MA19R05: Passive House Offering Program Theory and Logic Model – Final

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SUBMITTED TO:
Massachusetts Program Administrators

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Background

The Passive House program offering is part of a wider programmatic move toward achieving deep and sustained energy usage reductions in newly constructed buildings. Passive House is a building certification that achieves extremely low space conditioning loads by emphasizing design principles such as a well-insulated building envelope with minimal air leakage, optimized window performance, optimized solar and internal gains, balanced heat and moisture recovery ventilation, and minimized Heating, Ventilation, and Air Conditioning (HVAC) systems. The Passive House offering provides incentives to project teams for feasibility assessments, energy modeling subsidies, Passive House pre-certification, Passive House certification, and net performance bonuses based on the modeled energy savings.[1] The offering also includes trainings and technical support for various market actors pursuing Passive House projects.

The Massachusetts Program Administrators' (PAs') traditional Residential New Construction (RNC) program includes two pathways: the Multifamily High-Rise (MFHR) pathway and the Low-Rise (LR) pathway. The traditional MFHR path includes multifamily buildings that are four stories or higher, or buildings with central HVAC systems. The traditional LR pathway includes multifamily buildings that are three stories or lower, as well as single-family homes. The Passive House offering has taken a more holistic approach to the residential market: it includes all multifamily buildings with five or more units. However, single-family homes are not currently included as part of the Passive House offering.

As an add-on to the MA19R05 Passive House Assessment,[2] this report presents a final program theory and logic model (PTLM). The program theory is a formal description of the program's activities and the short-, medium-, and long-term outcomes each activity is designed to achieve. The logic model is a graphical representation of the program theory.

[1] https://www.masssave.com/saving/residential-rebates/passive-house-incentives
[2] http://ma-eeac.org/wordpress/wp-content/uploads/MA19R05_PassiveHouse_OverallReport_Final_2020.01.06.pdf

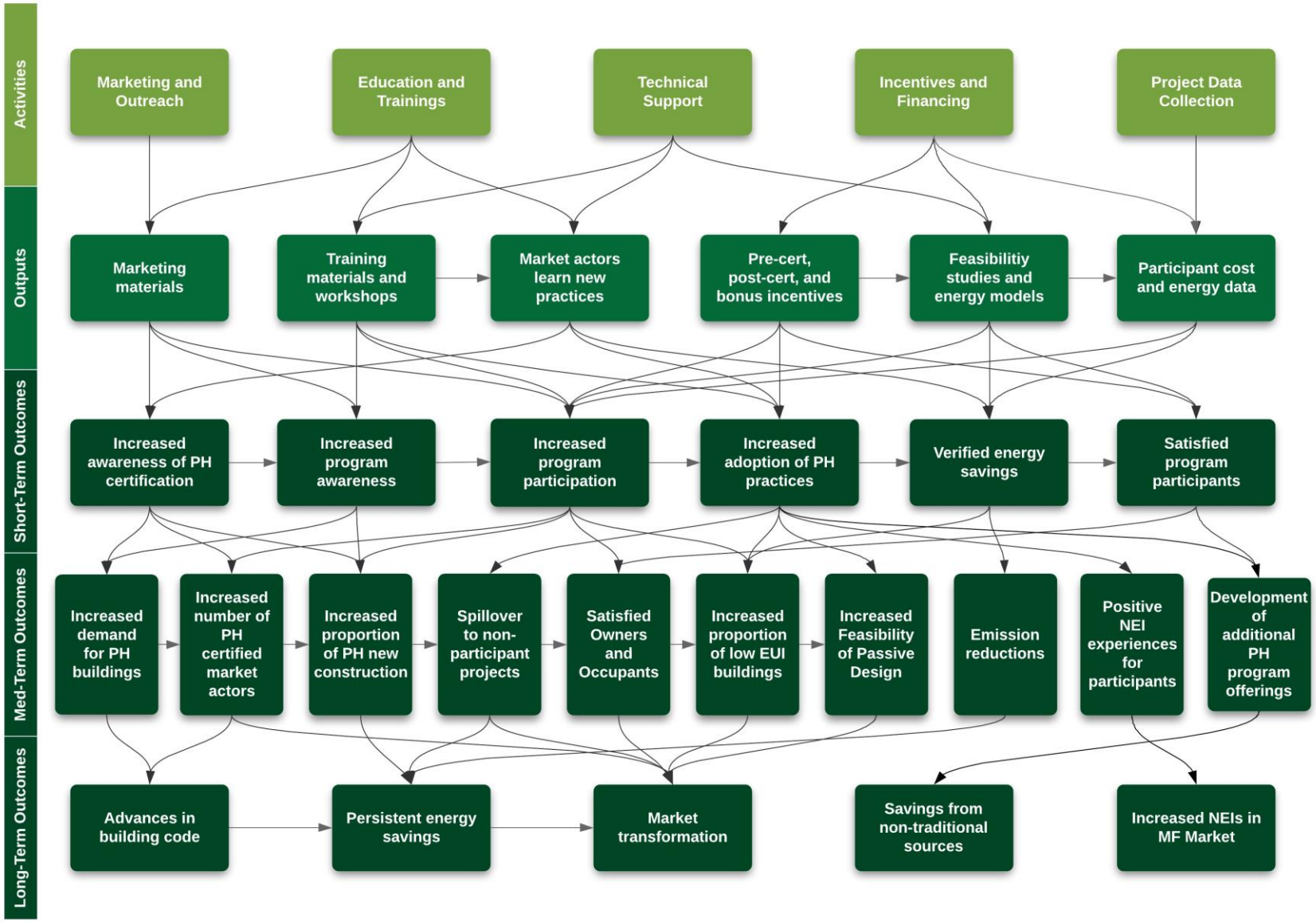
Section 1 Program Theory and Logic Model

