Potential Impacts of Using Off-site Construction for Multifamily and Public Housing

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Abstract

Off-site construction offers multiple benefits including increased quality, decreased construction waste, optimized energy efficiency, and faster construction times. The effectiveness of off-site construction in multifamily projects is gaining a larger understanding, but is still underutilized. When implemented at a larger scale, issues commonly seen with off-site construction can be worked through, partnering with local jurisdictions to set standards and processes for permitting and inspection. Local governments opting to use off-site construction for public housing would demonstrate the applicability of the construction method for similar high-density projects, public or private, elsewhere. With increased funding opportunities, incentive programs, and support from zoning ordinances, off-site construction could help address the current housing shortage.

The forthcoming paper examines the case for using off-site construction for public housing and multifamily buildings, with a look at countrywide examples in Sweden and a more detailed look at localized efforts underway in Minneapolis, Minnesota with the Minneapolis Public Housing Authority (MPHA). Minneapolis recently underwent a citywide rezoning to encourage multifamily construction, creating an opportunity for off-site construction multifamily projects. The MPHA completed a multisite housing project using off-site construction for multifamily public housing that will serve the population at or below 30% of the area median income. Minneapolis has also allowed low-income housing tax credits and tax-exempt bonds to further incentivize off-site construction. The impact of a citywide initiative to utilize off-site construction for multifamily housing in Minneapolis and the potential energy efficiency that can be achieved if off-site construction was constructed to the 2021 International Energy Conservation Code (IECC) and Passive House Institute standards will be examined.

Introduction

The United States is facing an affordable housing problem; estimates show a shortage of 7.3 million rental homes that need to be affordable and available to renters with extremely low incomes. Only 34 affordable and available rental homes exist for every 100 extremely low-income renter households (NLIHC 2023). Additionally, despite many advances in technology and tools, a construction worker in 2020 is less productive than a construction worker in 1970 (Economist 2024). This is partly due to the construction reluctance to change and embrace new methods. Off-site construction can be a solution to both problems.

Off-site construction offers multiple benefits including increased quality, decreased construction waste, optimized energy efficiency, and faster construction times. The effectiveness of off-site construction in multifamily projects is gaining a larger understanding, but is still underutilized. When implemented at a larger scale, issues commonly seen with off-site construction can be worked through, partnering with local jurisdictions to set standards and processes for permitting

and inspection. Local governments opting to use off-site construction for public housing would demonstrate the applicability of the construction method for similar high-density projects, public or private, elsewhere. With increased funding opportunities, incentive programs, and support from zoning ordinances, off-site construction could help address the current housing shortage.

Definition

Off-site construction comes in many different iterations with overlapping themes and terms often leading to misused terminology. “Off-site construction” is an umbrella term used to describe any part of the construction process completed “off-site” prior to being implemented/installed on the final location site. Many examples of off-site construction methods are currently being used in combination with traditional “stick-built” construction, such as roof framing on single-family homes. This paper only considers modular and panelized construction, both of which must be built to local codes and are most comparable to traditional building methods. This differs from manufactured housing that is built atop a chassis and delivered complete to its destination. These manufactured homes fall under the Housing and Urban Development (HUD) standards.

Benefits

The benefits of off-site construction are well documented but underappreciated. Benefits of off-site construction include, but are not limited to:

- Shortened project time by 20-50%, (Bertram 2019) and ability to construct during weather events that would halt typical construction projects;
- Less material waste, (70-90% reduction in volumetric modular construction, WRAP 2007);
- Improved working conditions, such as single-site climate-controlled environments, and increased workplace safety; and
- Less time impacting the surrounding area during construction, including minimizing site noise and street closures.

Some benefits that are especially important to consider for multifamily construction, such as faster construction completion, increased energy efficiency, and reduced costs, are highlighted below (NEEP, MEEA 2021).

