MICHAEL P. VICTORINO
Mayor

JORDAN MOLINA
Director

GARY L. I. AMBROSE
Deputy Director

WADE SHIMABUKURO, P.E.
Development Services Administration

RODRIGO "CHICO" RABARA, P.E.
Engineering Division

JOHN R. SMITH, P.E.
Highways Division

Telephone: (808) 270-7845
Fax: (808) 270-7955

COUNTY OF MAUI
DEPARTMENT OF PUBLIC WORKS
200 SOUTH HIGH STREET, ROOM 434
WAILUKU, MAUI, HAWAII 96793

July 12, 2022

Mr. Keith Kawaoka
Environmental Review Program
State of Hawaii, Department of Business, Economic Development and Tourism
Office of Planning and Sustainable Development
235 South Beretania Street, Room 702
Honolulu, HI 96813

SUBJECT: DRAFT ENVIRONMENTAL ASSESSMENT AND ANTICIPATED FINDING OF NO SIGNIFICANT IMPACT (DEA/AFONSI) MAUI COUNTY STREETLIGHT CONVERSION PROJECT (DPW PROJECT NO. 21-29) MAUI COUNTY, HAWAIʻI

Dear Mr. Kawaoka:

The County of Maui Department of Public Works (DPW) requests the subject Draft Environmental Assessment and Anticipated Finding of No Significant Impact (DEA/AFONSI) be published in the next issue of the Environmental Review Program's (ERP) bi-monthly bulletin, *The Environmental Notice*.

The required publication forms and files, including an electronic copy of the DEA/AFONSI in PDF format, have been provided to the ERP online submission platform. Concurrently with the electronic filing, and as required by HAR §11-200.1-5(e)(1)(B), printed copies of the DEA/AFONSI have been submitted to the Kahului Library and with the Hawaiʻi Documents Center.

Pursuant to Hawaiʻi Administrative Rules §11-200.1-20(b), publication of the DEA/AFONSI in *The Environmental Notice* initiates a 30-day public comment period for the public to provide comments regarding potential effects of the proposed action. Public comments should be submitted to Planning Solutions, Inc. (PSI) with copies to DPW.

Should there be any questions regarding this matter, please contact me at (808) 270-7845.

Sincerely,

JORDAN MOLINA
Director of Public Works

JM/KW (ED22-0605)
S:\ENG\PROJECTS\02 CIP\2021\21-29 LED Street Light Environmental Assessment\D Draft EA\21-29_LTR_KKawaoka OPSD_LED SL Conv_Draft EA Cover Ltr_7.13.22.docx

cc: Mākena White, PSI (electronic)
Brian Bilberry, Deputy Corporation Counsel (electronic)
DPW, Engineering Division, Traffic Section (electronic)

From: webmaster@hawaii.gov
To: DBEDT OPSD Environmental Review Program
Subject: New online submission for The Environmental Notice
Date: Thursday, July 14, 2022 4:41:20 PM

Action Name

Maui County Streetlight Conversion Project

Type of Document/Determination

Draft environmental assessment and anticipated finding of no significant impact (DEA-AFNSI)

HRS §343-5(a) Trigger(s)

- (1) Propose the use of state or county lands or the use of state or county funds

Judicial district

Maui - multiple districts

Tax Map Key(s) (TMK(s))

County right-of-way throughout the County of Maui

Action type

Agency

Other required permits and approvals

Work in Roadway Permit

Proposing/determining agency

County of Maui Department of Public Works

Agency contact name

Kurt Watanabe

Agency contact email (for info about the action)

kurt.watanabe@co.maui.hi.us

Email address or URL for receiving comments

makena@psi-hi.com

Agency contact phone

(808) 463-3120

Agency address

200 S. High Street
Room 401
Wailuku, HI 96793
United States
Map It

Was this submittal prepared by a consultant?

Yes

Consultant

Planning Solutions, Inc.

Consultant contact name

Makena White

Consultant contact email

makena@psi-hi.com

Consultant contact phone

(808) 550-4538

Consultant address

711 Kapiolani Boulevard
Suite 950
Honolulu, Hawaii 96813
United States
Map It

Action summary

The Maui County Streetlight Conversion Project involves the replacement of approximately 4,900 County-owned streetlight fixtures located along County roadways on the Islands of Maui, Molokaʻi, and Lānaʻi. The existing High Pressure Sodium (HPS) light fixtures would be removed and fully-shielded, energy-saving, wirelessly-controllable Light Emitting Diode (LED) light fixtures would be installed. The LED fixtures would have a correlated color temperature (CCT) of 2700K and comply with current administrative rules. The county would also implement adaptive lighting measures, including dimming, when and where appropriate.

Reasons supporting determination

The County of Maui Department of Public Works is providing an Anticipated Finding of No Significant Impact, based on the analysis of significance criteria provided in Chapter 5 of the Draft Environmental Assessment.

Attached documents (signed agency letter & EA/EIS)

- 2022-07_DEA-AFONSI-MauiStreetlightConversion.pdf
- 2022-07-12_DPWtoERP-DEAforStreetlightConversion.pdf

Action location map

- MauiCountyStreetlightConversionProject.zip

Authorized individual

Jim Hayes

Authorization

- The above named authorized individual hereby certifies that he/she has the authority to make this submission.

DRAFT ENVIRONMENTAL ASSESSMENT & ANTICIPATED FINDING OF NO SIGNIFICANT IMPACT, MAUI COUNTY STREETLIGHT CONVERSION PROJECT

PREPARED FOR:

County of Maui
Department of Public Works

PREPARED BY:

PLANNING SOLUTIONS

JULY 2022

TABLE OF CONTENTS

List of Appendices

List of Figures

List of Tables

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AFONSI	Anticipated Finding of No Significant Impact
BMP	Best Management Practice
BSTP	Band-rumped Storm-Petrel

CAA	Clean Air Act
CAB	Clean Air Branch
CCT	Correlated color temperature
CFR	Code of Federal Regulations
CIA	Cultural Impact Assessment
CRI	Color rendering index
CZM	Coastal Zone Management
DLNR	Department of Land and Natural Resources
DOFAW	Division of Forestry and Wildlife
EA	Environmental Assessment
EIS	Environmental Impact Statement
EMS	Emergency medical services
EPA	Environmental Protection Agency
ESA	Environmental Site Assessment
FEA	Final Environmental Assessment
FONSI	Finding of No Significant Impact
HAPE	Hawaiian Petrel
HAR	Hawai‘i Administrative Rules
HDOH	Hawai‘i State Department of Health
HDOH-WB	Planning and Design Section, Wastewater Branch
HDOH-ES	Environmental Services
HDOT	State of Hawai‘i, Department of Transportation
HEPA	Hawai‘i Environmental Policy Act
HRS	Hawai‘i Revised Statutes
IR	Infrared
LED	Light Emitting Diode
mgd	Million gallons per day
MNSRP	Maui Nui Seabird Recovery Project
msl	Mean sea level
NAAQS	National Ambient Air Quality Standards
NESH	Newell’s Shearwater
NFPA	National Fire Prevention Association
NHPA	National Historic Preservation Act
NHRP	National Register of Historic Places
NPDES	National Pollutant Discharge Elimination System
OCCL	Office of Conservation and Coastal Lands
OEQC	Office of Environmental Quality Control
OHA	Office of Hawaiian Affairs

SAAQS	State Ambient Air Quality Standards
SHPD	State Historic Preservation Division
SOS	Save Our Shearwaters Program
S/P	Scotopic/Photopic
SPD	Spectral Power Density
TMK	Tax Map Key
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
UV	Ultra-violet
WTSH	Wedge-tailed Shearwater

Chapter 1: INTRODUCTION

1.1 PURPOSE OF THE PROPOSED ACTION

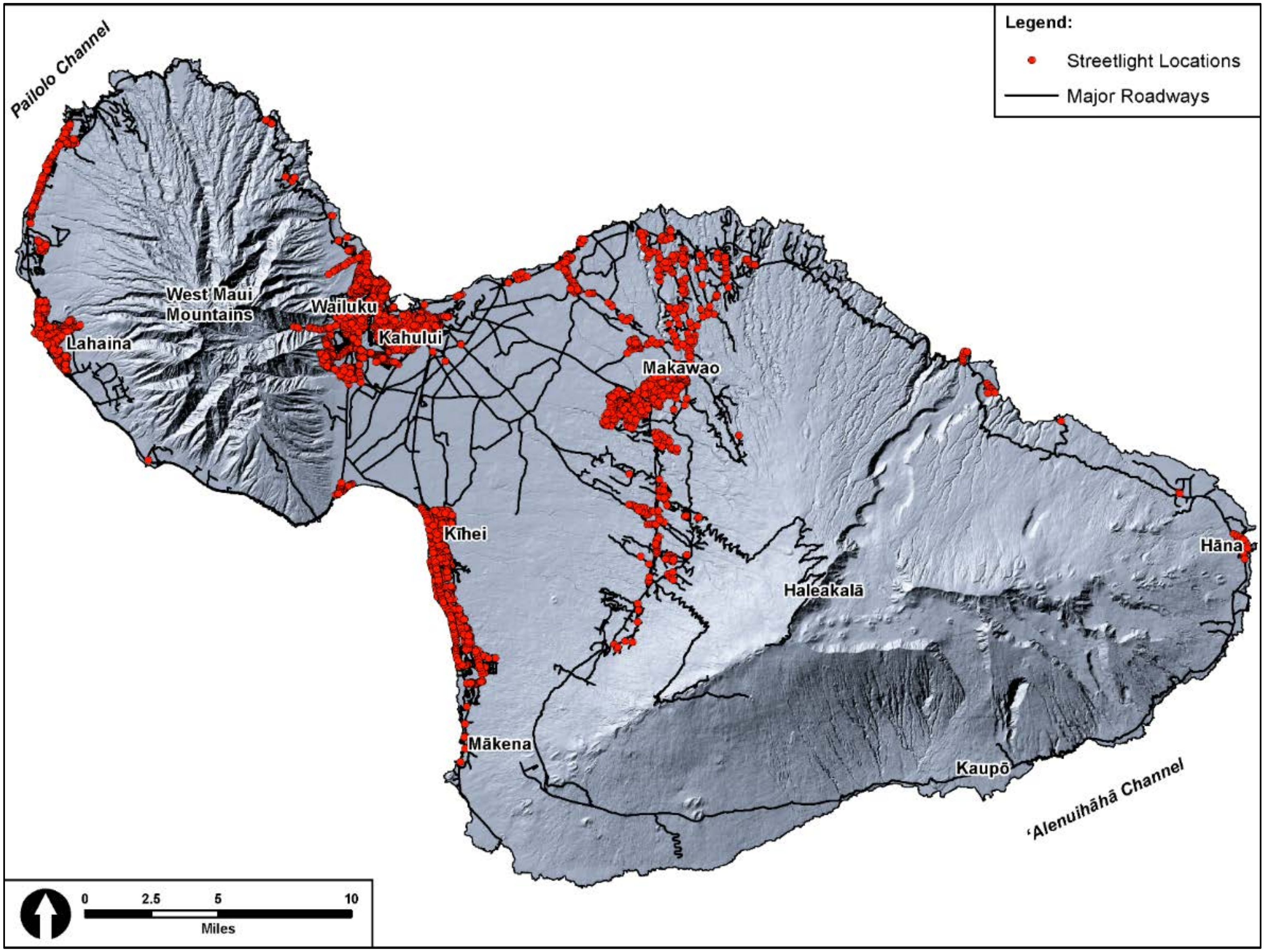
The County of Maui, Department of Public Works (DPW) is proposing to convert all County-owned High Pressure Sodium (HPS) streetlights to Light Emitting Diode (LED) streetlights.[1] The County of Maui consists of four islands (Maui, Lāna‘i, Moloka‘i, and Kaho‘olawe); County-owned streets are present on the islands of Maui, Lāna‘i, and Moloka‘i. The purpose of this Maui County Streetlight Conversion Project is to comply with Section 18.20.060 and Chapter 20.35, Maui County Code; Chapter 201, MC-15, *Street Lighting Standards* (MC-15; Appendix A).[2] The current street lighting standards were approved on January 12, 2018, to, among other things, increase roadway safety and visibility while simultaneously reducing energy consumption and County of Maui operating expenses.

The goal of Chapter 201, MC-15, *Street Lighting Standards* and the Maui County Streetlight Conversion Project, is to replace all county-owned HPS streetlights fixtures with LED streetlight fixtures in-kind. There is no intent to increase the existing level(s) of lighting or the existing number of streetlights on County-owned streets. Instead, the intent of the proposed action is to use more efficient LED fixtures that produce a better quality of light to provide a comparable level of illumination on County-owned streets as is currently provided by existing HPS fixtures. The specific LED fixtures which have been selected for the Maui County Streetlight Conversion Project have been assessed to achieve this goal (Section 2.1.1). The location of all County-owned streetlights on Maui is shown in Figure 1.1, their location on Moloka‘i is shown in Figure 1.2, and their location on Lāna‘i is shown in Figure 1.3.

[1] The County-owned streetlights addressed in this report are restricted to those lights that are within County of Maui rights-of-way expressly to provide lighting consistent with Chapter 201, MC-15, *Street Lighting Standards* and are overseen by the Department of Public Works (DPW). Other County-owned lights, some of which may appear similar to streetlights (e.g., at County parks, parking lots, and buildings), exist but are not part of the Proposed Action discussed in this report.

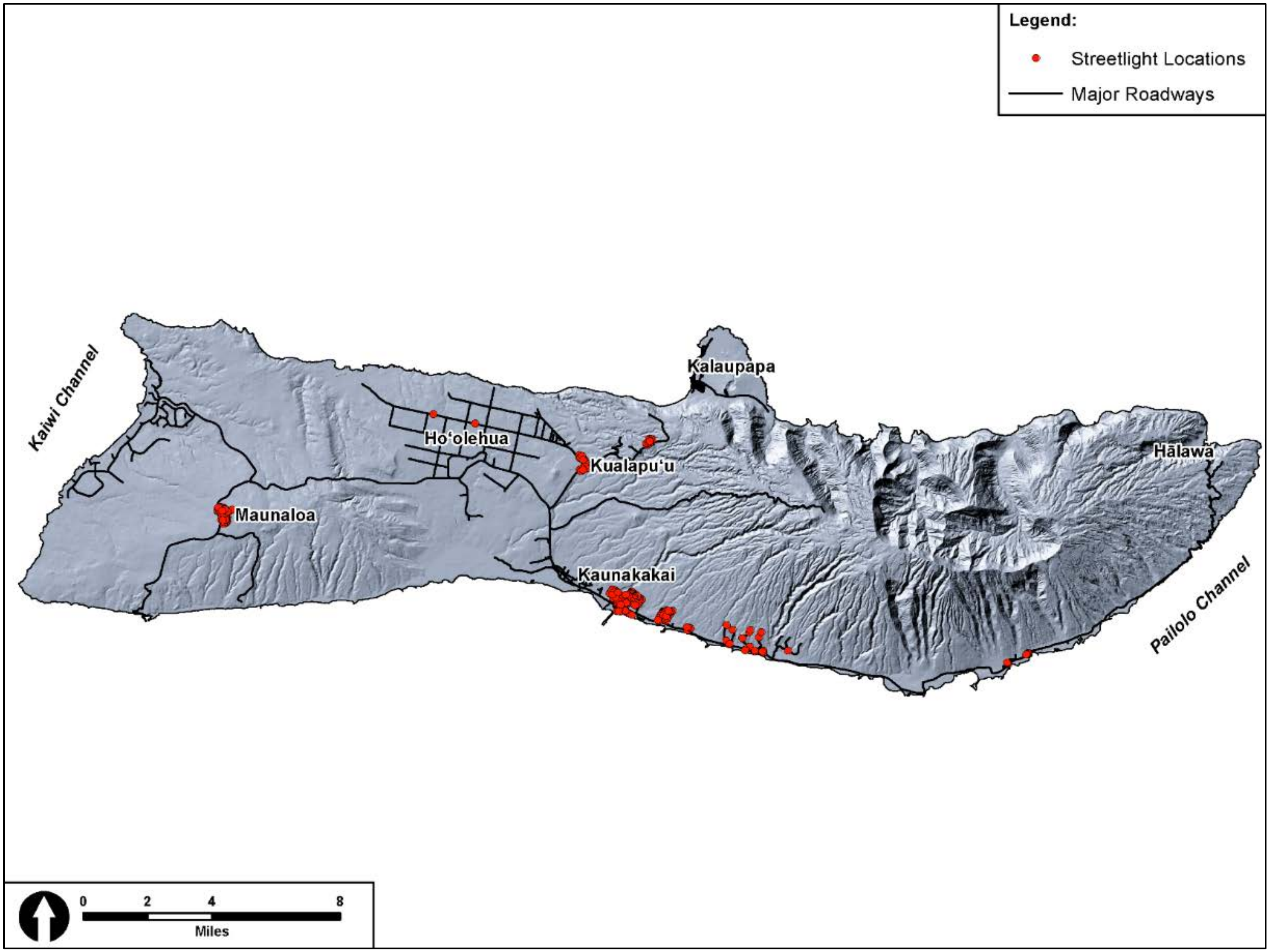
[2] Other entities own and operate streetlights within the County of Maui. For example, the State of Hawai‘i Department of Transportation, Highways Division, owns and operates the streetlights on state highways.

Figure 1.1 Locations of County-owned Streetlights on Island of Maui



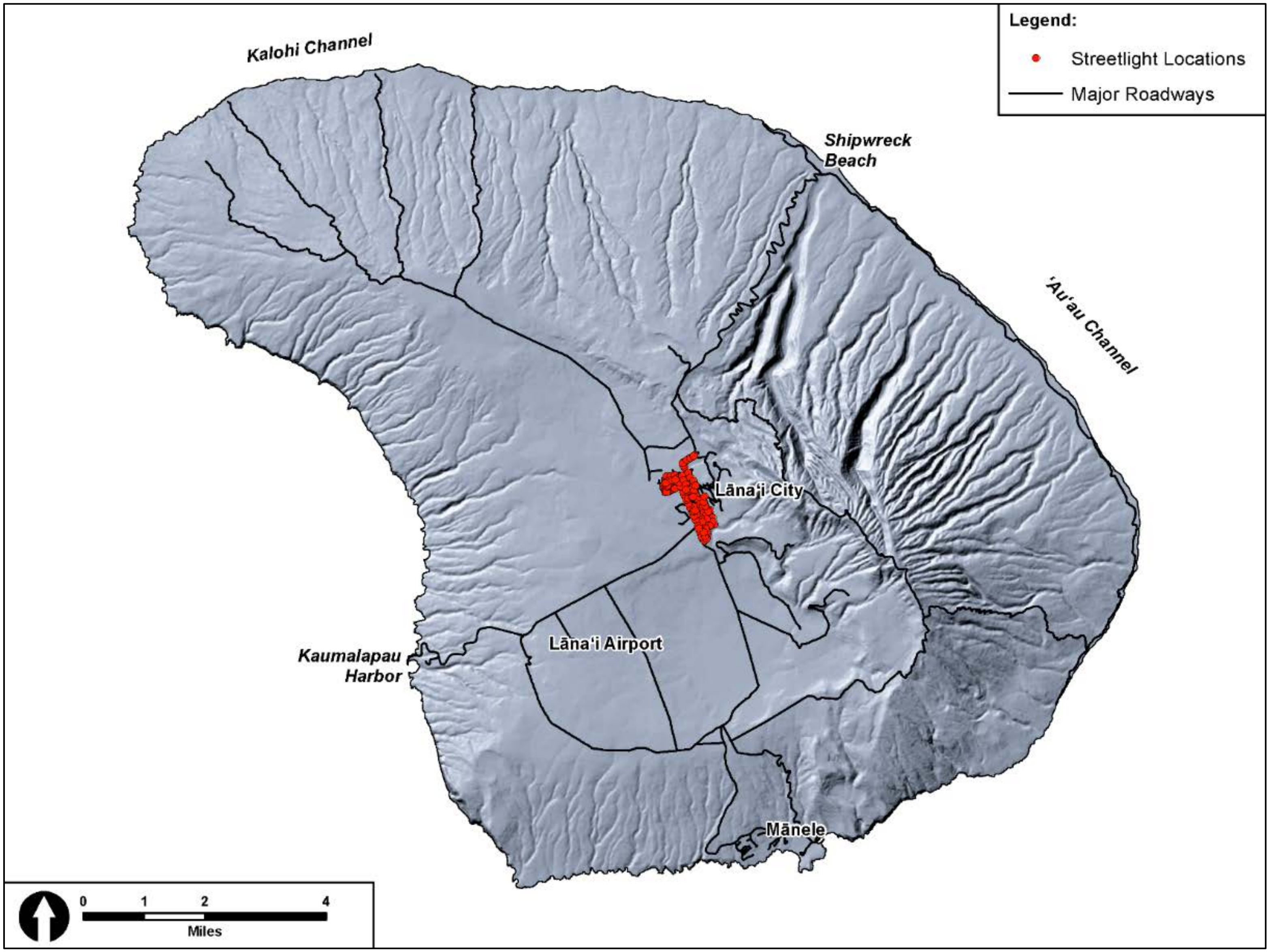
Source: Planning Solutions, Inc. (2021)

Figure 1.2 Locations of County-owned Streetlights on Island of Moloka'i



Source: Planning Solutions, Inc. (2021)

Figure 1.3 Locations of County-owned Streetlights on Island of Lānaʻi



Source: Planning Solutions, Inc. (2021)

1.2 NEED FOR THE PROPOSED ACTION

The proposed action is needed in order for the County of Maui to comply with the statutory requirements of Section 18.20.060 and Chapter 20.35, Maui County Code and the *Street Lighting Standards* (MC §15-201, Appendix A). Specifically, MC §15-201-6 *Lamp Standards* and §15-207-7 *Luminaire Standards* require that all technologies considered by DPW meet the following criteria:

> *MC §15-201-6 Lamp Standards*
>
> *(a) High pressure sodium or LED lamps or other fixtures approved by the director shall be the only allowed lamp on public and/or private right-of-ways; however, existing lamps other than high pressure sodium or LED lamps shall remain until they expire at which time they shall be replaced.*
>
> *(b) LED lamps shall meet the following requirements:*
>
> *i) [Correlated Color Temperature] CCT of less than 3000K.*
>
> *ii) [Scotopic/Photopic] S/P ratio of <1.2.*
>
> *iii) Blue light power content less than the corresponding blue light power content for HPS.*
>
> *iv) Adaptive controls to allow for dimming.*
>
> *(c) For roadways within the rural or agricultural areas, the maximum allowable wattage shall be 100 W HPS (or equivalent LED wattage) for internal road intersections and 150 W HPS (or equivalent LED wattage) for internal road intersections and 150 W HPS (or equivalent LED wattage) at intersections from a project with a major and/or minor collector road.*
>
> *(d) For roadways within the urban areas, the maximum allowable wattage shall be 150 W HPS (or equivalent LED wattage) for internal road intersections and 250 W HPS (or equivalent LED wattage) at intersections with a major or minor collector road.*
>
> *§15-201-7 Luminaire Standards*
>
> *Fully shielded luminaires shall be the only allowed fixture on public and/or private right-of-ways.*

1.3 ENVIRONMENTAL ASSESSMENT TRIGGER

Per Hawaiʻi Revised Statutes (HRS), Chapter 343, specifically §343-5: "Except as otherwise provided, an environmental assessment shall be required for actions that: (a) Propose the use of state or county lands or the use of state or county funds." The proposed action uses county lands (the county right-of-way [ROW]) and funds.

Per the DPW exemption list, the proposed action is eligible for an exemption from HRS Chapter 343. Nevertheless, DPW has voluntarily made the decision to prepare this Environmental Assessment (EA) to address concerns relating to the potential effects of the proposed action. This report is intended to fulfill that commitment, providing the detailed information and analysis needed to inform relevant agencies, organizations, and individuals regarding the potential implementation of the proposed Maui County Streetlight Conversion project. It is also intended to fulfill all the content and process requirements of HRS Chapter 343 and its implementing regulations contained in Hawaiʻi Administrative Rules, (HAR) §11-200.1.

1.4 OVERVIEW OF THE PROPOSED ACTION

This section provides a brief overview of the proposed action; details are provided in Chapter 2. The proposed action involves the replacement of approximately 4,900 County-owned streetlight fixtures located along County roadways on the Islands of Maui, Molokaʻi, and Lānaʻi. These fixtures are maintained by Hawaiian Electric Company, Inc. (henceforth, "Hawaiian Electric" or "the Company") on behalf of the County of Maui.[3] Work involved in the Maui County Streetlight Conversion Project includes the removal and disposal of existing streetlight fixtures and the installation of new streetlight fixtures. The existing fixtures have an HPS light source; the proposed light fixtures have an LED light source.

All project-related work would be completed in the County roadway ROW during normal business hours and will not necessitate full closure of any roadways or the diversion of traffic. The proposed action is anticipated to cost approximately $4 million and is expected to begin within six (6) months of the completion of the HRS Chapter 343 environmental review process. The total time required for implementation of the Maui County Streetlight Conversion Project is twelve (12) months.

1.5 EARLY CONSULTATION

A key component of the early planning effort for the proposed action was developing and implementing an early consultation program to inform public agencies and other interested parties to obtain their input regarding the project's purpose, scope, potential impacts, and recommended mitigation measures. Pursuant to HAR §11-200.18, DPW sought, at the earliest practicable time, the advice and input of the Maui County Planning Department, the agency responsible for implementing the *County of Maui 2030 General Plan: Countywide Policy Plan* (2010), other agencies having jurisdiction over resources with the potential to be affected by the proposed action, elected officials, and selected conservation organizations. Consequently, on August 20, 2019, DPW sent an early consultation letter to the agencies, organizations, and individuals identified in Table 1.1. The complete text of the scoping letter and all responses are provided in Appendix D.

[3] As of January 2020, Maui Electric Company, Inc., or MECO, along with Hawaiʻi Electric Light Company, Inc., or HELCO, have been united under the common name of Hawaiian Electric Company, Inc,. owned and operated by Hawaiian Electric Industries, Inc.

Table 1.1 Early Consultation

Recipient	***Addressee***	***Response***
U.S. Fish and Wildlife Service (USFWS)	Ms. Michelle Bogardus	Yes
U.S. National Parks Service (USNPS)	Mr. Stan Austin, Regional Director	No
U.S. Department of Transportation, Federal Highways Division (DOT-Highways)	Mr. Ralph Rizzo, Division Administrator	No
U.S. Army Corps of Engineers (COE)	Mr. Tunis McElwain, Chief	No
U.S. Federal Transit Administration	n/a	No
State Department of Education (HDOE)	Ms. Heidi Meeker	Yes
State Department of Health (HDOH)	Bruce Anderson, Ph. D.	No
HDOH, Environmental Planning	Ms. Laura McIntyre, AICP	No
HDOH, Maui Sanitation Branch	Ms. Patti Kitkowski	Yes
Board of Land and Natural Resources	Ms. Suzanne Case, Chairperson	No
Department of Land and Natural Resources (DLNR), State Historic Preservation Division (SHPD)	Alan Downer, Ph.D., Administrator	No
SHPD, History & Culture Branch	Hinano Rodriguez, Esq. Branch Chief	No
State Department of Transportation (HDOT)	Mr. Jade Butay, Director	Yes
State Department of Defense (HDOD)	Ms Doloris Cook, Administrator	Yes
Department of Hawaiian Home Lands (DHHL)	Mr. William Aila Jr., Chair	No
State Office of Planning (OP)	Ms. Mary Alice Evans, Director	Yes
State Department of Accounting and General Services (DAGS)	Mr. Curt Otaguro, Comptroller	No
Office of Environmental Quality Control (OEQC)	Mr. Scott Glen, Director	No
County of Maui, Environmental Management	Mr. Eric Nakagawa, Director	Yes
County of Maui, Fire and Public Safety	David Thyne, Fire Chief	Yes
County of Maui, Housing and Human Concerns	Ms. Lori Tsuhako, Director	Yes
County of Maui, Parks and Recreation	Ms. Karla Peters, Director	Yes
County of Maui, Planning	Ms. Michele McLean	Yes
County of Maui, Police	Tivoli Faʻaumu, Police Chief	Yes
County of Maui, Water	Mr. Jeffrey Pearson, Director	No
County of Maui, Emergency Management	Mr. Herman Andaya, Administrator	No
County of Maui, Office of the Mayor	Mr. Michael Victorino, Mayor	No
County of Maui, Office of Economic Development (OED)	Ms. Kay Fukumoto, OED Coordinator	No
Maui County Council	Kelly King, Chair	No
Maui County Council	Keani Rawlins-Fernandez, Vice Chair	No
Maui County Council	Tasha Kama, Presiding Officer Pro Tempore	No
Maui County Council	Riki Hokama, Council Member	No
Maui County Council	Alice Lee, Council Member	No
Maui County Council	Michael Molina, Council Member	No
Maui County Council	Tamara Paltin, Council Member	No
Maui County Council	Shane Sinenci, Council Member	No
Maui County Council	Yuki Lei Sugimura, Council Member	No
Office of Hawaiian Affairs (OHA)	Sylvia Hussey, Ed. D., Interim CEO	No
Hawaiian Telecom	n/a	No
Maui Electric Co., Inc., Engineering	Mr. Michael Grider, Director	No

Recipient	***Addressee***	***Response***
Blue Planet Hawaiʻi	Mr. Jeff Mikulina	No
Surfrider Foundation, Maui Chapter	Mr. Mike Ottman, Chairperson	No
Hawaiʻi Energy	Mr. Brian Kealoha, Executive Director	No
Maui Nui Seabird Recovery Project	Mr. Jay Penniman	Yes
Maui Tomorrow	Mr. Albert Perez, Executive Director	No
Sierra Club	Ms. Adriane Raff Corwin, Maui Group Coordinator	No
University of Hawaiʻi (UH) at Mānoa, Institute for Astronomy	Robert McLaren	Yes

Source: DPW (2019)

1.6 PERMITS AND APPROVALS

The proposed action does not require any further land use permitting or review prior to implementation. When Hawaiian Electric conducts the lighting conversion work on behalf of the County of Maui it will operate under an existing agreement with the County or obtain a project-specific Work to Perform Permit (MCC Chapter 12) from the County of Maui, Department of Public Works.

