Emerging Zero Net Energy Building Case Study

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OVERVIEW

Predicted Energy Use Intensity (EUI): 23.2 kBtu/sf/yr

Renewable Energy Production: 25.5 kBtu/sf/yr

Predicted Net EUI: -2.3 kBtu/sf

Predicted HERS Index: Unit A: -8, Unit B: 0

Home Sizes: 750-790 sf

Location: City of Providence, RI

Construction Type: Five single family new construction homes

Construction Years: 2019-2021

Occupation Date: December 2020 – Spring 2021

Total Development Cost: $1.5 million

SHERIDAN SMALL HOMES

The story of Sheridan Small Homes begins with a spark of inspiration stemming from Rhode Island School of Design (RISD) architecture students. In 2018, RISD students participated in the Race to Zero Student Design Competition, a collegiate design challenge sponsored by the U.S. Department of Energy. The students were selected as finalists for their affordable, energy efficient home prototypes.

Learning of their success, the City of Providence, RI saw an opportunity for the RISD students to help them achieve multiple city goals: provide more affordable housing, address climate change, and increase local workforce understanding of achievable, high performance construction techniques.

In Providence, RI, 70% of carbon emissions are from buildings. Cutting building energy use and removing fossil gas are key parts of the strategy to become carbon neutral by 2050, as detailed in the City's Climate Justice Plan.

The City approached the RISD team and Professor Jonathan Knowles about a partnership with One Neighborhood Builders, a community based affordable housing developer. The team found a three-quarter acre site zoned for multiple units, conveniently located on a bike path to downtown, near ballfields, and an adjacent neighborhood. The lot offered an opportunity for construction of new housing on lots typically not large enough for new homes. Working together, the team designed and developed five zero net energy, all-electric, solar-powered homes. As a zero net energy project, the homes are expected to produce as much energy as they consume over the course of the year.

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PROJECT DETAILS:

Climate Zone: 5a

Owner, Developer, and General Contractor: ONE Neighborhood Builders

Architect and PHIUS Consultant: BriggsKnowles A+D

Energy Consultant: CLEAResult

Mechanical and Plumbing: Pinnacle

Electrical: M&M Electric

Solar Consultant: SunWatt Solar

Building Trades Apprentices: Building Futures Rhode Island

Structural: Structures Workshop

Certifications: Pending PHIUS Passive House certification and U.S. Department of Energy Zero Energy Homes certification.

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Rendering of Unit A. South facing roof provides space for solar photovoltaics while the deep overhangs shade the windows in the summer months.

Each home in the Sheridan Small Homes community will be sold to income-qualified buyers with a starting price point of about $140,000. Two of the homes will be reserved for families earning no more than 80% of the area median income (AMI), which equates to $52,400 for a household of two and $65,500 for a family of four. The other three homes are reserved for families earning less than 120% AMI, or $78,650 for a couple and $98,300 for a family of four.

Planning and Design Approach

Project Goals

Sheridan Small Homes project goals include demonstrating the potential of pairing zero net energy design with affordable housing, and providing five income-eligible households with comfortable, functional, and affordable new homes. To achieve these goals, each of the partners incorporated unique and ambitious objectives that resulted in wide-reaching community and environmental benefits.

The City of Providence: Increase affordable housing availability, reduce carbon emissions from energy use in buildings, and promote clean energy sources.

RISD: Provide students with a hands-on opportunity to apply their design, innovation, and energy-responsible concepts to create zero net energy homes.

ONE Neighborhood Builders: Demonstrate the long-term viability of zero net energy affordable housing while training the next generation of construction professionals in zero net energy home construction.

Design Approach

ONE Neighborhood Builders instilled a broad vision of sustainability for the Sheridan Small Homes. In this project, the term ‘sustainability’ melded concepts of efficiency, reuse, durability, and affordability.

RISD enthusiastically applied their building science knowledge in this real-world application. Professor-Architect Jonathan Knowles guided the design development which was refined by students who rotated through their courses. About 40 students contributed overall, some participated for a portion of the project while others remained from start to finish.

Unit A first and second floor plans with efficient, compact design.

Passive House Institute U.S. Inc. (PHIUS) is a stringent building design and construction standard that requires very air-tight and well-insulated building envelopes as well as properly sized and balanced HVAC systems. Buildings that meet the PHIUS+ standard use 40-60% less energy for space conditioning than conventional buildings and include a thorough Passive House design verification protocol with a stringent quality assurance and quality control program performed on-site by specialized PHIUS+ Raters.

