

# The Modern Trinity; Affordable, Sustainable, Urban Infill Housing

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**ABSTRACT:** We are in an affordable housing crisis yet there are large areas of our cities with abundant vacant infill sites with the potential to address this problem. For example, in the Lower North District of Philadelphia about 3 in every 10 rowhome properties are vacant. Rather than recreate the former cramped row homes, this project proposes a new typology of smaller more affordable homes reoriented on the site to provide greater access to sunlight, fresh air, and green space. While not every location is feasible for this approach, the Lower North is ideal because 1. It contains an abundance of 800 potential, vacant infill lots, 2. Land prices are currently low enough to make multiple lot purchases more financially feasible, and 3. Since the area's median household income is well below the city average, these smaller homes are more affordable so local residents could stay in their neighborhood and escape the gentrification currently happening nearby. The Modern Trinity home is based on the regional Philadelphia Trinity House typology in which 3 single rooms are stacked vertically to create a house with a very small footprint. This design requires 3 adjacent vacant lots, but rather than 3 homes lined up along the street front, units are repositioned along the northern boundary with large south-facing windows overlooking a large communal green space formed from the other 2 lots. The southern orientation ensures all units have abundant sunlight for passive solar heating, daylighting, and PV power. Operable windows for cross ventilation and passive shading from overhanging balconies reinforce the sustainable design strategies.

**KEYWORDS:** urban, infill, housing, affordable, sustainable

## INTRODUCTION

The numbers defining our current housing crisis are daunting. In 2020, 30% of all households had “unaffordable” rent or mortgage payments, defined as exceeding 30% of monthly household income...and more than 1 in 7 households paid over half of their income on housing (Habitat for Humanity 2023). There is a national shortage of 7.3 million affordable and available rental homes for extremely low-income renters (National Low Income Housing Coalition 2023). And on top of this, population demographics are changing with greater demand by the Missing Middle sector of people, who do not fit the typical family structure and make a decent income, yet still cannot find affordable housing (Parolek 2020). While this presents a high hurdle to clear, there is still an untapped abundance of vacant land in our cities with enormous potential to address this problem.

Rather than just replace the former cramped, dark row homes, this project proposes a new typology of smaller homes reoriented to provide greater access to sunlight, fresh air, and green space. Not every location is feasible for this approach, but the Lower North district of Philadelphia was used as a test site for several reasons. First, it contains an abundance of scattered, vacant pockets of property with at least 3 adjacent lots on north-south oriented streets, which are necessary for this design parti. Second, the land prices are currently low enough to make multiple lot purchases, and when combined with modular construction techniques, can make these homes financially feasible. And third, the area's median household income is well below the city average so many who cannot afford the new market-rate homes currently being built could more likely afford these smaller homes.

## 1.0 DESIGN CONCEPT BACKGROUND

This new typology of sustainable and affordable smaller homes that are reoriented on the site, springs from previous design research for the Side Yard House (SYH), a concept of a long thin house, similar to the Charleston House typology. Because it would be very difficult to understand the current research without this background, some of that earlier research is included here for reference and clarity, but this specific paper focuses specifically on new *urban infill* research conducted within the past year. Both the SYH and this new concept are repositioned along the north border of the lot to prevent shading by the neighboring home to the south, with abundant south-facing windows looking into a communal green space on the south side. (e.g. Figure 1) The broad, south facade of the home contains the vast majority of the glazing with minimal fenestration on the east, west and north sides. This ensures all units have abundant sunlight for passive solar heating, daylighting, and PV power, while maintaining a well-insulated envelope with only the necessary amount of poorly insulating glass surface. Operable windows for cross ventilation, passive shading from the overhanging balconies, and the green side yard, all help cool the building passively to minimize the need for mechanical air conditioning and increase overall energy efficiency and resiliency.

As a single-family detached house on a larger lot, the SYH worked very well on sites where an entire *block* was vacant, (as in the test city of Detroit). However, it did not adapt well as a smaller, more affordable home for tight urban infill sites, thus by limiting the potential application opportunities.

