Outdoor Lighting: Blending Old and New
Introduction

Outdoor lighting is one of the many applications for which Williams College expends electricity. Like any other use of energy, examining the current status of outdoor lighting is an opportunity to save energy and money. New technology in light fixtures that conserves energy and can cut down on the college’s utility bill can replace older light fixtures that use unnecessary electricity. The key is to combine the function of the current light fixtures with the energy saving possibilities of newer fixtures. In other words, whatever change is brought about, whatever happens to the light fixtures on campus, the changes must function as well (or better) than the current outdoor lights that keep our campus safe and lit and nighttime. Of course, money is a factor as well, whatever money can be saved by changing the current outdoor lights must be considered in conjunction with the cost of changing said fixtures.

This study will outline a few possibilities in changing – improving, hopefully – outdoor lighting on campus. A major factor in planning a change in outdoor lighting is the payback time required for each plan: how long it takes for the college to start saving money from a change in outdoor lighting is important in deciding the best course of action.

Moreover, other factors in regards to outdoor lighting need be considered. First is the issue of safety: can the plan to improve outdoor lighting still comply with the codes the college must abide by in order to keep the campus properly lit at night? The Astronomy department’s concerns must also be considered. Nighttime outdoor lighting is very important to the Astronomy department (and to any professional or casual stargazer, for that matter) because anything that emits light at nighttime contributes to
light pollution. Light pollution in turn makes observing the stars more difficult. Another concern that will be addressed is the notion that technology is constantly being outdated. The “new” technology that we could hypothetically use in improving lighting could be antiquated in the next year. How can we account for the constant advancement of technology? Additionally, Outdoor lighting on campus also has important affects on safety concerns, health risks, protecting the ecology of local flora and fauna, and of course, conserving natural resources, according to the Dark Sky Society’s *Guidelines for Good Exterior Lighting Plans*.\(^1\)

*Outdoor Lighting at Williams College*

There are currently 406 outdoor street light fixtures on campus that stay on for an average of 10 hours per day. Those 406 fixtures include three types of different light fixtures.\(^2\) The most common is the William & Mary, of which there are over 300. The rest of the light fixtures on campus consist of Kim fixtures and King Luminaires. The commonalities between each type of fixture are that all three are roughly the same height off of the ground (the most obvious exception being the Kim fixtures in the Hollander Hall parking lot) and that they all emit light for an roughly the same 10 hour time period every day. What set apart the three types of fixtures are the design of the fixture head (the top part of the fixture that holds the bulb), the amount of electricity each type uses, and the kind of bulb inside the fixture head.

However, within each type of fixture there are some subtle yet important discrepancies. The majority of the William & Mary fixtures on campus use 175 Watts and have Metal Halide bulbs. However, there are two William & Mary fixtures in the
parking lot in front of Spenser Art Building that have “EarthBulbs”. The W&M fixtures that line the walkway from Hopkins Hall, by Sawyer and Holland Hall, and down to Dodd Circle relatively new W&M fixtures that only use 70 Watts. There is also a 70W W&M in the parking lot by Lansing Hockey Rink and Towne Field House. And lastly, there is a new W&M fixture with LED bulbs also in the parking lot by the hockey rink and the field house. The Kim fixtures, which use 135 Watts of electricity, are mostly uniform though there is one Kim fixture that was retrofitted with LED bulbs.

The age of each light fixture varies. Age even varies within a particular style of light fixture. The oldest light fixtures on campus are the majority of the W&M fixtures, which were erected before 1990. Some W&M fixtures however, such as the 70W fixtures that line the walkway by Hollander Hall, were installed along with the construction of Shapiro Hall and Hollander Hall in 2007. The installation of the Kim fixtures in both the walkway between Paresky Student Center and Sage Hall and the Kim fixtures in the parking lot north of Hollander Hall also coincided with the Academic Building’s construction. The King Luminaires that line the walkways surrounding Morley Science Labs were put in place during the Math/Science Quad renovations in 1998/1999.

