Scaling Up Passive House Multifamily: The Massachusetts Story

Kristen A. Simmons, ICF
Beverly Craig, Massachusetts Clean Energy Center
Luke McKneally, ICF
Jayne Lino, Massachusetts Clean Energy Center

ABSTRACT

Two years ago, there was one Passive House certified multifamily building in Massachusetts. Since then, two more have certified and five more have completed construction and are in the certification process. As of June 2022, an additional 135 buildings are in design or construction. Altogether, 141 buildings with 8,500 units are on the path to building and certifying to the Passive House Standard. How did this momentum build? What are the policies and incentives that have led to this transformation in the new construction market? What are the incremental costs to upgrade to the Passive House standard? Lastly, do these buildings perform as designed?

Interest in Passive House in Massachusetts began with building and policy experts who believed that the Passive House Standard would provide a pathway for the design of exceptionally low energy buildings. Early on, it was codified as alternative energy code compliance path, but it did not gain traction due to market barriers including incremental cost, training, and perceived risk to overcome these hurdles. In 2017, the Massachusetts Clean Energy Center (MassCEC) launched the Passive House Design Challenge to track incremental costs and validate modeled energy performance for eight buildings. Separately, in 2018 Berkshire Gas, Cape Light Compact, Eversource, Liberty, National Grid, and Unitil, collectively the Mass Save Program Administrators (PAs), launched an incentive offer for Passive House multifamily projects to accelerate market transformation. These incentives fund both pre-construction technical support and robust post-construction incentives. This paper will discuss the results to date of both these efforts.

Introduction

In 2008, the Commonwealth of Massachusetts adopted the Green Communities Act and Global Warming Solutions Act (GCA 2008 and GWSA 2008), which included the state's first greenhouse gas emissions reduction framework and gas emissions targets to address climate change. The acts call for Massachusetts to *pursue all cost-effective energy efficiency opportunities* and to limit statewide emissions to *at least 80 percent below the 1990 level* by 2050. As part of the plan to achieve these goals, buildings were included as one of five decarbonization sectors, and recommendations include "high performance, Passive House level of envelope efficiency" for new construction. Massachusetts has historically used its clean energy programs and top ranked energy-efficiency programs to carry out legislative policy goals.

Massachusetts is home to an active Passive House network that advocated for a policy framework promoting passive design for improved energy performance. Stakeholders met with the Massachusetts Department of Energy Resources, which was seeking to promote Passive House design to achieve the state's energy reduction targets. They also successfully lobbied the state's affordable housing agency, the Department of Housing & Community Development

(DHCD), to add bonus points for Passive House to their Qualified Allocation Plan (DHCD 2019), a competitive funding mechanism. Concurrently, the PAs were restructuring their programs—especially their new construction programs—in anticipation of reduced lighting savings, lower realization rates, and shrinking net to gross ratios as a result of improvements in energy codes and industry standard practice. Massachusetts PAs recognized an opportunity to address key program concerns, external stakeholder demand, and state emissions goals, by constructing an incentive framework centered around Passive House for multifamily buildings.

The savings potential of designing to the Passive House Standard is significant. Table 1 provides the Passive House source energy requirement for various certification options. In comparison, EnergyStar Portfolio Manager references the average Source Energy Use Intensity (EUI) for multifamily buildings as 118.1 kBtu/sf/year (EPA 2021). The most commonly required Passive House source energy requirement is 38.0 kBtu/sf/year, 68% less than EnergyStar Portfolio Manager's average.

A side note on certification options: There are two certifying bodies, Passive House Institute (PHI) and Phius, previously Passive House Institute U.S., which have independent certification requirements. PHI is the originator of the Passive House certification system, based on internationally tested and well-established building science and energy efficiency principles. Phius, previously Passive House Institute U.S., is a separate organization with a similarly rigorous certification system, including climate-specific targets to address different energy and humidity concerns in the variety of climate zones and conditions throughout the U.S. Phius updates their standard on a 3-year cycle established in 2015, updated in 2018, and most recently in 2021, and maintains a "Core" baseline certification and a "Zero" carbon certification added in 2021 in addition to the current standard for the cycle. Note that each certification option has additional requirements for heating & cooling loads, air sealing, and more.

Table 1. Passive House source energy requirements

Certification option	Source energy requirements
PHI	All spaces: 38.0 kBtu/sf/year Accounts for on-site generation and new off-site generation
Phius+ 2015	Residential: 6,200 kWh/person/year Commercial: 38.0 kBtu/sf/year Accounts for only on-site energy generation
Phius+ Core	Residential: 5,500 kWh/person/year Commercial: 38.0 kBtu/sf/year Accounts for only on-site energy generation
Phius+ 2018	Residential: 3,840 kWh/person/year Commercial: 34.8 kBtu/sf/year Accounts for both on-site and off-site energy generation

Despite the success of these efforts at a policy level, significant market barriers remained. The goal of both the MassCEC's Passive House Design Challenge and the PA's Passive House multifamily incentives is to overcome these hurdles to broad market adoption and pave the way for future code adoption so that the new construction 2050 gas emissions targets can be met. The market barriers were surfaced and illuminated through in-depth interviews with 25 market actors,

including developers, architects, engineers, builders, industry experts, and occupants (Giza-Sisson 2020). Four key areas were identified:

