Emerging Zero Net Energy Building Case Study

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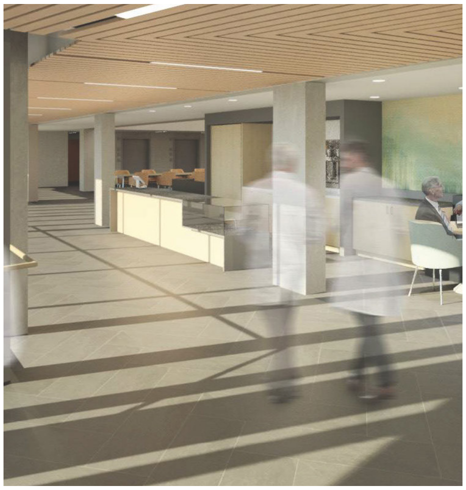

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OVERVIEW

Location: Chelsea, MA

Building Size: 243,000 sf

Construction Type: New Construction

Construction Year: 2020

Occupation Date: Summer/Fall 2022

Climate Zone: 5a

Total Project Cost: $199M

MODELED ENERGY STATUS:

Predicted EUI: 67 kBtu/sf/yr

Predicted On-site Renewable Energy Production: 10 kBtu/sf/yr

Predicted Off-site Renewable Energy Production: 57 kBtu/sf/yr

Net EUI: 0 kBtu/sf/yr

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CHELSEA SOLDIERS' HOME, COMMUNITY LIVING CENTER CASE STUDY

Established in 1882, the Soldiers' Home in Chelsea offers residential and long term care programs to eligible Massachusetts Veterans. In 2016, Payette Associates and BR+A Consulting Engineers began a design process to create a more dignified and modern residential care environment for veterans. Funding from the U.S. Department of Veterans Affairs (VA) required the building to reduce source energy and fossil fuel consumption by 65%, compared to the average existing assisted living facility and the Massachusetts State Division of Capital Asset Management and Maintenance (DCAMM) requested a carbon neutral building. Early in the design, the team agreed on a goal for a zero net energy (ZNE) building.

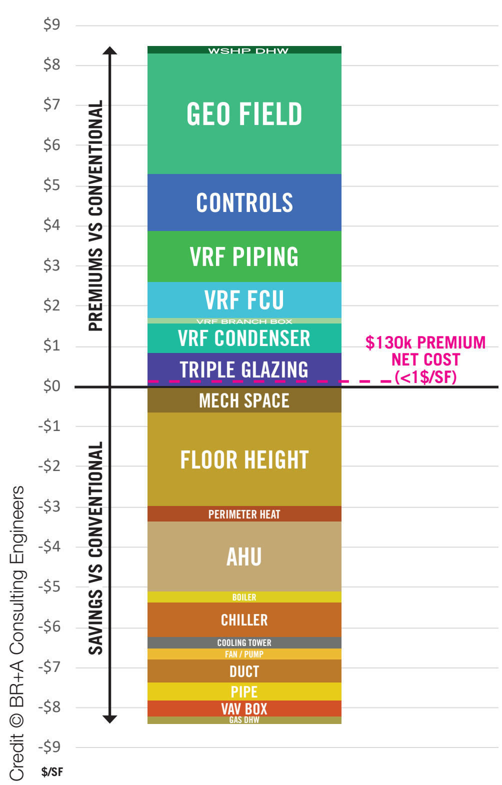
In 2022 the new Soldiers' Home will be poised at the top of Powder Horn Hill. For decades, this site housed a 150-foot tall red and white checkered water tower that provided clean water to the existing Soldiers' Home. A symbol of health, the water tower is being replaced with a new icon of the future – clean energy. The six-story, 243,000 square-foot modernized residential care facility will include an illuminated rooftop solar array, as a new emblem for 21st century Chelsea. Off-site renewable energy will be purchased to offset the total building energy consumption with renewable energy.

The new facility will include 11 resident "homes," each consisting of 14 private bedrooms clustered around shared common areas including a communal kitchen, dining areas, and living space. Each of the 154 private room consists of a bath, closet, and desk area. The building also includes administrative offices, physical and occupational therapy, community space, and a commercial kitchen that serves all facility food preparation needs.

