### **Supplementary Materials**

### **The Bright Darkness**

### Assessing Public Attitudes Towards Light Pollution in Princeton, MA and Recommending Approaches to Mitigation

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# **Appendix A: Princeton Outdoor Lighting Survey**

Princeton Outdoor Lighting Survey - Assessing the views of Princeton residents on light pollution as an environmental issue, sources of light pollution, and regulation for light pollution.

We are students from Worcester Polytechnic Institute in Massachusetts who are working with the Town of Princeton's Environmental Action Committee (EAC). Our goal is to learn about the views of Princeton residents concerning light pollution, which is the excessive or misdirected use of artificial light outdoors. Your participation is very important. It will help us learn more about light use in Princeton, and to identify feasible measures to reduce unnecessary or problematic light use. The survey should only take about 5 minutes and must be completed by May 1st.

Your participation in this survey is voluntary. You will not be asked for identifying information such as your name, email address, and Google Forms does not track your IP address. Therefore, your responses will remain anonymous. If you have questions at any time about the study or the procedures you may contact our research supervisor Professor Robert Hersh via email at hersh@wpi.edu.

ELECTRONIC CONSENT: Please select your choice below. You may print a copy of this consent form for your records. Clicking on the "Agree" button indicates that

- You have read the above information
- · You voluntarily agree to participate
- You are 18 years of age or older
- " Agree
- " Disagree

For the purpose of this survey a few key terms have been defined below.

### Key Terms

Light Pollution - The excessive or misdirected use of artificial light outdoors

Light Trespass - Any light that extends beyond its intended area of use, specifically property lines

Light at Night (LAN) - Exposure to light at normally dark times

Shielding - The use of a physical barrier around a light to properly direct light

### Survey Questions

The link to the Google Form containing the survey questions can be found here: <u>https://forms.gle/sUmHUeVGZBSfVBYMA</u>

- 1. How long have you lived in Princeton?
- 2. In the time that you have lived in Princeton, have you noticed a reduction in the number of stars that are visible in the night sky?
- 3. Please identify the three examples of light use listed below which you believe contribute the most to light trespass or light pollution in Princeton.
- 4. Light pollution affects my enjoyment of the night sky.
- 5. Everyone in Princeton should be able to see a clear, starry night sky.
- 6. Residential areas in Princeton that have lights on at night are safer than areas that do not.
- 7. Business/municipal areas in Princeton that have lights on at night after business hours are safer than areas that do not.
- 8. I am negatively affected by glare from street lights when driving at night in Princeton.
- 9. I would like to see more street lights added along Princeton streets.
- 10. Light trespass--any light that extends beyond its intended area of use, specifically property lines--has negatively affected me personally in Princeton.
- 11. I am concerned about how light pollution might negatively impact the night sky in Princeton in the future.
- 12. Scientific studies suggest that light pollution may interfere with the behaviors and circadian rhythms of plants and animals.

Over the past five years, have you noticed a decrease in the number of fireflies you have seen at night in Princeton?

- 13. From the list below, please select any methods for reducing light pollution which you would be willing to support in Princeton:
  - a. Shielding of outdoor commercial/municipal lights to direct light and limit light trespass
  - b. Retrofitting of bulbs for streetlights (e.g., wattages- amount of energy a bulb uses;

lumens-the amount of visible light emitted from a bulb)

- c. Turning off outdoor residential lights after a certain hour at night
- d. Motion sensors for outdoor commercial/municipal lights
- e. Retrofitting of bulbs for outdoor residential lights (e.g., wattages, lumens)
- f. Shielding on residential lights to direct light and limit light trespass
- g. Turning off outdoor commercial/municipal lights to direct light outside of business hours
- h. Motion sensors for outdoor commercial/municipal lights
- i. Shielding of outdoor commercial/municipal lights to direct light and limit light trespass
- 14. Do you have any other lighting concerns or observations?
- 15. Do you read the Environmental Action Committee's monthly newsletter, "The Green News"?
- 16. In the above image, do you live in zone A, B, C, or D?



## **Appendix B: Rick Rys Interview Questions**

Hello Mr. Rys. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by our project sponsors Claire Golding and Corey Burnham-Howard, who suggested we contact you given your current position as the PLMD Committee Chairman. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. We are trying to map out light pollution within Princeton. When researching the PMLD we found that they have approximately 1,500 customers and services 35 square miles with 86 road miles of poles, lines and hardware and a \$4,000,000.00 annual budget
  - a. If any, what kind of resources could you provide us with that indicate locations of light within Princeton?
    - i. Do you have a map/maps that show the relative placement of these lights?
    - ii. Does the PLMD have birds-eye photography of Princeton at night?
- 2. Princeton underwent the LED street light conversion project:
  - a. How much did it cost to make this switch, and how long did it take to make this switch?
  - b. Was there any consideration of any light shading technologies?
  - c. What is the current policy on getting privately owned street lights?
    - i. Were requested lights by residents changed (when PMLD changed the lights), or any private owned lights.. Sports fields, etc.?
  - d. How much money has been saved in terms of energy since the switch?
  - e. Have there been many complaints about the brightness of the lights following the switch?

- f. What percentage of the community would you say was in support versus opposition for this change?
- g. Were outreach materials created in this effort?
- 3. How are new policies introduced at the PMLD?
  - a. How do Princeton residents affect policy at the PMLD?
    - i. Is it just through the election of yourself and others in your position or is there a more direct way that residents influence the PMLD's workings
  - b. Is the PMLD currently taking any measures to address light pollution?
  - c. What incentives could the PMLD offer to residents to encourage a reduction in light pollution? (timers, light shields, etc..)
  - 3. In your perspective, what are the major sources of light pollution in Princeton? In the larger region (of Central MA)?
    - a. How would you characterize differences in light pollution in Princeton over the time you have spent living/working in Princeton?
    - b. What approaches might you take to encourage light pollution reduction to others within the community?
  - 4. There has been an uptick in residential development in the last decade in Princeton, to what extent has these developments contributed to light pollution in Princeton?
    - a. Are there any future developments in Princeton that you believe may increase light pollution?
  - 5. After hearing a little about our project and getting a sense of the questions and answers we are looking for, are there any specific people you think it would be beneficial to talk to (not necessarily PMLD related)?

# **Appendix C: Sean McKeon Interview Questions**

### Consent Script

Hello Mr. McKeon. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by our project sponsors Claire Golding and Corey Burnham-Howard, who suggested we contact you given your position as Manager at the PMLD. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. Do you have maps of Princeton that show the distribution of streetlights in the town and/or aerial view photography of the town at night?
  - a. If so, would you mind sharing those with us?
- 2. How are decisions about street lights on public properties made?
  - a. What goes into the process of an individual resident requesting a new streetlight?
  - b. What kind of lights are used for these streetlights?
- 3. Princeton underwent the LED street light conversion project:
  - a. How much did it cost to make this switch, and how long did it take to make this switch?
  - b. How much money has been saved in terms of energy since the switch?
  - c. Was there any consideration of light shading technologies?
  - d. Have there been many complaints about the brightness of the lights following the switch?
  - e. What percentage of the community would you say was in support versus opposition for this change?
- 4. Is the PMLD currently taking any measures to address light pollution?
  - a. What incentives could the PMLD offer to residents to encourage a reduction in light pollution? (timers, light shields, etc..)
- 5. New residential development in Princeton has increased over the last few decades, to what extent has new development contributed to light pollution in Princeton?
  - a. What future development (Public Works Building) may increase light pollution?

- b. What approaches might you take to encourage light pollution reduction to others within the community?
- 6. After hearing a little about our project and getting a sense of the questions and answers we are looking for, are there any specific people you think it would be beneficial to talk to (not necessarily PMLD related)?

## **Appendix D: Tom Sullivan Interview Questions**

### **Consent Script**

Hello Mr. Sullivan. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by our project sponsors Claire Golding and Corey Burnham-Howard, who suggested we contact you given your past positions on the Wachusett Mountain Advisory Council and National Grid and your current position on the Princeton Planning Board. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. Could you tell us a little bit about the period of time you were on the Wachusett Mountain Advisory Council and the discussion you had about lighting at the ski resort and the impacts that had for neighboring towns?
  - a. Could you help us understand how decisions about lighting at the mountain are made?
  - b. To what extent has the WMAC advocated for reduced lighting?
  - c. What are the constraints in your view to reducing light pollution at the mountain?
  - d. What opportunities do Princeton residents have to voice their concerns to the Ski area?
- 2. Does Princeton retain any position in the Wachusett Mountain Advisory Committee at this point in time?
  - a. If so, what voice do residents express in the appointment of this position and what role does this position play on the committee?
- 3. In your perspective, what are the major sources of light pollution in Princeton? In the larger region (of Central MA)?

- a. To what extent do you believe that the Wachusett Ski Resort contributes to the light pollution in Princeton?
- b. How would you characterize differences in light pollution in Princeton over the time you have spent living/working in Princeton?
- c. What approaches might you take to encourage light pollution reduction to others within the community?
- 4. There has been an uptick in residential development in the last decade in Princeton, to what extent has these developments contributed to light pollution in Princeton?
- 5. During your time on the Planning Board in Princeton, to what extent have light pollution concerns been raised?
- 6. Do you know of any lighting related issues in Princeton which a light pollution bylaw could help address? (Glare from streetlights, light trespass, lightening of the night sky, etc.)
- 7. What would be the best and/or most likely scenario for lighting regulation to be placed in town legislation? (i.e. we have found through our research that lighting bylaws are placed within existing zoning or nuisance bylaws by similar municipals)
  - a. What would be the most feasible path for lighting regulation to be passed, either being proposed as a zoning bylaw or a general bylaw?
- 8. What kinds of growth and development do you see in the future for Princeton?

# **Appendix E: John Mirick Interview Questions**

### **Consent Script**

Hello Mr. Mirick. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by our project sponsors Claire Golding and Corey Burnham-Howard, who suggested we contact you given your positions on the Princeton Land Trust and the Princeton Planning Board. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. During your time on the Planning Board in Princeton, to what extent have light pollution concerns been raised?
- 2. Do you know of any lighting related issues in Princeton which a light pollution bylaw could help address? (Glare from streetlights, light trespass, lightening of the night sky, etc.)
- 3. What would be the best and/or most likely scenario for a lighting bylaw in Princeton? (i.e. we have found through our research that lighting bylaws are placed within existing zoning or nuisance bylaws by similar municipals)
  - a. What would be the most feasible path for lighting regulation to be passed, either being proposed as a zoning bylaw or a general bylaw?
- 4. In your perspective, what are the major sources of light pollution in Princeton? In the larger region (of Central MA)?
  - a. To what extent do you believe that the Wachusett Ski Resort contributes to the light pollution in Princeton?
  - b. How would you characterize differences in light pollution in Princeton over the time you have spent living/working in Princeton?
  - c. What approaches might you take to encourage light pollution reduction to others within the community?

- 5. There has been an uptick in residential development in the last decade in Princeton, to what extent has these developments contributed to light pollution in Princeton?
- 6. What kinds of growth and development do you see in the future for Princeton?
  - a. Will any of this development contribute to light pollution in Princeton?
- 7. Princeton underwent the LED street light conversion project:
  - a. Have there been many complaints about the brightness of the lights following the switch?
  - b. What percentage of the community would you say was in support versus opposition for this change?
- 8. We understand that you and your family have lived in Princeton for many years. In the time you've lived in the town:
  - a. Have you noticed changes in the night sky caused by light pollution?
  - b. Has the attitude towards maintaining a rural environment in Princeton changed over time?
    - i. Is that attitude more or less prevalent now than it was before?
    - ii. Do you think Princeton residents would see maintaining a clear, dark sky as essential to that rural character?
  - c. Has the way the town develops and expands changed over time?
    - i. Residential vs. commercial development, type and proximity of residential properties, etc.