As the need for affordable housing is huge within these urban environments, this new phase of design research focused specifically on how the concept could be revised and applied to smaller homes on smaller infill lots within an existing block of row homes. Or rather, instead of a complete new set of dentures, just filling in the missing teeth. The passive energy strategies of the SYH transferred across to the new design but the scale, scope and size of the units were all completely revised downward to create smaller, more affordable, urban infill homes.

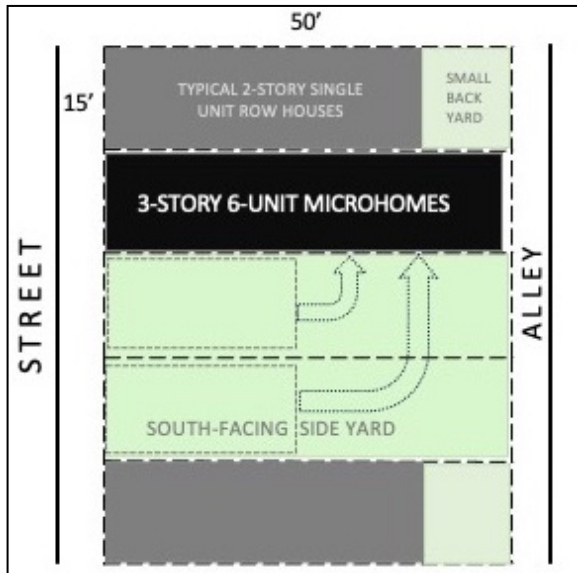


Figure 1: MT Concept Plan Diagram. Source: (Author 202)

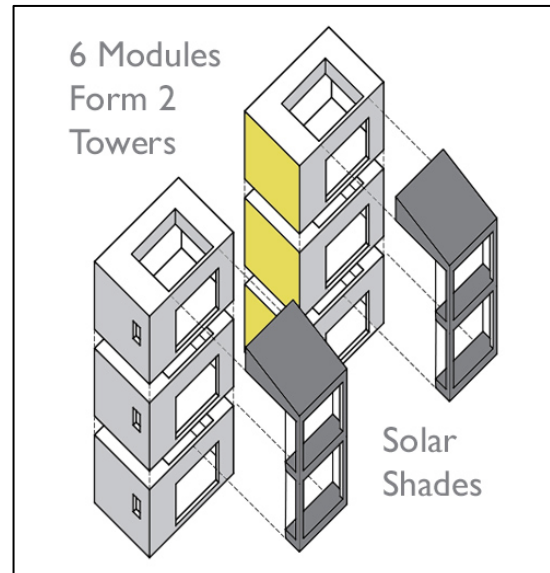


Figure 2: MT Concept Axonometric. Source: (Author 2023)

The concept for this new infill design combines the passive energy strategies from the Charleston typology with another traditional space-saving housing typology, Philadelphia Trinity House. The Trinity, also known as the “Father, Son and Holy Ghost” House, is a housing typology unique to Philadelphia in which 3 single rooms are stacked vertically and connected by a tight winding stair to create a house with a very small, space-saving footprint. (e.g. Figure 5) Kitchens are located on the ground level or basement, living areas on the middle floor, and a bedroom on the third. Originally, bathrooms were in backyard outhouses which makes incorporating them inside renovated versions more difficult. This new Modern Trinity (MT) typology updates the classic Trinity to improve on these issues while at the same time making the home more sustainable. (e.g. Figure 2) Like the SYH, units are still located along the northern lot line to maximize southern exposure, but because of the much narrower 15’ urban sites, 3 adjacent lots are required to create a large enough site. Two adjacent lots would not allow enough space on the south side for winter sunlight to reach overtop of the neighboring building or create a large enough side yard to be functional. However, even on a smaller site, the MT’s smaller footprint and vertical orientation uses considerably less land per unit and therefore allows for 2-9 units (depending on lot depth) per 3-lot site instead of one single, larger, detached SYH home. Rather than lining 3 Trinities up along the street front as was traditionally done, multiple units are repositioned along the northern lot boundary like the SYH with large south-facing windows that access the large communal green space. (e.g. Figure 3 & 4) Three single-floor flats stacked on top of each other, as has been traditionally done, would create the same amount of floor area but the units would not have equal access to light, air, and green space. The unit on the bottom would get less sun and air flow but would have access to the yard. Upper units would get more light and air but would have no access to the green space. With the Trinity design each unit get equal access to all.



