Increasing the Sustainability of Energy Research Laboratories

Flad Architects

A holistic approach to mitigating and offsetting the power demands of laboratories exploring sustainable energy solutions.

As the consumption of non-renewable resources continues to create significant environmental, social, and economic stress, the need for meaningful progress in sustainable energy research has never been more pressing. The scientific community is responding to that need by focusing increased efforts on renewable energy sources, including biomass, biofuels, fuel cells, wind energy, solar energy, and smart grid technologies.

Many organizations have determined they must either expand existing laboratories or create new, state-of-the-art facilities to meet the demands of their investigations. However, when making the decision to design and build a new laboratory, energy related research scientists are often faced with the challenge of balancing the needs of their research with their dedication to the responsible use of resources.

Scientific laboratories consume up to ten times more energy and water than standard commercial office buildings, making the spaces in which the research is conducted not just part of the solution but part of the problem. Labs are faced with additional energy drains, including higher air change rates, greater exhaust requirements, and increased levels of ambient light, as well as sensible heat loads emitted from lab equipment and computational servers. Further, as much of the lab equipment is highly specialized, there is a lack of energy efficient options to enable conservation.

Even if a research organization chose to view the laboratory's energy and water consumption as if it were "the price we must pay" for advances in this arena, they could find themselves bound by city, state, and federal mandates. Increased societal awareness of sustainability issues has fostered a growing trend of legislation dictating environmental standards for new construction. In the United States, an increasing number of governmental agencies are adopting polices either encouraging or requiring the use of "greener" building standards – affecting laboratory construction in those areas.

When sustainability is a core belief of an organization, as it is with most in the energy research arena, aligning a new state-of-the-art laboratory facility with that core belief can be a complex challenge.

This paper will focus on strategies for mitigating and offsetting energy use in high performance energy research laboratories by focusing on energy efficient and cost-effective synergistic initiatives implemented on a recent project.

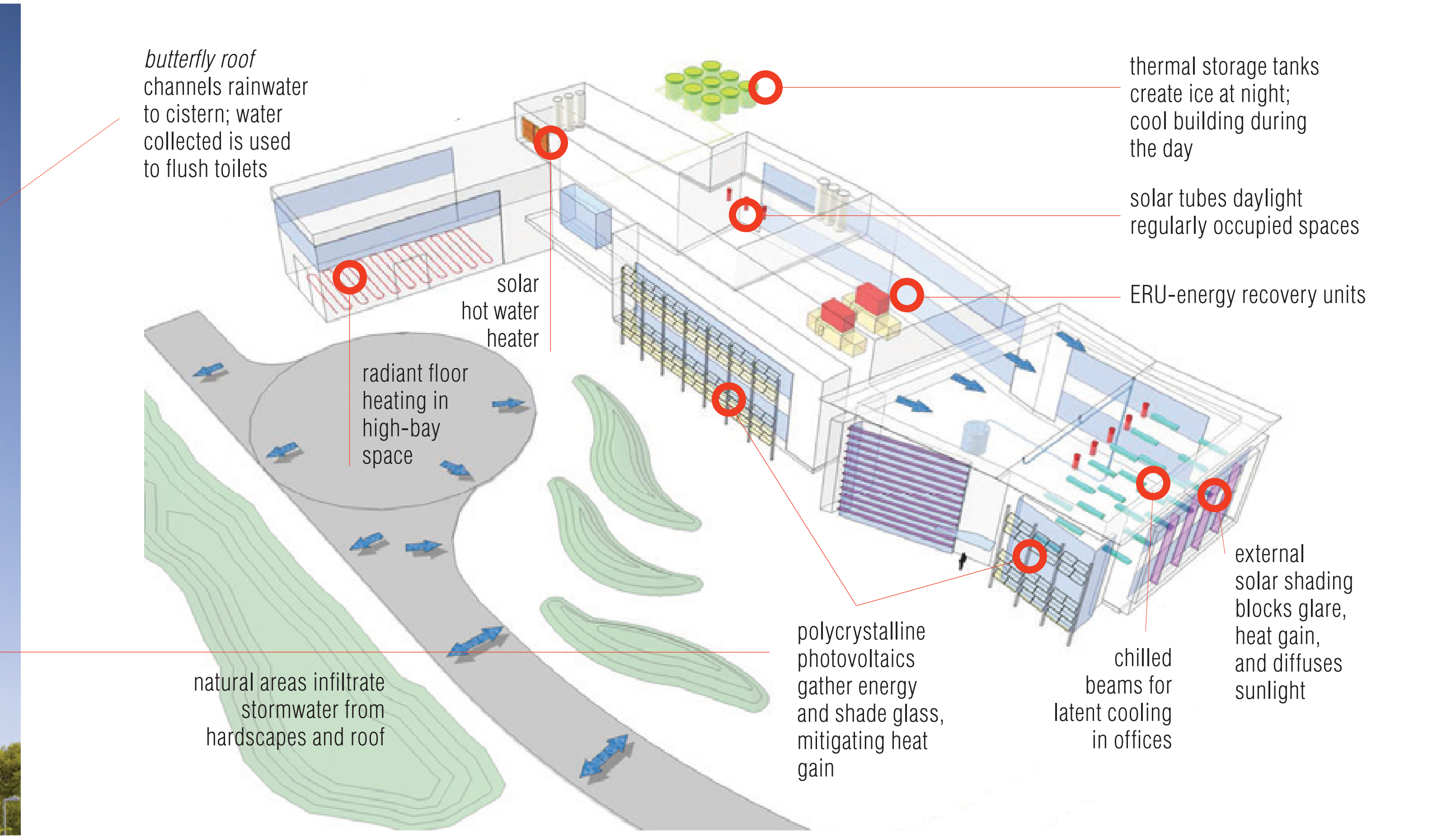
Located on Long Island in New York, Stony Brook University's Advanced Energy Center partners universities, research institutions, energy providers, private industry, and national Department of Energy (DOE) laboratories to develop advanced, cutting-edge technologies to explore more ways of producing clean energy, enhancing production from renewable sources, and finding efficient methods for distributing and storing energy. The facility's objective is to support a variety of interdisciplinary, flexible laboratories and technical spaces for researchers performing highly specialized investigations into solving the nation's next generation of energy issues.

