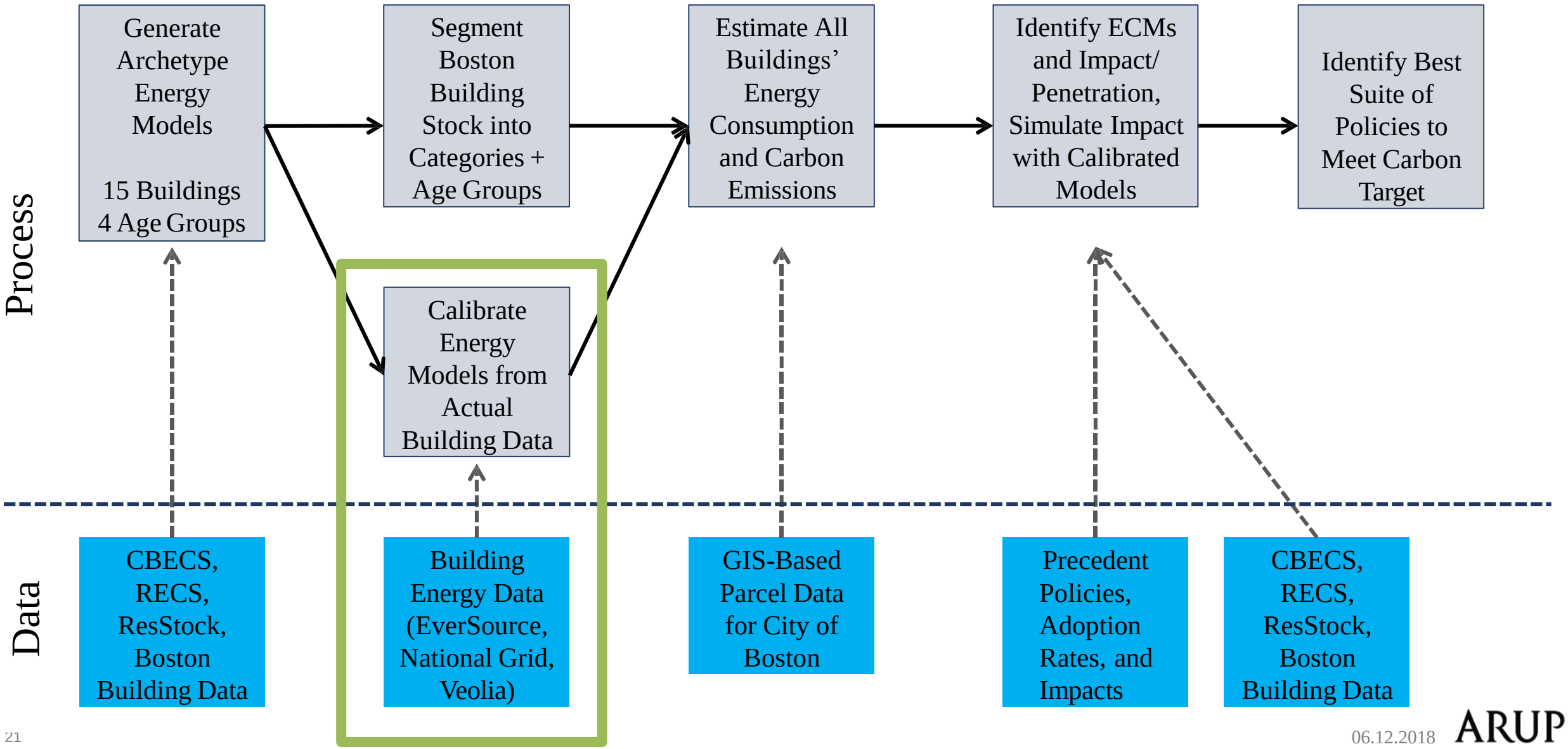
Boston Local Information

Building characteristics where available from parcel database, local expertise - informs and supercedes other data where available

Buildings Modeling Methodology

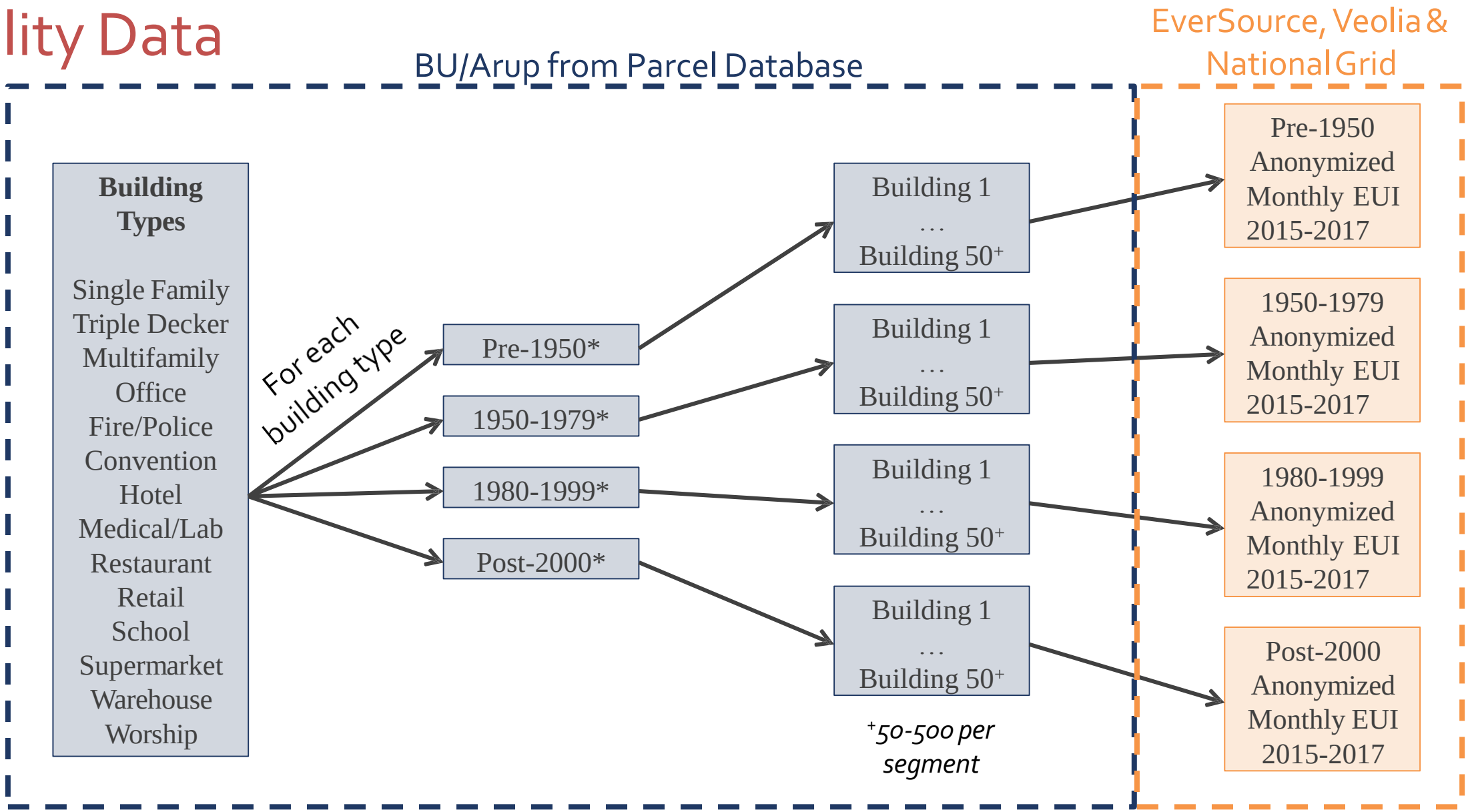


Modeling Methodology



ARUP

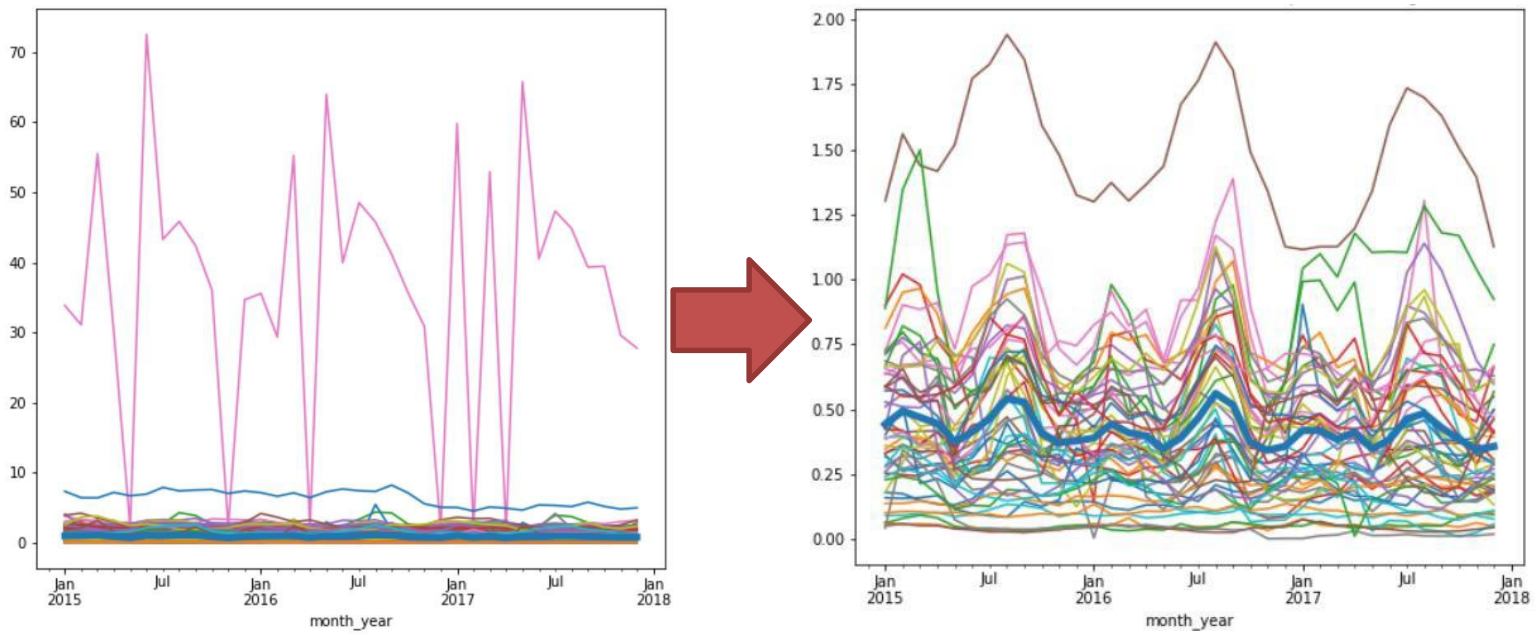
Utility Data



**Age ranges related to major changes in ASHRAE code for commercial buildings.*
Residential age groups are Pre-1945, 1945-1964, 1965-1990, and Post-1990

ARUP

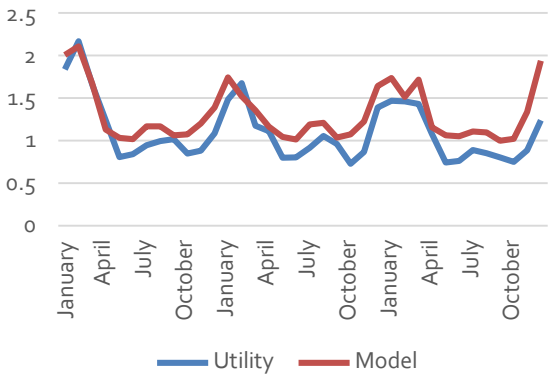
Utility Data Processing



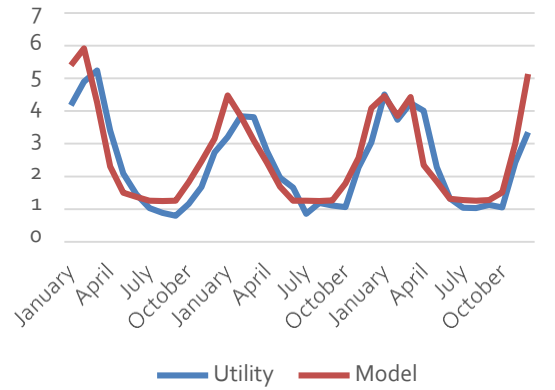
Calibration Large Multifamily

Pre-1950

Electricity (18.5% NMBE, 23.2% CV[RMSE])