*The College’s Light Fixtures At A Glance*

(See Appendix A for a campus map showing locations of specific types of fixtures)

**William & Mary (traditional)**

Quantity: Over 300
Location(s): Most parking lots, Paresky lawn, Dodd Circle, walkways between Hopkins Hall and Shapiro Hall/Sawyer/Hollander Hall, among other locations.
Energy use: 175W
Type of bulb: Metal Halide
Average lifetime: 10,000 hours
Description: Traditional W&M light fixtures are nearly ubiquitous on the Williams College campus. The traditional W&M fixtures were installed in the late 1980s. The 175W Metal Halide (MH) bulb that they use consumes more energy than any other type that is used at Williams. These lights are significant contributors to nighttime light pollution because they are designed to direct light towards the ground. Instead of having a bulb that points at the ground, the bulb in traditional W&M fixtures sits in the middle of a lantern with glass walls. The only thing preventing the bulb from shining in every direction are the ceiling and floor of the lamp. As a result, while light is directed at the ground a significant amount of light is also directed at an angle pointing into the night sky. A full-coverage fixture emits light only at a downward angle and prevents light from being directly pointed into the sky. Examples of full-coverage fixtures on the Williams College campus are the Kim fixtures and the King Luminaires.

70W William & Mary
Quantity: Approximately 10
Location(s): The pathway that runs between Hopkins Hall and Shapiro Hall, between Sawyer Library and Stetson Hall, to the east of Hollander Hall, and in the parking lot outside of Towne Field House/Lansing Hockey rink.
Energy use: 70w
Type of bulb: MH
Average lifetime: 10,000 hours
Description: These fixtures look the same as the traditional W&M fixtures, excluding what is inside the lamp itself. The 70W W&M fixtures use a MH bulb that instead of shining in all directions, sits at the bottom of the lamp and shines directly up into the inside of an upside-down a metal bowl. This structure directs the light from the bulb down at the ground and therefore reduces the amount of light that is emitted into the night sky. These lights are easy to spot at night because they shine a distinct pattern onto the ground (see bottom photo).
**LED William & Mary**

Quantity: 1  
Location(s): Parking lot by Towne Field  
House/Lansing Hockey Rink  
Energy use: 65W or 99W, can be adjusted  
Type of bulb: LED  
Average lifetime: 50,000 hours

Description: The LED lamp can easily be adjusted to either use 65W or 99W. The one fixture currently installed on campus is running at 65W, which is considerably dimmer than if it were running at 99W. The LED W&M fixture has two sets of LED bulbs attached to the top of the fixture’s head, inside the glass lantern. These two bulbs are angled down towards the ground. When only 65W are running, a little more than half of each set of bulbs turns on while the other bulbs in each set remain off.

---

**EarthBulb William & Mary**

Quantity: 2  
Location(s): Spenser Art Studio  
Energy use: 120W  
Type of bulb: EarthBulb  
Average Lifetime: 10,000 hours

Description: The EarthBulb gives off a yellow glow that sets it apart from other W&M fixtures on campus.

---

**Kim fixture**

Quantity: Approximately 10  
Location(s): Eph’s Alley (between Paresky Student Center and Sage Hall), between Paresky and the President’s house, Hollander Hall parking lot, Tunnel City parking lot at the end of Spring St. (off-campus).  
Energy use: 70W  
Type of bulb: Metal Halide  
Average lifetime: 15,000 hours

Description: The Kim light fixtures have full cutoff lamps that are shaped like shoeboxes. A full cutoff lamp is designed to reduce light pollution by focusing the bulb’s light towards the ground. Because the direction of the light is more focused than fixtures like
the traditional W&Ms, generally less energy is required. They were installed with the construction of Paresky Student Center and Hollander Hall. Compared to the traditional W&M fixtures, they emit far less light pollution.

**King Luminaire**

Quantity: Approximately 50  
Location(s): Morley Drive, Math/Science Quad, Dennison Park Drive.  
Energy use: 170W  
Type of bulb: Metal Halide  
Average Lifetime: 15,000 hours  
Description: These fixtures can be considered a combination of the traditional W&M fixtures and the Kim fixtures: they feature the full cutoff lamps of the Kim fixtures but the energy use of the W&M fixtures. The King Luminaires surround and near Morley Science Labs are important to the Astronomy department because they are in close proximity to the observatory. If they were not full cutoff they would present a serious problem for anyone observing the nighttime sky from Morley.

**Possibilities for Improvement**

The light fixture that uses the least amount of electricity is the LED retrofitted W&M fixture running at 65W instead of the full 99W. The 70W Kim fixtures and the 70W retrofitted W&M fixtures use only slightly more energy. Therefore the LED W&M fixtures, the Kim fixtures, and the 70W retrofitted W&M fixtures are the most ideal lights currently on campus strictly from an energy-conserving perspective.