1.7 ORGANIZATION OF THE ENVIRONMENTAL ASSESSMENT

The remainder of this EA is organized as follows:

- Chapter 2 describes the proposed action in detail.
- Chapter 3 describes the existing environment and analyzes the potential impacts on natural, cultural, and socioeconomic resources. It also outlines strategies for minimizing and mitigating unavoidable adverse effects.
- Chapter 4 discusses the consistency of the proposed action with relevant plans, policies, and controls at local, regional, state, and federal levels.
- Chapter 5 provides the justification for the anticipated determination of a Finding of No Significant Impact (FONSI) by considering each individual significance criterion with respect to the proposed action.
- Chapter 6 summarize the parties consulted during the preparation of this EA.

Chapter 2: DESCRIPTION OF PROPOSED ACTION

2.1 DESCRIPTION OF THE PROPOSED ACTION

The proposed Maui County Streetlight Conversion Project involves the replacement of approximately 4,900 County-owned streetlight fixtures located along County roadways on the islands of Maui, Molokaʻi, and Lānaʻi. These fixtures are maintained be Hawaiian Electric (formerly Maui Electric Co., Inc. in Maui County) on behalf of the County of Maui. Work includes the removal and disposal of the existing HPS light source(s), and the installation of proposed new light fixtures with an LED light source. The LED lights will replace the existing HPS streetlights in the same locations and with the same purpose; no new streetlights will be installed as part of the proposed action.

The Maui County Streetlight Conversion Project is planned for implementation in two distinct phases. The first phase will see retrofitting of lights in the central, urbanized portions of Maui Island, and the second phase will complete the remainder of Maui, Molokaʻi, and Lānaʻi. Table 2.1 summarizes the proposed phasing.

Table 2.1 Phasing of Maui County Streetlight Conversion Project

Phase	***Location***	***No. of Fixtures***
Phase 1 (central, urbanized areas)	Kahakuloa Waiehu Wailuku Kahului	1,687
	Kailua Hana	49
	Olowalu Nāpili	153
	Phase 1 Subtotal	***1,889***
Phase 2 (all other areas)	Lahaina Nāpili	369 and 62 decorative
	Māʻalaea Mākena	957
	ʻUlupalakua Kula Pukalani Makawao Haʻikū Kūʻau Spreckelsville	1,098
	Molokaʻi	365
	Lānaʻi	142
	Phase 2 Subtotal	***2,993***
Grand Total		***4,882***

Note: all fixtures are cobra head models unless otherwise specified.
Source: County of Maui (2021)

The Maui County Streetlight Conversion Project will include the installation of a wireless adaptive control system which will allow the County of Maui and Hawaiian Electric to remotely manage the operation of the streetlight infrastructure in real time and at the individual fixture level. This technology allows for dimming and brightening of individual streetlights, or groups of lights, and also includes remote system monitoring, providing notification when a fixture has failed or is in need of replacement. The proposed action will also include mapping, using Geographic Positioning Systems (GPS) technology, of the precise location of all County-owned streetlights in the County of Maui.

The following subsections provide additional detail regarding the process which the DPW has followed to date and will follow in the future as it implements the Maui County Streetlight Conversion Project.

2.1.1 Demonstration Project and LED Streetlight Selection Methodology

In the mid-2010s, when the County of Maui began to consider transitioning from its HPS streetlights to LED streetlights, it implemented a demonstration project so that the County and stakeholders could assess a range of options in-situ. The sections below describe the demonstration project.

2.1.1.1 *Project Design*

Hawaiian Electric (then operating as Maui Electric Co, Inc.) commissioned Johnson Controls International (JCI) to prepare an independent product study intended to evaluate the performance and characteristics of several LED streetlights. The goal of the study, conducted between June and July, 2016, was to provide an unbiased evaluation of select products along a stretch of the Maui Lani Parkway, located in Kahului, Maui, where 150W HPS streetlights were present. The products selected included products from multiple manufacturers and a range of color options. The intent of the demonstration project was two-fold: (*i*) perform a technical product-to-product performance evaluation with regard to operating behaviors in comparison to similar products and the manufacturers' published data; and (*ii*) obtain stakeholder input on street lighting preferences.

To accomplish the evaluation, six product groups from three manufacturers were installed on existing poles along Maui Lani Parkway. JCI, at the request of Hawaiian Electric, isolated the metered fixtures, and collected data for comparative evaluation in regard to color parameters and light output above and below the fixtures. Measurements were taken over three consecutive nights under clear conditions to provide the requested measurements under three light level conditions: (*i*) 100 percent lighting or no dimming, (*ii*) 75 percent lighting or 25 dimmed; and (*iii*) 50 percent lighting or 50 percent dimmed. An effort was made to take measurements free from transient and other outside contributing light sources, as well as tree and foliage obstructions. JCI's complete lighting study report is provided in Appendix B; the discussion in this Section is limited to characterizing factors which shaped the proposed action.

The following candidate LED fixtures were installed and evaluated: (*i*) General Electric (GE) 2700K; (*ii*) GE 3000K; (*iii*) Chips & Wafers (C&W) 2400K; (*iv*) C&W 3000K; (*v*) C&W 3200K; and (*vi*) Cree 3000K. All of the fixtures tested were full-cutoff (fully shielded) lights. Figure 2.1 provides the location(s) of the fixture test. The GE 2700K, C&W 2400K, C&W 3200K, and Cree 3000K products were installed in groups of four (e.g., mounted on four utility poles to create an area where they were the dominant source of artificial light on the roadway). The C&W 3000K product was installed in a group of three poles, while only one GE 3000K was installed. A control group of existing 150W, 2100K HPS fixtures were identified to serve as the baseline for comparison against the candidate LED fixtures. Table 2.2 illustrates each of the candidate fixtures evaluated during the demonstration project.

2.1.1.2 ***Measurement Methods, Results, and Discussion***

Table 2.3 summarizes the results for the candidate and control fixtures at 100 percent power. The 100 percent power setting was selected for an in-kind comparison of candidate fixtures with the existing HPS fixtures, which are not dimmable. Additional measurements, including those made when the fixtures were dimmed at 50- and 75-percent power, are provided in the complete lighting study report by JCI contained in Appendix B.

Relevant demonstration project observations included the following:

- All of the candidate LED fixtures used substantially less energy than the 150W HPS and produced light levels that exceeded the minimum luminance guidelines for roadways established by the American Association of State Highway and Transportation Officials (AASHTO), even at 50 percent dimming levels.
- All of the candidate LED fixtures produced some blue light (as defined in the County of Maui Street Lighting Standards – the sum of the energy produced between 405 and 530 nanometers). The light produced by most of the LEDs had a higher blue light content percent than HPS; at 100 percent power all of the LEDs had a lower blue light power content than the 150W HPS (Table 2.3).
- The HPS fixture had the lowest Correlated Color Temperature (CCT), Scotopic/Photopic (S/P) ratio,[4] and Color Rendering Index (CRI)[5] values while producing the highest lux output (Table 2.3).
- The LED fixtures with the lowest percentage of blue light (the C&W 2400K and the C&W 3200K) had the lowest CRI values (64 and 53, respectively), which were below what is typically expected from LED light sources (70 to 90). They also had the lowest S/P ratios of the LED fixtures (Table 2.3).
- All of the fixtures were fully shielded and produced little measurable light 1 meter (3.28 feet) above the fixture. The HPS and C&W 3000K fixtures produced 2 and 2.4 lux, respectively, above the fixture; all other fixtures produced between 1.6 and 1.8 lux above them.
- All candidate LEDs cast light more directionally downward than the HPS light. GE’s optics performed at a high level, with better control over the lit area.

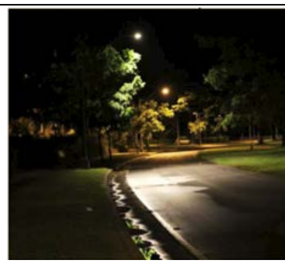
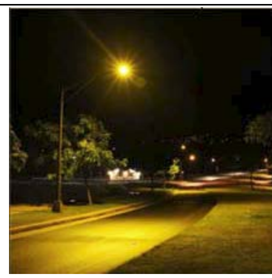
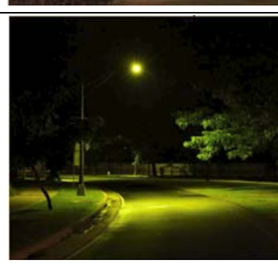
A final crucial consideration is that all of the candidate LED fixtures can be dimmed remotely, which is referred to as “adaptive lighting.”

---

[4] The S/P ratio is a multiplier that measures how much emitted light is useful to the human eye. A lamp with a higher S/P ratio, provides more visually effective lumens for human eyes to process.

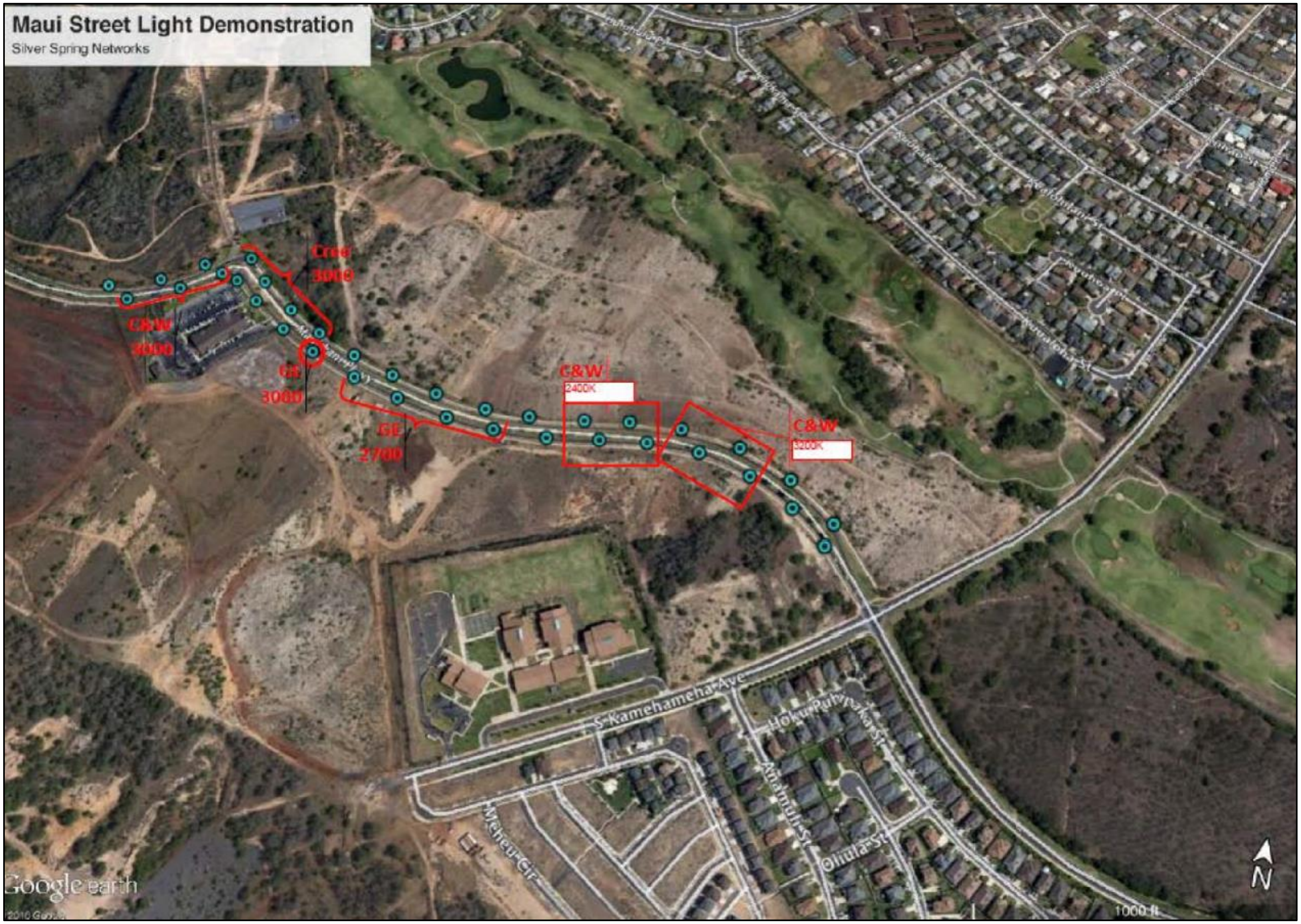
[5] IES defines the CRI of a light source as “A measure of the degree of color shift that objects undergo when illuminated by the light source, as compared with the color of those same objects when illuminated by a reference source of comparable color temperature.” It is generally a quantitative measure of the ability of a light source to allow the human eye to accurately identify the colors of objects as it would appear under natural light. The higher the value, the more colors are accurately rendered.

Table 2.2 Summary of LED Fixtures Evaluated during Demonstration Project

Model	***Demonstration Deployment***	***Model***
GE 2700K		ERL1 Series
GE 3000K		ERL1 Series
C&W 2400K		HIB-SLA-74-1-7-UN-GR-OR-2V-PC-SS-BT-EL
C&W 3000K		HIB-SLA-74-1-7-UN-GR-WW-2V-PC-SS-BT-EL
C&W 3200K		HIB-SLA-74-1-7-UN-GR-YL-2V-PC-SS-BT-EL
Cree 3000K		RSW Series

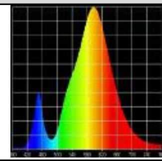
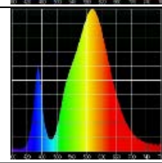
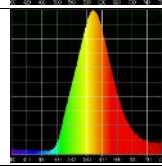
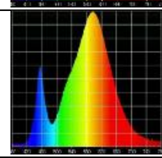
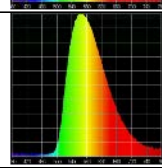
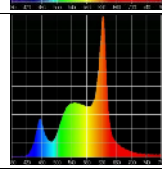
Source: Maui Electric Street Lighting Study (Appendix B).

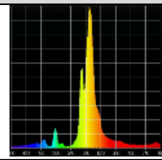
Figure 2.1 Map of Test Location and Fixtures



Source: Maui Electric Street Lighting Study (Appendix B)

Table 2.3 Summary and Analysis of Demonstration Project Measurements

Manufact-urer, Stated CCT, and Type	***Manufact-urer Power Rating / Measured Power Used (W)***	***Estimated Power Savings Relative to 150W HPS (%)***	***Measured Color Spectrum Distribution***	***Calculated[1] Blue Light Content (%)***	***Calculated[2] Blue Light Power HPS Comparison (%)***	***Measured Luminance (Lux)***	***Measured CCT (K)***	***Measured S/P Ratio***	***Measured CRI***
GE 2700K LED (Selected)	67 / 65	68		17.6	79	56.3	2789	1.09	71.23
GE 3000K LED	32 / 31	79 *		22.0	47 *	27.8	**3084**	**1.22**	72.45
C&W 2400K LED	55 / 59	71		5.8	21	30.6	2477	0.81	64.45
C&W 3000K LED	55 / 60	70		20.8	76	30.6	**3104**	**1.32**	76.71
C&W **3200K** LED	55 / 60	70		8.3	30	27.1	**3326**	1.00	52.64
Cree 3000K LED	50 / 49	76		21.0	70	19.1	**3055**	**1.44**	95.01

Manufact-urer, Stated CCT, and Type	*Manufact-urer Power Rating / Measured Power Used (W)*	*Estimated Power Savings Relative to 150W HPS (%)*	*Measured Color Spectrum Distribution*	*Calculated[1] Blue Light Content (%)*	*Calculated[2] Blue Light Power HPS Comparison (%)*	*Measured Luminance (Lux)*	*Measured CCT (K)*	*Measured S/P Ratio*	*Measured CRI*
GE 2100K HPS (existing)	150 / 200 (extra power due to ballast)	n/a		10	100	64.9	2132	0.61	8.28

Notes: An UPRtek MK350S Advanced Spectrometer was deployed to measure: (*i*) color spectrum distribution, (*ii*) luminance measured in lux; (*iii*) correlated color temperature (CCT), (*iv*) scotopic-to-photopic (S/P) ratio, and (*v*) color rendering index (CRI). Measurements were performed by taking instantaneous measurements from chest level with the site class pointing directly at the light source.

The last row, GE 2100K HPS, is the existing HPS streetlight currently in use in Maui County. It is provided here as a baseline for comparison.

Red text indicates a value that does not fully comply with Chapter 201, MC-15, *Street Lighting Standards*.

Estimated power savings was calculated using the measured power used by the LED and HPS fixtures.

1. Blue light content is the sum of energy (from UPRtek MK350S Advanced Spectrometer measurements) between 405-530nm divided by the sum of energy from 380-730nm.
2. The County of Maui Street Lighting Standards (§15-201-5) defines "blue light power content" as "the sum of energy between 405-530nm divided by the sum of energy from 380-730nm times the total power output in watts. The blue light power content for HPS is 10w for 100w HPS bulb, 15w for a 150w HPS bulb, and 25w for a 250w HPS bulb." In this table, the blue light power content is the "measured blue light content" times the "manufacturer power rating."

* Indicates this model is comparable to a 100W HPS, not a 150W HPS. Therefore, the estimated power savings and calculated blue light power comparison provided, which is relative to 150W HPS, is likely inappropriate.

Source: DPW (2016) and PSI.

2.1.1.3 ***Stakeholder Input***

In addition to the observations discussed in Section 2.1.1.2, as part of the demonstration project, selected members of stakeholder agencies and organizations were asked to rate their satisfaction with the demonstration lights. The names and affiliation of each participant is summarized in Table 2.4. Stakeholders, representing government agencies, businesses, and wildlife conservation interests were asked to attend the demonstration on the evening of August 11, 2016, and rate their satisfaction with the different demonstration light fixtures. Each of the attendees was provided with a questionnaire to complete; a blank sample of the questionnaire is provided in Figure 2.2. In total, 17 stakeholders participated in the process; 15 completed questionnaires were received the night of the stakeholder survey, the remaining 2 were submitted via email.

Table 2.4 Demonstration Project Stakeholder Participants

Name	***Affiliation***
Tom Behnke	Akolea at Kehalani
Jack Carter	Johnson Controls, Inc.
Cynthia Catugal	County of Maui, Public Works Commission
Michael Chang	Johnson Controls, Inc.
Jennifer Ferreira	Wesco Distribution, Inc.
Che Frausto	Save Our Seabirds
David Goode	County of Maui, Department of Public Works
Randall Harada	Wesco Distribution, Inc.
Jamie Ho	HDOT – Highways Division
Sgt. Kenneth Kihata	Maui Police Department
Kal Kobayashi	County of Maui, Energy Coordinator
Barbara Kojima	Maui Lani Community Association
Van Kumano	Illuminetix, Inc.
Mike Maberry	UH Institute for Astronomy
Lou Mamuad	Johnson Controls, Inc.
Patrice Matsumoto	County of Maui, Public Works Commission
Eric Miyasato	Pacific Electrical Sales Agency
Officer Justin Muliola	Maui Police Department
Carina Ohara	Hawaiian Electric Co., Inc.
Becca Pederson	Save Our Seabirds
Jay Penniman	Save Our Seabirds
Uvette Sakamoto	County of Maui, Public Works Commission
Emily Severson	Save Our Seabirds
Charlene Shibuya	County of Maui, Public Works Commission
Leslie Shirai	Wesco Distribution, Inc.
Dan Wagoner	Silver Spring Networks
Richard Wainscoat	UH Institute for Astronomy

Source: County of Maui (2016)

Figure 2.2 Demonstration Project Questionnaire

Maui Electric

Thanks for joining us tonight!
We'd like your help with a short survey and
Appreciate your participation.

L.E.D. STREET LIGHT DEMONSTRATION PROJECT

1. OF THE LIGHT FIXTURES UTILIZED IN THE DEMONSTRATION PROJECT, WHICH STREET LIGHT DID YOU PREFER?

Please select THREE types of lights you preferred the most.			
	LIGHT A		LIGHT E
	LIGHT B		LIGHT F
	LIGHT C		LIGHT H
	LIGHT D		

2. AT EYE LEVEL, HOW DO FEEL ABOUT THE AMOUNT OF GLARE FROM EACH LIGHT?

	No noticeable difference	Amount of glare is acceptable	There was too much glare
LIGHT A			
LIGHT B			
LIGHT C			
LIGHT D			
LIGHT E			
LIGHT F			
LIGHT H			

3. OVERALL, WERE YOU:

	Yes	No	No difference
Able to see further?			
Able to see fewer dark spots between street lights?			
Better able to see a pedestrian?			
Able to distinguish colors better?			

4. BY DIMMING STREET LIGHTS, DO YOU BELIEVE SAFETY AND SECURITY WOULD BE COMPROMISED? PLEASE EXPLAIN.

Yes	
No	
Not sure	

LED STREET LIGHT DEMONSTRATION PROJECT STAKEHOLDER MEETING 8/11/2016

5. DO YOU THINK AREAS WITH L.E.D. STREET LIGHTS INSTALLED WOULD BE:

	Yes	No
Safer		
More attractive		
Open to more traffic/activity		
Too bright		

6. WHAT REASONS DO YOU BELIEVE WOULD JUSTIFY CONVERTING STREET LIGHTS TO L.E.D.? PLEASE CHECK ALL THAT APPLY.

	Financial savings
	Increased public safety with better lighting
	More driver visibility
	Better for the environment and native wildlife
	None – The existing High Pressure Sodium lights are better
	Other – please explain:

7. DO YOU HAVE ANY ADDITIONAL COMMENTS?

____

____

____

8. ARE THERE QUESTIONS WE CAN HELP YOU WITH? IF SO, PLEASE INCLUDE YOUR NAME, TELEPHONE NUMBER AND EMAIL ADDRESS BELOW.

Question:

____

____

____

Name: ______________________________

Best phone number to reach you: ______________________________

Email address: ______________________________

Mahalo for taking the survey - your feedback is appreciated!

LED STREET LIGHT DEMONSTRATION PROJECT STAKEHOLDER MEETING 8/11/2016

Source: County of Maui (2016)

Table 2.5 provides the resulting rankings based on stakeholder input on the JCI demonstration project.

Table 2.5 Overall Stakeholder Satisfaction Ranking

Manufacturer and Model	*Light Source*	*Overall Community Satisfaction Ranking*
GE 2700K LED	LED	1st
GE 3000K LED	LED	2nd
Cree 3000K LED	LED	3rd
C&W 3000K LED	LED	4th
C&W 3200K LED [1]	LED	5th
C&W 2400K LED [1]	LED	5th
GE 2100K HPS[2]	HPS	7th

Notes: 1. These two fixtures were tied for 5th per stakeholder ranking according to overall satisfaction with fixture performance.
2. The GE 2100K HPS model is the fixture being replaced.
Source: JCI (2016)

In considering themes that emerged from the stakeholder's ratings, it is notable that the top four rated LED fixtures all had a blue light content in excess of 15 percent, a S/P ratio greater than 1.05, and a CRI above 70. The two lowest rated LED fixtures had blue light contents of less than 10 percent, an S/P ratio less than 1.05, and a CRI below 65. The existing HPS fixtures, which had the lowest CCT, S/P ratio, and CRI of any fixture, was ranked last. This demonstrates that while higher CCT LEDs are more efficient, subjectively, participants generally prefer lower (warmer) CCT LEDs, provided their output include sufficient blue light to make them appear white.

2.1.2 PRODUCT SELECTION

2.1.2.1 *Cobra Head Streetlights*

The vast majority (99 percent) of County-owned streetlights are "cobra head" style streetlights. All the streetlights considered during the demonstration project (Section 2.1.1) were cobra head style streetlights. This section discusses the LED product selected to replace the cobra head style HPS streetlight throughout the County of Maui.

In considering which light fixture to use for the Maui Streetlight Conversion Project, DPW considered a broad range of criteria including: (*i*) compliance with MC §15-201 (Appendix A); (*ii*) applicable health and human safety guidance, including AASHTO recommendations; (*iii*) the performance characteristics observed via the demonstration project (Section 2.1.1.2); and (*iv*) stakeholder satisfaction rankings obtained during the demonstration project (Section 2.1.1.3). The GE 2700K LED fixture was able to successfully meet all of these criteria, including being the highest rated by stakeholder participants in the demonstration project. Therefore, GE's Evolve® Roadway Lighting Single LED Module (ERL1) cobra head model series with a 2700K rating was selected as the fixture of choice for the Maui Streetlight Conversion Project.

The models available in GE's ERL1 series have been altered since the demonstration project was conducted in 2016. Therefore, the wattages and certain other values associated with the models available in the ERL1 series today and those used in the demonstration project are different.[6] The ERL1 2700K model series continues to provide the same CCT, CRI, and S/P ratio as the model tested during the demonstration project; the differences involve the lumens the different models

[6] The GE 2700K LED used in the 2016 Demonstration Project (Section 2.1.1) was rated by GE as 67 watts, which is consist with model ERL1-0-09 available in 2022.

produce and the watts required to produce their light output. The 2022 model details are provided in Appendix C.

Various wattages of HPS streetlight fixtures are present in the County of Maui. Roughly 88 percent of the approximately 4,900 HPS streetlights are 150W with the remainder being nearly evenly split between 100W and 250W. The County proposes to use the GE ERL1 2700K model series to replace the HPS fixtures as summarized in Table 2.6. The LED model utilized in the conversion project would be dependent on the roadway type, not the wattage of the HPS it replaces. This approach will better align the streetlights with AASHTO lighting guidance. The ERL1-0-06 model will be utilized to replace roughly 90 percent of the HPS fixtures, regardless of the HPS wattage, because the majority of the County-owned streetlights are on local residential roads and minor collectors. The remainder of the streetlights, which are on major collector roads, will be converted using ERL1-0-09 model fixtures.

Table 2.6: Summary of GE ERL1 Cobra Head LED Models Selected

Roadway Type	***Existing HPS Wattage (W)***	***HPS Estimated Initial Lumen Rating***	***GE 2700K LED Model and Normal Operation***	***LED Manufacturer's Initial Lumen Rating when Operated at 100%***
Local residential roads and minor collector roads	100 and 150	9,500 and 16,000, respectively	ERL1-0-06 operated at 100% lighting or 0% dimmed	5,700
Major collector roads	150 and 250	16,000 and 28,000, respectively	ERL1-0-09 operated at 100% lighting or 0% dimmed	8,000

Note: This table presents the "normal" operation of the selected streetlights. Section 2.1.5 outlines conditions and times during which the streetlights will be operated differently or alternative streetlight models may be selected.
Source: GE and County of Maui.

As summarized in Table 2.6, the lumen rating of the selected LED models is substantially lower than the lumen ratings of the HPS fixtures they will replace. It is possible to use an LED that produces fewer lumens and still meets AASHTO guidelines because the LED lights produce a better quality of light, with a higher S/P ratio and CRI than an HPS light (Table 2.3). During the demonstration project, the County found that the ERL1 2700K model tested met AASHTO lighting guidelines even when dimmed 50 percent.

The ERL1 models available from GE may continue to evolve over the coming years as new technology is integrated. The County of Maui may also choose to utilize streetlights from a different manufacturer in the future. Should this occur, the County of Maui will continue to select LED models (*i*) that are fully shielded; (*ii*) that have a CCT of 2700K, or lower; (*iii*) whose lumen rating and other qualities are sufficient to meet AASHTO guidelines; and (*iv*) that comply with the County of Maui administrative rules governing at the time.

Table 2.7 summarizes the selected GE ERL1 LED vis-a-vie the County of Maui code. The existing HPS lights are included in the table for reference and comparison purposes.