- **Training**: Market actors of all types stressed the importance for training to overcome limited industry knowledge and experience with Passive House design and construction.
- **Incremental cost:** Market actors were uncertain but suggested the incremental cost for constructing multifamily Passive House projects ranged from 2-10%. Much of this is related to building envelope upgrades—windows, insulation, higher quality air barriers and vapor barriers, design and construction of thermal-bridge-free details, mechanical ventilation, and air-sealing. Soft costs specific to Passive House include feasibility studies, energy modeling, and certification fees.
- **Risk & uncertainty**: Developers perceived significant financial risk to pursue a Passive House project. Financial incentives would increase project-cost certainty and reduce the risk.
- **Lack of public awareness**: Lack of public awareness and demand for more efficient building hinders the decision-making process of developers to pursue a Passive House project.

MassCEC Passive House Design Challenge: Incremental Cost of Early Affordable Housing Passive Projects

In 2017, MassCEC announced a Passive House Design Challenge for affordable multifamily new construction. The primary goal of the Challenge was to closely track incremental construction cost changes when improving a conventional multifamily building to meet the rigorous requirements of the Passive House standard. MassCEC hoped that the resulting data from the study would prove to developers and state policymakers, including the DHCD, that affordable housing design teams could upgrade to Passive House building construction for a modest cost increase, in exchange for substantial energy and greenhouse gas reductions. Other goals included an analysis of post-occupancy energy use, which would be compared to the Passive House modeled performance and increasing high performance construction capacity building within Massachusetts multifamily design and construction firms. The effort also hoped to increase the number of design and construction teams in Massachusetts that had experience building Passive House multifamily.

Projects taking part in the Passive House Design Challenge would receive incentives of up to $4,000 per unit to upgrade their design and seek Passive House certification. The incentive would be paid in three milestone payments (Table 2) during design and construction. By using milestones for payments, project teams benefit from early incentives which, in addition to off-setting design costs, are considered equity during financing. Milestone payments also ensured that incentive payments would be tied to actual results. Should a project not achieve a milestone, no payment would be made. Participating projects would also be required to share construction cost data, both hard and soft, and post-occupancy energy data.

Table 2. MassCEC Passive House Design Challenge Incentives

Milestone	Project Phase	Incentive/unit	Milestone
1	Design	$1,000	Hiring of Passive House consultant and rate
2	Design and/or Construction	$1,500	Passive House pre-certification
3	Post-construction	$1,500	Passive House certification

MassCEC selected 8 proposed buildings with a total of 540 units for the Design Challenge (Table 3). All buildings were deed-restricted low-income and were funded with Low Income Housing Tax Credits. All participating developers have construction and facility management experience in Massachusetts; both non-profit and for-profit developers were represented. The buildings are noted for their diversity in size, construction typology, design aesthetic, and location in Massachusetts. The buildings ranged from 30 units to 135 units. Some buildings are modern in appearance, and others mimic historic brick buildings. Locations include urban sites such as Boston and Cambridge as well as small towns like Gloucester, Hanson, and Holbrook.

Table 3. Design Challenge Projects and Characteristics

Project	Location	Site Type	Construction Type	Units	Gross Square Feet
Finch Cambridge	Cambridge	In-Fill	Podium	98	111,450
Old Colony 9th & Mercer	Boston	In-Fill	Podium	55	51,272
North Commons	Northampton	Suburban	Wood frame	53	55,538
Harbor Village	Gloucester	In-Fill	Podium	30	33,186
Depot Village	Hanson	Suburban	Wood frame	48	104,981
Mattapan Station (mixed use)	Boston	In-Fill	Podium	135	178,875
Holbrook Senior Housing	Holbrook	Suburban	Wood frame	72	53,675
Bartlett Station Lot D / Kenzi	Boston	In-Fill	Podium	50	45,031

All eight buildings in the Design Challenge were initially designed to comply with the Massachusetts Energy Code, International Energy Conservation Code (IECC) 2015 plus MA Stretch Code requirements. (The MA Stretch Code is an energy performance-oriented code beyond the "base" energy code, was adopted in Massachusetts in 2009 with local communities free to opt in.) Upon joining the Design Challenge, each building underwent design changes required to meet the required Passive House metrics. The initial design is used as the basis for the incremental cost analysis, the “base building.” It is worth noting that the initial design of some buildings may perform better than energy code requirements to meet the developers’ internal values and operational goals. This is common in affordable housing development, where

developers tend to be long term owners and must account for the overall cost of housing, including utilities. Finch Cambridge, for example, pursued Enterprise Green Communities certification prior to committing to Passive House in the Design Challenge. After completion, it received Passive House certification, plus certification from both Enterprise Green Communities and FitWel, a building standard focused on occupant health through urban and architectural design, including material choices, mechanical system design, and performance optimization.

