Beaton Residence

A new single family residence in Shrewsbury, MA that is line to become the 1st project in Massachusetts to achieve Passive House certification, perhaps the most rigorous standard for energy efficient construction in the world. No matter what geographical region, the goal of Passive House projects is for the interior of the building to stay at a comfortable temperature year round with minimal energy demand. Conventional heating systems are virtually unnecessary, as these low energy buildings are heated and cooled “passively” through passive solar design principles and heat recovery systems, while very little wanted heat is lost and very little unwanted heat is gained through a super insulated, super tight building envelope.

This new residence was designed as the primary residence for Matt and Laura Beaton. Recently elected as a state representative, Matt is both a general contractor who manages Beaton Construction and an energy auditor managing a separate building diagnostic company, Residential Energy Solutions. Empowered with these skills and knowledge, Matt hired Verdeco Designs, LLC to design a residence that could both fulfill his present and future family needs, but could also serve as a model home of 21st century energy efficiency and low impact design solutions.

And so, Verdeco Designs and Beaton Construction formed a “strategic partnership” to design and build this unique home with Matt serving the role as both client and general contractor. Many design options were analyzed throughout the design process, with considerations towards LEED green building certification and the future overall energy performance of the structure. Regarding the energy discussion, all major energy systems were evaluated on a cost/benefit analysis, but in the end, the “low-tech” adoption of the Passive House energy model won out as the optimal solution for the Beatons and their desire for a low maintenance, low-energy home.
41 Surrey Lane, Shrewsbury, MA was a previously undeveloped infill lot, a couple of blocks off Main Street and the center of town and only a few houses down the block from the Beatons former home. Matt and Laura were attracted by the close proximity to town and knowing the street and the neighbors well, they were comfortable purchasing the parcel of land even though the site had inherent challenges.

The lot had been recently subdivided from its eastern neighbor and had a narrow access. The property owner to the east was not open to converting their driveway to a common driveway, but even if they were open to such an easement, it would not be an easy design solution for accessing 41 Surrey Lane. This was because the new Beaton property sloped away from street and would require substantial fill to meet up with the neighbor’s somewhat level driveway that becomes more elevated as you enter the Beaton site. The south facing property was further restricted by 25 foot no-cut zones defining the building setbacks and by a small section of wetlands on the northern edge of the property. Good solar access, often a defining feature of high performance building design through passive solar heating, the ability to take advantage of “free energy” from the sun, was significantly challenged by mature oak trees that densely occupied the site. And yet perhaps the most challenging feature of developing the site was the abundance of large granite boulders that filled the property. There was evidence that some of the boulders had been dumped there by others, but there were also many huge, partially exposed boulders that made us question whether we might have considerable blasting to make room for even a modest foundation.
Design Development

Recently married, Matt and Laura Beaton wanted their new custom home design to accommodate both their present lifestyle preferences and future goals of starting a family. Laura loves to cook and they both enjoy visiting with friends as well as connecting with the outdoors. After an initial conversation to outline their goals, it became clear that the focus of the design would be centered around the kitchen, living and dining areas and that an open plan would best respond to their preference to visually connect these areas. In turn, the open plan of these primary areas was ideally suited to respond to one of their other main goals of the new residence, namely to build a high performance “green” home that Matt could use as an example to promote his energy and construction companies.

Design Development

The open plan concept for the kitchen, living and dining areas assisted the high performance home design as it more easily allowed a large shared interior volume to be oriented to the south and take advantage of passive solar design principles. With this basic consideration in mind, the longitudinal spine of the house was oriented along the site’s east-west axis, maximizing the solar exposure of the overall house volume. We then took inventory of the mature oak trees that would need to be removed to provide the solar resource and positioned the structure further back on the property to further optimize this resource. In analyzing the site, we noticed a large partially exposed boulder that was close to the southwest corner of our proposed house location and saw this as an opportunity to further expose the boulder and create a sunken garden area and partial walk-out basement that would also allow the solar resource to reach the basement level.