Table 2.7 Comparison of Proposed GE ERL1 Cobra Head LED Fixtures to the County of Maui Lamp and Luminaire Standards

Attribute	***Street Lighting Standards (MC §15-201-6 and -7)***	***Existing High-Pressure Sodium (HPS)***	***Proposed Light-Emitting Diode (LED)***
Correlated color temperature (CCT) in degrees Kelvin (K)	<3000	2100	2700
Scotopic to Photopic (S/P) Output Ratio	<1.2	0.6	1.09
Blue Light Power Content	Less than the corresponding power content for HPS	100W bulb = 10W	ERL1-0-06 2700K (46W) = 8.1W
		150W bulb = 15W	ERL1-0-06 2700K (46W) = 8.1W Or, rarely, ERL1-0-09 (68W) = 12W
		250W bulb = 25W	ERL1-0-09 (68W) = 12W
Adaptive controls to allow dimming	Required	Not available	Included
Maximum allowable wattage in rural and agricultural areas	100W HPS (or equivalent LED wattage)	100W or 150W	46W
Maximum allowable wattage in urban areas and at major and minor collector road intersections in rural and agricultural areas	150W HPS (or equivalent LED wattage)	150W or 250W	46W Or, rarely (on major collectors only), 68W
Maximum allowable wattage at major and minor collector road intersections in urban areas	250W HPS (or equivalent LED wattage)	250W	68W
Shielding	Fully shielded	Fully shielded	Fully shielded (can be fitted with additional shields)

Note: MC §15-201-5 indicates that "Blue light power content" means the International Dark Sky Association's (IDA) definition of blue light content or the sum of energy between 405-530nm divided by the sum of energy from 380-730nm times the total power output in watts. The blue light power content for HPS is 10w for 100w HPS bulb, 15w for a 150w HPS bulb, and 25w for a 250w HPS bulb.
Source: Compiled by PSI from MC §15-201-6 and -7; GE Current

2.1.2.2 *Decorative Streetlights*

Decorative streetlights owned by the County are present within the Lahaina Historic District. There are a total of 62 decorative streetlights in this area. The County's considerations of which light fixture to use for the Maui Streetlight Conversion Project in this application are similar to those for cobra head streetlights with the additional elements of (*i*) retaining an appropriately traditional, decorative style of streetlight in the historic district; (*ii*) providing superior illumination commensurate with the dense multi-modal mix of use and police presence that occurs throughout the night hours in this district; and (*iii*) recognizing that artificial light is ubiquitous in the historic district and that during most hours the County-owned streetlights likely make up a smaller portion of total artificial light than in other areas. For the purposes of efficient procurement and maintenance, the County would also like to use a product from the same supplier and manufacturer that provides the selected LED cobra head streetlight.

The LED streetlight that best addresses these considerations has been determined to be GE's Evolve® Post Top Salem® Traditional (EPST) model series. The existing HPS, which are 150W fixtures, will be removed and replaced with the EPST LED model on a one-for-one basis. Specifically, the EPST model that will be used is the one rated by GE to have a voltage of 120-277v, an output of roughly 7,500 lumen, generate an asymmetric (Type III) distribution of light, and have a CCT of 3000K. This specific model is rated by GE to have a typical system wattage of 74W. The CCT value was selected because it is the lowest CCT value available in this model series; should a lower CCT model become available in the future that complies with MC §15-201, the County will transition to that color. The asymmetric (Type III) distribution was selected because it directs the bulk of the light toward the sidewalk and roadway instead of the storefronts or ocean behind them.

Table 2.8 summarizes the selected GE EPST LED vis-à-vis the County of Maui code. The existing HPS lights are included in the table for reference and comparison purposes.

Table 2.8 Comparison of Proposed GE EPST LED Fixture to the County of Maui Lamp and Luminaire Standards

Attribute	***Street Lighting Standards (MC §15-201-6 and -7)***	***Existing High-Pressure Sodium (HPS)***	***Proposed Light-Emitting Diode (LED)***
Correlated color temperature (CCT) in degrees Kelvin (K)	<3000	2100	3000
Scotopic to Photopic (S/P) Output Ratio	<1.2	0.6	1.2 (est.)
Blue Light Power Content	Less than the corresponding power content for HPS	150W bulb = 15W	EPST-0-07 (65W) = 14.3W (est.)
Adaptive controls to allow dimming	Required	Not available	Included
Maximum allowable wattage in urban areas and at major and minor collector road intersections in rural and agricultural areas	150W HPS (or equivalent LED wattage)	150W	65W
Shielding	Fully shielded	Fully shielded	Fully shielded

Note: MC §15-201-5 indicates that "Blue light power content" means the International Dark Sky Association's (IDA) definition of blue light content or the sum of energy between 405-530nm divided by the sum of energy from 380-730nm times the total power output in watts. The blue light power content for HPS is 10w for 100w HPS bulb, 15w for a 150w HPS bulb, and 25w for a 250w HPS bulb.
Source: Compiled by PSI from MC §15-201-6 and -7; GE Current.

2.1.3 Replacement Process

The Maui County Streetlight Conversion Project involves the in-kind replacement of all HPS streetlight fixtures with new LED fixtures. All work will occur on the existing poles where the streetlights are installed; the project will not involve trenching, excavation, installation of new utility poles, or replacement of existing utility poles.[7] The streetlight replacement activities will typically involve the following at each streetlight location:

1. Disconnect power from the streetlights to be replaced.
2. Establish a safe work area on the roadway shoulder.
3. Assess the condition of the pole on which the streetlight fixture is mounted.
4. Using a boom truck, access the existing HPS streetlight fixture, confirm its wattage, and remove it.
5. Using a boom truck, install the appropriate new LED streetlight fixture (Table 2.6).
6. Install components necessary for the wireless adaptive control system.
7. Collect GPS coordinates for the streetlight.
8. Demobilize from the site.
9. Restore power to the streetlights.

Wastes generated by the process will be properly recycled or disposed of in compliance with all federal, state, and local regulations. Wastes that will require special processing include the HPS bulbs, which contain mercury, and the HPS ballast.

2.1.4 Conversion Completed to Date

The proposed action, as characterized in Section 2.1 of this report, was initially declared subject to an exemption from the HRS Chapter 343 (Section 1.4). Consequently, Hawaiian Electric (then operating as Maui Electric Co., Inc.) began implementing the Maui County Streetlight Conversion Project on November 13, 2018. Following the filing of a legal challenge to the appropriateness of the HRS Chapter 343 exemption declaration for the Maui County Streetlight Conversion Project, DPW voluntarily paused work in February 2019, and agreed to prepare an EA to evaluate the potential effects of the proposed action on the natural and human environment.

Prior to pausing work on the Maui County Streetlight Conversion Project, DPW and Hawaiian Electric had completed conversion of a portion of Phase 1 (Table 2.1); approximately 1,021 fixtures were replaced prior to pausing the work, which is roughly 54 percent of the Phase 1 streetlights.

2.1.5 Implementation of Adaptive Lighting

The Maui County Streetlight Conversion Project includes the implementation of several integral adaptive lighting measures as part of the proposed action. The County of Maui will implement

[7] If during the streetlight replacement process, existing poles are found to be damaged or degraded, then they will be replaced as part of a separate maintenance action prior to installation of the new LED streetlight fixture(s).

the measures outlined in this section during the conversion project and then during operation of the system for the foreseeable future.

2.1.5.1 ***<u>Streetlight Dimming</u>***

The entire streetlight system will be dimmed 20 percent during the seabird fledging season, from September 15 through December 15, with the exception of areas with relatively high and consistent pedestrian volume throughout the night (e.g., hospitals and other service facilities).[8]

Additional site-specific dimming may be implemented as outlined in Sections 2.1.5.2 and 2.1.5.3 and the County may choose to dim portions of the streetlight system during certain times of the night for other reasons, including cost savings, as needs are assessed and guidelines are modified.

When it comes to dimming streetlights, the Federal Highway Administration (FHWA) publication No. FHWA HRT-14-050, titled *Guidelines for the Implementation of Reduced Lighting on Roadways* (FHWA, 2014), provides guidance and suggestions. The guidelines identify several factors to consider when designing and implementing adaptive lighting, including: (*i*) posted speed limit, (*ii*) traffic volume, (*iii*) traffic composition, (*iv*) presence of medians, (*v*) presence of bike lanes, (*vi*) presence of sidewalks and/or potential for pedestrian conflicts, (*vii*) intersection density, (*viii*) presence of parked vehicles, (*ix*) the presence of other lights in the area, and (*x*) roadway geometry. These and other guidelines will be considered as the County implements the dimming specified in this document and develops additional dimming protocols in the future.

2.1.5.2 ***<u>Complaint or Event Driven Street Lighting Assessments</u>***

Throughout the County of Maui, complaint or event driven street lighting assessments will continue to be conducted. The County is periodically contacted by community members with requests or concerns related to streetlights. When this occurs, the County will respond appropriately. In addition, should an event occur where wildlife is documented to be adversely affected by artificial lighting, wildlife agencies and specialists will be consulted and a street lighting assessment of the area conducted as soon as feasible. The assessments will consider several adaptations to the streetlights in areas where complaints or events are reported. Those adaptations that will be considered include:

- *<u>Shielding</u>*. MC §15-201 requires, and the selected model (i.e., GE ERL1 streetlight) is, fully-shielded. Additional shields, including “house side,” “street side,” and “side shields,” can be added to most modern streetlight fixtures to reduce light trespass, including the selected GE ERL1 model, without adversely affecting their performance.
- *<u>Redistributing/dimming/eliminating</u>*. If streetlights are found to be too near each other or other artificial light sources, creating an area of artificial light that substantially exceeds applicable guidelines, the County may consider redistributing its streetlights along the roadway, dimming select streetlights, or eliminating individual streetlights to more evenly illuminate the roadway.

---

[8] As the streetlight control system is learned and improved, modifications to dimming protocols during the seabird fledging season may adapt, including programming that allows for various levels of dimming in coordination with the phase of the moon. In addition, the seabird fledging season period may change over time and will be based on USFWS and/or DLNR definitions of the core fledging season on Maui.

- *Adjusting height*. To address a complaint, the height of the fixture may be adjusted up or down, depending on the site conditions; if they are adjusted down, then it may be appropriate to dim them to account for a more concentrated light at street level. In the case of wildlife interactions, advantageous height adjustments would likely be restricted to increasing the height of the fixture in order to reduce the concentration of light reflecting off the ground surface into the sky.[9]

2.1.5.3 ***Street Lighting Assessments in Vicinity of Shoreline***

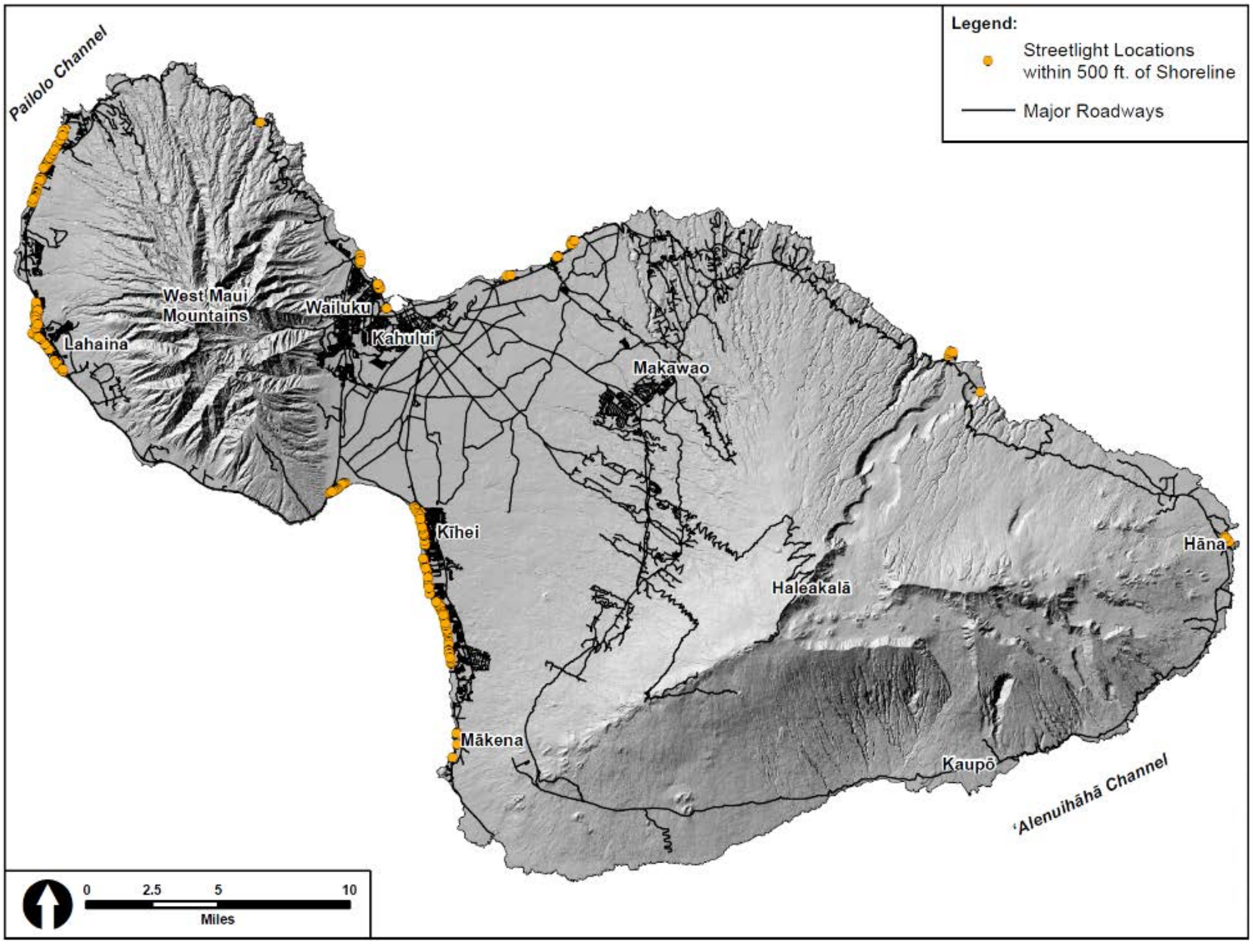
The County of Maui understands that the shoreline is where there is greater potential for artificial lights to adversely affect wildlife, including sea turtles and seabirds. At the same time, adequate street lighting along coastal County-owned roads is important for human safety, and a topic of community interest, particularly in the vicinity of coastal parks and access points. Therefore, during the proposed conversion project and thereafter, the County of Maui will proactively conduct assessments of street lighting in the vicinity of the shoreline. This effort will focus on areas where streetlights are present within 500 feet of a sandy shoreline but include all areas where streetlights are present within 500 feet of the shoreline of any kind. Sandy shorelines will be prioritized because they are areas where threatened and endangered sea turtle species may nest; other shoreline areas are included because seabirds protected by the Migratory Bird Treaty Act (MBTA) are known to nest along rocky shorelines.

The County of Maui will develop a shoreline street lighting assessment protocol that shall include viewing and assessing County-owned streetlights from: (*i*) the water line; (*ii*) the highest extent of sandy beach; (*iii*) physical obstacles, such as walls, near the beach; and (*iv*) areas within the County ROW that are frequented by pedestrians, bicycles, and other modes of transportation. These assessments will be made from both a human viewpoint (e.g., standing or sitting) and a wildlife viewpoint (e.g., eye level very near the ground). The assessment would address DLNR's *Guidelines for Adjusting Lighting at Facilities* in the Kaua'i Seabird Habitat Conservation Plan (KSHCP; currently available in Appendix E of the Draft KSHCP dated August 2019) and USFWS' suggestions in their scoping response letter (Appendix D).

There are roughly 280 County-owned streetlights within 500 feet of the shoreline (Figure 2.3 and Figure 2.4). All of them will be assessed within two years of restarting the proposed conversion project. Should an event occur where wildlife is documented to be adversely affected by artificial lighting, wildlife agencies and specialists will be consulted and a street lighting assessment of the area conducted as soon as feasible.

[9] The USFWS scoping letter response suggests that to minimize impacts to threatened and endangered species, the streetlight fixtures should be positioned "as low to the ground as possible to reduce ambient lighting."

Figure 2.3 County-owned Streetlights within 500 feet of the Shoreline on Maui Island

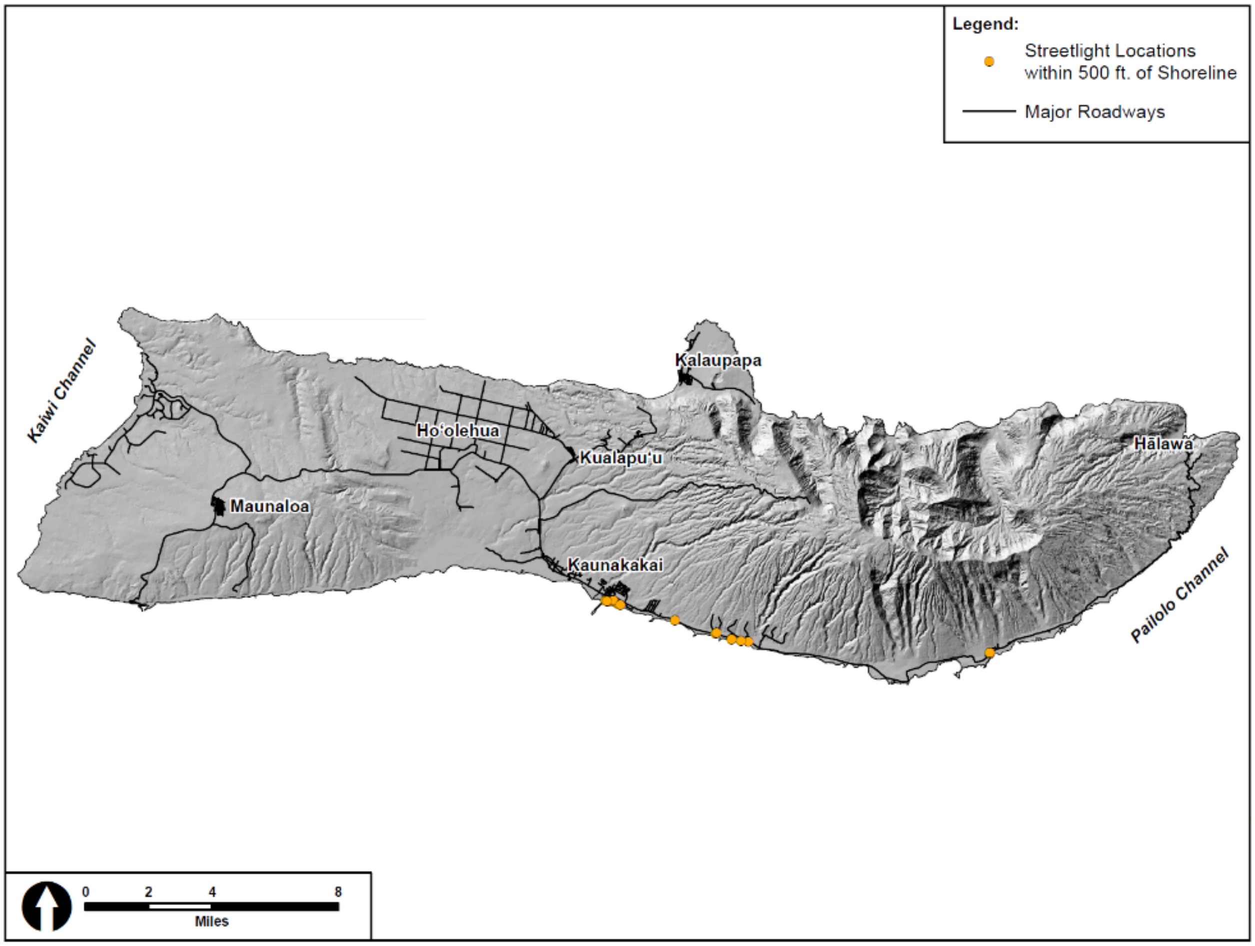


Source: PSI.

The assessments will consider several adaptations to the streetlights in the vicinity of the shorelines. Those adaptations will include:

- *<u>Shielding</u>*. MC §15-201 requires and the selected GE ERL1 streetlights are fully shielded. Additional shields, including "house side," "street side," and "side shields," can be added to most modern streetlight fixtures to reduce light trespass and lateral visibility, including the ERL1 model, without adversely affecting their performance.
- *<u>Relocating</u>*. For example, if the streetlight is mounted on the makai side of a roadway, the County may consider moving it to the mauka side of the road, if existing infrastructure makes this feasible, so that it continues to adequately light the roadway but is further from the beach.
- *<u>Redistributing/deactivating</u>*. If it is observed that streetlights are too close to each other or other artificial light sources, creating an area of artificial light that substantially exceeds applicable guidelines, the County may consider redistributing its streetlights or eliminating individual streetlights to more evenly illuminate the roadway.

Figure 2.4 County-owned Streetlights within 500 feet of the Shoreline on Moloka'i Island



Source: PSI.

- *Adjusting height*. The height of the fixture could be adjusted up or down, depending on the site conditions. Height adjustments may be deemed appropriate to (*i*) take advantage of intervening topography, structures, or vegetation in the area that could better shield the light when viewed from the shoreline; or (*ii*) move the light source out of the normal view plane of a sea turtle, which is normally achieved by increasing the height of the fixture so that is above a 30 degree vertical view plane from the beach.
- *Dimming*. Dimming of individual or groups of streetlights near the shoreline may be considered, particularly near known sea turtle nesting beaches during the sea turtle nesting and hatching period from May 15 through December 15.[10]
- *Utilizing alternative model*. In special cases, where other measures are deemed insufficient or ineffectual, the County will consider purchasing and installing an alternative model of streetlight fixture that only produces light wavelengths of 560 nanometers (nm) or longer.[11]

[10] This period may change over time and will be based on USFWS and/or DLNR definitions of the core sea turtle nesting and hatching season in the County of Maui.

[11] This potential adaptation addresses the 13th item of the Draft KSHCP's *Guidelines for Adjusting Lighting at Facilities* (Table 3.4) and the recommendation in the USFWS scoping response letter (Appendix D) that DPW "Use only bulbs with wavelength

2.2 PRELIMINARY SCHEDULE FOR THE PROPOSED ACTION

The major proposed action tasks, and their preliminary schedule for completion, are presented in Table 2.9 below.

Table 2.9 Preliminary Schedule for the Proposed Action

Task	***Estimated Start Date***	***Estimated Completion Date***
Pre-Assessment Scoping	8/20/2019	9/20/2019
Draft Environmental Assessment	6/10/2021	Summer 2022
Final Environmental Assessment	Summer 2022	Fall 2022
Other Permitting, Construction Bidding, and Contractor Selection	Winter 2023	Winter 2023
Convert Remainder of Phase 1 Streetlights	Spring 2023	Spring 2023
Convert Phase 2 Streetlights	Summer 2023	Summer 2024
Complaint or Event Driven Street Lighting Assessments (Section 2.1.5.2)	As needed	
Street Lighting Assessments in Vicinity of Shoreline (Section 2.1.5.3)	Fall 2023	Fall 2025

Source: PSI and Maui County

2.3 ANTICIPATED ACTION BUDGET

In 2018 the proposed action was anticipated to cost approximately $4 million. Roughly half of that cost has been incurred through the implementation of the majority of Phase 1 (Section 2.1.4) in 2018 and 2019. The cost to implement the remainder of the of the proposed action in 2023 and 2024 will likely be greater than the cost estimated in 2018.

2.4 ALTERNATIVES

2.4.1 FRAMEWORK FOR THE CONSIDERATION OF ALTERNATIVES

Title 11, Chapter 200.1, HAR contains the HDOH implementing regulations for environmental reviews, pursuant to HRS, Chapter 343. HAR §11-200.1-8 deals with agency actions such as the Maui County Streetlight Conversion Project. It requires that, for actions not exempt (see Section 1.2), the agency must consider the environmental factors and available alternatives, and disclose those in an EA or Environmental Impact Statement (EIS). HAR §11-200.1-18 establishes the process for the preparation and content of an EA. Among the requirements listed, HAR §11-200.1-18(d)(7) requires the identification and analysis of impacts of alternatives considered during the project planning.

In accordance with these requirements, the County of Maui considered a number of alternatives before determining that the proposed action described in Section 2.1 is its preferred alternative, allowing it to meet its purpose and need as defined in Sections 1.1 and 1.2. As can be seen from that discussion, the County of Maui's purpose is to comply with its *Street Lighting Standards in*

of 560 nm or greater (such as LED light bulbs with red, orange, or amber colored diodes; low pressure sodium, red or orange internally phosphor-LED fluorescent tubes) in any areas that are near ocean-side shorelines or otherwise contribute to ambient lighting that can be seen from the shoreline." This guideline/recommendation is primarily aimed at reducing potential effects on sea turtles.

the County of Maui, contained in MC §15-201 (Appendix A). To determine the technology that would best meet the purpose and intent of these standards, DPW employed the demonstration project described in Section 2.1.1, carefully selecting and vetting potential light sources against a wide set of criteria, both statutory and industrial (e.g., AASHTO, FCC). Because these standards are statutory requirements which are by their nature binding, DPW has determined that all alternatives which are included for consideration in this EA be capable of meeting them before they are eligible for full analysis. However, readers should note that one fixture, the C&W 3200K, was included in the 2016 demonstration project but does not meet the latest street lighting standards, promulgated in 2018.

2.4.2 ALTERNATIVES FOR DETAILED CONSIDERATION

Based on their experience with both the functionality and public response to the technologies incorporated into the demonstration project, DPW identified the alternatives characterized in the following subsections as meriting full analysis in this EA.

2.4.2.1 ***Proposed Action***

The "Proposed Action" alternative consists of implementation of the Maui County Streetlight Conversion Project, as described in Section 2.1. DPW's planning team, via data collected during the demonstration project described in Section 2.1.1, has concluded that converting the existing stock of cobra head streetlights throughout Maui, Molokaʻi, and Lānaʻi from 2100K HPS fixtures to GE 2700K LED fixtures and the small number of decorative streetlights in Lahaina from 2100K HPS fixtures to GE 3000K LED fixtures will best address the purpose and need for the project, as defined in Sections 1.1and 1.2, including meeting all of the lamp and luminaire standards described in MC §15-201-6 and -7 (Table 2.7). For these reasons, DPW considers this alternative to represent the preferred course of action.

The Proposed Action includes implementation of the adaptive lighting discussed in Section 2.1.5. Adaptive lighting is discussed as being an avoidance and minimization measure related to certain topics discussed in Chapter 3.

2.4.2.2 ***No Action***

Under the "No Action" alternative no additional streetlight conversion would occur. No further effort would be made, such as conversion of existing HPS fixtures to LED, or removing those LED fixtures which have already been deployed, as discussed in Section 2.1.4. As existing LED fixtures expire, they would be replaced by LED fixtures until the County's stock of LED fixtures is consumed, after which time the LED fixtures would be replaced by HPS fixtures.

The No Action alternative addresses neither the purpose nor the need for the proposed action. It is considered here pursuant to the content recommendations for EAs contained in HRS Chapter 343, and to provide a baseline for comparison and contrast with the action alternative.

2.4.3 ALTERNATIVES CONSIDERED BUT REJECTED

Pursuant to HAR §11-200.1-24(g)(h), and prior to determining that an EA was the appropriate level of environmental review, DPW contemplated a variety of reasonable alternatives, searching for ways to address the purpose and need in Sections 1.1 and 1.2, respectfully. This process included consideration of alternatives of a significantly different nature, including alternative designs and/or details that might present different environmental impacts, both positive and negative, and alternative locations for the proposed action. Ultimately, however, these alternatives were screened and eliminated from further consideration because they were not able to fully meet the purpose and need or where not substantially different from the Proposed Action (Section 2.4.2.1) or No Action (Section 2.4.2.2) alternatives. The following subsections provide a brief discussion of these alternatives, which are not considered further in this report.

2.4.3.1 ***Alternative Scale or Location***

An alternative scale project would consist of implementation of the same action at a smaller or larger scale. In this instance, the scale of the project is countywide and cannot be increased in scope beyond the jurisdiction of the County of Maui. Similarly, because the proposed action is needed to meet the statutory requirements of the County of Maui's streetlight standards contained in MC §15-201, which applies throughout the County, reducing the scale of the proposed action would result in failure to comply with this legal requirement and, as such, is not a practicable alternative. Because the scale and location of the County's roadways are not subject to modification, and due to the need to provide illumination along the ROWs, the County of Maui has determined that an alternative scale or location for the proposed action would not adequately address the purpose and need for the proposed action as described in Sections 1.1 and 1.2.

2.4.3.2 ***Alternative Timing***

As discussed in Section 2.1.4, some streetlights have already been converted. Thus, the Maui County Streetlight Conversion Project, as characterized in Section 2.1 is, in effect, already a delayed action and DPW cannot further delay the conversion of increasingly aged HPS streetlights and remain in compliance with applicable laws, regulations, and standards. Thus, DPW has concluded that an alternative timing, further delaying project implementation, is not a valid alternative and does not merit further consideration.

2.4.3.3 ***Continued Use of HPS Streetlights***

At the request of EarthJustice and the parties they represent, DPW has considered whether it is possible to immediately revert to the use of HPS fixture streetlights throughout Maui, Moloka‘i, and Lāna‘i. Under this scenario, the 1,021 fixtures which have already been converted to LED would be removed prior to their expiration, and restored to their prior HPS configuration, thus distinguishing it from the No Action alternative described in Section 2.4.2.2, and no further conversions to LED streetlights would occur.

Although this potential alternative can be distinguished from the No Action alternative, both this potential alternative and the No Action alternative would result in the same long-term condition – the entire County of Maui street lighting system consisting of only HPS. Therefore, this potential alternative is not substantially different from the No Action alternative and does not need to be considered in detail. Furthermore, like the No Action alternative, it addresses neither the purpose nor the need.

In addition to the considerations outlined above, GE no longer manufactures HPS streetlights. Other companies may continue to manufacturers HPS but their products may not be compatible with the County's streetlight infrastructure, which is configured for GE products. Modifying the streetlight infrastructure to be compatible with a new HPS product would increase the County's streetlighting costs. HPS obtained from other manufacturers may have slightly different color and light distribution characteristics than the GE HPS fixtures, changing people's perception of them and potentially increasing costs. Lastly, the reduction in competition within the HPS market as this product nears obsolescence is likely to increase material cost without an accompanying energy savings.

