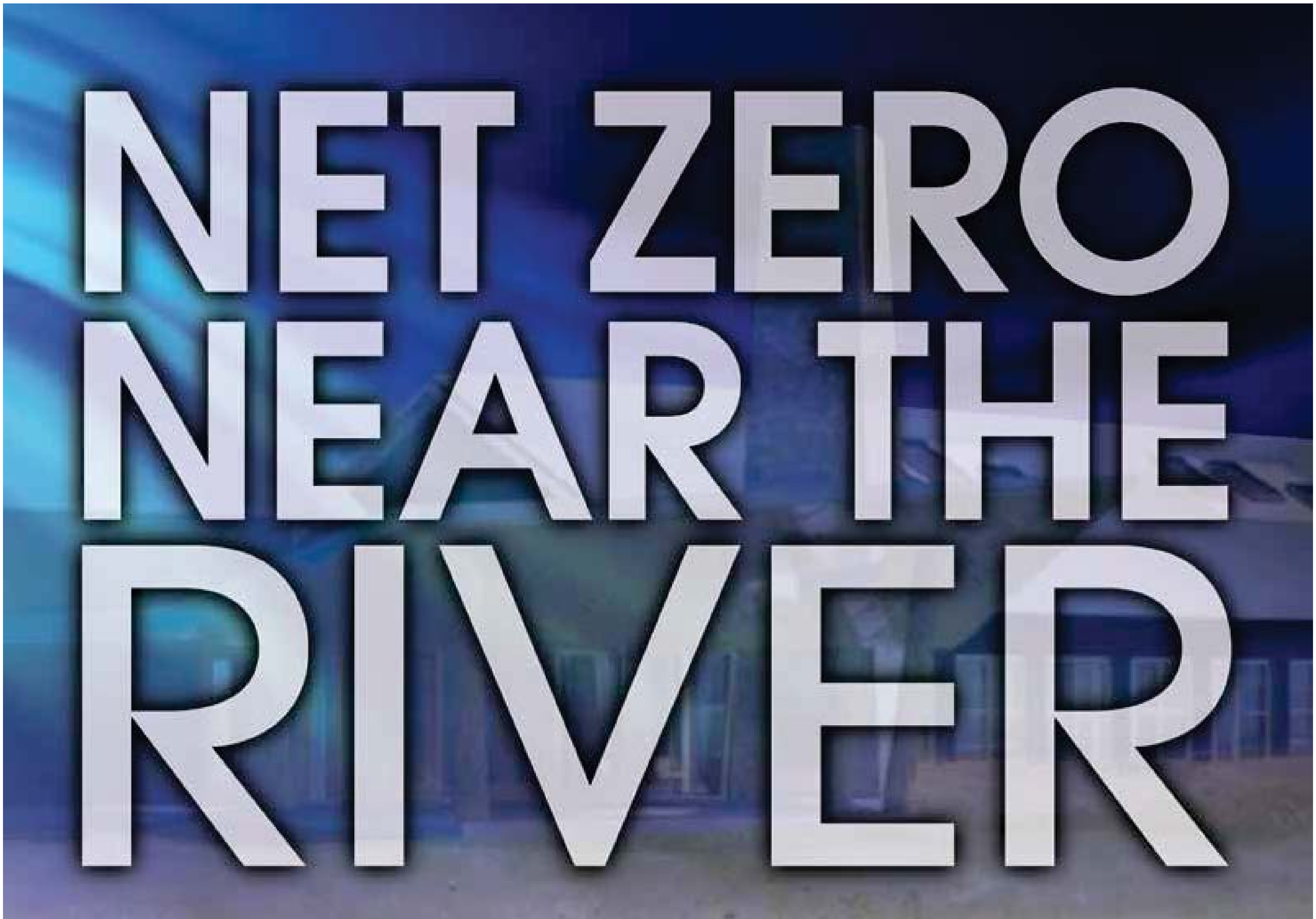
NET ZERO NEAR THE RIVER



A 70-structure campus at the top of the Mississippi has been in need of a serious retrofit. We join this major project in progress, studying not only the design selections but the tradeoffs and sacrifices along the way. Equally relevant, even a committed project team meets some tricky currents on the course to LEED success. Follow this particular team as they made headway at the headwaters.