# **Appendix F: Helga Kuechly Interview Questions**

### **Consent Script**

Hello Mrs. Kuechly. We are American students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by Professor Katherine Foo, who suggested we contact you as an expert on light pollution. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

Interview Questions for Dr. Kuechly

- 1. How long have you been working on light pollution issues?
- 2. Have you studied light pollution in America?
  - a. Are the most responsible technologies / institutions that contribute to light pollution the same in America as in Europe?
- 3. What have you found to be the largest contributor to light pollution?
  - a. How do the impacts of different types of lighting, residential, business, or street lighting, compare?
  - b. How impactful are changes that individuals make to their light usage compared to infrastructural lights or businesses?
- 4. What negative effects of light pollution on ecology have you noticed? On people?
  - a. Are the negative effects of light pollution on human health the same as, or related to, the negative effects associated with LAN (Light-At-Night)?
  - b. What negative effects of light pollution do you believe makes the most impact on an individual when they hear it and succeeds in convincing them to take action in reducing light pollution?
- 5. You have worked on citizen science projects related to light pollution and imagery of the night sky, could you give more detail on the goal of these projects and the most effective methods for outreaching to communities?
  - a. What are the potential benefits for communities to implement these sort of citizen science projects?
  - b. What tips would you have for getting communities involved in citizen science initiatives?
- 6. What sort of difficulties are typically associated with trying to obtain images that accurately depict the effects of light pollution?
  - a. How accurate would images of rural, residential environments be compared to

images of densely populated cities with much larger scale light pollution?

# **Appendix G: Peter Morrison Interview Questions**

### **Consent Script**

Hello Mr. Morrison. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by Gregg Tivnan, who suggested we contact you to inquire further on lighting regulation in Nantucket. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

Interview Questions for Mr. Morrison

- 1. Nantucket is similar to Princeton in many senses
  - a. It is known for its rural character
  - b. It recently just switched over to LED's
    - i. This was motivated by a grant. During your time with Nantuckets Civic League have you done much research on available grants in general?
      - 1. Do you have any suggestion on how to go about finding potential grants for Princeton?
- 2. In March you completed the public forum "Light Pollution and The 'Dark Sky' Movement"
  - a. One thing we are trying to do is map light pollution in Princeton, MA
    - i. Is the first figure on the newsletter from satellite imagery?
      - 1. Do you know of a link to this particular site which we could use on Princeton?
  - b. Another thing we are trying to do is create outreach outlining negative effects of light pollution and ways individuals can help reduce it
    - i. The NCL collaborated with NCTV for a public forum to raise awareness about the effects of LEDs and ways it could be reduced
      - 1. How did you decide that a public zoom forum was the best method?
        - a. Was there consideration for other forms of outreach (infographics, newsletters, etc.)?
      - 2. How willing was NCTV to collaborate for this?
        - a. Did you consider collaborating with other platforms as well?
      - 3. How was the attendance for the forum?

- 4. How was the engagement from the attendees
  - a. Were there many questions/concerns and if so what were they?
  - b. Would you recommend this is something that we do
- 3. It appears there is a "Nantucket Lights" google group as well as emails dedicated to people interested in the dark sky efforts
  - a. How has activity been on these sites
    - i. Have you found that many people are interested in the dark sky initiative?
- 4. We understand that Nantucket is one of the 41 Massachusett towns to adopt an outdoor lighting bylaw. Do you know...
  - a. What motivated the adoption of this bylaw?
  - b. How was this bylaw advocated for before its passing?
    - i. How was support for a lighting bylaw gauged (e.g. Surveys, interviews, town meetings?)
    - ii. What kind of outreach materials were used in the community before the passing of the bylaw? (e.g. Infographics, Newsletters)
    - iii. What are some positive differences seen in the community as a result of the lighting bylaw?
    - iv. What are some of the complaints for the community (if any) since the bylaw has been passed?

# **Appendix H: Tim Brothers Interview Questions**

### Tim Brothers Interview

### **Consent Script**

Hello Mr. Brothers. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by one of your colleagues, who suggested we contact you to inquire further on lighting regulations you've drafted for Pepperell and your work with the IDA. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. When/how did you realize that light pollution is a serious issue and its effects need to be addressed?
- 2. How has light pollution affected your work at the Wallace Observatory?
- 3. Does the Wallace Observatory run outreach programs to engage with the community, and if so do you think educational info about light pollution would fit into these programs?
- 4. What are your main roles as Vice President of the Massachusetts section of the IDA?
  - a. What are the main goals of the IDA as a whole, and maybe you could provide a brief breakdown of how they approach reaching these goals?
  - b. How important to the IDA is passing lighting regulations on a town level, state level, etc...?
  - c. Does the IDA typically work with towns to help them address lighting concerns or show people the impacts of light pollution?
- 5. We saw you've drafted a lighting ordinance that is going to vote in Pepperell, MA this June, could you tell us a little about the process of drafting those regulations? How did you engage with the community to get residents' perspectives? How were you able to show people the impacts of light pollution? How did you spark interest in light pollution?
  - a. Biggest challenges/pushback the ordinance faces?
- 6. What are the best methods or resources you've used to show people the impacts of light pollution and help them understand how to properly use lighting?
- 7. What would be the most important steps a town can take to properly address lighting and thoughtfully develop a plan to manage it in the future?

# **Appendix I: Tim Hammond Interview Questions**

### **Consent Script**

Hello Mr. Hammond. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by our project sponsors Claire Golding and Corey Burnham-Howard, who suggested we contact you given your position on the Wachusett Mountain Advisory Council. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. Could you tell us a little bit about your experience on the Wachusett Mountain Advisory Council?
  - a. What is the extent of actions and roles the Wachusett Mountain Advisory Committee has at this point in time?
  - b. What voice do residents express in the appointment of WMAC positions and throughout any decision making process?
- 2. Does the WMAC work with any local community groups or run any outreach programs to engage with the community?
- 3. Is the WMAC aware of any environmental concerns around light pollution affecting insects and animals such as birds?
- 4. Has the WMAC ever considered advocating for reduced lighting on the mountain?
- 5. What are the constraints in your view to reducing light pollution at the mountain?
- 6. What opportunities do Princeton residents have to voice their concerns to the Ski area?
- 7. Could you tell us anything you know about the lease held between the ski resort and DCR, specifically any regulations that are laid out within the lease?
- 8. What is your opinion on light pollution in Princeton..
  - a. Biggest sources/contributors?
  - b. View of the night sky in the time you've been a resident?

# **Appendix J: Kelly Beatty Interview Questions**

### **Consent Script**

Hello Mr. Beatty. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by Peter Morrison, who suggested we watch Nantucket's Light Pollution Forum and contact you to inquire further on your knowledge of light pollution. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

Kelly Beaty Interview Questions

- 1. When/how did you realize that light pollution is a serious issue and its effects need to be addressed?
- 2. Have you noticed a change in the night sky and what you're able to see, whether from your work or just stargazing from your residence?
- 3. What are/were your main roles for the Massachusetts section of the IDA?
  - a. What are the main goals of the IDA as a whole, and maybe you could provide a brief breakdown of how they approach reaching these goals?
  - b. How important to the IDA is passing lighting regulations on a town level, state level, etc...?
  - c. Does the IDA typically work with towns to help them address lighting concerns or show people the impacts of light pollution?
- 4. To what extent have you been involved with trying to pass statewide lighting legislation in Massachusetts?
  - a. Biggest challenges this legislation faces?
  - b. Main benefits to statewide lighting regulations and town lighting regulations?
- 5. What are the best methods or resources you've used to show people the impacts of light pollution and help them understand how to properly use lighting?
- 6. What would be the most important steps a town can take to properly address lighting and thoughtfully develop a plan to manage it in the future?
- 7. Do you know of any grants/free bulb demos which Princeton may be able to receive?
- 8. Could we utilize the PowerPoint presentations you used/created for Nantucket's forum when we offer outreach materials to the residents in Princeton, MA?

# **Appendix K: James Lowenthal Interview Questions**

### **Consent Script**

Hello Mr. Lowenthal. We are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in the rural town of Princeton in Massachusetts. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by a member of the Aldrich Astronomical Society, who suggested we contact you to inquire further on lighting regulations adopted in North Hampton and your work with the IDA. Would it be okay to record this interview to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission.

The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- 1. When/how did you realize that light pollution is a serious issue and its effects need to be addressed?
- 2. As a Professor of Astronomy, how do you think your understanding of light pollution ( or perspective) is different from somebody who is just learning of the effects of light pollution?
- 3. Have you noticed a change in the night sky and what you're able to see, whether from your work or just stargazing from your residence?
- 4. What are/were your main roles as President of the Massachusetts section of the IDA?
  - a. What are the main goals of the IDA as a whole, and maybe you could provide a brief breakdown of how they approach reaching these goals?
  - b. How important to the IDA is passing lighting regulations on a town level, state level, etc...?
  - c. Does the IDA typically work with towns to help them address lighting concerns or show people the impacts of light pollution?
- 5. To what extent have you been involved with trying to pass statewide lighting legislation in Massachusetts?
  - a. Biggest challenges this legislation faces?
  - b. Main benefits to statewide lighting regulations and town lighting regulations?
- 6. What are the best methods or resources you've used to show people the impacts of light pollution and help them understand how to properly use lighting?
- 7. We've seen you've written about the lighting regulations adopted in Northampton, could you tell us a little more about those? Also there was a LED conversion project that seems to occurred in conjunction with the regulations adopted and you had criticized the change of lights... could you tell us a little more about why and specifically the relationship

between implementing updated, energy efficient LED lights and light pollution concerns?

- a. Is it similar in cost and availability for towns to obtain warmer tone LEDs (PC amber LEDS)?
- 8. How/when was Northampton's City Lights group that you're involved with start?
  - a. Is there an official authority within the town or work with town officials?
- 9. What would be the most important steps a town can take to properly address lighting and thoughtfully develop a plan to manage it in the future?

# **Appendix L: Gail Walker Interview Questions**

### **Consent Script**

Hello Ms. Walker, we are students from Worcester Polytechnic Institute doing a research project on reducing light pollution in Princeton. We are working with the Environmental Action Committee (EAC) in the town. Your name was given to us by Peter Morrison, who suggested we contact you as a knowledgeable source for lighting bylaws and outreach within a community. Would it be okay to record this interview on our phones to make sure we capture your responses? If you would rather not, it's perfectly fine, we can just take notes instead. Do we have your permission to quote you in our report? Any information you share with us is completely confidential and will only be used for research purposes with your permission. The goal of this project is to assist Princeton's Environmental Action Committee by assessing the contributors and levels of light pollution within the town and strategies to reduce light pollution, ranging from voluntary measures local residents could take to drafting a light ordinance. To do so, we have developed four objectives: mapping light at night in Princeton, assessing the views of Princeton residents on light pollution, assessing the feasibility of a lighting bylaw in Princeton, and developing outreach materials for Princeton residents.

- What were the major goals of your outreaching programs?
- What aspects of the Nantucket community did you take into consideration when developing/structuring outreach programs?
- What are the potential benefits for communities to implement these sort of citizen science projects?
- What tips would you have for getting communities involved in citizen science initiatives?
- Did you receive any pushback from the Nantucket community when the bylaw was first getting pushed out?
- What did the pushback look like? And what were peoples' main concerns?
- How far in advance did you begin outreaching to the Nantucket community about light pollution?
- What kinds of programs/citizen-science programs/informational sessions/events did you put on?
  - i. What was most effective in sparking interest about the night sky/light

pollution in the community?

