Ministry of Foreign Affairs

DEEP ENERGY RETROFITS MARKET IN THE GREATER BOSTON AREA

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CADMUS

Final Report

Deep Energy Retrofits Market in the Greater Boston Area

Submitted: 13 October 2020

Prepared for:

The Netherlands Innovation Network

This report was commissioned by the Netherlands Enterprise Agency RVO. InnovationQuarter served as an advisor on the project.

Government of the Netherlands

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I. Introduction

Cadmus is supporting the Netherlands Innovation Network (NIN) by providing an overview of the deep energy retrofit market in the Greater Boston Area. This report is intended to help Dutch companies in identify strategic opportunities to enter or expand their business opportunities in the Greater Boston market.

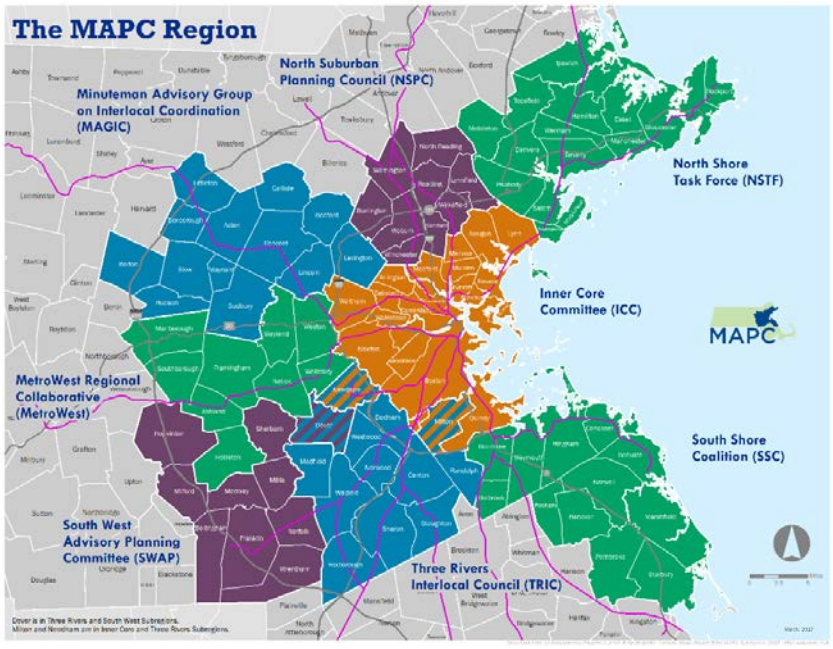
Cadmus synthesized key takeaways from a literature review, stakeholder interviews, and in-house expertise to assess market trends and identify opportunities and gaps related to deep building retrofits, with a focus on areas that aligned with Dutch interests. For the purposes of this study, Cadmus defined the following "primary focus areas": energy efficiency, renewable energy generation, alternative heating, energy storage, smart software solutions. Furthermore, "secondary focus areas" which are explored but to a lesser extent than the primary areas include: climate resilient design, advanced materials, and auxiliary retrofits. This report provides a market snapshot of primary focus areas describing the level of market entry opportunity (i.e. low, medium, high; based on technical maturity and cost-effectiveness) for Dutch innovators. In addition, this report provides an estimated economic potential of the prioritized technology subsectors over the next 5 to 10 years, and profiles various market actors for potential partnership opportunities.

To complete this report, Cadmus leveraged its expertise of over 10 years of experience working in both the Boston region and clean energy market, with state and local governments, utilities, clean tech companies, and non-profits like A Better City, MassCEC, Green Ribbon Commission, and the Metropolitan Area Planning Council.

Methodology

The findings of this report were guided by key takeaways from literature review on the deep decarbonization building retrofit market in Boston, data analysis from Cadmus internal databases on the Boston buildings market, and 11 interviews with Boston-based stakeholders spanning government organizations, building managers, advisory groups, designers, engineers, and tech providers. When hearing about Netherland's interest in the Boston market, *all stakeholders responded favorably and were interested to explore potential areas for collaboration*. While stakeholders did not necessarily pinpoint specific

Figure 1. Map of the MAPC region.



Netherlands' technologies they were already aware of, they cited strong impressions of a mature European market for building retrofits with the Netherlands being a strong player in it.

For the purposes of this analysis, the "Greater Boston Area" is defined as the Metropolitan Area Planning Council (MAPC) region (Figure 1). MAPC is the regional planning agency in eastern Massachusetts and consists of 22 cities and 79 towns surrounding the City of Boston.

II. Overview of Policy Drivers

- The Commonwealth of Massachusetts considers itself a leader in the movement to reduce GHG emissions and curb the impacts of climate change. The commitment is codified in legislation, the Global Warming Solutions Act, first passed in 2008.
- Massachusetts also passed the Green Communities Act (GCA) in 2008, a policy intended to promote energy efficiency, increase renewable energy resources, improve of state building code, stimulate innovation, and address energy affordability. This created the Green Communities Program, a designation program for communities that meet defined green criteria. (Most communities in Greater Boston have received Green Communities designation)
- In 2020, the Massachusetts Governor increased the state's goal and established a target of zero emissions by 2050. Within the Greater Boston region, numerous municipalities have adopted similar ambitious climate goals. The fourteen Mayors in the municipalities at the core of the region have formed the Metropolitan Mayors Coalition, and committed to carbon neutrality by 2050.
- Massachusetts is currently working on a 2050 Decarbonization Roadmap (supported by Cadmus) to identify a set of strategies for achieving their net zero target, including policies related to building code, electrification, and renewable energy.
- Massachusetts is currently considering a Net Zero Stretch Code, with a proposed bill in both the House and Senate. If passed, all applicable new buildings and qualifying large building renovations will need to meet the Net Zero Stretch Code requirements.[1]
    - Below the state level, the City of Boston is pursuing a Net Zero Building requirement which will apply to new construction. The City of Cambridge also is contemplating a similar Net Zero Code and intends to apply this policy to building retrofits in the future.
- Several municipalities in the region have been working to reduce the expansion of gas infrastructure in support of electrifications. For instance, municipalities like Newton and Arlington are considering gas connection restrictions. The Town of Brookline passed a bylaw that banned the installation of new gas/oil piping, fossil fuel boilers, and furnaces for gut renovations. However, this was overturned by the attorney general for conflicting with state codes.
- A couple of municipalities such as Belmont and Concord have identified strategic building electrification as their primary pathway for achieving municipal climate targets.
- Financial support for energy efficiency is primarily administered via a statewide incentive program knows as Mass Save. This program is funded through fees on electric bills, but typically focuses on subsidies for basic weatherization (i.e. air sealing and insulating), appliances, and efficient heating systems. Mass Save also runs an incentive program to support heat pumps. Increased **incentives to building owners for deep energy retrofits** (i.e. beyond basic weatherization) and financing innovations are also in development.
- In addition to Mass Save, in 2014 the Massachusetts Department of Energy Resources launched the Pathways to Zero Net Energy grant program to fund feasibility, integrated design, and construction

[1] Massachusetts became the first state to pass a Stretch Code in 2009 for buildings to go beyond the base Building Energy Code to improve energy performance.

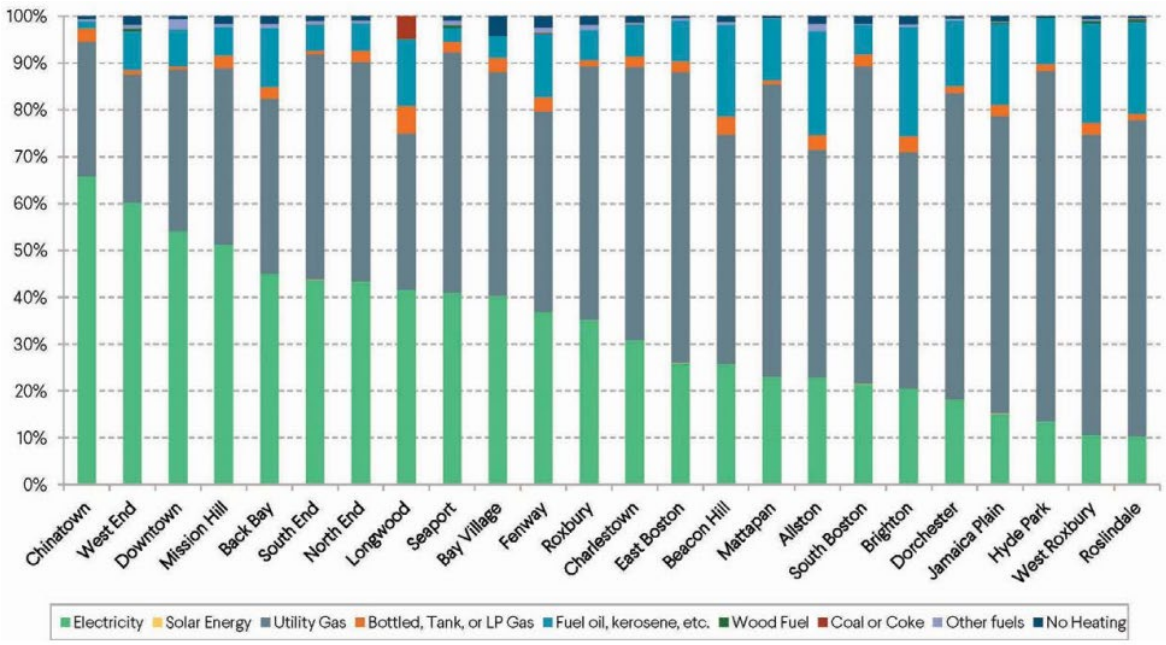
of new net zero energy buildings in Massachusetts.

