The National Optical Astronomy Observatory’s
International Year of Light 2015
Quality Lighting Teaching Kit
Workbook

Presented by

In partnership with
<table>
<thead>
<tr>
<th>K</th>
<th>What I Know</th>
<th>W</th>
<th>What I Want to Know</th>
<th>W</th>
<th>Where Can I Find What I Want to Know</th>
<th>L</th>
<th>What I Learned</th>
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How can we improve these streetlights and decrease the light pollution?

Streetlight 1:

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The National Optical Astronomy Observatory’s
IYL2015 QLT Kit
Shielding Lab Worksheet

What problem(s) did you solve?
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What problem(s) still could be addressed?
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How could you improve your design?
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Prototype 2:

Materials used:
Streetlight 2:

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Prototype 2:

Materials used:
Streetlight 3:

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What problem(s) still could be addressed?
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How could you improve your design?
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Prototype 2: _____________________________

Materials used: ____________________________
Conclusion: Look at your model up close and far away. What can you conclude about light pollution and shielding? Write a detailed summary about your procedures and discoveries in this lab today.
**K**
What I Know

**W**
What I Want to Know

**W**
Where Can I Find What I Want to Know

**L**
What I Learned

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Bulb Data Sheet

Bulb Type #1:

Bulb Wattage:

Bulb Lumens:

Hours Turned On In One Year:

Number of Bulbs:

Additional Notes:
Bulb Data Sheet

Bulb Type #2:

Bulb Wattage: ________________________

Bulb Lumens: ________________________

Hours Turned On In One Year: ________________________

Number of Bulbs: ________________________

Additional Notes:

________________________________________________________________________

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________________________________________________________________________

________________________________________________________________________
Bulb Type #3:

Bulb Wattage: 

Bulb Lumens: 

Hours Turned On In One Year: 

Number of Bulbs: 

Additional Notes:
Calculation Worksheet

Here is what you need to get started. This sheet will act as a reference throughout the rest of the calculations. Copy the information from the first three pages onto this page for convenience. Fill in each of these with the information from the bulb data sheets.

The gray square is used for the cost of electricity per kilowatt hour of all the electricity. Although there can be varying costs per kWh depending on the amount being used or the time of year, here we will use just one value so an average value should be assigned.

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For all bulbs:

Cost of electricity per kilowatt-hour\(^1\):  

\(^1\) For more information on this, see the last paragraph on page 8
The National Optical Astronomy Observatory’s
Quality Lighting Teaching Kit
Energy Calculation Worksheet

Use the numbers in the colors above to complete the next section of this worksheet. Repeat these steps for each type of bulb.

For this first set of calculations we will use **Bulb Type #1.** First we will find the efficacy of each bulb. The efficacy is the ratio of lumens to watts. The efficacy is related to the efficiency, but they are not the same thing. A larger efficacy means the bulb is more efficient. Which of the bulbs has the highest efficacy?

In this next step, we will calculate how many hours each bulb is on for in one year. This can be done by multiplying the number of bulbs and the estimated number of hours per year.

In this next step, we will find the energy used in year. Electric utility companies measure energy in a unit called watts. For example, if you have a 100-watt bulb and the light is on for 10 hours it uses 100W*10hours or 1,000Wh). To calculate the hours of energy used, the wattage (in watts) of the bulbs is multiplied by the estimated number the bulbs are turned on.
The National Optical Astronomy Observatory’s
Quality Lighting Teaching Kit
Energy Calculation Worksheet

Bulb Type #2

Step 1

\[
\frac{\text{Lumens of bulb}}{\text{Wattage of the bulb}} = \text{Efficacy of bulb Type 2}
\]

Step 2

\[
\text{Number of bulbs in Type 2} \times \frac{\text{Estimated hours per year}}{\text{Estimated hours used from all bulbs of Type 2}} = \]

Step 3

\[
\text{Wattage of bulb} \times \frac{\text{Estimated hours used from all bulbs}}{\text{Energy used in a year by all bulbs of Type 2}} = \]