As building codes and industry standard practices improve, the gap between RNC program participant practices and baseline practices has narrowed over time. This narrowing limits the potential savings associated with traditional new construction programs. Building to Passive House standards offers energy savings well beyond current program practices.[3] The energy savings, and associated building quality, can be major selling points for passive design and may lead to increased demand for these buildings. The successful execution of passive design requires specific knowledge and expertise from design, engineering, and construction professionals that will be accrued through education, training, and practical experience. The incorporation of passive design in project planning will impact project team dynamics and will have major repercussions on energy savings targets and building quality goals as the program proliferates.

The Passive House offering seeks to have transformational impacts on the RNC market – helping to make passive design more commonplace and, eventually, an industry standard practice. To position the program to meet this goal, our team, in coordination with PA implementation and evaluation staff, have developed a PTLM that describes the activities of the program, the outputs that follow, and the specific outcomes expected from program activity over the short-, medium-, and long-term. To ensure that outcomes are quantifiable, the PTLM includes indicators and associated data sources for measuring the occurrence of each outcome. Figure 1 displays the logic model illustrating the theory behind the Passive House offering. Each piece of the logic model is described below in the outline of the program theory.

[3] Please see Section 5 of the Passive House Overall Report for an examination of potential savings relative to current RNC Program levels: http://ma-eeac.org/wordpress/wp-content/uploads/MA19R05_PassiveHouse_OverallReport_Final_2020.01.06.pdf

Figure 1: Passive House Offering Logic Model



1.1 PROGRAM THEORY

1.1.1 Key Activities and Outputs

1.1.1.1 Marketing and Outreach

The PAs, though program staff, implementation contractors, and their partnership with Passive House Massachusetts, will work to reach customers and other market actors to raise awareness of the program and its offerings. This can be achieved through advertisements, marketing materials, and in-person visits at local U.S. Green Building Council (USGBC) meetings or other trade ally gatherings. External Passive House trainings may also provide an indirect outreach opportunity for the program. As time goes on, resources from another key program activity – project energy and cost data collection – will support marketing efforts with concrete performance and incremental cost data. This data can be used to develop case studies and other materials to provide real insight to project decision makers on the costs and savings they can expect to see by choosing Passive House.

- **Output:** Outreach materials are developed and delivered, and the program website is maintained and refined as needed. Additionally, early successful projects may be used as case study examples to generate media engagement, increase public interest, provide best-practice documents, and create a feedback loop.
- **Output:** Program staff participate in relevant industry organizations and form partnerships to conduct collaborative efforts.

1.1.1.2 Education and Training

The PAs have developed a three-pronged training effort that aims to reach a wide array of RNC market actors. The first initiative is a series of free lunch-and-learns that consist of high-level introductions to Passive House design, case studies of successful passive projects, and details on the factors needed to work passive design into project delivery. The second initiative is free and/or low-cost half-day trainings on building science best practices, including hands-on practical training and proper quality assurance. These trainings target a wide audience including, but not limited to, architects, builders, contractors, engineers, and developers. The third training initiative connects building sector professionals to Passive House accreditations by subsidizing the successful completion of Passive House certifications provided by either accepted Passive House certification body: Passive House Institute U.S. (PHIUS) or the Passive House Institute (PHI).

- **Output:** In-person training, educational webinars, and events are held.
- **Output:** Additional market actors are enrolled in Passive House certification courses and an increased number of accredited Passive House professionals enter the market.
- **Output:** Passive design principles (collectively both the measures and their low energy intensity levels) are incorporated into various aspects of project design and construction.
- **Output:** Forward Passive House design and construction practices and technology into different sectors (i.e., renovations and non-RNC).

1.1.1.3 Incentives

With passive design still in the early adopter phase, the program recognizes that there are several factors that can prevent a project from achieving final Passive House certification. Achieving Passive House certification is unlikely without early and sustained planning at the inception of a project and detailed energy modeling to guide the initial project design. Even then, there are several confounding factors that can prevent certification. To promote the best outcomes, the program requires that a certified Passive House professional be engaged on each project throughout the design and certification processes. Specifically, certified professionals will assist with initial technical assistance on the feasibility study, provide energy modeling services, conduct QA/QC, and provide building verification, all of which add to project costs. Passive House program incentives address these factors in two ways. First, incentives are designed to lower initial barriers to participation and reduce financial and project uncertainty by covering the full cost of feasibility studies and 75% of energy modeling costs prior to completing schematic design.[4] Second, these initial incentives, and an additional pre-certification incentive ($500 per unit), are not contingent on having the project achieve final certification.[5]

A project that achieves certification is eligible for the certification incentives ($2,500 per unit). If the project achieves reduced energy usage beyond the modeled performance targets, the project is eligible for additional net-performance bonus incentives.[6] Thus, a certified Passive House project is eligible for five separate incentive types: feasibility study costs, energy modeling costs, pre-certification, final certification, and net performance bonuses. In addition, a non-certified project that achieves pre-certification is still eligible for the post-construction net performance bonuses if they exceed their energy savings targets, meter their energy consumption, provide construction cost data, and submit it to the program.

