The Boston Climate Progress Report:

MAKING THINGS WORK: RETROFITTING THE SMALL BUILDING STOCK FOR BOSTON'S CLIMATE GOALS

A big lift necessary for Boston's climate progress

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By the **Dukakis Center for Urban and Regional Policy at Northeastern University**

SUPPLEMENTARY CHAPTER

1

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Boston's single-family and small multifamily homes are not being retrofitted at a sufficient extent or pace to support the city's climate goals. The residents of this stock, many of whom are renters, largely reflect the city's demographics. Nearly a third experience utility bills that are a burden relative to their income.

Achieving equitable decarbonization necessitates the promulgation of electrification and efficiency measures across this stock in a way that can substantially reduce—if not eliminate—emissions, lower the energy burden for the city's least well-off, and increase the quality of the living space enabling Boston's residents to thrive. Not only will this help to achieve Boston's climate goals, it will also improve health outcomes and increase the value of the building stock.

Ten thousand households (or 5,000 buildings) per year will need an intervention. In the near term, this includes electrifying appliances, simple insulation and air sealing, and getting heat pumps into homes in all possible arrangements, even if existing fossil fuel heating systems are retained and used as a backup. In the long term, this means steadily deeper efficiency retrofits and removing fuel use completely. Between 2019 and 2021, only 17 homes were fully electrified as part of a Massachusetts Clean Energy Center (MassCEC) pilot program. Permitted installations of heat pumps in any arrangement in 2021 were well under 200 but showed modest gains each year. This is a fraction of like-for-like gas system replacements and oil-to-gas conversions. While the 2022–2024 MassSave program significantly increases incentives and resources for building electrification and efficiency, it is too early to assess its impact.

The nature of Boston's small building stock and the nature of the interventions needed present several significant challenges.

Challenge 1:

Most of this stock is old, drafty, and dependent on fossil fuels for heating. Further, the stock is extensive and exhibits socioeconomic characteristics poorly suited for the rapid promulgation of improvements. Most residents and building owners do not have the financial or logistical capability to pursue such upgrades. Decarbonizing Boston's small building stock will require ongoing and progressive efforts to electrify current uses of fuels, enhance the buildings' energy use efficiency through improvements to the exterior shells, upgrade electrical systems, add solar panels, operate smartly with the grid, and potentially connect to new thermal distribution systems.

Challenge 2:

While full building electrification with deep energy savings can be done now, the market cannot yet deliver a decarbonization retrofit product for gas-served homes cost-effectively. The supply chains and workforce needed to facilitate this transition are in a state of growth but concerningly constrained. Many contractors dissuade customers from electrification strategies. There are now year-long waiting lists for some interventions.

Challenge 3:

The building stock is entangled in an old leaky gas system. An unmanaged exit of customers from it can burden those who cannot leave with higher costs. There are many examples where the cost of replacing a peripheral leak-prone gas pipe is significantly greater than the cost of closing the pipe and removing connected homes from gas service. Given the pending reduction in gas demand driven by electrification, there is a significant concern that those who are less able to electrify—renters and residents with lower access to financing and information—will be burdened with the cost of maintaining an increasingly underutilized and expensive-to-maintain system.

Challenge 4:

Current data resources and progress metrics are insufficient to guide the transition to ensure steady emissions reductions, manage costs, and ensure equitable outcomes. We have made the above assessments using several existing public datasets. However, ongoing evaluation of progress is challenged by the incompleteness of datasets and gaps within existing datasets. In particular, there are severe limitations in tracking how the transition impacts vulnerable communities.

This chapter reviews a long history of energy transitions in Boston and actions beyond the city to understand these challenges and potential solutions better. We identify four central action areas that need to be pursued by various entities to ensure that this stock makes sufficient progress in support of Boston's climate and equity goals.

ACTION AREA 1: Signal a Paradigm Shift to an Electric, Efficient, and Integrated Building Stock through:

1. **New Building Performance Standards:** Boston needs to advance its Zero Net Carbon Building Code. Massachusetts needs to require all-electric new construction for small residential buildings. Any questions regarding their cost effectiveness have been settled by both the state's recent analysis of new building construction and the incentives provided by the Inflation Recovery Act (IRA).
2. **Appliance Standards:** The state needs to anticipate the potential phaseout of replacement gas furnaces, boilers, and appliances and start developing a phaseout strategy similar to what is being done with non-zero-emissions vehicles as required by the state's recent climate legislation.
3. **Financing and Incentives:** The 2022–2024 MassSave plan significantly increases the incentives for building electrification. The Commonwealth and the City of Boston, with support from the Energy Efficiency Advisory Council, Action for Boston Community Development (ABCD), and utilities, need to immediately seek to understand how they can leverage the direct and programmatic funding offered by the Inflation Reduction Act to accelerate the adoption of electric appliances, upgrade home electric systems, and promulgate building electrification and efficiency upgrades. Particular attention should focus on prioritizing funding for low-income populations.
4. **Education and Engagement:** The City (through various agencies), ABCD, and numerous community organizations need to familiarize residents with the change that is coming, the benefits that it will bring, and what will be expected of them. This should happen in schools, churches, playgrounds, and other community spaces. Residents need to understand that this is as much about raising their homes' health, comfort, and livability standards as it is about reducing emissions. These are people's homes; for the city's population to thrive, their needs should be placed first as the transition evolves.

ACTION AREA 2: Develop the Market on the Supply Side through:

1. **Promoting Supportive Business Models:** The state and utilities should devise programs that make it easier for residents and homeowners to do more. Financing approaches such as on-bill financing, performance contracting, or property-assessed clean energy strategies have all yielded mixed results in the building sector. Still, these programs may need a second look as home retrofits scale in depth and numbers.

2. **Aggressively Pushing Down Costs:** Scaling electrification and deep efficiency practices through standardization and prefabrication will reduce costs. However, the industry may need a specific boost from dedicated investments or commitments. Such efforts are likely to start with state-sponsored pilot and incentive programs in large and medium-sized buildings that will trickle down capabilities to the small building stock.
3. **Developing a Capable Workforce:** This effort starts by engaging with local trades to identify the required skills (and training mechanisms needed to deliver those skills) at all career levels. It also seeks to eliminate historical barriers to women and people of color to maximize the potential pool of workers.

ACTION AREA 3: Ensure an Equitable Transition of Gas through:

1. **Developing Gas Transition Plans:** The state, mainly through regulation by the Department of Public Utilities (DPU), needs to develop a framework for the ongoing rightsizing of the gas system. Such a framework should also critically evaluate how to avoid burdening low-income households with the cost of this transition. The City should start developing its own gas transition and energy planning framework.
2. **Conducting Transition Implementation Pilot Studies:** In partnership with its gas and electric utilities, the City, MassCEC, and ABCD should immediately pursue and study street and neighborhood-level implementation pilots for various strategies to transition these areas off the gas network. The DPU would need to approve those pilots.

ACTION AREA 4: Improve Data Collection and Metrics through:

1. **Improving City Tracking of Energy Assets and Interventions:** The City, with support from the state in developing standards, should improve the Assessor's Office and Inspectional Services Division's tracking of building energy systems (heating type, fuel used, insulation, etc.).
2. **Requiring MassSave to Provide More Detail:** MassSave's energy spending and intervention reports should include more detailed data (e.g., detailed cost breakdowns, labor utilized, geographic information) to enable a better understanding of investment trends and patterns, particularly in how low-income communities benefit from the program.

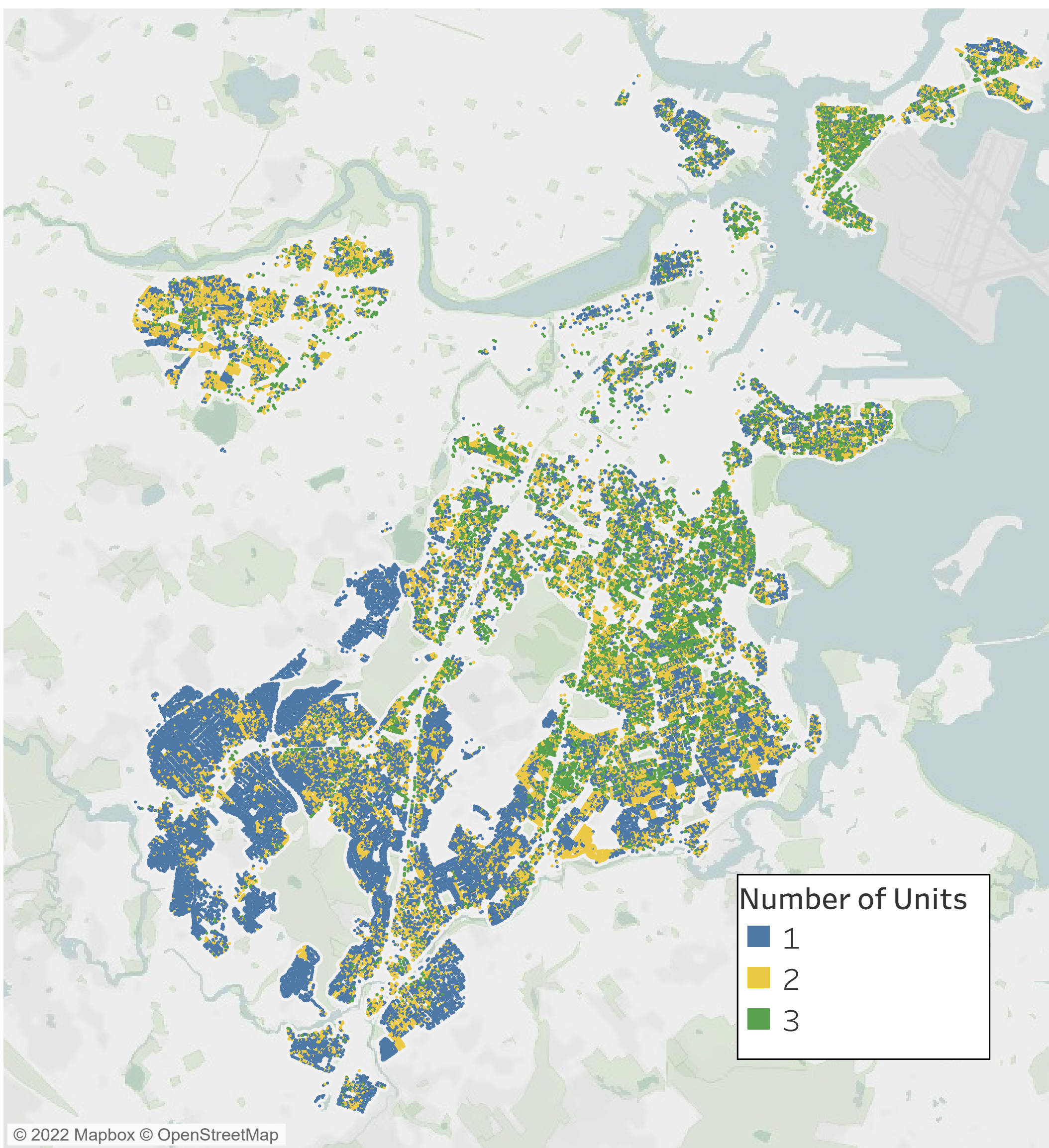
Boston—homeowners, residents, municipal government, community organizations, contractors—cannot decarbonize the small building stock without comprehensive state and federal action. However, it has an important role to play in catalyzing it, accelerating it, and making it more equitable.

2. INTRODUCTION

There are more than 275,000 households in Boston. Approximately half of them reside in nearly 70,000 single-family, two-family, and three-family buildings (Figure 1)—the *small residential building stock*. Eighty percent of these buildings were built before the Great Depression, ranging from the Revolutionary-era stately brick homes of Beacon Hill to the ubiquitous triple-deckers across the city that housed many immigrants arriving in Boston at the start of the 20th century. A smattering of postwar single-family homes encompasses the southern part of the city.

Figure 1. **Location of small multifamily housing colored by its number of units.**

Source: Boston Tax Assessor's Database



The city's small multifamily homes provided a pathway to wealth-building for immigrants who bought them and could rent out a floor or two.[1] Even for those who rented, the detached design improved livability over the prior era's tenements. While these buildings were built to use heat from the combustion of oil, gas, coal, and wood, they weren't designed to keep heat in. Over time, gas became the dominant heat source, provided by a distribution network that has entangled the city. Some pipes were installed when Lincoln was president.

The benefits this building stock provided to some were not available to all. Redlining scarred the city and limited the ability of African Americans—notably those arriving during the second great migration—to build wealth.[2] Social unrest in the 1960s and 1970s precipitated "White flight" from the city, leading to increased vacancy, underinvestment, and general deterioration of the building stock.[3]

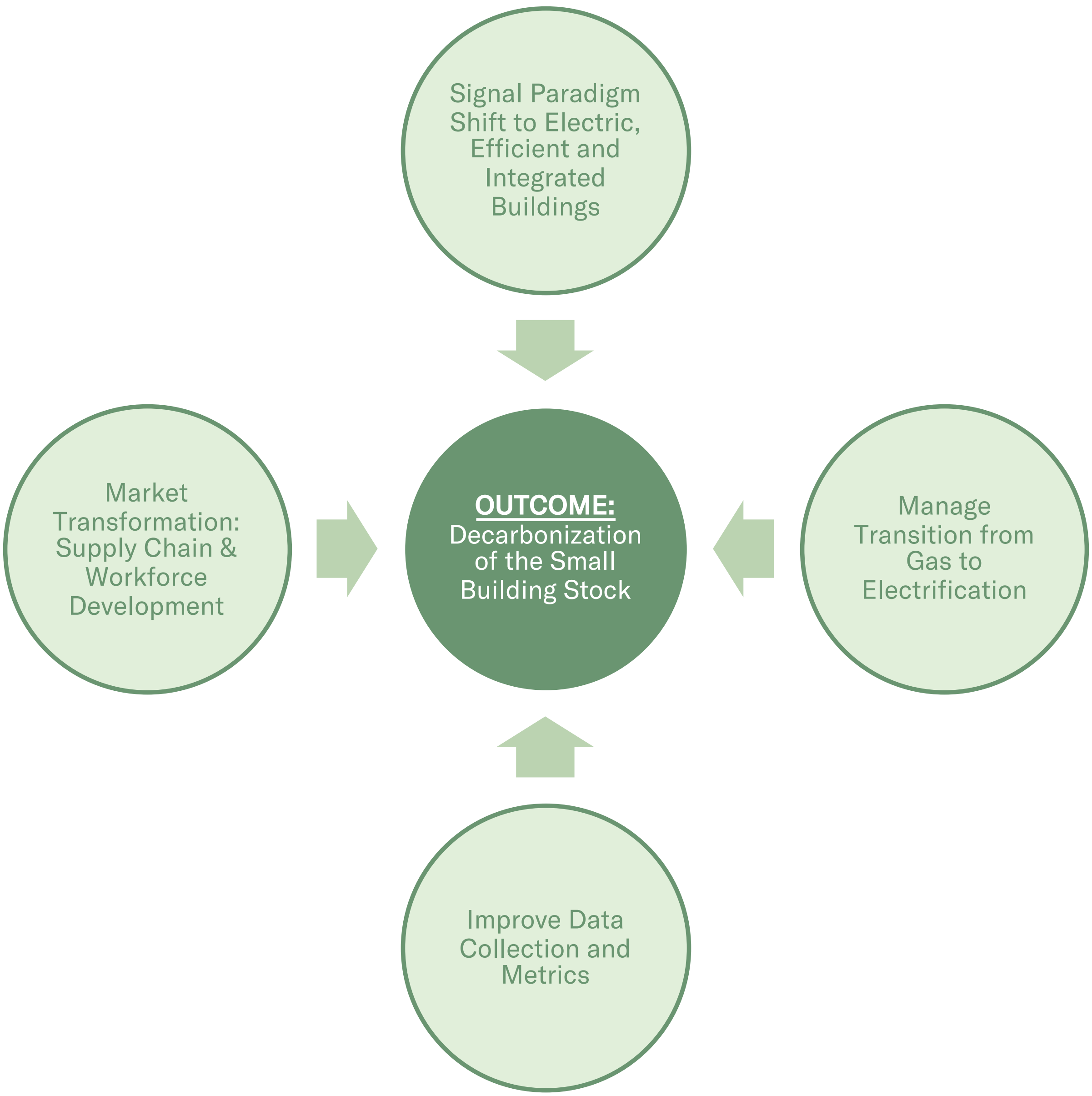
Following a period of rapid population and economic growth, many of Boston's residents are now crunched by the increasing cost of housing. While this boom has resulted in reinvestment in the building stock, it has led to displacement. Any associated improvements in the buildings' energy use have not been sufficient to align this stock with the City's climate goals. Simply put, Boston's small residential stock is not on track to provide basic societal needs,[4] let alone be decarbonized.

Carbon Free Boston[5] identified that electrification and substantial energy efficiency investments are needed to align Boston's building stock with the City's climate objectives. The report acknowledged the challenge of retrofitting Boston's building stock, notably its multitudinous century-old small residential stock. Since the report's release in 2019, there have been notable improvements in the performance of heat pumps and other electric technologies, strategies for achieving deep efficiency, and pilots in district-scale heating and cooling that have lowered the perceived challenges in this sector. Still, the challenges of cost, industry scaling, consumer acceptance, energy supply, and the sheer number of buildings are daunting—on average, 50 homes per week will need to be retrofitted over the next three decades.

The inaugural *Boston Climate Progress Report* focuses on these small residential buildings because the sector still lacks a comprehensive framework for ensuring equitable decarbonization to meet Boston's ambitious climate goals. This stands in contrast to the large building sector, which despite technical hurdles, has been *aligned in the direction of neutrality* through the City's updated Building Energy Disclosure Ordinance,[6] and in which strategies for broad decarbonization—such as the electrification of district steam—have begun to emerge.[7]

This report finds that *no such sectoral alignment has been made for the small residential sector and that there are real deficiencies in the small building sector transition,* despite recent, albeit insufficient, progress at the state and federal levels. Establishing an alignment needs to recognize the historical deficiencies of this stock and should be designed to rectify the inefficiencies, neglect, and inequities currently embedded in the stock. This chapter evaluates progress to date and offers recommendations for accelerating progress in four key action areas (Figure 2) to guide the alignment of efforts with the City's climate goals.

