Off-site Construction and Passive House Standards for Affordable Housing: A Case Study Review

JANUARY 2025

Table of Contents

Acknowledgements

This report reflects the invaluable contributions of multiple individuals.

We would like to recognize the report's lead author, Charlotte Weigel, Manager, Codes and Standards, Northeast Energy Efficiency Partnerships (NEEP). Several NEEP staff served key roles in the development of the report including Cornelia Wu, Director, Abigail Brown, Senior Associate, Dragana Thibault, Manager, Tasneem Osman, Associate, Andrea Krim, Manager, and Hunza Irfan, Intern. We would also like to thank Ryan Colker, Vice President of Innovation at the International Code Council for his contribution. Formatting and edits were provided by Lisa Cascio, Director of Communications and External Relations, and Marianne Michalakis, designMind.

NEEP would like to recognize and thank the following individuals who agreed to be interviewed for this report:
Lois Arena, Steven Winter Associates, Inc.
Vikas Enti, Reframe Systems
Andrew Fredrick, Croft
Karan Gupta, Elemental Consulting
Grayson Jordan, Castrucci Architecture
Rob Leonard, Beeson Acres Resources, LLC
Dylan Martello, Steven Winter Associates, Inc.

This material is based upon work supported by the United States (U.S.) Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Building Technologies Office, award number DE-EE0009084.

About NEEP

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities. Our vision is that the region's homes, buildings, and communities are transformed into efficient, affordable, low-carbon resilient places to live, work, and play.

Disclaimer: NEEP verified the data used for this white paper to the best of our ability. This paper reflects the opinion and judgments of the NEEP staff and does not necessarily reflect those of NEEP Board members, NEEP Sponsors, or project participants and funders.

Key Takeaways

- There is a shortage of affordable housing in the U.S. In 2023, there was a 7.3-million-unit gap in affordable rental units in the U.S. for extremely low-income households.[1] This shortfall will widen if construction of new affordable housing development slows. Increasing construction costs, which were accelerated during the COVID-19 pandemic, have slowed the pace of new affordable housing by limiting developers' ability to fund projects. Moreover, in the face of rising costs, limited assistance through affordable housing programs for new construction has become insufficient to incentivize some projects.[2] This study aims to:
  - Provide developers with examples of subsidized affordable housing projects that have employed off-site construction and Passive House standards or Passive House principles to reduce building life-cycle costs, which includes construction and utility costs, and provide recommendations on how success can be replicated.
  - Present policy changes to enable the use of these construction methods to reverse the affordable housing shortfall while providing equitable access to high-quality housing with reduced environmental impact.
- The study presents case studies from four projects located in Maine, Massachusetts, New York and Pennsylvania. Three of the four projects were subsidized affordable housing. All four used either volumetric or panelized modular off-site construction. Three received Passive House certification and one used Passive House principles to achieve superior energy efficiency.
- All four projects met or exceeded expectations to significantly reduce utility costs from the use of Passive House, and all interviewees noted the superiority of off-site construction to deliver buildings to Passive House standards versus stick-built construction. Construction costs for two of the four case studies were less than stick-built, code compliant buildings; the other two reached cost parity. These outcomes highlight that combining these construction methods can consistently reduce life-cycle costs, allowing developers to stretch their program funding further, and demonstrating the potential for these methods to expand the impact of affordable housing program funding to reduce the housing shortfall.
- These case studies also detail the challenges of using these construction methods, including a lack of familiarity among lenders, insurers, and other stakeholders; lack of experience with off-site methods among builders; novel communication issues in comparison to traditional stick-built projects; and higher upfront investment.

---

[1] National Low Income Housing Coalition. The Gap: A Shortage of Affordable Homes. March 2024. Available at: https://nlihc.org/gap?order=title&sort=desc

[2] Harmann, J. 2022. "Rising Construction Costs' Affordable Housing Impacts." Janover HUD Users. December 8, 2022. https://www.hud.loans/hud-loans-blog/rising-construction-costs-affordable-housing-impacts/

- The interviewees provide lessons for developers considering these building methods to help them maximize the cost benefits of these methods, including working with experienced build teams, engaging early with project stakeholders, and completing comprehensive cost-benefit analyses to ensure the best results.
- The interviewees emphasized that several policy changes are necessary to enable market penetration for off-site construction and Passive House standards in general, and to incorporate these construction methods into affordable housing. These include:
  - Remove regulatory barriers, such as density restrictions, that discourage new affordable housing projects, enable building code standards for off-site construction, and offer expedited permitting and inspections for these construction methods.
  - Reward these construction methods when scoring competitive affordable housing incentives to allow more access to these incentives.
  - Increase first-cost incentives for affordable housing built with these methods, and award incentives earlier in the construction process.
  - Prioritize resiliency and occupant benefits of Passive House efficiency in structuring incentive programs.
  - Educate communities about the benefits of resilient, energy-efficient affordable housing.
- In general, case study participants viewed off-site construction to Passive House standards as a viable model for affordable housing. However, some interviewees underscored the need to prioritize workforce training in Passive House stick-built construction, due to its prevalence relative to off-site construction combined with the great need for affordable housing. Others recommend relaxing efficiency standards to use Passive House principles instead of Passive House certification to strike a better cost-benefit balance.

Introduction

Shortfalls in subsidized affordable housing have expanded across the U.S. due in part to rising construction costs that limit developers' ability to fund projects and reduce the impact of affordable housing program funding. To address the shortfall, there is a need to identify solutions that alleviate these constraints on affordable housing development. This study aims to explore the viability of combining two potential solutions to reduce overall costs of affordable housing: off-site construction and Passive House.

An examination of four projects that employ these construction methods demonstrates their ability to lower overall costs and provides guidance to developers on how to minimize their challenges and maximize their benefits. These case studies also provide recommendations for policy levers that could be used to increase affordable housing development with these methods to address the shortfall while providing equitable access to more resilient, healthier housing.

Combining off-site construction and Passive House standards can increase affordable housing development while providing equitable access to high quality housing with reduced environmental impact.

The Scarcity of Affordable Housing

Nationwide, affordable housing, defined as housing that costs no more than 30 percent of a household's income,[3] is in short supply.[4] A household whose monthly housing costs, including utilities, exceeds 30 percent of its income is considered to be cost-burdened.[5] In 2021, almost 23 percent of homeowners and 49 percent of renters in the United States were cost-burdened, making them more likely to experience material hardships such as food insecurity and deferred health care.[6] Low-income households are more likely to be cost-burdened; in fact, in 2023, no state had an adequate supply of affordable rental housing for the lowest income renters.[7]

To assist low-income households with securing affordable housing, there are numerous affordable housing programs, including programs to incentivize new construction of affordable housing.[8] There are several factors, however, that limit these programs from meeting affordable housing needs for low-income households. Among them, soaring construction costs driven by increased costs of materials, labor and fuel have rendered affordable

---

[3] U.S. Department of Housing and Urban Development. 2011. "Glossary of Terms to Affordable Housing. U.S. Department of Housing and Urban Development Archives. Accessed on December 26, 2024. https://archives.hud.gov/local/nv/goodstories/2006-04-06glos.cfm

