PERFORMANCE TAKES OFF

Airports are often the face of a community, the first and last impression for the traveling public. Millions of people pass through U.S. airports each day, making them some of the most visible of public buildings. Because of their high use, each material and building system in airport facilities has to be able to withstand the expected wear and extended use cycle.

Outagamie County Regional Airport in Appleton, Wis., capitalized on its involvement in a federal pilot program to maximize the sustainability of an addition to the airport, a general aviation campus. It used funding and “best practice” strategies for a new general aviation campus. The resulting facility achieved LEED Platinum certification and serves as an example that airports, despite conventional wisdom to the contrary, can be designed and built to high-performance specifications.

In 2011, Outagamie Airport was one of 10 U.S. airports selected by the Federal Aviation Administration (FAA) to participate in the initial Sustainable Master Plan Pilot Program. Sustainability Master Plans fully integrate sustainability into an airport’s long-range planning. They use baseline assessments of environmental resources and community outreach to identify sustainability objectives that will reduce environmental impacts, realize economic benefits, and improve community relations. This fits with Outagamie Airport’s vision to “use a people-centered approach to provide our community superior aviation facilities, custom solutions, continuous economic development and a proactive workforce that enhances our reputation as judged by our customers, employees, board members, and region.”
For the pilot project, the airport proposed to develop a demonstration project that could be used as a real-life case study. The airport previously had developed a strategic goal of becoming carbon neutral by 2030. The master plan identified a phased-in strategy to achieve this goal.

Using the planning goals set forth in the Sustainable Master Plan, Outagamie Airport moved to build a general aviation campus to the south of the commercial air service passenger terminal that serves corporate or private travelers in addition to aviation enthusiasts.

To date, no other aviation passenger terminal facility had been built using a net zero energy approach. Outagamie Airport went against this trend. It used LEED specifications to deliver a facility that performs to a level that facility operators feel can be tweaked over the next couple of years to generate more energy on-site than it consumes.

Tying advantage of existing infrastructure, the new campus includes the general aviation terminal, a corporate hangar and a storage hangar capable of housing multiple corporate jets. Additional hangars are planned for the future, including the relocation of an existing hangar on airport property.

Aviation-approved general contractors, because they usually only work on airport projects, are largely unfamiliar with high-performance building practices. Also, funding sources (state and federal) were unclear on what the impact of the energy-efficiency goal on facility operations would be. Similarly, the return on investment was unknown, and ongoing operational training for both owners and tenants alike would have to be provided. Because it ventured so much into uncharted territory, the Outagamie Airport project could be seen as a true demonstration project.

**Budget**

For its participation in the pilot program, Outagamie Airport received federal Airport Improvement Program funding for its planning. In addition, the construction of the facility received partial federal funding.

As part of the owner’s decision to pursue a net zero energy facility, the design team was retained to calculate the design premium and the return on investment for the various proposed systems. It was determined that the premium was about 20% and that the ROI for primary systems was seven years or less. It is difficult to compare square-foot costs, as this building is of a modest size (8,200 ft²) while many airport facilities are significantly larger. Thus, the economies of scale in terms of contractor pricing were not realized. However, the awarded general contractor was familiar with most of the building assemblies and provided favorable pricing. The $375/ft² costs for the Outagamie Airport’s new General Aviation Terminal are in line with larger terminal buildings with the highest level of finish, which was our programmatic directive for this project.

**Energy Performance, Sustainability Goals**

As part of Outagamie Airport’s commitment to sustainability, ambitious energy performance and sustainability goals were set for the General Aviation Terminal building. The energy performance targets for the building are:

- Achieve 80% total energy savings, including renewable energy systems, compared to a typical code-compliant building of its type.

**BUILDING AT A GLANCE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Outagamie County Regional Airport General Aviation Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Appleton, Wis. (105 miles northwest of Milwaukee)</td>
</tr>
<tr>
<td>Owner</td>
<td>Outagamie County Regional Airport</td>
</tr>
<tr>
<td>Principal Use</td>
<td>General Aviation Terminal</td>
</tr>
<tr>
<td>Includes</td>
<td>Server Room, Simulator Room</td>
</tr>
<tr>
<td>Employees/Occupants</td>
<td>20</td>
</tr>
<tr>
<td>Expected (Design) Occupancy</td>
<td>20</td>
</tr>
<tr>
<td>Percent Occupied</td>
<td>100%</td>
</tr>
<tr>
<td>Gross Square Footage</td>
<td>8,150</td>
</tr>
<tr>
<td>Conditioned Space</td>
<td>8,150</td>
</tr>
<tr>
<td>Distinctions/Awards</td>
<td>LEED Platinum-LEED BD+C: New Construction v3—LEED 2009, 2014; American Council of Engineering Companies (ACEC) Best of State/Grand Award, 2014</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$3,075,000.00</td>
</tr>
<tr>
<td>Cost per Square Foot</td>
<td>$375</td>
</tr>
<tr>
<td>Substantial Completion/Occupancy</td>
<td>August 2013</td>
</tr>
</tbody>
</table>