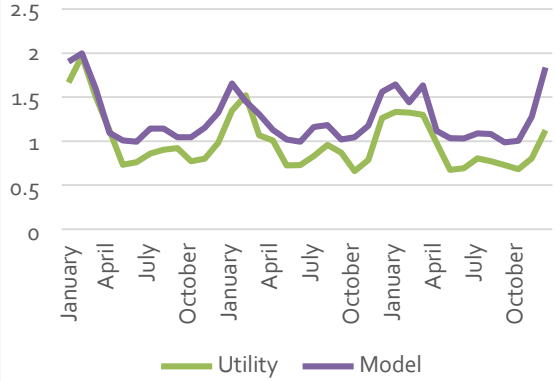


Gas (7.2% NMBE, 29.5% CV[RMSE])

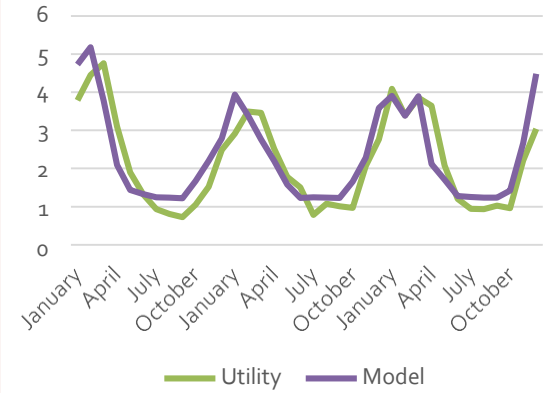


1950-1979

Electricity (26.0% NMBE, 29.5% CV[RMSE])

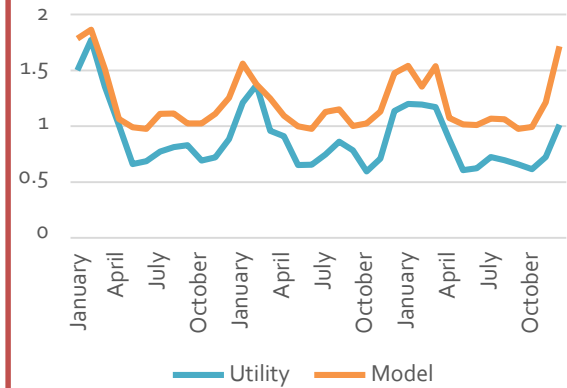


Gas (6.7% NMBE, 28.1% CV[RMSE])

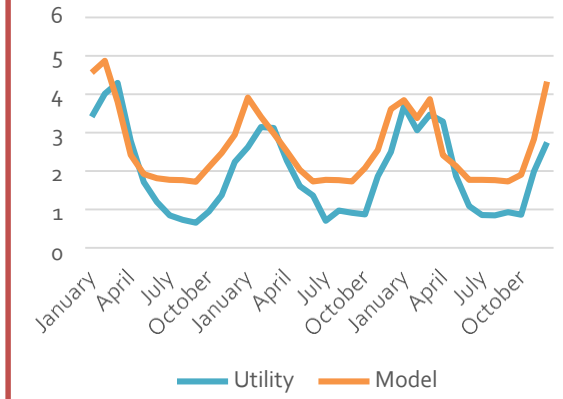


1980-1999

Electricity (34.5% NMBE, 37.2% CV[RMSE])

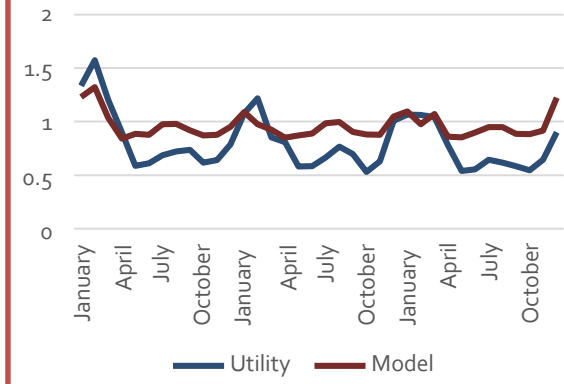


Gas (32.8% NMBE, 42.4% CV[RMSE])

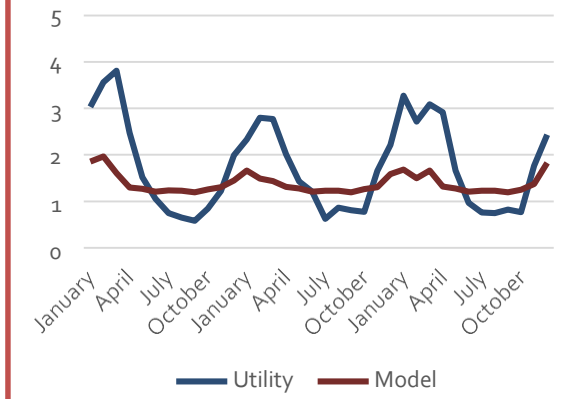


Post-2000

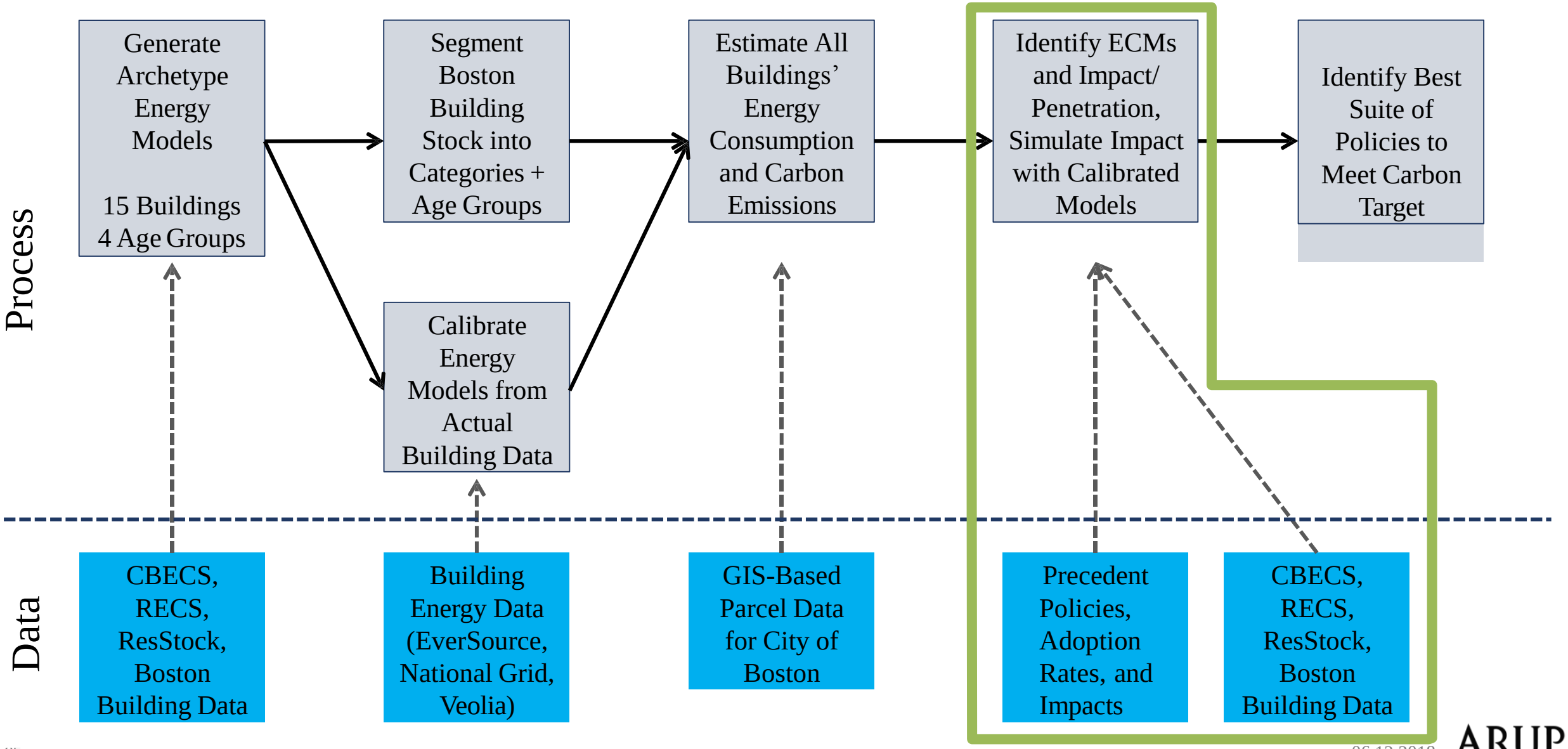
Electricity (20.2% NMBE, 29.8% CV[RMSE])



Gas (-20.8% NMBE, 50.3% CV[RMSE])



Modeling Methodology: Next Steps



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Modeling Methodology: Strategies

- Stretch building code
- Passive House standard
- Energy Use (EUI) Cap
- Emissions Cap
- Fuel switching (gas to electric)
- Fossil fuel free new construction
- ZNE new construction
- Increased lighting efficiency standards
- Increased HVAC efficiency standards
- Increased envelope requirements
- Required PV on rooftop
- Energy performance disclosure
- Mandate performance relative to BERDO
- Expanded BERDO reporting requirement
- Passive House retrofits
- Lighting efficiency retrofit program
- HVAC efficiency retrofit program
- Envelope efficiency retrofit program
- Deep energy retrofits
- Enhanced commissioning/ RCx
- Demand response
- On-bill saving suggestions
- EV charging
- Energy storage
- Incentives for more efficient appliances
- Cool roofs
- District energy

