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Roxbury E+ Townhomes: Boston

New Kid on the Block

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The Roxbury Energy Positive (E+) project, an urban townhouse prototype for high performance developer housing, was the first completed under the mayor of

Boston's E+ Housing Initiative. These townhouses have consistently generated more energy than they consume since their completion in 2013.

SAM OBERTER PHOTOGRAPHY

Conceived as a replicable prototype for family-friendly, energy-efficient urban townhomes, this four-unit project in Boston's Roxbury neighborhood is proving the possibilities for market-rate, high performance housing. Traditionally, highly sustainable housing has been designed on a custom basis, available to customers willing to pay the associated cost premium. This net positive energy project proves that sustainable housing can also be affordable for homeowners, make business sense for developers and help reinvigorate urban neighborhoods.

The City of Boston E+ (Energy Positive) Green Building program, a design competition and development initiative launched in 2011, aims to promote the next generation of green buildings. The pilot program focused on underutilized city-owned parcels in emerging neighborhoods, asking developers and architects to develop prototypical designs for energy positive housing.

While environmental sustainability was a key project driver, economic and social sustainability were also major goals of the initiative; construction budgets were intended to be market-typical, despite the high performance building features. The first project completed under the E+ program was Roxbury E+, a three-story wood-frame urban townhouse development.

Design Approach

The design team was selected for its expertise in designing modestly scaled, high performance urban homes for first-time home buyers. Balancing the requirements of high performance construction with local labor markets, urban context and neighborhood process, and developer-driven cost considerations creates a unique expression in each city and neighborhood in terms of scale, program, materials and energy strategy. But in each case, the high performance, low-cost equation relies on a few key moves: a simple massing; a tight, thick envelope with easily constructible detailing; and a minimal approach to systems and technological solutions.

Context and Process

The project was subject to a design review process by the Boston Redevelopment Authority (BRA) as well as typical zoning process and neighborhood meetings. After the initial competition design was secured, the team spent many months meeting with city officials and neighbors to refine the project's design.

The architectural character was influenced by the local vernacular of the immediate neighborhood, including clapboard siding in an array of colors, pitched roofs and large bay windows. An inverted bay connected the project to its context, and was critical to performance-based innovation.

Traditional bays face out and add surface area and exterior corners, which increase surface area and air sealing locations. By reversing the bay and having it bump in, it provided passive shading while locating the large windows under cover from the elements and eliminated the additional exposure of roof, floor, and exterior side conditions.

Massing

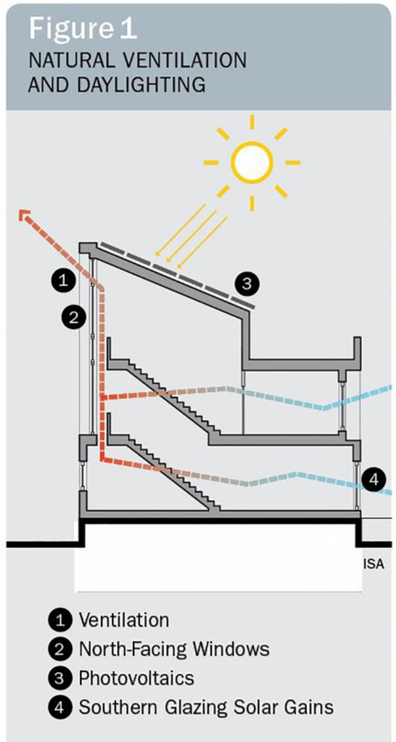
The massing for the Roxbury E+ project began with an elemental box—straightforward and affordable to construct, and predictable in its ability to be tightly air-sealed and insulated. The simple massing controls surface area-to-volume ratios, and reduces corners and joints where infiltration is most likely to occur. In response to its site context, the box was shaped through three operations:

1) The buildings step down the block in response to the local topography, expressing the character of the site and allowing for ideal solar orientation. Daylighting and solar access for photovoltaic panels at the south-facing sloped roof drove the project's north-south site orientation.

2) The roofs are southwardly sloped to maximize solar geometry for photovoltaic panels. The angle of the roof was evaluated at a number of different inclines, and the resulting geometry represents a compromise between ideal solar orientation, usable space on the third floor, and architectural and zoning considerations vetted through a public neighborhood process.

