

The Ups and Downs of Building Passive House, Modular, Affordable Senior Housing

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ABSTRACT

The Yonkers Housing Authority and its nonprofit partner the Mulford Corporation, is building affordable housing using modular construction designed to Passive House standards. The La Mora project opened in July 2024 and provides 60 energy-efficient apartments for seniors earning at or below 50% of area median income. Driven by the need for affordable housing in a community with increasing housing costs and an aging population, La Mora provides a comfortable, safe, and resilient space for seniors to age in place.

La Mora is one of the first-of-its-kind to integrate affordable housing, modular construction, and Passive House. This combination will result in a healthy and resilient building for the vulnerable population it serves. By building Passive House, La Mora requires significantly less energy to operate and will be resilient in the event of power outages due to extreme weather events. The modular units and off-site assembly provided high quality, cost and schedule flexibility during construction.

However, the project has major challenges. Passive House came at a cost premium, even before COVID-19 disrupted the construction industry. Supply chain issues continue to plague the project, forcing designers and contractors to adapt to volatile market conditions. Elevated technical and executional precision of the design demanded a steep learning curve and required additional consultants. Finally, site conditions and errors in construction posed major challenges to the budget and schedule.

This paper discusses the benefits and challenges of building La Mora, the business case for its major elements, how the project advances climate equity and resilience, and lessons learned along the way.

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Context: Yonkers, NY, the Yonkers Housing Authority, and La Mora

The City of Yonkers is the third largest city in New York State, located on the northern border of the Bronx abutting the Hudson River. The population hovers around 210,000 people, attracting young professionals due to its proximity to New York City. (Census) Its fast-developing waterfront is home to broad industry including Domino Sugar, Greystone Bakery, and even home to the largest sound stage east of the Mississippi (Lionsgate). In this environment of increasing housing costs and an aging population, the fastest-growing population in the city is senior citizens.

Yonkers has a long and complicated history being the only city with two separate desegregation orders – one regarding housing and the other regarding schools. In 1988, a federal judge held the city in contempt of court when it refused to propose and execute a plan to desegregate after finding that city officials intentionally fostered segregation over 40 years by concentrating subsidized housing in the southwest corner of the city and discouraging black people from living on the predominantly white east side of town (Yen 1988). The city is split into east and west sides by the Saw Mill River Parkway. The east side of the city was historically preferred by wealthier residents while the west side was developed into a more urban setting, now home to the city's business district and waterfront development.

Southwest Yonkers today has some of the most economically and socially challenged neighborhoods in the New York City metro region. One in four residents live in some form of subsidized housing and more than 80% of public-school students are eligible for free/reduced lunch. In some census tracts, median income is below \$30,000 for a family of four, an astonishing low amount in a high-cost region. Southwest Yonkers is officially a federal Community Block Grant Zone, a State Environmental Justice area, and a priority for the State's Regional Economic Development Council. It is a major destination for immigrants as well, with more than 40 languages spoken in the public schools.

As a result of its history, the Yonkers community suffers from pervasive environmental problems – including widespread and unaddressed brownfields, contaminated waterways, polluted air, and a lack of access to high quality open spaces and healthy food choices. Major Environmental Justice issues include:

- More than 200 vacant lots, including dozens of contaminated brownfields sites
- Hundreds of vacant and abandoned homes with potential lead paint issues
- An absence of safe and well managed green spaces, including several large deserted parks
- A revitalized, but still contaminated Saw Mill River, with high levels of fecal coliform runoff and dangerous industrial metals buried in the sediment
- Regular stormwater overflow events due to the combined sewer system
- Prohibitions for sustenance fishing on the Hudson River
- A breadth of public health problems including obesity, violence, drug abuse, and diabetes, as identified by local hospitals in recent community surveys
- One major grocery store serving more than 80,000 people
- High rates of pediatric asthma exacerbated by heat and air pollution from the County's waste-water treatment plant and many bus and truck companies based in Southwest Yonkers.

On top of this broad spectrum of problems, climate change is now a leading concern. In the last decade, the city and the region have been severely affected by extreme weather events,

including three hurricanes. Yonkers has one of the nation’s steepest topographies, a five-mile waterfront on the Hudson River – part of the NYC Harbor coastal system - and three river valleys, which concentrate rapidly-moving water in vulnerable neighborhoods. Hurricane Sandy’s storm surge, for example, pushed brackish water into a new, multi-million-dollar park along the Saw Mill River at the confluence of the Hudson, causing millions of dollars of damage to downtown streets, businesses, and the public library. Southwest Yonkers is also a prime example of a historically marginalized area created by policies and practices over the last century such as redlining, capital flight, and public-school disinvestment that concentrated more vulnerable, low-income people of color in one densely-built area. The local landscape still bears the scars of a century of disinvestment with hundreds of vacant lots, a dearth of trees, and few high-quality green spaces. The area also has high rates of obesity, asthma, and cardiovascular disease. Each of these factors - the coastal geography, the dense built environment, poverty, and public health challenges - are exacerbated by extreme weather.

