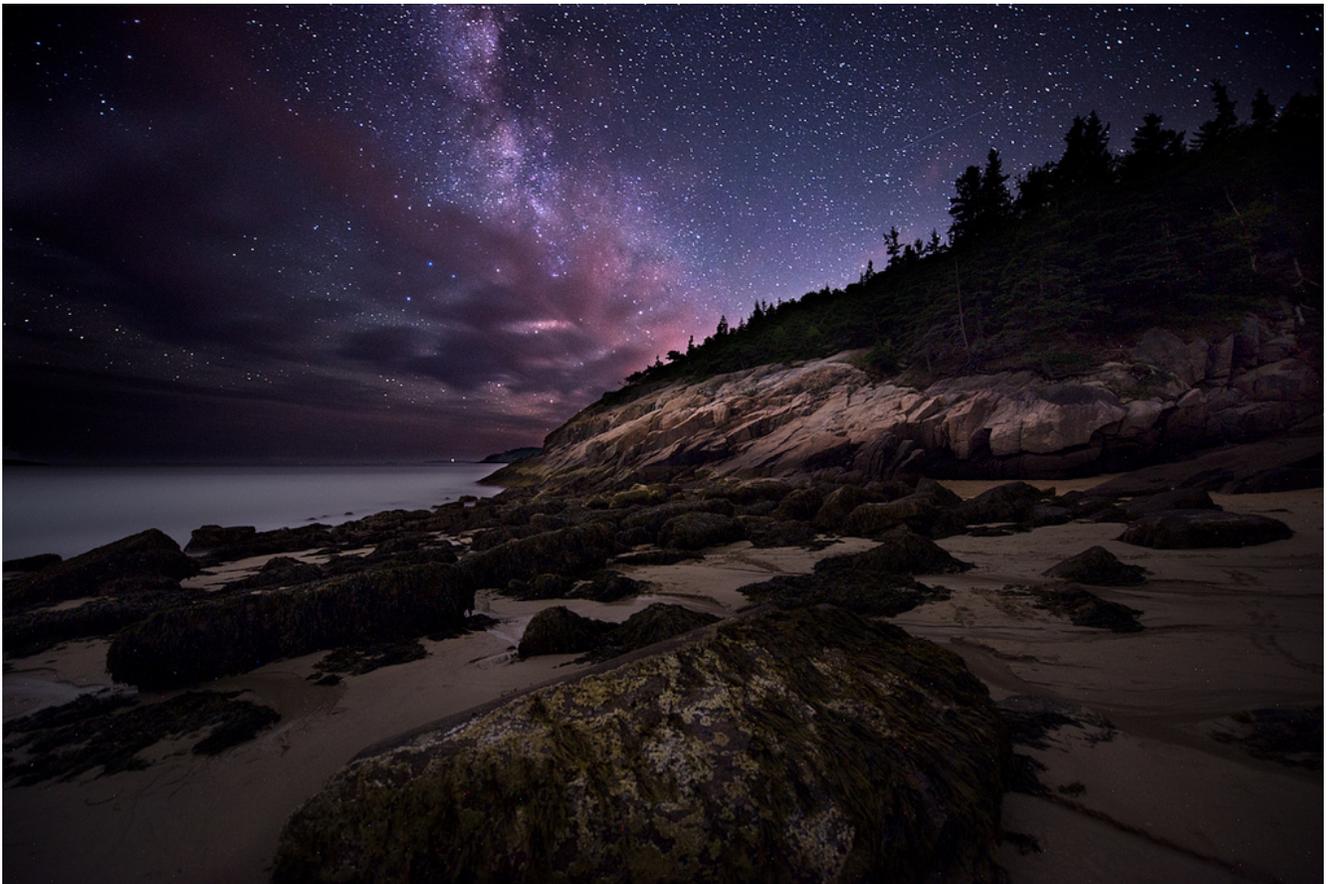


# Reducing Acadia's Light Pollution

Applied Policy Project - Prepared for Acadia National Park



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**Disclaimer:** The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

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## List of Abbreviations/Acronyms

NSP - National Park Service

IDA - International Dark-Sky Association

DSP - Dark-Sky Park

FOA - Friends of Acadia

LOT - League of Towns

APP - Applied Policy Project

LOT-DC - League of Towns - Darkness Coalition

DST - Dark-Sky Taskforce

LC - Lighting Consultant

LOT-DSP- League of Towns - Dark-Sky Partnership

SQM - Sky-Quality Meter

NELM - Visual Limiting Magnitude

WPI - Worcester Polytechnic Institute

## Executive Summary

Acadia National Park is among the most visited national parks in the United States, attracting millions of people per year. Thousands of those visitors come to the park for “astro-tourism,” as Acadia has become one of the premier stargazing locations on the east coast. There remains, however, the continued threat from light pollution from the surrounding communities that negatively affects Acadia’s darkness, contributing to a lesser visitor experience and potentially harming native ecosystems. Although park management and community organizations have engaged in significant efforts to decrease Acadia’s nighttime light levels and raise awareness among visitors and locals regarding the importance of darkness, the park still seek to continue to decrease light pollution. This report developed policy options that could help solve the long-term policy goal of decreasing nighttime lighting levels within and around Acadia while also using the International Dark-Sky Association’s Dark-Sky Park designation requirements as a reasonable, short-term policy benchmark.

Working within existing organizations, the policy options crafted to address Acadia’s nighttime lighting levels were analyzed both qualitatively through a criteria evaluation and quantitatively through a Benefit Cost Analysis. The options included 1) the formation of a Darkness Coalition within the League of Towns, 2) a reimagining of the Worcester Polytechnic Institute Dark-Sky Project into the Dark-Sky Taskforce, 3) the creation of a Lighting Consultant position paid through the Friends of Acadia Wild Acadia initiative, and 4) the combination of Coalition and the Taskforce into the League of Towns - Dark-Sky Partnership (LOT-DSP).

**The report recommends the adoption of Option 4 - the creation of the LOT - DSP.** While this option does not provide the greatest estimated monetary net value compared to the Status Quo in the quantitative evaluation, it still provides an estimated benefit of about \$105 million over the course of five years and is the strongest option in the qualitative analysis. The LOT - DSP provides the best opportunity for Acadia to achieve legitimate and long-lasting nighttime light level reduction.

## Introduction

This policy analysis seeks to provide the client, Acadia National Park, with a detailed report that addresses the policy problem - **Acadia National Park's nighttime lighting levels are too high** - developing a plan to decrease these nighttime light levels within the park boundaries. While light pollution has the potential to disrupt the natural habitats of wildlife, the park's chief concern surrounding light pollution is how increased sky-glow (light pollution) denies visitors the opportunity to appreciate the full experience of the night sky. Over the past few years, Acadia has developed into a leader of low light pollution levels on the east coast, bolstering the park's reputation as one of the premier stargazing locations on the Eastern seaboard. Conservation efforts for reducing light pollution are continuous, and decreasing the park's nighttime lighting levels is an annual goal.

While there are certain units of measure to determine the true darkness of the night sky, it is helpful for organizations to have benchmarks to measure their progress. Achieving the designation as an International Dark-Sky Association Dark-Sky Park (IDA DSP) will serve as an appropriate indicator of the major steps Acadia has taken to decrease light pollution.

## Costs to society for not addressing

There is a certain value of the night sky, which is difficult to calculate because of the aggregation of personal preferences. However, if Acadia chooses not to address the issue of high nighttime light levels, the park would not only negatively affect its wildlife and its visitors' experiences, it would also lose an invaluable source of revenue for the communities surrounding the national park. As will be explained in further detail later, Acadia has become a popular destination for "astro-tourism," which is tourism devoted to stargazing. Should the park not further reduce its nighttime lighting levels, the surrounding communities could lose an opportunity to generate substantial revenue.

Since the creation of the Acadia Night-Sky Festival in 2009 and the first local town lighting ordinance, Acadia's reputation has increased as a premier spot for stargazing. The park is ranked as high as sixth on independent websites that list the top locations in the U.S. in which to star gaze.<sup>1</sup> **The opportunity for increased capital in the surrounding communities as well as the threat to visitor experience and wildlife habitats makes decreasing light pollution a top conservation priority.**

# Background and Literature Review

## Acadia National Park

Acadia is one of the most visited National Parks, with visitor numbers totaling over two million annually.<sup>2</sup> Tracing its origins back to 1916 when the original land was set aside as Sieur de Monts National Monument, Acadia National Park received its current name on January 19, 1929.<sup>3</sup> As the park has grown, Acadia National Park Service (NPS) staff now work to protect roughly 50,000 acres of land.<sup>4</sup> Acadia's mission follows the NPS' to "... preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations."

The park is part of the NPS' Northeast Office, which provides higher-level directives and initiatives for numerous national parks under its jurisdiction.<sup>5</sup> Within the organization, there are directorates that specialize in areas such as business services, partnerships and science, information resources, natural resource stewardship and science, park planning, partnerships and civic engagement, and visitor and resource protection. Park leadership seeks to create a space that conserves the natural environment while giving visitors an opportunity to engage with nature.<sup>6</sup>

Acadia constantly strives to conserve its natural environments and resources. One of the resources that is receiving increased attention - darkness - has become a major focus of the park's conservation plan. Demonstrating the park's commitment to darkness, in 2008 "...Acadia created its Night Sky Initiative. Acadia, in conjunction with the Bar Harbor Chamber of Commerce, Friends of Acadia, Acadia Astronomical Society, Jackson Laboratory, and other key community businesses and organizations, [then] created the Acadia Night Sky Festival."<sup>7</sup>

**What sets Acadia apart from many other National Parks is the intimate relationship the park has with the surrounding communities.** As will be discussed later, the local communities around Acadia have demonstrated concerted conservation efforts to maintain and sustain the park that provides them with an invaluable source of tourism and revenue. Along with the Night Sky Festival, working with the local communities to try to diminish light pollution and preserve the night sky, Acadia has seen a decrease in sky glow and an increase in stargazing attention, resulting in the park being recognized as a leader in dark sky conservation.<sup>8</sup> While hindered by the proximity of the surrounding

communities and their effect on total light pollution, Acadia is still considered a preeminent destination for “astro-tourism.” Attracting stargazers and astronomical attention has only furthered the conservation efforts within the park and with other groups not directly associated with the NPS.