2.4.3.4 ***Filtering Selected Streetlights***

Another alternative course of action which the County of Maui considered at the request of litigants was the possibility of adding an additional filter to the GE 2700K LED fixtures to reduce the quantity of blue light they emit. However, county-wide implementation of this course of action has been determined not to be supported by scientific evidence. Further, adding a filter to the LED streetlights would be considered by GE to be an alteration of the product; such an alternation would void the limited warranty provided by GE. The County and Hawaiian Electric rely on the manufacturer's warranted to control costs and manage liability. The County is unwilling to void the warranty; therefore, this alternative is not considered in detail.

2.4.3.5 ***Use of Different LED Streetlights***

A final alternative which DPW has evaluated consisted of employing an alternative LED fixture in place of the GE 2700K LED fixtures selected by the County. Some stakeholders believe that certain alternative LED fixtures, such as those with a lower blue light content, may better avoid or minimize the potential for County streetlights to impact protected wildlife. However, DPW has evaluated this possibility and determined that it is not a viable course of action for reasons bulleted below.

- A lower blue light content alternative would not provide better shielding than the Proposed Action, as required by existing and proposed lighting standards.
- The availability of low blue light content streetlights that reliably provides the adaptive controls called for in MC §15-201-5 is unknown because none of the fixtures tested in the demonstration project had a blue light content lower than 5.8 percent and none of the major manufacturers of cobra head streetlights offer models that produce less than 2 percent blue light.
- The potential wildlife impacts associated with an alternative that exclusively utilized a fixture that produces light with a low blue light content (e.g., less than 2 percent) would likely be similar to the impacts associated with the Proposed Action. This is partially because (*i*) there is no evidence that seabird light attraction would be dramatically reduced using a low blue light content fixture that generated sufficient light to meet applicable human safety guidelines; and (*ii*) the Proposed Action includes the adaptive lighting outlined in Section 2.1.5, which could include the use of low blue light content fixtures in certain shoreline situations, as discussed in Section 2.1.5.3.
- The lessons learned from the demonstration project include that residents and agency representatives prefer streetlights that have a blue light content in excess of 15 percent, a S/P ratio greater than 1.05, and a CRI above 70 (Section 2.1.1.3). An LED or other

type of fixture having a blue light content of less than 2 percent would likely have a S/P ratio of less than 0.8 and a CRI of less than 50. The public and safety agencies would find a low blue light content alternative unappealing and potentially detrimental to their safety.

- The County of Maui Police Department indicated in their scoping letter (Appendix D), that LED lighting is recommended in Crime Prevention Through Environmental Design practices due to the fact that LEDs allow colors and objects to be more visible and appear sharper. These benefits are only realized when the LED utilized produces a broad spectrum of light A low blue light content alternative would not produce a broad spectrum of light and, therefore, would not allow colors and objects to be more visible and appear sharper than they do when illuminated by HPS. A low blue light content alternative would be inconsistent with Crime Prevention Through Environmental Design practices.

Chapter 3: EXISTING ENVIRONMENT, POTENTIAL IMPACTS, AND MITIGATION

This chapter describes the potential environmental effects of the Maui County Streetlight Conversion Project and its alternatives, as described in Chapter 2. This chapter is organized by resource category (e.g., water quality, air quality, noise, etc.). The discussion under each topic includes: (*i*) an overview of existing conditions on the project site; (*ii*) the potential environmental impacts that may occur as a result of implementation of one or more of the alternatives considered in this EA; and, where appropriate (*iii*) any measures that the County will take to avoid, minimize, or mitigate potential adverse effects. The scale of the discussion and analysis is commensurate with the potential for impacts. Where appropriate, the larger environmental context (e.g., all of Maui County) is discussed, and in other cases the focus is narrower. The discussion of impacts also distinguishes between short-term impacts (e.g., those occurring when equipment and personnel are actively implementing the streetlight conversion) and those that may result over the long-term as a result of the Maui County Streetlight Conversion Project.

The resource topics covered in this Chapter are divided into the following categories:

1. Resources that do not have the potential to be measurably or significantly affected by Proposed Action or the No Action alternative. They are briefly summarized in Section 3.1.
2. Resource that have the potential to be measurably or significantly affected by the Proposed Action or No Action alternative. These topics are discussed in detail in Section 3.2 through 3.4. In those sections the existing conditions of each resource is characterized, followed by a discussion of the potential impacts, and their mechanisms, that may result from the alternatives. Where potential for impacts is assessed, it is followed by a discussion of measures to avoid, minimize, or mitigate them.
3. Cumulative impacts are discussed in Section 3.5.

3.1 RESOURCE TOPICS EXCLUDED FROM DETAILED ANALYSIS

The resource topics in this section are those that do not have the potential to be affected by Proposed Action or the No Action alternatives. They are briefly summarized here in the interest of completeness and to provide context for readers, but there is no attendant discussion of impacts because none of the activities considered as part of the Maui County Streetlight Conversion Project have the potential to significantly affect them.

3.1.1 AIR QUALITY

As required by the Clean Air Act, each state is required to provide a framework for regulating air quality and to develop plans to attain and maintain the National Ambient Air Quality Standards. The HDOH Clean Air Branch has adopted State Ambient Air Quality Standards that apply within the State of Hawaiʻi, which in some cases are more stringent than national standards. Air quality in the County of Maui is generally characterized as excellent, and is classified as being in attainment with regard to both National and State standards. Aside from minor emissions from

Hawaiian Electric vehicles/equipment during the conversion process and subsequent maintenance of the streetlighting system, neither of the alternatives will affect air quality.

3.1.2 Historic Resources

The scope of activities associated with the Proposed Action and the No Action alternatives is limited to converting and/or replacing the streetlight fixtures on existing utility poles located in heavily modified County of Maui roadway ROWs. No grubbing, grading, tunneling, trenching, mining, extraction, or any other kind of earthwork will be done. Therefore, no impacts to archaeological or historic resources are anticipated.

3.1.3 Cultural Resources and Practices

The *Guidelines for Assessing Cultural Impacts*, adopted by the Environmental Council of the State of Hawaiʻi on November 19, 1997, identify several possible types of cultural practices and beliefs that are subject to assessment. These include subsistence, commercial, residential, agricultural, access-related, recreational, and religious and spiritual customs. The guidelines also identify the types of potential cultural resources, associated with cultural practices and beliefs, that are subject to assessment. Essentially, these are natural features of the landscape and historic sites, including traditional cultural properties. None of these features, sites, properties, or practices, if present within the County roadway ROW, will be significantly affected by the Proposed Action and No Action alternatives because they are limited to short durations of daytime work to convert and/or replace the streetlight fixtures on existing utility poles using methods similar to those employed for many years to maintain the existing streetlighting system.

3.1.4 Climate

The windward, or north through northeast-facing sections if the Hawaiian Islands, including Maui, Molokaʻi, and Lānaʻi, generally have a consistent year-round supply of trade winds that bring frequent, brief rain showers. The wetter period of the year in windward areas depends on the individual island and the elevation, but generally occurs in the months of spring. The highest peaks, such as Haleakala on Maui, can receive several inches of snowfall. Conversely, the leeward sides of the island(s), which are the southwest through southeast sides of the islands, are more arid. Parts of the islands are extremely dry; some southwest locations receive less than 12 inches of rainfall per year and support only desert-adapted vegetation. In general, the wetter season is winter and the dryer season is summer. The Proposed Action and No Action alternatives do not involve any tasks which could affect the regional climate or area-specific microclimates.

3.1.5 Geology, Topography, and Soils

Like the other Hawaiian Islands, Maui, Molokaʻi, and Lānaʻi were formed by magma that erupted from a submarine hotspot on the earth's crust. The islands consist of shield volcanoes that have become deeply eroded and partially veneered by much later volcanic activity. Because the Proposed Action and No Action alternatives do not involve any grubbing, grading, tunneling, trenching, mining, extraction, or any other kind of earthwork, there is no potential for them to adversely impact the existing geology, topography, or soils.

3.1.6 HYDROLOGY, GROUNDWATER, AND SURFACE WATER

All of the Hawaiian Islands, including Maui, Molokaʻi, and Lānaʻi, are a chain of volcanic islands in the Pacific Ocean. The hydrology of each island is a product of their respective climate and geomorphology. Each of these islands has ground water available in some locations depending on the age and the geologic structure of the island. Surface water resources are affected by the size of the drainage basin, the groundcover present, and the types of land use(s) present in adjacent areas, which can affect the amount of runoff generated.

Neither the Proposed Action nor No Action alternative involve any activities which would: (*i*) make a withdrawal from any aquifer; (*ii*) make any contribution to any aquifer; (*iii*) alter any surface waterbody; (*iv*) make any discharge into any surface waterbody; (*v*) change the size of a drainage basin; (*vi*) change the groundcover present; or (*vii*) change the land uses on the islands. Therefore, they will not significantly impact hydrology.

3.1.7 NATURAL HAZARDS AND CLIMATE CHANGE

None of the activities related to the Proposed Action and No Action alternatives would contribute to the prevalence of, or vulnerability to: (*i*) fire; (*ii*) earthquakes; (*iii*) geological hazards; (*iv*) floods; (*v*) tsunami inundation; or (*vi*) hurricanes or tropical storms. In addition, the Maui County Streetlight Conversion Project will not contribute to climate change or sea level rise, nor will it make the County of Maui more susceptible to impacts related to these processes. To the extent that climate change is related to greenhouse gas emissions, the switch from HPS to more efficient LED streetlights will reduce the emissions of greenhouse gases associated with producing energy to light the County's roadways.

3.1.8 NOISE

Hawaiʻi Administrative Rules, Title 11, Chapter 46, Section 4 (HAR, §11-46-4) defines the maximum permissible community sound levels in A-weighted decibels (dBA). These limits differ according to the kind of land uses that are involved, as defined by zoning district, and time of day (i.e., daytime or nighttime). The maximum permissible sound levels specified in HAR, §11-46-4(b) apply to any excessive noise source emanating from within the specified zoning district, as measured at or beyond the property line the noise is emanating from. However, mobile sources, such as the construction equipment and/or motor vehicles that will be used to conduct the streetlight conversions and maintenance per the Proposed Action and No Action alternatives, are not governed by these noise limits. Instead, construction noise levels above the limits in HAR, §11-46-4 are regulated using a curfew system whereby noisy construction activities are not permitted during nighttime, on Sundays, and on holidays unless the project obtains a "noise variance." Because all of the conversions and maintenance activities will be conducted during normal daytime work hours, no noise variance is required. Consequently, no significant impacts are anticipated.

3.1.9 PUBLIC INFRASTRUCTURE AND SERVICES

Because the Proposed Action and No Action alternatives will not involve any excavation and rely on existing public infrastructure, without adding an new load or demand, neither of the Proposed Action nor the No Action alternative has the potential to adversely affect public infrastructure such as utilities, public schools, parks, hospitals, or roadways. Neither will they limit or place additional burden on public services such as police, fire, and emergency medical services. Consequently, DPW anticipates no adverse impacts to these resources.

3.1.10 SOLID AND HAZARDOUS WASTE

The Proposed Action and No Action alternatives considered in this report will generate some solid waste as existing and/or expired streetlight fixtures are removed and replaced. Neither alternative will produce substantial quantities of waste. The alternatives are anticipated to produce similar quantities of waste, but the Proposed Action is likely to, over time, produce less waste because LED fixtures tend to last longer than HPS fixtures. To the extent possible, Hawaiian Electric and DPW will employ reuse and recycling measures. Nevertheless, some proportion of the fixtures will end up in area landfills on Maui, Molokaʻi, and Lānaʻi; the quantities of material will be small relative to other waste streams received by those facilities and the capacity of these facilities. Because of the modest quantities of solid waste and absence of hazardous waste involved with the alternatives, no significant impacts are anticipated.

3.1.11 TRAFFIC

In the county seat of Kahului-Wailuku and other urban areas on Maui, traffic levels are typical of urban core areas throughout the islands, experiencing distinct AM and PM peaks associated with work and school related travel. Elsewhere throughout the County of Maui, and in particular on the rural islands of Lānaʻi and Molokai, traffic is typically light to moderate. While implementation of either the Proposed Action or the No Action alternative will require periodic work in County ROWs, and may include single-lane closures in some instances, these service interruptions will be brief and diffuse, occurring at different times and places throughout the County as conversion phased work continues (see Table 2.1) and then ongoing maintenance takes place. Because these interruptions will be brief, intermittent, and diffuse, they will not cause significant impacts to area roadways. Hawaiian Electric will obtain any necessary Permit to Work on County Highway from the DPW, Development Services Administration (DSA), as needed, prior to commencing work.

3.2 WILDLIFE

The presence of certain types of nighttime artificial lighting has been shown to adversely affect particular nocturnal wildlife species. This section identifies the wildlife present in the County of Maui that are of concern and assesses the potential for the Proposed Action and No Action alternatives to adversely affect them. The analysis presented in this section is informed by the *Maui County's LED Street Light Conversion Wildlife Technical Report for an Environmental Assessment* report prepared by Hamer Environmental LP, and included as Appendix E.

3.2.1 REGULATORY CONTEXT

There are several regulations concerning wildlife that are applicable to this assessment; they include:

- *Endangered Species Act (ESA).* The purpose of the ESA is to protect and recover endangered and threatened species and the ecosystems upon which they depend.

Species can be "listed" as threatened or endangered under the ESA. The ESA prohibits the "take" of endangered and threatened species without special exemption.[12] The U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) oversee compliance with ESA for terrestrial and marine species, respectively.

- *Federal Migratory Bird Treaty Act (MBTA).* The MBTA of 1918, as amended (16 USC § 703-712), prohibits the take of migratory birds and makes it unlawful to pursue, hunt, take, capture, kill, possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product without proper authorization. The USFWS oversees compliance with the MBTA.
- *HRS Chapter 195D*. This state-level regulation has many parallels to the ESA. State-listed species include all of those listed federally as well as additional species that the state chooses to list as threatened or endangered. Chapter 195D has similar provisions concerning the take of listed species. The DLNR, Division of Forestry and Wildlife (DOFAW) oversees implementation of Chapter 195D.

3.2.2 Existing Conditions

There are many species present within the County of Maui that are listed as threatened or endangered at the state and/or federal level or are protected by the MBTA. The Proposed Action and No Action alternatives represent a potential threat to a small number of those protected species. In USFWS' letter dated September 20, 2019, responding to the EA scoping letter (Appendix D), it identified seven species as warranting discussion in this EA. DOFAW did not respond to the EA scoping letter.

Based on the scoping input for this EA and agency input on similar undertakings in Hawai‘i, the eight species listed in Table 3.1 are considered in this EA. The list includes the seven species identified by USFWS plus another seabird, protected by the MBTA, that is known to be affected by artificial lighting.

The following sections provide a brief overview of the status of these species within the County of Maui. Details concerning the status of the Hawaiian Petrel (*Pterodroma sandwichensis* [HAPE]), Newell's Shearwater (*Puffinus newelli* [NESH]), Hawksbill sea turtle (*Eretmochelys imbricata* [HAST]), and Green sea turtle (*Chelonia mydas* [GRST]) are provided in Appendix E.

[12] Under the ESA, "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (16 USC § 1532(19)). Further, "harm" includes significant habitat modification or degradation that results in death or injury to a listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). "Incidental take" means take that is incidental to, and not the purpose of, the conduction of an otherwise lawful activity.

Table 3.1 Protected Species Considered in Detail

Species (common name; Hawaiian name; Latin name)	ESA and Chapter 195D Listing	Input Provided in USFWS Scoping Letter
Hawaiian Petrel (HAPE); ʻUaʻu; *Pterodroma sandwichensis*	Endangered	Concerned Proposed Action poses an increased risk to species
Newell’s Shearwater (NESH); ʻAʻo; *Puffinus newelli*	Threatened	Concerned Proposed Action poses an increased risk to species
Band-rumped Storm-Petrel (BSTP); ʻAkeʻake; *Oceanodroma castro*	Endangered	Concerned Proposed Action poses an increased risk to species
Wedge-tailed Shearwater (WTSH); ʻUaʻu kani *Ardenna pacifica*	None (MBTA)	Not mentioned
Hawksbill sea turtle (HAST); Honuʻea; *Eretmochelys imbricata*	Endangered	Concerned Proposed Action poses an increased risk to species
Green sea turtle (GRST); Honu; *Chelonia mydas*	Threatened	Concerned Proposed Action poses an increased risk to species
Blackburn’s sphinx moth; *Manduca blackburni*	Endangered	Risks should be included in EA, designated critical habitat is present in the vicinity of the Proposed Action
Hawaiian hoary bat; ʻŌpeʻapeʻa; *Lasiurus cinerus semotus*	Endangered	Risks should be included in EA

Source: USFWS letter dated September 20, 2019 (Appendix D), compiled by PSI.

3.2.2.1 Seabirds

3.2.2.1.1 Hawaiian Petrel

Prior to the arrival of Polynesians, sub-fossil evidence indicates HAPE were common throughout the Main Hawaiian Islands. Currently, HAPE breeding colonies are known to exist on Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, and the island of Hawaiʻi. It is estimated that one-third of the State’s population, or 1,500 adult and subadult birds, are associated with breeding colonies in the County of Maui. The most well-known County of Maui colonies are near the summit of Haleakalā among the lava flows, where there is little to no vegetation, and in the hills above Lānaʻi City in mesic montane forest.

The species was federally listed as endangered in 1967; critical habitat for the species has not been designated. HAPE are believed to be in decline in Hawaiʻi, with a 78 percent decline estimated on Kauaʻi between 1993 and 2013; however, the population in the Haleakalā colony, where predator control is conducted, appears to be stable or increasing.

HAPE are a pelagic gadfly petrel, spending much of their time at sea resting or foraging. HAPE measures 16 inches in length and has a wing span of approximately 36 inches; have dark grayish black and white coloration (Figure 3.1); and have a distinctive call that sounds like âoo ah ooâ, as well as calls that resembles the yapping of a small dog. During the breeding season, which varies somewhat by island but generally occurs from March through November, adult HAPE visit their colonies on land and, when successful, couples lay a single egg in a burrow. To access their colonies, most adult HAPE fly from the ocean to their inland colonies between 10 and 50 minutes after sunset. In the morning, adult HAPE begin moving to sea in numbers while it is still completely dark and most are at sea before sunrise. After the adults cease attending to their young, the chicks fledge from their burrows and make their first flights to the ocean between roughly October 15 and December 15.

Figure 3.1 Photographs of Hawaiian Petrel

Source: Daniel L. Webster and Andre Raine.

3.2.2.1.2 Newell's Shearwater

Approximately 90 percent of the global population of NESH breeds on Kauaʻi, therefore, what is mostly known about this species is based on data collected from that island's populations. On Kauaʻi, most breeding colonies are in steep and wet areas between 660 and 3,700 feet in elevation. The population status of NESH in the County of Maui is not known; based on a 2001 radar study, it was estimated that ≥ 140 NESH were coming ashore daily on the island of Maui. Although NESH have been documented on Molokaʻi and Maui, there are no well-known or monitored natural NESH colonies in the County of Maui. A social attraction project referred to as Makamakaʻole has been in operation in West Maui since 2013; in 2019 the project reported that NESH visited 22 of the artificial burrows at Makamakaʻole.

NESH were first listed as threatened in 1975; critical habitat for the species has not been designated. NESH are believed to be in decline in Hawaiʻi, with a 94 percent decline estimate on Kauaʻi between 1993 and 2013.

NESH are a pelagic bird which forages over deep water east and south of Hawaiʻi. They are typically 12 to 14 inches long, have a wingspan of 30 to 35 inches, weighs approximately 14 ounces, and have a glossy black plumage above, and white below (Figure 3.2). Like HAPE, NESH have a distinctive low, moaning call; the Hawaiian name for the bird, ʻAʻo, is an onomatopoeia of the call. During the breeding season, which on Kauaʻi is known to occur from April through November, adult NESH visit their colonies on land and, when successful, couples lay a single egg in a burrow. To access their colonies, most adult NESH fly from the ocean to their inland colonies between 30 and 90 minutes after sunset. In the morning, adult NESH begin moving to sea in numbers while it is still completely dark and most are at sea by dawn. After the adults cease attending to their young, the chicks fledge from their burrows and make their first flights to the ocean between roughly October 15 and December 15.

Figure 3.2 Photographs of Newell's Shearwater

Source: Robin W. Baird and Jack Jeffrey Photography.

3.2.2.1.3 Band-rumped Storm-Petrel

BSTP occur throughout the tropical and subtropical portions of the Pacific and Atlantic Oceans and worldwide likely number between 20,000 and 200,000 breeding pairs. The population breeding in the Hawaiian Islands is thought to be small, possibly only a few hundred pairs. They have been observed on Kauaʻi, Lehua Islet, and the island of Hawaiʻi. It is possible that some breeding pairs are present in the County of Maui. The species was federally listed as endangered in 2005; critical habitat for the species has not been designated.

BSTP are a small seabird about 8 inches long, weighing less than 1.5 ounces. It is a blackish-brown bird with an evenly-cut white rump band and uppertail-coverts (Figure 3.3). During the day, adults spend their time foraging on the ocean surface. Breeding adults visit their nest sites after dark, where they can be detected by their distinctive calls. On Kauaʻi breeding adults arrive in late May and fledglings depart the nest in October to mid-November. Breeding on Kauaʻi and Lehua Islet has primarily been observed to occur in steep, sparsely vegetated cliff faces near the coast with small numbers breeding in inland vegetated valleys.

Figure 3.3 Photographs of Band-rumped Storm-Petrel

Source: Daniel L. Webster and Tracy Anderson.

3.2.2.1.4 Wedge-tailed Shearwater

The WTSH is a burrow-nesting seabird that is found globally in the tropics and subtropics (Figure 3.4). WTSH prefer to breed along the coastal shores of the main islands and on offshore islets; they can breed in upland volcanic slopes as well.

Figure 3.4 Photograph of Wedge-tailed Shearwater

Source: Brian Sullivan.

The species is not listed as threatened or endangered, but is protected by the MBTA. Overall global populations of this species are either stable or on a downward trend and estimated at over five million birds with approximately 40,000 to 60,000 pairs breeding in the main Hawaiian Islands.

Like HAPE and NESH, WTSH fly from the ocean to their colonies after sunset and depart their colonies before sunrise. In the County of Maui, the MNSRP studies and tracks WTSH colonies at Kamaʻole III Beach Park (Kīhei, Maui), Waiheʻe (Maui), Hoʻokipa (Maui), Hāwea Point (Maui), Molokini Islet, and Moʻomoni (Molokaʻi). Their breeding period typically begins in March and fledglings leave the burrow in late November to late December.

3.2.2.1.5 Overview of Threats to Seabirds

Threats to Hawaiʻi's seabirds, including HAPE, NESH, BSTP, and WTSH, are predominately anthropogenic. Briefly, the terrestrial threats include:

- *Predation*. These seabirds exhibit strong natal philopatry (tendency to return to birth site to breed) and high nest-site fidelity. These behavioral traits, along with a protracted nesting period and ground nesting habitat, result in great vulnerability of eggs, chicks, and adults to predation by introduced mammals (rats, cats, mongoose, dogs, pigs, and Barn Owls) at the breeding colonies.
- *Habitat modification*. This factor is especially relevant to HAPE and NESH that nest in high elevation forest habitats, but can also affect WTSH. Habitat loss and degradation from invasive plant species or natural catastrophe (e.g., hurricane or wildfire) is often compounded with predation as reduction in dense native canopy cover can provide access for predators into breeding colonies. Further, pigs, goats, deer, and other mammals modify the habitat by eating and trampling native vegetation and

spreading invasive plants (such as guava and ginger) that can then in turn modify the habitat to the point of excluding breeding seabirds.

- *Collisions*. This factor is especially relevant to HAPE and NESH that nest in high elevation forest habitats and regularly fly near artificial structures at night, but may also affect WTSH. Collision with artificial structures such as utility lines, wind turbans, antennas, towers, and buildings can kill seabirds particularly breeding adults moving to and from montane breeding colonies in the dark.
- *Light attraction*. Seabirds can be adversely affected by artificial nighttime lights in a manner referred to as "light attraction" or "fallout." They can become confused around, or blinded by, certain bright artificial light sources during nocturnal flights to and from the ocean and their breeding colonies. Should this happen, they may circle the lighted area until colliding with structures or becoming exhausted. In either case, birds that "fallout" of the sky and land on the ground are unable to take off, making them susceptible to predation, dehydration, starvation, and being hit by cars. This threat is discussed further in Section 3.2.2.1.6.

It has been suggested that the joint effects of these threats has resulted in the rapid decline in HAPE and NESH populations mentioned above. In addition to human caused terrestrial threats, other threats are likely to affect meta-population numbers, including (*i*) stochastic events, such as storms; (*ii*) at-sea factors, which are poorly known and may include marine pollution, plastic ingestion, overfishing, and fisheries bycatch; and (*iii*) climate change.

3.2.2.1.6 Existing Effects of Artificial Nighttime Lighting on Seabirds

The USFWS states in their scoping response letter that, "Biological effects of artificial light to animals may include altered behavior and physiological changes such as alternations in cortisol production and immune function." While this may be true, the only known impact of artificial lights on the subject seabird species is light attraction.

Most of what is known about seabird light attraction and fallout in Hawaiʻi comes from information collected by the Save Our Shearwaters (SOS) Program on the island of Kauaʻi and the Maui Nui Seabird Recovery Project (MNSRP) in the County of Maui. Both SOS and MNSRP recover light attracted seabirds, evaluate them, and assist in their recovery, if warranted (MNSRP does this in concert with the Hawaiʻi Wildlife Center). The programs then release them, when possible. Typically, more than half of the recovered grounded fledglings are released; it is not known if being grounded and released has a substantial effect on the long-term viability of a seabird.

The information from these programs suggest that it is unusual for adult seabirds to experience light attraction fallout. The adult seabirds makes many trips over or near artificially lighted areas each breeding season. Despite these frequent exposures, rarely are adult seabirds found grounded during the breeding period. Fledglings are more susceptible to light attraction fallout when they first take to the sky during each species' fledging period. Fledgling fallout is more likely to occur on overcast or moonless nights. On Kauaʻi, the greatest NESH fallout occurs in years when the new moon coincides with peak fledging.

Over an 11-year period (2009-2019), data indicates that MNSRP recovered more grounded WTSH than any other seabird species and did not recover any grounded BSTP. Over that period, on average, MNSRP annually recovered 11 grounded HAPE on the island of Maui, 1.5 grounded HAPE on the island of Lānaʻi, and 0.73 grounded NESH fledglings on the island of Maui.

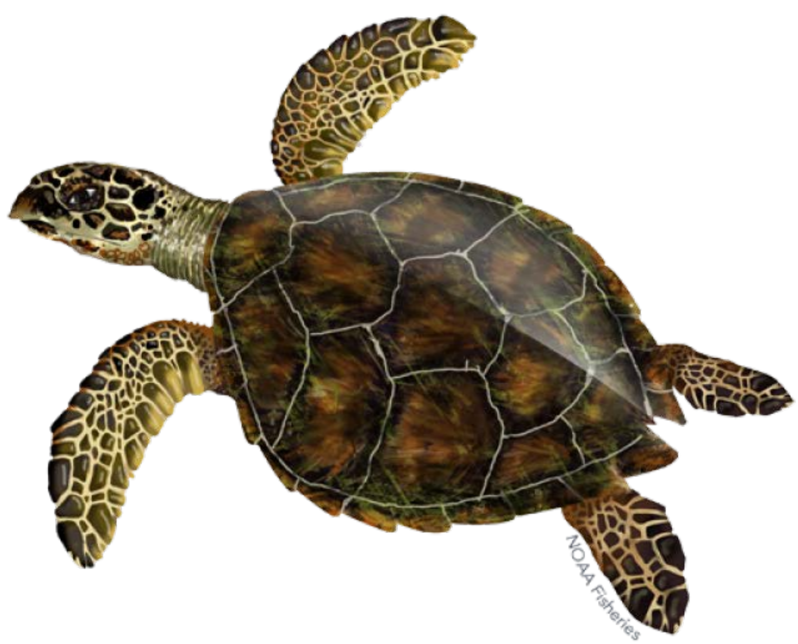
Data on the number of grounded seabirds from MNSRP and the SOS Program on Kauaʻi are not directly comparable because they and their respective island community do not place the same level of emphasis on recovering grounded seabirds. In addition, the populations of the subject seabirds are much different on Kauaʻi (90 percent of the NESH population breeds on Kauaʻi) and Kauaʻi is a smaller island with fewer human residents. Nevertheless, for context, on Kauaʻi over a five year period (2014 through 2018) the SOS Program annually recovered an average of 9 HAPE, 177 NESH, less than one BSTP, and 123 WTSH. Of interest, since the breeding populations of NESH and HAPE on Kauaʻi are thought to be similar, the fact that they are recovered at a ratio of 20:1 on Kauaʻi suggests that NESH fledglings are more susceptible to light attraction than HAPE fledglings.

3.2.2.2 ***Sea Turtles***

3.2.2.2.1 Hawksbill Sea Turtle

HAST (Figure 3.5) have been protected under the ESA since 1970. The Hawaiian Archipelago population inhabits waters of the central Pacific and typically remain in offshore waters of the archipelago and nearshore waters of the main Hawaiian Islands all their lives. HAST that breed elsewhere inhabit the tropical eastern and western Pacific, Indian, and Atlantic Oceans. Globally, the species is declining throughout its known range. The adult population in Hawaiʻi remains on the brink of extirpation due to natural and anthropogenic threats, including historical harvest for their shell.

Figure 3.5 Photograph of Hawksbill Sea Turtle



Source: NOAA.