Growth

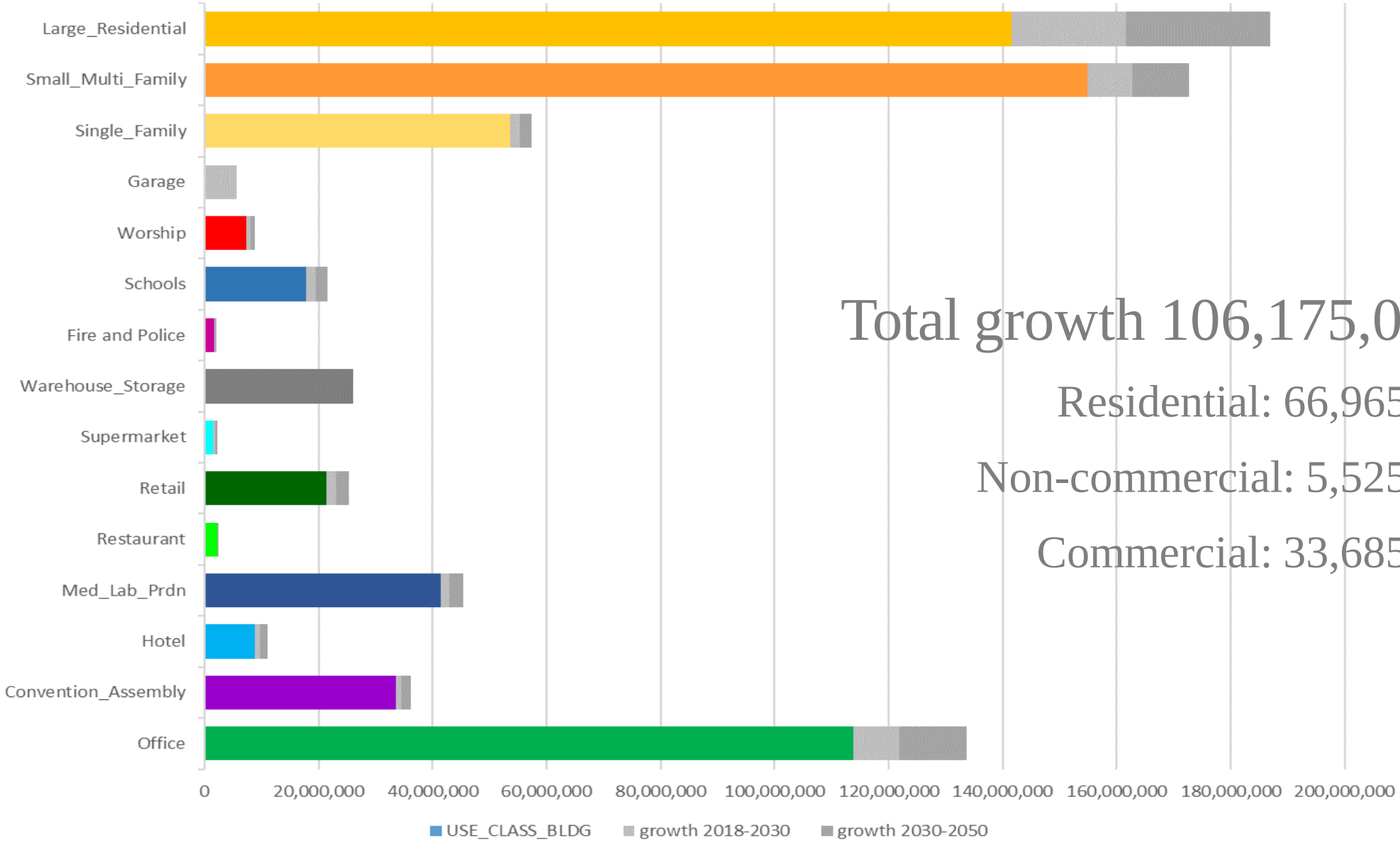
existing **2017 Area (SF)**

turnover − Demolition + Replacement

growth + New Construction

= Future building stock

BUILDING GROWTH



Total growth 106,175,000 SF

Residential: 66,965,000 SF

Non-commercial: 5,525,000 SF

Commercial: 33,685,000 SF

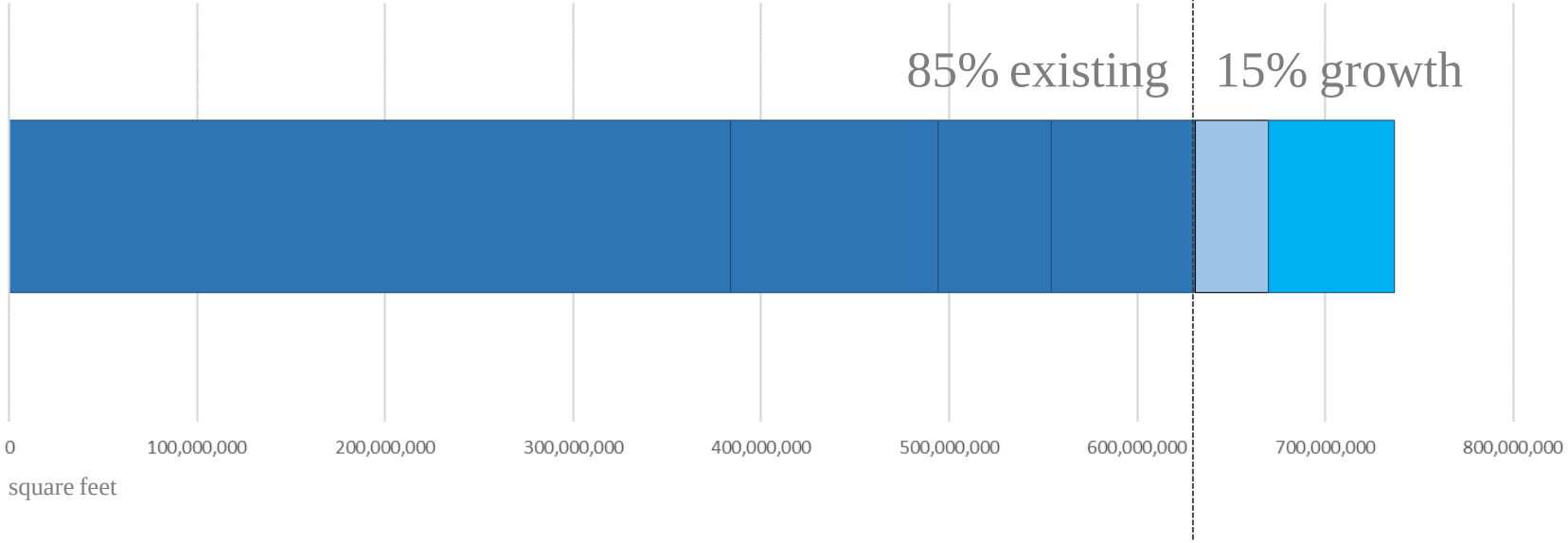
Boston's Building Stock 2050

Total growth 106,175,000 SF

Residential: 66,965,000 SF

Non-commercial: 5,525,000 SF

Commercial: 33,685,000 SF



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WHO IS ADOPTING

Commercial

Public entities

Institutions

Developers

Property owners

Owner occupiers

Tenants

Residential

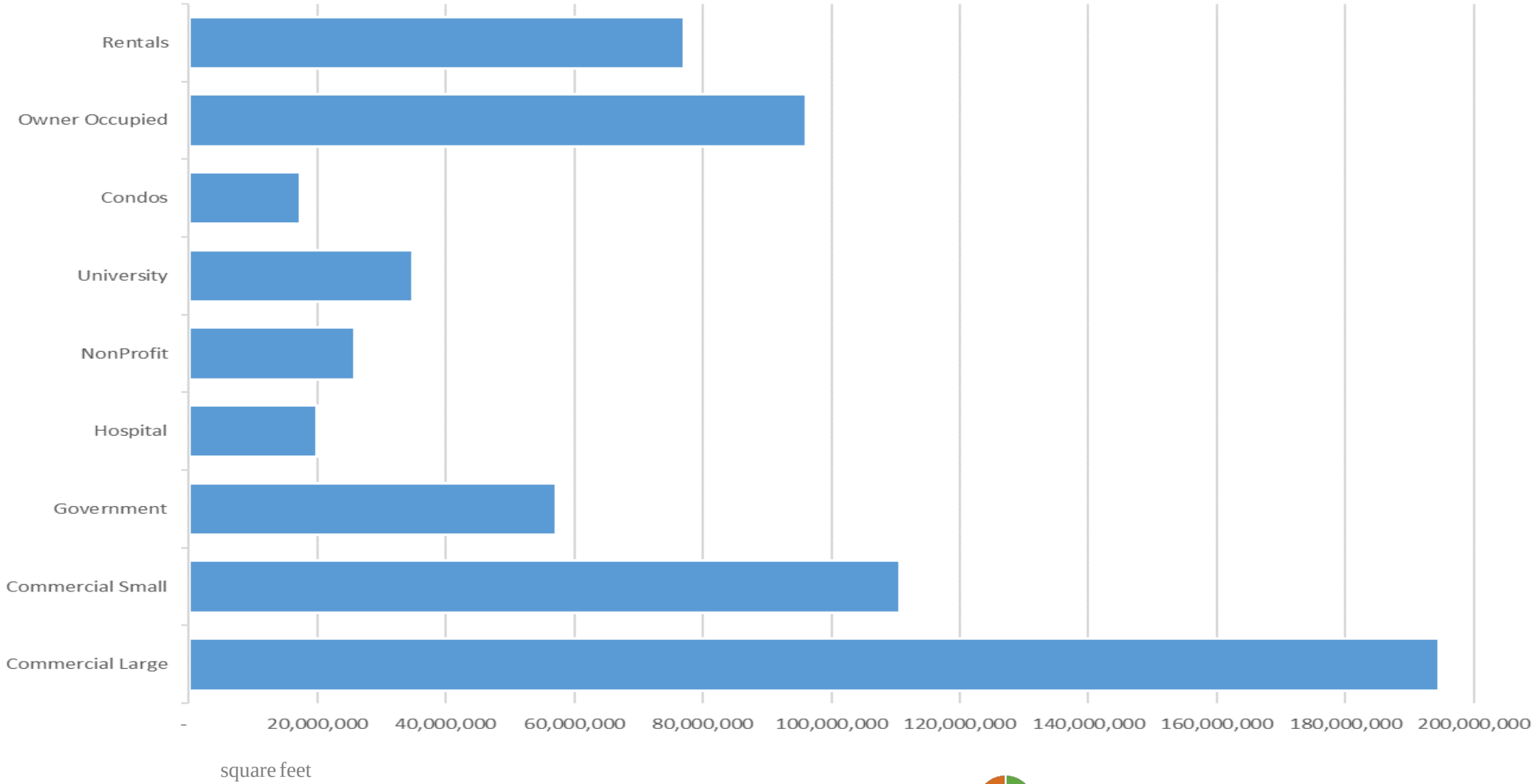
Owners

Condo Associations

Landlords

Tenants

WHO IS ADOPTING



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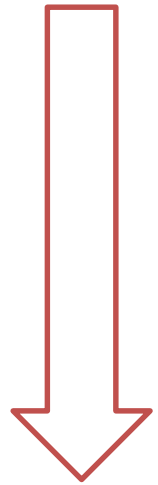
Adoption Rate Methodology

Four (4) to be developed;

- Mandate
- Performance
- Incentive
- Prescriptive

Hierarchy of data;



- Boston
- Massachusetts
- National
- International

Building Energy Reporting Disclosure Ordinance

Mandated disclosure

1st reporting year was 2014 for calendar year 2013	Non-residential buildings > 50,000 SF and Set of non-residential buildings on 1 tax parcel id > 100,000 square feet
1st reporting year was 2016 for calendar year 2015	Non-residential buildings > 35,000 SF
1st reporting year was 2015 for calendar year 2014	Residential buildings > 50,000 SF or 50 units
1st reporting year was 2017 for calendar year 2016	Residential buildings > 35,000 SF or 35 units

Building Energy Reporting Disclosure Ordinance

Mandated disclosure and buildings to complete an energy action or assessment every five years beginning in 2019

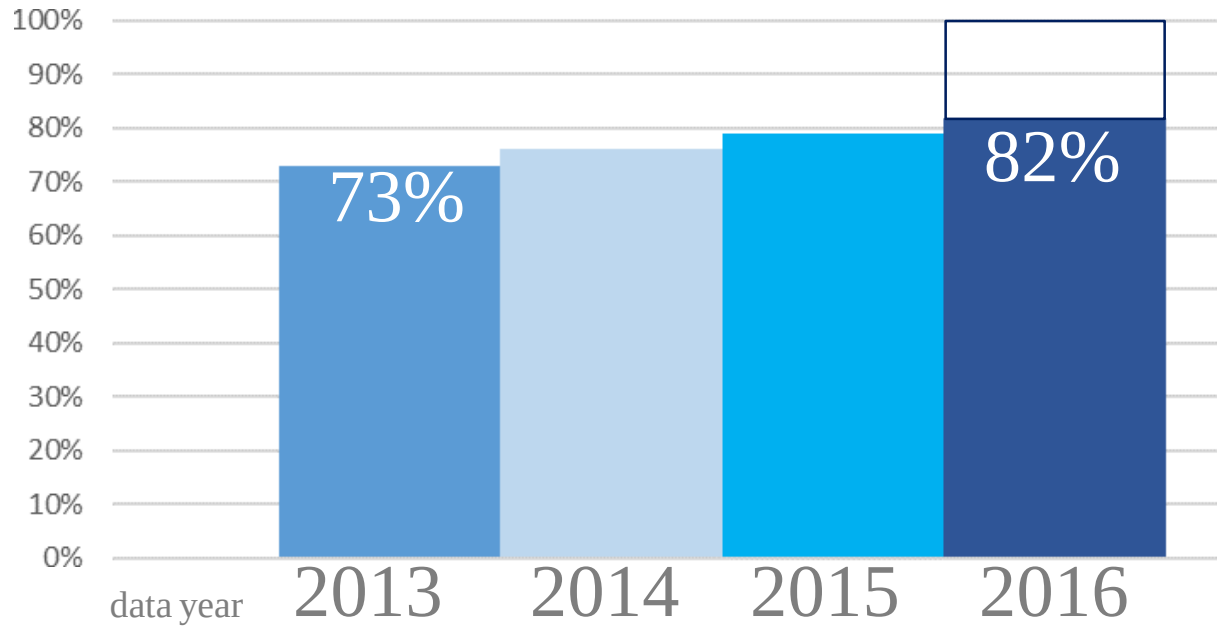
Owner or tenant shall be subject to enforcement or penalties for failure to comply with the requirements of this ordinance during the first year of their required compliance set forth in subsection (d).

