Zero Energy Buildings in Massachusetts: Saving Money from the Start

2019 REPORT

USGBC
MASSACHUSETTS

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About Us

The USGBC Massachusetts Chapter (USGBC MA) is a member-based community advocating for green buildings at the state and local level. We provide green building education, build community, engage in advocacy, research and develop tools, celebrate success, and foster leadership opportunities for sustainable building practitioners.

We drive sustainable and regenerative design, construction, and operation of the built environment. We envision a thriving and diverse community, creating a built environment of net positive systems of water and energy, of financial and social equity, and of ecological and human health.

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Introduction

The Fourth National Climate Assessment reports that our global climate continues to change rapidly and that the northeastern region of the United States is particularly vulnerable to sea level rise and extreme weather events. To avoid the worst of these impacts, scientists and leaders agree that we must reduce greenhouse gas (GHG) emissions and do so as soon as possible. One major source of these emissions comes from the energy consumed by buildings.

According to the United Nation's 2018 *Global Status Report,* buildings were responsible for 40% of energy-related carbon dioxide (CO2) emissions in 2017, while in major cities like Boston, buildings are responsible for 66% of GHG emissions. This same report also notes that the global building stock is expected to double by 2060, with two-thirds of the building stock that exists today still in existence. While this could be an immense footprint, reduction of building sector GHG emissions can be achieved through the creation and maintenance of zero energy buildings (ZE), which generate as much renewable energy on and/or off-site as they use in a year. The City of Boston's recently released *Carbon Free Boston* report identifies building energy efficiency as a top priority. It is clear that to curb greenhouse gas emissions we must reduce energy use in the built environment by retrofitting existing buildings and constructing new buildings to achieve zero energy standards.

Climate science tells us that we need to achieve carbon neutrality by mid-century to avoid the most catastrophic consequences of climate change and that we need to limit our emissions aligned with the Paris Climate Accord of a 1.5 degree world. While the Massachusetts Building Energy Stretch Code set a new bar for energy efficiency, it does not go far enough to drive energy reduction in new construction and is not aligned with science. Any new building not designed to be ZE today will need to be retrofitted to be so later, costing the owner more money. So, why are we still designing and constructing buildings to minimum code standards when it is so clear that we need to and can do better?

In May of 2018, USGBC MA, in partnership with Massachusetts Climate Action Network, Northeast Energy Efficiency Partnerships, and the Metropolitan Area Planning Council, held a Zero Net Energy Municipal Summit at Roxbury Community College during which we asked participants: What are the barriers to building ZE buildings? The number one cited obstacle was cost, followed by regulations. This report seeks to understand whether the notion that additional first costs for ZE buildings is an outdated perception or a reality, and to identify policy and regulatory changes to make building ZE the standard.

This report highlights only a sampling of the work done by the amazing practitioners we have here in the Commonwealth, practitioners who work each day toward zero energy buildings. With the combined efforts of our building industry professionals, the researchers at our great colleges and universities, our citizen advocates, our elected leaders, our state agencies, and the innovative businesses in Massachusetts, **we will transform the way we build**. Massachusetts is already a national leader and is uniquely positioned to take the next step and show the world how ZE buildings can reduce carbon emissions all while having a thriving economy.

MEREDITH ELBAUM, AIA, LEED AP
Executive Director, US Green Building Council Massachusetts Chapter

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Executive Summary

A growing body of evidence suggests zero energy buildings are possible today with no added upfront cost and make for smart investments. Utilizing readily available products, practices, and technologies, new ZE houses, apartments, offices, schools, institutions, and labs are being constructed in increasing numbers. With state and utility rebates for energy efficiency and renewable energy measures, these projects are being delivered at little or no additional first cost.

However, as we found at our municipal summit, stakeholders and decision-makers across the building industry continue to cite increased upfront costs as the primary barrier to ZE buildings and the cost benefits over the building's life cycle are rarely assessed.

With the support of the Barr Foundation, USGBC MA engaged Integral Group to assess ZE building costs, model performance, and conduct life-cycle cost assessments in an effort to determine if increased costs for ZE buildings in Massachusetts are a reality or myth. We also sought to understand how practices, regulations, and legislation could change to further support ZE building construction. We considered local construction practices, costs, building codes, climate conditions, energy costs, and the energy efficiency incentives currently available in Massachusetts. With this background in mind, the results reveal five key findings:

1. ZE buildings are being built in Massachusetts today with zero additional up-front costs.
2. Return on investment for ZE Existing and New Office Buildings can be as little as one year for ZE ready buildings.
3. Of the six building types studied, all can be Zero Energy Ready (ZER) for upfront costs of 0 – 7%, and when zero energy, all types break even in eight years or less when there are no additional upfront costs.
4. Existing office buildings retrofitted to zero energy, with renewables, can produce a return on their investment in as little as five to six years, given today's incentive structure.
5. Building energy demand can be reduced 44 – 54% across all building types with technology that's readily available today.

The Economics of Zero-Energy Homes, a recent study published by the Rocky Mountain Institute (RMI, 2019), found that, with utility energy efficiency rebates, there is no added cost for a new zero energy ready single-family home in Boston. Bristol Community College has demonstrated that zero energy buildings can in fact reduce first costs; with grants and rebates, the Sbrega Health and Science Building was completed under budget and annually saves $115,000 in utility expenses due to energy efficiency measures. A comparative market analysis of the recently completed E+ 156 Highland Street residential development, in Boston, found that low-energy homes with solar photovoltaics (PV) and third-party certifications have higher market value than comparable developments. With the normalization of construction costs, ZE buildings can start saving money on day one and can be affordable and profitable.

In practice, projects typically move beyond the "reasonable set of energy conservation measures" used in this study to achieve ZE performance.

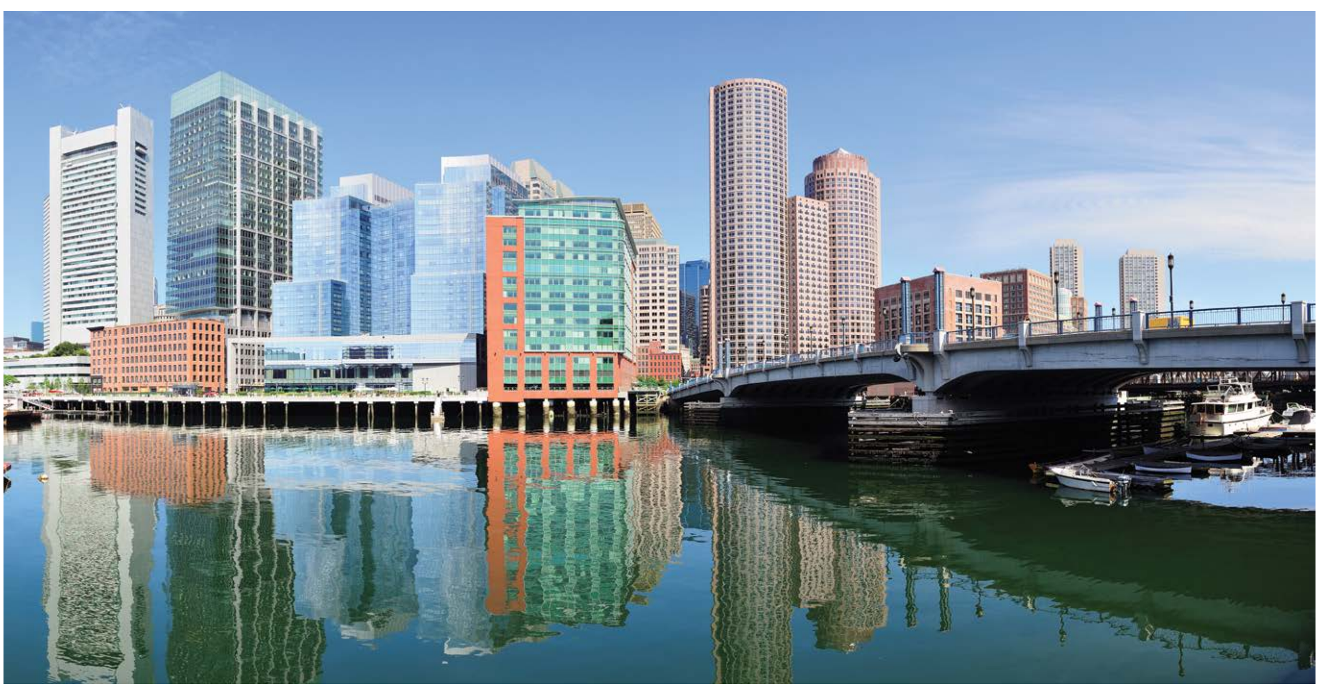
Policy Recommendations

The consultant team reviewed the 2009 report, *Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force*, a landmark study on net zero energy building practices and what it would take to make net zero energy buildings mainstream in Massachusetts. This report provides recommendations on how to further advance net zero energy building policy in Massachusetts. Some of the most important new actions and updates include:

- Develop a State Green Bank.
- Study the success of the Renew Boston Trust model.
- Develop a standard for integrated green roof and solar.
- Create a zero energy stretch code as a compliance path to the state energy code and establish date-specific targets for mandatory zero energy code adoption in Massachusetts.
- Require annual benchmarking and disclosure of energy performance for all commercial and multifamily buildings.
- Establish Building Energy Performance Standards for large existing commercial and multifamily buildings.
- Require home energy scoring and scorecard disclosure in conjunction with specific transactions (e.g., inspections or renovations), including at time of sale or rent.
- Work with residential loan providers to bundle solar installation and deep energy retrofit costs into mortgage at time of sale; investigate mortgage buy-down programs for current homeowners.
- Develop point-based incentive programs/performance-based procurement protocols for public projects to incentivize ZE projects.
- Require third-party retro-commissioning on all state buildings.
- Adopt new energy efficiency standards for appliances not covered under federal laws.

Conclusions

The perception that zero energy buildings always cost more upfront and over the long term is a myth; the reality is that zero energy buildings are a smart investment. There are actions we can take to make achieving ZE buildings easier. This study and the exemplary projects highlighted within can be used as a guide to looking past perceived obstacles and as a template for promoting zero energy buildings as smart investments.



Boston, MA. Photo credit: iStock/ rabbit75_ist

Background

Massachusetts is already a national leader in green building deployment. In 2017, the state had the most square feet on a per capita basis of Leadership in Energy & Environmental Design (LEED) projects installed, at 4.48 square feet per capita.[1] Massachusetts is also the #1 state in energy efficiency policy according to the American Council for an Energy-Efficient Economy (ACEEE).[2]

However, in the face of climate change, the Commonwealth of Massachusetts and leading municipalities, including member cities of the Metro Mayors Coalition, aim to address the urgent need to radically and quickly reduce greenhouse gas (GHG) emissions; they are seeking to go further and move toward becoming zero carbon communities. The Global Warming Solutions Act sets a statewide goal of reducing GHG emissions 80% by 2050, relative to a 1990 baseline. Cambridge set a goal of zero emissions from all buildings citywide by 2040. Somerville has pledged to be a carbon neutral community by 2050. Boston, with the Green Ribbon Commission in 2019, completed the *Carbon Free Boston* research report, which quantified strategies for meeting Boston's goal of being carbon neutral by 2050. Amherst has adopted bylaws mandating that all new municipal buildings be zero energy, with 100% of energy for the community coming from renewable sources by 2050. Other cities in the state are completing or embarking on similarly ambitious planning efforts. To achieve these ambitious goals, both new buildings and existing buildings in Massachusetts must rapidly move toward being zero energy.

In 2009, the Commonwealth of Massachusetts published *Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force,* a landmark study on net-zero energy building policy and practices and what it would take to make net zero energy buildings mainstream in Massachusetts.

FIGURE 1

Why Buildings?

The buildings and construction sector is a key actor in the fight against climate change: it accounted for 36% of final energy use and 39% of energy and process related emissions in 2017 globally.

SOURCE: https://www.unenvironment.org/resources/report/global-status-report-2018

[1] U.S. Green Building Council (2018). "U.S. Green Building Council Releases Annual Top 10 States for LEED Green Building Per Capita." Accessed November 1, 2018. https://www.usgbc.org/articles/us-green-building-council-releases-annual-top-10-states-leed-green-building-capita

[2] American Council for an Energy-Efficient Economy (2018). "ACEEE State Scorecard: Massachusetts." Accessed November 1, 2018. https://database.aceee.org/state/massachusetts

According to that report, "a zero net energy building is one that is optimally efficient and, over the course of a year, generates energy on-site in a quantity equal to or greater than the total amount of energy consumed on-site."[3] In the years since, other definitions of zero energy buildings have been introduced, including the U.S. Department of Energy (DOE) definition that a zero energy building (the federal definition left out the word "net") is "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." Zero emissions means that the building or community, in net over the year, does not contribute GHG emissions to the atmosphere due to using renewable energy sources equal to 100% of energy use. For the purposes of this report, zero energy and zero emissions are the same. The terms *zero energy* (ZE), *zero net energy* (ZNE), and *net-zero energy* (NZE) are used interchangeably in the marketplace, and all are used in this report and only account for a building's operational energy. They do not consider embodied energy or GHG emissions in construction. Recognizing site and regulatory challenges to including solar PV, it is also important to recognize *zero energy ready* (ZER) or *net zero energy ready* (NZER) buildings, which the DOE defines as "a high-performance building that is so energy efficient that all or most annual energy consumption can be offset with renewable energy."

Several certifications are available from the International Living Future Institute and New Buildings Institute for zero energy and positive energy buildings. (The New Buildings Institute and ILFI used to offer competing ZE certifications, but now jointly administer the Zero Energy Certification.) The U.S. Green Building Council also developed LEED Zero, a complement to its LEED (Leadership in Energy and Environmental Design) green building rating system, which verifies the achievement of net zero goals for energy, as well as transportation, waste, and water.

FIGURE 2

DEFINITIONS

Zero Emissions:
Generates and/or purchases enough renewable energy to offset emissions from all energy used in the building over a year.

Zero Energy:
Generates as much renewable energy as it consumes over a year.

Positive Energy:
Generates more energy than it consumes over a year.

Zero Energy Ready:
Reduces energy through energy conservation measures to the point that the remaining energy can be offset with renewable energy.

E+ 273 Highland St, Boston - Multifamily Residential (23 units) LEED Platinum and net energy positive (HERS 37 / with solar PV, -3). Rees-Larkin Development with Studio G Architects. The E+ Green Building Program is an initiative of the Department of Neighborhood Development and the BPDA. Image credit: Studio G Architects.

[3] Commonwealth of Massachusetts, (2009) *Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force,* March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

One challenge that has emerged is how to deliver a ZE building in a dense urban context. Generally, buildings over six stories have too much floor area, relative to their roof area, to generate enough electricity from solar PV on-site to completely offset their energy consumption, regardless of how energy efficient they are. And, in a dense urban context, buildings often cover most of the site, leaving little to no additional space on the ground for on-site solar generation. To some extent, this may be mitigated through the use of other innovative technologies, such as sewer heat recovery or biogas-driven fuel cells.

Another challenge to delivering ZE buildings are high-energy use types such as laboratories, hospitals, and buildings that house restaurants or data centers. Thus, in many cases, building owners must go off-site to purchase additional renewable energy in order to get to zero. Multiple ZE certifications now allow for the use of off-site renewable energy to qualify, provided that they meet several conditions. First, the building must be optimally efficient and have fully leveraged all on-site renewable energy generation potential. Furthermore, the renewable energy must be procured through a long-term power purchase agreement (PPA) for which the renewable energy credits (RECs) are then retired by the owner. These may be either direct PPAs, wherein the buyer directly purchases the supply of electricity, or virtual PPAs, where the buyer pays the seller the difference between an agreed price and the wholesale electricity price, thus providing financial certainty and supporting the development of projects that are "additional." In the modeling for this study, most of the buildings are modeled as using some off-site renewable energy, purchased through long-term PPAs. Of the six building types modeled in this study, only the K-12 school and single-family home models were able to meet their annual energy loads with on-site renewable energy. As the Case Studies demonstrate, additional building types, including low-rise multifamily residential and institutional buildings, are already achieving ZE performance.

The key question in the marketplace that this study seeks to address for Massachusetts is whether ZE buildings are cost effective. Multiple studies have been conducted around the country on the upfront cost premium of ZE buildings. The findings of these studies are detailed in Figure 3: *ZE Studies in the U.S.*

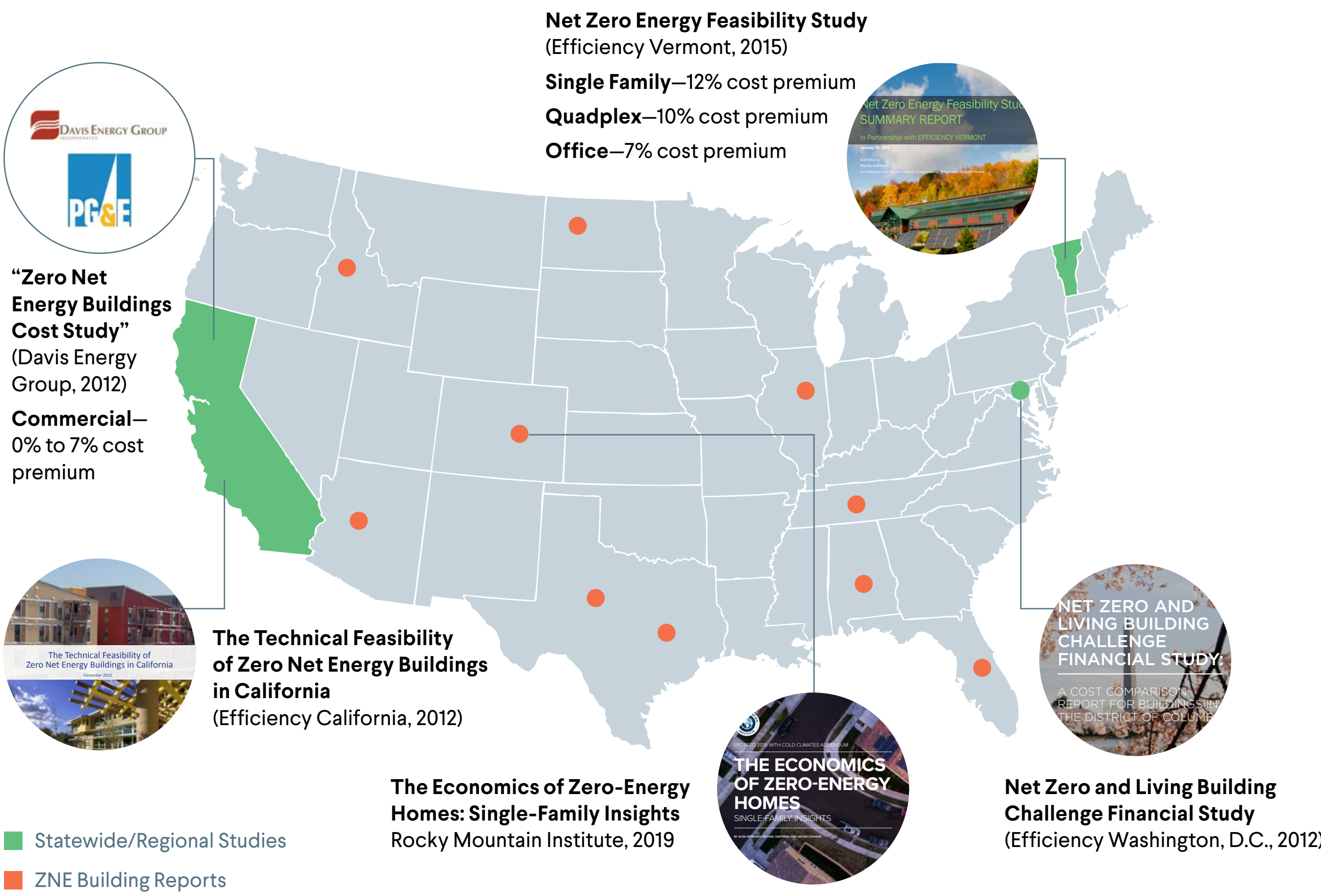
GENERALLY, BUILDINGS OVER SIX STORIES HAVE TOO MUCH FLOOR AREA, RELATIVE TO THEIR ROOF AREA, TO GENERATE ENOUGH ELECTRICITY FROM SOLAR PV ON-SITE TO COMPLETELY OFFSET THEIR ENERGY CONSUMPTION, REGARDLESS OF HOW ENERGY EFFICIENT THEY ARE.

Our methodology section elaborates on the finding of these reports. Although our report builds on these earlier studies, in some cases we use different methodologies when conducting energy modeling and life-cycle cost analysis to identify the energy and cost savings that can be delivered by ZE buildings.

FIGURE 3

ZE Studies in the US

Multiple studies have been conducted around the county on the upfront cost premium of ZE buildings.



However, when people consider ZE building cost, they are often *only* considering the upfront costs, without considering the costs over the life cycle of the building. Only addressing upfront costs limits our ability to make smart and cost-effective decisions. The current reality, unfortunately, is that construction budgets and operating budgets are often separated, an approach that results in wasted money and resources. Our approach, then, was to paint a more complete picture of the long-term costs and benefits of ZE buildings, and identify how long it took for energy savings to outpace the upfront costs.

The following report summarizes USGBC MA's findings surrounding the life-cycle costs for zero energy buildings in Massachusetts and includes sample energy models for six different building types. Using the Commonwealth's 2009 Getting to Zero report as a base, we suggest additional policy recommendations to support the next wave of zero energy buildings in the state. The six building types we studied for this report are intended only to illustrate the feasibility of ZE buildings under several different conditions, but the methodology outlined can be applied to many additional scenarios and building types.

Case Studies

Prior to energy and cost modeling, the team collected data on ZE buildings in Massachusetts as precedents for the study. To collect this data, the team reached out to designers and contractors in the Commonwealth who have experience in ZE design. Our team requested design parameters and costs for building envelope measures, HVAC, domestic hot water, lighting, and plug loads. In response to the requests, the team received data on six buildings—three educational and three residential—as presented below. Appendix A includes the detailed results of these case studies. Highlights from some of the case studies are included as sidebars in between sections of this report.

King Open/Cambridge Street Upper School

BUILDING TYPE: K-12 School

LOCATION: Cambridge, MA

SIZE: 270,000 sf

Bristol Community College John J. Sbrega Health and Science Building

BUILDING TYPE: Teaching Lab

LOCATION: Fall River, MA

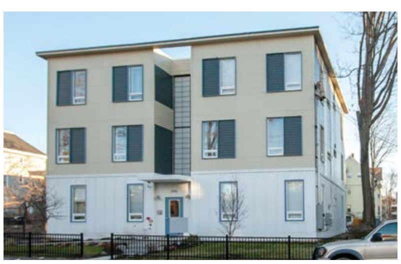
SIZE: 50,600 sf

RW Kern Center

BUILDING TYPE: Welcome Center, School

LOCATION: Amherst, MA

SIZE: 17,000 sf



246 Norwell Street

BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

SIZE: 4,518 sf

E+ Marcella Street

BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

SIZE: 7,883 sf

The Distillery North

BUILDING TYPE: Multifamily Residential

LOCATION: Boston, MA

SIZE: 58,800 sf

Photo and image credits (l) to (r): Top row: Arrowstreet, Edward Caruso, Robert Benson Photography. Bottom row: Stephen Daly, Sam Orberter, Trent Bell Photography.

CASE STUDY: John J. Sbrega Health and Science Building

<1% Cost Premium
0% after grants & incentives
$115,000/yr savings

LOCATION: Bristol Community College, Fall River, MA

PROJECT SIZE: 50,600 sq. ft.

COMPLETED YEAR: 2016 (New Construction)

BUILDING TYPE: Academic Laboratory

ARCHITECT: Sasaki Architects

MEP: Bard Rao + Athanas Consulting Engineers

STRUCTURAL: RSE Associates

CIVIL: Nitsch Engineering

GEOTHERMAL: Haley and Aldrich

CODE: Jensen Hughes

TOTAL BUILDING COST: $32.5 Million

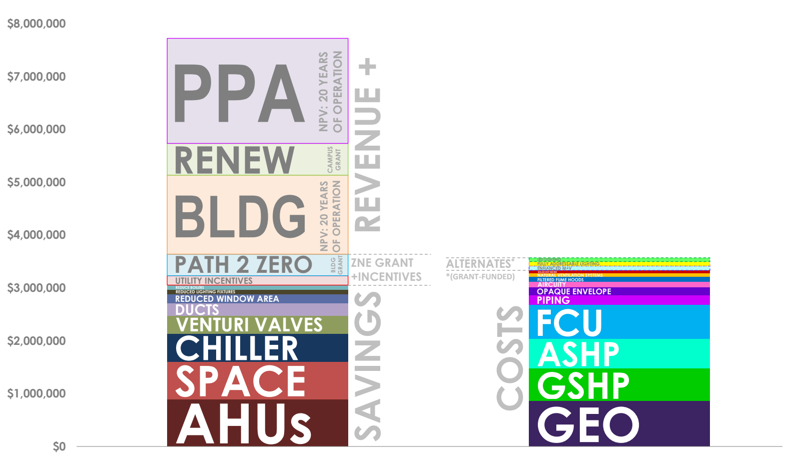
A first of its kind in Massachusetts, Bristol Community College led the way in achieving a NZE academic laboratory building for the sciences with the John J. Sbrega Health and Science Building. Designed by Sasaki, the building can generate enough on-site energy to power an energy-intensive building program within the New England climate. The building provides instructional labs and support spaces for various science and health fields. In achieving NZE, the project provides a model for others. From the beginning of the schematic design phase of the project, the client and the design team worked to deliver a NZE building without increasing the project budget. Throughout the project, the client, contractor, and design team collaborated to find possible savings that would offset any theoretical performance premiums without compromising quality. The finished building had less than 1% first cost premium, and no premium after counting grants and utility incentives, with more than $115,000/yr. savings in utility costs due to energy efficiency. Strategies include: geothermal, filtered fume hoods, air quality monitoring, DOAS with enthalpy wheels and fan coil units, airtight envelope with better than code assembly U-value, and natural ventilation.

$600/sf COST/SF

$115,000 ANNUAL ENERGY SAVINGS

50 kBtu/sf/yr SITE EUI

58 kBtu/sf*yr PV OUTPUT



This chart (on the left) shows first cost savings from the base case combined with ZE revenue (grants, renewables, operational savings) compared to the building's actual construction costs. The finished building had less than 1% first cost premium.

Image Credit: Bard Rao + Athanas Consulting Engineers

Photo credit: Edward Caruso

Methodology

The following section provides details on the methodology used to develop the ZE cost models for Massachusetts. This process involved regular engagement with industry stakeholders, iterative rounds of energy modeling, and an intensive life-cycle cost analysis. For the purposes of this report, we studied low-energy buildings with on-site renewable energy sources and, as needed, off-site renewable sources for annually meeting the building energy loads.

ENERGY MODELING

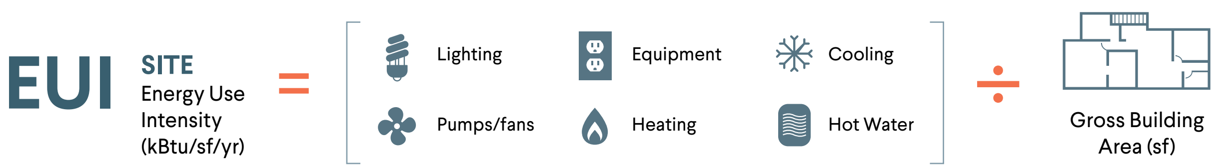
To assess the potential for ZE across the state of Massachusetts, six different building types were selected as representative of the building stock (summarized in Figure 7: *Prototype Model Data*). Prototype models developed by the U.S. Department of Energy were then used for energy analysis.

DEFINITIONS

FIGURE 4

Energy Use Intensity

The amount of energy a project uses per square foot over the course of a year.



Source: Oregon Sustainability Center

FIGURE 5

Zero Energy

A zero energy building generates as much energy as it consumes on an annual basis. To achieve zero energy a project first reduces energy use through efficiency measures and optimizes for renewables. Once zero energy ready, the project requires renewable energy on-site and/or off-site to offset the remaining energy use.