PHOTO COURTESY URBANICA

Drawing inspiration from the surrounding neighborhood, the north building façade incorporates a double-height reverse bay window, which provides diffuse daylighting and prevents excessive heat gain.



The building section is tuned to maximize solar geometry for photovoltaic panels and north-facing daylighting, while allowing for passive cross ventilation.

3) A north-facing reverse bay window at each unit allows for generous natural light and cross ventilation (Figure 1), while echoing the playful surface geometries of surrounding residential fabric. The large openings on the north façade offer diffuse daylighting for interior spaces year-round, while recessed southern-facing windows are tuned to provide daylight and solar gain in the winter and shade in the summer. East and west glazing on corner units is minimized and shaded to prevent excessive heat gain in early morning and late afternoon.

Envelope

Through past experience with developer-driven high performance housing in the Philadelphia and Chicago markets, the design team gained an understanding of envelope design as related to energy code requirements and local labor market dynamics. Chicago's code requires continuous exterior insulation, pointing toward a wood-frame wall assembly with exterior rigid insulation, while Philadelphia's labor market conditions make double-stud, wood-frame walls a less expensive and more easily executable choice.

Lessons from these experiments helped shape Roxbury E+'s envelope design, which was adjusted to reflect Boston's humid continental climate. Warm summers are followed by cold winters, with snowfall totals that can exceed 100 in. Annual rainfall averages between 40 to 60 in.

These climate features necessitated a calibrated relationship between active heating and cooling systems, and passive envelope and siting strategies. A thick, tight envelope allowed heating and cooling systems to be adequately scaled rather than oversized, as is typical in residential design-build HVAC.

The E+ homes incorporate thermally robust double-stud walls with R-41 blown-in cellulose insulation and a certified air infiltration rate of 0.57 at 50 air changes per hour (ach) at 50 Pa, a level comparable to Passive House requirements. Roofs and floors are also well-sealed and highly insulated, at R-69 and R-52, respectively.

Triple-glazed windows with U-values of 0.105 complete the robust exterior envelope. High-efficiency heat recovery ventilators (HRVs) are used to moderate air exchanges within a well-sealed envelope, exhausting stale air and supplying filtered, fresh air with minimal energy loss.

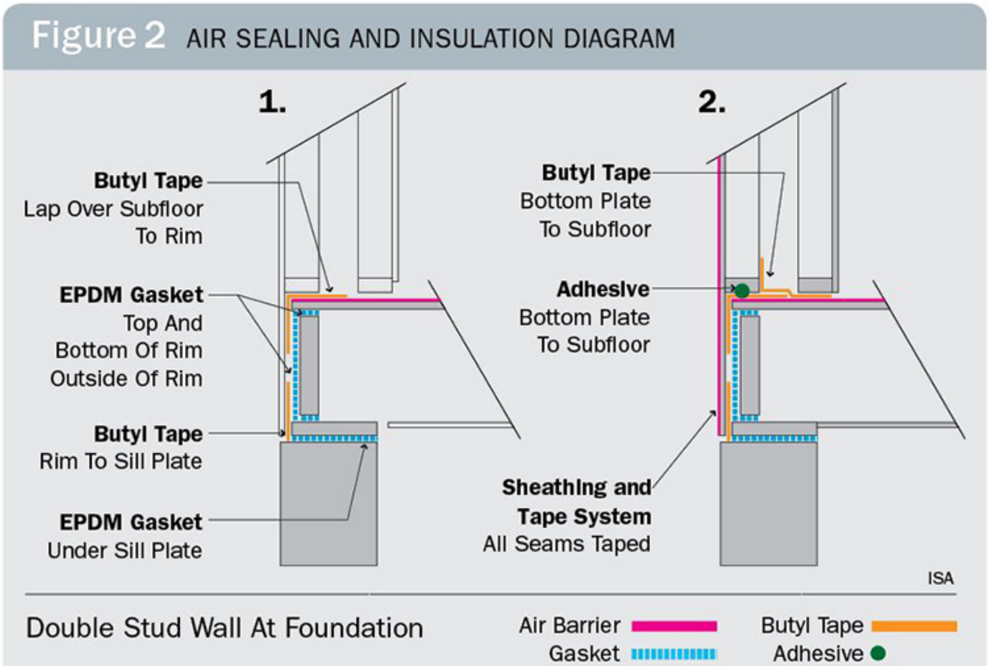
The framing strategy for the project aimed to achieve high performance while reducing construction waste. The adjustable distance between the two walls allowed for tuning of the total wall thickness to meet appropriate insulation values determined through the energy modeling process.