Figure 3: Floor Plan. Source: (Author 2023).

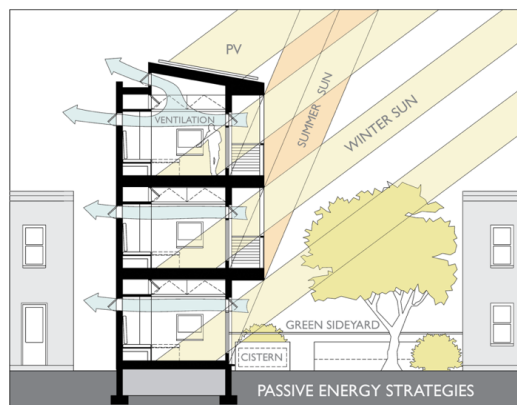
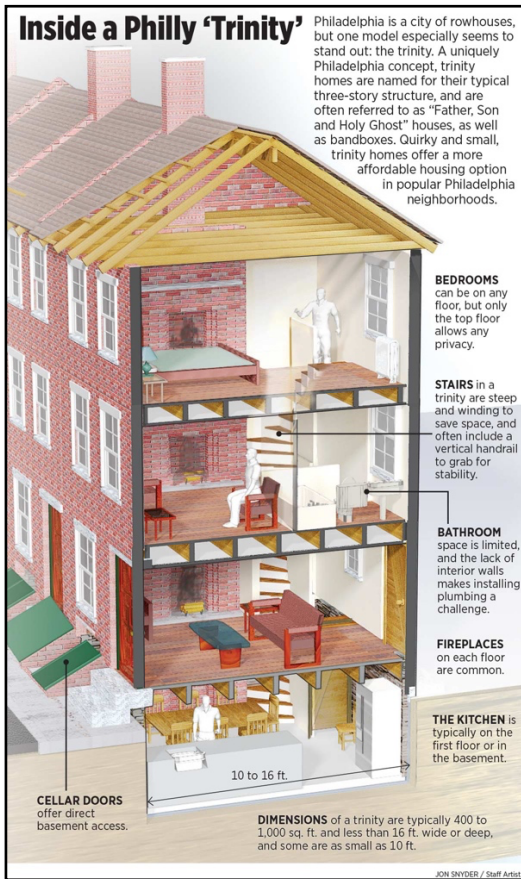


Figure 4: Section with Passive Energy. Source: (Author2023)

## 2.0 LOCATION RESEARCH

The previous research into side-yard housing utilized larger and more contiguous sites with little to no existing buildings. Grey, Green and Brownfield sites were used in suburban locations and entire vacant *blocks* with medium size lots for urban sites (as in Detroit). This degree of open land allowed the freedom to insert and repeat the housing pattern across a large area so an entire neighborhood of sustainable middle-income homes could be built on these sites. However, this approach had a couple flaws. The homes were too large to be affordable to lower-income buyers and, with large blocks of open land becoming rarer, it did not work well on the available smaller infill sites. This severely limited the potential sites, so for this design to be truly feasible on a larger scale, it needed to be able to adapt to urban infill conditions and become much more affordable to lower income buyers.