- ii. How did you follow up with the community after these events took place?
- iii. How receptive was the community when it came to learning about light pollution? Did people express their concerns for light pollution and/or show that they wanted to make a change in their daily lives to reduce light pollution?
- What are the best methods or resources you've provided to people to show them the impacts of light pollution, and help them understand how to properly use lighting?
  - a. For nantucket, a website..

# **Appendix M: EAC Newsletter**

\*\*Disclaimer: The current version of the EAC Newsletter we drafted below is <u>NOT</u> in its final form. The EAC will be revising it to fit the format and audience of their Newsletter after we have completed the term of our project period, and will provide us with any additional feedback they'd like to see in potential revisions from us.

### THE BRIGHT DARKNESS

Authors: Liam Cox, Mary Decelles, Alex Kelleher & Sophia Puch Date: May 2021

### What is Light Pollution?

Astronomers suggest that our Milky Way Galaxy contains a hundred billion stars (Howell, 2018). But when you look up at the night sky from where you live, how many stars can you actually see? According to the 2016 "World Atlas of Artificial Night Sky Brightness", 99% of the public in both the United States and Europe are unable to experience a night of natural celestial light because of light pollution. Light pollution is the excessive use of artificial light in areas that are naturally dark. It causes effects including sky glow, glare, and light trespass, which all prevent the natural glow of stars in the sky from being seen with the naked eye. As industrial and city development increases, artificial light becomes more prevalent over time.

Sky glow appears as a blanket of light over densely populated areas such as Boston, or Worcester (see Figure 1). Glare is created by light which shines horizontally from lighting technologies, and often causes discomfort or loss of visual senses (see Figure 2). An example of glare is the light that comes from bright LED car headlights on roads at night, which frequently blind drivers moving in the opposite direction for a few seconds. Lastly, light trespass occurs when unaimed artificial light spills onto nearby property which it was not originally intended to illuminate (see Figure 3). This is common in areas where compact development is present, and a neighboring home may have lights that not only light their driveway, but also light the driveway of surrounding homes.



Figure 1. The photo above depicts the effects of light pollution on the night sky in the form of sky glow. The photo was captured near a parking lot in Ontario, Canada lit by bright LED lights (Nielsen, 2017).



Figure 2. The photo above depicts light pollution in the form of light trespass, with the light illuminating more than just the intended subject (NELPAG, 2006).



Figure 3. The image above depicts an example of glare, an effect of light pollution which can cause visual impairment and discomfort (NLPIP, 2003).

### What are the effects of light pollution on humans?

Bright artificial lights projected into the atmosphere disrupts human and animal life. In humans, effects of light pollution such as sky glow, light trespass and glare causes visual discomfort and impairment and disturbs the enjoyment of the natural night sky, so that people see fewer stars than they should.



Figure 4. A photo from before and after the 2003 Northeast power outage. (Carlson, 2003)

Excessive exposure to artificial lights heavily influences our natural circadian rhythms and our relationship with sleep. Our sleep-wake cycle, which is monitored and maintained by our hypothalamus, or our natural clocks, perceives all light as a signal to remain awake and stay alert. But, as the day carries on and the sky becomes darker, the hypothalamus begins to release signals and hormones throughout the rest of the body which indicates a resting period for our bodies and biological processes. When interrupted by artificial lighting, including light trespass, the body's natural circadian rhythms are unable to distinguish for itself the differences between the waking and sleeping period. Prolonged and repeated disruption causes dysfunction of organs and systems within the body like the heart, lung, esophagus, and spleen (Luyster, et al. 2012) and causes other side effects like depression and headaches (Khorram et. al, 2014).

Researchers linked some psychological issues, such as feelings of loneliness, anxiety and depression, as consequences of exposure to light pollution in both young adolescents and adults (Medic, G., Wille, M. and Hemels. M., 2017). The widespread use of LED lights emits a large amount of blue light into the sky. Excessive exposure to these blue lights, which stimulate parts of our brains to keep us alert, can have a drastic effect on an individual's mental health. Since blue light suppresses release of melatonin, chronic interference with the natural circadian rhythms inherently affects an individual's mental health, and mood. "…living in urban settings artificially shifts melatonin production cycles away from natural circadian rhythms, and that spending time in more natural, low-LAN settings restores these patterns" (Min, 2018, 19). Urban settings are densely populated, well-developed and brightly lit. With higher emissions of blue

light, more people are going to be affected by light pollution. The same analytical study suggests that missing a natural view of the night sky also affects one's mental wellness. "Researchers in the field of ecopsychology talk about the 'missing sky factor' that is, how light pollution creates the absence of nighttime sky and loss of the grandeur of infinite stars" (Min, 2018, 19). Missing this connection to the planet, people are unable to experience the awe and peace which comes with admiring the night sky. In an environment where the natural celestial sky is not as visible, people are more likely to develop psychological and physiological issues because of their increased exposure to light pollution.

Most of the exposure people get from artificial Lights at Night are through lights within their own home, emitted from technologies such as a television, cellphone or laptop screen which emit blue light. Since the circadian rhythms guide physiological processes within all organisms like cell signaling and regulation, light pollution's interruption of circadian rhythms can affect brain wave patterns and hormone productions (Chepesiuk, 2009). Such interruption in an individual's circadian rhythm and endocrine physiology has also been linked to health problems which can lead to cancer or accelerated tumor growth, especially in cancers that rely on hormones to grow, like breast and prostate cancers (Spivey, 2010). Strong evidence supporting the connection between exposure to artificial light-at-night (LAN) and patients diagnosed with breast cancer was presented in a study conducted at the University of Connecticut.

"...epidemiologist Richard Stevens and colleagues at the University of Haifa, showed that higher population-weighted country-level LAN levels were associated with higher incidence of breast cancer. A sensitivity test indicated a 30-50% increased risk of breast cancer in countries with the highest versus lowest LAN levels" (Kloog, et al. 2010).

This theory which associates breast cancer risks and diagnoses to exposure to high LAN levels is known as the "Light-at-night" theory (Stevens, 2009). Studies that explore the root causes of such association theorize that melatonin suppression is one of the pathways which lead to increased breast cancer risks or accelerated tumor growth. Furthermore, since melatonin is controlled by the circadian rhythms within our bodies, many researchers and scientists conclude that the light-at-night disrupts and confuses the body's natural melatonin regulation.

#### What are the effects of light pollution on plants and animals?

In animals, artificial light at night can disorient and cause discomfort to their senses, impact their hunting and foraging patterns, breeding cycles, and symbiotic relationships.

Birds are not nocturnal by nature, but as a result of light pollution, they are commonly awake throughout the night and sing when they should be resting. "For example, diurnal animal are active longer than they normally would be, and birds in cities have even been observed to forage at night during the winter" (Da Silva, et al., 2015). Similar to many other animals, birds will also frequently fly into tall, brightly lit buildings and hurt themselves.

With a bright, dark sky, predators which hunt at night, such as cougars, have a higher vantage point finding food because their prey are unable to hide themselves in true darkness (University of Michigan, 2020). This puts populations of prey at risk, and affects the rest of the food chain causing an imbalance in the food chain. Breeding and migratory patterns are also

heavily impacted by light pollution. Since blue light emissions influence natural time-clocks in all humans, plants and animals, increased exposure to this light affects when many animals begin their migration or hibernation (Chepesiuk, 2009). Nocturnal pollinators and insects are heavily impaired and misdirected by light pollution. Distracted by these bright lights, many insects will circle illuminated areas for hours throughout the night and die by morning, "...either by being gobbled up by predators or simply from exhaustion" (Daley, 2019) Plant life which depends on these insects for pollination, or which benefit from their symbiotic relationships are also affected because they are frequented less by the pollinators. Comparing the nocturnal visits of wildlife in an artificially lit space to a naturally dark one, researchers discovered a 62% reduction in visits to plants growing in areas that were artificially lit (Celeste Stevahn Owens, 2019). This ultimately comes full circle, because animals depend on plant life for food and survival, so that a decrease in their output negatively affects animal life.

#### How can we characterize light pollution in Princeton?

Princeton is a small town of about 3,500 residents, located in central Massachusetts. It is known for hiking and skiing on Wachusett Mountain. The town would like to maintain its rural character, as described in the land use goals within the 2020 Environmental Action Plan, in part by "ensuring minimal light pollution in the night sky (Environmental Action Committee, 2020, pg. 77)".

According to the Environmental Action Committee, "The population of Princeton is changing and increasing, and every new house or new owner is a potential contributor to nighttime light pollution" (EAC project description). With little area in Princeton zoned ideally for commercial and industrial uses, the majority of new development will be residential. Princeton has already seen an uptick in residential development in the past five years (Gardner, 2020, pg. 14). Outside of land development, Princeton changed their street lights from high pressure sodium technologies to LED technologies in 2017, which resulted in an increase in light pollution. Though LED lights are much more energy efficient, they also emit more blue light into the atmosphere, so its effects on the surrounding environment and humans is much greater. Comparing Figure 5 to Figure 6 below, there has been an increase in light radiance in Princeton's center from 2012 to 2020, as well as an increase throughout Princeton's roadways aiding the decrease of dark area. The new street lights Princeton implemented can be seen around a rotary in East Princeton in Figure 9, as well as the lights placed in Princeton's town common in Figure 10. There is also expectation of a new public safety building being constructed within the next five years, which has the potential to increase effects of light pollution.

Wachusett Mountain Ski Area, to the north of the town, is one of Princeton's largest commercial attractions, offering night skiing seven days a week during the winter seasons. The largest impact the Ski Area has on light pollution occurs during the ski season months when night skiing opens to the public. With hours extending into the late night for skiing and grooming slopes, the LED lights illuminating directly towards the snow creates a glow in the night sky that is the prominent contributor to sky glow in Princeton. Figure 8 is an image taken from the light pollution map utilizing the National Oceanic and Atmospheric Administration's (NOAA) Visible Infrared Imaging Radiometer Suite (VIIRS) 2020 data, it shows the level of radiance of light within Princeton and surrounding communities. Comparing this to Figure 5, representing the 2012 data, there has been a clear increase in light radiance on Wachusett Mountain due to the skiing operations. This is partly attributed to the installation of 200W and 400W LED floodlights in 2017, to replace outdated metal halide technology used previously to light the ski slopes

(Wachusett Mountain Ski Area History, 2021). In Figure 11 the LED floodlights illuminating the ski slopes can be seen. Light pollution present in Princeton can be attributed in some capacity to all aspects of the town's development and growth, therefore understanding the impacts of existing and potential future lighting is important to curb the effects of light on the night environment.



**Figure 5.** Satellite imagery from the NOAA's VIIRS 2012 data, depicting the level of radiance of light pollution in Princeton (lightpollutionmap.info, 2012).

**Figure 6.** Satellite imagery from the NOAA's VIIRS 2020 data, depicting the level of radiance of light pollution in Princeton (lightpollutionmap.info, 2020).



**Figure 7.** The Zenith sky brightness scale, used to identify the levels of light pollution in an area by looking at the satellite imagery from figures 5 and 6 (lightpollutionmap.info).



**Figure 8.** Wachusett Mountain Ski Area produces a change in radiance of 10.79% per year during ski season (lightpollutionmap.info, 2020).

Other contributors to light pollution within the town can be associated with residential lighting throughout the town. There is not any guidance to direct how and where these lights can be placed, so more often than not, they are poorly directed and cause light trespass and glare to neighboring buildings and homes. Lastly, sky glow emitted from the lights of surrounding cities and towns like Boston, Worcester, Leominster and Holden also affects the night sky over Princeton, adding to the bright darkness above the town.