Acadia hopes to continue this trend of increasing sky darkness through continued educational efforts and partnerships with local communities while seeking a designation as an IDA DSP.

## Acadia Budget

According to the National Park Service’s 2016: Fiscal Year 2016 Budget Justifications, Acadia requested \$8.022 Million in Federal Appropriations.<sup>9</sup> This APP report is under the assumption that the actual appropriated amount was more likely closer to the 2011 mark of \$7.9 million (actual appropriated amount for 2016 could not be found).<sup>10</sup> Not only does Acadia receive substantial funds from the federal government, the park helps generate millions of dollars in revenue for the surrounding communities due to visitors to the area. A figure calculated by the NPS showed that Acadia generated an “...estimated economic impact on surrounding communities of \$271 million and 3400 jobs.”<sup>11</sup> On the other hand, a continuing concern for Acadia is the \$68.3 million in deferred maintenance costs, with over half of that amount attributed to a backlog on park road and bridge upkeep, leading to worries regarding the park’s ability to invest financially in further light pollution prevention measures.<sup>12</sup>

## Preserving Darkness

A natural resource frequently neglected, darkness is an essential part of an environment’s well-being. For the NPS, darkness has in recent years, become a conservation priority. The NPS’ Natural Sounds and Night Skies Division focuses on preserving the natural sounds and the night skies for America’s National Parks. More specifically, the NPS’ Night Sky Team (within the Night Skies Division) works across the country in over 30 national parks, measuring the effects of light pollution.<sup>13</sup>

Beginning as early as 2001, the NPS began looking at lighting levels across U.S. parks to provide a baseline of knowledge for average park darkness as well as a unit of measurement for cross-park analysis.<sup>14</sup> By taking numerical data of nighttime light levels

over time, the team is able to determine the long-term trends of light pollution in the parks. This information is compiled and given over to the National Oceanic and Atmospheric Administration to be included in the Visible Infrared Imaging Radiometer Suite (VIIRS). From this data collected by the parks service, VIIRS is used to create an interactive nighttime world map that displays lighting levels in the various parks. The manpower and effort put into the formation of this data set demonstrates the parks service's early and continued commitment to conserving the night sky.

While not one of the most popular or widely known conservation efforts, the importance of dark sky preservation stems from the effect sky glow or light pollution has on wildlife. With excessive nighttime light, animal sleep patterns can be disrupted and fragile ecosystems have the potential to be severely damaged. In a National Geographic article regarding light pollution, Urban Wildlands Group Biogeographer Travis Longcore said, "Wildlife species have evolved on this planet with biological rhythms—changing that has profound effects."<sup>15</sup> The Florida Fish and Wildlife Commission says that light pollution does the following:

Attracts some organisms (moths, frogs, sea turtles), resulting in them not being where they should be, concentrating them as a food source to be preyed upon, or just resulting in a trap, which exhausts and kills them. Repels some organisms, excluding them from habitat where they might otherwise make a living. Makes it a form of habitat loss. Alters the day/night patterns, resulting in not getting enough sleep, not having enough down time for the body to repair itself, alters reproductive cycles.<sup>16</sup>

Excessive lighting also can result in the alterations of flight patterns of birds. Michael Mesure, Executive Director of the Fatal Light Awareness Program, said, "Over 450 bird species that migrate at night across North America are susceptible to collisions with night-lit towers, including threatened or endangered species like the cerulean warbler and Henslow's sparrow."<sup>17</sup> Other species such as reptiles and insects – invaluable parts of the food chain – are also negatively affected by light pollution, damaging ecosystems.

**Excessive nighttime light not only affects wildlife and fragile ecosystems, it also restricts the ability of individuals to stargaze and appreciate the night sky.** Most people rarely experience significant darkness today, and, as a result, it is likely that subsequent generations will come to know little of a dark night sky.

Therefore, the NPS mission to protect darkness is two-fold. Not only does the parks service seek to conserve wildlife and the environment of its parks, but it also attempts to preserve the natural beauty of the park for its visitors. Preserving darkness in parks allows visitors to see and appreciate much more of a true night sky than available elsewhere.

## International Dark-Sky Association

The IDA is “...the recognized authority on light pollution and is the leading organization combating light pollution worldwide.”<sup>18</sup> According to the IDA webpage, the mission of the organization is to “...protect the night skies for present and future generations,” and their goals include advocacy and education for night sky conservation, promoting more darkness-friendly outdoor lighting, and giving the public the tools to help conserve the night sky.<sup>19</sup>

The IDA also recognizes localities that exceptionally conserve their night sky and make demonstrated educational efforts for darkness conservation. One such IDA recognition is the DSP designation as mentioned previously:

An IDA Dark Sky Park (DSP) is a land possessing an exceptional or distinguished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment. The land may be publicly owned, or privately owned provided that the landowner(s) consent to the right of permanent, ongoing public access to specific areas included in the IDA designation.<sup>20</sup>

Parks that engage in significant light pollution educational efforts that meet the darkness levels below (these values will be explained further) can achieve designations of Gold, Silver, or Bronze:<sup>21</sup>

Dark-Sky Park Lighting Standards	Gold	Silver	Bronze
Visual Limiting Magnitude (NELM)	>6.8	6.0-6.7	5.0-5.9
Bortle Sky Class	1-3	3-5	5-6
Unihedron Sky Quality Meter (M/arcsec <sup>2</sup> )	>21.75	21.74-21.00	20.99-20.00

**While Acadia continually strives for greater levels of darkness, achieving the DSP Silver or Gold designation is a reasonable goal for park management.**

Eight other National Parks have achieved the DSP designation.<sup>22</sup> Of those, almost all are in the Western United States. By becoming a DSP, Acadia could become the first Dark-Sky National Park on the Eastern seaboard. This would be a major accomplishment for the park, which is currently looking to gain more national attention post its 2016 Centennial Celebration.<sup>23</sup> Gaining the designation would only add to Acadia's prestige, further increasing the public attention on the park's superior night skies and increasing tourism. **The designation will also make it easier for future lighting ordinances to pass in surrounding towns, due to the suspected increase in tourism caused by the designation.**

## Measuring Darkness

As mentioned above, the standards for the Gold, Silver, and Bronze designations are defined by three different darkness measurements. The first, the Visual Limiting Magnitude scale, is essentially the brightness of the stars an individual can see with the naked eye in a specific area of the night sky.<sup>24</sup> The Limiting Magnitude is an observer-specific measurement that looks for the relative dimness of the stars in the night sky.<sup>25</sup> According to the Saguro Astronomy Club, a 30-year old Astronomy club based in Arizona:

Stars can be easily seen in suburban skies down to 4th magnitude, and at dark sites, down to greater than 6th magnitude with the naked eye. The limiting magnitude is the magnitude of the faintest star that can be seen. This would be easy if we could figure out which star was the faintest. Unfortunately faint stars are not in any order in the sky and comparing two faint stars that are some distance apart is very difficult.<sup>26</sup>

An example of a Visual Limiting Magnitude table can be found in the Appendix (see Figure 1).

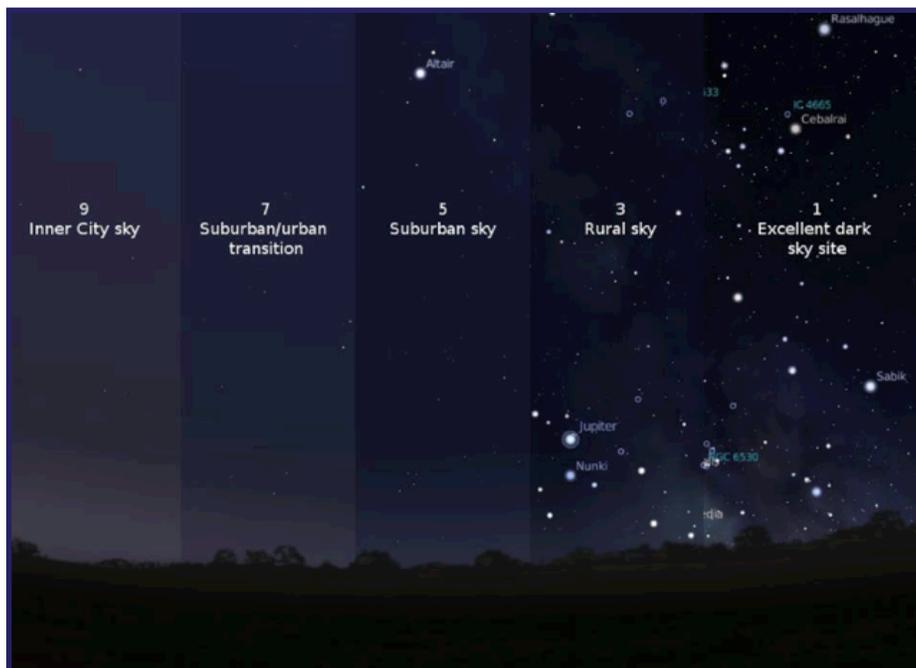
However, there are significant downsides to using the Visual Limiting Magnitude as the only form of measurement of a sky's relative darkness. As pointed out in text below the table, there are "...differences in initial assumptions about sky conditions, visual acuity and others. Your results may vary."<sup>27</sup> Saguro also points out the problems with this measurement saying, "The method is observer specific."<sup>28</sup>

Some stargazers felt that the Visual Limiting Magnitude measurement was often inaccurate, and so in 2001, John Bortle published an article in the publication *Sky and Telescope*, in which he created a nine-level scale that was able to account for some of the

variance found in the Visual Limiting Magnitude index.<sup>29</sup> Since his scale was published, it has been dubbed the “Bortle Sky Class.”