Figure 2. **The four action areas for decarbonizing Boston's small building stock.**



The first action area is to **signal a paradigm shift to an electric, efficient, and grid-integrated building stock**. Grid integration includes the addition of distributed energy resources such as solar, storage, and flexible loads. Energy efficiency and grid-integration make electrification practical and cost-effective. Consumers should see and experience such building upgrades as creating value through healthier, more comfortable, and more resilient homes. We evaluate progress in the technical approach and the underlying policy that directs the building stock to pursue these interventions. *Just as there is a growing expectation that consumers will transition to an EV in their next vehicle purchase, there needs to be a clear understanding that heating and other fuel-based appliances will be largely electrified in their coming replacement cycles.*

Second, a **rapid market transformation** that incorporates supply chain and workforce development is needed to deliver the above solutions and overcome knowledge gaps and inertia affecting the industry on the supply side. The cost of these electrification and efficiency interventions needs to decline through the development of scalable and repeatable practices bolstered by local manufacturing and a well-trained workforce. *Just as supply chains, infrastructure, and workforce are being actively cultivated for deploying wind turbines, similar interventions are needed to support the deployment of electrification and efficiency at scale.*

Third, a **managed and tactical transition will be necessary** to overcome the misalignment of goals between energy providers and consumers. Boston's small residential buildings are entangled in an old and expensive to maintain gas distribution system. Electrification will require upgrades to the electric distribution system. Tactical closure of the gas system in select street segments and neighborhoods will reduce the risk of underutilized and stranded assets. Management of the transition is essential for ensuring that those with the least ability to leave the gas system are not burdened with the transition costs. In some cases where housing is sufficiently dense, shared energy resources may be cultivated to support the elimination of combustion heating from homes. *Coordination among gas utilities, electric utilities, residents, the City, and future energy providers is essential for a well-managed transition.*

Finally, facilitating the transition will require filling knowledge gaps through **improved data collection and metric tracking** to monitor progress, assess how efforts are achieving equity objectives, and learn from successes and challenges. Current data resources are siloed and not designed to assess progress adequately. *Simple data collection and management reforms, opening data sets, and developing common metric frameworks can improve planning, accountability, and outcomes.*

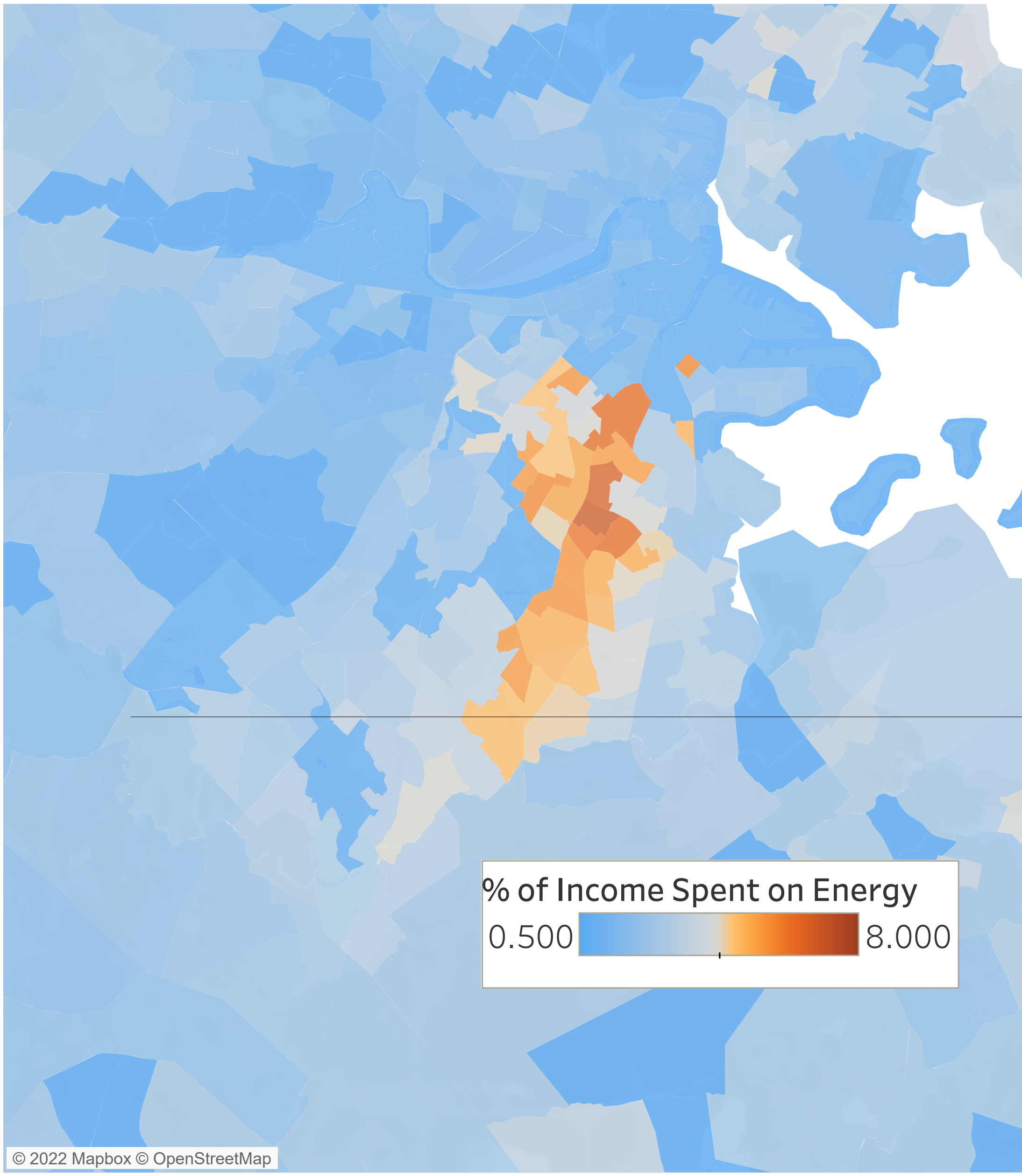
Both policy and market forces will drive electrification. This may yield cost savings or increases for others in the near term. In the long term, analyses by the state and the state's gas utilities show that homes that remain exclusively dependent on gas heat will experience two to three-fold increases in their heating bill.[8–10] These homes are more likely to have less agency to change their home energy systems: renters, low-income households, immigrants, and other marginalized communities.

The average annual home energy cost for a typical Boston household was about $2,160 in 2021 or about 2 percent of the average household income.[11] While the bill ($1,810) is slightly smaller for the bottom third of Boston's residents (those at or below 200 percent of the Federal Poverty Level), costs begin to exceed 6 percent of income for this group. For the lowest quintile of the population, it can exceed 10 percent. This energy-burdened population is highly concentrated in Dorchester and Roxbury (Figure 3). Increases in energy bills for these homes will be catastrophic and are not an acceptable outcome of the transition. Planners in this sector must better understand how to manage these costs, particularly given the significant investment needed to bring homes to a decarbonized standard.

Small-to-medium multifamily buildings housing low-income and minority populations are also more likely to be neglected and the least efficient and healthy. The reasons for this are many but generally include lack of investment, absentee landlords, a history of lax code enforcement, and limited attention. The result is a perpetuation of harm through building-induced illness, unnecessarily high energy costs, and mental health problems.[12] These issues disproportionately harm Black and immigrant communities and stem from historical racist practices such as redlining. Upgrading the building stock can serve as a reparation for this neglect and begin to rectify past harms.

Figure 3. **Average energy burden by census block in Boston.**

Source: LEAD tool[13]



Comprehensive building electrification and efficiency improvements will lead to more equitable outcomes for society. However, the transition has the potential to be immensely disruptive and chaotic in ways that may challenge intentional efforts to achieve equitable outcomes. Electrification is generally cost-effective in the long run but may incur significant transition costs, particularly in the near term.

A home that electrifies now may incur higher energy bills than a home that electrifies in 15 years. Both would be insulated from projected spiraling increases in gas rates in the 2040s. Further complicating matters is the timing of equipment replacement. A gas-for-gas replacement today may save money in the near term (assuming historical gas rates) but locks in higher energy costs in the long run. These dynamics and those associated with scaling back the gas system create significant challenges in maintaining fairness from street to street and from generation to generation.

Various frameworks for incorporating equity principles in building decarbonization have been developed.[14–18] Many of these emphasize types of equity, such as those focused on fairness (distributional) or inclusion (procedural), among other categorizations. None have sufficiently addressed how to apply these principles under such complex dynamics.

Thus, this chapter humbly focuses on the principles of *fairness* and *accessibility*—based on the respective concepts of distributional and procedural equity—to guide its evaluation of progress concerning equity. **Ensuring fair outcomes** means the transition must make housing electric, efficient, affordable, healthy, and comfortable without causing displacement. **Accessibility** stipulates that people should be engaged in and understand the transition and be confident in the potential for better living space.

While reducing emissions is the ultimate goal, increased attention must be given to the underlying drivers of emissions (e.g., the pace of electrification, fuel consumption, etc.) and the ability of institutions to take action to influence these drivers. As such, we take a holistic view of what needs to happen in the small building sector and focus our attention on the underlying drivers and institutions that will ultimately shape how fast Boston reduces emissions in this sector.

This chapter uses the theme of *making things work* to address the monumental challenge of enacting equitable decarbonization of the building stock. As documented below, this phrase was used to describe the changes that needed to be made to every gas appliance in every gas-connected home as part of the transition from manufactured gas to natural gas in the 1950s.

The next section reviews this event and other energy transitions over the past 400 years as a backdrop for understanding how the city overcame specific barriers to make those transitions work. It then seeks to draw lessons from how energy efficiency has been promulgated to low-income households over the last decade. It draws additional lessons from current progress in the large building stock and progress made beyond Boston.

It uses these vignettes to assess what hasn't worked for improving the small building stock before discussing how to make it work. Along the way, it makes progress assessments to understand trends and evaluate how different actors have or have not been making things work. It finishes by raising questions for the community to consider over the coming year as efforts to scale the transition take off.

3. 400 YEARS OF ENERGY EFFICIENCY & TRANSITIONS

Table 1. **Timeline of Boston's Energy Transitions**

TIME PERIOD	ENERGY TRANSITION
1630 – early 1900s	Wood heat, and eventually some coal stoves
Mid 1800s	Illumination by town gas and whale oil
1880s	Electricity arrives
1900s	Gas utility consolidation and the rise of household use of gas and fuel oil for heat
1950s	The arrival of natural gas
1970s	Beginning of the energy efficiency era
2000s	A slowly growing focus on decarbonization

For the first half of Boston's existence, wood served a crucial dual purpose for its inhabitants: It was used for heat, and the land from which it was cleared was used to grow food. This changed the landscape of New England. Pre-Revolutionary War wood consumption was inefficient—90 percent of the heat generated by burning went out the chimney. The first drafty chimneys would let cold air back in when the fire was out.

Innovations in the design of stoves and fireplaces by Ben Franklin and Count Rumford (a Woburn native turned loyalist) sparked an efficiency revolution that reduced the amount of wood needed to heat a building. Eventually, metal stoves evolved from these early designs, leading to even larger efficiency gains. Such gains and the ability of metal stoves to contain and remove the exhaust made the adoption of coal practical. Coal was more energy dense than wood but had to be transported from mines out of state. The adoption of these technologies was slow but steady in the new country's growing urban cities, including Boston.

In the early 19th century, demand for illumination in buildings and along streets spurred the beginning of shared efforts to distribute energy across the city. In 1822, a group of individuals formed the City Gas Company and petitioned Boston's Board of Aldermen to approve the city's first integrated infrastructure to deliver a novelty: *flammable gas.* A subsequent vote by the Massachusetts General Court charted the Boston Gas Light Company. It wasn't until 1829 that the first distributed gas was piped to streetlamps in front of Faneuil Hall. Interestingly, this *manufactured gas*—created from wood gasification in the absence of oxygen—was carbon neutral by some of today's standards. Still, the gasworks was a source of soot and ash, leading to long-term health problems for workers and neighbors.

As the city grew, so did the gas system. Cast iron pipe was laid down broadly across the city in the late 1800s and early 1900s. On many streets, gas mains from multiple utilities weaved around each other. By the early 20th century, the state and City organized this chaos into consolidated local gas distribution utilities. Many pipes from this era still deliver gas to buildings, big and small, across the city.

HISTORICAL BARRIER	MITIGATION
Misalignment of Goals: Boston's energy consumers, government, and investors all had the potential to benefit from the establishment of shared energy resources (e.g., public utilities) but needed alignment to ensure that such systems could operate safely and cost-effectively.	The creation of the regulatory compact: The City, and ultimately the state, created a structure to align the goals of energy consumers, investors, and the public.

At the turn of the century, the rapid construction of small multifamily housing—the triple deckers—leveraged this system. They were built to last but not to keep in the heat.

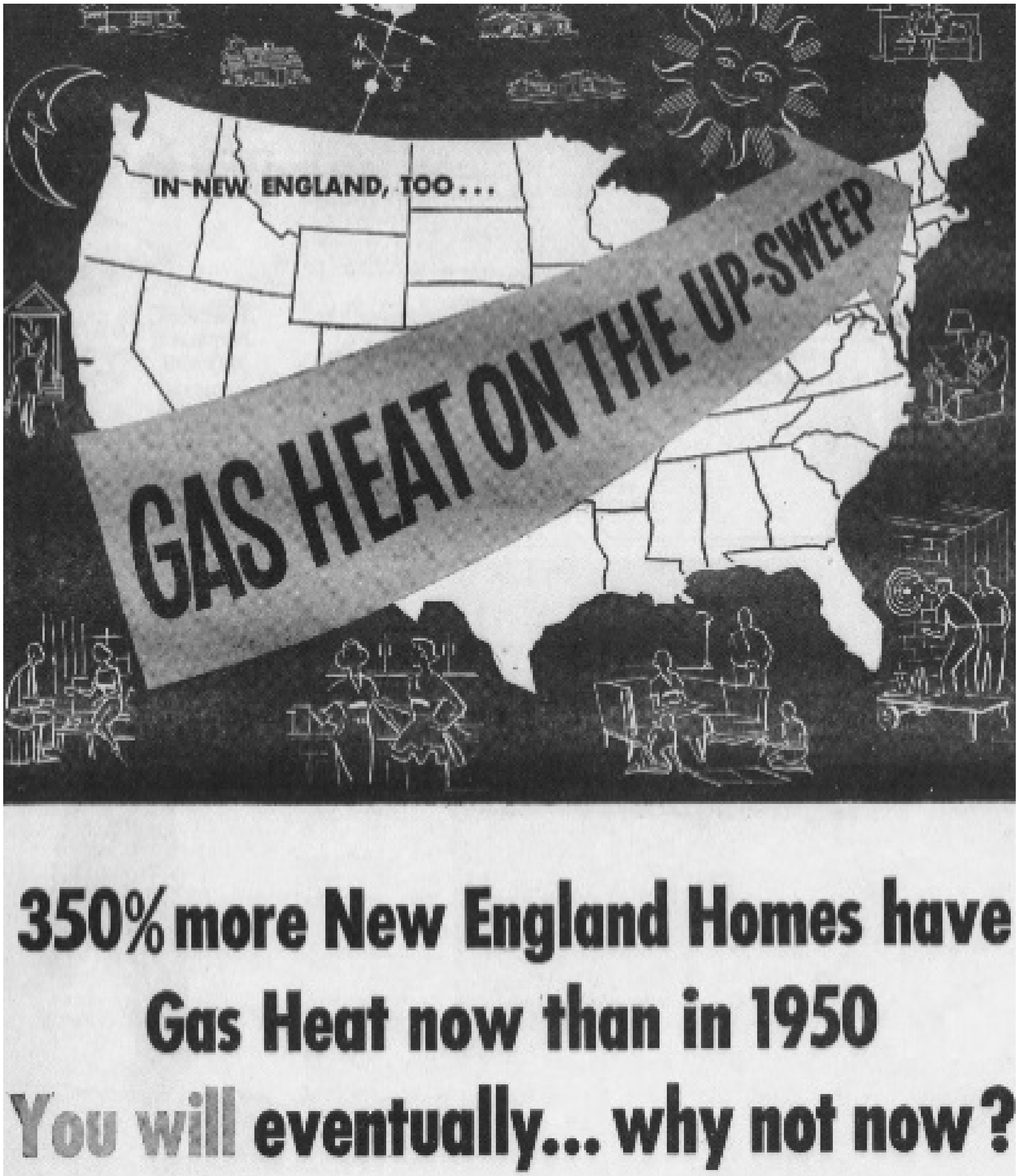
Electricity came to Boston in 1882 and was first used for illuminating streets, but electric lighting eventually came into homes with new appliances designed to use that electricity. This presented a competitive threat to the gas industry that forced it to innovate. The Boston Gas Company aggressively marketed new uses for gas, such as water heating and cooking—sometimes offering a free gas stove for residents who committed to ongoing gas service. This made gas more enticing and accessible. However, it was not without its perils; manufactured gas was incredibly unhealthy and sometimes fatal, containing high concentrations of carbon monoxide and other noxious contaminants.

The arrival of *natural gas* to Boston in the 1950s, following the construction of the Tennessee Gas Pipeline, brought reductions in the price of gas and safety benefits. This laid the groundwork for increased adoption of gas over the following decades. Before this happened, existing equipment—stoves, furnaces, water heaters—had to be retrofitted one by one to be compatible with the new purer gas. A former president of the Boston Gas Company, John Bacon, described the effort:

"We bought a company from the South. They were good at it. They had these trucks with lathes and machine shops, and they went from house to house and did the work. They hit Boston, of course, which had some of the oldest appliances in the country. And we had to alter every range, every water heater, every single appliance. If we couldn't get to a house on the list, we'd keep trying to get in it, until the end, when we'd connect an area. If the houses weren't converted, they were cut off. We had a couple of situations where he had to break in to get the appliances converted. We'd get a permit from the city, and we'd have an officer with us, and we'd go there and make things work."

HISTORICAL BARRIER	MITIGATION
Inertia and technical feasibility: The change from manufactured gas to natural gas required replacing burner tips on every legacy gas furnace and appliance over a relatively short time.	Boston Gas invested in the workforce and supply chain infrastructure to rapidly update equipment. Persistent outreach ensured that most homes were converted. Homes that failed to comply were cut from service.

Figure 4. **Boston Gas Company advertisement in the Boston Globe, September 30, 1959.**



The consequences of this transition were monumental. The unhealthy production of manufactured gas in the Northeast quickly ceased, improving air quality. With increasing adoption, the delivered gas was safer and cheaper than the alternatives. Adoption soared with marketing (Figure 4). For more than 50 years, the gas market share steadily grew because of the allure of "cooking with gas" and its competitive and practical (no need for a delivery) advantages over oil or wood. Eventually, gas could *sell itself* on its price and *aesthetic* advantages.

The 1970s energy crisis spurred the establishment of modern building energy codes, energy efficiency retrofits, and awareness that energy costs could burden low-income populations.[19] New buildings were now built to specific performance standards—when such codes were enforced. The federal government started addressing the energy burden of low-income populations through the Weatherization Assistance Program (1976) and the Low-Income Energy Assistance Program, which sponsored energy efficiency actions and utility bill assistance. Community Action Agencies—local organizations, empowered by the War on Poverty's Economic Opportunities Act to provide services to local low-income organizations—were tasked with administering these programs. The Commonwealth chipped in funding for workforce development, which resulted in the creation of several weatherization companies, which are still in operation today.

Approximately 15,500 low-income units were weatherized in Boston between 1977 and 1997. Most of these were 1–4 family structures. Consumers could expect a 10–15 percent drop in energy bills. Further, nearly 3,000 furnaces and boilers were replaced over these two decades under a sister program focused on updating antiquated heating systems. Funding for the Weatherization Assistance Program steadily rose during the mid-'80s, but with the sagging of energy prices in the early '90s, funding and weatherization activity dwindled. As with many other investments in alternative energy stemming from the energy crisis, the building-efficiency workforce and industry contracted during this time. Inconsistent funding hampered momentum.

The Utility Restructuring Act of 1997 established a permanent funding stream for energy efficiency programs and tasked the utilities to work with Community Action Agencies to promulgate energy efficiency in low-income households. It also reduced barriers keeping low-income households from accessing these programs, such as by expanding the eligibility criteria beyond participation in the electric utility discount rate. Additionally, the act increased coordination among utilities, Community Action Agencies, and contractors, developed the energy efficiency market, and streamlined the workflow to reduce costs and achieve greater typical energy savings (~20–30 percent) per project.

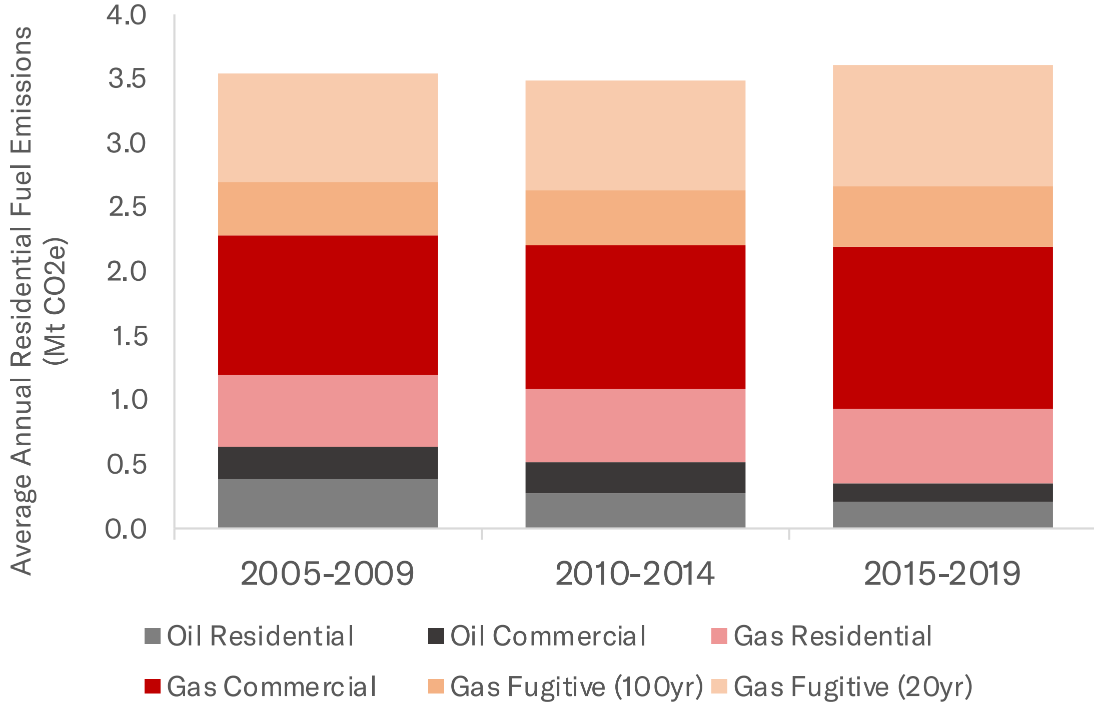
HISTORICAL BARRIER	MITIGATION
Funding gap: Evolving political focus led to a decline in low-income energy efficiency funding and work.	Creating a durable energy efficiency funding stream through utility bill payments helped create a pool of funding that enabled continuous investment.
Inertia: The decline in efficiency program funding led to industry and workforce contraction.	Coordination among Community Action Agencies, utilities, and contractors helped to revitalize the industry after a slowdown in work.
Knowledge gap: Households eligible for energy efficiency programs lacked awareness of their eligibility and capabilities to participate in no-cost energy efficiency programs.	The new policy broadened eligibility by reducing requirements and paperwork, enabling more significant levels of participation that better matched the community demographics.