Violations range from $35.00 - $200.00 per violation, up to $3,000 per calendar year.

Building Energy Reporting Disclosure Ordinance

In 2018, BERDO requires the following portfolios to report their annual energy and water usage for January 1, 2017 - December 31, 2017:

- Nonresidential buildings that are 35,000 square feet or larger.
- Residential buildings that are 35,000 square feet or larger, or have 35 or more units.
- Any parcel with multiple buildings that sum to 100,000 square feet or 100 units.



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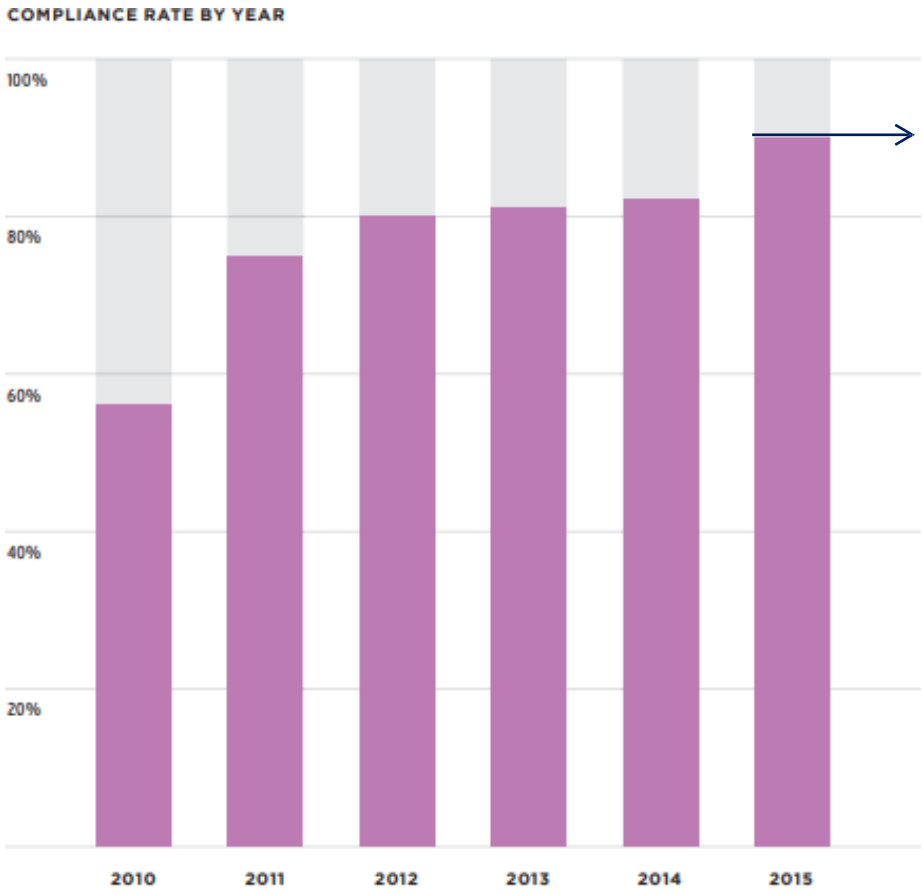
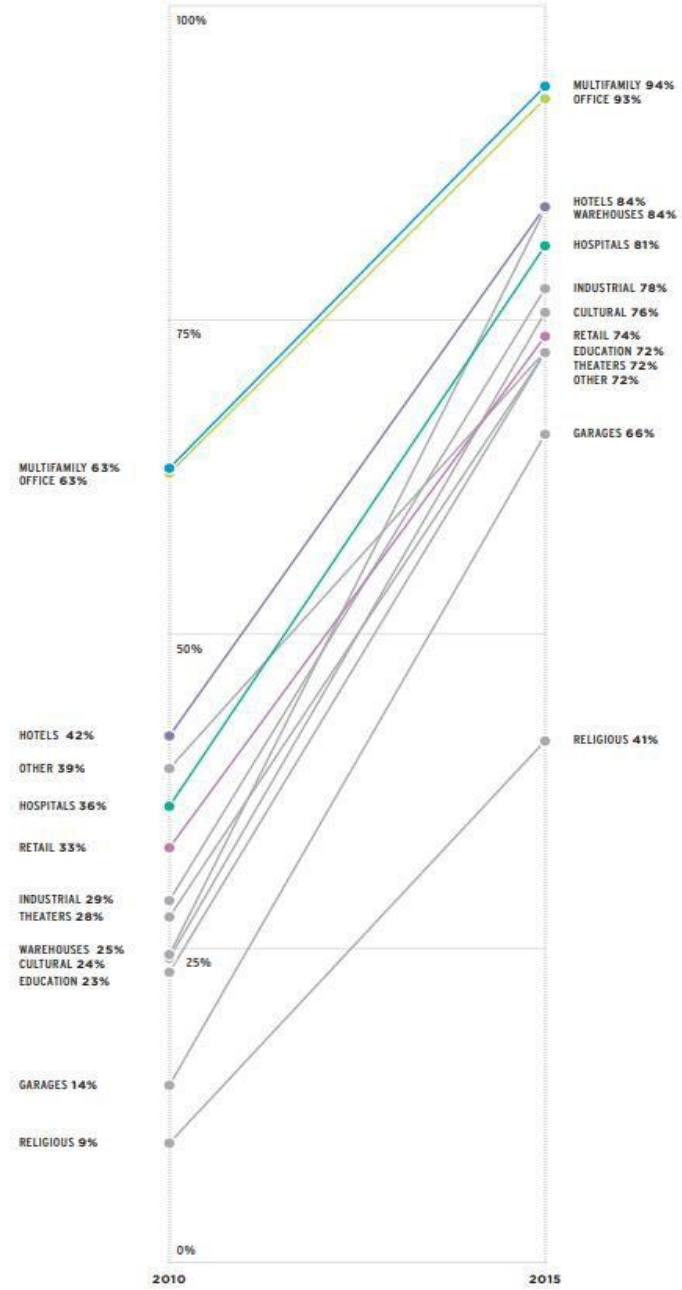
NYC Local Law 84



90%

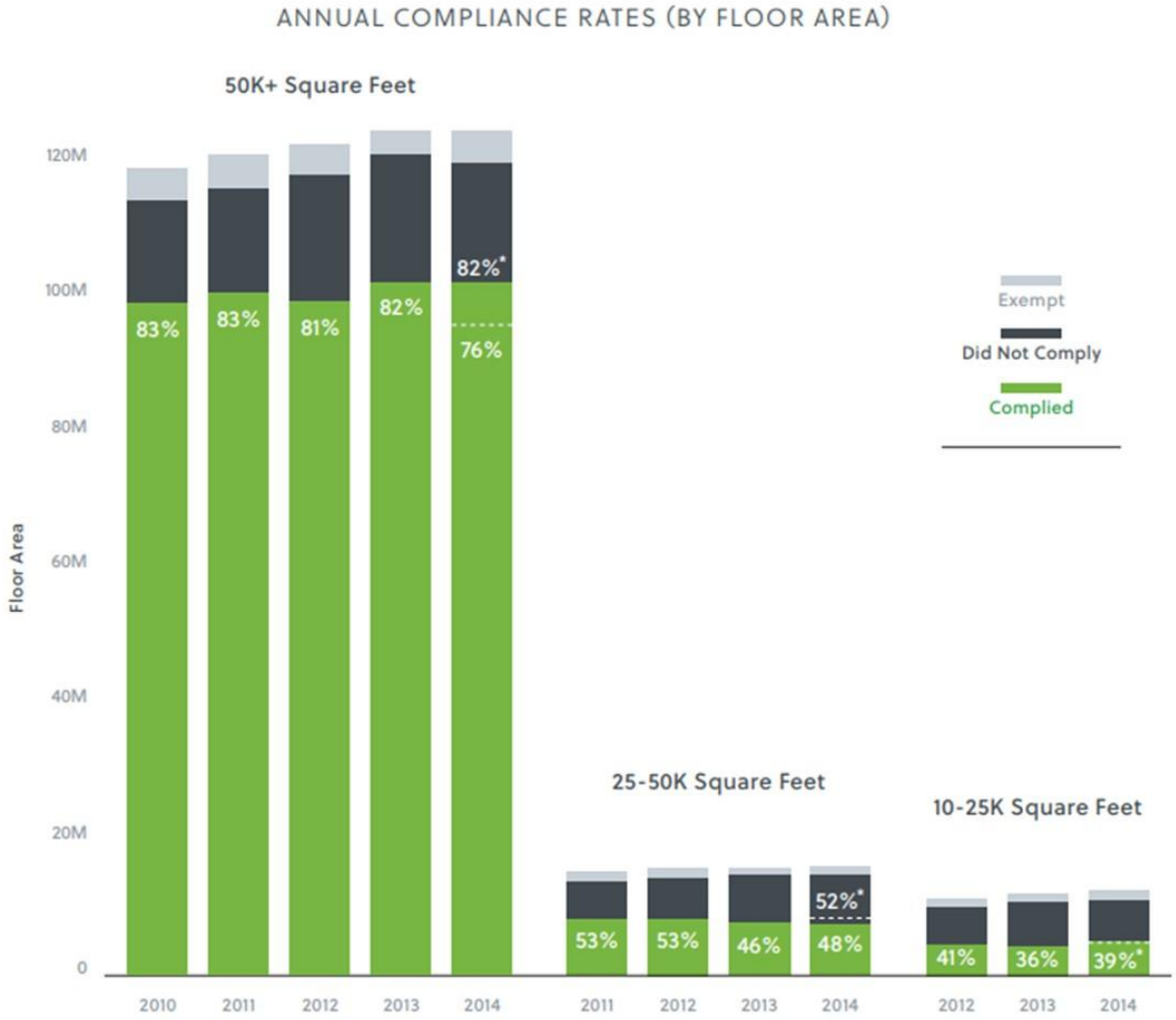
FIGURE 34
Local Law 84 Compliance Rate Changes by Sector
Multifamily and office buildings had the highest benchmarking compliance rate. Since 2010, warehouses and garages have seen the largest compliance improvements.
DATA: LL84 & LL84 COVERED BUILDING LIST



Source: http://www.nyc.gov/html/gbee/downloads/pdf/UGC-Benchmarking-Report-101617-FINAL.pdf

ARUP

San Francisco



Source: https://sfenvironment.org/sites/default/files/fliers/files/sfe_gb_ecb_performancereport.pdf

Existing Commercial Buildings (ECB) Energy Performance Ordinance

Commercial buildings > 10,000 sf conditioned space

1,847 private sector buildings applicable +

465 municipal facilities and schools

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QUESTIONS

- What does this tell us for the future programs we need to design?
- How should Carbon Free Boston be categorizing various owner classes?
- What strategies will be best driven by incentives, what strategies will be best driven by mandates?
- How can we leverage limited data on adoption from those existing programs and policies in Boston and in other cities to inform our forecasts and policy design?
- Neutrality will require a large scale technology transition on existing buildings that has not yet been experienced. How does Carbon Free Boston forecast behavior?
- What barriers to deep adoption will Boston experience? How can these barriers be overcome?

