Energy Efficient Lighting in Historic Buildings

Cheryl Rezabek, Wisconsin Division of State Facilities
Jim Mapp and Barbara Smith, Wisconsin Division of Energy Services
Jim Cavallo, Kouba-Cavallo Associates

ABSTRACT

Historic buildings provide for visitors a rendering of the past that emphasizes the beautiful and the grand and reinforces a sense of pride of place. Historic buildings can leverage these positive associations to effectively demonstrate energy efficiency technologies. This paper reports on the incorporation of modern, energy efficient lighting into the Wisconsin State Capitol, the Orpheum Theater (a historic movie theatre), the University of Wisconsin Memorial Student Union, and the Governor's Executive Residence. These historic buildings serve as highly visible role models showing how much energy efficient lighting can be incorporated into sensitive public showcases. Technologies used include CFL, cold cathode CFL, and high color temperature lighting. There is a review of barriers to implementation that are prominent in historic buildings, such as color rendition, historical accuracy, wiring limitations, and aesthetic non-obtrusiveness. Approaches used to overcome these barriers will be outlined. Methods of demonstration are described, including public tours and displays and other methods. Results support the thesis that energy efficient lighting improvements were feasible, aesthetically acceptable, and reduced costs for both maintenance and energy savings.

Why Historic Buildings Are Important to the Energy Efficiency Community

Historic buildings can serve as powerful and highly visible demonstrations of energy efficient lighting technologies. Historic buildings are noteworthy cultural sites, common and accessible enough to make good demonstrations in many communities. Historic preservation can dovetail with efforts toward energy efficiency and environmental sustainability. According to the National Trust for Historic Preservation, "Historic preservation is an effective tool for valuing and protecting our environmental resources, including those that have already been expended as well as those not yet used. Because it encourages us to reuse sound older buildings instead of abandoning or demolishing them, and to revitalize existing neighborhoods instead of building sprawling new subdivisions, preservation is 'recycling' on a grand scale" (NTHP 2008).

There are synergies available when government agencies seek goals of energy efficiency and historic preservation in one project. Already government agencies play a special role in establishing guidelines, leveraging resources, and setting an example in historic buildings. At the federal level, the National Park Service maintains the National Register of Historic Places (NPS 2008). Government agencies also maintain a large number of historic buildings. This paper reviews how a state energy office facilitated energy efficient lighting demonstration projects in several government buildings and a private sector theater.

Historic Building Case Studies

A review of these projects in Wisconsin will show that energy efficient lighting improvements in historic buildings can be aesthetically acceptable and reduce energy and maintenance costs. Lighting projects are the focus of the work described here. Table 1 lists several Madison, Wisconsin, buildings that will be used as illustrations in this paper.

Table 1. Some Wisconsin Historic Buildings

Building	Characteristics
Wisconsin Capitol	Seat of government. Renaissance Revival, American Beaux-Arts style. 1906-1917. National Historic Landmark.
UW Memorial Union	Student union with diverse range of daily activities. 1927.
Orpheum Theater	Films and live music, restaurant. French Renaissance interior, art deco style. 1920s. National Register of Historic Places.
Governor's Executive Residence	Georgian classical revival style, 1920-1928.

Wisconsin Historical Society, Wisconsin Department of Administration

First, the paper will review these case studies. Next, there will be a review of barriers to energy efficiency in historic buildings and how to overcome those barriers. Finally, transferability of these projects and methods of demonstration will be summarized.

Wisconsin State Capitol Building

Lighting presents a significant saving opportunity in this highly visible public building (ECW 2006; Wisconsin State Government 2008). The building is 448,000 square feet and almost all lighting in this large building is traditional screw-in incandescent light bulbs. Changing light bulbs is a primary activity for at least one full-time staff person. Beginning in the 1980s, state energy office staff made periodic efforts to introduce compact fluorescents on a trial basis in a few locations. With a few exceptions, this lighting was deemed unacceptable and not retained. After 2003, staff launched new efforts to try compact fluorescents in trials in selected applications. Oil overcharge funds were used to underwrite the trials. After some months of adjustment, the effort was deemed a success, and in 2006 and 2007 facilities staff decided to change major areas of the facility to compact fluorescent lighting.