- **Output:** Incentives are incorporated into projects' financial proformas and issued at various stages of the project timeline and at various levels, depending on certification status and post-occupancy performance.
- **Output:** Certified professionals are engaged at project inception and assist in the completion of feasibility analyses, energy modeling, pre-certification, and certification.

1.1.1.4 Technical Support

Most project technical support will be completed by leveraging third-party consultants trained in accordance with the requirements set forth by PHIUS or PHI. These consultants will engage in feasibility studies and energy modeling prior to the completion of schematic design, and will shepherd the project along through pre-certification and, if applicable, certification. Prior to this, the program will offer technical support to project teams in the conceptual and early schematic

[4] One hundred percent of feasibility costs are covered to a maximum of $5,000, and modeling incentives max out at $500 per unit or $20,000.
[5] Pre-certification is when the project is designed to meet Passive House standards but has not yet been constructed.
[6] For example, if a 100-unit project achieves certification the owners will have received a per-unit incentive of $500 for pre-certification and $2,500 for final certification, totaling $3,000 per unit for a total of $300,000 in project incentives; if they produce 500,000 kWh in savings they would be eligible for the net-performance bonus ($0.75 per kWh, minus the pre/final certification incentives). The net performance bonus would be an additional $75,000, resulting from the difference of the total performance bonus ($375,000) and the total certification incentives ($300,000). Feasibility and initial energy modeling incentives are not included in the certification total.

design phases to encourage Passive House as a project goal and design strategy. Early project design charrettes, facilitated by the program, will cover the strategies and energy conservation measures (e.g., insulation, window types, mechanical ventilation) needed to seriously pursue Passive House certification. Charrettes will also help establish and facilitate the connection between the project team and the necessary Passive House consultants who will provide technical assistance. The program will provide continued support to the design team to maintain focus on energy reduction targets.

Another element of the program's technical support will provide education and technical support to policy makers. This includes highlighting the quality control required for Passive House to expedite permit, environmental, and zoning reviews for projects. The program will also provide technical support to further Passive House in affordable housing policies. In addition, municipalities may set energy use intensity (EUI) requirements for development; the program will provide technical support to those jurisdictions.

- **Output:** Charrettes are held with the project team to explore Passive House as a project goal and establish any outstanding requirements needed to position the project for certification.
- **Output:** Policymakers include or further the inclusion of Passive House in various ways, including development guidelines (permitting, environmental, zoning), affordable housing policies, and state and municipal policies.

1.1.1.5 Project Data Collection (post occupancy consumption and construction costs)

One goal of the Passive House program is to achieve observed energy savings, rather than relying on modeled savings estimates. The program will require project participants to meter and provide data to the program for electric consumption, fossil fuel consumption, and on-site renewable energy generation. This information will allow the PAs to understand how passive designs perform post-occupancy relative to modeled estimates. It should be noted that over time it may be possible to transition performance bonus incentives to actual performance rather than estimated savings based on modeling results. The program will also require participants to provide construction and soft cost data to inform the incremental costs associated with Passive House projects.[7] Data on the incremental costs of passive design relative to traditional construction are limited. More certainty on incremental costs will help stakeholders in the decision-making process regarding whether to pursue Passive House certification.

- **Output:** Building energy performance data is analyzed, comparisons between actual and modeled performance are made, comparisons to non-participant projects and traditional RNC program participants are made, and marketing and educational materials (e.g., case studies and best practice guides) are developed.
- **Output:** Incremental cost data is tracked and analyzed to monitor trends in costs and develop incremental costs for program cost-effectiveness; data is used for creating

[7] Soft costs are costs associated with the project achieving Passive House certification but are not related to the material and system costs for construction (i.e., certification fees, additional energy modeling costs, etc.).

marketing and educational materials (e.g., case studies) aimed at developers and other market actors.

1.1.2 Short-term Outcomes

Short-term outcomes of the Passive House offering will typically follow directly from the various program activities. Short-term impacts will generally be limited to program participants. These outcomes, if realized, will lay the foundation for creating broader market effects once the program timeline shifts to the medium- and long-term. Generally, a medium-term outcome would be caused by a short-term outcome and a long-term outcome would be caused by a medium-term outcome. A short-term outcome would likely occur one to three years following program intervention. The expected timing of the outcome does not limit the timeline in which it can be measured. For example, an outcome expected to occur in the short term can still be measured more than three years after program intervention and a long-term outcome should have a baseline established in the very near term.

1.1.2.1 High Program Awareness and Participation

Two program activities increase awareness of and participation in the program among market actors, owners, and occupants: (1) marketing materials and outreach efforts and (2) education and training events. The first informs market actors that the new program offering exists and what benefits passive design brings. The second provides market actors with the knowledge necessary to push them from simply being aware to having confidence they can participate effectively. In addition to generating market actor confidence, the trainings will help flesh out the technical benefits of Passive House. Below, we describe improvements in program satisfaction, which can also fuel program participation levels.