BUILDING FUNCTIONS:

- 154 Long-Term Care and Dementia Care Beds
- Administration
- Physical and Occupational Therapy
- Community and Activity Spaces
- Chapel
- Central Kitchen

ZNE CONSTRUCTION COST



Lessons Learned

- Hiring a team with experience in ZNE has advantages for an owner. Experienced teams can reduce upfront costs by transferring lessons learned from previous projects. ZNE training can quickly guide teams to cost-effective solutions while reducing design time. Past involvement is helpful, but any assumptions still need to be carefully studied to confirm and optimize the application to the unique conditions of any project.
- Integrated systems thinking is critical toward reducing upfront costs. For example, incorporating triple glazed windows eliminated the need for perimeter heating, reducing the number of mechanical systems.
- Predicted energy consumption of 64% less compared to the ASHRAE 90.1-2013 baseline, and effectively eliminate fossil fuel consumption with only a $1 per square foot upfront cost premium.
- Building occupants feel more ownership when they engage in the design process. In the Chelsea Soldiers' Home project, full-scale room mockups provided an opportunity for the design team to receive valuable feedback from future residents, staff, and visitors.
- A landmark iconic building does not need to sacrifice energy efficiency and can act as a symbol for a future of high performance buildings served by clean energy sources.

Planning and Design Approach

Project Goals

Designing the new building, the team followed the VA's Small Home Model Design Guide. The design standards provide an outline to design spaces for veterans to receive the highest possible quality of life. The Guide presents room layout templates, building system criteria, material finishes, and operational needs, among other guidelines to offer residents the best quality of care.

At the end of schematic design, DCAMM requested a more "iconic" building since it was replacing the historic and landmark water tower on Powder Horn Hill. The redesign did not require initial goals to be adjusted, but it allowed the design to highlight the goals in greater prominence, like lighting the PV array.

As the design progressed, studies were conducted to validate the team's initial ideas. Daylighting models identified window placement and proper shading. Energy modeling defined the building energy systems and the high performance envelope.

Costs and Benefits

Integrated systems thinking reduced the upfront cost of the building, allowing for the inclusion of highly efficient systems. A conventional facility may have been designed as an all-air variable air volume (VAV) with reheat heating ventilation and air conditioning (HVAC) system with large air handling units (AHUs.) Optimizing the design and incorporating a dedicated outdoor air system (DOAS) reduced the size of the AHUs, eliminated a conventional water-cooled chiller plant, and resulted in significant space savings. These upfront savings offset the cost of the ground source bore field, triple glazing, and the addition of a second energy recovery wheel for each AHUs.

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PROJECT TEAM:

Owner: Massachusetts Division of Capital Asset Management and Maintenance (DCAMM)

Architect: Payette Associates, Inc.

Contractor: Consigli Construction Co., Inc.

Energy Consultant: BR+A Consulting Engineers

Structural Engineer: LIM Consultants, Inc.

Landscape Architect: Studio 2112

Mechanical and Plumbing Consultant: BR+A Consulting Engineers

Electrical Consultant: ART Engineering

AWARDS:

USGBC Green Building Showcase Market Leader – Health & Wellness

CERTIFICATIONS:

Targeting LEED Gold and Zero Net Energy Certifications

The nearly all-electric design (emergency back up and select commercial equipment use natural gas) reduced modeled site energy use by 64% compared to the ASHRAE 90.1-2013 baseline, with only a $1 per square foot construction cost premium compared with a typical building. The incremental cost, before renewables, has a simple payback in less than one year.

Stakeholder Engagement

Starting early in design, all stakeholders worked together to understand the needs and express the design requirements. The design team, Soldiers' Home administrators, staff and residents, Massachusetts Department of Veterans Services, Department of Health and Human Services, and Asset Management Board participated in design workshops and toured similar facilities. The early collaboration was essential to create shared experiences and a common language.

With the resident rooms at the center of the design, they mocked up a room onsite to better understand the space and collect feedback from the core stakeholders, future residents, and residents' families. Future users provided their reactions, which helped to refine the design for a better experience for all.

Energy Modeling

The design team's familiarity with similar projects gave them confidence that ZNE was achievable, and they identified the main energy conservation measures necessary to meet the objective. First, experience told them that triple glazed windows would eliminate the need for perimeter heating. Second, they knew that a ground source system paired with heat pumps could provide the most efficient heating and cooling. Energy modeling after the stakeholder's workshops validated the energy reduction assumptions and refined the envelope and HVAC options.

Three HVAC options were evaluated using a combination of energy modeling and life cycle cost analysis (LCCA.) The LCCA assessed the cost of construction, energy, maintenance, and replacement over 40 years. The first HVAC system the team studied was a central ground source heat pump (GSHP) chillers with DOAS and fan coil units to condition each zone. Second, a GSHP DOAS with individual zoned GSHPs. And the third, a water source heat pump (WSHP) DOAS with ground source variable refrigerant flow (GS-VRF) for each zone.

The modeling and LCCA confirmed that the first option was the most expensive due to the higher cost of the central heat pump chiller plant, 4-pipe hydronic distribution to every zone, and greater space requirements. The second option offered the lowest cost but required too many individually zone GSHPs. The third option was the winner, as it resulted in the lowest overall net present cost.