The Bortle Sky Class Classification System is as follows:

- Class 1: Excellent dark-sky site
- Class 2: Typical truly dark site
- Class 3: Rural sky
- Class 4: Rural/suburban transition
- Class 5: Suburban sky
- Class 6: Bright suburban sky
- Class 7: Suburban/urban transition
- Class 8: City sky
- Class 9: Inner-city sky



Each of these classes has particular features that must be seen by the naked eye in order for a particular site to be considered a certain class.<sup>30</sup> A visual representation of the Bortle Sky Class (often helpful in conceptualizing the differences between the classes) can be found above.<sup>31</sup>

According to Bortle, he developed his measurement system to aid the amateur astronomer in figuring out if the night sky is dark enough for the appropriate observation, saying, "...you need accurate criteria for judging sky conditions when documenting unusual or borderline observations, such as an extremely long comet tail, a faint aurora, or subtle features in galaxies."<sup>32</sup>

While the IDA uses both the above methods to evaluate the darkness of a location, neither measurement provides a true, unbiased reading of nighttime light levels. That is why the IDA also uses a third light measurement system, the Unihedron Sky Quality Meter (SQM), to precisely measure the brightness of the night sky in magnitudes per square arcsecond.<sup>33</sup> The SQM requires a Unihedron device to accurately measure the precise light levels in a given night sky. As described by the Unihedron website, an object's magnitude is a measurement of its brightness. Therefore, "The term magnitudes per square arc second means that the brightness in magnitudes is spread out over a square arcsecond of the sky. If the SQM provides a reading of 20.00, that would be like saying that a light of a 20th magnitude star brightness was spread over one square arcsecond of the sky."<sup>34</sup> See Figure 2 in the Appendix for a table of some SQM values for some of the main features in the night sky alongside their relative Luminance and Magnitudes per square arcminute values.

The SQM provides a normalized and consistent method of measuring the night sky's brightness. It provides the most reliable measurement for comparison between locations and gives those locations exact lighting standards to meet to reach DSP status.

## Previous Research

Working alongside Acadia National Park, Worcester Polytechnic Institute (WPI) measures and studies the nighttime lighting levels within the park boundaries. The Dark-Sky Team, under the direction of Frederick Bianchi, is a group of students from WPI that have conducted lighting studies in Acadia in 2009, 2013, 2014, and 2015. The long-term goal of the Dark-Sky Team is to "...establish a stewardship program and ethic for protecting the night sky, and implement a monitoring program to detect future changes. The team will take action to promote night sky stewardship inside and outside of the park by engaging in outreach with the towns on Mount Desert Island."<sup>35</sup>

Publishing in each of the aforementioned years, the Dark-Sky Team provides excellent background, first-hand measurements of the night sky within Acadia, and a

complete lighting inventory of Acadia's light fixtures. Using GIS software, the team's reports also include detailed lighting maps of the park (see image below).<sup>36</sup>

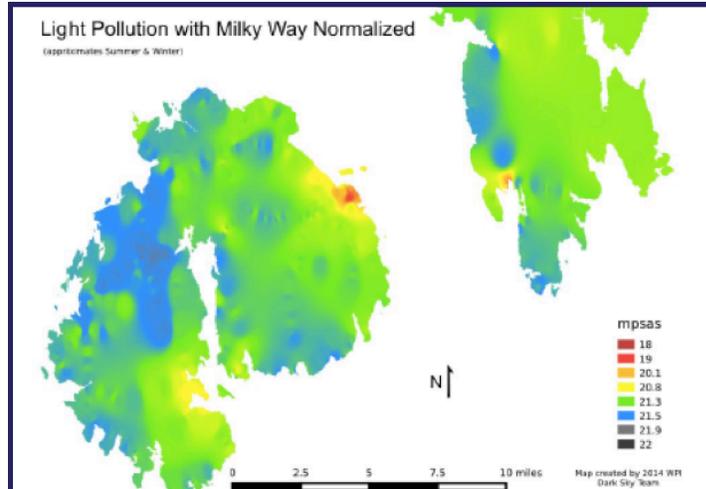


Figure 7: Milky Way Normalized Map

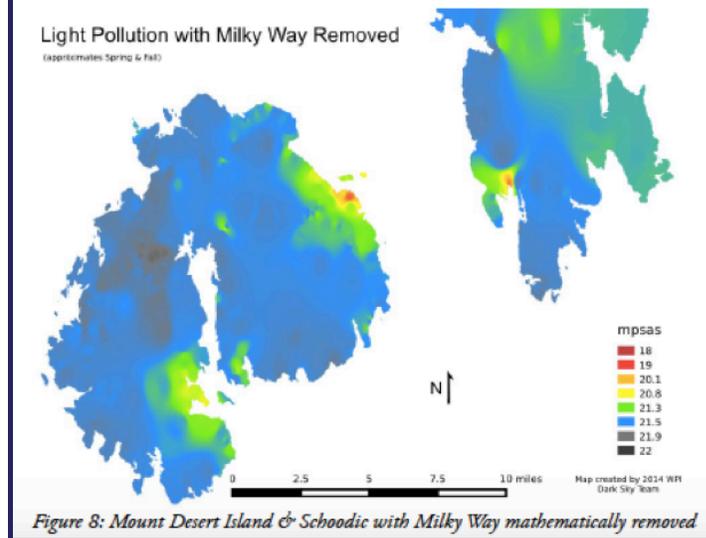


Figure 8: Mount Desert Island & Schoodic with Milky Way mathematically removed

## Mount Desert League of Towns (LOT)

Serving as a unitary policy body for the towns surrounding the park, the Mt. Desert LOT is composed of nine towns within Hancock County, Maine, in addition to Acadia National Park.<sup>37</sup> The sitting members on the LOT are mainly town managers or “first selectmen” who perform functions similar to town managers. The LOT meets once a month and receives policy directives from an annual policy-priority meeting of elected town

officials. **In 2016, one of those priorities is the reduction of light pollution through town measures and new lighting ordinances.**<sup>38</sup>

## **Friends of Acadia (FOA)**

FOA is composed of citizens separate from the NPS and was formed in 1989 to “... preserve(s), protect(s), and promote(s) stewardship of the outstanding natural beauty, ecological vitality, and distinctive cultural resources of Acadia National Park and surrounding communities for the inspiration and enjoyment of current and future generations.”<sup>39</sup> This group works directly for Acadia’s conservation, facilitating volunteer work, donations, and events that benefit Acadia.

According to Conservation Director, Stephanie Clement, the FOA Board of Directors determined the non-profit’s current conservation priorities as follows: natural resources restoration (Wild Acadia), reducing congestion and traffic issues, youth engagement, and investments in the trails and carriage roads. While further night sky conservation efforts would fall under the jurisdiction of the Wild Acadia initiative, the current board-directed focus of Wild Acadia is preserving Acadia’s watersheds.<sup>40</sup>

## **Legislative History**

The towns surrounding Acadia demonstrated their willingness to aid in the park’s darkness with the passage of several lighting ordinances. As early as November 2009, Bar Harbor, one of the largest communities near Acadia adopted a lighting ordinance that required all new commercial, residential, and municipal buildings to have downward facing light fixtures with light caps.<sup>41</sup> Since this 2009 Bar Harbor lighting requirement, other localities such as Mt. Desert and Ellsworth have written similar lighting ordinances attempting to decrease their nighttime light levels for Acadia’s dark-sky benefit.

## Achieving the Policy Goal

This report will now explain the each for evaluation of policy option and the details behind those policy options. Each will then be evaluated on a qualitative and quantitative basis. Using the outcomes provided by the qualitative and quantitative analyses as a guide, a recommended alternative will be suggested along with an implementation strategy for executing the policy.

## Explanations of Policy Options

### Status Quo

Fortunately for Acadia, the communities that surround the park solidly support efforts to reduce light pollution as demonstrated above. In 2009, the local community surrounding Acadia, Bar Harbor, held their annual Conservation Commission and adopted a city ordinance that over time would require “night sky friendly outdoor lighting” on all new construction.<sup>42</sup> By 2009, the first Acadia Night Sky Festival was held to “...celebrate the starlit skies of Downeast Maine through education, science, and the arts.”<sup>43</sup>

By continuing the Status Quo, Acadia Park Staff can reasonably expect light levels to remain relatively constant for the future. While this will require no funding, maintaining the Status Quo will not help the park achieve its goal of continuing to reduce light pollution, nor will Acadia achieve its desired designation as an International DSP.

### Option #1: The League of Towns Darkness Coalition (LOT-DC)

Although Acadia is an entity separate from but affected by the light produced by the surrounding communities, there is greater difficulty implementing initiatives to reduce light pollution. The most effective path to the communities as a whole is through the Mt. Desert LOT. The organization has political standing in the surrounding communities, allowing any action it takes to have legitimacy. According to Chair of the LOT, Durlin Lunt, one of the recent long-term policy priorities of the LOT is to decrease light pollution.

With this in mind, Acadia should work with the LOT to develop a Darkness Coalition. This would be a sub-group of the larger body of the LOT that will work specifically on light reduction initiatives. The LOT-DC will spread educational information on the benefits of nighttime light level reduction and the estimated economic benefit of

increased astro-tourism. Finally, the LOT-DC will work with Acadia to increase compliance of lighting within the park. A coalition of this sort will have substantial influence in the surrounding townships and will directly adhere to the policy goals of the LOT members for 2016. With the formation of such a group, the LOT signals a commitment to dark-sky preservation in both the short and long run.

## **Option #2: The Dark-Sky Taskforce (DST)**

The current Dark-Sky Project of WPI works directly with Acadia to measure the park's light levels and light fixture compliance. An interview with Dark-Sky Project leader, Frederick Bianchi, reflected the group's willingness to adapt its role for Acadia's benefit.

Therefore, Acadia Staff could create the DST – a rebranding and rethinking of the Dark-Sky Project's role. Whereas the Dark-Sky Project focus was insular, the DST would be equally community and park focused. The DST would be charged with working towards increased park lighting compliance while also planning, preparing, and executing educational initiatives in the surrounding communities to inspire light pollution reduction. In addition, under the direction of John Kelly of Acadia and Frederick Bianchi of WPI, the Taskforce would carry out “lighting audits” as a complementary service to receptive businesses and homes in the surrounding communities.<sup>44</sup> These audits would allow businesses and citizens to see their level of compliance with local lighting ordinances and how to best decrease their impact on light pollution levels.