[4] Joint Center for Housing Studies of Harvard University. 2023. "The State of the Nation's Housing 2023." Joint Center for Housing Studies of Harvard University. Accessed on December 26, 2024. https://www.jchs.harvard.edu/sites/default/files/reports/files/Harvard_JCHS_The_State_of_the_Nations_Housing_2023.pdf

[5] Office of Policy Development and Research. (n.d.). "CHAS: Background. "HUD User. Accessed on December 26, 2024. https://www.huduser.gov/portal/datasets/cp/CHAS/bg_chas.html

[6] Joint Center for Housing Studies of Harvard University. 2023. "The State of the Nation's Housing 2023." Joint Center for Housing Studies of Harvard University. Accessed on December 26, 2024. https://www.jchs.harvard.edu/sites/default/files/reports/files/Harvard_JCHS_The_State_of_the_Nations_Housing_2023.pdf
Shamshuddin, S. et al. 2021. "Housing Cost Burden, Material Hardship and Well-Being." *Housing Policy Debate*. 32(3): 413-432.

[7] National Low Income Housing Coalition. The Gap: A Shortage of Affordable Homes. March 2024. Available at: https://nlihc.org/gap?order=title&sort=desc

[8] Chapman, M. 2024. "What is Affordable Housing?" National League of Cities. January 8, 2024. https://www.nlc.org/article/2024/01/08/what-is-affordable-housing/

housing incentives insufficient to bridge financing for many of these projects and decreased the number of projects that can receive incentives.[9]

Utility allowances from state housing authorities keep housing costs within the 30 percent threshold for low-income households in federally assisted public housing.[10] Energy efficiency is a mechanism to lower the required utility allowances in existing affordable housing, and as such, is a potential lever to decrease the overall cost of affordable housing, liberating funding to incentivize much-needed development of additional, new affordable housing. Prioritizing construction methods that decrease the overall costs of building new affordable housing is an opportunity to accelerate affordable housing development as well.

Off-Site Construction Can Decrease Construction Costs

Off-site construction is a process that involves manufacturing components or modules of a building in a controlled factory setting, followed by an on-site assembly.[11] This method of construction offers numerous advantages relative to stick-built construction, including reducing the cost of construction through accelerated construction timelines, efficient use of materials, and economies of scale. Off-site construction offers numerous important supplemental benefits as well. Working in a climate-controlled environment enhances worker safety by reducing exposure to the elements and can improve the quality of the final product through more precise manufacturing processes and by reducing environmental exposure issues that can result in hazards like mold growth. Moreover, centralized manufacturing of off-site construction can reduce environmental impact through reduced waste and minimized time, noise, and dust disturbances for neighboring residents.[12]

Despite its advantages, off-site construction has faced challenges. The regulatory requirements can be difficult to navigate. Because significant portions of construction happen in the factory, code officials must review and inspect off-site components before the components leave the factory. Many states deal with this challenge by regulating off-site construction through programs at the state level, although each program operates a bit differently, which detracts from the efficiencies inherent in off-site construction.[13] Some states allow the

---

[9] Harmann, J. 2022. "Rising Construction Costs' Affordable Housing Impacts." Janover HUD Users. December 8, 2022. https://www.hud.loans/hud-loans-blog/rising-construction-costs-affordable-housing-impacts/

Hernandez, K. 2022. "Rising Construction Costs Stall Affordable Housing Projects." April 25, 2022. https://stateline.org/2022/04/25/rising-construction-costs-stall-affordable-housing-projects/?aid=b5c71c9a-0f2a-4c55-9b51-8418d3d87a86

U.S. Government Accountability Office. The Affordable Housing Crisis Grows While Efforts to Increase Supply Fall Short. October 2023. Available at: https://www.gao.gov/blog/affordable-housing-crisis-grows-while-efforts-increase-supply-fall-short#:~:text=However%2C%20rising%20land%20and%20construc-tion,pace%20with%20these%20increased%20costs

[10] U.S. Department of Housing and Urban Development. (n.d.) "Utility Allowances." U.S. Department of Housing and Urban Development. Accessed on December 26, 2024. https://www.hud.gov/program_offices/public_indian_housing/programs/ph/phecc/allowances

[11] Northeast Energy Efficiency Partnerships. Off-Site Construction: Meeting Passive House and Zero Energy Ready Home Requirements. January 2024. Available at: https://neep.org/sites/default/files/media-files/offsite_construction_paasivehouse_zeroenergy_homerequirements_final.pdf

[12] Thibault, D. 2024. "Benefits and Opportunities of Off-Site Construction: Analysis of Indiana and Pennsylvania." Presentation at 2024 ACEEE Summer Study on Energy Efficiency in Buildings. (Month) https://aceee2024.conferencespot.org/event-data/pdf/catalyst_activity_48299/catalyst_activity_paper_20240722160748328_a069946d_27fe_460e_8328_87b14558435f

[13] International Code Council. Primer on Off-Site Construction, Codes, Standards and Compliance. August 2022. Available at: https://solutions.iccsafe.org/ultimate-guide-to-off-site-construction

use of third-party and remote virtual inspections, streamlining and providing certainty in approval timelines. The second complication is that many in the building industry lack experience and familiarity with off-site construction practices. This can be mitigated by workforce training programs, collaboration with experienced firms, or policy incentives to encourage industry adoption.[14] Despite these challenges, the reduced cost of off-site construction could improve the viability of affordable housing projects.

Passive House Standards Improve Energy Efficiency

Passive House is a stringent energy-efficient building standard. Passive House buildings require minimal levels of energy for heating and cooling by using elevated levels of insulation, continuous insulation, minimized air infiltration and thermal bridging, high-performance windows and doors, controlled mechanical ventilation with heat recovery, and solar radiation control. Achieving Passive House standards can reduce heating and cooling costs up to 75 percent compared to average new builds. Passive House buildings also provide improved indoor air-quality and enhanced comfort for residents.[15] A 2023 survey of 45 Passive-House-certified stick-built multifamily buildings in New York and Massachusetts showed their cost of construction, was 3.5 percent higher than standard build counterparts, but with utility and federal incentives, reached cost parity to build.[16] This cost analysis did not include the utility cost savings conferred by the energy efficiency of Passive House. The reduction in utility costs can offer a way for Passive House to reduce overall costs of affordable housing programs, while providing more resilient, healthier, and more comfortable homes for occupants.[17]

Off-Site Construction, Passive House Standards, and Affordable Housing

Combining the cost savings of off-site construction with the utility savings of Passive House standards could provide an ideal model for increasing overall affordable housing development. Indeed, off-site construction offers some advantages over on-site construction in meeting Passive House standards. Off-site construction allows more precise manufacturing and assembly of building components to reduce air infiltration and thermal bridging and offers better quality control to ensure Passive House standards are met.[18]

This report details the experience of four projects in the Northeast that employed off-site construction methods and were built to Passive House standards or using Passive House principles to understand the realities of using these methods to deliver affordable housing projects. Lessons learned from these case studies will help