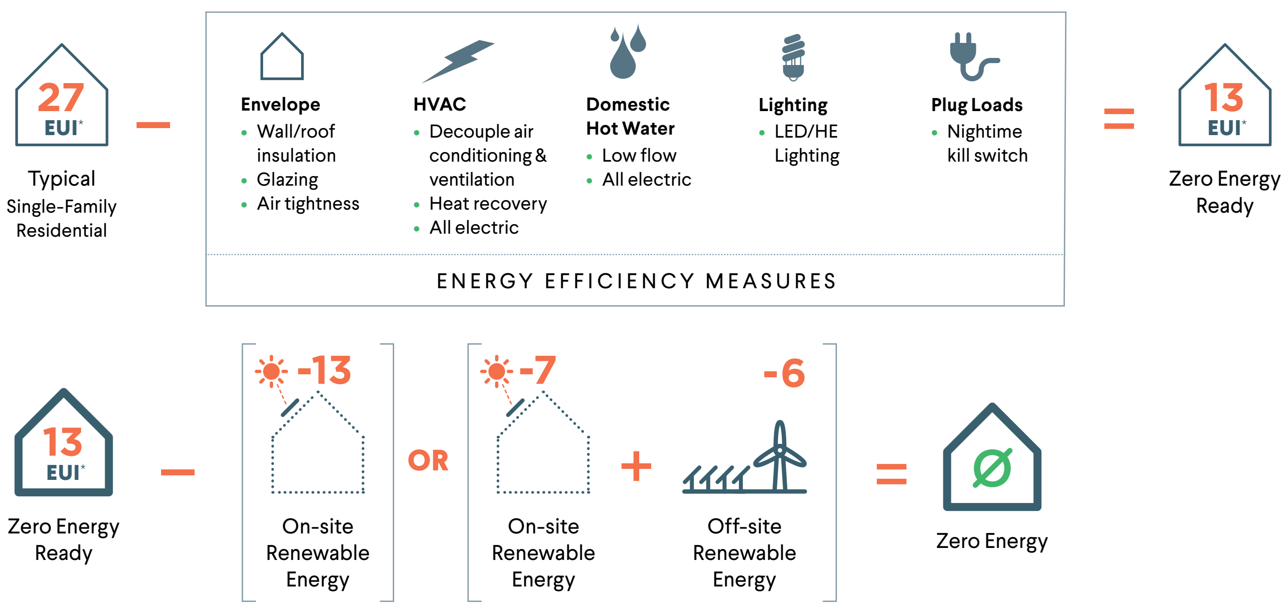


FIGURE 6

Methodology

The team ran energy models and life-cycle cost assessments for six building types in Massachusetts

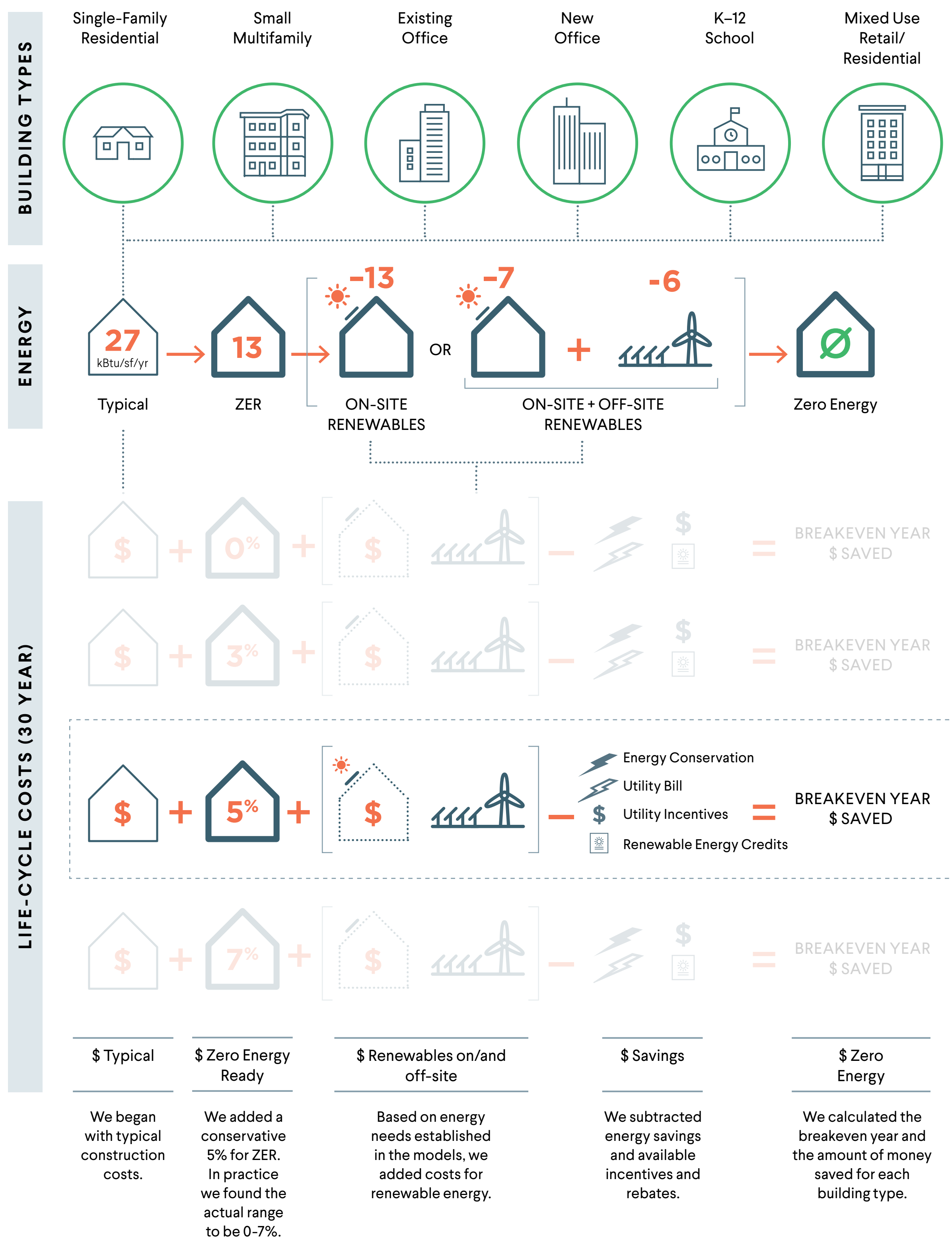


FIGURE 7

Prototype Model Data

Six different building types were modeled in this study with the parameters identified here.

1 Existing Office	2 New Office	3 K–12 School	4 Mixed Use Retail/Residential	5 Small Multifamily	6 Single-Family Residential
498,588 Sq Ft	498,588 Sq Ft	73,959 Sq Ft	56,241 Sq Ft	10,804 Sq Ft	3,600 Sq Ft
11 Stories	11 Stories	1 Story	5 Stories	3 Stories	2 Stories
9'-00" Floor-to-Floor Height (ft)	9'-00" Floor-to-Floor Height (ft)	13'-00" Floor-to-Floor Height (ft)	16'-10" Floor-to-Floor Height (ft)	8'-6" Floor-to-Floor Height (ft)	8'-6" Floor-to-Floor Height (ft)
38,353 Roof Area (Sq Ft)	38,353 Roof Area (Sq Ft)	73,959 Roof Area (Sq Ft)	22,500 Roof Area (Sq Ft)	3,601 Roof Area (Sq Ft)	1,265 Roof Area (Sq Ft)

To conduct the energy analysis, energy simulations were carried out in OpenStudio Version 2.6, which runs on the EnergyPlus simulation engine. Each simulation was run with a typical meteorological year for Boston, Massachusetts. For each building type, two scenarios were simulated: a minimally code-compliant building, hereafter referred to as the "typical" design, and a highly efficient ZE-ready design, hereafter referred to as the ZER design. The typical design uses design parameters in line with the International Energy Conservation Code (IECC) 2015, the current energy code of Massachusetts. Modeling inputs for the typical scenarios can be found in Appendix A.

The ZER design for each building type was determined based on the previously described case studies, along with insight from industry practitioners. Many different energy efficiency measures were utilized for the ZER design, as summarized in Figure 8: *Energy Efficiency Measures for ZE Design*. The report represents all results from the energy simulations in terms of energy use intensity (EUI), the annual energy consumption per square foot per year (see Figure 4: *Energy Use Intensity*). For the purposes of this study, the prescribed building parameters were not refined after modeling to improve performance to ZE.

FIGURE 8

Energy Efficiency Measures for ZE Design

Many different energy efficiency measures were utilized for the zero energy ready designs.

Envelope
- Increased wall/ roof insulation
- Improved glazing
- Improved air tightness

HVAC
- Decoupled conditioning and ventilation
- Heat recovery ventilation
- All electric HVAC (heat pumps)

Domestic Hot Water
- Low flow fixtures
- All electric DHW (heat pumps)

Lighting
- LED/high efficiency lighting
- Daylighting & occupancy controls

Plug Loads
- Nighttime kill switch

Solar Photovoltaic Generation

To achieve ZE, each of the building types uses on-site renewable energy generation and, where building energy loads are not met on-site, some use off-site renewable energy generation. The research team used a combination of the following methods to calculate potential on-site solar photovoltaic (PV) energy generation. First, an hourly solar generation profile was generated for Boston, using the NASA database of solar irradiance and the Modern-Era Retrospective Analysis for Research and Applications (MERRA) dataset. Next, the hourly profile was converted to an annual solar potential for the site, in kWh/kW. This solar potential was then used with a selected PV efficiency and roof area to calculate the PV size, in kW, and annual PV generation, in MWh. All assumptions for solar PV analysis are presented in Table 1: *Solar PV Assumptions*. The results section of the report includes a summary of the PV size and generation for each building type.

The Chelsea Soldiers' Home New Community Living Center will be a 236,000 sf assisted living facility, designed to achieve Class D Zero Net Energy with a predicted site EUI below 60 kBtu/sf*yr. Systems include: high-performing envelope, natural ventilation, geothermal, water-source heat pumps, and a 0.7MW PV array canopy above the roof. This was achieved at a construction cost premium of 0.1% of project cost. With the anticipated $750,000 in incentives and grants, it costs less to build than the business as usual case. Owner: DCAMM, Architect: Payette, Mechanical Engineer: BR+A. Image credit: Payette.

FIGURE 9

Units of Energy

Common units of energy and abbreviations.

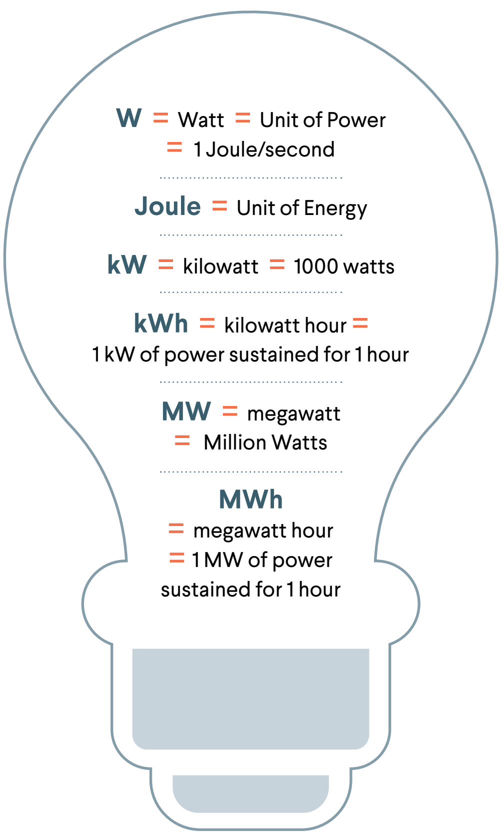


TABLE 1

Solar PV Assumptions

These assumptions were used for the solar PV analysis in this report.

1,104	Solar Potential (kWh/kW)
17	PV efficiency (W/SF)
70%	Roof Coverage

Life-Cycle Cost Analysis

To assess the financial feasibility of ZE design in the state of Massachusetts, the research team conducted life-cycle cost analysis (LCCA). This analysis incorporates all upfront costs, recurring costs, and incentives over a desired life span of the project. The following details how each of these factors were determined.

Upfront Costs

The upfront costs for the baseline design scenario of each building type were calculated using the dollar per square foot values provided by Daedalus Projects, Inc., to capture the local construction, labor, and material costs for metro Boston. The baseline upfront costs for each building type are presented in Table 2: *Baseline Upfront Costs*. In markets with lower building costs, all financial analyses will be more favorable, especially for new office and small residential construction.

Calculating first costs for the proposed ZE designs was a bit more complex. First costs in construction and renovation projects are highly dependent on material and finish selection, cost of labor, location and site constraints, and, most importantly, the design strategies and effectiveness of integrated project planning. Accelerating advances in ZE building practices and products are driving down first costs. According to previous studies conducted by the Davis Energy Group,[4] ZE premiums for commercial, institutional, and multifamily buildings range from zero to 7%. Rocky Mountain Institute's Fall 2018 cost study, "The Economics of Zero Energy Homes—Single-Family Insights," found that with utility incentives, zero energy homes in metro Boston cost less to build when compared to conventional homes.

Additionally, our team garnered information from the ZE case studies in Massachusetts that resulted in similar incremental cost ranges for projects in the state. It was therefore decided that feasibility with four different cost premiums would be investigated: 0%, 3%, 5%, and 7%, with 0% cost premium reflecting projects such as the Bristol Community College John J. Sbrega Health and Science Building and the more recent Boston E+ Green Building, where ZE was achieved at no additional upfront cost.

TABLE 2

Baseline Upfront Costs Provided by Daedalus Projects, Inc.

Building Type	Price ($/sf)
Existing Office	$195.00
New Office	$500.00
K-12	$365.00
Mixed-Use	$290.00
Small Multifamily	$325.00
Single Family	$250.00

The goal in any ZE project is to identify the packages of energy efficiency that deliver the highest energy reduction with the most cost-effective capital investment. For many zero energy buildings, the additional objective is to find energy reduction measures that cost less than the cost of providing additional renewable generation. This leads to an approach that focuses on cost trade-offs in durable parts of the building (for example, higher performing building envelopes, which can help reduce the size of HVAC systems), rather than focusing on high-cost and typically more complex equipment.

IT WAS THEREFORE DECIDED THAT FEASIBILITY WITH FOUR DIFFERENT COST PREMIUMS WOULD BE INVESTIGATED: 0%, 3%, 5%, AND 7%.

[4] Davis Energy Group (2012). California Zero Net Energy Buildings Cost Study. Pacific Gas and Electric Company. https://newbuildings.org/sites/default/files/PGE_CA_ZNE_CostStudy_121912.pdf

Building Green's 2014 Article, "How to Build Green at No Added Cost,"[5] makes it clear that there are many factors that drive first costs on a project. Zero energy goals need to be established from the start of the project when the owner issues a request for proposals. Zero energy projects at no cost demands an integrated design team with all players working toward ZE goals from the start, making good decisions early in design. Strategies might include reducing window-to-wall ratios or reducing the floor-to-floor height. An integrated design team can tunnel through barriers by offsetting increased costs, for example, of a higher performing building envelope with simplified mechanical systems.

The amount and quality of the glazing can impact costs significantly. Elizabeth Galloway, in "Re-Examining Glass Building Design," illustrates increased glazing costs more in terms of first costs and energy performance. As well, Payette's 2012 *Report on the Thermal Performance of Facades* shows how important construction detailing is to thermal performance. The research found that exterior assemblies were typically 50% less effective than theoretical models due to thermal bridging.

Incentives

Buildings designed to ZE are often eligible for numerous incentive programs that enable savings in upfront and operating costs. Table 3: *Commercial and Residential Incentives* summarizes sample incentives available in Massachusetts for energy efficiency. Our analysis used rates from National Grid. The incentives were factored into the cost model for each building type.

Another incentive that is applicable to some ZE designs is the Massachusetts Geothermal Alternative Energy Credit. This incentive is awarded on an annual basis to buildings that use ground-source heat-pump-based systems (sometimes called geothermal). The incentive currently pays $23.44/MWh of annual building heating energy provided by the geoexchange system (minus the source energy of any associated chillers and pumps). This incentive was applied to the cost model for the new office prototype.

Final incentives for on-site solar pv were also included in the life-cycle cost assessment. The federal government offers a tax incentive for solar PV that offsets 30% of the upfront cost of systems, though this is set to decline over the next five years down to 10%. In addition, the state provides a recurring incentive for solar PV generation called the Solar Massachusetts Renewable Target (SMART) program. The SMART program compensates solar projects based on their generation capacity, along with the service territory's capacity block, which indicates how far along that service territory is in achieving its goals for solar PV capacity. For the LCCA, this report assumes that the prototype buildings fall within capacity block 3. Table 4: *SMART Program Compensation Rates* illustrates the compensation rates for different generation unit capacities. These also used rates from National Grid. In addition to these compensation rates, each prototype building receives a compensation rate adder of $0.01843/kWh for falling within the category of a Building Mounted Solar Tariff Generation Unit.

Additional incentives, such as the Massachusetts Solar Loan Program, which provides reduced rate loans for solar PV installations, are not included in the LCCA yet clearly improve the financial performance and cost effectiveness of a potential ZE project.

TABLE 3

Commercial and Residential Incentives

(rates from National Grid)

Building Type	Category	Incentive
Commercial	Electric	$0.35/kWh saved
	Gas	$0.75/therm saved
Residential	Single Family	$2,000
	Small Multifamily	$1,000/unit
	Midrise Multifamily	$600/unit

TABLE 4

SMART Program Compensation Rates

(rates from National Grid)

Generation Unit Capacity	Compensation Rate ($/kWh)
Low income less than or equal to 25 kW AC	$0.32989
Less than or equal to 25 kW AC	$0.28686
Greater than 25 kW AC to 250 kW AC	$0.21514
Greater than 250 kW AC to 500 kW AC	$0.17929
Greater than 500 kW AC to 1,000 kW AC	$0.15777
Greater than 1,000 kW AC to 5,000 kW AC	$0.14343

[5] Roberts, T (2014, March), "How to Build Green at No Added Cost", Environmental Building News, Volume 23(3), pp1-9, https://www.buildinggreen.com/feature/how-build-green-no-added-cost

Energy Cost

To calculate the annual energy costs, hourly electricity and gas consumption was extracted from each baseline and ZE proposed energy model. Our analysis used rates from National Grid. The electricity rate structure is dependent upon monthly electricity consumption, monthly peak demand, and season. These rates include all charges associated with supply, transmission, and distribution. Electricity rates are presented in Table 5: *National Grid Electricity Rates*. The gas rate structure is dependent upon monthly gas consumption and season. Gas rates are presented in Table 6: *National Grid Gas Rates*.

For the ZE proposed design, our team assumed that all energy would be provided by on-site and off-site renewable generation. All ZE designs are assumed to be net metered. Any remaining energy demand not met by on-site solar was assumed to be purchased from off-site solar and wind farms via a power purchase agreement (PPA). Our analysis assumed off-site renewable energy costs of $0.11/kWh. The cost of on-site solar PV was estimated at $2.45/W of installed PV panels.

TABLE 5

National Grid Electricity Rates

Service Categories	Service Descriptions	Peak Demand Rate ($/kW)	Summer On-Peak Electricity Rate ($/kWh)	Summer Off-Peak Electricity Rate ($/kWh)	Winter On-Peak Electricity Rate ($/kWh)	Winter Off-Peak Electricity Rate ($/kWh)
G-1: General Service Small C&I	<10,000 kWh/month, <200 KW peak demand	$0.00	$0.185	$0.185	$0.203	$0.203
G-2: General Service Demand	>10,000 kWh/month. <200 KW peak demand	$8.00	$0.146	$0.146	$0.161	$0.161
G-3: Time of Use	Avg monthly peak demand >200 KW for 3 consecutive months	$5.76	$0.158	$0.152	$0.174	$0.168
R-1: Regular Residential	Individual apartment or individual dwelling	$0.00	$0.220	$0.220	$0.238	$0.238
R-4: Time of use	Avg monthly usage >2,500 kWh for 12 months	$0.00	$0.292	$0.193	$0.310	$0.211

TABLE 6

National Grid Gas Rates

Category	Subcategory	Rate
Monthly Fee		$100
November-April	First 900 therms/month	$0.2486/therm
	Over 900 therms/month	$0.3100/therm
May-October	First 900 therms/month	$0.1666/therm
	Over 900 therms/month	$0.2066/therm

Financials

To assess the financial performance of the ZE buildings against their respective baselines, the net present value (NPV) of each case was calculated. The NPV is the difference between the present value of cash inflows and cash outflows, over a specified period. This is a useful metric for capital budgeting. To calculate the NPV, all the above-mentioned first costs, design incentives, recurring incentives, and utility payments were incorporated. This analysis was conducted for a period of 30 years. The LCCA also assumed values for discount rates and energy escalation rates, based on industry stakeholder input. These assumptions are documented in Table 7: *Financial Assumptions*. A sample screenshot of the tool used to conduct the LCCA is displayed in Figure 10. The results of the cost study are presented in this report as the net present value of cost savings (ZE with respect to the baseline), normalized by building square footage (NPV/sf).

It should be noted that this analysis assumes the building developer/owner continues to earn revenue from renters for energy costs they would have otherwise paid, and therefore 100% of energy cost savings are awarded to the developer/owner. Running the analysis this way creates business model limits for ZE design from which a choice can be made for the best split of cost savings between developer and tenants using green—or energy—aligned lease structures.

There are alternate real estate financing structures available to ZE building developers. Assessing those alternatives is beyond the scope of this study and not included.

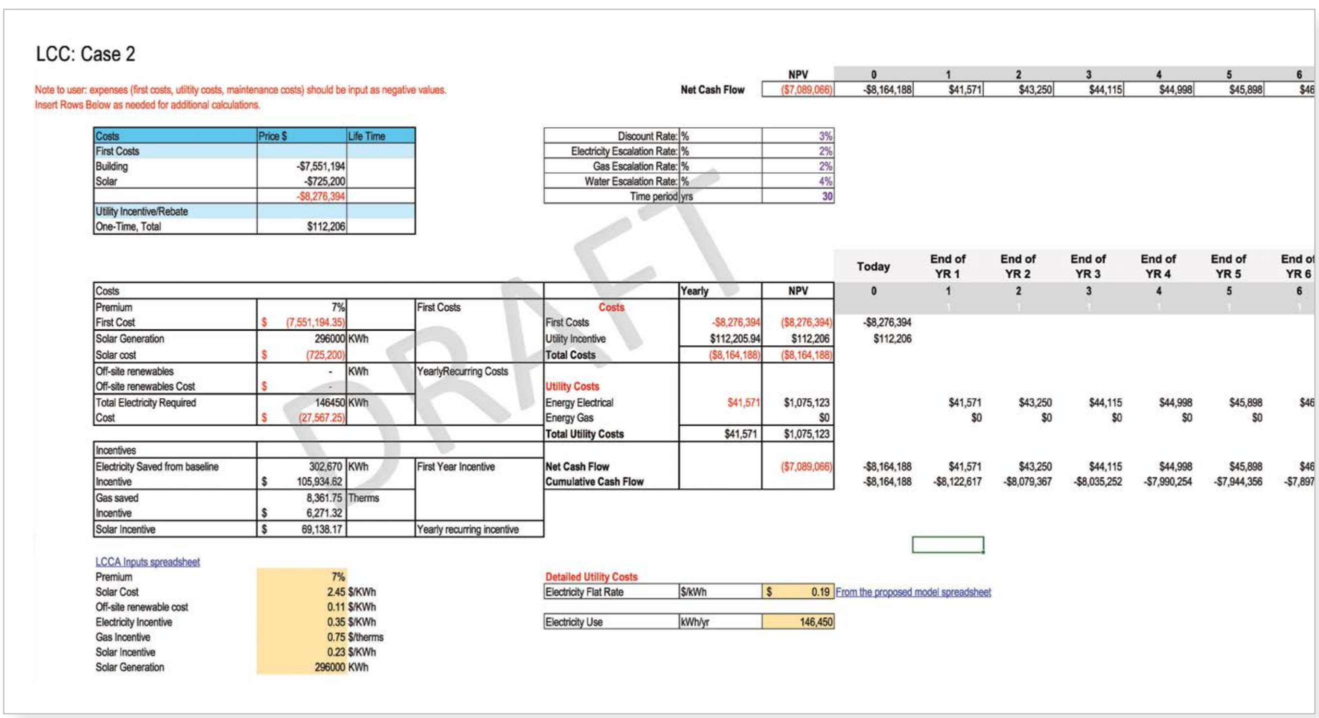
TABLE 7

Financial Assumptions

Parameter		Value
Time Period		30 years
Discount Rate	Offices	6%
	Other	3%
Escalation Rate	Electricity	3%
	Natural Gas	3%

FIGURE 10

Sample Screenshot of Portion of the Life-Cycle Cost Analysis Tool



CASE STUDY: King Open/Cambridge Street Upper School

Saving Energy Through Occupant Engagement

LOCATION: Cambridge, MA

PROJECT SIZE: 270,000 sq. ft.

COMPLETED YEAR: 2019 (planned)

BUILDING TYPE: Public elementary and middle schools, public library

ARCHITECT: Arrowstreet & William Rawn Associates

MEP: Garcia, Galuska, Desousa

STRUCTURAL: LeMessurier

CIVIL: Nitsch

LANDSCAPE: Copley Wolff Design Group

NET ZERO CONSULTANT: InPosse

GEOTHERMAL: CDM Smith

LEED: Soden Sustainability

TOTAL BUILDING COST: $130 Million

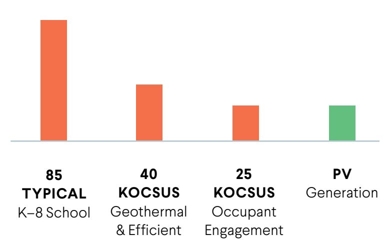
$480/sf COST/SF

$195,043 (42%) ANNUAL ENERGY SAVINGS

25 kBtu/sf SITE EUI

1,300 MWh PV OUTPUT

EUI (ENERGY USE INTENSITY)



The occupants of ZE buildings can have critical impacts on a project's ability to achieve zero energy goals. Occupants directly impact energy use in many ways, from cooking, to use of electronic devices, to hot water consumption. In Cambridge, Massachusetts, almost every classroom within the original King Open School and Cambridge Street Upper School had its own mini-kitchenette with a microwave, coffee maker, and mini-fridge, increasing plug load and energy costs. In 2015, the city developed its own net zero emissions action plan. This school complex, known as the King Open/Cambridge Street Upper Schools and Community Complex, is the first project to meet the action plan.

During the feasibility study for the new complex, the design team asked teachers why they felt they needed kitchen equipment in every classroom and listened to the answer: there was only one staff room and it was too far away—up to 700 feet in some cases. The teachers needed to be near the classrooms they supervised, but the school schedule did not allow them to get to the one staff room. They wanted their new school to be a building that fosters collaboration among the staff despite working in different classrooms. To meet this vision, the school's design includes small clusters of classrooms with a central "Team Room" for collaboration and building community. The Team Room also provides a kitchenette that is nearby and easily accessible for all staff in that cluster, eliminating excess equipment. The result is a reduction in both cost and energy consumed within the building.

Modeled impact of some of the user engagement strategies.

- Shared Staff Team Rooms = 7% Energy Savings
- Temperature Ranges = 2% Energy Savings
- Building Organization by Use = 13.6% Energy Savings

Image credit: Arrowstreet

Energy Modeling Results

From the energy models described in the methodology section, annual energy consumption and annual PV generation of the six types of buildings were determined for both the baseline and ZE proposed designs. This section provides details on energy consumption and generation for each building type.

The majority of energy savings accrue from heating energy, mainly due to the switch from natural gas boilers to heat pump technologies, as seen in the energy use intensity (EUI—energy use/sf/year) graphs displayed in the following section. The additional energy savings come from better fenestration, improved envelope, higher efficiency mechanical systems, higher efficiency domestic hot water systems, lighting, plug loads, and controls.

EUI IS A METRIC TO BENCHMARK BUILDINGS AND COMPARE THE PERFORMANCE OF DIFFERENT BUILDINGS AND BUILDING TYPES. THE EUI GRAPHS DISPLAYED IN THE FOLLOWING SECTION PROVIDE A HELPFUL METHOD FOR COMPARING THE ENERGY CONSUMED AND GENERATED (USING SOLAR PV) PER SQUARE FOOT FOR EACH BUILDING TYPE.

For the purposes of this study, the prescribed building parameters were not refined after modeling to improve performance to ZE. With thoughtful building form, envelope, and system refinements, modeled energy loads could be further reduced and on-site solar PV generation increased.

