THE NET-ZERO PUTNEY FIELD HOUSE

Setting a New Standard for K-12 School Athletic Buildings

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Exterior of the Putney Field House - New England's first net-zero energy educational building

Climate change, global warming and economic instability are not going away. As architects, interior designers, facility managers, building owners, manufacturing and product vendors we know that we contribute heavily to these problems we face. While there is no clear road map to follow for solutions, there are positive examples in our midst! The Net-zero Putney School Field House, which opened in 2009, offers a new vision and standard to follow. Learn how "Choices in Sustainability" helped the school to select the Net-zero option and how it clarified the process. Through our project with Putney we know it's possible to design and build Net-zero buildings today. By sharing the Field House story we hope to advance how to design and build a more predictable, sustainable, Net-zero, and carbon reducing future.

INTRODUCTION

The project began appropriately with a power failure in the middle of a snow-storm. While interviewing for the project in late winter of 2007, we improvised without power in the well daylit library and started a great conversation with the Putney School which is still continuing today. Perhaps the outage emphasized our message of offering the school community choices for sustainability and different ways to think about the new Field House they needed so much.

Net-zero energy buildings (NZEBs) generate as much energy as they consume on an annual basis (including all loads, not just electric). The energy used is created on site from renewable sources like wind, solar, geothermal or biomass. Typically, the Net-zero building is connected to the electricity grid, using the grid to balance production fluctuations of renewable energy sources resulting in annual Net-zero consumption.

Bill and others from our team shared how a building could be seen as an investment with a return over time, whether over a generation or in just a few years depending on the level of energy efficiency measures and addition of renewable energy technologies. Beginning at the interview, our team offered five options starting at a typical building and moving to a Net-zero building. Then over the following months, we showed the Putney School how the design and building process could enhance their progressive educational vision, their financial stability, and their sustainable values.

THE PUTNEY SCHOOL

Visionary educators founded the independent high school in 1935 on a farm in southern Vermont; on progressive values stemming from the work of John Dewey. Today its 500 acre hilltop site has a dynamic and innovative campus with a working farm as well as a village organization of school buildings, residential halls and until recently an inadequate sports facility.

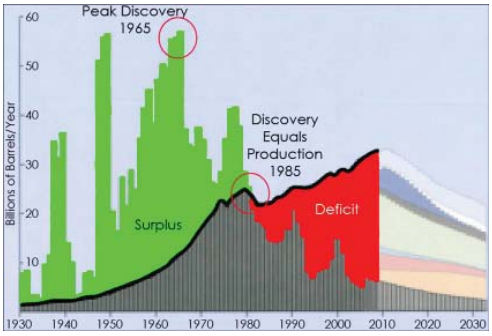
Timeless Vermont values and a love of the land form the basis for the innovative and rigorous academic, arts and outdoor programs. A generation ago, they championed sustainability only they called it stewardship. The roughly 225 students and 90 faculty/staff immerse themselves in a learning culture prizing environmental and social values grounded in a meaningful work program.[1] Along with traditional academics they work year round on the farm: growing plants and food, tending to livestock, milking cows and managing their woodlot. They hold weekly all school sings, a time when everyone gathers sharing songs and coming together as a community. Until recently, they didn't have a central place for indoor sports and wellness activities, so essential during cold Vermont winters. Thus, they needed a new Field House, and more importantly, they wanted a new building which fit their mission and set a new standard in sustainability and wellness for the country.

Students studying at the Putney School

BUILDINGS ARE A BIG PART OF THE PROBLEM

Buildings use almost 40% of primary energy[2], 72% of electricity[3] and produce 39% of greenhouse gas emissions in the US.[4] Accepting this impact, business as usual approaches to design and construction won't help. Increasingly, building design, engineering, construction

and development professionals realize how we design and construct our buildings must change. These factors, along with rising energy costs are driving the trend of high performance buildings as measured by the growth in popularity of LEED & Energy Star programs. Today there is a movement to go beyond high performance building to Net-zero by utilizing micro-load envelopes and renewable power technologies. The Putney School Field House is at the forefront of this new movement. Following is an overview of the process we took with the Putney School to achieve Net-zero and the promise of a positive energy future.