Efficient framing strategies designed to optimum value engineered (OVE) framing techniques increased total area of insulation while mitigating waste. Studs and joists are no more than 24 in. apart, and joists align with wall studs to ensure direct structural load paths, allowing for single top plates.

Wall corners are framed with two studs (rather than three or four), and framed openings are sized appropriately to reduce jack and king studs at the sides. Fifty-one percent of construction waste was diverted from landfills to be recycled.

Robust air sealing is equally critical to an efficient wall assembly. In recognition that high performance detailing is often novel for residential contractors, the design team deployed its past experience with communicating details to insulation installers and framers to achieve atypical construction techniques.

Color-coded air sealing and insulation diagrams (Figure 2) were developed to guide subcontractors and installers through the appropriate sequence ofinsulation, gasket, tape and caulk installation to ensure tightly sealed and insulated roofs and floors. Special



The design team developed highly simplified air sealing sequencing diagrams to think through the relationships of various types and locations of insulation and air sealing components. These color-coded images were used to communicate these more complicated details to the construction team. The transition shown is where above-grade frame walls rest on the foundation.

attention was paid to the intersection of assemblies, a common trouble spot for infiltration. While designing a tight envelope is important, energy performance is determined in equal measure by craftsmanship and field decisions made by builders on site, and a close collaboration between designers and builders was crucial to this project's success.

Systems

While a tight, robust envelope drives down energy use, projected use must be simulated, and energy production systems must be installed to offset predicted use. For residential construction, the unpredictable nature of residents' energy loads is a challenge. Targeting projected use is difficult with an unknown number of residents who have variable schedules, and it is hard to predict the impact of post-occupancy energy monitoring data available to residents. An iterative process of rigorous energy modeling used software that is specifically designed for residential projects, and tested and optimized energy performance of multiple design solutions during the concept design and pre-construction phases.

Selecting specialized versus stock equipment and appliances was also a design challenge. Early energy models used super low-energy appliances that proved to be out of reach for the project budget, difficult to source, and inappropriate for a prototypical market-rate housing project.

The team decided that stock appliances and fixtures would be balanced by high performance renewables modeled to produce enough energy to offset target use. Final energy models showed a solar photovoltaic array that would produce energy at a rate exceeding occupant demand, producing Home Energy Rating System Index (HERS) scores between -6 and -9, and allowing the buildings to feed surplus power back to the grid (click here for more information about the HERS Index).

HRVs are used to provide fresh air into and exhaust stale air out of each home. While typical homes allow for infiltration at leaky construction junctions and operable windows and doors, homes that are tightly sealed need a mechanical means of air exchange. HRVs are a low-energy means of tempering fresh air by using heat exchange between exhaust air and fresh air, and retain approximately 70% of energy already spent to heat or cool the fresh air.