It is estimated that about 50 to 100 mature females are nesting at 20 beaches around the main Hawaiian Islands, primarily on the island of Hawaiʻi. They will utilize both low and high energy beach and appear to prefer steep beaches and coarse sand. The USFWS indicated that "Hawksbill sea turtles exhibit a wide tolerance for nesting substrate (ranging from sandy beach to crushed coral) with nests typically placed under vegetation." Between 1991 and 2014, nine nesting females were documented and banded on the island of Maui. Nesting season can begin as early as mid-May, with hatching events from July to as late as early January, for a nearly eight-month nesting activity window. Only breeding adult females come ashore at night to nest.

The known or suspected HAST nesting beaches in the County of Maui include those listed in Table 3.2. HAST may utilize other beaches for breeding, especially more remote ones that are not easily monitored. In addition, HAST adults may rest on other beaches and are known to utilize broad near-shore and off-shore areas for foraging.

Table 3.2 Known or Suspected HAST Nesting Beaches in the County of Maui

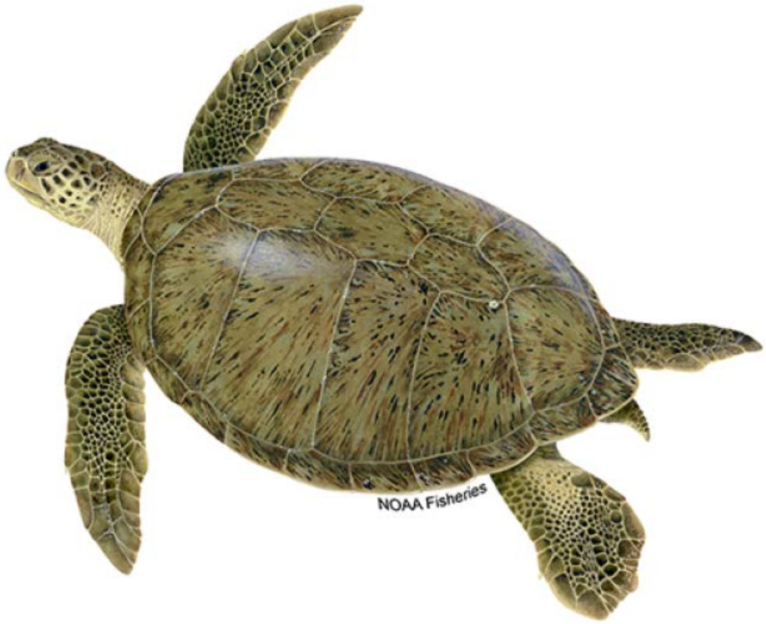
Island	***Coast***	***Hawaiian/Common Beach Name***	***Other Known Names***
Maui	South	Kealia Beach	Sugar Beach
		Kawililīpoa Beach	Waipuʻilani/Uluniu Road
		Kalepolepo Beach	
		Pālauʻea Beach	White Rock
		Puʻu Ōlaʻi	Little Beach
		Oneloa Beach	Mākena/Big Beach
	East	Hāna Bay	
		Koki Beach	
		Hāmoa Bay	
Molokaʻi	East	Hālawa Beach	
Lānaʻi	North	Shipwreck Beach	

Source: Appendix E.

3.2.2.2.2 Green Sea Turtle

In 1978, the Hawaiian subpopulation of GRST (Figure 3.6) was listed as threatened. Worldwide populations of the GRST have seriously declined as a direct result of overharvesting of turtles and eggs. Conversely, the Hawaiian GRST population has increased significantly since being protected. The vast majority of the Hawaiian GRST population (96 percent) nests on the French Frigate Shoals; a portion of the remainder nest in the County of Maui. In the County of Maui, GRST begin to mate in March, lay eggs between mid-April and late-August, and hatchlings emerge between July and early-December.

Figure 3.6 Photograph of Green Sea Turtle



Source: NOAA.

The known or suspected GRST nesting beaches in the County of Maui include those listed in Table 3.3. GRST may utilize other beaches for breeding, especially more remote ones that are not easily monitored. In addition, GRST adults may rest on other beaches and are known to utilize broad near-shore and off-shore areas for foraging.

Table 3.3 Known or Suspected GRST Nesting Beaches in the County of Maui

Island	*Coast*	*Hawaiian/Common Beach Name*	*Other Known Names*
Maui	South	Kawililīpoa Beach	Waipuʻilani/Uluniu Road
	West	Hanakaʻōʻō Beach	Canoe Beach
		Kamehameha Iki	Park 505 Front Street / Shark Pit
		Kaʻanapali Beach	Kahekili Beach / Black Rock
		Honokahua Bay Beach	Ironwood / D.T. Fleming
	North	Waiheʻe Beach	Waiehu Beach
		Kaʻehu Beach	Nehe Point
		Kanahā Beach	Kite Beach
		Spreckelsville Beach	Stable Road
		Baldwin Beach	
		Pāʻia Bay	
		Hamakuapoko Beach	Maliko Bay
		Hoʻokipa Beach	
	East	Unnamed black sand beach	
Molokaʻi	West	Moomomi Preserve	
		Kawaaloa Bay	
Lānaʻi	North	Polihua Beach	

Source: Appendix E.

3.2.2.2.3 Overview of Threats to Sea Turtles

Historically, a primary threat to sea turtles was harvesting by humans for their eggs, meat, and shells. This is no longer a threat for the sea turtle populations in Hawai‘i. Modern threats to Hawai‘i’s sea turtles, including HAST and GRST, include:

- *Predation*. Invasive/introduced wildlife like mongooses, cats, and rats dig up and eat turtle eggs and prey on hatchlings that emerge from the nest. Marine predators also target hatchlings and adults, but they are the same predators that have existed for millennia.
- *Beach activity*. Human activity such as coastal development, beach driving and recreation, and campfires on beaches can disrupt nesting activity, damage eggs, and adversely affect hatchlings.
- *Artificial nighttime lighting*. Artificial nighttime lighting can adversely affect both adult and hatchling HAST, but are more likely to affect hatchlings. Adult turtles coming to shore to nest may be disturbed by lighting and not successfully nest. Once hatchlings emerge from the nest cavity, they tend to orient toward the brightest direction; they may orient in the wrong direction when artificial lights are present, resulting in them expiring from dehydration, exhaustion, predation, or being runover by vehicles. This threat is discussed further in Section 3.2.2.2.4.
- *Habitat loss*. Invasive plant species like Guinea grass can take over native plant habitat, preventing nesting and entangling hatchlings.
- *Fisheries bycatch and entanglement*. Sea turtles of all ages can be caught or accidentally entangled in fishing gear. When this happens, the sea turtle typically drowns because it could not come up for air. A related threat is that sea turtles can swallow sharp hooks, which can damage the soft tissue of the throat, stomach, intestines, or other vital organs.

In addition to these threats, other threats are likely to affect meta-population numbers, including (*i*) stochastic events, such as storms; (*ii*) additional at-sea factors such as marine pollution and plastic ingestion; and (*iii*) climate change and sea level rise, which is leading to beach erosion.

3.2.2.2.4 Existing Effects of Artificial Nighttime Lighting on Sea Turtles

As previously described for seabirds in Section 3.2.2.1.6, the USFWS states in their scoping response letter that “Biological effects of artificial light to animals may include altered behavior and physiological changes such as alternations in cortisol production and immune function.” While this may be true, the only known impacts of artificial lights on the subject sea turtle species are the behavioral changes associated with light attraction. The discussion in this EA is limited to the behavioral changes, but the County of Maui recognizes that those changes may have knock-on effects such as cortisol production and immunity function.

It is difficult to monitor and establish when artificial lights have an adverse effect on sea turtle nesting. Observations at eight HAST nesting beach on the island of Maui from 1991 to 2014, identified 63 “false crawls,” which is when an adult turtle crawls up the beach in a manner consistent with egg laying but does not lay any eggs. Monitors recorded 78 nests over that same period of time. It is not known to what extent, if any, artificial lighting played a role in the false crawls.

The more easily recognizable artificial light affects occur when sea turtles are clearly light attracted and wander beyond their normal terrestrial realm and encounter vehicular traffic. In 1993, and again in 1996, an adult HAST apparently became light attracted and was killed crossing North Kīhei Road. There have been no reports of adult GRST becoming light attracted in the County of Maui.

In the County of Maui, there have been two known incidents of HAST hatchlings being attracted to artificial nighttime light sources. In 2009, near the vicinity of 575 S. Kīhei Road, hatchlings from two HAST nests emerged, were immediately attracted to car lights, and were killed crossing Kīhei Road. In a second event that same year, only 16 hatchlings were rescued from an entire clutch in an area of Kealia Beach. No reports of GRST hatchlings being adversely affected by artificial lights could be found.

3.2.2.3 ***Other Species***

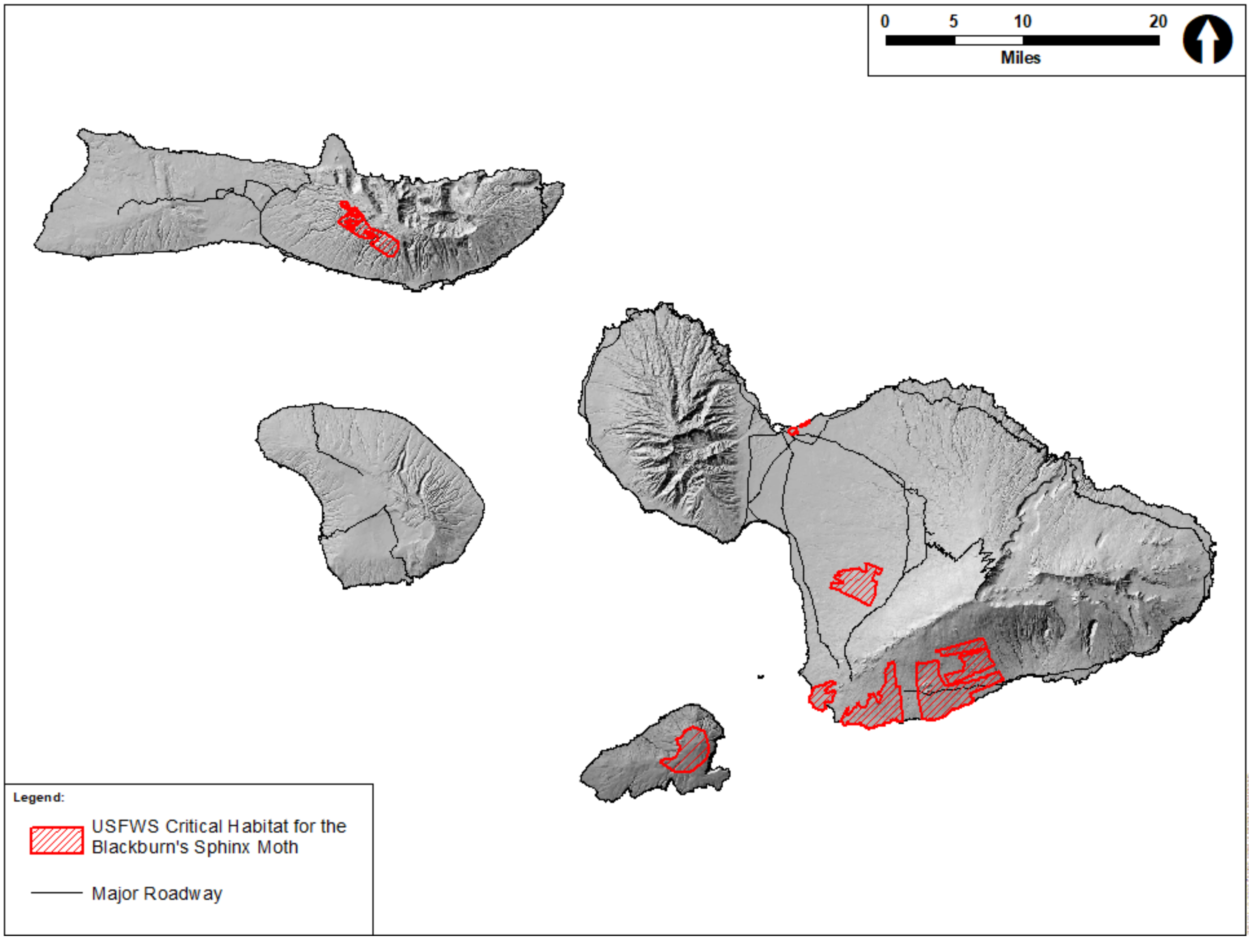
3.2.2.3.1 Blackburn's Sphinx Moth

The Blackburn's sphinx moth is listed as an endangered species; critical habitat for the moth was designated in 2003, which is shown in Figure 3.7. It is one of Hawai‘i's largest native insects with a wing span of up to five inches. The moths are overall gray with black bands across the top of their wings and five orange spots on each side of their abdomen (Figure 3.8). Caterpillars are large and can be bright green or purple/gray, both with scattered white speckles across their back and a horizontal white stripe on the side of each segment.

Adult moths feed on nectar from native plants, including beach morning glory (*Ipomoea pes-caprae*), ilie‘e (*Plumbago zeylanica*), and maiapilo (*Capparis sandwichiana*); larvae feed upon non-native tree tobacco (*Nicotiana glauca*) and native ‘aiea (*Nothocestrum* sp.). To pupate, the larvae burrow into the soil and can remain in a state of torpor (aestivate) for up to a year (or more) before emerging from the soil. Soil disturbance can result in death of the pupae.

The Blackburn's sphinx moth population size is unknown. It is believed that the largest population occur on Maui Island and Hawai‘i Island. They mostly occur in coastal, lowlands, and dry forests in areas receiving less than 50 inches of rain per year. The designated critical habitat (Figure 3.7) in the County of Maui includes large areas on the southern portion of Haleakalā below 5,000 foot elevation, the uplands of the island of Kaho‘olawe, an area in East Moloka‘i between 700 and 1,100 foot elevation, and, in the area of Kahului Airport on Maui, Kanahā Beach Park and Kanahā Pond State Wildlife Sanctuary. At Kanahā Pond, caterpillars have been observed on dune restoration plantings.

Figure 3.7 Blackburn's Sphinx Moth Critical Habitat



Source: Planning Solutions, Inc. (2022)

Figure 3.8 Photograph of Blackburn's Sphinx Moth

Source: Maui Magazine.

3.2.2.3.2 Hawaiian Hoary Bat

Hawaiian hoary bat is an endangered endemic mammal found throughout the main Hawaiian Islands, including Kaua‘i, O‘ahu, Lāna‘i, Maui, Moloka‘i, and Hawai‘i. It has been observed visiting the island of Kaho‘olawe. No critical habitat has been designated for this species. The Hawaiian hoary bat is a distinctively marked bat with long narrow wings (Figure 3.9). Its forearm measures roughly 2 inches and bats weighs 0.7 to 1.3 ounces.

Figure 3.9 Photograph of Hawaiian Hoary Bat

Source: United State Geological Survey.

The bats roost alone or with dependent young in native and nonnative trees, typically more than 15 feet tall. The pupping season extends from June to September; adults will leave their young unattended in trees and shrubs when they forage. Hawaiian hoary bat primarily feed on nocturnal moths and beetles, which they hunt in flight across a wide array of habitat types and plant communities from sea level to at least 11,800 feet above sea level. Activities related to reproduction and pup rearing tend to take place in the low- to mid-elevations and movement to higher elevations occurs after pups fledge.

In the County of Maui, bat activities has been detected across the islands of Molokaʻi and Maui all months of the year. Bat activities have also been documented on Lānaʻi and Kahoʻolawe in August, September, and October, before dropping in December and January. Most times of the year detection have been higher in remnant forests than in the shrubland. They are known to utilize areas of low development, provided food and shelter resources are available.

The primary anthropogenic threats to the bats are: (*i*) disturbances, such as tree trimming, during the pupping season; (*ii*) become entangled in barbed wire fences; (*iii*) being hit by wind turbine blades; and (iv) habitat loss due to development and urban sprawl.

3.2.3 POTENTIAL IMPACTS

This section discusses the potential short-term (construction phase) and long-term (operational phase) impacts of the Proposed Action and No Action alternatives. The short-term activities will be similar under either alternative because streetlights will need to be periodically replaced as they expire, regardless of which alternative is implemented. The construction/maintenance process is described in Section 2.1.3 and does not involve unusual activities or equipment.

Under either alternative, streetlights will produce artificial nighttime light in the County of Maui into the foreseeable future. The long-term impacts can vary by alternative to the extent that the wildlife present is affected differently by the HPS and LED generated light. Operation of the streetlights under the Proposed Action is described in Sections 2.1.2 and 2.1.5. It is important to understand that the Proposed Action does not involve the addition of new streetlights or changes to the location of existing streetlights, unless a detailed, post-LED-conversion assessment (Section 2.1.5.3) concludes that a change in location (lateral or vertical) would avoid or minimize potential impacts. Therefore, the potential long-term impact to wildlife, and other resources, is not a question of whether streetlights impact wildlife or not. Instead, the potential long-term impact is solely to assess whether any of the subject species will be adversely impacted by the proposed change from HPS to the selected LED fixtures.

3.2.3.1 ***Compliance with Agency Guidelines***

To evaluate whether any of the subject species will be adversely impacted by the proposed change from HPS to LED fixtures, this assessment will first consider the extent to which the two alternatives comply with agency guidelines to minimize artificial light impacts on wildlife. The primary guidance in Hawaiʻi is the Draft KSHCP's *Guidelines for Adjusting Lighting at Facilities*.[13] The recommendations in the USFWS's scoping response letter (Appendix D) all have parallels in the Draft KSHCP's guidelines. The guidelines address concerns related to both seabirds and sea turtles. Table 3.4 summarizes each alternative's compliance with the guidelines.

[13] These guidelines were established for a broad range of land uses, including commercial, industrial, resort, and institutional. Not all the guidelines are applicable to streetlights.

Table 3.4 Summary of Alternative's Compliance with the Draft KSHCP's *Guidelines for Adjusting Lighting at Facilities*

Guideline		*Proposed Action (LED)*	*No Action (HPS)*
1.	Deactivate non-essential lights during seabird fallout season (September 15 to December 15) and/or turtle nesting season (May 15 to December 15), as appropriate.	Complies. The adaptive lighting (Section 2.1.5) aspect of the Proposed Action addresses this measure. Briefly, streetlights are considered essential, but they will be dimmed during seabird fallout season and assessments and actions will be taken to address potential turtle impacts.	Does not comply. Streetlights would not be deactivated or dimmed during these seasons.
2.	Install full cut-off light fixtures.	Complies.	Complies, existing fixtures have been shielded and future fixtures would be full cut-off.
3.	Shielding light fixtures.	Not applicable. All fixtures are full cut-off, no additional shielding necessary.	
4.	Angle lights downward.	Complies.	Complies.
5.	Place lights under eaves.	Not applicable.	Not applicable.
6.	Shift lighting according to the moon phase.	Can comply. The adaptive lighting (Section 2.1.5) aspect of the Proposed Action addresses this measure.	Cannot comply. HPS streetlights cannot be shifted (dimmed).
7.	Install motion sensors for motion-activated lighting.	Impractical. However, as this guideline recommends, adaptive lighting (Section 2.1.5) means streetlights can be dimmed when activity levels on the streets decreases.	Impractical and cannot comply.
8.	Decrease lighting levels. Following guidelines and standards established by the appropriate agency or professional and technical organization.	Complies. The streetlights were designed to comply with applicable AASHTO guidelines when they were installed. The implementation of adaptive lighting measures (Section 2.1.5), could result in decreased light levels during certain periods of the year or times of night.	Complies, the streetlights were designed to comply with applicable AASHTO guidelines when they were installed.
9.	Decrease visibility of interior lights.	Not applicable.	Not applicable.
10.	Use light-less technologies.	Not applicable.	Not applicable.
11.	Plant vegetation around lights to reduce light visibility.	Not applicable.	Not applicable.
12.	Lower height of lights.	Generally impractical but will be considered in coastal settings as discussed in Section 2.1.5.3.	Generally impractical.
13.	Use longer light wavelengths. In coastal areas use LPS; red, orange, or amber LEDs; true red neon, and other lighting sources that produce light wavelengths of 560 nm or longer. Where HPS are used, add a filter to exclude transmission of wavelengths less than 570nm.	Does not comply. However, as discussed in Section 2.1.5.3, where streetlights are near the coastline and other avoidance and minimization measures are assessed to be insufficient, DPW will consider installing alternative lights that produce light wavelengths of 560 nm or longer.	Does not comply.

Source: Draft KSHCP, Appendix E. Compiled by PSI.

As summarized in Table 3.4, the Proposed Action complies with the guidelines to a greater degree than the No Action alternative. As such, it would be expected that the Proposed Action would have less impact on wildlife than the No Action alternative if the intensity and spectrum of light produced under the two alternatives was identical. As outlined in Section 2.1.1.2 and Table 2.3, the fixtures are different and do produce different intensities and spectrums of light. The selected LEDs will be operated in a manner that results in them producing less total light energy than the HPS they replace. However, the LEDs emit a greater percentage of their energy in wavelengths less than 530 nm (they have a greater blue light content) than HPS (Table 2.3). To examine this further, the EA will consider whether wildlife behavior may be affected by the change in the spectral power densities (SPD) of artificial light in the nighttime environment as a result of the Maui County Streetlight Conversion Project.

3.2.3.2 ***Seabirds***

The subject seabirds (HAPE, NESH, BSTP, and WTSH) are not present in the terrestrial environment where and when short-term construction and maintenance work will occur during implementation of the Proposed Action or No Action alternative. This is because all construction and maintenance work will occur during daytime hours along maintained County roadway ROW. Therefore, no short-term impacts to seabirds are anticipated.

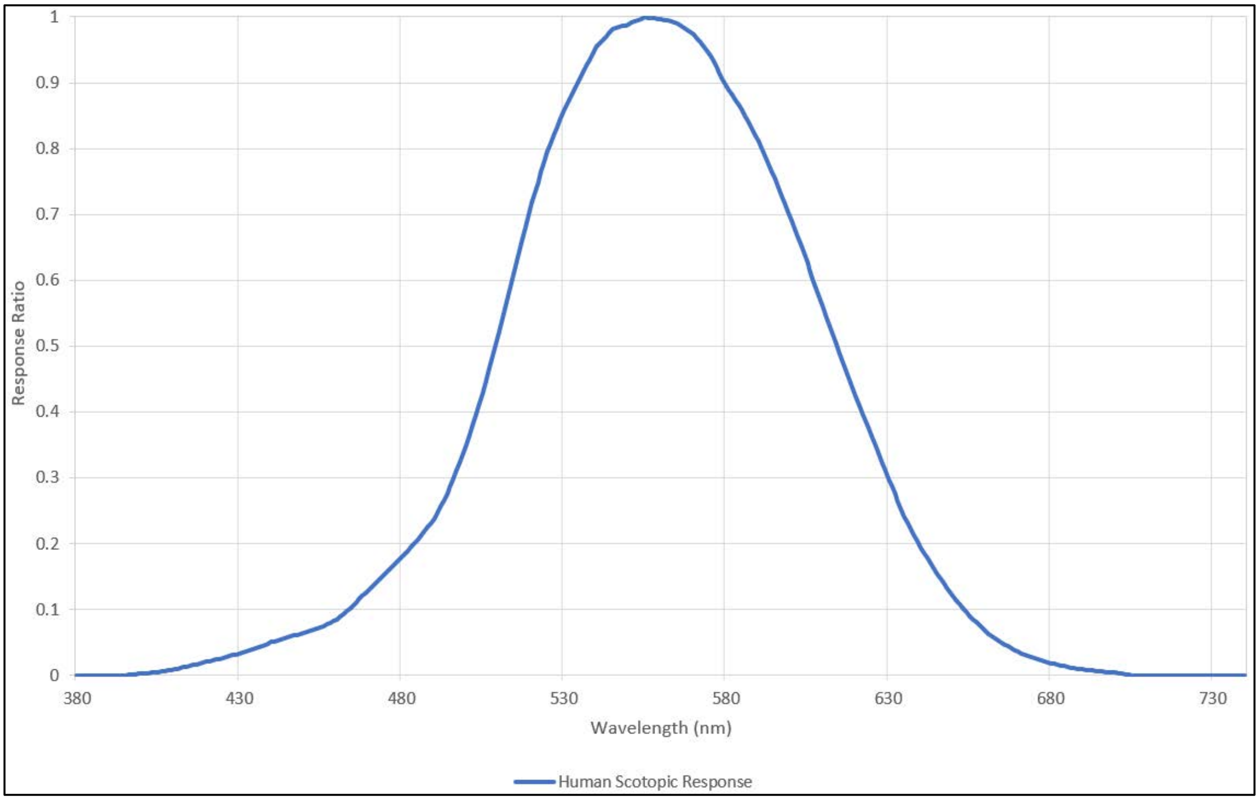
Furthermore, of the seabird threats (Section 3.2.2.1.5), the Proposed Action and No Action alternatives could only play a role in the light attraction threat. Nothing about the alternatives will influence seabird predation, seabird collisions, or habitat loss. Therefore, this section focuses on light attraction.

3.2.3.2.1 Light Intensity and Spectrum Considerations

Streetlights are usually selected based on their lumen output. Lumen is a measure of flux, or how much light energy a light source emits (per unit time) as perceived by the human eye. It is based on the human response to different wavelengths of light (Figure 3.10). As discussed in Section 2.1.2, when converting from HPS to LED, the lumen output is a significant factor in the selection of the appropriate product (e.g., LEDs with certain lumen outputs are recommended to replace 100W, 150W, and 250W HPS). Provided the recommendations are followed, this results in humans perceiving the LED as having a similar brightness as the HPS it replaced.[14] The LED selected to covert roughly 90 percent of the streetlights is the ERL1-0-06 2700K LED. That model of LED would typically be used to replace a 100W HPS. Therefore, the discussion of light intensity and spectrum considerations in this section focuses on a comparison of a 100W HPS and a ERL1-0-06 2700K LED. However, because roughly 88 percent of the County's streetlights are 150W HPS, the most common conversion will be from a 150W HPS to a ERL1-0-06 2700K LED. That conversion represents a greater reduction in light energy than a 100W HPS to a ERL1-0-06 2700K LED conversion.

[14] Due to the LED's better S/P ratio and CRI than HPS, in most cases the LED produces less total light energy visible to humans than the HPS it is recommended to replace.

Figure 3.10 Human Response Curve

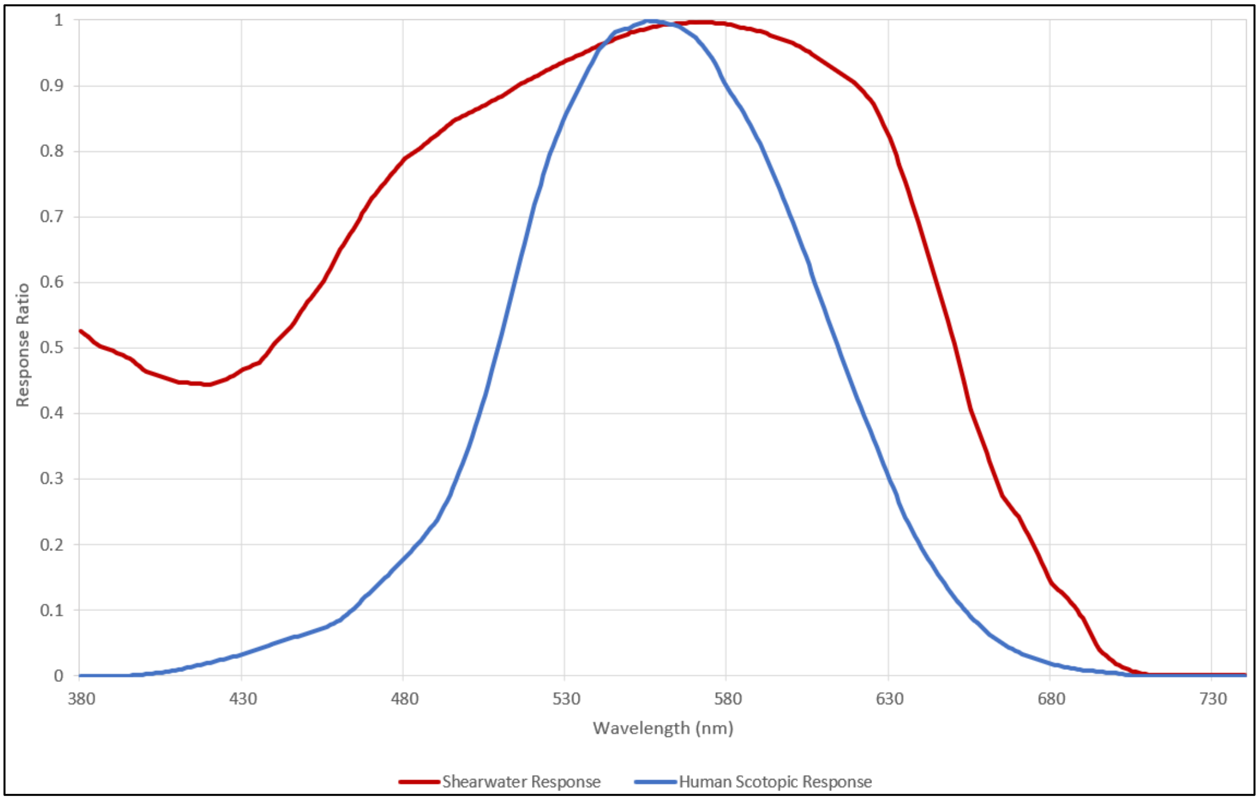


Source: Curren 2020-06-29.