Along with organizing the conceptual design program with the client goals, we agreed to hire Richard Brown of Certified Energy Ratings to serve as both an energy consultant and our US Green Building Council (USGBC) LEED for Homes Provider in order to set up the green building certification process. With our design intentions clearly outlining a “green” model home, we all felt that LEED certification would be imperative to make the construction accountable with our design Intentions. Filling out the LEED for Homes Project Checklist we started to organize the design development around the following main categories: site impact, water efficiency, energy, materials, and indoor air quality.

We felt comfortable with the basic house concept, so we started to refine the plan layout, develop potential wall sections, and investigate our options on energy systems. As we discussed the costs and benefits of various building envelope upgrades from standard 2x6 exterior wall construction we also discussed our main options for heating systems. With natural gas not being available in the street and a general disdain for oil as a heating fuel, we started to focus on geothermal heat pumps, air source heat pumps, and radiant floor heat integrated within a solar thermal system and propane back-up. As we further analyzed the costs, benefits, and potential maintenance of these systems, the Beatons looked for our recommendation, and it is here where we introduced them to the Passive House option.
Passive House Overview

The Passive House energy standard was developed in Germany and has been established in Europe for years. Borrowing directly from the Passive House US website – www.passivehouse.us - the Passive House concept represents today’s highest energy standard with the promise of slashing the heating energy consumption of buildings by an amazing 90%. Widespread application of the Passive House design would have a dramatic impact on energy conservation. Data from the U.S. Energy Information Administration shows that buildings are responsible for 46% of greenhouse gas emissions annually and 76% of all electricity generated by U.S. power plants goes to supply the Building Sector [Architecture2030]. It has been abundantly clear for some time that the Building Sector is a primary contributor of climate-changing pollutants, and the question is asked: How do we best square our building energy needs with those of our environment and of our pocketbook? In the realm of super energy efficiency, the Passive House presents an intriguing option for new and retrofit construction; in residential, commercial, and institutional projects.

A Passive House is a very well insulated, virtually air-tight building that is primarily heated by passive solar gain and by internal gains from people, electrical equipment, etc. Energy losses are minimized. Any remaining heat demand is provided by an extremely small source. Avoidance of heat gain through shading and window orientation also helps to limit any cooling load, which is similarly minimized. An energy recovery ventilator provides a constant, balanced fresh air supply. The result is an impressive system that not only saves up to 90% of space heating costs, but also provides a uniquely terrific indoor air quality.

A Passive House is a comprehensive system. “Passive” describes well this system’s underlying receptivity and retention capacity. Working with natural resources, free solar energy is captured and applied efficiently, instead of relying predominantly on ‘active’ systems to bring a building to ‘zero’ energy. High performance triple-glazed windows, super-insulation, an airtight building shell, limitation of thermal bridging and balanced energy recovery ventilation make possible extraordinary reductions in energy use and carbon emission.

Performance Characteristics

- Airtight building shell ≤ 0.6 ACH @ 50 pascal pressure, measured by blower-door test.
- Annual heat requirement ≤ 15 kWh/m²/year (4.75 kBTU/sf/yr)
- Primary Energy ≤ 120 kWh/m²/year (38.1 kBTU/sf/yr)

In addition, the following are recommendations, varying with climate:

- Window u-value ≤ 0.8 W/m²K
- Ventilation system with heat recovery with ≥ 75% efficiency with low electric consumption @ 0.45 Wh/m³
- Thermal Bridge Free Construction ≤ 0.01 W/mK

The building science research culminated in the development of the Passive House Planning Package (PHPP) which projects detailed heat load, heat loss, and primary energy usage for individual building parameters. The latest version of the PHPP also projects cooling, cooling loads, and latent cooling. Based on feedback from many detailed data logged buildings, the software is constantly refined and incorporates updated calculations for various climates around the world.