However, replacing every light fixture on campus with a Kim fixture is extremely expensive – considerably less expensive than retrofitting W&M fixtures that are already erected on campus.

Thus, this study will examine the possibility of retrofitting the 308 traditional W&M fixtures on campus, considering the LED W&M and the 70W W&M as potential retrofitted fixtures.

70W W&M fixtures are already being used on campus and are known to meet the lighting codes that the college must abide by. The LED W&M fixtures, however, have
not yet been tested. Therefore, it is important to first test whether the LED W&M fixtures will provide enough nighttime light to meet codes before their installation can be considered an adequate plan for energy conservation.

Retrofitted LED William & Mary fixtures and lighting codes

Article VI, C, (6), of the Code of Williamstown reads:

Lighting. Parking areas to be used at night shall be illuminated with lights so designed and placed as to provide sufficient illumination of the ground below, for the safe passage and identification of vehicles and pedestrians in immediate areas and so as to meet the standards of 70-5.4D. An average of from 0.3 to 0.5 footcandle lighting level throughout the parking area shall be required for safe and sufficient illumination. Where lighting levels in excess of the above average are deemed necessary by owners, lessees or others exercising control of said parking areas, a lighting level in excess of 0.5 footcandle may be authorized on special permit by the Board of Appeals upon its determination that the standards of 70-5.4D will still be met, and that the increased level is important to safety.

Measurements were taken from one LED W&M and its surround light fixtures at 11:00 PM on a relatively clear May night. Below are three tables, each containing measurement taken from the same parking lot on the same night (see Appendix B for a visual representation of the parking lot and its lighting). Table 1a shows measurements taken at varying distances away from the LED W&M (Light (a), see Appendix B). The four sets of measurements in Table 1a were each taken on an axis connecting Light (a) to another light in the parking lot (see Appendix C). For instance, the footcandle measurements listed for “Light (a) to Light (b)” were taken on the axis connecting Light (a) to Light (b).
<table>
<thead>
<tr>
<th>Distance from Light (a) (feet)</th>
<th>3</th>
<th>9</th>
<th>15</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis connecting (a) to (b)</td>
<td>0.65 fc</td>
<td>1.30 fc</td>
<td>1.21 fc</td>
<td>0.47 fc</td>
</tr>
<tr>
<td>Axis connecting (a) to (c)</td>
<td>0.28 fc</td>
<td>0.84 fc</td>
<td>0.93 fc</td>
<td>0.19 fc</td>
</tr>
<tr>
<td>Axis connecting (a) to (e)</td>
<td>0.28 fc</td>
<td>0.56 fc</td>
<td>1.30 fc</td>
<td>0.47 fc</td>
</tr>
</tbody>
</table>

Average luminescence (footcandle): 0.71

Table 1b

Measurements of luminescence taken from a traditional W&M behind Driscoll dining hall, 1:00 AM, clear night

<table>
<thead>
<tr>
<th>Distance from light fixture (ft.)</th>
<th>3</th>
<th>9</th>
<th>15</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminescence (footcandle)</td>
<td>0.56</td>
<td>1.21</td>
<td>0.84</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Average luminescence (footcandle): 0.70

Table 1c

Measurements of luminescence taken from a 70W W&M along the walkway to the east of Hollander Hall, 11:00 PM, clear night

<table>
<thead>
<tr>
<th>Distance from light fixture (ft.)</th>
<th>3</th>
<th>9</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminescence (footcandle)</td>
<td>0.84</td>
<td>5.67</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Average luminescence (footcandle): 2.27

Table 1d

Measurements of luminescence taken from a 175W W&M at the northern most point of Thompson parking lot and to the west of Poker Dormitories, 10:30 PM, clear night

<table>
<thead>
<tr>
<th>Distance from light fixture (ft.)</th>
<th>3</th>
<th>9</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminescence (footcandle)</td>
<td>0.90</td>
<td>1.49</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Average luminescence (footcandle): 0.86

The average lighting level surrounding Light (a) (the LED W&M) is above the range that the Code of Williamstown requires, but so are the averages taken in three areas that are known to abide by the code (as shown in Tables 1b, 1c, and 1d respectively). Thus, it can be inferred that the “average” found from Table 1a is in fact not the average
light level in the parking lot outside of Towne Field House and Lansing Hockey Rink. Possible explanations for why the average found from Table 1a is higher than expected are 1) a disproportionate number of readings were taken close to the light fixture where the light shines brighter, 2) light emitting from the light fixtures underneath the hockey rink’s overhand are in close proximity to the LED W&M

What the average from Table 1a shows, when compared to the respective averages from Tables 1b-1d is that the light emitted by the LED W&M is most likely very comparable to the light emitted from light fixtures that are known to satisfy the required codes. It is impossible to tell from these data the footcandle output of any given light (nearby lights are a factor that dramatically varies and is difficult to account for), but the averages from Tables 1b and 1d are so close to the average from Table 1a that it is likely the LED W&M emits the appropriate amount of light.