Decision Process

Changes in the Capitol Building are under the oversight of several organizations including the Department of Administration (DOA), acting as facility manager; and the State Capitol and Executive Residence Board (SCERB). SCERB's purpose is to direct the continuing and consistent maintenance of the property, decorative furniture and furnishings of the capitol and the Executive Residence[1]. DOA took a leading role in launching the lighting trials and evaluating the trials' performance. High level DOA staff reviewed the lighting trials. Results of the trials were discussed and led to a decision to make significant moves toward fluorescent

[1] SCERB is authorized by state statute s.16.83(1).

lighting. A major driver was the need to demonstrate responsible environmental practices, energy efficiency and a reduction in carbon emissions. Another factor was the 2006 Governor's Executive Order 145 directing state facilities to adopt energy efficiency goals and sustainable building standards for new, existing and leased state building space (WOG 2006).

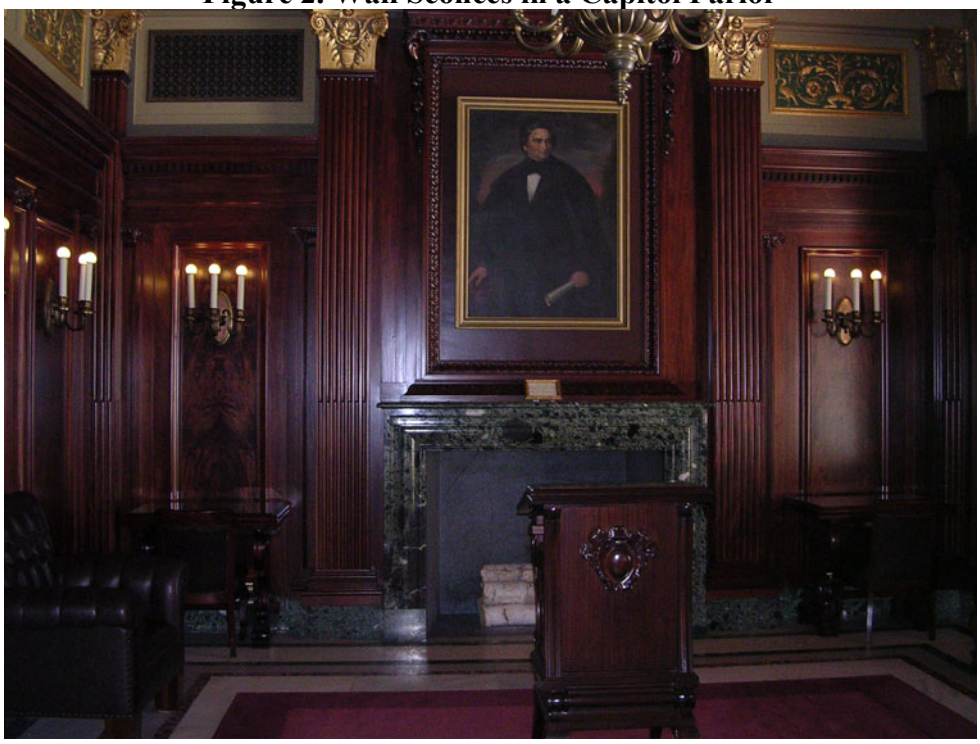
Lighting Changes

Between 2006 and 2007, an estimated 6,000 light bulbs were changed. In house maintenance staff installed the bulbs. Maintenance personnel at each building helped identify areas with good potential for lighting conversions. If the converted lighting was not acceptable, either because of the appearance of the bulbs or the light quality, another type of compact fluorescent bulb was selected. Plastic-covered ballasts at the base of CFL bulbs were considered an aesthetic barrier in a number of cases. More savings is available: facility staff estimates that at least another 1,000 light bulbs are good candidates for change out in the near future.

The project included installation of a number of specialty CFLs, including torpedo and small globe-style bulbs. In addition, working in this historic building presented an unusual problem: the first CFL replacements offered were considered much too bright by maintenance staff. For example, in the Assembly Parlor chandeliers, 100 watt incandescent bulbs were initially replaced with 15 watt CFLs. The resulting light was so much brighter that staff tried lower wattage CFLs before deciding that 11 watt CFLs provided the best replacements. Figures 1 and 2 show example applications of lighting in the Capitol.