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The University of Minnesota's Itasca Biological Station and Laboratories is one of the regions premier inland biological field stations. Located on the eastern shore of Lake Itasca, the campus is walking distance to the headwaters of the Mississippi River. Established over 100 years ago, the biological "station" is actually a small campus owned by the University of Minnesota and operated by the College of Biological Sciences. The campus comprises 70 northern Minnesota rustic-style buildings that have been used to support field biology courses and provide living quarters for students and teachers. However, while they have exceeded their life expectancies, they have consequently also come to need a variety of repairs.

With an eye toward updating the largely untouched and deteriorating infrastructure, the University of Minnesota, in 2006 and again with an update in 2009, developed a Master Plan for the redevelopment of the campus, charting a path toward a "… vibrant and sustainable future for the Itasca Biological station." The spirit of the plan was to capitalize upon the strengths of the existing infrastructure, respect the historical significance and the environmental character of the buildings on the campus, but to also demonstrate a plan toward becoming "…a net zero energy, self-sustaining community."

MASTER PLAN AND GOALS

The 2009 Master Plan noted that a key to a renovated, updated sustainable campus would be the development of a new campus center that would replace three obsolete buildings and would provide approximately 11,000 sq ft of new classrooms, laboratories, administrative offices, a library, and a multipurpose/lecture space. Such a campus center building would serve as an