- **Indicator A:** Rates of awareness of the new program offering.
    - **Data sources:** Surveys designed to assess program awareness and understanding of program offerings among participant and non-participant owners, builders, designers, engineers, architects, developers, owners' project managers (OPMs), and sustainability consultants.
- **Indicator B:** Rates of program penetration relative to the residential multifamily market and relative to the traditional MFHR and LR program (penetration can be broken down by level of program engagement [e.g., performed feasibility assessment, attained pre-certification, attained final certification]).
    - **Data sources:** Program databases, Dodge and/or CMD data, U.S. Census building permit counts.[8,9,10]

[8] Dodge Data & Analytics: https://www.construction.com/toolkit
[9] Construction Market Data: https://www.cmdgroup.com/
[10] U.S. Census Building Permits Survey: https://www.census.gov/construction/bps/

1.1.2.2 Increased Understanding and Awareness of Passive House Certification, Practices, and Benefits

Education and training, marketing and outreach, project data collection, and the involvement of passive house professionals in participating projects may all lead to increased understanding among a wide array of participating market actors about the certification processes, design principles, and benefits provided by passive design. This understanding lowers barriers and may boost Passive House demand among project decision-makers in the broader RNC market. This is due to these individuals' ability to provide critical information and experience gained from initial program participation to future project teams as the program timeline shifts to the medium term.

- **Indicator A:** Participant understanding and awareness of Passive House benefits.
    - **Data sources:** Surveys designed to assess participant and non-participant market actors' knowledge of Passive House benefits and challenges. Market actors include building operators, customers, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.
- **Indicator B:** Participant understanding and awareness of Passive House design principles.
    - **Data sources:** Surveys designed to assess participant and non-participant market actors' knowledge of Passive House design principles (measures that promote energy efficient construction). Market actors include building operators, customers, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.
- **Indicator C:** Participant understanding and awareness of Passive House certification processes
    - **Data sources:** Surveys designed to assess participant and non-participant market actors' knowledge of Passive House certification processes. Market actors include building operators, customers, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.

1.1.2.3 Increased Adoption of Passive Design and Building Practices by Participant Market Actors

Program-sponsored trainings and Passive House accreditation courses (advertised and subsidized by the program) may lead to an increase in the number of Passive House certified multifamily buildings, and the adoption of passive design and construction practices among participating market actors. Program-sponsored trainings can reach a wider pool of market actors with less detailed trainings on Passive House benefits and best practices in building science. Passive House accreditation courses will provide a narrower subset of individuals with deep knowledge of passive design practices to carry forward.

- **Indicator A:** Self-reported building/operation practices of participating market actors.
    - **Data sources:** Surveys designed to assess the adoption of Passive House design and construction practices with participant and non-participant builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.

1.1.2.4 Verified and Enhanced Program Energy Savings

The Passive House offering may produce actual, observed energy savings from the required energy metering by project participants. Note that monitored energy results may show some inconsistency compared to modeled results throughout the short-term window of one to three years.[11] In-depth interviews (IDIs) with market actors highlighted the need for owners and occupants to *learn* the building for a one-year period before it is operating at the intended efficiency. Conversely, building occupation may ramp up gradually, causing the building to show artificially low energy usage in the early stages that increases as time goes on. Allowing energy usage to normalize is important for understanding how the building will perform in the long term and what the level of savings the program will expect to see over the life of the building. Once that normalization has occurred, observed energy savings should be compared to the energy models to verify if the project is below, meeting, or exceeding estimated performance.

Because the goal of the program is to provide deep and sustained energy savings beyond what is achieved by the existing RNC program, observed energy consumption data should be compared to data from participants in the traditional RNC program to understand the added level of savings being achieved by Passive House program participants; both participants that achieve full certification and participants that do not. Passive House participants should achieve lower EUI than traditional RNC program participants. Passive House participants should also be compared to non-participant projects as new baseline multifamily market assessments occur to understand to what extent the savings exceed baseline practices. Measurement of this outcome can start in the short term but will continue to be a key metric into the medium term as well, with attention paid to any major trends.

- **Indicator:** Participant building energy usage compared to energy model estimates, to traditional RNC program project files, baseline results, and billing data.
    - **Data sources:** Participant energy metering data provided to the program, billing data, project energy models, traditional RNC program data, and baseline data.

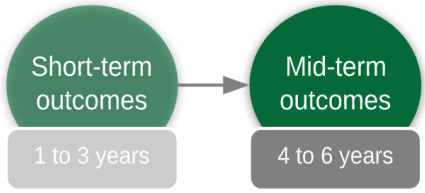
1.1.2.5 High Participant Satisfaction with Program

Participants who receive recognition for successfully certified projects, and who benefit from an enhanced incentive structure that subsidizes deep technical assistance and offers new bonus incentives, may show increased satisfaction with the program. While participant satisfaction is not a market effect, it is an early indication that (1) the program offerings and outcomes resonate positively with market actors and (2) market effects may be sustained by high rates of program participation.

- **Indicator:** Level of participant satisfaction with program support, services, and incentives.
    - **Data sources:** Surveys with participating building operators, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.

[11] If the program identifies that energy consumption results are not meeting modeled estimates due to occupant behavior, the program should develop an occupant education activity to reduce variances in actual and estimated energy consumption due to occupants.

1.1.3 Medium-term Outcomes



Medium-term outcomes represent an inflection point when the outcomes of program interventions start to be felt in the broader multifamily RNC market. Medium-term outcomes will most likely occur four to six years after program intervention.