Summary of Boston Area Retrofit Market & Sectors

- Rather than groundbreaking technological innovations, interviewees **anticipate (1) incremental efficiency improvements in existing technologies** (e.g. mechanical systems and smart appliances, electrical/lighting equipment, and building energy management systems), **and (2) less disruptive retrofit methods** (e.g. building envelope improvements) across the subsectors. Paired with increased economies of scale, these will reduce cost premiums and encourage more widespread adoption.
- Stakeholders anticipate policies to shift focus away from energy conservation and into **carbon emissions reduction** (e.g. while switching fuels does not produce significant energy efficiency improvements, it does achieve notable emissions reductions).
    - Stakeholders speculated that strategic electrification of heating and cooling will play a major role in this shift.
- Buildings in the region are fueled by a variety of energy sources (Figure 2) predominantly natural gas, electric resistance heating, or oil. A handful of properties, mostly residential, are heated by air source heat pumps. Electrification of buildings with heat pumps and similar technologies is a central tenant of the region's decarbonization strategies. These plans also note the value of energy efficiency in enabling electrification and reducing costs.

Figure 2. Home heating energy use by Boston neighborhood.

Source: Data from US Census Bureau, 2012-2016 American Community Survey: 5-Year Estimates



- One of the main challenges for tech providers is the complex process for service delivery (i.e. multiple actors at each stage: design, construction, development, sales, etc.). This is especially true

for smaller companies, so **new integrated business models** are expected to gain traction as the market continues to develop (e.g. Cooling as a Service pay-per-service model).

- In the event of a new presidential administration, stakeholders anticipate more significant **investment from the federal government** (e.g. Green Recovery Act) that will continue to drive the market.
    - Several stakeholders recognized the aging workforce and the shortage for clean tech workers, like heat pump installers. The City of Boston is actively advancing clean energy workforce development programs.

Impact of COVID-19

- The COVID-19 pandemic has brought attention to a number of building needs, such as **improved ventilation, air quality monitoring, integrated building management controls, and overall building resiliency.**
    - Stakeholders expect economic recovery efforts will pair policies and programs to improve standards for healthy buildings and in-unit ventilation with incentives to replace inefficient and high-emitting technologies.
- The impact of COVID-19 on typical business operations varies based on the sector: contractors undertaking more external work (e.g. rooftop PV, external building insulation cladding) have seen fewer substantial changes in overall business. In some instances, operations were able to continue online (e.g. virtual home energy audits).
    - For example, **HVAC providers have experienced fewer disruptions as opposed to building performance contractors who operate more within the home** (e.g. blower door test). Firms like American Microgrid Solutions commented they are currently busier than ever.
    - MassCEC indicated that while tech and service providers largely experienced a dip in the market due to COVID-19, as of late August, most were on track to avoid net negative annual performance. The **main challenges providers faced were due to lag times and upstream supply chain disruptions** (e.g. equipment delivery was delayed, site visits were temporarily discontinued prior to re-opening phases, etc.).
- The economic recession following COVID-19 has deterred some consumers from prioritizing costly deep energy retrofits. Nevertheless, stakeholders noted demand remains strong and the market is expected to bounce back, though there was not a clear consensus on timeline.
    - Because state and municipal budgets have been altered to support COVID-19 response and recovery, **programs and incentives to support retrofit activities have been affected**. Many programs, however, have notably expanded in order to meet their yearly targets following disruptions. For instance, Mass Save, an organization that offers energy saving programs and services, was forced to halt some programs during state-wide lockdown. They have since resumed and with increased spending targets for various programs (e.g. prior to the COVID-19 pandemic, Mass Save covered 75% of the cost of envelope improvements for small residential properties. Now, Mass Save will cover 100% of the costs for approved insulations for a limited time). Similarly, MassCEC's also modified some of its pilot programs

in March to include additional incentives (e.g. extension of incentives to clean heating and cooling rebate projects).

- Since March, shelter-in-place and social distancing orders have limited the occupancy of commercial spaces. In the short term, office buildings and other commercial centers are expected to continue operating at a reduced rate, and a few businesses are even expected to go fully remote. Some owners have presently deprioritized energy investments into their buildings. As a result, Mass Save has increased incentives for small business and large commercial/industrial customers.
    - While there is a reduced demand for commercial leases in the immediate/short-term, those still looking for spaces are generally following the expected trends outlined in this memo. For example, demand for improved ventilation and air filtration has risen as an emerging need and selling point in all building typologies.[2]
    - Commercial building owners now have an emerging need to **modify energy control operations from full-scale operations to partial operations**, however some buildings' existing control strategies do not allow this.
- More data and analysis are needed to understand the impact of COVID-19 and remote workers on building greenhouse gas emissions and the impact of shifting energy use from commercial to residential subsectors.

[2] Colin Booth from Placetailor Inc. highlighted this need especially among health care professionals. Placetailor completed a project in mid-March, during the initial stages of Boston's COVID lockdown, with high-performing energy recovery ventilators and air filtration systems. He noted the units sold out almost entirely to medical professionals.

III. Economic Opportunity Assessment

The MAPC region (Figure 1) is home to nearly 350,000 buildings, totaling nearly 3 billion square feet across urban, suburban, and rural communities (Table 1). Housing is by far the most common building type and is therefore a central component of the building energy retrofit market.

Table 1. Square Footage and Number of Buildings by Type in Greater Boston

Type of Building	Square feet (millions)	Buildings
Commercial	766	13,490
Multi-Family	878	86,271
Single Family	1,178	245,548
Total	2,822	345,220

In the City of Boston, which serves as a good proxy for surrounding urban municipalities, there are 38,852 small multi-family buildings occupying nearly 150 million square feet and 7,618 large multi-family buildings covering approximately 90 million square feet. On the other hand, while there are 30,564 single family homes, they only make up about 55 million square feet. Small multifamily, or "triple deckers," are typically 2-4-unit buildings; large multifamily buildings have 5 or more units. The market potential for small multi-family buildings is notable given the sheer volume of this typology in the urban core. Additional opportunities for other building typologies are discussed in *Other Gaps and Opportunities for Innovation* under Section 4.

To estimate the market opportunity in the building sector, Cadmus used current economic and building sector data to assess a potential scenario. Since building electrification in the MAPC region is still a very nascent market, the scenario assumes the entire building stock of the region represents a market opportunity for building electrification over the next 10 years consistent with state and local goals. Based on the Commonwealth's goals as well as costs and trends related to stock turnover (timing when a building is fit for a deep retrofit), the scenario assumed the following:

1. **Deep Retrofit[3]:** one third of the region's pre-1950 buildings undergo a deep energy retrofit and heating electrification in the next 10 years.
2. **Electrification Only:** All post-2000 buildings and half of buildings built between 1980 and 2000 were assumed to only require heating electrification with no efficiency measures applied.
3. **Electrification + Envelope:** The remainder of buildings from pre-1950,1950-1980, and 1980-2000 were electrified with cost effective weatherization and envelope (insulation and air barrier) efficiency measures.