---

[14] Thibault, D. 2024. "Benefits and Opportunities of Off-Site Construction: Analysis of Indiana and Pennsylvania." Presentation at 2024 ACEEE Summer Study on Energy Efficiency in Buildings. (Month) https://aceee2024.conferencespot.org/event-data/pdf/catalyst_activity_48299/catalyst_activity_paper_20240722160748328_a069946d_27fe_460e_8328_87b14558435f

[15] Passipedia. What is a Passive House? September 2022. Available at: https://passipedia.org/basics/what_is_a_passive_house

[16] The Passive House Network. Safe at Home: How All-electric, multi-family Passive House buildings deliver comfortable, cost-effective climate resilience. July 2023. Available at: https://passivehousenetwork.org/wp-content/uploads/2023/07/Passive-House-Network-Summer-2023-Report-Safe-at-Home.pdf.pdf

[17] New York City Department of Housing Preservation and Development. 2021. Multifamily Passive House: Connecting Performance to Financing. New York City Department of Housing Preservation and Development. https://be-exchange.org/wp-content/uploads/2021/03/20210316_PH-Performance-to-Financing.pdf

[18] Northeast Energy Efficiency Partnerships. Off-Site Construction: Meeting Passive House and Zero Energy Ready Home Requirements. January 2024. Available at: https://neep.org/sites/default/files/media-files/offsite_construction_paasivehouse_zeroenergy_homerequirements_final.pdf

developers understand how to best employ these methods to create viable affordable housing projects and will inform policymakers on how to best enable Passive House off-site construction to help alleviate the affordable housing shortage for low-income households.

Methods

The research team aimed to identify case studies based on the following criteria: 1) use of off-site construction techniques, either with prefabricated panels or modules, 2) Passive House certification or the use of Passive House principles without certification, and 3) inclusion of subsidized affordable housing. Because this is a niche topic, not every case study adheres to all the criteria, as outlined in Table 1 below. The research team interviewed architects or off-site construction manufacturers who worked on the projects to understand the design, planning, and construction benefits and challenges of employing off-site construction to build to Passive House standards, as well as the outcomes of the project and key takeaways from the process. To supplement the findings of the case studies, the research team consulted additional Passive House experts with experience in affordable housing.

Table 1. ***Overview of case study characteristics*****.**

Name	The Whitehall Apartments	Arlington Accessory Dwelling Unit (ADU)	Croft Single Family Home	Bethany Senior Terraces
Location	Spring City, PA	Arlington, MA	Orono, ME	Brooklyn, NY
Building Typology	Mid-rise residential	Single family	Single family	Mid-rise residential
Size (ft2)	52,781	900	3,500	40,000
# Units	49	1	1	58
Interviewee(s)	Rob Leonard, Beeson Acres Resources, LLC and Karan Gupta, Elemental Consulting	Vikas Enti, CEO, Reframe Systems	Andrew Frederick, Founder/ Principal, Croft	Grayson Jordan of Castrucci Architecture
Type of off-site construction	Prefabricated Panels	Volumetric Modular	Prefabricated Panels	Volumetric Modular
Affordable housing?	Yes	Yes	No	Yes
Passive House certification	PHIUS + 2015	Phius ZERO	Passive House compliant - not certified	PHIUS + 2018

Note: Developed by Passive House Institute US, PHIUS+ 2015 was the first climate-specific passive building standard, accommodating different climate zones in the U.S. similar to other model building codes. PHIUS+ 2018 is an updated standard, replacing PHIUS + 2015 in 2019.[19] Phius ZERO is a zero energy standard that uses a current PHIUS passive building standard, Phius CORE, but prohibits the use of on-site fossil fuels and allows for on-site or off-site renewable energy to reduce source energy use to zero.[20] Passive House compliant means that the project was built to Passive House standards as described above but was not certified.

[19] PHIUS. 2018. PHIUS+ 2018 Passive Building Standard. PHUS. https://www.phius.org/sites/default/files/2022-04/PHIUS%2B%20Certification%20Guidebook%20v2.1.pdf

[20] PHIUS. N.d. Phius standards. PHIUS, Accessed on January 19, 2024, https://www.phius.org/standards

Case Study 1: THE WHITEHALL APARTMENTS

Developer: Mission First Housing Group (with Architectural Concepts, Caldwell Heckles & Egan Construction and Build SMART)

Interviewees: Rob Leonard, Beeson Acres Resources, LLC and Karan Gupta, Elemental Consulting

Description of Project

Completed in 2017, the Whitehall Apartments is a 52,781-square-foot, 49-unit affordable housing development in Spring City, Pennsylvania for veterans. The developer, Mission First Housing Group, worked on this project with CH&E Construction and off-site construction manufacturer Build SMART, using their Prefabricated Wall System and Foundation System to facilitate meeting Passive House standards. While this was the first Passive House project for Mission First, Build SMART had many years of experience meeting Passive House standards with their products. Rob Leonard and Karan Gupta, who worked at Build SMART on the Whitehall Apartments, helped to provide the information for this case study.

Project Design and Planning

Project financing came through numerous sources, including the Federal Low Income Housing Tax Credit (LIHTC) Program, a competitive affordable housing incentive program.[21] State public housing authorities use a Qualified Allocation Plan (QAP) to award these credits based on various criteria including community impact and development characteristics. Preceding this project, the Pennsylvania Housing Finance Authority (PHFA) recently added Passive House certification as a criterion for QAP points, motivating Mission First to build to Passive House standards. Mission First also leveraged the modeled reduction in utility costs characteristic of Passive House standards to secure a larger mortgage. Mission First highlighted that greater access to capital allowed them to build more housing, furthering the non-profit's mission to provide affordable, equitable, safe, and sustainable homes. The use of Build SMART's prefabricated foundation, wall, and building enclosure systems reduced the overall construction cost, estimated at $153 per square foot compared to an estimated $165 per square foot for PHFA's similar non-panelized code-built developments.

Besides having the appropriate site characteristics for development, Mission First chose the project location to meet the local need for veteran housing because of the site's proximity to health services and public transportation. The location did not present space-restrictive challenges sometimes experienced with off-site construction such as transportation size limitations or access to staging space. Customized options were available to meet design requirements to integrate and refurbish the 150-year-old Whitehall Inn with the new proposed construction, as shown in Figure 1. The team modified the design to use as many standard panel sizes as possible

[21] Tax Policy Center. n.d. "What is the Low Income Housing Tax Credit and how does it work?" Tax Policy Center. Accessed on December 26, 2024. https://taxpolicy-center.org/briefing-book/what-low-income-housing-tax-credit-and-how-does-it-work

to create replicable structures, achieving economies of scale for cost- and time savings. The off-site construction techniques introduced some design challenges, including requiring a redesign of the stairs and elevator to accommodate the panelized wall system, which was easily surmountable.

Construction Phase

Figure 1. *The Whitehall Apartments while under construction*.
The historic Whitehall Inn, rehabilitated as part of this project, sits in front of the new construction.