Rapid Completion Timeline

One benefit to off-site construction, especially in partnership and understanding from the authoritites having jurisdiction (AHJ) is the speed of project completion. One of the ways this is possible is through foundation work and site preparation, which can be done simultaneously with the construction of the structure itself. Unlike many other industries, construction methods (especially for residential buildings) have not changed or embraced technological advances for many decades thus missing efficiencies. Moving construction to a more industrialized setting and utilizing automation technology widely accepted in other industries, such as the automotive industry, could help construct buildings more efficiently. As an example, a precut engineered lumber package compared to a traditional stick-built home will install 50-60% faster (ICC 2024). The National Association of Home Builders (NAHB) estimates, “a typical modular house can be

move-in ready in about three months". Overall, it is estimated that off-site construction can reduce the project schedule by 20-50% (NAHB 2024).

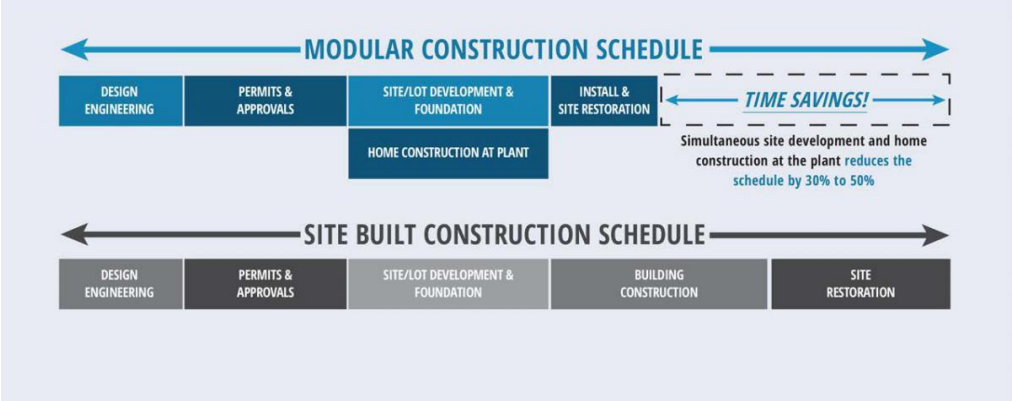

Figure 1: Modular Home Construction Schedule, *Source:* MHBA 2024a.

Permitting and inspections are often time-consuming parts of the homebuilding process, for both local jurisdictions and the developer. Off-site construction allows for an ongoing partnership with the jurisdiction, creating a streamlined process. The International Code Council and Modular Building Institute (ICC/MBI) Off-site Construction Standards (discussed later in this paper) can be implemented to ensure this process goes smoothly and this benefit is fully realized, as off-site construction is generally treated very differently from jurisdiction to jurisdiction.

Energy Efficiency

Buildings utilizing off-site construction methods must adhere to the same local building codes, including energy codes, as traditionally constructed buildings. Additionally, off-site construction can be built to above-code standards. A super-efficient envelope achieved through off-site construction methods provides major operational energy savings to the occupant, provides a more comfortable and healthier indoor environment, and allows for a right-sized HVAC system. A home built using structurally insulated panels (SIPs), a method of off-site construction, can achieve air tightness of 1.0 ACH(50)[1], exceeding national model code requirements of 3.0 ACH(50). For example, the Palo Alto Apartments, a low-rise multifamily structure in Menlo, California which was built using SIPs, achieved air tightness of 0.2 ACH(50), and received the Leadership in Energy and Design (LEED) Platinum certification (Premier 2024), the highest level recognized by the green building program.

[1] Air Changes per Hour, at 50 Pascals

COST CATEGORY	SITE-BUILT	MODULAR
Construction Costs	77,140.00	65,560.00
Structure	71,123.00	59,543.00
Foundation	6,017.00	6,017.00
Cost per square foot	38.57	32.78
Land Costs	35,314.00	35,314.00
Improved lot	34,113.00	34,113.00
Site preparation	1,201.00	1,201.00
Financing Costs	2,895.00	1,298.00
construction financing	2,895.00	1,298.00
inventory financing		
TOTAL COST	**115,349.00**	**102,172.00**
Source: "Factory and Site-Built Housing—A Comparison for the 21st Century," NAHB Research Center, 1998		

Image 2: Modular Homes vs. Site Built Homes Costs, *Source:* MHBA 2024b.