Figure 1. Light Standards in the Capitol Rotunda

Figure 2. Wall Sconces in a Capitol Parlor



Outdoor light standards provided a different savings opportunity, because of their night use, as shown in Figure 3. Originally 100 watt incandescent bulbs lit these outdoor standards. Trials with lower-wattage and higher color temperature CFLs showed potential. Eventually the replacement chosen for this application was a 4 watt CFL in 4100 degrees Kelvin, a higher color temperature. The use of higher color temperature lighting, especially at night, can produce acceptable light at lower wattages. The energy savings were considerably greater than in a standard incandescent-to-CFL replacement. Maintenance staff obtained additional performance improvements because the longer-lived CFLs required less frequent replacements. Identifying burned out bulbs in outdoor standards was particularly inconvenient since maintenance staff worked primarily a daytime schedule. Also, winter snow and ice made removing the outer glass globes for these fixtures difficult. Fixture globes were expensive and breakages were costly. CFLs reduced the incidence of broken fixture glass because fewer bulb changes and globe removals were needed.

For some customers, the barrier to using CFLs is the extra first cost. For example, a typical residential consumer may pay about 25 cents for an incandescent bulb in contrast to several dollars for a CFL. For the Capitol project, the differential first cost in light bulbs was less dramatic. Instead of using the most common general service incandescent bulbs, Capitol maintenance staff had switched to longer-lived, lower voltage incandescents years ago. These long-lived bulbs cost about $2 each. The cost of the CFLs was $3 and up. The difference in first cost to switch from incandescents to CFLs for this project was less than expected.

Figure 3. Outdoor Light Standards at the Capitol

Savings were significant from the lighting project in the Capitol. As in other commercial buildings, lighting operating hours are much longer than in a residential setting. Although the facility is closed in the evenings, large areas remain lit past closing time. This generated great need for constant light bulb replacement. The electric bill savings from this project so far is estimated to be at least $43,000 annually or 30% of the annual electric bill of $142,000. These savings do not include air conditioning savings and reduced maintenance costs from the switch to the longer-lived bulbs.

LED Holiday Lights

Prior to the main lighting trials in the Capitol, an early success story was the change of holiday lights to LEDs. Every December, a large holiday tree from the northern forest is installed in the Capitol rotunda extending up through several floors of the building's atrium. The Governor or First Lady typically oversees the lighting of the tree to public fanfare. In 2005, state energy office staff worked with facility managers at the Capitol to switch to LED holiday lights. The Governor released a statement praising the energy savings of this new type of decorative lighting. Now each year a large placard is also displayed in the Capitol beside the tree, telling the public about the 2,400 LED lights. Fact sheets on LEDs are also available to visitors to the facility in December.

Capitol facility staff believe the holiday light change is an improvement. A primary concern with the old lighting was the overload of electrical circuits. Replacing C-7 incandescent light strings with LED equivalents resulted in a wattage draw reduction of around 99%, and corresponding energy savings. Another benefit was the reduced glass breakage. Glass C-7 lights were heavy and fragile, especially when staff had to attach them to such a large tree. The lighting strings often resulted in broken glass on the floor, a safety problem and an extra cost and hassle. Staff found that dropping the LED strings was not a problem because the strings typically do not

break when dropped as they are covered in epoxy rather than glass. The lights are also cooler, providing additional safety and less drying to the tree. State facility staff are now extending their use of LED holiday lights to more facilities, such as the Executive Residence and campus student unions.

Memorial Union

The University of Wisconsin-Madison Memorial Union has implemented small-scale, incremental efforts to change lighting in the building (ECW 2006; University of Wisconsin-Madison 2008). The project began when state energy office staff approached facility managers at the Union in 2005 and 2006. With the approval of management, front line maintenance staff worked to implement lighting changes through trial and error. State energy office staff played a facilitation role, providing samples of specialty CFLs and consulting on issues and problems as they arose. Maintenance staff proved very motivated and receptive to trying compact fluorescent lighting. After a short time, they took initiative in ordering new types of CFLs from their regular distributors. Table 2 shows the improvements made.