As of March 2022, five of the buildings are occupied and three others are in construction. Of the completed projects, two have been certified as PHIUS+ 2015; two are undergoing final certification review; and one, Depot Village, is no longer seeking certification after pre-certifying. Depot Village was able to get design and pre-certification funding for reaching those milestones, so there was a soft landing despite not achieving the Standard's verification requirements on overall enclosure air infiltration. Additional incentives were also paid by Mass Save. It is predicted the remaining other projects will complete construction in 2022 and will achieve Passive House certification.

During construction, cost data was tracked for each project contemporaneously, as well as for its hypothetical doppelganger, the base building. The result was ongoing incremental cost data throughout design and construction, broken out by specification categories and construction phases. Using data from the 7 projects that are certified or are seeking certification, including 3 still in construction, the average increase is 2.3% (Table 4). The incremental cost average may change once change orders have been finalized for the projects still in construction. Note that incentives from MassCEC or Mass Save which would offset the additional incremental cost are excluded from the analysis. These results are consistent with a study completed by the North American Passive House Network which found incremental costs to range between 1% and 8% for Passive House projects (NAPHN 2021).

Table 4. Design Challenge Projects and Incremental Cost to Upgrade to Passive House

Project	Project status	Certification Standard	Certification Status	Incremental Cost
Finch Cambridge	Complete	PHIUS+ 2015	Certified	1.4%
Old Colony 9th & Mercer	Complete	PHIUS+ 2015	Pre-Certified, Certification pending	3.5%
North Commons	Complete	PHIUS+ 2015	Certified	4.3%
Harbor Village	Complete	PHIUS+ 2015	Pre-Certified, Certification pending	1.8%
Depot Village	Complete	PHIUS+ CORE	Pre-Certified, Not Certified	n/a*
Mattapan Station (mixed use)	In construction	PHIUS+ 2015	Pre-Certified	2%**
Holbrook Senior Housing	In construction	PHIUS+ CORE	Pre-Certified	1.5%**
Bartlett Station Lot D / Kenzi	In construction	PHIUS+ CORE	Pre-Certified	1%**

Incremental cost represents the difference between Passive House requirements and the developer's standard of design, typically IECC 2015, with the Massachusetts Stretch Energy Code Overlay. *Depot Village will not be certified, so the increment cost data is not applicable. **Projects in construction show incremental cost through February 2022. The final incremental cost will be calculated at completion.

Design Challenge Lessons Learned: Old Colony 9th & Mercer

Designed for independent living seniors aged 62 or older with median income of 60% or less of the Area Median Income, Old Colony 9th & Mercer is a simple volume containing 55 1-bedroom units, plus 4,500 SF of ground floor space for health and wellness services. The building is in the heart of South Boston and is part of the third phase of for-profit developer Beacon Communities' redevelopment of Old Colony, a LEED certified neighborhood development. This project is pending Passive House final certification at a 3.5% incremental cost over the base building. This incremental cost includes all additional costs for Passive House including certification and excludes incentives which would offset the incremental cost. Lessons learned from Old Colony 9th & Mercer, shared below, are representative of what was found in other Passive House Design Challenge projects.

What makes up the 3.5% incremental cost to achieve Passive House? The additional cost includes direct hard construction costs, construction labor and materials, as well as soft costs, non-tangibles including design, systems commissioning, etc. that are specific to Passive House.

Most of the incremental cost was related to hard construction costs including materials and labor to improve the energy efficiency, comfort, and resilience of the building. Some of this was offset by savings related to Passive House. For example, the heating and cooling system was reduced in capacity because improvements to the building envelope's energy efficiency reduced heating and cooling demand, saving over $400,000 in construction cost. Incremental cost increases occurred across many categories, with the largest increases in the following categories:

- Window shading features to prevent summer overheating
- Ventilation upgrades to supply fresh air to living and bedrooms
- Air sealing
- Window upgrades

The soft cost increase was typically related to sustainability consultation services related to Passive House modeling and certification. These include the Certified Passive House Consultant (CPHC) whose services include Passive House energy modeling and modeling updates as needed during construction. This modeling is essential for designing a building that meets the Passive House performance metrics as well as for certification. The CPHC also coordinates between the Passive House certifying body and the project team, submitting the project documentation. Although the CPHC may perform other tasks, such as submittal review, construction site visits, and more, that scope was included in the base building and is therefore not an additional cost related to Passive House. Also included in the base building scope was HERS Rater services. With the change to Passive House, more comprehensive PHIUS+ HERS Rater services were required. PHIUS+ HERS Rating requires both additional construction site visits and commissioning and testing at completion. The total additional soft costs were just above $32,000 and were incurred during both the design and construction phases.

Design Challenge Lessons Learned: Best Practices

- Experience and Training Matter:
    - Projects with architects that have passive house training and/or passive house experience had the lowest incremental cost and the easiest time with getting multifamily buildings to passive house certification.
    - There also appears to be an inverse relationship between the number of project team members with Passive House training and incremental cost and ease of certification.
- Building Matters:
    - Simple massing and roofs are less expensive. Projects with complex massing and/or roofs had significantly higher incremental cost.
    - Window upgrades were typically required.
        - Buildings almost always need tripled glazed windows in Massachusetts.
        - Casement style windows and French doors should replace double hung windows and sliding glass doors.

