Linking Sustainability and Housing Affordability to Neighborhood Design Compatibility

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ABSTRACT: *While economic and social policy models have failed to move the public demand to build more affordable housing in Austin, Texas, urgent environmental, sustainability and climate change realities may finally demonstrate how it is in everyone's self-interest to build more affordable urban Zero Net Energy (ZNE) housing now. Residents of Austin's older urban neighborhoods have been reluctant to accept zoning changes that would allow large numbers of urban middle density housing units, fearing the higher densities would not be compatible with the character of their existing single-family detached (SFD) scaled neighborhoods. SOLEIL Homes presents a ZNE middle density housing model combining affordability and sustainability to add a new standard for neighborhood compatibility. The SOLEIL model allows existing neighborhood residents to visualize a modest middle density increase (31.1 units per acre), ZNE energy efficiency, and affordability to maintain diversity and compatibility with the character of Austin's SFD scaled urban neighborhoods. The SOLEIL factory-built modular housing model lowers construction costs by 20% and the middle density allows more housing units to share – and thus lower – raw land costs, addressing the primary cause of rising home prices. Through its green building design, evaporative cooling rain gardens and enhanced energy conservation features, SOLEIL achieves a low Energy Use Intensity (EUI) ZNE Ready rate of 7.9 kBtu/ft2-year, and with the addition of a 5.14 KW per unit Community Solar PV system, the SOLEIL units achieve a Zero Net Energy home classification. A rainwater harvesting design reduces water use to less than 30 gallons per capita day. SOLEIL units achieve neighborhood design compatibility and energy efficiency at a sales price affordable to residents with an income of less than 80% of Austin's annual median family income (MFI). By extending ZNE sustainable housing to include the affordable and moderate housing markets, enough urban units could be built by the end of this decade to meet Austin's affordable housing demand and help forge a pathway to reduce the city's carbon footprint CO2e/year by 50% by 2030.*

KEYWORDS: Climate Change Mitigation, Housing Affordability, Middle Density, ZNE

INTRODUCTION

The 2015 United Nations Paris climate agreement set a target of limiting the global average temperature increase to less than 3.6˚ Fahrenheit (2˚ Celsius) above pre-industrial levels by 2050 to avoid the worst impacts of climate change. (1) In response, the City of Austin, Texas (COA) adopted a new Climate Equity Plan in 2021 that sets a target to become a net-zero community wide CO2e/year emissions by 2040. Austin's pathway to achieve this goal links affordable housing, and zero net energy (ZNE) housing at an increased density that is compatible with the design character of Austin's existing urban neighborhoods. In Austin the electricity and natural gas used to power residential buildings and the transportation fuels used to power vehicles traveling between home and work account for 83% of Austin's Community Greenhouse Gas Emissions (10.8 million metric tons of CO2e/year in 2022). (2) Austin's Climate Equity Plan requires a 50% reduction in the city's community greenhouse gas emissions by the end of this decade. To achieve a change of this magnitude will require significant revisions to COA policies on how and where housing is built. Specifically, Austin must reduce the operational energy use of all its existing housing stock by 25% and add another 100,000 new ZNE housing units to meet demand and for 80% of these new housing units to be built within Austin's urban neighborhoods to reduce transportation carbon emissions. Since two-thirds of the city's housing market is for moderate and affordable units, it is imperative that affordable middle density ZNE housing models compatible with the scale of Austin's urban neighborhoods be constructed in large numbers to achieve Austin's climate change mitigation goals.

1. COMPATIBILITY: NEIGHBORHOOD SCALED MIDDLE DENSITY HOUSING TRANSITION ZONING.

A sample 19,279 ft^2 site in Central East Austin's Blackland Neighborhood, comprised of three adjoining lots zoned single family (SF-3) is used as a case study analysis to develop the SOLEIL Homes model. (3) Located in a historically black urban neighborhood now experiencing gentrification, the site is in a proposed half-block housing density transition zone bordering neighborhood streets lined with single-family detached houses to the south and denser four-story Vertical Mixed Use zoned housing along a core transit corridor to the north. The housing density transition zone would allow housing densities up to 31.1-dwelling units per acre, a maximum height of 34-feet, a maximum building area to site area ratio of one to one, a maximum building coverage area to site area ratio of 50% and a maximum impervious surface site coverage of 60%. When the site impervious coverage ratio exceeds the current SF-3 allowable of 45% (4) a green stormwater infrastructure (GSI) system is required to assure that storm water flow will not exceed the flow currently existing from the site. To address concerns about the design compatibility building scale of middle density in their single family detached (SFD) scaled neighborhood, SOLEIL provided a physical model that allows residents to visualize a middle density scaled housing design project.