Global oil discovery peaked in 1965. Since 1985, oil discoveries have been less than consumption. Source: peakoil.net

THREE SIMPLE STEPS: A FRAMEWORK FOR NET ZERO

The Putney School wanted an exemplary green building for its' new Field House. Throughout the process we worked together to determine the appropriate level of performance for the building and simplified building systems to show that ultra high performance buildings need not be complex. The process began with the following framework:

1. Establish building performance metrics (like car mileage)
2. Reduce building loads to renewable ready standards
3. Add renewable energy sources (or plan for adding renewables in the future)

After setting up this framework we followed the **MACLAY ARCHITECTS 12 Steps to Net-zero Innovation**:

1. **Care for** clients' vision, program needs, brand, functional and environmental considerations
2. **Listen, collaborate** and **lead** an innovative and inclusive community design process
3. **Generate clear goals, objectives and choices** to focus creativity and success
4. **Synthesize a vision** and like centered design embodying the client's core mission, brand and other requirements
5. **Provide** and **track clear metrics** to insure outcomes consistent with visions and goals
6. **Analyze options to facilitate** prudent choices
7. **Document and Share** design to build support
8. **Focus on the details** – construction drawings and specification documentation
9. **Anticipate challenges during construction,** look for opportunities to innovate
10. **Optimize costs, Generate value!**
11. **Support funding efforts** to maximize donor, grant and foundation support
12. **Learn, celebrate, evolve** and **spread** the word!

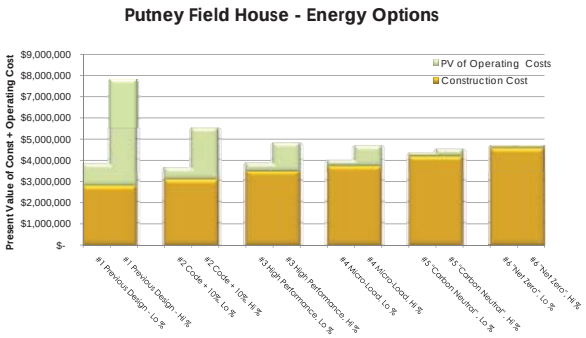
VALUE DRIVEN PROCESS

The school and design team developed the project vision directly from the school's mission. The Putney School is about living fully; intellectual engagement; creative play and progressive learning for a sustainable future. Their school vision was translated for the project to focus on **creating a model for the future through energy conservation, social and physical wellness.** These ideas stayed with us throughout the entire process by their prominent placement on top of all of our meeting minutes issued during each phase of the project. These goals were translated to a project purpose which stated: **"Design and build a model, environmentally focused, Net-zero Field House that embodies Putney School's core beliefs, and is unique in the country."** Doing so helped the team and stakeholders keep the big picture in mind as it's so easy to lose sight of it throughout an intensive design and construction process.

CHOICES IN SUSTAINABILITY

Throughout design, the team provided choices for energy performance levels and associated costs with each of these options for the Putney School to evaluate. These levels began at a Base Building Model and moved up to High-Performance, Micro-Load, Carbon-Neutral, and a Net-zero Building Model. All levels were compared based upon initial capital costs and 30-year operating costs with 5% and 15% fuel cost escalation rates. This was coupled with how they would contribute to the school's short, medium and long-term goals in terms of environment and energy sustainability.

It was determined through this comparison, that at a 5% fuel cost escalation rate the total capital costs and 30-year operating costs were about equal for the Net-zero and code



Energy choices explored for the Putney Field House based on high (15%) and low (5%) inflation rates for the cost of oil. (Energy Analysis by Energy Balance)

compliant base building. At a fuel escalation rate of 15%, the School would have saved a million and a half dollars on a three-million dollar project after thirty years. Accounting for

these considerations, the Putney School selected the Net-zero facility option. With this overarching goal, the school and design team moved the project forward into schematic design.