Mass Save Passive House Multifamily Incentives and Workforce Training

Separate from Passive House Design Challenge, the PAs worked with stakeholders, local networks of professionals, and advocates to develop and introduce a new Passive House incentive offer for multifamily residential new construction projects of 5 units and more. In addition to incentives, a workforce training initiative was also launched. It was hoped that both efforts would overcome the identified market barriers, including perceived risk, incremental cost, and lack of training. As described in detail in Giza-Sisson 2020, the Passive House incentive includes tiers for different design and construction activities as shown in Table 5 to help mitigate the market concerns identified.

Table 5. Mass Save Passive House Multifamily Incentive Structure

Incentive timing	Activity	Incentive Amount	Max. Incentive
Pre-construction	Feasibility study	Up to 100% of Feasibility Costs	$5,000
	Energy modeling	75% of Modeling cost	Up to $500 per unit with a cap of $20,000
	Pre-certification	$500/unit	No Cap
Post construction	Certification	$2,500/unit	
	Net performance bonus	$0.75/kWh	
		$7.50/Therm	

The number of projects that have taken advantage of the Passive House incentives since they were launched in August of 2019 are shown in Table 6 for each stage of the available incentives. Projects that complete the Feasibility stage with Charrette may decide to continue through Passive House energy modeling and pre-certification, although some do withdraw to participate in the Mass Save standard path incentives. Projects have withdrawn for a variety of reasons, including concerns about team experience, perceived cost increases, and project

financing, as well as timing and logistics for projects that may have progressed through stages of design prior to fully understanding the available offerings and 3rd party Passive House pre-certification process.

Table 6. Mass Save Passive House Multifamily Incentives Paid Program Inception

Incentive stage	Projects	Incentives paid	Project status at payment
Feasibility/charrette	99	$ 478,585	Schematic design
Modeling	19	$ 199,597	Design development, construction documents
Pre-certified	23	$ 409,500	Construction documents, bidding, construction
Certified	1	$ 245,000	Construction complete, verified

Figure 1 shows the enrollment of projects by estimated year of completion upon registration. Participation in later years reflects early enrollment for long project design and development schedules. Unit counts for enrolled projects are shown by year of estimated completion and cumulatively in Figure 2.

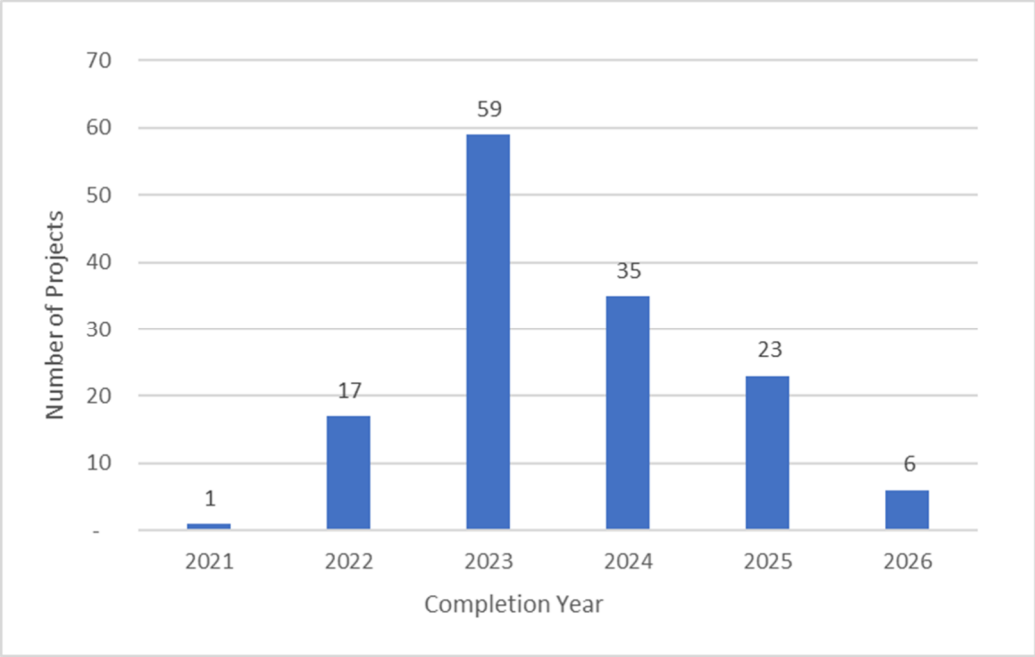

Figure 1. Number of enrolled Passive House projects by estimated year of completion.
Source: Mass Save 2022.