Figure 1: SOLEIL 14-unit middle density housing model proposed for a ½ block housing density transition zone. Source: (Garrison 2021)

The SOLEIL model design limits building heights along neighborhood local streets to two-stories in height and breaks up the massing of the project using deep balconies and front porches that sit back 15-feet from the street. The elevated front lawns and xeriscape landscaping provide privacy for street-facing row homes without building privacy fencing. Rather than attempt a fake historical reproduction of the Swiss farmhouses or the bungalow style of Blackland's earlier times, SOLEIL homes achieve design compatibility by using domestic gable roof forms similar in size to the older houses in the neighborhood, and with their 14-foot-wide front porches they are aesthetically compatible with the scale and character of the existing Blackland neighborhood. Based on the physical model, the neighborhood association found the proposed middle density to be in keeping with the character of their neighborhood. The middle density overlay zoning allowed 14-SOLEIL housing units, averaging 1,200-square-foot in size, to be built on the 19,279-square-foot site zoned for the three SF-3 lots. The SOLEIL Housing model was then used as an economic, sustainability and design compatibility comparison to the three three-story SFD units and the two two-story Accessory Dwelling Units that were built on the site under SF-3 zoning in 2022-2023.The Travis County Central Tax Appraisal District in 2020 (5) assessed the property value for the three SF-3lots at $425,000 for each lot. When raw land prices are this expensive, it pushes the sales price of a home built on the site up to the luxury class level. A developer typically would like to keep the raw land costs below 20-25% (6) of the home sales price. For example, one SFD house built on one of the lots in 2022 is a 3-bedroom, 2-bath, 2,245-square-foot, 3-story home with a market sales price of $1,100,000. (7) The raw land cost ($425,000) represents 39% of the home sales price. The $1.1 million house is too expensive for existing neighborhood residents and twice the square footage of typical Blackland houses. Neighbors labeled the house a "McMansion" and opposed its development.

As an economic alternative, the raw land cost for the 14-unit SOLEIL homes is $91,300 per unit. This allows the developer to build smaller 1,200-square-foot housing units with an affordable (8) market sales price of $367,116 each. Their raw land costs are 25% of the home sales price. Additionally, because middle density only adds a modest increase of energy and water efficient housing units, utility infrastructure demands can be met without drastically increasing the utility infrastructure capacity of existing urban single-family detached scaled neighborhoods.

2. AFFORDABILITY: PREFABRICATED MODULAR FACTORY-BUILT HOUSING CONSTRUCTION

Factory-built modular construction can reduce costs by approximately 20% through benefits that include bulk purchasing of building materials, better controlled indoor work conditions, more experienced factory workmanship, assembly line efficiency, automation, and reduced construction times. Local building code compliant prefabrication is a process in which a modular home is constructed off-site, under controlled indoor plant conditions and then shipped to a site where modules are assembled to form a multifamily housing project. The construction process uses a selected unit or module, such as a rectangle or other subcomponent, which is used repeatedly in an assembly line construction process. The modules are constructed in a factory, trucked to the site where they are unloaded using a crane and then placed on a concrete perimeter beam foundation and stacked together to form row houses. The modules arrive at the site with fully finished interiors, MEP systems, windows, doors, cabinets, kitchens, bathrooms, and interior finishes. The row houses are put together by connecting the stacked modules to stairway modules, and the entire project is assembled on site in just a few days.