Figure 9. Images of lighting taken near the rotary in East Princeton.



Figure 10. Image taken of Princeton town common.



Figure 11. Image of Wachusett Mountain ski trails lit up at night (Hours of Operation, 2021).

#### What did we discover from the results of our survey in Princeton, MA?

We developed a survey which ran from April 12 to May 1 and received 255 responses. Based on 2019 census data, we estimate that about 2,750 Princeton residents are at least 18 years old. Since our consent script disqualified any respondents younger than 18, 9.27% of the eligible population responded to our survey (U.S. Census Bureau, 2019). Below we have isolated the questions which stand out the most in our survey and their key takeaways.

#### Survey respondents identify sources of light pollution and trespass.

Moreover, more than 80% of respondents were able to identify some example of light use within the town which was contributing to light trespass or light pollution, shown in Figure 12. These survey responses show that Princeton residents believe that light pollution exists

#### within the town.

3. Please identify the three examples of light use listed below which you believe contribute the most to light trespass or light pollution in Princeton. 252 responses



#### Survey respondents are concerned about the night sky.

Perhaps the most important of the questions we asked Princeton residents, though, are those which looked towards the future. Respondents overwhelmingly agreed that every Princeton resident should be able to see a clear, starry night sky, with under 6% disagreeing. The results of this question are shown in Figure 13.



5. Everyone in Princeton should be able to see a clear, starry night sky. <sup>254</sup> responses



These results are similar to those of another survey conducted in Siasconset, a village on Nantucket. In that survey, 75% of respondents reported that continued visibility of the stars at night was 'very important' (Siasconset Survey). Over 60% of those surveyed also responded that they were concerned about the future of light pollution within Princeton and preserving its night sky, shown in Figure 14. Both the IDA and experts we interviewed identified that capitalizing on pre-existing enthusiasm for the night sky was one of the most effective means of outreach and avenues to create support for a bylaw, so these results are encouraging in that regard.



11. I am concerned about how light pollution might negatively impact the night sky in Princeton in the future. 253 responses

#### Some survey respondents had further concerns.

We also included an open-ended question in our survey which asked about further concerns Princeton residents had related to lighting or light pollution. Moving past those who were angered by our conducting of a survey at all, some of the results were interesting. The number of write-in responses which asked for more and less street lights respectively were about equal. Some used the write-in response to reiterate that residential lights were an issue in the town. We found two respondents' write-ins to this effect particularly poignant:

"Spotlights in residential yards are becoming more common and definitely contribute to light pollution and trespass. I would like to see it regulated with wattage requirements and limitations on hours they can be used. As more people move here from city settings they tend to bring their city light expectations with them and it's ruining some of our natural rural settings."

"Noticed with my neighbors they want to light the exterior of their house with blinding lights. Post lights as well as spot lights. All the lights I install are pointed at the ground and shielded like they do in dark sky communities"

Both of these respondents seemed to take issue with their neighbors' outdoor lights. One references their compliance with dark-sky standards, while the other asks for regulation on residential lighting and notes that migration from urban areas to Princeton brings additional lighting with the influent population. Outside of discussing residential lights, some respondents

Figure 14. Results of survey question 11.
directed us to look elsewhere to target our light pollution reduction efforts, either solely at Wachusett Mountain Ski area or at other towns and cities with more lightning. Five respondents told us that light pollution is not an issue in Princeton. Additionally, some respondents expressed concerns over the rights of residents and an aversion to new regulations.

#### **Routes to Mitigating Light Pollution**

#### **Outreaching to the local community**

We looked to Nantucket, MA as a guide to identifying best methods for community outreach and identified different effective and ineffective outreach approaches. Speaking to the Vice President of the Siasconset Civic Association, we learned of what forms of outreach worked in the town, and what didn't. The first unsuccessful approach took on the idea of a Night-Sky Watch Party, which encouraged the community to gather at the beach and stargaze. Though it was an interactive method for connecting the community to the night sky, the turnout however was much less than anticipated. A similar effort to spread light pollution awareness was also carried out through a low-lumen bulb giveaway. Despite there being free items involved, residents were not interested. While recounting these experiences, she concluded that the community simply were not interested or invested enough to go out of their way to reach for these programs so they had to be approached from where they are.

Instead, what proved to be most effective within the Nantucket community was advocacy through existing lighting concerns. Residents would approach Gail Walker with any issues they had about light trespass or glare and she would try to facilitate conversations between herself, the resident who posed the concern, and a town official who could help to solve the problem. The residents which live in Nantucket are mostly seasonal, and therefore don't have any direct representation in the town government. So facilitating these discussions on a personal level not only conveyed to residents that they could trust her, but also provided an opportunity for linking lighting concerns to light pollution. Therefore, community outreach is most effective when it meets residents where they are. By addressing their concerns or appealing to the things they already care about, they are more likely to reach out for the opportunities and resources to understand light pollution. Tim Brothers shared similar remarks, and recommended building connections with environmentalists, since they are already motivated to protect and preserve the environment. Again, drawing in on this "care" factor during advocacy will make outreach more effective.

Nantucket also held a virtual public forum, where community activists, and light pollution experts spoke about light pollution. They engaged the audience by helping them identify good lighting approaches from the bad, as well as providing supportive data and astrophotography to display the presence of light pollution in the area. The importance of this forum was that it served as an opportunity for the community to learn more about light pollution on their own accord, and when they wanted to invest in developing a better understanding.

Individuals might also consider getting involved with organizations and outreach programs that advocate for preservation of the night sky. A prominent organization in the light pollution world is the International Dark-Sky Association (IDA). The IDA works to "...protect the night skies for present and future generations" (darksky). On its website, the IDA provides countless resources for spreading awareness of the effects of light pollution and ways people can

act and advocate within their hometowns. One of the programs they have which strongly encourages active engagement by people is called Globe at Night. Globe at Night engages users by asking them to observe and map the night sky visible to them from where they are in the world. The data collected is then saved and stored within the program so it can be compared to other user's night sky visibility results.

#### **Alternative Lighting Technologies**

Light pollution can be significantly reduced by utilizing better lighting technologies. The IDA suggests several lighting options which serve the same functions as ones already in place but contribute less to light pollution. LEDs with a warm color temperature (the IDA recommends 3000K or less) can be used in place of their 4000K blue-white counterparts. The warmer light which they emit disperses less into the night sky and causes less glare because of the longer-wavelength and correspondingly lower-energy light. Additionally, many LED lights are capable of multiple color temperatures. Installing drivers to lower the color temperature of those LEDs can be hugely impactful, in many cases lowering the color temperature by as much as 1000K. Equipping lights with shields, opaque barriers which restrict the direction of light, eliminates light shining directly upwards and significantly reduces glare (Outdoor Lighting Basics, 2018).

Light pollution can also be reduced through better use of lighting technologies. Many outdoor lights remain on all night despite not being in use the entire time. The addition of motion sensors to lights ensures that they remain off when not needed. Additionally, outdoor lights are commonly brighter than is necessary for their intended purpose, especially as lights transition from older bulbs to LEDs which are brighter at the same wattage. In many cases, lower-watt bulbs or the installation of dimmers would reduce their brightness without impairing their function. A secondary advantage of using less light, either by dimming or selectively turning off lights, is saving on energy costs. When Cambridge, MA renovated its streetlights in 2014 the newly-installed LEDs were equipped with drivers attached to a wireless control system. Using that system, the lights could be dimmed from their maximum brightness and set to dim further later in the night. Cambridge dimmed over 7,000 streetlights in this manner. In doing so, they found that the effects of light pollution were significantly reduced and that electricity costs were cut by \$500,000 a year (Lenkauskas, S., 2014).



Figure 15. Postcard by the International Dark-Sky Association promoting alternative lighting options (IDA, 2021).

#### **Drafting and Implementing Bylaws**

Another method to curb light pollution is to pass outdoor lighting regulation. In New England, every state besides Massachusetts has passed statewide lighting regulation which mandates that publicly-funded lighting meet certain standards. In Massachusetts, however, efforts to pass statewide legislation have repeatedly failed. Those efforts continue with the current bill "An Act to improve outdoor lighting, conserve energy, and increase dark-sky visibility" which was proposed by Senator Cynthia Creem and Representative Sean Garballey with input from the Massachusetts Chapter of the IDA. In lieu of statewide legislation, 41 municipalities in Massachusetts have passed their own lighting regulations, either as a standalone bylaw or included in their zoning bylaws (IDA, 2020). These bylaws contain provisions which can be separated into two broad categories. Prescriptive provisions regulate specifications of lighting technologies, such as the lumens and color temperature of lights. Performative provisions regulate lights as they are in use, regulating where lights are aimed and the foot-candle brightness of illuminated surfaces. Bylaws vary in complexity, but most have the performative provision that light should be directed and shielded such that it does not shine across property lines. Additional common provisions include restrictions on the brightness of lights and the maximum height at which they can be mounted. Some bylaws also regulate lights' color temperature and hours of operation. Most bylaws exempted lights which were installed before the bylaw's passage.

## How do I help?

Ultimately, strides made against light pollution to preserve the natural dark sky are only made possible by individuals who actively work to outreach and advocate for the issue. With even just a little bit of knowledge and interest in how to preserve the night sky, people can make

more informed decisions about the lighting technologies which they could employ in their own lives. These individual and collaborative efforts combined are key to combating light pollution.

To learn more about light pollution in general, we encourage you to reach out for sources like the International Dark-Sky (IDA) site, the Aldrich Astronomical Society's (AAS) webpage and our final inter qualifying project report titled "The Bright Sky: Assessing Public Attitudes Towards Light Pollution in Princeton, MA and Recommending Approaches to Mitigation". The International Dark-Sky Association, or IDA works to protect the night sky from light pollution. Their site has a bountiful list of outreach materials and articles which detail the effects of light pollution on humans and animals as well as condensed educational materials on lighting alternatives to consider. The Aldrich Astronomical Society, or AAS works to promote a deeper understanding of the night sky. Based in Paxton, MA, the society offers many engaging programs and workshops for anyone to attend and learn about the night sky. Lastly, the EAC tasked our WPI Intergualifying Project team to conduct the initial background and field research to understand the best approaches to mitigate light pollution within Princeton. This included identifying key sources contributing to light pollution, evaluating the pros and cons of existing methods used to reduce light pollution, and researching current lighting regulations used in Massachusetts municipalities in order to recommend best practices and draft language for a lighting bylaw in Princeton. All our research and findings are condensed in our final report, which can be accessed through the EAC's webpage.

(Resources utilized for the EAC newsletter article are the same as the resources listed below in our Bibliography. They were not included in this section here to avoid repetition.)

# Appendix N: Harvard, MA Lighting Bylaw



§ 12	25-40 § 125-40
	(4) Residential lighting and temporary decorative lighting such as holiday lighting.
Ε.	For the purpose of these provisions, light source includes any refractor or globe.
	:2

# **Appendix O: 3 Aspects of Light Pollution Images**

Images depicting light pollution



**O1.** The photo above depicts the effects of light pollution on the night sky in the form of sky glow. The photo was captured near a parking lot in Ontario, Canada lit by bright LED lights (Nielsen, 2017).



**O2.** The photo above depicts light pollution in the form of light trespass, with the light illuminating more than just the intended subject (NELPAG, 2006).



O3. The image above depicts an example of glare, an effect of light pollution which can cause visual disability and discomfort (NLPIP, 2003).

# **Appendix P: LED Technology**

## LED Bulbs

There are four main types of general LED bulbs. These are shown in Figure P1.



P1. Four main types of general LED bulbs (Types of LED Lights, n.d.).