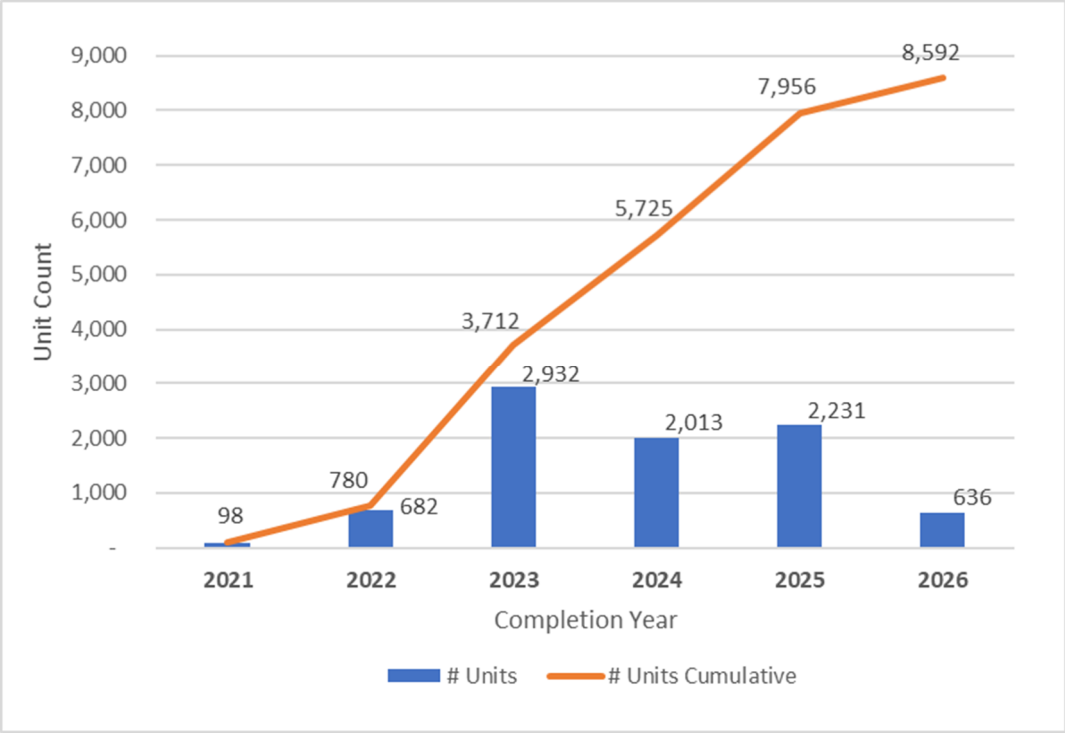

Figure 2. Enrolled Passive House project unit counts by year of estimated completion. *Source*: Mass Save 2022.

Passive House projects within the program can include any number of stories if more than 5 units are within a single building's continuous envelope. Breaking down the project types by number of stories, as shown in Figure 3, demonstrates the current demand for high performance housing in the low and mid-rise residential market.

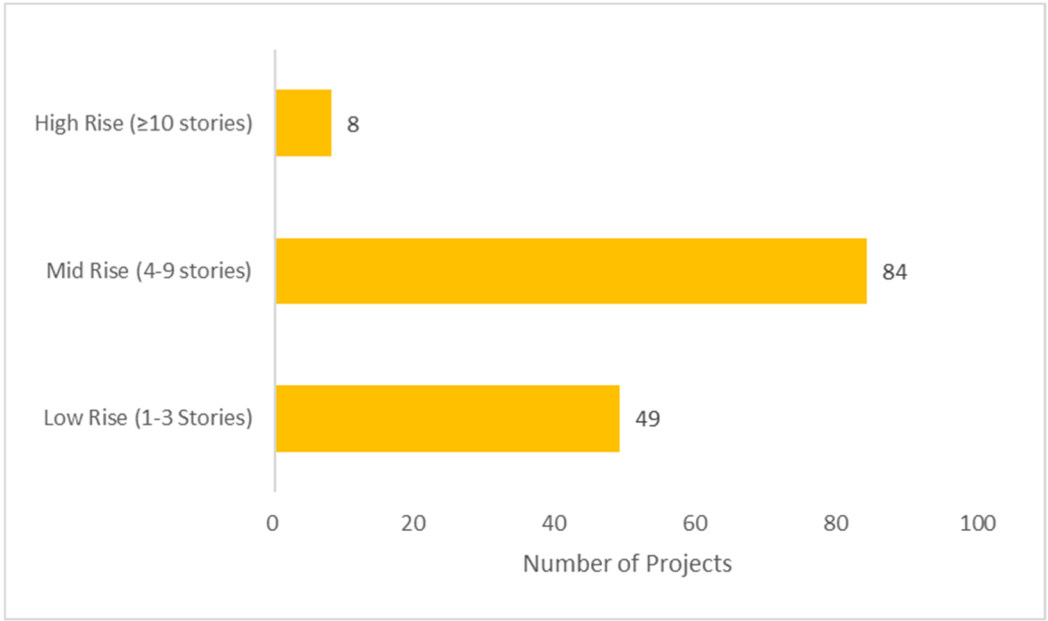

Figure 3. Enrolled Passive House projects by number of stories. *Source*: Mass Save 2022.