Seabirds perceive light differently than humans; this can be seen when comparing the human response curve to the NESH response curve (Figure 3.11).[15] This shows that the NESH's response is broader than human's; it peaks in the green and yellow portions of the spectrum, like human's, but is higher in comparison to a human's in the orange, red, and especial blue portions of the spectrum. Thus, two artificial light sources that humans perceive as having similar brightness may appear to be much different to seabirds if a substantial portion of the energy they produce is in the red or blue portions of the spectrum.

[15] Since HAPE, NESH, BSTP, and WTSH are all nocturnal seabirds, their response curves are thought to be similar. Because NESH appear to be the protected species known to breed in the County of Maui that is most susceptible to light attraction, its response curve is used to evaluate impacts to all seabirds considered in this report.

Figure 3.11 Human and NESH Response Curves

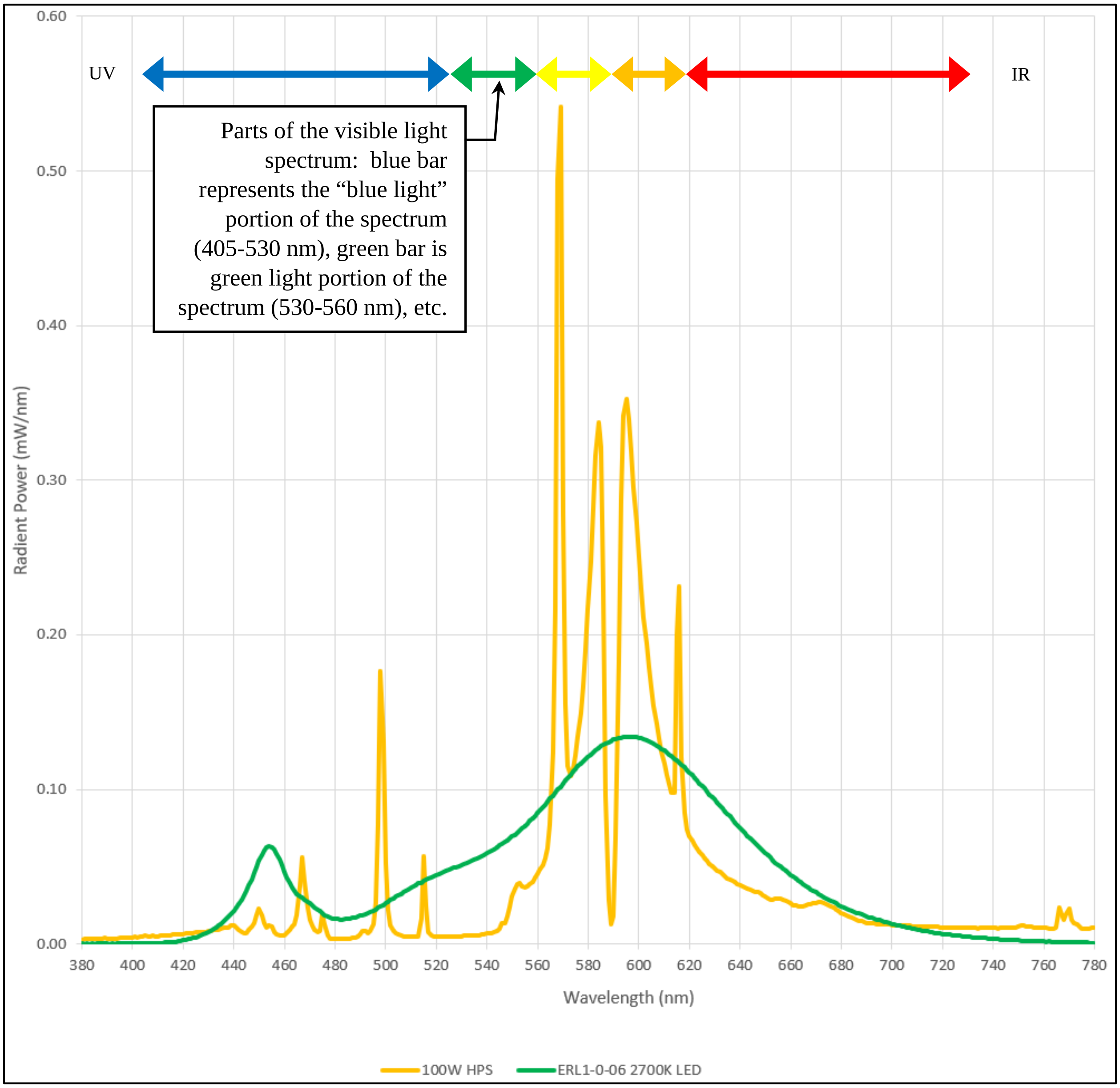


Source: Curren 2020-06-29 and Longcore 2018.[16]

These response curves can be overlain on the measured energy output of the two fixtures (their spectral power densities [SPD]) to assess how humans and seabirds may perceive the lights differently. Figure 3.12 illustrates the unadjusted SPD of the two fixtures, the GE ERL1-0-06 2700K LED and the GE 100W 2100K HPS. This shows that the HPS has discrete peaks in the blue, yellow, and orange portions of the spectrum with the peaks in the yellow and orange portions of the spectrum being dominant. This is what gives HPS its yellowish color, a low CCT, and poor CRI (20.5). In comparison, the LED has a smoother output across the spectrum with a primary hump across the green through red portions of the spectrum and a secondary/lower hump in the blue part of the spectrum. This results in a higher, but still "warm" CCT and a much better CRI (72.5). This graph also extends into the ultra-violet (UV) and infrared (IR) parts of the spectrum. Human eyes do not see radiation at those wavelengths. As shown, although the HPS produces more energy in the UV and IR wavelengths than LED, neither source produce substantial energy in the UV or IR wavelengths. Therefore, UV and IR wavelengths are not discussed further.

[16] The curve of the "Newell's Shearwater" response in the Longcore paper was digitized by Curren because the paper does not provide the actual data points.

Figure 3.12 Comparison of LED and HPS Spectral Power Density



Note: Both light sources operated at 100 percent power (no dimming of the LED).
Source: GE Currents, compiled by PSI.

Integrated across the spectrum shown in Figure 3.12, the difference in the total amount of energy produced by the 100W HPS and LED model that will replace it is negligible; the relative percent difference (RPD)[17] is 2.1 percent with the LED producing slightly more energy than the HPS. With 333 100W HPS in the field, this is a relatively uncommon conversion. When the ERL1-0-06 2700K LED replaces a 150W HPS, which it will do in more than 4,000 cases, the LED will produce substantially less energy than the HPS; the RPD is 49 percent in this case. When the LEDs are dimmed 20 percent during the seabird fledging season (Section 2.1.5.1), the RPD is 20.1

[17] Relative percent difference (RPD) is calculated as follows: (the difference of two numbers)/(the average of the two numbers) x 100.

and 69 percent with the LED producing less light energy than the 100W and 150W HPS, respectively.

Figure 3.13 and Figure 3.14 show how the human and NESH response curves, respectively, result in different perceptions of the same light source. Human vision, with its peak response in the green and yellow portion of the spectrum, accentuates those green and yellow portions of the spectrum and flatten the others. The low response in the blue spectrum essentially flattens the LED fixture's secondary/lower hump in the blue portion of the spectrum. Shearwater vision has a stronger response in the blue potion of the spectrum than humans, but, like humans, the peak shearwater response is in the green to orange portion of the spectrum. Because of the shearwater's stronger blue response, the secondary/low blue hump in the LED output is retained, but muted because the LED's blue hump occurs near a trough in the shearwater's response.

When integrated across the spectrum shown in Figure 3.13, it is found that when both fixtures are operated at 100 percent power the 100W HPS and the ERL1-0-06 2700K LED fixtures appear very similar to the human eye (RPD=8%) in terms of the brightness of the light produced: 33.8 lumens vs. 31.2 lumens, respectively. When the ERL1-0-06 2700K LED is operated at 80 percent power (20 percent dimming) during the seabird fledging season (Section 2.1.5.1), the RPD is 30.4 percent with the LED producing fewer lumens than the HPS.[18]

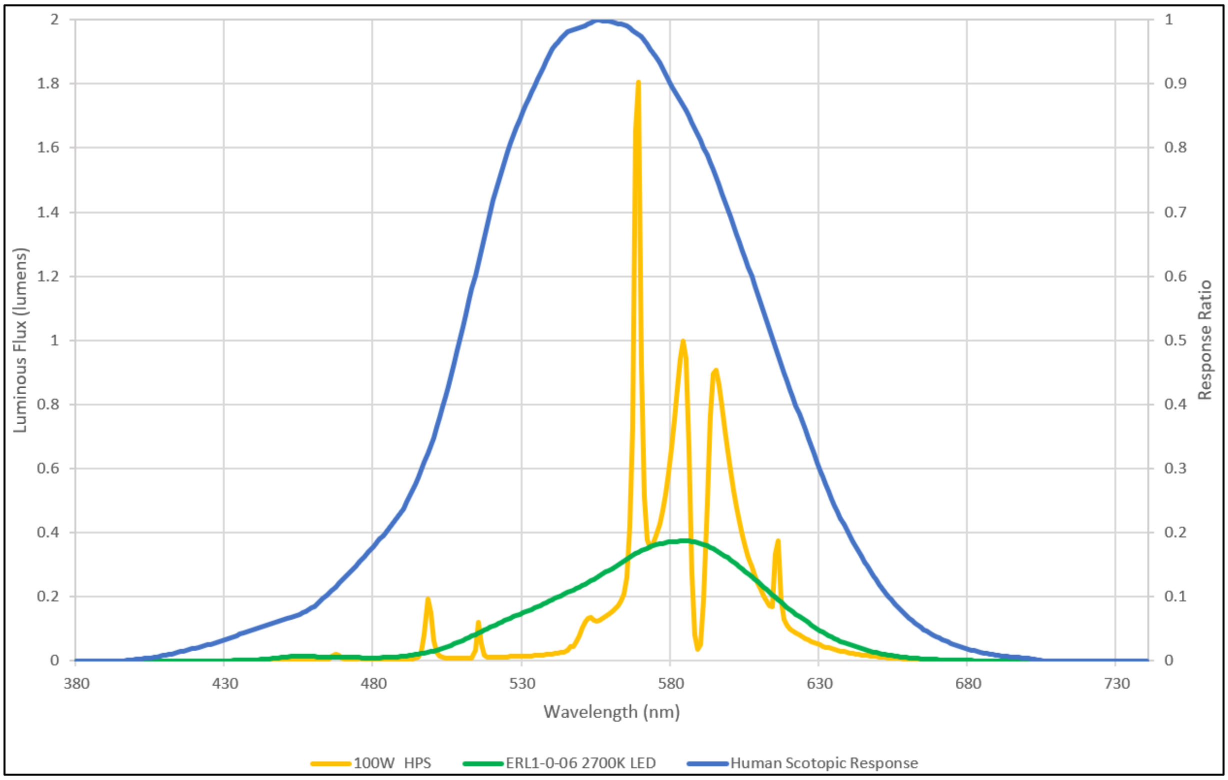
When both fixtures are operated at 100 percent power, the shearwater eye perceives the 100W HPS and the ERL1-0-06 2700K LED fixtures as nearly identical (RPD=0.2%) in terms of the brightness of the light produced: 46.6 vs. 46.5, respectively. When the ERL1-0-06 2700K LED is operated at 80 percent power (20 percent dimming) during the seabird fledging season (Section 2.1.5.1), the RPD is 22.5 percent with the LED producing less NESH-perceived light than the HPS.

The more common case will be when a 150W HPS is replaced by a ERL1-0-06 2700K LED fixture. In that case, a NESH would preserve the LED to be substantially dimmer than the HPS (RPD = 51.2 percent at 100 percent power and 71.4 percent at 80 percent power).

Because the HPS and LED fixtures broadcast the light they produce differently, the difference between them may appear greater depending on, for example, the angle at which the fixture is viewed. It has been observed that the LED fixture casts its light more evenly where it is intended (within the County ROW) and has less light at low angles to the horizon, resulting in less light trespass into neighboring areas.

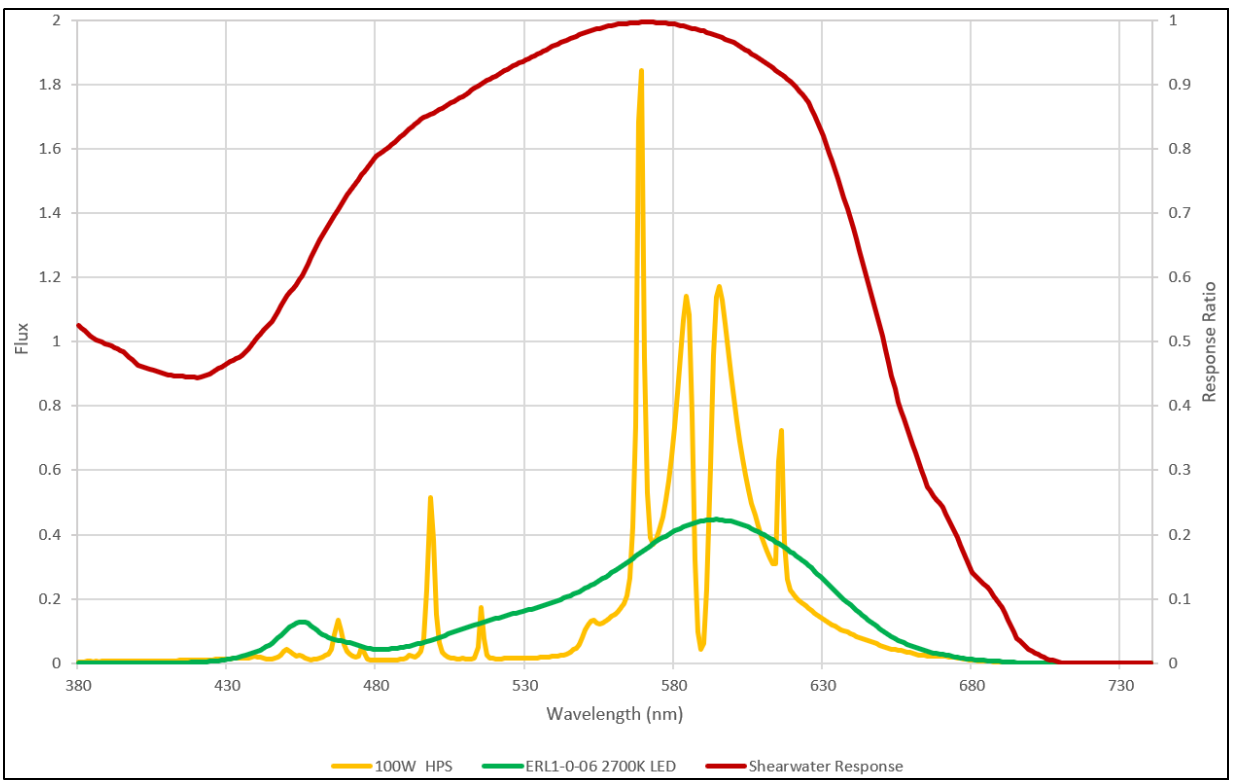
[18] The fact that it produces fewer lumens is offset by its superior S/P ratio and CRI so that it provides a similar level of comfort and safety for humans as the HPS it replaces.

Figure 3.13 LED and HPS Spectral Power Human Response



Source: PSI

Figure 3.14 LED and HPS Spectral Power NESH Response



Source: PSI

3.2.3.2.2 Conclusions

The most relevant considerations when assessing the impact of the Proposed Action on seabirds are:

- Seabirds will not be adversely affected during short-term construction and maintenance activities.
- The selected LED fixture complies with more of the relevant wildlife guidelines than the HPS fixture (Section 3.2.3.1). The selected LED fixture is a full cut-off light, resulting in less light trespass than HPS, and would be controlled in a manner intended to avoid wildlife impacts.
- In the vast majority of the conversions (over 4,000 cases), 150W HPS will be converted to ERL1-0-06 2700K LED resulting in substantially less light energy being immitted (RPD = 49 percent) and seabirds will perceive the light as substantially dimmer (RPD = 51.2 percent). In all other cases, seabirds will perceive the LED to be essentially identical to or dimmer than the HPS it replaces.
- During the seabird fledging season, when the greatest impacts associated with artificial light occur, the LEDs will be dimmed 20 percent (Section 2.1.5.1) using the wireless adaptive control system which will allow the streetlight infrastructure to be remotely controlled in real time. This will further reduce the amount of artificial light energy in the environment.
- On Oʻahu, where the State of Hawaiʻi Department of Transportation converted HPS streetlights to LEDs rated at 4000K and 3000K (which have a higher blue light content than the 2700K model selected by the County of Maui and were not dimmed), studies indicated that WTSH fallout did not change after the conversion.

Given these important factors, under the Proposed Action alternative the County-owned streetlight's contribution to seabird fallout, if any, would be expected to decline. The Proposed Action would <u>not</u> have a significant adverse effect on the subject seabirds; it would have a beneficial effect on them.

When considering the potential impact of the No Action alternative, it is recognized that to the extent that some street lights have already been converted to LED (Section 2.1.4), some of the benefits outlined above will be realized until those LED fixtures are returned to HPS. In the long term, the No Action alternative would result in similar artificial light conditions as those that existed in 2018. The County-owned streetlight's contribution to seabird fallout, if any, would not be expected to change.

3.2.3.3 ***<u>Sea Turtles</u>***

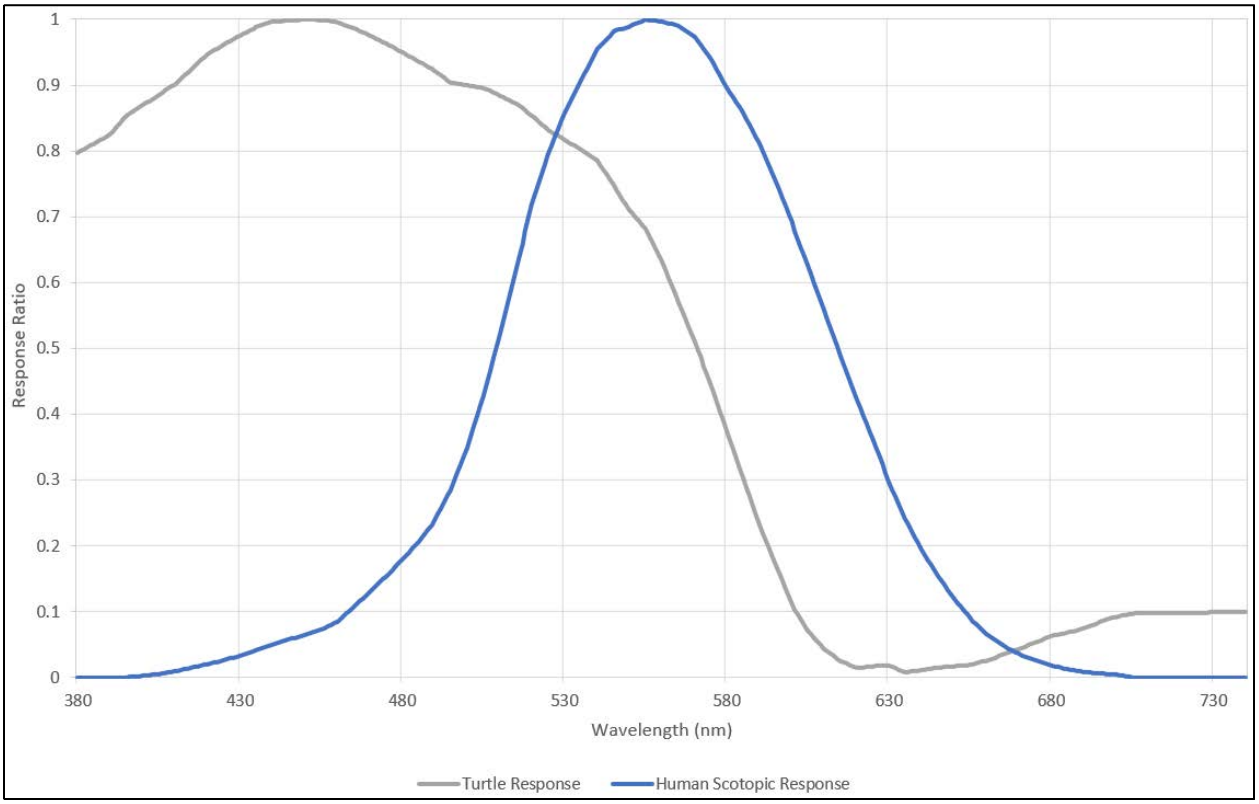
The subject sea turtles (HAST and GRST) are not present in the terrestrial environment where the short-term construction and maintenance work will occur during implementation of the Proposed Action or No Action alternative. All construction and maintenance work will occur during daytime hours along maintained County roadway ROW. During those hours, the County roadway ROWs near beaches are characterized by regular multi-modal traffic. The equipment used and activities conducted for Proposed Action and No Action construction and maintenance would not generate noise, dust, or other conditions that are substantially different than that normally present along roadway ROWs. Therefore, no short-term impacts to sea turtles are anticipated.

Furthermore, of the known threats to sea turtles (Section 3.2.2.2.3), the Proposed Action and No Action alternatives could only play a role in the light attraction threat. Nothing about the alternatives will influence sea turtle predation, beach activity, or habitat loss. Therefore, this section focuses on light attraction.

3.2.3.3.1 Light Intensity and Spectrum Considerations

Like seabirds (Section 3.2.3.2.1), sea turtles perceive light differently than humans. This can be seen when comparing the human response curve to the GRST hatchling response curve (Figure 3.15).[19] This shows that the GRST's eye response peaks in the blue portion of the spectrum and gradual decreases across the green, yellow, and orange portions of the spectrum. This is substantially different that the human response. Thus, two artificial light sources that humans perceive as having similar brightness may appear to be much different to sea turtles. Specifically, lights rich in blue light that appear dim to humans may appear bright to sea turtles.

Figure 3.15 Human and GRST Hatchling Response Curves



Source: Curren 2020-06-29 and Longcore 2018.[20]

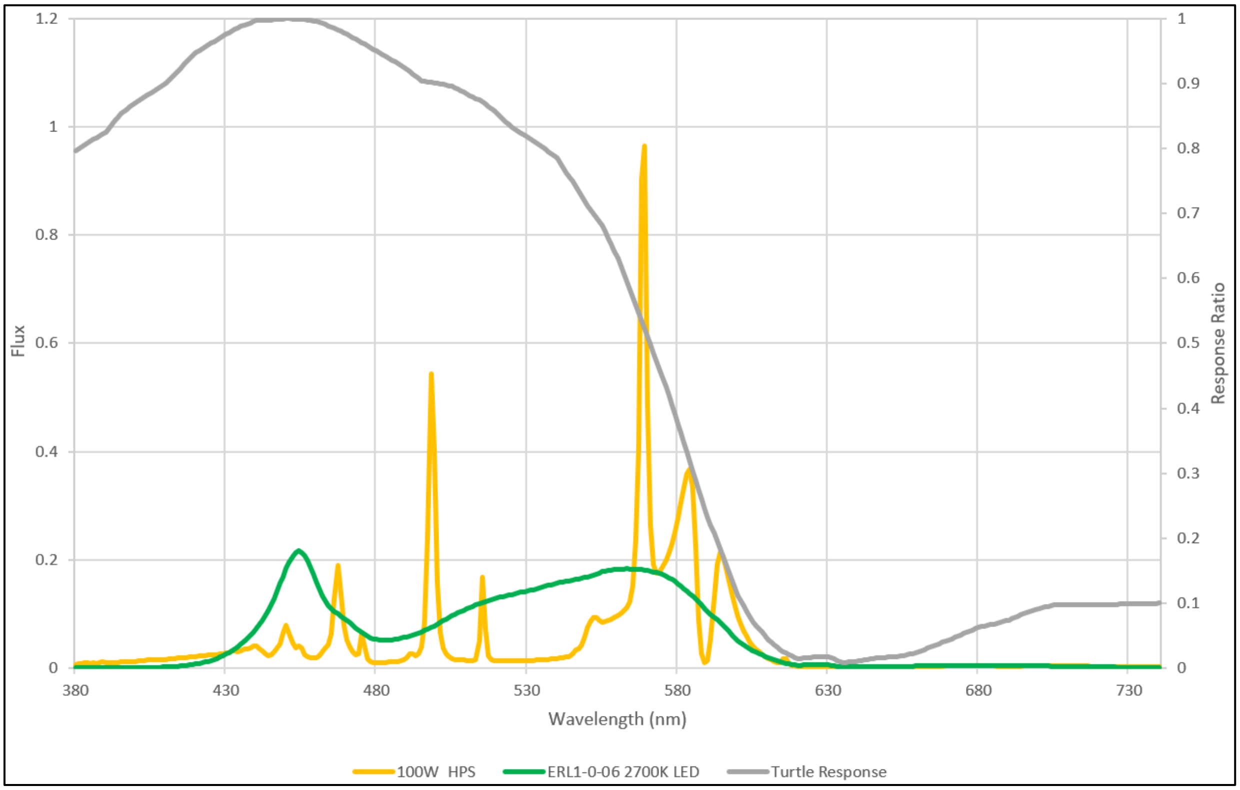
[19] Since HAST and GRST are both sea turtles with similar breeding and foraging habits, their response curves are thought to be similar. Because hatchlings are most susceptible to light attraction, the GRST hatchling response curve is used to evaluate impacts to all sea turtles considered in this report.

[20] The curve of the "Green Turtle Hatchling" response in the Longcore paper was digitized by Curren because the paper does not provide the actual data points.

These response curves can be overlain on the measured SPD of the two fixtures to assess how humans and sea turtles may perceive the lights differently. Figure 3.12 illustrates the unadjusted SPD of the two fixtures, the GE ERL1-0-06 2700K LED and the GE 100W 2100K HPS, which is discussed in Section 3.2.3.2.1.

Figure 3.13 and Figure 3.16 show how the human and GRST response curves, respectively, result in different perceptions of the same light source. With the sea turtle's peak response in the blue portion of the spectrum, the HPS' blue peaks become much closer to the HPS peaks in the yellow and orange portions of the spectrum; it also results in the LED's secondary/low hump in the blue portion of the spectrum having a higher flux value than the primary LED hump in the green to red portions of the spectrum.

Figure 3.16 LED and HPS Spectral Power GRST Hatchling Response



Source: PSI

When both fixtures are operated at 100 percent power, the sea turtle eye would perceive the LED fixture as being somewhat brighter (RPD=25%) than the 100W HPS: 21.8 vs. 17.0, respectively. The 280 County-owned streetlights within 500 feet of the shoreline (Section 2.1.5.3) are the primary concern when considering impacts to sea turtles. That subset of streetlights are almost all 150W HPS that will be converted to ERL1-0-06 2700K LED. In those cases, the LED will appear dimmer to the turtle than the HPS it replaces (RPD = 27.1 percent).

Because the HPS and LED fixtures broadcast the light they produce differently, the difference between them may appear greater depending on, for example, the angle at which the fixture is viewed. It has been observed that the LED fixture casts its light more evenly where it is intended (e.g., on the roadway) and has less light at low angles to the horizon, resulting in less light trespass into neighboring areas, including nearby beaches.

3.2.3.3.2 Streetlights in Proximity to Shoreline and Identified Sea Turtle Nesting Beaches

There are a limited number of County of Maui-owned streetlights in close proximity to the beaches identified as beaches where sea turtle nest. There are roughly 280 County-owned streetlights within 500 feet of the shoreline (Figure 2.3 and Figure 2.4). As summarized in Table 3.5, of those 280 streetlights, only 48 of them are within 500 feet of a beach identified as a sea turtle nesting beach.

Those 48 streetlights near a nesting beach have a greater likelihood of adversely effecting sea turtles than other streetlights within 500 feet of the shoreline. Of those, the streetlights visible from the beach on S. Kīhei Road near Kealia Beach and Kalepolepo Beach, where sea turtles have been affected by light attraction in the past (Section 3.2.2.2.4), have the greatest likelihood of adversely effecting sea turtles. Those streetlights would be among the first ones assessed for additional avoidance and minimization measures as specified in Section 2.1.5.3. Briefly, those avoidance and minimization measures may include: (*i*) shielding, (*ii*) relocating, (*iii*) redistributing/deactivating, (*iv*) adjusting height, (*v*) dimming, and/or (*vii*) utilizing alternative fixtures. The utilization of alternative fixtures, which would occur if other measures are deemed insufficient or ineffectual, would fully address DLNR's guideline 13 (Table 3.4) by employing streetlights that produce light wavelengths of 560 nm or longer.