1.1.3.1 Increased Demand for Passive House Buildings in the Multifamily RNC market

The demand for passive building designs generated among program participants may move into the broader market. This outcome could occur even sooner than the medium term; however, due to varied project timelines based on project size, larger projects will likely see this outcome occur in the medium term. It may be worthwhile to assess the demand for Passive House multifamily buildings with builders, renters, and condo or apartment purchasers earlier than four years after the start of implementation. Perceptions of program influence on these and other indicators will be important to assess during measurement.

- **Indicator A:** Proportion of new buildings that are Passive House-certified or pre-certified.[12]
  - **Data sources:** Certified Projects Databases from PHIUS and PHI.
- **Indicator B:** Increasing requests for passive designs in project RFPs.
  - **Data sources:** Surveys with architects, builders, developers, owners, OPMs, designers, and Passive House consultants.
- **Indicator B:** Increased mentions of Passive House accreditation in advertisements and real estate listings.
  - **Data sources:** Surveys with builders, developers, owners, OPMs, Passive House consultants, renters, and apartment or condo purchasers.

1.1.3.2 Increased Number of Passive House-certified and Skilled Market Actors

The Passive House offering currently subsidizes Passive House accreditation courses. Given this, growth in the number of Passive House professional certifications will likely be measurable in the short term. Even so, the increase is expected to be more substantial in the market overall in the medium term. Increasing demand for passive designs may lead to an increased number of Passive House-certified market actors (which will likely help achieve more Passive House certified buildings, making this a positive feedback loop). Exposure to more general training and education provided by the Passive House offering may further motivate those market actors who have not pursued a certification to do so as their familiarity with passive building and design practices increases in the short term.

Skill in passive design and construction is a related outcome that is distinct from certification and achieved though continued experience with passive projects. More skilled market actors may

[12] Databases of certified projects with locations, dates of construction, and/or certification are maintained for both PHIUS (link to database) and PHI (link to database).

impact the market by lowering the incremental costs of pursuing passive design and increasing the chances of successful certification efforts.[13]

- **Indicator A:** Proportion of market actors with a passive house certification.[14]
  - **Data sources:** PHIUS and PHI certified professional lists.[15]
- **Indicator B:** Self-reported levels of skill in Passive House practices (e.g., air sealing, eliminating thermal bridging, sizing HVAC equipment, pricing projects, energy modeling).
  - **Data sources:** Surveys with participating and non-participating building operators, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.

1.1.3.3 Increased Proportion of New Construction that is Passive House-certified or Pre-certified

Increasing demand for Passive House buildings – another medium-term outcome – may contribute to more passive buildings but will not itself indicate if a greater proportion of multifamily new construction consists of passive projects. Progress in transforming the market will be reflected through an increased market share for passive buildings in the medium and long terms.

- **Indicator A:** Proportion of new buildings that are Passive House-certified or pre-certified compared to Massachusetts multifamily construction permits.[16]
  - **Data sources:** Certified Projects Databases from PHIUS and PHI, and census permitting data.

1.1.3.4 New Passive Design and Building Practices Carried over to Non-participant Projects

In the medium-term, the program can expect to see training and skills spill over into the broader RNC market. The techniques, tools, and equipment that the market actors learn to use when working on participating passive projects can be carried over to non-participating projects. More specifically, an increase in the number of Passive House-certified market actors with practical experience contributes to this outcome. This outcome is most relevant for design (architects and engineers) and construction (builders, mechanical, engineering, and plumbing (MEP) contractors, insulation contractors, etc.) professionals.

- **Indicator A:** Reports of applying knowledge/skills for high-performance building practices or operation practices learned through the program.

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[13] IDIs with market actors, covered in the final Passive House Assessment report, indicated that cost is a major barrier to pursuing Passive projects – lack of market familiarity with Passive practices causes builders to inflate their prices in bidding, and lack of Passive House-related skills can hinder the ability to find efficiencies in project execution.

[14] PHIUS certifications include Certified Passive House Consultants (CPHC), PHIUS Certified Builder, PHIUS+ Rater, and PHIUS+ Verifier. PHI certifications include Certified Passive House Designer/Consultant and Certified Passive House Tradesperson.

[15] PHIUS: https://www.phius.org/find-a-professional/find-a-phius-cphc-. PHI: https://cms.passivehouse.com/en/training/find-professional/

[16] PHIUS and PHI both provide databases of certified projects (here and here) with locations and dates of construction and/or certification.

- **Data sources:** Surveys designed to assess which passive principles have been adopted as standard practices with participating building operators, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.

- **Indicator B:** Baseline market assessments and reports that characterize changes in standard multifamily construction practices.
  - **Data sources:** Multifamily baseline studies, market characterizations, and reports of changes in standard multifamily construction practices.

1.1.3.5 High Owner and Occupant Satisfaction

Owners and occupants of Passive House buildings are likely to be pleased with the energy savings they realize and other benefits (e.g., thermal comfort and indoor air quality) they reap from the occupation and operation of Passive House buildings. While participant satisfaction is not a market effect, it is an indication that market effects may be sustained by high rates of program participation. Positive experiences with these buildings can also help boost demand in the broader RNC market.