Cost Savings

Off-site construction can be more cost-effective than stick-built construction. Like many economies of scale, affordability benefits can increase as the project size increases.. Large scale project units can be replicated quickly as variance from unit-to-unit can be minimal. Off-site construction can save up to 20% on the cost of construction for a three- or four-story wood-frame multifamily apartment building, translating to significant savings for consumers (MBI 2023).

Another aspect impacting housing construction cost is weather, which off-site construction can minimize. Working in a controlled climate environment allows projects to avoid inclement weather and prevents cost increases due to delays and damage to building materials. Also, due to speed of completion, building owners utilizing off-site construction for multifamily projects can get units rented out and create cash-flow quicker than standard construction, leading to an overall cost benefit.

Less Community Disruption

Off-site techniques can reduce construction disruptions to the local community. With most of the work being done off-site, outside noise and air pollution is minimized. In "stick built" construction there are 600 cuts for a single-family home required on-site versus nearly no additional cutting required on-site for modular buildings (Bierne 2019). Cutting material creates noise pollution as well as particulate matter that could affect neighbors. Fewer material delivered to the site means less on-site air pollution and less noise pollution from trucks supplying materials, with studies showing 80% fewer vehicle movements to sites (Make UK 2024). All of this, plus shorter time on-site from contractors, means there is less construction activity disrupting the local community.

Improved Working Conditions

Off-site construction can present building trades with improved working conditions. With continued declines in the construction job market, skilled and unskilled labor is harder to attract. According to the U.S. Labor Bureau, there were 434,000 vacant construction jobs in 2019 (Holt 2021). The construction industry has trouble recruiting new workers for different reasons, some of which can be alleviated from industrialized construction. One of the drawbacks to standard construction is exposure to the elements. Cold weather in the winter and extreme heat in the

summer means construction workers are exposed to uncomfortable and dangerous working conditions. With the trend of continued warming, construction workers in extremely hot climates, especially in the southern United States, may not be able to perform their duties as it will be outside the threshold for safe workable conditions. Outdoor workers have died of heat stroke when the day's maximum Heat Index was only 86°F (OSHA 2024). Moving to an indoor industrialized setting provides workers with conditions that allow year-round safer and more predictable work. The benefit of working at one climate-controlled location versus multiple job sites susceptible to weather events could be a draw for people entering the workforce and inherently create a safer, more comfortable, work environment.

Challenges

Off-site construction is not without challenges. Determining if off-site is appropriate often depends upon job site variables and project scope. Two specific challenges include unfamiliarity with off-site construction methods and access to sites for installation and delivery.

Unfamiliarity surrounding off-site construction can be a deterrent to people looking to build a home, builders considering utilizing the practice, or even cities choosing to deploy large-scale projects using off-site methods. There is a conflation between manufactured housing of the past, which is associated with being inefficient and low-quality. This idea has stuck in the mind of the United States public opinion, wherein people associate off-site construction with lower quality, unsightly, construction (Zonta 2024). Education and outreach is needed to show the public that permanent modular construction meets the same building codes traditionally constructed buildings must meet and can even be of higher quality.

Unfamiliarity also seeps into the code enforcement process with off-site construction. There is often confusion around the inspections and permitting of these homes, since most, or all, of the assembly happens off-site. If the jurisdiction in which the project is being completed is not experienced with the permitting process, the project may be delayed. For example, in typical stick-built construction the inspection process entails examining the work before the finalization process; to determine if the wall assembly was completed correctly, inspectors check insulation amounts and installation techniques prior to final drywall being installed. However, in off-site construction, panels and modules arrive at the job site in their completed form with little access to interior cavities and aspects; if there is no protocol or understanding in place for where (or if) these components were inspected at the factory, this will inevitably cause delays in code enforcement.