## **Option #3: Lighting Consultant (LC)**

From interviews with other DSPs, one of the most beneficial actions taken by park leadership on the park's way to becoming a DSP was having one individual in charge of retrofitting of light fixtures within the park. While Acadia is unable to bring on another staff member due to budgetary constraints or allocate this duty to an existing employee due to administrative constraints, park leadership could instead bring on an Acadia-registered volunteer who is reimbursed for their time and efforts through Friends of Acadia.

Specifically, this policy option calls for Acadia to bring on a full-time volunteer to go through the park measuring the light levels from various fixtures and retrofitting lights and fixtures to increase compliance under the IDA guidelines. According to the 2015 WPI report, lighting within the park was 55.06 percent compliant with IDA guidelines, just more

than 10 percent below the 66 percent required for a provisional DSP status.<sup>45</sup> In addition, this LC would also be responsible for writing Acadia's DSP application to the IDA.

## Option #4: The League of Towns-Dark-Sky Partnership (LOT-DSP)

The final policy option combines the duties and responsibilities of the Coalition with the Taskforce. The Coalition would still be created, assembling members of the LOT to devote efforts specifically for darkness conservation. The DST would also alter their existing responsibilities and begin performing lighting audits and increasing Acadia lighting compliance. However, the DST would report their light pollution lighting audit findings to the Coalition each year. Frederick Bianchi would serve as the liaison between the Taskforce members and the Coalition. Furthermore, the DST could recommend future measures for the Coalition to implement to address certain concerns, and the Coalition could give the DST future assignments to study specific areas of lighting concern.

Finally, the DST would be responsible for preparing Acadia's application for DSP status to the IDA once lighting compliance within the park is reached. Once completed, the Taskforce will submit the application to the Coalition, which will act as the pre-submission review board. If passed, the Coalition will submit the application to the IDA. If failed, the application will return to the DST to perform edits.

## Qualitative Criteria

Policies can be evaluated using wide-ranging criteria. However, a superior policy analysis will customize and weight evaluative criteria considering the desired policy goal. The overarching goal of this report is to develop a policy that will decrease nighttime lighting levels within the park. **The criteria with which each alternative will be evaluated are political feasibility, legal feasibility, administrative constraints, budgetary constraints, public support, and lighting reduction.**

### 1) Political Feasibility

As mentioned previously, Acadia finds itself in a situation where the behavior and actions of others (the surrounding communities) affect the nighttime lighting of the park. This is extremely important to remember when thinking about how Acadia could influence the policies of the local communities. The park has no enforcement mechanism, and

therefore it cannot issue a policy and expect the community to follow the policy's ruling. Political feasibility is a key factor in the evaluation of the criteria for any policy option. An option's political feasibility will be identified as high, medium, or low.

## **2) Legal Feasibility**

While more conceptually easy to understand than some of the other criteria, legal feasibility is still an important portion of any policy analysis. Acadia must ensure that any policy adopted is within the legal limits of both the NPS and the local communities. A great policy option that fails to fully adhere to the law will not be adopted. All policy options need also to be evaluated in terms of the local lighting ordinances in the surrounding communities. Extra weight will be given to those options that help create an enforcement mechanism for the local lighting ordinances.

Legal feasibility will be measured in the binary. Policy options will receive a "Yes" if it is legal and a "No" if there is a legal hurdle that will stifle the policy option's implementation.

## **3) Administrative Feasibility**

After speaking with many members of the NPS, it became apparent that the staffs of many National Parks are stretched thin, their time constraints significant. Therefore, all policy options will be analyzed and evaluated in terms of the increased burden the policy will place on the Acadia staff. This is especially important when considering the time horizon for any option. It may be that a policy can be completed, but it might require a longer time to accomplish due to lack of staff availability. All options need to have specific timelines to determine if an option is viable with the staffing and administrative constraints facing the park. Policies that require additional administrative duties for others in existing organizations outside the park will also be evaluated. An option's administrative feasibility will be identified as high, medium, or low.

## **4) Budgetary Feasibility**

Any policy option proposed needs to be evaluated in terms of the budgetary constraints on Acadia. Policies that can get around requiring significant extra funding from the NPS will receive extra weight, as that process is often lengthy and difficult. Further

analysis of Acadia's financial situation shows the significant deferred maintenance costs, demonstrating the park's inability to spend large sums of money implementing new policies. Policies that require funding from secondary actors such as existing organizations will also be factored into the evaluation. An option's budgetary feasibility will be identified as high, medium, or low.

## 5) Public Support

Being located exceptionally close to towns and communities in the Mt. Desert area, light from the surrounding public affects the nighttime light levels within the park. Therefore, any policy suggested must take into account the relative public support. A policy will be ineffective in accomplishing nighttime light level reduction within Acadia if the public does not also buy into the option. As is difficult with most criteria that attempt to determine support levels for particular policies, the aggregation of preferences is often incredibly challenging. Therefore, the options' estimated levels of public support will be identified as high, medium, or low.

## 6) Lighting Reduction

Perhaps the most important criterion, each policy option will be evaluated by looking at the estimated impact the option will have on reducing nighttime lighting levels. Since there will be no way to officially measure the lighting reduction impact, this analysis will be future looking with precise estimates of the lighting levels from policy options. Relative effectiveness in terms of lighting reduction will be identified as high, medium, or low.

## Qualitative Evaluation of Each Policy Alternative

Using the criteria stated above, each option is evaluated qualitatively with the simple metrics of high, medium, or low.

## Status Quo

The local communities are, overall, very supportive of measures to decrease nighttime lighting levels. Most of the surrounding towns have adopted some kind of lighting ordinance to decrease excessive light pollution. This began as early as 2009 with the Bar Harbor lighting ordinance.<sup>46</sup> According to the Worcester Polytechnic Institute's (WPI)

recent studies, the nighttime lighting levels over the past three years have remained relatively constant.<sup>47</sup> It is reasonable to expect over the long-term that light levels will remain relatively constant or will decrease slightly with the lighting ordinances.

## Option #1: League of Towns Darkness Coalition (LOT-DC)

**Politically, this option is mostly feasible (High-Medium).** The LOT recently stated a long-term policy goal of further dark-sky preservation, which is a positive sign for the likelihood of this option's approval within the League. However, it is unclear if the members of the LOT would deem such a suggestion effective. While Acadia has a seat on the LOT, there are nine other representatives that have equal say in the actions taken by the League and who may choose to pursue other lighting reduction efforts.

**This option does not violate any law** nor does it exceed Acadia's limitations of working with outside organizations as stated in Title 16 U.S. Code Section 341.<sup>48</sup>

This solution is meant to put a low of an administrative burden on park personnel; however, it does add a significant burden to a couple of members of the LOT who would be responsible for the Coalition. Due to this extra burden and their time constraints, there is a greater possibility that the League will be unable to achieve the goals of this option. Therefore, the **administrative feasibility is estimated to be Medium.**

From a budgetary standpoint, this option should not require significant funding. The formation of the Coalition would not require any funds from either Acadia or the LOT. There are certain costs associated with retrofitting of light fixtures within and outside the park, however, the LOT would cover these expenses or work with the surrounding communities and town councils to raise the funds necessary for retrofittings in the long-term. **Budgetary feasibility for the LOT-DC is High.**

**Public support for the option should be High.** Pushback from this option should be negligible or non-existent. The public recognizes and respects the LOT as a collective policy-suggesting body of the area's largest political stakeholders. The actions of the League, as a result, have significant legitimacy with the surrounding populations. Furthermore, the public has already demonstrated their acceptance of darkness preserving political actions with the lighting ordinances.

Compared to the other options, it is estimated this option will decrease surrounding light pollution by some medium amount. Due to the factors above and the sway of the

LOT on the surrounding areas and communities, should the option be implemented, there will be enough public buy-in that **moderate light reduction will occur (Medium)**.

## Option #2: The Darkness Task Force

**Politically, this option is feasible (High).** The leadership of the Dark-Sky Project has expressed the willingness to change the focus and expand the role of the project for Acadia's benefit. In addition, the lighting audit idea was suggested by the leader of the Dark-Sky Project, demonstrating the group's interest in working both within and outside the park.

Legally, **the option adheres to the law.** The option does not violate Acadia's legal limitations written in Title 16 U.S. Code Section 341.<sup>49</sup>

This solution is meant to put as low of an administrative burden on park personnel as possible; however, it does add a significant burden to the WPI Dark-Sky Project team members. As mentioned previously, the WPI group is willing to accept greater responsibility for the benefit of Acadia's night skies. Therefore, **administrative feasibility is High for this option.**

From a budgetary standpoint, this option should not require significant funding, and, ideally, WPI will contribute more funds to the Dark-Sky Project to facilitate the Taskforce's directives. There are certain costs associated with retrofitting of light fixtures within and outside the park, however, the DST would help would cover these expenses or work with the surrounding communities to raise the funds necessary for retrofittings in the long-term.

**Budgetary feasibility for the DST is High.**

Public support for the option could be both positive and negative. WPI is not a local group, therefore, some residences/commercial businesses could feel uncomfortable with the idea of the Taskforce either performing lighting audits or distributing educational material on the importance of dark skies on their properties. People would then decline the opportunity to see their nighttime light levels from these audits. It is also possible that many of the public will support the actions of the DST because of its connection with Acadia. This connection could provide the Taskforce with the legitimacy needed to allow some individuals support the DST's responsibilities in the communities. **Public support is estimated to be Medium** for this option.

