



# Off-Site Construction: Meeting Passive House and Zero Energy Ready Home Requirements

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## Key Takeaways

- Off-site construction has demonstrated the ability to meet Passive House principles, including thermal, air, moisture, and radiation control, contributing to low energy consumption and occupant comfort.
- Off-site construction can facilitate the seamless incorporation of HVAC systems, renewable energy technologies, and smart appliances, and help meet the Zero Energy Ready Home standards.
- Challenges like transportation logistics, skilled labor, and insulation grading require proactive planning, coordination, and training to ensure successful off-site construction for these standards.
- Misconceptions about off-site construction, such as that it involves mobile homes with limited designs that result in home uniformity, has confusing regulations, or lacks flexibility, must be addressed through enhanced education and awareness to fully realize its potential.

## Introduction

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. This form of construction offers many [benefits](#) including energy efficiency, time and material savings, less disruption of project sites, reduced emissions from construction, and job opportunities. As the construction industry has recognized the importance of sustainable building practices, building standards such as Passive House and the U.S. Department of Energy (U.S. DOE) [Zero Energy Ready Home](#) programs have emerged. The Passive House standard sets requirements for energy efficiency, thermal comfort, and indoor air quality, while Zero Energy Ready Home aims to create highly energy efficient homes capable of offsetting their energy consumption through the use of renewable energy sources. This brief examines the potential of off-site construction to meet the requirements of the Passive House and Zero Energy Ready Home standards.



## Off-Site Construction and Passive House Requirements

Passive House represents an advanced energy-efficiency building standard that prioritizes occupant comfort and sustainability, while reducing environmental impacts.<sup>1</sup> Passive House strategies are utilized globally. In North America, the two options for passive building certifications are [Passive House Institute](#) (PHI) and [Phius](#) (formerly known as Passive House Institute U.S.). Central to the Passive House concept are its principles that emphasize airtightness, superior insulation, thermal bridge-free design, high-performance windows and doors, and controlled mechanical ventilation with heat recovery. Adhering to these principles, Passive House buildings achieve remarkably low energy consumption for heating and cooling while providing a consistently comfortable indoor environment.

Off-site construction has several inherent advantages that can make it easier to meet Passive House requirements, such as precise manufacturing and assembly, rigorous quality control, enhanced airtightness, and thermal performance. Plant Prefab, an off-site home manufacturer, collaborated with Richard Pedranti Architect to design and build off-site constructed Passive House-certified homes in varied sizes and styles without encountering significant challenges.<sup>2</sup> The off-site construction method can be used to meet the Passive House core principles including thermal control, air control, moisture control, and radiation control.<sup>3</sup>

### Thermal Control

Off-site construction could effectively meet Passive House requirements for thermal control through precise manufacturing and assembly of building components.<sup>4</sup> In controlled factory environments, specialized materials and insulation can be precisely cut and accurately integrated into each module or panel.<sup>5</sup> The consistency and accuracy of these processes significantly reduces thermal bridging and heat transfer throughout the building envelope. Moreover, the enhanced insulation and airtightness achieved in the factory-controlled setting can contribute to superior thermal performance, maintaining comfortable indoor temperatures with minimal energy consumption.

### Air Control

The controlled and precise manufacturing processes of off-site construction allow for a tighter fit between building components, which contributes to minimal air leakage points. Gaskets, seals, and insulation are carefully

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<sup>1</sup> Northeast Energy Efficiency Partnerships (NEEP). Guide to Passive House. Available at: [https://neep.org/sites/default/files/media-files/passive\\_house\\_resource.pdf](https://neep.org/sites/default/files/media-files/passive_house_resource.pdf).

<sup>2</sup> Rote, L. 2021. "New Prefabricated Passive Homes from Plant Prefab and Richard Pedranti Architect." GB&D. February 10. <https://gbdmagazine.com/prefabricated-passive-homes/>.

<sup>3</sup> Fleisher, G. 2023. "Modcoach's Six Steps to Building a Passive Home." Modular Home Coach. April 19. <https://modularhomesource.com/modcoachs-six-steps-to-building-a-passive-home/>.

<sup>4</sup> ROCKWOOL. Modular Passive House Bella Bella Case Study. Available at: <https://www.rockwool.com/north-america/advice-and-inspiration/case-studies/modular-passive-house-bella-bella-case-study/>.