Additionally, there may be a lack of knowledge around the financing of off-site construction projects. Lenders may be hesitant to provide financing due to a lack of familiarity with this method of construction (and may require a higher level of equity investment (Gude 2023). With traditional construction methods, the lender will provide capital upfront in the form of a construction loan to get the project started, as they will have the land and any completed work as collateral in the event the project never receives a buyer. This ensures the lender will still have the ability to recoup some or all their initial capital. However, with off-site construction, if the project never reaches the final stage, most of the work may have been performed and perhaps never moved to the final location, potentially making it more difficult for lenders to recoup their investment.

Finally, there are specific logistical conditions required to get panels and modules delivered to the jobsite for off-site construction, and not all locations will be appropriate to installing large components or entire units. Upon arrival, panels, modules, and building

components must be craned into place; narrow roads or job sites with lots of tree cover or overhead electrical lines may not be conducive to utilizing off-site construction methods.

Addressing Challenges through Awareness

Challenges in off-site construction can be minimized through awareness, especially when there is a partnership or understanding between the public and private sector. When municipalities understand the planning, inspection, and deployment process, they can proactively set up a system that allows the full benefits that off-site construction offers. One way this can be facilitated is through adoption of new 1200 series standards laid forth by the International Code Council and Modular Building Institute discussed in the section below.

Multifamily projects have become the modular industry's number one sector since 2020 (MBI 2023). Getting the greenlight on multifamily or public housing projects can set into motion the creation of hundreds of new units while addressing the bottlenecks of off-site construction once upfront such as potential zoning issues, site planning, and energy modeling. The completion of such projects can create its own momentum where trust and familiarity with the method can lead to more widespread acceptance and use.

Building Standards

Standards are the first step to increasing awareness and lessening the uncertainty of the off-site construction process. The ICC/MBI Standards are one way to streamline this process. So far three areas of focus have been addressed by these standards. In brief, the standards laid forth by the ICC and MBI are as follows:

ICC/MBI 1200: This addresses planning, design, fabrication, and assembly. This first edition standard provides planning and preparation requirements such as the role of the architect, modular manufacturer, construction manager or general contractor, and material procurement and lead times. It also outlines the requirements for a controlled manufacturing environment, supply chain integration, and the fabrication process and on-site assembly.

ICC/MBI 1205: The scope of this first edition standard is to provide minimum requirements to safeguard the public health, safety, and general welfare, and address societal and industry challenges for the inspection and regulatory compliance of off-site and modular construction. It addresses the inspection, approval, and regulatory compliance of off-site residential and commercial construction components as well as their assembly and completion at the final building site.

ICC/MBI 1210: The scope of this standard is to provide minimum requirements to safeguard the public health, safety, and general welfare, and address societal and industry challenges for the energy efficiency and water conservation of off-site construction projects and the planning, designing, fabricating, transporting, and assembling of commercial and residential building mechanical, electrical, and plumbing (MEP) system elements. This includes the componentization and modularization of elements of MEP systems, the incorporation of MEP systems in componentized, panelized, or modularized building elements, and the achievement of energy efficiency and water conservation requirements in off-site construction. (ICC 2024).

Cities or states can implement these standards in combination with existing code requirements. For example, the energy efficiency requirements outlined in ICC/MBI 1210 default to the existing energy conservation codes/standards of the jurisdiction. Prior to the 1200 Series Standards, jurisdictions were forced to develop their own methods to handle off-site

construction, creating a patchwork of regulations and processes that made it difficult for inter-state and even inter-city project rollouts. Though off-site construction requires buildings to meet all local codes, these standards help cities, builders and manufacturers know there is a vetted process in place to allow off-site construction to be implemented safely and effectively. As of 2024, two states, Utah and Virginia, have adopted the codes (MBI 2024).

Opportunities

This section highlights additional opportunities demonstrated through off-site construction projects that could be further utilized to address the housing crisis in the United States with energy efficient housing.