The Municipal Housing Authority for the City of Yonkers (hereinafter “MHACY” or the “Authority”) is the largest landlord in the City and Westchester County with approximately 1760 apartments serving over 3,000 residents with more apartments in development. In and around 2017, the Authority undertook a major redevelopment effort through the Department of Housing and Urban Development’s RAD Rental Assistance Demonstration) program, attracting over \$750M of private investment in the form of Low-Income Housing Tax Credits into its housing stock. The Authority is also a leader in climate resiliency and sustainability in alignment with New York State’s goals (NYS 2022). In partnership with area nonprofits, the Authority has undertaken many environmental and sustainability initiatives, attracting almost \$1M from New York State’s Environmental Facilities Corporation’s Green Innovation Grant Program and \$1M from the United States Environmental Protection Agency’s Environmental Justice Government to Government Grant Program for green infrastructure upgrades across its portfolio. Recognizing Yonkers’ demographics, history and need for climate resiliency drove MHACY’s decision to pursue its latest development, La Mora Senior Apartments.

La Mora is MHACY’s latest new construction project. When completed, it will consist of 60 low-income apartments for seniors (age 55+) earning under 50% of the Area Median Income. The overarching goal for La Mora is to provide a comfortable, safe, and resilient space for low-income seniors to age in place.

Building During Covid-19

The Covid-19 pandemic posed several challenges during the construction of La Mora, as it did for the rest of the world. Unfortunately, it is nearly impossible to segregate the effects of Covid from the challenges that the project experienced associated with Passive House and modular construction as discussed below. Although the project experienced significant uncertainty and delay with respect to supply chain issues and other disruptions in the construction industry, this paper will not discuss those Covid-related issues but will instead focus on the benefits, costs and lessons learned from Passive House, modular construction.

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Passive House: Benefits, Costs and Lessons Learned

Benefits of Passive House: Sustainability, Resiliency and Long-Term Affordability

MHACY elected to pursue the Passive House building performance standard for La Mora in alignment with its sustainability goals and to provide senior residents with a resilient building with lower cost energy and higher resiliency for weather related utility disruptions (White 2019). Passive House is a set of design principles for attaining a rigorous level of energy efficiency while also creating comfortable indoor living spaces (White 2020). It is a performance-based building certification that focuses on the dramatic reduction of energy use for space heating and cooling. Passive House buildings achieve:

- Drastically lower energy use and operational cost savings (Wright 2020)
- Healthy air quality from ventilation systems
- Consistent and comfortable room temperatures without air drafts
- Increased natural lighting and quieter acoustic conditions
- A more resilient and comfortable building

Complementary to increased energy-efficiency, the quality of the building driven by Passive House will make La Mora extremely resilient. The building will enjoy the benefits of superinsulation in the event of power outages and extreme weather events, which have become more frequent in Yonkers, since the building will not experience dramatic temperature swings. Although not required by Passive House, MHACY also elected to install an emergency generator on the project which will provide electricity to critical medical equipment and allow residents to shelter in place for extended periods of time.

The third major factor in deciding to pursue Passive House is preserving long-term affordability for the residents of La Mora. Within the past few years, the Authority has experienced significant utility rate increases. In 2021, the cost of electricity increased 40%, and then another 20% in 2022 with increases expected to continue. Volatility in energy prices has proven to be difficult to predict and impossible to control. La Mora will use significantly less energy thanks to the Passive House building envelope, which is a benefit that the building will enjoy indefinitely.

Costs of Passive House: Premiums, Change Orders and Delays

Pursuing the Passive House Certification came at a substantial cost. The cost differential between material elements being Passive House quality versus conventional or code-compliant quality was not calculated, but higher performing building products are consistently more expensive than lower quality products of the same type. Table 1 provides some comparison between traditional (code-compliant) building elements with Passive House-required building elements to help focus on certain areas of additional expense. This elevated cost was accounted for in the contract documents.