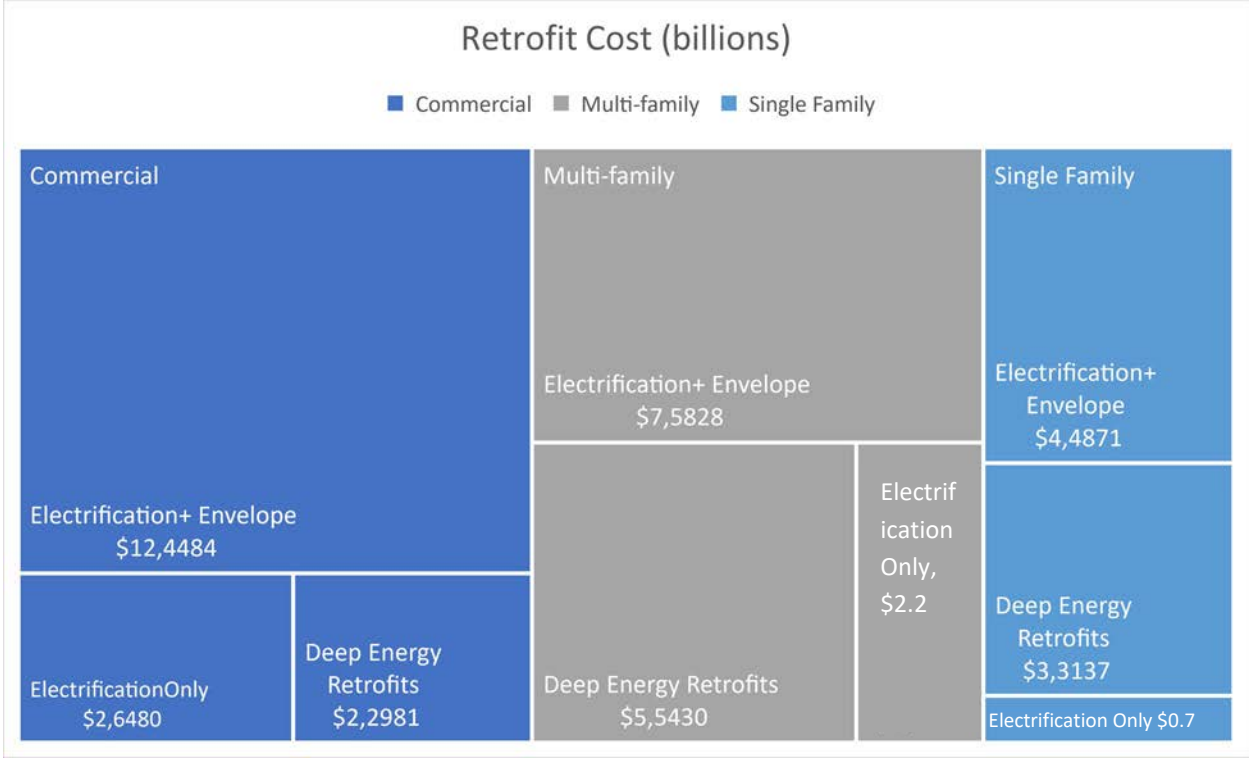
[3] This option is the most extensive of an effort of the three options, using a whole building analysis to decrease on-site energy use by ~50% compared to its baseline

Table 2. Retrofit Market Opportunity by Building Number and Estimated Cost

Type of Building	Electrification +Envelope (# of buildings)	Electrification Only (# of buildings)	Deep Energy Retrofits (# of buildings)	Estimated Retrofit Cost ($ billions)
Commercial	8,293	3,684	1,514	$17.3B
Multi-Family	54,111	21,453	10,617	$15.3B
Single Family	168,472	45,967	31,019	$8.5B
Total	230,876	71,141	43,150	$41.1B

Results of this analysis indicate that the building retrofit market in the next ten years is estimated to be valued at around $41 billion, with nearly 42% of that value coming from commercial buildings. While the number of single-family homes vastly outnumber other building types in the Greater Boston region, its smaller aggregate market size may not directly suggest a weaker opportunity due to potential lower barriers to entry for developers. Additional detail on retrofit cost by building type is show below (Figure 3).

Figure 3. Retrofit Cost (in billions, USD)



IV. Market Snapshot

The following section provides a market snapshot of various clean energy technologies by subsector. This section is organized first by primary focus areas, followed by a high-level overview of secondary focus areas (Table 3). Focus areas were determined collaboratively with NIN during the scoping phase of this study to represent the key subsectors of the retrofit market.

Each primary focus area describes the extent to which needs are currently being met within the sector, key technology gaps, and where available, the overall state of technology deployment. Example projects, pilots, and programs are also included.

Table 3. Primary and Secondary Focus Areas

Primary Focus Areas	Secondary Focus Areas
Alternative Heating	Climate Resilient Design
Energy Efficiency in Buildings	Auxiliary Retrofits
Renewable Energy Generation	Advanced Materials
Energy Storage	
Smart Software Solutions	

This section concludes with a description of opportunities for integrated solutions and other market gaps.

Interpreting Table 4: Summary of Market Technology Status

Table 4 summarizes the *market status* of a non-exhaustive list of primary focus area technologies. This table is organized by low, medium, and high opportunities for Dutch innovators to supplement the market. Note "status" here is subjective and represents areas of consensus feedback heard from interviewed stakeholders, Cadmus experts, and desk research.

- **Low Opportunity:** technologies generally regarded as commercially available and cost-effective.*
- **Medium Opportunity:** while technically mature, these technologies are either not yet cost-effective,* often lacking from economies of scale, or have notable potential for improvement (e.g. size optimization, lightweight, etc.).
- **High Opportunity:** Technologies in this category are either unavailable, in very early stages in the market, or significantly cost prohibitive. As a result, there has been little adoption to date.

* While noted here as "*cost-effective*," all technologies have potential for improved efficiencies to continue to reduce costs and promote greater adoption. Cost effectiveness of certain technologies is also dependent on specific building characteristics, such as the fuel source (e.g. oil, natural gas) and the state of the building envelope (e.g. air source heat pumps are not cost-effective options in poorly insulated buildings).

Table 4. Summary of market technology status of various primary focus area technologies.

Sector	Market Technology Status			
	Low Opportunity (Technology/Services Available, Cost Effective)	***Medium Opportunity*** (Technology/Services Available, Not Cost-Effective)	***High Opportunity*** (Technology/Services Unavailable or not Significantly Available)	***Other*** (Little Interest in Technology/Service)
Alternative Heating	▪ Small-scale air source heat pumps	▪ Large-scale air source heat pumps ▪ Ground source heat pumps ▪ Solar hot water/ heat pump water heaters ▪ Energy recovery ventilators	▪ Solar assisted heat pumps ▪ Waste heat recovery ▪ Air-to-water heat pump ▪ Small-scale variable refrigerant systems	▪ Solar assisted geothermal[4]
Energy Efficiency Buildings	▪ Air sealing ▪ Insulation (cellulose, spray foam, etc.)	▪ Prefabricated structural panels ▪ Façade redesign strategies ▪ High performance windows	▪ Non-invasive insulation materials	▪ High embodied carbon insulation and foams[5]
Renewable Energy Generation	▪ Rooftop solar PV	▪ Lightweight solar PV panels	▪ Hydrogen Fuel Cells	▪ Small-scale wind energy
Energy Storage	▪ Integrated solar + storage battery technology	▪ Size optimized Distributed Energy Resources (DER) equipment	▪ DC-ready appliances	
Smart Software Solutions	▪ Smart control systems	▪ Improved demand/grid management ▪ Smart control system (in small residential properties)	▪ Artificial intelligence /machine learning in systems controls ▪ Virtual Power Plants	

[4] Solar assisted geothermal has not seen substantial cost reductions and was noted as being heavily dependent on incentives for cost effectiveness.

[5] High embodied carbon insulation, foams, and other building materials are expected to phase out.

Alternative Heating

Transitioning thermal technologies, both space and water heating/cooling, to renewable sources and away from fossil fuels are developing in the Boston market. However, this technology is still not yet cost competitive with natural gas in neither the commercial nor residential properties. Alternative heating solutions, like air source heat pumps (ASHPs), are often disregarded due to high upfront costs and long payback periods. Like many other clean energy technologies, there is a need for greater efficiency in order to improve cost-effectiveness.

The state of deployment of thermal technologies is low. Cadmus experts estimate less than 5% statewide penetration rate for 2.4 million homes in Massachusetts. MassCEC rebated approximately 20,000 ASHPs from 2014-2019, over 500 ground source heat pumps (GSHPs) since 2013, and over 1,200 solar hot water systems (SHWs) since 2011. Though these values likely underestimate the total number of installations completed, they still show the overall picture of low market penetration of thermal technologies.

Additionally, MassCEC launched a Whole-Home Heat Pump pilot in 2019 aimed at demonstrating electrification in this portion of the building stock. Initial results from this project have been positive, validating the strategy of packaging heat pumps with efficiency measures. Such programs are intended to overcome two key barriers to heat pump adoption: (1) Increasing consumer and contractor familiarity with heat pumps, and (2) Overcoming a consumer and contractor preference for "like-for-like" replacement of furnaces and boilers at the end of equipment life.

In addition to greater technological efficiency, ***key market gaps and needs in heating and cooling technologies include:***

- **Large-scale ASHPs**

ASHPs currently on the market are small, modular, and not well suited for large spaces (e.g. multi-family and commercial properties).

- **Solar hot water (SHW)**

While the technology is mature, the market *has not seen notable cost reductions for heat pump water heating technology.* Presently, SHW adopters have relied heavily on incentives to make the economics work. Additional SHW challenges include competing with solar PV for roof space and general lack of awareness for technology.

- **Solar assisted heat pumps (SAHPs)**

SAHPs integrate heat pump technology with an outdoor solar panel component. *This technology has not yet significantly penetrated the Boston market.* The need for auxiliary heat source to supplement solar, especially during cold or cloudy periods, is a notable drawback of this technology in addition to performance drops during these periods.

- **Small-scale variable refrigerant flow (VRF) systems**

The main gaps or challenges with VRF systems include: *indoor unit size* (the smallest VRF units is about a ½ ton and therefore inflates the cost in smaller properties), *limited ventilation capacity* (ventilation that

complies with ASHRAE Ventilation for Acceptable Indoor Air Quality standards and maintains humidity and filtration), and *efficient system refrigerant charge*. Additionally, there are concerns of refrigerant leakage compromising emissions reductions.