Photo credit: Rob Leonard

Build SMART's staff provided on-site training for the assembly of their panelized system. With many years of experience optimizing their installation protocols, training took minimal time. Leonard and Gupta also highlighted that Build SMART's use of conventional materials and tools for installation reduced friction in training workers who had not previously worked on prefabricated projects. Specialized parts and tools for assembling prefabricated components increase the complexity of installation for on-site workers. The speed of training and installation provided significant cost savings and contributed to the project meeting construction timeline and budget goals.

With its manufacturing facility located in Kansas, Build SMART faced some challenges in documenting compliance with local building regulations. These issues were primarily mitigated by providing local officials with extensive photo documentation of panel fabrication, as well as working directly with the local building department to address any code concerns regarding the geofoam prefabricated foundation system.[22] Despite the compliance challenges that off-site construction introduced, the precision allowed by off-site factory manufacturing of the wall panels facilitated meeting Passive House requirements for superior airtightness and

[22] Build SMART J-Form Foundation is a prefabricated insulated foundation system for on-grade slab foundations. https://buildsmartna.com/wp-content/uploads/2022/12/Build-SMART_J-FormFoundationSystemEngineeringGuide_20191210.pdf

insulation. Build SMART optimized "Just-in-time delivery"[23] of the building components by collaborating with Murus, a structural insulated panel manufacturer located in Mansfield, PA, who assembled and manufactured the panelized systems.

Post-Construction Outcomes

The Whitehall Apartments exceeded performance standards to meet Passive House certification, and feedback from owners and occupants has been positive, especially concerning energy savings and comfort. Passive House certification led to utility bills more than 90 percent lower than conventional code-built construction, and operational cost savings are significant. Of the original motivations for using these construction methods, the energy savings and construction efficiency in particular exceeded expectations. While Mission First acknowledged that they had some skepticism about the potential success of their first experience with these construction methods, they found it a viable model to carry forward into future projects.

Figure 2. ***The completed Whitehall Apartments.***

Photo credit: Mission First Housing Group and Columbus Property Management

Recommendations

Leonard and Gupta recommended prioritizing the use of off-site construction to build affordable housing to Passive House standards due to its cost-effectiveness, energy efficiency, quality assurance, quality control, and minimized construction timelines. They offered numerous recommendations for affordable housing developers interested in employing these construction methods in their projects. First, there is a high degree of inconsistency in understanding and enforcement of regulations among local building officials across different

[23] Just-in-time delivery of materials improves construction efficiency by minimizing obstacles at the job site and reduces the risk of damage to materials. https://lean-construction.org/lean-topics/just-in-time/

jurisdictions. They recommend early engagement with all project stakeholders, including building officials, to facilitate education and avoid misunderstandings later in the construction process.

Leonard and Gupta recommended employing an experienced off-site manufacturer that understands the requirements and building science related to Passive House building standards and uses conventional construction methods to reduce resistance from on-site workers unfamiliar with prefabricated construction installation. More complicated prefabricated systems can be daunting for builders and installers. Moreover, a lack of familiarity can lead to increased construction cost bids from general contractors. Construction teams can benefit from testimonials about prior installations to proactively address myths as well.

Leonard and Gupta found that developers and construction teams often do not comprehensively estimate building construction costs and building owners do not fully calculate the short- and long-term operational costs. As a result, construction teams run the risk of undervaluing the efficiency gained in construction operations from using off-site manufacturing to Passive House standards. Faster construction leads to earlier occupancy, which lowers the total interest paid over the life of the loan. Passive House standards confer savings on short- and long-term building maintenance and replacement costs that are also often unaccounted for in cost comparisons. The improved air tightness of Passive House buildings decreases chances for mold and inferior indoor air quality, increasing the lifetime of windows and the building structure itself, two elements that are often points of failure and expensive capital replacements. Incorporating these benefits into cost analyses could lead to more favorable financing terms and increased access to affordable housing incentives.

Leonard and Gupta highlighted several strategies policymakers could pursue to enable these construction methods for affordable housing. First, states have the authority to determine the competitive criteria for awarding affordable housing construction incentives. Including Passive House certification in the QAP scoring criteria, as Pennsylvania has done, will increase the number of projects that apply for and receive these incentives. Second, universal standards for off-site construction can avoid inconsistency in enforcement across states, and streamlined permitting processes can enable developers to take advantage of its many strengths.

To benefit both affordable housing and market-rate construction, policymakers should integrate Passive House standards into state building energy codes. For example, the Massachusetts stretch energy code now requires multifamily residential buildings greater than 12,000 square feet to achieve Passive House certification. Leonard and Gupta emphasized the practicality of applying Passive House certification to these larger building typologies, as the potential benefits of the enhanced envelope requirements of Passive House increase with greater interior volume relative to building surface area. Incorporating superior energy efficiency into the code would also promote other virtues of energy-efficient design such as improved air quality, noise attenuation, and building durability. They went further to say that insurance companies should consider the health, safety, and resiliency benefits of these construction methods in calculating insurance premiums, incentivizing developers to consider these methods with improved margins due to lower insurance costs.

Case Study 2: THE ARLINGTON ADU

Developer: Housing Corporation of Arlington (with Reframe Systems)
Interviewee: Vikas Enti, Reframe Systems

Description of Project

This project is a 900-square-foot Accessory Dwelling Unit (ADU) completed in September 2024 by the Housing Corporation of Arlington (HCA) in Arlington, Massachusetts (MA). HCA worked with Reframe Systems, a volumetric modular manufacturing company, which leverages its expertise in robotics to deliver low-carbon, modular homes built in their Andover, MA microfactory.[24] In volumetric modular manufacturing, factory-finished, prefabricated modules are stacked and joined in interlocking pieces on-site to form the complete building.[25] The Arlington ADU was Reframe's first project and HCA's first investment in affordable homes meeting the highest efficiency standards. The ADU is Passive House Zero certified. Reframe handled all aspects of the project, from site preparation to installation, streamlining the process and ensuring better coordination of the construction process than other off-site construction projects.

Reframe's business model centers on delivering carbon- and cost-efficient homes. Vikas Enti, CEO of Reframe Systems, explained that the typical cost of residential construction breaks down into 35 percent for material, 35 percent for labor, and 30 percent for management and overhead. Enti described the cost savings of Reframe's method of off-site construction. Directly employing the workforce used from start to finish for construction minimizes markups from using subcontractors. Automation in a factory environment allows a transition from skilled to general labor. This limits the risks associated with the installation of auxiliary systems, such as electrical, by reducing the required skills. Finally, although Reframe did not achieve economies of scale in material purchasing in this pilot project, subsequent projects benefit from this advantage over stick-built projects as they scale up their manufacturing.

Project Design and Planning

Following the passage of the ADU bylaw in Arlington,[26] Reframe approached HCA with the idea of building an ADU using Passive House standards, which aligns with HCA's vision of providing safe, environmentally sound, affordable housing. Among HCA's portfolio of available properties, the chosen site was deemed suitable for an ADU based on sufficient space for module access and installation. Due to the size of the modules, sites selected for volumetric modular projects must have sufficient access for wide-load trucks, staging space for a crane and truck for installation, and minimal overhead obstacles such as powerlines and trees.