Table 2. Examples of Lighting Conversions Made in Memorial Union

CFLs installed	Incandescent wattage per bulb	CFL wattage per bulb	Hours in use per day	Number of bulbs replaced	Annual kWh savings
Rathskellar	40 60	7 9	16 16	138 30	26,595
Great Hall	120	36	8	165	40,471
Tripp Commons	40 60	7 9	8 8	145 40	13,972 5,957
Travel Center	75	9	9	40	8,672
Hallways	60	9	20	48	17,870
Stairwells	120	14	20	20	15,476
Outside	120 120 120	14 14 26	10 10 10	40 40 20	15,476 15,476 6,862
Guest rooms	60	9	4	60	4,468
LGBT Center	60	9	9	48	8,042
Games Room	60	9	16	48	14,296
TOTAL	1115	181		882	202,568

In general, building staff received few comments on the changes which showed there was less aesthetic sensitivity to lighting changes than expected. In many areas, the common "twist-style" CFLs worked well. Several areas had lighting located behind wooden scrims on the upper perimeter of the room. Other areas had light bulbs under cloth shades. The twist-style CFLs worked well in these locations, producing similar light output to the incandescents. Maintenance staff benefited because they no longer had to bring out ladders as often to change hundreds of

bulbs more than 20 feet off the ground. Building users were satisfied. The success of these measures illustrate the importance of non-visible measures in historic buildings.

Dimmable lighting was needed in a number of areas where dimmer switches were installed. Both twist-style and reflector-style dimmable CFLs were installed. Maintenance staff dated and tracked the installed CFLs to verify lifetimes and identify early-failure problems. Globe and circular styles, and warm white and daylight styles were also used. The incidence of burned-out bulbs throughout the facility dropped. There were few complaints. There do continue to be early failure problems with dimmable R30 reflector floods. The lighting changes are saving $12,154 annually on the facility's electric bill. These savings do not include air conditioning or maintenance savings. There is much more potential for similar changes in the facility.

Figure 4. Orpheum Theater Lobby

Orpheum

Until recently, Madison's Orpheum Theater was lit with virtually all screw base incandescent lighting, as shown in Figure 4 (Orpheum Theater 2008). Using a trial and error approach, state energy office staff worked with theater owners and maintenance staff to install CFLs in many areas. Some surprising specialty CFL choices were preferred. In the main, ornate theater room, owners installed white and purple twist CFLs, behind the glass of decorative wall sconces. Significant energy savings was realized in work rooms and storage areas with simple twist CFLs and LED Exit signs.

This facility is characterized by darkly colored furnishings and low light levels. Decorative colored glass fixtures and chandeliers promoted opportunities for colored lighting and wall accent washing. In pendant ceiling fixtures, facility managers chose warm white light in some areas and cooler light in others. Theater facility owners accepted globe style CFLs for many applications. Colored CFLs in red and yellow were installed elsewhere. Hall and restaurant-area lighting was changed to decorative and color-changing LED bulbs. Flame-tip cold cathode CFLs in a very warm white were installed in some wall sconces. Challenges in

basic maintenance include significant wear and tear from live music shows attracting large young and late night audiences. Apparently the theater in its early days was much more brightly lit. Owners had de-lamped certain areas in the theater room to reduce electric and maintenance costs and to conform to evolving tastes in evening entertainment atmosphere. In recent years, the theater's lighting scheme was aesthetically eclectic. For example, outside the front doors, all the light bulbs had been removed from the underside of the marquee, which overhangs the sidewalk. Patrons frequently gathered in this area. Recently to improve the look, owners installed 2 watt globe CFLs on this under hang, drawing pedestrians in to the theater and giving the facility a more finished look from the street. The total power demand for this lighting effect was less than 100 watts. Facility owners proved surprisingly flexible in considering new styles of lighting. Their main interests appeared to be enhancing the decorative effects of their lighting, saving money, and addressing their maintenance challenges. With the CFLs, lighting levels were also improved in several areas of the facility that needed additional lumens.

Figure 5. Governor's Executive Residence

Governor's Residence

The Governors' Executive Residence appeared to be a difficult site for energy savings. The house consists of both public and private space, and the public areas were lit with primarily decorative styles of clear flame tip light bulbs as shown in Figure 5. Initially, staff addressed the less visible areas of the building. The staff installed a surprising 254 CFLs, in twist style bulbs from 11 watts to 42 watts. For example, a large basement area was initially lit with numerous 135 and 200 watt incandescents, and these were changed to 42 watt CFLs.

Decorative lighting was more difficult to convert. A number of sample bulb types were provided and the final decision was made by the First Lady. After months and numerous trials, 120 of the decorative wall sconce bulbs throughout the residence were replaced with 4 watt dimmable, candelabra base cold cathode CFL bulbs and 50 of the regular base of the same style.

The lights in these public areas are only turned on when entertaining so hours of operations are not equivalent to other public building operations. Initial calculations for energy savings are $330 annually or 3% of the $12,600 annual electrical cost for the mansion.