- **Small-scale ground source heat pumps (GSHPs)**

Several projects in the Metro Boston region have incorporated GSHPs into their design.[6] Project costs and drilling time (length of noise exposure) could be reduced by using *more advanced drilling equipment* – such as those used in fossil fuel extraction – and a *more experienced workforce*. However, this will require a critical mass of potential projects to justify the resources needed for these technologies and skills. This barrier could be overcome by public-private investment in early projects to facilitate industry scaling. As the industry grows and becomes more capable and efficient, it can access a larger market of smaller projects.

- **Air to water heat pump (AWHPs)**

Compared to Europe, AWHPs are generally more nascent in the US market with few state/utility programs supporting it. This technology is not readily commercially available, especially given New England's cold climate. On the residential side, demand is largely driven by the desire for cooling, which is more challenging to achieve with AWHP. Many homes in New England use forced hot air to provide AC, which cannot be as easily or affordably provided at the residential level by AWHP. This is primarily a product of distribution systems: air to water heat pumps need low temperature water distribution since heat pumps cannot raise temperature efficiently beyond ~120-140 degrees Fahrenheit.

- **Others**
    - Opportunity to integrate energy recovery ventilators (ERVs) with other HVAC equipment and domestic water heating.
    - Waste heat recovery systems have not seen a substantial uptake in the Massachusetts market. These technologies are more common at the industrial level.

Below are example projects or pilots tackling the challenges in alternative heating and cooling:

- Sanden Heat Pump Water Heaters (uses CO2 as refrigerant)
- Mass Save's Electric Heating & Cooling Rebates program
- Mass Save's 0% Interest HEAT Loan
- MassCEC's Whole-Home Air Source Heat Pump pilot program
- MassCEC's Residential- and Small-Scale Solar Hot Water program
- MassCEC and Massachusetts Department of Energy Resources' (DOER) demand aggregation program: HeatSmart Mass

[6] HEET, a local renewable energy-focused NGO, conducted a GeoMicroDistrict Feasibility Study assessing the potential for neighborhood or district-scale GSHP implementation in the utility right-of-way, with the intent to replace aging gas infrastructure. The study found that a GeoMicroDistrict could meet most of the heating and cooling needs of existing and new residential buildings, as well as part of the needs of commercial buildings. The study noted that while the costs were notable, the costs could be integrated into a reasonable utility-rate, similar to gas or electricity delivery. The findings of the study have prompted Eversource to file several petitions with the Massachusetts Department of Public Utilities to conduct pilot projects.

Energy Efficiency in Buildings

Improving building efficiency and reducing energy consumption are crucial components of building decarbonization. Enhancing building efficiency is also critical when integrated with alternative heating/cooling technologies, like ASHPs. In order to maximize cost savings for thermal technologies, the building envelope must be as tight as possible. Better design support tools (especially to reduce heat transfer from buildings shaped like a "U" or an "E") and integration of shading products into system controls for easier operation are both areas for technical improvement.

There is significant opportunity for building envelope enhancements such as façade restoration and panelization, particularly in buildings built prior to 1950. A very small percentage of the building stock thus far has undergone energy efficiency upgrades, despite being vital for achieving local and state climate targets. Smart thermostat data (e.g. NEST) can be used to identify buildings with high airflow needs that would be good candidates for deeper efficiency retrofits focused on envelope improvements.

The following building efficiency challenges were highlighted:

- **Prefabricated panels**

Stakeholders *are interested in leveraging offsite manufacturing construction through prefabricated panels*, like structurally insulated panels, to reduce cost and efficiency of retrofits. While the technology is currently available, greater demand and economies of scale are needed to spur cost effectiveness (e.g. a retrofit innovation pathway).

- **Façade redesign**

Buildings undergoing substantial renovations require more cost-effective and less intrusive methods of façade redesign. Interviewees identified that many buildings undergoing significant façade replacements are first motivated by aesthetic purposes, and then use the opportunity of major renovations to also enhance the property's energy efficiency to meet building code requirements.

- **Air sealing**

Air sealing has reached maturity in the market but would benefit from *improved standards development* (i.e. simplified measurement protocols) and *systems integration*.

- **Non-invasive insulation materials**

There is a need for improved strategies to insulate the building envelope that are both minimally disruptive to the homeowner and hyper-effective.

Below are sample pilots and projects related to building energy efficiency:

- MassCEC's Triple Decker Design Challenge
- Mass Save's Passive House Incentives for multi-family buildings (e.g. free feasibility study)
- Mass Save's Passive House Training for workforce development
- World Trade Center façade retrofit
- Building Envelope Materials received MassCEC and Department of Energy funding to develop a minimally invasive retrofit insulation process for enclosed roof cavities

- Sunrise Erectors was identified as an industry leader in façade renovation
- WinnCo received a grant from the Department of Energy to explore cost and performance of unitized panels

Renewable Energy Generation

Renewable energy technology is mature and well established in the market, but there remain over a half a million buildings in the Metro Boston region that are candidates for roof top solar. Most of these are single family or small multi-family residences. We estimate a market size of between $10 and $30 billion dollars.

Stakeholders agree that while there is *room for improvement in technological efficiency*, the main barriers arise from *soft costs* (i.e. non-hardware costs, like cost of permitting or labor). In terms of roof space prioritization, *solar energy* is considered a top priority in the dense urban core (e.g. Boston, Cambridge, Somerville). According to Solar Energy Industry Association[7], Massachusetts has nearly 3000 MW of installed solar with over 106,000 installations. This figure is expected to increase by 1,400 MW over the next 5 years, especially as stakeholder anticipate utilities become increasingly more open to microgrids. Massachusetts also has 419 solar companies in the state, including 71 solar manufacturers and 150 solar installers/developers.

In terms of small-scale building-level renewables, *solar energy is the most attractive option for property owners.* Wind energy, for instance, is being utilized more as large-scale offshore projects to reach 2050 targets. Small-scale urban wind energy was noted by interviewees as being more for "demonstrational purposes" and not expected to significantly increase given the high costs, tricky technology, few incentives to homeowners, and challenges deploying in an urban setting.

Despite significant improvement in renewable energy deployment in recent years, some challenges persist producing opportunity for innovation, such as:

- **Panel weight**

Solar panels can pose a challenge for existing buildings where the roofs were not designed to carry significant additional weight, and structural upgrades can be prohibitively challenging.

- **System flexibility and grid management**

Enhanced control of generation resources and energy storage, and improved grid management and demand response can more greatly increase the penetration of solar PV.

- **Hydrogen fuel cells**

In 2018, the Northeast Electrochemical Energy Storage Cluster (NEESC)'s Hydrogen and Fuel Cell Development Plan estimated Massachusetts has the potential to install 250 MW of stationary fuel cell generation[8]. Hydrogen fuel cells are a mature technology, yet not economically viable in the market.

[7] Solar Energy Industry Association (2020). Massachusetts Solar. https://www.seia.org/state-solar-policy/massachusetts-solar

[8] This Report also contains analyses and maps of market potential for hydrogen and fuel cell stationary applications.

One of the most commonly cited barriers to widescale adoption is *the scarcity of supportive infrastructure.* (e.g. refueling stations). Greater investment is needed in the production and distribution of fuel cells to reach economies of scale.

The state formed a Massachusetts Hydrogen Coalition in 2004 to accelerate research, development, and deployment of hydrogen, fuel cells, and other related technologies. The Coalition now has over 30 members. Currently, hydrogen refueling stations can be found at numerous Massachusetts Bay Transportation Authority (MBTA) facilities, managed by Nuvera.

- **Others**
    - Competing roof space with heating, ventilation, and air-conditioning (HVAC) equipment
    - Large-scale integration solar into electrical generation transmission systems
    - Solar panels as shading structures (e.g. solar canopies over building parking)

Sample pilots and incentives include:

- Solar Massachusetts Renewable Target (SMART) incentive payments.
- MassCEC and DOER's demand aggregation program: Solarize Mass
- While less efficient, Merlin Solar overcomes the weight challenge with flat, lightweight solar panels that adhere directly onto the roof.
- Ivys Energy Solutions: SimpleFuel, hydrogen generation and dispensing appliance

Energy Storage

While the technology for energy storage is mature and well established in the market, there is a low rate of adoption in the Boston Area. Battery technology is seen as being at an earlier stage, but following a similar trajectory as the development of the solar energy market. As batteries are becoming more stable, less prone to issues or failure, and have an increasingly smaller physical footprint, developers are now focusing on making them increasingly more efficient, reliable, cost-competitive, and wearable (e.g. better weather-resistant).

Currently, the greatest barriers to large-scale deployment emerge from *uncertainty in regulatory treatment, barriers in wholesale market rules, and lack of specific policies to promote storage technologies.* A 2017 Massachusetts Energy Storage Initiative State of Charge Report states the most significant hurdle to widespread storage deployment is the lack of clear market mechanisms to transfer ratepayers' cost savings to the storage project developer.