Cost of retrofitting W&M fixtures and money saved

Assuming that both the LED W&M and the 70W W&M meet lighting codes, then they are the two best options for improving the energy consumption of outdoor lighting. It would cost $980 to retrofit one W&M with an LED bulb (includes the price of labor). It would cost $400 to retrofit one W&M with a 70W MH bulb. The college currently spends $0.14 per kWh.

Table 2a

Energy use and cost for an individual light fixture

<table>
<thead>
<tr>
<th>Type of retrofitted fixt.</th>
<th>Energy use (W)</th>
<th>kWh per day</th>
<th>Cost per day ($)</th>
<th>Cost per year ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional W&amp;M</td>
<td>175</td>
<td>1.75</td>
<td>0.25</td>
<td>89.43</td>
</tr>
</tbody>
</table>
Table 2b

Energy use and cost of the 308 W&M fixtures if they were retrofitted, two options

<table>
<thead>
<tr>
<th>Type of W&amp;M</th>
<th>KWh per day</th>
<th>Cost per day ($)</th>
<th>Cost per year ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional W&amp;M</td>
<td>539</td>
<td>75.46</td>
<td>27542.9</td>
</tr>
<tr>
<td>65W LED W&amp;M</td>
<td>200.2</td>
<td>28.028</td>
<td>10230.22</td>
</tr>
<tr>
<td>70W W&amp;M</td>
<td>215.6</td>
<td>30.184</td>
<td>11017.16</td>
</tr>
</tbody>
</table>

Table 2c

<table>
<thead>
<tr>
<th>Type</th>
<th>Saved daily ($)</th>
<th>Saved yearly ($)</th>
<th>Saved yearly (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65W</td>
<td>47.432</td>
<td>17312.68</td>
<td>123,662</td>
</tr>
<tr>
<td>70W</td>
<td>45.276</td>
<td>16525.74</td>
<td>118,041</td>
</tr>
</tbody>
</table>

Table 2d

<table>
<thead>
<tr>
<th>Type of retrofit</th>
<th>Cost per retrofit ($)</th>
<th>Cost to retrofit 308 W&amp;M fixtures ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65W LED W&amp;M</td>
<td>980</td>
<td>301,840</td>
</tr>
<tr>
<td>70W W&amp;M</td>
<td>400</td>
<td>123,200</td>
</tr>
</tbody>
</table>

Table 2e

Besides the cost for installing the retrofit and the amount of money saved in electricity use, the other factor that determines the payoff time is the maintenance required in changing the bulb for each option. It is estimated that to fix a 70W retrofitted W&M when the light source reaches the end of its life would be $26 for the lamp, $100 for the ballast, and $125.60 (4 hours of work at $31.40 per hour) for the labor, reaching a total of $251.60.

The cost of fixing 308 fixtures with lamps that have reached their lifetime would be $77,492.80
<table>
<thead>
<tr>
<th>Type</th>
<th>Bulb</th>
<th>Lifetime (hours)</th>
<th>Lifetime (years)</th>
<th>Cost of maintenance per year ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad. W&amp;M</td>
<td>MH</td>
<td>10,000</td>
<td>2.7397</td>
<td>28285.14</td>
</tr>
<tr>
<td>65W LED W&amp;M</td>
<td>LED</td>
<td>50,000</td>
<td>13.6986</td>
<td>5656.99</td>
</tr>
<tr>
<td>70W W&amp;M</td>
<td>MH</td>
<td>10,000</td>
<td>2.7397</td>
<td>28285.14</td>
</tr>
</tbody>
</table>

The cost of maintenance per year was determined by dividing $77,492.80 by each type’s lifetime in years.