Table 1: Comparing Traditional and Passive House Building Elements

Building Element	Code-Compliant Building	Passive House Building
Windows	Double-pane acceptable	Triple-pane, Passive House Component certification required

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Ventilation	Simple fans acceptable, sometimes not required at all (in naturally ventilated buildings)	Continuous ventilation with energy recovery required
Airtightness	0.4 CFM/SF tested at 50 Pa	0.06 CFM/SF tested at 50 Pa
Thermal Bridging	Not a concern in traditional building	Heavily modeled to decrease risk for moisture issues

In addition to the initial material cost premiums, the project experienced many Passive House related change orders during construction. Table 2 below lists the change order cost that La Mora experienced related to accommodating the Passive House standard. In total, the project experienced \$359,469.36 in Passive House-related change orders.

Table 2: La Mora Passive House-Related Change Orders

Change Order Subject	Description	Cost
Water Heating Revision	The domestic water heating system transitioned from a conventional electric resistance tank-type water heating system to a heat pump-based system after Passive House modeling reflected an unacceptable energy usage projection.	\$256,362.08
Additional Modular Unit Air Infiltration Scope	Joints between modular units needed additional air sealing as required to address Passive House-related infiltration and testing issues.	\$46,432.57
PHIUS Window Details	Window sills required additional end dams and sealant to ensure airtightness at joints.	\$18,947.29
Preliminary PHIUS Testing	Cost to construct temporary enclosures and prepare modular units for PHIUS blower door test.	\$5,760.76
Additional Air Sealing of Exterior Walls	Additional air sealing was required at the exterior walls of the terrace and lower level to ensure proper airtightness.	\$14,353.11
Relocation of Hot Water Heat Pumps	The heat pumps required by the Water Heating Revision did not fit into the space allocated for them, which would not have happened had the PHIUS model initiated the change in systems.	\$17,613.55

The project also experienced Passive House-related delays. Aside from the delays associated with change orders mentioned previously, the building did not initially pass the Passive House-required blower door test, which the initial construction schedule did not account for. The partial preliminary blower door test results conducted on August 25, 2023 averaged 0.116 CFM/SF (between pressurization and depressurization testing) and prompted additional air sealing to be performed on site, including additional taping at the windows and sealing of

exterior walls.¹ The first whole-building blower door test was conducted on February 20, 2024 which resulted in a result of 0.13 CFM/SF, still over double the allowed airtightness under the PHIUS standard, which is 0.06 CFM/SF. Remediation of air leakage pathways and retesting took significant time, and eventually the contractor (on the PHIUS Consultant's advice) decided to pursue an aerosol-type air sealing system. This process will be completed in early June of 2024. In all, the air sealing effort (remediation and retesting) took 5 months to come into compliance under the PHIUS standard. The building's modular construction compounded the already difficult air tightness standard because access to air leaks was limited. For example, the mating joints of the modules could not be taped retroactively once the modules were craned into place. More detail on this issue is discussed below.

Lessons Learned: Building a Design Team, Contract Considerations

Building an experienced design team. Passive House is a performance-based standard, meaning that the building must undergo specific, rigorous testing to ensure the quality of the building after construction.² This is a key element to understand at the beginning of design and is important to consider at each stage of the project.

During design, special attention must be made to ensure that the Contract Documents capture specific air sealing, taping, insulation, waterproofing and vapor barrier detailing associated with the Passive House envelope. This requires a certain heightened expertise and level of detail of the architect of record, or additional consultants who specialize in designing high performance buildings and should be considered when choosing an architect and/or sustainability consultants at the beginning of the project. An experienced and dedicated team will be proactive in making design-related decisions as they relate to Passive House requirements.

The La Mora team consisted of an architect of record and a separate Passive House consultant, each contracted to the owner. While this is an acceptable structure, in retrospect, ownership would have preferred to have the Passive House consultant subcontracted to the architect of record for efficiencies in both contracting and communication.

Additionally, a rigorous Passive House-specific review of the design documents should be integrated into the design schedule and budget before any documents are passed to the contractor. A well fleshed-out design with special attention to Passive House will minimize both Requests for Information (RFIs) and change orders during construction.

Contract construction and negotiation. Passive House-specific contract construction and negotiation can save significant time, cost, and confusion during construction. One of the major points of friction during construction of La Mora was due to confusion related to the contractor's obligations with respect to airtightness testing. The contract did not incorporate specific Passive House or performance testing language, which resulted in ambiguity and differing opinions by ownership and the contractor. Further, the contractor specifically indicated an exclusion for testing during contract negotiations. One of the most difficult aspects of Passive House certification is the blower door test, which requires the building to be pressurized both positively and negatively to meet an extremely low air leakage through the envelope. It is not abnormal to fail the blower door test on the first try and adjust the building to seal remaining leaks. This

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¹ The purpose of the preliminary test was to provide a general idea of whether the completed air sealing details were sufficiently executed to pass a whole-building test.