An emergent focus on climate change in the 2000s accelerated efficiency efforts and positioned Massachusetts and Boston as national leaders in energy efficiency. Notably, the Boston Planning and Development Agency's (BPDA) adoption of the Green Building and Climate Resiliency Guidelines (Article 37) in 2007 integrated climate into developing new buildings. Simultaneously, the MassSave efficiency program, charted in 2008 by the state's Green Communities Act, has supported energy savings in buildings across the city since its genesis. Because of these policies, Boston has been ranked the top city in the country by the American Council for an Energy-Efficient Economy from 2014 to 2019[20] and has been in the top five since then.

The impact of these policy actions has been remarkable. Building sector emissions in Boston have remained flat from 2005 to 2019 (Figure 5). This is despite a rebound in the city's population (+30 percent), unprecedented economic growth (30 percent greater workforce), and an unprecedented and rapid expansion of the city's building stock (+12 percent increase in floorspace). Associated energy upgrades and higher-performing new construction have improved the building stock's health, comfort, and energy efficiency.

Figure 5. **Average annual emissions for five-year blocks from fossil fuel use in Boston.**

Source: Boston Community Greenhouse Gas Inventory Energy Estimates. Eversource and National Grid provided gas consumption data to the City of Boston. The U.S. Census Bureau's American Community Survey and Energy Information Agency's Residential Energy Consumption Survey were used to calculate residential oil consumption. Commercial oil estimates were obtained from the EPA State Emissions Data Systems and downscaled to Boston on a commercial square footage basis.



This success hides an apparent dichotomy in the residential sector that has consequences for Boston's climate goals and energy equity. Many of Boston's large managed residences, especially its low-income housing, have benefited from Massachusetts' nation-leading energy efficiency programs. Here, economies of scale and clear benefits for public and private property owners and managers enable high levels of efficiency program participation. In these properties, it is easier to get into every household and *make things work*.

Alternatively, much of Boston's small building stock falls through the cracks. Residents of many small rental units with low levels of owner occupancy and low-to-moderate income homeowners have limited access to information about such programs and remain untouched by MassSave. Comprising half of Boston's housing units and a quarter of Boston's building space, these homes present a particular challenge to the City's decarbonization goals. To understand why we first look at the efficacy of efforts to improve the low-income large building stock.

4. WHAT'S BEEN WORKING: LOW-INCOME EFFICIENCY PROGRAMS IN LARGE MULTIFAMILY BUILDINGS

A focus on low-income communities has reduced emissions and energy burdens for many across Boston over the last decade. While many of these successes have been gained in the large residential public and subsidized building stock, critical lessons from this effort for the small building stock include:

- **Maximizing participation is essential for ensuring equitable outcomes.** Casting a large net and using data to identify potential gaps can ensure that retrofits are proceeding in a way that represents the population at large.
- **Develop repeatable and scalable strategies.** ABCD's streamlined process minimizes effort on the part of residents. This should inform the design of future public and private retrofit offerings.
- **Plan to mitigate undesirable outcomes by prioritizing people.** Housing improvements should not spur displacement. It will be essential for policymakers to evaluate direct and indirect strategies for avoiding displacement due to upgrades in low-to-moderate-income housing.

The Green Communities Act not only drastically increased funding for low-income energy efficiency retrofits but also established the Low Income Multifamily Retrofit Program to systematize the delivery of energy efficiency measures to large multifamily structures across the state. Boston was poised to benefit from this program with its large stock of medium-to-large public and subsidized housing. In these buildings, thousands of square feet and scores of housing units could be retrofitted as part of a single project. This contrasts with the arduous customer acquisition needed to recruit many small homes into energy efficiency programs to achieve a similar impact. The multifamily program was intentionally designed to leverage existing, experienced institutional infrastructure. This section reviews how the program has been achieving its goals.

Signaling the Paradigm Shift: State and Federal Law Made Energy Efficiency and Energy Affordability a Priority for Low-Income Households

For nearly half a century, the state and federal governments have sought to minimize the impact of energy costs on low-income households through energy efficiency and fuel assistance programs. To maximize inclusion and reach, such programs are operated by anti-poverty Community Action Agencies that operate within the communities they serve and are staffed by community members. These organizations actively seek to remove barriers to energy efficiency.

Action for Boston Community Development (ABCD) is Boston's Community Action Agency. This nonprofit organization was established under the federal 1964 Economic Opportunity Act to lift communities out of poverty through expanded educational opportunities, community support programs, and workforce development. Community Action Agencies like ABCD have been a cornerstone of the modern social safety net by being a one-stop shop for social services located and operated within their communities.

They are also the *social safety insulation* that administers a variety of programs to reduce the burden of energy costs on low-income households. These programs fall into two overarching categories:

Energy Bill Assistance

- Low-Income Home Energy Assistance Program (fuel assistance)
- Utility discount rate enrollment support
- Utility bill advocacy and payment support (arrearage management)

Zero-Cost Energy Efficiency

- Energy efficiency home improvements
- Weatherization assistance
- Energy conservation education

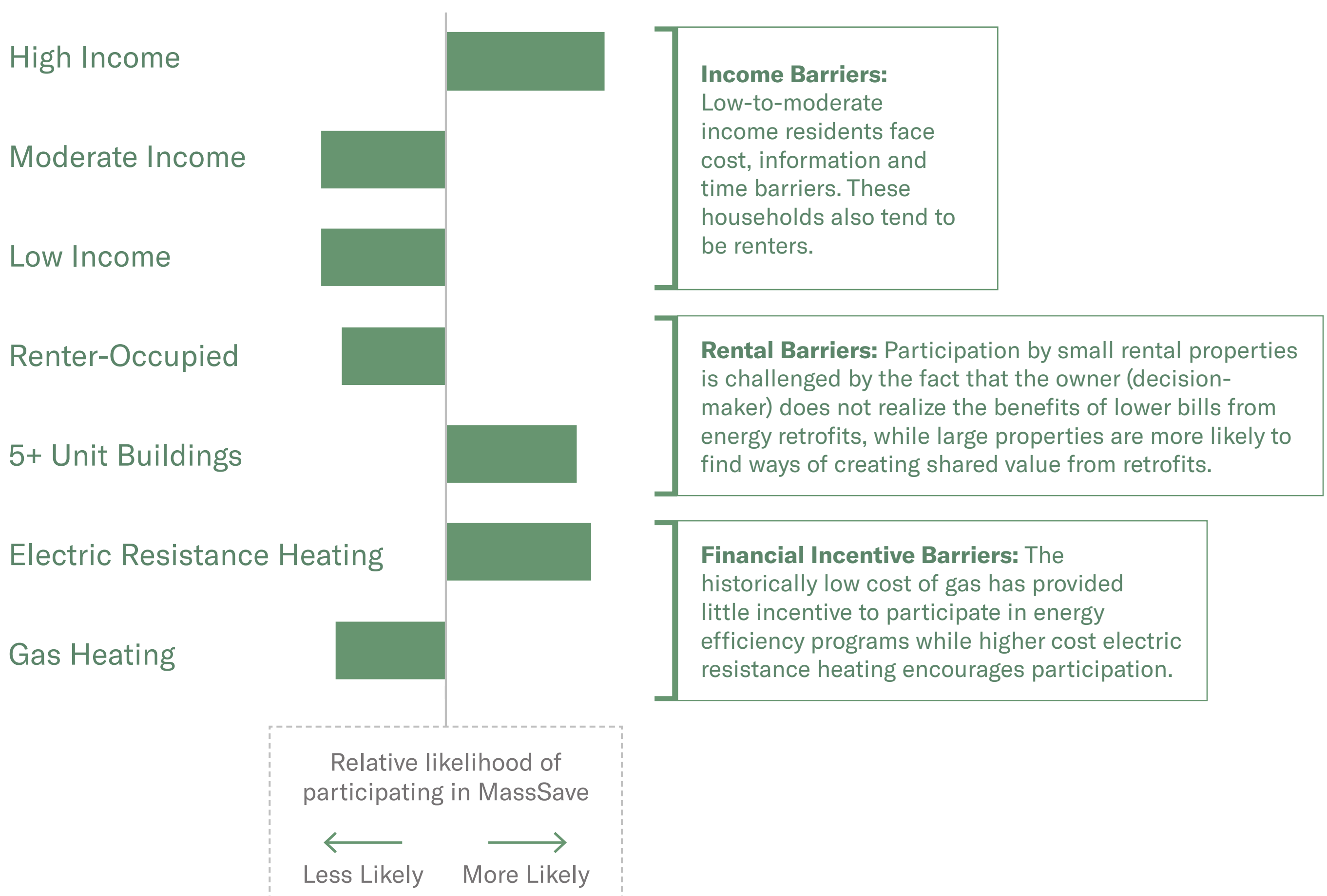
ABCD works with its sister action agencies through the Low-Income Energy Affordability Network (LEAN), a statewide association of nonprofit agencies that coordinate the delivery of government-funded, utility bill–funded, and other energy efficiency services to low-income utility customers at no cost. In this role, ABCD is the low-income program administrator for MassSave and works to ensure that the low-income population can reap the benefits of the energy efficiency programs they pay for in their utility bills.

ABCD and similar Community Action Agencies have been filling this role since the development of the Weatherization Assistance Program and Low-Income Heating Assistance Program in the late 1970s. LEAN evolved out of an effort to coordinate these programs across Massachusetts in the 1990s. Following utility restructuring (1997) and the Green Communities Act (2007), they have been primarily supported by a dedicated allocation of utility energy efficiency program bill charges.

Lack of household participation in energy efficiency programs is well correlated with the characteristics of the low-income population: renters, limited incomes, lack of trust in government or utilities, and limited education (Figure 6).[21]

Figure 6. **Correlation between census block group attributes and energy efficiency program participation weighted by consumption.[21]**

Source: Residential Nonparticipant Market Characterization and Barriers Study Reference



ABCD uses a mix of strategies to ensure its energy efficiency benefits reach its target population. Low-income energy efficiency programs are designed to serve households at or below 60 percent of the Massachusetts median income; however, identifying this population can be a challenge. Community Action Agencies take a multi-faceted approach to promulgating its benefits. As the administrator of the Low-Income Energy Assistance Program (LIHEAP), ABCD facilitates enrollment in utility discount rates and fuel oil assistance through a streamlined process. Applicants need proof of income, identity, residency, Social Security numbers of household members, and the most recent heating and water bills. Once approved, utility-paying residents are enrolled in the discount rate classes, while fuel oil customers notify their suppliers of eligibility. Using several linked datasets, ABCD checks to see whether the household's residence has previously received energy efficiency upgrades and offers its services if needed. Additionally, ABCD reaches out to clients when new energy efficiency technologies become available and their residence is a good candidate.

Most participants meet the 60 percent income threshold requirement, but income is not the only determinant of eligibility. Recipients of other social programs can also enroll in utility discount rates. The utility then coordinates with ABCD by providing the complete list of enrolled discount rate customers to reach out and offer energy efficiency services.

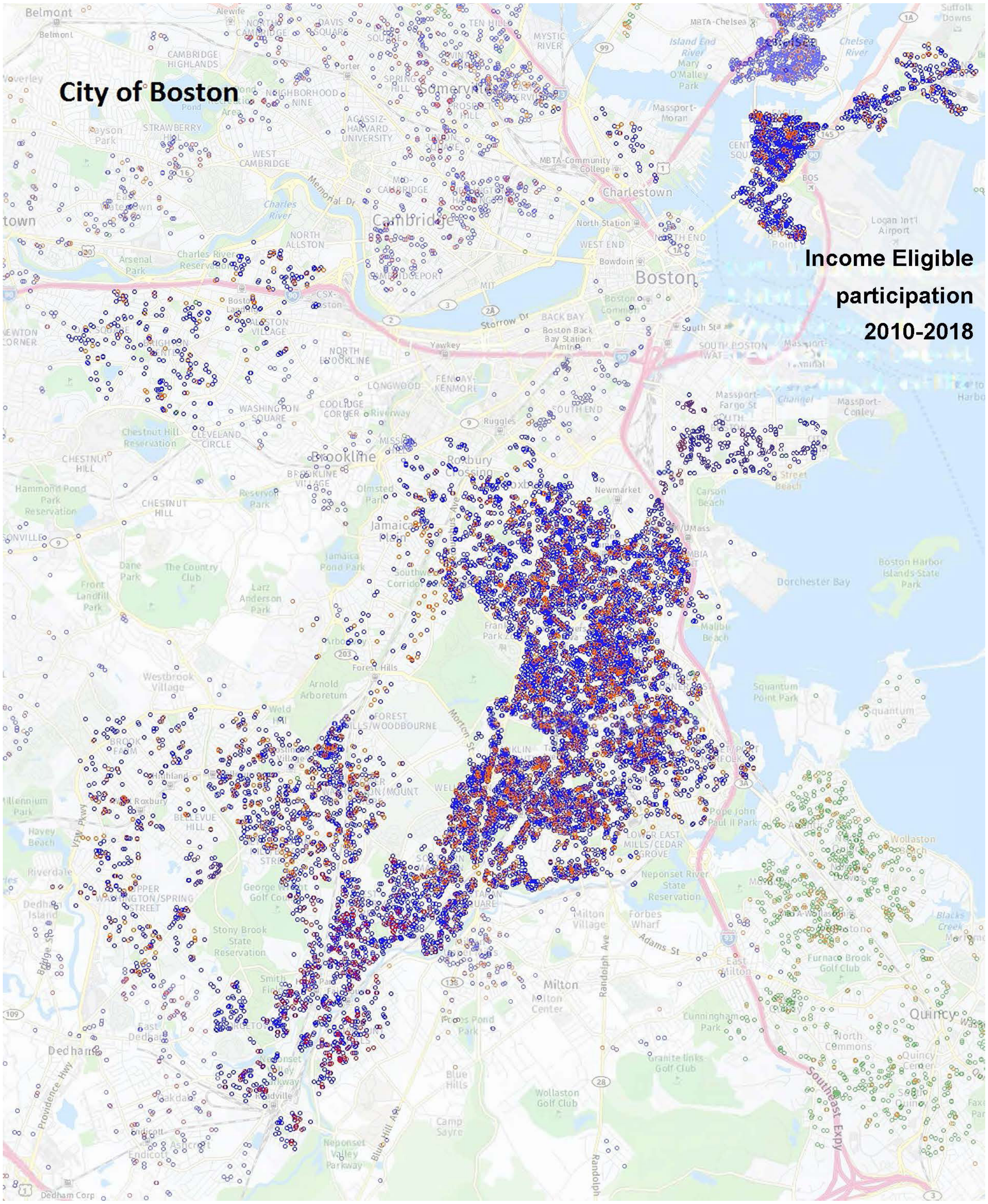
While this process captures many households, a significant number can still be missed. These typically include households where the cost of heat or electricity is included in the rent. While these households are still eligible for fuel assistance, the lack of a bill or awareness creates additional barriers to enrollment.

Further, residents move in and out of eligibility. People may lose a job, enter this category for a year, and then reenter the labor market—the COVID-19 pandemic marked a spike in customers on fuel assistance. As a result, a quarter of the eligible population is new in any given year, with a similar number cycling out of eligibility.

This allows for more buildings to be eligible for low-income no-cost retrofits over time than the actual size of the population. As a result, the number of homes improved under the low-income energy efficiency program in the last decade (Figure 7) exceeds 95 percent of eligible households across the city.

Figure 7. **Map of residential buildings retrofitted through ABCD's administration of the MassSave low-income program.**

Map provided by ABCD.

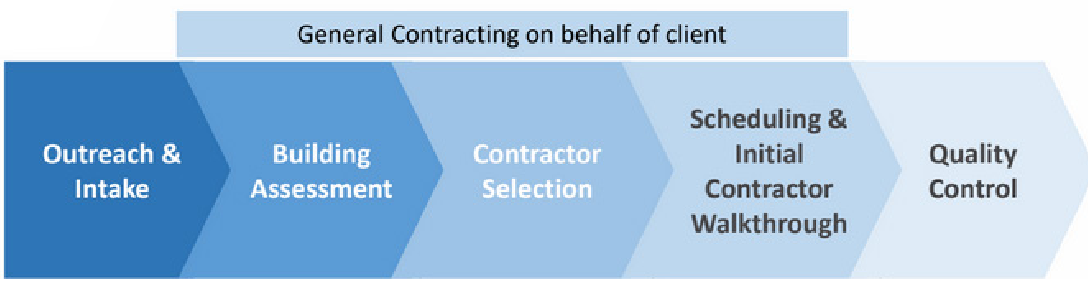


ABCD's years of experience have developed an institutional skillset for managing the tenant-landlord relationship and dealing with the challenge of split incentives. The agency often works directly with and conducts outreach to eligible large private housing complexes if 50 percent of the units are rented to households below 60 percent of the Massachusetts median income threshold. With most to all costs covered, large public (e.g., Boston Housing Authority) and private affordable housing owners—who typically have low access to capital—see this as a valuable benefit.

The hassle of dealing with contractors is also a significant barrier to participation in efficiency programs, even when funding and interest exist. Removing that hassle has been a central element of success in reaching the low-income population.

Figure 8. **ABCD's energy efficiency project quarterbacking approach.**

Source: Action for Boston Community Development (ABCD)



ABCD seeks to take as much of the aggravation out of energy efficiency and electrification as possible by facilitating the process through "quarterbacking" (Figure 8). Once eligible housing units are identified, ABCD brings in preselected qualified energy auditors to assess the needs of the building. Based on that assessment, ABCD chooses a licensed, prescreened contractor best suited for the role. Energy auditors manage the contractors throughout the project. After completion, the auditors conduct quality control inspections. Large buildings may have more involvement from the landlord, given the intensive nature of some projects.

The quarterbacking model aims to deliver high-quality, verifiable energy work at no cost to the owner or renter. ABCD takes advantage of bulk purchasing programs and ongoing relationships with contractors to keep program costs low.

The measures applied to small residential buildings include weatherstripping, insulation, and appliance upgrades. For gas-heated homes, old furnaces are typically upgraded to high-efficiency furnaces. Heat pump installations are becoming more common in oil and electric-resistance heated homes. Larger buildings require more customization and involvement but ask little of the resident.

BARRIER	MITIGATION
Inertia and knowledge gaps among consumers: The perceived financial and logistical hassle of energy retrofits, as well as lack of familiarity with them, is a well-documented barrier to program participation.	ABCD's no-cost and low-hassle approach minimizes burdens for residents. ABCD's multi-pronged mission, community presence, and multi-language support help to raise awareness of these programs among low-income households.
Conflicting interests: The split incentive problem is a pernicious issue in low-income housing.	By developing a streamlined process and learning from prior work, ABCD has developed best practices for navigating the tenant-landlord relationship and demonstrating the value of energy efficiency improvements to landlords.
Funding limitation: Retrofits are expensive. The typical small residential contracting model is riddled with inefficiency that leads to high costs.	ABCD actively keeps retrofit costs low by working directly with contractors to streamline the process, track costs of specific interventions, and reduce customer acquisition inefficiencies.

Market Development: Scaling Up Electrification

New technologies often have significant implementation challenges—heat pumps are the latest example. Overcoming these challenges requires rapid learning in manufacturing, planning, installing, maintaining, and using new technologies. Workforce development efforts often take years to pay off and should be considered an ongoing element of building decarbonization programs for the foreseeable future.