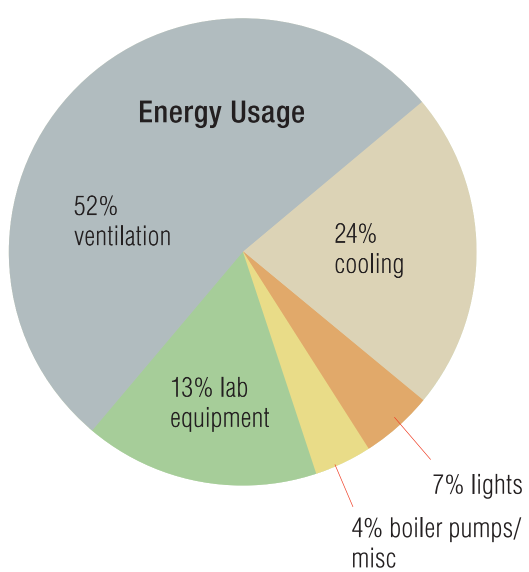
The facility concentrates on five scientific thrust areas which include: renewable energy systems, hydrogen energy, fuel cell technology, biofuels, and smart grid applications. Core laboratories supporting the Center's flexibility include a solar optics greenhouse, chemical synthesis lab, a Nuclear Magnetic Resonance (NMR) suite, and high-bay demonstration scale space, as well as nanotechnology and microscopy labs.

The site for the Center is part of a new research and development campus, exclusively designed to house private development and academic partnerships. Independent of the University's current infrastructure, this site does not have central utilities or municipal sewer systems, creating opportunities for forward-thinking, high-performance buildings. Other utility concerns for the site included mitigating increased "peak" utility rates imposed by the local utility during high-use periods.

Stony Brook University's commitment to campus sustainability has led them to initiate a wide range of successful environmental initiatives, including implementing a water conservancy pilot program, installing solar powered lights at mass transit stops, and using only biodegradable consumer packaging and utensils in all of its food service locations. In addition to Stony Brook University's initiatives, the State of New York has an aggressive Executive Order curbing energy utilization in all State-funded projects.

Consistent with the University's environmental initiatives, the State's Executive Order, and the scientific mission of the Center itself, the design and construction of the facility incorporates multiple sustainable design principles to meet its goal of Platinum certification, the highest level of certification attainable in the U.S. Green Building Council's (USGBC) LEED® (Leadership in Energy and Environmental Design) program.