Similarly, after considering a range of choices presented by the design team, the School decided to seek LEED certification for this project, in order to confirm their efforts under a third party verification system. The project is registered under the LEED-NC 3.0 System and is on track for LEED Platinum Certification with documentation close to finalization.

ENHANCED EFFICIENCY BEFORE RENEWABLES

Working with the School we began with our three step process which emphasized reducing overall building energy use before purchasing and installing expensive renewable sources. As part of this approach we oriented the building to the south, with the long side within 15 degrees of true north for passive solar heating and improved daylighting. This minimized overheating from early morning eastern sunlight and low western sunlight, which results in less cooling demand on the building systems.

Secondly, to further reduce energy use, we super-insulated the building enclosure, increased air-sealing, accurately sized mechanical cooling and heating equipment, and increased daylighting and the use of lighting controls. Daylight harvesting decreases reliance on electric lighting, and decreases the need for larger mechanical systems, ducts and higher equipment loads to deal with excess heating from lighting systems. Our team used energy modeling to accurately determine insulation levels, equipment sizing, and eliminate wasteful and expensive overdesign. Using these techniques we reduced energy use 45% below what is allowed by ASHRAE 90.1-2007, a necessary step to maximize the value of added renewable technologies.

We call these super-insulated building which are optimized to allow for net-zero performance **micro load buildings.** It is critical to reduce loads to a micro load level initially to make the addition of renewable technologies cost effective initially or in the future when striving for Net-zero. [5]

AN INCLUSIVE WELLNESS VISION

In the quest to create a center for wellness, both physical and social, the school wanted to create a Field House for all students, not those simply involved in school athletics. To address this concern, we brainstormed and generated a range of program ideas in design workshops together. This resulted in the inclusion of spaces to support a spectrum of activities including badminton, volleyball, basketball, indoor soccer, yoga, foosball, rock climbing, socialization spaces and places to study. As a result the building program appeals to the whole of the student body and faculty/staff.

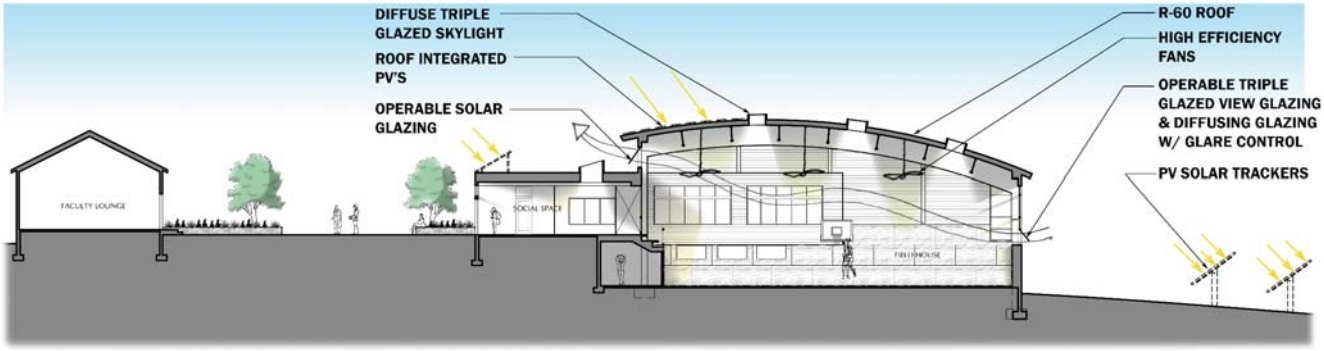
COLLABORATIVE, INTEGRATED & ITERATIVE DESIGN

The collaborative design process drew on the skills and specific expertise of not only the professional design team but the school community as well. The design team included faculty, staff, board members, students, local community members, and members from the professional design team.

All team members were involved in the process from conception through construction. We led the design team in the creation of choices and possibilities for the School community to consider as they clarified their vision and goals for the project. Having the construction manager involved early helped us as well as other professional design team members brainstorm different methods and choices to achieve energy and aesthetic project goals in conjunction with budgetary targets.