The private space in the basement was recently remodeled to include a kitchenette, a meeting area and a recreational area for the family. In this remodel, the lighting included recessed lights with CFLs, wall sconces and undercabinet lighting.

Barriers to Energy Efficiency in Historic Buildings

The case study projects described above successfully overcame barriers to integrating energy efficient lighting into historic buildings. Some of these barriers included color rendition, historical accuracy and aesthetic non-obtrusiveness. Below is discussion of approaches to overcoming the barriers to energy efficiency in other historic building projects.

Meet Aesthetic Standards with Alternate Approaches

Historic buildings try to recreate a semblance of the appearance when the building was in its infancy. However, sometimes the same effect can be created through contemporary alternative approaches. For example, many 1890s era buildings strove for the "golden glow" aesthetic. The Willard Hotel in Washington, D.C. and the White-Eastman House in New York are examples. Golden glow style lighting may appear initially surprisingly dim and decidedly yellow to a modern visitor. However, this light was once considered very elegant. Originally it was created with direct current (DC) incandescent bulbs. Most historic buildings recreate this atmosphere with incandescent lighting on AC circuits. However, a similar effect can be achieved with CFLs behind golden glass sconces. New lighting forms, such as LEDs and cold cathode, allow additional flexibility that was not available in the past. Color and other effects are possible, along with improved safety and durability.

New lighting can create desired color effects, effects that may be needed to balance out the natural aging effect of paint and furnishings. Irreplaceable fixtures can be preserved longer because long-lived bulbs need changing less often, creating less risk of breaking fixture glass. Efficient lighting can reduce the use of air conditioning, which is of course not a historically accurate element of these buildings. New styles of light fixtures can produce effect of candles, which CFL and LEDs provide without open flames.

Use the changeover to efficient lighting to improve the opportunity for appreciation of decorative spaces. Improved lighting can allow visitors to observe ceiling friezes and other architectural details. More efficient lighting tends to have a light spectrum with less ultraviolet, creating less wear on curtains, carpets, and furniture.

Address Working Areas of Building

Historic buildings often have relatively modern areas in working offices and break rooms. These areas are often excellent candidates for the latest energy efficient technology. There are few aesthetic barriers. Offices can be outfit with ENERGY STAR table lamps and office equipment. Vending machines can be retrofit to use highly efficient lighting or to reach ENERGY STAR performance levels. Exit signs are required even in historic buildings. Using the traditional fixtures, exit signs can be re-lamped with LEDs. Where possible, projects can use

extra long life CFLs, such as 15,000 hour CFLs or 25,000 hour cold cathode CFLs. This frees maintenance staff to focus on other needs in the building.

Leverage Ongoing Maintenance

Even historic buildings need ongoing maintenance. Light bulbs burn out, and fixtures break. Each of these provides a natural opportunity to consider a higher efficiency replacement. Maintenance projects generally have lower levels of scrutiny and oversight. Financial outlays are lower and there are accordingly fewer levels of approval. Starting with simple lighting upgrades can build interest and support for larger capitol improvements.

Often facility staff are aware of inefficient lighting but postpone upgrades until there is approval for a major facility renovation. This can delay upgrades for years. The advantage of an incremental light bulb change project is that it is quick and simple. When only screw-base lighting it used, it is even easier. Existing maintenance staff can install the lighting as their schedule allows. There is no need to wait for committees, multiple layers of approvals, and major outlays of capitol. The lighting improvements described here were pursued apart from major facility upgrades. By the time these facilities do undertake major upgrades, the savings from the lighting improvements will have paid for the cost several times over. Furthermore, environmental benefits from this energy savings begin to accrue earlier as well. In most cases, it is easier to implement measures as an ongoing maintenance expense rather than a capitol improvement expenditure. Ongoing maintenance is often funded under sum sufficient rather than itemized capital expenditures.

Transferability of Project

A surprising one third of lighting energy used in commercial buildings comes from incandescent lighting (USDOE 2002). The potential to save energy in commercial buildings from changing light bulbs alone is enormous. Much of this lighting is from standard general service incandescent light bulbs, for which CFLs are an acceptable replacement in many cases. Many of the energy saving measures outlined in these case studies apply directly to other non-historic buildings, both residential and commercial.