ABCD has been rolling out air-source heat pumps for five years. During this time, it has worked with utility efficiency programs, heat pump manufacturers, vendors, MassCEC, contractors, and expert engineers to develop and promulgate best practices in heat pump implementation. These efforts include monitored pilots in all sizes of buildings. The lessons learned from pilots and early installation projects help inform future implementation strategies leading to reductions in installation costs and improved outcomes. While electrification efforts in the small residential stock have primarily focused on homes with oil or electric resistance heating, ABCD seeks to get gas-fueled homes "electrification ready" with various weatherization, insulation, and electrical upgrades.

ABCD coordinates with several other entities to develop job training programs to ensure that the people doing the work represent the communities in which they are doing it.

BARRIER	MITIGATION
Inertia and knowledge gaps in the industry: The industry and workforce are used to the status quo and are averse to risky new approaches.	Active coordination among all market participants is essential for scaling solutions by promulgating best practices, guiding workforce development programs, and supporting the growth of supply chains.
Inertia in workforce demographics: Lack of a diverse workforce can impact community ownership of the transition. Communities are less likely to embrace the transition if the workforce doesn't reflect their demographics.	Incorporate socio-demographic objectives into workforce development programs. Actively reach out to underrepresented communities. Develop resources for minority-owned and operated businesses.

Managed Transition: Avoiding Displacement

It is well documented that energy efficiency interventions add value to the home, and there is some evidence that this has the potential to lead to higher rents and promote displacement. Protections must be put in place to ensure that residents are not displaced.

ABCD integrates protections for residents in its work. For privately owned buildings, ABCD requires landlords to agree not to raise rents for three years and to justify any rent increases for several years after the energy work.

BARRIER	MITIGATION
Misalignment of goals: Investment in homes leads to increases in value, enabling property owners to increase rents. This has the potential to counteract affordable housing goals.	Property owners who receive upgrades must keep rent stable for several years following the upgrades.

Data: Ensuring Equitable Participation

Even with the most effective outreach efforts, institutional barriers can lead to exclusion and the perpetuation of harm. Robust tracking and efforts to include historically marginalized groups are essential for achieving fair outcomes.

ABCD seeks to overcome such barriers by being a one-stop shop, operating in the communities it serves, and offering several services simultaneously. This is part of a broader effort to integrate climate needs into traditional social needs. If a resident engages with ABCD on a food security issue, ABCD will check to see if that resident's housing unit is eligible for energy services. Marketing for ABCD's and LEAN's services are offered in 14 languages other than English. ABCD has 15 offices and service centers across Boston. As a result, ABCD's served population matches Boston's demographics.

BARRIER	MITIGATION
Inertia: Institutionalized barriers to minority, immigrant, and low-income populations continue to hinder efforts to reduce emissions, increase affordability, and deliver other tangible benefits to households.	Robust data tracking ensures accountability and can be used to highlight the existence of institutionalized barriers.

5. WHAT IS STARTING TO WORK IN BOSTON'S LARGE BUILDING STOCK

A concerted focus on sectoral decarbonization is already making things work in Boston's large building stock. This has been achieved by a coalition that understood that it could leverage leadership, networks, and strong policy development to affect change. Key lessons from this effort for the small building stock include:

- **Establish a firm decarbonization framework.** The small building stock needs a directional policy similar to BERDO 2.0; such a policy likely needs to arise at the state level.
- **Scale back barriers.** Larger buildings deliver more opportunities for reducing emissions per engagement point. The returns on time invested in overcoming barriers are higher. For the small building stock, it will be essential to scale back key barriers such as permitting, contractor selection, and access to financing.
- **Leverage social networks.** Networks comprising property owners and advocacy organizations (A Better City, Green Ribbon Commission, etc.) have helped to develop shared decarbonization goals and disseminate best practices in the large building stock. Neighborhoods and community organizations can play similar roles in decarbonizing small buildings.

- **Build expertise around systems integration and problem-solving.** Opportunities abound for more efficient and smartly electrified buildings, even in the small building stock. This can be achieved by developing a workforce, industry, and products that continuously pursue improvement in technological performance and implementation practice.
- **Improve data collection for tracking progress.** The original incarnation of BERDO shone a light on the magnitude of emissions from the city's large building stock. Tracking specific indicators of progress in the small building stock will also help to highlight the magnitude of the problem and help to guide progress.

Carbon Free Boston identified the large building stock as the "low-hanging fruit"[2] based on the ability to achieve significant reductions through a small number of touch points. This assessment was based on historical trends. Most of the city's gains in energy efficiency have accrued within its largest buildings. This stock comprises about half of the city's floor space and emissions but less than 5 percent of the number of buildings.

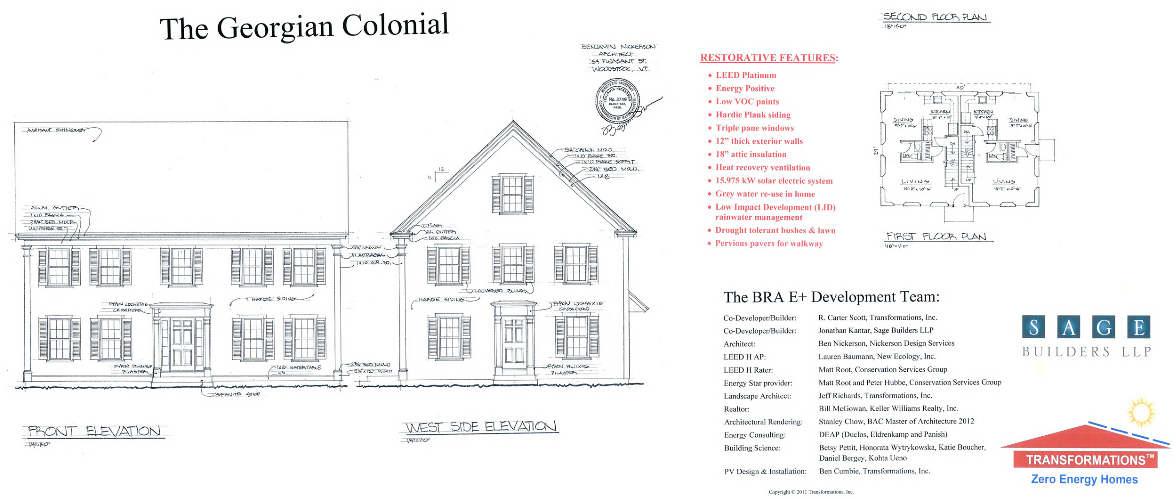
Given this dynamic, the City focused much of its recent climate policy development on the large building stock in its 2019 Climate Action Plan Update[3] and subsequent effort to update the Buildings Energy Disclosure Ordinance. While much of the policy has been designed with the nature of the large building stock in mind, it and some related activities do have significant implications for the small building stock.

Signaling the Paradigm Shift: Decarbonizing New Construction and Existing Buildings in Boston

Quite possibly the most impactful work the City of Boston has done in launching climate action has been though the development of aggressive and innovative building performance codes over the past 15 years and the recent directive to decarbonize the large building stock through the expanded Building Energy Disclosure Ordinance (BERDO 2.0). So far, these policies are not yet notable for their emissions reductions but have evolved to be critical foundations for decarbonizing Boston's building stock. They are policy signals that have leveraged Boston's position, the City's ability to influence development, and the tool of transparency to catalyze change.

Figure 9. **Design schematic for E+ construction in the Fort Hill neighborhood of Roxbury completed in 2018.**

Source: Boston E+ building program.[22]



On the new construction front, the City has been actively involved in using its influence to demonstrate all-electric new construction in several small and medium-sized housing projects. The E+ (energy positive) green building program[22,23] was a collaborative initiative between the Environment Department, the Department of Neighborhood Development, and the Boston Planning and Redevelopment Agency (BPDA) to demonstrate best practices in the creation of all-electric homes that, coupled with solar array, can generate more energy than they consume. Participation was voluntary, but the program provided funding to winning designs. While the initiative supported a handful of homes, it was foundational in advancing high-performance building practices with architects, developers, contractors, and utility partners. Such activity serves as a policy signal to these groups that a paradigm shift is coming.

This learning set the stage for implementing increasingly ambitious building performance standards in new construction through informal and formal mechanisms. The Office of Housing is responsible for managing the City's residential real estate and guiding the development of affordable housing projects. As a property owner and developer, the City has significant influence over this portion of the housing stock. But unlike the E+ initiative, there had been a clear tradeoff: Every extra dollar spent on improving building performance was one less dollar that could be spent on building more affordable housing.

That tradeoff is now moot; in most cases, the construction of all-electric high-performing buildings can save residents money relative to fossil-fuel-consuming buildings. After applying knowledge gained from efforts such as the E+ program to projects in an *ad hoc* fashion, the Office of Housing—with support from the

BPDA and Environment Department—has implemented Zero Emissions Building Design Standards[24] for new housing projects developed by the Office of Housing. The requirements and guidelines seek to streamline the development process by providing performance standards such as an electric primary fuel requirement and specifications for building shells and equipment.

Since 2007 the BPDA's Article 37 Green Building and Climate Resiliency Guidelines[25] have been used to guide private commercial and residential development projects that are subject to the large project review requirements of Article 80.[26] In recent years, this mechanism and experience gained through the activities listed above have allowed the BPDA to encourage more all-electric and electrification-ready development. **This impact has been striking, with over 20 million square feet of recent development achieving actual energy use 35 percent or greater below the state energy code**.

In September 2022, the BPDA released its proposed Zero Net Carbon (ZNC) update[27] to Article 37. The ZNC code seeks to establish standards to regulate emissions from both construction and operation while maximizing onsite renewable energy generation and prompting building operators to purchase renewable energy to cover energy demand for what is not generated on-site. The focus on the construction *life-cycle* or *embodied carbon* emissions is an innovative approach intended to address the emissions associated with the materials used in construction and waste generated in demolition.[i] While the proposed update does not explicitly require all electric construction, it uses several mechanisms and emissions requirements to favor electrification heavily.

The proposed ZNC code—if adopted—provides a critical signal to the building sector that high-performance, electric buildings are the future paradigm. Even though its GHG emissions impact is small, such policy is again essential for preparing the trades, supply chains, developers, and other implementors for tackling the existing building stock. Its adoption will set a strong signal that Boston is ready to lead the Commonwealth, particularly if the Commonwealth accepts Boston's application to pilot a fossil-fuel-free building code.

Alongside these efforts, the City's Environment Department updated BERDO to align with the City's net-zero goals by establishing a declining emission cap on large buildings. Buildings not compliant with the cap will pay a hefty alternative compliance fee of more than $230 per ton of carbon dioxide emitted. The regulation covers fuel combustion, steam use, and electricity emissions. It is anticipated that under the current regulatory design, most buildings will achieve compliance in 2030 by purchasing renewable energy certificates.

i. According to the ZNC proposal study such emissions can account for half of a building's emissions over its first 20 years.

After that point, those buildings must actively reduce their fossil fuel consumption. Vicinity Energy, the district energy provider for Boston and Cambridge, is anticipated to electrify its district steam production by the early 2030s, reducing approximately a million metric tons of emissions across Cambridge and Boston—approximately one-sixth of Boston's 2019 GHG emissions.[7,28] This is happening because Boston began to regulate large buildings' emissions through BERDO, and Vicinity is a single touchpoint for most of Boston's emissions.

The solutions for each building will undoubtedly vary, and buildings such as hospitals may still need combustible fuel for reliability and resilience. Still, the high compliance fee will likely promote significant electrification and efficiency measures across this stock.

This focus on large buildings also—because of Boston's nature—can deliver significant equity benefits. As noted above, most of Boston's lowest-income residents live in large public and subsidized housing.

This signaling was not all done by fiat. Informational networks facilitated by the MassCEC, Green Ribbon Commission, and A Better City helped to accelerate the acceptance of building decarbonization. Organizations such as LISC (Local Initiatives Support Corporation), ABCD (Action for Boston Community Development), and RMI (formerly Rocky Mountain Institute) are all focused on developing decarbonization strategies for the large residential sector. Leading institutions such as Boston University have promulgated lessons learned from their efforts to deploy new strategies such as geothermal heat pumps (described below). Through MassSave, the energy efficiency program administrators (utilities) have been working to develop the resources and workforce needed to deliver energy efficiency to large commercial buildings. Even with large buildings, signaling can be spurred by grassroots efforts.

BARRIER	MITIGATION
Inertia and knowledge gaps: Hesitation and lack of translating commitments into hard action in the large property owner space were hindering necessary planning and action.	The City of Boston established a clear direction for the large building stock by adopting an emissions cap with a meaningful penalty for not meeting that cap. The ability of the City to set this direction was enabled by the work of some of the city's more climate-forward property owners and networks that sought to build a coalition to reduce emissions from the city's large building stock.

Market Development: Bringing New Technologies into Practice

Variable refrigerant flow (VRF) heating and cooling is a heat pump arrangement in which an outside heat exchanger can service the individual thermal needs of multiple zones—one room in a building can be heated while the other can be cooled. In complex building types with diverse heating needs, VRFs can provide very efficient heating electrification.

While VRFs are common in the industry and can be broadly applicable, unlocking their ability to integrate diverse heating and cooling needs is a challenge for retrofits. This challenge has hindered the development of industry and workforce experience in VRF retrofits. To address this issue, the MassCEC, from 2017 to 2019, ran a commercial VRF pilot program. This statewide program provided nearly $2 million in incentives to 21 new and existing commercial buildings in Boston to deploy VRFs to service nearly 1 million square feet of space.

By offering incentives and thus promoting technical learning among contractors, the MassCEC VRF program jump-started the VRF retrofit industry. The program identified challenges and learning opportunities around equipment sizing, installation arrangements, refrigerant charging, and financial outcomes that are being used to guide best practices going forward.

While VRFs are a rooftop solution, Boston University is pursuing electrification by digging beneath the building. The university's new 19-story data science center will be all-electric and utilize thirty 1,500-feet-deep wells for ground source heating and cooling. The university tested three technologies to find the best strategy for drilling wells.

Drilling the pilot and remaining wells required sourcing expertise and equipment from out of the state. This suggests that significant cost savings would be achieved if a local industry could be developed. That would be a game changer, as it is already projected that this building will cost less to build and operate than a natural gas–served building.

BARRIER	MITIGATION
Inertia and knowledge gaps: Contractors and property owners are risk-averse and unaware of new solutions. This hinders the adoption and deployment of new technology.	By providing incentives and programmatic support, the MassCEC helped to increase familiarity with commercial VRFs. By leveraging its institutional capacity, profile, and resources, Boston University launched a market in large building electrification via geothermal.

Transition Planning: New District Solutions for Existing Midsized Buildings in Mixed-Use Neighborhoods

Boston's gas utilities Eversource and National Grid are launching pilots for geothermal networks as potential replacements for the gas distribution system. While it is not clear yet whether Boston will host one of these pilot sites, the utilities are looking at mixed-use districts with sufficient energy use density and diverse building loads, which are common in many of Boston's neighborhoods. One project in Framingham includes an affordable housing complex.[29]

Such systems blend the characteristics of the VRF and single-building geothermal strategies above. The ground serves as the primary source or sink of heat, enabling long-term seasonal energy storage. By linking together buildings, the network allows for sharing heating and cooling loads—one building's waste heat is another's heat source. This makes them potentially highly effective in mixed-use areas. Using a community or utility model enables costs to be spread across users and time.

While these pilots have yet to commence and are anchored on medium-sized buildings, they have the potential to demonstrate several essential elements of gas transition planning. First, they are developing a new potential solution for a complicated segment of the building stock that would allow for decommissioning gas infrastructure in the district. Second, they create a model for gas utilities potentially to transition to or for new energy entrants to invest in. Third, the pilots include small residential buildings to better understand the applicability to this segment of the building stock.

BARRIER	MITIGATION
Misalignment of goals: The gas utilities business model is at risk due to distributed electrification strategies.	The geothermal network concept is a potential transition strategy for the gas utility to maintain some of its customer bases while facilitating efficient electrification.

Data: BERDO

BERDO was implemented to highlight the emissions of Boston's large buildings by requiring reporting of emissions. The process has not been without flaws; since each property owner must self-report, there is a high potential for mistakes.[30] The recent state climate legislation requires utilities to report energy consumption data in large buildings.[31] This should improve accuracy and consistency. However, aggregate energy consumption may not provide a meaningful enough picture of a building's impact. Reporting should also seek to include data on peak electricity and heating demand.

Beyond energy consumption data, BERDO's requirement for buildings to report emission reduction measures will be informative for tracking decarbonization practices and strategies as they are implemented.

BARRIER	MITIGATION
Knowledge gaps: Fractured data collection leads to mistakes and the inability to use data for robust understanding and analysis.	Mandatory reporting of energy data from utilities and standardization of reported data from all entities can reduce mistakes and improve the utility of collected data sets.

6. PLACES THAT ARE MAKING THINGS WORK IN SMALL RESIDENTIAL HOMES

No one place has yet to figure out how to make the small building decarbonization transition work at scale. However, several lessons can be learned from initiatives in other places:

- **Make consumers and the industry aware that electrification is coming.** Customers need to understand that some degree of electrification will deliver increased value despite some transition costs and hassle.
- **Focus on pushing down costs.** Market scaling will likely reduce the cost of deep electrification and efficiency for small residential.
- **Early transition planning is essential.** Planning will enable signaling and smartly managing costs for gas system rightsizing.
- **Collect data to inform and better plan decarbonization.** Structured data collection will be valuable for homeowners, occupants, and energy transition planners.

Signaling the Paradigm Shift: Electrification Mandates, Standards, and Incentives

Brookline, Berkeley, Eugene, New York, and Los Angles are among a growing list of municipalities that have attempted to ban, have banned, or are in the process of banning new natural gas hookups for residential new construction, if not other classes of buildings. While these policies apply to new buildings, electrification of the new building stock is a cost-effective and practical no-brainer that halts the growth of the gas system. It can be done now, so it should, and in doing so, further establish electric and high-performance building practices.

Following several European countries' footsteps, California has approved a plan to phase out replacement furnaces for most existing residential buildings.[32]

A more immediate strategy for signaling a pending electric paradigm in existing residential buildings would be to immediately require all new and replacement central air conditioning units to be heat pumps.[33] The equipment is nearly identical, with the heat pump having an inexpensive reversing valve that allows it to move heat in both directions. Several organizations have proposed that states and the federal government establish equipment standards to require this, along with rebates to cover any cost differential.

Many jurisdictions have begun handing out heat pump incentives to consumers. Programs in Italy, New York, California, Denver, and other places have been so successful that they have run out of their allocated funds faster than expected.[34] In many of these places, there are year-long waiting lists for work. Consumers who were not able to snag a rebate feel left out.

BARRIER	MITIGATION
Inertia and knowledge gaps: Consumers and contractors are used to existing heating systems and are reluctant to take risks on new technologies.	Building and appliance standards have a long successful history of cost-effectively mainstreaming best technology and best practices. Incentives provide a complementary carrot to reduce risk, close cost gaps, and spur adoption.

Market Transformation: Scaling Deep Efficiency and Electrification Through Standardization—Energiesprong

Traditional approaches to deep energy retrofits are invasive. These typically could only occur during comprehensive or gut retrofits, making their potential applicability limited or costly. The concept of integrated façade retrofits has recently emerged as a strategy to achieve significant energy savings with little disruption.[35] While costs are relatively high now, it is anticipated that with further market development, costs could be pushed down to make such retrofits practical and affordable for the small building stock.

The nonprofit Energiesprong (which translates to *Energy Leap*) was launched in 2010 with funding from the Dutch government to spur high-performance all-electric retrofits in Dutch public housing.[36] Using a performance pricing model, the cost of the retrofits for the property owner is financed from energy savings. The model has been applied across the Netherlands because the consistency of housing there enabled standardization in external envelope approaches.

In the Energiesprong approach, well-insulated exterior panels are prefabricated at a local manufacturing facility before installation on the exterior of a building. These panels add insulation to the home, improve moisture control, and sometimes integrate heating and cooling equipment. Fuel-based heating systems and appliances are replaced with electric alternatives. Energy demand is reduced by over 50 percent with little disruption to the inside of the house. The minimal disruption to the living space and the on-bill financing makes it a straightforward process for many customers.

The New York State Energy Research and Development Authority (NYSERDA) is importing this approach to the United States.[37] NYSERDA is piloting the approach with all sizes of multifamily buildings. The approach is to lead with low-income housing and let the market follow.