Early in design, the RISD team utilized the Passive House Institute U.S. (PHIUS) modeling software tool. Energy modeling helped to maximize the homes' energy performance and confirm that the designs met the program requirements to achieve PHIUS+ 2018 certification. The PHIUS+2018 standard reduces the energy needed to condition the building and can be used to achieve zero net energy goals.

The student design team created two prototypes, "Unit A" and "Unit B." The designs are similar in size, each has two bedrooms and one and a half bathrooms. Unit A has two balconies, one on each floor while Unit B has one large balcony upstairs.

Community Engagement

Considering how the homes would integrate with the adjacent neighborhood, the team hosted a community meeting to garner input from neighbors. The effort built community support and resulted in interest from potential buyers.

The feedback provided real-world insights from potential homeowners on how they expected to use the space. Community input solidified the "great room" design concept—a floor plan that includes high ceilings and a connected living room and kitchen. Although the design team had considered smaller, efficiency-sized kitchen appliances, potential buyers conveyed the importance of having standard-sized appliances for cooking and entertaining.

Neighbors were interested in porches and balconies that connect indoor and outdoor spaces and make the homes feel larger. They also provided key perspectives on fixtures and siding.

The Long-Term Benefit of Construction Workforce Training

A unique aspect of this project was its commitment to engage Building Futures Rhode Island, a construction apprentice program for low-income community members. The project trained 40 people on Passive House techniques. Leveraging Building Futures Rhode Island reduced construction costs and provided long term industry benefits by training workers on advanced building practices.

Energy Efficiency Strategies and Features

Passive House Standards, Envelope, and Air Tightness

Since heating and cooling are the largest energy loads in a home, the design team focused on maximizing the building envelope to allow for a downsized, all-electric heating and cooling system. While the concept is simple, careful attention must be paid to the details to ensure proper execution.

Credit ©BriggsKnowles A+D

Unit A rendering in a dense environment.

Envelope. The team initially imagined utilizing a prefabricated panel wall and roof assembly to ensure quality construction. However, working with Building Futures Rhode Island, it became more important to engage the trainees in on-site Passive House construction.

Passive House requires a super-insulated exterior with a contiguous air barrier that connects from roof to foundation. The Sheridan Small Homes R-45 2x6 wall assemblies are heavily insulated, including 4" of continuous exterior polyisocyanurate (polyiso) insulation. Some polyiso insulation was donated from a deconstruction project, reducing costs and diverting materials from the landfill.

Foundation. The homes were designed without basements, reducing the costs associated with excavating, concrete, and basement insulation. Instead, the team used shallow frost footings, which provide cold weather durability without excavation below the frost line. The system is comprised of horizontal expanded polystyrene (EPS) insulation around the outside of the exterior wall footing, and vertically at the footing perimeter. In addition, there is continuous R-40 under-slab insulation, which reduces winter heat transfer from ground contact.

Thermal Mass. Combining slab-on-grade and south-facing windows offers thermal comfort to the homeowners. In winter, the concrete floor serves as thermal mass, storing heat gained from the large south-facing windows during the day and radiating heat back to the living space throughout the evening. This approach improves occupant comfort and reduces heating needs in the winter. In the summer, window overhangs shade the windows and reduce heat gain.

Windows. Windows are a critical part of the design. The homes were thoughtfully oriented in a south-facing arc to maximize solar production and take advantage of solar heat gain in the winter. The team prioritized using highly efficient and affordable windows while providing plenty of natural light to minimize electric lighting needs and provide a healthy living space. The team chose a triple-paned window with a 0.143 U-value and tilt-turn capability, so occupants have flexible options for opening their windows. The European imported windows were comparable in cost to higher-end windows from a traditional U.S. hardware store.

Air Tightness. A key component of Passive House buildings is a tight building envelope, achieved through a continuous air barrier. The tight air barrier minimizes envelope air and water leakage. The extremely air-tight envelope allowed downsized HVAC equipment, reducing the upfront cost.

Building Future Rhode Island apprentices were trained in the careful detailing of the air barrier in wrapping the entire envelope, paying particular attention to the under slab, windows, and roof details to ensure a tight seal.