- **Indicator:** Level of participant satisfaction with owners and occupants experience with participant buildings.
  - **Data sources:** Surveys designed to assess program satisfaction with participating customers, owners, and operators.

1.1.3.6 Increased Proportion of New Buildings that are Low EUI

All program activities are intended to lead participant buildings to EUIs that are lower than they would have been in absence of the Passive House offering. However, program activities may also lead to reduced EUIs in the overall market as the timeline stretches out and program impacts spill over into the broader market. The measurement of this outcome is anticipated to start in the medium-term, but impacts may not be noticeable until later in this period. Most of the previously discussed outcomes lead either directly or indirectly to this outcome. The primary drivers of this outcome are increased demand for passive buildings, an increased proportion of new buildings that are Passive House certified or pre-certified, new practices being carried over to non-participant projects, and increased amounts of skilled or certified market actors.

- **Indicator:** Proportion of new buildings that are low EUI.
  - **Data sources:** Metered data from participating buildings, billing data of participating and non-participating buildings, U.S. Energy Information Administration (EIA) Commercial Buildings Energy Consumption Survey (CBECS) and Department of Energy Building Performance Database (BPD).[17,18]

[17] https://www.eia.gov/consumption/commercial/
[18] https://www.energy.gov/eere/buildings/building-performance-database-bpd

1.1.3.7 Increased Feasibility of Passive Design

Increasing demand for, and presence of, passive buildings might suggest increased feasibility, but concrete evidence that the added costs and challenges associated with designing and building to passive standards is important for determining if the program is positioning itself to bring about market transformation. Many other short- and medium-term outcomes directly or indirectly impact this outcome, including an increased number of skilled or certified market actors, new Passive House practices being carried over to non-participating projects, and an increased understanding and awareness of Passive House design benefits. In the medium term, observing lower incremental costs and more confidence among designers, contractors, and developers about their chances of completing a Passive House project for a similar budget as traditional projects would suggest that feasibility is increasing in the overall market. Measurement of this outcome regarding market actor attitudes toward feasibility should pay particular attention to the role that program initiatives have played.

- **Indicator:** Incremental cost decreases relative to past Passive House program participants and industry standard practice construction.
    - **Data sources:** Passive House program participant cost data; Passive House incremental cost study; surveys with builders, designers, developers, and owners; and existing incremental cost data, such as findings from the Final Passive House Assessment Report.[19]
- **Indicator:** Market actor attitudes toward passive design feasibility.

Data sources: Surveys designed to assess cost and project feasibility with owners, developers, contractors, designers, engineers, and Passive House consultants.

1.1.3.8 Emissions Reductions

While this is not a stated program savings goal or a traditional market effect the program aims to measure in the current framework, successful program interventions may result in medium- and long-term emissions reductions that may help meet state regulatory goals. Early Passive House adopters work to include renewable energy in their project designs (both on-site and off-site) to offset emissions from energy consumption and meet certification requirements. The requirements to achieve Passive House certification innately require some form of renewable energy generation; thus while the program does not claim savings for renewable energy generation, it does serve as a conduit to actualize renewable energy generation. Passive House buildings' reduced space conditioning requirements provide projects with a greater opportunity to include the addition of renewable energy systems cost-effectively as the size of the renewable systems can be reduced. In addition, proponents and early adopters of passive design have enthusiastically embraced the concept of reducing embodied energy in buildings, and many Passive House experts have stated they work to reduce the use of materials with high levels of embodied carbon whenever they can to lower the life-cycle emissions of the buildings they design. It is possible that these attitudes and priorities will become more prevalent in the long term, further boosting the emission reductions caused by program interventions. While early adopters and

[19] http://ma-eeac.org/wordpress/wp-content/uploads/MA19R05_PassiveHouse_OverallReport_Final_2020.01.06.pdf

Passive House proponents have stated intentions to reduce embodied carbon, it remains to be seen whether the next wave of Passive House practitioners will adopt the same philosophies. If the program anticipates measuring emission reductions in the future, providing designers with resources, guidance, and technical support on how to effectively reduce the embodied carbon of the building may lead to additional benefits, such as lifetime emission reductions in program buildings.

- **Indicator:** Reduced lifetime greenhouse gas emissions from participant buildings compared to traditional program and non-program buildings (i.e., operational energy savings, fuel selection, material selection).
    - **Data sources:** Surveys designed to assess material selection, fuel choices, and operational energy savings with participant and non-participant market actors (developers, architects, engineers, builders, subcontractors). Modeling and analysis conducted on lifetime emission savings, greenhouse gas analysis on program results, comparisons with traditional program and multifamily baseline results.

1.1.3.9 Positive NEI Experienced in Participant Buildings

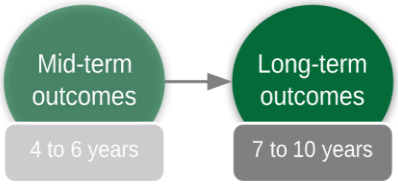
IDIs with market actors familiar with Passive House highlighted the major non-energy impacts (NEIs) that result from passive design. Many interviewees suggested these benefits were just as important as the energy-related benefits. Passive building design may lead owners and occupants to experience NEIs, such as fewer tenant complaints and tenant turnover, improved thermal and auditory comfort, reduced operational and maintenance costs, and increased indoor air quality. In addition, passive buildings may remain at a comfortable temperature and be able to self-sustain during a power outage for much longer than a building only built to code. Market actors suggested these NEIs may lead to positive impacts on occupant health, increased work productivity, and overall increase in building resiliency. This outcome may also occur in the short-term. Generally, NEIs are measured as their own impacts apart from market effects as they are very complex to isolate and measure. We do not suggest measuring NEIs under the market effects framework, rather specific NEIs should be targeted for further research to quantify the associated benefits.