Above: Seen from above, the general aviation terminal is sited between hangar buildings without impacting solar gain for the photovoltaic array throughout the year.
• Ensure that the building’s energy consumption, beyond what is produced on-site, is emissions-free by purchasing renewable energy certificates and/or carbon offsets to meet the requirements for a Class D Net Zero Energy Building (NZEB), also known as a Net Zero Emissions Building. A net zero emissions building produces (or purchases) enough emissions-free RE to offset emissions from all energy used in the building annually. Carbon, nitrogen oxides, and sulfur oxides are common emissions that NZEBs offset. To calculate a building’s total emissions, imported and exported energy is multiplied by the appropriate emission multipliers based on the utility’s emissions and on-site generation emissions (if there are any).

In addition, the building was to be designed and constructed according to ASHRAE Standard 189.1–2009, Standard for the Design of High-Performance Green Buildings.

Design
The consultant and the airport agreed that the building’s core design idea should be performance driven, and every design choice—from the structural system to the exterior envelope to interior materials—was made to optimize performance.

To achieve the energy performance and sustainability goals, the General Aviation Terminal design incorporates many energy-efficient features, including:
• Optimal building shape, orientation, and thermal massing;
• A high-performance building envelope (roof, walls, windows);
• Enhanced lighting and daylighting design;
• A geothermal heat pump system for heating and cooling;
• A hot water radiant floor system, which is also served by the geothermal system;
• An air-to-water heat pump domestic hot water heater; and
• A 26 kW photovoltaic system.

Above Sited to maximize southern exposure, the terminal is also shallow enough to allow for deep penetration of light during daytime hours.

Left The terminal uses high performance glazing, which mitigates exterior solar heat gain while allowing maximum views from the interior.

### ENERGY AT A GLANCE

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Energy Use Intensity (EUI) (Site)</td>
<td>36.3 kBtu/ft²</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.4 kBtu/ft²</td>
</tr>
<tr>
<td>Electricity (From Grid)</td>
<td>29.6 kBtu/ft²</td>
</tr>
<tr>
<td>Renewable Energy (PV)</td>
<td>6.3 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Source (Primary) Energy</td>
<td>100 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Energy Cost Index (ECI)</td>
<td>$1.51/ft²</td>
</tr>
<tr>
<td>Annual On-Site Renewable Energy Exported</td>
<td>7.7 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Net Energy Use Intensity</td>
<td>22.3 kBtu/ft²</td>
</tr>
<tr>
<td>Savings vs. Standard 90.1-2004 Design Building</td>
<td>40%</td>
</tr>
<tr>
<td>Carbon Footprint</td>
<td>4.2 lb CO₂e/ft²⋅yr*</td>
</tr>
<tr>
<td>Percentage of Power Represented by Renewable Energy Certificates</td>
<td>17%</td>
</tr>
<tr>
<td>Number of Years Contracted to Purchase RECs</td>
<td>2</td>
</tr>
<tr>
<td>Percentage of Carbon Deferred by Purchasing Offsets</td>
<td>43%</td>
</tr>
<tr>
<td>Number of Years Contracted to Purchase Offsets</td>
<td>2</td>
</tr>
<tr>
<td>Heating Degree Days (Base 65°F)</td>
<td>9,110</td>
</tr>
<tr>
<td>Cooling Degree Days (Base 65°F)</td>
<td>494</td>
</tr>
<tr>
<td>Annual Hours Occupied</td>
<td>4,600</td>
</tr>
</tbody>
</table>

*Carbon footprint includes the purchased CO₂ offset and “exported” PV. If exported PV is excluded, the carbon footprint is 7.6 lb CO₂e/ft²⋅yr.

