THE ART OF Efficiency

BY CAROL BINTZ AND PAUL BERNARD

Andrew Weber

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 CO_2 monitors. This system, combined with the use of 95% submicron-rated filters for all gallery space, ensures consistently excellent indoor air quality.

Opposite 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.

Top Right Skylights in galleries where works of art are less light sensitive provide natural lighting. This skylight in the Museum's Classic Court helps illuminate the antiquities collection. A new energy-efficient skylight was installed in Classic Court in 2012 as part of a gallery renovation.

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.

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BUILDING AT A GLANCE

Name Toledo Museum of Art

Location Toledo, Ohio

Owner
Privately endowed nonprofit institution

Principal Use Public art museum
- **Includes** Café, 45 galleries, 15 classroom studios, concert hall, lecture hall and the Museum Store

Employees/Occupants 150 employees; average of 1,201 visitors per day

Occupancy 100%

Conditioned Square Footage 280,000 (includes main building and crafts building, which are served by a single HVAC system)

Cost
- **Original Building (1912)** $400,000
- **Addition (1926)** $800,000
- **East and West Wings (1933)** $2 million

TIMELINE FOR Upgrades

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.

1992

- 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.

1993–1996

- 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.

1997–1999

- Began implementation of variable frequency drive (VFD) technology versus flow setters 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.

2000–2002

- Replaced numerous gallery air handlers due to age.
- Implemented CO_2 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.)
- Replaced 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.

2003–2004

- 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 steam use. The electrical output is fed back into the Museum grid.

2005–2007

- 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.)

2008–2009

- Installed 101 kW of solar panels on the east wing of the building.

2010–2011

- Installed an additional 100 kW of solar panels on the center and west wing roof.
- Began early testing and implementation of LED lighting in select areas.

2012–2013

- Installed a 360 kW solar canopy in the center of the main parking lot. The lot was also outfitted with LED lighting on the perimeter and under the solar canopy.
- Most interior common area lighting was upgraded using LED lighting sources. Museum staff is evaluating the latest generation of LED lamps for gallery use. When fully implemented, staff expect an additional demand reduction of 90 kW.

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The temporary exhibit "Fresh Impressions: Modern Japanese Prints," opened in October 2013. The exhibit space is the first gallery at the Toledo Museum of Art to be illuminated by LED lighting. The 10-year lifespan of LED greatly reduces the need for light bulb changes, allowing maintenance staff to focus on other projects that were previously outsourced.

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The Toledo Museum of Art's main building, constructed in 1912, contains 250,000 ft^2 of exhibition, classroom and office space on two levels. In 1991, the year before officials began energy efficiency improvements, the May electricity bill for the Museum was $52,000. In May of 2013, it was $5,000.

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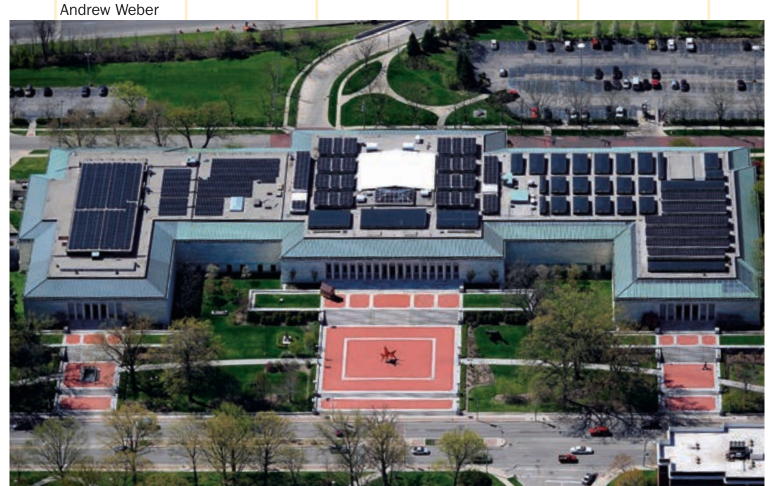

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Above and Right While renovating its main parking lot in 2012, the Toledo Museum of Art added a solar canopy and LED lighting. Two electric vehicle charging stations also were installed, allowing Museum patrons to recharge as part of their $5 parking fee.

Left This aerial view shows the 200 kW rooftop solar panel installation. Since the Museum is located within a historic district, panels were installed flat rather than at an angle, so they would not be visible from the ground.

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Canaday Gallery, a 5,000 ft^2 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 artwork, 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 through 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 $282,264 in American Recovery and Reinvestment Act (ARRA) funds was given through the Ohio Department of Development via the State Energy Plan program. The Ohio Department of Development provided $140,640 through the Advanced Energy Fund program. The balance was paid for by the Museum.