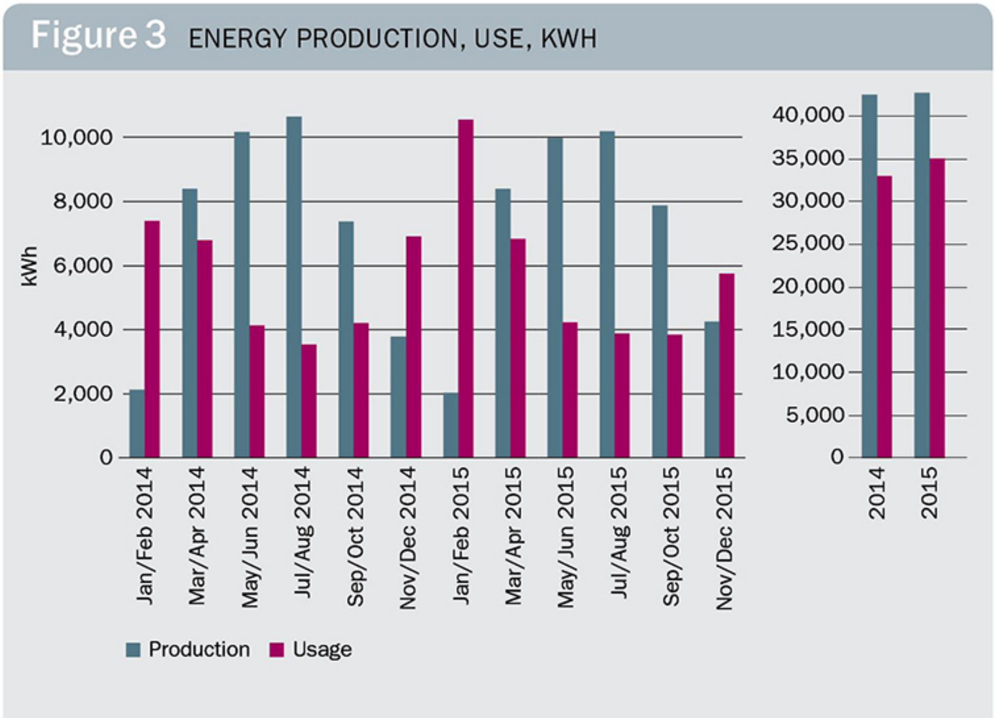
Two outdoor air-to-air heat pumps are tied to three ductless mini-split units, which provide heating and cooling. Each floor is zoned separately for greater control over indoor environment and less wasted energy.

The mini-split units have integrated programmable thermostats and wireless remote controls for easy homeowner adjustment. The ductless system was selected to provide more efficient heating and cooling, with fewer runs from heat and cooling generation to site (as in a split ducted system), and nets far less wasted energy than a typical home's heating and cooling system.

Each townhouse is equipped with 38 solar PV panels and a solar thermal panel. Domestic hot water is generated via the thermal panels with an electric backup system.

Through a grant from the Massachusetts Clean Energy Center, an energy monitoring consultant installed sensors tracking electricity consumption, production, and occupant comfort in each home for three years post-occupancy. During the first year, the solar array produced 42,496 kWh, while the building energy consumption was 32,934 kWh (Figure 3). The remaining excess electrical production was fed back to the grid.

In the years since, the project has consistently generated approximately 7,600 kWh/year more than it consumes. Actual site energy use intensity (EUI) for the four homes is 15.18 kBtu/ft^2, which is slightly lower than the predicted performance at 16 kBtu/ft^2.



Each of the four homeowners was able to generate enough electricity through renewables within the first year of operation to "bank" credit with the utility company, resulting in no electric bills. The local utility company allows users not only to store credit, but to appropriate that credit to other users within their system. One homeowner was able to bank a few thousand dollars' worth of credit and is currently interested in forwarding that credit along to local family members in other homes.

Performance data for the project is made public through an online and smartphone dashboard interface, creating a feedback loop encouraging homeowners to reduce consumption. Up-to-date energy metrics can be seen at https://secure.embue.com/eplus-dashboard/.

Water

The E+ project's roof discharge is captured on site through an underground infiltration system and regulated overflow to the municipal sewer system. A total of 87% of rainwater from a maximum anticipated 24-hour, two-year storm can be managed on site.

Landscape design incorporating permeable paving and native, drought-tolerant species increase site infiltration. Each townhouse is equipped with a 50-gallon rain barrel (concealed under the deck) for harvesting rainwater for garden irrigation. To further reduce the building impact on the water cycle, all plumbing fixtures are low flow, and toilets are dual flush. Energy Star-rated dishwashers and washing machines conserve water and energy.

Photo courtesy Urbanica

Materials

Building materials for the E+ project were chosen to be robust and long-lasting, with locally sourced and environmentally sound products prioritized during procurement according to LEED guidelines. The exterior siding materials are a combination of high-quality fiber cement siding, Forest Stewardship Council Certified-wood trim, and metal composite panels installed in a rain-screen assembly.