² As opposed to a more conventional prescriptive-based method as dictated by local building code.

testing can be prepared for in the construction contract by clearly defining the parties responsible for preparing for testing, performing the testing, and executing additional air sealing measures in the case of a test failure. It is also best practice to incorporate preliminary air sealing testing into the schedule before the building is complete to make any necessary adjustments before testing the whole building.

It is also possible to gain contractor buy-in for passing the required Passive House testing using the construction contract by using a retainage or incentive for proactive air sealing. Although the contract documents should ideally include all the necessary air sealing details, many Passive House details require a higher level of quality control and attention by the general contractor than conventional construction. By assigning a monetary incentive to testing results, ownership may incentivize the contractor to focus on quality control before the testing takes place. Although neither state nor federal financing incentives are offered with respect to this specific issue, the Contract Documents can be used to provide such incentives. At La Mora, no such incentive was used, and the airsealing had to be completed out of the typical sequence of events. At La Mora, the airsealing was one of the very last items to be completed.

Another useful clause that could be incorporated into the construction contract is to require a certain level of Passive House experience or training within the core construction team³. Training is available through a number of commercial providers, which would ensure a baseline understanding of the Passive House Standard, its requirements, best practices and certification process.⁴ The general contractor for La Mora did not have experience with Passive House before the project, which posed a difficult learning curve issue throughout the project. This can be avoided to some extent by requiring that the contractor (specific personnel dedicated to the project) either have experience with the Passive House standard before committing to the project or by requiring Passive House training and/or credentialing before breaking ground.

Finally, the project schedule should incorporate ample time for iterative energy modeling. The design team's decisions must be modeled using complex software and may need adjustment based upon results. Similarly, upon commencement of construction, the construction schedule should incorporate time and budget for submittal review by the energy modeling team in the case of equipment substitutions which effect the energy usage or efficiency of the building.

Modular Construction: Benefits, Costs and Lessons Learned

Modular construction is a process in which a building is constructed off-site, under controlled plant conditions, using the same materials and designing to the same codes and standards as conventionally built facilities. Buildings are produced in “modules” that when put together on site, reflect the identical design intent and specifications of the most sophisticated site-built facility (Fannie Mae 2020). McKinsey has commented on modular construction's potential for profound impact with the potential to yield significant cost savings with additional potential gains in full-life costs (Bertram et. al. 2019).

The financing of La Mora was primarily sourced from the New York Housing Finance Agency, New York State Homes and Community Renewal. That financing required that all on-site labor to be paid prevailing wage rates. The nature of modular construction avoids some of this cost since the modules are considered a manufactured product. Because the modular units

³ This should also be a strong consideration during procurement of the general contractor.

⁴ Passive House training is available through numerous green building groups including the Passive House Network (online), Passive House Massachusetts, the Building Energy Exchange (NYC) or Emu Passive.

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are considered a manufactured product, the New York Housing Finance Agency did not require the laborers working on the modules to be paid prevailing wage rates. Therefore, the project was able to avoid on-site labor costs by opting to build the modules off site and crane them into place. Considering the high cost of labor in New York, pursuing modular construction made sense for La Mora. Although there was still a significant amount of on-site labor for which the prevailing wage requirement did apply, the project was able to avoid substantial cost through this method.

For La Mora, the building modules were pre-constructed in Moosic, PA, transported and craned into place after the concrete foundation was poured. Aside from the avoided labor cost discussed above, the modular method of construction also positively contributed to the construction schedule. A major error was made during the surveying and foundation stage of the project when the foundation was poured approximately 10 feet from the building's intended siting. Fortunately for the project, construction did not come to a complete halt since the modules could continue being manufactured off site while the on-site contractor paused work. Therefore, this error had minimal effect on the overall construction schedule.

Combining modular construction with Passive House proved to be the most challenging aspect of construction. Because the responsibility to ensure the integrity of the exterior envelope was shared between the modular manufacturer and the general contractor, there was a gap for ambiguity with respect to responsible parties. For example, one issue that triggered an expensive change order during the assembly of the boxes was the issue of air sealing the mating joints between the modular boxes. As a result, the design team expended significant effort developing the sealing detail while the boxes were being set. This lack of detailing undoubtedly contributed to the subsequent airtightness challenges discussed in the previous section.