Passive House

Affordable housing has been a significant driver of multi-family Passive House standard utilization. About half of all Passive House projects in development in the U.S. are affordable housing projects, illustrating the cost-effectiveness of green building design (Jensen 2023). Passive House buildings lower energy usage by up to 80% compared to a standard building at a similar price point (PHIUS 2024). Forty-five multi-family Passive House buildings in New York and Massachusetts have been surveyed in recent years and findings indicate the average cost to construct a Passive House building is just 3.7% more than standard construction, and in some cases cheaper when factoring in incentive programs. By combining incentives from utilities, affordable housing finance programs, and federal tax credits and rebates from the Inflation Reduction Act, many multi-family Passive House buildings can be more economical to build than standard projects (Salmonsen 2023).

Off-site construction methods can achieve the Passive House standards. The Show Home on Black Street, a single-family home, by Module Design, was certified to the Zero-Energy Ready Home standard using off-site construction (US DOE 2024c). A multi-family project in Canada created a 6-unit, 2-story modular Passive House townhome for the Yale First Nation. The project was delivered 6 months after the contract was signed and became the first multi-family modular Passive House constructed in a First Nations community in Canada (Blackbox 2024).

Sweden: The Off-site Construction Leader

Off-site construction has been used for decades and is the norm in Sweden. 84% of single-family homes in Sweden are created wholly, or in part, in factories, versus the 3% currently seen in the United States (Freed 2023). Sweden’s efforts to standardize off-site construction has allowed for streamlined processes and production, and a stronger positive public opinion of those buildings. Consequently, the widespread acceptance of off-site construction has created its own momentum wherein the government creates regulations that facilitate its use, and more people prefer that method of construction.

Sweden also implemented a countrywide performance-based building code that makes it easier for factories to design buildings and builders to construct them, as the requirements are the same no matter where the home is being built (Freed 2023), and manufacturers can innovate new ways to meet the performance-based requirements. These code and standard requirements

require more work upfront but eliminate the need for inspections in later phases of construction, since the process gets verified as meeting code.

Continually advancing their industry, a company in Sweden, Lindbäcks Bygg, recently opened a factory that is able to produce more than 25,000 square feet of turnkey housing per week, building construction into something more closely resembling car manufacturing. This amount of square feet is roughly 28 average-sized New York City apartments every week and almost 1500 apartments a year from one factory alone (Architizer 2024), creating a blueprint for a level of output that could be replicable in other parts of the world.

While the off-site industry in the United States has been largely underutilized, other countries, such as Sweden, have fully embraced the method and have built systems that allow benefits to be fully realized. While Sweden and the United States certainly have differences (such as size and population), lessons learned from their experience can be applied to the U.S., particularly on a region-by-region basis. Factories in the United States could be placed in areas where their shipping radius could reach the maximum amount of people, including expanded set-up in a way to distribute to similar climate zones while simultaneously.

Minneapolis Public Housing Authority

Minneapolis recently underwent a citywide rezoning to encourage multifamily construction, creating an opportunity for off-site construction of multifamily projects. One such project that utilized these benefits on a large scale was the Family Housing Expansion Project (FHEP) by the Minneapolis Public Housing Authority (MPHA). The MPHA partnered with a modular company to create 84 affordable housing units in 16 apartment buildings on a multisite project (Wilson 2023). All units are available to households at or below 30% of the Area Median Income. This partnership resulted in a 30% reduction in construction time (Wilson 2023), allowing residents to move in months earlier. The FHEP was made possible through financing across various partners as listed below:

- $19.9 million in equity from Low-Income Housing Tax Credits (US Bank Community Development Corporation)
- $12.5 million contribution from MPHA
- $8.9 million permanent loan to cover project costs (Citi Community Capital)
- $4.6 million in federal ARPA dollars awarded from the City of Minneapolis
- $1.4 million Local Housing Incentives Account (LHIA) award from the Metropolitan Council
- $1.2 million award from the City of Minneapolis' Affordable Housing Trust Fund (AHTF)
- $500,000 award of Hennepin County's Affordable Housing Development Accelerator fund
- US Bank Community Development Corporation also provided a $25 million construction loan via Housing Revenue Bonds issued by Minneapolis' Community Planning and Economic Development department (MPHA 2024)

