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.

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.

### Building at a Glance

<table>
<thead>
<tr>
<th>Name</th>
<th>Toledo Museum of Art</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Toledo, Ohio</td>
</tr>
<tr>
<td>Owner</td>
<td>Privately endowed nonprofit institution</td>
</tr>
<tr>
<td>Principal Use</td>
<td>Public art museum</td>
</tr>
<tr>
<td>Includes</td>
<td>Café, 45 galleries, 15 classroom studios, concert hall, lecture hall and the Museum Store</td>
</tr>
<tr>
<td>Employees/Occupants</td>
<td>150 employees; average of 1,201 visitors per day</td>
</tr>
<tr>
<td>Occupancy</td>
<td>100%</td>
</tr>
<tr>
<td>Conditioned Square Footage</td>
<td>280,000 (includes main building and crafts building, which are served by a single HVAC system)</td>
</tr>
<tr>
<td>Cost</td>
<td>Original Building (1912) $400,000 Addition (1926) $800,000 East and West Wings (1933) $2 million</td>
</tr>
</tbody>
</table>

### Case Study

**The Toledo Museum of Art**
TIMELINE FOR UPGRADES

- Began implementation of variable frequency drive (VFD) technology versus flow setpoints or bypass valves on pumps.
- Installed VFDs to control all fan operations based on occupancy and seasonal requirements.
- Continued lighting upgrades with compact fluorescent and electronic ballasted T8 sources in common areas.
- Installed a 350 ton natural gas engine drive chiller, with hot water heat recovery from the engines.
- Sampled all systems, determined what the systems should be doing, reviewed required parameters for various functions, and 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 VFDs to control all fan operations based on occupancy and seasonal requirements.

**1992**
- Using run time and horsepower to determine priority, replaced older motors with high-efficiency models.
- Began replacement and upgrades of inefficient lighting sources based on hours of use and impact on electrical demand profile.
- Installed a dual fuel, direct-fired absorption gas chiller to reduce peak demand, taking advantage of a lower cost fuel source and providing an alternate source of climate control for the collection.

**1993**
- Replaced numerous gallery air handlers due to age.
- 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 three steam boilers; one was significantly downsized.
- Installed new building automation system (BAS).
- Added a new and larger heating water supply and return line to the Museum for future recovered energy use.

**1994**
- 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 hot water generated by these units is used for heat, reheat and as a source of energy to heat domestic water, offsetting natural gas to produce electricity much more efficiently than electricity from conventional grid sources, resulting in significantly reduced emissions.

**1995**
- Installed additional VFDs and implemented electrical demand control strategy across all equipment. (Gallery support equipment cannot be cycled off. Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.)
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
- Installed new building automation system (BAS).

**1996**
- Added a new and larger heating water supply and return line to the Museum for future recovered energy use.
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**2001**
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**2002**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2003**
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**2004**
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**2005**
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**2006**
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**2007**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2008**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2009**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2010**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2011**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2012**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
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**2013**
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.
- Testing and monitoring determined that it is possible to slow the equipment down during peak electrical periods about 10% without an unacceptable impact on conditions.

**1992-2013**
- 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.
- Installed a new and larger natural gas engine drive chiller, with hot water heat recovery from the engines.
**High Performing Buildings**  Winter 2014

**2012**

1991

32 33

[Image 48x548 to 373x784]

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 work, such as these Japanese prints.

**LIGHTING THE WAY TO EFFICIENCY**

Lighting upgrades have been a major component of the Toledo Museum of Art’s energy efficiency efforts. The first upgrades began in 1993 and have continued throughout the years with compact fluorescent and electronic ballasted T8 and LED lighting sources in common areas. In October 2013 the Museum converted its first gallery to LED lighting for the temporary exhibition “Fresh Impressions: Modern Japanese Prints.” The 135 new bulbs are energy efficient, help protect these delicate prints from UV light and cut HVAC costs in the gallery by 20% because, unlike incandescent bulbs, they emit no heat. As lighting technologies have advanced, so has the quality of the light that is produced. Every light bulb is assigned a score based on the color rendering index, or CRI, which measures the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source. A score of 100 is perfect. A Museum’s goal is to get as close to 100 as possible, so when visitors view a work of art, they are seeing its true colors. The lights the Museum is currently testing are at 93 CRI, and as the technology improves, reaching 100 CRI isn’t impossible. The Toledo Museum of Art is one of only a handful of institutions in the nation testing preproduction samples of these bulbs.

**Costs**

Though the Museum does not release detailed information on its financial transactions except as required by law, a summary of the costs related specifically to the three phases of solar initiatives over the years is available.

**Phase 1 (2008).** This first phase was funded by a $147,500 Ohio Department of Development solar project grant for installation of the solar photovoltaic system on the roof. The balance of the project was paid for by the Museum.

**Phase 2 (2010).** Two grants helped fund this phase. A total of $202,264 in American Recovery and Reinvestment Act (ARRA) funds was given through the Ohio Department of Development via the Ohio Department of Development and Reinvestment Act (ARRA) helps fund this phase. A total of $140,640 through the Ohio Department of Development and Reinvestment Act (ARRA) helps fund this phase. A total of $147,500 Ohio Department of Development and Reinvestment Act (ARRA) helps fund this phase.

**Phase 3 (2012).** The Museum added a 360 kW solar canopy to its main parking lot that was funded by private investors in a power purchase agreement. The building’s microturbines were funded in part by the Ohio Department of Development and Museum capital funds. Lighting upgrades were covered with Museum operating funds.

**ENERGY AT A GLANCE**

- Annual Energy Use Intensity (EUI) (kWh/ft²)
- Natural Gas Use (kWt/ft²)
- Electricity (From Grid) (kWt/ft²)
- Renewable Energy (On-Site Solar PV Production) (kWt/ft²)
- Natural Gas Data from 2012-13 includes gas used for the natural gas engine drive chillers and microturbines.
- The building uses nearly all of the electricity produced by the on-site photovoltaic arrays. Building consumption data for PV-produced electricity is not available. Site EUI and Annual Source Energy were calculated using the PV production data.
- Return on Investment

**BUIDLING ENVELOPE**

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

**ENERGY USE**

- Grid Electricity Consumption (kWt/yr)
- Natural Gas Use (kWt/yr)
- Solar Photovoltaic Production (kWt/yr)*

**Return on Investment**

The Museum estimates that the electrical bill would be upward of $75,000 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 $14,000 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.

* Natural gas data from 2012-13 includes gas used for the natural gas engine drive chillers and microturbines.
* The building uses nearly all of the electricity produced by the on-site photovoltaic arrays. Building consumption data for PV-produced electricity is not available.
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.

New LED lights illuminate the south portico of the Museum’s 101-year-old main building.

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The canopy, combined with the solar array on the roof and the other energy conservation efforts, has 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 79% 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

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