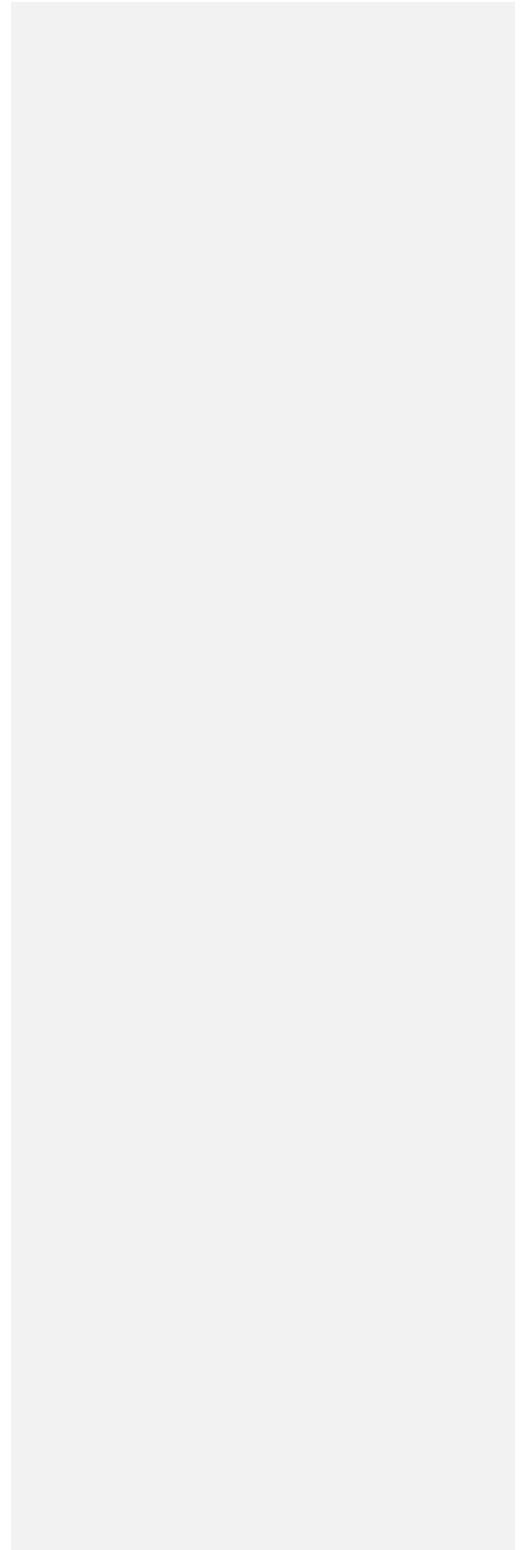
Similar lessons learned discussed above with respect to Passive House can be applied to the modular manufacturer, ensuring a qualified design team and contract construction and negotiation. Special attention should be paid when dealing with a modular manufacturer without specialized expertise in Passive House, since many of the air leakage pathways can only be addressed during the construction of the modules. Although the modular manufacturer must build to the specification within the contract documents, the design team should collaborate closely and frequently to ensure quality control and design intent. Special attention should also be paid with respect to "or equal" building materials and techniques. For example, the design team should closely inspect the modular shop drawings for any discrepancies that deviate from contract documents, paying close attention to insulation materials and thicknesses, air sealing details, taping and liquid applied air barrier details, etc.

Conclusion

In conclusion, the La Mora project stands as a testament to innovation and perseverance in addressing the pressing need for affordable, sustainable housing for seniors in Yonkers. Despite encountering significant challenges, from navigating the complexities of Passive House standards to managing supply chain disruptions exacerbated by the COVID-19 pandemic, the project has remained steadfast in its commitment to creating a resilient and inclusive community.

By integrating modular construction with Passive House design principles, La Mora not only offers energy-efficient and comfortable living spaces but also sets a new standard for affordable housing development. The project's emphasis on sustainability, resilience, and long-term affordability reflects a forward-thinking approach to urban development, one that prioritizes the well-being of residents and the environment alike.

Moreover, La Mora's significance extends beyond its immediate impact on housing provision. It serves as a model for equitable development, addressing historical disparities and environmental injustices while fostering community resilience in the face of climate change. As La Mora nears completion, its journey serves as a reminder of the importance of collaboration, adaptation, and forward-thinking in addressing the complex challenges of affordable housing. By leveraging innovative approaches and lessons learned from its development, La Mora paves the way for a more sustainable and inclusive future for Yonkers and beyond.



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