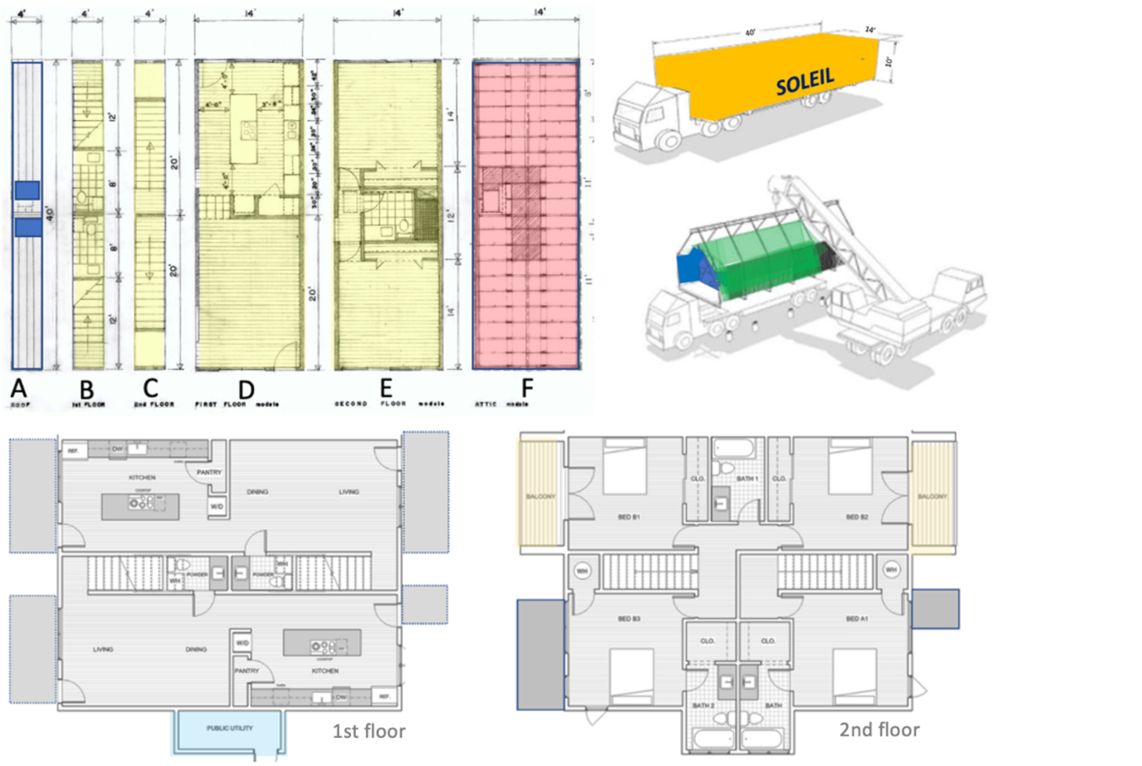

Figure 2: Prefabricated factory-built row housing modules shipped to the site and stacked together. Source: (Garrison 2021)

The SOLEIL module costs were based on 2022 prices quoted by Oak Creek Modular Homes in Fort Worth, Texas. (9) While the SOLEIL design is different than the standard Oak Creek modular home design, the company will build custom modules when the number of modules is significant enough to justify the set-up costs. SOLEIL meets this requirement building 28-14'W x 40'L x 11'H home modules, 14- 4'W x 40'L x 11'H stairway modules and 10- 14'W x 40'L x 8'H @45˚ sloped roof modules. An Oak Creek standard modular home similar in size to a SOLEIL row house costs $126,562 (July 2022 dollars). Because the SOLEIL project includes more expensive materials, finish upgrades, electrical and appliance upgrades, the SOLEIL units are slightly more expensive at $138,895 per modular unit delivered and assembled on site. On-site construction costs another $60,321 per unit for site prep and finish out work including site grading, perimeter concrete pier foundations, under floor bladder cisterns, exterior rainscreen FRP siding, galvalume roofing, rain garden courtyards, pervious paving, living fencing, a community garden roof deck located above the SOLEIL flats, a roof deck shading pergola to support PV panels, utility infrastructure systems, exterior lighting, and xeriscape landscaping. Quality materials and finishes are used to assure SOLEIL will meet highest quality for standard construction (moderate income market) at an "all in" base cost of $199,216 + $11,600 in energy efficiency upgrades $210,816 ($175/square-foot).

3. SUSTAINABILITY: MICROCLIMATE SITE DESIGN, ENHANCED ENERGY CONSERVATION AND ZNE SOLAR PV POWER

Enhanced energy conservation features are incorporated into the SOLEIL Homes design to meet the requirements of a U.S. Department of Energy (DOE) ZNE READY home certification. These features include: 1) a microclimatic site design featuring evaporate cooling, shading, and solar induced stack ventilation; 2) specifying Austin Energy Green Building (AEGB) program multi-family five-star green building features (10) which is similar the DOE ZNE Ready Home (ZERH) rating (11), and 3) incorporating Passive House super insulation energy conservation standards. (12)

3.1 Microclimate site design

Microclimate is defined as the regional climate modified by local site conditions. The proximity of SOLEIL buildings provides for reciprocal building shading and creates courtyards. By placing the housing units at the perimeter of the site around a courtyard and by locating the PV panels as a shading awning above the roof of the SOLEIL flats, the PV panels are out of the solar shadow of surrounding buildings and trees throughout the year. Microclimate courtyards are used as both a green stormwater infrastructure (GSI) control system and for the climate modifying aspects of evaporative cooling from adjacent vegetation.