### WATER AT A GLANCE

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Water Use</td>
<td>8,000 gallons</td>
</tr>
<tr>
<td>(estimated)</td>
<td></td>
</tr>
</tbody>
</table>
AIA Convention 2015: May 14–16, Atlanta
Get on the A-list! Visit aia.org/convention
The project is located on a previously developed site designated for development of the airport’s existing general aviation facility, which was built in 1963. It was ideal to locate a long, narrow building on the site. This is consistent with the common “pier” design of airport buildings, which is a simple design that allows for a high capacity of aircraft to be parked along the sides. The orientation allows maximum southern exposure while enabling daylight to penetrate deep into the building from curtain wall or skylight penetrations. Thus, all occupied spaces are daylit (including rest rooms), which lowers artificial light use via the use of sensors.

Other energy-efficiency measures include in-floor radiant conditioning, thermal mass with enhanced envelope insulation, occupancy sensors for lighting and mechanical systems, natural ventilation, a rainwater capture cistern for water reuse, and high-efficiency electrical, mechanical and plumbing systems. In addition, building materials were selected for their durability, low maintenance and indoor air quality attributes.

All indoor materials used are low to no VOC-emitting. Also, selected materials (wood, glass, concrete, porcelain tile) are nontoxic, inert and able to be repurposed in the supply chain. Cradle-to-cradle materials were also used. Vinyl wall covering, where used, was chlorine free. Vestibule walk off mats (recycled tire rubber) capture foot-borne particulate matter from people entering the building. Most important, natural ventilation was used with operable windows to allow for nighttime flushing of heat gained during summer days, while also allowing for a reduction in heating/cooling during pleasant fall and late spring days.

Both the aviation industry and the region have a long history of using long-span glulaminated beams for the primary structure (especially barrel-vaulted volumes). All of the wood used on the project was FSC certified. Local materials and qualified trades were used to reduce transportation costs and support the local economy.

The exposed structure of wood laminated beams harken back to early aviation hangars and add warmth to the interior. The building’s skeleton is exposed. The gently curving of the beams passes from inside to out and provides a sense of softness.

The exterior is a mixture of colors, textures and equipment. Stone, metal panel and wood intersect at several angles. The south-facing metal roof is covered by 26 kW solar photovoltaic panels that are visible
Cedar boards commonly found in northern lodges/cabins run horizontally for the majority of the first floor, drawing occupants’ eyes from the door you enter after you park your car to the door you use to catch your plane.

Windows or skylights provide daylighting in nearly every space, including rest rooms and stairwells. LED lighting is used both indoors and outdoors and is controlled by both the building automation system and daylight sensors to provide dimming during well daylit hours.

### Designing For A Cold Climate

Appleton, which is 30 miles southwest of Green Bay, Wis., and 105 miles northwest of Milwaukee, has a climate that is particularly cold in winter. In January, the average high temperature is 24.6°F (−4.1°C). February’s average high temperature is 28°F (−2.2°C).

Designing a tight, super insulated envelope was critical for this project. Rigid insulation and closed-cell spray foam urethane insulation was used in walls, floors and roofs. In addition, the prevailing winter winds were modeled when looking at exterior doors and overhangs. Using a masonry mass for the interior (walls and floors) allows heat from the winter sun to be captured and radiated over the course of a 24-hour period. Radiant floor heating is a proven method in cold climates for user comfort.

### Other Major Sustainable Features

- **Geothermal field (vertical bores)** provides 100% of heating and cooling to building.
- High-efficiency geothermal heat pumps with 21 EER, multiple speed compressors and ECM motors.
- Natural ventilation using operable windows when ambient conditions are favorable.
- **Air-to-water heat pump** provides all domestic hot water needs.
- Insulated translucent roof panels provide visible light transmittance of 48% with no solar glare.

### Designing for 100 Years

Designed for a baseline lifespan of 100 years, the terminal takes a loose-fit, long-life approach where it is flexible enough to adapt to the changing needs of an unknown future. As the saying goes, the

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**KEY SUSTAINABLE FEATURES**

- **Water Conservation** Rain cistern collects water off roof that is used to irrigate plantings around building. No other irrigation is required based on careful selection of native plantings.
- **Recycled Materials** Recycled wood flooring, Recycled content in polished concrete floors, porcelain wall/floor tile and quartzite counters. Recycled/relocated landscape materials (plant material and boulders).
- **Daylighting** All occupied spaces have access to natural light. Photocells are used to dim overhead lighting when adequate amount of daylight exists.
- **Individual Controls** Task lighting provided at all working surfaces. Temperature control zones based on predicted occupancy type. For example, the pilots’ area is only intermittently occupied and has individual thermostat control.