Modeling Case Study: Office Retrofit

Natural Gas

Electricity

Emissions Intensity
(kg CO_2eq per square foot)

EFFICIENCY:
- Retro-commissioning
- Equipment replacement
- Envelope improvement
- Lighting retrofit
- Deep-energy retrofits

With **80%** Renewable Grid

THERMAL ELECTRIFICATION:
- Hydronic conversion
- Water-source heat pumps
- Electric boiler

With **80%** Renewable Grid

GETTING TO ZERO:
- Rooftop solar
- Renewable procurement
- Offsets

Current → With Efficiency Measures Only → Efficiency + Thermal Electrification → Zero GHG

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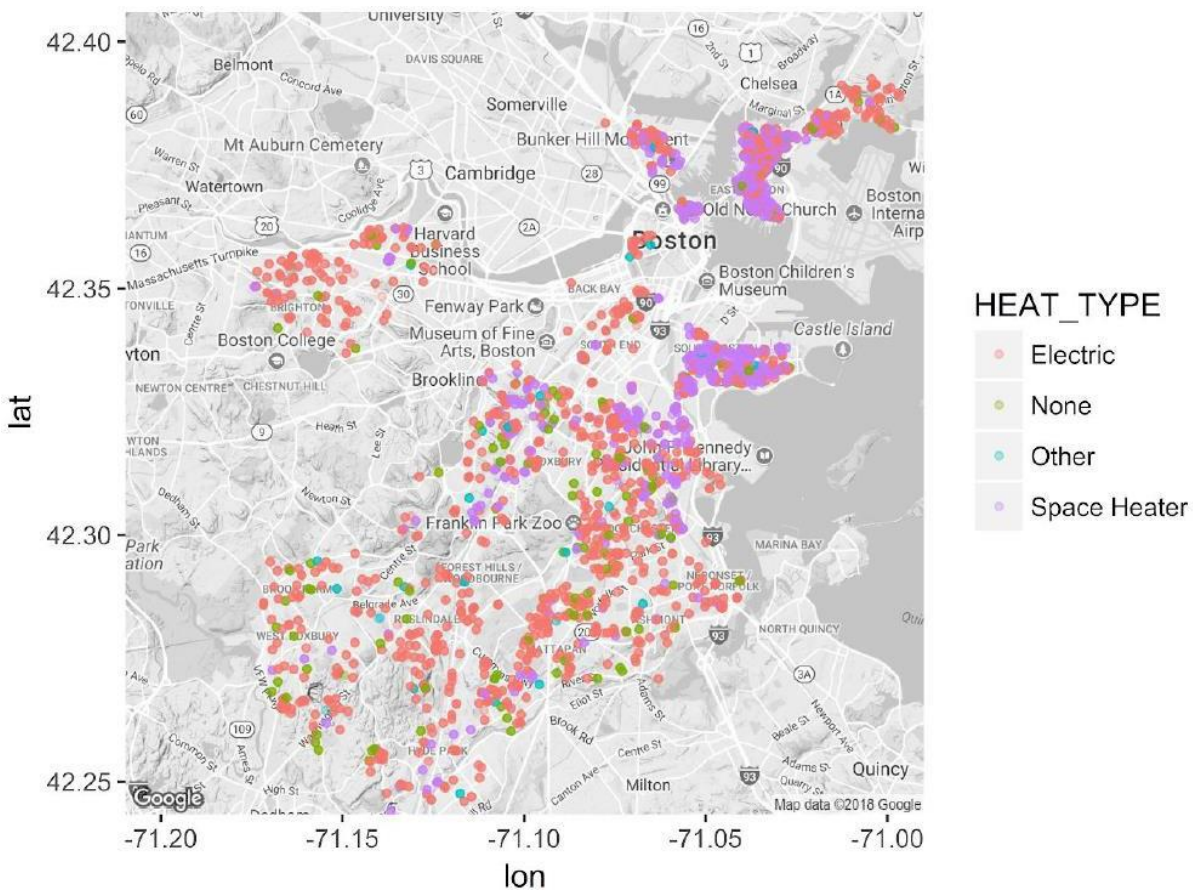
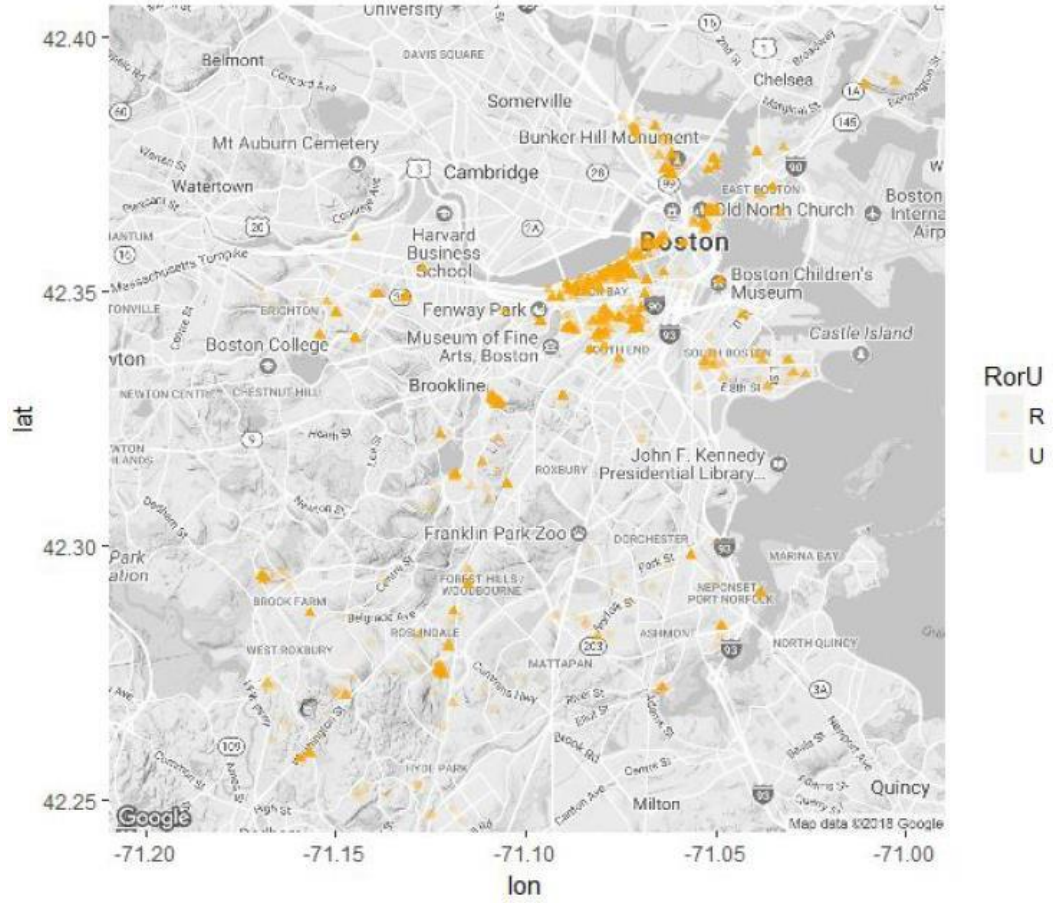
Equity in the Buildings Sector Heating Type



Conventional Electric Heating



Heat Pumps

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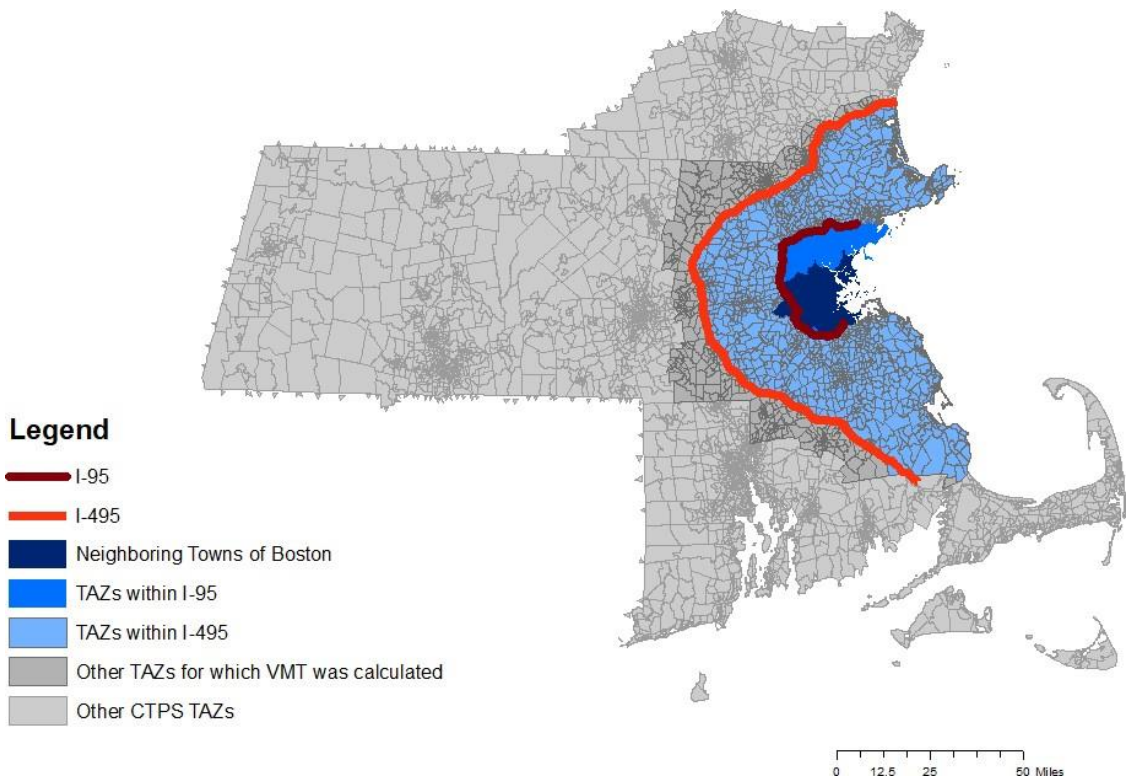
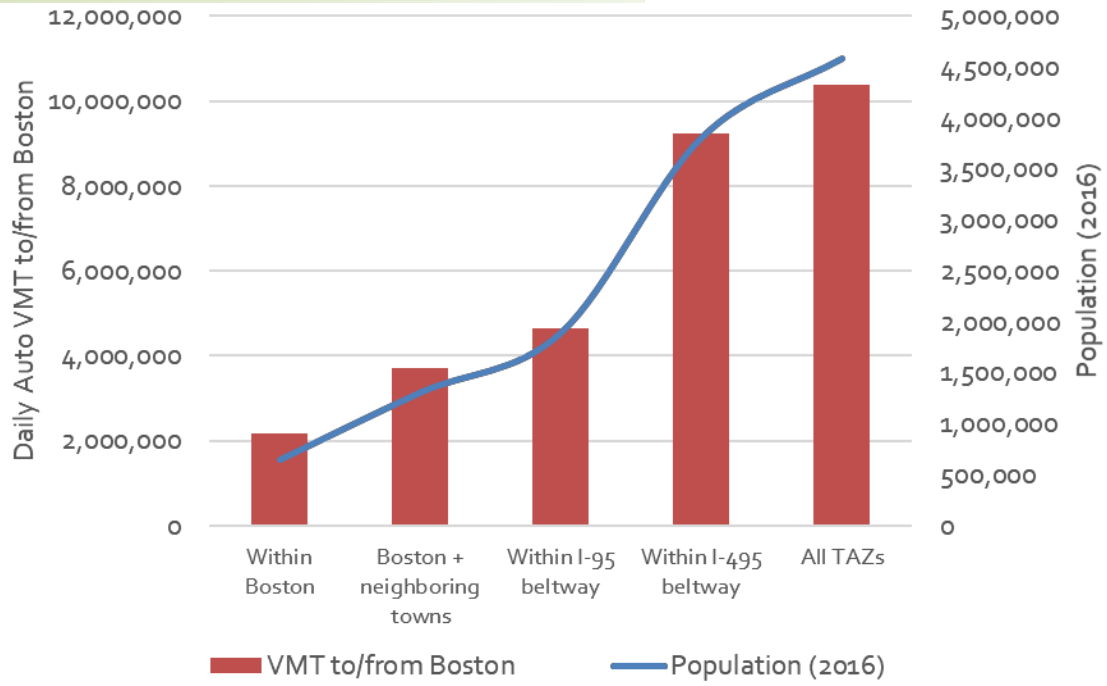
Boston's Transportation Ecosystem