In addition to improved efficiency in battery performance, several additional gaps in the storage market emerged, including:

- **Distributed Energy Resources and Locational Value**

With electrification of heating and vehicles, electricity distribution infrastructure's needs and costs will dramatically increase. This can be offset by improvements in energy efficiency or through adoption of distributed energy resources, such as solar panels or storage. Because of the local nature of electricity

distribution, utilities are focused on maximizing *locational value*[9]. Once utilities complete their needs assessments, there should be more opportunities for *system and resource integration via specialized hardware and software* to maximize potential co-location of solar and storage, or the use of Vehicle-to-Grid. Opportunities exist to *develop business models to provide guidance to property owners, utilities and municipal planners* about the best and most cost-effective implementation of these resources.

- **Size optimization**

Smaller residences may not have sufficient space to house large battery storage equipment. Often times DER equipment competes with other systems equipment vital for maintaining a function residence (e.g. electrical or mechanical equipment) for space, thus posing a prohibitory challenge. Optimally sized equipment would subsequently minimize the total investment needed and operational expenses from the consumer while providing the energy required. Size optimized technology has not yet achieved economies of scale.

- **DC ready appliances**

Despite being a very nascent market, DC end uses are expected to more forcefully enter the market within the next 5-10 years. In the meantime, more research and development are needed to develop mature DC-ready appliances.

Sample energy storage projects, pilots, and incentives include:

- Energy Storage Initiative study and funding to grow electric energy storage
- Mass Save's ConnectedSolutions incentive
- Advancing Commonwealth Energy Storage (ACES) program provided by MassCEC and DOER
- Greentown Labs and Schneider Electric: "Bold Ideas 2020" Energy Storage Challenge
- American Microgrid Solutions: solar generation and battery storage at Shillman House, Framingham

Smart Software Solutions

Advanced metering is crucial for grid modernization and developing products and services that align with specific consumer patterns. However, according to the U.S. Energy Information Administration, *less than 20% of Massachusetts residential customers had a smart meter in 2016*.[10] Furthermore, in 2018, the Massachusetts Department of Public Utilities rejected utilities' plan for widescale deployment of advanced metering infrastructure (AMI), citing high costs, premature deployment, and other

[9] I.e. deploying distributed energy resources to strategic locations on the grid for the purposes of grid management, energy resilience, etc.

[10] U.S. Energy Information Administration (2017), Annual Electric Power Industry Report. https://www.eia.gov/todayinenergy/detail.php?id=34012

weaknesses in the business case.[11] Until the utilities can put forward a satisfactory plan, the future of smart meters, particularly in small residential properties, remains uncertain.

The future of building and facility management is moving towards integrating smart software controls into everyday operations in greater volume. While control systems have been in the market for years, they are cost prohibitive for smaller projects and have expensive subscription costs to curtailment service providers like CPower. Interviewees identified leading management products by Stem, JELI, and DemandQ.

The following were identified as market gaps in the smart software space:

- **Better performing smart meters in large multi-family buildings**

Meters located in basements of large multi-family buildings struggle to transmit low-power wireless signals throughout the building to reach individual units above. Actors are *looking to European and Asian solutions (e.g. powerline carrier technologies) to improve communication networks* in hard-to-access meters.

- **Virtual power plants (VPP)**

Tapping into DER and battery storage, a VPP allows for these resources to communicate with one another via the cloud and serve as a large generator. Though not widely commercially available, SunRun and Genereac have this feature.

- **Artificial intelligence and machine learning**

Greater use of artificial intelligence and machine learning for building systems operations and facilities management (e.g. identify broken HVAC unit, predict when maintenance needed, etc.). For building owners with numerous properties, there is a need for a smart portfolio management system that provides the ability to track equipment, operations, and performance across buildings.

Below are example projects or pilots tackling the challenges in smart software:

- Unitil Energy virtual power plant pilot with ReVision Energy and Eguana Technologies
- Advanced Energy Intelligence's interactive energy map of the City of Boston for portfolio management

Secondary Subsectors

Climate Resilient Design

- **Energy storage**

[11] Greentech Media (2018). Massachusetts Rejects Smart Meter Rollouts, as Competitive Energy Undermines the Business Case. https://www.greentechmedia.com/articles/read/massachusetts-rejects-smart-meter-rollouts-as-competitive-energy-undermines

In addition to cost-effectiveness, energy storage is of increasing interest to building owners for energy resiliency. Back-up batteries ensure access to power in the event of electrical grid failure. Cities around the U.S., like San Francisco, are integrating energy storage into its emergency response plans. These planning discussions are still in early stages in the Boston region (e.g. the municipalities of Beverly and Wayland have partnered with MAPC and MA DOER to use battery storage to support and protect critical infrastructure during emergency events).

- **Flood resilient design**

As waterfront areas continue to be an area of major growth and significant development in region, resilient design is at top of mind for developers. A Better City's Voluntary Resilience Standards outlines market options for large commercial buildings in Boston to improve resilient design in the event of flooding.

- **Vegetated Roofs**

Outside of strictly energy retrofits, vegetated roofs (including green roofs, blue-green roofs, and purple roofs, among others) are additional strategies to address stormwater management, mitigate urban heat, and improve urban resiliency. While this space is continuously evolving, purple roofs are emerging as leaders given the lightweight technology and high retention potential.

Auxiliary Retrofits

- **Flood retrofits**

In the event of substantial damage from flooding, renovations must comply with flood regulations and applicable energy standards. As building owners undergo flood retrofits, electrical, mechanical, HVAC equipment may need to be elevated to be above the base flood elevation level. These instances present opportunities to replace old, high-emitting technologies with more efficient systems. When conducting site elevation retrofits, property owners can use recycled materials in the fill to reduce costs and improve circularity.

- **Historic preservation**

Historical buildings undergoing preservation are points of opportunity for deep energy retrofits.

- **Roof upgrades**

Buildings undergoing roof upgrades for non-energy related reasons may enhance the roof further to account for renewable generation and/or low carbon heating equipment.

Advanced Materials

- **Insulation Material**

Building Envelope Materials (BEM), a firm that has developed a closed cell polyurethane foam as insulation material observed a growing opportunity for advanced materials that improve energy efficiency as state utility renewable energy funds have exhausted most easy, low cost improvements

and are looking for other options to invest in.[12] BEM also remarked that the main constraint they faced was from contractors, as the installation of advanced materials can be a physically demanding task that is hard to find consistent labor availability for.

Integrated Solutions

Stakeholders expressed significant interest in integrated, as opposed to single issue, solutions. The following items emerged as opportunities for integrated and innovative solutions that combine multiple technologies or services.

- **Alternative heating and building envelope enhancements**

In order for alternative heating technologies to be cost effective, building envelopes must be efficient. Integrated and efficient envelopes (i.e. air sealed, well insulated, window and glazing design, etc.) reduces the energy use and operating costs, and therefore the quantity and size of HVAC systems needed further reducing costs.

- **Smart software for integrating solar and storage**

Cost-effective and efficient strategies are needed to better integrate intelligent software with solar panels, battery storage, and inverters. Ideally, this technology could either be used as a single unit or be able to integrate into existing solar arrays, and allow communication between the user and other home systems.

- **Renewable generation and electric vehicle charging**

Electric vehicles (EVs) are continuing to penetrate the Boston market more substantially and at increasingly more cost-effective rates with notable support from the local and state government. Solar PV energy can be integrated with EV for cleaner charging. EV batteries can even serve as back-up power for home energy through extractable modular battery technologies.

[12] For more on Massachusetts Renewable Energy Trust Fund, see https://programs.dsireusa.org/system/program/detail/732

Other Gaps and Opportunities for Innovation

- **Single and Small Multi-Family Homes**

As previously noted, the small residential sector represents the greatest opportunity in terms of number of buildings. Decarbonizing this stock will require electrification of heating and cooking systems, and energy efficiency measures appropriate to the age and design of the buildings.

While the application of these technologies is straightforward and readily implementable, the magnitude of the market presents significant opportunities and scaling challenges. Feedback from the MassCEC's HeatSmart Program, a grassroots heat pump rebate program, has found that specialized contractors that focus only on electrification and efficiency tend to deliver the best results. By operating lean, these contractors can leverage their experience to quickly identify any challenges that may result in problems (incorrect system sizing, etc.). However, the number of contractors currently remains small.

Given the large size of the market and its barriers, there are a number of potential opportunities for supporting contractors or operating as a contractor. Data assets such as public building data (permits, assessor's data) and demographics datasets can be used to identify likely customers and reduce customer acquisition costs. [13]

- **Public Sector Buildings**

There are approximately 100 municipalities in Greater Boston. Recent climate action plans of Boston, Cambridge, Somerville and other communities within the region have specifically called for net zero new municipal buildings, or investment in energy efficiency and electrification in existing municipal buildings. This cohort, while small, is singled out in these plans due to cities' direct ownership of these assets – as opposed to private sector assets which cities' abilities to regulate are currently limited. As such cities are leading by example. Given commonalties in public sector buildings uses (schools, libraries, public housing, offices, and maintenance) there is an opportunity to provide "packaged" solutions to cities in their municipal decarbonization efforts.