Design charrette with Putney stakeholders

The inclusion of the entire school community was key to the success of the design process. The integrated design process began at kickoff meeting and continued throughout the project with design workshops, charrettes, and presentations. We led multiple day-long workshops focused on goal-setting and programming; building siting; building concept massing and then later, detailed design. These also included the development of an interior student social space and overall selection of materials, finishes and building equipment for the building. On each of these visits to the school we spoke at the all school morning assembly to present past work, outline the activities for the day and invite participation of the entire community in the

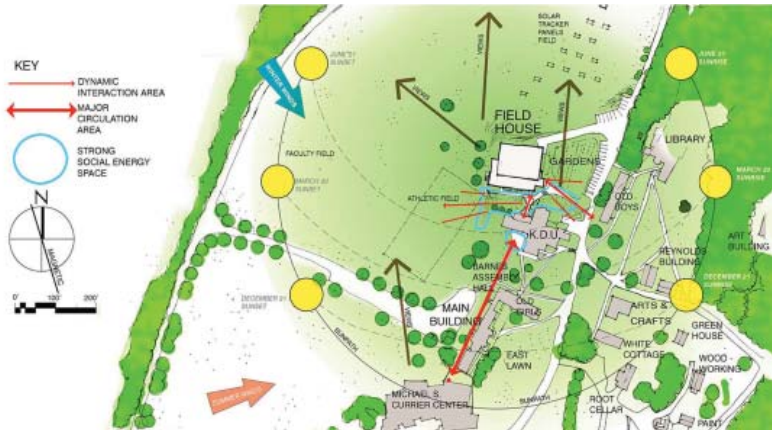


Building section describing main efficiency features of the Putney Field House

afternoon charrette. Morning work with the Field House building committee helped us prepare for the afternoon charrette and advance project decision making, while the afternoon charrette allowed us to receive input from the larger school community.

SOCIAL ENERGY & CAMPUS CONNECTION

The Putney School Field House is more than a sports facility, it is part of the hub of the campus, and home to a unique and



Site plan indicating design forces for the Putney Field House

inspiring place, the Social Space. The Social Space design was generated through a collaborative design process. It included student leaders, all students interested in becoming involved with the design process, faculty members, administrators, and professional members of the design team. A day-long charrette allowed brainstorming of additional ideas and refining the vision for the space. The Putney School and the design team conceived of the Social Space as a primary source of student energy both in the building and on the campus. The space is closely connected to the KDU, the home of the dining hall with views and pedestrian paths. A shared outdoor space lies between the buildings, with open grassy areas, curving stairs and low-walls extending into the courtyard. Through this intersection, a tight-knit, pedestrian friendly, infill solution is created. The incorporation of student art into the building is another way of generating social energy beyond the realm of physical fitness. Over time, students will be designing and installing art tiles throughout the building, along the wood wainscotting.