	# of TAZs	Population (2016)	Daily Auto VMT to/from Boston
All TAZs	2730	4,581,650	10,378,614
Within Boston	447	645,570	2,181,776
Boston + neighboring towns	844	1,306,816	3,705,161
Within I-95 beltway	1092	1,893,541	4,634,740
Within I-495 beltway	2208	3,806,442	9,238,448

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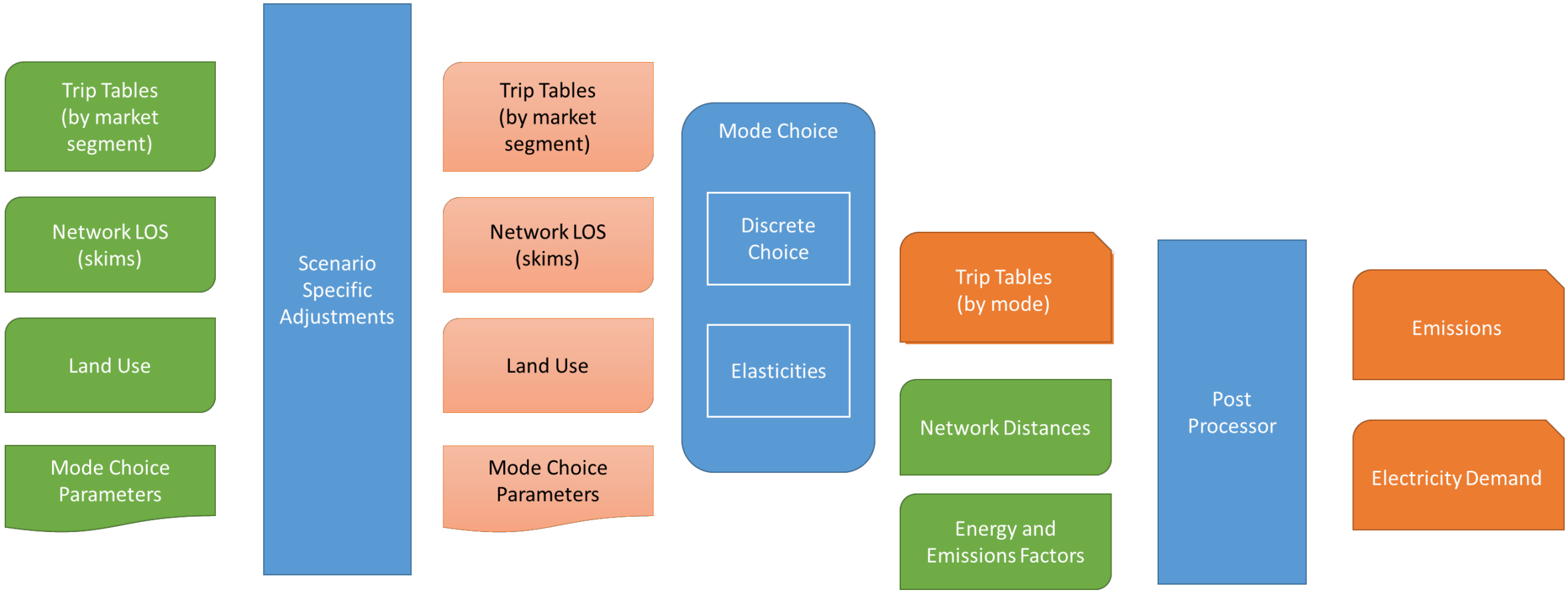
Transportation Sector Model



Transportation Model Segments

Travel Behavior

- Trip purposes
  - Work
  - School
  - University
  - Pick-up / drop-off
  - Non-home based

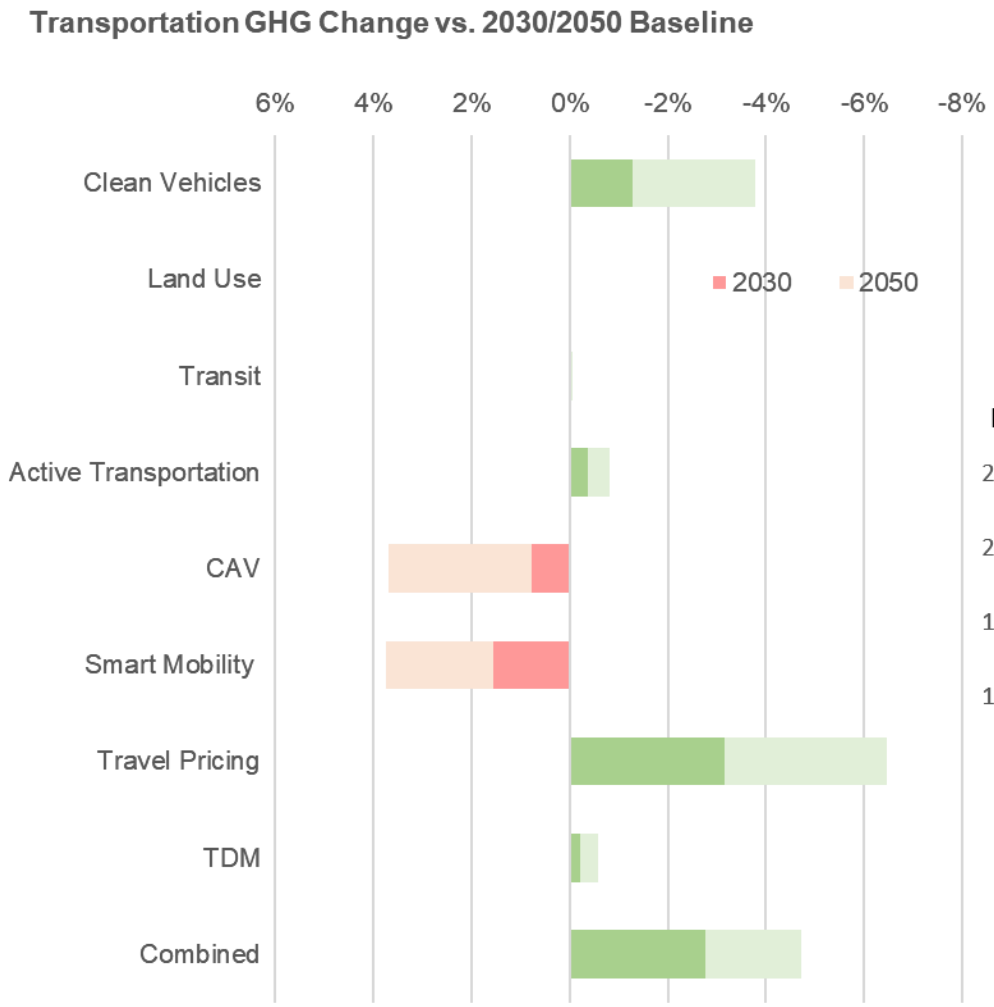
Level of Service

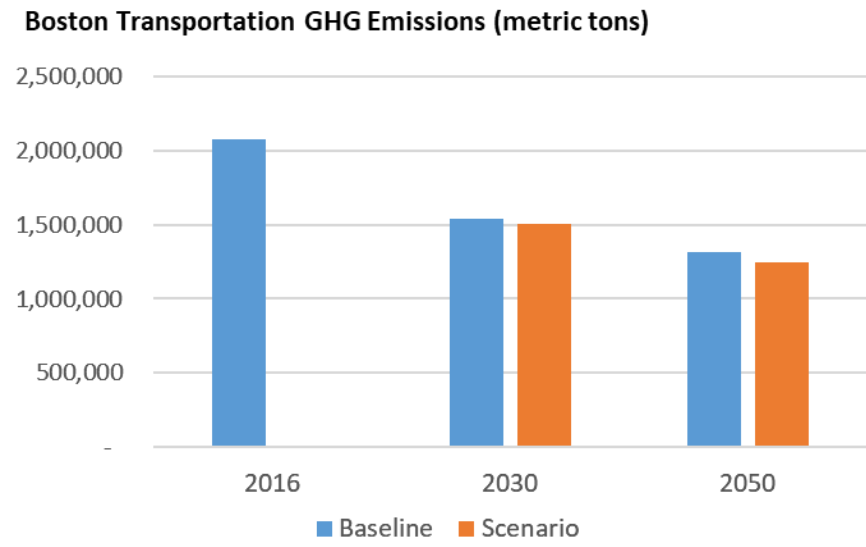
- Auto travel time (in and out of vehicle) and cost (tolls and operating costs)
- Transit travel time (in and out of vehicle) and cost (fare)
- Non-motorized distance and time

Trips

- Production (home-end) to attraction (activity-end)
- Mode
  - Drive Alone
  - Shared-Ride (2/3+ for Work)
  - Bike
  - Walk
  - Walk to Transit
  - Drive to Transit (Bus, Subway, Commuter Rail, Boat)
- Time of day
  - AM
  - MD
  - PM
  - NT