Single Family Homes & Efficiency Requirements

There is currently no requirement for single family homes in Massachusetts to pursue energy efficiency improvements unless they are undergoing a substantial improvement. Upon renovation, they are required to comply with the state building code, which establishes standards for insulation, building materials, etc. A more aggressive set of standards, referred to as "the Stretch Code" has been adopted by many communities across the Commonwealth, including a majority of those in the Greater Boston region, see this map. Many single-family homeowners voluntarily pursue energy efficiency improvements in attempt to reduce electricity costs. Massachusetts has established an incentive program, MassSave, that helps homeowners receive free energy audits and provides rebates on many common improvements, including insulation and air sealing, as well as the purchase of energy efficient heat systems and appliances.

Visit these sites for more information on the Massachusetts Stretch Code and MassSave.

[13] MassGIS contains publicly available datasets and shapefiles, including Census/demographic data.

However, given the COVID-19 pandemic, municipalities may be resource-limited in the near term.

- **Lab/Hospital Ventilation**

Laboratories and hospitals are a particular challenge for decarbonization given their high demands for ventilation. During the first months of the COVID-19 pandemic many lab and hospital property owners cited the increased need for ventilation as something that would make it harder to cost effectively decarbonize their buildings. New air scrubbing or energy savaging technologies would help these buildings improve indoor air quality and reduce energy consumption to meet both goals. For example, enVerid modules pairs energy efficiency with improved air quality.

Greater Boston contains nearly 50 million square feet of laboratory and hospital space with an estimated $1 billion retrofit market size, and much of this stock is likely to have ventilation systems near or past depreciable lifespans.

- **Energy Audits and Data**

Conducting comprehensive energy audits remain costly. Auditing the entire Boston market would range from $300 million to over $1 billion. However, with increased focus on decarbonization efforts and maximizing locational value, there could be large value in mapping out priority and cost-effective decarbonization opportunities. As demand increases, there is opportunity to revisit strategies that failed to take off in the past such as thermal imaging, remote sensing, image analysis, comparative benchmarking, and leveraging thermostat and operational data, to more rapidly and cost effectively conduct audits.

V. Actor Profiles

Key Market Actor Types

Overview

To support Dutch clean tech business efforts to better understand the various players within the Boston retrofit market, Cadmus has outlined 9 relevant **market actor types**, including: government, designers, engineers, property managers, tech providers, non-profits, large institutional customers, research institutes, and utilities. For each actor type, Cadmus has outlined a description of their role and influence in the buildings retrofit landscape and includes a sample list of actors.

Of the actor types described, designers and engineers are most engaged in deep energy retrofits and efficiency practices. The onus to realize innovative solutions, however, stems from their clients' (i.e. building owners) requests. Property owners and managers who choose to go beyond energy efficiency requirements do so when they have awareness for and care about sustainability efforts. In large commercial and multifamily properties, owners generally follow the interest of their tenants.

Meanwhile, tech providers promote their technologies so that those manufacturing high performance building materials and systems are more engaged in championing the concepts of energy efficiency (and, by proxy, their products) to building owners (and the designers/engineers they rely on). As new supportive legislation (e.g. building performance standards, stretch code amendments, etc.) slowly drive the market, government relies on designers/engineers to know what is needed to ensure compliance. When unfamiliar, these designers/engineers then leverage tech providers to identify the products needed.

Actor Types

Actor Type:	Government
Description	Government actors currently play a central role in driving the Greater Boston building retrofit market. There are multiple layers of government and agencies that influence different aspects of building development, design, finance and permitting. In Massachusetts the State Government is responsible for building codes and local governments are responsible for building permits and inspections. In many cases, key incentive programs are administered through state agencies, including the Massachusetts Clean Energy Center and Massachusetts Department of Energy Resources. Boston's Building Energy Reporting and Disclosure Ordinance (BERDO) requires large commercial and multifamily residential buildings[14] to report their annual energy use and conduct an energy

[14] Buildings that meet the following criteria are required to comply: (1) Nonresidential buildings that are 35,000 square feet or larger. (2) Residential buildings that are 35,000 square feet or larger, or have 35 or more units. (3) Any parcel with multiple buildings that sum to 100,000 square feet or 100 units.

	assessment or significant energy action every 5 years. The City of Cambridge also has a Building Energy Use Disclosure Ordinance (BEUDO) requiring large properties[15] disclose energy usage. The Stretch Energy Code is an appendix to the Building Code that gives communities the option to go beyond to improve building efficiency in new constructions. There are currently 284 municipalities in Massachusetts that have adopted the current Stretch Code (see this map by community). However, as noted above, a new Net Zero Stretch Code is currently being proposed. Additionally, some municipalities, like Boston, Somerville, Brookline, and Watertown, among others, have passed zoning ordinances to require applicable buildings to meet LEED standards. Boston and Cambridge both have net-zero action plans in place. MAPC is currently working with the Towns of Arlington and Natick and the City of Melrose to currently draft their net-zero plans. Other strategies to stimulate building decarbonization of interest for regional municipalities in the region include carbon emissions performance standards for private buildings.
Sample Local Actors	▪ City of Boston ▪ City of Cambridge ▪ Massachusetts Clean Energy Center (MassCEC) ▪ Boston Green Ribbon Commission (BGRC) ▪ Boston Planning and Developing Agency (BPDA) ▪ Metropolitan Area Planning Council (MAPC) ▪ Massachusetts Department of Energy Resources (DOER) ▪ U.S. Department of Housing and Urban Development (Green Retrofit Program) ▪ Boston Housing Authority
Actor Type:	Building Owners and Managers
Description	Building owners and managers are required to comply with building codes, ordinances, standards and other regulations that support deep energy retrofits. They are also responsible for conducting business in ways that support climate and sustainability goals, with many owners volunteering to go beyond energy standards. Large commercial and multi-family buildings generally act in the interest of their tenants, and the trend is moving increasingly towards more efficient, integrated buildings. Generally, building owners own and operate their heating, cooling, and hot water systems, and therefore hold the power to transition these systems away from fossil fuels and into cleaner, electric technologies, like heat pump technologies. Industry leaders, like Boston Properties and Winn Companies are paving the way for green buildings by employing emission reduction and energy conservation measures in their own portfolios, such as building envelope enhancements, strategic electrification, and HVAC and lighting upgrades. In the Greater Boston Area, Boston Properties and Winn Companies operate nearly 50 buildings and over 80 buildings, respectively.
Sample Local Actors	▪ Boston Properties ▪ Winn Companies ▪ Alexandria Real-Estate Equities ▪ Equity Residential ▪ JLL Boston ▪ HYM Investment Group
Actor Type:	Designers
Description	Building designers and architects play an integral role in informing building owners about the opportunities and design solutions for building retrofit projects. Passive house and net zero design

[15] Buildings that meet the following criteria are required to comply: (1) One or more non-residential building(s) where such building(s) singly or together contain greater than 25,000 square feet. (2) Residential unit with more than 50 units. (3) Municipal properties greater than 10,000 square feet.

Sample Local Actors	concepts are increasingly gaining traction. As buildings undergo major renovations, it is crucial for architects to design well-insulated projects with high performing envelopes and mechanical systems and, where possible, integrate renewable energy generation. ▪ Studio G Architects ▪ Architerra ▪ Sasaki ▪ Arrowstreet ▪ Amacher & Associates Architects ▪ Gensler ▪ Zero Energy Design ▪ Placetailor Associations ▪ Touloukian Touloukian Inc. ▪ Reverse Architecture ▪ Resilient Design Institute (RDI)
Actor Type:	Building Engineers
Description	In addition to leading retrofit projects, building engineers are also conducting much of the research in building sustainability (e.g. feasibility studies, trend analyses, building performance lab analytics, etc.). Many engineers also participate in local committees and professional associations; such as the Boston Society for Architects (BSA) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); to maintain appraised of technological innovations. There is an upwards trend of engineering firms going beyond compliance requirements and developing energy-positive projects. Some firms recognize the need for decarbonization and energy efficiency in their operations and are setting goals for themselves. For example, Burro Happold set the following targets: all new building projects to be zero net carbon (ZNC) by 2030, and all projects (new construction and substantially improved) to be ZNC by 2050.
Sample Local Actors	▪ Stantec ▪ Buro Happold ▪ Thornton Tomasetti ▪ Turner Construction ▪ Arup
Actor Type:	Tech Providers
Description	Tech providers are the local firms that supply the goods and services for deep energy retrofits. These main areas where tech providers operate range from building envelope and façade materials, battery storage, smart software, and other forms of low- or no-carbon technologies, such as solar PV and ASHPs. For a comprehensive list of local tech providers, see MassCEC's list of portfolio companies and commercially-ready technologies. Included in the list below are also clean technology startup incubators that support the commercialization of start-up technologies. Some incubators, like Greentown Labs, also provide shared equipment and lab space, opportunities for community collaboration and peer learning, and prototype manufacturing assistance. Other tech providers beyond the scope of this analysis include: wastewater treatment, battery recycling, and community solar technologies and services, among others.
Sample Local Actors	▪ Schneider Electrics ▪ Stem ▪ American Microgrid Solutions ▪ Enel X ▪ Sunrise Erectors ▪ Demand Q ▪ New England Solar Hot Water ▪ Guardian Energy Management Services ▪ Sun Run ▪ ENGIE Services U.S. ▪ Greentown Labs ▪ Boston Robotics
Actor Type:	Non-Profits