Incentives Lessons Learned: Best Practices

- Keep the incentive program design simple:
    - Design phase incentives such as the Passive House feasibility study subsidy and Passive House energy modelling cost share encourage the exploration of Passive House certification by project teams.
    - Flat rate incentives are easily understood and predictable, making them easy to communicate. This structure reduces the developer's perceived financial risk, as compared to traditional incentive design where the incentive award is finalized post-construction.
- Plan for soft landings: Projects can withdraw from the Passive House Multifamily path at any time without penalty. Projects that do not certify (after pre-certifying) remain eligible for pay-for-savings incentives at the Passive House rates. This provides a level of security to reassure developers and design teams that even if they did not receive final certification, their costs, effort, and the learning process would be supported.
- Education, training, and workforce development: It is critical to concurrently provide educational subsidies for design and construction professionals. This knowledge will also spill over into design of other high-performance buildings that do not seek PH certification. Since the launch, over 2,500 have attended a variety or webinars and workshops.

Do Passive House Buildings Perform as Designed? Post-Occupancy Energy Performance of Passive House Certified Multifamily Buildings

All of this would be moot if the buildings do not perform as designed. Unfortunately, modeled energy performance has not always accurately predicted operating energy use. To justify the investment in additional cost, predicted performance must be beyond doubt. Over the last 5 years new energy disclosure ordinances have come into existence. At the same time, greater numbers of Passive House multifamily buildings completed construction and were occupied. The result is publicly available data about the post-occupancy energy use of Passive House multifamily buildings. It is now possible to compile actual energy performance of completed projects to see if, once built, Passive House certified multifamily buildings live up to the dramatic level of energy savings predicted by their energy models. Additionally, the data can be used to see how these buildings compare to standard construction of similar building types built during the same period.

Using disclosure data from Boston and Philadelphia, it is possible to compare site energy use intensity (EUI) of completed Passive House certified multifamily projects to similar new construction buildings. Site EUI is calculated by dividing the total energy consumed by the building in one year by the total gross floor area of the building. The EUI metric allows for easy comparison of buildings by use type, regardless of specific project characteristics, size, or geographic location. An additional direct comparison of two nearly identical buildings New Hampshire rounds out the analysis.

Benchmarking Passive House in Boston

The City of Boston's Building Energy Reporting Disclosure Ordinance (BERDO) was enacted in 2013 and came into effect in 2017. BERDO obligates all residential buildings greater than 35,000 SF and/or thirty-five units to report their energy use annually. (Non-residential buildings greater than 35,000 SF must also report their energy use.) Total energy is reported, regardless of meter or fuel type, providing a public dataset of building-specific data and metrics, including site EUI (City of Boston 2021).

Luckily, the first Passive House certified multifamily building in Massachusetts is in Boston and subject to BERDO, providing an opportunity for direct comparison. Distillery North, a 28-unit market rate building was completed in 2017 and Passive House certified by the Passive House Institute U.S. (PHIUS). Using the BERDO data, other multifamily buildings that completed construction within in the same period were identified. Only buildings that provided complete BERDO data were included for analysis. An additional layer, LEED certification data, was cross referenced with the BERDO list (USGBC 2022). The result is a comparison (Figure 4) of 78 multifamily buildings, which completed construction between 2010-2019, including the Passive House certified Distillery North building. The data reported in 2021 reflects energy use in 2020.