TRANSPORTATION: LOW IMPACT SCENARIO





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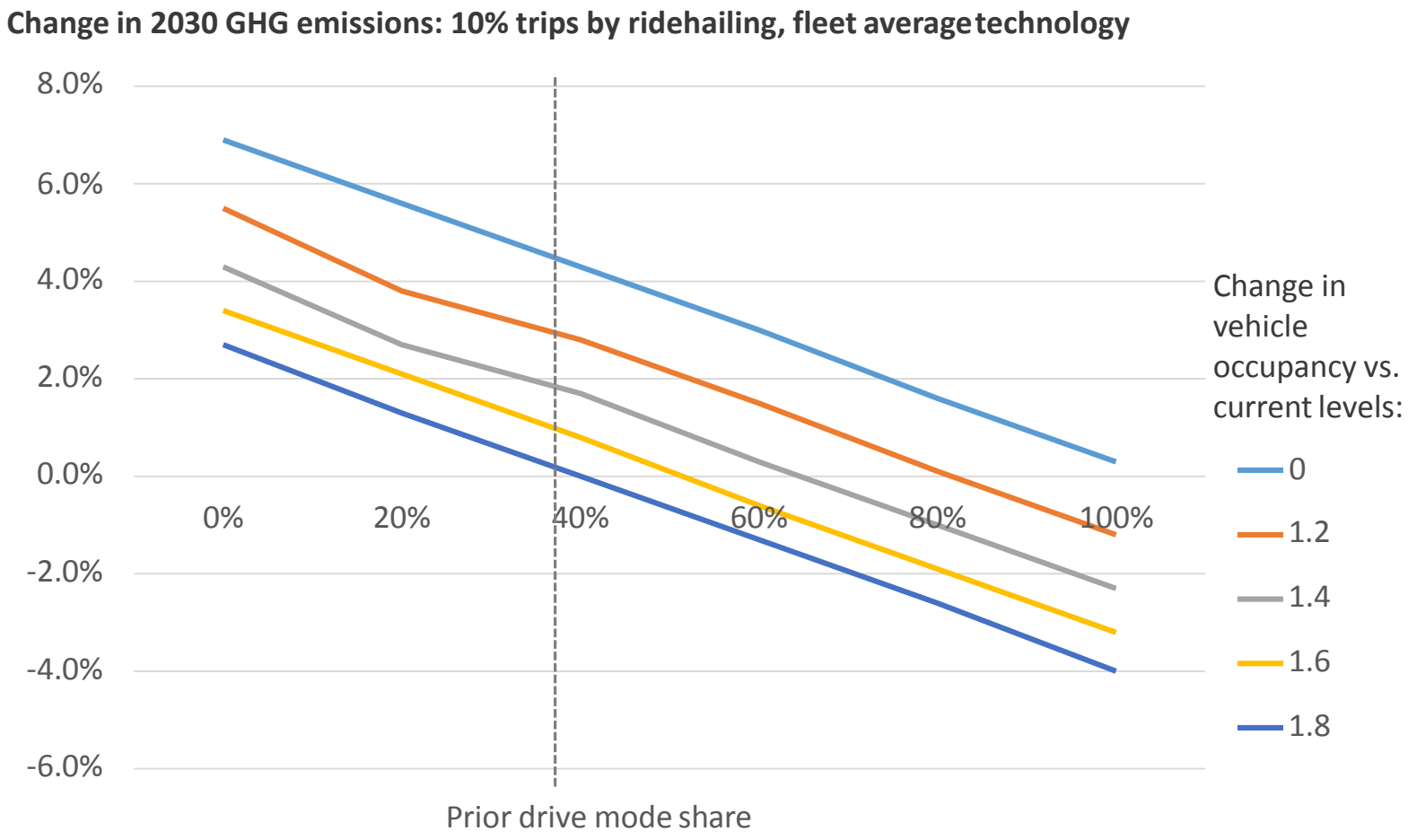
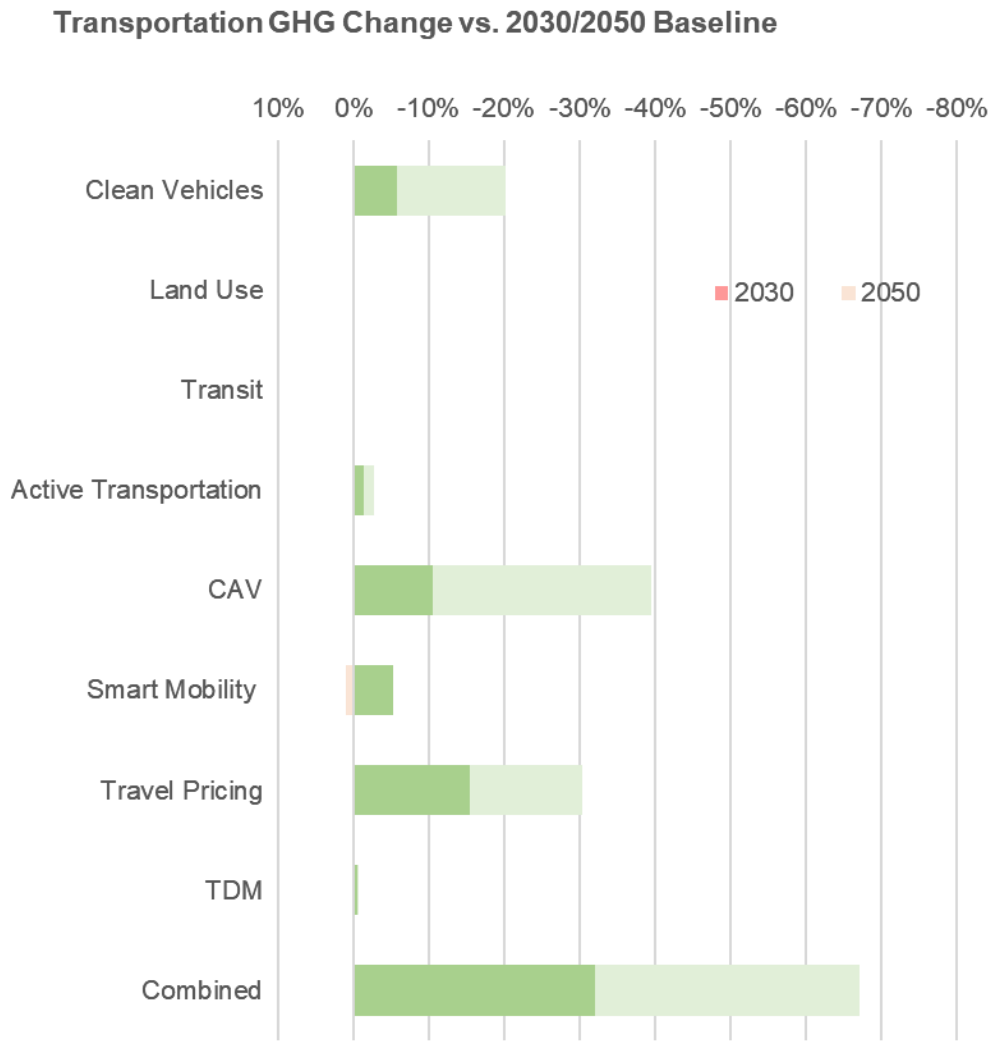
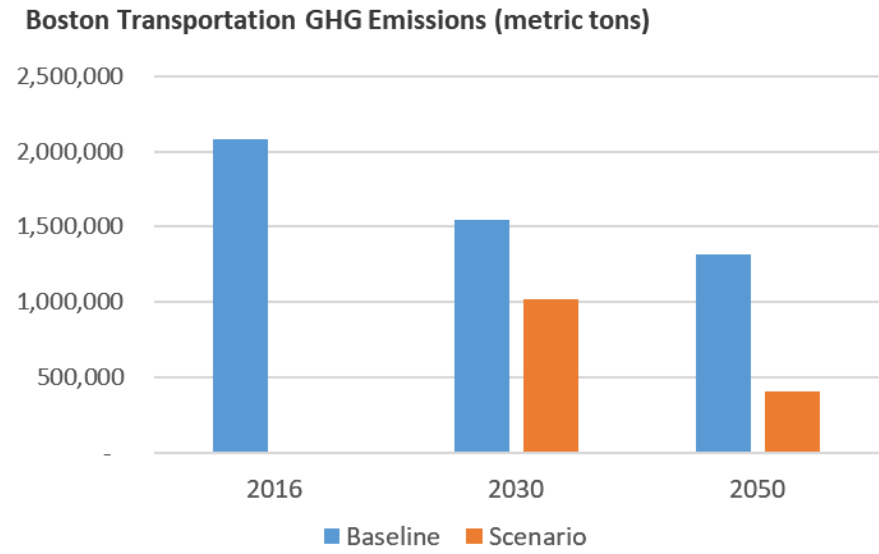
Interactive Effects: Smart Mobility



TRANSPORTATION: HIGH IMPACT SCENARIO





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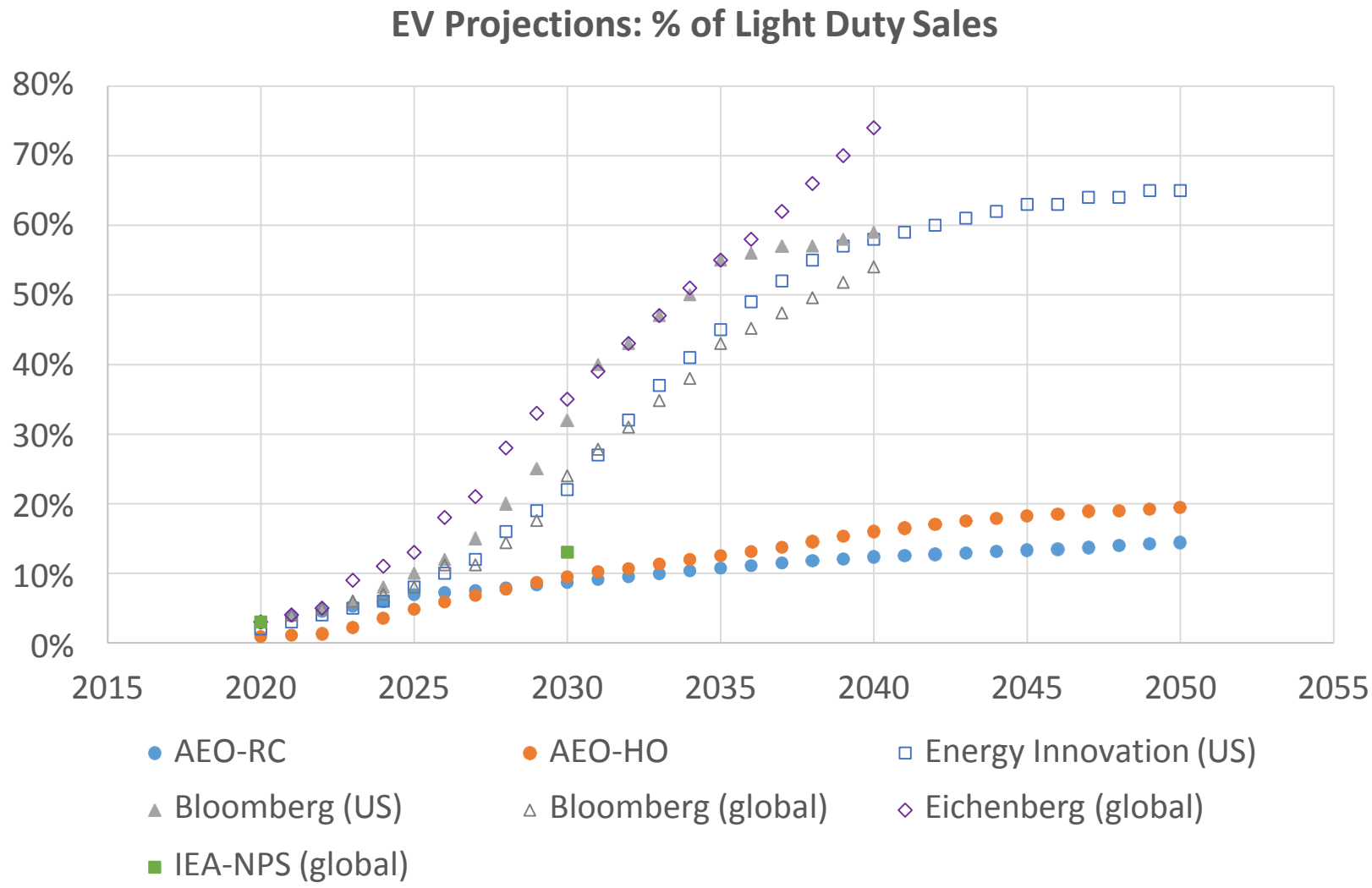
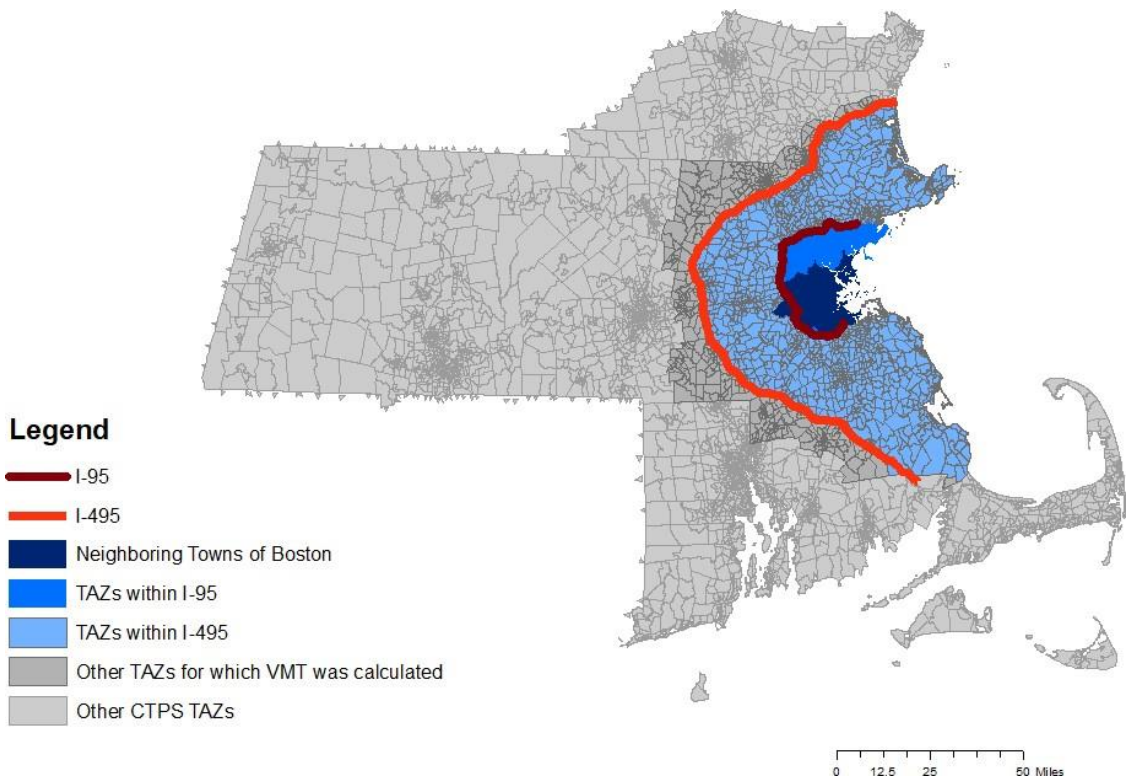
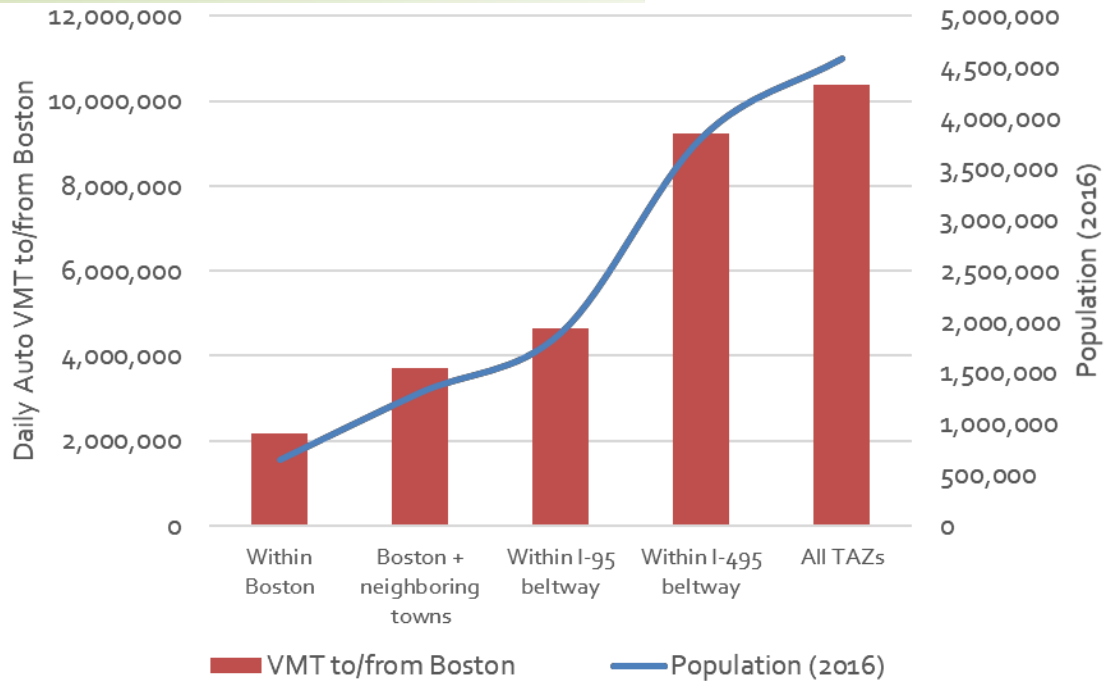
Uncertainty In Future Technologies