Bulb Type #3

Step 1

\[
\frac{\text{Lumens of bulb}}{\text{Wattage of the bulb}} = \text{Efficacy of bulb Type 3}
\]

Step 2

\[
\text{Number of bulbs of Type 3} \times \frac{\text{Estimated hours per year}}{\text{Estimated hours used from all bulbs of Type 3}} = \]

Step 3

\[
\text{Wattage of bulb} \times \frac{\text{Estimated hours used from all bulbs}}{\text{Energy used in a year by all bulbs of Type 3}} = \]
Knowing how much energy each type of bulb uses is great. But it is easier to understand the energy being consumed if it is in one large number. So next we will add together the energy used for all of the bulbs.

Because of how quickly watt-hours add up, the term kilowatt hour is used to represent 1000 watt hours. You can convert the number of watt hours to kilowatt hours by dividing the number of watt hours (or energy) by 1000. We use kilowatt hours when handling a large number of watt hours so that it is a more manageable number.

An important part component of light pollution is the enormous cost of that is required to keep the lights turned on. The amount of money spent on lighting can be a huge issue for anybody. Electric utility companies charge for electricity by the kilowatt-hour (kWh). Next we will calculate how much it costs to use the amount of kilowatt-hours around your building. You can ask a district administrator for a school, your parents for your home or a business administrator for a local business about the cost per kilowatt-hour from their electricity company.
Electricity is most commonly produced from coal, hydropower, or nuclear power. When chemicals are burned, greenhouse gases are emitted that contribute to air pollution and global warming. The final important aspect of light pollution is the amount of greenhouse gases that are emitted during the production of electricity. Greenhouse gases are measured by the mass of the carbon dioxide gas. Depending on what is used to produce the electricity the greenhouse gases the emissions are typically 0.55kg to 0.99kg for every kilowatt-hour. Because it’s hard to know exactly, we’re going to use an average of 0.84kg per kilowatt-hour. To calculate how much greenhouse gas is produced, you need to multiply the kilowatt-hours used in a year by 0.84kg/kWh.

\[
\text{Kilowatt-hours used in a year} \times 0.84 \frac{\text{kg}}{\text{kWh}} = \text{Amount of greenhouse gas produced while powering outdoor lighting each year}
\]

If you know what kind of fuel your area uses (coal, natural gas, etc), you can check out this website and calculate your own conversion factor! You’ll also need to convert pounds to kilograms.

http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
Using the description of your setting, use the space on the next page to draw what your setting looks like as if you are looking at it from above. Put down a sticker for where your lights should go. Each sticker of a different color should represent one type of light. In the space provided, make a legend for what each color represents. For example, a blue sticker could represent a globe light, or a yellow sticker could represent a low pressure sodium light. It’s up to you! Just make sure you specify what each color means in your legend.

Legend
Use the space below to draw your setting, putting down stickers where the lights should go:
Now that you've finished drawing your setting and putting in where all the lights should go based on your original setting, what do you observe about your setting and the lights? Use the space below to write down your observations.

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Bulb Data Sheet

Bulb Type #1:

Bulb Wattage:

Bulb Lumens:

Hours Turned On In One Year:

Number of Bulbs:

Additional Notes:

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Bulb Data Sheet

Bulb Type #2:

_________________________________________

Bulb Wattage:  

Bulb Lumens:  

Hours Turned On
In One Year:

Number of Bulbs:  

Additional Notes:

____________________________________________________

____________________________________________________

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Bulb Type #3:

Bulb Wattage: 

Bulb Lumens: 

Hours Turned On In One Year: 

Number of Bulbs: 

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Bulb Type #2

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\]

Step 2

\[
\text{Number of bulbs in Type 2} \times \text{Estimated hours per year} = \text{Estimated hours used from all bulbs of Type 2}
\]