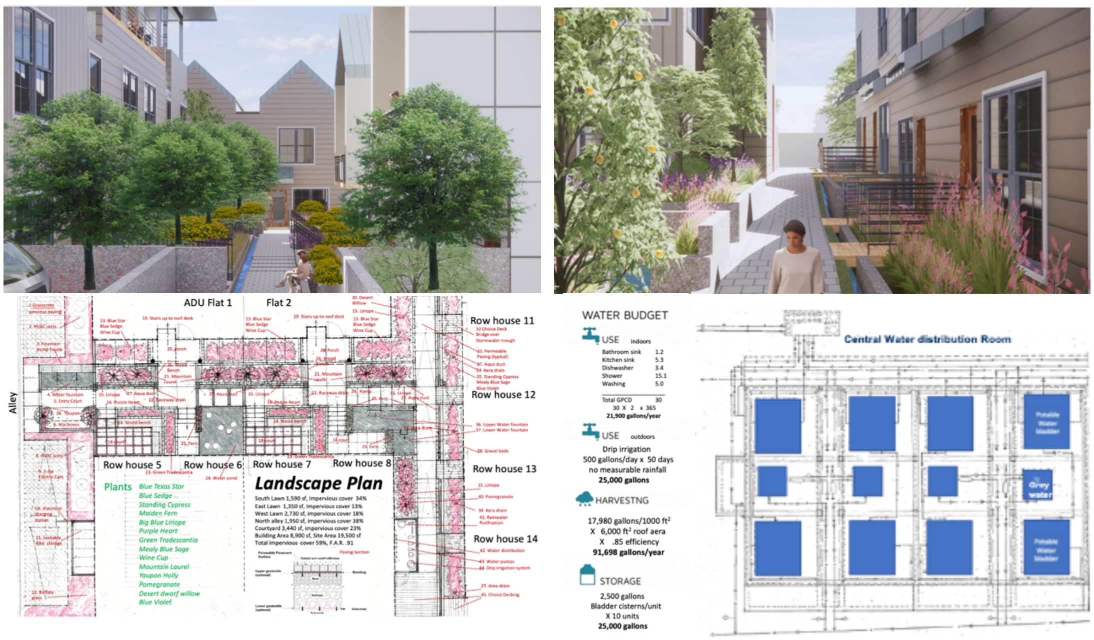

Figure 3: East-West and North-South Courtyards with GSI rain gardens and evaporative cooling. Source: (*Garrison 2021*)

Plant transpiration creates evaporative cooling in the courtyards. Plants shade the ground and leaves transpire moisture, which cools the air when the moisture evaporates. The daily maximum surface temperature at a given location is dependent on the amount of **radiant energy** converted to sensible heat. Rainwater harvesting available for irrigating the rain garden plants and their subsequent moisture evaporation increases latent heating by adding water vapor to the **atmosphere**. As a result, relatively little energy remains to heat the air, and the sensible heating of the air near the ground is minimized. (13) Daily maximum temperatures are not as high in the evaporative cooling microclimates of the rain garden courtyards reducing localized temperatures by as much as 15˚F and reducing adjacent building thermal loads by approximately 13%. (14) When temperatures soar to triple digits, the accompanying relative humidity drops down to below 40% and that is when evaporative cooling works best. Rainwater harvested from SOLEIL's galvalume roofs during spring months is stored in bladder cisterns located in the underfloor crawl spaces of the row houses. The 25,000-gallon total capacity of the combined cisterns will meet the irrigation needs of the rain gardens and xeriscape landscaping during summer droughts lasting up to 50 continuous days without any measurable rainfall. The rainwater cisterns along with low water use plumbing fixtures and appliances reduce SOLEIL's water use to less than 30-gallons per capita day. (15)

3.2 Enhanced energy conservation features

Austin, Texas is classified as a sub-humid climate located in zone 2A defined by the International Energy Conservation Code (IECC). The residential annual energy use benchmark for an average Austin home built to 2015 IECC code standards is 13,801 kWh/year, (16) which equates to an Energy Use intensity (EUI) of 23.9 kBtu/sqft-year, (13,801 kWh x 3.412 Btu/kWh /1,865 sqft, the average home size in Austin). Newer homes in Austin built since the 2015 IEEC code tend to average 12,000 kWh/year or within a range of 13% more energy efficient than the 2015 IECC code as builders preparing for the enforcement of the 2021 IECC code, now tend to include more Austin Energy Green Building (AEGB) features in their standard construction practice. (17) These features include, minimum R-13 exterior wall insulation, R-30 ceiling insulation, window U-value less than .34 and a solar heat gain coefficient (SHGC) of less than .4, along with a minimum HVAC