Table 3.5 Known or Suspected HAST Nesting Beaches in the County of Maui

Island	*Coast*	*Hawaiian/Common Beach Name*	*Species Associated with Beach*	*Summary of County-owned Streetlights within 500 feet of Beach*
Maui	South	Kealia Beach	HAST	The nearest County road is S. Kīhei Road, there are 5 streetlights along that stretch of road, there is substantial resort development between the road and the beach.
		Kalepolepo Beach	HAST	S. Kīhei Road is immediately adjacent to the beach and there are 14 streetlights on this stretch of road, all on the mauka side of the road.
		Kawililīpoa Beach	HAST and GRST	There are several County roadways with 19 streetlights within 500 feet of the beach; in almost all cases, there is residential, apartment, resort, and recreational uses between the road and the beach.
		Pālauʻea Beach	HAST	There are no streetlights in the area.
		Puʻu Ōlaʻi	HAST	There are no streetlights in the area.
		Oneloa Beach	HAST	There are no streetlights in the area.
	West	Kamehameha Iki	GRST	There are 3 decorative streetlights on the makai side of Front Street, which are roughly 300 from the beach.
		Hanakaʻōʻō Beach	GRST	There are no streetlights in the area.
		Kaʻanapali Beach	GRST	There are no streetlights in the area.
		Honokahua Bay Beach	GRST	There are no streetlights in the area.
	North	Waiheʻe Beach	GRST	The nearest streetlight is over 800 feet away.
		Kaʻehu Beach	GRST	The nearest County road is Lower Waiehu Beach Road, the streetlights on that road are more than 500 feet from the beach.
		Kanahā Beach	GRST	The nearest County road is Amala Place, there are 4 streetlights on that road.
		Spreckelsville Beach	GRST	The nearest streetlight is on Paani Place; it is roughly 500 feet from the beach.
		Baldwin Beach	GRST	There are no streetlights in the area.
		Pāʻia Bay	GRST	The nearest streetlights are mauka of Hana Highway, more than 600 feet from the beach.
		Hoʻokipa Beach	GRST	There are no streetlights in the area.
		Hamakuapoko Beach	GRST	There are no streetlights in the area.
	East	Unnamed black sand beach	GRST	Unknown
		Hāna Bay	HAST	The nearest County roadway is Uakea Road, there are 2 streetlights within 500 feet of the beach.
		Koki Beach	HAST	There are no streetlights in the region.
		Hāmoa Bay	HAST	There are no streetlights in the region.
Molokaʻi	East	Hālawa Beach	HAST	There are no streetlights in the region.
	West	Moʻomoni Preserve	GRST	There are no streetlights in the region.
		Kawaʻaloa Bay	GRST	There are no streetlights in the region.
Lānaʻi	North	Polihua Beach	GRST	There are no streetlights in the region.
	North	Shipwreck Beach	HAST	There are no streetlights in the region.

Source: PSI.

3.2.3.3.3 Conclusions

The most important considerations when assessing the impact of the Proposed Action on sea turtles are:

- Sea turtles will not be adversely affected during short-term construction and maintenance activities.
- The selected LED fixture complies with more of the relevant wildlife guidelines than the HPS fixture (Section 3.2.3.1). The selected LED fixture is a full cut-off light, results in less light trespass than HPS, and would be controlled in a manner to avoid wildlife impacts.
- With the selected ERL1-0-06 2700K LED used to replace the 150W HPS near the shoreline, sea turtles will perceive the LEDs to be dimmer than the HPS they replace (Section 3.2.3.3.1).
- The County of Maui will conduct street lighting assessments in the vicinity of the shoreline (Section 2.1.5.3) as part of the Proposed Action. Through this assessment, additional avoidance and minimization measures will be administered, where appropriate, for sea turtles. Briefly, those measures may include shielding, relocating, redistributing/deactivating, adjusting height, dimming, and/or utilizing alternative fixtures. The utilization of alternative fixtures, which would occur if other measures are deemed insufficient or ineffectual, would fully address DLNR's guideline 13 (Table 3.4), which is primarily related to avoiding adverse effects on sea turtles.

Given these important factors, under the Proposed Action the County-owned streetlight's contribution to sea turtle light attraction, if any, would be expected to decline. The Proposed Action would <u>not</u> have a significant adverse effect on the subject sea turtles; it would have a beneficial effect on them.

When considering the potential impact of the No Action alternative, over the long term artificial light conditions would be similar to those that existing in 2018. The County-owned streetlight's contribution to sea turtle light attraction, if any, would not be expected to change.

3.2.3.4 ***<u>Blackburn's Sphinx Moth</u>***

The Blackburn's sphinx moth may be present in the vicinity of certain short-term construction and maintenance work associated with both the Proposed Action and the No Action alternative. However, neither alternative involves the installation of new utility poles or other ground disturbing activities. As described in Section 2.1.3, the equipment required to perform the field activities will temporarily park in the County roadway ROW, either on a paved surface or landscaped shoulders. The vast majority of the County roadway ROW where these activities will occur is regularly maintained and the plants on which the adult moth and the moth's larvae feed are not present. The locations with the greatest likelihood of these plants being present and hosting the moth in the work area are where the County's streetlights occur near designated critical moth habitat. The only location where streetlights are in close proximity to critical habitat for the moth is near Kanahā Beach Park and Kanahā Pond State Wildlife Sanctuary. As shown in Figure 3.17, as with other County ROW, the area where construction and maintenance vehicles would be situation during implementation of the alternatives near the park and sanctuary is well maintained and no plants potentially hosting the moth would be disturbed.

Figure 3.17 Photographs of Streetlights near Kanahā Beach Park and Kanahā Pond State Wildlife Sanctuary

Source: Google Streetview (photos identified as being captured in 2019).

Although there is no information regarding the moth's response to different light wavelengths, it is not anticipated that the light produced by the selected LED will affect moth behavior in a manner that is substantially different than HPS light. Given this and the lack of a short-term impact to the moth during construction and maintenance, it is assessed that neither the Proposed Action nor the No Action alternative will have a significant impact on the Blackburn's sphinx moth.

3.2.3.5 ***Hawaiian Hoary Bat***

The Proposed Action and No Action alternatives do not involve (*i*) trimming trees or shrubs taller than 15 feet, or (*ii*) installing or using barbed wire. As such, neither alternative is anticipated to have an effect on Hawaiian hoary bats.

3.3 HUMAN HEALTH AND SAFETY

3.3.1 EXISTING CONDITIONS

The County of Maui-owned streetlights provide adequate lighting where it is desired. Where they are present, they providing lighting in a manner that is consistent with applicable AASHTO guidelines. As such, they adequately provide for human health and safety within the County ROW.

The HPS streetlights utilized by the County comply with the guidelines by emitting light with discrete peaks in the blue, yellow, and orange portions of the spectrum with the peaks in the yellow and orange portions of the spectrum being dominant (Figure 3.12). This is what gives the HPS streetlights their yellowish color, a low CCT, and poor CRI (20.5). It also results in HPS lighting have a moderate blue light content of 10 percent (Table 2.3).

3.3.2 POTENTIAL IMPACTS

There has been some concern expressed that the conversion of streetlights from HPS to LED could have unintended adverse effects on human health. The American Medical Association's *Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting* paper (AMA 2016) indicated that the core concern was the disruption of circadian rhythmicity. It states that (*i*) several studies implicate bright, short wavelength (blue light) as having a short-term detrimental effects on sleep quality, and (*ii*) that a "white" LED lamp is at least 5 times more powerful in influencing circadian physiology than a HPS light based on melatonin suppression. The report then recommends that when communities convert to LED streetlights, they choose fully shielded fixtures with lower CCT ratings.

The County of Maui has selected LED streetlights (Section 2.1.2) that comply with the American Medical Association's recommendations: they are fully shielded and the vast majority of them have a low CCT rating of 2700K.

Many other metropolitan areas, including Honolulu, have converted their streetlights to LED over the last 10 years. Most of those areas have employed LEDs with 4000K and 3000K CCT ratings because they provide greater cost savings and better CRI than 2700K LEDs. Although CCT is not always a good predictor of blue light content, as can be seen in Table 2.3, when it comes to mass-produced LED streetlights, the higher the CCT, the higher the blue light content. Therefore, the bulk of the country has installed streetlights with a higher blue light content than the LED fixtures selected by the County of Maui. Substantial adverse human health effects attributable to changes in the artificial lighting in those metropolitan areas have not been reported.

Based on these considerations, the potential for the proposed Maui County Streetlight Conversion Project to have adverse effects on human health is nominal and less than significant.

3.4 SCENIC AND VISUAL RESOURCES

3.4.1 EXISTING CONDITIONS AND REGULATORY CONTEXT

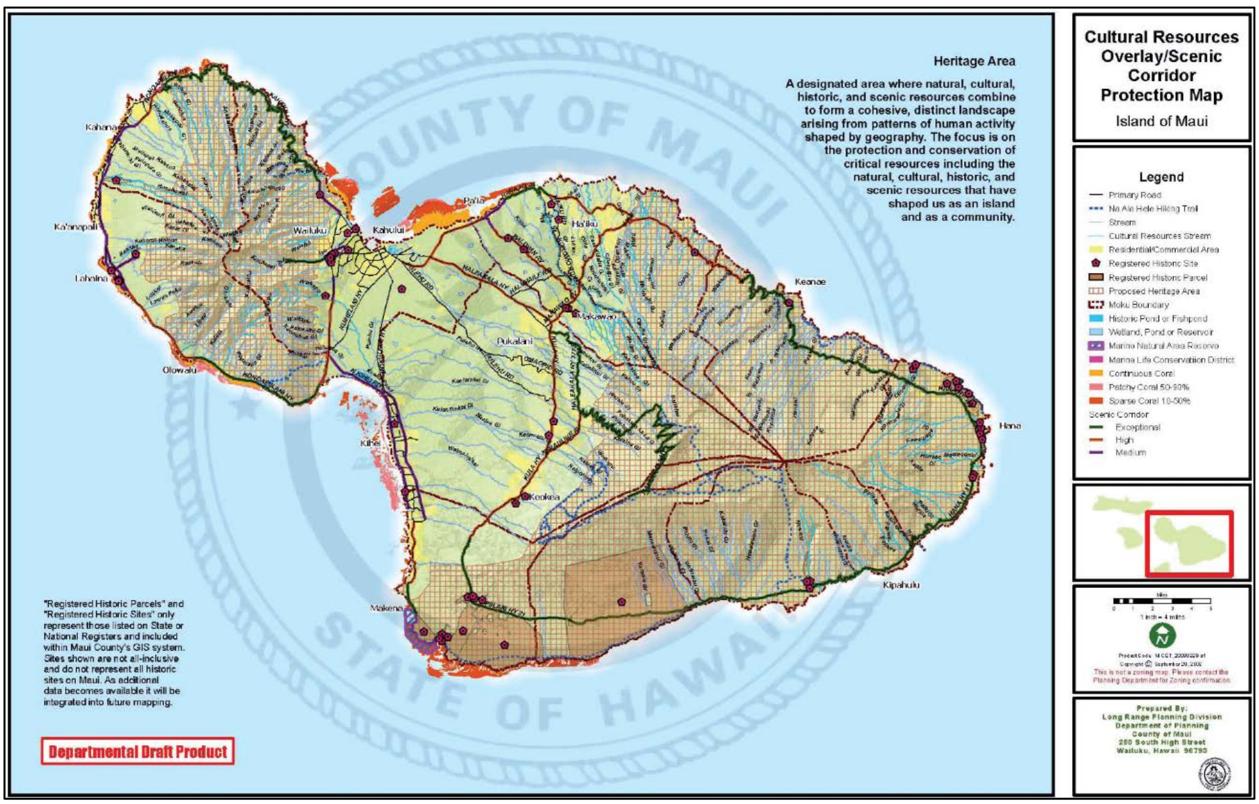
The *County of Maui 2030 General Plan: Countywide Policy Plan* identifies loss of scenic resources as a primary concern, and establishes the protection of scenic resources as a priority, stating that (County of Maui 2010):

> *The islands of Maui County are world famous for their beautiful scenic resources. These resources are diverse and include developed and undeveloped sections of shoreline, tropical rainforests, rugged valleys, mountains with jagged peaks, vast open spaces, historic towns and settlements surrounded by productive agricultural land, and panoramic Pacific Ocean views. The beauty of these scenic resources enriches the quality of life for residents and serves as a primary visitor attraction…Protection of valued scenic and natural resources is a priority…*

On behalf of the County of Maui, Long-Range Planning Division, Chris Hart & Partners, Inc. prepared the *County of Maui 2030 General Plan: Scenic Resources Inventory Report*. This report was sanctioned by the County of Maui to support the preparation of the *County of Maui 2030 General Plan*; it's purpose is to identify scenic roadway corridors based on an inventory and ranking of public views from major State and County roadways. The information in that inventory is used to develop policies and tools to better protect Maui's scenic resources for future generations. The scope of that inventory was limited to the island of Maui and did not include Molokai or Lānaʻi.

To construct the inventory, planners observed the following methodology: (*i*) document inland and coastal scenic resources and open space along major State and County Roadways within each region of Maui; (*ii*) describe and classify a view's content and character; (*iii*) document the views classified in the *Maui Coastal Scenic Resources Study* (1990); (*iv*) evaluate views based on the 1981 George Park's Highway, Alaska and 1996 Scenic America methodologies; (*v*) rate the views as exceptional, important, or unimportant; (*vi*) classify the corridor as urban, rural, agricultural, or natural; (*vii*) rate the corridor as exceptional, high, medium, or low; and (*viii*) develop maps identifying the location and rating of scenic corridors (Figure 3.18).

Figure 3.18 Maui Island Plan Scenic Corridor Protection Map



Source: County of Maui (2010)

The scenic resource protection policies of the *County of Maui 2030 General Plan* and the findings of the *Scenic Resources Inventory Report* were then applied to the *Maui Island Plan* (MIP), *Molokaʻi Community Plan* (MCP), and *Lānaʻi Community Plan* (LCP) prepared by the County of Maui, Planning Department, Long Range Planning Division. In addition to depicting scenic corridors, these plans also define the threats to scenic resources which it is intended to address: (*i*) degradation of scenic resources; (*ii*) limited access to scenic resources; (*iii*) inappropriate building and landscape design; and (*iv*) loss of agricultural and open lands to development (County of Maui 2012). Pursuant to that, MIP, §2.5 summarizes the scenic resources issues as follows:

> ***GOALS, OBEJCTIVES, POLICIES, AND ACTIONS***
>
> ***Goal:***
>
> *2.5 Maui will continue to be a beautiful islands steeped in coastal, mountain, open space, and historically significant views that are preserved to enrich the residents' quality of life, attract visitors, provide a connection to the past, and promote a sense of place.*
>
> ***Objective:***
>
> *2.5.1 A greater level of protection for scenic resources.*
>
> ***Policies:***
>
> *2.5.1.a Protect views to include, but not be limited to, Haleakalā, ʻĪao Valley, the Mauna Kahalawai (West Maui Mountains), Puʻu Ōlaʻi, Kahoʻolawe, Molokini, Molokaʻi, and Lānaʻi, Mauna Kea, Mauna Loa, sea stacks, the Pacific Ocean, and significant water features, ridgelines, and landforms.*
>
> *2.5.1.b Identify, preserve, and provide ongoing management of important scenic vistas and open space resources, including mauka-to-makai and makai-to-mauka view planes.*
>
> *2.5.1.c Protect "night sky" resources by encouraging the implementation of ambient light ordinances and encouraging conversion of all sources that create excessive light pollution, affecting our ability to view the stars.*
>
> *2.5.1.d Protect ridgelines from development where practicable to facilitate the protection of public views.*
>
> *2.5.1.e Protect scenic resources along Maui's scenic roadway corridors.*

The *Maui Island Plan* goes on to lay out a series of implementing actions intended to achieve the objectives cited above, including Implementing Action 8:

> *2.5.1-Action 8 Develop and adopt regulations to protect night-sky resources from encroachment by the built environment, and limit night-light emissions and light-intensity levels.*

The statutory requirements of the *Street Lighting Standards* (MC §15-201, Appendix A) were developed with these goals, objectives, policies, and implementing actions as guiding principles. The *Molokaʻi Island Plan* (2018) and *Lānaʻi Island Plan* (2016) have similar provisions, although they lack the same level of specificity, and identify only generalized scenic resources to be protected.[21]

Table 3.6 summarizes the scenic resources designated for protection in each plan.

[21] The *Molokaʻi Community Plan*, §3.3A notes that, "a photo inventory of Molokaʻi' s scenic resources was conducted and mapped but has not been rated for resource value. The Maui County General Plan 2030 Scenic & Historic Resources, Inventory & Mapping Methodology Reports provide guidance on visual quality ratings based on eleven factors used to evaluate and prioritize scenic resources. In addition, the inventory and mapping work has not yet occurred to develop the Scenic Roadway Corridors Management Plan and Design Guidelines."

Table 3.6 Protected Scenic Resources in the County of Maui

Source	*Island*	*Resource*
Maui Island Plan, §2.5.1a	Maui	Protect views to include, but not be limited to, Haleakalā, ʻĪao Valley, the Mauna Kahalawai (West Maui Mountains), Puʻu Ōlaʻi, Kahoʻolawe, Molokini, Molokaʻi, and Lānaʻi, Mauna Kea, Mauna Loa, sea stacks, the Pacific Ocean, and significant water features, ridgelines, and landforms.
Molokaʻi Community Plan, §3.3	Molokaʻi	Scenic views and corridors are abundant and diverse on Molokaʻi. They include land, sky, sea, and historic structures at a variety of scales and locations: urban, rural, agricultural, and open spaces. Views of nature, including ocean, hill slopes, valleys, ridgelines, springs, waterfalls, and coastlines can be seen nearly continuously from roadways that cross the island or follow the coast.
Lānaʻi Community Plan, §5	Lānaʻi	Scenic views and scenic view corridors are abundant and diverse on Lānaʻi. Scenic views combine land sky sea and historic structures at a variety of scales and locations including urban rural agricultural and open natural settings. Views of nature such as the ocean hill slopes valleys ridgelines and coastlines are abundant from the roadways that cross the island or follow the coast.[22]

Source: County of Maui (2010, 2016, 2018)

In 2018, the County of Maui adopted MC §15-201 *Street Lighting Standards*. The purpose of these standards, as defined in MC §15-201-3, is stated as follows:

> *<u>§15-201-3 Purpose</u>. These rules provide standards for outdoor lighting that, while providing a level of safety for vehicular and pedestrian traffic, do not excessively interfere with nighttime viewing and avoid glare and light trespass onto private property. These rules also encourage the conservation of electricity.*

This updated policy allows the County of Maui to take advantage of broad spectrum (i.e., white light) street lighting technologies, including LED fixtures. These advanced LED technologies are more energy efficient and longer lasting than the HPS fixtures currently in general use around the County of Maui. This new policy also allows the County of Maui to select street lighting that dim in the late evening hours when reduced pedestrian and vehicular traffic justify lower light levels. The purpose of the following subsections is to discuss the potential impact the introduction of this new technology may have on visual and aesthetic resources throughout Maui, Molokaʻi, and Lānaʻi.

3.4.2 LIGHTING SCIENCE AND DEMONSTRATION PROJECT FINDINGS

For several decades the lighting community has discussed the need to revise the photometric practice to recognize that the color content of light has a significant effect on vision, particularly peripheral vision, in outdoor, low light conditions such as nighttime drivers and pedestrians experience; this is sometimes referred to a *mesopic* vision. The International Commission on Illumination's (CIE, from its French acronym) *Recommended System of Mesopic Photometry* (CIE

[22] The *Maui County General Plan 2030: Scenic Resources Inventory* and *Mapping Methodology* provides guidance on visual quality ratings based on eleven factors. A partial photo inventory of Lānaʻi scenic resources was conducted and resources were mapped but not rated for resource value. MCC, §2.80B.070(E)(9) requires the community plan to contain a list of scenic sites and resources. This *Lānaʻi Community Plan* contains policies and actions that focus efforts to complete the inventory and rating of Lānaʻi scenic resources

2010), summarizes the scientific basis for the recommended system and provides guidelines for its use and application.[23] Following that, the Illuminating Engineering Society of North America (IES) published *Technical Memorandum 12 Spectral Effects of Lighting on Visual Performance at Mesopic Lighting Levels* (IES 2012). The conclusion of both of these documents is that an HPS fixture, which gives off an orange-pink light, can be replaced with a broad spectrum white (i.e., LED) streetlight that emits less total light for equal or better visibility. LED street lighting has become an attractive technology because it provides as good or better visibility while emitting less total light and requiring less total energy.

As part of the demonstration project characterized in Section 2.1.1, six different LED light fixtures from three manufacturers were installed on existing poles at regular intervals along Maui Lani Parkway. In addition to assessing various parameters such as color content, S/P ratio, etc. it also considered the holistic visual effect that each light fixture produced when deployed in the field (Table 2.2). As can be seen from the photographs in that table, some fixtures including the selected GE 2700K LED produce a relatively evenly-distributed, broad spectrum white light which allows for true to life color recognition. Conversely, lights which have a more skewed light spectrum distribution, like the C&W 2400K and HPS 2100K, produce a light which is predominantly composed of red, orange, and yellow light, which tinges the illuminated area accordingly.

Due of this phenomenon, LED fixtures such as the selected GE 2700K LED streetlight have the potential to provide a more accurate color rendition than the existing HPS fixtures, and without emitting excessive amounts of potentially harmful blue light. This understanding has been tested and substantiated in numerous conversion projects in the United States and via the Maui demonstration project, with confirming photographs provided in Table 2.2.

3.4.3 Potential Impacts

Neither the Proposed Action nor the No Action alternative will have any direct adverse impacts on the protected scenic or visual resources identified in Maui County, Maui, Molokaʻi, or Lānaʻi planning documents and summarized in Table 3.6. All of these scenic and visual resources would continue to appear as they do now; no new visual element that could block or obscure the identified views will be installed. Only the most attentive viewers would notice the difference between an HPS streetlights fixture and a LED streetlights fixture while they are inert. In addition, because most of the protected vistas are either invisible or only partially visible during the nighttime, any change in street lighting will only have the potential to create a very minor impact.

The Proposed Action would have modest beneficial impacts to nighttime scenic and visual resources, and more generally to County of Maui ROWs on all three islands, during nighttime and low light conditions. These modest benefits would accrue due to several factors:

- The general consensus of lighting and transportation officials is that an HPS fixture, which gives off an orange-pink light, can be replaced with a broad spectrum white (i.e., LED) streetlight that provide equal or better visibility, with more faithful color rendition (a higher CRI), while emitting fewer lumens.

[23] The CIE is an international, independent authority on illumination with member countries spanning the globe. The CIE provides an international forum for the discussion of all matters relating to the science, technology, and art in the fields of light and lighting. It also publishes standards, reports, and other publications concerned with the science, technology, and art of lighting.

- The proposed GE 2700K LED fixtures are dimmable, allowing DPW to use only as much light as needed, where and when it is needed.
- The proposed GE 2700K LED fixtures create less light trespass, defined as light directed laterally away from the intended area of illumination, and less light pollution, defined as upwards directed light that can contribute to nighttime "glow," reduction in night sky visibility, and light attraction by native wildlife.

For these reasons, DPW has concluded that Proposed Action will have no adverse impacts and will provide modest benefits to scenic and visual resources, as identified in County of Maui planning documents.

When considering the potential impact of the No Action alternative, over the long term artificial light conditions would be similar to those that existed prior to 2019. The impact of the County-owned streetlights on scenic and visual resources would not be expected to change.

3.5 CUMULATIVE IMPACTS

This section evaluates whether the Maui County Streetlight Conversion Project, while individually limited in scope, might contribute to significant impacts on the natural or human environment when considered cumulatively along with other projects in the County of Maui. A cumulative impact is an impact on the environment which results from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency, organization, or individual undertakes such other actions. A cumulative impact occurs when the incremental environmental effects of the project added to other past, present, and reasonably foreseeable future actions result in substantial significant impacts.

Relevant past actions within the context of the Proposed Action include the development of County's roadway network on which streetlights are now operated. The present action is the Proposed Action, which has a broad geographic extent but is not part of a larger project and does not commit the County to any specific future course of action. Relevant reasonably foreseeable future actions include those actions within the County of Maui that have progressed beyond the conceptual stage and would involve the installation of streetlights by the County or by another entity with the intent of dedicating the street and streetlights to the County (e.g., a new housing development). There are several such reasonably foreseeable future actions, including Waikapu Country Town, Wailuku Apartments, Waikapu Development Ventures, Haliimaile Residential Subdivision, Waiale Road Extension, Liloa Drive (North-South Collector Road) Extension, Kaiaulu o Kukuia, Kaiaulu o Halelea, Kaiaulu o Kupuohi, Kehalani Project District, Hale Kaiola, and Kilohana Makai. The broad impacts of those foreseeable actions are evaluated in project-specific documents and permit applications.

The Proposed Action would not meaningful change the character of the urban landscape created by past actions. The Proposed Action would not require foreseeable actions to meaningfully modify their plans or resulting in their impacts being substantially different than those disclosed. In fact, relative to the No Action alternative, the Proposed Action would avoid and minimize the potential impacts of past and future streetlights as outlined in Section 3.2.3. Furthermore, relative to the No Action alternative, the Proposed Action is not anticipated to have a significant impact on other resources (Sections 3.1, 3.3, and 3.4). Consequently, the use of the selected LED streetlights by past, present, and foreseeable actions would not result in a significant cumulative effect on any resources.

Chapter 4: CONSISTENCY WITH LAND USE PLANS, POLICIES, AND CONTROLS

This chapter discusses the relationship of the Maui County Streetlight Conversion Project to applicable land use plans, policies, and controls at the County, State, and Federal level. Compliance with existing regulations and requirements helps ensure that the Proposed Action will not result in significant impacts on current land use policies and programs at the local, regional, and national level.

4.1 COUNTY OF MAUI

4.1.1 COUNTY OF MAUI 2030 GENERAL PLAN: COUNTYWIDE POLICY PLAN (2010)

The *Countywide Policy Plan* (CWP) was adopted by Ordinance No. 3732 and took effect on March 24, 2010 (it superseded the *Maui General Plan*, which had last been updated on April 23, 1993). The CWP provides broad goals, objectives, policies, and implementing actions that indicate the desired direction for the future of the County of Maui. This includes: (*i*) a vision statement and core values; (*ii*) an explanation of the plan-making process; (*iii*) a description and background information regarding Maui County today; (*iv*) identification of guiding principles; and (*v*) a comprehensive list of countywide goals, objectives, policies, and implementing actions related to a set of core themes. The core themes of the CPW are:

- Protect the Natural Environment
- Preserve Local Cultures and Traditions
- Improve Education
- Strengthen Social and Healthcare Services
- Expand Housing Opportunities for Residents
- Strengthen the Local Economy
- Improve Parks and Public Facilities
- Diversify Transportation Options
- Improve Physical Infrastructure
- Promote Sustainable Land Use and Growth Management
- Strive for Good Governance

Furthermore, the CWP provides the policy framework for the development of the *Maui Island Plan* and the nine Community Plans. While the CWP does not provide any specific guidance regarding street lighting, it does contain several provisions applicable to the Maui County Streetlight Conversion Project, including those related to reducing the County's carbon footprint and protecting the night sky. The following sections of the CWP contain policies and goals most applicable to the Maui County Streetlight Conversion Project, followed by a discussion of their relationship to the Proposed Action:

Countywide goals, objectives, policies, and actions

A. Protect the Natural Environment

Goal: Maui County's natural environment and distinctive open spaces will be preserved, managed, and cared for in perpetuity.

Objective:

3. Improve the stewardship of the natural environment.

a. Preserve and protect natural resources with significant scenic, economic, cultural, environmental, or recreational value.

f. Reduce air, noise, light, land, and water pollution, and reduce Maui County's contribution to global climate change.

Discussion: The Maui County Streetlight Conversion Project is consistent with the goal of preserving, managing, and caring for the natural environment. The proposed conversion of streetlights in the County of Maui from GE 2100K HPS to GE 2700K LED fixtures will result in a reduced expenditure of energy for streetlights and concomitant savings in total cost for street lighting. An HPS 100W fixture requires 150W of power; the additional 50W is consumed by the ballast. The selected LED replacement fixture (model ERL1-0-06 2700K) requires only 47W when operated at full power (Appendix C). This results in a minimum estimated power savings between the existing and proposed fixtures of approximately 67 percent, to adequately light the ROW. Further, this figure represents a minimum savings, because the new LED fixtures are dimmable and will be operated dimmed at least part of the year. While there are too many confounding factors to determine the exact reduction in greenhouse gas emissions, there is little doubt that the substantial reduction in energy required would also result in lower emissions of airborne pollutants.

In addition, the Proposed Action would reduce light pollution in general, including sky glow, and reduce the likelihood of light-induced wildlife impacts because: (*i*) the proposed GE 2700K LED fixtures produce less light than the HPS fixtures they would replace, while still meeting applicable guidelines; and (*ii*) The LED fixtures are fully shielded and create less light trespass than the HPS fixtures they would replace. Because the Proposed Action would result in reductions of air and light pollution in the County of Maui, it will better protect the natural environment of the County of Maui, and be consistent with the goals and objectives of the CPW.

Additional discussion of the Proposed Action's consistency with the CPW's provisions related to scenic and visual resources may be found in Section 3.4.1.

4.1.2 MAUI ISLAND PLAN (2012)

Discussion of the Proposed Action's consistency with the MIP's provisions related to scenic and visual resources may be found in Section 3.2.2.1.

The MIP is intended to assess conditions, trends, and issues specific to the island of Maui. It provides policy direction for the use and development of land, extension and improvement of transportation services and infrastructure, development of community facilities, expansion of the island's economic base, provision of housing, and protection of natural and cultural resources. In addition, it goes on to establish policies to manage change and to direct decisions about future land use and development. Finally, it provides the foundation to set capital improvement priorities, revise zoning ordinances, and develop other tools for policy implementation.