Increasing the educational materials regarding light pollution and performing lighting audits should decrease nighttime light levels by some level, but not as much as the LOT-DC,

due to the estimated potential lack of public buy-in and support. **Lighting reduction is Medium for the DST.**

### Option #3: Lighting Consultant

**Politically, this option is barely feasible.** Following discussions with Stephanie Clement, Conservation Director of Friends of Acadia, it became apparent that a position such as this, while aligned with the goals of FOA's Wild Acadia initiative, does not fit into the current programmatic focus area of watershed conservation determined by the Board of Directors. If dark-sky preservation could be framed in such a way as to make this option fit within the conservation of watersheds (perhaps framing as the preservation of the nighttime aesthetic appeal of a particular watershed), there is a possibility for approval by FOA.

Legally, **the option adheres to the law**, and does not violate Acadia's legal limitations written in Title 16 U.S. Code Section 341.<sup>50</sup>

This solution requires very little administrative burden on Acadia personnel or FOA. This individual would work in an almost autonomous manner, reporting progress to John Kelly of Acadia and Stephanie Clement of FOA. **Administrative feasibility is High.**

From a budgetary standpoint, this option would require funding an individual full-time for an estimated year's worth of work. Before discounting, the per year estimate at \$15/hour for a 262 day work year is at a minimum of \$31,320. There are certain costs associated with retrofitting of light fixtures within the park, however, it is hopeful FOA would help cover these expenses. **Budgetary feasibility is Low.**

Public pushback for such an option is estimated to be negligible or non-existent. Since this option's directives are entirely within Acadia, the public should not be resistant to this policy alternative. **Public support is High.**

This option is estimated to have the most immediate impact on nighttime light levels within the park. Following interviews with other DSPs that implemented similar positions, this option should provide greater immediate compliance with IDA lighting guidelines and further decrease Acadia's light levels. However, because all of the actions of this position are within Acadia, there is assumed to be no impact on the surrounding communities. Therefore, in the short-run, the light levels will decline in Acadia, but once Acadia reaches high levels of compliance, this option will not continue to help decrease light levels as it has no impact on the public's light pollution. **Light reduction is High for this option.**

## Option #4: The League of Towns-Dark-Sky Partnership (LOT-DSP)

Politically, this option is feasible. While still suffering from the same possibility that some on the LOT could choose not to support such a policy, it is highly unlikely the LOT would not approve this alternative, considering this option both meets their 2016 policy goals and removes much of the administrative burden on the LOT members. In addition, the Dark-Sky Project is interested in expanding their role with Acadia, and it is unlikely they would be unsupportive of such an option. **Political feasibility is High.**

Legally, **the option adheres to the law** and does not violate Acadia's legal limitations written in Title 16 U.S. Code Section 341.

This solution requires very little administrative burden on Acadia personnel. This option also decreases the amount of extra work required by members of the League of Towns that are involved with the Coalition, increasing their likelihood to agree to such a solution. The Dark-Sky Project is also willing to accept a greater administrative burden. **Administrative feasibility is High.**

From a budgetary standpoint, this option should not require significant funding, and, ideally, WPI will contribute more funds to the Dark-Sky Project to facilitate the Taskforce's directives. There are certain costs associated with retrofitting of light fixtures within and outside the park, however, the DST and/or the LOT would help cover these expenses or work with the surrounding communities to raise the funds necessary for retrofits in the long-term. **Budgetary feasibility for the LOT-DSP is High.**

Whereas public support was lower for the DST option, this policy is estimated to have greater public buy-in due to the partnership with the LOT. Being associated with the LOT should help ease some of the public uneasiness of having a non-native group performing lighting audits and distributing educational material. **Public support for this option is High.**

This option is estimated to achieve the provisional Dark-Sky Park designation second quickest behind the lighting consultant option and to have the highest capability of producing the greatest long-run nighttime lighting reduction. **Lighting reduction is High.**

## Qualitative Analysis Outcomes Matrix

	LOT-DC	DST	LC	LOT-DSP
<b>Political Feasibility</b>	High-Med	High	Low	High-Med
<b>Legal Feasibility</b>	Yes	Yes	Yes	Yes
<b>Administrative Feasibility</b>	Med	High	Low	High
<b>Budgetary Feasibility</b>	High	High	Low	High
<b>Public Support</b>	High	Med	High	High
<b>Estimated Lighting Reduction</b>	Med-High	Med	Med-High	High

## Quantitative Analysis

### Benefit Cost Analysis

In addition to the qualitative evaluative criteria, a quantitative, benefit cost analysis (BCA) was conducted to estimate the dollar benefits and costs of each option relative to the Status Quo. The time frame for the BCA was five years, and the estimated dollar impacts were discounted at 3 percent per year per - the discount recommendation found in OMB Circular A-4.<sup>51</sup> A sensitivity analysis using a 7 percent discount rate was also performed.

The benefits estimated and monetized included economic benefit, savings from reduced electricity consumption, and environmental benefit. The costs, also estimated and monetized, were retrofitting light fixtures within and outside the park, new employee salaries, and the costs associated with decreased safety in terms of crime and transportation from nighttime light reduction.

### 1) Economic Benefit

The first benefit identified for this analysis was the economic benefit of Acadia based on the dollar impact on local economies from increased tourism. Each year, the NPS

releases its economic impact study, which quantifies the dollar impact each park has on the surrounding economy. By finding the average amount spent per visitor and the rate of increase in the dollar benefit per year, a general projection was made for the economic impact of the park if present trends continue. Based on the qualitative estimation of the effectiveness of the various alternatives, the increase in the number of visitors per year was estimated. Following each option's respective projection for five years, the amounts were discounted and summed.

## **2) Electricity Savings**

The next benefit was the estimated savings of reduced electricity consumption due to a particular policy. This option involved finding the amount of electricity consumed in the Bar Harbor area and estimating the amount consumed within and outside the park by light bulb type – 60 Watt incandescent or IDA recommended LEDs. Based on the estimated qualitative impact of the options, the relative estimated percentage shifts in use of incandescents to LEDs were projected. Following each option's respective projection for five years, the amounts were discounted and summed.

## **3) Environmental Benefit**

The final benefit analyzed was the estimated environmental benefit of a darker night sky. This was calculated using a Willingness to Pay (WTP) model developed through a contingent valuation study by economists at Missouri State University. The contingent valuation study measured the WTP of visitors of four different Western National Parks. It is important to note that this is one of the only studies of its kind. The model used comes from a draft of the study by the Missouri State Economists that contains slight data errors. Permission to use this draft was granted from the authors. Using a regression output of the study, visitor statistics for Acadia were plugged in and aggregated. Based on the estimated qualitative impact of a particular option, the specific assumptions about the preferences of Acadia's visitors were altered slightly. Finally, an adjustment to the WTP model was made to account for Acadia's frequent foggy weather (dark-sky obscuring weather) compared to the other parks outlined in the Missouri State WTP model. Following each option's respective projection for five years, the amounts were discounted and summed.

#### **4) Cost of Retrofitting/Replacing Light Fixtures**

The first cost calculated was the estimated retrofitting price of each of the options both within and outside the park. Based on the estimated qualitative impact of a particular option, the relative increases of LEDs and the relative decreases in incandescents were estimated for each. Following each option's respective projection for five years, the amounts were discounted and summed.

#### **5) Cost of Hiring New Employees**

The next cost calculated was the cost of hiring new employees in the Mt. Desert area. Since only one option required new hires, the cost was projected and discounted for the Lighting Consultant with all other options reflecting a cost of \$0. A simple wage calculation for an individual hired full-time, working an average 262 days per year was calculated at \$15 per hour.

#### **6) Safety Costs**

The final cost was the estimated safety cost in transportation and crime for each option. If an area decreases street lighting, there is frequently a slight increase in the number of crashes and crimes, both violent and property. Using studies that sought to demonstrate the percent increase of crashes and crime in areas lit versus unlit, a price of an accident or crime was projected out for each option. Based on the estimated qualitative impact of a particular option, the relative percent increases of crashes and crime were estimated. Following each option's respective projection for five years, the amounts were discounted and summed.

### **Quantitative Evaluation of Each Policy Option**

#### **Status Quo**

It is assumed that due to the budgetary and administrative constraints currently facing the park, there will be no further lighting reduction or compliance within the park or outside the park without a new policy.

## Economic Benefit

According to annual economic output studies conducted by the National Parks Service, Acadia generates over \$200 million of economic benefit each year. By projecting the trend of the benefits per the estimated visitor totals for the next five years, a total rounded value after discounting of the economic benefit Acadia will provide if present trends continue is about **\$1.934 billion**.

## Electricity Savings

After calculating the amount of electricity consumed in Acadia, the amount consumed in the residences around the park, and the average numbers of incandescents and LEDs used in the average home, the total amount of electricity saved by using LEDs if present trends continue was estimated to be about **\$2.1 million**.

## Environmental Benefit

Using the WTP model and assuming certain characteristics about the visiting Acadia population, the current, discounted environmental benefit if present trends continue for the next five years is estimated to be about **\$447 million**.

## Retrofitting within the Park

The lighting expenses within Acadia for the next five years discounted, using the same techniques as the electricity saved, if present trends continue would be about **\$19,000**.

## Retrofitting outside the Park

The lighting expenses outside Acadia for the next five years discounted, using the same techniques as the electricity saved, if present trends continue would be about **\$4.5 million**.

## Cost of Hiring New Employees

Finally, since the Status Quo does not require the hiring of another individual, the estimated hiring costs are **\$0**.

## Safety Costs

Annual safety costs were divided into transportation and crime, which was further divided into violent and property crime costs. Together, the estimated cost of all crime and

car crashes in Bar Harbor at night on unlit roads over the next five years discounted if present trends continue is about **\$5.5 million**.

## LOT-DC

### Economic Benefit

The LOT-DC will create a significant amount of buy-in from the local communities due to the influence the League has with the people of the area. By forming a coalition dedicated to the reduction of light pollution, the League effectively signals to the public the importance of this issue to the communities. This will create buy-in and lighting reduction in the towns, decreasing the Park's light pollution and furthering Acadia's reputation as a premier star gazing location in the Northeast, increasing park visitation by an estimated 300 more visitors per year. The resulting economic benefit of Acadia with this policy over the next five years discounted is about **\$200 million greater than the Status Quo**.