Platinum certification is a significant recognition that the building and its energy utilization meet the highest level of quality regarding energy performance, as well as occupant health, improving employee productivity, and water usage; effectively reducing the overall impact on the local ecosystem while reducing operating costs to the owner.

The Center is in the final stage of processing its certification, receiving two points more than the amount required to achieve LEED Platinum certification. Once certified, it will not only be the first LEED Platinum project on Stony Brook University's campus, but one of only a handful of Platinum certified high level science laboratories in the nation.

In this case, a Platinum certified project equates to reducing the overall energy and water consumption of the building by approximately 40 percent from the baseline set forth by ASHRAE (the American Society of Heating, Refrigerating and Air-Conditioning Engineers). This effectively allows the lab to behave and consume energy resources as if it were an office building.

Design Strategy

From the beginning of the development process, the design team determined that no solitary tactic could compensate for the Center's increased energy consumption. Therefore, the design team used a holistic design and engineering approach to the

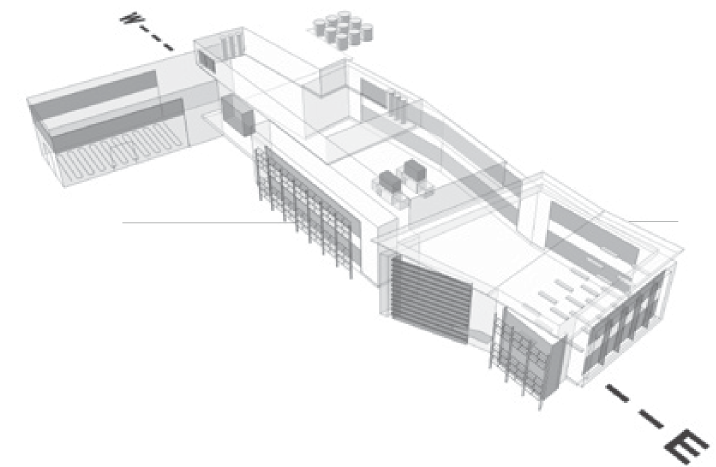
project, utilizing multiple applied energy reduction strategies, functioning in concert to create a synergistic effect. The design team determined that combining these energy efficient strategies with on-site renewable energy initiatives was the best means by which to achieve the greatest integrated response – one that was superior in performance to a series of individual tactics.

The design team focused on a balance of qualitative environmental responses and a quantitative energy efficiency and economic strategy. In order to achieve Platinum certification on this project, each sustainable design strategy was evaluated to ensure it was not only producing financially sound results, but that all strategies worked in harmony, leveraging their effects and compounding the collective impact.

The science and mission of the facility will change over time, but the building and its performance will endure and improve throughout its existence. The design team not only needed to plan for flexible labs, it needed to plan a flexible mechanical system, coupled with a high performance building envelope which can scale up or down as power and performance demands require. Long-term sustainable solutions were created by employing appropriate high performance environmental engineering systems through a calculated process of design, planning, and systems integration.

Flad Architects selected seven principles to govern the interwoven strategies for our holistic sustainable design approach.

- Optimize the facility's performance, exterior shading, and the use of natural light, through an analytical determination of the Building Orientation on the site.
- Offset energy usage during peak demand periods by Capturing Energy with building-integrated photovoltaics (BIPV).
- Implement passive design strategies and install occupancy sensors to control the use of the lighting, ventilation, and exhaust systems for both the office and lab spaces, as part of Facility Planning.
- Utilize a white roof for Reflecting Light and diminishing the "heat island" effect on the surrounding microclimate.
- Cooling spaces through hydronic distribution and recovering energy from exhaust streams to pre-condition intake air, as part of the HVAC Strategies.
- Hedge peak energy rates and pre-condition water with Thermal Energy.
- Provide real-time energy and water utilization data to Empower Users to participate in maintaining and improving the building's performance over the course of its life.