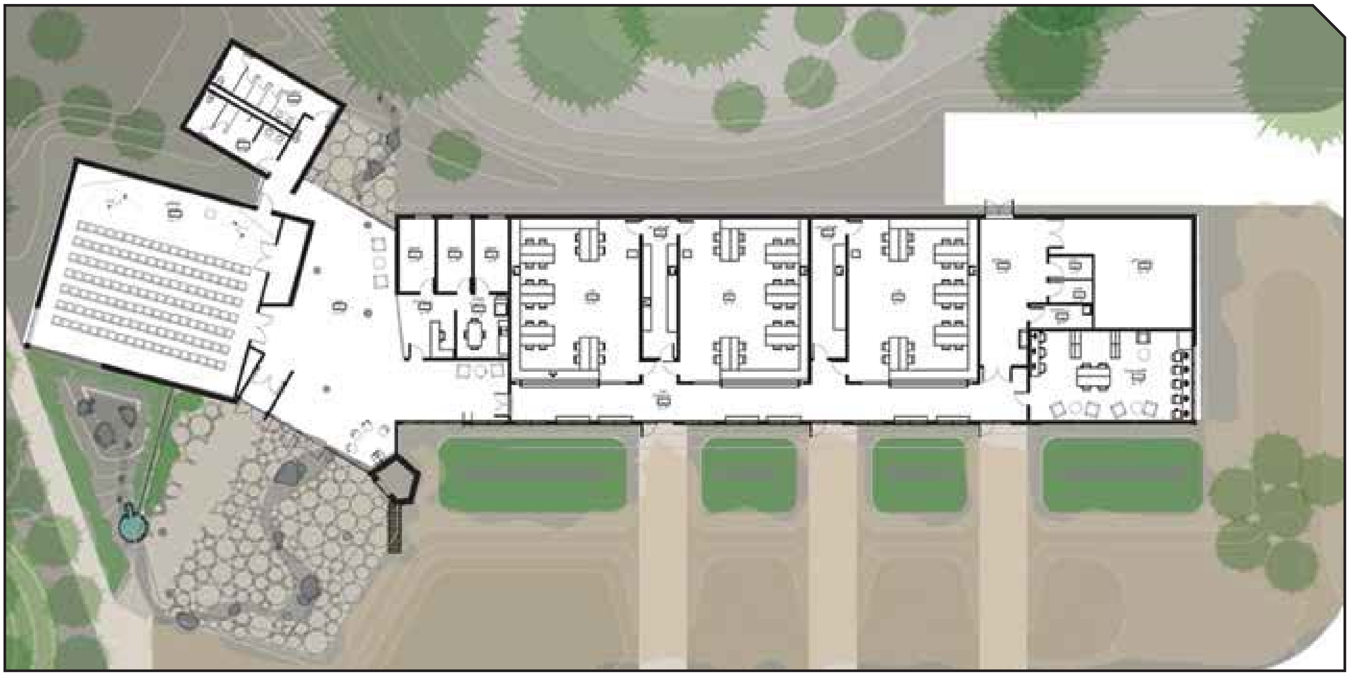

FIGURE 1. The floor plan for the University of Minnesota's Itasca Biological Station and Laboratories.

academic focal point for the campus' students, faculty, and visiting lecturers as well as represent a model for the campus' future sustainable development. With the intent to be a net-zero energy building, one of those goals will be embodied in the campus center itself, thus furthering the overall campus goal of sustainability and energy independence.

Reflecting on the experience of being principle contributors to the design of the Itasca Biological station allows for examination of the process of designing a net zero energy building. Of particular interest here was the collaborative effort used by the design team, with an emphasis on the mechanical and electrical approaches to reaching our team's design goals. First, we will share the initial goals and metrics used to define net zero energy, and then address the reconciliation of our net zero energy goals with the available budget. Finally, we will compare the final design with the initial project goals.

The design team realized early on that the key to the development of a high-performance building would be in the implementation and management of a committed integrated design approach. The first step in this process was a pre-design retreat, an intense but rewarding two-day session at the campus for the purpose of developing a roadmap to move us through the design process. Day one of the retreat was spent walking the campus, meeting with staff and touring the campus infrastructure, gaining a better understanding of the needs for the campus in general, and the campus center in particular. A good deal of time was spent at the proposed site of the campus center, gaining a better understanding of building orientation and site issues.

Day two of the retreat focused on goal setting. We convened a full day meeting attended by representatives of the campus, including the campus' director of the field station, and the design team consisting of the architect, mechanical, electrical, and structural engineers, the technology consultant, and landscape architect. The university provided its own internal commissioning team which was present at the retreat, as were representatives of the University of Minnesota's Center for Sustainable Building Research, the project's sustainability consultant. The mechanical engineering group provided the energy modeling expertise.

The goal setting began with a broad discussion of what constitutes a net zero building. While net zero has a number of definitions as a project goal, the Itasca Biological Field Station defined its goal as no overall energy consumption over a typical weather year under typical usage by the university. The building would be attached to the local energy grid with the capability to draw energy from the grid when onsite demand is greater than generation capacity, or to feed the grid when demand from the building is less than what onsite generation is producing.

Energy Utilization Intensity (EUI) goals were established at this meeting. We agreed to the goals and benchmarks as set forth in the 2009 Master Plan. In addition, we would comply with the State of Minnesota's sustainable design requirements for publically funded buildings (known as Minnesota Sustainable Building 2030 (SB 2030) energy standards), and would strive to achieve LEED Platinum, NC v. 2009. To assist in EUI goal setting we looked at case studies of existing high-performance buildings. We reviewed information published by the National Renewable Energy Laboratory (NERL) as well as published information on the Aldo Leopold Legacy Center. For this project our team established 20 kbtu/sf/yr as the EUI goal.

The discussion also settled on specific MEP design goals for the project, including the following.

- The building envelope will have a wall insulation value of approximately R60 and a roof value of approximately R70.

FIGURE 2. The university lab design included a number of energy-saving applications, including a dedicated outdoor air system and photovoltaics. Energy modeling predicted that the building would exceed the proposed energy baseline by 50%.

- All occupied spaces shall be provided with natural daylight.
- All occupied spaces shall have capability of natural ventilation, given the climate conditions of the site.
- The common lobby area and the lab corridor, known as the "sun corridor," shall be minimally conditioned in winter and shall not be actively conditioned in summer.
- Ground source heat pumps shall be the source of winter heat/summer cooling. The system shall be designed to accommodate future expansion into the campus at large, and shall include an exterior vault sized to handle a future expanded geothermal well field for this purpose.
- Sensible heating and cooling shall be served by a radiant floor slab and zoned per major group occupancies.
- Ventilation shall be served by a DOAS, which shall deliver conditioned outdoor air to each occupied zone via displacement ventilation floor diffusers. The outdoor air flow rate is based on zone level CO2 sensors. The DOAS unit is provided with total (sensible and latent) energy recovery.