### Electricity Savings

With the increased buy-in from the local communities due to the influence the League has with the people of the area, lighting reduction in the towns and efforts to increase Acadia's compliance over the course of five years will result. It is assumed it will take Acadia all five years to reach the 90 percent compliance figure. It is also assumed Acadia will be 8.6 percent more compliant each year. Since the LOT will have influence in the communities, it is assumed the average household use of LEDs over incandescents will increase to at least 50 percent LEDs usage by the beginning of year three and will remain constant thereafter. The total estimated electricity savings from this option after five years discounted is about **\$2.4 million**.

### Environmental Benefit

As the sky gets darker with the Coalition's actions and stargazing becomes even more popular in Acadia, more astrotourism will occur and a greater number of the total visitors will be more willing to pay a greater amount for a darker night sky. It was assumed that the percentage of visitors bringing stargazing equipment increased to 12.5 percent and the percent willing to pay after being asked twice decreased slightly to 40 percent (assumed because more people are willing to pay when asked the first time, less are willing to pay more the second time asked). This decrease in WTP after being asked twice

could also be the result of the minor error in the original WTP data set mentioned above. Therefore, the total amount all visitors are willing to pay after five years discounted is about **\$510 million**.

### Retrofitting Within the Park

Assuming the same time frame as above for the electricity savings, the five-year total cost of these retrofittings within the park discounted is about **\$34,000**.

### Retrofitting Outside the Park

Assuming the same time frame as above for the electricity savings, the five-year total cost of these retrofittings outside the park for the entire population of Bar Harbor discounted is about **\$7.2 million**.

### Cost of Hiring New Employee

This option does not require the hiring of any new employees - **\$0**.

### Safety Costs

It is estimated that due to the decrease in nighttime lighting from the policy, the Coalition will result in an estimated 0.5 percent increase in crashes and in crime. Therefore, the total safety costs for the entire Bar Harbor population at night on unlit roads and due to crime over the next five years discounted is about **\$8.7 million**.

## Dark-Sky Taskforce

### Economic Benefit

The Darkness Taskforce will conduct free lighting audits on surrounding businesses and homes. It will also distribute informational materials to the surrounding communities regarding the importance of the night sky. With the greater amount of information available to the population, the nighttime lighting levels should decline slightly and a furthering of Acadia's reputation as a star gazing location should occur, prompting increased tourism by an estimated 250 more visitors in years four and five. There will be a delay in visitor numbers due to the hesitancy of some of the local community members of having the non-local group performing these outreach efforts. The five-year total economic benefit of this option discounted is about **\$100 million greater than the Status Quo**.

## Electricity Savings

Due to perceived effectiveness of the lighting audits and the educational material distribution, the Darkness Taskforce will have a slightly larger effect on light savings in the towns (residential/businesses) and a slightly smaller effect on electricity savings within the park compared to the Darkness Coalition. Assuming the lighting audits and educational distribution is successful, it is assumed the Taskforce can get residential/commercial use of LEDs up to 50 percent by 2018 and 60 percent by 2019. It is also assumed that Acadia's compliance will rise to 80 percent by the end of the five years. The total amount of electricity savings of this option over the five years discounted is estimated to be about **\$2.6 million**.

## Environmental Benefit

The Darkness Taskforce will result in more people bringing stargazing equipment compared to the Status Quo, (10 percent). Due to the increase in astrotourism, the percent willing to pay after being asked twice decreased slightly to 40 percent (assumed because more astro-tourists are assumed to be willing to pay more when asked the first time, less are willing to pay more the second time asked). This decrease in WTP after being asked twice could also be the result of the minor error in the original WTP data set mentioned above. The total estimated environmental benefit over the five-year period for all visitors discounted is about **\$484.6 million**.

## Retrofitting Within the Park

Assuming the same time frame as above for the electricity savings, the total estimated cost for retrofittings within Acadia over the five-year period discounted is about **\$32,000**.

## Retrofitting Outside the Park

Assuming the same time frame as above for the electricity savings, the total estimated cost for retrofittings for all of Bar Harbor over the five-year period discounted is about **\$13 million**.

## Cost of Hiring a New Employee

This option does not require the hiring of any new employees - **\$0**.

## Safety Costs

Due to the decrease in nighttime lighting from the policy but the slower effectiveness of the policy on the Bar Harbor public, the Taskforce will result in an estimated 0.3 percent increase in crashes and in crime. Therefore, the total safety costs for the entire Bar Harbor population due to crime and crashes on unlit roads over the next five years discounted is about **\$8.3 million**.

## Lighting Consultant

### Economic Benefit

It was estimated that The LC would have the greatest estimated impact on lighting reduction within the park (one individual dedicated to retrofitting park lighting will result in greater compliance and a darker park night sky). This individual's efforts will also enable the park to reach Dark-Sky Association lighting compliance the fastest. Therefore, there will likely be a slight boost in tourism from the honor of being named a Dark-Sky Park (increase in Astro-tourism of 500 more visitors per year). However, as mentioned previously, this option is expected to have little to no effect on the surrounding communities' nighttime lighting. The estimated total five-year discounted economic impact of this policy is about **\$300 million greater than the Status Quo**.

### Electricity Savings

The Lighting Consultant will have largest impact on electricity savings within the park, because of the significant amount of time-spent focuses on Dark-Sky Association compliance. It is assumed the consultant can get compliance with IDA guidelines to 80 percent within a year and 90 percent within two years and stay at this level thereafter. This option is estimated to have the little to no effect on community electricity savings because this consultant will not engage with the community in any significant way. The total estimated five-year discounted electricity savings is about **\$2.2 million**.

### Environmental Benefit

The Lighting Consultant will have the greatest impact on the numbers of those that brought star gazing equipment (more IDA compliance will result in the Dark-Sky Park designation and more visits from dedicated star-gazers). The number of visitors that brought star gazing equipment will increase to 15 percent. This option is not estimated to

have an impact on the numbers who are willing to pay after being asked twice because the Dark-Sky Park designation will result in an increase in overall visitors and astrotourism (as stated previously, because more visitors for astrotourism are assumed to be willing to pay more when asked the first time, less are willing to pay more the second time asked. Other park visitors are assumed to pay slightly more when asked a second time, resulting in the same percentage as the Status Quo). This decrease in WTP after being asked twice could also be the result of the minor error in the original WTP data set mentioned above. The total estimated five-year discounted environmental benefit is about **\$558 million**

### Retrofitting Within the Park

The lighting consultant will require the largest amounts of funds upfront for retrofitting within the park because most retrofits will be performed with the first two years, but the smallest costs in the later years. The total estimated cost for retrofittings within Acadia over the five-year period discounted is about **\$27,000**.

### Retrofitting Outside the Park

Similar to the above, however, the lighting consultant will have an estimated no effect on retrofittings outside the park. Therefore, its **costs are equivalent to those of the Status Quo - \$4.5 million**.

### Cost of Hiring a New Employee

This is the only option that includes this cost. It is estimated to require over the five-year period discounted about **\$200,000**.

### Safety Costs

Since the lighting consultant's work will only be within in the park. The effect on crime and wrecks will be negligible and is assumed to be **similar to the Status Quo - \$5.5 million**.

## Darkness Partnership

### Economic Benefit

Finally, the LOT-DC, along with the Lighting Consultant, is expected to have the greatest impact on the economic output as the surrounding towns buy-in to the initiatives. Due to the influence of the League and the efforts to distribute educational material and

conduct lighting audits by the Taskforce, there is will be an estimated 500 visitor increase visitors per year. The total economic benefit of this option over the five-year period discounted is estimated to be about **\$300 million greater than the Status Quo.**

### Electricity Savings

This option is assumed to take Acadia all five years to reach the 90 percent compliance figure. It is also assumed Acadia will be 8.6 percent more compliant each year. Since the League of Towns will have influence in the communities, we assume household use of LEDs over incandescents will increase to at least 50 percent LEDs by the beginning of year three and will remain there for the later years. The total electricity savings of this option over the five-year period discounted is estimated to be about **\$2.2 million.**

### Environmental Benefit

This option is estimated to have the same effects on those who bring their own stargazing equipment and those who are more likely to pay after being asked twice as the Lighting Consultant option. Both are estimated to increase tourism for the same reasons in similar amounts. Therefore, the environmental benefit of this option over the five-year period discounted is estimated to be about **\$558 million.**

### Retrofitting Within the Park

Assuming the same time frame as above for the electricity savings, the total estimated cost for retrofittings within Acadia over the five-year period discounted is about **\$35,000.**

### Retrofitting Outside the Park

Assuming the same time frame as above for the electricity savings, the total estimated cost for retrofittings in the surrounding communities around Acadia over the five-year period discounted is about **\$8.3 million.**

### Cost of Hiring a New Employee

This option does not require the hiring of any new employees - \$0.

### Safety Costs

Due to the decrease in nighttime lighting from the policy but the slower effectiveness of the policy on the Bar Harbor public, the Partnership will result in an estimated 0.6

percent increase in crashes and in crime. Therefore, the total safety costs for the entire Bar Harbor population due to crime and crashes on unlit roads over the next five years discounted is about **\$8.9 million**.

## Quantitative Outcomes Matrix (in Millions of \$ over 5 years)

	Status Quo	LOT-DC	DST	LC	LOT-DSP
<b>Economic Benefit</b>	1,934.0	1,934.2	1,934.1	1,934.3	1,934.3
<b>Electricity Savings</b>	2.1	2.4	2.6	2.2	2.2
<b>Environmental Benefit</b>	447	510	485	558	558
<b>Retrofitting Costs within Park</b>	0.02	0.04	0.03	0.03	0.04
<b>Retrofitting Costs outside Park</b>	4.5	7.2	13	4.5	8.3
<b>Hiring New Employees</b>	0	0	0	0.2	0
<b>Safety Costs</b>	5.5	8.7	8.3	5.5	8.9
<b>NPV Compared to Status Quo</b>	-	<b>60.6</b>	<b>27.1</b>	<b>111</b>	<b>104.1</b>

## Recommendation

**Acadia National Park Staff should choose to pursue the League of Towns – Dark-Sky Partnership option.** While it does not provide the highest dollar benefit of the options examined, it is still predicted to generate a substantial benefit of \$104.1 million over the next five years compared to the Status Quo. While this figure is highly dependent on the economic projection, the relative differences between the benefits of the options are well founded. In addition to the large monetary benefit, the LOT-DSP is also the most feasible and effective from a qualitative standpoint compared to all other options. The analysis demonstrates that the combination of the Coalition and the Taskforce into one policy made up for some of their respective deficiencies as individual options. Finally, although the

Lighting Consultant provides the largest estimated monetary benefit, it is not considered to be feasible from a political, administrative, or budgetary standpoint.