- **Indicator:** The number of positive NEIs experienced as a result of the Passive House offering.
    - **Data sources:** Research and studies conducted on specific NEIs relative to Passive House and program participation; market actor surveys designed to assess NEI identification and both positive and negative experiences of passive design (developers, architects, builders, owners, and occupants).

1.1.3.10 Development of Additional Passive House Offerings

One benefit that may be seen throughout the life of the Passive House offer for multifamily new construction is the ability for the PAs to leverage program design, trainings, lessons learned, and the market transformation framework to pilot additional Passive House or net-zero offerings. This may include expanding into the single-family RNC market, residential retrofit market, or non-residential retrofit market to achieve deep energy savings throughout Massachusetts. This would also feedback into emissions reductions, described above.

- **Indicator:** The number of Passive House offerings expanding into other market sectors in Massachusetts.
    - **Data sources:** PA and EEAC three-year plans; interviews with PAs and implementations staff; surveys designed to assess demand for passive design with market actors in other market sectors (developers, architects, engineers, builders, subcontractors, occupants).



1.1.4 Long-term Outcomes

The following long-term outcomes would be expected to occur seven to ten years after program intervention.

1.1.4.1 Advances in Building Codes and Regulations

As the program promotes passive design elements in all new construction, particularly in the form of Passive House certified projects, it is possible the state will acknowledge the increased use of high-efficiency design practices among market actors. In turn, this may lead to significant advancements in the energy code, which may affect all RNC buildings in the form of statewide mandates for efficiency. Similarly, demand for and construction of high-performance buildings may encourage communities to develop their own local zoning ordinances.

- **Indicator A:** Changes in building code (e.g., inclusion of Passive House and ZNE stretch codes).
    - **Data sources :** Municipal/state code documents, documentation of PA efforts to change or amend building codes to include Passive House levels of efficiency.
- **Indicator B:** Perceptions of program influence on code changes.
    - **Data sources:** Surveys and/or Delphi Panels with code officials, industry experts, and regulatory representatives.

1.1.4.2 Persistent Energy Savings in Market Overall

Most outcomes directly or indirectly result in persistent energy savings in the overall market. Typically, passive design creates buildings that use less energy for heating and cooling over their useful lifetimes, while increased education and awareness among the people occupying and operating the building addresses behavioral aspects that impact energy consumption, such as plug loads and the use of windows and operable shading. These energy savings also reduce emissions and contribute to overall state regulatory goals for emission reductions.

The lower energy consumption of passive buildings coupled with on-site renewables may decrease the burden on the power grid and can make the power grid more resilient as greater emphasis on strategic electrification takes place over the long term. As program penetration increases to the broader multifamily market, the impact and implications of an increased proportion of newly constructed multifamily buildings designed to passive standards will contribute to an overall increase of completely (or mostly) electric buildings. While it is likely that passive

projects will utilize electric space heating and cooling systems; the current options for electric water heating are very limited. The addition of electric space heating may trigger winter peak demands, let alone the potential impacts to the grid from future electric water heating solutions as strategic electrification efforts broaden. While the winter peak demand impact on grid resilience may be attributed to broader strategic electrification efforts, the impact on the grid specific to passive buildings - increased utilization of electric systems in lower load buildings compared to increased utilization of electric systems in non-passive buildings - should be considered by the program.

- **Indicator A:** Reductions in EUI in new multifamily residential buildings.
  - **Data sources:** Metering data provided by participant buildings**,** billing data of participant and non-participant buildings, CBECS, and BPD.
- **Indicator B:** Perceptions of program influence.
  - **Data sources:** Surveys and/or Delphi Panels designed to assess program influence over persistent energy savings with participant and non-participant building operators, owners, builders, designers, engineers, architects, developers, OPMs, and sustainability consultants.
- **Indicator C:** Observed lower energy consumption and peak demand from participant projects.
  - **Data sources:** Metering data provided by participant buildings**,** billing data of participant and non-participant buildings, CBECS, and BPD.

1.1.4.3 Increased NEIs in the Multifamily New Construction Market Overall

As Passive House takes over a greater share of the overall multifamily new construction market, more and more buildings may experience the NEIs that have been created by participant projects. The expansion of NEIs is viewed by Passive House proponents as a key benefit of the building standard, especially if passive design can achieve greater penetration into the affordable housing market and further socioeconomic equality with these positive non-energy outcomes.

- **Indicator:** Increased NEIs experienced in broader multifamily market.
  - **Data sources:** Increased penetration of Passive House buildings in the multifamily market; increased use of passive design principles in the multifamily market; surveys designed to assess NEI experiences with traditional program and non-program market actors (developers, architects, builders, owners, and occupants).

