The Toledo Museum of Art has received global recognition for its collection of 30,000 works of art, its innovative and extensive education programs and its architecturally significant 36-acre campus. It stands out in another way as well. Over the last 20 years, big and small improvements have been made to reduce overall energy consumption inside and outside its 101-year-old main building. The Museum has achieved these savings while maintaining the highest standards—never once putting the art in jeopardy.

The Toledo, Ohio, museum’s main building—designed by Edward B. Green and Harry W. Wachter—opened in 1912. In the years following, the Museum underwent four renovations and expansions. Its campus now includes six buildings and an outdoor sculpture garden, which attract some 375,000 people a year who visit the privately endowed nonprofit museum free of charge.

The Museum’s energy efficiency efforts—phased over time and implemented primarily by an in-house team—have focused on reducing energy consumption through investments in solar power, energy-efficient lighting, microturbines and chillers. All have been implemented while maintaining specific temperature and humidity levels required to preserve the collection and without compromising the gallery experience for visitors.

Savings have been reinvested into mission-supporting programs, such as exhibitions, educational offerings and guest artist opportunities (See Fun at the Museum sidebar on Page 34). The Museum is one of only a handful of museums in the nation to institute this comprehensive array of sustainable practices and is viewed as a model—not just for other museums, but also for arenas and other large-scale buildings that require significant amounts of energy to operate.

In May of 2013 marked a major milestone for the Museum’s sustainability efforts when the on-site solar arrays briefly produced more electricity than the main building consumed from the grid. The Museum went off the electrical grid several more times during the summer. During these periods, the facility used a combination of solar energy and electricity produced by the Museum’s natural gas-powered microturbines.

In 1992 the Museum decided to pursue a plan that would allow it to reduce costs by reducing energy consumption incrementally on a tight, nonprofit budget. The Museum took advantage of technology as it evolved and continues to do so.

For instance, the Museum had the first microturbine installation in Ohio and was the first in the state to enter into a net metering agreement with First Energy, which allows the Museum to flow surplus power back to the grid and pay only for net consumption. In addition to energy efficiency measures, the Museum installed demand-based ventilation using CO₂ monitors. This system, combined with the use of 95% submicron-rated filters for all gallery space, ensures consistently excellent indoor air quality.

The Toledo Museum of Art, which opened in 1912, is located in the city’s Old West End Historic District, which is on the National Register of Historic Places. The distinguished low and horizontal white marble building, designed by Edward B. Green and Harry W. Wachter, is articulated by a row of 16 columns, a copper roof and a frieze of acanthus leaves. It has been renovated and expanded four times since its original opening.

The Toledo Museum of Art facilities team works with various lighting manufacturers to test new products in the galleries. In 2012, LED bulbs were installed in a corner of the Dutch galleries to test for color quality. Signage explains the experiment to Museum visitors.

Below The Museum facilities team works with various lighting manufacturers to test new products in the galleries. In 2012, LED bulbs were installed in a corner of the Dutch galleries to test for color quality. Signage explains the experiment to Museum visitors.

Above The Toledo Museum of Art, which opened in 1912, is located in the city’s Old West End Historic District, which is on the National Register of Historic Places.
Examined all systems, determined what the systems should be doing to support existing operations, reviewed required parameters for various areas, such as galleries versus common areas.

Began the process of tuning up boilers and chillers.

Examined all systems, determined what the systems should be doing to support existing operations, reviewed required parameters for various areas, such as galleries versus common areas.

Continued lighting upgrades with compact fluorescent and electronic ballasted T8 sources in common areas.

Installed a VFD to control all fan operations based on occupancy and seasonal requirements.

Installed a 350 ton natural gas engine drive chiller, with hot water heat recovery from the engines.

Implemented CO2 monitoring in all areas to permit occupancy demand-based ventilation rather than a fixed volume of outside air. (Galleries are, of necessity, conditioned 24/7. The space is significantly occupied for an average of 20% of the hours.)

Installed four microturbine combined heat and power units. These units burn natural gas to produce electricity much more efficiently than electricity from conventional grid sources, resulting in significantly reduced emissions.

The Toledo Museum of Art’s 20-year quest to improve its operating efficiency and reduce electrical consumption has involved a combination of mechanical improvements; the installation of a large solar array, LED and fluorescent lighting; and the use of microturbines and natural gas chillers. The mostly in-house projects have been overseen by Museum staff.

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**HIGH PERFORMING BUILDINGS**

**Winter 2014**

**Canaday Gallery, a 5,000 ft² temporary exhibition space, is illuminated by LED lighting. These bulbs emit no UV rays or forward heat, making them an excellent choice to illuminate the light-sensitive art works, such as these Japanese prints.**

**KEY SUSTAINABLE FEATURES**

- Daylighting
- Clerestory skylights in most galleries
- Building Automation System
- On-Site Solar Arrays
- Electric Car Charging Station

**BUILDING ENVELOPE**

- **Walls**
  - Type: 12 in. thick Vermont marble
  - Location: Latitude 41.67
  - Orientation: north/south