Therefore, should Acadia begin the formation of the LOT-DSP, it should take the following steps:

- Hold a strategic planning session with Acadia staff to further develop the new structures and responsibilities for the Taskforce and Coalition.
- Meet with the leader of the Dark-Sky Project, Frederick Bianchi, and discuss the new, proposed responsibilities.
  - Specifically set out benchmarks for increased compliance and completion of the IDA Dark-Sky Park application.
  - Better formulate the concept of lighting audits.
- Meet with the leader of the LOT, Durlin Lunt, to discuss the formation of the Coalition and how this option helps the League achieve its long-term policy goal of decreasing light pollution.
  - Develop the relationship of the Coalition with the Taskforce and formulate a plan of action for the next five years for the Partnership as a whole.
- Work with the Taskforce to develop informational material to be distributed throughout the surrounding communities.
  - This material should include information regarding the benefits of decreased nighttime light levels, especially the economic benefit. It should also discuss the formation of the Partnership and explain the concept of the lighting audits.

## Appendix

Figure 1<sup>52</sup>

# Limiting Magnitude

Aperture (inches)	Aperture (mm)	Limiting Magnitude (method 1)	Limiting Magnitude (method 2)
1/4	6	7.5	6.3
.31	8	8.2	6.9
2	50.8	12.2	11.0
3	76.2	13.1	11.8
4	101.6	13.7	12.5
5	127.0	14.2	12.9
6	152.4	14.6	13.3
8	203.2	15.2	14.0
10	254.0	15.7	14.5
11	279.4	15.9	14.7
12	304.8	16.1	14.8
14	355.6	16.4	15.2
16	406.4	16.7	15.5
17	431.8	16.8	15.6
18	457.2	17.0	15.7
20	508.0	17.2	16.0
22	558.8	17.4	16.2
24	609.6	17.6	16.4
30	762.0	18.1	16.8
32	812.8	18.2	17.0
200	5080	22.2	21.0

Method 1  $M_L = 3.7 + 2.5 \cdot \log_{10}(D^2)$  where D = aperture in mm.  
 From "VISUAL ASTRONOMY FOR THE DEEP SKY" by Roger N. Clark.

Method 2  $M_L = 9.5 + 5.0 \cdot \log_{10}(D)$  where D = aperture in inches.  
 From "THE OBSERVATIONAL AMATEUR ASTRONOMER" by Patrick Moore.

The differences in columns reflect differences in initial assumptions about sky conditions, visual acuity and others.  
 Your results may vary.

**Figure 2<sup>53</sup>**

	<u>SQM Values</u>		
	Luminance Nit = cd/m <sup>2</sup>	Magnitudes per square arcsec                  arcmin	
Sun	3E+9	-10.7	-19.6
Venus (max elong)	15000	+1.9	-7
Clear daytime sky (at horizon)	10000	+3	-6
Full Moon	6000	+3.6	-5.3
Mars at perihelion	4000	+3.9	-5.0
Overcast daytime sky (at horizon)	1000	+5	-4
Jupiter	800	+5.7	-3.2
Saturn	700	+5.9	-3.0
Heavy daytime overcast (at horiz)	100	+8	-1
Uranus	60	+8.6	-0.3
Neptune	30	+9.3	+0.4
Sunset at horizon, overcast	10	+10	+1
Clear sky 15 min after sunset (horiz)	1	+13	+4
Clear sky 30 min after sunset (horiz)	0.1	+15	+6
Fairly bright moonlight (at horizon)	0.01	+18	+9
Moonless, clear night sky (at horiz)	1E-3	+20	+11
Moonless, overcast night sky (at horiz)	1E-4	+23	+14
Dark country sky between stars (zenith)	3E-5	+24	+15

## Benefit Cost Analysis Technical Appendix

The following is a technical appendix of the performed Benefit Cost Analysis. Specifically, this shows how each step of the analysis was calculated and performed. For the corresponding spreadsheet for the analysis, please contact Locher Grove.

### Economic Benefit

1) The economic projections were taken from the National Parks Service Annual Economic Impact reports. The Economic Impact per Visitor was calculated as simply the total estimated impact divided by the total number of visitors to Acadia in that respective year.<sup>54, 55, 56, 57</sup>

- 2) The differences between the economic impacts of various years was calculated and averaged for the average rate of increase in economic impact per visitor per year.
- 3) The economic projections were taken from the Economic Impact study of Galloway National Park in Scotland.<sup>58</sup> All numbers had to be converted to US dollars for an accurate comparison. The Economic Impact per visitor was calculated by simply taking the estimated dollar impact total and dividing that figure by the total number of visitors to Galloway in that respective year. Noticing that Galloway generates about \$20 of economic impact less per visitor, a simple \$20 adjustment to the dollar impact per visitor was made in order to scale the figures in order to make them more comparable to Acadia's economic impacts per visitor.
- 4) This step involved projecting the number of visitors to Acadia in future years by finding the average rate of visitation increase to Acadia per year and adding the average rate of visitation increase per year to the previous year's visitation total to 2020.
- 5) This step took the average rate of increase of economic output per visitor for both NPS and Galloway (calculated in in steps 2 and 3) and simply added it to the economic impact of the previous year to 2020.
- 6) These projections were the calculated economic outputs for 2015 and future years multiplied by the projected number of visitors in future years for each option. These were then discounted at OMB recommended 3 percent each year. Option specific increases in visitation assumptions are in red next to their respective option.
  - Option 1 - Estimated 300 more visitors per year
  - Option 2 - Estimated 250 more visitors per year
  - Option 3 - Estimated 500 more visitors per year
  - Option 4 - Estimated 500 more visitors per year

## Lighting Benefit and Cost

- 1) This is the Maine-published data for the total amount of electricity consumed in Maine in 2012 as well as the price of that electricity by kWh according to the consuming actor.<sup>59, 60</sup>
- 2) Using plug-ins from existing literature that provided the national averages for electricity consumption by light type, this step calculated the per year electricity costs of LEDs and incandescents. By looking at the average electricity consumption per year by bulb type, the amount saved per year in electricity per LED bulb was calculated and discounted out for the next five years.<sup>61</sup> For the sake of simplicity and lack of existing literature, only the incandescent to LED ratios were calculated for residences using the kWh consumption Maine cost for residences.
- 3) According to the footnoted source to this step, the average bulb life cycle was used to calculate the number of each type of bulb necessary for a five year period.<sup>62</sup>
- 4) Using the above, this step calculated the number of bulbs necessary for one light fixture over a five year period and the total cost of the bulbs required for that one fixture. <sup>63, 64</sup> This used the plug-in from Step 3 to assume that an incandescent bulb lasts for about a year and a half and a LED lasts for 25 years on average.

5) An existing study by the U.S. Department of Energy provided the average number of lamps in the average Maine house - 63. The ratio of LEDs to incandescents used in the average Maine home was assumed by the consultant to be 3 incandescents to every 1 LED. A further assumption was that all 63 lights in the home were used for 2 hours per day at a time of darkness that could effect nighttime lighting levels (outdoor lighting, lights shining through windows, etc.). This is most likely a larger assumption. This step also calculated the total cost and electricity savings per house by light type (incandescent and LED) per year by multiplying the number of lights in a house by their respective total cost and savings calculated in the steps above.<sup>65</sup>

6) Using a lighting inventory study conducted in 2015 by the Worcester Polytechnic Institute's Dark-Sky Project, the level of light compliance (to International Dark-Sky Association guidelines) within Acadia National Park was determined to be 53 percent of 1000 total light fixtures. It was assumed for the sake of this analysis that those non-compliant fixtures were incandescents and those in compliance were LEDs. This compliance figure was then used to calculate the current totals spent on bulbs by type per year and the amount of electricity savings per year by LEDs.

7) This step was the first calculation of the Status Quo. Using the figures calculated in Steps 5 and 6, the dollar amount saved with LED usage per year (electricity savings) was calculated and discounted for both Acadia and the Bar Harbor community to 2020. The current estimated costs of light replacements both in the community and Acadia per year was also calculated and discounted out to 2020.<sup>66</sup>

8) These were the calculations for the option-specific electricity savings. Each option contained an assumption regarding the option's specific estimated effectiveness in increasing LED usage in both Acadia and the towns. This was estimated in a separate qualitative analysis. For all light calculations, there are gaps in payments because an incandescent bulb has an average life of 1.5 years. Therefore, it is assumed that all bulbs in a house are purchased all at once and then are replaced as needed in the following years. If LED usage increases in years in which incandescents burn out years, that is what causes a spike in price of bulbs. buying of bulbs occurs in years (1, 2, & 4).

Option 1 - It is assumed it will take Acadia all five years to reach the 90 percent compliance figure. It is also assumed Acadia will be 7.4 percent more compliant each year. Since the League of Towns will have influence in the communities, it is assumed household use of LEDs vs incandescents will increase to at least 50 percent LEDs by the beginning of year three and will remain there.

Option 2 - Assuming the lighting audits and educational material distribution is successful for this option, it is assumed the Taskforce can get residential/commercial use of LEDs up to 50 percent by 2018 and 60 percent by 2019. It is also assumed that Acadia's compliance will rise to 80 percent by the end of the five years.