SOME TOUGH CHOICES

Geothermal was an easy decision for the team as natural gas was not available on-site. When compared with the alternative of propane for heating and condensing units for cooling, as was current method of conditioning campus buildings, geothermal stood out as the best alternative. Geothermal also allowed for expansion to other campus buildings, consistent with the overall campus master plan. A previous conductivity test, and successful use of the test well to later be the borehole for a small water to air heat pump for a cabin, gave the campus director confidence that geothermal would be reliable, easy to maintain, and would serve the overall campus well.

Radiant heating and cooling then followed as a perfect strategy for this project. The low energy temperatures of a radiant system provided optimal energy efficiency as well as optimal comfort. Radiant cooling would be a suitable means to serve the sensible cooling loads, while the DOAS handled the latent loads and supplemented the sensible cooling on peak cooling days.

Beyond the building's high-performance low-energy mechanical systems, a photovoltaic (PV) system was determined to be the best option for an on-site renewable energy source sized to produce energy and meet the building's demand goals.

Other strategies were discussed at the retreat but placed into a "to be considered" category. We had a defined budget, and certain decisions required us to take a close look at both first costs and lifecycle costs. Some of the more significant strategies considered at the retreat, but eventually eliminated from consideration, included the following:

- Biomass as an onsite renewable
- LED lighting serving the whole building
- Digital lighting control
- Composting toilets
- Grey water
- Solar thermal for domestic water (instantaneous electric heat was selected)
- Mechanically controlled windows for natural ventilation mode of operation (see below for further discussion)
- Power monitoring/measurement

Composing toilets was one of the difficult decisions to remove from the project. The campus is served by a traditional waste water system utilizing a lift station at the Itasca State Park. It