Boston's Transportation Ecosystem





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Co-Benefits & Equity in Transportation Sector

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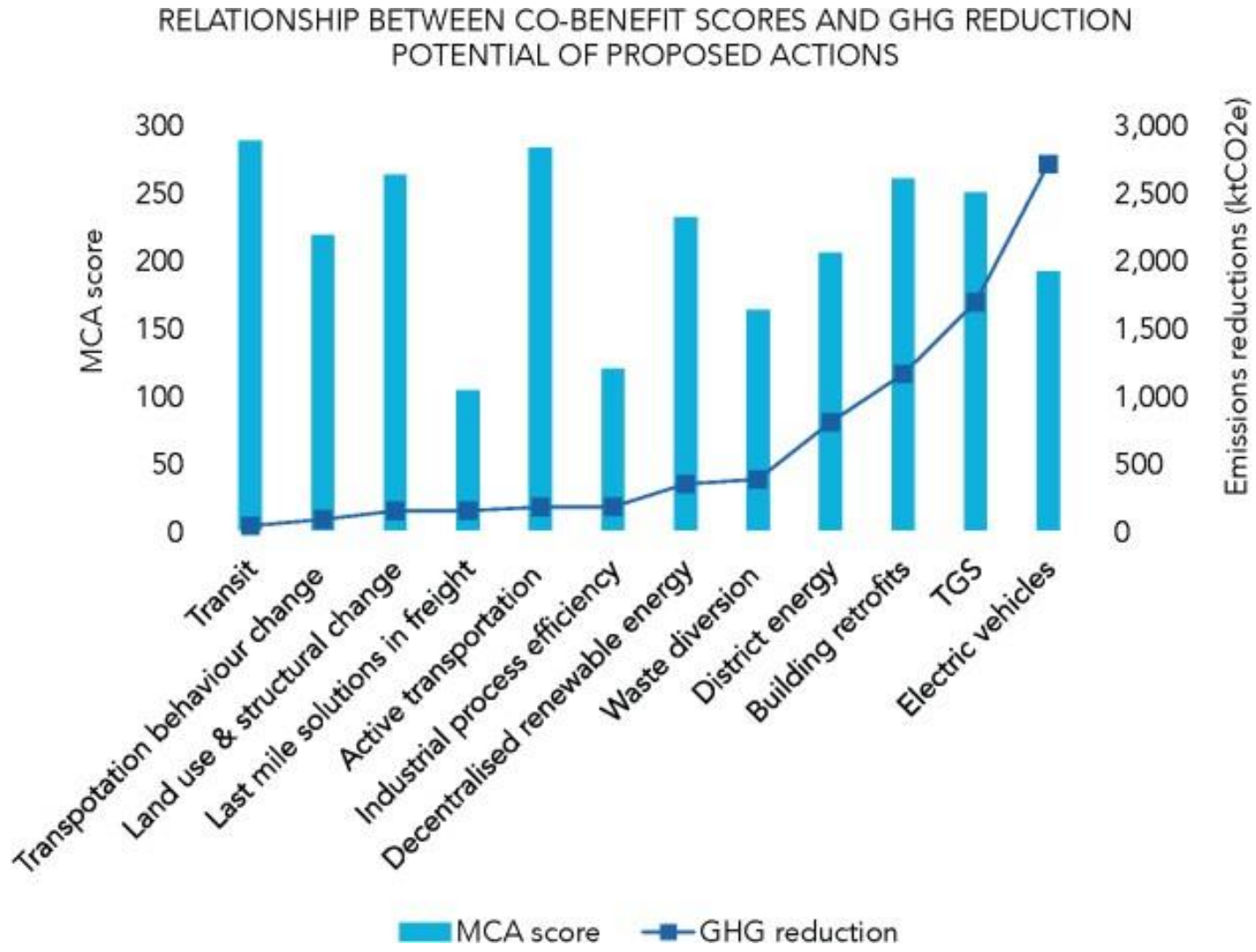
Co-Benefits & Equity in Transportation Sector



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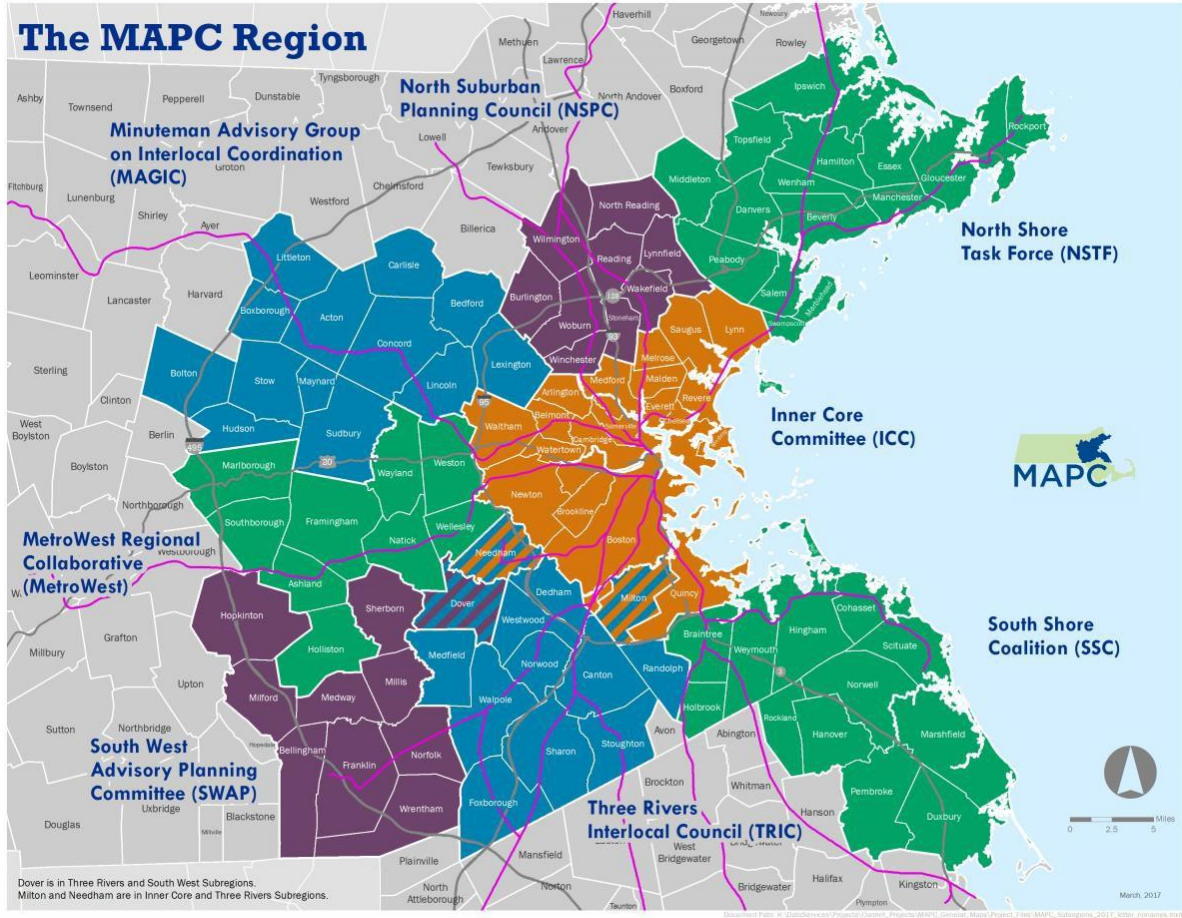
56 % QUICK
19% EXERCISE
6% INEXPENSIVE
1% ENVIRONMENT
WHY COPENHAGENERS CYCLE

Solid Waste

- Boston is going through a zero waste planning process
  - Reduce waste generation
  - Improve diversion strategies
- Calculating emissions reductions is challenging
  - Waste sector emissions models utilize LCA
  - Displaced production credits are uncertain and not dynamic
- Opens the door to consumption emissions

Long-term Goals

- Scale Approach
  - Partner with Metropolitan Area Planning Council in regional plan update
  - Identify other cities
  - Integrate water planning
- Standardize Platform
  - Cloud based container for easy spin up
- Identify Partners
  - C40
  - National Labs/JGCRI/EPA/DOE



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DISCUSSION

E+E UNIT UPDATES

YVE TORRIE

DIRECTOR OF SUSTAINABILITY

A BETTER CITY

SUSTAINABLE BUILDINGS INITIATIVE

- BERDO Focus Group
- Boston Smart Utilities Workshop
- Case Studies

GREEN RIBBON COMMISSION COMMERCIAL REAL ESTATE WORKING GROUP

- Final deliverables from 2017-2018 Workplan:
  - Memo on city level resilience audit /retrofit program
  - Memo on city E+ program for small commercial
- EEAC Comments
- Flood Resiliency Overlay Zoning & Design Guidelines

POLICY AGENDA

1. Environmental Bond Bill
2. An Act to Promote a Clean Energy Future

A BETTER CITY

For more information contact
Yve Torrie

Ytorrie@ABetterCity.org 617.502.6247