Interior finishes with low emissions content promote healthy indoor air quality, and recycled materials were used wherever possible. Blown-in cellulose insulation is 100% recycled, and 30% fly ash content is incorporated in the concrete foundation.

All wood framing, trim, and finish woodwork was made from locally sourced, FSC-certified wood. Kitchen countertops are Greenguard-certified composite quartz, and cabinetry is made from bamboo slab doors and no-added-urea-formaldehyde (NAUF) composite wood casework.

Cost and Payback

The E+ townhomes were built for a construction cost of $\$195/ft^2$, a markup of 10% to 15% for comparably sized and located conventional developments. The additional initial costs were incurred for extra framing, materials, and insulation in the passive envelope, as well as the high efficiency windows and HRV equipment. Of the three market-rate units, two were pre-sold, and the one affordable income unit was entered into a lottery pool.

The project was made financially feasible by a number of strategic financial initiatives. The project team received $120,000 in grant funding from the City of Boston for Green Building and Affordable Housing, and the homes were built on a formerly city owned lot, which was acquired by the developer for extremely low cost.

The construction team received assistance from the Helping Hammer Program of the New England Regional Council of Carpenters for siding, drywall and flooring installation. These carpentry crews were teamed with the project as a learning opportunity for their apprentices to get hands-on experience with more energy-efficient construction practices for a new apprentice training program.

Lasting Impact

The Roxbury E+ project team targeted sustainability not simply as a technological fix to environmental problems, but rather as a relationship of responsibility among individuals, communities and the environment. The mixed-income development included a subsidized affordable unit (offered to individuals with an income no more than 80% of the area median income) and three market-rate units to support a diverse neighborhood while aiding in revitalization.

Economic sustainability for the project began with reduced long-term energy and operations costs for residents. The project also trained local construction workers in sustainable practices, supporting an effort to create green collar jobs in the Boston area.

Post-construction and pre-occupancy, mechanical equipment and systems were tuned and tested to ensure that they were functioning as designed. A detailed homeowners' manual was provided, and walkthroughs were conducted to train buyers on the operations and maintenance of their homes. A comprehensive public awareness campaign incorporating a website, signage, public tours, and open houses aimed to educate the neighborhood at large about green building practices and green collar job opportunities, positioning the project as a catalyst for local economic revitalization.

Conclusion

Boston's E+ Green Building program requirements set the project challenge—to create an energy positive building on a tight urban site in an economically disadvantaged housing market. The Roxbury E+ project team's holistic design approach took into account the risks and rewards of bleeding edge technology for energy performance—along with the competing stakeholder agendas for neighborhood change, cost efficacy, and regulatory constraints—to develop a prototypical model for high performance production housing with a proven track record. •

About the Authors

Kara Medow, R.A., is the Philadelphia studio director for ISA, a design and research office based in Philadelphia. Brian Phillips, AIA, LEED AP, and Deb Katz, LEED AP, are principals at ISA.

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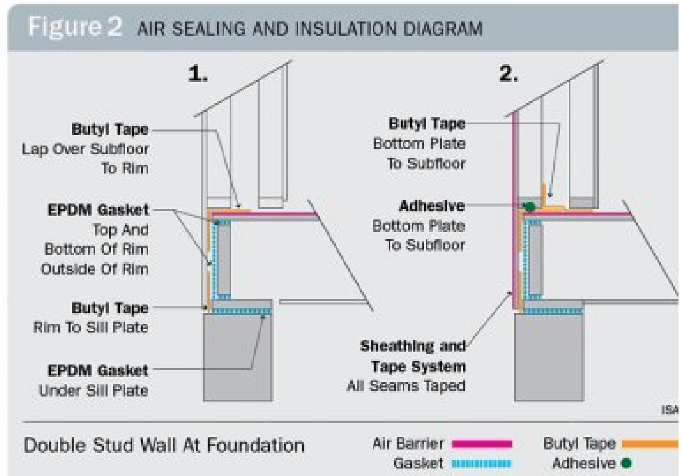

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