After three years of operation, the Dr. Martin Luther King, Jr. School & Putnam Avenue School in Cambridge, MA, is operating at a site EUI of 24 kBTU/sf/yr and outperforming this report's predicted energy models for K-12 Schools of 25 kBTU/sf/yr. The construction costs without photovoltaics were only 1% more than our baseline of $365/sf. Photovoltaics on the roof provide 45-50% of the school's energy. Owner: City of Cambridge, Architect: Perkins Eastman, Mechanical Engineer: AKF, Photo credit: Sarah Mechling, Perkins Eastman.

EXISTING OFFICE BUILDINGS

According to the energy modeling outputs, the baseline existing office building would use 71.5 kBtu/sf/year and the ZE proposed existing office building would use 33.9 kBtu/sf/year, while generating 3.4 kBtu/sf/year using rooftop PV. The model shows 53% energy savings in existing office buildings, 57% of which is due to reduction in heating energy. Because the modeled ZE building was proposed to be 11 stories, there is insufficient roof area, relative to total floor area, to meet all energy needs on-site. Therefore, the model shows that supplemental energy from off-site renewables would be required to achieve zero energy.

71.5 kBtu/sf BASELINE	**10%** % PV ON-SITE
33.9 kBtu/sf ZER	**53%** ENERGY SAVINGS

EXISTING OFFICE ENERGY USE

FIGURE 11

Energy Consumption—Existing Office

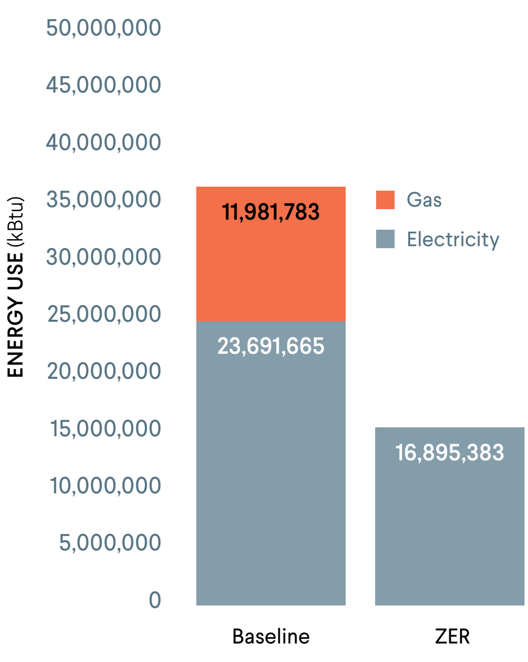
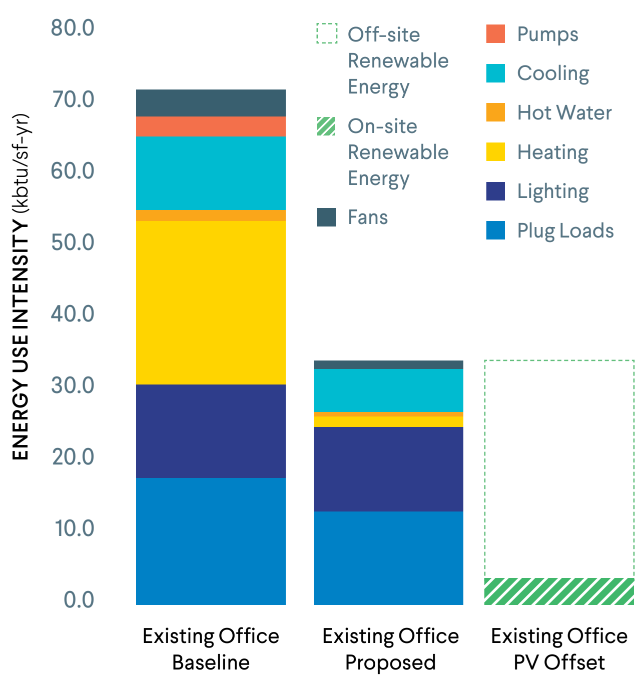


FIGURE 12

EUI Breakdown and PV—Existing Office



NEW OFFICE BUILDINGS

According to the energy modeling outputs, the baseline new office building would use 51.5 kBtu/sf/year and the ZE proposed new office building would use 28.9 kBtu/sf/year, while generating 3.4 kBtu/sf/year using rooftop PV. The new office baseline has lower energy consumption than an existing office, due to the slightly higher efficiency gas boiler and better fenestration and insulation. The ZE proposed design shows 44% savings in energy. The decrease in percentage of energy saved is attributed to the fact that the baseline for new office building was already more efficient due to stronger energy codes, hence reducing relative improvement opportunities. One key energy savings measure for new offices is the use of a nighttime kill switch, which saves 37% of plug load energy demand. Because the energy consumption is greater than on-site PV generation, off-site renewables would be required to achieve zero energy.

51.5 kBtu/sf BASELINE	**12%** % PV ON-SITE
28.9 kBtu/sf ZER	**44%** ENERGY SAVINGS

NEW OFFICE ENERGY USE

FIGURE 13

Energy Consumption—New Office

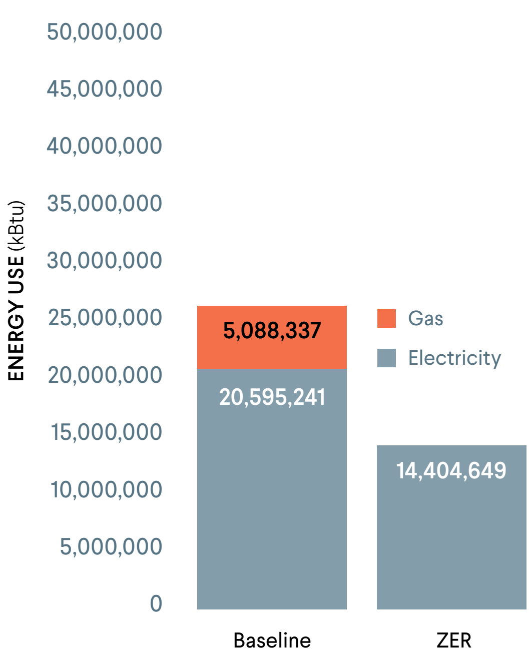
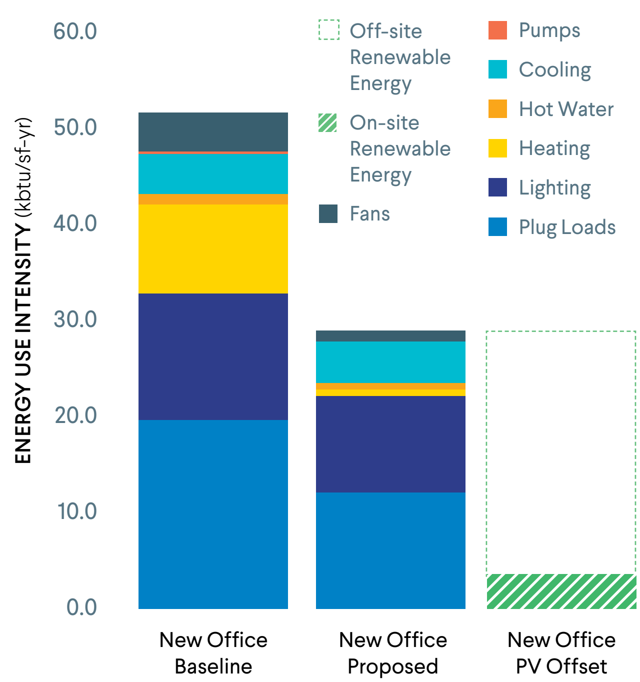


FIGURE 14

EUI Breakdown and PV—New Office



K–12 SCHOOL BUILDINGS

According to the energy modelling outputs, the baseline K-12 school building would use 44.9 kBtu/sf/year, and the ZE proposed K-12 school building would use 25.0 kBtu/sf/year. The K-12 school has the largest roof area and hence the highest PV generation opportunity. If PV panels were installed to the fullest extent possible over the roof of the school, it would generate 44.8 kBtu/sf/year. Because this level of overbuilding of PV would not be economically rational and might run into interconnection roadblocks, the model assumes instead that the PV is sized to exactly match the projected energy consumption, generating 25 kBtu/sf/yr. Off-site renewables are not required to achieve zero energy.

44.9 kBtu/sf BASELINE	**100%** % PV ON-SITE
25 kBtu/sf ZE READY	**44%** ENERGY SAVINGS

It is interesting to note that because of the greater on-site PV potential, even less efficient school buildings may be able to achieve zero energy using on-site PV generation. The proposed energy efficient ZE building would have a 44% energy savings over the baseline, so long as it was converted to be all-electric.

K–12 SCHOOL ENERGY USE

FIGURE 15

Energy Consumption—K-12 School

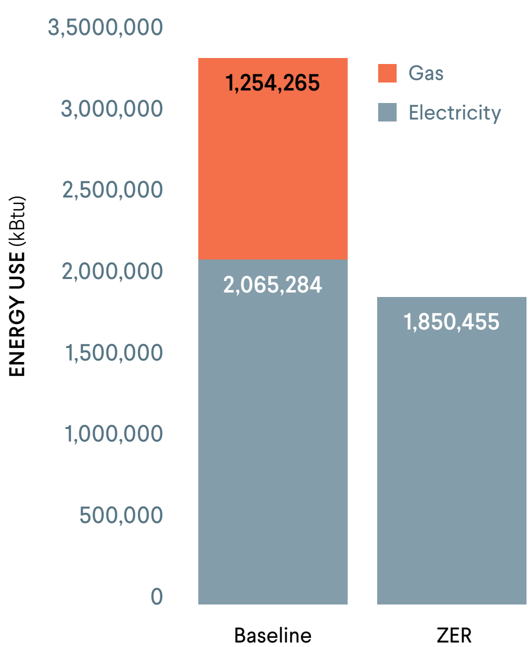
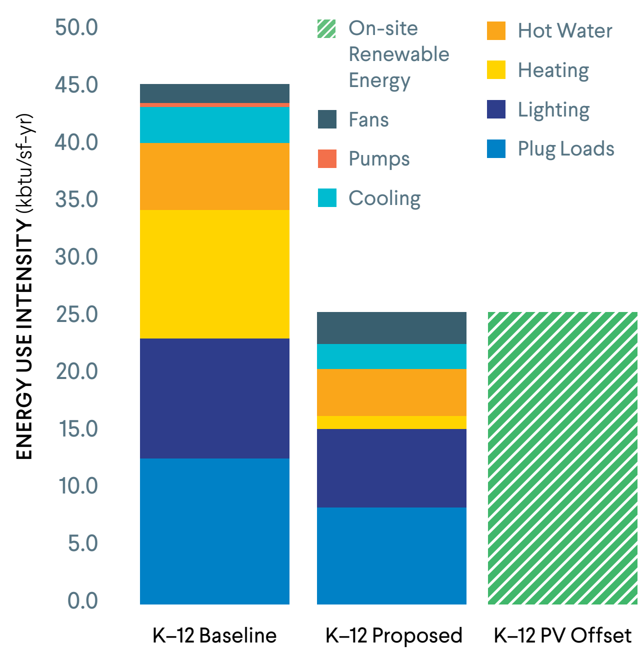


FIGURE 16

EUI Breakdown and PV—K-12 School



MIXED-USE BUILDINGS

According to the energy modelling outputs, the baseline mixed-use building would use 42.1 kBtu/sf/year and the ZE proposed mixed-use building would use 23.3 kBtu/sf/year, while generating 17.9 kBtu/sf/year using rooftop PV. Mixed-use buildings revealed energy savings of 45%. This is due to the dramatic reductions in heating energy consumption from the baseline to the ZE proposed model. Because the energy consumption is greater than on-site PV generation, some off-site renewables would be required to achieve zero energy.

42.1 kBtu/sf BASELINE	**77%** % PV ON-SITE
23.3 kBtu/sf ZE READY	**45%** ENERGY SAVINGS

MIXED-USE ENERGY USE

FIGURE 17

Energy Consumption—Mixed Use Building

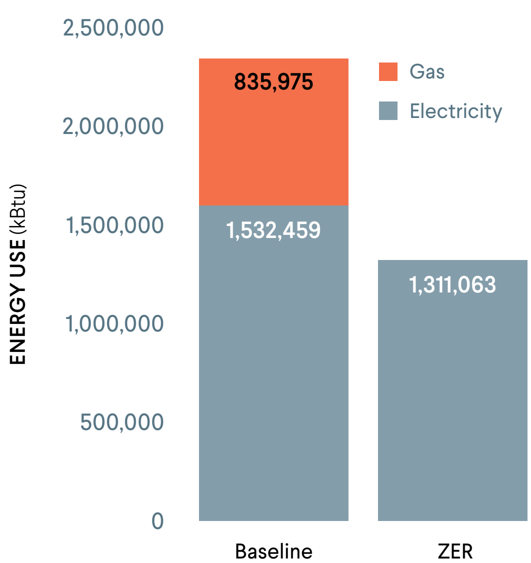
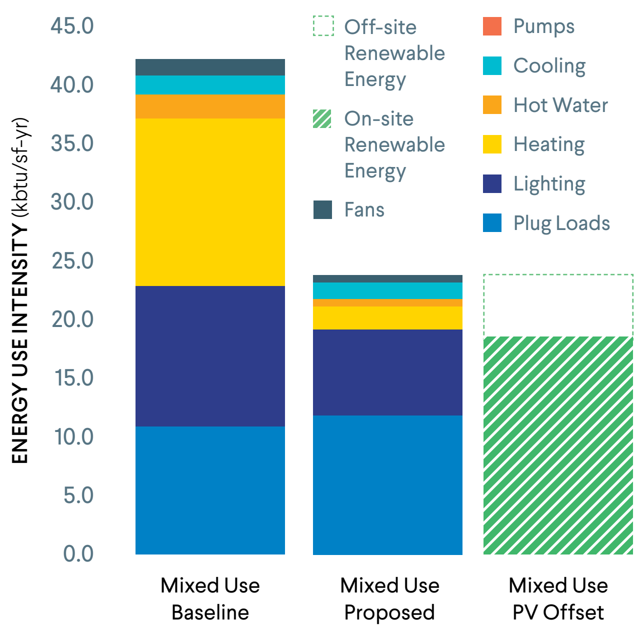


FIGURE 18

EUI Breakdown and PV—Mixed Use Building



SINGLE-FAMILY HOMES

According to the energy modelling outputs, the baseline single-family home would use 27.6 kBtu/sf/year and the ZE proposed single-family home would use 12.8 kBtu/sf/year. If rooftop PV were built to full potential, the panels would generate 15.8 kBtu/sf/year using rooftop PV. As with the K-12 School, a cost-effective ZE building does not need this much excess PV, so the model assumes that the solar PV on the single-family home is sized to generate 12.8 kBtu/sf/yr; off-site renewables are not required. Residential buildings tend to have a higher percentage of heating energy in total energy use compared to commercial buildings. Single-family homes show 54% energy savings compared to the baseline, of which 72% is a reduction in heating energy. The model primarily shows significant energy reduction in heating and domestic hot water system demand.

27.6 kBtu/sf BASELINE	**100%** % PV ON-SITE
12.8 kBtu/sf ZE READY	**54%** ENERGY SAVINGS

SINGLE-FAMILY ENERGY USE

FIGURE 19

Energy Consumption—Single Family

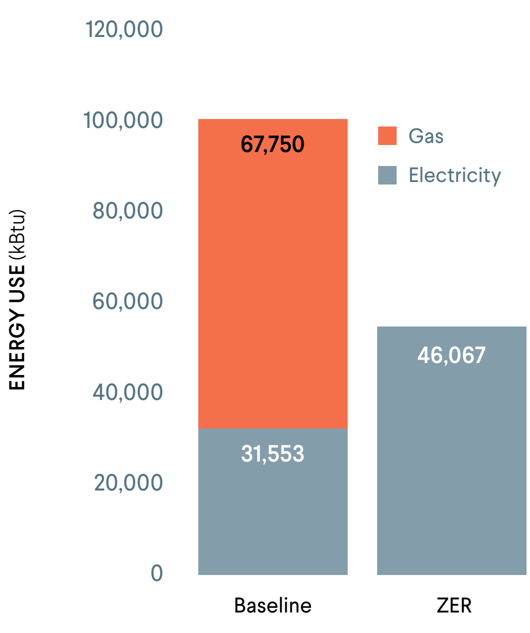
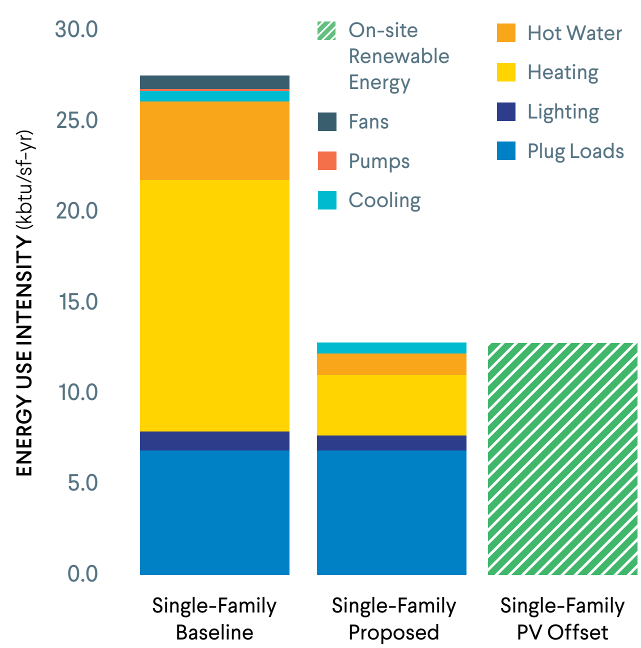


FIGURE 20

EUI Breakdown and PV—Single Family



SMALL MULTIFAMILY BUILDINGS

According to the energy modeling outputs, the baseline small multifamily building would use 41.0 kBtu/sf/year and the ZE proposed small multifamily building would use 17.8 kBtu/sf/year, while generating 15.0 kBtu/sf/year using rooftop PV. There are 56% energy savings in small multifamily buildings compared to the baseline. The model shows 84% of the energy savings corresponding to reductions in heating energy demand. Because the energy consumption is greater than on-site PV generation, some off-site renewables would be required to achieve zero energy.

41 kBtu/sf BASELINE	**84%** % PV ON-SITE
17.8 kBtu/sf ZE READY	**56%** ENERGY SAVINGS

SMALL MULTIFAMILY ENERGY USE

FIGURE 21

Energy Consumption—Small Multifamily

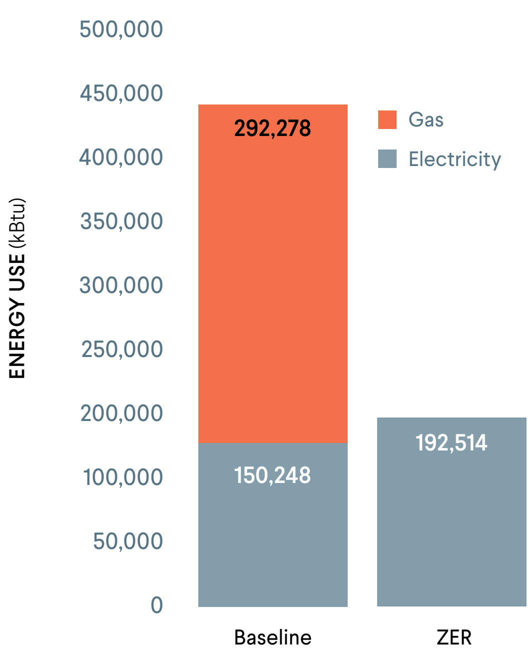
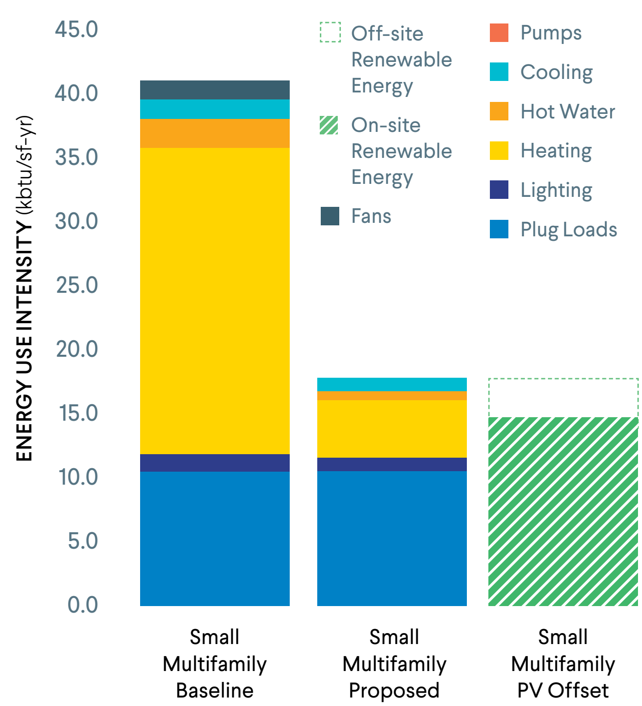


FIGURE 22

EUI Breakdown and PV—Small Multifamily



CASE STUDY: E+ Marcella Street—Cash Positive from Day One

A part of the City of Boston's E+ Green Building Program, which is piloting energy positive, LEED Platinum multifamily housing, E+ Marcella Street is a four-unit row house project in Boston's Roxbury neighborhood. The building form and orientation maximize winter solar heat gain and performance for solar PV and thermal panels on the roof. With the addition of passive envelope strategies and efficient mechanical systems, the project achieved a HERS rating of –9 and LEED for Homes Platinum certification.

Compared to similar nearby conventional buildings, construction costs were approximately 4% to 7% more, primarily due to the unfamiliar double wall framing approach, high-efficiency windows, and ASHP and ERV mechanical systems. However, strong buyer interest in the LEED Platinum net positive homes enabled the developer to contract sale of the three market rate units prior to construction completion and at above market prices. The fourth unit, which is deed restricted affordable, was sold to a prequalified buyer chosen by lottery. The low-energy use and resulting reduced utility expenses effectively normalized the premium purchase price for the homeowners. The buyers had the option of leasing or purchasing the solar PV systems. With the PV system and financing expenses offset by tax credits, SREC revenue, and owner expenses for energy use below the equivalent utility charge, the systems have been cash positive from day one.

Annually, the four units generate enough excess energy to power a conventional three-bedroom home.

LOCATION: 226-232 Highland Street, (Roxbury) Boston

BUILDING AREA: 7,883 SF (1,850 SF per Unit)

BUILDING TYPE: Multifamily Residential

COMPLETED YEAR: 2013 (New Construction)

ARCHITECT: Interface Studio, Urbanica

ENGINEER: Engineering Design Build

TOTAL DEVELOPMENT COST: $1.9 Million

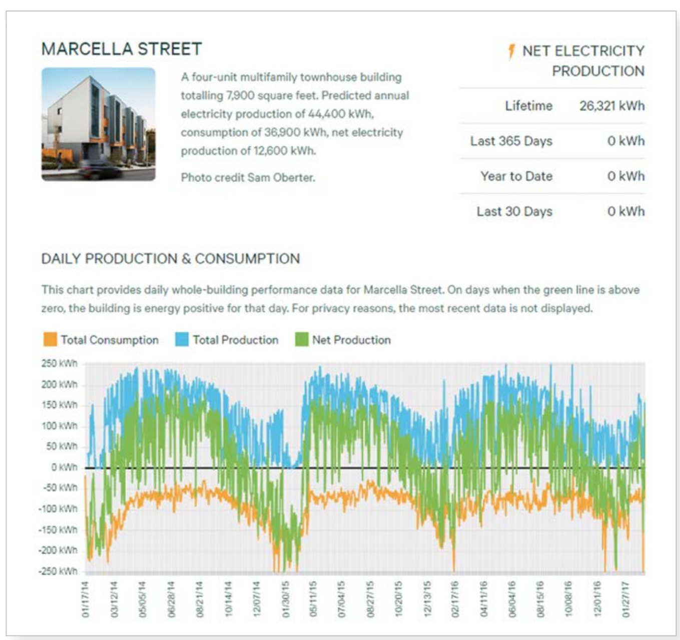


Photo credit: Sam Orberter

Image Credit: https://secure.embue.com/eplus-dashboard/

Life-Cycle Cost Analysis Results

From the life-cycle cost analysis described in the methodology section, cumulative annual expenditure and net present value costs were determined for each of the six building types for both the baseline and ZE proposed designs. This section provides details on the LCCA results for each building type.

The cumulative annual expenditure cost shows how much money would be spent on any given building in terms of upfront capital and operational costs over 30 years. This includes construction first cost, on-site solar PV system cost, utility expenditures, and, when necessary for achieving ZE performance, off-site renewable energy purchases. The values plotted in the following graphs are the net present value, calculated by taking into consideration escalation rates for utilities and discount rates for each building type, as mentioned above.

The LCCA shows that all the building types modeled reach a point of time in the building's life at which any potential ZE premiums would pay for themselves and begin to save money over the baseline. The payback period and the percentage of cost savings of the ZE models over the baseline are different for each building type. The incentives and off-site renewables (0.11$/kWh vs standard 0.22$/kWh electricity rate) also increase the financial benefits for ZE buildings in Massachusetts. There are also strategies for limiting or negating first cost premiums using integrated design for energy efficiency outcomes and PPAs for the on-site solar systems; the comparative impact of using a PPA for on-site PV is discussed in Appendix B.

The LCCA model outputs show the cumulative difference in annual expenditure between the ZE and typical buildings. The breakeven year is the point in the graphs where the difference becomes positive. The net present value cost savings are the value of cumulative cost difference over a 30-year period.

For all LCCA results, except for the sensitivity analysis discussed below, a conservative 5% cost premium for ZE buildings was assumed. ZE studies show cost premiums of 0% to 7%. Premiums of less than 5% have already been seen in several Massachusetts projects. We selected 5% as a median point to create a standardized, conservative assumption.

Fort House is a five-unit residence in the Highland Park Neighborhood of Roxbury, MA. The design/builder, Placetailor, expects to complete the project in Fall of 2019 with a predicted site EUI of 13 kBtu/sf/yr. The project will achieve Zero Energy for less cost per square foot than this report's baseline small residential building. Image credit: Placetailor.