<sup>5</sup> Ryder, Z. 2022. "Prefabricated High-Performance Homes." *Offsite Builder*. September 6. <https://offsitebuilder.com/prefabricated-high-performance-homes/>.



integrated into building elements to achieve the desired airtightness. This approach ensures that a building's whole building air leakage reduction goals are met, minimizing heat loss, drafts, and energy waste.

### **Moisture Control**

Off-site construction is well-suited to meet the moisture control requirements of Passive House. In the manufacturing phase, off-site construction teams can incorporate precise moisture management measures into building components, which may involve creating dry storage rooms for building materials and utilizing moisture-resistant materials. Storing building materials in a climate-controlled environment and dry storage minimizes the risk of moisture-related issues like mold formation.<sup>6</sup> Additionally, incorporating airtight construction methods, as explained above, and high-performance windows and doors in the off-site constructed home, enables off-site construction to significantly minimize the risks associated with increased levels of condensation and moisture penetration.

### **Radiation Control**

Radiation control, which consists of managing solar heat gain and loss, can also be successfully addressed through off-site construction methods. By strategically positioning high-performance windows and utilizing advanced glazing technologies during component manufacturing, a building can optimize solar heat gain in winter while minimizing excessive heat gain in summer. Off-site construction can contribute to the controlled and precise integration of airtight window systems, effectively reducing heat gain and loss. Additionally, designers can orient a building strategically to maximize solar heat gain in winter and minimize solar heat gain in summer.<sup>7</sup>

## **Off-Site Construction and Zero Energy Ready Home Requirements**

The Zero Energy Ready Home standard established the base for exceptionally energy efficient residential buildings. Certification requirements under Zero Energy Ready Home vary based on the building type. Some of the main design features include an effective thermal envelope, whole-house water protection, efficient heating, cooling, and ventilation systems, and the incorporation of advanced smart appliances and features, and renewable energy systems. Phius integrated the Zero Energy Ready Home protocol into its certification program, aligning the requirements between the two.<sup>8</sup>

One of the inherent advantages of off-site construction is its ability to precisely integrate energy-efficiency components during module manufacturing. The controlled factory environment ensures precise insulation placement, airtightness, and specific installation of high-performance windows and doors. Through this

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<sup>6</sup> BECC Modular. <https://beccm modular.com/>.

<sup>7</sup> Fleisher, G. 2023. "10 Keys for Building 'Energy Efficiency' Into Multistory Modular Buildings." Modular Home Coach. June 3. <https://modularhomesource.com/10-keys-for-building-energy-efficiency-into-multistory-modular-buildings/>.

<sup>8</sup> Phius. "Project Certification Overview." <https://www.phius.org/certifications/projects/project-certification-overview>.



process, off-site construction effectively mitigates thermal bridging and minimizes air infiltration, fulfilling the foundational prerequisites for a high-performance building envelope as stipulated by the Zero Energy Ready Home standards. By extension, the same attributes that enable off-site construction to meet the Passive House requirements also position it well to align with the demands of a Zero Energy Ready Home. Moreover, off-site construction enables easy integration of highly efficient heating, ventilation, and air conditioning (HVAC) systems within building components during the manufacturing process.<sup>9</sup>

Off-site construction can also accommodate the integration of renewable energy systems into building components. Solar-ready design and wiring, along with provisions for ENERGY STAR-rated smart appliances, can be seamlessly integrated during manufacturing. An additional advantage of using off-site construction in building to the Zero Energy Ready Home standard is the ability to save time and deliver highly energy efficient homes in a shorter timeframe. Recently, DOE in collaboration with Module Design [demonstrated](#) how off-site construction can help in accelerating the building of Zero Energy Ready homes.<sup>10</sup>

## Addressing Challenges

Implementing off-site construction for Passive House and Zero Energy Ready Home may present some challenges and limitations that must be addressed to ensure the successful integration of these building approaches. Transporting large and heavy prefabricated modules to construction sites can present logistical and financial challenges, especially for locations with limited access for delivery. Adequate planning and coordination are necessary to overcome potential transport issues and ensure the timely and safe arrival of prefabricated components. Evaluating alternative transport methods, optimizing delivery routes, and exploring partnerships with coordination experts could help mitigate the financial burden. In addition, coordination with local authorities could minimize disruptions during component delivery.

Off-site construction offers enhanced quality control, but ensuring consistent workmanship during off-site construction and on-site assembly is crucial. Most construction professionals are accustomed to traditional building techniques, and they may lack the training and expertise required for off-site construction practices. The success of off-site construction relies on skilled labor to assemble and install prefabricated components. Proper training of off-site construction workers and on-site assembly workers is essential to maintain the high standards of energy efficiency and construction quality required for Passive House and Zero Energy Ready Home.