---

[24] Reframe defines a microfactory as one that is digital, rapidly deployable and has a small footprint.

[25] Stream Modular. n.d. "Volumetric Modular Construction: the Benefits and Challenges." Stream Modular. Accessed on December 23,2024. https://streammodular.com/blog/what-you-need-to-know-about-volumetric-modular-construction/

[26] In 2024, the town passed a zoning bylaw allowing ADUs up to 900 square feet to be built in single-family zoning districts.

HCA did not face off-site construction-related challenges in financing this project; it was funded through grants and leveraging property equity. However, in subsequent projects, Reframe has encountered lenders who are unfamiliar with this type of construction. While lenders of Federal Housing Administration-backed loans cannot discriminate based on home type, they may need additional education to become comfortable with off-site construction techniques. In addition, off-site manufacturing can create insurance challenges for developers and site owners because some insurers will not cover the modules until they are installed. Developers should factor this challenge into the construction timeline.

Construction Phase

Because Reframe handles all aspects of construction, they avoid challenges in securing workforce for their projects. Notably, Reframe employed 60 percent of the workforce on this project as apprentices. Enti was pleased with the 48-day start-to-finish timeline with this, their first project, although they have set a goal of a 30-day turnaround in future projects. Installation required minimal time and disturbance at the job site. Neighbors expressed their appreciation for the lack of noise disturbance during the project.

Figure 3. ***Modules under construction in the Reframe factory***

Photo credit: Reframe Systems

Reframe did not experience some of the compliance challenges with inspections and permitting that exist in other states because Massachusetts allows third-party plan reviews and inspections. As Enti and the Reframe team look to expand their business into other states, they anticipate potential compliance challenges in states where this is not the case[27].

Modular factory manufacturing allowed the project to meet air tightness requirements more reliably. Enti commented that off-site construction offered advantages to meet Passive House standards and did not introduce any challenges.

[27] Some states only allow local plan reviews and local inspections.

International Code Council National Testing Agency. n.d. "Plan Review Inspection Jurisdictions." International Code Council National Testing Agency. Accessed on December 23, 2024. tps://www.icc-nta.org/services/off-site-construction/jurisdictions-map/

Post-Construction Outcomes

Figure 4. ***Completed ADU installed at the site.***

Photo credit: Reframe Systems

The performance of the building exceeded Reframe's expectations; the air tightness of the ADU surpassed the requirement for Phius ZERO certification. Efficiencies gained from Reframe's methodology on this pilot project resulted in a 30 percent decrease in the cost of construction and a 2.5 times faster construction timeline than a stick-built estimate. Consistent with Reframe's goals of reducing life-cycle carbon associated with construction, they reduced the embodied carbon of the project by 85 percent, using helical pile foundations in-lieu of a concrete foundation, wood fiber and recycled cellulose insulation, and cork flooring, among other measures.[28]

Reframe has taken many lessons from the Arlington ADU project, including the realization that using Passive House principles without pursuing Passive House standards and certification is better suited to their company goals. While the project exceeded some requirements for Passive House certification, Reframe nonetheless

[28] The life-cycle carbon emissions of a building include embodied emissions, which occur in four phases: the product phase, the construction phase, the use phase, and the end-of-life phase. Embodied emissions do not include energy use from the operation of the building. Most embodied emissions occur during the building product stage, which includes the supply and transport of raw materials, and the manufacturing of construction materials. Calculating the life-cycle carbon emissions of a building results in a more complete picture of the environmental impact of the building.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. 2024. Embodied Carbon Reduction in New Construction. U.S. Department of Energy. https://www.energy.gov/sites/default/files/2024-02/bto-abc-embodied-carbon-022624.pdf

Lamber, M., & Lewis, M. 2024. Embodied Carbon 101. Carbon Leadership Forum. https://carbonleadershipforum.org/embodied-carbon-101-v2/

learned that the energy savings achieved by Passive House standards do not offset the increased material costs and embodied carbon needed to meet higher wall R-values for certification.[29] Rather, they found using continuous insulation, a Passive House principle, with a reduced R-value relative to the certification requirement is optimal to meet their cost- and carbon-efficiency goals and reduces the amount of mold mitigation required for thicker wall insulation.[30] Reframe strives to reduce energy use over the life of the building but combines that metric with embodied carbon and the cost of construction to find a balance that meets their goals. For Reframe, the outcome of that calculation results in a retreat from Passive House certification requirements in future projects.

Recommendations

Although not a challenge in this project, Enti emphasized that volumetric modular construction will not work at every site due to the clearance requirements for installation. He advised that developers first look across a portfolio of locations for properties that would work. Once the project team identifies a site, they should invest early in on-site studies. He suggested that modular residential projects undertake soil studies like those required for commercial projects to inform the type of foundation best suited for the site. In addition, Enti recommended engaging stakeholders early and often by bringing lenders and inspection departments to the factory to educate them on what to expect with the project.

Enti suggested that policymakers adopt construction cost incentives for single-family new construction built to Passive House standards to enable more investment in these types of projects. Massachusetts' current incentives can serve as a model for other states.[31] Any legislation should aim to meet cost parity with stick-built construction of similar typologies. In addition, off-site construction requires a larger investment earlier in the construction process than stick-built construction. Therefore, providing incentives earlier will enable investment in these construction methods. Finally, states should enact standards for off-site construction approvals to remove obstacles to investment and enhance consistency in compliance requirements.

---

[29] The Phius CORE 2021 prescriptive requirement for opaque above-grade walls in Climate Zone 5 is R-32-48. https://www.phius.org/sites/default/files/2022-07/Phius%202021%20%28Prescriptive%29-%20Reference%20R-Values%20Table%20-%20Final%20Zone%20Tables.pdf

[30] Some Passive House requirements, including increased insulation, can increase the embodied carbon of a building. These impacts can be mitigated through the choice of materials such as those used by Reframe in this project.

Bernstein, F. 2022, Taking a holistic approach to embodied carbon. Architectural Record. https://www.architecturalrecord.com/articles/15852-taking-a-holistic-approach-to-embodied-carbon#:~:text=The%20study%20found%20that%2C%20compared,huge%20increase%20in%20embodied%20carbon.

[31] Massachusetts provides a $25,000-$40,000 incentive for single family new construction (1-4 units) that receives Passive House certification: https://www.masssave.com/en/residential/programs-and-services/new-home-construction/single-family

Case Study 3: CROFT SINGLE-FAMILY HOME

Developer: Croft
Interviewee: Andrew Frederick, Croft

Description of Project

This project involved the construction of a Passive House compliant single-family home in Orono, Maine, a small town along US Route 2. Croft, the project leader, is dedicated to designing and manufacturing carbon-negative buildings using all-natural, locally, and responsibly sourced materials. Croft had extensive experience with both prefabricated and Passive House projects, which contributed to the seamless integration of these methods. The costs for this custom project were comparable to stick-built of a similar type, whether Passive House or non-Passive House.

Croft originally intended that the lot, which is located in town, host a single-family home along with six affordable housing units. However, the additional units could not proceed due to regulatory barriers, including zoning requirements for private roads and walkable downtown neighborhoods. Despite these setbacks, Croft successfully completed the single-family home using off-site construction methods. The 3,500-square-foot home employs panelized prefabricated components.