EXISTING OFFICE BUILDINGS

The existing office building modelling shows a quick breakeven point at year 6 and cost savings of 10% over the baseline building in 30 years. The financials for existing buildings look very good because the average existing buildings in Massachusetts are relatively inefficient, and so major energy and cost savings can be realized. In reality, some existing buildings can be challenging to retrofit to ZE depending on their capacity to take the weight of solar panels on their roofs, potential historic building restrictions, and other obstructions.*

10%	**Year 6**
$ SAVINGS	BREAKEVEN

EXISTING OFFICE CUMULATIVE ANNUAL USE

FIGURE 23

Cumulative Annual Expenditure Comparison—Existing Office ($/sf)

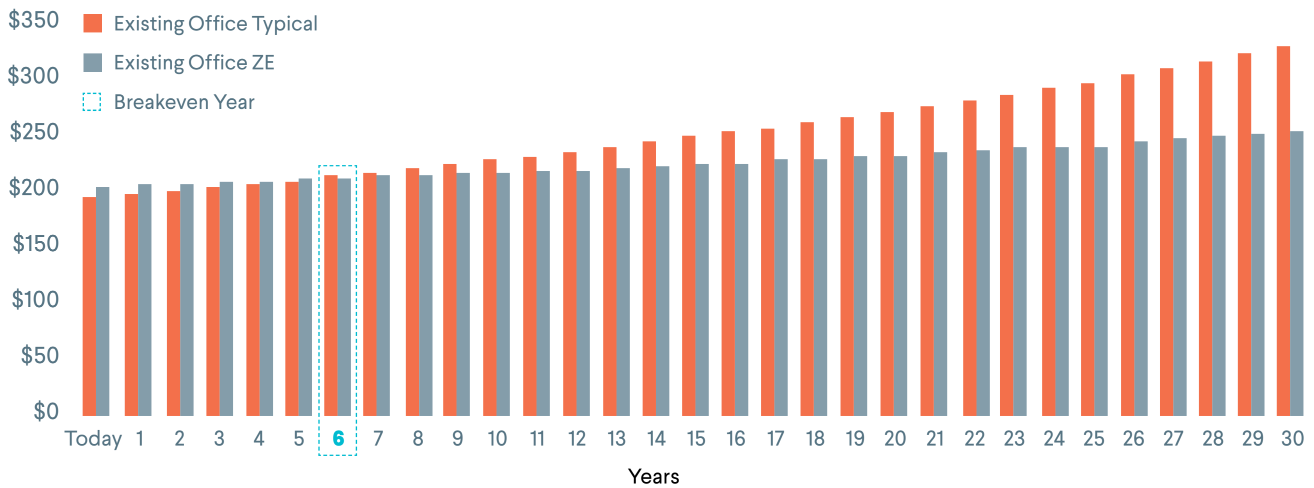
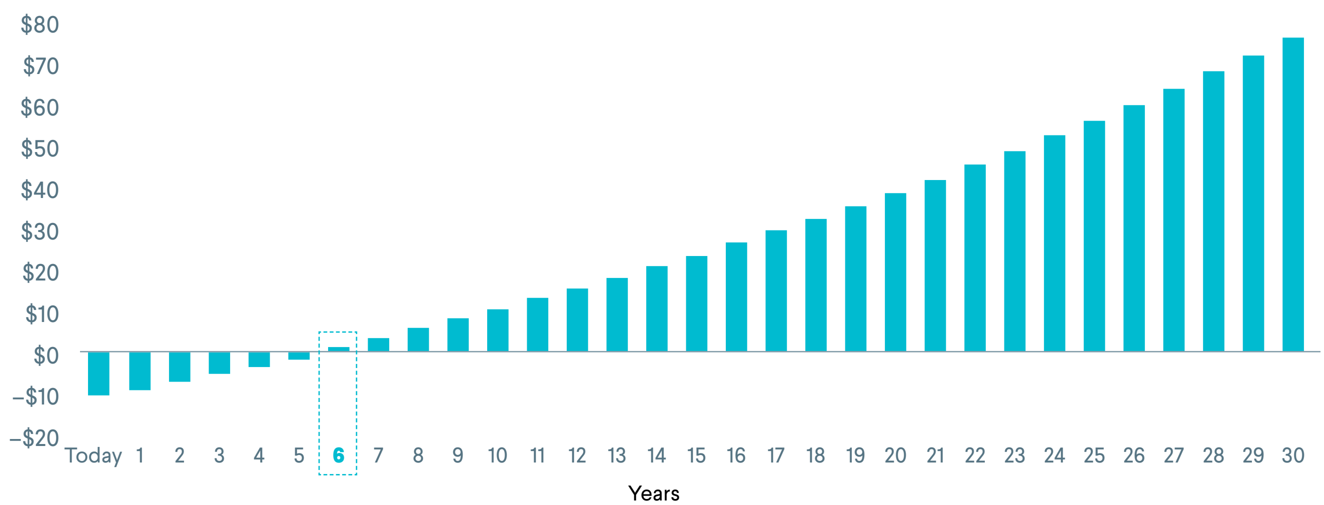


FIGURE 24

Cumulative Annual Cost Difference Between ZE and Typical—Existing Office ($/sf)



*Assumes 5% cost premium for ZER

NEW OFFICE BUILDINGS

New office buildings have a cost savings of 0.3% and show a breakeven point at 15 years, substantially later than that of existing office buildings. This can be attributed to the limited energy efficiency and improvement opportunities a new building has over its baseline versus an existing building baseline, as well as the $500/sf assumed first costs for construction of new office buildings in Boston.*

0.3%	Year 15
$ SAVINGS	BREAKEVEN

NEW OFFICE CUMULATIVE ANNUAL USE

FIGURE 25

Cumulative Annual Expenditure Comparison—New Office ($/sf)

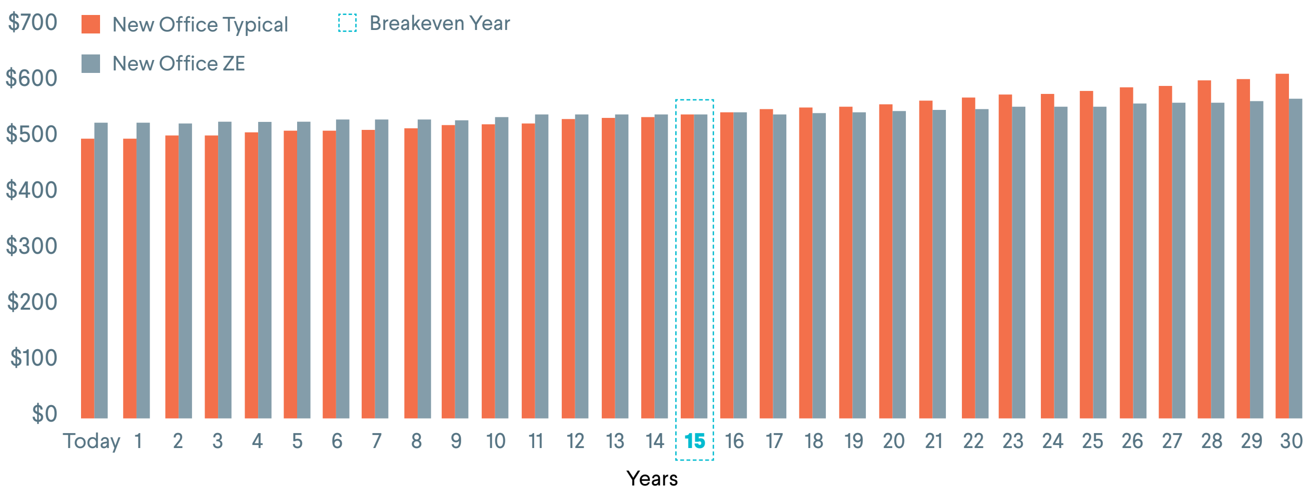
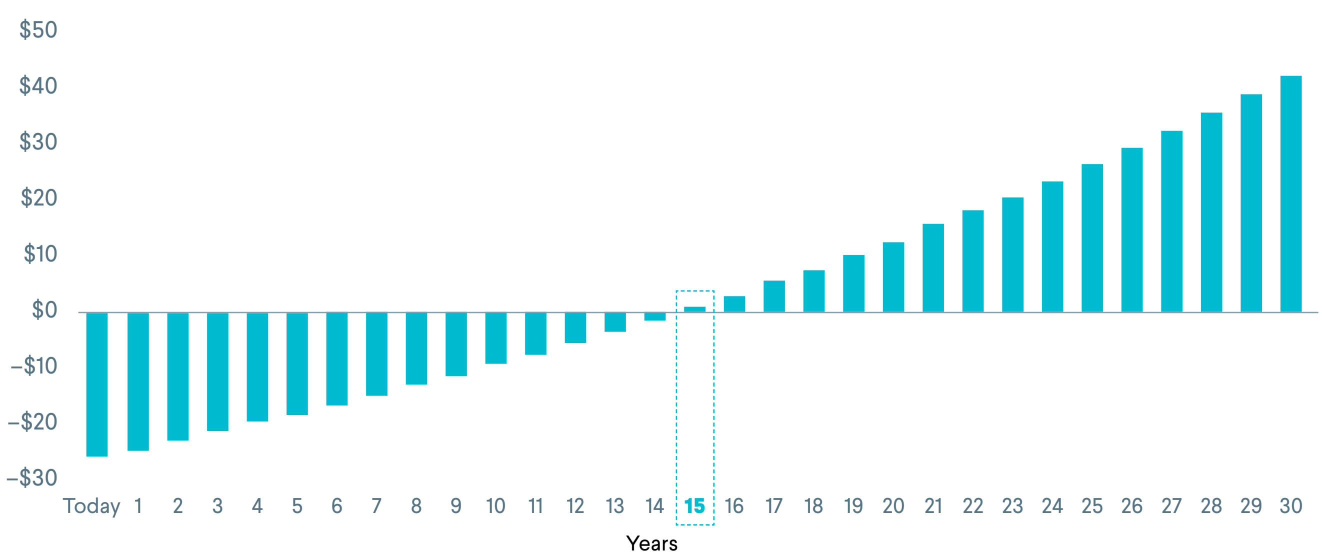


FIGURE 26

Cumulative Annual Cost Difference Between ZE and Typical—New Office ($/sf)



*Assumes 5% cost premium for ZER

K–12 SCHOOL BUILDINGS

K–12 school buildings show a cost savings of 4.8% and a payback period of 15 years. For consistency, this assumes the school is capturing the upfront cost savings afforded by the Investment Tax Credit (ITC) for solar PV. If the school is a public sector or nonprofit school that cannot claim tax incentives, the cost savings are 3.6% (NPV of $15/sf), and the payback period is 17 years. In this scenario, the school might do well to use a PPA for on-site solar PV; this option is discussed in Appendix B.

4.8%	Year 15
$ SAVINGS	BREAKEVEN

Public schools may be eligible for additional funding and other resources from the Massachusetts School Building Authority. These resources were excluded from this study.*

K–12 CUMULATIVE ANNUAL USE

FIGURE 27

Cumulative Annual Expenditure Comparison—K-12 ($/sf)

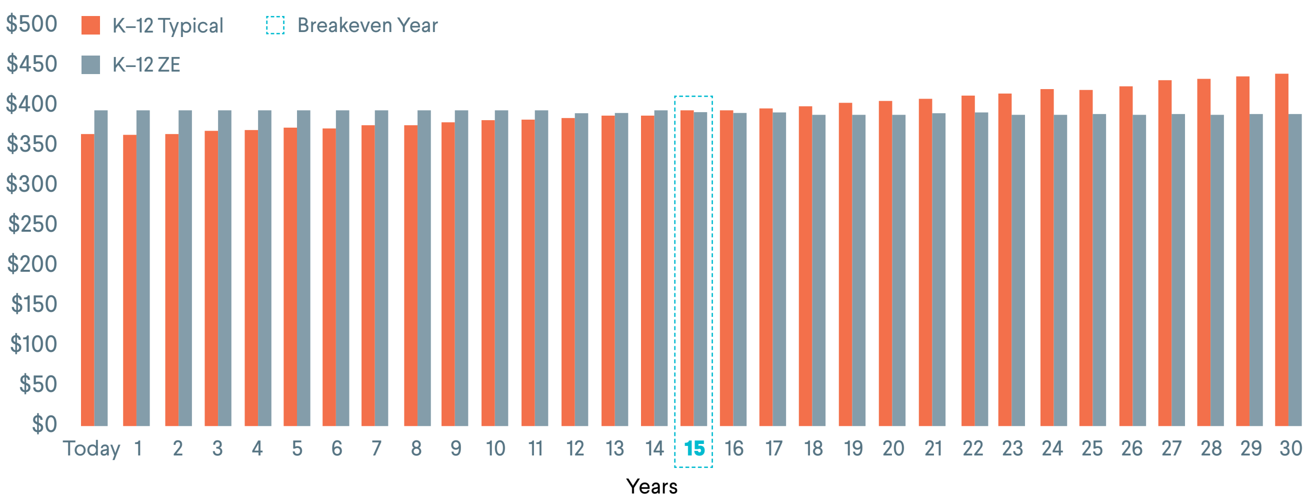
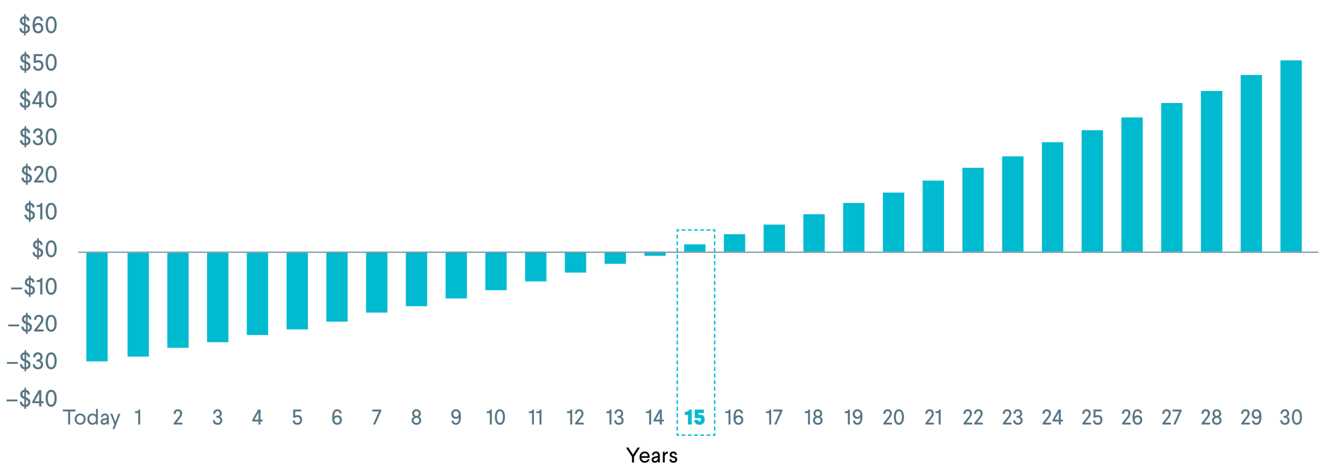


FIGURE 28

Cumulative Annual Cost Difference Between ZE and Typical—K-12 ($/sf)



*Assumes 5% cost premium for ZER

MIXED-USE BUILDINGS

Mixed-use buildings show 6.8% cost savings over 30 years with a payback period of 13 years.*

6.8%	Year 13
$ SAVINGS	BREAKEVEN

MIXED-USE CUMULATIVE ANNUAL USE

FIGURE 29

Cumulative Annual Expenditure Comparison—Mixed Use ($/sf)

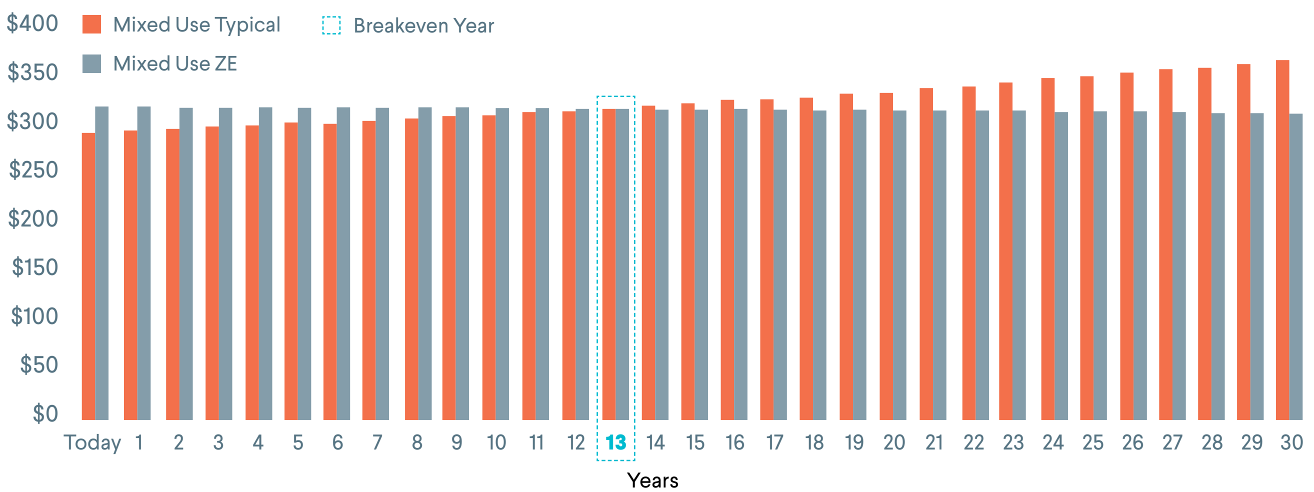
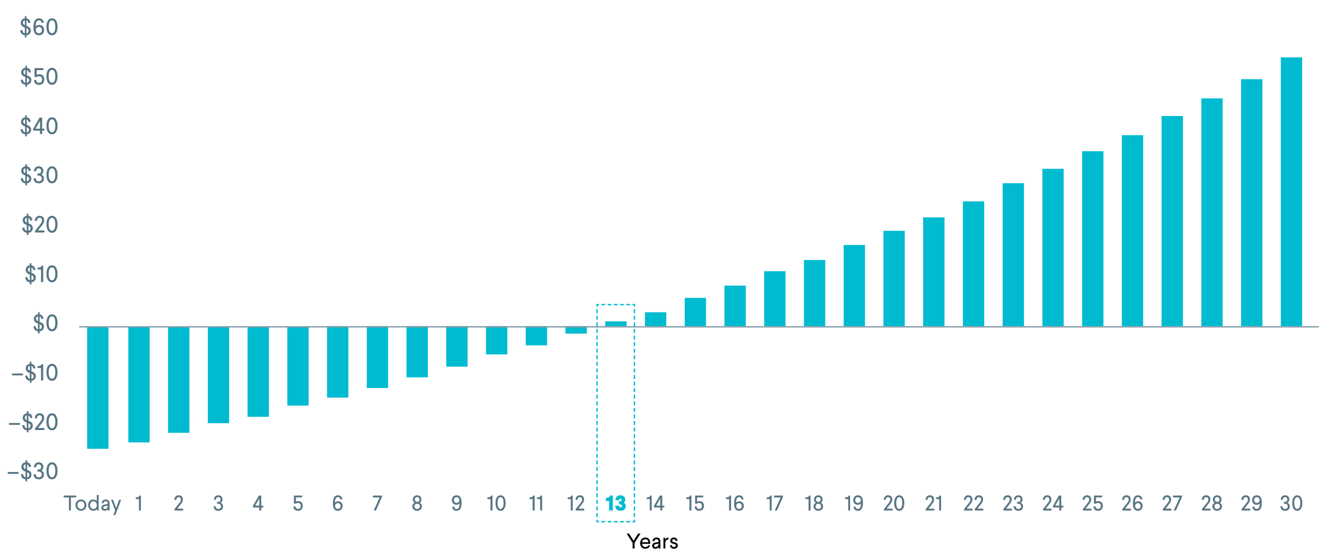


FIGURE 30

Cumulative Annual Cost Difference Between ZE and Typical—Mixed Use ($/sf)



*Assumes 5% cost premium for ZER

SINGLE-FAMILY HOMES

The graphs show a cost savings of 4.3% over the 30-year period for single-family homes. Due to the lower solar incentive, with the same solar installation cost, residential buildings have a higher payback period of 15 years.*

4.3%	Year 15
$ SAVINGS	BREAKEVEN

SINGLE-FAMILY CUMULATIVE ANNUAL USE

FIGURE 31

Cumulative Annual Expenditure Comparison—Single Family ($/sf)

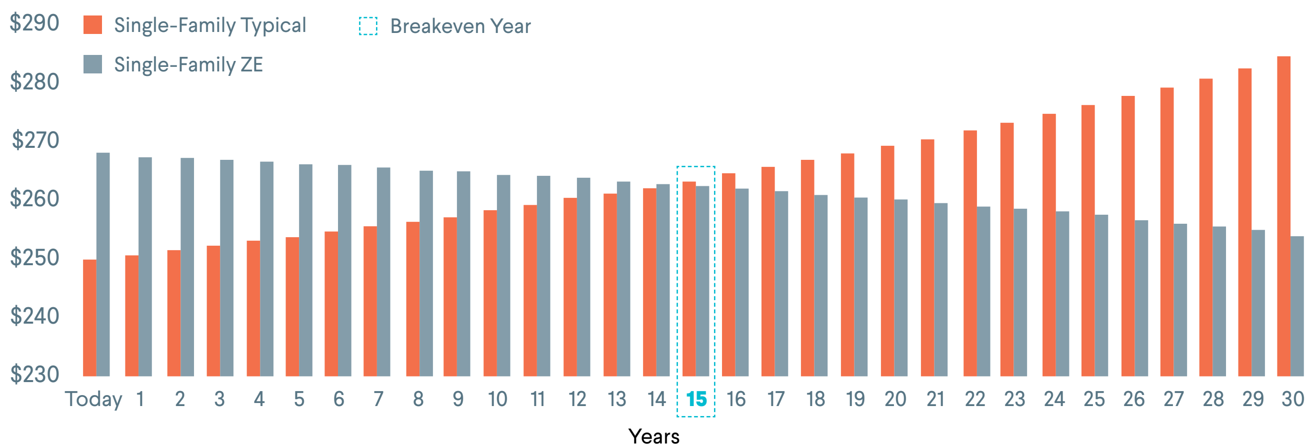
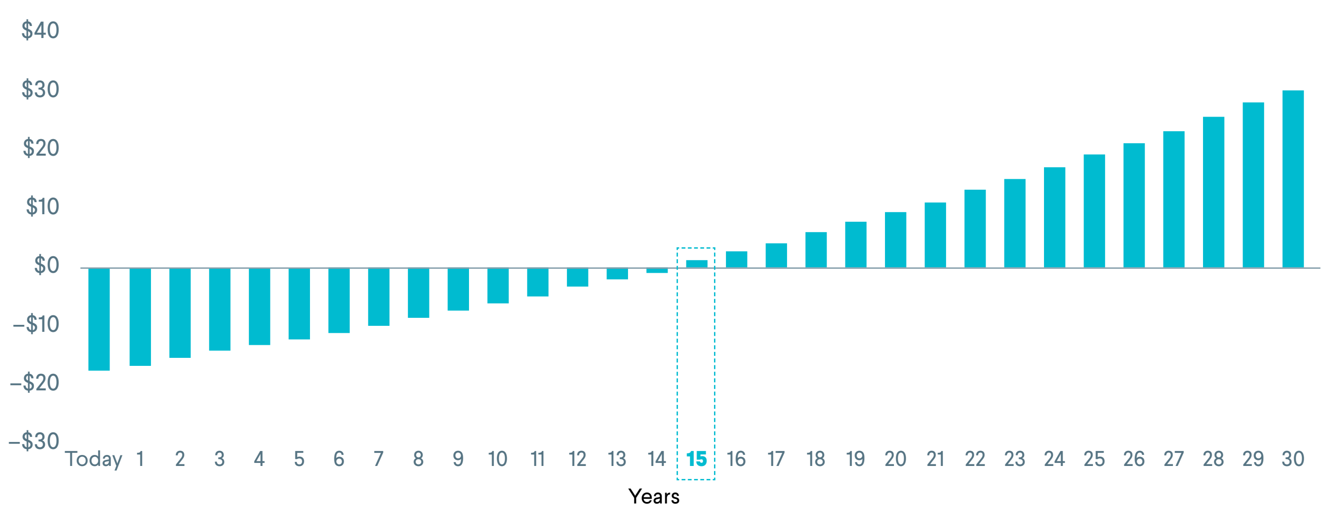


FIGURE 32

Cumulative Annual Cost Difference Between ZE and Typical—Single Family ($/sf)



*Assumes 5% cost premium for ZER

SMALL MULTIFAMILY BUILDINGS

The graphs show a cost savings of 1.3% and a payback period of 19 years for small residential buildings, due to the comparatively low solar incentives available for this sector, combined with relatively high first costs.*

1.3% $ SAVINGS	Year 19 BREAKEVEN

SMALL MULTIFAMILY CUMULATIVE ANNUAL USE

FIGURE 33

Cumulative Annual Expenditure Comparison—Small Multifamily ($/sf)

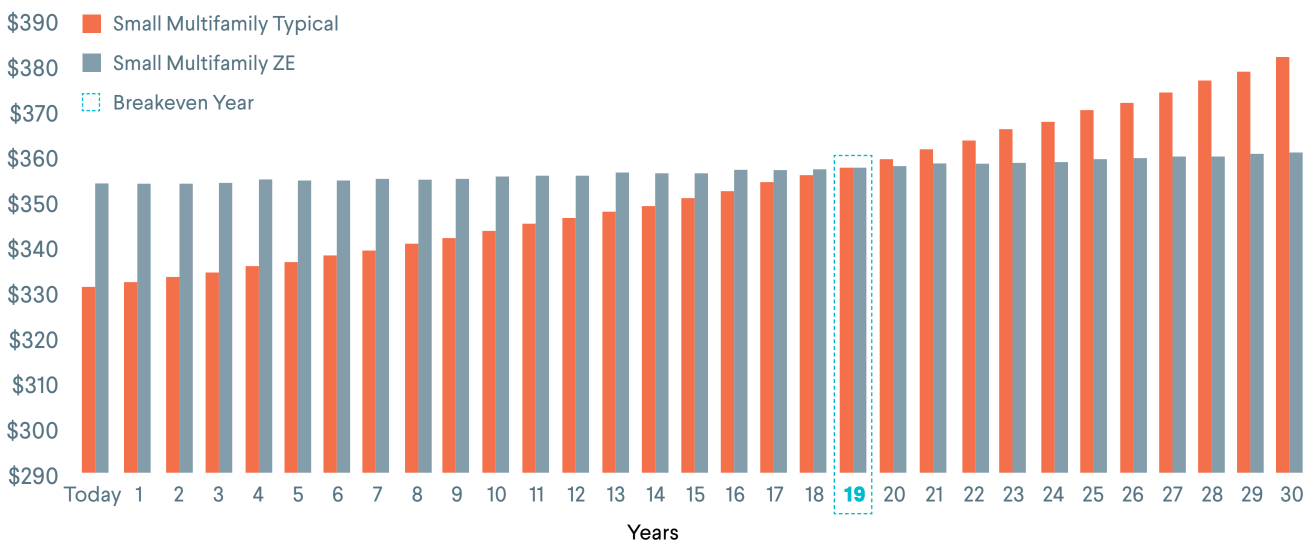
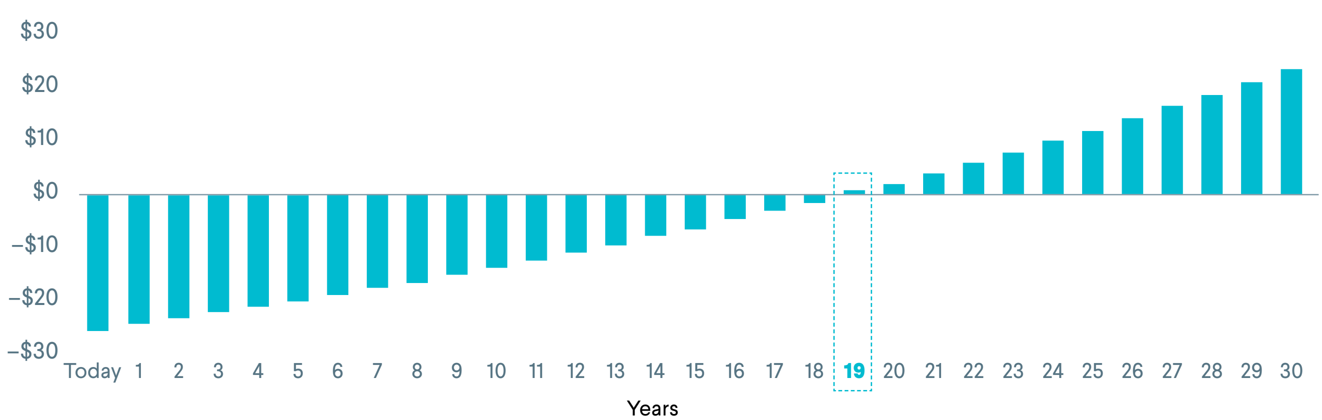


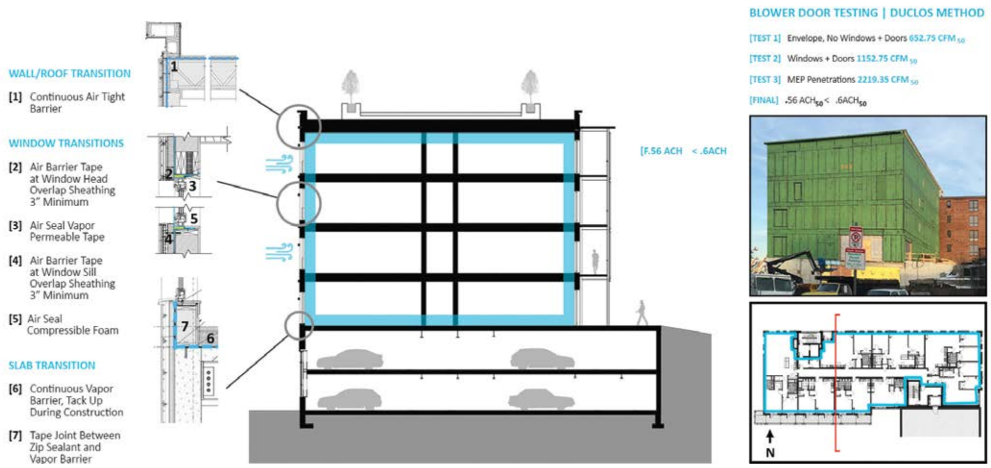
FIGURE 34

Cumulative Annual Cost Difference Between ZE and Typical—Small Multifamily ($/sf)



*Assumes 5% cost premium for ZER

CASE STUDY: The Distillery North



Conceived to establish a replicable standard for high-quality, low-carbon development, The Distillery North is the first multifamily Passive House Certified project in Massachusetts and the cornerstone of a vision for a truly sustainable community. Through radical simplicity and rigorous attention to detail, the building demonstrates exceptional energy reduction while maximizing health, comfort, and resilience.