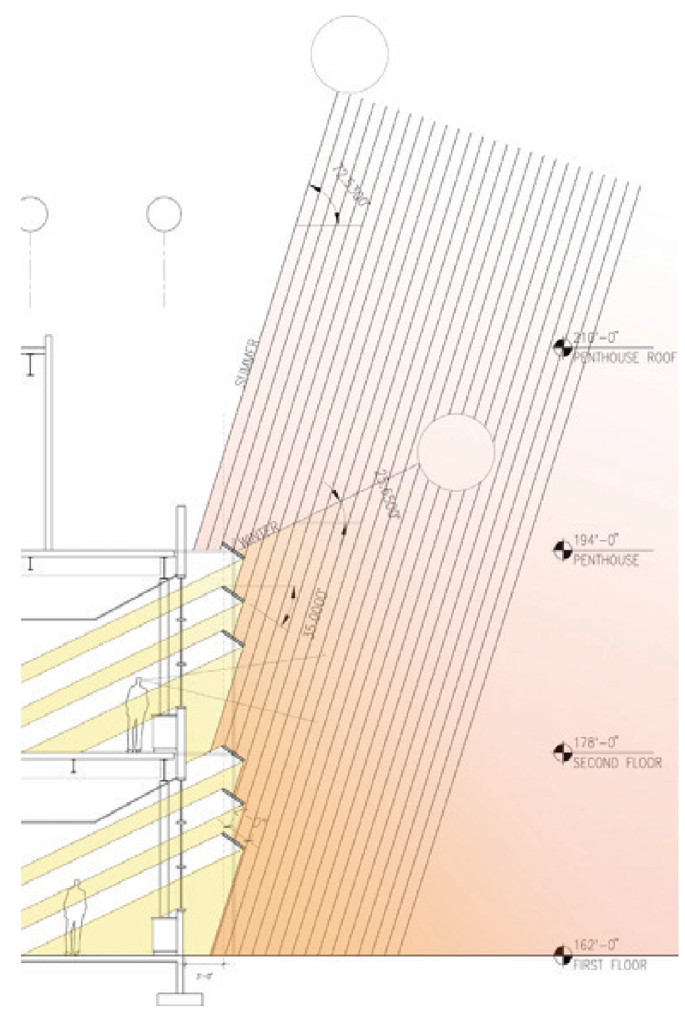
Building Orientation

Quality daylighting and correct solar building orientation are considered the cornerstone for all sustainable building architectural responses because they enable many other energy conservation and performance efforts. A building's orientation will directly influence peak heating, cooling, and artificial lighting loads. Designers must create an artful balance between the use of natural light for illumination and the containment of the thermal impact of that light.

By studying solar orientation, shading, and incidence, as well as seasonal solar energy availability, a designer can unleash the potential energy savings of a building. Architects and engineers today are well equipped to run computational analysis early in the design process, using programs such as EcoTect™ and eQUEST®. These programs help design teams to understand the benefits of local climate and meteorology, allowing designers to provide owners and users a detailed model of each design idea, as well as its impact, cost, payback terms, and how it can be holistically integrated into other design strategies. By bundling this information together, designers and owners can collaborate to review complex solutions, and their respective costs, to reach informed decisions regarding sustainable design.

In the northern hemisphere, low angle morning and evening sunlight is the most difficult to control using exterior shading devices. This can also be the most common source of glare, causing occupant discomfort. For the Center, Flad Architects utilized a dominant east-west building orientation allowing us to minimize low-angle light penetration in both the morning and late afternoon by facing short façades toward the sun on both the east and west sides of the building. This not only mitigates user eye strain, but maximizes the exposure of the building in the north and south directions, which can be used to positively affect both the building's performance and occupant satisfaction.