**ENERGY AT A GLANCE**

**Annual Energy Use Intensity (EUI) (Site)**
- 38.98 kBtu/ft²

**Electricity (From Grid)**
- 20.2 kBtu/ft²

**Natural Gas**
- 14.7 kBtu/ft²

**Renewable Energy (On-Site Solar PV Production)**
- 4.1 kBtu/ft²

**Annual Energy Use Data**

**Energy Production (kWh)**
- Solar Photovoltaic: 6,316,800

**On-Site Solar Arrays**

**Building Automation System**

**Clerestory skylights in most galleries**

**Daylighting**

**ENERGY USE**

<table>
<thead>
<tr>
<th>Month</th>
<th>Grid Electricity Consumption (kWh)</th>
<th>Natural Gas Use (MCF)</th>
<th>On-Site Solar Photovoltaic Production (kWh)</th>
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<tbody>
<tr>
<td>January</td>
<td>705,600</td>
<td>2,479</td>
<td>3,452</td>
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<tr>
<td>February</td>
<td>367,200</td>
<td>3,614</td>
<td>4,635</td>
</tr>
<tr>
<td>March</td>
<td>573,600</td>
<td>2,851</td>
<td>4,229</td>
</tr>
<tr>
<td>April</td>
<td>442,800</td>
<td>3,773</td>
<td>4,638</td>
</tr>
<tr>
<td>May</td>
<td>3,500</td>
<td>2,479</td>
<td>4,229</td>
</tr>
<tr>
<td>June</td>
<td>657,600</td>
<td>2,851</td>
<td>4,638</td>
</tr>
</tbody>
</table>

**Return on Investment**

The Museum estimates that the electrical bill would be upward of $750,000 annually without the microturbines and other energy saving improvements. With them, the Museum’s electrical consumption is reduced by about a quarter, resulting in an electricity bill that is approximately $12,000 to $4,000 less per month. At a cost of about $150,000 each, the microturbines paid for themselves in about four years. Reclamation is another way the microturbines pay for themselves.
The microturbines reclaim heat from the turbine exhaust and generate 180°F hot water for Museum space conditioning and domestic use. Recapturing waste heat helps manage the Museum’s internal humidity and maintain the 70°F/50% relative humidity environment required by museums to protect works of art.

The variable frequency drives operate mechanical system fans and pumps at the speed that’s required to do the job, often about 75%, rather than its standard speed. VFDs have been a cornerstone of the Museum’s energy saving efforts; while the equipment cost was $4,000, the museum has realized $2,000 in monthly savings on one project, for a payback of two months.

Results
The power generated by the parking lot canopy solar array—one of the largest in Ohio—provides more than half of the building’s electricity requirements on a sunny day, reducing annual grid electricity consumption by almost a quarter.
LESSONS LEARNED

Start with a Tune-Up. At the beginning of this journey, the Museum audited all of its systems, giving everything a tune-up and ensuring the systems were operating as designed—essentially recommissioning the entire building—and then proceeded to look at what the sustainability goals were relative to how the building performed at that time.

Trial and Error. As expected over the project’s 20-year span, some things have worked while others were promptly discarded. But the $100 spent on something that didn’t live up to its promise was quickly recouped when the Museum implemented an alternative that performed better than expected.

A good example: lighting in the galleries. The first generation of LED lights weren’t suitable for illuminating and protecting art—they had quality and reliability issues. For instance, the lights sometimes produced a color shift or visible patterns, creating conditions that were not optimal for viewing art. Museum staff bypassed LEDs at this time. Museum operations staff also experimented with various forms of fluorescent lighting with mixed results. Some of these lights resulted in poor color rendering, eliminating them as an option.

Now that the technology has dramatically improved, LED fixtures are being introduced into the galleries, where old incandescent lights—50 to 60 W each—frequently burn out from continual use. The new 12 W bulbs boast a decade-long life span, resulting in significant savings when multiplied by 1,000 bulbs. The long life span also decreases labor costs associated with constantly replacing bulbs, allowing maintenance staff to focus on other projects that were previously outsourced. In addition, the new lights are better for the environment—higher aluminum content means they are recyclable, with no mercury-related disposal issues. Another benefit: LEDs produce far less heat, resulting in reduced cooling costs. The lighting in the renovated parking lot is also provided by new LED fixtures, which provide greater illumination while using less electricity.

Do Your Homework. A solar viability study predicted the amount of solar energy that could be generated at the Museum based on its regional location and calculated the estimated payback period for the solar arrays. These projections helped the Museum staff decide to pursue solar energy.

When considering new technologies such as LEDs, the operations staff performs upgrade studies, initially using the new technology on a trial basis. These studies help identify any problems and prevent wasted money since the first generation of many new technologies has glitches that lead to shortened life spans.

The canopy, combined with the solar array on the roof and the other energy conservation efforts, have allowed the Museum to feed electricity back to the electric grid on many of the sunniest days during the summer of 2013.

The Museum’s investment and willingness to incorporate new technologies has paid off significantly, reducing the electrical use in the main building by 70% from 1992 to 2012.

While natural gas use has increased during the past 20 years, this increase is primarily due to the use of gas-powered microturbines that cost-effectively produce electricity and reduce overall energy costs. The Museum’s annual energy use intensity for July 2012–June 2012 was 30.90 kBtu/ft².

Conclusion

Saving energy means saving money, and the museum continues to look for the most energy-efficient systems available. Energy stewardship has allowed the Museum to protect its collection, maintain jobs and do the right thing for the environment while plowing money back into the activities that support its educational mission.

ABOUT THE AUTHORS

Carol Bintz is chief operating officer of the Toledo Museum of Art in Ohio.

Paul Bernard is director of physical plant and capital projects at the Toledo Museum of Art in Ohio.