Of these four types of lights, recessed LED light bulbs provide the safest option in terms of light pollution. The standard LED bulb, the flood LED bulb, and the globe LED bulb all emit light throughout a broad space rather than at a direct target, and therefore would counteract any attempt to reduce wasted light.

There are four main types of decorative bulbs as well. These are shown in Figure P2.



**P2.** Four main types of decorative LED bulbs (Types of LED Lights, n.d.).

Between these four types of bulbs, Track LED light bulbs provide the safest option in terms of light pollution, because like Can LED bulbs, they produce the most directional light. Bulbs such as the Candelabra LED, and especially the Edison and Tub LED, all scatter light at a wide ranged area. The success of a light effectively directing light can be extended beyond the bulb's design. Shielding technologies can further develop acceptable directioning of light.

#### **Choosing the Correct Bulb**

As LED technology is expected to increase in the coming years, the presence of LEDs cannot be ignored. Since their energy and cost savings are notable, many towns have switched away from other types of lighting towards LEDs, including Princeton, MA. LEDs are potentially the most harmful type of light bulb considering their common blue illuminance. However, LED bulbs come in different types, shapes, color temperatures, and brightness levels, which all influence the level of impact an LED can have on light pollution. Since not every LED option is safe for the environment, choosing the correct LED is important in reducing light pollution. One characteristic of an LED bulb that should be assessed is how well it's light is directed.

#### **Shielding Technologies**

Light fixtures come in countless shapes and sizes. Figure P3 shows a visual from the International Dark Sky Association of unacceptable versus acceptable light fixture designs. The right side of the image shows designs which wrap light in a way so that it is directed downwards.



P3. Harmful versus helpful light fixtures for light pollution reduction (Outdoor lighting basics, 2018)

Reconstructing lighting fixtures so that light is directed downwards will produce positive results as there will be less skyglow. Figure P4 shows lights with different shields, how light will be directed in correspondence to the given shield, and how the escaped light will affect the night sky. From the leftmost light design, having no shield, it can be seen that light radiates in every direction, and masks the stars with its over-illuminance. On the right side of the figure, the light fixture has a rounded, dome-shaped shield, and light is pointed towards the ground only. This

redirecting of light allows for better visibility of stars. LED bulbs' are often compatible with recessed downlights designs.



P4. Light fixture results (Living in harmony, 2021).

#### **Alternative Lighting Colors**

Blue lights, such as LEDs, may be inexpensive and energy efficient. Unfortunately though, the brightness and temperature of their common blue light is harmful to human health. One study confirmed this idea by performing an analysis on common types of lights and their effects on human eye photoreceptors. The study found that lamps triggering the eye the most, and therefore giving off the most pollution, were the ones with strong blue emission, such as LEDs (Falchi, F., 2011). Amongst animals, human vision is the least sensitive. (Gatson, K. J., 2021). Given the effects of blue light on humans, blue must be even more potent to organisms such as spiders which have an eye sensitivity of 10,000 times a human's (Gatson, K. J., 2021). Blue lights contribute heavily to light pollution. Replacing these household and outdoor lights with warmer toned light bulbs will produce more positive results. Figure P5 shows a color temperature scale chart for different types of light bulbs and their corresponding Kelvin temperatures. High pressure, warm light LED, incandescent, and halogen bulbs all provide environmentally friendly options. As the chart shows though, there are also more dangerous LED bulbs that reach the blue zone. Specific LEDs that reach this zone of color should be avoided when selecting a bulb. To mitigate light pollution, less Kelvins is better than more Kelvins, regardless of whether the bulb is incandescent, LED, or anywhere in between.



**P5.** LED Color Temperature Scale Chart in Kelvins, for different types of light bulbs (Choosing the RIGHT Lightbulb, n.d.).

#### **Infrastructural Programming**

Installing motion sensored lights will ensure that lights regularly remain off unless absolutely necessary. If the duration of lighting can not be decreased, another option is to dim lights. Not only will dimming lights reduce negative health effects and sky glow, but it will also reduce energy costs. Results from 2014 of a dimmining implementation system in Cambridge, MA supported both of these statements. Cambridge dimmed approximately 7,000 streetlights by 50%. The city found that the stimulatory effects on non-visual responses fell below 40%, therefore decreasing the risk of sleep and circadian rhythm disruption. They also found that their electricity costs were cut by \$500,000 per year (Lenkauskas, S., 2014). Additional to color-temperature tuning, smart LED bulbs have dimming tuning availability.

Dimming has to do with Lumens, which is the unit of measurement for the amount of light a bulb gives off. Figure P6 shows a brightness chart of different types of bulbs in Lumens, versus energy in Watts. A standard bulb takes about six times as many Watts to achieve the same number of Lumens, or brightness, as an LED bulb would. This means that it does not take much energy for an LED bulb to become extremely bright, making a dimming switch to be a considerable feature in trying to reduce light pollution if LED bulbs are selected.

BRIGHTNESS IN LUMENS	200+	400+	700+	900+	1300+
STANDARD	25W	40W	60W	75W	100W
HALOGEN	18W	28W	42W	53W	70W
CFL	6W	9W	12W	15W	20W
LED	4W	6W	10W	13W	18W

# LED LUMENS TO WATTS CONVERSION CHART

P6. LED brightness versus energy (Types of LED Lights, n.d.).

# **Appendix Q: Survey Advertisement (Flyer)**



A group of juniors from Worcester Polytechnic Institute (WPI) is looking for your input as they work on a research project in Princeton. Please consider helping them by completing a survey on Outdoor Lighting in Princeton. This WPI team is working with the Town of Princeton's Environmental Action Committee to learn about the views of Princeton residents concerning light pollution. Your participation will help them learn more about light use in Princeton.

Through interviews with light pollution experts and town officials, and through survey results from Princeton residents like you, the students will be able to identify feasible measures to potentially address light pollution. Please complete the survey by April 30 by following the QR code below, or through the Town of Princeton Environmental Action Committee webpage.



# **Appendix R: Locations for Night Sky Imagery**

#### Locations we've isolated for pictures

- Base of Wachusett Mt
- Intersection of Gates Rd and Thompson Rd
- Princeton Center/Common
- Parking for Mt House Trail
- The corner of Merriam Rd and Sterling Rd
- The corner of Worcester Rd. and Ball Hill Rd.
- Krashes Field
- Country Lane off of Beaman Rd
- Etsy Rd
- Lovers Ln turn into Old Mill Rd
- Calamint Hill S intersection with Ball Hill Rd
- Boylston Park
- Rt 31 (too dark at night)
- Bigelow Rd
- Mass Audubon's Wachusett Meadow Wildlife Sanctuary
- Off of Hubbardston Rd in far corner of Princeton (42°26'53.3"N 71°57'42.6"W)
- Crow Hill Climbing parking
- Rocky Pond Rd.
- Mirick intersection with Pine Hill rd
- Echo Lake trail Westminster rd

#### Locations for Pictures of Sky in Circle Order

- Princeton Common
- PMLD, parking lot
- Thomas Prince School
- Calamint Hill Rd S x Ball Hill Rd
- Boylston Park
- Bigelow Rd
- Gates Road x Thompson Road
- MA Audubon's Wachusett Meadow
- Mountain Rd (View of Boston)
- Echo Lake Trail
- Mountain House Trail
- Mirick Rd x Pine Hill
- Wachusett Mountain
- Crow Hill Climbing Parking
- Rocky Pond Rd
- Country Ln
- Krashes Field (rte 31)
- Merriam Rd x Sterling Rd

MA Municipalities with Bylaws						
<u>Town</u>	<b>Population</b>	Annual Income	<u>Area</u>	<u>Density</u>		
Princeton	~4,000	~120K	35.8 sq mi	0.01 sq mi/person		
Truro	~2,000	~81K	26.3 sq mi	0.01 sq mi/person		
Boxborough	~6,000	~141K	10.4 sq mi	0.002 sq mi/person		
Rowley	~6,000	~78K	20.4 sq mi	0.003 sq mi/person		
Dalton	~7,000	~72K	21.9 sq mi	0.05 sq mi/person		
Lincoln	~7,000	~128K	15.0 sq mi	0.07 sq mi/person		
Blackstone	~9,000	~81K	11.2 sq mi	0.001 sq mi/person		
Georgetown	~9,000	~111K	13.2 sq mi	0.001 sq mi/person		
Plainville	~9,000	~90K	11.6 sq mi	0.09 sq mi/person		
Lancaster	~8,000	~90K	28.2 sq mi	0.04 sq mi/person		
Littleton	~10,000	~125K	17.6 sq mi	0.06 sq mi/person		
Middleton	~10,000	~132K	14.4 sq mi	0.07 sq mi/person		
Townsend	~10,000	~75K	33.1 sq mi	0.03 sq mi/person		
Pepperell	~12,000	~86K	23.2 sq mi	0.002 sq mi/person		

# **Appendix S: Towns Demographically similar to Princeton**

# **Appendix T: EAC-Requested Deliverables**

# **T1. Recommended Best Practices**

## T1.1. Step by Step Recommended Outreach Plan

## **General Recommendations**

As community activists in Princeton, members of the EAC can help facilitate connections made between the residents and light pollution issues.

- From the results of our survey and interviews with town officials in Princeton, we anticipate that many residents have complaints of light trespass and glare which derive from nearby streetlights, flood lights or porch lights.
- If approached by residents with concerns about lighting technologies, the EAC could foster a relationship between the resident, the EAC, and a town official who could help address the issue. Through their interactions, they will be able to connect with residents about light pollution issues.
  - Gail Walker-*Vice President of Siasconset Civic Association* (gailwalker101@gmail.com)
  - Peter Morrison- Co-President of Nantucket Civic League (petermorrison@me.com)
  - Both these individuals worked closely on the outreach campaigns in Nantucket and could provide lots of great insight.
    - Permission has been granted for presentation of <u>slides from Nantucket</u> <u>Outreach</u> Forum (The authors requested we notify them if they are to be shared or distributed\*)
      - Lauren Sinatra- *Nantucket's Energy Coordinator* (<u>lsinatra@nantucket-ma.gov</u>)
      - Leslie Snell- *A former Light Enforcement Officer in Nantucket* (<u>lsnell@nantucket-ma.gov</u>)
      - Kelly Beatty, *Member of MA-IDA, Senior Editor for Sky Telescope Magazine* (kbeatty@darksky.org)
- The EAC can also appeal to residents about light pollution by sparking conversations through topics which may appeal to the community, such as protecting wildlife or conserving the rural character of the town.

# **Direct Outreach**

# 1. Town officials and energy coordinators

a. This group includes: Town Selectboard, the Planning Board, and the Princeton Municipal Light Department.

- b. Outreaching first to these well respected and influential individuals in town is important, since they have the abilities to make very impactful decisions within the town.
- c. Outreach to them would include attending public board meetings, and presenting a brief presentation (see PowerPoint presentations folder) on what light pollution is, and how it affects the environment and the people in Princeton.

### 2. Business owners

- a. Bringing awareness to business owners in town could allow them to make more informed decisions for available lighting alternatives the next time they change their lights.
- b. Incentives: Saving on electricity costs, by turning off lights after operational hours.
- c. Outreach to them by sharing IDA outreach materials with them.