The project also benefitted from more than $500,000 in equity through solar tax credits, which more than doubled because of the recent federal Inflation Reduction Act. The project's solar system (361.6 kW) is projected annually to cover nearly 30% of all electrical consumption

in the new homes (Arras 2023). Additionally, Minneapolis has allowed 4% low-income housing tax credits and tax-exempt bonds to further incentivize the use of off-site construction.

As evidenced above, many methods exist to get a project like this off the ground. Brian Schaffer, Assistant Director of Planning for the Family Housing Expansion Plan from Minneapolis Public Housing Authority, shared additional insight into how the project came to fruition.

The MPHA conducted price exercises looking at different building methods and modular came out as the most viable method. In speaking with Mr. Schaffer, he indicated a project of similar scope would typically take 18 months, but with modular it took 13 months. The result was $500,000 in savings.

To help spread awareness about off-site construction, the MPHA talked at thirteen different neighborhood groups. Surrounding neighborhoods were worried the buildings would be cheap construction. The MPHA wanted the public to know these structures are resilient and that Rise (the manufacturer) was already making strides in the city with other large scale multifamily projects previously completed in the city. The MPHA wanted the public to know they were creating energy efficient, durable housing and to dispel the notion that off-site construction is cheap and low quality. MPHA's goal is to try to get as energy efficient as possible in all cases and they have even explored smaller projects getting to Net Zero.

The MPHA is hoping this will be a catalyst for other organizations to follow their example. HUD (Housing and Urban Development) expressed they are intrigued by the work being done and looking for opportunities to deploy similar methods throughout the country.

Modeling Energy Savings through Multifamily Off-Site Construction

One of the most significant benefits of utilizing off-site construction is the potential maximization of energy efficiency. The section examines the impact of energy-efficiency requirements, coupled with the adoption of the new ICC off-site construction standards.

Minnesota was chosen as a state to model largely because of the recent project success with MPHA, and additionally because of a potential appetite for adopting energy-efficient requirements for new buildings.[2] If Minnesota were to adopt a requirement for multifamily construction to be off-site to reach a minimum of 2021 IECC or to Passive House Institute United States (PHIUS) standard, it would help address the affordable housing shortage while being mindful of energy use and simultaneously bringing houses to the market quicker than standard construction. Additionally, adopting the ICC/MBI 1200 Series Standards would facilitate widespread adoption and implementation.

To understand the impact of energy efficiency, the authors analyzed typical low-rise multifamily buildings in Minneapolis. BEopt models were run comparing the Reference home/building (low-rise MF at Minnesota energy code [2012 IECC w/amendments]: 772.8 MMBtu) with Option 1 (2021 IECC Residential: 692.1 MMBtu) and Option 2 (Passive House standards: 652.3 MMBtu, 652.3-505.1 = 146.9MMBtu with 10kW PV System).

[2] Legislation passed in 2023 and 2024 requiring consistent efficiency updates to commercial and residential energy codes in Minnesota, to eventually achieve 80% and 70% efficiency over the 2006 IECC, respectively.