Option 3 - It is assumed Acadia compliance will get up to 80 percent compliance within year 1 and 90 percent within 2. Also Assumed this option will have no effect on the surrounding community

Option 4 - It is assumed it will take Acadia all three years to reach the 90 percent compliance figure. It is also assumed Acadia will be 12.3 percent more compliant each year. Since the League of Towns will have influence in the communities, we assume household use of LEDs vs incandescents will increase to at least 60 percent LEDs by the end of year 5

9) These were the calculations for the option-specific light replacement/retrofitting costs. Assumptions regarding the options' effectiveness in increasing LED usage in Acadia and the towns

was estimated through a separate qualitative analysis (See option-specific assumptions above in Step 8).

## Environmental Benefit

- 1) These are the results from the CV study performed by Missouri State University Economists used to inform this WTP Model.<sup>67</sup>
- 2) These are the logistic results from the same Missouri State University study. The regression result on the far right was the one used to create this WTP model.
- 3) This step created the WTP model based on the regression results (each regression coefficient was multiplied by its variable then summed with the the other variables that were also multiplied by their regression coefficient).
- 4) Taken from the Economic benefit section, this is the projection of the number of Acadia visitors in the next five years (See Step 4 of the Economic Benefit section above).<sup>68</sup>
- 5) Looks more specifically at some of Acadia's visitor demographics to see if any of these statistics could inform of the values in this WTP model.<sup>69</sup> Analysis of this data informed the age breakdown of Acadia visitors for the WTP variable, *Age Over 65*, and the *Length of Stay* Variable in the WTP model. The rest of the Status Quo assumptions were estimated by the consultant.
- 6) Step 6 is the adjustment for Acadia's frequently foggy weather. It is assumed that people's WTP decreases when they cannot see the night sky. Therefore it was assumed that visitors are WTP 1/4 the total WTP estimate as visitors on cloudless nights for a darker sky. Finding the total number of cloudless nights (sunshine days equated for cloudless nights) to be about half of all days in a year, half of Acadia's visiting population was assumed to pay the full WTP estimate, and the other half was assumed to pay a quarter of the WTP estimate. This adjustment was used for every option evaluated.<sup>70</sup>
- 7) Using the WTP model and the assumed average demographic characteristics of Acadia visitors, the total WTP of all Acadia visitors was calculated by year and discounted if present trends continue.
- 8) Using the WTP model and the assumed average demographic characteristics of Acadia visitor, the two highlighted variables were altered according to each options' specific estimated impact on visitation to Acadia (increased Astrotourism). These estimates were determined from a qualitative analysis performed separately. Please note that the WTP seems to have some unusual result where an increase in the percent of visitors who are more likely to be willing to pay after being asked twice actually lowers the WTP estimate. The assumptions below attempt to provide some kind of explanation for this phenomenon.
  - Option 1 - Assumed the percent of visitors that brought stargazing equipment increased to 12.5 percent due to the increase in astro-tourism and the percent willing to pay after being asked twice decreased slightly to 40 percent (assumed because more astrotourists are assumed to be willing to pay more when asked the first time, less are willing to pay more the second time asked).

- Option 2 - Assumed the percent of visitors that brought stargazing equipment increased to 10 percent due to the increase in astro-tourism and the percent willing to pay after being asked twice decreased slightly to 40 percent (assumed because more astrotourists are assumed to be willing to pay more when asked the first time, less are willing to pay more the second time asked).
- Option 3 - Assumed the percent of visitors that brought stargazing equipment increased to 15 percent due to the increase in astro-tourism. This option is not estimated to have an impact on the percent who are willing to pay after being asked twice because the Dark-Sky Park designation will result in an increase in overall visitors and astrotourism (as stated previously, because more visitors for astrotourism are assumed to be willing to pay more when asked the first time, less are willing to pay more the second time asked. Other park visitors are assumed to pay slightly more when asked a second time, resulting in the same percentage as the Status Quo).
- Option 4 - Same assumptions as Option 3.

## Crash Costs

- 1) Using data from a Maine Transportation Department study, the number of annual crashes and fatalities were calculated for Bar Harbor. By finding the proportion of the Bar Harbor population as a total of the population of Hancock County (Bar Harbor is in Hancock County, ME), the total number of fatalities per the Bar Harbor population was calculated.<sup>71</sup>
- 2) From data from the NHTSA and assumptions from literature, this calculation "...assum[ed] that nighttime traffic accounted for approximately 25% of the total volume on an urban freeway, calculated night/day crash rate ratios as three times the number of nighttime crashes divided by the number of daytime crashes. The lighted sites together for all types of crashes had an average night/day crash rate ratio of 1.43; for the unlighted freeway sites, the ratio was 2.37. The author interpreted these ratios as follows: An average lighted freeway with 1000 crashes during the day would be expected to experience 475 crashes at night, while an unlighted freeway of comparable volume would be expected to have 790 crashes at night. This results in a theoretical 40% reduction ( $p < 0.01$ ) in nighttime crashes (all types) with the addition of lighting."<sup>72</sup> Therefore, in this step, the number more crashes in the US at night on an unlit road compared to a lit road was calculated using the above figures.
- 3) This step was a simple calculation that took the US crash averages found in Step 1 and found the number of crashes in Bar Harbor per year by the Bar Harbor population.<sup>73</sup>
- 4) Using the data from Steps 2 and 3, this was a simple calculation of the number of crashes and fatalities in the Bar Harbor area per year at night on unlit roads versus lit roads.
- 5) Plug-ins from NHTSA and the CDC allowed the total cost of all fatalities to be calculated for the Bar Harbor area by finding the total cost of fatalities in car accidents in Maine and dividing that by the number of total fatalities then multiplying that by the estimated number of fatal accidents in Bar Harbor per year. The property cost for crashes was calculated as the total property cost of all crashes in the US divided by the number of crashes in the US to get the cost per crash. This was then multiplied by the number of crashes in Bar Harbor annually.<sup>74, 75</sup>
- 6) Assuming each crash severity type occurs at the same frequency, using a NHTSA plug-in, the total cost of crashes in Bar Harbor per year for non-fatal crashes was calculated. Using the proportion

of accidents at night (Step 2), this was then projected for the total cost of crashes per non-fatal crashes at night on unlit roads vs lit roads in Bar Harbor per year.<sup>76</sup>

7) Using the numbers generated in Steps 5 and 6, Step 7 calculated the total cost of crashes (fatal, non-fatal, and property damage) in Bar Harbor per year at night on unlit roads vs lit roads. A further calculation was needed to put the figures in 2015 \$ from 2013 \$ by multiplying by the inflation rate of 1.02.

8) The total found in Step 7 was calculated over five years and discounted. This was the Status Quo calculation.

9) Step 9 involved the individual policy option calculations. These assumed a small percentage increase in all types of crashes due to a decrease in the nighttime lighting of roads. The percentage was estimated through the perceived effectiveness of the options in a qualitative analysis performed separately.

Option 1 - Assuming League of Towns Option results in a 0.5 percent increase in crashes in Bar Harbor at night.

Option 2 - Assuming Dark-Sky Taskforce Option results in a 0.3 percent increase in crashes in Bar Harbor at night.

Option 3 - Because the Lighting Consultant's duties are entirely focus within the park, it is assumed this policy option will have no effect on the cost of crashes in Bar Harbor.

Option 4 - Assuming the Partnership results in a 0.6 percent increase in crashes in Bar Harbor at night.

## Crime Costs

1) This is simply a chart from existing data regarding crime by type frequency in Bar Harbor per year.<sup>77</sup>

2) Using the data in Step 1, this was a simple calculation of the total number of crimes by type in Bar Harbor per year based on the population of Bar Harbor.

3) Using a plug-in from the literature, the percentage of violent crime at night was found - 63 percent. The percent of property crime that occurred at night was determined using a plug-in from a study of burglaries in Texas.<sup>78, 79</sup> This calculation assumed the number of burglaries were proportional to the rest of property crime and Texas, and that burglary rates are similar for all other states.

4) Using the data in step 3, this step calculated the percentage of property crime that occurs at night on average assuming that at least half of the unknown burglary times from the Texas study occurred at night.

5) From a plug in from a Bureau of Justice study, the percentages of crime by type by location were found. The percentage of crime by type by location was then calculated by multiplying the number of crimes in 2012 (2013 was not used due to a seemingly high number of violent crimes) found in Step 2 by the ratio of crime of each location.<sup>80</sup>

6) Using the figures in Step 5 and multiplying those by the percentages generated in Steps 4 and 5, the number of crimes by type by location per year in Bar Harbor at night was calculated.

7) From a study published by the National Society of Biotechnology Information, the estimated cost of each crime by type was recorded. The national averages of the percentage of violent crime by type was also recorded.<sup>81</sup> The average annual cost of all crime by type for the Bar Harbor at night was then calculated using these numbers.

8) Step 8 involved the creation of a simple matrix of the cost of crime by type by location per year at night in Bar Harbor. The total numbers of each crime (Step 6) were multiplied by the total cost of each crime (Step 7).

9) Step 9 was the total cost of all crimes in Bar Harbor per year discounted for 5 years. This was the Status Quo calculation.

10) Step 10 involved the individual policy option calculations. These assumed a small percentage increase in all types of crime due to a decrease in the nighttime lighting of locations. The percentage was estimated through the perceived effectiveness of the options in a qualitative analysis performed separately.

Option 1 - Assuming League of Towns Option results in a 0.5 percent increase in all crime in Bar Harbor at night.

Option 2 - Assuming Dark-Sky Taskforce Option results in a 0.3 percent increase in all crime in Bar Harbor at night.

Option 3 - Because the Lighting Consultant's duties are entirely focus within the park, it is assumed this policy option will have no effect on the cost of crime in Bar Harbor.

Option 4 - Assuming the Partnership results in a 0.6 percent increase in all crime in Bar Harbor at night.

## Hiring Costs

1) Step 1 was simply an arbitrary wage estimate multiplied by 8 hours worked per day by the average number of days worked in a year.

2) This was the yearly wage calculation discounted over the 5 years and summed.

## Report Work Count

(Excluding Appendix and References)

**10,740**

## Honor Pledge

Signed: Locher M. Grove

3/2/16

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