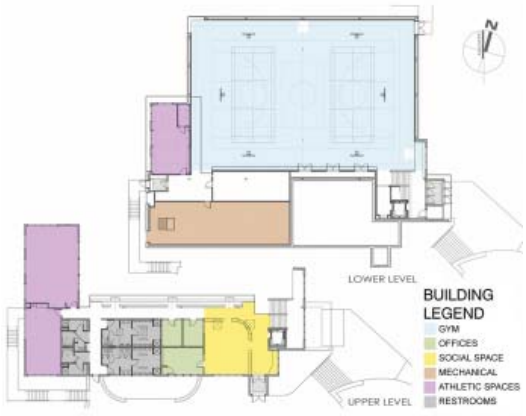
CONNECTING TO THE SUN, SKY, EARTH & AIR

While we designed the Field House to dramatically reduce energy use, we also connected it to the sun, sky, earth and air. How these forces work together shapes the experience of the building occupants both in physical comfort and emotional well being. We maximized daylighting and solar exposure by orienting the building along the east/west axis. We promoted site interconnectivity with views through strategically located windows. Ample skylights, windows and fixed, light-guiding window louvers bring daylight deeply into the entire building, reducing electric lighting demands and animating active interior spaces including the gym. The building is bermed into the hillside which provides increased insulation and reduces the heating loads. Through the use of the stack-effect and night time flushing of warm building air through operable clerestory windows, natural ventilation cools occupants and continually circulates air. Light-colored roof and concrete walkways reflect heat from the sun, reducing building cooling loads and reducing transfer of heat from adjacent outdoor spaces, reducing the heat island effect into the building. These strategies function both to connect users with the natural forces of the sun, sky, earth and air and to reduce energy consumption in this cohesive center for wellness.

BUILDING PROGRAM

The 16,734 gross square foot (GSF) building has two floors. The 11,574 GSF first floor includes a large multi-purpose gym with resilient sport flooring with a rock climbing wall on one end. It also contains the ski waxing room for cross country skiing, a mechanical room, storage and circulation spaces. The 5,160 GSF second floor has the student social space, an open bleacher area overlooking the gym, offices, locker areas, a flex space for aerobics and movement exercise, a strength and conditioning room and composting toilets. The social space overlooks the gym while the strength and conditioning room extends over the gym slightly with large expansive windows allowing strong visual connection in both directions. An elevator and gracious interior stair connects the two levels.

On-site bike storage and changing rooms are provided to promote activity and wellness.



First and second floor plans for the Putney Field House

LEED EVERY STEP OF THE WAY

An initial LEED assessment was performed examining what credits were relevant to meeting the project goals. Possible credits were tabulated to reach an initial goal of LEED Platinum. At each successive stage of design, the LEED matrix was reviewed again to ensure meeting the Platinum level certification goal. We began the project under the USGBC LEED V2.2 for New Construction (NC) and changed midway adopting the LEED 2009/ V3.0. The upgraded system includes the addition of regional credits and an expanded point distribution system in energy.

WATER QUALITY & EFFICIENCY

No irrigation was installed. To minimize water use and creation of waste, low-flow toilets, waterless urinals and composting toilets exceed water conservation goals. The composting bins for the toilets are located in the mechanical room and are anticipated to be emptied once a year

BUILDING ENCLOSURE & ENERGY USE

Achieving a Net-zero ready envelope requires super-insulation and extensive attention to air-sealing and minimizing thermal bridges of the building enclosure. To reduce energy use to 45% below a code base building we included high insulation levels: **R60 Roof, R45 Walls, R20 Slabs, R20 Foundation walls below grade, R5 Windows, and achieved an air infiltration rate of 0.065 cfm/sq ft.** These standards go way beyond current energy code and high performance building levels. This is part of what makes the Field House building so unique and a standard setting building for other schools to follow. Blower door testing was also conducted to assess air-sealing and detailing effectiveness and the contractor to take corrective measures to seal leaks when they showed up. The air-sealing results were the lowest of any of the high performance building we have yet designed, showing the commitment of the builders and their subcontractors to meeting and surpassing the already high project air-sealing standards.