For example, New York City used the Energiesprong approach to experiment with electric passive house retrofits. The pilot, which started in 2020, was Casa Pasiva, a four-story, 46-unit building in Brooklyn's Bushwick neighborhood. The $20 million deep retrofit project replaces existing heating systems with electric systems, then installs new facades on the buildings. The buildings will meet passive house standards and reduce energy costs by 60–80 percent. Residents remained in place during construction.

Such deep retrofit strategies were documented to lower utility bills. Residents also expressed satisfaction with the improvement in comfort. Further, these buildings are now more resilient as they can maintain comfort and safety during a power outage more than traditional buildings.

While the diversity of the smaller building stock presents significant challenges to standardization, pilots and scaling in the industry on more significant buildings will increase opportunities to lower costs and develop the supply chain.

BARRIER	MITIGATION
Technical and cost feasibility: The cost of comprehensive deep energy retrofits is prohibitively high because, under current practice, everything is a custom job, with most of the work being performed on-site.	Standardization of retrofits and offsite prefabrication can lower retrofit costs and improve performance outcomes. Standardization also increases opportunities to reduce embodied emissions associated with retrofits.

Transition Planning: California

California has launched comprehensive transition planning at the state and local scales. At the state, utility, and regulator levels, the State has begun working with stakeholders on a Gas Resource Infrastructure Planning Framework[38] to monitor and guide the gas transition at regular intervals. Simultaneously the California Energy Commission has launched a Tactical Gas Decommissioning Project that seeks to better understand the process for strategic, cost-effective retirement of gas infrastructure serving all types of buildings.[39]

For example, the City of Palo Alto commissioned its municipal utility to quantify the cost of electrifying single-family homes on the utility.[40] The City found that upgrades necessary to support electrification would raise electric rates by 1.2–3.8 percent but noted that some of that cost would have occurred anyway with vehicle electrification and that there could be offsetting savings from avoided investment in the gas system.

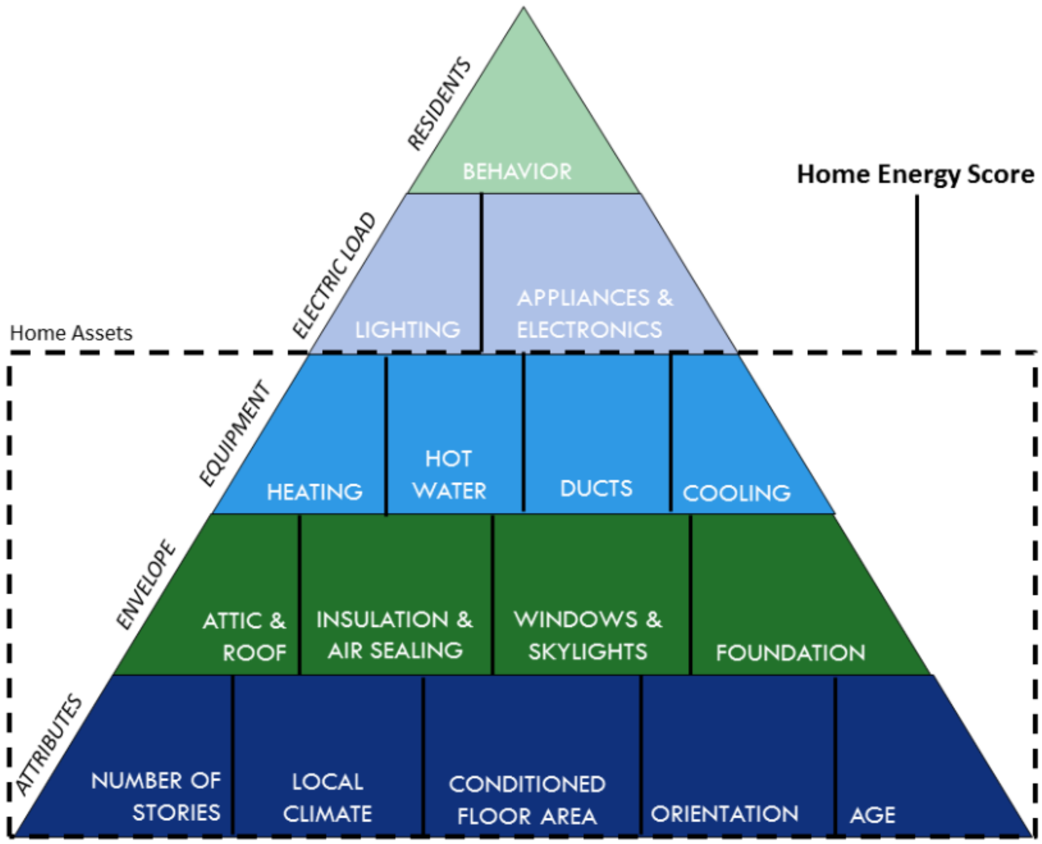
BARRIER	MITIGATION
Misalignment of goals: The gas utilities business model is at risk due to distributed electrification strategies. States must protect ratepayers from the cost, safety, and reliability implications of a death spiral caused by a significant exodus of customers from the gas system.	California has instituted comprehensive gas system planning to manage the transition. Cities' independent planning can help empower municipal energy planners and building owners with the data they need to accelerate building electrification.

Data: Building Energy Scorecarding and Building Pathways

Building, particularly home, energy scorecarding has been developed primarily to improve the transparency of home energy costs to potential renters and homebuyers. It has been equated to a miles-per-gallon rating on automobiles. Scorecarding leverages data collected in a typical home energy audit to develop an overall rating that conveys a home's energy performance.

Figure 10. **Illustration of assets tracked in home energy scorecards.**

Source: United States Department of Energy



The U.S. Department of Energy's Better Building Solution Center has developed the industry standard approach to building scorecards that evaluates home assets (Figure 10) and energy bills to come up with an easy-to-understand and compare rating.[41] The scorecarding framework can also convey potential energy savings associated with various improvements. The scorecarding approach has been adopted by several cities and states. However, use is typically associated with energy audits, and reporting is voluntary. Further, the assessment and ratings focus on energy rather than emissions.

Underlying the score is valuable information on the building's energy assets and performance that can be used to develop and guide data-informed decarbonization strategies. Although not directly tied to the scorecarding approach, the Massachusetts Clean Energy Center's recent Buildings Decarbonization Pathways Pilot[42] seeks to collect similar data through a decarbonization assessment to develop building-specific decarbonization plans. The pilot ultimately aims to identify common decarbonization pathways and assist building owners in understanding the process of decarbonizing a building.

This data collection and planning approach provides building owners and occupants with a clear picture of the potential costs and interventions that will likely be needed to better plan for decarbonization. The organization of building asset data also helps energy and decarbonization planners identify both areas of opportunities and challenges.

BARRIER	MITIGATION
Knowledge Gaps: The state of the small building stock is obscure to energy planners and most owners. This makes it difficult to identify opportunities for a cost-effective transition.	More standardized and comprehensive data collection can improve building owners' and implementors' understanding of the building stock and help inform the deployment of cost-effective strategies.

7. HOW TO MAKE THINGS WORK IN THE SMALL RESIDENTIAL SECTOR

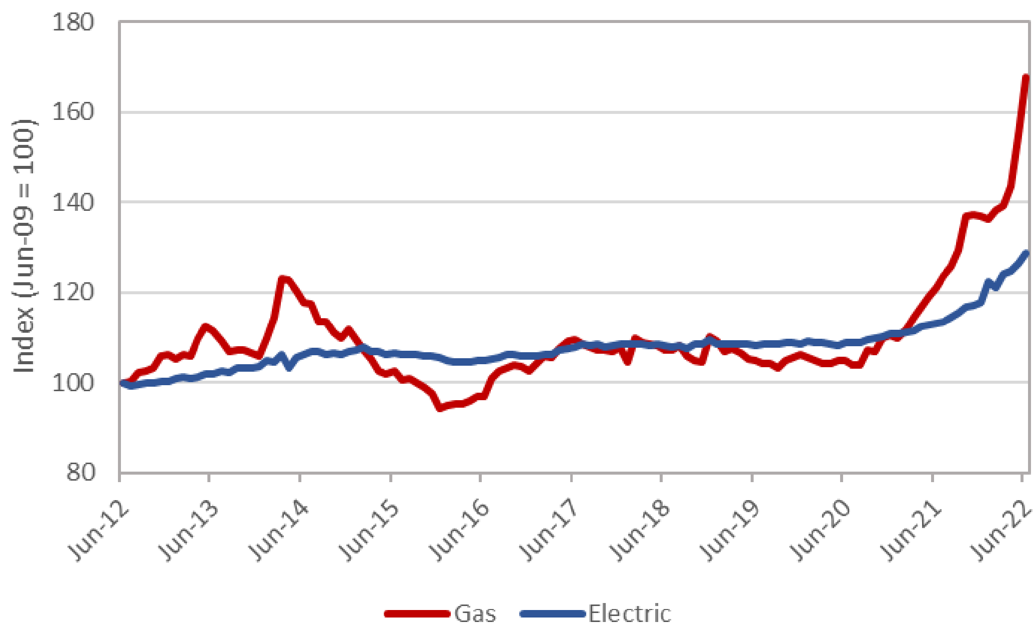
Over the last three years, Bostonians have become reacquainted with their homes. The start of the COVID-19 pandemic saw parents scrambling to turn their bedrooms into home offices safe from Zoom-bombing toddlers while the kids' bedrooms doubled as classrooms. While some households rediscovered the value of a multigenerational *pod,* crowded homes exhibited higher rates of COVID-19.

Those with means rebuilt some of their spaces to make the new normal work—if supply chain issues did not delay their projects. For those on the margins, the state of the living space mattered less than the compounded effects of the pandemic and the existing constrained housing market.[4] An unprecedented expansion of the social safety net and efforts to halt evictions allowed many to keep their heads above water.

Now, the reverberations of the Russian invasion of Ukraine threaten residents with sharp increases in their energy bills (Figure 11). Boston's least well-off could see their energy bills rise to consume as much as a fifth of their income.

Figure 11. **The national consumer price of electricity and gas in U.S. cities over the past decade.**

Source: FRED[43]



A crisis can spur innovation. Three—COVID-19, energy shortage, and climate disruption—can drive a revolution, especially if they intersect at home. The home rests at the base of Maslow's hierarchy, and these crises have already catalyzed a need and desire for healthier, more comfortable, decarbonized homes.

Electrification swaps reliance on fossil fuels for local ambient heat extracted from the air and water surrounding the home. Complementary people-focused *efficiency* measures make buildings more comfortable and healthier. *Integration* of efficiency and electrification together with energy supply systems ensures affordability. Altogether, these actions can lead to some advantageous outcomes (Table 2).

Table 2.
Outcomes of Electrified, Efficient, and Integrated Homes

PRIORITY	OUTCOMES
Resilient	Well-insulated, air-tight homes can maintain healthy temperatures in extreme weather and power loss.
Healthy	Removing combustion cooking and leaky gas distribution improves air quality and physical health.[44,45]
Local Investment	Capturing energy from the sun, the surrounding air, and the earth reduces reliance on fossil fuels. This shifts spending from out-of-state purchases of fuels to investment in local capital assets.
Integrated Systems	Integrating buildings with energy distribution systems (via smart meters, thermal networks, vehicle-to-grid, or vehicle-to-home charging) accelerates decarbonization.
Affordable Bills	Lower energy demands and reliance on local energy resources (renewable electricity) lead to lower and more stable energy bills.
Thriving People	Modern, affordable, comfortable, and healthy buildings improve residents' well-being, allowing them to thrive better in life and work.

As many of Boston's small homes enter their second century, they are poised to be revitalized by rapidly improving technologies and practices that reduce emissions and enhance the livability of these homes. It has already been happening. Between 2010 and 2020, New England added approximately a quarter million housing units, but during this time, the region added air conditioning to four times as many—*one million*—housing units; likely half of these were in Massachusetts.[46] This fact alone emphasizes the potential of rapid technology adoption.

Given both the rapidly improving performance and perceived value of electric heating systems and appliances, it can be expected that the market—along with growing state and federal incentives—will drive a *gradual electrification* that increasingly erodes the market share of gas but is too slow to achieve the City's emission reduction targets.

Conversely, Boston's old electric distribution system and the region's workforce would be severely challenged by an impetuous pace of electrification.[8,47] While this case is unlikely in the near term, it is conceivable that a gradual and unmanaged electrification could snowball as households (that have the means) reduce their gas use and depart the distribution system, leaving those who remain on it bearing the increasing costs of maintaining the system, further accelerating attrition to stimulate a utility death spiral with consequences for equity, climate goals, and energy supply systems.

Boston's existing homes need to electrify at a managed pace consistent with the City's climate goals and appropriately ambitious in the face of real constraints on the scaling up of efforts—a pace that challenges but is attainable.

Any of the transitions described above would be unprecedented in their level of building interventions and implications for the utility networks that will be affected by rapidly shifting energy demand. Both a gradual and impetuous electrification risk missing climate goals and could result in high costs that severely burden those who are least able to transition and are least able to afford it.

Therefore, to ensure progress toward Boston's goals, there needs to be a clear industrial policy *signal* for *consistent and appropriately ambitious* electrification of the small building stock. This signal needs to be reinforced by ensuring steady market development to support this change and sufficient transition planning to manage costs and ensure optimal outcomes for ratepayers, particularly those sensitive to energy prices. Achieving these goals requires a more comprehensive understanding of energy assets, market capacities, and infrastructure, now and as the transition proceeds through more robust *data and tracking*.

These actions reinforce one another and thus need to be executed immediately and in tandem. The following sections review the need and rationale for these approaches and offer specific recommendations for ensuring success.

The previous sections of this chapter reviewed examples of each of these actions across Boston's history, other jurisdictions, and other sectors. These themes are summarized in Table 3.

Table 3. **Key Lessons from Actions Outside the Small Building Stock**

ACTION	LESSONS
Build and maintain momentum.	Efforts must ensure continuous progress in scaling building electrification, efficiency, and energy system integration. Adjustments need to be made, but premature scaling back can hinder progress.
Use broadly inclusive approaches along with targeted strategies to maximize participation.	Energy efficiency programs have expanded their reach by reducing barriers to participation for everyone (e.g., expanding eligibility requirements) while deploying targeted actions to groups that face specific barriers (language-isolated, renters, etc.).
Act ambitiously now.	Immediately begin planning for ambitious transformations that take time to evolve: upgraded electrical systems, supply chain, workforce development, and neighborhood solutions.
Actively communicate.	Learn and disseminate learning fast. Networks have worked well for catalyzing change in the large building stock. Small contractor learning and neighbor-to-neighbor interactions will become more critical when focusing on the small building stock.

Making things work here requires a multifaceted understanding of progress beyond counting and tracking emissions. Evaluating progress requires focusing on the evolution of energy consumption over time, the state of and changes to the building stock, and assessing the policy and market ecosystem driving change. The following sections evaluate progress in these areas while applying the above learnings to develop actions to drive progress and make things work.

Electrification, Efficiency, and Integration

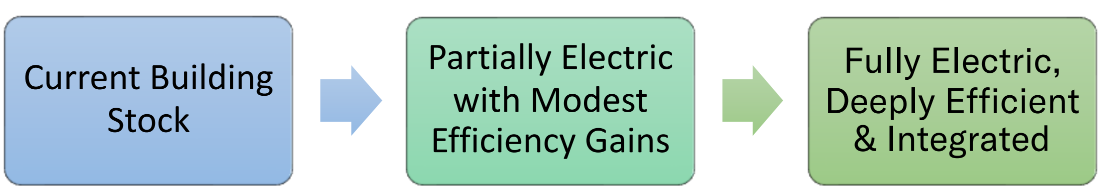
The transition from manufactured gas to natural gas required interventions in every gas appliance in every household across Boston. Older appliances were swapped out completely, while most others required a contractor-executed replacement of burner tips—often in a customized fashion. Homes typically converted all gas appliances in a couple of hours. Converting the entire building stock only took a couple of years. Here the utility, with regulatory approval, set a clear signal that change needed to happen fast. With support from the City's permitting office, they made things work when a household was reluctant or hard to reach.

The decarbonization of the small building stock will take decades and cannot rely on a knock on the door from inspectional services to make it happen. *Consumers need to welcome this upgrade while being guided to change.* Where the switch from manufactured gas to natural gas barely affected consumers' experiences, this transition will be more noticeable. Despite the health impacts, consumers should not feel like they are being forced to give up gas cooking, grilling, or fireplaces,[ii] but instead, feel like they are building a better home.

What Needs to Happen: A consistent and appropriately ambitious electrification

The decarbonization of single-family and small multifamily homes will be an ongoing process over the next several decades that may occur all at once in a building or through several steps spread across the years (Figure 12). Over time, these homes will become more electric, efficient, and integrated with broader energy system. These improvements to buildings can and should be expected to continue even when Boston achieves net-zero emissions; deeper efficiency and integration may further reduce costs and better use resources over time.

Figure 12. **Conceptual phases of small multifamily decarbonization.**



ii. Truck-delivered propane is an adequate substitute in these situations that will allow for customers to exit gas distribution systems.

The types and scale of changes can be broken down into two categories:

1. **Incremental electrification steps** that are designed to reduce reliance on fuel are immediately scalable across the building stock and are generally cost-saving. These include:
   - Conversion of central AC units to heat pumps at the end of life
   - Replacement of gas stoves and water heaters with electric appliances at the end of life
   - Installation of mini-split heating systems in homes with older and inefficient but viable heating systems (e.g., steam boilers and hot water).
   - Application of basic efficiency measures (weatherstripping and blow-in insulation)
   - Preparation of home electrical panels and services for when new electric loads (including EVs and rooftop solar) are added.

2. **Comprehensive electrification strategies** that support the elimination of fossil fuels in buildings but are not yet ready for scaling due to high costs and an insufficient marketplace. Some options could be implemented now but require more time and effort to scale and bring down costs. These include:
   - Whole home electrification retrofits with complete heating system overhauls.
   - Prefabricated exterior panel retrofits that seek to achieve deep building efficiency.
   - Street and neighborhood scale retrofits and interventions that seek to reduce reliance on aging gas distribution systems—perhaps using new thermal networks.

This approach seeks to maximize the promulgation of heating electrification and modest efficiency measures across the building stock as quickly as possible while pursuing deeper levels of electrification and efficiency over the long run. Recent analyses by the state[6] and the gas utilities[7] have demonstrated that phasing can deliver significant cost savings and overcome various scaling barriers while achieving the necessary emissions reductions.

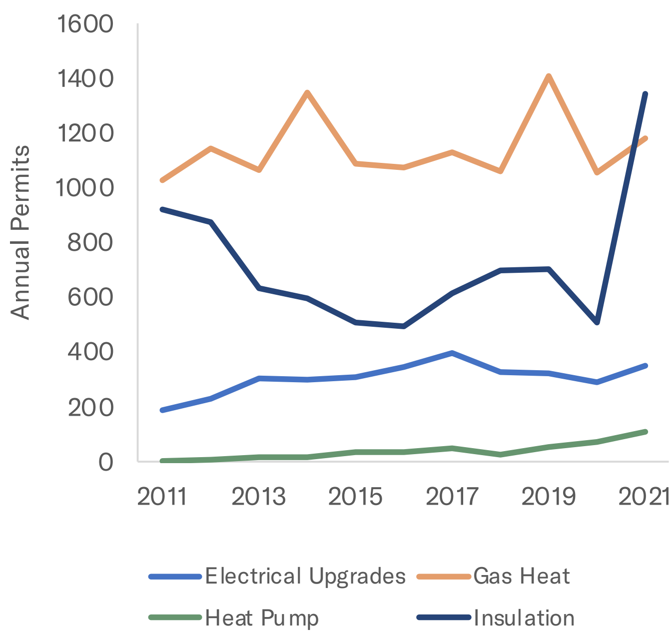
Based on the recommendation of Carbon Free Boston,[2] the City's 2019 Climate Action Plan Update[3] set a target of retrofitting 80 percent of existing buildings with electrification with 30–50 percent reductions in heating demand by 2050. This target was based on the understanding that even the most ambitious transformation would be challenged by unforeseen barriers to scale, but lacked a specific strategy for how to get there.

This target is consistent with the state's near-term goal for heat pumps, a soft target of 1 million heat pump (housing unit) installs by 2030.[8] For comparison, ISO New England has forecasted 780,000 installs over the next decade.[48] Scaling these to Boston based on the city's housing stock and population shares implies the city needs to complete as many as 100,000 installs over the decade. The city and state are currently well behind those targets.