Panelized construction involves prefabricating flat components, such as walls, floors, and roofs, in a factory and assembling them on-site, whereas volumetric modular construction entails creating fully enclosed building modules that are transported to the site for final assembly. Andrew Frederick, founder of Croft, explained that the project team chose panelized construction for this project due to the project team's experience with panelized systems and their compatibility with Passive House design goals. Frederick further explained that panelized construction offers greater flexibility in design and allows for easier transportation and assembly. Additionally, using panelized construction often results in fewer redundant materials at connection points, helping to lower overall costs. These benefits made panelized construction the most suitable choice for the project.

Design and Planning

The homeowners already owned the land, which predetermined the site location, and its in-town location was a key factor in the project's development. Regulatory barriers encountered in this project highlight the broader challenges facing Maine's affordable housing initiatives, particularly in meeting the state's goal of creating 84,000 affordable units by 2030.

The key motivations for employing off-site construction and Passive House standards for this project included:

- Achieving low heating and cooling energy demand intensity (TEDI) that exceeds energy code standards;
- Reducing the building's life-cycle climate impact;

- Enhancing building resiliency;
- Minimizing construction's impact on neighbors including noise and disruption.

The design and planning phase required precision, with Croft opting to digitally catalog all plan details before cutting any materials. While this level of planning is demanding, it allowed Croft to have greater accuracy and efficiency during construction. Regulatory challenges included zoning and permitting issues, which prevented the construction of additional affordable housing units on the lot.

Construction Phase

The construction phase was smooth, with minor transport challenges related to delivering prefabricated components to a site in a rural town. Croft's in-house team of trained workers ensured seamless assembly of the panelized components. The project met both budget and timeline goals, demonstrating the reliability of off-site construction methods.

Using off-site construction facilitated achieving Passive House standards by employing natural, plant-based straw insulation, which contributed to the project's carbon storage potential.

Post-Construction Outcomes

Croft completed construction in November 2024. One month later, the homeowners had yet to need to turn on their heating system, reflecting the energy efficiency achieved through Passive House standards. The home's energy demand is approximately 90 percent lower than a code-compliant, stick-built home of comparable size.

Recommendations

Frederick concluded that off-site construction paired with Passive House standards should be prioritized for affordable housing, and he offered several recommendations for future projects. First, avoid focusing on the first costs alone to ensure durability and occupant health. Frederick stressed that focusing only on initial construction costs undermines long-term affordability and occupant health. Energy-efficient buildings, like the Orono project, provide significant operational cost savings while ensuring better indoor air quality and building durability. Developers should also emphasize the use of locally sourced, climate-friendly materials to yield greater environmental and economic benefits than building performance/efficiency alone. Frederick suggested that selecting materials from local suppliers can minimize transportation emissions, ensure compatibility with regional building practices, and promote economic growth. The Orono project used plant-based insulation, achieving carbon neutrality while meeting Passive House standards. He argued that Passive House certification without addressing embodied carbon undermines a broader goal of reducing environmental impacts.

Frederick highlighted the need for developers and policy makers to engage communities to reduce opposition and stigma around affordable housing initiatives. He recounted how a similar project in Portland was canceled due to a last-minute complaint from a neighbor, despite extensive public outreach. Community resistance such

as this illustrates the importance of proactive engagement. Frederick noted that the stigma around affordable housing often stems from misconceptions about its impact on neighborhoods. Education and outreach emphasizing the benefits of affordable housing—such as economic revitalization and housing for local workers—can help mitigate opposition.

Frederick provided recommendations for policy changes to encourage new affordable housing built with off-site construction to Passive House standards. Several recommendations target easing regulatory barriers, including adjusting minimum frontage and setback requirements. Croft's project in Orono originally included plans for six affordable housing units in addition to the single-family home. However, the project failed to meet permitting qualifications due to requirements for a private road and proximity to a "walkable downtown neighborhood." These frontage and setback requirements prevented the inclusion of affordable housing units, even though the landowners themselves advocated for them. Frederick described these requirements as unrealistic and counterproductive, particularly for addressing Maine's affordable housing goals.

Policymakers should also revise density zoning requirements to accommodate affordable housing needs, reduce permitting delays, and streamline inspection protocols. Density restrictions often limit the feasibility of integrating affordable units into projects, particularly in urban and suburban areas where land is scarce and expensive. Lengthy inspector timelines can disrupt the construction process for off-site Passive House projects. Simplified permitting and inspection protocols would reduce such delays.

Finally, Frederick suggested encouraging lenders to include building performance in mortgage calculations. Frederick noted that lenders could offer lower mortgage rates for high-performing homes, incentivizing developers and homeowners to adopt energy-efficient building practices. Such policies could help balance first costs with long-term savings.

Case Study 4: BETHANY SENIOR TERRACES

Developer: Riseboro Community Partnership (with Paul A. Castrucci Architecture, Whitely Manufacturing, and L Riso and Sons)

Interviewee: Grayson Jordan, PCA

Description of Project

Bethany Senior Terraces (BST) is a 40,000-square-foot affordable housing residential building for low-income seniors (39 units) and recently homeless individuals (19 units), located in Flatbush, Brooklyn, New York. The design team used Passive House standards and off-site modular construction for BST. NEEP interviewed Grayson Jordan of Paul A. Castrucci Architecture (PCA), the architect on this project, for this case study. The developer was Riseboro Community Partnership, the modular builder was Whitley Manufacturing of Leola, Pennsylvania, and the onsite contractor was L Riso and Sons.

Jordan had previous experience with affordable housing projects that attained Passive House certification, but BST was his first project using modular off-site construction to achieve these aims. Of the on-site contractors, only the steel erection subcontractor had previously worked on an off-site construction project, but this was their first modular residential project.

Design and Planning

Riseboro knew the project would be a Passive House-certified affordable building before deciding to use modular construction. They initially suggested using modular construction because of its promise of a condensed construction time, various environmental benefits, and limited disturbance to neighbors. Riseboro was particularly interested in modular construction based on the cost-saving potential associated with both construction and building operations. PCA, who already had considerable experience designing Passive-House-certified affordable housing projects, was willing to take on the challenge of modular construction because they wanted to learn a new skill. They also found the project to be a good fit for modular construction, largely because senior housing is dense and repeatable, as it is often comprised of only studio- and one-bedroom apartments. Like the Whitehall Apartments, this project benefited from improved QAP scoring for Passive House certification to receive Low Income Housing Tax Credits, as well as city and state incentives that included a $750,000 New York State Energy Research and Development Authority grant based on the use of both modular construction and Passive House standards.

Riseboro predetermined the site location because it was a sizeable single lot that had previously housed another large building. The main limitation for modular construction associated with the site was that road size constraints along the route between the factory and the site limited the size of the truck bringing modular structures to the site. This is a consideration for any off-site construction project and did not prove to be a substantial hindrance for BST. The project team also ran into some staging difficulties with space and accessibility because of the dense, urban location within New York City.