Description	There are numerus non-profits in the Boston area committed to advancing the retrofit market, with varying extents and focus areas. For example, some organizations (e.g. NEEP) are concentrating on regional collaboration to connect stakeholders in business initiatives that support decarbonization goals. Another example are non-profits that provide HVAC/energy services (e.g. ABCD's Weatherization Assistance Program).
Sample Local Actors	▪ Innovation Network for Communities: Building Electrification Initiative (BEI) ▪ A Better City (ABC) ▪ Northeast Clean Energy Council (NECEC) ▪ Action for Boston Community Development (ABCD) ▪ New Ecology ▪ Northeast Energy Efficiency Partnerships (NEEP)
Actor Type:	Large Institutions
Description	Greater Boston is a hub for higher education and healthcare services. University campuses and medical centers are high energy users with large potential for significant cost and energy savings due to economies of scale. Many large institutional consumers already have strategic energy management plans (SEMPs), or a roadmap for strategic energy planning and investment, demonstrating their interest in efficiency upgrades. For example, Mass General Hospital's SEMP sets targets for energy consumption reduction and increased use of renewable energy sources. Larger buildings also provide greater opportunities for "bundling" clean tech solutions (e.g. distributed generation, microgrids, combined heat and power) and have more space to house large equipment that would otherwise be infeasible in smaller residential properties. These institutional players are also interested in a "portfolio management" approach, seeking energy efficiency opportunities across a campus or set of buildings and properties.
Sample Local Actors	▪ Boston University ▪ Harvard University (e.g. Hilles Library) ▪ Milton Academy ▪ Mass General Hospital ▪ Boston Medical Center ▪ Colonnade Hotel ▪ Harvard Pilgrim Health Care ▪ JSB Industries (office in Lawrence, MA) ▪ Kraft Sports Group (Gillette Stadium) ▪ Partners Healthcare (data center in Needham) ▪ Museum of Science
Actor Type:	Research Institutes
Description	Research institutes are driving the analysis of building retrofits performance and technologies as well as the challenges of deep decarbonization. Research in this field cover all primary and secondary subsector focus areas, and range considerable. Examples of ongoing research in this field include: Accelerating the Energy Transition: Pathways for Carbon Neutral Buildings (BU ISE), smart heating and cooling systems (CGBC), life cycle tradeoffs for insulation retrofits (CGBC), and more.
Sample Local Actors	▪ Harvard Center for Green Buildings and Cities (CGBC) ▪ Rocky Mountain Institute (national) ▪ Boston University Institute for Sustainable Energy (BU ISE)
Actor Type:	Utilities
Description	In Massachusetts, natural gas and electricity are deregulated markets, meaning consumers are able to purchase their electricity from a number of retail suppliers. The Greater Boston region is served by Eversource, National Grid and several other municipal electricity providers (see this map for more details). Local utilities play several different roles in the buildings retrofit market: ▪ Utility data is crucial to accurately evaluate building performance and determine energy and

cost savings before and after an energy retrofit.

- Utilities offer various programs to support energy retrofits ranging from energy efficiency and weatherization, heat pump rebates, battery storage to reduce peak demand from the grid, etc. The MassSave program is utility-led initiative that provide energy assessments and financial incentivizes for building efficiency improvements to its customers.
- Utilities often champion studies for further research and pilot projects to evaluate the performance of retrofits (e.g. the National Grid Deep Energy Retrofit Pilot).

Sample Local Actors

- National Grid
- Eversource
- Unitil

Actor Profiles

Cadmus outlined 8 **actor profiles** below, each includes a description of the organization, relevant case studies, and points of contact , where available.

Government

City of Boston: Boston Planning and Development Agency (BPDA)

The City of Boston has committed to net neutrality by 2050, with a goal to retrofit and electrify at least 80% of existing buildings stocks. In its 2019 Climate Action Plan Update, Boston established a series of policy initiatives for building decarbonization and greenhouse gas emissions reduction, such as setting a carbon emissions performance standard for privately owned buildings, among others. Boston is also seeking to expand financing mechanisms for retrofits, expand workforce development programs for building decarbonization, and develop guiding documents for buildings to meet deep energy retrofit goals. These strengthened policies are expected to significantly drive the market.

- **Relevant Policies**

The City of Boston is currently undergoing a process to strengthen its green building zoning requirements to a zero net carbon standard. Building developers undergoing major renovations must submit a Carbon Neutral Assessment, per Article 37 of zoning review requirements. Additionally, by 2021, properties undergoing substantial improvements will not receive approval from the Boston Planning and Development Agency (BPDA) if they do not meet zero net carbon (ZNC) or ZNC-ready requirements.

- **Contact**

John Dalzell, Senior Architect for Sustainable Development

City of Boston Partnership with the Innovation Network for Communities: Building Electrification Initiative (BEI)

BEI is supporting 6 U.S. cities, including Boston, by providing the tools, resources, and strategies to equitably accelerate the transition of building systems away from fossil fuels and toward high efficiency electric technologies. To achieve this goal, BEI is working with city governments to implement strategies that develop their local market for heat pumps by increasing demand and building local supply chains;

develop partnerships with states, utilities, manufacturers, and other regional and national actors that will be needed for the long-term transition; and invest in equitable strategies that prioritize the needs of frontline communities.

- **Relevant Projects**

In Boston, BEI is working with the City to identify retrofit packages for electrification and energy efficiency in small and multifamily buildings, with technical assistance support from Cadmus. This project includes a market segmentation analysis to update the Boston building inventory, the development of retrofit strategy recommendations for select typologies (e.g. air source heat pumps, heat pump water heaters, air to water heat pumps, weatherization, solar PV, and replacement/displacement strategies), program design to encourage electrification, and guidance for workforce development in energy and/or HVAC-related fields.

The final market segmentation report can be found here, along with the Boston building inventory and excel workbook of analyzed retrofit strategies and final recommendations for retrofit packages.

- **Contact**

Jenna Tatum, Director

Massachusetts Clean Energy Center (MassCEC)

Largely funded through electric bill surcharges, MassCEC is a quasi-public agency (i.e. independent government corporation, governed by Board of Directors, and publicly funded) dedicated to developing the clean energy economy and workforce. MassCEC funds over 40 programs across various clean energy subsectors ranging from financial incentives for clean energy adoption, incubation services (e.g. financing) for startups and tech development, and workforce development programs.

- **Relevant Projects**

The ongoing Triple Decker Design Challenge seeks to identify replicable solutions for deep decarbonization in small multifamily buildings and achieve net zero in this typology. MassCEC's demand aggregation programs like Solarize Mass and HeatSmart Mass reduce installation prices for consumers through a competitive installer selection and group purchasing process at the municipal level. Since 2011, Solarize Mass has support 3,759 contracted systems, or 25,661 kW, in 85 communities. Since its pilot in 2018, HeatSmart Mass[16] has led to 345 contracted systems in 15 communities. Additional relevant projects include the Whole-Home Air-Source Heat Pump pilot program and Residential- and Small-Scale Solar Hot Water program.

- **Contacts**

Meg Howard, Program Director
Beverly Craig, Senior Program Manager

[16] Includes air-source heat pumps, ground-source heat pumps, solar hot water, and automated wood heating

Building Developer

WinnCompanies

WinnCompanies is an award-winning national developer and manager of high-impact housing communities setting the standard for green affordable housing in both new construction and existing buildings. WinnCompanies is a Better Buildings Challenge partner and has undertaken numerous building retrofit projects. WinnDevelopment, a part of WinnCompanies, leads solar power development on multifamily buildings guided by principles of sustainable development and energy efficiency. In Boston, project teams are experts in state and local incentives (e.g. Home Performance with Energy Star) and certification programs (e.g. LEED and Enterprise Green Communities).

- **Relevant Projects**

Castle Square Apartments: Constructed in the 1960s, Castle Square Apartments is an affordable housing complex located in the South End of Boston. Along with other key partners, like MA DOER and the Castle Square Tenants Organization, WinnCcompanies led the largest deep energy retrofits project in the nation, at the time in 2011. The Castle Square Apartments retrofit is largely recognized as a "best example" in Boston and was identified in a majority of stakeholder interviews. Retrofits included a new super-insulated shell wrapped around the concrete building in addition to an insulated reflective roof, high efficiency windows, and extensive air sealing. Castle Square Apartments now also feature solar hot water systems, LED and CFL lighting, and high efficiency appliances. Total energy use reduced by 36%.

Oliver Lofts: Originally built in 1867, Oliver Lofts has undergone historic preservation and energy retrofits to transform it into today's high-performing building. This property is Boston's only mid-rise, multi-family redevelopment project designated as LEED Platinum.