Seasonal Energy Efficiency Rating (SEER) of 14 or above. A 2023 AEGB certified home has an average annual electrical use of approximately 9,600 kwh/year which equates to an EUI of17.56 kBtu/ sqft -year. To achieve a 5-star AEGB rating Austin home builders must add additional green building measures and energy conservation features that reduce the home's annual electrical use by a minimum of 55% below code to 5,400 kWh/year which equates to an EUI of 9.88 kBtu/ sqft -year. Reducing a home's annual electrical use by 55% below the benchmark code home is the minimum rating to qualify for a DOE ZERH certification. (18) The AEGB 5-star and the ZERH features include, R-19 wall insulation, bridging wall board insulation, R-49 ceiling insulation, window U-value less than .26 and a SHGC of .25 or less, improved hot water heating efficiency and a minimum HVAC SEER of 15 or above as well as energy-star rated lighting and appliances.

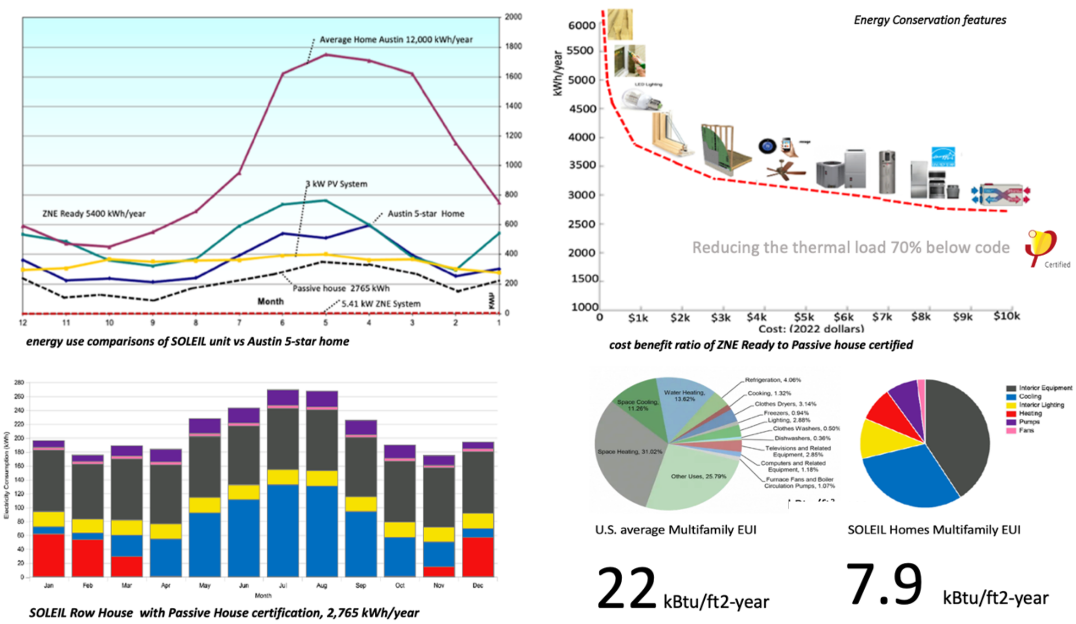

Figure 4: Zero Net Energy Ready classification using enhanced energy conservation features. Source: (Garrison 2021)

Before SOLEIL Homes are sized for a roof-top solar photovoltaic (PV) power system to become ZNE homes, they should consider even more energy conservation measures to lower the housing project per unit power load to reduce the number of required PV panels to make the power system more economical. (19) Therefore, SOLEIL adopted Passive House super insulation standards to reduce total annual electrical use by 77% below the 2015 IECC code Austin benchmark home. The SOLEIL Homes built to the Passive House standards reduced the annual electrical load to 2,765 kWh/year which is an EUI of 7.9 kBtu/sqft-year (For a 2-bedroom, 1- and ½-bath, 1,200 sqft SOLEIL attached row house unit). PHI and PHIUS certified measures include, R-23 wall insulation, R-57 ceiling insulation, window U-value .17 or less and a SHGC of .2 or less, low e-3 heat mirror windows, responsive exterior window shading, heat-pump water heating, a minimum HVAC SEER of 16 or more, LEED lighting, high energy-star rated fixtures and appliances, well-sealed exterior building envelope with .22 air changes per hour along with an Energy Recovery Ventilator (ERV) to assure adequate amounts of interior fresh air and a smart energy management system thermostat.