Converting incandescents to CFLs in a commercial setting saves energy and reduces peak demand. Savings are greater than in a residential setting because lighting in a commercial building setting often operates for many more hours a day than. Also, commercial lighting is frequently on during peak times. Planners can use general rules of thumb to estimate the energy savings potential from changing to CFLs. If the Wisconsin state government is assumed to pay about 6.25 cents per kWh for electricity for its facilities, over the 8,000 hour lifetime of a typical CFL, the savings are about $1 for every two watt reduction.

Historic Buildings as Demonstrations of Energy Efficiency

Historic buildings can serve a demonstration function well, as they are often particularly visible. For example, thousands of school children in Wisconsin visit the State Capitol Building every year. Similarly, the Memorial Union at the University of Wisconsin's flagship campus in Madison is visited frequently by the 41,000 student body, as well as faculty and staff. Its entertainment facilities and outdoor patio are also heavily patronized by the community and

visitors throughout the year. These visitors use and enjoy these buildings. In addition, visitors often feel these buildings "belong" to them, because they are funded through public revenues. Many such facilities promote themselves through regularly scheduled public tours and other special public events. Even for private historic buildings such as the Orpheum Theater, visitors can feel a sense of ownership because of the role the building plays in the culture. For example, the Orpheum is the site of emotionally and culturally important events such as presidential candidate addresses, key art and environmental films, weddings, etc.

Given this popular feeling, historic buildings make excellent demonstration vehicles for focusing people's attention on energy efficient lighting. Visitors to historic buildings realize that these buildings have more aesthetic constraints than a typical building. Thus implementing efficient lighting technologies in a historic building can provide a more powerful demonstration than a demonstration in a functional-looking building with no historic connection.

Public promotion of an energy efficiency demonstration is a key step to making it effective. Once the energy saving measures are installed in a project, the real work of demonstration begins. Tours, fact sheets, press releases, and other approaches are available to communicate the project details to the public. For example, virtual or on-line tours are possible. At the Memorial Union art gallery, organizers provided a blank book for comments about lighting changes. Numerous visitors to the art gallery took time to reflect on the lighting experiments, leaving a comment in the book. The comments were diverse and thoughtful. A majority were positive. In another approach to reach industry people, project coordinators organized a special tour of the Memorial Union and the Capitol for local lighting professionals.

Conclusion

Historic buildings are often good candidates for energy efficient lighting upgrades. Replacing screw-based incandescents with CFLs is a particularly simple approach to start a lighting upgrade. Maintenance staff can pursue incremental lighting changes along with ongoing maintenance tasks, rather than waiting for major retrofits. A good place to start changing lighting is in building areas where light bulbs are not directly visible or in the modern work spaces in these buildings. With a greater range of CFL types available today, results are more likely to be aesthetically acceptable to decision makers and building users and visitors than in the past. Substantial energy and demand savings is available, along with maintenance savings and non-energy benefits as well. By changing to energy efficient lighting, organizations maintaining historic buildings can satisfy concerns of their agency and the visiting public and burnish their environmental image.

References

[ECW] Energy Center of Wisconsin. 2006. "ENERGY STAR® Lighting in Two Historic Madison Buildings." http://www.ecw.org/prod/lightingfactsheet.pdf. Madison, Wisc.: Energy Center of Wisconsin.

[NPS] National Park Service. 2008. "National Register of Historic Places." http://www.nps.gov/nr/. Washington, D.C.: National Park Service.

[NTHP] National Trust for Historic Preservation. 2008. http://www.preservationnation.org/issues/sustainability/. Washington, D.C.: National Trust for Historic Preservation.

Orpheum Theater. 2008. http://www.orpheumtheatre.net/. Madison, Wisc.: Orpheum Theater.

[WOG] Wisconsin Office of the Governor. 2006. *Executive Order #145: Relating to Conserve Wisconsin and the Creation of High Performance Standards and Energy Conservation for State Facilities and Operations.* April 11. http://www.wisgov.state.wi.us/journal_media_detail.asp?locid=19&prid=1907. Wisconsin Office of the Governor.

Wisconsin State Government. 2008. "Wisconsin State Capitol Virtual Tour." http://www.wisconsin.gov/state/capfacts/tour_select.html. Madison, Wisc.: Wisconsin State Government.

[USDOE] United States Department of Energy. 2002. *U.S. Lighting Market Characterization, Vol. 1: National Lighting Inventory and Energy Consumption Estimate.* Washington, D.C.: United States Department of Energy.

University of Wisconsin-Madison. 2008. "Wisconsin Union Photo Tour." http://www.union.wisc.edu/phototour/.