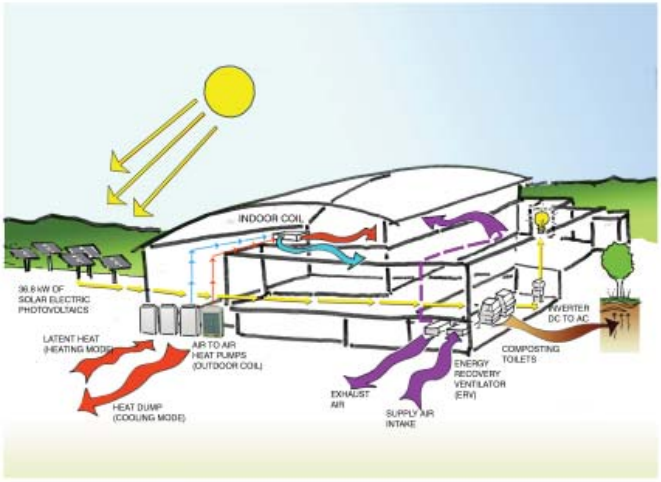


Diagram of mechanical systems and the relationship with the natural world

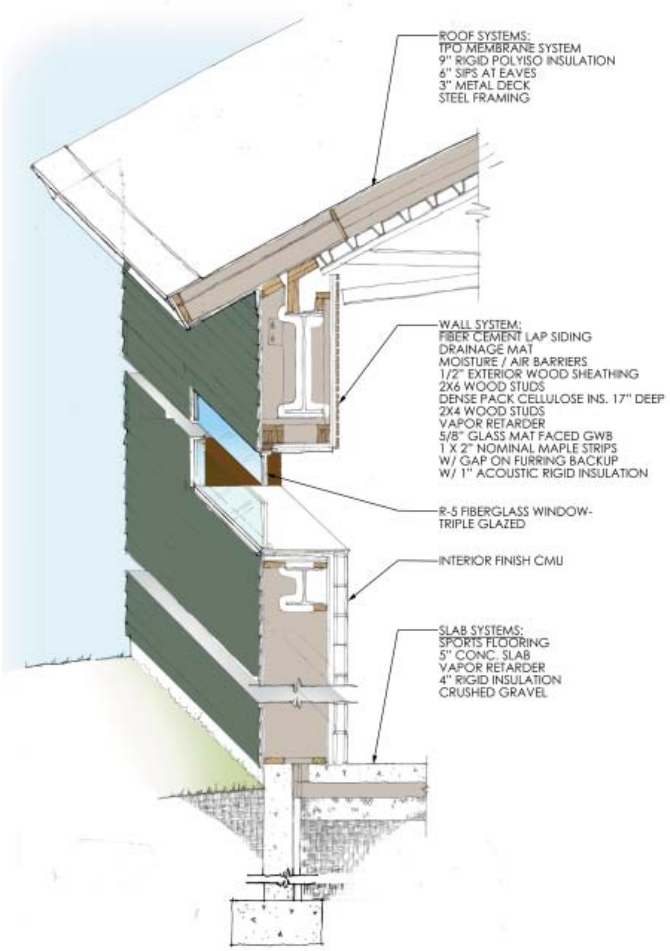
Models for the Putney School Field House indicate that energy intensity numbers for this building will be much lower than other comparable buildings. Models informed by the actual energy usage for the first half of the year, show an energy intensity of 11 kbtu/square foot/yr for the building. With this energy intensity number, the Putney School Field House uses 45% less energy than the standard new base case building under ASHRAE 90.1-2007. As compared to average existing buildings the Putney Field House illustrates an even greater reduction. The EPA sets a benchmark for average college/university campus buildings at 120 kbtu/square foot/year, which means that the Putney Field House is performing 91% better than a comparable existing building.

An **energy intensity number** refers to a measure which takes into account the total energy used by a building in one year. Normalized by square foot for easy comparison, an energy intensity number is often reported in kbtu (thousand btu) / square foot/ year and includes consumption from all building energy sources.

MECHANCIAL SYSTEMS & ENERGY EFFICIENCY

The design and building team considered ground-source heat pumps and air source heat pumps, by modeling the various options and associated costs. The air source heat pump system was selected as optimum for the project.

An air source heat pump is an energy efficiency device that heats in the winter and cools in the summer using a refrigeration cycle to move energy between indoor and outdoor air. This building specifically did not require any cooling, so the air source heat pump is used only for heating during the summer months. In heating mode, the heat pump evaporates a refrigerant in the outdoor coil, pulling heat from the outside air. Once the gas is compressed it passes to the outdoor coil and condenses, releasing heat to the inside of the building. Energy savings occur through the use of selector boxes to control and/



Wall section describing details of the building enclosure

HEALTHY MATERIALS OVERVIEW

• Concrete composed of 20% fly ash reduces carbon footprint on a pound per pound basis

• Over 50% of construction waste diverted from disposal, recycled or reused

• Site-harvested character-grade maple used for wainscoting and gymnasium paneling Harvested on site and milled locally to support the regional economy, reduce travel distance and minimize resources needed to deliver wood to the site