A Passive House may be designed in any architectural style.
Beaton Residence - Passive House Design

Quickly after introducing the Beatons to the Passive House option they became intrigued by this strategy and directed us to pursue this rigorous standard. We started working with Passive House consultant Paul Panish of Deep Energy Group and Advanced Building Analysts to analyze our conceptual plans and guide us on the goal to achieve PH certification. It soon became clear that even with greatly improving the thermal insulation and air sealing of our building envelope, our initial plans had significant massing issues that challenged a passing grade of the comprehensive energy model. This was largely due to a wrap around front porch and extruded section of the main house rectangle that added shading elements to the south elevation. After further discussing the issues surrounding an optimal design for the Passive House energy model, we redesigned the massing of the structure and eliminated the challenging shading features.

The following section diagram outlines the main design components we implemented within the building envelope to achieve Passive House certification. Increased thermal insulation is clearly a key component of this strategy and the 20" nominal thickness of the exterior walls (created by 14" TJI joists used as curtain wall & a 2 x 6 structural wall) may surprise many individuals, but along with the preference of the Passive House Institute to use cellulose insulation, which has a lower environmental impact to manufacture than most all other insulation options. Matt Beaton owned the equipment to blow the dense pack cellulose making the increased insulation more affordable. Other features to note are the rigorous attention to airseal the seams throughout the structure as well as the need to eliminate thermal bridging, the transference of heat through solid materials. Both the 14" curtain wall and the 10" of rigid insulation below the isolated basement slab are clear design strategies to eliminate thermal bridging. Overall, it should also be noted that the increased cost of these design strategies, including the triple pane windows, could be justified by virtually eliminating the need of a central mechanical system, which subject to the system selected, might have cost tens of thousands of dollars to install plus a few thousand dollars annually to operate and maintain. In the end, all the Beatons needed to install was two wall mounted Mitsubishi mini-split air source heat pumps, to act as space heaters, and serve as back up heating, cooling, and dehumidification sources.
Basement Plan

- Bedroom
- Bath
- Utility
- Hall
- Unfinished Storage
- Recreation Room
- Sunken Garden / Patio
- Up
Second Floor Plan
Elevations

South Elevation

East Elevation

West Elevation

North Elevation

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Green Features & LEED Certification

At this writing, the Beaton families have recently moved into the residence and are still completing the finishing details on the interior of the home. They hope to progressively complete exterior stone veneer and patio work outlined within the design documents as well as continue to add native plants to their surrounding landscape. Nevertheless, as previously mentioned, many “green” features were incorporated into the construction of the residence and formally documented into our LEED for Homes application targeting Gold certification level.

The overall goals of green buildings are often described as attempts to design and build structures that have less of an impact on our natural environment. This consideration is often framed in terms of the disturbance of natural habitat, the depletion of natural resources, as well as the overall health of the building occupants. Along with our innovative design approach to create a low energy, high performance building through the subscription of the Passive House energy model, the following items represent key design elements to complement this effort in creating a more “green” and lower-impact design project:

- Minimize site disturbance, development footprint, and impact on local hydrology
- Use of only drought resistant, native plantings – no irrigation system
- Mill oak trees cut on site and reuse material as flooring and interior trim
- Reuse on site stone as building veneer, retaining walls, patios, exterior, steps and walkways
- Integrate used brick as decorative thermal mass interior wall of “great room” to promote passive solar heating principles
- Solar thermal heating system for domestic hot water
- High efficiency plumbing fixtures for low water use
- High efficiency lighting package, including LED fixtures and “smart home” technology to promote increased monitoring and controllability
- Heat Recovery Ventilator (HRV) to provide controlled fresh air exchange and stale air exhaust while minimizing heat loss
- Energy efficient appliance package
- Daylighting design features, including solar tube skylight and interior openings to share natural sunlight
- FSC certified framing materials to guaranty responsible harvesting of wood products
- Waste management program to guaranty maximum amount of construction waste created on site would be recycled
- Zero VOC paints, finishes, and adhesives to eliminate potentially harmful off gases from construction materials and finishes
- Many environmentally friendly products with high recycled building material content as well as high durability features in order to diminish maintenance and additional manufacturing costs