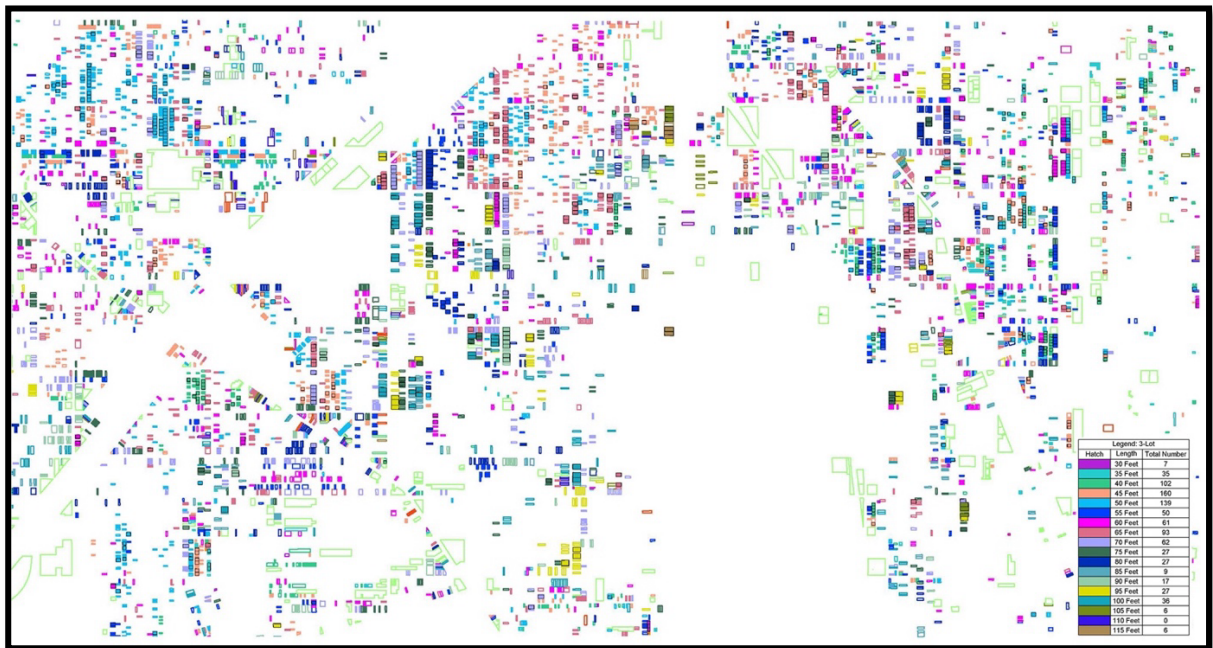


**Figure 5:** Trinity. Source: (Jon Snyder, Phila. Inquirer 2017)

**Figure 6:** 3-Lot Sites. Source: (Google Maps & Author 2023)

Since this concept requires a potentially rare site made up of 3 adjacent lots on north-south oriented streets, it was important to first identify a location with a sufficient number of useable sites to confirm the project's viability. The Lower North District just north of center city Philadelphia is an ideal location for several reasons. First, the 6-square-mile district contains approximately 34,000 rowhome lots of which roughly 8,000 are vacant, or almost 25% (Philadelphia Planning Commission 2014). (e.g. Figure 6) Second, the Lower North sits in a prime location just north of downtown with excellent public amenities like transportation, commercial zones and institutional facilities, (Temple University sits squarely in the center of the district). Yet, the majority of the area has not yet been overtaken by gentrification and new development (as is happening in neighboring districts). And third, land prices are currently low enough to keep land costs for multiple lot purchases low enough to make the project financially feasible. This is important because the area's median household income is well below the city average, so many who cannot afford the market rate homes currently being built around them could afford these smaller homes and not be forced out of their neighborhood.

Even though there are over 8000 vacant lots in the district, this design concept requires 3 *adjacent* lots on north-south running streets, so it was critical to ensure there were enough sites that met this condition. So, a GIS (Geographic Information System) study was conducted to identify the total quantity of 3-lot sites along with the lot depth dimensions. The results, shown in the map below, revealed that there are just over 800 3-lot sites on N-S streets in the workable range of 40' to 100'+ in depth. (e.g. Figure 7) Using some simple math, with about 800 potential sites, a conservative average of 3.5 units per site, and an average of 2 people per unit, it would be possible to house about 5,600 people in the Lower North using this design. These numbers suggest this approach is not limited to a few select sites but is applicable on a large scale in this district.