1.1.4.4 Savings from Non-regulated Loads and Non-traditional Measures

One potential opportunity for savings from the Passive House offering is the inclusion of non-regulated loads (i.e., plug loads vs. lighting, HVAC, and envelope loads) and non-traditional measures, such as ventilation, that impact the EUI reduction of buildings.[20] The PAs should begin

[20] Regulated loads are a result of building energy consumption from fixed building services such as space heating and cooling, hot water, lighting, etc., that are inherent in the design of the building. Unregulated loads are a result of building energy consumption from a system or process that is not controlled or included in the regulated building

to explore the implications for claiming savings from non-traditional sources in the short term in order to determine the impacts and feasibility to claim savings from non-traditional measures. It should be noted that plug loads are generally a function of occupant behavior and, therefore, the program may likely have to incorporate occupant education plans and the inclusion of smart technology strategies (such as advanced power strips, smart thermostats, etc.) into the offering.

- **Indicator:** Increased number of claimable measures included in user-defined reference home (UDRH) for the Passive House program offering.
    - **Data sources:** Interviews with PAs, implementation contractors, and industry experts on program evaluation; updates to the UDRH from the traditional MFHR and LR programs; research conducted on implications and savings potential from non-regulated loads and non-traditional measures.

1.1.4.5 Market Transformation

The increased proportion of buildings that are Passive House-certified or pre-certified, spillover of market actor practices to non-participating projects, increased demand for and construction of passive buildings, and "locking in" of savings through code enhancements may help to transform the multifamily new construction market towards greater efficiency. Together, all of the market effect indicators can be used to indicate of market transformation. Throughout the transformation process, we would expect to see a general shift of market actors' perceptions of the normalcy of passive buildings. Essentially, passive buildings would become commonplace through the market transformation process and become a standard outcome in new construction.

- **Indicator A:** A majority of short, medium, and long-term outcomes are measured and there is a major presence of Passive House construction observed in the broader multifamily market in Massachusetts.
    - **Data sources:** Market effects indicators are measured and compared against baseline conditions; Surveys, interviews, and/or Delphi Panels to assess market transformation; Passive House levels of efficiency are observed in baseline market assessments.
- **Indicator B:** There is a major presence of Passive House construction observed in neighboring states, where contractor spillover between markets occurs (i.e., Connecticut, Rhode Island).
    - **Data sources:** Program evaluation reports in neighboring states; reports of increased rates of Passive House in border markets; Passive House project and certified professional databases; surveys designed to assess the number of passive projects completed outside of Massachusetts by program participants.

1.1.5 Additional Program Theory Elements

1.1.5.1 Resources

systems and can include energy consuming systems such as elevators, security systems, external lighting, laptops, cooking, AV equipment, and other appliances.

Program resources allow the Passive House offering to carry out the activities outlined above. The primary resources of the offering may include program budgets; program and sales staff efforts; program staff, Passive House consultants, and market actor expertise; relationships with market actors; past, present, and future evaluation research; partner organizations; and existing tools from outside organizations. The Passive House certification bodies – PHIUS and PHI – and the experts they train and employ will be key resources for the Passive House offering.

1.1.5.2 Stakeholders

The Passive House offering will interact with a number of stakeholders to achieve the intended program outcomes. These include state officials, customers, building operators, occupants, building owners and OPMs, Passive House consultants, energy managers, designers, design-build firms, architects, engineers, construction managers, general contractors, subcontractors of various trades, developers, realtors, appraisers, and lenders.

1.1.5.3 External Factors

To accurately understand the impacts the program has achieved, evaluators must place the program within a larger context affected by several external factors. To avoid attributing too much weight to a program's success or failures in achieving its outcomes, evaluators must consider external factors.[21] The main Passive House certification bodies, PHIUS and PHI, are actively seeking to increase the market share of passive buildings and have a financial interest in doing so based off their fees from project and individual certifications. The Passive House offering seeks to tap into this to boost training and technical expertise, and increase the success of the program, but must be cognizant of the parallel efforts of these organizations. In addition, there is the Massachusetts PAs' redesigned C&I new construction program, which now features participation pathways dedicated to getting projects Passive House certified. Many municipalities have adopted codes or regulations that require efficiency levels beyond the Massachusetts base energy code. This affects both the baseline efficiency of buildings in those areas and the level of knowledge and expertise of market actors who operate there. In the case of the Passive House offering, we should also consider the Massachusetts Clean Energy Center Passive House design challenge, the inclusion of Passive House as a compliance pathway in the building code, municipal mandates, municipal and state advocacy and support, Department of Energy and Resources support and advocacy, non-profit training and certification efforts, grassroots organizations, and changes in energy or utility costs.

1.1.5.4 Barriers to Program Participation

External factors that represent barriers to program participation are discussed in the IDI results section and elsewhere in the Final Passive House Assessment Report. Some of the barriers discussed there include the following:

- Lack of customer awareness of Passive House
- Financing requirements and availability
- Prioritization of aesthetics over efficient design (e.g., glazing percentages, interior finishes)

[21] Some external factors are negative – dynamics or entities that *deter* energy-efficient building. These are considered market barriers.

- Perceptions of financial uncertainty and upfront costs
- Lack of demand or recognition of the value of passive design
- Lack of knowledge, expertise, availability, and willingness among market actors
- Conflicting priorities among market actors
- Technical feasibility
- Broader economic variables
- Cost (time and money) to become Passive House certified for both professional and buildings.
- Uncertainty of results (e.g., energy savings achieved, comfortable living)