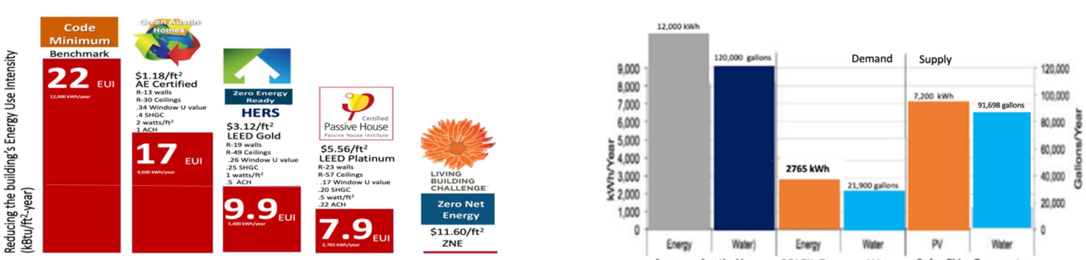

Figure 5: ZNE U.S. DOE classification with the addition of a community solar power system. Source: (Garrison 2022)

Austin low-rise residential and multifamily building permits require IECC Manuel J HVAC sizing calculations. (20) When these calculations are applied to a SOLEIL row house (Passive House standards), the peak HVAC load is calculated at 1,800 Btu/hour (or 1 ton of HVAC per 800 ft2 of floor aera). Each SOLEIL housing unit has its own 19- SEER air source heat pump heating and cooling system and heat pump domestic hot water system. During hot summer conditions, the air source heat pump will supply cool forced air to dehumidify and cool air to maintain interior comfort at 75˚F. The cooling load and the heating load were calculated using peak design high and low outdoor temperatures of a 110˚F outdoor summer high temperature and a 10˚F outdoor winter low temperature. The simulation estimated a peak thermal load of 17,899 Btu/hour summer and 10,800 Btu/hour winter. Given the summer dominant cooling load, a 1.5-ton, 19-SEER air source heat pump for cooling and heating is specified for each SOLEIL housing unit.

3.3 Zero Net Energy PV community solar power systems

To achieve a zero-net-energy operational power performance, the SOLEIL housing units' photovoltaic panels were added to the project. SunWatts Mono Sol XL solar PV Monocrystalline C-Si panels with 20% efficiency, 450 watts, (23.5 sqft/panel) were added in two locations: On the Poquito St. row house south-facing roofs, 48-PV panels are fixed mounted at a tilt angle of 45 degrees and at an azimuth angle of 190-degrees. And across the central north-south courtyard an additional 112-PV Sunwatts panels are mounted on the roof pergola above the SOLEIL flats. They are fixed mounted at a tilt angle of 3-degrees and a 190-degree azimuth angle. In combination the panels provide a 72kW PV power system. (21)

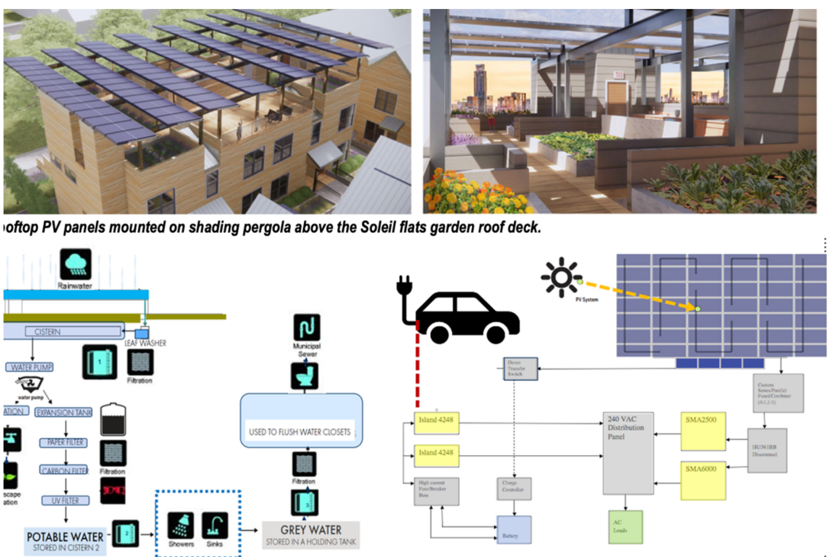

Figure 6: SOLEIL 72 kW (5.14kW per unit) AE Community Solar PV power system with water and power storm resilience. Source: (*Garrison, 2021*)