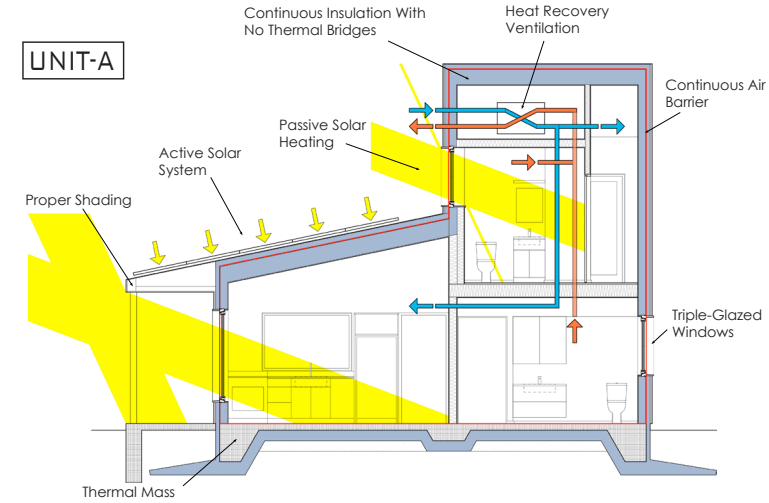
The tightness of the envelope is measured through air changes per hour (ACH). A new home built to Rhode Island's 2015 building code requires three to five ACH, while a Passive House envelope is often less than 1 ACH. The preliminary blower door test for Sheridan Small Homes measured air leakage at 1.3 ACH, meaning that every hour, about one and one-third the volume of air in the home naturally exchanges through leaks in the building envelope. Mechanical ventilation is continuously circulated through the ERV to ensure adequate fresh air exchange without wasting energy.

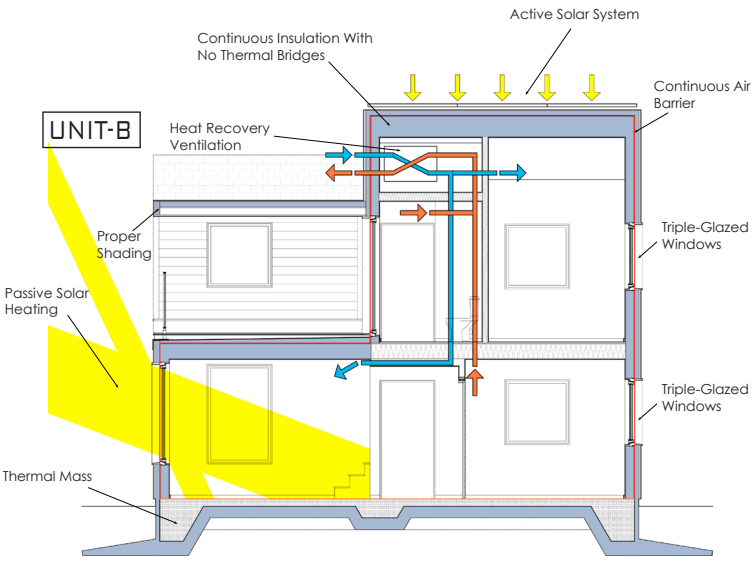
Heating, Ventilation, and Air Conditioning (HVAC)

The well-designed envelope allowed the team to reduced costs by utilizing a smaller heat pump heating and cooling system. Separating the heating and cooling from the ventilation also allows each system to focus on their designed task and work independently to save energy. Being all-electric, the cost associated with excavating for and laying gas lines to the homes was eliminated.

Heating and Cooling. A similar home built to code may have needed a 12,000 Btu heating unit. The air-tight construction allowed for a single, 9,000 Btu mini-split, ductless heating and cooling system to adequately serve the home and reduce first costs. A single mini-split duct is located in the two-story great room. An exchange transfer duct allows for conditioned air transfer between the first and second floors to ensure thermal comfort.

Ventilation. A small, 80 cubic feet per minute energy recovery ventilation (ERV) is the sole ventilation system. The ERV captures the energy contained in the exhaust of conditioned air—that would otherwise normally be expelled and wasted—and uses it to pretreat/precondition incoming outdoor air. It maximizes fresh air intake and minimizes the heating and cooling load that would be needed to treat the air without an ERV.





The homes have been designed to optimize solar gain in the winter and block the gain in the summer. A tight air barrier, continuous insulation, and minimal thermal bridging create a superior thermal envelope. The passive measures allow for minimally sized active heating and cooling along with balanced ventilation.

Credit ©BriggsKnowles A+D

Unit B rendering highlighting the connection between the indoor and outdoor living space in a densely organized home arrangement.

Lighting and Appliances

All-LED lighting is predicted to use 30-50% less energy than the Rhode Island building code. The refrigerator, dishwasher, washing machine and dryer are all ENERGY STAR© rated appliances.

Domestic Hot Water

The design team considered various efficient water heating options including tankless on-demand heaters and highly efficient heat pump water heaters. The on-demand system used excessive energy and the heat pump water heater cost did not fit the budget. They ultimately selected a space-saving, 94% efficient 38-gallon standard electric resistance water heater. In Unit A, the water heater is located under the stair. In Unit B, the hot water heater is located in an attic mechanical room.