### Table 2f

<table>
<thead>
<tr>
<th>Type</th>
<th>Amount saved through maintenance per year ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65W LED W&amp;M</td>
<td>22,628</td>
</tr>
<tr>
<td>70W W&amp;M</td>
<td>0</td>
</tr>
</tbody>
</table>

Thus, the payoff time for both the 65W LED option and the 70W MH option can be determined through the following equation, in which y=years; M=money saved yearly through maintenance reduction; S=money saved yearly through electricity reduction; and C=cost to retrofit:

\[
C < (S \cdot y) + (M \cdot y) \Rightarrow C < y \cdot (S + M) \Rightarrow \frac{C}{(S + M)} < y
\]

### Table 2g

<table>
<thead>
<tr>
<th>Type of retrofit</th>
<th>Years until payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>65W LED W&amp;M</td>
<td>7.56</td>
</tr>
<tr>
<td>70W W&amp;M</td>
<td>7.46</td>
</tr>
</tbody>
</table>

### Conclusion

Though the LED lamps use slightly less electricity than the 70W W&M light fixtures (see Table 2a), and each bulb would last five times as long as a 70W W&M (Table 2e), they cost more than twice as much to retrofit as the 70W W&M MH fixtures (Table 2d). This major difference between the LED and 70W MH options in the price to retrofit the 308 W&M fixtures on campus is part of why the 70W MH retrofit option
would save slightly more money. Roughly 7.5 years is in fact significantly longer than
the optimal payback time that would be desirous for such a project. Ken Jensen,
Mechanical Maintenance Supervisor suggests 4-5 years as the ideal.

Both options would significantly reduce the electricity used by outdoor light
fixtures and the LED 65W option would save more energy (see Table 2c). From a
strictly environmental perspective, the LED 65W option is more energy conservative.

The 70W MH option would reduce electricity use significantly and would save
more money than the LED 65W.

Further Work

The Astronomy department should be consulted on the benefits (and potential
consequences) of both retrofit options. Both options would presumably please the
Astronomy department considering that they direct light downwards more so than the
traditional W&M fixtures. Thus, if the 308 W&M fixtures were retrofitted with either
option, it is possible that there would be less light pollution disrupting nighttime use of
the Morley observatory. However, the Astronomy department’s approval is unlikely for
this specific project even if it could be helpful. Full-coverage light fixtures the size of the
W&M fixtures are generally only helpful within roughly 100 yards of an observatory.
Any type of light fixture 100+ yards away from an observatory generally contributes the
same amount of light pollution into the night sky. Most of the W&M fixtures that
could be retrofitted are further than 100 yards away from Morley Science Labs (see
Appendix A).
Another benefit of both plans is that the LED 65W option and the 70W MH would not, arguably, be a way to save energy and simultaneously maintain the campus’s nighttime aesthetics. Replacing the W&M fixtures on campus with Kim fixtures would incur a significant change in the campus’s “look” at nighttime, not to mention a very significant cost. It would be prudent to identify parties concerned with the campus’s aesthetics and determine if they would approve of the two retrofit options.

Special Thanks

Ken Jensen for his wisdom and his enthusiasm for energy conservation; Steven Souza for introducing me to the many issues surrounding outdoor lighting; Alex Rubin and Marcus Morrissette for their willingness to take time away from Game 1 of the NBA’s 2010 Western Conference Finals featuring the Los Angeles Lakers vs. the doomed Phoenix Suns; Iliyana Hadjistoyanova for beginning her budding acting career in the made for GEOS 206 film, Rubo and Ily’s Night Out On The Town; and to the professors and students of GEOS/ENVI 206
There are in fact more than 406 and more than three types of outdoor light fixtures on campus, but there are only three types of light fixtures that are built into the ground. Others are attached to buildings and will not be considered in this study.

Most websites selling 175W Metal Halide lamps list their average lifetime to be between 10,000 and 20,000 hours. Ken Jensen, Mechanical Maintenance Supervisor, has considerable experience working with the 175W MH bulbs in the traditional W&M fixtures on campus and estimates their average lifetime to be 10,000 hours.

According to 1000Bulbs.com, a website that sells EarthBulbs and other light bulbs, the 120W EarthBulb has an average lifetime between 8,000 and 10,000 hours. For this report, the most optimistic estimation will be considered.

Interview with Steven Souza, Observatory Supervisor, Williams College, May 4, 2010.


Interview with Steven Souza, Observatory Supervisor, Williams College, May 4, 2010.