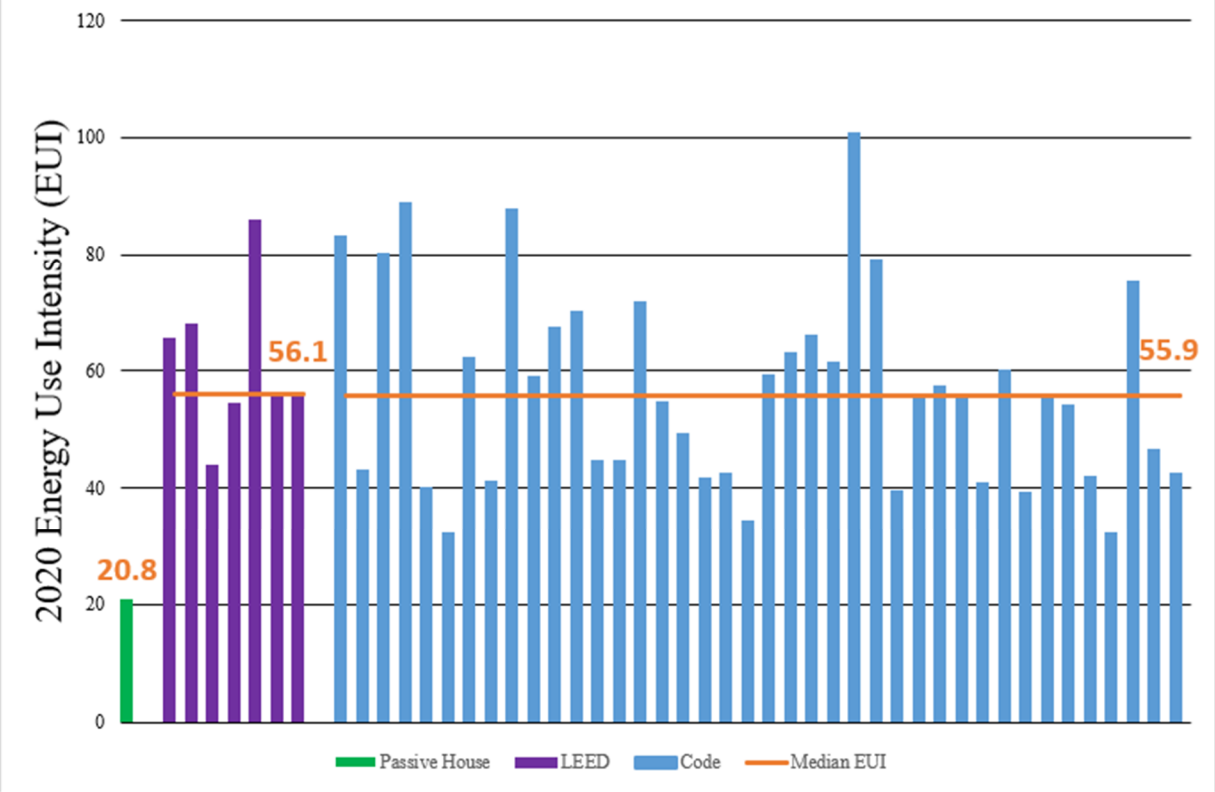

Figure 4. 2020 energy use intensity in kBtu per square foot per year (kBtu/sf/yr) for multifamily buildings constructed in Boston, MA between 2008 – 2019. Categorized by voluntary standards achieved. Distillery North is labeled as Passive House. Source: MassCEC

Distillery North's site EUI is 20.8 kBtu/sf/yr. The average EUI for the non-Passive House buildings is 56.4 kBtu/sf/yr. In comparison to the LEED certified and code buildings, Distillery North is using 63% less energy per square foot. This is better than the 40%-60% range of expected energy savings anecdotally assumed for Passive House buildings. There is little difference between LEED certified and non-LEED building average EUI (56.1 and 55.8 respectively), although there are striking differences between individual buildings within each category.

Would additional Passive House certified projects demonstrate a wide variation in performance like the non-Passive House buildings? Because the Passive House standard sets EUI-related performance targets and requires extensive construction verification, Passive House certified projects would be expected to perform within a narrower range.

Benchmarking Affordable Passive House Buildings in Philadelphia

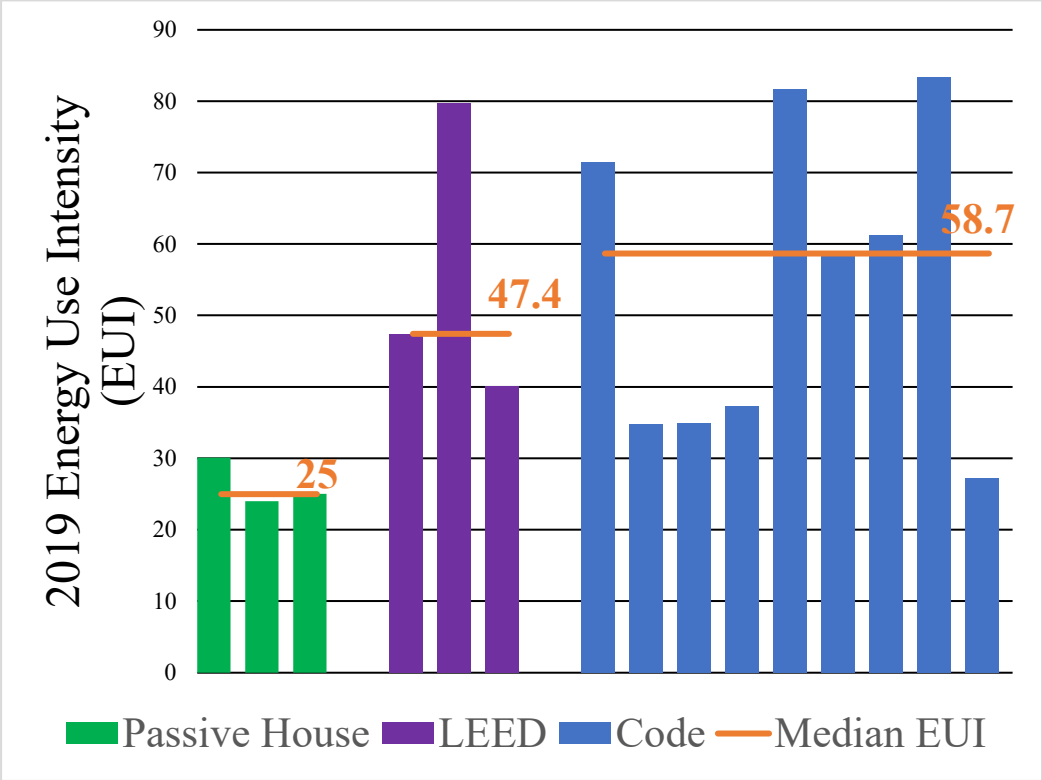

Figure 5. 2019 actual energy use intensity in kBtu per square foot per year (kBtu/sf/yr) for deed-restricted low-income multifamily buildings in Philadelphia, PA (City of Philadelphia 2022). Categorized by voluntary standards achieved. Source: Green Building United

Philadelphia has a disclosure ordinance like Boston's and is the location of multiple Passive House multifamily buildings. Because of data quality issues, the analysis (Figure 5) focused on 15 deed-restricted affordable multifamily buildings that completed construction since 2010, including three Passive House pre-certified and certified buildings. The average EUI for the Passive House buildings is 25 kBtu/sf/yr. The average EUI for the non-Passive House buildings is 54.8 kBtu/sf/yr. In comparison to the LEED certified and code buildings, the Passive

House buildings average 52% less energy per square foot, within the anecdotal 40%-60% range of expected energy savings.