# 3. General community

- a. Fostering partnerships with:
  - i. <u>The Aldrich Astronomical Society (AAS)</u>
- Jim Zebrowski- President of the AAS (jimz@alrich.club & jjz60@yahoo.com)
- Steve Gallo- Construction Coordinator of the AAS (sgallo@gallobuilders.com)
- Kevin Boucher- Information Technology and Membership Database Manager (kevinboucher@comcon.net)
  - a. <u>Adopt a Library Telescope:</u> The AAS has helped bring telescopes to 163 libraries (Aldrich.club, 2021). The goal of this program, as stated on their site is to "...foster scientific literacy, and provide people-who have never looked through a telescope- with the chance to experience the excitement that comes from discovery" (Aldrich.club, 2021). Since the telescopes are located in public libraries accessible to anyone, it allows access to the telescopes by anyone and they can be borrowed from the library just like one would with any book they wanted to read. This would be a great way of engaging the Princeton community with the night sky more directly.
  - b. <u>Astrophotography:</u> Similar to direct engagement through the Adopt a Library Telescope program, spreading astrophotography to the community and showing residents that the stars and the moon are present above their heads could spark care in residents and encourage further engagement with the movement. The AAS holds many Astrophotography presentations, now easily accessible over zoom for anyone to log onto and view. They also have a lot of available astrophotographs on their site for anyone to view.
  - c. <u>Scouts, STEM and Seniors:</u> The AAS has also volunteered with the Boy and Girl Scouts, helping many meet requirements in their scouting program by sharing "...all about telescopes, science imaging, light pollution and constellations" (Aldrich.club, 2021). Through these programs, they are able to spark interests for astronomy in young students who can go on to share

this interest with others. The AAS also volunteers for after school enrichment programs, bringing a similar program structure as with the scouts to these students, and also exploring "...current events and topics in astronomy, space science, telescopes, and telescope making. Audio visual presentations are tailored to the unique needs of each group" (Aldrich.club, 2021). Lastly, connecting with Senior citizens, the AAS also has well developed programs which spreads light pollution awareness and provides opportunities for them to appreciate and engage with the night sky.

- ii. The International Dark-Sky Association (IDA) and their resources.
  - 1. Working alongside the volunteers and prominent figures within the Massachusetts chapter of the IDA to help execute outreach within Princeton (all who have offered to give a presentation):
    - i. James Lowenthal- President of MA-IDA, Professor of Astronomy at Smith College (jlowenth@smith.edu)
    - ii. Tim Brothers- *Vice President of MA-IDA, Manager of MIT Wallace Observatory* (bro@mit.edu)
    - iii. Kelly Beatty- *Member of MA-IDA, Senior Editor for Sky Telescope Magazine* (kbeatty@darksky.org)
  - 2. Outreach Materials: The IDA has many public outreach materials available for anyone to download and share. These educational public outreach materials include brochures offered in English, Spanish and Arabic which covers content such as:
  - a. "Protecting Night Skies for Present and Future Generations" (IDA)
  - b. "Light Pollution Can Put Your Health at Risk" (IDA)
  - c. "<u>Light Pollution Can Harm Wildlife</u>" (IDA)
  - d. "Outdoor Lighting, Crime, and Safety" (IDA)
  - e. "Light Pollution Wastes Energy and Money" (IDA)
    - 3. They also have <u>postcards</u> and <u>infographics</u> with a quick summary of light pollution as an issue, which can be shared to the community.
    - 4. <u>Globe At Night</u>: This is a citizen-science program which works to bring awareness to the impacts of light pollution by encouraging residents from all over the world to log their observations and visibility of the night sky onto the site (accessible through laptop or mobile phone). Each month, a different constellation is selected for program users to identify in the night sky from where they are, and users could log in to track their overall night sky visibility.
  - a. 6 Step Instruction Guide: Globe at Night 6 Steps
- b. Outreaching through local institutions

These organizations below have been contacted by our team to develop outreach programs with, however we have only received a response from the library. Our recommendations for the EAC

is to work in partnership with the AAS, to spread advocacy to these institutions with programs listed beneath the AAS section. We also recommend expanding outreach to these groups through the resources listed beneath the IDA section above.

- i. <u>Princeton Public Library</u>
  - 1. Director Erin Redihan email: eredihan@cwmars.org
    - a. In an email chain with Erin Redihan: "The library would be interested in hosting a presentation. We're at a funny point right now--we're open to the public, but not holding events indoors. If you wanted to hold an outdoor program, we could schedule something for the summer. If you wanted to do something indoors, we are hoping to start hosting events in the fall and could schedule something then. I'd offer to post flyers, posters, etc. If you wanted to share information with me about other events you are planning, we'd be happy to post them on our website and Facebook page. I'm also happy to talk about other ideas you might have for collaboration. Feel free to email me here or call the library (978-464-2115)."
- ii. <u>Thomas Prince Elementary School</u>
  - Address: 170 Sterling Road, Rte. 62 Princeton, MA 01541 Telephone: 978-464-2110 Fax: (978) 464-2112 Tammy Boyle, Principal
  - 2. Potentially implement AAS' pre-existing after school programs to engage students at the school with the night sky through workshops and informational sessions which feature their telescopes and astrophotography.
  - 3. Potentially teach students about Globe at Night, and encourage them to observe the night sky with their families using the website.
- iii. <u>Wachusett Meadow Wildlife Sanctuary</u>
  - Email: wachusett@massaudubon.org Address: 113 Goodnow Road, Princeton, MA 01541 Phone: (978) 464-2712
  - 2. Potentially implement Globe at Night during International Dark Sky week.
  - 3. Potentially host sky-watch parties to encourage night sky observation and community engagement.
  - 4. Potentially invite light pollution experts or astronomers as guest speakers to host informational sessions and lectures.

# T1.2. Warrant Article

Article [#]: To see if the Town will vote to enact [location within zoning bylaw] of the Town of Princeton Zoning Bylaw, entitled "Outdoor Lighting", for the purpose of regulating the use of

light outdoors such that the night sky is preserved along with the rural character of the town, including future editions, amendments or modifications thereto, with an effective date of **[Date]**, a copy of which is on file with the Town Clerk, or take any other action relative thereto.

Currently, light use is not regulated within the town, except during the site plan reviews which occur before the construction of new commercial or municipal development. Improper light use contributes to light pollution in the forms of sky glow, light trespass, and glare, all defined in the document. Passage of this article would adopt an outdoor lighting chapter of Princeton's zoning bylaw. This chapter would regulate light use such that light pollution is minimized through proper shielding and aiming of luminaires and by regulating the color temperature of new lights. This chapter would apply to new municipal, commercial, **[or residential]** construction as well as the replacement of any pre-existing luminaires therein.

Advisory Committee Opinion: To Be Determined

# T1.3. Bylaw Language

# [Chapter #]: Outdoor Lighting

#### **Intent Statement:**

(Adapted from Pepperell, MA draft provided by Tim Brothers)

The Town of Princeton hereby finds and determines that the welfare and enjoyment of Princeton is associated with its rural character, including its nighttime ambience. It is recognized that light pollution, as defined in this Bylaw, is a nuisance to the residents of Princeton as it negatively impacts human health and contributes to the loss of our night-sky heritage. Preserving and protecting the night sky enhances the general well-being of residents, as well as the use and enjoyment of property, through the use of appropriate lighting practices. Current and future outdoor lighting systems should be designed, constructed, installed, and maintained to:

- 1. Minimize *light pollution* to the greatest extent possible, especially blue light, resulting from the use of outdoor lighting, as it causes negative effects on human health, road visibility, the well-being of nocturnal organisms such as turtles, fish, bats, pollinators and other insects and reduces agricultural yields;
- 2. Protect residents from unwanted light, *light trespass*, that negatively affects the enjoyment of property, disrupts the natural circadian rhythm of humans, wildlife and agriculture, as well as being a form of energy waste;
- 3. Control *glare* to ensure safe navigation for motorists and pedestrians, as well as increasing the safety and security of Princeton;
- 4. Minimize *skyglow*, to preserve the residents of Princeton's ability to see the Milky Way galaxy against a dark sky;
- 5. Provide adequate light for the safe performance of outdoor tasks at night.

## Standards:

(Adapted from Abington, MA zoning bylaw)

- a) All outdoor light fixtures subject to this bylaw shall be shielded and control glare and light trespass.
- b) Any luminaire with a lamp or lamps rated at a total of more than 2,000 lumens shall be of fully shielded design and shall not emit any direct light above a horizontal plane passing through the lowest part of the light emitting luminaire.
- c) All luminaries, regardless of lumen rating, shall be aimed in such a direction and equipped with whatever additional shielding, lenses, or cutoff devices are required to eliminate light trespass onto any street or abutting lot or parcel and to eliminate glare perceptible to persons on any street or abutting lot or parcel.
- d) All lamps subject to this bylaw shall have a minimum color temperature of 2,000 K and a maximum color temperature of 3,000 K. (If including a color temperature provision)

# **Definitions:**

(Adapted from Pepperell, MA bylaw draft and Abington, MA zoning bylaw)

- Color Temperature: the color appearance of the light that comes from a light source, also referred to as correlated color temperature (CCT). The apparent color of a light source is measured in Kelvin or "K." A low color temperature corresponds to "warm." Incandescent lamps are in the range of 2,700 K. "Cool" light comes from sources such as cool white fluorescent lamps operating at 4,100 K. Lights appear bluer above 4,100 K.
- 2. *Glare:* Intense and blinding light emitted by a lamp that reduces visibility and creates visual discomfort and/or momentary blindness.
- 3. Lamp: The bulb or other light-emitting portion of a luminaire, not inclusive of any
- 4. reflective or refractive optics used to direct light.
- 5. *Light Pollution:* Any adverse and/or obtrusive effect of the use of outdoor light at night. Also, any inappropriate or excessive use of artificial light.
- 6. *Light Trespass:* Any light emitted by a luminaire that shines directly or indirectly beyond the property on which the luminaire is installed and increases the illuminance above the original (natural) illumination level as measured at the lot line in footcandles.
- 7. *Luminaire*: A complete lighting assembly, consisting of a lamp, housing, optic(s), and other structural elements, but not including any mounting pole or surface.
- 8. *Skyglow*: a glow in the night sky deriving from an artificial source.

# Exemptions:

(3 and onwards adapted from Pepperell, MA bylaw draft)

The following are exempt from compliance with all provisions of this Bylaw, except as noted:

- 1. Street lights installed and maintained by the Princeton Municipal Light Department. (allows for the regulation of the privately-owned HPS lamps while exempting streetlights)
- 2. Light from one- and two-family residential uses. (If exempting residential light)
- 3. Residential holiday, string, festoon, and similar decorative lighting.
- 4. Lighting required by law to be installed on motor vehicles.

- 5. Emergency lighting, only for as long as emergency conditions so identified by public safety personnel continue to exist. This includes the activities of law enforcement, fire and other emergency services.
- 6. Lighting employed during repairs of roads, utilities and similar infrastructure, including unshielded lighting, provided that such lighting is deployed, positioned and aimed such that the resulting glare is not directed toward any roadway.
- 7. Any form of lighting whose use is mandated or otherwise governed by any legal jurisdiction superior to that of the Town of Princeton.
- 8. Temporary lighting required to save life, limb or property from imminent peril, provided that use persists only during the hours of the peril.
- 9. Temporary lighting for events sponsored by the Town or for which a Town license or other approval has been issued, such as concerts, fairs, and festivals.

#### T1.4. After the Bylaw Attempt

Regardless of the success of the attempt to pass the outdoor lighting bylaw, outreach activities should continue. In the case that the bylaw is successful in passing with all the included provisions, community awareness of light pollution remains important because sometimes the community is unaware of lighting regulation, as was seen in the Siasconset survey provided to us by Gail Walker. In the case that the bylaw passes without residential or color temperature regulations, outreach remains important to encourage voluntary adoption of methods to reduce light pollution caused by residential light. In the case that the bylaw does not pass, further outreach would improve its chances to pass in the future, and could encourage voluntary adoption of better lighting practices.