Step 3

\[
\text{Wattage of bulb} \times \text{Estimated hours used from all bulbs} = \text{Energy used in a year by all bulbs of Type 2}
\]

Bulb Type #3

Step 1

\[
\frac{\text{Lumens of bulb}}{\text{Wattage of the bulb}} = \text{Efficacy of bulb Type 3}
\]

Step 2

\[
\text{Number of bulbs of Type 3} \times \text{Estimated hours per year} = \text{Estimated hours used from all bulbs of Type 3}
\]

Step 3

\[
\text{Wattage of bulb} \times \text{Estimated hours used from all bulbs} = \text{Energy used in a year by all bulbs of Type 3}
\]
Knowing how much energy each type of bulb uses is great. But it is easier to understand the energy being consumed if it is in one large number. So next we will add together the energy used for all of the bulbs.

\[ \text{Energy used in a year by Bulb Type 1} + \text{Energy used in a year by Bulb Type 2} + \text{Energy used in a year by Bulb Type 3} = \text{Energy used for in a year by all bulbs} \]

Because of how quickly watt-hours add up, the term kilowatt hour is used to represent 1000 watt hours. You can convert the number of watt hours to kilowatt hours by dividing the number of watt hours (or energy) by 1000. We use kilowatt hours when handling a large number of watt hours so that it is a more manageable number.

\[ \frac{\text{Energy used in a year by all bulbs}}{1000} = \text{Kilowatt-hours used in a year} \]

An important part component of light pollution is the enormous cost of that is required to keep the lights turned on. The amount of money spent on lighting can be a huge issue for anybody. Electric utility companies charge for electricity by the kilowatt-hour (kWh). Next we will calculate how much it costs to use the amount of kilowatt-hours around your building. You can ask a district administrator for a school, your parents for your home or a business administrator for a local business about the cost per kilowatt-hour from their electricity company.

\[ \text{Kilowatt-hours used in a year} \times \text{Cost per kilowatt hour} = \text{Amount spent on outdoor lighting} \]
Electricity is most commonly produced from coal, hydropower, or nuclear power. When chemicals are burned, greenhouse gases are emitted that contribute to air pollution and global warming. The final important aspect of light pollution is the amount of greenhouse gases that are emitted during the production of electricity. Greenhouse gases are measured by the mass of the carbon dioxide gas. Depending on what is used to produce the electricity the greenhouse gases the emissions are typically 0.55kg to 0.99kg for every kilowatt-hour. Because it’s hard to know exactly, we’re going to use an average of 0.84kg per kilowatt-hour\(^2\). To calculate how much greenhouse gas is produced, you need to multiply the kilowatt-hours used in a year by 0.84kg/kWh.

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\(^2\) If you know what kind of fuel your area uses (coal, natural gas, etc), you can check out this website and calculate your own conversion factor! You’ll also need to convert pounds to kilograms.  
http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
The National Optical Astronomy Observatory’s
IYL2015 QLT Kit
Planning Worksheet

Name ______________________________
Setting ____________________________
Role _______________________________

What have you learned about your assigned role?
__________________________________________________________________________________________
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How are you going to use your role to fix the lighting in your setting?
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How is your group going to solve the lighting problem(s) in your setting?
__________________________________________________________________________________________
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Before you begin planning your City of the Future, use the checklist/questions below. The questions on the checklist are all things you should take into consideration and think about while you’re planning and trying to fix the lighting problem(s) in your setting:

- Are my lights shielded?
  - If so, how are they shielded?
- Is the light going only where I want it to go? (i.e. is it task-oriented?)
- Are my lights more energy efficient than they originally were? (From your Energy calculation worksheets)
  - Can/should they be even more energy efficient?
- How expensive are my lights?
- How expensive is it to keep my lights on?
- How many lights does my setting have?
  - How many lights does my setting need?
- How long do the lights need to be on for?
- Where should the lights be?
- Am I decreasing the amount of light pollution from my original setting?
- Am I addressing the problems from my original setting?
- Is my role helping to design my city of the future?
  - Have we taken into consideration:
    - Safety
    - Urban planning
    - The environment (wildlife, energy)
    - The medical component
- What is the color rendition (the CRI numbers on the “Types of Light” handout) of my lighting?
Now, using the space on the next page, you’re going to design your new and improved setting. Your drawing should be similar to what you did in the “Blueprint Worksheet”. You’ll be drawing your setting again, but this time, you’ll put down your new lighting plan. So, after your group has decided how many lights and what types of lights your setting should have, you’ll put down stickers where you and your group think the lights should go. Just like with the “Blueprint Worksheet”, each sticker will represent one streetlight, and you will create a legend to show what kind of light each sticker color represents. In the space below, you can also draw in any additional plans you and your group has thought of.

**Legend**
Use the space below to design your new and improved setting (be sure to point out how your role plays its part and to include the designs you made to a street light on your Shielding Lab Worksheet):
| Continued designing space if needed: |
Use the space below to briefly explain, in words, the design of your city of the future.

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How has your group decreased or minimized the light pollution in your setting? (You can specifically reference things from your above design)

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How has your group fixed the problem(s) from your original setting? (You can specifically reference things from your above design)

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__________________________________________________________________________________________
__________________________________________________________________________________________
Bulb Type #1:

Bulb Wattage:  

Bulb Lumens:  

Hours Turned On In One Year:  

Number of Bulbs:  

Additional Notes:

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
Bulb Type #2:

Bulb Wattage:

Bulb Lumens:

Hours Turned On

In One Year:

Number of Bulbs:

Additional Notes:
Bulb Data Sheet

Bulb Type #3:

Bulb Wattage:

Bulb Lumens:

Hours Turned On In One Year:

Number of Bulbs:

Additional Notes:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Calculation Worksheet

Here is what you need to get started. This sheet will act as a reference throughout the rest of the calculations. Copy the information from the first three pages onto this page for convenience. Fill in each of these with the information from the bulb data sheets.

The gray square is used for the cost of electricity per kilowatt hour of all the electricity. Although there can be varying costs per kWh depending on the amount being used or the time of year, here we will use just one value so an average value should be assigned.

<table>
<thead>
<tr>
<th>Bulb Type #1: ___________________</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bulbs needed:</td>
<td></td>
</tr>
<tr>
<td>Wattage of the bulbs:</td>
<td></td>
</tr>
<tr>
<td>Lumens of light:</td>
<td></td>
</tr>
<tr>
<td>Estimated hours turned on during a year’s time:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bulb Type #2: ___________________</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bulbs needed:</td>
<td></td>
</tr>
<tr>
<td>Wattage of the bulbs:</td>
<td></td>
</tr>
<tr>
<td>Lumens of light:</td>
<td></td>
</tr>
<tr>
<td>Estimated hours turned on during a year’s time:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bulb Type #3: ___________________</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bulbs needed:</td>
<td></td>
</tr>
<tr>
<td>Wattage of the bulbs:</td>
<td></td>
</tr>
<tr>
<td>Lumens of light:</td>
<td></td>
</tr>
<tr>
<td>Estimated hours turned on during a year’s time:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For all bulbs:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of electricity per kilowatt-hour(^1):</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) For more information on this, see the last paragraph on page 8
The National Optical Astronomy Observatory’s
Quality Lighting Teaching Kit
Energy Calculation Worksheet

Use the numbers in the colors above to complete the next section of this worksheet. Repeat these steps for each type of bulb.

For this first set of calculations we will use **Bulb Type #1**. First we will find the efficacy of each bulb. The efficacy is the ratio of lumens to watts. The efficacy is related to the efficiency, but they are not the same thing. A larger efficacy means the bulb is more efficient. Which of the bulbs has the highest efficacy?

In this next step, we will calculate how many hours each bulb is on for in one year. This can be done by multiplying the number of bulbs and the estimated number of hours per year.