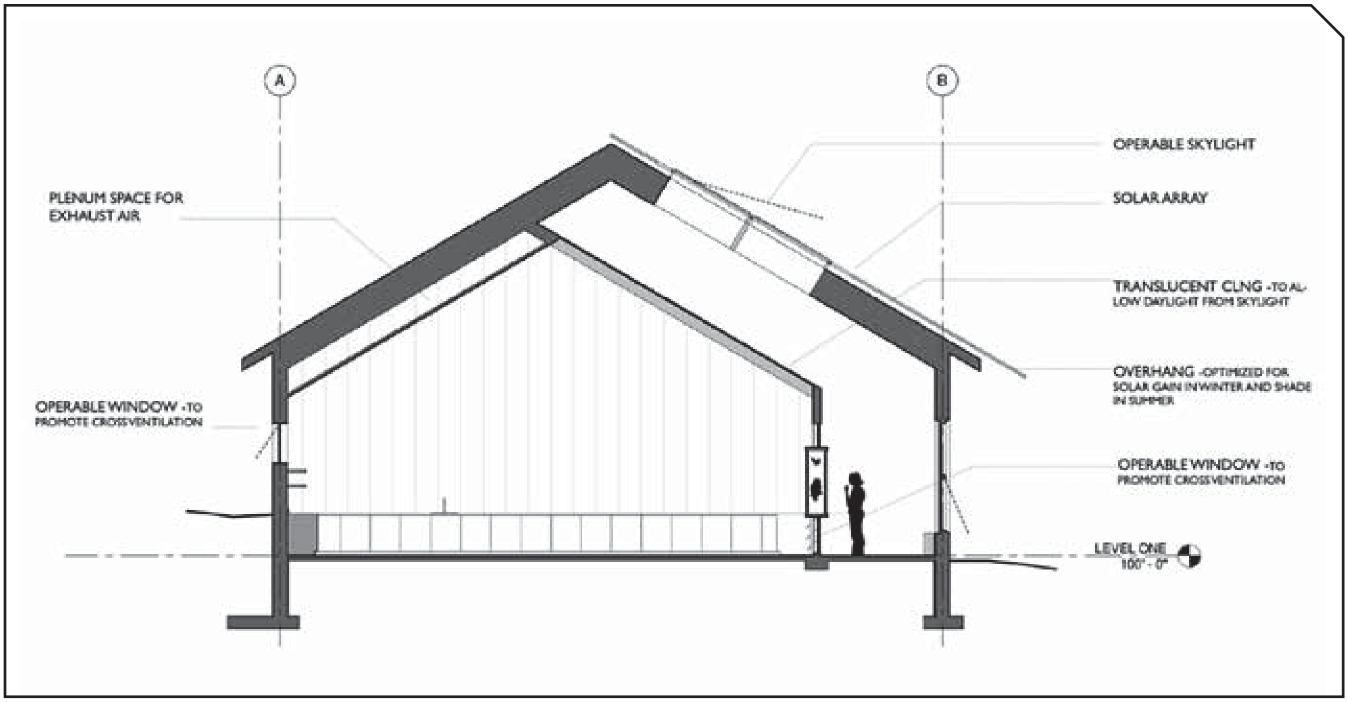

FIGURE 3. This cross section of the lab demonstrates the placement and installation of equipment for optimal energy savings.

would have made a significant improvement in wastewater reduction if the campus center were taken “off the grid.” Ultimately, concerns for maintenance and operation of a composting system, as well as first costs, prohibited that strategy from moving ahead. In all the following cases, decisions to eliminate strategies were made both by recommendations based on overall lifecycle cost analysis, and through the construction manager’s value engineering process where first costs were deemed too high, and where alternative systems were available that met the overall intent of the project goals.

The other difficult decision was to eliminate the power metering of each major system (lighting, plug loads, HVAC). The team understood the importance of this metering for a net zero energy building, but ultimately, due to budget constraints we decided that metering would be added as funds were available, outside of the construction budget.

DEBATES: NATURAL VENTILATION AND PV ARRAYS

Once the optimal building system types were determined, and as the design progressed, the gradually enhanced energy model became a key design tool to assist the team in optimizing the components of construction, including the PV array. With the strategy of PV offsetting building energy consumption, there is a natural trade-off between building energy performance and the size of the PV array required to achieve net zero. The available construction dollars could go toward making the building more efficient or toward a PV array with a larger capacity. This is the basic premise of the question: What is the most cost-effective way to achieve net zero at the Itasca Biological Field Station?

To answer this question, the design team again turned to collaboration as a tool, relying on the expertise of the construction manager, the engineers, the architect, and the engineers’ energy modeler. A multitude of options were modeled through an iterative process to identify the trade-offs between combinations of building elements in order to optimize them. A super-insulated building with triple paned high-performance glazing would provide superior thermal performance that would reduce the size of the mechanical systems in the building, reduce the number of geothermal wells, and shrink the PV field, but the overall cost would exceed the project budget.

Ultimately, through the realization that the constructability and cost of the PV array on anything beyond what was available on the south facing pitch of the main roof, the capacity of on-site generation was determined to be optimal at 40 kW. This size of the PV field would produce an offset for our building with a EUI of approximately 18 kBTU/sf/year. The envelope, lighting, and mechanical systems were then dialed in to provide the necessary energy performance.

Since natural ventilation was a significant design element consistent with the overall project goals, the design team had to decide how to incorporate it into the design. This challenge was also considered a risk to the project since natural ventilation, when not beneficial, can hurt energy performance. Through typical meteorological year weather bin analysis, the benefit of perfectly optimal natural ventilation had the potential to reduce energy usage by 4 kBTU/sf/year. In order to ensure optimal use of natural ventilation, that would require complete automation with no manual control. This was not acceptable to the university, nor was it in the project budget. When confronted with the trade-off of accounting for this in the energy model, the university agreed to take on the risk of sub-optimal manual control of the natural ventilation systems. If the build-