- **Contact**

Darien Crimmin, Vice President of Energy and Sustainability

Technology Developer

Greentown Labs

Greentown Labs is the largest startup incubator for climate and clean energy technology in North America. Headquartered in Somerville, Greentown Labs supports its members by providing a space, lab equipment, and legal and professional services. Many Greentown startups, like Embue (building management software), were able to successfully penetrate the market and become commercially available. Startups have access to an equipped machine shop, a prototyping lab, a wet lab, and an electronics lab, in addition to entrepreneurial mentoring and access to Greentown's network of partners and industry investors.

- **Relevant Projects**

BOSteRDAM Cleantech Link: Greentown labs and the Dutch InnovationQuarter have launched a market expansion program to support entrepreneurs in the US and Netherlands. The program will allow companies to form partnerships and facilitate market entry.

Greentown Labs has a number of startups entering the buildings retrofits market. Relevant member companies include: AeroShield (super-insulating windows), Techstyle Materials (energy efficient building material), Vespr Solar (PV module attachment), Titan Advanced Energy Solutions (battery storage), Transaera (ultra-efficient cooling system), and many others.

- **Contact**

Andrew Takacs, Senior Director of Innovation and Portfolio

Building Envelope Materials (BEM)

Backed by grant funding from MassCEC, U.S. Department of Energy, and CertainTeed/Saint Gobain, BEM has developed a closed cell polyurethane foam as insulation material. By developing their pinhole insulation technology to inject their foam into wall cavities in a minimally disruptive manner, BEM's insulation material aims to be easily deployable in retrofit projects. BEM's technology has increased insulation values from R10 to R23 and has been demonstrated to reduce energy usage by 25% or more, in typical 1950's-era fiberglass insulated wall.

- **Relevant Projects**

The Boston Housing Authority (BHA) has engaged BEM to use its material to retrofit about 10,000 electrified housing units. This project was the culmination of BEM building a relationship with BHA during its earlier funding stages to better understand interests from building owner's perspective, and the successful completion of pilot projects to BHA's satisfaction.

- **Contact**

Doug Lamm, CEO

Designers

Studio G Architects

Studio G is an architecture and interior design firm focused on environmental, economic, and social sustainability. Their portfolio ranges from designing sustainable residences, commercial centers, schools, and gathering spaces all around the Greater Boston area.

- **Relevant Projects**

In 2018, Studio G renovated the 1968 Haverhill District Courthouse by conducting structural and energy efficiency upgrades, including a new HVAC system, high performing windows, and LED light fixtures throughout the site. Studio G has been awarded several ultra-sustainable E positive projects in the Boston area, such as E+ Marcella Highland and E+ Parker Terrace Housing, pairing passive house principles with on-site renewable energy generation.

- **Contact**

Sayo Okada, Program Manager and Passive House Consultant

Large Institutional Customers

Boston University (BU)

With its own Climate Action Plan, BU set a goal to be carbon neutral campus-wide by 2040. As a result, sustainability and energy efficiency are key drivers of all construction projects for both new construction and building retrofits. In 2019 alone, projects ranged from: campus-wide solar feasibility study, lighting upgrades, Energy Star appliance replacements, façade/window replacements and weatherization. BU also contains the Institute for Sustainable Energy, which co-authored the Carbon Free Boston Buildings Technical Report and is conducting ongoing research on building decarbonization.

BU has 176 small multi-family-like student housing buildings. BU is conducting ongoing research on one property to understand the procedures, costs, and challenges related to retrofitting the typology to net zero and passive house design. Researchers are modeling the impact of what costs and impact would be of three conservation measures intended to reduce infiltration losses.

- **Relevant Projects**

In 2015, BU completed a façade retrofit of the Law Tower, originally constructed in 1965. This project included building system upgrades, building envelope repairs, façade restoration, and window replacements, among other things. Additionally, in 2014, BU upgraded the lighting at the Track and Tennis Center with efficient LED bulbs and smart controls. The fixtures were projected to save 770,000 kWh annually, or a 40% reduction in energy use.

More information on BU's development projects can be found on their sustainability website.

- **Contact**

Dennis Carlberg, Associate Vice President for University Sustainability

VI. Appendix

Literature Review

Carbon Free Boston Report Summary Report and Energy Technical Report
Published in 2019 by the Green Ribbon Commission at the request of Mayor Martin J. Walsh, the Carbon Free Boston report identifies specific steps for the City of Boston to meet its goal of carbon neutrality by 2050. The report recommends three mutually reinforcing strategies: 1. deepen energy efficiency, 2. electrification and 3. purchase of 100% clean energy. Improving the efficiency of buildings is a top priority as 2/3 of Boston's greenhouse gas (GHG) emissions come from buildings, including the use of electricity, heating oil, and natural gas used to supply heat and hot water. The report notes that existing buildings will pose a significant challenge as 85% of Boston's projected 2050 building square footage exists today. In particular, buildings constructed prior to 1950 are in need of retrofits and most "have less insulation, are less airtight, and use older, inefficient equipment, all of which result in higher energy use and GHG emissions compared with newer buildings." The report also notes that Boston is in the midst of a major building boom and has added 4-6 million square feet of new building space per year since 2014. The residential sector presents a growing market and the report projects the addition of 77,500 new housing units by 2050. While Boston will seek to require new construction meet net zero building codes, the report identifies a need for deep energy retrofits of 2,000-3,000 buildings per year.

The Commercial Net Zero Energy Building Market in Boston, a 2017 report by the Boston Green Ribbon Commission and A Better City, identified commercial buildings as contributing to 52.2% of the City of Boston's greenhouse gas (GHG) emissions.[17] The report situates the net zero energy building market as a key sector for growth to support city and statewide goals to achieve ambitious emissions reductions targets. It highlights that in cold-weather climates like Boston, in addition to on-site renewables a combination of a shift in energy mix through suppliers, overall energy efficiency improvements, and more widespread off-site renewable energy (RE) purchase options are needed for more net zero buildings in Boston. Operations and maintenance capacity, higher additional capital costs for renewable energy technologies, and perceptions of feasibility are cited as three main barriers to overcome. The report concludes with case studies of successful, cost-efficient retrofit and new construction projects.

Thermal Electrification of Large Buildings in the Commonwealth, a 2020 study also written by A Better City and the Green Ribbon Commission with support from Cadmus, highlighted both most prevalent and emerging technology options for electrification. By transitioning the processes for heating, cooling, and hot water to non-fossil fuel-based options, buildings can significantly reduce their energy expenditures. Air source heat pumps, variable refrigerant flow heat pumps, and ground source heat pumps were identified as the most common technologies used while hydrogen, air-to-water heat pumps, and district geothermal as emerging technology options that could be poised to enter the market soon. High upfront

[17] Most actions taken since 2017 are still in planning and designing phase, thus the consultant team believes this number is still relevant and up to date

costs, a lack of compelling policy and regulatory incentives, and split incentives between tenants and building owners were cited as three challenges for further adoption of building electrification.

Additional resources recommended by interviewees, include:

- Research Gap Analysis for Zero-Net Energy Buildings (2019), California Energy Commission.[18]
- The Building Electrification Primer for City-Utility Coordination (2019); Cadmus Group, BEI, USDN, and CNCA.[19]
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Interest in International Technologies and Initiatives

Across all 11 interviews, there was strong interest in partnering with Dutch/European companies to scale up adoption of technologies and fill local market gaps. This included interest in small-scale versions of existing technologies (e.g. heat pumps, central hot water systems, etc.) and affordable prefabricated structures[28].

The following are names of specific international companies, technologies, or initiatives that stakeholders highlighted during the interview phase.

- Energiesprong:
  - Dutch initiative, prefabricated panels and integrated whole-home approach
- Fraunhofer:
  - German-based, has Boston Center for Manufacturing Innovation
- Scneider Electric
  - European multinational company, various clean energy technologies
- Gutex
  - German-based, insultation products
- Zehnder
  - Swiss-based, heat and energy recovery ventilation units
- Bouwgroep Dijkstra Draisma (BGDD):
  - Dutch-based, facade panel supplier
- Good Life Heating:
  - Portuguese manufactured, solar hot water solutions
- Sanden:
  - Japanese-based, CO2 heat pump water heater
- Merlin Solar
  - Philippines-based, light-weight PV integration with shingle/other roof types
- Navien:
  - Korean-based, water heaters

[28] One interviewee identified the use of panels as shading structures as an additional method to enhance the building envelope, like the Germany company GLASSCON's façade design.

This is a publication of
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This publication was commissioned by the ministry of Foreign Affairs.

Publication number: RVO-182-2020/RP-INT

NL Enterprise Agency is a department of the Dutch ministry of Economic Affairs and Climate Policy that implements government policy for Agricultural, sustainability, innovation, and international business and cooperation. NL Enterprise Agency is the contact point for businesses, educational institutions and government bodies for information and advice, financing, networking and regulatory matters.

Netherlands Enterprise Agency is part of the ministry of Economic Affairs and Climate Policy.