Each façade is designed to thoughtfully respond to its diverse context, while addressing solar orientation to ensure optimal performance. Warm terracotta wraps the building along the two street fronts, offering a contemporary counterpoint to the adjacent masonry existing building. Corrugated metal clearly articulates the junctions between the new and existing buildings. The southern façade is laced with a metal balcony system, which provides important solar protection, as well as a private outdoor space overlooking the central shared courtyard. Inside the building, the generous corridor, with its cork flooring and enhanced lighting, provides added accessibility and an opportunity to mingle and view art created by the local artist residents.

As a pioneer in Passive House design, the design team was challenged to refine and simplify the detailing to accommodate traditional building methods and readily available products, which ultimately allowed for cost-effective construction. The Distillery North combines a super-insulated, airtight envelope with intelligent ventilation to substantially minimize heating and cooling loads and reduce overall energy demand. The Distillery North achieves a total Primary EUI of 22.4 kBTU/sf/year compared to the ASHRAE 2010 Source EUI baseline for mid-rise apartment buildings of 131.4 kBTU/sf/year—a reduction of 83%. It also achieved 100 points, and thus is Platinum Certified under the LEED for Homes Midrise version 3 rating system. Not only is this a substantial carbon reduction, but it results in a vastly superior interior environment for all. Residents have expressed delight over the quietness of the building in this busy urban environment and real health improvement resulting from the high-quality filtered air.

Passive House
82% energy reduction

LOCATION: South Boston, MA

PROJECT SIZE: 28 Units

COMPLETED YEAR: 2017

BUILDING TYPE: Live/work

ARCHITECT: ICON

MEP: Peterson Engineering

22.4 kBtu/sf SOURCE EUI

Image credit: ICON Architecture

Summary

Below are summaries of the payback periods and cost savings per square foot for each building type. Each of the commercial buildings has a payback period ranging from 6 to 15 years; the small multifamily residential model shows the longest payback period. The low savings for new offices stem from the high assumed first costs and the strength of the baseline energy code (leaving less room for savings). The increased discount rate for commercial offices stems from the higher opportunity cost for investing in large commercial property. Existing offices, and larger mixed-use buildings, show the greatest cost savings potential.

FIGURE 35

Breakeven Year by Building Type*

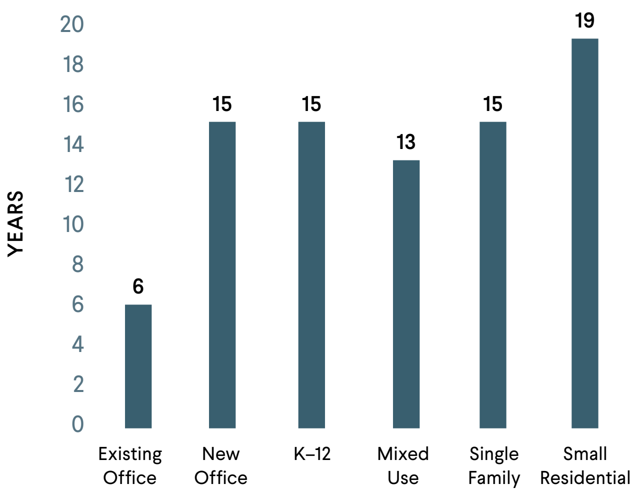
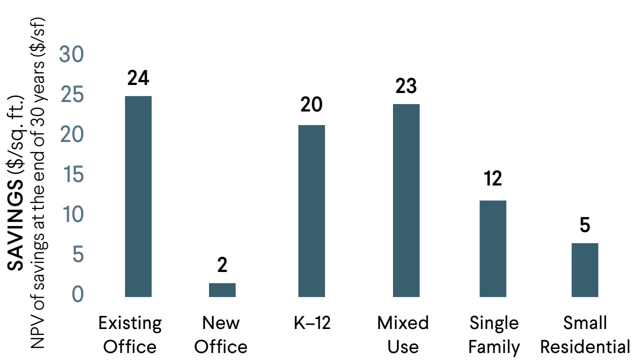
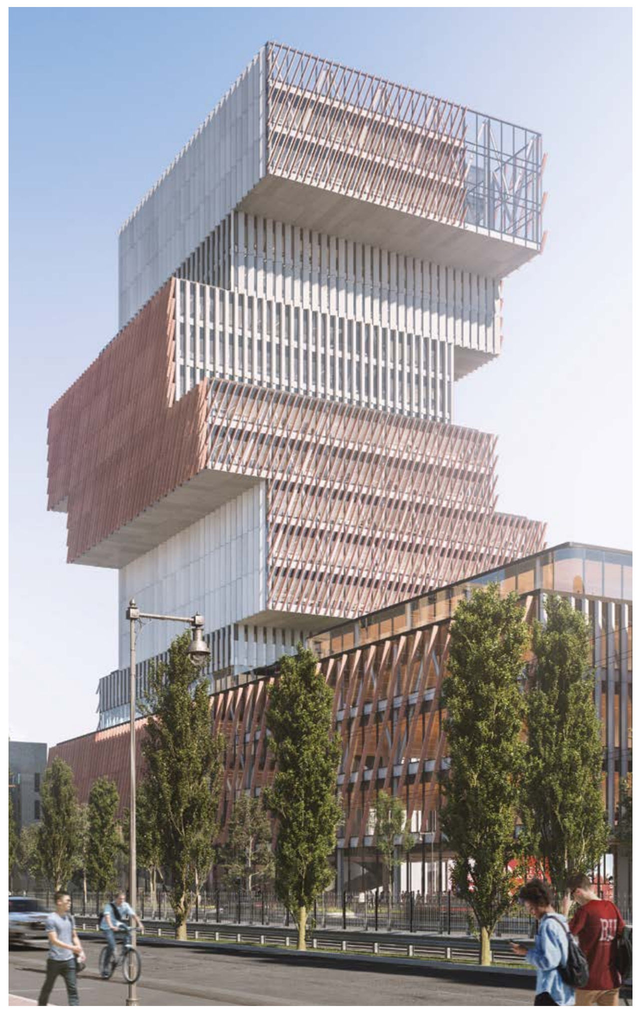


FIGURE 36

Cost Savings by Building Type*

NPV of savings at the end of 30 years ($/sf)



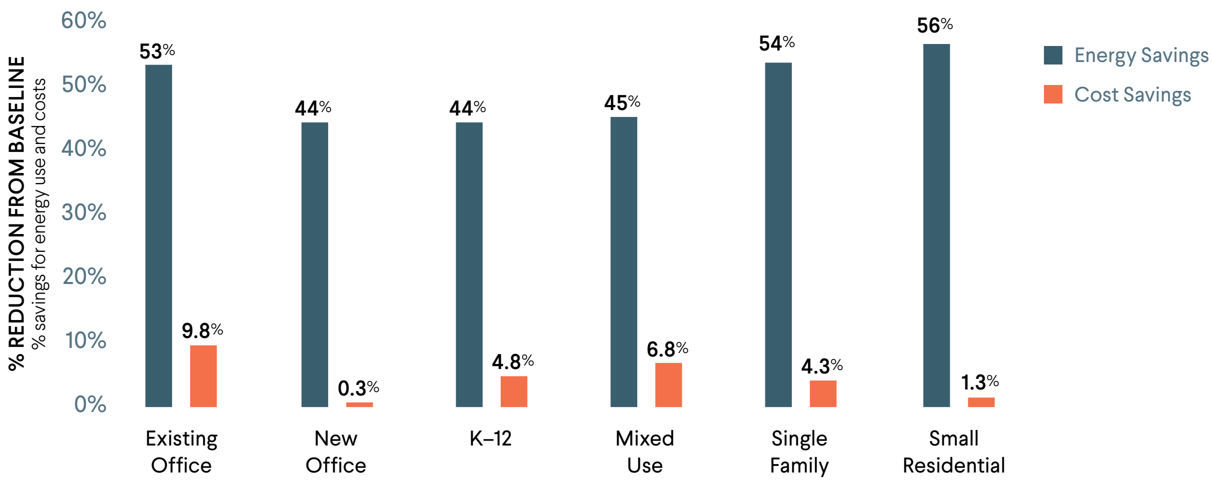


The BU Data Sciences Center will be a 345,000 square foot, 19-story building that will achieve Class D Zero Net Energy. The building has an anticipated site EUI of approximately 40 kBtu/sf*yr and will rely on 100% renewable electricity, eliminating fossil fuel consumption. This was achieved at a cost premium well below 1% of construction cost. The payback period is estimated to be less than two years. Owner: Boston University, Architect: KPMB, MEP Engineer: BR+A, Geothermal Engineer: Haley&Aldrich. Image credit: Norm Li/KPMB.

*Assumes 5% cost premium for ZER

FIGURE 37

Percent Reduction in Energy and Cost by Building Type*



First Cost Premium Sensitivity Analysis

The analysis was done assuming a 5% cost premium for all ZER buildings. A sensitivity analysis was performed by varying the cost premium for each type of ZE building from 0% to 7%. A 0% additional first cost premium represents a scenario in which there is no added first cost for designing a ZE building, except for on-site solar (though that could also be mitigated by using a power purchase agreement structure). The results of this sensitivity analysis can be found in Figures 38 and 39.

In the second figure, the results show the net present value of cost savings over 30 years as a percentage of the total NPV of the project over 30 years. As would be expected, there is a direct relation between a decrease in first costs for ZE and the payback period and cost savings, which underlines the need for delivery of cost-effective energy efficiency. With no upfront cost for ZE, the payback period was as low as one to eight years across the building types. The projects highlighted in this report show that ZER and ZE buildings can be built for little added first cost. As more of these projects are built, the costs will decline with experience.

The Belmont Middle and High School is a 445,100 sf four-story building that is anticipated to achieve Class D Zero Net Energy. The building has a predicted site EUI of approximately 30 kBtu/sf*yr and is designed to rely on 100% renewable electricity (from on-site and off-site sources), eliminating fossil fuel consumption. Because the reduction in building operating costs is greater than the bond payments associated with the ZNE-enhancements, the net cash flow is positive from year one. Therefore, the payback is immediate. Owner: Town of Belmont, Architect: Perkins+Will, Mechanical Engineer: BALA. Image credit: Perkins and Will.

*Assumes 5% cost premium for ZER

FIGURE 38

Payback Periods for Different First Cost Premiums

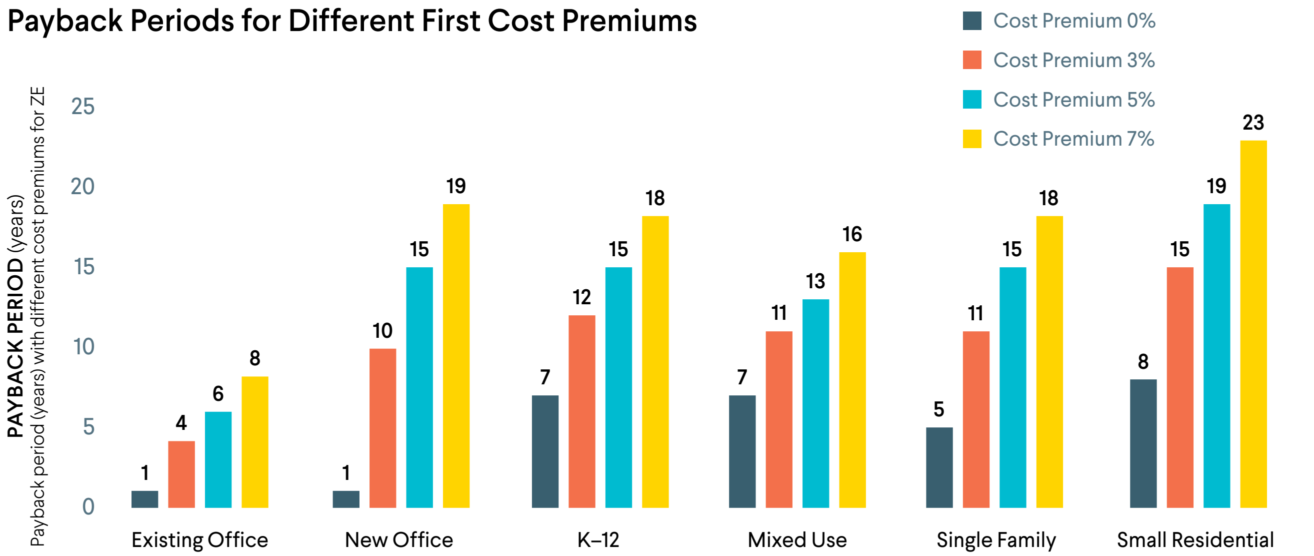
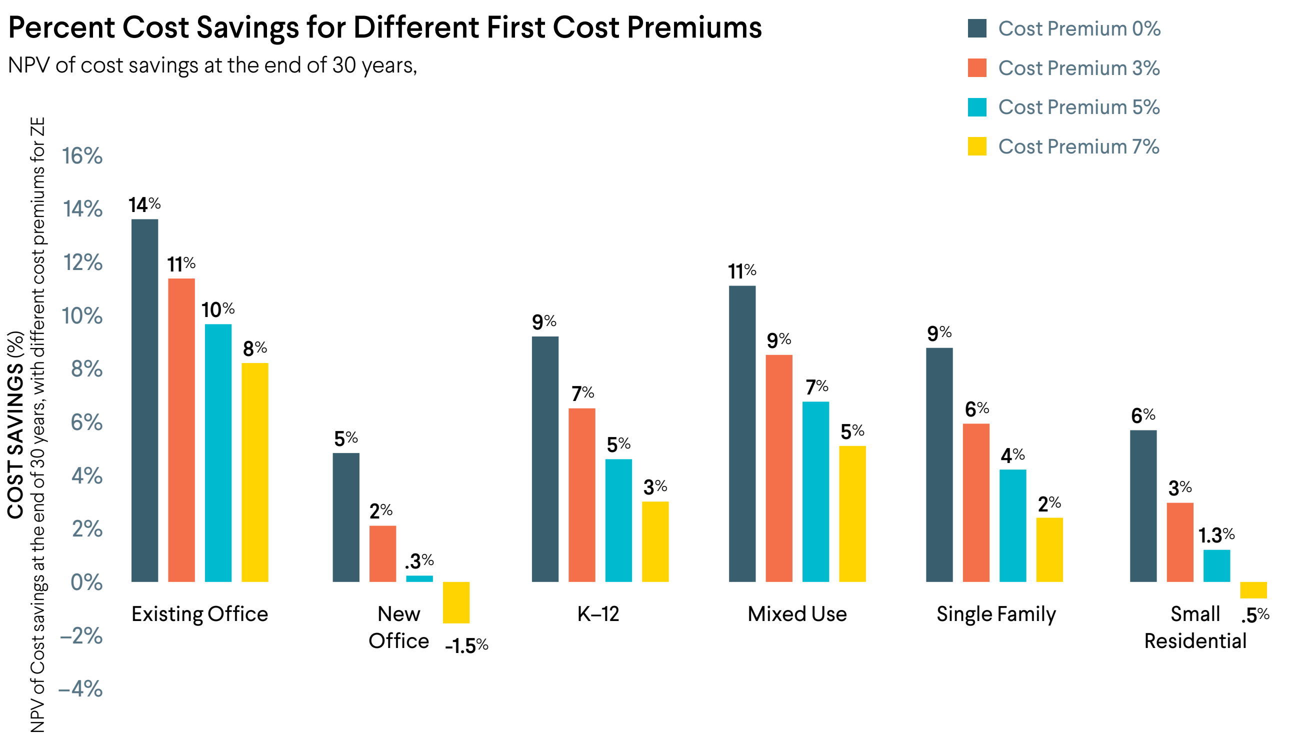


FIGURE 39

Percent Cost Savings for Different First Cost Premiums

NPV of cost savings at the end of 30 years,



Policy Recommendations

Municipal Workshop

On July 12, 2018, the USGBC Massachusetts team held a ZNE Municipal Roundtable at the Reggie Lewis Center in Roxbury to discuss zero energy buildings and policies for cities and towns in the state. Other organizations also participated in the event, including the Northeast Energy Efficiency Partnership (NEEP), Metropolitan Area Planning Council (MAPC), Massachusetts Climate Action Network (MCAN), and Integral Group. The Roundtable was a platform for municipal staff, committee members, elected officials, and concerned citizens to come together to learn and share about the path to ZE buildings for cities and towns in Massachusetts. Following an educational presentation on the concepts of ZE and brief case studies, each attendee was tasked to engage with their peers and asked a series of questions pertaining to ZE. All the responses and feedback from the event were recorded and are summarized below. These findings helped inform the modeling results discussed earlier and the policy recommendations covered in this section.

Seventy-five people attended the workshop, including municipal leaders, architects, engineers, and concerned citizens. The attendees came from twenty different municipalities, including major urban, suburban, and gateway municipalities in Massachusetts. These municipalities have some existing policies and plans that already support the development of ZE buildings. Figure 40 shows the cities that were represented at the workshop, and some of the current relevant initiatives by city, based on attendee responses. However, the list below is not exhaustive of all municipal-level initiatives in Massachusetts, or even in the cities represented; the list is based on attendees' knowledge at the time of the event of initiatives occurring in their city. Hopkinton, Melrose, Quincy, and Waltham were also represented in the roundtable, but data points for those cities were not discussed at the event.

FIGURE 40

Current ZE Initiatives by City, Based on Workshop Attendee Responses

ACTON
2 Schools Merging to 1

CONCORD
80% GHG emissions reduction by 2050, high performing high school

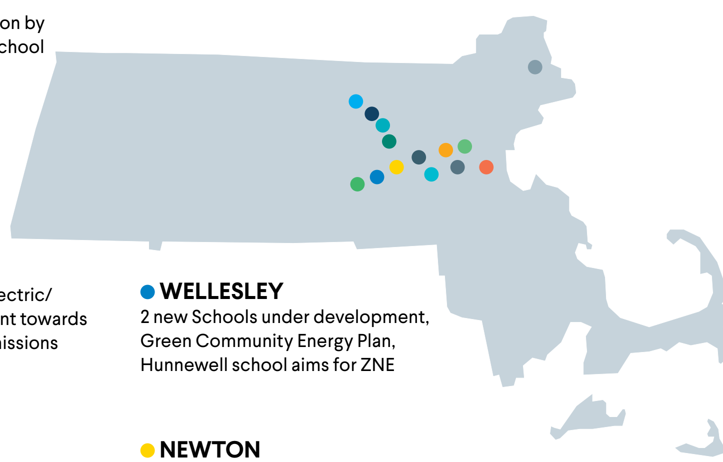
LINCOLN
Solarize programs in collaboration with Concord and Carlisle

BELMONT
New High School to be all electric/ ZNE, Belmont Light movement towards purchasing more RE, 80% Emissions Reduction Goal by 2050

FRAMINGHAM
Transitioning to City Government, Working to establish a sustainability agenda

DEVENS
Possible ZNE + Redevelopment strategies for residential homes

CAMBRIDGE
80% reduction of GHG by 2050, net zero annual emission for buildings city wide by 2040, Harvard's Net Zero Plan



WELLESLEY
2 new Schools under development, Green Community Energy Plan, Hunnewell school aims for ZNE

NEWTON
Green Newton, Newton Coalition forClimate Action

IPSWICH
Climate Action Plan, 25% GHG Reduction by 2020

SOMERVILLE
Carbon Neutral by 2050, Somerville High School aims for LEED silver and solar ready, future city hall and high school ZNE ready, Library Rennovation/Historic Structure/Goals for High performance

BOSTON
Boston Climate Action Plan, Carbon-free by 2050, Boston E+ Green Building Program

BROOKLINE
High School Expansion, Brookline Climate Action Plan, 80% GHG emissionsby 2050

NEEDHAM
New Housing Development, Solarize + Green Needham Plan

Attendees were also asked: "What would you like to see happen in your municipality in 3-5 years related to ZE?" Table 8 shows the responses by municipality.

TABLE 8

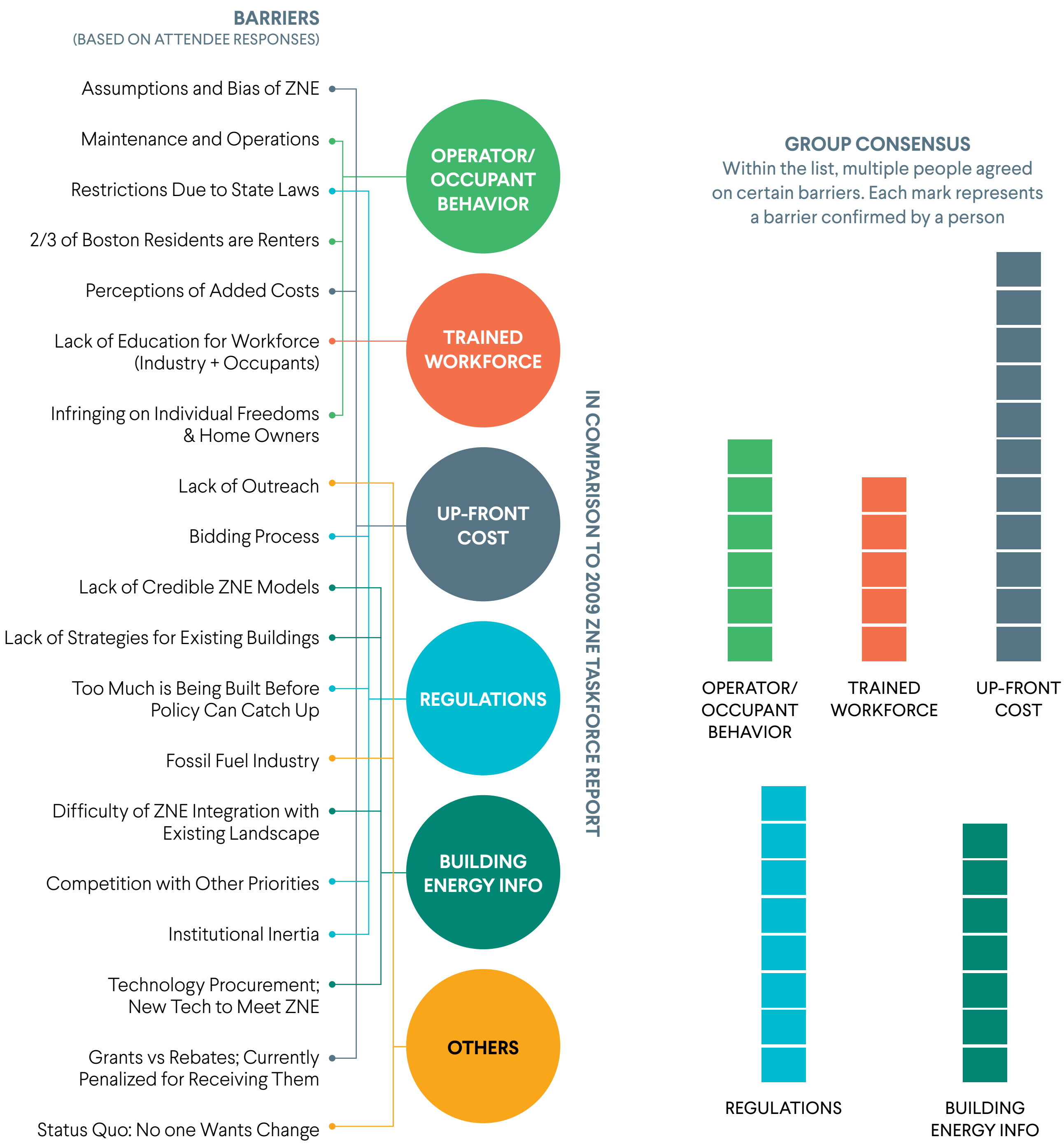
Envisioning Future Goals Within 3-5 years (Based on Attendee Responses)

Town	Future Goals
Boston	ZE buildings for underdeveloped neighborhoods and low/middle income residents; expand E+ Green Building Program to include mid-rise residential and commercial buildings with ZE as baseline requirement; focus ZE buildings in underdeveloped neighborhoods for low/middle income residents; create incentives for new buildings following Passive House standards; update Boston's Climate Action Plan to include recommendations from the *Carbon Free Boston* report. Passive House standards include zero net carbon standards for new construction and programs to promote zero net carbon retrofits of existing buildings.
Brookline	ZE requirement for small residential by 2050; power aggregation; incentives for ZE; creation of model ZE code; statewide progress; more bike paths; zoning by-laws for new buildings to be ZE.
Belmont	A scoring system for grants or incentive system; a way to defer technology decisions—PV today vs. PV in 2 years; commitment to ZE municipal projects.
Cambridge	Stretch codes; requirement process for local planning to fit with state 2030 GHG Plan.
Concord	At least one ZE town building.
Devens	Expand on existing ZE examples; ZE becoming standard.
Hopkinton	Solar in new elementary school.
Ipswich	Adopt stretch code; create municipal ZE code; integrate renewable energy systems in planning laws.
Lincoln	Smith Brooks High School be ZE; 100% enrollment in CCA; 10% reduction in fossil fuel usage; PV at landfill and school; create community solar farm; build battery storage.
Needham	Town-wide solar PV field; high performance buildings.
Newton	Power aggregation with % of renewable energy; aggressive GHG reduction plan; ZE stretch code.
Melrose	Create a ZE plan by 2050; engage more residents; aggregation for renewable energy power purchase; grants for ZE retrofits.
Quincy	Adopt ZE goals for all buildings; ZE zoning for all new construction; adopt community aggregation with significant increase in clean energy.
Roxbury	Drive down cost for residents by implementing renewable energy and load mitigation measures; energy efficiency audits for existing buildings.
Somerville	Net zero zoning for all buildings; pass new zoning regulations.
Waltham	Drive down cost for residents by implementing renewable energy and load mitigation measures; energy efficiency audits for existing buildings; all construction be ZE; goal toward 100% RE by 2030.
Wellesley	Both new schools be ZE; town-wide solar in the overlay district; municipal buildings, and especially schools, be ZE; ZE residential by 2025; educate all residents on ZE.
Other Responses (Town/City Unknown)	Mid/low income ZE housing; educated occupants + customers of ZE; best practice in design; housing authority; ZE for planned replacements; public awareness; large ZE institutions/school buildings; scoring system and grant incentive system for Passive House; commitment to ZE for all municipal projects; all new construction be ZE; strategic electrification; 100% renewable by 2030; pass ZE zoning regulations requiring solar and geothermal for all commercial projects; expand to emergency preparedness with ZE plans.

Attendees of the roundtable were also asked the question, "What obstacles are you facing pertaining to ZE buildings?" Figure 41 visualizes the responses to this question comparing attendee responses to barriers identified in the 2009 *ZNE Taskforce Report*.

FIGURE 41

Barriers to ZE: "What obstacles are you facing pertaining to ZE?"



Relatedly, attendees were asked the questions, "What is needed in order to achieve the visions recorded for the earlier question? What would you like to see happen in your municipality in 3-5 years related to ZE?'" Figure 42 visualizes the responses to this question.

At the end of the event each group submitted one "big idea" and voted on which one they were most interested in or believed was the idea that needs to be implemented. Figure 43 details the most popular ideas.

FIGURE 42

Pathway to ZE (Based on Attendee Responses)

What is needed in order to achieve the visions recorded from the past question?