PCA faced a design challenge in figuring out how to make the repeated modular structure appear visually interesting. Jordan also mentioned that, while not an issue for this project, integrating modular structures to meet a project's intended scale can conflict with zoning height requirements. Stacking modular units creates double-thick floors and ceilings. Therefore, at some point, a modular building would "lose a floor" in relation to a stick-built building of the same height, a relevant consideration for a project seeking to maximize building height in a location where zoning laws restrict total building height, such as New York City.

Financing was not an issue on this project, however PCA still learned valuable lessons. For example, Jordan recommended that the construction bond, secured for assurance that the contractor will complete the work, should be larger for modular off-site construction than for stick-built construction. Due to the increased risk of investing a large proportion of the construction budget into work located off-site, he suggested that securing a bond sufficient to cover as much of the off-site work as possible would be ideal. Moreover, releasing more funding upfront could speed up the off-site process and allow on-site work to begin sooner.

Construction Phase

Figure 6. ***Bethany Senior Terraces under construction.***

Photo credit: Grayson Jordan

The on-site construction team's inexperience with off-site construction and a lack of familiarity between the on-site and off-site teams created challenges during construction. Scope confusion amplified this friction and led to over a month of overall delays. Due to miscommunications on construction specifications, the on- and off-site teams had different interpretations of the work they needed to complete at their respective locations. As a result, when modules arrived on site, the on-site team discovered that there was more work to complete the installation than they had anticipated. The steel subcontractor, who had previous experience with off-site construction, made suggestions about potential issues to anticipate based on their prior experience.

A large challenge of the project was that the general contractor was unwilling to purchase the modular structures directly from the factory, which was the original intent of the project scope. This was due to pandemic-related price spikes and a lack of trust between contractors. To mitigate this issue, the building owner had separate contracts with the factory and the general contractor. The team created a responsibility matrix to limit the owner's risk and cover any potential scope gaps.

A state-approved third-party inspection agency conducted in-factory code inspections of off-site components under the New York State Factory Manufactured Buildings program. Because this was their first off-site project, the project team had some trust issues with the off-site code inspection process because it was a different process than that used in on-site built projects and took place remotely.

There were also several technical challenges during construction. First, using energy recovery ventilation (ERVs) and modular construction together made air tightness testing more difficult. In PCA's previous stick-built affordable Passive House projects, only two places had to be sealed off for a blower door test, but because they used modular construction, the ERVs and their associated ductwork created 108 penetrations that required sealing. Second, the weather introduced unwanted moisture and temperature changes, so Jordan recommended installing the final roof as quickly as possible to avoid climatic issues. Finally, although unrelated to the Passive House certification, design choices in columns and walls also slowed the construction process.

Although there were many pain points along the construction journey, a new group of contractors now has experience with modular construction and the ability to better complete a similar project in the future. Repeated projects using the same team as they gain experience with the unique attributes of modular construction projects will facilitate trust between on-site and off-site teams.

Post-Construction Outcomes

Figure 7. ***A rendering of Bethany Senior Terraces when completed*****.**

Photo credit: Grayson Jordan

The team achieved the project goal of constructing a modular, affordable housing building to Passive House standards although there is no feedback from residents on building performance as the building is still unoccupied.

PCA's initial cost estimate for BST was around $425-$500/square foot, however, project pricing took place before the COVID-19 pandemic and construction occurred after the pandemic. Jordan was unclear about the precise final costs, but estimated they were near the higher end of the initial budget range. A primary cost-saving benefit of modular building is the condensed project time and limited on-site time. Due to the novelty of these construction methods for the build team, unforeseen issues led to construction delays that drove costs higher than expected, although they still achieved about the same cost as stick-built construction. Jordan emphasized that there was a large learning curve for all parties, but because PCA gained experience on this project they can now anticipate the common issues with modular construction that led to delays on this project. This will allow them to take better advantage of scheduling efficiencies and lower costs on future projects.

Recommendations

Off-site construction is a strong tool that can aid in the construction of many types of buildings. Prefabrication can offer great benefits in construction, as project teams become more familiar with modular concepts and repeatable designs create efficiencies.

Jordan outlined several recommendations for affordable housing developers interested in building Passive House or Passive-House-informed projects with these prefabrication methods. First, assemble a team with experience in modular construction to avoid some of the pitfalls associated with pioneering a novel approach; more exposure and experience will better unlock the efficiencies promised by off-site construction. When working with teams that are unfamiliar with each other or with off-site construction, developers can build trust by including safeguards against friction such as establishing clear expectations for the scope of work of each team, communicating expectations clearly, and locking in pricing early.

Developers should select a site carefully to accommodate off-site construction and to ensure sufficient space for staging and delivery of prefabricated materials. Developers should also secure a larger construction bond upfront to maximize the speed offered by off-site construction and to mitigate the risk associated with a single vendor delivering the bulk of the work.

Jurisdictions interested in encouraging projects that combine modular construction with Passive House in large, affordable housing projects may also need to increase their zoning allowance for the height of these buildings. The New York City Department of Buildings' Office of Technical Certification and Research looks at niche technical issues and is well-versed in modular design and Passive House. Jordan suggested it would be helpful to have more support from the city via this department for site logistics such as permitting, so permits can be issued in anticipation of site work.

Other Perspectives on Optimal Construction Methods for Affordable Housing

The team also interviewed Dylan Martello and Lois Arena, both Passive House experts with Steven Winter Associates, to gather additional perspectives on using off-site construction to deliver Passive House affordable housing. Consistent with case study participants, they highlighted that the quality control offered by off-site construction eases the challenge of meeting Passive House standards; precise manufacturing allows sealing that stick-built construction cannot match, especially around windows. Off-site construction is more consistent due to the assembly of repeated structures. Developers realize the cost savings of off-site construction when manufacturers can take advantage of economies of scale and experienced build teams take advantage of reduced on-site construction times, particularly in areas with high labor costs. However, despite the potential benefits, they suggested that the need for workforce training in stick-built Passive House construction is a more urgent obstacle to integrating these efficiency standards into affordable housing than promoting off-site construction due to the higher prevalence of stick-built construction.

Finally, regardless of the construction method, policies that deliver incentives for new affordable housing construction earlier in the project will enable more affordable housing development. Program administrators do

not pay affordable housing incentives until the project team completes construction and building officials issue final permits, which essentially requires developers to front these costs for long periods of time. The financial model for affordable housing needs to change to make these projects feasible for developers.

The Way Forward for Developers

Most case study participants endorsed combining off-site construction and Passive House standards to deliver affordable housing. The energy efficiency of Passive House can provide benefits for both the occupants and the developer, and off-site construction can lower the cost of construction while meeting the air tightness standards of Passive House more easily. Combining the lessons learned and recommendations from the different case studies revealed clear steps that developers can take to facilitate the use of Passive House principles and modular construction in affordable housing projects and maximize their benefits:

- Engage early with project stakeholders, especially with local building officials and lenders. Do not assume they are familiar with these building methods. Early engagement provides an opportunity for education to avoid confusion later in the process.
- Work with experienced manufacturers and construction teams that understand these building methods to maximize the time-saving benefits of off-site construction.
- To compare costs with alternative construction methods, calculate the full value of these methods, including often-overlooked cost advantages such as earlier occupancy with modular projects and reductions in long-term capital replacement costs due to smaller, significantly less complex mechanical systems and increased longevity of building envelope components such as windows.
- Space constraints with delivery and staging of materials will prohibit use of these methods in some sites, particularly with volumetric modular construction. When possible, look across a portfolio of properties to determine where these methods can be practically used.