---

**BUILDING ENVELOPE**

<table>
<thead>
<tr>
<th>Roof</th>
<th>Type</th>
<th>Continuous insulation above deck</th>
<th>Overall R-value</th>
<th>R-35</th>
<th>Reflectivity</th>
<th>45%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Type</td>
<td>Concrete masonry unit (CMU) with insulated metal panels</td>
<td>Overall R-value</td>
<td>R-21</td>
<td>Glazing Percentage</td>
<td>28%</td>
</tr>
<tr>
<td>Basement/Floor</td>
<td>Slab Edge Insulation R-value</td>
<td>R-10</td>
<td>Under-Slab Insulation R-value</td>
<td>R-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows</td>
<td>Effective U-factor for Assembly</td>
<td>U-0.40</td>
<td>Solar Heat Gain Coefficient (SHGC)</td>
<td>0.24</td>
<td>Visual Transmittance</td>
<td>48%</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude</td>
<td>44.249</td>
<td>Orientation</td>
<td>Rectangular shape with long axis running East to West</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As part of the LEED certification process, the project implemented a measurement and verification (M&V) program to verify that the building is performing optimally and to make corrections as necessary. M&V was conducted for the 12-month period after the building systems were determined to be operating as intended—February 2014 to January 2015.

During the measurement and verification process, opportunities for optimizing the building’s performance are identified. Several issues were identified:

• Energy use at night was higher than expected;
• Geothermal loop pressure was set considerably higher than expected, resulting in both redundant geothermal loop pumps running continuously at high speed;
• Heat pump operation issues; and
• Outdoor air intake flow measurements were unstable.

Addressing these issues with the suggestions presented in the Building Performance Analysis section later in this article will help the General Aviation Terminal save on operating costs as well as demonstrate the facility’s ongoing commitment to energy efficiency and sustainability.

The following sections describe in detail the energy use profile of the Outagamie’s General Aviation Terminal during its first year of operation.

### Performance

The energy performance of the General Aviation Terminal from February 2014 to January 2015 is summarized in Table 1. The actual performance (metered data) of the building is compared to that expected from the design energy model.

The data in Table 1 shows that the building is consuming 21% more energy than modeled during the design phase of the project. This is because how the building was actually operated, including the operational schedule for the building and the size of the plug loads, differ from assumptions made.

#### TABLE 1  ENERGY PERFORMANCE, DESIGN MODEL COMPARISON

<table>
<thead>
<tr>
<th>Annual Data</th>
<th>As-Designed Model</th>
<th>2014–2015 Measured Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Consumption (PV not included) (kWh)</td>
<td>63,000</td>
<td>86,000</td>
</tr>
<tr>
<td>Natural Gas Consumption (therms)</td>
<td>230</td>
<td>26</td>
</tr>
<tr>
<td>Photovoltaic (PV) Production (kWh)</td>
<td>30,900</td>
<td>33,390</td>
</tr>
<tr>
<td>Total Annual Energy Use Intensity (kBtu/ft²)</td>
<td>29</td>
<td>36</td>
</tr>
<tr>
<td>Annual Net Energy Use Intensity (kBtu/ft²)</td>
<td>16</td>
<td>22</td>
</tr>
</tbody>
</table>

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**Electrical Energy Consumption.** As shown in Figure 1, the General Aviation Terminal used more energy than expected from February 2014 to January 2015. Both heating and cooling seasons saw greater than expected energy use. During the shoulder seasons when heating and cooling demands are reduced, the building performed more closely to expectations. This comparison indicates that the issues causing increased energy use are related to the heating and cooling performance.

The model predicted line was calculated using actual weather data for the period of September 2013 to August 2014.

**Gas Energy Consumption.** In February 2014, structural modifications were implemented which temporarily stopped the operation of the fireplace. When completed, the fireplace has remained off as the interior temperatures were more constant than during the initial few months of occupancy. Natural gas was only used for a fireplace design as an architectural feature and not needed to heat the building so there was no adverse effect of turning off the natural gas and fireplace.

**Photovoltaic Energy Production.** The General Aviation Terminal is equipped with a 26 kW photovoltaic panel system. These panels produce electricity. This energy is fed directly to the building. If the PV system feeds more energy than can be consumed by the building, that excess will flow back out to the grid. The local utility, We Energies, credits the airport for every kWh that flows out to the grid.

In Figure 2, model and actual PV system performance are compared. The two lines are similar. The model predicted line was not calculated with actual weather data from the past year, but instead used “typical” weather data. In reality, some months were sunnier than normal, while others were less sunny, which explains the deviations in the lines.
consumption in the building over the first year of operation.