CATEGORIES

RESIDENTIAL BUILDINGS

- **Small Residential Stretch Code**
- Progressive Property Tax to Discourage Oversized Residential Construction
- ZNE Affordable Housing
- **Home Energy Scorecards**
- **Structured Financing System**

DEVELOPMENT + EDUCATION

- ZNE Zoning for All Buildings
- Climate Action Plan
- **Occupant + Owner Education**
- Network with Other Cities
- **Education for City Officials**
- Disclosure + Upgrade Ordinances
- Needs a Consistent Dialogue
- Town Roadmap for Energy Goals
- Central Source for Info Sharing

COMMERCIAL BUILDINGS

- **ZNE Commercial Stretch Code**
- Carbon Neutral Requirement for Additions
- **More Accessible Financial Incentives**

SOCIAL SHIFT

- Demonstrations + Models to Show Examples of Successful ZNE Projects
- Public Awareness and Interest in ZNE
- Educate Younger Generation to be More Involved in Politics
- Rigorous Commitment to Net Zero/ Net Positive Design
- Continuing Education + Outreach to Communty
- Promoting Strategic Electrification

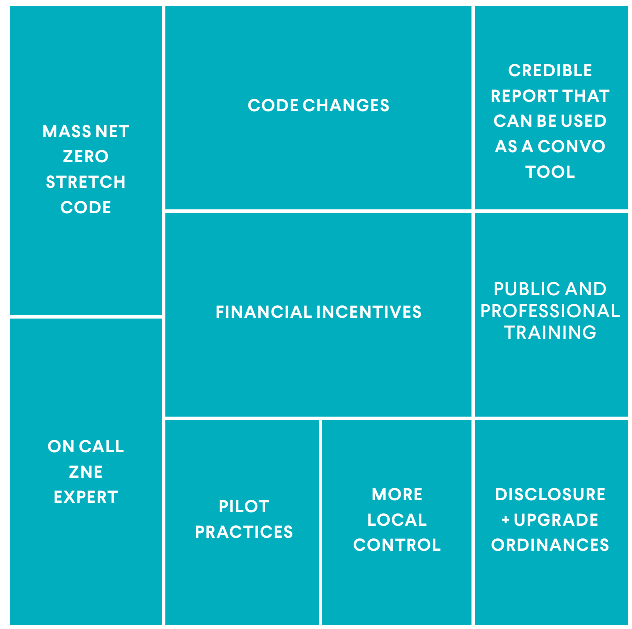
STATE-OWNED BUILDINGS

- All State-Owned Buildings be ZNE or Energy Efficient
- **More Accessible Financial Incentives**
- **Public Report of Energy Performance**

*** Common Conclusions with the 2009 *ZNE Taskforce Report***

FIGURE 43

Most Popular "Big Ideas" from Roundtable



Review of 2009 ZNE Taskforce Report

Following the municipal roundtable, the consultant team also reviewed the 2009 report, *Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force,* a landmark study on net zero energy building practices and what it would take to make net zero energy buildings mainstream in Massachusetts.[6] The team reached out to stakeholders to determine progress to date on the recommendations found in the report, and regional and national best practices on net zero energy policies. What follows is a set of recommendations on how to further advance net zero energy building policy in Massachusetts.

The 2009 report contained 44 recommended actions—14 for the commercial sector, 10 for the residential sector, 8 for state-owned buildings, and 12 actions related to workforce development, technology, and education. A review of the actions finds that 17 (38%) of them have been completed and require no further update. Another 12 (27%) are in progress. The remaining 16 (34%) have not been started. For some of the actions that are in progress, the action language is clear, but the action is ongoing and should continue. For others, a revision to the action text will help yield success, either by updating the action language to the current policy, or by clarifying what success and completion would look like. The national policy and engineering landscape for net zero energy buildings has changed significantly in the past decade.

Appendix C lists all 44 existing actions, provides an update on action progress and status, and presents recommendations to retire the action, retain the action as is, or revise and update it. The status updates for all the actions also serves as a survey of existing ZE policy in the Commonwealth. Below, we discuss some of the most important new actions and updates. Minor, but substantive, alterations are recommended for seven additional actions discussed in Appendix C.

Policy Recommendations for Commercial Buildings

COMMERCIAL ACTION: **Develop State Green Bank to leverage private capital for ZE projects using public dollars as seed money.**

LEVEL: **State**

LEGISLATIVE CHANGE NEEDED? **Yes**

Green banks are typically public or quasi-public entities that leverage private sector capital to increase the overall level of investment in renewable and low-carbon energy. The investments needed to make zero energy buildings mainstream and default in Massachusetts, and to achieve the Commonwealth's goals, exceed what can be done with public money alone. Three neighboring states—Connecticut, New York, and Rhode Island—already have Green Banks, each with slightly different models. Massachusetts is thus in an enviable position, having a regional market that is already used to Green Banks and good regional examples and talent from which to draw. Individual cities could create their own Green Banks; however, a statewide Green Bank is likely to be more effective. Legislation to create a statewide Green Energy Development Bank has been introduced but has not been adopted.

Municipal representatives discussing obstacles and strategies for zero energy at USGBC MA's ZNE Municipal Roundtable in July 2019. Photo credit: USGBC MA.

6 Commonwealth of Massachusetts, (2009) *Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force,* March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

COMMERCIAL ACTION: Study the success of the Renew Boston Trust model and explore expansion to other cities or statewide.

LEVEL: State and/or City

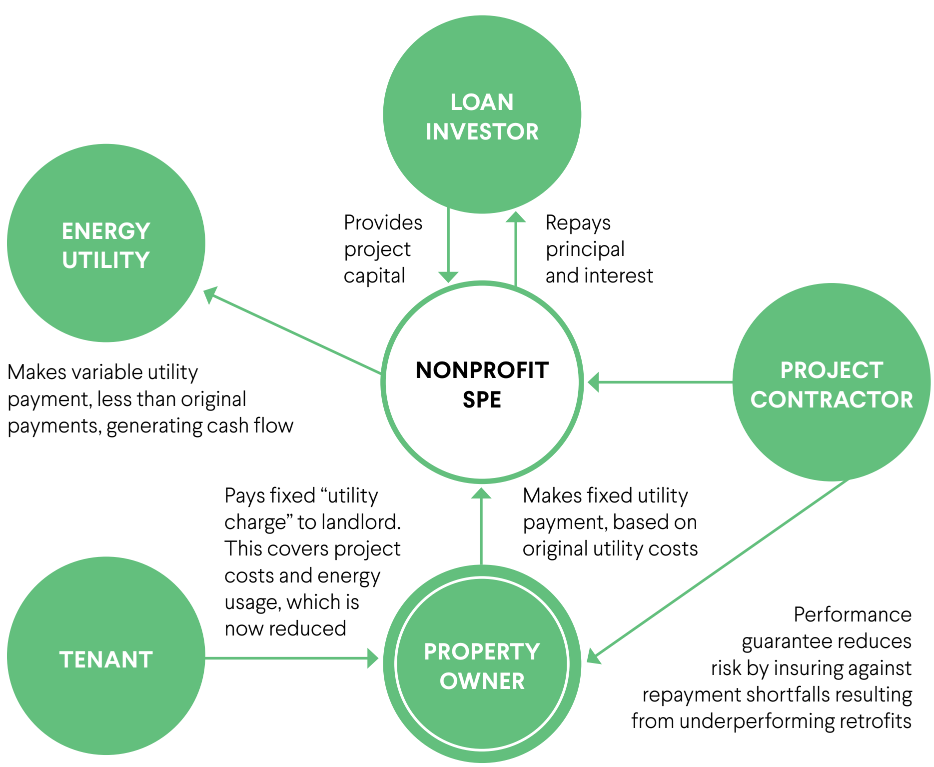
LEGISLATIVE CHANGE NEEDED? No

The Renew Boston Trust (RBT) model is a new financial model that uses structured finance to provide private investment into energy efficiency and renewable energy projects with performance guarantees. The government entity creates a nonprofit special purpose entity (SPE), which enters into a managed utilities service partnership with the property owner (in this sense, it is somewhat similar to an energy services company [ESCO]). As shown in Figure 44, the SPE collects fixed utility payments for a period from the owner, and then pays the new lower payments to the utility, using the delta of the money saved from the efficiency project to repay the loan investor. The contractor must provide a performance guarantee for the SPE to assure investors. RBT's innovation is to provide an energy services agreement with performance guarantees sufficient to attract private capital at scale, and to do it in a way that does not affect the credit rating of the government. By aggregating projects, the Trust also allows the benefits of structured finance and the ESCO model to be made available to many smaller buildings than is traditionally the case. The Trust specifically targets mid-cycle energy efficiency investments, to catalyze retrofits sooner than they would otherwise occur. Because of the huge opportunity of energy efficiency, and the urgency of reducing GHGs, advancing retrofits earlier in a building's life cycle is critical.[7]

The RBT model was authorized by a state statute in 2008, so the model could be scaled to other jurisdictions in the state. RBT remains in the advanced design phase and the first projects are being launched now. The Commonwealth and other municipalities should monitor the progress and success of RBT and see if it can be duplicated. Neighboring municipalities could also explore opportunities to execute projects using RBT without starting their own separate programs.

FIGURE 44

Relationships Between Different Stakeholders



7 C40 Cities (2017). "Urban Efficiency II: Seven Innovative City Programmes for Existing Building Energy Efficiency." C40 Cities. London, UK. 48-65. https://issuu.com/c40cities/docs/urbanefficiencyii_final_hi_res__1_

COMMERCIAL ACTION: Develop standard for integrated green roof and solar projects to provide the market with regulatory certainty.

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? Not necessarily; it depends on whether the current barriers are in legislation or if changes could just be made to regulations.

Green roof projects and solar projects are often seen as conflicting, mutually incompatible uses of roof space. Local and state regulations can perpetuate this view by artificially limiting the storm water retention that can be claimed by a building that has solar panels over parts of the green roof. In practice the two types of projects can work well in unison—there are racking systems that use the green roof media as ballast, thus limiting extra weight issues and costs from the solar array, and the green roof can help keep the solar panels cooler, which increases their performance. Other jurisdictions have created guidelines for integrating green roof and solar projects to ensure that storm water regulations and goals are met, while also supporting deployment of solar. The Commonwealth should review existing regulations at state and city levels to identify any places where solar energy and green roofs are in conflict and establish new standards that align them. This will increase regulatory certainty and enable maximum on-site renewable energy generation throughout the Commonwealth.

COMMERCIAL ACTION: Create a zero energy stretch code as a compliance path to the state energy code and establish date-specific targets for mandatory zero energy code in MA, while also advocating for similar efforts nationally.

LEVEL: State

LEGISLATIVE CHANGE NEEDED? The Board of Building Regulations and Standards has sole authority to promulgate the Massachusetts State Building Code (MSBC). However, legislative codification of zero code target dates would help ensure success.

Energy performance standards were added into the building code in Massachusetts; however, to truly support ZE buildings, more certainty is needed. As a first step, a zero energy stretch code should be created as a compliance path for the energy code, as has been done in Washington, D.C.'s proposed energy code. Then, a date-specific target, one to three code cycles out, should be set to make the zero energy code the default mandatory code. By putting down a firm marker of when new construction and major renovation projects will need to be ZE and clarifying what that would look like in current code language, Massachusetts will create regulatory certainty and clarity around the ZE goals while also increasing demand. ZE buildings can be built with little to no cost premium over conventional buildings, but the marketplace has to be developed enough for low and zero-cost premium zero construction to become standard.

COMMERCIAL ACTION: Develop zero code language modeled on language from Architecture 2030 or Appendix Z of the proposed District of Columbia Energy Conservation Code. Code language should allow multiple alternative compliance paths including Passive House+, ILFI's Zero Energy Certification, LEED ZERO and the Living Building Challenge, to acknowledge and support advances in building technologies and certification programs.

LEVEL: State

LEGISLATIVE CHANGE NEEDED? No

We propose that the index for new buildings and major renovations under this optional path should be ZE. Architecture 2030 and the District of Columbia have provided clear examples. To support advances in the industry, the Commonwealth should consider allowing one or more deep green certifications that achieve ZE or ZER levels of energy performance to be alternative compliance paths for any optional ZE code. Passive House+, ILFI's Zero Energy Certification, LEED ZERO and the Living Building Challenge are four clear examples of alternative compliance paths. The Massachusetts Department of Energy Resources (DOER) should have the ability to name additional standards as needed, after sufficient review.

COMMERCIAL ACTION: Require annual benchmarking and disclosure of energy performance for all commercial and multifamily buildings, starting with the largest buildings, including public display of energy performance certificates/scores.

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? Yes

The types of transparency policy this action represents have evolved since 2009; public disclosure has occurred most commonly as a benchmarking and online transparency requirement, leveraging ENERGY STAR Portfolio Manager. Boston and Cambridge already have such laws at the local level. Some jurisdictions, including New York City, Chicago, and Austin, Texas, require the display of energy certificates or ratings in a public area, but these requirements are linked to a larger benchmarking program. Therefore, we propose a similar revision of this action for the Commonwealth, or for municipal governments other than Boston and Cambridge. California provides a good model of how to implement statewide energy disclosure when some cities have already moved ahead; so long as the city regulation equals or exceeds the statewide requirements, compliance with the city policy is sufficient for compliance with the state policy.

COMMERCIAL ACTION: Establish Building Energy Performance Standards for large existing commercial and multifamily buildings, based on leading models from other jurisdictions and specific research to be conducted in MA.

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? Yes

Greater specificity will aid adoption and can build on developments elsewhere in the nation. Several jurisdictions, including Washington State, New York City and Washington, D.C., have passed legislation establishing Building Energy Performance Standards (BEPS) for all larger commercial and multifamily buildings.[8] A similar action could be undertaken by the Commonwealth, or at the city level by Boston or other leading cities. Because of the highly varied building stock and local conditions, a one-size-fits-all BEPS is unlikely to be successful. Therefore, the appropriate next step is to track this issue, and study what standards are most appropriate to buildings in the cities or state.

Other Commercial Actions:

Slight revisions are also proposed for actions C5 and C11; see Appendix C for details.

Policy Recommendations for Residential Buildings

RESIDENTIAL ACTION: Require home energy scoring, and scorecard disclosure in conjunction with specific transactions, inspections, or renovations, including at time of sale or rent.

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? No

Due to privacy concerns, annual reporting of all individual residential home or unit energy use is not advisable, nor likely to have much market impact. Once limited to disclosures around transactions and improvements, these can be merged into one action.

Governor Baker proposed home energy scorecard legislation in 2018 that would require energy audits with a scorecard prior to listing for sale; stakeholders could advocate for this legislation. Research shows that to make a meaningful difference in market behavior, scorecards must be available to prospective buyers early in the home search process, when multiple home options are being evaluated.[9] If the energy scorecard is simply another disclosure document like lead paint disclosures, it will be ignored and have little to no market impact. The most effective path would be to add this information directly into the Multiple Listing Service (MLS). However, this action could prove challenging to achieve due to potential for realtor opposition—even though disclosing energy performance has been shown to increase home sale value and decrease time on the market.[10]

[8] District of Columbia (2018). "Clean Energy DC: The District of Columbia Climate and Energy Action Plan," August 2018. https://doee.dc.gov/sites/default/files/dc/sites/ddoe/page_content/attachments/Clean%20Energy%20DC%20-%20Full%20Report.pdf

[9] Houston, Megan et. al (2016). "Catalysing Efficiency: Unlocking Energy Information and Value in Apartment Buildings," Institute for Market Transformation. Accessed October 15, 2018. https://www.imt.org/wp-content/uploads/2018/02/IMT_CatalyzingEfficiency_2016.pdf

[10] Elevate Energy (2015). "Chicago Homes that Disclose Energy Costs Have a Higher Close Rate." April 21, 2015. Accessed October 15, 2018. https://www.elevateenergy.org/energy-cost-disclosure-higher-close-rate/

Enabling disclosure at point of sale also has the potential to help homebuyers finance improvements when they are signing mortgage agreements. The most advantageous time to finance solar and other energy improvements is during point-of-sale as those systems can be cash-flow positive from day one if bundled into a primary mortgage. State and city policymakers should work with the banking and real estate industry to explore options for financing projects at point-of-sale. It can be a win-win-win situation—banks have larger loans, real estate professionals can make higher fees on the transaction, and homeowners can install valuable equipment like solar, be cash flow positive from day one, and increase the value of their properties. See R9 for more discussion on this topic.

RESIDENTIAL ACTION: **Work with loan providers to bundle solar installation costs, and deep energy retrofit costs, in mortgages at time of sale, and investigate mortgage buy-down programs for current homeowners.**

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? No

Massachusetts has a "Home MVP" offering for retrofit financing of up to $25,000 at 0% APR. Such a program is useful, but this action is about mortgage write-downs, and further language may help clarify the issue. The time of sale and mortgage is a powerful point of intervention for homes—relative to the overall mortgage, the cost of solar installation and deep energy retrofits is comparatively small. However, once a sale has been completed, new homeowners are often unwilling to take on additional projects and financing. Bundling home upgrades and renewable energy at time of sale, and writing down any increased mortgage costs, provides a powerful and cost-effective incentive.

Other Residential Actions:

Slight revisions are also proposed for actions R1, R5, R6, and R8; see Appendix C for details.

Policy Recommendations for Commonwealth and Municipal Buildings

GOVERNMENT ACTION: **The Commonwealth government and municipal governments should develop point-based incentive programs/performance based procurement protocols for public and publicly financed projects that offer incentives for Passive House+, ZE, and Living Building Challenge projects. If successful, educate private sector on procurement models for expansion to private market.**

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? No

Municipalities and the Commonwealth should utilize a performance-based procurement approach for public building projects, creating a structure in RFPs for awarding teams that meet higher levels of energy performance, including Passive House+, ZE, positive energy, and Living Building Challenge certification. If designed properly, a performance-based procurement approach leads to delivery of high performance without additional impact on project budgets. Including this in the RFPs will inspire bidding teams to deliver deeper performance at low cost, rather than simply adding in higher costs to meet some requirement. If this model is successful, the Commonwealth should educate and promote it to potential private sector partners.

GOVERNMENT ACTION: **Study the success of the Renew Boston Trust model and explore expansion to other cities or statewide.**

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? No

As discussed in the commercial policy section, the Renew Boston Trust (RBT) is an innovative new model for financing energy efficiency projects. While the Trust is relevant to commercial buildings, the model is being used to fund municipal energy efficiency retrofits. The City of Boston is currently engaged in a $10 million pilot across 37 facilities, using the RBT to self-finance upgrades by monetizing future energy savings.[11]

[11] Swing, B (2017). "Energy Transformation in Cities." Advanced Energy Group. Accessed November 1, 2018. https://static1.squarespace.com/static/570b03987c65e49ce6174883/t/59c418f52278e77eb860cf25/1506023673230/City+of+Boston+AEG+Sep+2017.pdf

Other municipalities should study the success of the pilot and investigate creating a similar structure. The state could also set up a similar model to RBT and make it available to smaller municipal building portfolio owners.

STATE ACTION: Require third-party retro-commissioning of all state buildings on a regular interval, no less than once every 10 years.

LEVEL: State and/or City

LEGISLATIVE CHANGE NEEDED? No

The Massachusetts LEED-Plus standard requires third-party commissioning for all new construction, and new state buildings are conducting third-party commissioning for construction projects. However, retro-commissioning should also be addressed. Retro-commissioning is a systematic process that evaluates and optimizes the existing base building systems (including the HVAC systems, electrical and lighting systems, and building envelope) to ensure that they are running properly. Typical retro-commissioning measures include recalibrating sensors and controls, and cleaning and repairing existing equipment. Various studies have identified retro-commissioning as one of the most cost-effective procedures to increase the energy efficiency of existing buildings. However, over time, much operational efficiency will be lost, so retro-commissioning should be repeated on regular intervals to be effective. Municipal governments can also undertake this action for their own buildings.

Policy Recommendations for Technology, Workforce, and Education

ACTION: In 2019, work with the Northeast Energy Efficiency Partnerships (NEEP), the National Association of State Energy Officials (NASEO), and the legislature to adopt new energy efficiency standards for new types of appliances not covered under federal preemption laws.

LEVEL: State

LEGISLATIVE CHANGE NEEDED? Yes

This action calls for the promulgation of state-specific efficiency standards for appliances. Appliance standard updates have been considered by the legislature, but not adopted. Many potential federal standards were evaluated under the prior Federal Administration, but not approved by the current Administration. Therefore, there is currently an excellent opportunity to advance significant new appliance standards at the state level that have not been preempted, with minimal technical effort or cost. NEEP, NASEO, and the Institute for Market Transformation have been working with states to advocate for stronger state appliance standards and can support this effort, which should be undertaken before 2020 for maximum effect.

Further Research

Embodied Carbon

Though this study focused primarily on zero energy buildings, it is also important that policymakers and building project teams consider the embodied carbon in building materials when they are promoting ZE policies and programs and designing ZE projects. In some cases, it can take many years for even a super-efficient and renewably powered zero energy building to "make up" for the embodied carbon in the materials to achieve true carbon neutrality, in addition to the other environmental impacts of building construction.

All buildings result in some negative environmental impacts throughout their life cycles, even those built to the highest green building standards. The manufacturing of building materials involves extraction of raw materials, transportation of those materials to manufacturing facilities, and energy consumption during production (as well as pollution outputs). Materials are transported to sites during construction, and construction equipment uses energy to install the materials (while also generating waste in the process). During operation, buildings consume energy and require additional materials for equipment replacements and maintenance. And finally, end-of-life for buildings involves deconstruction, demolition, and disposal of materials. While zero energy buildings have an environmental impact in all of these phases, they are most successful in reducing impact in the operations part of the building's life.

New research and tools have been developed to analyze these embodied environmental impacts and quantify them using life-cycle analysis in an effort to provide information that will enable project teams to minimize the externality impacts of building design and construction. The Carbon Leadership Forum, housed at the University of Washington, has put together a practice guide and technical guidance for the life-cycle assessment of buildings (www.carbonleadershipforum.org/lca-practice-guide/). The National Institute for Standards and Technology (NIST) has software called Building for Environmental and Economic Sustainability (BEES), available at www.nist.gov/services-resources/software/bees. The Athena Sustainable Materials Institute has an EcoCalculator (www.athenasmi.org/our-software-data/ecocalculator/) as well as other tools. SimaPro has LCA software: simapro.com. Autocase has developed an automated triple bottom line analysis tool: autocase.com. Tally has a plug-in for Revit: choosetally.com. There are other life-cycle analysis tools available as well, many of which can be found on the Carbon Leadership Forum website: carbonleadershipforum.org/lca-practice-guide/practice-guide-resources/.

City-Specific Implementation Plans

Many of the policy recommendations outlined above can be undertaken at the city level. However, every city is different and the set of policies that are appropriate will vary based on the city's size, building stock, staff capacity, and other factors. A model like the Renew Boston Trust or a Building Energy Performance Standard, for example, will be most effective in larger jurisdictions with significant commercial building stock and good governmental staff capacity. A small town with mostly single-family housing stock, in contrast, would find much more impact from the residential strategies outlined than the commercial ones. Municipalities seeking to increase their stock of ZE buildings should review strategies and develop a city-specific implementation plan.

ALL BUILDINGS RESULT IN SOME NEGATIVE ENVIRONMENTAL IMPACTS THROUGHOUT THEIR LIFE CYCLES, EVEN THOSE BUILT TO THE HIGHEST GREEN BUILDING STANDARDS. THE MANUFACTURING OF BUILDING MATERIALS INVOLVES EXTRACTION OF RAW MATERIALS, TRANSPORTATION OF THOSE MATERIALS TO MANUFACTURING FACILITIES, AND ENERGY CONSUMPTION DURING PRODUCTION (AS WELL AS POLLUTION OUTPUTS).

Conclusions

The broad availability of low-energy products and systems, growing availability of experienced service providers, and demand for better building performance are bringing down the costs for zero energy buildings and driving practices into the mainstream.

Project developers need to set zero energy goals early in the process to keep costs in control. For example, developers that want a 60% glazed building to be zero energy know that it is important to spend money in better glazing and systems to meet their goals. Teams are beginning to look beyond the first costs, if any, of constructing zero energy buildings to realize operational benefits, improved occupant comfort and performance, better return on investments (ROI), and alignment with corporate values. A life-cycle cost assessment includes the value of operational savings, reduced maintenance, and better market performance with first cost considerations to more completely determine potential benefits and financial ROI. Just as municipalities learned with LED streetlights that first cost premiums were quickly recouped by reduced maintenance, energy savings pay an ongoing dividend.

Building energy performance, long the byproduct of other building design and engineering decisions, should be a planned outcome established at the initiation of a project and fully integrated into the planning process. Emerging is a new generation of low-energy buildings with renewable energy sources that annually achieve zero and even positive energy performance.

Expanding the development of zero energy buildings is an essential action for meeting carbon reduction goals, increasing climate resiliency, and achieving energy security across the Commonwealth.

ZE BUILDINGS ARE POSSIBLE TODAY IN MASSACHUSETTS AT NO ADDED FIRST COST. IN ADDITION, WHEN PERFORMANCE IS ASSESSED ACROSS THE BUILDING LIFE CYCLE, ZE BUILDINGS ARE THE CLEAR WINNERS. WE MUST CHANGE THE PERCEPTION THAT THESE BUILDINGS COST MORE AND BREAK DOWN THE BARRIERS. THIS REPORT IS A STEP IN THAT DIRECTION.