**Figure 7:** GIS Map of Vacant 3-Lot Sites in the Lower North District. Source: (Trisha Kawa 2023)

### 3.0 UNIT SIZE VARIATIONS

Due to shifting household demographics and market interests, there is a tremendous mismatch between the available housing stock in the United States and the type of housing that people want and need....The household and cultural demographics of the United States have shifted dramatically-nearly 30 percent of all households are now single person. By 2035, one in five Americans will be over the age of sixty-five, and households without children will make up 84 percent of change in households between 2015 and 2025. (Parolek 2020, 1-2)

Demographics of home buyers today have changed greatly from the average 4-person family of mother, father and two children. Non-traditional family structures now require a variety of housing options that are not readily available and/or affordable. Further, groups in the Missing Middle demographic such as aging parents, boomerang children, young couples and single parents often do not need, and cannot afford, the larger houses being built today. So, there is a need for a variety of smaller, lower-cost homes in a range of sizes. To address this, the Modern Trinity homes come in 4 different 3-story models. The smallest unit is a tiny 250 square feet single-story microhome for single residents that can be stacked 3 units high. While not a true Trinity by definition, it forms one while creating 3 units using the same volume of space. The slightly larger 3-story Trinities have an internal stair connecting cooking, living, and sleeping levels. These are geared towards couples and are available in 3 sizes with floor areas of 750, 900 or the largest at 1050 square feet that includes an additional bedroom. For deeper lots that come with corresponding higher land costs, a duplex model was developed to increase land use efficiency by maximizing the number of dwelling units per site. Below are further descriptions of each unit.

#### 3.1 The microhome

These smallest units are single 20' long modules that are stacked 3 units high (to form a Trinity) and are accessed by an external shared stair that can serve 3 or 6 units. They combine all functions in one space, similar to a Single Room Occupancy room or studio apartment, so are intended for a single person. Because of the small floor area, a space saving strategy is applied that borrows from airline overhead storage bins. A U-shaped space containing functional "wet" zones with storage bins above surrounds a taller central convertible living and sleeping space. They are by far the most affordable but have a limited audience due to their small size. The balconies used to provide passive shading also provide some exterior spatial relief to the upper units.