What Has Been Happening: A Slow Start Hindered by Entrenched Behavior

Figure 13. **Left: permits issued over the last decade for various energy system interventions in the small residential stock. Right: map of permit locations for gas and heat pump interventions, 2019-2021.**

Source: City of Boston Inspectional Services Division Issued Permits



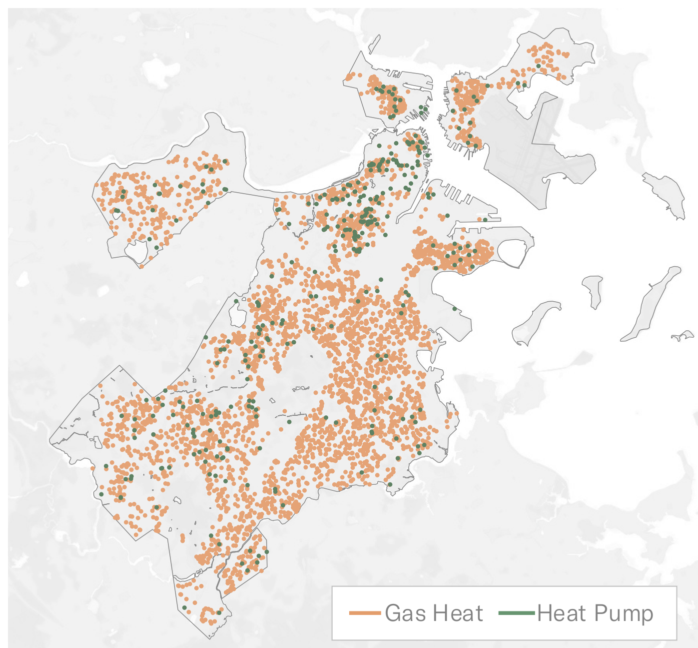


Table 4. **Energy Indicators of Residential Building Decarbonization**

Permit and rebate data for small residential buildings were obtained from the City of Boston Permit Database and MassCEC Heat Pump pilot program databases.[49,50] Incentives, customer counts, and consumption indicators cover all residential buildings.

INDICATOR		ESTIMATE
Building Changes	Heat pump installs[49,50]	< 200 in 2021
	Fuel system retirements	Net gain of 1,000-2,000 gas systems
	Electrified appliances	Likely small
	Electric service upgrades[49]	300-400
	Building envelope improvements	600-800 primarily blow-in insulation
	Rooftop solar[49]	600
	Incentives[51]	$25M-$35M
Energy Consumption	Gas customers[52]	+8,300 new customers (1% annual growth) from 2015-2020. For comparison, growth in electric customers was +21,000.
	Gas consumption[28]	Over the last decade, consumption has been effectively flat with some weather variability despite customer growth.
	Electricity consumption[28]	Effectively flat over the past decade despite customer growth.
	Delivered fuel customers[28,53]	-10,000 (6.6% annual decline) between 2015-2020, with most homes switching to gas.
	Delivered fuel consumption[28,46,53]	~6.6% annual decline between 2015-2020

The application of electrification and efficiency measures in the small building stock is developing. The trajectory to scale is unclear, however, and likely lagging what is needed to decarbonize this sector on pace to achieve Boston's net-zero goal. We make this assessment with high confidence based on the indicators presented in Figure 13 and Table 4.[iii]

There are several notable elements from this data:

- The combustion of oil and gas has modestly declined across the entire residential sector. It is reasonable to assume that it has remained flat or declined in the small residential stock.
- In 2021, just over 100 permits were issued for heat pump installations in the small residential stock in Boston. Despite this small number of installs, adoption has been growing yearly.
- Historical permitting data is consistent with MassCEC heat pump rebate data from 2015 to 2019. Notably, during this time, 98 rebates went to households that did not use fossil fuels for backup.
- From 2019 to 2021, the MassCEC conducted 18 whole-home electrification pilots in Boston.
- For the last decade, permitted like-for-like gas heating replacements hovered around 1,200–1,600 per year; oil-to-gas conversions hovered around 2,000 per year.

Data regarding rooftop solar installs is cleaner and can be used to draw some helpful insights on technology adoption in the building space. Figure 14 shows the number of installs by year and where solar is being installed. The dip in installs starting in 2017 emanated from a change in solar incentives being offered by the state. Before this time, the state offered generous but functionally temporary programs (SREC I and SREC II). In 2016 the state implemented the less generous but more durable Solar Massachusetts Renewable Target (SMART) program. This transition and lowering of funding led to a temporary dip in solar panel installations that had ramifications for the industry across the state.

iii. These indicators were compiled from various data sources, including Boston's Inspectional Services Division Permit Database,[49] MassCEC rebates,[50] MassSave public reporting,[51] utility reports,[52] and various datasets aggregated by the City of Boston for its Community Greenhouse Gas Inventory.[28,46,53] It should be noted that some of these indicators—as well as those used by the City in the inventory and used to generate Figure 2—include activity in all residential buildings. Small residential buildings comprise approximately half of the floor space and housing units. It is possible and likely that trends in the small and large residential stocks are similar or diverge. Further, this data misses an unknown amount of unreported activity. Given that our focus on change is so small, we are confident in our assessment. However, ongoing monitoring of progress, particularly to ensure equitable outcomes, requires more robust data resources. This is discussed later.

Annual permitted electrification, efficiency, and integration interventions need to rapidly scale to 10,000 per year. The current pace is shockingly insufficient to achieve the City's climate goals, but it is not surprising. Building electrification has only emerged as the consensus and dominant strategy for decarbonizing buildings. Net zero became state policy in 2020, which, due to planning cycles, could only begin to influence energy efficiency programs in 2022. A fog of uncertainty has delayed action; the fog has now lifted, and there is much catching up to do.

Figure 14. **Solar installs – as measured by closed permits – by year for small residential.**[49]

Source: City of Boston Inspectional Services Department

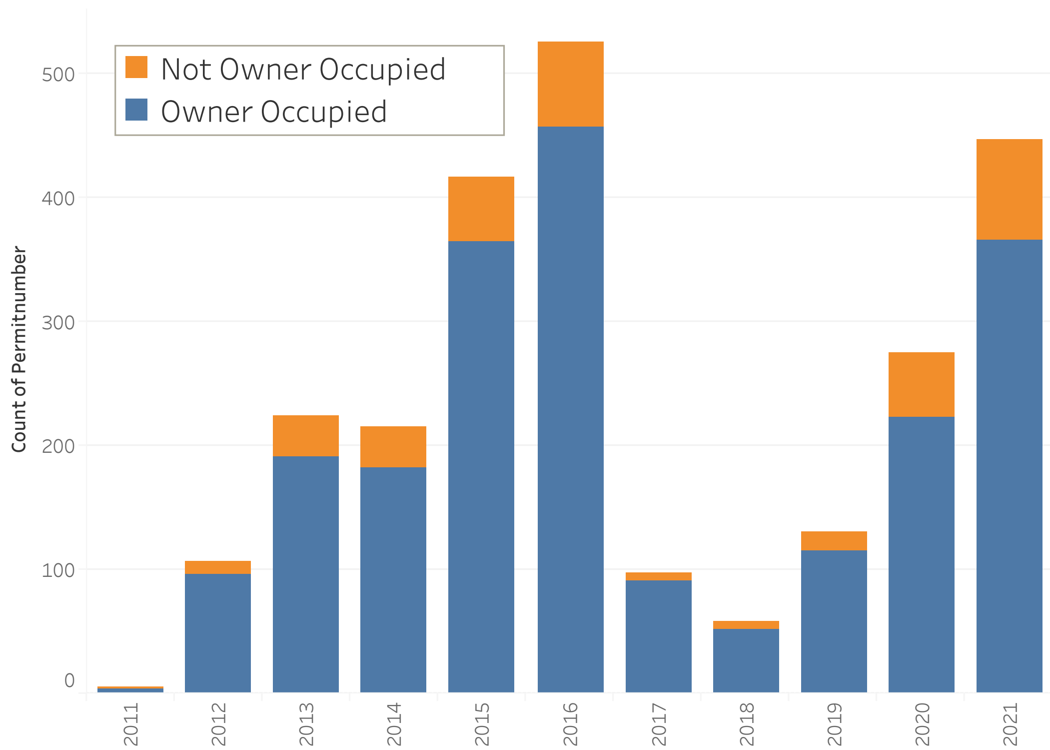
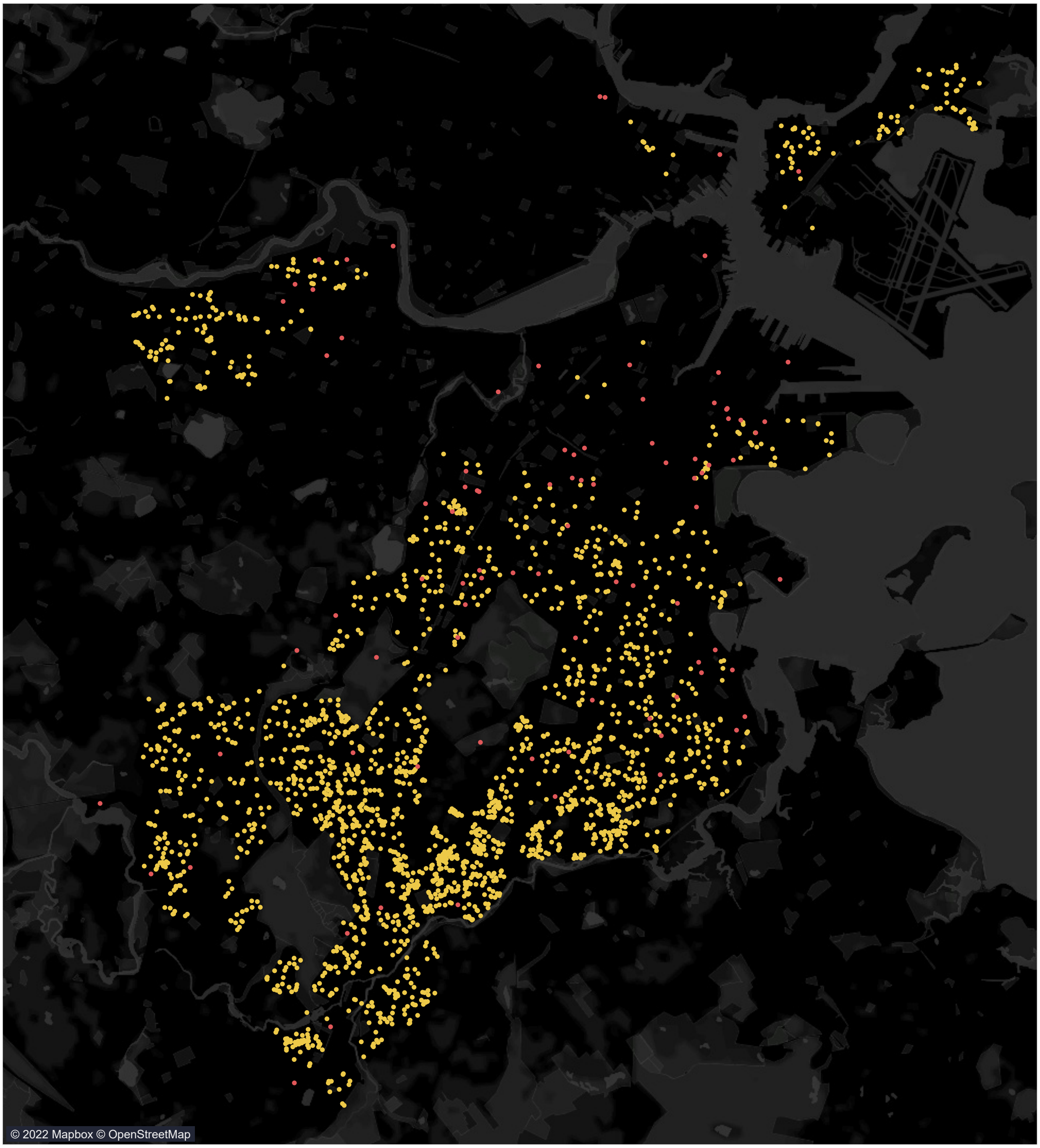


Figure 15. **All solar installs across the city, 2011–2021.**

Source: City of Boston Inspectional Services Department



How to Make Things Work: Signal a Paradigm Shift to an Electric, Efficient, and Grid-Integrated Building Stock

The technological solutions for decarbonizing the building stock exist; however, significant knowledge gaps, funding gaps, and inertia barriers must be overcome. Further, there are emerging signs that Boston's old electric distribution system may challenge the technical feasibility of electrification.

Policymakers, utilities, developers, property owners, residents—everyone—must understand the dire need to rapidly scale up electrification efforts as foundational to achieve net zero goals. Framing this as a choice of either *electrification or something else* fails to recognize the complexities of the transition and creates—perhaps intentionally by some entities—a perception of ambiguity. While some questions remain about where, at what scale, and for how long fuels and pipelines will continue to be used, the need to electrify the bulk of heating is now the consensus strategy for building decarbonization.[iv] The City's adoption of BERDO 2.0 (as discussed above) has set a clear direction to decarbonize Boston's large building stock by 2050. This is already spurring action, planning, and the implementation of solutions. In the light-duty vehicle sector, Massachusetts is following California's lead. The Commonwealth has provisionally required the sunsetting of non-zero-emissions vehicles by the end of 2035.[31] Given the technological outlooks, both targets are appropriately ambitious. They have sufficient oversight and flexibility to adapt to a changing environment. Both strategies are supported by a mixture of financial incentives and customer education.

A similar approach described herein can be used for decarbonizing Boston's small building stock. However, because this sector is so diffuse and complex, it needs to be comprehensive and requires concerted action by several implementers.

ACTION ITEM: Establish fossil fuel–free new construction standards

Implementors: City of Boston, Massachusetts Department of Energy Resources (DOER), State Legislature

All-electric, high-performing new building construction standards are essential for signaling a paradigm shift to electrified buildings. The BPDA should adopt the proposed Zero Net Carbon Code. The State (DOER) should approve Boston's application to become one of 10 communities to establish fossil fuel–free building codes. The City should leverage Inflation Reduction Act (IRA) funding for municipalities to plan and implement advanced building codes. Boston should seek to ensure the success of this pilot to drive DOER or the legislature to adopt these practices statewide by 2025, if not earlier.

iv. The Commonwealth's gas distribution companies even acknowledge this in their "future of gas" plans.[54,55]

The clearest signal to send on the importance of building electrification, efficiency, and integration is the construction of such buildings. While it does not directly address existing buildings, it will establish this type of building as the standard in the minds of consumers and contractors.

Living in all-electric high-preforming new construction is cheaper for occupants than continued reliance on fuels, according to a study commissioned by DOER to inform the 2022 update to the state building code.[56] Despite this finding, DOER, did not allow Massachusetts communities to adopt a fossil fuel–free building code.

Responding to this lack of leadership, the state legislature has since allowed 10 communities to apply to pilot fuel-free construction in their building code.[31] Under the leadership of Mayor Michelle Wu, Boston has filed a home rule petition to be one of these communities.[57] This is on top of other actions by the City to push forward new building construction standards that favor electrified new municipal buildings.[58,59]

The IRA set aside $1 billion to assist states and cities with developing, implementing and enforcing building energy codes, with $670 million dedicated to efforts that focus on advancing the Zero Energy Code.[v] Boston should work with DOER to leverage these funds to advance the new construction code.

Boston is seeking to lead the way and—if awarded participation—must demonstrate effective and successful implementation of the fossil fuel-free code that prompts either DOER or the legislature to establish these practices in a statewide code by 2025.

ACTION ITEM: Zero-emissions appliance and heating equipment standards

Implementors: Massachusetts Department of Energy Resources (DOER), State Legislature, Federal Government

The state needs to pursue the implementation of zero-emissions appliances, heating equipment, and building performance standards for existing buildings. Standards are likely to be implemented at the state and federal levels. Still, the City of Boston has a role to play in enforcement. Over the next three years, the State (DOER) should monitor: (1) California's adoption and implementation of zero-emissions heating standards;[61] (2) the impacts of the Biden administration's proposed rule on furnace efficiency standards;[62] and (3) the adoption of heat pumps and evolution of practices in Massachusetts spurred on by the MassSave 2022–2024 plan. By the end of 2025, DOER should be considering a schedule for zero-emissions standards that drives the small residential market toward

v. As defined by the 2021 International Energy Conservation Code[60]

predominantly electric replacements by the late 2030s.[vi] At the earliest practical point, the state or federal government should establish standards that require all central AC replacements to be heat pumps.

Appliance and heating equipment zero-emissions standards[vii] will be essential for signaling a paradigm shift to electric buildings and ensuring the durable alignment of the existing stock with climate targets. The standard applies to new equipment: Customers retain the right to use existing equipment they may have and repair it. Updates to the building envelope could be triggered by roof or siding updates.

The cheapest time to electrify or apply deep efficiency measures is at the end of the life of existing assets. Appliance and heating system replacements often occur unexpectedly when homeowners have limited time to evaluate and plan for alternatives. Limited contractor experience with electric retrofits also adds a barrier. If homeowners pursue such a like-for-like replacement, they have locked their investment into an asset that will still be reliant on fossil fuels for one to two decades. Acknowledging these barriers, setting zero-emission appliance standards is the most direct way to drive electrification forward.[viii]

Such standards should be ambitiously consistent with climate targets with the intent of prompting customers and contractors—as well as the grid—to be prepared for such changes at an appropriate pace. The adoption of standards promotes homeowners to be prepared; contractors to change practices; new, more efficient

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vi. Despite its conjecture that buildings will steadily electrify, this chapter is hesitant to advise all electric heat in all small residential buildings at this point, given notable cost, resource, and emissions tradeoffs associated with doing so. There may be some value in the very limited use of fuel-based heating in some homes, certainly as a transitional strategy but also in the long run.

vii. Net-zero appliance and equipment standards are distinct from a clean heat standard such as that considered by Vermont and investigated by the Massachusetts Commission on Clean Heat. Such standards seek to regulate the production of heat—as opposed to the emissions of the equipment—by creating a market-like mechanism that allows for both electrification and renewable fuels to be used to attain compliance. This report views such standards as insufficient and possibly contradictory to smart signaling on electrification. They allow for the sector to defer electrification and instead achieve compliance through the use of renewable fuels enabling the lock-in of combustion-based equipment. This exposes gas customers to potential long-run cost increases coming from increasing delivery costs and the high cost of renewable fuels. Further, it conflates complex transitional issues occurring in separate sectors: gas transition; bioenergy; and renewable electricity supply.

viii. Conceivably such standards could include combustion-based technologies such as those that use hydrogen or renewable fuels, allowing for their use in some application-specific situations. However, it is likely for cost and practicality purposes that electric solutions will be favored for more buildings. Further, California is expected to regulate this equipment via its efforts to reduce criteria pollutants such as ozone and nitrogen oxides, which would effectively exclude combustion equipment.

practices and business models to arise; and the electric utility to perform the necessary upgrades to support electrification.

Standards seek to catalyze such changes. However, it requires comprehensive financing and enabling actions designed to ensure that the standard does not become a burden for low-to-moderate-income households. Plenty of lead-time can give all actors a chance to adapt, adjust, and experiment.[ix] To ensure that the paradigm shift does not create a burden or result in political backlash, it must be implemented to balance various objectives, including decarbonization, cost, infrastructure needs, equity, etc. This can be achieved using the complementary strategies discussed below.

ACTION ITEM: Leverage the incentives available under the MassSave 2022–2024 plan and the IRA

Implementors: City of Boston, Massachusetts Department of Energy Resources (DOER), ABCD

The 2022–2024 MassSave incentive structure combined with the tax credits for building electrification and efficiency measures in the Inflation Reduction Act offers unprecedented incentives for broad building decarbonization action. With this funding on the table, the City of Boston, ABCD, and other community organizations with support from the Commonwealth need to maximize their residents' ability to take advantage of these incentives. Policymakers at all levels should constantly monitor the use and impact of incentives to ensure long-term durable financing to support the transition.

Adequate financial support is necessary to ensure consumer acceptance, further drive adoption, and ensure that households of all levels are not burdened by the costs of complying with a mandate. While electrification coupled with efficiency and integration is the lowest-cost decarbonization strategy for buildings, it requires a significant up-front investment that can be a significant barrier to adoption.