Photo credit: iStock/Rocky89

Appendix A: Modeling Data

Case Study Results

TABLE 9

Case Study Results

Project	Envelope	Lighting/Plug Loads	HVAC	DHW
King Open / Cambridge St Upper School & Community Complex	High Insulation (Walls: U-0.044, Roof: 0.022), Air Tightness, High Performance Glazing (U-0.3-0.49, SHGC-0.37, WWR 42%)	LED Lights (0.29 W/sf), Daylighting, Occupancy Sensors, Plug Load Controls	Geothermal WWHP, DOAS w/ Displacement Ventilation, Heat Recovery Ventilation, Radiant Heating/Cooling Panels, Active Chilled Beams	Ground Source Heat Pump with Supplementary Solar Thermal System
Bristol Community College John J. Sbrega Health and Science Building	High Insulation (Metal Framed Wall: U-0.049, Concrete Wall: 0.079, Roof: U-0.045), High Performance Glazing (U-0.037, SHGC-0.25, 22% WWR)	LED Lighting (0.58 W/sf), Occupancy Sensors, Daylighting, 2 W/sf conference room plug load, 1.5 W/sf office plug load	DOAS w/ Heat Recovery, Fan Coils, 150 Ton Ground Source Heat Pump, 120 Ton Air Source Heat Pump, Lab Flow Controls, Natural Ventilation in Atrium	Solar Thermal w/ Natural Gas Backup
RW Kern Center	High Insulation (Metal Framed Wall: R-35, Concrete Wall: R-20, Roof: R-60), High Performance Glazing (U-0.13, SHGC-0.34, 42% WWR), Air Tightness (0.34 ACH @ 50 Pa)	LED Lighting (0.52 W/sf), Daylighting, Occupancy Sensors, Automated Exterior Shades	DOAS w/ Heat Recovery, Air Source Heat Pump w/ VRF (COP 3.4)	Electric Resistance Water Heaters
246 Norwell Street	High Insulation (Walls: U-0.021, Roof: U-0.012), Air Tightness (.05 cfm/sf façade), High Performance Glazing (U-0.25, SHGC-0.42)	Did not receive data	Heat Recovery Ventilators (89% eff), Heat Pump Space Heating	Heat Pump DHW (6.6 gal/person/day)
E+ Marcella Street	High Insulation (Wall: R-40, Roof: R-62), High Performance Glazing (U-0.139, low-E, triple-pane), Air Tightness (0.57 ACH @ 50 Pa)	Daylighting, LED and CFL Lighting, EnergyStar Equipment	Passive Solar Heating, Natural Ventilation, ERV (75% eff), Mini-Split Heat Pumps	Solar Thermal (2.4 Energy Factor), 80 gal Storage Tank, Efficient Fixtures (1.5 gal shower head & faucets)
The Distillery	High Insulation (Walls: R-27, Roof: R-60), High Performance Glazing (U-0.134, SHGC-0.4)	Daylighting, CFL Lighting, EnergyStar Equipment	Mini-split Air Source Heat Pumps Heat Recovery Ventilators (HRVs) at 92% Heat R ecovery Efficiency	High Efficiency (94%) Condensing Gas Water Heaters and (qty-3) 119 Gallon Insulated Storage Tanks Low-Flow Fixtures (0.5 GPM Lavatories, 1.28 GPF toilets, 1.5 -2.0 GPM Showerheads & 1.5 GPM Kitchen Sink)

Energy Modeling Inputs

TABLE 10

Baseline Envelope Inputs

Parameter	K-12 School	Mixed Use —Retail	Mixed Use —Res	Large Office, New	Large Office, Existing	Small Multifamily	Single-family Res
Walls	Metal Framed U-0.050	Metal Framed U-0.050	Metal Framed U-0.050	Metal Framed U-0.050	Mass Wall U-0.15	Wood Frame U-0.05	Wood Frame U-0.05
Roof	U-0.037	U-0.037	U-0.037	U-0.037	U-0.076	Wood Frame U-0.02	Wood Frame U-0.02
Glazing U-value	U-0.42	U-0.42	U-0.42	U-0.42	U-0.62	U-0.38	U-0.38
Glazing SHGC	0.40	0.40	0.40	0.40	0.45	0.40	0.40
Shading	None	None	None	None	None	None	None
Window-Wall Ratio (WWR)	35%	10.5%	35%	55%	45%	17%	15%
Window Frames	Metal	Metal	Metal	Metal	Metal	Wood	Wood
Infiltration	0.0448 cfm/ SF wall	0.0448 cfm/ SF wall	0.0448 cfm/ SF wall	0.0448 cfm/ SF wall	0.0448 cfm/ SF wall	3 ACH50	3 ACH50

TABLE 11

Proposed Envelope Inputs

Parameter	K-12 School	Mixed Use —Retail	Mixed Use —Res	Large Office, New	Large Office, Existing	Small Multifamily	Single-family Res
Walls	Metal Framed U-0.044	Metal Framed U-0.044	Metal Framed U-0.044	Metal Framed U-0.044	Mass Wall U-0.15	Wood Frame U-0.025	Wood Frame U-0.025
Roof	U-0.022	U-0.022	U-0.022	U-0.022	R-13 U-0.076	Wood Frame U-0.016	Wood Frame U-0.016
Glazing U-value	U-0.3	U-0.3	U-0.3	U-0.3	U-0.62	U-0.3	U-0.3
Glazing SHGC	0.25	0.25	0.25	0.25	0.45	0.25	0.25
Shading	None	1' Fixed Overhangs	1' Fixed Overhangs	None	None	1' Fixed Overhangs	1' Fixed Overhangs
Window-Wall Ratio (WWR)	35%	10.5%	35%	55%	45%	17%	15%
Window Frames	Metal Ther-mally Broken	Metal Ther-mally Broken	Metal Ther-mally Broken	Metal Ther-mally Broken	Metal	Wood	Wood
Infiltration	0.57 ACH50	0.57 ACH50	0.57 ACH50	0.57 ACH50	0.57 ACH50	0.57 ACH50	0.57 ACH50

TABLE 12

Baseline HVAC & DHW Inputs

Parameter	**K-12 School**	**Mixed Use —Retail**	**Mixed Use —Res**	**Large Office, New**	**Large Office, Existing**	**Small Multifamily**	**Single-family Res**
Primary HVAC System Type	PVAV-DX Cooling/ HW Heating (Sys 4)	(8) PSZ-AC-DX Cooling, Gas Heating (Sys 11)	(8) PSZ-AC-DX Cooling, Gas Heating (Sys 11)	PVAV-DX Cooling/ HW Heating (Sys 4)	Pneumatic VAV- CHW Cooling, HW Heating	PTAC-DX Cooling, Gas Heating (Sys 10)	PTAC-DX Cooling, Gas Heating (Sys 10)
Fan Power (in)	CFM* 0.0013+1.15	CFM* 0.00094+1.15	CFM* 0.00094+1.15	CFM* 0.0013+1.15	CFM* 0.0013+1.15	CFM* 0.00094+1.15	CFM* 0.00094+1.15
Fan/Motor Efficiency (%)	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%
Economizer	Diff Dry Bulb	Diff Dry Bulb	Diff Dry Bulb	Diff Dry Blub	Non-functioning	None	None
Ventilation System	Integrated with cooling	Integrated with cooling	Integrated with cooling	Integrated with cooling	Integrated with cooling	Integrated with cooling	Integrated with cooling
Cooling Equip-ment Efficiency	3.57 COP	3.85 COP	3.65 COP	6.17 COP	4.0 COP	3.1 COP	3.1 COP
Heating Equip-ment Efficiency	80% (Gas-Fired Boiler Efficiency)	80% (Gas-Fired Boiler Efficiency)	80% (Gas-Fired Boiler Efficiency)	80% (Gas-Fired Boiler Efficiency)	74% (Gas-Fired Boiler Efficiency)	80% (Gas-Fired Efficiency)	80% (Gas-Fired Efficiency)
DHW System	200 Gal Gas Water Heater 80% Eff	(8) 40 Gal Electric	(1) 1150 Gal Electric	300 Gal Gas Water Heater 81% Eff	200 Gal Gas Water Heater 78% Eff	Gas Water Heater 80% Eff	Gas Water Heater 80% Eff
DHW Peak Flow Rate	6.96 GPM	0.10 GPM	0.56 GPM	7.48 GPM	7.48 GPM	0.11 GPM	0.02 GPM

TABLE 13

Proposed HVAC & DHW Inputs

Parameter	K-12 School	Mixed Use —Retail	Mixed Use —Res	Large Office, New	Large Office, Existing	Small Multifamily	Single-family Res
Primary HVAC System Type	DOAS w/ 75% HR, VRF	DOAS w/ 75% HR, Fan Coils	MiniSplit Heat Pumps, HRV (75% eff)	DOAS w/ 75% HR, Fan Coils (Chilled Beams)	DOAS w/ 75% HR, Fan Coils	MiniSplit HP, HRV (75% eff)	MiniSplit HP, HRV (75% eff)
Fan Power (in)	5.0 in	5.0 in	5.0 in	5.0 in	5.0 in	4.0 in	4.0 in
Fan/Motor Efficiency (%)	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%	75%/90%
Economizer	None	None	None	None	None	None	None
Ventilation System	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)	Dedicated air system with heat recovery (75% eff)
Cooling Equipment Efficiency	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)	GSHP (avg 3.57 COP)	avg. 2.8 COP	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)
Heating Equipment Efficiency	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)	GSHP (avg 3.57 COP)	avg. 2.8 COP	ASHP (avg 3.57 COP)	ASHP (avg 3.57 COP)
DHW System	Heat Pump	Heat Pump	Heat Pump	Heat Pump	Heat Pump	Heat Pump	Heat Pump
DHW Peak Flow Rate	5.57 GPM	0.08 GPM	0.45 GPM	5.98 GPM	5.98 GPM	0.09 GPM	0.01 GPM

TABLE 14

Ventilation Rates

Building Type	Space Type	OA Rate per person	OA Rate per SF [CFM/SF]	Exhaust [CFM/SF]
K-12 school	Cafeteria	7.5	0.18	-
	Classroom	10	0.12	-
	Corridor	-	0.06	-
	Gym	20	0.18	-
	Kitchen	7.5	0.18	0.7
	Lobby	5	0.06	-
	Mechanical	-	-	-
	Office	5	0.06	-
	Restroom	-	-	50 cfm/WC
Mixed use	Retail	7.50	0.12	-
	Residential Apartment	15.00	-	20 cfm/restroom
	Residential Corridor	-	0.06	-
	Residential Office	5	0.06	-
New office	Corridor	-	0.06	-
	Large Office	5	0.06	-
Existing office	Large Office	5	0.06	-
Small Multifamily	Living Unit	15.00	-	20 cfm/restroom
Single-Family Res	Living Unit	15.00	-	20 cfm/restroom

TABLE 15

Internal Loads

Building Type	Space Type	OA Rate per person	OA Rate per SF [CFM/SF]	Exhaust [CFM/SF]	Baseline Lighting Load [W/SF]	Proposed Lighting Load [W/SF]
K-12 school	Cafeteria	0.100	0.50	-	0.65	0.40
	Classroom	0.025	1.00	-	1.24	0.70
	Corridor	-	0.20	-	0.66	0.60
	Gym	0.007	0.50	-	0.72	0.50
	Kitchen	0.020	1.50	17.54	1.21	0.95
	Lobby	0.030	0.50	-	0.9	0.85
	Mechanical	-	3.00	-	0.95	0.40
	Office	0.005	1.50	-	1.11	0.70
	Restroom	-	0.20	-	0.98	0.65
Mixed use	Retail	0.015	1.00	-	1.59	1.00
	Residential Apartment	2 for first bed-room + 1 for each additional bedroom	0.50	0.68	0.38	0.38
	Residential Corridor	-	0.20	-	0.66	0.6
	Residential Office	1 person	1.50	-	1.11	0.7
New office	Corridor	-	0.20	-	0.66	0.55
	Large Office	0.005	1.50	-	0.98	0.55
Existing office	Large Office	0.005	1.50	-	0.98	0.65
Small Multifamily	Living Unit	2 for first bed-room + 1 for each additional bedroom	0.50	0.68	0.38	0.38
Single-Family Res	Living Unit	2 for first bed-room + 1 for each additional bedroom	0.50	0.68	0.38	0.38

Appendix B: LCCA Results for Deep Energy Efficiency + Power-Purchase Agreements

In the main report, the base case LCCA models assume an increase first cost of 5% for deep energy efficiency and that the on-site Solar PV is being installed as part of the construction project and paid for by the building owner. However, the building owner could instead opt to execute a PPA for the on-site solar. This appendix presents the results for all five building types if on-site solar is provided via a PPA, analogous to how the off-site renewables are procured.

Because the per-kWh incentives are stronger for rooftop PV in Massachusetts, we assume that the rate for the on-site solar PPA is $0.08/kWh, based on regional PPA rates from Lawrence Berkeley National Laboratory (LBNL). For building types where all energy needs can be met with on-site PV, this becomes the PPA rate; for other scenarios, the remainder of the electricity is supplied via an off-site PPA with a rate of $0.11/kWh. We also ran a sensitivity analysis for a $0.5/kWh on-site solar PPA rate. There are no first costs to the owner for the PPA. As summarized in Table 16, the PPA option for on-site solar appears to perform marginally better for the Existing Office and Small Residential Case studies. A PPA at $0.05/kWh is also better for K-12 schools where the Investment Tax Credit cannot be used, as is the case with government and nonprofit schools. Eliminating the ITC savings drops the NPV cost savings for the K-12 school ownership scenario to $15/sf, and lengthens the payback period to 17 years. Specific results follow.

TABLE 16

Comparison of Paybacks for Owning the On-Site Solar vs. Using a PPA*

	With Ownership of On-Site Solar		**With PPA for On-Site Solar @ $0.08/kWh**		**With PPA for On-Site Solar @ $0.05/kWh**	
	Breakeven Year	$/sf savings	Breakeven Year	$/sf savings	Breakeven Year	$/sf savings
Existing Office	6	24	6	25	5	26
New Office	15	2	20	-8	19	-7
K-12 School	15	20	16	11	13	18
Mixed Use	13	23	14	13	13	18
Single Family	15	12	22	0	18	3
Small Residential	19	5	18	6	15	10

*Assumes 5% cost premium for ZER

EXISTING OFFICE BUILDINGS

The existing office building modelling shows a quick breakeven point at year 5 and cost savings of 10% over the baseline buildings in 30 years.*

10%	Year 5
$ SAVINGS	BREAKEVEN

EXISTING OFFICE CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 45

Cumulative Annual Expenditure Comparison—Existing Office (On-Site PPA scenario) ($/sf)

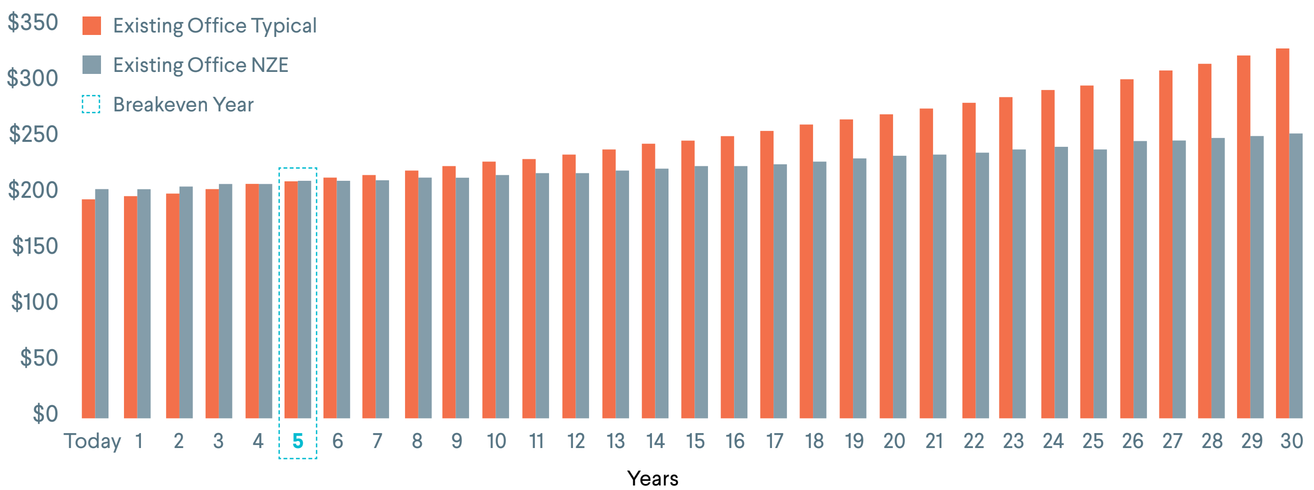
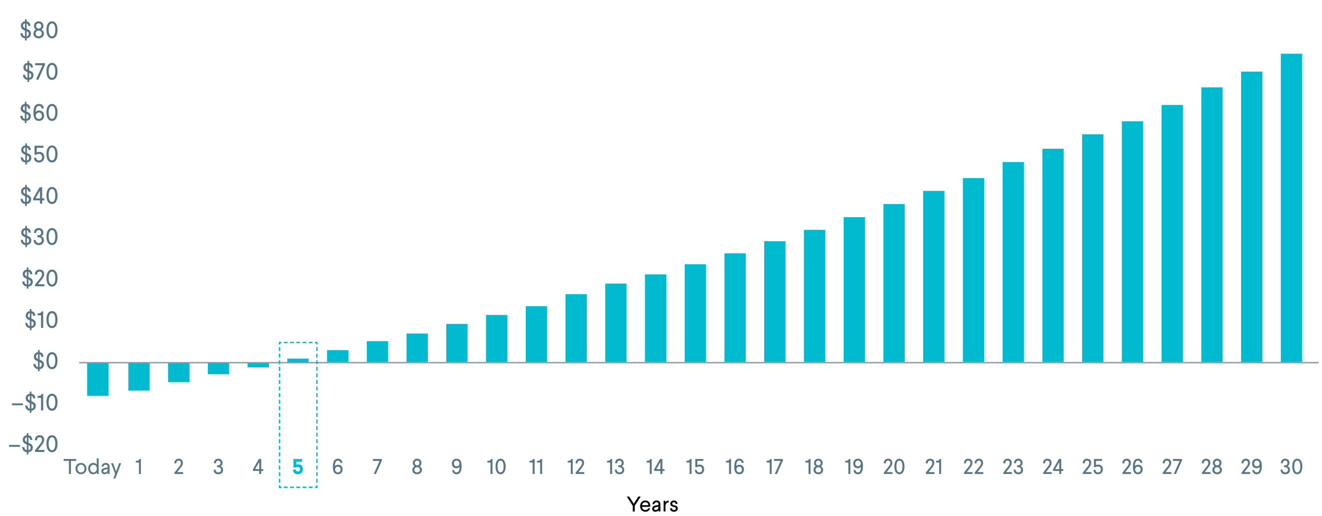


FIGURE 46

Cumulative Annual Cost Difference Between ZE and Typical—Existing Office (On-Site PPA scenario) ($/sf)



* Assumes 5% cost premium for ZER

NEW OFFICE BUILDINGS

New office buildings show a breakeven point at 19 years. Considering the total cost of building a new office building, putting the on-site solar in a PPA is not cost effective.*

-1.5%	Year 19
$ SAVINGS	BREAKEVEN

NEW OFFICE CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 47

Cumulative Annual Expenditure Comparison—New Office (On-Site PPA scenario) ($/sf)

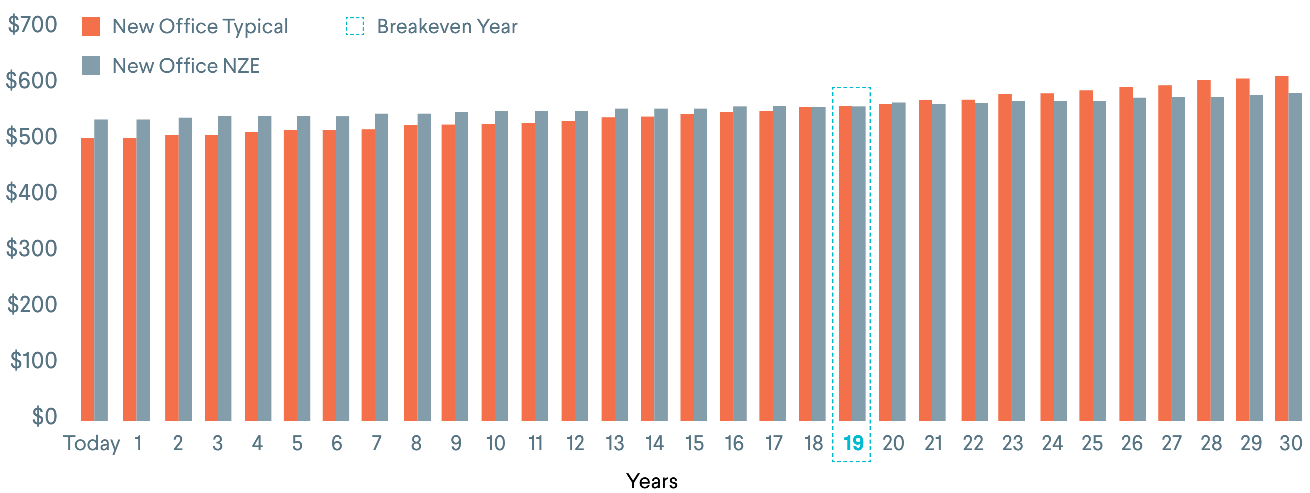
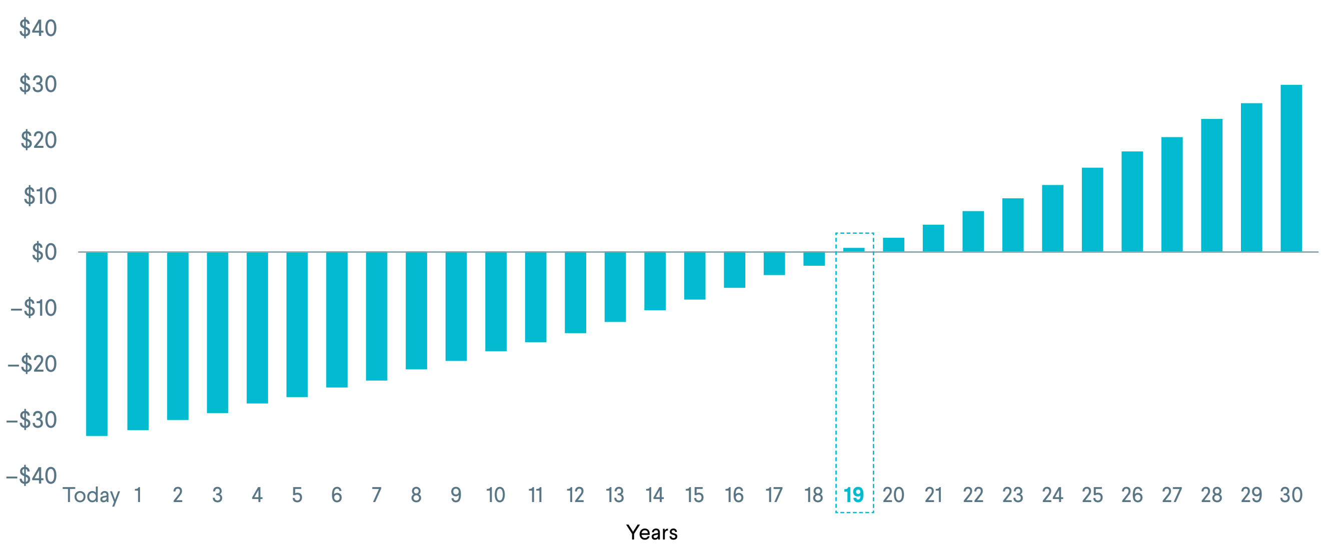


FIGURE 48

Cumulative Annual Cost Difference Between ZE and Typical—New Office (On-Site PPA scenario) ($/sf)



* Assumes 5% cost premium for ZER

K–12 SCHOOL BUILDINGS

K-12 School buildings show a cost savings of 2.7% and a payback period of 15 years.*

2.7%	Year 15
$ SAVINGS	BREAKEVEN

K–12 CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 49

Cumulative Annual Expenditure Comparison—K-12 (On-Site PPA scenario) ($/sf)

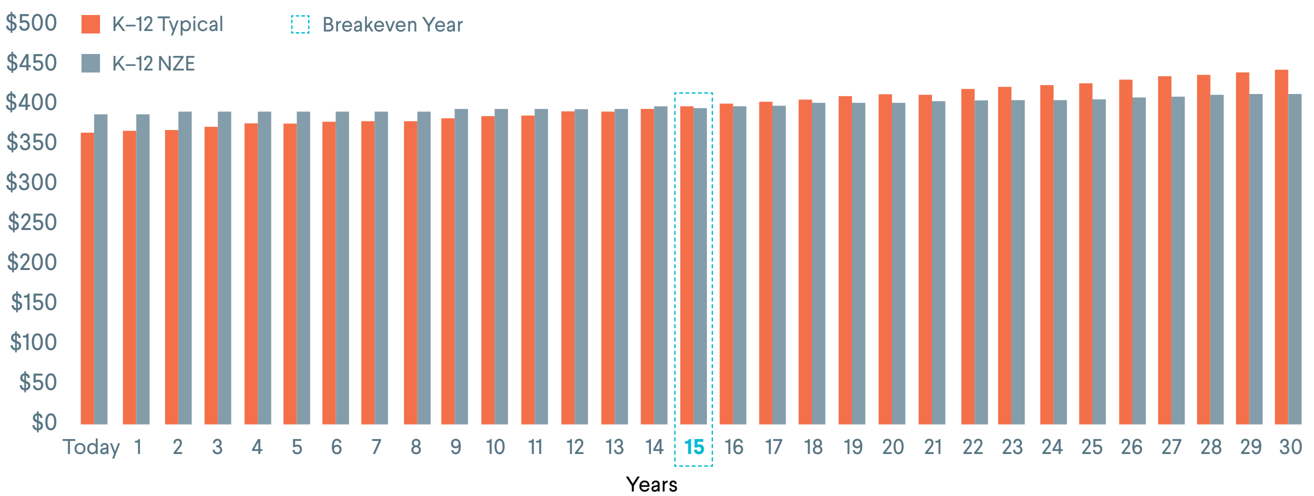
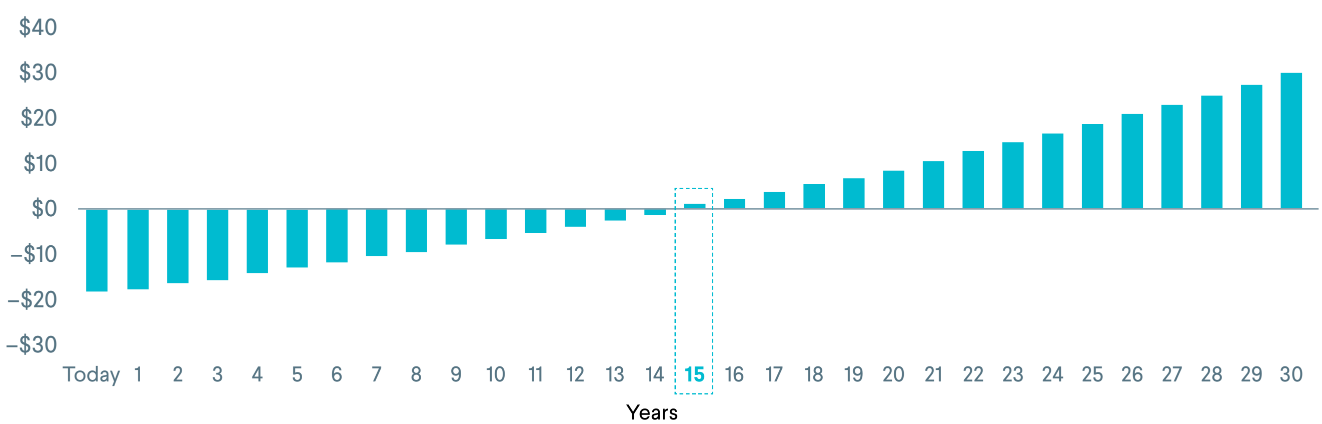


FIGURE 50

Cumulative Annual Cost Difference Between ZE and Typical—K-12 (On-Site PPA scenario) ($/sf)



* Assumes 5% cost premium for ZER

MIXED-USE BUILDINGS

Mixed-use buildings show 3.8% cost savings over 30 years with a payback period of 13 years.*

3.8%	Year 13
$ SAVINGS	BREAKEVEN

MIXED-USE CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 51

Cumulative Annual Expenditure Comparison—Mixed Use (On-Site PPA scenario) ($/sf)

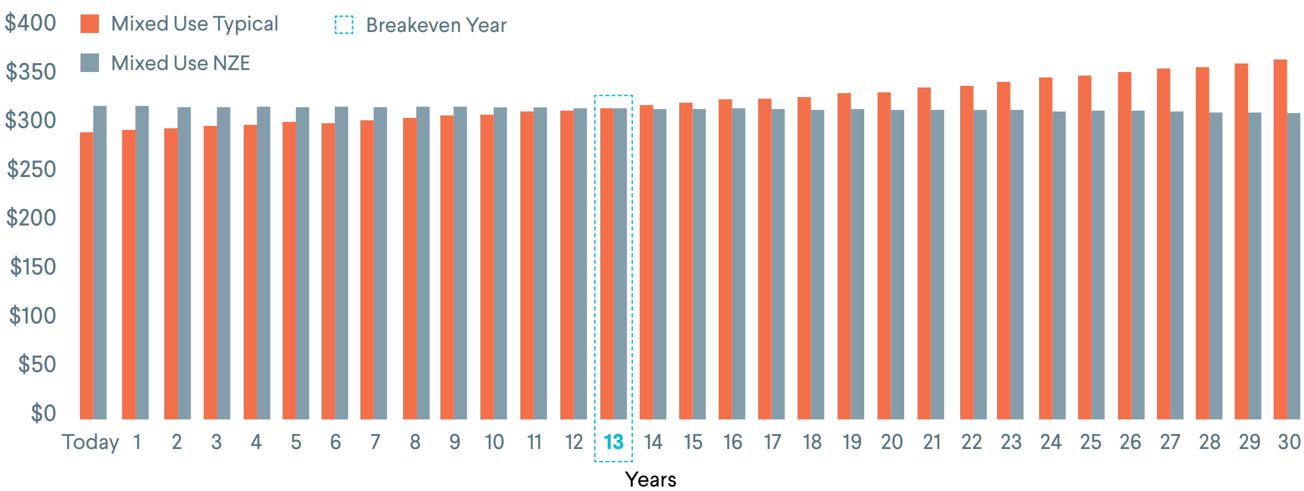
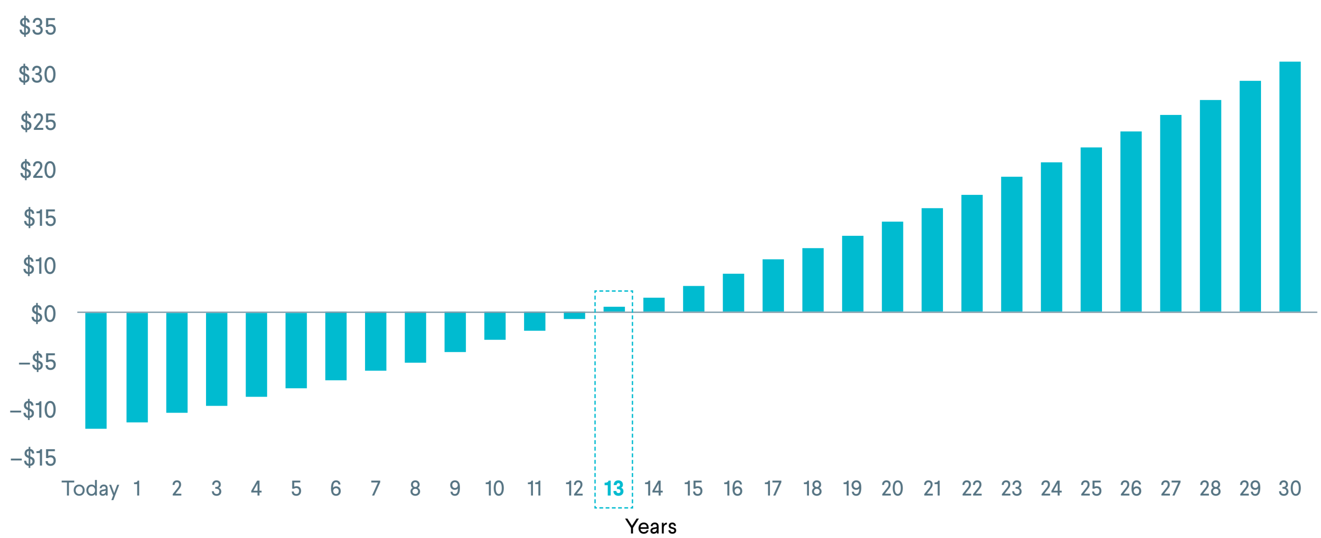