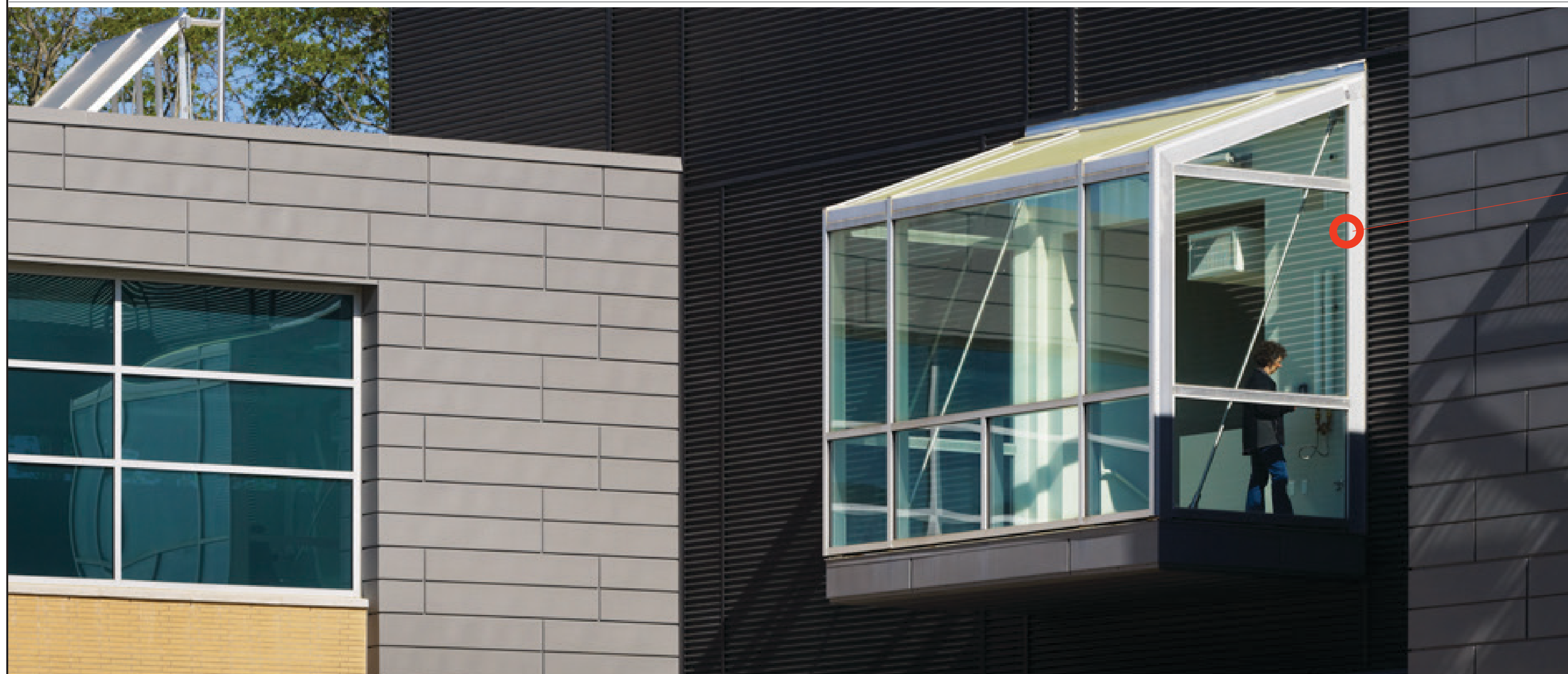
During summer days, when the path of the sun is higher in the sky, the Center utilizes shading devices on the windows and south façade to reduce unwanted heat gain, thereby diminishing the amount of energy used for cooling. During winter months, the path of the sun is lower in the sky, allowing the sunshine to bypass the shading devices to increase light penetration into the building, thereby diminishing the amount of energy used for heating.



Capturing Energy

Providing shading for windows is not a new concept. As described above, using awnings and other architectural features to reduce sunlight penetration reduces the solar impact on the interior space. This has been part of the architectural response for millennia. However, only recently have architects and engineers been able to work together not only to block light from overheating interior spaces, but to capture that solar energy and utilize it to fuel the cooling systems of the facility itself.

All too often photovoltaic cells have been relegated to inconspicuous locations on the roofs of buildings. Their bulky encasements have been widely viewed as non-aesthetic architectural elements to be masked from view. However, with recent advancements in the production of photovoltaic and other solar cells, such as thin-film, they can find usefulness in unexpected applications.



For the Advanced Energy Center, Flad Architects designed multi-tiered shades to reduce sunlight penetration; however, these shades were composed of photovoltaic cells to capture that solar energy directed at the southern facing elevation, instead of merely blocking it. These BIPV sun shades and their support structures were incorporated into the overall design of the south façade, moving beyond their obvious function to become part of the overall design aesthetic of the built environment and becoming an advertisement for some of the renewable science research being conducted within its walls.

Working directly with the MEP engineering firm, Flad Architects estimated the solar shading effect of the feature saves approximately five tons of cooling capacity, or 6,300 kWh per year, while the energy created by the photovoltaic cells provides the building with 11,800 kWh per year.