The 2022–2024 MassSave plan puts the financing for electrification in place but retains some scaled-back fossil fuel incentives. Table 5 lists various electrification-focused incentives made available to all customers in this cycle. The plan also made some enhancements for low-to-moderate-income customers that would typically cover the total cost of home electrification. However, low-income households are not eligible for an all-electric conversion unless such a conversion reduces costs. Typically this happens with oil-to-electric conversion and not a gas-

ix. The City of Zurich, Switzerland is in the process of retiring large portions of its gas system and planning future retirements. Districts currently undergoing retirements were given 30-year lead times. Districts under consideration for future retirements are being given at least 15-year lead times.[63]

to-electric conversion.[x] This and ongoing incentives for more efficient fossil fuel heating systems for all customers continue to permit and even encourage the lock-in of fossil fuel equipment.

These generous incentives have sparked a surge in home electrification activities. And then, in August, the federal government passed the Inflation Reduction Act (IRA), adding additional incentives for small households (Table 5).

The IRA tax credits will favorably augment the MassSave incentives and spur uptake. The low- and moderate-income incentives are game-changers. Incentives for upgrading electrical systems address a key cost barrier and problem in many older homes. Like the 2022–2024 MassSave plan, the IRA did include some modest incentives for high-efficiency fossil fuel equipment. Such incentives are a modest-yet-unnecessary drag on electrification efforts and should be removed when practical.

The IRA is a solid nationwide signal for the future electrified and efficient building paradigm. Boston must seize the opportunity to focus this signal on its homes. While the administration of these programs is developing, Community Action Agencies and state energy offices will likely have a critical role in targeting and disseminating the funds. The City must adapt its permitting apparatus quickly to be an enabler while working to educate its constituents. Advocacy organizations, community groups, churches, foundations, and neighborhoods all have a role to play in facilitating neighbor-to-neighbor education.

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x. In the 2022 climate bill[31] the legislature prohibited MassSave from issuing fossil fuel incentives going forward.

Table 5. **Home-Electrification Incentives Available to Households under the 2022–2024 MassSave Plan and the Inflation Reduction Act**

MassSave[64]

- **$750** for a heat pump water heater*
- **$500** for an induction range
- **$50** for EnergyStar certified electric dryer
- **$1,250** for ASHP per ton up to $10,000*
- **$10,000** for whole home ASHP electrification*
- **$2,000** for GSHP per ton up to $15,000*
- **$15,000** for whole home GSHP electrification*
- **75%–100%** off insulation*

*Additional incentives for low-income households resulting in no-cost retrofits under certain situations.

IRA: Energy Efficient Home Improvement credit (25C)

Deduct 30% of home upgrades from taxes up to $600 per measure and $1,200 per year:

- Insulation
- Electrical panels
- Doors
- Windows
- Ventilation

An additional 30% of the project value, up to $2,000, is available for heat pump installs.

IRA: Energy Efficient Home Improvement credit (25C)

Updates solar tax credit to allow a 30% deduction and include integrated battery storage.

IRA: High-Efficiency Electric Home Rebate Act

Cash rebates for low-income households; moderate-income households receive the same rebates but are capped at half the project cost.

- **$8,000** for a heat pump
- **$1,750** for heat pump water heater
- **$840** for an electric stove
- **$4,000** for an upgraded electric panel
- **$2,500** for upgraded electric wiring
- **$1,600** for insulation & weatherization

IRA: HOMES Rebate Programs

~$2,000 per household allocation to state agencies to provide rebates for comprehensive home energy retrofits.

ACTION ITEM: Education

Implementors: City of Boston, MassSave, ABCD, Community Organizations

The paradigm shift must reach households and be welcomed as a permanent guest. Bostonians are about to experience changes to their homes–some will be unnoticeable, some will be noticeably good, and all will need acceptance. Early adopters need to espouse the benefits without appearing preachy or privileged. The City, utilities, and community organizations need to develop resources and mechanisms that reach those on the margins.

Natural gas utilities leveraged person-to-person and neighbor-to-neighbor interactions to grow, and so must electrification. The Boston Gas Company once operated showrooms where potential customers could try out gas cooking and other appliances with the support of a sales representative. Natural gas expanded into the suburbs that were not built around it via neighborhood informational parties that sought to enroll enough customers to support system expansion.

Electrification, efficiency, and integration can do the same. Evidence indicates that neighbor-to-neighbor interactions accelerate the diffusion of new technologies, including building heating, ventilation, and air conditioning systems.[65] These range from sharing an induction cooktop to tours of retrofitted electric homes. As blocks experience gas pipeline replacement, education may take the form of neighborhood organizing and canvasing to educate residents on the costs associated with pipeline replacement, the benefits of electrification, and advocacy for an alternative.

Additional effort will be required for those on the margins: language-isolated, elderly, time burdened. These groups require additional outreach efforts such as translating materials into multiple languages, reaching out to community organizations, and publicizing via traditional and alternative media outlets.

Building decarbonization science should be integrated into high school curriculums, with students empowered to conduct door-to-door outreach and research in their communities. Demonstrations of efficient electric buildings should occur at the Museum of Science and with a mobile exhibit that travels the neighborhoods.

Such education can spur action and create long-term durable change by transforming the building retrofit market.

Market Development

Decarbonization shifts energy spending away from out-of-state fossil fuels to in-state renewable energy resources. Building electrification reduces reliance on distant extractive industries. Instead, it shifts spending to capital improvements in the home that utilize local energy resources—the ambient heat in the air and earth. This shift will require new equipment, labor, and business models.

The COVID-19 pandemic and its aftermath profoundly affected appliance and home energy equipment supply chains. Increasing demand and disruptions to manufacturing and shipping meant that many home improvement projects got delayed by months. The problem has been especially acute with electric infrastructure such as meters and circuit boxes.

Challenges in getting work done have also been exacerbated by a tightening labor market that has increased costs and wait times. Contractors have noted difficulties in hiring and retaining skilled workers.[66] In August 2022, unemployment in Massachusetts reached 3.5 percent.[67] The number of jobs required to meet the state's 2030 emissions targets[8] would bring unemployment back to its pre-pandemic level of 2.9 percent—and a third of those are needed to support the building interventions. Such a tight labor market is highly concerning, indicating that the Commonwealth and Boston do not have the trained workforce it needs to achieve their goals.

Homeownership has always been a double-edged sword: The ability to shape one's space is constantly challenged by the coordination and time required to do it. But homes without owner-occupants face further challenges to upkeep. While the financial incentives to pursue energy updates noted earlier are likely to spur homeowners to act, the new benefits of the IRA add a layer of complexity to the process.

The policy signaling described above will not achieve its goals if the market cannot deliver the paradigm shift. Generally, the energy retrofit industry and its boosters in state and local government have been aware of these challenges and have been working on workforce development since the 1980s. However, the scale of the needed industrial flip is unprecedented and requires constant attention over the next decade.

What Needs to Happen: Guide Supply Chains and Workforce to Deliver

The market needs to deliver a product and an installation process that homeowners and residents are excited about bringing into their homes. This needs to happen on three fronts:

1. **Retrofits need to be affordable and exhibit continuous improvement in outcomes.** Currently, the project cost of electrifying a home dramatically exceeds the cost of replacing fossil fuel equipment. The generous financing resources discussed in the previous section help most homes bridge this gap while keeping costs low as the industry scales. High-cost strategies such as geothermal well drilling and building envelope improvements may have relatively large opportunities for cost reductions. These should also be aggressively pursued.

   Simultaneously, the manufacturing and retrofit processes should seek to improve performance (e.g., the efficiency and longevity of heat pumps or the performance of efficiency retrofits) and offer additional value (e.g., improved heating and cooling zoning capabilities). Such outcomes (e.g., enhanced equipment efficiency) may be preferable to equipment cost reductions and could be encouraged by targeted rebate adders and standards.

2. **The retrofit experience must be streamlined to ease barriers to customer participation.** The interventions to one's home may be desired and financially accessible but logistically overwhelming. While most homes may have very similar outcomes as part of a retrofit, the pathway there may differ by home and customer preferences. Homeowners need guidance through this process via a trusted entity.

   Transaction costs—such as contractor selection and negotiation—drag on resources and must be reduced. Further, good outcomes and improvements in building performance should be guaranteed. Customers need education on strategies for how their homes could evolve over several decades if they are not ready to retrofit everything all at once.

3. **A capable and diverse workforce needs cultivation. Good employment opportunities won't be lacking.** Ensuring good outcomes at low costs relies on a well-trained workforce. With the rapid flip of the HVAC industry toward electric strategies, there is a clear need for training and retraining workers of all trades and levels. This starts in high school by directing youth to these trades and training. It continues by coordinating all industry stakeholders to promote best practices.

   Residents will be more accepting of the projects if the work is done and led by people who reflect their community. This requires eliminating historical barriers to women and people of color and enabling them to grow businesses that serve their communities.

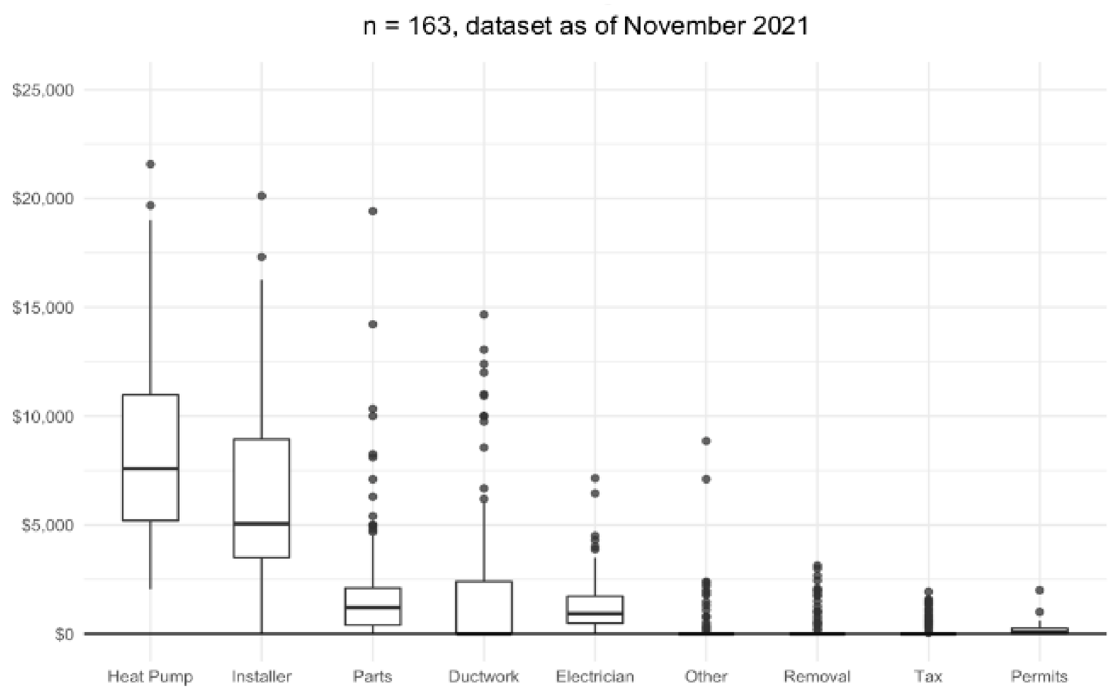
Anecdotal Evidence

While writing this chapter, one author solicited bids to replace an existing ducted air conditioning system with a heat pump at their home. An initial quote of $20,000 was received. This included equipment that the authors were able to value at $5,000. Being knowledgeable about heat pump install costs made public by the MassCEC, the author requested a revised lower quote. The contractor subsequently offered a quote of $60,000 because of “new complicating factors.” A second contractor was solicited and offered a quote of $12,000. This was in line with prices and labor estimates at the time of the publication of this chapter. The process took four months.

The other author purchased an induction stove that was delayed by four months due to supply chain constraints.

Figure 16. **Distribution of project costs for homes retrofitted under MassCEC’s Whole Home Retrofit Pilot.**[50]

Figure adapted from McBride 2022[68]



What Has Been Happening: Scaling Up Electrification

Over the past several years, Massachusetts Clean Energy Center (MassCEC) has played a critical role as a market transformation catalyst. In the small residential sector, it piloted rebate programs for any type of air source and ground source heat pump installs, then developed incentives for whole home (single-family) retrofits, and more recently began whole small multifamily retrofits. Alongside the incentives and work provided by these pilot programs, the MassCEC coordinated with contractors, workforce development programs, and manufacturers to better understand and disseminate pilot learnings.

These efforts (started in 2015) underpinned the core residential strategy in the 2022–2024 MassSave plan. In addition to the rebates noted above, the plan incorporated several comprehensive strategies for scaling up electrification and efficiency practices (Table 6). The reader is encouraged to review the plan for a detailed assessment of barriers and a breakdown of these key strategies for a more comprehensive understanding of these strategies.

Table 6. **Intervention Strategies for Accelerating the Decarbonization of the Residential Building Stock in MassSave's 2022–2024 Plan**[66]

STRATEGY	OUTCOME
Increasing Equitable Service	Removes barriers and targets messaging
Community First Partnership Program	Facilitates neighbor-to-neighbor messaging
Workforce Development	Build electrification capability; train and retain diverse workers
Scaling Up Residential Electrification	Enhance customer and contractor familiarity with electrification
Easing Participation	Phasing in electrification where appropriate
Engaging Contractors and the Market	Improve contractors' ability to offer electric strategies

The 2022–2024 MassSave plan is notably comprehensive in efforts to transform the market to encourage participation, overcome exclusionary barriers, enhance the workforce, and shift the market to electrification. The plan embraces partial displacement of fuel heating at its core, stating that:

> "These experiences contribute toward the overall momentum noted in the [partial electrification] strategy above and allow the specific customer to become more comfortable with heat pumps in their home. This sets the stage for them to move to fully electric heating in the future, as new practices, improved pricing, and new technology may make a fully all-electric home more achievable."

This principal will be essential for driving market transformation in the coming years. However, the plan's focus on historical cost-effectiveness measures overlooks essential elements of advancing electrification as ambitiously as practical, the benefits associated with reduced methane leaks, and the fact that earlier electrification makes it easier to rightsize the gas system.

Despite this, the plan's strategic initiatives are an appropriately conscientious and ambitious pivot—but not entirely sufficient transition—to market transformation. The 2022 state climate bill will ensure that plans embrace electrification more completely[31]

The plan's focus on increasing the size and diversity of the workforce is notable. Most contractors report significant difficulty in recruiting new employees. African Americans are moderately underrepresented in the energy efficiency workforce, while women only comprise 13 percent of it. The plan addresses this by comprehensively focusing on all parts of the workforce pipeline, from high school engagement and training to developing opportunities for minority and women-led businesses.

The plan also seeks to improve MassSave's Residential Coordinated Delivery program, which aims to provide customers with a streamlined process for engaging with auditors and contractors and guides to rebates and financing. This program has improved participation and customer experiences; however, rebate delays are common,[69] and the process is not as smooth as the low-income offering.

Finally, the plan seeks to work with manufacturers to drive market transformation across workforce training and supply chain support.

And then, in August, the federal government Passed the IRA.

How to Make Things Work: Develop the Market on the Supply Side

The 2022–2024 MassSave plan marked an inflection point in market development that the IRA will now boost. The coming years are both an opportunity to accelerate progress and an experiment in industrial policy. The actors in this small building sector must simultaneously be ambitious and learn from failures and successes.

With these programs in place, implementors need to focus on the fundamentals to develop a market that can deliver on small building electrification, efficiency, and integration.

ACTION ITEM: Execute a paradigm shift in workforce development

Implementors: Boston Public Schools, DOER, MassSave, and MassCEC

Achieving these targets will require a shift in the career guidance of young people. While various agencies and actors in this sector have invested deeply in workforce development efforts, those efforts have struggled to yield sufficient workers. These efforts need to continue, but to increase yields, potential workers need to be funneled into these programs early in their careers. High school graduates need to be shown that a non-college career pathway can be financially and personally rewarding. Such a pathway can help create durable wealth in low-income communities. To be successful, all industry participants and society must establish a new vision and path for young people.

For nearly two generations, the guidance that attending a four-year college is the core path to achieving financial stability has hampered the flow of students to trade or vocational training. There has been a persistent myth that trade jobs were lower paid and of lower stature. If there was any truth to this, that sentiment is changing quickly. As efforts to decarbonize ramp up, related jobs are expected to pay well and offer stable employment in the coming years.[8]

Action on this front needs to go bigger than the concept of a public sector Civilian Climate Corps[70] and include efforts to build up the workforce and its skills in the private sector trades. It needs to begin with green education in early school and develop vocational school and community college programs to provide future workers with the skills they need early in their careers. It also requires the licensing authorities to find ways to responsibly relax barriers to workforce expansion.

Such efforts can and should focus on whole career development, seeking to give trainees the skills to advance and lead throughout their careers. These efforts can help lift marginalized populations and communities out of poverty and build wealth.

ACTION ITEM: Push down costs while scaling up the industry

Implementors: MassCEC, DOER, MassSave, Contractors, Manufacturers, and Other Industry Participants.

A larger workforce coupled with an improved supply chain can be used to push down costs. Supply chain improvements can include automation of work, standardization of practices, development of local manufacturing hubs, and better dissemination of best practices among industry participants. Leveraging funding from the IRA, the state and industry must engage in efforts to develop a regional industrial base for transforming the building stock and determine best practices for doing so.

Various strategies exist for pushing down costs while scaling industrial capacity in building electrification retrofits:

1. Practice standardization – as the number of retrofits scales, so do opportunities to establish best practices to reduce project time and costs while improving outcomes.
2. Offsite prefabrication – shifting work from buildings to offsite preassembly facilities can lower costs and reduce challenges to working on site (e.g., the Energiesprong process).
3. Local manufacturing – build local production facilities where opportunities for cost reduction and contractor training exist.
4. Technological transfer and learning across regions – coordinate with industries in other regions to develop skills that will be helpful here (e.g., Southern U.S. oil drilling experience can inform better geothermal drilling in the Northeast).
5. Transparency in practices and costs among industry and customers helps to control costs.

The IRA allocated $500 million in financing to use the Defense Production Act to scale up domestic heat pump manufacturing and energy efficiency supply chains. This will likely include funding and cost-sharing for developing manufacturing hubs to produce heat pumps and similar equipment. State agencies and the local industry should coordinate on leveraging IRA funds to scale up local industrial capacity.

ACTION ITEM: Encourage the development of new business models to streamline the delivery of services

Implementors: Industry, MassSave, MassCEC, City of Boston

Promote business models that make it easier for residents and homeowners to do more at a lower cost. Financing approaches such as on-bill financing, performance contracting, or property-assessed clean energy strategies have all yielded mixed results in the building sector. Still, these programs may need a second look as home retrofits scale in depth and numbers. The state and industry should seek to encourage such programs where practical.

The 2022–2024 MassSave plan and IRA double down on strategies that provide up-front incentives to overcome financial barriers. There is good evidence that has worked so far. However, it is not clear whether this is scalable. In the case of MassSave, it is not yet clear whether publicly guided utility-managed bill-financed energy efficiency programs are sustainable. The tax credits in the IRA have the potential to be durable but are small. Combined, they create administrative headaches for customers that can be a barrier to participation.

To ensure ongoing progress, customers need a one-stop shop (e.g., ABCD's quarterbacking process) with transparent pricing. This may take the form of a competitive performance contracting market, prepackaged building retrofit pathways, and more durable taxpayer-funded incentives. These programs should be designed to ensure that public funds drive progress and outcomes for homeowners.

As the new funding landscapes evolve, industry participants should seek to guide the development of such innovative business models to provide new scalable solutions for transforming the small building stock.