Modeling was used to fine-tune energy demands, including the control logic, to reject heat to the bore field during the summer to prepare the ground for the heat extraction that occurs in the winter.

Energy Efficiency Strategies and Features

Envelope

High performance building envelope studies evaluated the window to wall ratio, window shading, and room views. The walls were optimized to include a 38% window to wall ratio, meaning 38% of the wall consists of triple-glazed aluminum, thermally broken windows (0.24 U values and 0.35 shading coefficient), and 62% of the wall is composed of R-26 opaque exterior walls with limestone brick. A window shading analysis confirmed that a 12" protrusion around the windows would shade 20% of the glazing; lowering internal solar heat gain reduces internal cooling demands, saving energy in the summer. The daylight and views study helped to balance room privacy with city and harbor views.

Lighting and Daylighting

The team evaluated three building configurations and orientations to optimize the use of non-electric light, views, and VA's Small Home Model Design Guide requirements. The Guide recommends visual considerations, including providing daylight access, glare control, and finish material color/value contrast, among other guidelines. Daylight combined with an all light-emitting diode (LED) design, and daylight responsive controls will allow the lighting to adjust to maintain the target brightness level, reducing energy. The combined efforts resulted in an average 0.82 watts/sf lighting power density.

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HVAC

From previous project experience, the design team understood that decoupling heating and cooling systems from the ventilation system would deliver massive energy reductions. The decoupling strategy holds complimentary benefits. The smaller size of the ventilation distribution ducts lowered the height of the building, staying under the code high-rise definition, and reduced the square footage of the mechanical equipment, providing more usable space for the veterans and staff.

Ventilation

Ventilation is often the biggest driver of energy in residential care facilities, so the design optimized the amount of ventilation and the energy necessary to heat and cool each space with a layered approach.

First, natural ventilation is offered in the resident rooms and communal living rooms. The resident rooms have manually operable windows, with a green/yellow/red-light system at the staff workstations, to indicate when the outdoor conditions are appropriate. In contrast, the living room windows are motorized and controlled by the building automation system (BAS). The BAS operates the windows based on the optimal outdoor temperature, humidity, wind speed, and lack of precipitation. When the BAS identified open windows in any space, the ventilation supply is turned off, and the exhaust air remains available for the operation to maintain designed air change rate requirements and/or CO2 levels.

Second, the BAS turns off active ventilation in unoccupied spaces, like administrative offices after hours. Third, active ventilation only provides tempered ventilation air and does not heat or cool the building. The energy recovery wheels within the AHUs capture energy from the exhaust air to preheat or cool the incoming outside air. The Soldiers' Home is unique in that a second wheel,

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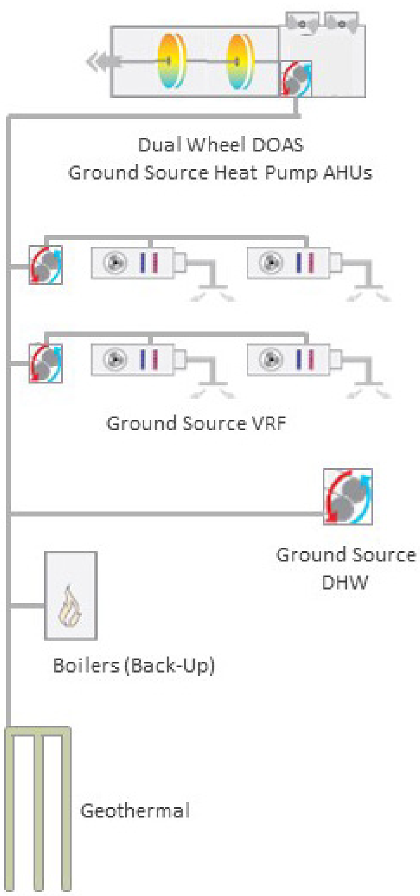
in series with the first wheel in each WSHP AHU, runs in the summer to further dehumidify and reheat the air after the cooling coil. In the winter, the second wheel provides additional exhaust air heat recovery.

When the energy recover wheels cannot supply all of the necessary heating or cooling, compressors in the WSHP AHUs transfer energy to or from the ground source loop. The transferred energy is sent to the AHU refrigerant coil to adjust the outdoor air temperature and humidity before it is supplied to the zones within the building.



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HVAC and DHW systems connected to the ground source system.

Heating and Cooling

The design team followed a common ZNE project strategy – use the earth's constant temperature to transfer heat. The most efficient form of heating and cooling uses the earth's energy to preheat and cool a medium to transfer energy before heat pumps raise and lower the temperature to the design target. The energy model and LCCA proved that the combination of a WSHP DOAS with GS-VRF systems would condition the zones most efficiently.