# T2: Comparative table of Lighting Bylaw

Town	Light Type	Shielding	Direction	Lumens	Kelvin	Hours of Operation	Pole Height	Residential	Streetlights	Commercial	Municipal	Zoning or General	Grandfathering
Truro		х	x	x			x	x		x	x	General	5 years to update
Boxborough	x	х	x	I		x	x	x	I	x	x	Zoning	Anything predating
Rowley		х	x	x		x	x	I		x	x		Pre-2001
Dalton		х										Zoning	
Lincoln	x	x	x									Zoning	
Blackstone		x	x				x	x	x	x	x	Zoning	
Georgetown		I	I									Zoning	
Plainville		х	x	I								Zoning	Anything predating
Lancaster	x	х	x	x	х	x	x	I		x	x	Zoning	Anything predating
Littleton	x	х	x				x			x	x	Zoning	
Middleton	x	x	x	I		x		x		x	x	Zoning	
Townsend	x	x	x	x	x	x		I	x	x	x	Zoning	Anything predating
Pepperell	x	x	I	I	x	x	x	x	x	x	x	General	Anything predating
	Key:	Symbol	Meaning										
		x	This provis	This provision is present in the bylaw									
		I	This provis	sion is pres	sent in the b	ylaw, but is irregular in	n some way						

## **T3: Grant Research**

# **State or Federal Grant Programs**

Find. apply. succeed. (n.d.). Retrieved May 03, 2021, from <u>https://www.grants.gov/search-grants.html</u>

Government Grants							
Who (Grant Name)?	What (Focus Area)?	Where (Organizatio n Name)	How (Eligibility)?	How much?	When (Close Date)?		
		Enviro	onment				
PD-20-7643	Environment al Sustainability	National Science Foundation	Open	Number of Awards: 103 Total Funding: \$7,066,000	N/A		
EPA-R1-HC- 2021	2021 Healthy Communities Grant Program	Environment al Protection Agency	N/A	Number of Awards: 10 Total Funding: \$300,000	5/20/2021		
	•	Nigh	t Sky				
18-576	Advanced Technologies and Instrumentati on	National Science Foundation	Unrestricted	Number of Awards: N/A Total Funding: \$8,000,000	11/15/2021		
18-575	Astronomy and Astrophysics	National Science Foundation	Unrestricted	Number of Awards: N/A Total Funding:	11/15/2021		

	Research Grants			\$48,500,000	
		Electrica	l/Energy		
DE-FOA-000 2472	Assisting Federal Facilities with Energy Conservation Technologies (Affect) 2021	Department of Energy Golden Field Office	N/A	Number of Awards: 20 Total Funding: \$13,000,000	7/16/20
		Infrast	ructure		
RFA294-201 0-113	Community Infrastructure Development Program	Agency for International Development West Bank, Gaza USAID-West Bank	N/A	Number of Awards: 1 Total Funding: \$100,000	N/A

(UPDATED) 17 environmental grants to fund your project. (2020, September 28). Retrieved April 25, 2021, from <u>https://blog.temboo.com/environmental-grants/</u>

Other Grants Organizations						
Who (Grant Name)?	What (Focus Area)?	How (Eligibility)?	How much?	When (Application)?		
Mosaic Momentum	Organizations working towards environmental protection and justice regarding emergent infrastructure needs and technology	Environment Protection and Healthy & Just Communities	Varies	Rolling Admission		
Patagonia	Projects around environmental conservation and social responsibility	501c3 or smaller	\$5,000-\$20,000	Open application, one proposal per year		
The Rockefeller Foundation	Programs around health, power, education, environment, climate/resilienc e, innovation, and co-impact	501c3	Varies	Periodic open rolling admissions		
Bloomingbird	Programs in arts, education, environment, gov. innovation, and public health space	Existing partners		Invitation Only		
Environmental Protection Agency (EPA) Environmental Education & Environmental Justice	Initiatives related to water, sanitation, and hygiene, environmental education, conservation, etc.	501c3	\$10,000-\$150,00 0	Open rolling admissions		

Biden's Infrastructure Plan (Potential Grant Money)				
Amount	Description			
\$20 billion	Create regional innovation hubs that would support community-led projects			
\$180 billion	Advance US leadership in critical technologies, upgrade the US's research infrastructure and establish the US as a leader in climate science, innovation and research and development			

#### **Other Financial Incentives**

#### MassSave

We are mass save. (n.d.). Retrieved May 03, 2021, from https://www.masssave.com/en

Eligibility (Can only apply to Wachusett Ski Mountain)

- a. only open to Massachusetts residential electric customers of Cape Light Compact JPE, Eversource, National Grid, or Unitil.
- b. Discounts are valid from January 1, 2021 through December 31, 2021, subject to availability.
- 1. No cost energy assessments.
- 2. Residential Rebates and Incentives
  - a. LED light bulbs and light fixtures at a discounted price
    - i. may be available at no cost through the Income Eligible Program.
- 3. Business Rebates and Incentives
  - a. Demand Response & Storage
    - i. Businesses of all sizes can earn incentives for using less energy when others are using more.
  - b. Lighting and Lighting Control Upgrades
    - i. Incentives include:
      - 1. Remote Mounted Occupancy Sensors
      - 2. Daylight Dimming Systems
      - 3. Occupancy Controlled Step-Dimming Systems
      - 4. Wall-Mounted Occupancy Sensors
      - 5. Wall-Mounted Vacancy Occupancy Sensors
      - 6. Photocell Sensors (lighting systems on 24/7)
      - 7. High Bay Occupancy Control Systems
  - c. Massachusetts and Rhode Island Commercial Upstream Lighting Program

# For a limited time, take advantage of incentives up to **\$250** on eligible fixtures with controls!

Lamp Fixture Type	Promotional Incentive
1x4, 2x2, 2x4 LED Troffer w/ Controls DLC – Standard	\$90
1x4, 2x2, 2x4 LED Troffer w/ Controls DLC – Premium	\$90
1x4, 2x2, 2x4 LED Troffer Retrofit Kit w/ Controls DLC – Standard	\$85
1x4, 2x2, 2x4 LED Troffer Retrofit Kit w/ Controls DLC – Premium	\$85
Exterior: Low Output w/control (250-5,000 lumens)	\$115
Exterior: Mid Output w/control (>5,000-10,000 lumens)	\$140
Exterior: High Output w/control (>10,000-30,000 Lumens)	\$190
Exterior: Very High Output w/control (>30,000 Lumens)	\$240
High/Low Bay: Mid Output w/controls (>5,000-10,000 lumens)	\$190
High/Low Bay: High Output w/controls (>10,000-30,000 Lumens)	\$215
High/Low Bay: Very High Output w/controls (>30,000 Lumens)	\$250
LED Strip/ Wrap w/ Control	\$55
Stairwell Kit, Low-Output w/sensor	\$90
Stairwell Kit, Mid-Output w/sensor	\$115

#### **Energy Star Homes**

Energy star. (n.d.). Retrieved May 03, 2021, from https://www.energystar.gov/

(Sells more efficient lighting options)

#### 1. Light Bulbs

#### What types of light bulbs should I look for?

Choosing between the various LED light bulb types that are ENERGY STAR certified, as well as deciding where to use them can be daunting. Here you'll find guidance on choosing the right bulbs for your fixtures and locating a convenient retailer.

For an interactive learning experience, check out the Choose a Light Guide.

• ENERGY STAR certified LED bulbs are available in a variety of shapes and sizes for any application.

• The ENERGY STAR Light Bulb Purchasing Guide (PDF, 652 KB) can help you find the right bulb for your light fixture.

- ENERGY STAR certified bulbs use less power (watts) than incandescent bulbs.
  - Learn more about brightness!
- ENERGY STAR certified bulbs are available in a variety of shades.
  - Learn more about color and mood!
- Not all ENERGY STAR certified bulbs are dimmable.
  - $^{\circ}\,$  If you need a dimmable light bulb, please check the packaging before you make your purchase.

#### 2. Decorative Light Strings

If you're buying new light strings to decorate your home this holiday season, choose ENERGY STAR certified LED light strings to save energy and to help protect the environment—that's a gift our planet will really appreciate. In fact, a decorative light string that has earned the ENERGY STAR uses 75 percent less energy than an incandescent light string.

SAVE EVEN MORE

- Celebrate all night. Certified LED light strings can last up to 10 times longer than traditional incandescent strands, meaning fewer light string replacements.
- Safety first. ENERGY STAR LED light strings are cool to the touch, reducing the risk of fire.

If all decorative light strings sold in the United States were ENERGY STAR certified, the energy cost savings would grow to about \$850 million each year and 9.9 billion pounds of annual greenhouse gas emission would be prevented, equivalent to the emissions from 940,000 vehicles.

#### 3. Better Technology Energy Savings

### **CLTC Research**

The California Lighting Technology Center (CLTC) has actively worked with the manufacturing community to develop and test bi-level exterior lighting solutions.

Bi-level street and parking area luminaires

- Alternative to HID
- LED and induction luminaires with integral occupancy sensor and bi-level control
- About 30% energy savings for a controlled LED area luminaire and 75% energy savings for a controlled cobrahead induction area luminaire
- Instant to 6-year payback for new construction (compared to traditional high-pressure sodium) and 5- to 15-year payback in retrofits



Bi-level cobrahead induction luminaire at California Polytechnic State University

#### Bi-level HID wall packs

- Alternative to HID without bi-level control
- HID luminaires with integral occupancy sensor and bi-level control
- About 40% energy savings for controlled luminaires

Bi-level smart LED parking garage luminaire

- Alternative to HID
- Up to 40% energy savings using LED technology
- Additional 30% energy savings using occupancy-sensor-based bi-level control



Bi-level HID wall pack at Chico State University



Bi-level LED parking garage luminaire at Sacramento State University

# Free awareness campaign materials

Who?	What?	Where?
Princeton Environmental Action Committee	Newsletter Article	Green New's Month of May
International Dark Sky Association	Public Outreach Materials (brochures, postcards, infographics, videos, presentations, letters, etc.)	Public Outreach Materials   International Dark-Sky Association (darksky.org)
	<ul> <li>Specific Materials:</li> <li>What is light pollution a effects? <ul> <li>IDA-General B (darksky.org)</li> </ul> </li> <li>Light Pollution and Hur <ul> <li>Light-Pollution and Hur</li> <li>Light-Pollution and Ani</li> <li>Light Pollution and Ani</li> <li>Light-Pollution and Ani</li> <li>Light-Pollution-f(darksky.org)</li> </ul> </li> <li>Waste of Energy and M <ul> <li>Light-Pollution-glish.pdf (darksl)</li> </ul> </li> <li>Reduction Strategies <ul> <li>Stop Light Pollut(darksky.org)</li> <li>Light-to-Protect Responsible-Out(ast1485.png (204))</li> </ul> </li> </ul>	und what are it's negative <u>rochure_2020.pdf</u> nan Health <u>Can-Put-Your-Health-at-Risk-</u> <u>ksky.org</u> ) mal Health <u>Can-Harm-Wildlife-English.pd</u> le, and Safety <u>ug-Crime-and-Safety-English.p</u> oney <u>Wastes-Energy-and-Money-En</u> <u>cy.org</u> ) <u>ution Postcard-front</u> <u>-the-Night-Five-Principles-for-</u> <u>tdoor-Lighting-IDAIES-01-204</u> <u>48×1485</u> ) (darksky.org)

\*\*Note: anyone can print the outreach materials, but an IDA member can get these materials printed for free