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.

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/ft^2
- Natural Gas 20.2 kBtu/ft^2
- Electricity (From Grid) 14.7 kBtu/ft^2
  - In 1992 80 kBtu/ft^2
- Renewable Energy (On-Site Solar PV Production) 4.1 kBtu/ft^2

Annual Source Energy 57 kBtu/ft^2

Heating Degree Days (Base 65°F) 6,185 (five-year average)

Cooling Degree Days (Base 65˚F) 1,035 (five-year average)

Annual Hours Occupied 3,500

Note: Energy data represents main building and adjacent crafts building, which are served by the same HVAC system. Renewable Energy EUI represents energy produced by the on-site solar panels. The building uses nearly all of the electricity produced by the photovoltaic arrays, except when the PV arrays occasionally produce more electricity than the building consumes. Building consumption data for PV-produced electricity is not available. Site EUI and Annual Source Energy were calculated using the PV production data.

Floto + Warner

The world renowned Toledo Museum of Art Glass Pavilion is enclosed by a continuous glass wall. The Pavilion houses glass blowing hot shops, cold glass working spaces, flameworking studios and the Museum's extensive collection of glass objects. Microturbines and chillers help heat and cool the building, capturing and recycling heat generated by the glass furnaces.

ENERGY USE

	Grid Electricity Consumption (kWh)		Natural Gas Use (MCF)		On-Site Solar Photovoltaic Production (kWh)**
	1991–92	2012–13	1991–92	2012–13*	2012–13
July	705,600	181,377	2,479	3,452	19,931
August	639,600	154,804	2,229	3,400	19,094
September	674,400	133,063	2,114	4,229	11,124
October	555,600	86,038	2,699	4,503	8,130
November	541,200	86,280	3,060	4,635	7,707
December	409,200	84,560	2,851	5,122	12,261
January	367,200	78,812	3,614	5,845	16,340
February	380,400	75,533	3,482	5,293	20,991
March	369,600	76,695	2,958	5,115	42,076
April	442,800	96,822	3,677	4,773	55,896
May	573,600	81,337	2,736	4,396	77,181
June	657,600	69,852	2,853	4,638	41,987
Total	**6,316,800**	**1,205,173**	**34,752**	**55,401**	**332,718**

* 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.

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 $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.

Top Left **Replacing incandescent lights in the Museum's grand Peristyle Theater with compact fluorescent lights provided significant energy savings and better illumination to highlight the paintings on the upper walls.**

Top Right **The Museum's ongoing sustainability efforts inspired chef Drew Ruiz to plant an organic garden adjacent to the Museum. A first-time gardener, Ruiz consulted with local horticulturists on the project. The garden's produce is served in the Museum's café and catering operation.**

Above **Toledo is known as the Glass City for its manufacturing prowess. The Toledo Museum of Art campus was also the birthplace of the American Studio Glass Movement. Glass furnaces run at 2,200°F, 24 hours a day, so the Museum captures the generated heat to provide space conditioning, domestic hot water and deicing for the underground loading dock.**

FUN AT THE MUSEUM

The Toledo Museum of Art was voted America's favorite museum in 2010 by the readers of Modern Art Notes, a popular blog written by Washington, D.C. based art critic and writer Tyler Green.

The Museum is known for its innovative and extensive education programs, which help fulfill its mission to integrate art into the lives of people. Recently added programming includes tours and activity kits designed to engage babies and young children in the exhibitions to build "visual literacy." Programming is also offered specifically for those with early-stage memory loss.

In 2012, the Museum celebrated the 100-year anniversary of its main building. Events included "Girl Scout Night at the Museum," which involved art projects, flashlight tours and a sleepover in the galleries for 1,500 Scouts.

Anniversary year exhibits included "Museum People: Faces of TMA," which consisted of nearly 700 floor-to-ceiling headshots of Toledo Museum of Art community members of all ages — visitors, supporters, volunteers and staff. Another exhibit featured Edourad Manet's formal portraiture and his scenes of family and friends in the context of everyday life. The Museum was the only U.S. venue for the show.

The Museum's 250,000 ft^2 main building consists of 4.5 acres of floor space on two levels. Features include 45 galleries, 15 classroom studios, a 1,750-seat peristyle concert hall, 176-seat lecture hall, Museum Café and Museum Store.

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.

BUILDING TEAM

Most energy-efficiency work done in house over the past 20 years.

Building Owner/Representative
Carol Bintz and Paul Bernard, Toledo Museum of Art

Advertisement formerly in this space.

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.

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

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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 38.98 kBtu/ft^2.

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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