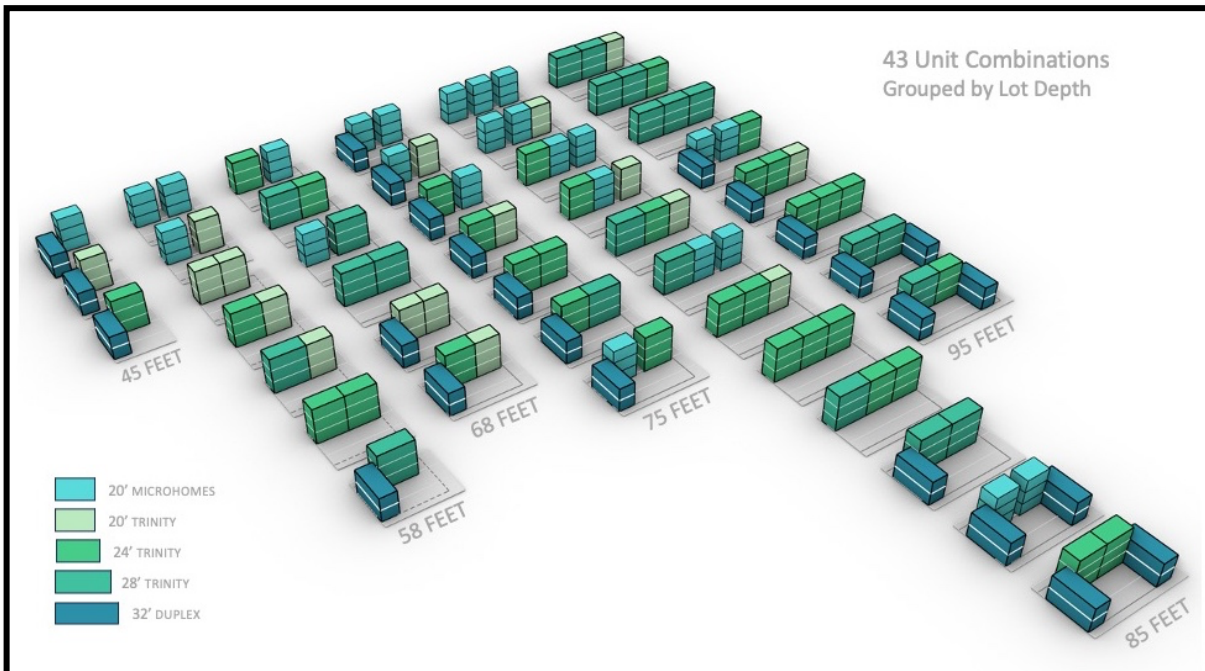
#### 3.2 The trinities

The majority of the homes would be Trinities composed of 3 units stacked vertically connected by a private internal stair. They consist of a live-in kitchen/dining on the ground floor, living/work space on the second and sleeping/bath on the third. They come in 3 lengths of 20', 24' and 28' (based on the 4' module of construction materials to minimize cut-off waste) to adapt to site depth dimensions and buyers' variable budgets. They are intended for a couple but the largest unit could accommodate a small child as well. Each unit has a patio and 2 balconies overlooking the green space.

#### 3.3 The duplex

As lots slowly increase in their depth dimension, they cannot always accommodate another full unit length along the north lot line. So, to maximize the number of units per site, the Duplex is rotated 90 degrees and sited along the street front and if deep enough, along the back lot line as well, to fit in another unit. If this unit was made into a 3-story Trinity in this orientation, it would block too much south-east and south-west sunlight to the other units. So, it

is kept only 2 stories high to allow sun access while maintaining the street’s urban wall and increase privacy from the sidewalk. It is the longest unit at 32’ long so can accommodate all of the kitchen/dining/living functions on the ground floor and allows room for 2 bedrooms and bath on the second. The extra bedroom accommodates owners with children or live-in relatives. This unit does not face south so a skylight over the internal stair volume would be used to bring in natural sunlight, but the living spaces still face into the green garden.



**Figure 8:** Unit Combination Options. Source: (Trisha Kawa 2023)

As mentioned above, while collecting GIS research of vacant lots, it was noticed that while the width of the lots remained fairly constant, between 14 feet and 16 feet, the depth varied greatly with the vast majority ranging between 45 feet and 95 feet. As the lot depth determines how many units can fit, we tested the various unit combination options based on triple-lot depth and discovered 43 different arrangements were possible, from a minimum of 2 units to a maximum of 9 units per site. (e.g. Figure 8) This offers a great variety of options for accommodating diverse owner demographics. The multiple module combinations possible per site create a wide variety of units that can accommodate the range of diverse, non-traditional family structures required for missing middle housing. One owner could rent out entire property to separate residents. Or, with this range of units possible per site, a single family could own a building lot comprised of three or four units of various sizes in which their siblings, parents, and/or adult children could live together in support each other. Unused units could also be rented out as Accessory Dwelling Units to help defray the mortgage costs. As shown in the graphic above, there are multiple combinations possible to adapt to a variety of buyer demands.

#### 4.0 AFFORDABLE MODULAR CONSTRUCTION

The Lower North District overall has a below-average income level so it is crucial to keep construction costs low to create as much access to housing as possible. There are several strategies used to promote low initial cost. First, the smaller than average size of the homes themselves translates directly to lower per-square-foot costs for all the units. Costs can be further reduced through the use of pre-manufactured, modular construction which costs an average of 10% to 20% less than stick built construction.