During the University's off-season, the photovoltaic array can funnel unused energy back into the utility's grid to receive credit. Stony Brook University was able to participate with their local power provider to receive financial incentives for using PV and having measures put in place for putting energy back into their system. These energy optimization credits, in addition to other incentives, resulted in saving over $500,000 for this project. Beyond the statistical data lies a remarkable environmental balance. As with much of the Northeast, Long Island, New York, is subject to "peak" utility rates, where energy costs are higher when demand is higher, in late afternoon and in the summer sun. The elegance of this integrated design solution is that it generates the most energy when utility rates are at their highest, not only offsetting the use of that energy, but offsetting the increased cost of that energy.

Facility Planning

In conjunction with the building's solar orientation, facility planning helped maximize the Center's energy efficiency. ASHRAE guidelines require most laboratories to have from six-to-twelve air changes per hour (ACH) when occupied. Labs with higher solar gain exposure use more energy to maintain comfortable temperature and humidity levels. However, labs with higher ACH requirements use less to maintain thermal comfort. Striking a balance between solar gain and ACH frequency can provide energy savings.

For example, if heavy chemistry lab spaces typically need twelve or more ACH to maintain ASHRAE ventilation requirements, they can be located on the south façade. The energy savings for maintaining the air's conditioning in a higher ACH environment will mitigate the increased energy use for dealing with the solar gain. This particular planning strategy was implemented throughout the facility, ensuring the maximum return on the Center's energy investment in the laboratory spaces.

To achieve even greater compounding energy savings in all lab spaces, occupancy sensors were installed to determine if a particular laboratory or office space was in use at any given time. When occupancy is low, lighting, ventilation, and exhaust levels will be automatically reduced to the minimum amounts allowable for environmental and health and safety standards. These measures alone effectively contribute from 12 to 20 percent toward the facility's overall energy demands.

Reflecting Light

The standard practice of using a dark membrane roofing material with a low albedo (low solar reflectance) creates a cycle of localized energy and atmosphere related issues. The sun heats the roof, and, therefore, the interior temperature of the building. This increases the HVAC system demands, utilizing more energy to cool the building. Insulation and other materials are foiled as an effort to mitigate the problem, as these surface materials are eventually worn down by the constant exposure to the solar radiation, requiring ongoing maintenance and replacement over the life of the building.

To reduce this solar impact on the entire facility, the Center's design calls for a white, or "cool," roof. This concept uses a material with a high albedo to reflect both the infrared and ultraviolet light away from the building. As the high albedo roof does not experience the same dramatic temperature increase as a conventional roof, the HVAC systems use less energy compensating for the solar impact. Other benefits derived from using a cool roof include a reduction in the amount of insulating materials required, and reduced maintenance costs from deterioration caused by the ultraviolet light, as well as reduction or elimination of the building's contribution to the urban heat island effect.

From a carbon perspective, a study on albedo conducted by three current and former Lawrence Berkeley National Laboratory scientists (Hashem Akbari, Arthur Rosenfeld, and Surabi Menon) examined the impact of white roofs and surfaces on urban heat islands for almost twenty years, but in 2004 they decided to take a look at the impact on climate change. What they found was that every 100 square feet of roof area transformed from a dark color to white is the equivalent to offsetting the emission of one ton of heat-trapping, atmospheric CO^2.

Other Department of Energy laboratories suggest that the savings on cooling loads by using highly reflective roof surfaces are over 40 percent in the United States' South and Southwest regions, but in the Northeast and cooler climates, some of the savings gained by lowering cooling costs in the summer may result in higher heating costs in the winter. However, the investment for a highly reflective roof over a traditional dark membrane roof is minimal, many high albedo products are 10 percent or less in additional initial costs and, in warmer climates, the return on investment may be less than one year.

HVAC Strategies

Laboratories expend a significant amount of energy moving, exchanging, and conditioning air throughout the building. Most lab spaces require once-through air with 100 percent exhaust. Solutions for addressing this issue resulted from exploring the idea that it requires much less energy to move water than it does to circulate air. Some office heat loads can be conditioned through chilled water applications, such as using chilled beams.

Chilled beams achieve their cooling effect by convection. Located at the ceiling, they use finned elements through which chilled water is passed to remove heat from a space. Passive beams work with natural convection while active beams offer increased cooling capacity by using a fan to increase airflow over the element.