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<sup>9</sup> Melhoff, D. 2017. "5 Ways the Latest HVAC Solutions Offer a Perfect Fit for Modular Buildings." *The ACHR NEWS*. October 1. <https://www.achrnews.com/articles/135751-ways-the-latest-hvac-solutions-offer-a-perfect-fit-for-modular-buildings>.

<sup>10</sup> Module. 2021. "Delivering Design-Forward, Zero Energy Ready Homes Using the Power of Off-Site Construction" (Video). September 7. Facebook. <https://www.facebook.com/modulehousing/videos/delivering-design-forward-zero-energy-ready-homes-using-the-power-of-off-site-co/1028441361260672/>.



Home energy rating programs like Passive House and Zero Energy Ready Home require on-site inspection of the quality of the insulation installed—also known as “insulation grading.” Since off-site modular construction is factory based, it means energy raters cannot appropriately grade the insulation. According to the latest version of ANSI/RESNET/ICC 301-2022, Section 4.2.2.3 Insulation Inspections there is an exception for modular and manufactured homes using an In-Plant Inspection Agency (IPIA), This means that insulation may be inspected at the factory instead of on-site, and that the home can still meet the program requirements without the need for a rater to verify the insulation grade.

Off-site construction has the potential to significantly contribute to meeting home energy rating programs like Passive House and Zero Energy Ready Home. Nevertheless, builders, architects, and homeowners lack familiarity with off-site construction methods, resulting in widespread misconceptions. These misconceptions are comprehensively addressed in a dedicated [resource developed by NEEP](#). There is a clear need for enhanced education and awareness regarding off-site construction. Bridging the knowledge gap empowers individuals to explore the advantages of this type of construction. Embracing off-site construction could help accelerate the use of this method to meet Passive House and Zero Energy Ready Home standards.

## Conclusion

Off-site construction holds immense potential in meeting the rigorous requirements of Passive House and Zero Energy Ready Home standards. Through its precise manufacturing and assembly processes, off-site construction effectively addresses key design features of thermal control, air control, moisture control, and radiation control necessary for Passive House buildings. Additionally, its ability to seamlessly integrate energy efficient components, such as high-performance windows, HVAC systems, and renewable energy technologies, aligns with the criteria for Zero Energy Ready Homes. Furthermore, off-site construction can contribute to the accelerated adoption of these sustainable building standards. The [National Association of Home Builders](#) estimates that off-site constructed home projects can be completely finished in approximately three months.

While off-site construction offers numerous benefits, project teams must address up front challenges related to transportation logistics and availability of skilled labor as well as the need for enhanced education and awareness. Nevertheless, proactively addressing these challenges and leveraging strategic solutions will enable the construction industry to embrace off-site construction for creating energy efficient homes. Ultimately, harnessing the potential of off-site construction and integrating it with the principles of Passive House and Zero Energy Ready Home programs could lead to faster and more cost-effective construction of energy efficient homes, benefiting not only individual homeowners but also communities, cities, and the environment at large.



### **Resources:**

**Best Builders for Passive Houses Prefab and Modular Homes.** Prefab Review. July 6, 2022.

Available at: <https://www.prefabreview.com/blog/best-builders-for-passive-houses-prefab-and-modular-homes>

**It's All Electric! High Performance Net Zero Modular Home** (Video). Dave Cooper. November 3, 2020.

Available at: <https://www.youtube.com/watch?v=k-cxCZsBGk8>

**Residential Off-Site Construction: Misconception vs. Reality.** Northeast Energy Efficiency Partnerships.

Available at: [https://neep.org/sites/default/files/media-files/off-site\\_construction\\_misconceptions\\_benefits.pdf](https://neep.org/sites/default/files/media-files/off-site_construction_misconceptions_benefits.pdf)

**Guide to Passive House.** Northeast Energy Efficiency Partnerships.

Available at: [https://neep.org/sites/default/files/media-files/passive\\_house\\_resource.pdf](https://neep.org/sites/default/files/media-files/passive_house_resource.pdf)

**A Guide to Zero Energy Ready Homes.** Northeast Energy Efficiency Partnerships.

Available at: [https://neep.org/sites/default/files/media-files/zerh\\_resource\\_guide.pdf](https://neep.org/sites/default/files/media-files/zerh_resource_guide.pdf)