Solar Energy

The five homes are arranged in a south-facing crescent shape to maximize solar production. The five rooftops are equipped with 78 320-watts photovoltaic (PV) rooftop solar panels: Unit A rooftops have 18 panels, and Unit B rooftops have 12 panels. The PV panels are expected to produce at least as much energy as the homes consume over the course of the year. This includes all energy loads in the house: water heating, plug loads, and heating and cooling—which can account for up to 50% of a home's energy bill in the Northeast. Thanks to Rhode Island Renewable Energy Growth Program (REG Program) administered by National Grid, excess energy produced will be sold back to the grid to the financial advantage of the homeowners.

Development Costs and Financing

To maximize affordability and energy efficiency, the project sought opportunities for reducing first costs. Some ways in which the project costs were reduced include:

- Eliminating trenching, pipelines, and permitting for natural gas lines and connections.
- Excluding basements avoided the cost of excavation, concrete, basement insulation, and labor.
- Utilizing Building Futures Rhode Island (which charged a much lower, flat fee) for construction services instead of a traditional general contractor.
- Engaging RISD for design services instead of a conventional design firm.
- Focusing on insulation and airtightness allowed for downsizing the HVAC systems.
- Leveraging / repurposing donated materials, including some insulation and kitchen cabinetry.

Construction hard costs such as materials, labor, mechanical, electrical, plumbing, and all site work totaled $1,213,018 or $242,604 per house. These costs exclude utility connections, septic costs, land cost, permitting, design costs and energy modeling. The total development cost was about $1.52 million, or about $304,000 per home.

Credit ©BriggsKnowles A+D

Two Unit As under construction. The house on the left shows the continuous exterior insulation and rain screen system prior to siding installation.

The project was funded through a variety of sources, including:

- Rhode Island Housing construction loan.
- Grants from the Rhode Island Housing Homeownership Investment Fund.
- Zero Energy for the Ocean State (ZEOS), a program in partnership with Rhode Island Housing and the Rhode Island Office of Energy Resources and National Grid.
- Home Investment Partnership Program (HOME), a federal program funded through the Department of Housing and Urban Development and distributed by the City of Providence, Rhode Island.
- A private donor.

Looking Ahead: Long-term Energy Monitoring and Maintenance

To assure these all-electric, solar powered homes function as planned, ONE Neighborhood Builders will serve as a property manager. Like a condo association fee, ONE Neighborhood Builders will collect a monthly fee from homeowners to cover the cost of maintenance—landscaping/grounds, garbage service, solar PV maintenance, garbage collection, the monthly utility delivery service fee, and other ongoing maintenance.

As a requirement of having received funding through ZEOS, ONE Neighborhood Builders will monitor the complex's energy use over time. Each home is equipped with energy monitoring system that collects ongoing energy use data delineated heating and cooling, ventilation, laundry, hot water, and plug loads. When problems are observed, ONE Neighborhood Builder or the homeowner can remedy the issue in a timely manner. Data collected from these homes can inform priorities for future affordable housing developments.

Challenging the conventional mindset that affordability and sustainability is not financially feasible, Sheridan Small Homes demonstrates that compact, zero-emissions housing can help provide affordable, comfortable, and beautiful homes to low-income families.

Homeowners will be able to monitor their energy use through an online app. New homeowners will receive information about operating their new all-electric home, including information about the solar energy produced, HVAC operations, and use of the ERV.

Lessons Learned

Challenging the conventional mindset that affordability and sustainability is not financially feasible, Sheridan Small Homes demonstrates that compact, zero-emissions housing can help provide affordable, comfortable, and beautiful homes to low-income families. The Passive House construction is air-tight and super insulated, which prevents moisture from entering the home, avoiding mold and associated health problems over the long term. The project has amounted to a quadruple-win:

1. RISD students gained real-life experience applying design, innovation, and energy-responsible design concepts such as efficiency, solar, and on-site energy optimization, and other passive design strategies to design zero net energy homes.
2. Upcoming construction workforce trainees gained valuable hands-on experience in zero net energy construction.
3. The City of Providence gained progress toward achieving climate change goals, and additional affordable housing units.
4. Low-income families have beautiful new homes with low monthly utility bills, located with convenient access to mass transit or biking for commuting.

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National Grid is an electricity, natural gas, and clean energy delivery company serving more than 20 million people through our networks in New York, Massachusetts, and Rhode Island. We offer technical assistance, financial incentives, and other support to accelerate market uptake of zero net energy and zero net energy ready buildings. In Rhode Island, our Residential New Construction Program offers support to all new homes or major renovations to help achieve the greatest energy efficiency possible.

Learn more at nationalgridus.com/RI-Business/Energy-Saving-Programs/New-Construction-Major-Renovations

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