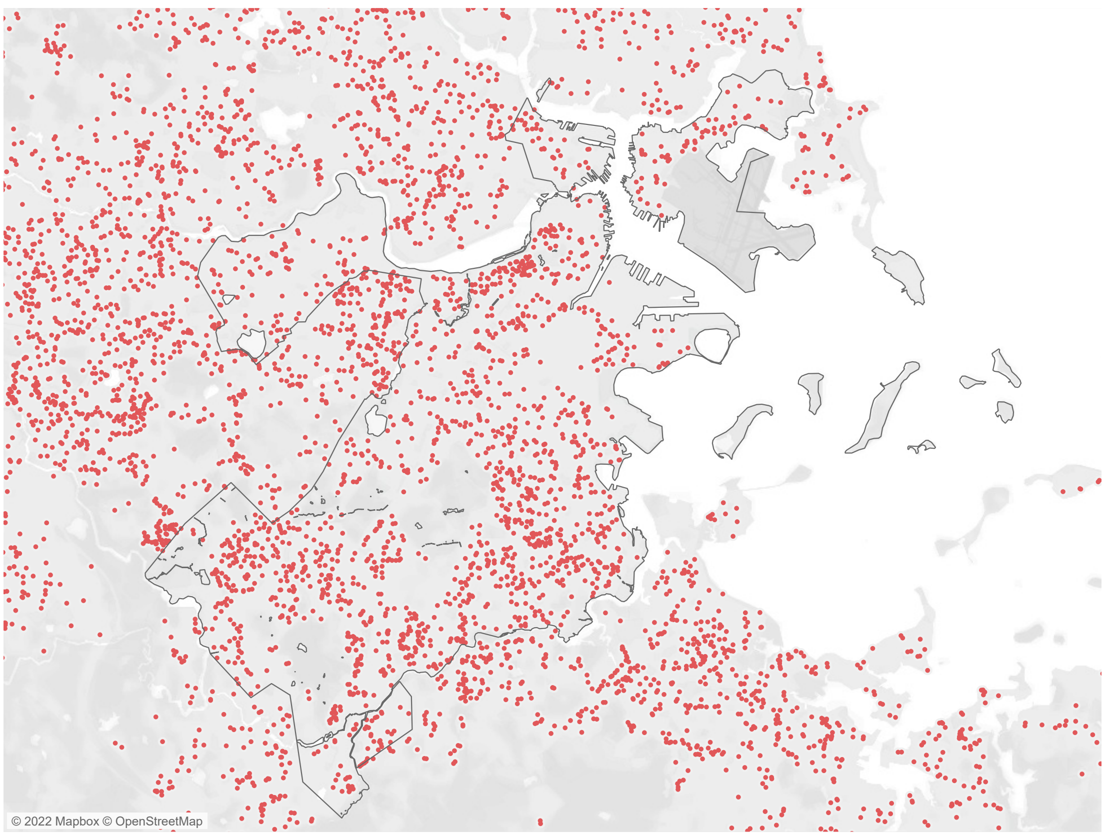
Alongside this, the City of Boston's Inspectional Services Department should streamline the building permitting process for electrification retrofits. For example, California has implemented app-based solar permitting approvals to reduce errors, wait times, and permit costs.[71]

Facilitate a Smooth Transition off Gas

A century-old gas system serves many of Boston's small homes. The system is showing its age. Cast iron pipes gridding much of Boston have been stressed by a century of urban activity and development, leading to an increasing occurrence of fractures. Once kept moist and air-tight by the humid manufactured gas, the compound joining iron pipes has been dried out and cracked by 60 years of the drier natural gas.

Figure 17. **Location of unrepaired methane leaks (2019) in Boston**

Source: compiled by HEET72 from various Utility DPU filings.



Efforts to reduce leaks by replacing these pipes are not reducing the methane seeping into the atmosphere[73] and are rapidly rising in cost.[74] Much of the leaked methane emanates from the pipes and appliances within the buildings. Evidence is accumulating that natural gas appliances, particularly stoves, lead to the accumulation of toxic compounds in the indoor air due to leaks and combustion.[44,45] Across the state, marginalized populations have been disproportionately exposed to natural gas leaks.[75] In Boston, it is a problem for everyone (Figure 17).

Simultaneously the gas system is at risk of customer attrition as electrification scales up. Reduced gas sales will lead to the need for the utility to raise rates, further incentivizing customer attrition. While the rise in rates may not become burdensome for at least a decade, planning today can help avoid locking in to a system that grows more expensive with the future underutilization of gas assets.

While the *Boston Climate Progress Report*'s chapter on Energy Planning focuses on how energy planning should proceed overall, this section focuses on defining the planning and transition needs specifically as it relates to the small building stock relationship with the gas distribution system.

What Needs to Happen: Develop Locally Focused Plans to Transition the Gas System

Given these challenges, Boston and its gas utilities must begin a rightsizing process to smartly scale back the gas system over the next several decades. The process will need to proceed in a regulatory framework overseen by the Department of Public Utilities and likely established with the support of new legislation that enables the DPU to regulate rightsizing. Given that gas system rightsizing needs to occur locally, the City of Boston will need to be involved in some elements of such planning. Residents, property owners, and businesses will need to be involved early.

The goal of gas system rightsizing is to reduce the capital and maintenance costs associated with the gas system by targeting expensive-to-maintain parts of the gas system for retirement. A recent analysis conducted by the Massachusetts gas utilities demonstrated that targeted electrification of costly-to-maintain and repair segments of the system could result in significant cost savings on select parts of the system.[10]

Gas system rightsizing needs to consider several factors listed in Table 7 that illustrate favorable conditions for the process.

Table 7. **Factors Influencing Gas System Maintenance versus Rightsizing**

FAVORS MAINTAINING GAS ASSETS	INFLUENCING FACTOR	FAVORS GAS SYSTEM RIGHTSIZING
Newer pipes	Age and health of the gas pipe	Older leak-prone pipe
Complex loads that challenge electrification	Energy demands	Loads that can be easily and cost-effectively electrified
Older systems that have a lower priority for upgrades	Potential for the distribution system to handle electrification	Newer or soon-to-be upgraded electric distribution systems
Dense environments can potentially constrain fuel storage	Suitability of non-pipeline fuels to complement electrification	Space is available for non-pipeline fuel system
Low potential for alternative thermal resources	Availability of alternative thermal resources	High potential for geothermal, thermal networks, waste heat, or similar resources
Rightsizing results in unfair burdens for affected homes	Social considerations	Rightsizing does not result in unfair burdens for affected homes

The last factor deserves some additional consideration and explanation. Depending on the context, rightsizing may result in favorable and unfavorable outcomes for the affected community. Maintaining the gas system may also result in positive and negative outcomes. These may evolve at different paces over time. For example, electrifying a segment now may raise costs for the affected households in the near term but keep costs for that segment and ratepayers lower in the long run. Replacing a gas pipe to mitigate a leak reduces leaks on the street but does not address the problem of leaks in the home. Potential impacts must be identified, evaluated, and mitigated in each project exploring gas system rightsizing.

What Has Been Happening: GSEP and Utility Planning

The current legislative and regulatory framework is insufficient to ensure an equitable rightsizing of the gas system that is on pace for Boston to achieve its goals. Utility proposals to decarbonize the gas system through expensive and risky strategies—rather than aggressively pursuing rightsizing—put the transition at risk. Both of these failures create a leadership gap.

In 2014 the Commonwealth developed an innovative program to mitigate leaks associated with aging pipeline gas distribution infrastructure. The Gas Safety Enhancement Program (GSEP) allowed gas utilities to accelerate the replacement of leak-prone pipes to improve the system's safety while reducing emissions.

The program was designed for the state's Global Warming Solutions Act–era goal of reducing emissions by 80 percent by 2050, which would have likely permitted the operation of a gas distribution system at scales similar to today. Since adopting this program, the City and Commonwealth have committed to a net-zero goal—the effective elimination of emissions.

The cost of replacing leak-prone infrastructure is estimated to average $2.5 million per mile in National Grid's territory in 2021.[74] National Grid's 2022 GSEP plans include several projects in Boston that exceed $7 million per mile.[72] In many cases, these costs exceed the cost of electrifying served buildings. Costs are expected to rise at a pace exceeding that of other energy investments because of the complexity of street work in the urban environment. Much of this cost—from installing new pipes with 40-year lifetimes—is at risk of being unrecoverable from the current customer base as customers electrify.

Recent efforts to repair and replace aging gas infrastructure have had little impact on reducing emissions, partly because many of the leaks emanate from the (behind the meter) gas distribution system in the buildings themselves.[73] There is no plan for eliminating these leaks. In all, 2.5 percent of the gas entering Boston's distribution system escapes into the atmosphere.

Despite these challenges, both of Boston's gas utilities—National Grid and Eversource—largely envision maintaining the gas system at approximately its current size.

In October 2020, the Attorney General tasked the DPU with investigating how the state's investor-owned gas distribution companies would align their operations with the state's net-zero goals. The DPU subsequently tasked the companies to conduct their own study of possible pathways and propose plans for supporting the state's efforts to achieve net zero.

The plans largely propose to maintain the gas system at the current scale, with some parts of the system being retired completely or replaced with networked geothermal systems. In the plan, emissions reductions are achieved through partial electrification with gas backup and blending renewable natural gas and hydrogen into the pipeline.

While partial electrification will likely be an essential transitional strategy, the stock will continue to become more electric and efficient to a point where the cost of maintaining a low-throughput gas distribution system exceeds the cost of decommissioning it and removing connected homes from the system. Integration of renewable natural gas and hydrogen at the scales proposed by gas utilities runs into significant economic barriers given the high costs of such fuels and competition for them and their feedstocks.

How to Make Things Work: Ensure an Equitable Transition of Gas

The 2022 climate bill put an effective pause on the “future of gas” proceeding by prohibiting the DPU from sanctioning any utility plan before the conducting of an adjudicatory proceeding. The legislation further called for a review of the GSEP program. It is anticipated that the new gubernatorial administration will revisit these issues in a more proactive way. The following items are recommendations for the administration and cognate entities.

ACTION ITEM: Develop gas system rightsizing plans

Implementors: DOER, DPU, Utilities, City of Boston

The state, mainly through regulation by the Department of Public Utilities (DPU), needs to develop a framework for the ongoing rightsizing of the gas system to be conducted locally with support from the utilities. The framework should address near-term (alternatives to GSEP pipeline replacement) and long-term (district-scale decommissioning) gas system rightsizing. Such a framework should also critically evaluate how to avoid burdening low-income households with the cost of this transition. The City should not wait on the DPU or the utilities to begin such planning. It should instead focus on developing potential alternative energy strategies and transition resources for early gas decommissioning sites.

An early focus of gas system rightsizing would be to identify street segments slated to be scheduled for gas pipeline replacement that are good candidates for others. Planning at both the street and the district levels should seek to identify potential alternative thermal resources (e.g., geothermal), opportunities for integration across buildings, electric system upgrade costs, and building retrofit needs. Planning should be done in a way that helps resident engagement in and preparation for the transition. Planning should leverage improved utility and City-aggregated data sets as described in the next section.

ACTION ITEM: Expand transition pilot studies

Implementors: DPU, gas utilities, City of Boston, MassCEC, impacted residents. Legislation may be needed.

In partnership with its gas and electric utilities, a public and nonprofit coalition (City, ABCD, MassCEC, etc.) should immediately pursue street and neighborhood-level implementation pilots to transition these areas off the gas network. Pilots for utility-operated networked geothermal are currently underway, but non-network replacement strategies must be better understood. The DPU would likely need to approve these pilots.

Such pilots should evaluate and develop best practices for neighborhood-scale electrification to identify potential challenges and mitigating strategies for electrification and gas system rightsizing. Such pilots should explore whole building electrification alongside strategies that employ a delivered fuel (e.g., propane) to support peak heating (or, for some holdouts, cooking) needs.

In the absence of such pilots, grassroots neighborhood action should organize to bring attention to the high cost of gas pipeline replacement by beginning to electrify or commit to electrifying their homes and appliances.

Making the Data Work for Tracking, Learning, and Accountability

Boston does not know the emissions associated with the small building stock with any meaningful accuracy for assessing progress and planning. Further, an emphasis on emissions as the core metric of progress is misplaced as it is a secondary indicator that obscures many of the underlying aspects of change discussed above.

Evaluating progress toward climate goals should instead focus on metrics describing the application of electrification and efficiency measures. Further metrics monitoring the state of the workforce and supply chain can help ensure that the underlying ecosystem is supporting progress.

Given the nascent state of the thermal transition, this chapter is confident in its findings and recommendations, despite the lack of ideal data. However, more robust data and reporting frameworks are essential for ongoing progress tracking, ensuring accountability across parties, and ensuring equitable outcomes. The data and the mechanisms needed to aggregate and report on it largely exist. They are, however, not implemented in a way that readily supports these goals.

What Needs to Happen

There needs to be a transparent and detailed tracking and accountability framework focused on the three action areas noted above: deploying electrification, efficiency, and integration; market development; and transition planning. To support equitable outcomes, data collection and reporting frameworks need to be designed in a granular way that tracks interventions across geographic and social groups. This ensures accountability in building retrofits and intervention programs to ensure fairness and reparations through improving the low-income housing stock.

What Has Been Happening

Data is being collected and analyzed for existing programs and resources but not in a way consistent with the City's net-zero goals.

For the City's Community Greenhouse Gas Inventory, the City tracks energy consumption by fuel using aggregate utility-provided consumption values and estimates of delivered fuel use. The City Assessor's Office collects nominal data on building energy assets,[76] using standard practices for real property valuation. While the Assessor's Office has recently improved its collection of energy asset data, the current approach does not capture the properties of the building that would be relevant for a rapid transition to net zero.

MassSave has been more focused on building interventions across the building stock. Energy efficiency programs such as MassSave engage in substantial evaluation, measurement, and verification (EM&V) of program success and performance. Historically such analysis and data collection were focused on efficiency. With MassSave's new mandate to align with the state's climate goals, it needs to focus more actively on carbon reduction and elimination.

The 2022–2024 MassSave Three-Year Plan[66] includes several new aspects to its EM&V program, including:

1. Improved tracking of strategic electrification.
2. Tracking to identify barriers and evaluate progress in key residential populations (low- and moderate-income customers, renters, and English-isolated customers).
3. Improve integration of data sets and provide data to key stakeholders.
4. Acknowledgment that the MassSave program administrators need to improve their understanding of electrification and customer participation as it proceeds and scales up new programs.

These actions can better align the MassSave program with the state's climate goals but are incomplete, and it is unclear how MassSave will go about collecting, organizing, and reporting.

How to Make Things Work: Improve Data Collection and Metrics

Improving data resources needs to happen on two fronts: understanding the state of the buildings and understanding the state of implementation. Municipalities such as Boston have typically had oversight of the former for property valuation and building code enforcement purposes. Understanding the state of implementation has largely occurred at the state level but is currently not sufficiently focused on decarbonization and is fragmented. The following two sections present strategies for improving decarbonization.

ACTION ITEM: Improve building asset tracking for building decarbonization or building score cards

Implementors: City of Boston Assessor's Office, MA Dept. of Revenue Local Services Division, City of Boston Inspectional Services Division

Municipal assessor's offices are mandated to collect data relevant to the valuation of a building. As the economy rapidly decarbonizes, the energy systems of a building will play a larger role in influencing the building's value and operational economics. Currently, collected data is insufficient for planning purposes and does not adequately convey the energy state of the building to potential buyers who may need to invest to achieve decarbonization goals. It gives a snapshot of the building stock at a point in time, which may lag the actual state of the stock.[xi]

Recommend tracking areas for the small residential building stock.

- Fossil heating systems and appliances
- Heat pump arrangements
- Building/unit shell status
- Electric service and size
- Connection to gas service
- Fuel tanks
- EV charging
- Smart panels/meters
- Energy resource (solar/storage) capacity

xi. Currently, many city assessor's databases track some fundamental energy assets: heating fuel, heating type (steam, forced hot water, forced hot air), and insulation.

The Commonwealth's Local Services Division should establish standards for tracking building energy assets for the small residential stock. Doing so would create a rich data set that would aid decarbonization planning while also educating current and potential homeowners and occupants about the energy state of their buildings. With support from the Inspectional Services Division, the Assessor's Office should track relevant energy assets such as those identified in Table 3, particularly those related to gas. The data should be detailed where feasible, tracking the age of equipment or solar or storage capacity values. The Assessor's Office will likely have to coordinate with the City of Boston's Inspectional Services Department, perhaps MassSave, and other relevant state programs overseeing solar and storage to ensure accuracy. This data collection raises an important question that should be considered during implementation: Should home energy performance and assets be factored into the valuation of a property, thus increasing tax liability?

The U.S. Department of Energy provides a framework for the Home Energy Score[41] (described above), which can be leveraged for defining new fields for tracking. A critical consideration of expanding the assessor's data to include energy use data was conducted in Washington State.[77]

ACTION ITEM: Standardize MassSave and implementation data for decarbonization

Implementors: MassSave, Energy Efficiency Advisory Council, potential third-party auditor.

The MassSave program collects a treasure trove of data but it is not actively or consistently used to support decarbonization. Such data is not only important for tracking progress but also for understanding the drivers of progress. Data tracking and reporting should include detailed intervention tracking with the ability of municipalities to understand progress better; tracking of intervention and equipment costs with sufficient granularity to understand the drivers of costs; and monitoring of workforce development and needs. Such transition tracking could be performed by the utility program administrators themselves, be a function of the Energy Efficiency Advisory Council (EEAC), or be conducted by a third party. The program administrators will need to transmit consistent data sets to the EEAC or the third party in the latter two cases.

An independent review of MassSave's 2022–2024 EM&V efforts should be conducted in parallel with the evolution of the EM&V program in this cycle:

- Are the EM&V research and reporting providing sufficient information on the promulgation of energy efficiency and electrification measures to empower municipalities (e.g., Boston), the state, and other supporting organizations to drive progress toward climate goals?
- Is the data providing sufficient insights into how populations with lower energy efficiency participation rates—notably, renters, low-income, and marginalized communities—are receiving benefits and how the promulgation of benefits to these populations can be improved?
- Is the MassSave EM&V program sufficient for moving forward with these goals? Should progress and program evaluation of decarbonization and equity goals happen within MassSave or via an independent auditing mechanism?
- Create a publicly accessible standardized database of projects that includes main project cost categories (e.g., equipment, supplies, labor, etc.), installation details (project size), installer company, descriptive building data (e.g., conditioned floor space), and anonymized geographic identifiers (e.g., ZIP Code/census block). This will allow for independent evaluation of project costs and trends over time. Project transparency will also help drive down costs by providing information to residents on how much they should expect to pay and which contractors are likely to provide greater value.

8. CONCLUSION

After four centuries of burning fuels for heat, it is clear that Boston must shift away from combustion and modernize its buildings for our future climate. The need to do so emerges from a culmination of factors:

- **Climate:** For the last 15 years, the city has recognized that it needs to reduce its emissions to align with worldwide climate efforts to limit global warming to less than 2 degrees Celsius. Boston's buildings and the gas distribution system serving it are the city's largest source of emissions.
- **Resilience:** The city's building stock must be resilient to the worst impacts of climate change, including providing sufficient cooling and being resilient to extreme weather events.
- **Repairing Past Harms:** The community increasingly recognizes the ongoing prevalence of social injustices and that such injustices require rapid amelioration. These include several economic and health burdens from historical neglect of the building stock.
- **Health:** The COVID-19 pandemic and the maturing science of healthy buildings have emphasized the need for improved air quality.
- **Energy Security:** The 2022 energy crisis sparked by Russia's invasion of Ukraine has underscored the need to rapidly reduce reliance on fossil fuels and leverage local energy resources. Such resources include ambient heat from the ground and air, the solar shining on Boston's roofs, and the wind off Massachusetts' shores.

Rising to face these challenges requires a shared commitment to another energy transition that will allow the city to continue to grow and equitably prosper. Doing so requires modernizing the built environment across the city to nearly eliminate reliance on fuels, reduce energy demand to maximize affordability, improve occupant comfort, and be healthy.

It is also essential to make amends while meeting the needs of the climate crisis. Ensuring that buildings meet safety, health, and energy standards is a widely accepted tenet of society. It is why over the past 75 years, communities have established and enforced building codes. The problem is that older buildings and buildings that have seen lax code enforcement do not achieve these standards. Such buildings are disproportionately home to low-income, minority, and immigrant communities. Older buildings with faulty energy systems, structural deficiencies, and outdated appliances exacerbate many of the problems these communities face. Increased costs and decreased comfort, for example, sharpen economic hardship and are associated with adverse mental and physical health outcomes.

Meeting the climate crisis is an opportunity to rejuvenate Boston's building stock to better house its constituents in a way that creates social value. The fundamental challenge of decarbonizing the building stock is the high up-front cost of electrification and efficiency that takes years to pay off for the occupant. However, the near-term and long-term social benefits do more than justify modernizing the buildings to net zero.

Doing so will take a concerted effort and evolve over decades. Such an effort needs to start now.

Questions for Implementors and the Community to Consider

- Is MassSave in its current form—administrated by the utilities—capable of achieving the City's and the Commonwealth's climate goals? Does a new organization need to be created?
- How should rates be redesigned to incentivize electrification, efficiency and the adoption of distributed energy resources in a way that balances fairness and equity across the building stock?
- Should municipalities lead on building electrification policy, or should the state develop a more consistent framework?
- More data will assist planners, implementors and contractors accelerate efforts and lower costs. Are there any privacy concerns among data providers that need to be addressed? Should privacy be a barrier to improved data aggregation and transparency?

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