For the Advanced Energy Center, the design team selected passive beams for the office space to mitigate the heat generated by computers, copiers, and other equipment. With an energy savings of approximately $4,000 per year, the system will pay back its original investment in less than five years. Additional energy optimization was designed for the Center by employing energy recovery into the HVAC system. Depending on the season, a recovery system uses the exhaust air to pre-cool or pre-heat the outdoor intake air. As there are various types of energy recovery systems available, owners and users should educate themselves on the type of system which is most appropriate for their circumstances.

Thermal Energy

As an additional element to the facility's energy management plan, a thermal energy storage and solar-thermal system was implemented to help offset the expense of purchasing power at peak daytime rates.

Off-peak cooling systems, such as thermal ice storage, use electricity to freeze water in special insulated tanks that contain refrigerant-filled coils. These coils circulate ethylene or propylene glycol and a water mixture that is chilled to well below freezing. At night when energy demand is low, the water is frozen and is ready to be used to cool the air the next day during peak demand. Once the system is "charged," it requires very little energy to stay cold in stand-by mode until it's ready to be used to cool the air for the laboratory.

Thermal Energy/ Empowering Users

As the building starts to warm up during the hotter part of the day, the air-conditioning turns on, and the chilled refrigerant from the off-peak cooling system keeps the building's air cool. The glycol cycles through the ice-filled tanks periodically to cool back down after being exposed to the hot air, and eventually, this heat exchange melts the ice. At night, the system charges again, re-freezing the melted ice, and preparing the system for the next hot day. By shifting this portion of the air conditioning's energy use to off-peak hours, the cost of conditioning the air during the day is dramatically reduced. The thermal energy storage system will provide an energy cost savings of $11,000 per year or up to 6 percent of the facility's energy use.

Laboratories utilize a great deal of tempered and hot water for such activities as glassware washing and waste chemical dilution. The Center utilizes solar-thermal technology to precondition domestic water to offset power required to create hot water.

At its core, a solar water heater uses sunlight to warm water. The solar collector turns the sun's radiation into heat. There are two types of solar applications: active and passive. The one used on the Center is an active direct system; moving water through the solar collectors, which resemble photovoltaic panels, and then into storage tanks.

Both of these thermal applications contribute toward reducing the building's demand on power required to operate during those peak hours when utility rates are high and subject to brownouts. These two systems have contributed from three-to-five percent toward the building's energy optimization during the time of day energy rates are greatest.

Empowering Users

One of the most overlooked sustainability measures in an energy laboratory is knowledge. The client base for these types of labs demands the opportunity to be able to monitor and collect valuable data on how their research experiments can influence a building's overall performance. They also want to know how their own building or lab is performing relative to base code and other campus buildings. In addition to wanting to be housed in the best performing facility, they want to be able to understand how their facility is performing and participate in that performance.

Sophisticated energy monitoring systems, coupled with user-friendly interfaces, are allowing facility users and operators to monitor real-time and historical building HVAC performance data. People now want to understand, manage, and compare their building's resource consumption with

others, in real-time. Software and hardware enable a building's users to connect personal electricity, water, and natural gas consumption with the actions and events that take place within buildings.

The Advanced Energy Center will employ a touch-screen device in the lobby of the building for users and the public to become more aware of the facility's carbon footprint, its impact on the local ecosystem, its performance, and cost savings. With this information in hand, the users will be able to adjust their work practices to be more energy efficient.

Conclusion

By using a multi-faceted holistic approach, the design team was able to either mitigate or offset a much larger amount of the facility's energy use than by utilizing singular line item type strategies. Through optimized building orientation, managed light reflection, architectural shading, on-site energy production, thermal energy storage, and energy recovery, we are better able to help energy researchers represent their dedication to sustainability within their own facilities, while keeping them functional, responsive, and aesthetically fulfilling.

Each energy laboratory will have a unique thrust or combination of activities with varying scales of development. While there is no preordained approach to sustainable laboratory design, the local climate and power utility rates should forge a sustainability response which is most appropriate to that specific facility. As each facility is unique, every holistic sustainability solution plan will require a different investment and payback period.

Several dozen states, hundreds of municipalities, development authorities, and local utility companies are providing financial incentives and rebates working toward a more renewable and sustainable world, meeting the present needs of science without compromising the ability of future generations to meet their energy needs.

Through implementing a holistic approach to sustainable design, a facility can benefit from a greater response from the collected strategies working in tandem. Allowing a building to improve its performance throughout its lifetime enables an energy research facility to focus on solutions for our global and future energy needs while simultaneously reducing its own environmental footprint.