The SOLEIL Homes (Passive House Standards) is estimated to require only 61PV panels to become a ZNE housing project. Because the SOLEIL Community Solar design provides 160 PV panels, they will provide more electricity than the housing project needs. During a typical summer day excess PV power is sent back into the electrical grid where it can be used by other customers. At night the housing units pull power from the electrical grid. If the housing units use less energy than they produce, under a Community Solar lease agreement Austin Energy would pay the SOLEIL residents at a rate of $0.03 per kWh for their excess power. On an annual basis if the housing project supplies more power to the electrical grid than it uses it is considered a zero net energy project. (22) The estimated cost of SOLEIL's PV panels is $0.81/Watt-dc x 72 kW PV system equals $58,320 and after the maximum AE PV rebate of $35,000 equals $23,320 cost plus installation and inverter costs to the owner. This up-front solar PV cost is too expensive for affordable home buyers, but Austin Energy offers a Community Solar program for affordable multifamily housing without any out-of-pocket expenses to the residents. SOLEIL is planned to use the Community Solar Program option and therefore no costs for the solar system are not included in the ZNE housing construction budget.

4. LINKING COMPATIBILITY, AFFORDABILITY, AND SUSTAINABILITY TO CLIMATE CHANGE MITIGATION

An Austin housing market survey identified two first-home buyer groups as the primary market for new middle density homes in urban East Austin (23) including, 1) younger tech-savvy environmentally conscious singles and couples looking for housing close to downtown and its urban amenities and, 2) younger black home buyers who would like to live in an older historically black East Austin neighborhood. While the market survey found location was most important to both homebuyer groups, equally important was value. These first-time homebuyers are willing to pay a little more for energy and water-efficient housing. How much more? Additional costs for green building features should not exceed the amount of savings generated from lower utility bills within a timeframe ranging form in 5-10 years. For each SOLEIL certified green building home energy conservation features add approximately $1,420 ($1.18/sqft) but lowers annual electrical use by more than 13% with a 2.8-LCC (Life Cycle Cost) year payback. The AE 5-star or ZERH certified features add an additional $3,744 ($3.12/sqft) but reduce the annual electrical load by 55% with a 4.2-LCC year payback. Passive house standards add $6,436 ($5.36/sqft) but reduce the thermal load by an estimated 77% with a 6.8-LCC year payback. The total green building and energy conservation upgrades add $11,600 to the sales price of a SOLEIL housing unit but pay for themselves in energy savings in less than ten years. The sales price of a SOLEIL housing unit is equal to, the raw land costs ($91,300) + construction costs ($199,216) + enhanced energy efficiency upgrade costs ($11,600) + soft costs including, marketing, sales, overhead, fees, etc. ($15,000), COA zoning and permit fees exempted for affordable housing + developer's fee and investor equity return ($50,000 per unit) equals a sales price of $367,116 per unit ($306/ft2). At a sales price of $367,116 every SOLEIL unit qualifies as COA affordable housing for homebuyer couples who make less than 80% of Austin's annual MFI. Although the SOLEIL units would be initially affordable, if only a few projects like SOLEIL are built, investors will quickly buy the units and then flip the units (reselling them) to other buyers at much higher prices. If the demand for middle density urban housing remains high and the inventory remains low, achieving affordable urban housing in Austin will remain a challenge. However, if large numbers of affordable middle density ZNE housing units were built in every Austin urban neighborhood, using ½ block middle density housing transition zoning, market supply could rapidly increase to meet market demand, and affordable home prices would likely stabilize. When affordable housing units are developed in partnership with a non-profit neighborhood community design corporation (CDC) using land trusts, lower income residents can receive assistance in reducing the financial impacts of rising property taxes and HOA assessments and facilitate large numbers of units to be built.

CONCLUSION

Because two-thirds of Austin's housing market is for moderate income buyers (below 135% of Austin annual MFI) and lower income buyers (below 80% of Austin annual MFI), and if Austin residents can reach a consensus on enacting housing transition zoning in Austin's urban neighborhoods to allow large numbers of ZNE middle density housing to be built to meet market demands, then significant climate change mitigation can be achieved to meet Austin's goal of becoming a net-zero greenhouse gas emissions community by 2040.