# Free inspirational speakers/presentations

Who?	What?	Where?	When?	How?
Kelly Beatty Lauren Sinatra Leslie Snell	Light Pollution Forum	PowerPoint presentations	Once permission is granted	Sent by Peter Morrison
Tim Brothers	Speaker	TBD	TBD	Talk
Kelly Beatty	Speaker	TBD	TBD	Talk

# T4: Technologies Most Effective in Reducing Light Pollution

Hardware	Cost and Benefits	Dark Sky Qualifications	Uses	Available at
Amber Full Cutoff Wall Pack <sup>1</sup>	\$480	<ul> <li>Eliminates blue light</li> <li>Shielded</li> <li>Reduces glare</li> <li>Zero uplight</li> <li>Amber(2200K)</li> </ul>	<ul> <li>Security</li> <li>Parking lots</li> <li>Pathways</li> <li>Decks</li> <li>Residential</li> <li>Primarily commercial</li> </ul>	ilp-inc.com
Amber Area Light <sup>2</sup>	\$371.43 Dimmable driver included	<ul> <li>No blue light</li> <li>Zero uplight</li> <li>Shielded</li> <li>Amber (2200K)</li> </ul>	<ul> <li>Area lighting</li> <li>Parking lots</li> <li>Security</li> <li>Commercial</li> </ul>	Homelectrical.com
Wall Pack Pro Series <sup>3</sup>	\$181.53	<ul><li>Zero uplight</li><li>Reduces glare</li><li>3000K</li></ul>	<ul> <li>Security</li> <li>Parking lots</li> <li>Pathways</li> <li>Decks</li> <li>Residential</li> <li>Primarily commercial</li> </ul>	Green Electrical Supply
Outdoor LED Barn Light <sup>4</sup>	\$259	<ul> <li>Shielded</li> <li>Reduces glare</li> <li>Zero uplight</li> <li>3000K</li> </ul>	<ul> <li>Residential</li> <li>Commercial</li> <li>Decorative light</li> </ul>	Cocoweb
Volt Mushroom Brass	\$49.97	• Zero uplight and	Walkways	voltlighting.com

Path and Area Light⁵		glare • Reduced Blue light • 2700K or 3000K	<ul><li>Paths</li><li>Flowerbeds</li><li>Residential</li></ul>	
Metroscape MPTR <sup>6</sup>	Robust options including dimmers, motion sensors, etc	<ul><li>Zero uplight</li><li>Reduces glare</li><li>3000K</li></ul>	<ul> <li>Road</li> <li>Streets</li> <li>Business</li> <li>Facade</li> <li>Parking lots</li> </ul>	Signify.com
Baselite K Series Sign Light Fixture K2 <sup>7</sup>	\$84.21 Various color options and mounts	<ul><li>Zero Uplight</li><li>Reduces glare</li><li>3000K</li></ul>	<ul><li>Sign lighting</li><li>Commercial</li><li>Business</li></ul>	electricalgopher.com
Stargazer Flagpole Downlight <sup>8</sup>	\$558 Fake rock power supply	<ul> <li>Zero uplight</li> <li>Reduces glare</li> <li>Amber (2200K), 3000K option</li> <li>Photocell option</li> </ul>	• Flag poles	Eagle Mountain Flag and Flagpole
PAR 38 Floodlight with PAR Shield <sup>9</sup>	Shield ~ \$29.95 for 2 Any PAR 38 bulb ~ \$12 - \$20	<ul> <li>Zero uplight</li> <li>Reduces glare</li> <li>Minimizes light trespass</li> </ul>	• Residential flood lighting	parshield.com
Amber Full Cutoff Wall Pack	Amber Area Light	Wall Pack Pro Series		
--	---	---		
Spec Sheet: <u>https://ilp-inc.com/wp-content/uplo</u> ads/2018/07/WPCM-100WLED-AMBER <u>-FWC.pdf</u>	Spec Sheet: <u>https://ilp-inc.com/wp-content/uplo</u> ads/2018/07/AL-100WLED-AMBER-FW C.pdf	Spec Sheet: <u>https://www.atlaslightingproducts.c</u> <u>om/downloads/dl/file/id/310/product/597/</u> <u>wps13led_cut_sheet.pdf</u>		

Outdoor LED Barn Light	Volt Mushroom Brass Path and Area Light	Metroscape MPTR
Spec Sheet: <u>https://www.cocoweb.com/barn-ligh</u> <u>ts/gooseneck-barn-lights/customizable-old</u> <u>age-indoor-outdoor-led-barn-light#.W37x</u> <u>cNhKi7N</u>	Spec Sheet: <u>https://volt-product-docs.s3.us-east-</u> <u>2.amazonaws.com/ss-VPL-340-G2S-VER</u> <u>5.N.pdf</u>	Spec Sheet: <u>https://www.signify.com/api/assets/ v1/file/content/37eb550e8ce746588632a8</u> <u>7f0146701e/MetroScape-MPTR-spec.pdf</u>

Baselite K Series Sign Light Fixture K2	Stargazer Flagpole Downlight	PAR 38 Floodlight with PAR shield
		Shielded / Properly-aimed PAR Floodlights
Spec Sheet: <u>http://www.lightdisty.com/media/sp</u> ecsheets/baselite/SIGN-LIGHTSspecsheet <u>1.pdf</u>	Spec Sheet: <u>https://emflag.com/content/StarGaz</u> er%20Spec%20Sheets/2020%20SG-EHS. pdf	Spec Sheet: <u>https://www.parshield.com/shop.ph</u> p

### **References for Table**

<sup>1</sup>Where to buy:<u>https://ilp-inc.com/product-category/outdoor/amber-full-cutoff-wall-pack/</u> Spec Sheet:

https://ilp-inc.com/wp-content/uploads/2018/07/WPCM-100WLED-AMBER-FWC.pdf

#### <sup>2</sup>Where to

buy:https://www.homelectrical.com/100w-led-area-light-w-front-side-glare-shield-1925-lm-120v -277v.ilp-al100wledunivambert4fgsupmb.1?utm\_source=googleBase&utm\_medium=CSE&utm \_campaign=CSE&scid=scplpILP-AL100WLEDUNIVAMBERT4FGSUPMB&sc\_intid=ILP-AL 100WLEDUNIVAMBERT4FGSUPMB&campaignid=10508693207&adgroupid=104762129995 &creative=447295314705&matchtype=&network=g&device=c&keyword=&gclid=Cj0KCQjw1 a6EBhC0ARIsAOiTkrFa0Vgx7AcZ-b7S5ypFHHGeZ5tUjpovVy01xVuGufPIuvTX-cwqRU4aAt RHEALw\_wcB

Spec Sheet: https://ilp-inc.com/wp-content/uploads/2018/07/AL-100WLED-AMBER-FWC.pdf

## <sup>3</sup> Where to

buy:<u>https://www.greenelectricalsupply.com/search.aspx?grade=commercial&amp%3Boperating-voltage=100-277v&amp%3Blog=false&cri-color-rendering-index=81&manufacturer=50&fixture-t ype=wall-pack</u>

Spec

Sheet:<u>https://www.darksky.org/our-work/lighting/lighting-for-industry/fsa/fsa-products/#!/Atlas-Wa</u> <u>II-Pak-Pro-Warm-Edition/p/93540141</u> /category=12627269

#### <sup>4</sup>Where to

buy:https://www.cocoweb.com/barn-lights/gooseneck-barn-lights/customizable-oldage-indoor-ou tdoor-led-barn-light#.W37xcNhKi7N

Spec

Sheet:<u>https://www.cocoweb.com/barn-lights/gooseneck-barn-lights/customizable-oldage-indoor-outdoor-led-barn-light#.W37xcNhKi7N</u>

<sup>5</sup>Where to buy:Buy - <u>https://www.voltlighting.com/mushroom-brass-path-light</u> Spec Sheet -

https://volt-product-docs.s3.us-east-2.amazonaws.com/ss-VPL-340-G2S-VER5.N.pdf

<sup>6</sup>Where to

buy:<u>https://www.signify.com/en-us/products/outdoor-luminaires/road-and-urban-lighting/urban/posttop/metroscape-led-post-top-mptr</u>

Spec

Sheet: https://www.signify.com/api/assets/v1/file/content/37eb550e8ce746588632a87f0146701e/ MetroScape-MPTR-spec.pdf

# <sup>7</sup>Where to

buy:<u>http://electricalgopher.com/baselite-k-series-k2.html?fee=6&fep=4610&gclid=CjwKCAjwhM</u> mEBhBwEiwAXwFoEa8I-WETDfX\_yukTYFWk88YuB8zdoxA50bD9wp6P5XPblQkqKpgr3RoC1 H4QAvD\_BwE

Spec Sheet: http://www.lightdisty.com/media/specsheets/baselite/SIGN-LIGHTSspecsheet1.pdf

<sup>8</sup>Where to

buy:<u>https://emflag.com/stargazer-flagpole-downlight-w-external-halyard-stationary-truck-sg-ehs/</u> Spec Sheet:<u>https://emflag.com/content/StarGazer%20Spec%20Sheets/2020%20SG-EHS.pdf</u>

<sup>9</sup>Where to buy/Spec Sheet:<u>https://www.parshield.com/shop.php</u>

#### **T5: Research on Effects of Light on Crime**

In towns and cities alike, many commercial or industrial buildings, businesses, and schools leave their lights on throughout the night and into the next day, cycling more light pollution into the night sky. This is usually an effort to deter crime. The U.S. National Institute of Justice concluded that increased lighting failed to reduce crime (IDA). Furthermore, according to the IDA, poor lighting creates a false sense of security. Lighting actually allows criminals to see what they are doing more easily. This consideration is applicable to crimes such as vandalism and graffiti, both of which "thrive on night lighting" (IDA). Though people tend to associate light with improved development and environments, a Chicago study found that after upgrading and improving lights throughout the city, there was a 21% increase in reported crime offenses (see figure below). Bright street lamps and artificial lights give these criminals better visibility of their intended targets, and make victims more vulnerable. Over illumination contributes to light pollution and wastes energy and money by failing to serve its intended purpose.



Figure. Chicago study showing the results of a study pre and post alley light installation (Morrow, 2000).

# **Appendix U: Authorship**

Although each section was written by a primary author as indicated below, the report in its entirety was edited and reviewed by all authors in collaboration.

Introduction	AK
Background	All
What is Light Pollution?	SP
What Effects does Light Pollution Pose for Humans?	SP
What are the Effects of Light Pollution on Plants and Animals?	SP
What are the Drivers of Light Pollution?	MD/SP
Why is it Difficult to Address?	MD
Lack of Public Awareness	MD
Economics	MD
Inconsistent Enforcement	MD
What has been done Before to Address Light Pollution?	LC
Determining the Scale of the Problem	LC
Assessing Public Attitudes	LC
Developing Targeted Awareness Campaigns	LC
Promoting Technical Advancement in Lighting	LC
Drafting and Implementing Bylaws	LC
How can we Characterize Light Pollution in Princeton?	AK
Methods	All
Goal Statement	All
Assess Current Lighting Technologies in Princeton	AK
Interview Princeton Municipal Light Department	AK
Assess the Views of Princeton Residents on Light Pollution and Regulation	LC/AK/MD

Determine the Feasibility of a Lighting Bylaw in Princeton	LC/AK
Identify Strategies to Motivate Princeton Residents to Voluntarily Reduce their use of Excessive Artificial Light	LC
Princeton's EAC Monthly Newsletter	SP
Findings	All
Light Pollution in Princeton, MA	AK
Princeton Residents' Views on Light Pollution	LC
Options to Mitigating Light Pollution in Princeton	SP/MD
Community Outreach and Engagement within Princeton, MA	SP
Bylaw	MD
Recommendations	All
Community Outreach	SP
Developing a Bylaw	LC
Limitations	AK