Once again, there is wide variation in performance of the LEED certified and code buildings, possibly reflecting differing design goals of the building owners. For example, at least one of the code-built buildings targeted achieving net zero energy on site, even though it did not seek Passive House or LEED certification. Within the Passive House buildings, variation exists within a relatively narrow tolerance. The Passive House certified buildings' individual EUIs are 24 and 25. The building that only achieved pre-certification has an EUI of 30.1. Perhaps the lesson here is that while high performing energy efficient buildings can be designed in a variety of ways, the Passive House standard provides a roadmap for achieving consistent energy performance results and that the best results are achieved when projects are certified.

A Direct Comparison in New Hampshire

Lakes Region Community Developers (LRCD) in New Hampshire owns and operates 365 affordable rental units in New Hampshire. Included within their portfolio are two 24-unit buildings with the same plan and basic design elements, completed 10 years apart. LRDC's architect revised the design of the first building (Gilford Village Knolls Phase II) as needed in the design of the Phase III building to achieve the Passive House standard. The revisions included typical Passive House features for the climate zone such as triple-glazed windows and continuous insulation. The result provides a comparison of energy performance for two nearly identical buildings, one with standard construction built to code versus the other with Passive House certified construction (Table 7).

Utilizing multi-year performance data (Resilient Buildings Group 2018), the average EUI for the Passive House building is 25 kBtu/sf/yr. The average EUI for the non-Passive House building is 49.2 kBtu/sf/yr. In comparison to the standard building, the Passive House building averages 49% less energy per square foot.

Table 7. Performance Comparison of Gilford Knolls Phases II and III

	Gilford Knolls Phase II	Gilford Knolls Phase III
Year completed	2008	2018
Standard	LEED (not certified)	PHIUS+2015 certified
Avg. Site EUI (kBtu/sf/yr)	49.2	25.0

Conclusion

The ongoing transformation of the Massachusetts new construction multifamily market to Passive House performance levels began slowly, then accelerated quickly. Early on, building and policy experts who believed that the Passive House Standard would provide a pathway for the design of exceptionally low energy buildings incorporated it in the legislative framework code

and building code compliance pathways. When that proved to have negligible impact on the market, stakeholders, including non-profits, rate payers, the active Passive House network, and others, expanded their efforts by lobbying. Their targets, including DHCD, Mass CEC, and Mass Save, could potentially have significant policy impact to better recognize and reward projects aggressively seeking to reduce energy consumption. The outcome of this lobbying includes DHCD's prioritization of Passive House projects in competitive funding, Mass CEC's Passive House Design Challenge, and Mass Save's Passive House multifamily incentive offer and workforce training initiative. Singularly, any of these initiatives would have affected the market; but launched almost in parallel, they have led to market transformation.

It would be difficult to tease out the impact of each program on the overall market transformation. In a competitive financing market, DHCD's policy change supplied a compelling reason for developers to build to the Passive House standard. Mass CEC's Passive House Design Challenge promised to reduce developer's perceived financial risk of Passive House by providing financial incentives in exchange for significant project data, including costs and post-occupancy energy data. Using the provided data, Mass CEC completed a robust incremental cost analysis, finding that the average incremental cost increase is 2.3%. The eight buildings that took part in the Passive House Design Challenge are evidence of the feasibility of Passive House in the Massachusetts multifamily new construction market. Altogether, the incremental cost study, the eight completed projects, as well as the experiences of those working on the project, including contractors, architects, engineers, addressed some of the previously identified hurdles to broad market transformation, including incremental cost and perceived risk and uncertainty.

Mass Save's Passive House multifamily incentive offer and workforce training initiative has a significantly broader impact than the efforts of DHCD and Mass CEC, due to the regulatory framework, the size of the territory served, and the focus on both low income and market rate buildings. The result is 141 buildings currently targeting Passive House Certification. The phased incentives significantly reduce incremental cost, and flat rate incentives reduce perceived risk and uncertainly. Robust workforce training ,including workshops and cost share for credentials, are expanding industry knowledge on all levels, additionally reducing risk and potentially incremental cost as well. Currently almost half of eligible multifamily buildings that enroll in the Mass Save incentive program are choosing the Passive House path over the standard incentive path.

In conclusion, many individuals and organizations are responsible for the market transformation that has occurred in Massachusetts. Initial policy efforts began around 2010. Transformation began in 2017 with a key policy change and study. It later accelerated in 2019 due to utility-provided incentives and training.

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