There were some recommendations that were unique to a single case study, but nonetheless insightful:

- Choose an off-site manufacturer that uses conventional construction materials and tools to ease acceptance and training of on-site workers; reducing novelty in the scope of the on-site work will reduce friction with the on-site construction team.
- Consider securing a larger construction bond to mitigate the risk of the large upfront investment associated with off-site manufacturing.

Interestingly, the Whitehall Apartments developer mentioned they leveraged the increase in net income conferred by the energy savings from Passive House to improve their financing conditions, which allowed them to invest in more affordable housing. Rob and Leonard noted though that the incentive for energy savings will depend on who pays the utilities, and that lowering utility allowances paid by the government in subsidized affordable housing can free up funding for other construction projects.

The Way Forward for Policymakers

Participants agreed on several recommendations for policymakers, some of which would enable market rate and affordable housing of Passive House standard buildings or off-site construction. Many of these reaffirm conclusions from earlier work by this team on off-site construction.[32] Policymakers can take the following steps to promote the use of these construction methods:

- Integrate standards such as ICC/MBI 1200 and 1205 Standards for Off-site Construction into the model building code to create consistency in compliance and enforcement across states.
- Support expedited permitting and streamlined inspections for these building methods.
- Adopt accommodating zoning laws, including relaxing height requirements that inhibit the scalability of modular off-site construction.
- Encourage lenders to consider building performance rather than focusing only on first costs.
- Prioritize the occupant benefits of Passive House standards such as improved indoor air quality, noise reduction, and resiliency when structuring incentive programs
- Include Passive House standards as a risk-reduction measure to incentivize with insurance premium discounts in state-backed property insurance programs or from private insurers in the same way that fortified roofs are incentivized in some states[33]

Several policy recommendations target affordable housing specifically. Policymakers can take the following actions to increase new affordable housing projects built with these methods.

- Integrate Passive House standards into the QAP scoring criteria for LIHTCs across more states.[34] Importantly, the number of points awarded needs to be sufficient to incentivize developers. When Pennsylvania awarded eight percent of points for Passive House certification, in the three years following the change 28 percent of project proposals for LIHTCs were for Passive House projects. Some states award a smaller proportion of points for Passive House, which provides less incentive.[35] States can use a similar strategy to incentivize off-site construction.[36]
- Implement first cost incentives for affordable housing built with these construction methods and deliver affordable housing incentives earlier in the project to assist with the large upfront costs

---

[32] Thibault, D. 2024. "Benefits and Opportunities of Off-Site Construction: Analysis of Indiana and Pennsylvania." Presentation at 2024 ACEEE Summer Study on Energy Efficiency in Buildings. (Month) https://aceee2024.conferencespot.org/event-data/pdf/catalyst_activity_48299/catalyst_activity_paper_20240722160748328_a069946d_27fe_460e_8328_87b14558435f

[33] The Fortified Roof Program from the Alabama Department of Insurance encourages insurers to provide discounted property insurance premiums for a roof that has been reinforced to meet a "fortified"criteria.

Pating, A. & Moore, R. 2025. Can FAIR plans help build a more resilient future? Natural Resources Defence Council. https://www.nrdc.org/bio/alfonso-pating/can-fair-plans-help-build-more-resilient-future#:~:text=While%20insurance%20itself%20will%20not,Sustainable%20Finance%20Climate%20Adaptation

[34] Currently, 19 states include Passive House standards in QAP scoring criteria. https://www.phius.org/resources/policy-work/qualified-allocation-plans

[35] North American Passive House Network. Policy Resource Guide June 2019. (June 2019). Available at: https://passivehousenetwork.org/wp-content/uploads/2023/10/NAPHN19-Policy_Resource-singles.pdf

[36] Virginia's QAP includes a non-prescriptive benefit for projects that incorporate methods that decrease construction time and cost, which could include off-site construction. https://www.nibs.org/files/pdfs/NIBS_OSCC_Fannie-Mae-multifamily-construction-toolkit.pdf

- Relax regulatory barriers that hinder affordable housing developments such as private road requirements, setback and road frontage requirements, walkability criteria, and density restrictions.
- Engage communities to reduce opposition and stigma around affordable housing to increase support for policy changes.

Although several of our interviewees considered their projects to be highly successful, combining Passive House certification with modular construction is not the best option for every affordable housing project. Route access and staging space requirements limit the use of volumetric modular construction. In addition, based on their experience constructing the Arlington ADU, Reframe Systems pivoted to using Passive House principles with their method of volumetric modular construction to meet their carbon- and cost-efficiency goals rather than seeking Passive House certification. Frederick also emphasized the need to prioritize a reduction in embodied carbon in building projects to minimize the overall environmental impact of the building industry. Off-site construction reduces embodied carbon in the construction phase by reducing waste. Passive House reduces emissions from building operations, but some requirements, such as increased insulation, can increase embodied carbon. Croft and Reframe both mitigated embodied carbon in their projects through the use of low-carbon intensive materials. Developers who want to maximize the life-cycle cost benefits of off-site construction and Passive House as well as minimize environmental impacts will need to understand how reducing embodied carbon while achieving Passive House standards impacts the overall cost to build.

Martello and Arena also cautioned that while off-site construction can result in reduced labor costs (as in the Reframe project), using modular construction methods may only be financially advantageous in areas where labor shortages are driving up stick-built construction costs. However, the case studies highlighted here indicate that cost savings are possible, especially when a comprehensive analysis is completed. Finally, while all interviewees acknowledged the benefits of enhanced energy efficiency for affordable housing, Martello and Arena concluded that training workers on how to build Passive House standards in the field should be a higher priority to relieve a more urgent constraint around building affordable housing to these standards.

Conclusion

The conclusion of this work supports the use of off-site construction to build affordable housing that meets Passive House standards. This set of case studies also reveals numerous challenges to building with these methods to maximize their benefits. The participants offered recommendations to overcome these challenges, many consistent with earlier findings of this team in previous work exploring the costs and benefits of off-site construction. All interviewees highlighted the ability of off-site construction to facilitate meeting Passive House standards, and its potential to do so at a reduced cost. However, it was clear that jurisdictions need to update policies to overcome the inertia prohibiting more widespread expansion of these methods into the affordable housing market, including providing a competitive edge in the calculation for awarding affordable housing incentives. Some case study participants expressed frustration over the inadequacy of policy initiatives to promote these building methods to provide healthier, more resilient affordable housing. Implementing enabling policies has the potential to kick off a virtuous cycle of reduced construction costs and improved efficiency, reducing the overall costs per unit to facilitate a much-needed expansion of affordable housing development across the United States.