Energy Performance Targets in kBTu/SF/Year

Energy Star Median for Existing Buildings	LEED Baseline (Energy Code Performance)	LEED Energy Model	Actual Energy Model without Natural Ventilation	Actual Energy Model with Natural Ventilation	Optimal Site Photovoltaic Electric Production
116	57.1	27.8	21.4	18.0	18.0

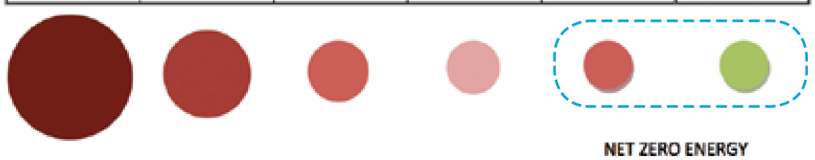

FIGURE 4. Energy performance targets in kBTU/sf/year.

ing occupants don't use the natural ventilation systems when they are advantageous, or use them when they are disadvantageous, it will put the building into a net consumption energy profile. See Figure 3 for a building cross-section at lab space illustrating use of natural ventilation.

Throughout the process, BIM tools were utilized to share information across all disciplines of design. Using SketchUp and Revit as common BIM tools, the architects and engineers could easily share modeling information, allowing both groups to independently create energy, daylight, natural ventilation, and thermal mass studies sharing the same base model. As one of the final checks to the PV array design, a shading analysis was conducted through Revit. This analysis showed that a tall spire designed to be a prominent architectural feature of the building would shade parts of the PV array throughout the day. When even a small corner of a PV panel is shaded, the panel's ability to produce electricity is greatly reduced. The spire had to be redesigned so that maximum production of the PV field would not be impeded by shading, and the net zero goals of the project could be achieved.

LOOKING AHEAD AND BEHIND

Since this project was funded by a public University in Minnesota, it was required to achieve LEED certification and meet the state of Minnesota's SB 2030 goals. The submission and approval process includes creating an energy model that includes strict guidelines as to how the building's components are modeled. For the Itasca Biological Field Station, a number of the nuances required in LEED modeling conflicted with how the building would actually be used, and largely for the worse. This required the creation of a separate energy model from the one that would be used for certification and the other used for design.

The conclusion of this effort paired an optimal photovoltaic field for the building's design with an aggressive yet attainable modeled energy performance that would match in an average weather year. Variations in weather and usage are anticipated, but mathematical perfection in offset is not a productive goal on this project. In summary, over the life of this building, the total energy used less the total energy produced will be negligible compared to a building designed for standard modern performance. As indicated in Figure 4, the final design energy model shows that the team met our original EUI goal of 20 KBTu, with LEED energy modeling indicating the proposed building would exceed the baseline by over 50% (based on ASHRAE 90.1-2007).

Presently, the project is under construction. The scheduled date of project completion is December 2014. The project is on the borderline between LEED Gold and LEED Platinum (LEED design credits have yet to be submitted).

The road to achieve our attempted goal of net zero energy has often been difficult. It required commitment from all team players to actively participate in the decisionmaking process, and it frequently demanded compromise on long-held beliefs. Team players often had to step out of their comfort zones in making decisions. We have learned that developing a net zero energy project requires early, active, and continuous collaboration, including the contributions of the construction team during the design phase. It is not a linear process, but often iterative. It sometimes requires spiral thinking, re-evaluating various options until the right solution becomes apparent.

It is our hope that upon completion of project commissioning, we will be able to revisit the project and present a follow-up report that focuses on operation and building performance and how well the operation matched the team's goals and modeled expectations. **ES**

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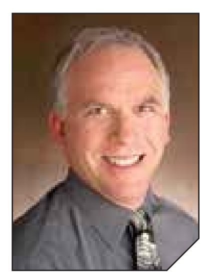

James Miller has ten years of experience in the design of mechanical systems and energy analysis for new and remodel construction projects. As the engineer of record on the Itasca Biological Field Station, he led the mechanical design efforts. His project tasks included energy modeling, options identification and optimization, design and projection, and will include construction administration through the completion and close-out of the project.