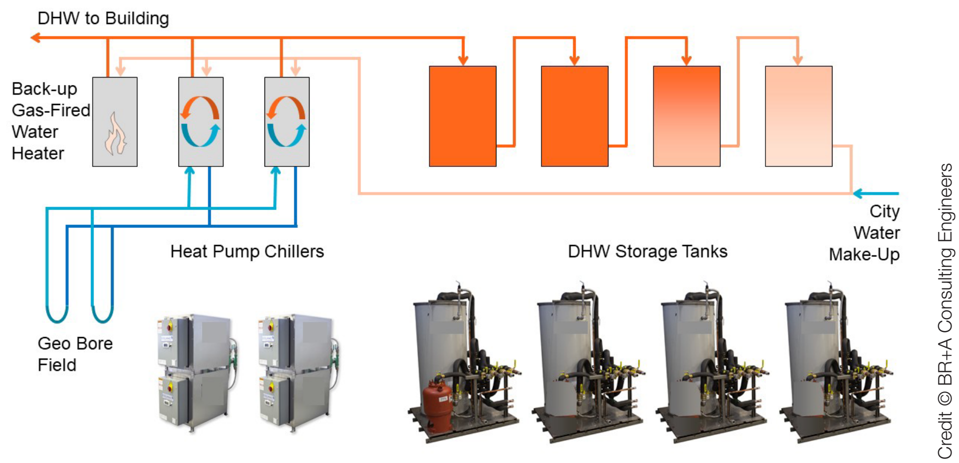
Each floor has two small mechanical closets with a GS-VRF condensing unit. The unit transfer energy to or from the ground source loop and sends heated or cooled refrigerant to the VRF terminals to condition each zone. Maintenance staff can readily access the compressors for servicing, without going outside or disrupting the residents.

Both the WSHP AHUs and GS-VRF systems connect to the central ground source loop, which transfers heat via water running through 145 boreholes drilled 500' into the earth. In the winter, the ground becomes a heat source, and in the summer it is a heat sink, taking advantage of the thermal mass of the bedrock and groundwater.

Because two sources of heating are required for health care buildings, gas condensing boilers are available for back up heating if the ground source wells are not available. The intent is that the boilers do not operate on a day to day basis.

Domestic Hot Water

The ground source system also serves the domestic hot water system. Two scroll compressor heat pump chillers make 140 degrees F domestic hot water, and that is stored in super-insulated tanks to have enough hot water to meet peak hot water demands. As a cost-saving strategy, the building only has two heat pump chillers, but they cannot service the peak alone. The chillers run more frequently to charge up a series of four hot water storage tanks. Together, they provide enough hot water to meet the peak demand. Back-up gas boilers exist for domestic hot water use, but they are otherwise absent in day to day operations.



Domestic hot water system connected to the ground source system.

Renewable Energy Generation

The six-story, 243,000 square-foot modernized resident care facility will include an illuminated 0.5-megawatt rooftop solar array above the roof, expected to be seen across town. The outstretched PV array extends past the building footprint and will also be a prominent feature when approaching the building. The bi-facial solar panels will increase the energy output, and certified off-site renewable energy will offset the grid consumed energy.

The panels also serve as an energy conservation measure by shading the windows, which reduces solar heat gain and minimizes cooling in the summer.

Occupant Engagement

Staff and resident behaviors will have an enormous impact on building energy consumption. Moving from the 1946 facility into a contemporary, state-of-the-art 21st-century building will require occupants to understand the system capabilities. Just as the resident engagement was influential during the planning stages, the residents will have the option to learn about the mindful energy actions they can make to save energy. Residents can control the temperature of their rooms through operable windows, zoned thermostats, and window shades. Staff stations will include a notification light as to when the outdoor conditions are appropriate to open the residents' windows, as desired.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A live stream of how much energy the solar array generates will be publicly available to building residents, staff, and visitors. The resident engagement and education on the energy efficiency opportunities will be developed as the occupancy date approaches.

Future Plans

The 2020 COVID-19 pandemic impacted the region during construction, suggesting a few changes to the design to improve resident health and enhance disease prevention strategies. Additional handwashing sinks will be located throughout the building, and the need for isolation rooms will be evaluated.

When the new facility opens in 2022, the existing building will be demolished, and the site will be combined with the adjacent Malone Park. The combined seven-acre site will be redeveloped into an accessible landscape for the veteran residents and the public.

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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 Commercial & Industrial New Construction Program offers support to all new commercial buildings or major renovations regardless of project size, complexity or function, 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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