In this next step, we will find the energy used in year. Electric utility companies measure energy in a unit called watts. For example, if you have a 100-watt bulb and the light is on for 10 hours it uses 100W*10hours or 1,000Wh). To calculate the hours of energy used, the wattage (in watts) of the bulbs is multiplied by the estimated number the bulbs are turned on.
# The National Optical Astronomy Observatory’s Quality Lighting Teaching Kit

## Energy Calculation Worksheet

### Bulb Type #2

<table>
<thead>
<tr>
<th>Step 1</th>
<th>[ \frac{\text{Lumens of bulb}}{\text{Wattage of the bulb}} = \text{Efficacy of bulb Type 2} ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>[ \times \text{Number of bulbs in Type 2} = \text{Estimated hours used from all bulbs of Type 2} ]</td>
</tr>
<tr>
<td>Step 3</td>
<td>[ \times \text{Wattage of bulb} = \text{Energy used in a year by all bulbs of Type 2} ]</td>
</tr>
</tbody>
</table>

### Bulb Type #3

<table>
<thead>
<tr>
<th>Step 1</th>
<th>[ \frac{\text{Lumens of bulb}}{\text{Wattage of the bulb}} = \text{Efficacy of bulb Type 3} ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>[ \times \text{Number of bulbs of Type 3} = \text{Estimated hours used from all bulbs of Type 3} ]</td>
</tr>
<tr>
<td>Step 3</td>
<td>[ \times \text{Wattage of bulb} = \text{Energy used in a year by all bulbs of Type 3} ]</td>
</tr>
</tbody>
</table>
Knowing how much energy each type of bulb uses is great. But it is easier to understand the energy being consumed if it is in one large number. So next we will add together the energy used for all of the bulbs.

\[ \text{Energy used in a year by Bulb Type 1} + \text{Energy used in a year by Bulb Type 2} + \text{Energy used in a year by Bulb Type 3} = \text{Energy used for in a year by all bulbs} \]

Because of how quickly watt-hours add up, the term kilowatt hour is used to represent 1000 watt hours. You can convert the number of watt hours to kilowatt hours by dividing the number of watt hours (or energy) by 1000. We use kilowatt hours when handling a large number of watt hours so that it is a more manageable number.

\[ \text{Energy used in a year by all bulbs} \div 1000 = \text{Kilowatt-hours used in a year} \]

An important part component of light pollution is the enormous cost of that is required to keep the lights turned on. The amount of money spent on lighting can be a huge issue for anybody. Electric utility companies charge for electricity by the kilowatt-hour (kWh). Next we will calculate how much it costs to use the amount of kilowatt-hours around your building. You can ask a district administrator for a school, your parents for your home or a business administrator for a local business about the cost per kilowatt-hour from their electricity company.

\[ \text{Kilowatt-hours used in a year} \times \text{Cost per kilowatt hour} = \text{Amount spent on outdoor lighting} \]
Electricity is most commonly produced from coal, hydropower, or nuclear power. When chemicals are burned, greenhouse gases are emitted that contribute to air pollution and global warming. The final important aspect of light pollution is the amount of greenhouse gases that are emitted during the production of electricity. Greenhouse gases are measured by the mass of the carbon dioxide gas. Depending on what is used to produce the electricity the greenhouse gases the emissions are typically 0.55kg to 0.99kg for every kilowatt-hour. Because it’s hard to know exactly, we’re going to use an average of 0.84kg per kilowatt-hour\(^2\). To calculate how much greenhouse gas is produced, you need to multiply the kilowatt-hours used in a year by 0.84kg/kWh.

\[
\text{Kilowatt-hours used in a year} \times 0.84 \text{ kg/kWh} = \text{Amount of greenhouse gas produced while powering outdoor lighting each year}
\]

\(^2\) If you know what kind of fuel your area uses (coal, natural gas, etc), you can check out this website and calculate your own conversion factor! You’ll also need to convert pounds to kilograms.

[http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11](http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11)