• More than 50% of the wood is Forest Stewardship Council (FSC) certified, meaning it is sustainably harvested

• Recycled content make up 20% of materials used including structural steel materials and light-gauge wall framing, dense pack cellulose insulation and recycled rubber gym flooring as well as furniture used within the building

• Low- or no-VOC paints, finishes and adhesives used throughout the project

• Furniture upholstery is 100% post-industrial recycled polyester and can be recycled after use

• No chlorofluorocarbons (CFCs) used throughout the project

• 62% of construction debris recycled or reused

• Manual roller shades made of non-PVC screen cloth (a "Cradle-to-Cradle" product) block direct sun-light and reduce glare in south facing windows. Open fabric weave allows occupants to enjoy the view through the windows while shades are lowered.

or shut down individual zones as well as by preheating air in extreme cold.

Another aspect of the mechanical system is Energy Recovery Ventilation which is a controlled ventilation system that reduces energy loss. In winter, it transfers heat from warm inside air being exhausted to fresh (cold) supply air. In summer, it also supplies fresh air for ventilation and transfers water vapor to control indoor air humidity levels. Benefits of this system include improved indoor air quality through fresh air introduction and reduced energy from heat transfer. Small ERV's are used for the offices and a larger one located in the mechanical room serves the remainder of the building.

To reduce energy use further, a networked building automation system was installed maximizing the building's efficiency and occupant comfort (lighting, heating, cooling, and ventilation). High-performance energy efficient light fixtures and low energy equipment motors were also selected. All lighting fixtures are on occupancy and daylighting sensors and all building ventilation is on occupancy and carbon dioxide sensors. Though the building can

March 2010 energy bill showing a credit of $69 based on the PV panels producing more energy than the Field House used

be programmed to function almost on its own, one of the most important aspect to remember in designing a Net-zero building is teaching the client how to use the building. The new building becomes a dynamic environment which responds to outdoor conditions, which is often a completely different experience for users that are used to opening the window when it is warm out and turning the lights on when they enter a room. Developing a comfort in the users so they can determine when the building is performing right or wrong can make a large difference in use patterns which relates to energy costs in the future.

Putney students collecting wood from the school grounds

RENEWABLE ELECTRICITY

To achieve Net-zero goals a substantial investment in renewable energy sources was required. Various building mounted and site mounted solar electric photovoltaic options were studied, priced and assessed for performance, long-term value, cost and aesthetics. 36.8 KW of solar tracking collectors were eventually selected from these options and installed on the north side of the Field House in an open field with full southern exposure. The Vermont Clean Energy Development Fund provided $184,000, almost 50% of the funding for the purchase and installation of the PV system. Maclay Architects assisted the owner with the process.

MATERIAL EVALUATION & SELECTION

Throughout design we continuously offered the School choices in material and equipment selection to be used in the building. We conducted a thorough product and material research process examining functional performance, LEED point contributions, cost, durability and lifespan. Given the collaborative process, we assembled comparative worksheets which were presented to the school community for review during school workshop days. By collaborating with consultants, vendors and our construction manager we found high value solutions addressing durability, appearance, environmental performance and cost.

INDOOR ENVIRONMENTAL QUALITY

To achieve exceptional indoor environmental quality a number of measures were taken in terms of indoor air quality, daylighting and views. Operable windows and windows on automatic operators allowed for natural ventilation and night-time flushing of interior air as well as no air-conditioning. All composite woods are formaldehyde-free. The building's interior environment meets the ASHRAE indoor air quality standard and includes CO2 monitoring as well as ample opportunities for daylighting and views. Fixed, light-redirecting louvers were installed in the gym clerestory to deliver daylight deep into the Field House, reducing the need for artificial lighting and lowering heat loads on mechanical systems. Adjustable light redirecting window blinds from Warema are installed in the Social Space to enhance daylighting. For solar glare control, Eco Veil roller shades are located on south facing windows. An exterior mounted, motorized, fabric window awning reduces solar gain and undesired glare on west-facing windows. Networked building automation systems maximize the building's efficiency and occupant comfort (lighting, heating, cooling, and ventilation).