There are multiple reasons for this overnight energy consumption. A major factor is that the geothermal loop pumps are both operating 24 hours a day, seven days per week at 85% speed.

In the original design, the two pumps were never supposed to run simultaneously. Instead, the pumps were supposed to run in a lead/lag configuration, switching status on a weekly basis. During the operation, the design team instructed the general contractor to temporarily run both pumps to resolve an issue with insufficient flow and heat pumps tripping out. The design team determined that reducing the flow to the individual heat pumps would reduce the total flow and pressure sufficiently to allow for the operation of only one pump. This strategy required replacement of the automatic flow control valve which has not yet been done.

Another factor that differs from initial assumptions is the overnight energy consumption of one of the heat pumps, designated as HP-10. This heat pump conditions the server room and is required to maintain a constant temperature setpoint 24 hours per day, seven days per week. The setpoint is currently 65°F (18°C), which is lower than assumed. The heat pump runs almost continuously day and night to maintain these cooler conditions.

In addition to the loop pumps and HP-10, there are likely some miscellaneous electrical loads running overnight, including computer equipment lights, vending machines, refrigerators, freezers, etc. These smaller loads will require a more detailed survey of building equipment to fully understand.

**LESSONS LEARNED**

Assumptions of plug loads (i.e., user equipment) did not match actual use. It would be beneficial to educate owners that the energy model input data represents our assumptions and we do not know what they actually will be installing. The design team was probably a little optimistic on what how much energy the facility would use, particularly at night.

It would be beneficial to train the owner and end users on the impact of plug loads and energy behavior (i.e. turning devices off) during the design phase.

The daily energy profile in the energy simulations should be reviewed so that unrealistic assumptions are avoided even while it might look favorable on an annual basis.

Due to higher than expected pressure drop through the heat pumps, both pumps needed to operate to reach required differential pressure setpoint (20 psi) to avoid tripping heat pumps when the heating demand got high. This forced both pumps to run at around 80% speed or higher even when few or no heat pumps were on due to the pump curve and minimum pressure setpoint with the result of increased energy consumption.

The utility installed a meter for the back feed electricity into the grid when production exceeded use but did not meter correctly (too low). This made it seem like the building did not perform as well as it actually did since we assumed all solar-generated electricity not sent back to the grid was used by the building. This has since been corrected.

Daylighting sensors needed to be adjusted so that the lights were dimmed when there was adequate light from windows.

The training of the operational personnel was not provided to all the operators that needed the training.

Continuous monitoring for at least one year is needed to ensure correct operation in all modes.

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**Building Performance Analysis**

As part of the M&V procedure, the design team examined the performance of the General Aviation Terminal from February 2014 to January 2015 and identified issues that are causing high energy use in the building.

The energy model developed by the design team expected a sharp decrease in energy use from around 7 p.m. until 4 a.m. However, the building maintains a fairly consistent use of energy at night. Actually, energy use increases slightly around 7 p.m., and the drop in energy use overnight is not precipitous. Facility energy use hovers around the 5 kW range, with only slight deviations, such as the 7 p.m. spike. The energy model was likely too optimistic. Using additional energy use at night has caused 25% to 50% of the total additional energy
**Final Thoughts**

Since this project began, it has attracted a large amount of attention within the aviation industry. When presented at conferences across the country, the imagery has been well received, but the performance numbers have garnered the most interest. As a Chicago-area newspaper article described, it was generally assumed that net zero energy aviation buildings were not possible. In addition, blending high design and high performance were often considered mutually exclusive. The energy performance results from February 2014 to January 2015 bear out the challenges present with this building type.

The airport retained the design team to pursue LEED certification after the design phase was completed and construction had commenced. Performance and design goals aligned closely with LEED metrics and Platinum status was achieved. The ability to react to constant changes, maintain the original budget and produce both a visually stunning and energy-efficient facility was a success for client and consultant alike. The lessons learned are an added benefit that can provide a road map for future buildings and advancing brand identity for the airport.

Post-occupancy studies from both owner and tenant found that the building has been a source of pride. From a branding perspective, it has been wildly successful and other facilities are under way that will incorporate or mirror its design or performance strategies. Educating and encouraging the benefits of ultra-low energy use will be an ongoing aspect of building ownership. It is the goal of the airport to incorporate the suggested strategies herein to become a net zero facility in the future.

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**ABOUT THE AUTHOR**

Matt Dubbe, AIA, is Market Leader, Architecture for Mead & Hunt in Minneapolis.