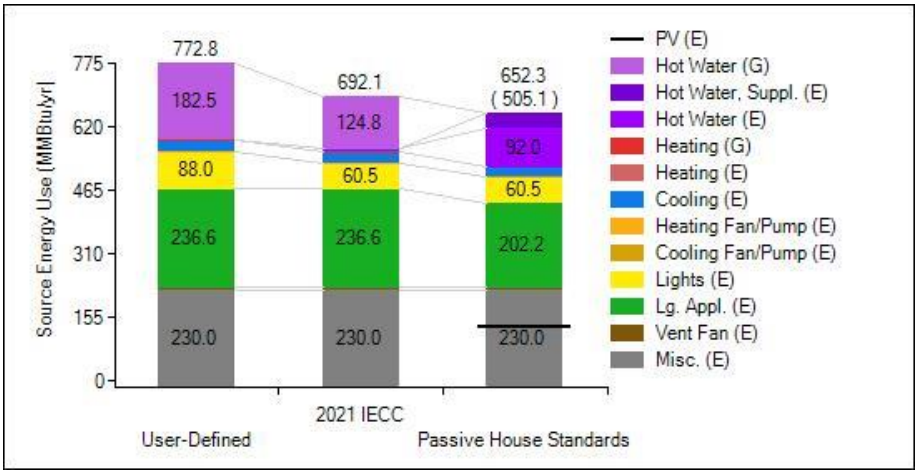

Figure 1. BEopt Model of low-rise MF Source Energy Use at MN current energy code, 2021 IECC, and PHIUS

Savings numbers were then multiplied by the average number of units per year in Minneapolis, which is about 20,000 (Kim-Eng, Starling, and Yudhishthu 2024). A quarter of all proposed multifamily projects are low-rise (Anderson 2021), totaling around 5,000 units/year in Minneapolis. The authors then applied an assumed rate of construction to be off-site. Using the rate of off-site construction in Sweden (85%, etc.): 85% * 5,000 = 4,250 Units of off-site construction-built units. For these calculations, low-rise multifamily buildings were defined as 12-unit buildings: 4,250 units/12 units per building = about 350 buildings.

The calculation of the total potential future annual energy savings in Minneapolis when guaranteeing 100% compliance with 2021 IECC by using 85% off-site construction for low-rise multifamily is as about **28,245 MMBtu savings/year.**

772.8 MMBtu/year - 692.1 MMBtu/year = 80.7MMBtu/year savings for one building

4,250 units/12 units per building = about 350 buildings

350 * 80.7 MMBtu = 28,245 MMBtu savings/year

The calculation of the total potential future annual energy savings in Minneapolis when guaranteeing 100% compliance with PHIUS by using 85% off-site construction for low-rise multifamily is about **42,175 MMBtu savings/year** without a PV system.

772.8 MMBtu/year - 652.3 MMBtu/year = 120.5 MMBtu/year savings for one building

4,250 units/12 units per building = about 350 buildings

350 * 120.5 MMBtu = 42,175 MMBtu savings/year without PV system

When adding solar, the calculation of the total potential future annual energy savings in Minneapolis when guaranteeing 100% compliance with PHIUS by using 85% off-site construction for low-rise multifamily is about **219,065 MMBtu savings/year** with 10kW PV.

772.8 MMBtu/year – 6,146.9 MMBtu/year = 625.9 MMBtu/year savings for one building

4,250units/12units per building = about 350 buildings

350 * 625.9 MMBtu = 219,065 MMBtu savings/year with 10kW PV system

Ten-year savings. If extrapolated over the next ten years, if 85% of low-rise multifamily housing in Minneapolis was off-site and built to 2021 IECC, the total energy savings is **282,450 MMBtu savings**. If built to PHIUS, 10-year savings are estimated to be **421,175 MMBtu savings** without PV and **2,190,650 MMBtu savings** with 10kW PV.

Saved construction time. Off-site methods can save construction time, also adding to the benefits of the above scenarios. To calculate potential time saved, we assumed 18 months typical build time for traditional construction, equaling 6,300 "months" of work for the average 350 buildings used above. Using the 20%-50% quicker build time for off-site construction referenced by the NAHB earlier could equal **1,260-3,150 "months" of saved labor per building per year.**