The Austin Energy fuel mix used to generate electrical power impacts the conversion rate of kWh used to measure the carbon fuel emissions emitted to generate electrical power. In 2021 AE's electrical power generation fuel mix (coal, hydro, gas, wind, solar, nuclear) was 68% from non-carbon fuels and by 2030 it is scheduled to be 93% non-carbon. In 2021 the AE fuel mix customer carbon rate was .739 pounds CO2e/kWh. By applying the AE fuel mix rate to an average Austin Home's annual electrical use (12,000 kWh/year X .739 metric tons of CO2e/kWh) divided by 2,204.6 lbs./metric ton equals 4.6 metric tons CO2e/year-unit. A SOLEIL row house (passive house standards) contributes only .92 metric tons CO2e/year and a SOLEIL ZNE row house with zero-net operational energy consumption use would eliminate 4.6 metric tons of CO2e/year. Embodied energy (EEH) use should be added to the household operational use along with household waste and household transportation emissions too define the total household carbon footprint. The embodied material carbon emissions (MCE) are the (upstream) carbon emissions contribution for mining, manufacturing, transportation, and construction of the building materials used to build a home. By applying the volume and weight of each material and its embodied energy content provided by a Carbon Calculator website, (24) the initial embodied energy of each SOLEIL housing unit was estimated at 17.9 metric tons CO2e, which is a 40% reduction below the average U.S. townhouse embodied energy contribution (E.I.A.) estimated at 29.9 metric tons of CO2e. SOLEIL Homes are built using an extensive amount of wood-based building materials, recycled and reclaimed materials and low embodied energy building materials and finishes. The estimated SOLEIL row house 17.9 metric tons CO2e embodied energy emissions equate to a rate of 31.8 lbs. of CO2e/ft2, which is well blow AE's recommended maximum embodied carbon emissions rate for buildings of 100 lbs. of CO2e/ft2. The EEH emissions spread over a 30-year LCC time frame and ongoing maintenance and material replacement embodied energy costs were estimated to add approximately 1.2 metric tons CO2e/year.

Waste management in Austin represents 3% (327,000 metric tons) of Austin's community carbon dioxide equivalent footprint annually. The City of Austin Resource Recovery Plan is committed to a zero-waste goal to reduce the amount of trash sent to landfills by 90% by the year 2040. The diversion rate at the end of fiscal year 2021 was 41.96%. This diversion through recycling and reductions in per capita and construction solid waste levels reduced Austin's waste management carbon footprint by 137,209 metric tons of CO2e/year.

Where Austin residents live and how they get around has an important impact on carbon emissions. In Austin, per capita vehicle miles traveled (VMT) per day has been steadily increasing for decades, mirroring suburban population growth. In 2010, Austin's average per capita transportation related CO2e emissions was 4.8 metric tons CO2e/year. Seventy-four percent of Austin 's transportation-related emissions came from singleoccupancy private cars and trucks mostly commuting to and from work. Suburban residents living in lower-density sprawling developments have a greater dependency on carbon-intensive automobiles to access their daily needs in contrast to their Austin's urban neighbors. The SOLEIL Homes project is in an older urban neighborhood just 150 feet from an urban transit stop and within walking distance to neighborhood retail, restaurants, and other urban amenities. The urban location and the SOLEIL Homes shared electric zip-car program are projected to reduce SOLEIL Homes per capita transportation emissions to 2.4 metric tons CO2e/year. If 100,000 new SOLEIL-like ZNE units were built within Austin's urban neighborhoods by 2030 (when at that time all new buildings must be ZNE), Austin could reduce transportation emissions down to 3.6 Mmt CO2e/year by 2030 and 2.4 Mmt CO2e/year by 2040.

Adding 100,000 new ZNE affordable housing units by 2030 would not only meet Austin's affordable housing demand, but it would also save 580,000 metric tons of carbon emissions per year over Austin's current average benchmark home. This would be in addition to the savings achieved by reducing all of Austin's existing 467,291 residential units and 50,451 commercial buildings energy use annually by 25%, an estimated savings of (1,250,000) + ZNE homes (580,000) equals 1,830,000 metric tons CO2e/year. And by adding waste management (137,209) + transportation (2,400,000) equals a total reduction in carbon dioxide equivalent emissions of 4,037,209 metric tons of CO2e/year. To achieve Austin's goal of reducing its 2021 community carbon footprint of 10.8 million metric tons of CO2e/year by 50% by 2030, Austin will need to reduce its industrial, refrigerants and natural gas carbon footprint by 25% (650,000 metric tons CO2e/year). Austin must then add carbon sequestration programs that will sequester carbon emissions of 712,791 metric tons CO2e/year. Austin's goal of being a net-zero carbon emissions community by 2040 is optimistic but by linking affordability, sustainability, and neighborhood compatibility together in new housing policies on how and where housing is built demonstrates how neighborhood compatible, affordable ZNE middle density housing is the most scalable pathway to reduce Austin's carbon footprint by 50% by 2030.

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