FIGURE 52

Cumulative Annual Cost Difference Between ZE and Typical—Mixed Use (On-Site PPA scenario) ($/sf)



* Assumes 5% cost premium for ZER

SINGLE-FAMILY HOMES

Due to the size of incentives available to single-family homeowners under the SMART program, using a PPA for on-site solar PV for single-family homes is not cost effective, showing 0% cost savings over the 30-year period and a 22-year payback.*

0%	Year 22
$ SAVINGS	BREAKEVEN

SINGLE-FAMILY CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 53

Cumulative Annual Expenditure Comparison—Single Family (On-Site PPA scenario) ($/sf)

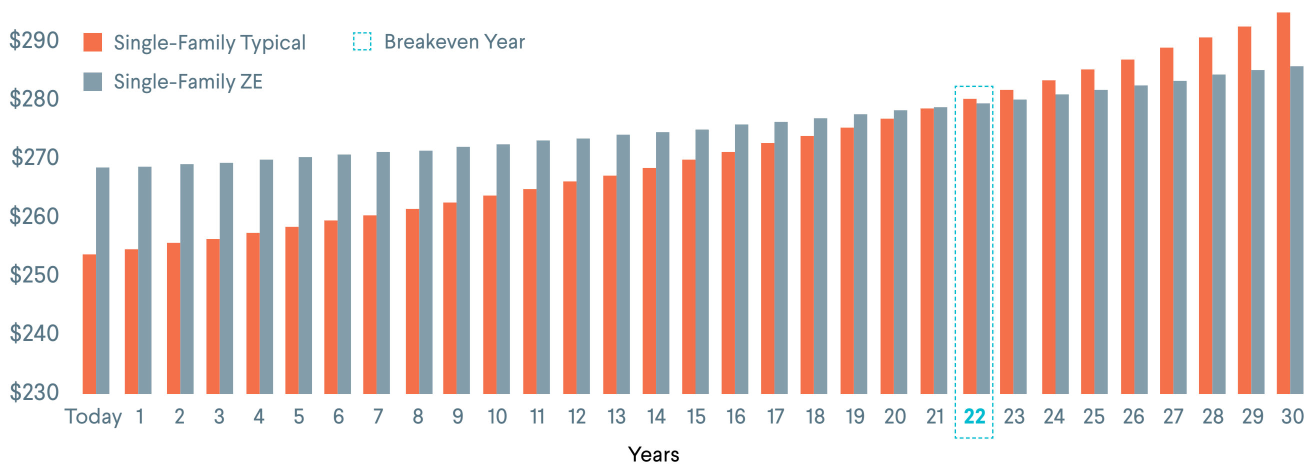
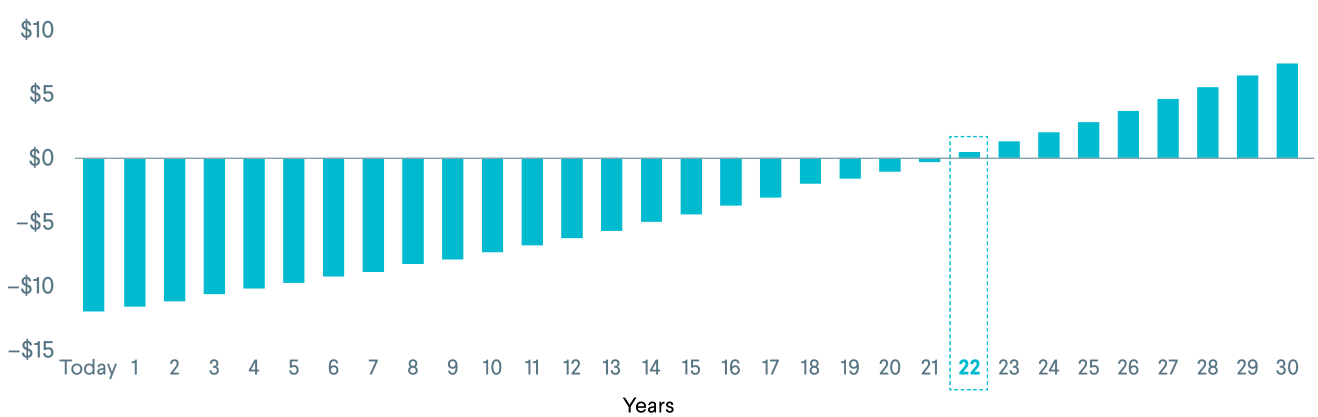


FIGURE 54

Cumulative Annual Cost Difference Between ZE and Typical—Single Family (On-Site PPA scenario) ($/sf)



* Assumes 5% cost premium for ZER

SMALL MULTIFAMILY BUILDINGS

The graphs show a cost savings of 1.6% and a payback period of 17 years for small residential buildings—this is the only building type where the PPA option for on-site solar is noticeably better.*

1.6%	Year 17
$ SAVINGS	BREAKEVEN

SMALL MULTIFAMILY CUMULATIVE ANNUAL EXPENDITURE COMPARISON

FIGURE 55

Cumulative Annual Expenditure Comparison—Small Multifamily (On-Site PPA scenario) ($/sf)

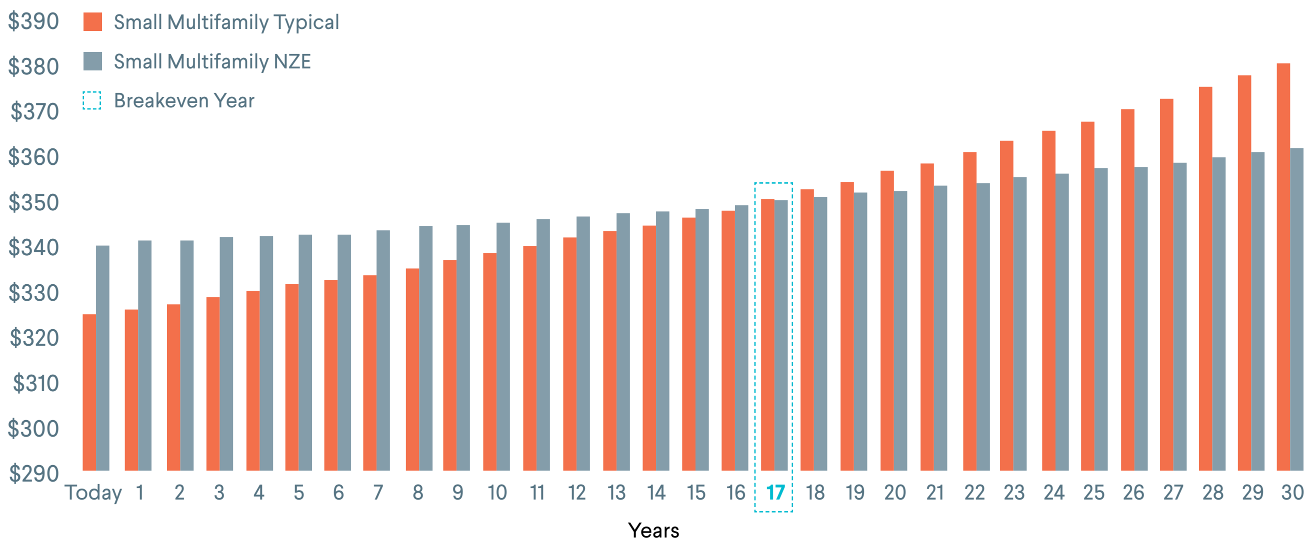
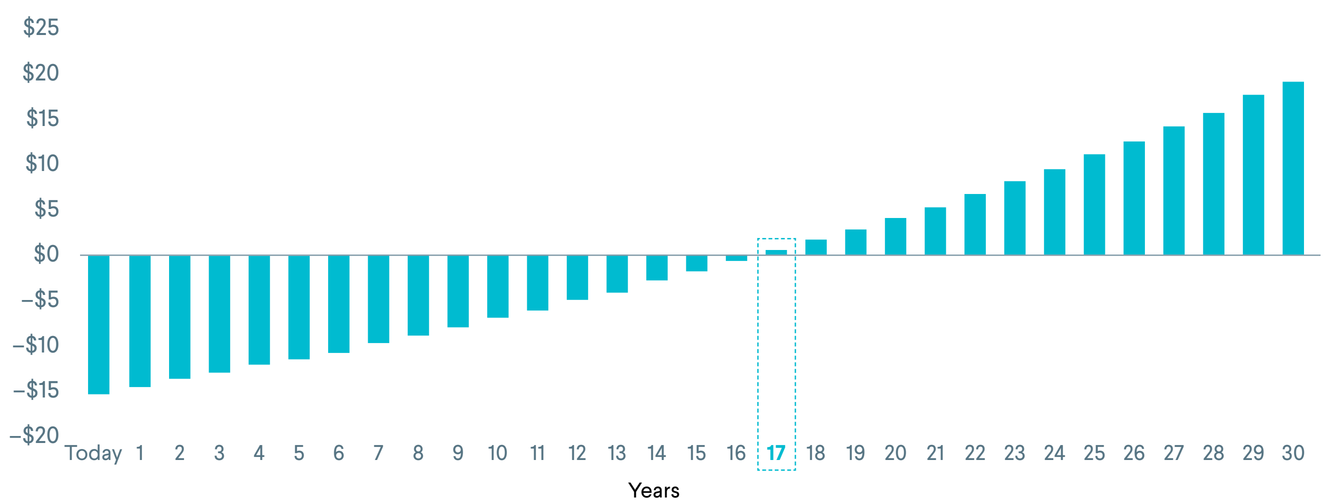


FIGURE 56

Cumulative Annual Cost Difference Between ZE and Typical—Small Multifamily (On-Site PPA Scenario) ($/sf)



* Assumes 5% cost premium for ZER

Appendix C: Policy Matrix

New Recommended Commercial Actions

	Discussion	Recommended Action	Status	Imple-mentation Level	Difficulty	Legislative Change?
Commercial Action	Massachusetts should look to examples in Connecti-cut, New York, and Rhode Island to establish a "Green Bank" that can leverage pri-vate capital to accelerate ZE building projects.	New Commercial Action: Develop Green Bank to leverage private capital for ZE projects using public dollars as seed money.	New Recom-mendation	State	**	Yes
Commercial Action	The Renew Boston Trust (RBT) model is a new financial model that uses structured finance to pro-vide private investment into energy efficiency and renewable energy proj-ects with performance guarantees.	New Commercial Action: Expand Renew Boston Trust Model to com-mercial buildings in other cities or statewide.	New Recom-mendation	State and City	**	No
Commercial Action	Green roof and solar proj-ects are sometimes seen as conflicting. This is a needless concern as there are co-benefits of inte-grating both technologies. By establishing best prac-tice guidelines for how to install solar on green roofs and removing regu-latory conflicts between these two approaches to utilizing roof space, the Commonwealth will spur development and accel-erate both solar capacity growth and storm water retention.	New Commercial Action: Develop standard for inte-grated green roof and solar projects to provide the market with regula-tory certainty.	New Recom-mendation	State and City	*	Depends of nature of existing barriers

Updates to Commercial Actions from 2009 Report (C)

2009 Report Action[12]	Discussion	Recommended Action Revision, If Applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
C1. Establish energy performance standards for new buildings and major renovations by building type.	Energy performance standards are defined in the building code, but they will need to be strengthened and linked specifically to ZE targets.	Recommended Action Revision: Create a zero energy stretch code as a compliance path to and establish date-specific targets for mandatory zero energy code in MA, and advocate for similar targets nationally.	Not Started	State	**	No
C2. Improve building code prescriptive energy requirements for new buildings and major renovations.	The building code is improved and updated every three years in line with national codes. This is an ongoing action that will require continued involvement at the national level to advocate for stronger codes, and prompt statewide adoption of new codes.	Retain action as is	In Progress	State	*	No
C3. Revise energy performance standards for new buildings and major renovations, indexed to exemplars in MA and elsewhere.	The task force set a goal of zero net-energy building standards, but DOER is also exploring other exemplar buildings and standards, including Passive House.	Recommended Action Revision: Develop zero code language modeled on language from Architecture 2030 or DC's proposed Appendix Z. Code language should allow multiple alternative compliance paths including Passive House+ and Living Building Challenge, to acknowledge and support advances in building technologies and certification programs.	Not Started	State	**	No
C4. Require "solar-readiness" for new construction and major renovations and actively promote PV installation.	Adopted with the MA 9th Edition Code in 2017.	Remove action	Complete	State	-	No
C5. Require all state-funded public school projects to adopt new state performance standards and comply with the MA-CHPS standard.	Incentives are currently provided by MSBA for MA-CHPS adherence, but requirements for state-funded projects are still needed.	Recommended Action Revision: Require all state funded school projects to achieve CHPS and initiate performance-based procurement to drive towards net zero energy.	In Progress	State	*	Yes

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Commercial Actions from 2009 Report (C)

2009 Report Action[12]	Discussion	Recommended Action	Status	Imple-mentation Level	Difficulty	Legislative Change?
C6. Require publicly displayed energy certificates for all buildings.	It may be appropriate to link this requirement, if enacted, to a statewide mandate for benchmarking of energy performance. Boston and Cambridge have local laws, and these requirements also exist at the state level in CA and WA. Several cities, including NYC and Chicago, have incorporated requirements for public display of energy certificates or scores.	Recommended Action Revision: Require annual benchmarking and disclosure of energy performance for all large commercial and multifamily buildings, including public display of energy performance certificates/scores.	Not Started	State and City	**	Yes
C7. Require electricity sub-metering for new buildings and major renovations and move toward sub-metering of all buildings.	Submetering is allowed but is optional. It could become required, by mandating it in legislation and/or the building code. When mandating submetering for existing buildings, it is best to begin with commercial spaces, due to concern around cost increases in affordable housing.	Retain action as is.	Not Started	State	***	Yes
C8. Expedite state permitting for projects that meet "stretch" standards.	An expedited or first-in-line permitting process should be created for projects meeting stretch goals. Programs that allow stretch projects to jump to the front of the line have proven easier to implement than programs that more generically talk about "expediting permits." Encourage municipalities to also implement expedited permitting for such projects.	Retain action as is	Not Started	State and City	*	No

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Commercial Actions from 2009 Report (C)

2009 Report Action[12]	Discussion	Recommended Action	Status	Imple-mentation Level	Difficulty	Legislative Change?
C9. Develop and urge the municipal adoption of model zoning that promotes "stretch" projects.	DOER's Green Communities Division works with municipalities to reduce energy use and adopt the stretch code, in order to become a "Green Community." As of July 2019, 272 communities have adopted the stretch code, totaling over ~82% of MA population. To continue the vision of this action, MA should urge municipalities to implement mandatory requirements for high performance buildings for projects that request zoning relief or variance. Model zoning that addresses concerns around set-backs, treatment of solar, any height issues, etc., should be developed and promulgated.	Retain action as is	In-Progress	State and City	*	Yes, at local level
C10. Establish energy performance standards for existing buildings by building type.	This action relates to Building Energy Performance Standards (BEPS), which could be linked to benchmarking requirements discussed in Action C6. BEPS is being actively considered in multiple cities around the U.S. The next step should be to conduct a study of what standards are most appropriate in MA.	Recommended Action Revision: Establish BEPS for large existing commercial and multifamily buildings, based on leading models from other jurisdictions and specific research to be conducted in MA.	Not Started	State and City	***	Yes
C11. Launch a competitive ZEB grant and loan program.	DOER awarded $2.9 million to 25 commercial and residential projects through the "Pathways to Zero" grant program, launched in 2014. Massachusetts is now also incentivizing Passive House construction and working with Mass Save energy efficiency programs to incentivize Passive House and ZER homes.	Work with the Mass Save programs to offer incentives for zero net energy homes and similarly energy-efficient homes.	Completed	State	*	No

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Commercial Actions from 2009 Report (C)

2009 Report Action[12]	Discussion	Recommended Action	Status	Imple-mentation Level	Difficulty	Legislative Change?
C12. Establish an investment tax credit for energy improvements.	Commercial PACE has been adopted in MA, but PACE may not be appropriate to all projects. MA should establish investment tax credits to incentivize energy projects.	Retain action as is	Not Started	State	**	Yes
C13. Expand eligi-bility for renewable energy rebates.	New SMART incentive for solar PV was implemented in fall 2018. Incentives for an array of renewable thermal technologies (e.g. air and ground heat pumps, solar thermal, biomass) were established in 2018 through expansion of the Alternative Portfolio Stan-dard (APS.)	Retain action as is	In-Progress	State	*	No
C14. Allow build-ing owners to sell metered renewable energy to tenants.	This action called for allowing building owners (or others) to sell "utility-metered renewable energy" to tenants. Effec-tively, this is "community solar." This is allowed under the new SMART program, with tenants receiving credit through the "Alternative On-Bill Credit." In this manner, a building owner could sell metered renewable solar electricity as community solar to tenants. An older building, with a single meter installed prior to July 1, 1997, can legally submeter electricity, and as such could install a solar system behind the meter and sell the generated power to tenants.	Retire Action	Completed	State	***	Yes

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Residential Actions from 2009 Report (R)

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
R1. Establish energy performance standards for new homes and major renovations based on HERS Index.	DOER worked with the Office of Public Safety, and the BBRS instituted HERS ratings as an option in base code and a requirement in stretch code. HERS ratings started at 75 in 2008 and dropped to 65 or 70 with the initial stretch code, then 55 with renewable energy trade-offs with the updated stretch energy code since 2017. As the action was to establish targets, it is complete, but the targets can and should be adjusted over time. Recommending new HERS targets is beyond the scope of this study.	Continue to increase the stringency of energy performance standards for new homes and major renovations by reducing the HERS targets.	Complete	State	*	No
R2. Develop a Massachusetts Home Energy Rating System.	The RESNET HERS rating was adopted first in MA code in 2009, and then as the ERI pathway in the International Energy Conservation Code (IECC) beginning with the IECC 2015.	Retire action.	Complete	State	-	No
R3. Require home energy ratings in conjunction with specific transactions, inspections, or renovations.	Governor Baker proposed home energy scorecard legislation in 2018, which would require energy audits with a scorecard prior to listing for sale. DOER's RCS guidelines have been updated to require scorecards with Mass Save home audits and post-improvement scorecards for renovations under Mass Save. However, legislation requiring home energy ratings is still needed. Legislation should also ensure this information is added to the Multiple Listing Service (MLS). DOER should track legislation and advocate for passage.	Require home energy scoring and scorecard disclosure in conjunction with specific transactions, inspections, or renovations, including at time of sale or rent.	Not Started	State	***	Yes
R4. Measure and provide annual energy use data in all homes.	Residential energy disclosure on an annual basis may be challenging. Including disclosure at the time of sale or rent is more feasible in the single-family context. With an adjustment to transaction time, R3 & R4 become one action.	Merge into R3	Not Started	State	***	Yes

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Residential Actions from 2009 Report (R)

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Implementation Level	Difficulty	Legislative Change?
R5. Launch a deep energy retrofit pilot demonstration program.	Mass Save implemented a deep energy retrofit (DER) pilot, followed by a partial deep energy retrofit initiative by National Grid from 2013-2015. Participation was low and costs were high in both programs. DOER established a working group in 2016 and launched the HomeMVP pilot in 2017. More recently the Mass Save program leads have proposed a renovations and additions initiative for the 2019-2021 plans.	Work with Mass Save program administrators to reinvigorate a deep energy retrofit program for single-family and small multifamily homes.	Not Started	State and City	**	No
R6. Develop a ZNE performance monitoring protocol.	A pilot monitoring protocol and program would be useful to do.	Conduct pilot study that identifies, monitors, and tracks over five-plus years the performance of net-zero-energy homes.	Not Started	State	*	No
R7. Develop and urge municipal adoption of model zoning that addresses existing regulatory barriers.	Like C9, DOER and cities should develop model zoning to address regulatory barriers to ZE homes, such as setbacks, height restrictions, and historical preservation rules.	Retain action as is	Not Started	State and City	*	Yes, at local level
R8. Expand home energy weatherization rebate program to incentivize super-insulation retrofits.	This action faced the same challenges as R5. Weatherization rebates have historically been insufficient to cover the costs of super-insulation retrofits. State funds to supplement federal weatherization monies will be needed.	Increase from state and utilities to provide supplement to home energy weatherization programs, to cover the cost of more extensive insulation and deeper energy efficiency.	In-Progress	State	*	No
R9. Co-sponsor a mortgage write-down program for deep energy retrofit projects.	Massachusetts has a “Home MVP” offering for retrofit financing of up to $25,000 at 0% APR. Such a program is useful, but this action is about mortgage write-downs, and further language may help clarify the issue.	Work with loan providers to bundle solar installation costs, and deep energy retrofit costs, in mortgages at point of sale, and investigate mortgage buy-down programs for current homeowners.	Not Started	State and City	**	No

[12] All “2009 Report Actions” come from: Commonwealth of Massachusetts, (2009). “Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force.” March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Residential Actions from 2009 Report (R)

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
R10. Establish a ZNE revolving loan fund; investigate a zero net energy bond.	This would be a good tool for the state to either offer directly or through a Green Bank, were one to be created.	Retain action as is	Not Started	State	*	Yes, if through Green Bank

New Commonwealth and Municipal Buildings Proposed Actions (S)

	Discussion	Recommended Action	Status	Imple-mentation Level	Difficulty	Legislative Change?
New Action	This is best replaced with a new action on the same theme.	Recommended Action Revision: The State and cities should develop point-based incentive /performance-based procurement programs for public and publicly financed projects that create a structure to promote higher performing buildings in RFPs. If successful, educate private sector on the model for expansion to private market.	New Recommendations	State and City	*	No
New Action	As discussed in the commercial policy section, the Renew Boston Trust (RBT) is an innovative new model for financing energy efficiency projects. The model can be used to promote commercial building energy projects and also fund municipal energy efficiency retrofits. The City of Boston is currently engaged in a $10 million pilot across 37 facilities, using the RBT to self-finance upgrades by monetizing their future savings. Other municipalities should study the success of the pilot and investigate undertaking similar measures.	Study the success of the Renew Boston Trust-Municipal model and explore expansion to other cities or statewide.	New Recommendations	State and City	**	No

12 All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Commonwealth and Municipal Buildings from 2009 Report (S)

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
S1. Adopt a prescriptive standard for new buildings and major renovations that requires: a. Adherence to the requirements of the NBI Core Performance Standard. b. Optimized building orientation. c. Adherence to DCAM/DOER requirements for solar ready roofs. d. Minimum on-site renewable energy generation, where feasible, or compara-ble generation at an alternate location.	The Massachusetts LEED Plus standard requires new construction projects to exceed the energy code requirements by at least 20%. As the code requirements ratchet down, so too does this requirement. Additionally, state facilities have greatly increased the amount of solar PV installed on state sites, from 1 MW in 2010 to more than 23 MW in 2018.	Retire action	Complete	State		No
S2. Adopt a perfor-mance standard by building type based on DOE Commercial Benchmark Models for all new construction and major renovation.	The state still needs to work to establish EUI targets for building types for new construction and major renovation. Where feasible, such targets should be at ZER levels.	Retain action as is	Not Started	State	*	No
S3. Install advanced metering in new buildings or in build-ings that undergo major renovation.	Interval at more than 20 million sq. ft. of state buildings and all meters are connected to an analysis tool that allows operators to respond to actual building performance.	Retain action as is	In-Progress	State	*	No
S4. Verify and publicly report energy performance.	Leading by Example posts energy consumption data for the entire state portfolio of buildings and reports such data to the US DOE's Better Buildings Challenge each year.	Retain action as is	Complete	State	*	No

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Commonwealth and Municipal Buildings from 2009 Report (S)

2009 Report Action	Discussion	Recommended Action Revision, if applicable[15]	Status	Imple-mentation Level	Difficulty	Legislative Change?
S5. Require third-party building commissioning and re-commissioning.	The LEED Plus standard requires third-party commissioning for all new construction. However, retro-commissioning is not yet addressed.	Require third-party retro-commissioning of all state buildings on a regular interval, no less than once every 10 years.	In-Progress	State	**	No
S6. Provide building operator and occupant training.	MAFMA through CAMM provides an array of building operations and technology training to state staff; additional trainings have been conducted by the MassCEC.	Retire action	Complete	State		No
S7. Conduct regular review of state standard implementation.	Leading by Example reviews LEED documentation for new construction projects to ensure that projects are meeting the LEED plus standard requirements.	Retire action	Complete	State		No
S8. Recommend a new standard for state-funded projects.	This is best replaced with a new action on the same theme.	Retire and replace with new action	Not Started	State		No

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Updates to Workforce Development (W), Technology Development (T), And Education (E)

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
W1. Support Home Energy Rating System (HERS) Rater training.	Massachusetts Clean Energy Center (Mass-CEC) offers a variety of resources to provide training and increase the number of clean energy jobs in the Common-wealth. In addition, there are a number of trainings offered through Mass Save. Workforce programs were not examined in detail in this study and thus we recommend, absent future contrary findings, that all actions should be retained.	Retain action as is	Complete	State	*	No
W2. Enable the training and licensing of sufficient numbers of energy assess-ment and auditing professionals.		Retain action as is	Complete	State	*	No
W3. Enable the training and licensing of sufficient num-bers of renewable energy installation professionals.		Retain action as is	Complete	State	*	No
W4. Develop training programs to increase the number of energy efficiency service providers and weath-erization specialists.		Retain action as is	Complete	State	*	No
W5. Develop a com-prehensive continuing education and training program for the build-ing industry, including architects, engineers, and builders, and regu-lator communities.		Retain action as is	Complete	State	**	No
T1. Emphasize building energy technology in the missions of the Clean Energy Technol-ogy Center.	These actions are designed to be ongoing and so should continue.	Retain action as is	Complete	State	*	No
T2. Support the growth of the state's energy measurement and control technology industry.		Retain action as is	Complete	State	*	No
T3. Promulgate state-specific energy efficiency standards for appliances, as appropriate.	Appliance standard updates have been considered by the legisla-ture, but not adopted.	Recommended action revision: In 2019, work with NEEP and NASEO and the legis-lature to adopt new energy effi-ciency standards for new types of appliances where there is no federal preemption.	Not Started	State	*	Yes

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Workforce Development (W), Technology Development (T), And Education (E) from 2009 Report

2009 Report Action[12]	Discussion	Recommended Action Revision, if applicable	Status	Imple-mentation Level	Difficulty	Legislative Change?
E1. Develop and disseminate zero net energy/retrofit consumer guidance.	Information about ZEBs is included on DOER's website; however, specific guides would be useful to increase uptake. Collaboration with leading municipalities may be helpful. In addition, this guidance should be produced for both businesses and consumers.	Develop and disseminate zero net energy retrofit guides for residents and businesses.	Not Started	State and City	*	No
E2. Develop a statewide ZNE marketing campaign.	While DOER provides information on ZEBs on their website, and works to develop educational materials, there is yet no state marketing campaign.	Retain action as is	Not Started	State	*	No
E3. Require elementary and secondary schools to teach students about building performance.	This has not yet occurred. However, education needs will vary greatly by student age and there is no one-size-fits-all solution, so the state should establish pilot programs to design strategies, in addition to the creation of any mandate.	Require elementary and secondary schools to teach students about building performance. DOER should work with the Department of Elementary and Secondary Education and local jurisdictions to develop pilot programs that can be promulgated.	Not Started	State and City	**	No
E4. Identify, validate, and publicize project exemplars.	This has been done by DOER through the Pathways to Zero program, Leading by Example programs, and other efforts. As building technologies and ZE strategies continue to innovate, it is important to continue to publicize exemplary projects.	Retain action as is	In-Progress	State and City	*	No

[12] All "2009 Report Actions" come from: Commonwealth of Massachusetts, (2009). "Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force." March 11, 2009. https://www.mass.gov/files/documents/2016/08/pw/zneb-taskforce-report.pdf

Appendix D: Additional Resources

General Resources

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Appendix E: List of Figures and Tables

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USGBC
MASSACHUSETTS