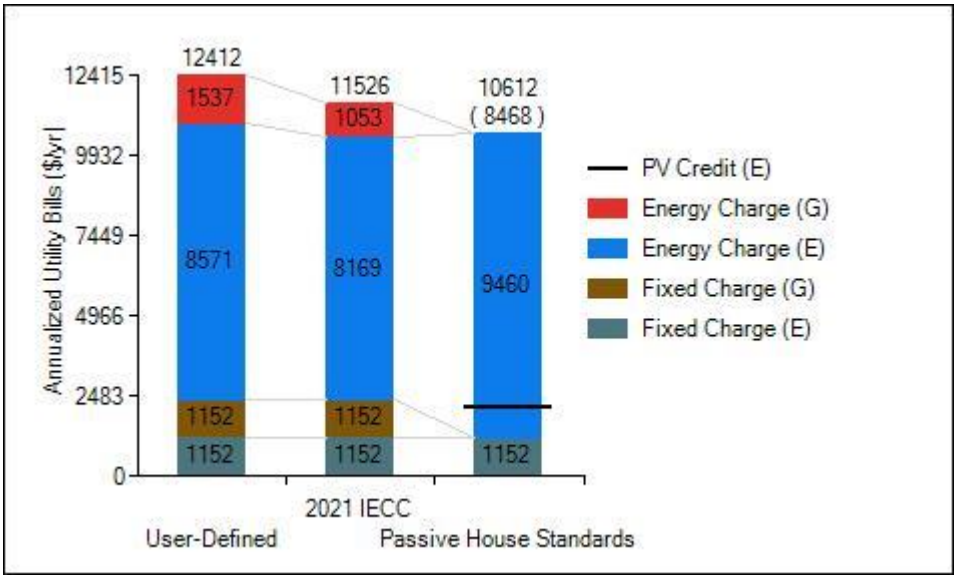

Figure 2. BEopt Modeling of Annualized Utility Bills at MN current energy code, 2021 IECC, and PHIUS

Total annual utility bill savings. BEopt models comparing the Reference structure with Option 1 and Option 2 show the Annualized Utility Bills and potential energy savings for renters in those buildings. The potential total utility bill savings for building low-rise MF to the 2021 Standard are estimated to be around **$310,100/year.** The potential utility bill savings for building to PHIUS are estimated to be **$630,000/year** without a PV system and **$3,593,800/year** with a 10kW PV system.

2021 Standard: $12,412 – $11,526 = $886/year * 350 buildings = $310,100/yr

PHIUS: $12,412 – $10,612 = $1800/year * 350 buildings = $630,000/yr without PV

PHIUS: $12412 - $2144 = $10,268 * 350 buildings = $3,593,800/yr savings w/10kW PV

Conclusion

Off-site construction is one piece of the puzzle addressing a complex issue of providing ample affordable housing. With the numerous advantages off-site construction can offer, the construction industry's full potential has yet to be realized. The uptake of off-site construction for multifamily and public housing has begun to increase and steps are being established to help the adoption process become more streamlined and accessible to other communities. As public opinion and education about the industry improves, so will the demand for off-site construction, as indicated by current trends.

The relationship between the industry and government is an important part to help get widespread adoption. As accomplished in Minneapolis and the newly proposed statewide initiative in Minnesota, zoning in cities must be reevaluated to encourage higher density and to reap the benefits that go with increased population density and an uptick in available housing units. Cities must also adopt a set of standards that make the process more efficient; this can be achieved by adopting the ICC/MBI 1200 Series Standards that make the process consistent between jurisdictions, while simultaneously striving for more stringent energy efficiency standards. This has been achieved in a nationwide deployment as evidenced by the off-site construction industry in Sweden.

The housing shortage could be solved more quickly and cost-effectively using off-site construction than typical construction. If Minnesota were to adopt these recommendations, for example, 1260-3150 “months” of construction time per year could be saved in Minneapolis by utilizing off-site construction based on the analysis conducted in this paper. Building to the 2021 IECC, the potential energy cost savings could be $310,100/year on new multifamily buildings and if brought to PHIUS standards with a PV system, savings would be as high as $3,593,800/year. As off-site construction adoption increases, the benefits will be compounded. Overall, off-site construction for multifamily housing and public housing in the United States has not been utilized to its full potential, but as cities learn to embrace the industry and facilitate its deployment, it can prove to be key in addressing housing issues while simultaneously adhering to stringent energy efficiency standards.

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