In 1969 the US federal government launched *Operation Breaththrough*, an initiative to produce more factory built houses, but it didn’t work as today only 2 percent of single-family homes in the US are factory built (Appelbaum 2023). But builders are increasingly returning to the advantages of modular construction as construction costs keep skyrocketing. The Micro-Trinity flows the standard dimensioning of premanufactured construction. All modules are a nominal 12’ wide to fit on a flatbed truck and the lengths are sized using the 4-foot module of standard construction materials to create unit lengths of 20’, 24’, 28’ and 32’ increments, with 2 of the smaller units being able to fit on a 53’ flatbed truck.

While producing precise cost estimates would require further in-depth analysis, current pricing data was used to derive some rough home cost estimates. Current construction costs in Philadelphia average around \$124 per square foot for very basic construction (Marshall 2024). As with all real estate, land costs vary per location. However, current asking prices in the LND for smaller vacant sites range from as low as \$13K up to \$50K for larger lots. Three adjacent lots added together would cost from \$40K to \$150K, but as larger lots hold more units, when divided by the units per site the average land cost per unit is roughly the same at about \$20K (and less for the smaller microunits). Using the U.S. Health and Human Services latest 2023 Poverty Guidelines of \$14,580 annual income for a single person and \$19,720 for a couple, the Microhome is the only model affordable for the Extremely Low-Income bracket (Office of the Assistant Secretary for Planning and Evaluation 2023). However, based on the above

stated determination of affordability as no more than 30% of income spent on housing, the average household income required to purchase these homes indicates that most units fall within the range of the intended Low-Income and Missing Middle housing market. The chart below compares these estimates by unit type. (e.g. Table 1)

**Table 1:** Construction Cost Estimates. Source: (Author 2023)

| Unit Type   | Total Area | Construction at \$124 psf <sup>7</sup> | Land Costs / Units / Site | Total Housing Costs | Monthly Mortgage, 6% APR | Annual Income Req'd @ 30% |
|-------------|------------|--|---------------------------|---------------------|--------------------------|---------------------------|
| 20' Micro   | 260 sf     | \$32,240                               | \$10,000                  | <b>\$42, 240</b>    | \$253                    | <b>\$10,100</b>           |
| 20' Trinity | 780 sf     | \$96,720                               | \$20,000                  | <b>\$116,720</b>    | \$700                    | <b>\$28,000</b>           |
| 24' Trinity | 936 sf     | \$116,064                              | \$20,000                  | <b>\$136,064</b>    | \$815                    | <b>\$32,600</b>           |
| 28' Trinity | 1,092 sf   | \$135,408                              | \$20,000                  | <b>\$155,408</b>    | \$932                    | <b>\$37, 280</b>          |
| 32' Duplex  | 832 sf     | \$103,168                              | \$20,000                  | <b>\$123,168</b>    | \$738                    | <b>\$29,500</b>           |

Affordability is not only addressed as initial construction costs but is also considered with operating costs. Being able to afford to buy a house does not guarantee the ability to pay for its operation. To keep utility bills low, the units are designed to be well-insulated and sealed as close to Passive House standards as individual budgets allow. Plus, a photovoltaic system (potentially purchased using government subsidies) can even further reduce utility bills. The PV system and extra insulating materials needed would be rather minimal because of the small home size and shared walls/floors but would still increase initial construction costs by 5% or more. However, these costs would be tempered by the 10% - 20% saving from modular construction and somewhat cancel out each other. The SYH was tested with the Sefaira software program for thermal and daylighting efficiency and performed well. The Modern Trinity is currently starting testing.



**Figure 9:** Perspective Rendering of Modern Trinity Homes. Source: (Zach Winton 2023)

## CONCLUSION

The southern orientation and 3 adjacent lot requirements of the Modern Trinity mean it is limited in its overall application. However, many US cities were laid out on a north-south grid and (shamefully) have a great deal of abandoned infill sites still available for development. The Lower North District of Philadelphia, as well as many neighborhoods in cities like Detroit, are prime locations for this type of project that can help to combat the lack of affordable housing while simultaneously fighting to preserve our planet.

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