KEY LESSONS LEARNED

- **The Choices Process:** The "Choices for Sustainability" process can help to set the design and construction process up for success. By doing the upfront analysis and giving choices to the client, everyone is able to stay on the same page throughout the process as well as fostering a strong sense of teamwork.
- **Keep it Simple:** Keep choices of individual sub-systems simple, durable and less complex to allow easier integration with other systems, easing building performance and operation.
- **Educational Signage:** Informative and interesting signage helps to extend the message of a green building and can reinforce the mission, values and brand of the organization as well as helping to achieve a LEED innovation point.
- **Commissioning Buildings:** Manage early involvement of building commissioning professionals by having them truly review drawings and specifications at early and later stages. Build accountability into the process.
- **Completing and Submitting LEED:** Be proactive about managing the process upfront with clear deliverables, schedules and incremental progress reviews.
- **Values Driven Process with LEED:** Provides a neutral, shared standard helping to focus team on goals and shared outcomes.

EARLY BENEFITS TO THE PUTNEY SCHOOL

While the Field House has been operational for less than a year, the school has seen some early benefits. In the middle of January, they held their first ever home basketball game. The building is being used consistently from 7am to after 10pm (The online building software measuring energy use shows this). They are giving lots of tours to outside visitors interested in exploring the building. Potential students and their families are deeply impressed by the Field House and the commitment to sustainability it shows. With the Field House completion, Putney has seen a three-fold growth in media exposure. And most importantly, it has seen its first negative power bill for March of this year. As the sunnier summer approaches, the power bills should progressively continue into the negative until the fall when it cools again, with the end result we anticipate a Net-zero building on an annual basis. Inspired by this result, the Putney School has decided to extend their vision to begin an all campus energy masterplan which potentially will begin later in the year.

CONCLUSION

The example of the Putney School Field House and its "Choices in Sustainability" process demonstrates that it is possible to design and build Net-zero school buildings today even in Vermont's challenging climate. As Net-zero buildings become more prevalent, practical knowledge on how to get to "Zero" will continue to grow. Sharing how this building was conceived, designed and built will serve as a model for others to follow today. By pursuing the steps of adopting building performance metrics, reducing building loads to renewable ready standards and adding renewable energy sources appropriately, we will all have a better chance at a more predictable, sustainable, and carbon reducing future using the Net-zero model.

ENDNOTES

1. New England Association of Schools and Colleges Commission on Independent Schools, Report of the Visiting Committee 4-19-4/22, 2009, 3
2. Environmental Information Administration (2008(, EIA Annual Energy Outlook.
3. Energy Information Administration (2008), Assumptions to the Annual Energy Outlook.
4. Environmental Information Administration (2008(, EIA Annual Energy Outlook.
5. Maclay, William 2009. "Net-zero Buildings: Providing stable returns in an unstable world" found at http://www.maclayarchitects.com/images/stories/pdf/Zero_Energy_Buildings_Stable_Returns.pdf, accessed June 1, 2010.

Photography Credits: The Putney School and Maclay Architects

Full Project Team: Owner - The Putney School, Architect - Maclay Architects, Construction Manager - DEW Corporation, Civil Engineer - Heindel & Noyes, Landscape Architect - Cynthia Knauf Landscape Design Inc., Structural Engineer - Engineering Ventures, Energy Consultant - Energy Balance, Lighting Design - Naomi Miller Lighting Design, Mechanical, Plumbing & Fire Protection Engineer - Kohler & Lewis, Electrical Engineer - William Bissell

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Maclay Architects specializes in creative, healthy and ecological architectural design. Firm President William Maclay, AIA, LEED-AP, has been recognized as a leader in green building design for more than 35 years. Through its team of LEED-accredited professionals, the firm offers a full range of architectural services for all phases of residential, commercial and institutional projects.

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