With specific regard to land use and urban development, the MIP notes the following:

> *Streets are one of the most basic elements of urban form – they play a significant role in shaping the framework and character of neighborhoods. Inappropriate street design can encourage speeding, limit pedestrian mobility, and degrade the aesthetic quality of the built environment. Well-designed streets generally have the following characteristics:*
>
> - *Proper proportion and width;*
> - *Relationship to adjoining buildings and setbacks;*
> - *Shade;*
> - *Sidewalks;*
> - *Street trees;*
> - *Lighting;*

In addition to the recommendation for effective lighting as a part of well-designed streets, the MIP specifically advocates for greater energy efficiency and self-sufficiency. While much of the discussion understandably relates to the identification and development of new sources of renewable energy, there is considerable emphasis given to energy efficiency on the part of consumers, including the County of Maui, in its discussion of energy policy:

> *Maintaining a stable energy grid requires regulation and management of energy generation and distribution resources to enable diverse, distributed suppliers to generate energy in a way that optimizes available supplies while maintaining reliable electric service. Multiple factors are involved with maintaining a stable energy grid including improving energy generation, transmission and distribution infrastructure, providing more options for suppliers and end-users to regulate energy generation and consumption, and creating viable means for new energy suppliers to feed into the grid.*

This discussion of energy policy is further operationalized in Chapter 6 of the MIP, where it establishes the following goal, objective, and policy:

> *GOAL, OBJECTIVES, POLICIES, AND ACTIONS*
>
> *Goal:6.10*
>
> *Maui will meet its energy needs through local sources of clean, renewable energy, and through conservation.*
>
> *Objective:*
>
> *6.10.1 Reduce fossil fuel consumption. Using the 2005 electricity consumption as a baseline, reduce by 15 percent in 2015; 20 percent by 2020; and 30 percent by 2030.*

Policies:

6.10.1.a Support energy efficient systems, processes, and methods in public and private operations, buildings, and facilities.

6.10.1-Action 1 Work with the Energy Management Program to:

(1) Audit County facilities, operations, and equipment;

(2) Develop programs and projects to achieve greater energy efficiency and

reduction in fossil fuel use;

Discussion: As the above passages of the MIP make clear, it is a policy document oriented towards establishing broad goals, objectives, and policies across a wide variety of domains, often with significant overlap. Specific priorities identified in the selected sections above include: (*i*) well designed and well-lit roadways; (*ii*) a stable electrical grid produced, in part, by more efficient and better regulated energy consumption; and (*iii*) a resultant reduction in the Count of Maui's dependence on imported fossil fuels for power. The proposed Maui County Streetlight Project is consistent with, and upholds, each of these broad purposes by implementing use of more efficient, dimmable LED street lighting. As discussed in Section 1.2, the GE 2700K LED fixtures which have been selected are fully compliant with the design guidelines adopted into law as MC §15-201 *Street Lighting Standards in the County of Maui*. In addition, as shown in Table 2.3, the LED fixtures consume approximately 67 percent less energy when running at full power when compared to the existing GE 2100K HPS fixtures now in use, while providing further energy-savings potential via their scalable dimming technology. Finally, by reducing their demand for energy to supply street lighting, the County of Maui can make a significant contribution to the reduction in demand for fossil fuel-powered generation.

4.1.3 MOLOKAʻI COMMUNITY PLAN (2018)

The *Molokaʻi Island Community Plan Update* revises the 2001 MCP and maps, adding new elements required by MCC §2.80B, while integrating policies from the *County of Maui 2030 General Plan*. The updated MCP consists of a vision statement, goals, policies and actions to guide the desired direction of the island's future. Technical studies and issue papers provide data to support the plan's policy recommendations. The final document also includes an implementation and monitoring plan.

In Section 8.6 of the MCP, the report notes that the cost of power in the County of Maui is higher than on the U.S. mainland for a variety of reasons, including no economies of scale in Hawaiʻi's market due to the relatively small population base, the use of imported crude oil to fuel the power plants, and Hawaiʻi's consequent vulnerability to fluctuations of the global crude oil market. With these challenges in mind, the MCP establishes goals, policies, and actions intended to address them:

C. GOAL, POLICIES, AND ACTIONS

Goal Molokaʻi will meet its energy needs through development of local clean renewable energy sources and implementation of energy efficiency and conservation measures.

Policies

3. Support programs that provide incentives to use more efficient vehicles, appliances, lighting, and other energy consuming devices.

Discussion: While the Maui County Streetlight Conversion Project will not, in of itself, develop any sources of locally-produced power, renewable or otherwise, it will make a substantial positive contribution to improving Molokai's energy efficiency and conservation. The proposed GE 2700K LED fixtures consume approximately 67 percent less energy when running at full power when compared to the existing GE 2100K HPS fixtures (and providing further energy-savings potential via their dimming technology). Finally, by reducing their demand for energy to supply street lighting, the County of Maui can make a significant contribution to the reduction in demand for fossil fuel-powered generation. Because of the MCP's stated support for programs that incentivize efficient lighting, DPW believes that the Proposed Action is consistent with these goals and policies of the MCP.

4.1.4 LĀNAʻI COMMUNITY PLAN (2015)

Discussion of the proposed action's consistency with the LCP's provisions related to scenic and visual resources may be found in Section 3.4.1.

The LCP was first adopted in 1983 and first updated in 1998. Between 2004 and 2012, new plan elements were imposed by state law, and in 2015 the LCP Update was issued to bring the issues and strategies identified in the LCP into the 21st century. The LCP is organized into thirteen chapters, a maps section and an appendices. The specific domains addressed in the LCP include: (*i*) environment and natural Resources; (*ii*) hazard mitigation; (*iii*) cultural-historic resources; (*iv*) scenic resources; (*v*) economic development; (*vi*) infrastructure and utilities; (*vii*) public facilities and services; (*viii*) land use; (*ix*) urban design; (*x*) housing; (*xi*) governance; (*xii*) implementation; and (*xiii*) monitoring. While most of the provisions of the LCP do not relate directly to street lighting or related issues, substantial emphasis is placed on improving energy efficiency and reducing the island's reliance on electricity produced with fossil fuels:

B ISSUES AND STRATEGIES

Issue 1 Lanai has the highest electricity rates in the state

Strategy 1A Work with MECO and PUC Consumer Advocate to find ways to reduce electricity rates for Lanai

Strategy 1 B Promote conservation and reduction of power usage by residential commercial and resort consumers

Strategy 1C Explore technologies and the integration of information technologies and mechanisms that would improve the efficiency and reliability of the electrical grid

Further, in the broader context noted above, the LCP promotes efficiency via adoption of new, more efficient lighting technology:

C GOAL POLICIES AND ACTIONS

GOAL Increase the proportion of electricity that is generated from renewable sources to reduce electricity costs and Lanai dependence on fossil fuels

Policies

1 Support the increased use of renewable energy sources

2 Maintain and support consumer incentives to promote the installation of renewable energy systems

3 Promote energy conservation and awareness programs including the use of compact fluorescent lights CFL solar hot water and conservation behaviors

Discussion: As with the MIP and MCP, the LCP is a broad planning document that only tangentially touches on the topic of lighting, infrastructure, and energy efficiency measures. However, in that context, it is clear that the Maui County Streetlight Conversion Project is consistent with these common issues, strategies, goals, and policies of the LCP. Via the adoption of 67 percent more efficient GE 2700K LED fixtures, the Proposed Action promotes energy conservation and the reduction of power usage for the purposes of street lighting across the County of Maui.

4.1.5 MAUI COUNTY CODE

The Maui County Streetlight Conversion Project's consistency with applicable provisions of the Maui County Code, specifically the statutory requirements for street lighting contained in MC §15-201 *Street Lighting Standards*, is discussed in Section 2.1.2 of this report and summarized in Table 2.7.

4.2 STATE OF HAWAI‘I

4.2.1 HAWAI‘I STATE PLAN, HRS CHAPTER 226

Adopted in 1978 and last revised in 1991, the *Hawai‘i State Plan* is intended to guide the long-range development of the State by:

- Identifying goals, objectives, and policies for the State and its residents;
- Establishing a basis for determining priorities and allocating resources; and
- Providing a unifying vision to enable coordination between the various counties' plans, programs, policies, projects and regulatory activities to assist them in developing their county plans, programs, and projects and the State's long-range development objectives.

The *Hawai‘i State Plan* is a policy document. It depends on implementing laws and regulations to achieve its goals. While not all sections of the *Hawai‘i State Plan* are directly applicable to the Maui County Streetlight Conversion Project, the most relevant are identified and discussed below:

§226-18 Objectives and policies for facility systems--energy. (a) Planning for the State's facility systems with regard to energy shall be directed toward the achievement of the following objectives, giving due consideration to all:

(2) Increased energy security and self-sufficiency through the reduction and ultimate elimination of Hawaii's dependence on imported fuels for electrical generation and ground transportation;

(b) To achieve the energy objectives, it shall be the policy of this State to ensure the short- and long-term provision of adequate, reasonably priced, and dependable energy services to accommodate demand.

(c) To further achieve the energy objectives, it shall be the policy of this State to:

(2) Ensure that the combination of energy supplies and energy-saving systems is sufficient to support the demands of growth;

(4) Promote all cost-effective conservation of power and fuel supplies through measures, including:

(A) Development of cost-effective demand-side management programs;

(C) Adoption of energy-efficient practices and technologies; and

(D) Increasing energy efficiency and decreasing energy use in public infrastructure;

(5) Ensure, to the extent that new supply-side resources are needed, that the development or expansion of energy systems uses the least-cost energy supply option and maximizes efficient technologies;

(6) Support research, development, demonstration, and use of energy efficiency, load management, and other demand-side management programs, practices, and technologies;

(8) Support actions that reduce, avoid, or sequester greenhouse gases in utility, transportation, and industrial sector applications;

Discussion: These relevant provisions of the *Hawai'i State Plan*, given statutory status as HRS, §226, make clear the emphasis the State of Hawai'i places on developing energy efficiency and a reduction in energy use for public infrastructure. As noted previously, while the proposed Maui County Streetlight Conversion Project will not develop new sources of local, clean energy, it does provide an opportunity to significantly reduce the amount of electricity the County of Maui uses to meet its street lighting needs, much of which would likely be produced by fossil-fuel fired power plants. Because the Proposed Action of replacing the existing GE 2100K HPS fixtures with new, more efficient GE 2700K LED streetlights will offer an estimated 67 percent energy savings when operated at full power, DPW has concluded that the Maui County Streetlight Conversion Project promotes the adoption of energy efficient technology, will reduce the County's use of electrical power, and is consistent with these objectives and policies of the *Hawai'i State Plan*.

4.2.2 STATE LAND USE LAW, HRS CHAPTER 205

Chapter 205, HRS established the State Land Use Commission and gives this body the authority to designate all lands in the State as Urban, Rural, Agricultural, or Conservation District. The counties make all land use decisions within the Urban District in accordance with their respective county general plans, development plans, and zoning ordinances. The counties also regulate land use in the State Rural and Agricultural Districts, but within the limits specified by HRS, Chapter 205. The basic function of each of the districts, briefly summarized, are as follows (see HRS, §205-2):

- The *Urban District* establishes the boundaries for areas currently urban use and provide a sufficient reserve area for foreseeable future urban growth.
- The *Rural District* is comprised of land composed primarily of small farms mixed with very low-density residential lots, generally consisting of not more than one house per half-acre and a minimum lot size of not less than one-half acre.
- The *Agricultural District* gives the greatest possible protection to those lands with a high capacity for intensive cultivation of food crops, crops for bioenergy, orchards, forage, forestry, animal husbandry, and game or fish propagation.
- The Conservation District establishes the boundaries of forest and water reserve zones.

Because the Maui County Streetlight Conversion Project encompasses all of Maui, Molokai, and Lanai, work related to it is likely to occur in all four State Land Use Districts. However, because all of the work is limited to the replacement of existing GE 2100K HPS streetlights with new GE 2700K LED fixtures, no new permitting such as a Conservation District Use Permit, is required. Further, this conversion of existing streetlights will not prevent, limit, or otherwise affect appropriate uses of these districts. Thus, DPW has concluded that the proposed action is consistent with State of Hawaiʻi land use law, as defined in HRS, §205.

4.2.3 COASTAL ZONE MANAGEMENT PROGRAM, HRS 205A

The objectives of the Hawaiʻi Coastal Zone Management (CZM) Program are set forth in Hawaiʻi Revised Statutes, Chapter 205A. The program is intended to promote the protection and maintenance of valuable coastal resources. All lands in Hawaiʻi are classified as valuable coastal resources. The State Office of Planning and Sustainable Development administers Hawaiʻi's CZM Program. A general discussion of the Proposed Action's consistency with the objectives and policies of Hawaiʻi's CZM Program follows.

4.2.3.1 ***Recreational Resources***

Objective: Provide coastal recreational opportunities accessible to the public.

Policies:

1. *Improve coordination and funding of coastal recreational planning and management; and*
2. *Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:*
3. *Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;*
4. *Requiring replacement of coastal resources having significant recreational value including, but not limited to, surfing sites, fishponds, and sand beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;*

5. *Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;*
6. *Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;*
7. *Ensuring public recreational uses of county, state, and federally owned or controlled shoreline lands and waters having recreational value consistent with public safety standards and conservation of natural resources;*
8. *Adopting water quality standards and regulating point and nonpoint sources of pollution to protect, and where feasible, restore the recreational value of coastal waters;*
9. *Developing new shoreline recreational opportunities, where appropriate, such as artificial lagoons, artificial beaches, and artificial reefs for surfing and fishing; and*
10. *Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, and county authorities; and crediting such dedication against the requirements of section 46-6.*

Discussion: The proposed action will have no effect on coastal recreational resources. While some portion of the conversion process and resulting LED street lighting will be visible from nearby portions of the coastline, once complete, the area will be indistinguishable from its current state during the daytime, with only minor differences notable at night due the change in lighting. No aspect of the project will disrupt any ongoing use of coastal recreational areas or resources.

4.2.3.2 ***Historic Resources***

Objective: *Protect, preserve, and, where desirable, restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.*

Policies:

1. *Identify and analyze significant archaeological resources;*
2. *Maximize information retention through preservation of remains and artifacts or salvage operations; and*
3. *Support state goals for protection, restoration, interpretation, and display of historic resources.*

Discussion: The Maui County Streetlight Conversion Project is solely intended to convert existing GE 2100K HPS streetlights to new, more efficient GE 2700K LED fixtures. All of the work related to the project will occur on existing poles located in existing County of Maui ROWs and similar areas. No new earthwork of any kind will occur as part of the proposed action. Section 3.1.2 discusses the reasons why DPW has concluded that the Proposed Action does not have the potential to affect archaeological or historic resources. SHPD will be provided with a copy of this EA for review and their comments, if any, will be reproduced in the Final Environmental Assessment (FEA).

4.2.3.3 ***Scenic and Open Space Resources***

Objective: *Protect, preserve, and, where desirable, restore or improve the quality of coastal scenic and open space resources.*

Policies:

1. *Identify valued scenic resources in the coastal zone management area;*
2. *Ensure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;*
3. *Preserve, maintain, and, where desirable, improve and restore shoreline open space and scenic resources; and*
4. *Encourage those developments that are not coastal dependent to locate in inland areas.*

Discussion: Coastal open space and scenic resources will not be adversely affected by the Maui County Streetlight Conversion Project. While work related to the proposed conversion of streetlights will be visible from some public vantage points, this would be for only a brief time. Once converted, the streetlights should be nearly indistinguishable from their existing condition during the daytime, with the difference in lighting quality noticeable only at night, with truer colors and less light pollution and trespass than is the case at the present time. The Proposed Action will require no modification of natural landforms and will not interfere with public views of, or along, the shoreline.

4.2.3.4 ***Coastal Ecosystems***

Objective: *Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.*

Policies:

1. *Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;*
2. *Improve the technical basis for natural resource management;*
3. *Preserve valuable coastal ecosystems, including reefs, of significant biological or economic importance;*
4. *Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land and water uses, recognizing competing water needs; and*
5. *Promote water quantity and quality planning and management practices that reflect the tolerance of fresh water and marine ecosystems and maintain and enhance water quality through the development and implementation of point and nonpoint source water pollution control measures.*

Discussion: The Proposed Action will not interact with or effect coastal ecosystems or any other waterbody, as described in Section 3.1.6.

4.2.3.5 ***Economic Uses***

Objective: *Provide public or private facilities and improvements important to the State's economy in suitable locations.*

Policies:

1. *Concentrate coastal dependent development in appropriate areas;*
2. *Ensure that coastal dependent development such as harbors and ports, and coastal related development such as visitor industry facilities and energy generating facilities, are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and*
3. *Direct the location and expansion of coastal dependent developments to areas presently designated and used for such developments and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:*
    - *i. Use of presently designated locations is not feasible;*
    - *ii. Adverse environmental effects are minimized; and*
    - *iii. The development is important to the State's economy.*

Discussion: The Maui County Streetlight Conversion Project is not a coastal development and would not lead to any changes in the concentration or location of existing or future coastal developments. The work required to implement the Proposed Action would occur solely on existing poles within County ROWs.

4.2.3.6 ***Coastal Hazards***

Objective: *Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution.*

Policies:

1. *Develop and communicate adequate information about storm wave, tsunami, flood, erosion, subsidence, and point and nonpoint source pollution hazards;*
2. *Control development in areas subject to storm wave, tsunami, flood, erosion, hurricane, wind, subsidence, and point and nonpoint source pollution hazards;*
3. *Ensure that developments comply with requirements of the Federal Flood Insurance Program; and*
4. *Prevent coastal flooding from inland projects.*

Discussion: None of the activities related to the Proposed Action would contribute to the prevalence of, or vulnerability to coastal hazards such as tsunami, storm waves, stream flooding, erosion, subsidence, or pollution. Neither will the Proposed Action encourage or contribute to coastal development which might be susceptible to these coastal hazards.

4.2.3.7 ***Managing Development***

Objective: *Improve the development review process, communication, and public participation in the management of coastal resources and hazards.*

Policies:

1. *Use, implement, and enforce existing law effectively to the maximum extent possible in managing present and future coastal zone development;*
2. *Facilitate timely processing of applications for development permits and resolve overlapping or conflicting permit requirements; and*
3. *Communicate the potential short and long-term impacts of proposed significant coastal developments early in their life cycle and in terms understandable to the public to facilitate public participation in the planning and review process.*

Discussion: The DPW has initiated contact and continues to work cooperatively with all government agencies with oversight responsibilities to facilitate efficient processing of permits and informed decision making by the responsible parties. In addition, DPW has, via public outreach and this EA, attempted to communicate the potential impacts of the Maui County Streetlight Conversion Project to the public in clear and understandable terms.

4.2.3.8 ***Public Participation***

Objective: *Stimulate public awareness, education, and participation in coastal management.*

Policies:

1. *Promote public involvement in coastal zone management processes;*
2. *Disseminate information on coastal management issues by means of educational materials, published reports, staff contact, and public workshops for persons and organizations concerned with coastal issues, developments, and government activities; and*
3. *Organize workshops, policy dialogues, and site-specific mediations to respond to coastal issues and conflicts.*

Discussion: The public will be provided an opportunity to review and comment on this DEA, pursuant to the requirements of HAR, §11-200.1.

4.2.3.9 ***Beach Protection***

Objective: *Protect beaches for public use and recreation.*

Policies:

1. *Locate new structures inland from the shoreline setback to conserve open space, minimize interference with natural shoreline processes, and minimize loss of improvements due to erosion;*

2. *Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and*
3. *Minimize the construction of public erosion-protection structures seaward of the shoreline.*

Discussion: The project poses no risk to beaches. No structures are planned seaward of the shoreline, and no interactions with littoral processes would be involved.

4.2.3.10 ***Marine Resources***

Objective: *Promote the protection, use, and development of marine and coastal resources to assure their sustainability.*

Policies:

1. *Ensure that the use and development of marine and coastal resources are ecologically and environmentally sound and economically beneficial;*
2. *Coordinate the management of marine and coastal resources and activities to improve effectiveness and efficiency;*
3. *Assert and articulate the interests of the State as a partner with federal agencies in the sound management of ocean resources within the United States exclusive economic zone;*
4. *Promote research, study, and understanding of ocean processes, marine life, and other ocean resources in order to acquire and inventory information necessary to understand how ocean development activities relate to and impact upon ocean and coastal resources; and*
5. *Encourage research and development of new, innovative technologies for exploring, using, or protecting marine and coastal resources.*

Discussion: The proposed project does not have the potential to adversely affect marine resources relative to the existing situation.

4.3 FEDERAL LEGISLATION

4.3.1 NATIONAL HISTORIC PRESERVATION ACT

The *National Historic Preservation Act* is not applicable to the proposed project because it is not a federal undertaking.

4.3.2 CLEAN AIR ACT (42 U.S.C. §7506(C))

As noted in Section 3.1.1, any emissions from Hawaiian Electric vehicles and equipment conducting the streetlight conversion are anticipated to be very minor, temporary, and diffuse. The vehicle and equipment operators will also employ BMPs to control emissions during the streetlight conversion process. Once the conversion is complete and the new GE 2700K LED fixtures are placed into service, they will not produce any direct emissions themselves. Neither will they alter air flow in the area, nor have any measurable effect on the area's microclimate.

4.3.3 CLEAN WATER ACT (33 U.S.C. §1251, ET SEQ.)

The *Clean Water Act*, formally known as the Federal Water Pollution Control Act (33 U.S.C. §1251, et seq.) is the principal law governing pollution control and the water quality of the nation's waterways. The Maui County Streetlight Conversion Project, as discussed in Section 3.1.6, will not result in any impact to nearby surface waters or aquifers. DPW does not anticipate seeking any approvals from the U.S. Army Corps of Engineers or the HDOH Clean Water Branch under the Clean Water Act.

4.3.4 COASTAL ZONE MANAGEMENT ACT (16 U.S.C. §1456(C)(1))

Enacted as Chapter 205A, HRS, the Hawai'i CZM Program was promulgated in 1977 in response to the Federal *Coastal Zone Management Act of 1972*. The CZM area encompasses the entire State of Hawai'i, including all marine waters to the extent of the State's police power and management authority, as well as the 12-mile U.S. territorial sea and all archipelagic waters. Section 4.2.3 discusses the consistency of the Maui County Streetlight Conversion Project with the CZM Program's ten policy objectives.

4.3.5 ENDANGERED SPECIES ACT (16 U.S.C. §§1531-1544)

The *Endangered Species Act of 1973,* as amended 1976-1982,1984, and 1988 (16 U.S.C. §§1531-1544), provides broad protection for species of fish, wildlife, and plants that are listed as threatened or endangered in the United States or elsewhere. The act is not applicable to the proposed project because it does not involve a federal action or the taking of a listed species.

4.3.6 FLOOD PLAIN MANAGEMENT (42 U.S.C. §4321, EXECUTIVE ORDER NO. 11988)

Executive Order 11988 Floodplain Management directs all Federal agencies to avoid, if possible, development and other activities in the 100-year base floodplain. This Executive Order is not applicable to the proposed project because it is not a federal undertaking and does not involve development within a flood plain.

Chapter 5: ANTICIPATED DETERMINATION

5.1 SIGNIFICANCE CRITERA

Hawai‘i Administrative Rule §11-200.1-14 establishes procedures for determining if an EIS should be prepared or if a Finding of No Significant Impact (FONSI) is warranted. HAR §11-200.1-14(d) provides that proposing agencies should issue an environmental impact statement preparation notice (EISPN) for actions that it determines may have a significant effect on the environment. HAR §11-200.1-13(b) lists the following criteria to be used in making that determination.

In most instances, an action shall be determined to have a significant effect on the environment if it:

1. Involves an irrevocable commitment to loss or destruction of any natural or cultural resource;
2. Curtails the range of beneficial uses of the environment;
3. Conflicts with the State’s long-term environmental policies or goals as expressed in Chapter 344, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders;
4. Substantially affects the economic or social welfare of the community or State;
5. Substantially affects public health;
6. Involves substantial secondary impacts, such as population changes or effects on public facilities;
7. Involves a substantial degradation of environmental quality;
8. Is individually limited but cumulatively has considerable effect on the environment or involves a commitment for larger actions;
9. Substantially affects a rare, threatened, or endangered species, or its habitat;
10. Detrimentally affects air or water quality or ambient noise levels;
11. Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters;
12. Substantially affects scenic vistas and viewplanes identified in county or state plans or studies; or,
13. Requires substantial energy consumption.

5.2 FINDINGS

The potential effects of the proposed CSO Decommissioning Project and its action alternatives, as described in Section 2.1 and Section 2.4.2, respectively, were evaluated relative to these thirteen significance criteria. DPW's findings with respect to each criterion are summarized in the following subsections.

5.2.1 Irrevocable Loss or Destruction of Valuable Resource

The Maui County Streetlight Conversion Project consists of the removal of existing GE 2100K HPS fixtures from existing poles and replacing them with new, more efficient GE 2700K LED fixtures. It does not involve the loss of any significant or valuable cultural or natural resources and is intended solely to upgrade existing public infrastructure.

5.2.2 Curtails Beneficial Uses

The removal of existing HPS streetlight fixtures and their replacement with more modern and efficient LED fixtures is intended to promote beneficial use of existing county ROWs, and will not curtail beneficial uses of the ROW or adjacent areas.

5.2.3 Conflicts with Long-Term Environmental Policies or Goals

The Maui County Streetlight Conversion Project is consistent with all applicable plans, policies, and controls, as discussed throughout Chapter 4, including the *Hawaiʻi State Plan*, the *County of Maui 2030 General Plan*, and other relevant planning documents. It is consistent with the State's long-term environmental policies and goals as expressed in HRS, Chapter 344 and elsewhere in state law.

5.2.4 Substantially Affects Economic or Social Welfare

The Proposed Action will not have substantial effects on economic or social welfare. Its purpose is solely to allow the County of Maui to transition its existing stock of streetlights on Maui, Molokaʻi, and Lānaʻi from obsolete HPS fixtures to modern, more efficient LED streetlights, pursuant to the requirements of *Street Lighting Standards in the County of Maui*, MC §15-201.

5.2.5 Public Health Effects

The Maui County Streetlight Conversion Project will not adversely affect air or water quality, including water sources used for drinking or recreation. Neither will it generate substantial emissions that will have an adverse effect on public health. As discussed in Section 3.3, LED conversions have not be shown to be detrimental to human health.

5.2.6 Produce Substantial Secondary Impacts

The Proposed Action will not produce substantial secondary impacts. The Maui County Streetlight Conversion Project will not foster population growth, promote economic development, or stress public facilities or services. Instead, it is intended to allow the County of Maui to responsibly update its street lighting per the terms of the *Street Lighting Standards*, MC §15-201.

5.2.7 Substantially Degrade the Environment

The Proposed Action will not have substantial long-term effects. The work will temporarily elevate noise levels and generate limited vehicle and equipment emissions during the conversion process, but these impacts will be very minor, localized, and of limited duration. Adequate measures will be taken to ensure that the effects of the conversion process are brief and minimal.

5.2.8 Cumulative Effects or Commitment to a Larger Action

The Maui County Streetlight Conversion Project does not represent a commitment to a larger action and is not intended to facilitate substantial economic or population growth. It is intended solely to convert existing GE 2100K HPS fixtures with new and more efficient GE 2700K LED fixtures, pursuant to the requirements of the *Street Lighting Standards*, MC §15-201.

5.2.9 Effects on Rare, Threatened, or Endangered Species

No rare, threatened, or endangered species will be affected by the proposed conversion of streetlights on Maui, Molokaʻi, and Lānaʻi. In addition, the Proposed Action will not utilize or otherwise affect a resource or habitat needed for the protection of rare, threatened, or endangered species. In fact, as detailed in Section 3.2.3, the Proposed Action will benefit protected species by avoiding and minimizing potential light attraction threats to seabirds and sea turtles.

5.2.10 Affects Air or Water Quality or Ambient Noise Levels

As discussed in Section 3.1.1, Section 3.1.6 and Section 3.1.8, noise levels and airborne emissions will briefly increase during the conversion process, but only to a very minor degree localized around the pole(s) being converted. BMPs will be implemented and any effects will be brief, relatively minor, and restricted to the immediate vicinity of work. Once the Maui County Streetlight Conversion Project is completed, it will not produce any airborne emissions, waterborne pollution, or noise.

5.2.11 Environmentally Sensitive Area

The work related to the Maui County Streetlight Conversion Project will occur throughout Maui, Molokaʻi, and Lānaʻi. While some of these areas may be classified as environmentally sensitive, the Proposed Action will not increase the vulnerability to natural hazards of flood plains, tsunami zones, beaches, erosion-prone areas, geologically hazardous lands, estuaries, fresh water or coastal waters, and will not have any effect on such areas.

5.2.12 Affects Scenic Vistas and View Planes

As discussed in Section 3.4, the new lighting that will be installed as part of the proposed Maui County Streetlight Conversion Project will, by intent, be visible from a variety of areas throughout the County of Maui. However, the Proposed Action will generally improve nighttime visibility, and will not adversely affect any scenic vistas identified in any county or state plans or studies, and will not be detectable during the daytime when street lighting is not in use.

5.2.13 Requires Substantial Energy Consumption

The work required to implement the Maui County Streetlight Conversion Project will require the use of some energy, mostly by diesel-powered work vehicles and equipment. However, once these relatively brief operations are complete, the Proposed Action would produce a substantial drop in the energy requirement needed for street lighting in the County of Maui.

5.3 ANTICIPATED DETERMINATION

In view of the foregoing, DPW has concluded that the Proposed Action will not have a significant adverse impact on the environment. Consequently, DPW anticipates issuing a FONSI for the Maui County Streetlight Conversion Project.

Chapter 6: CONSULTATION AND DISTRIBUTION

6.1 SCOPING PERIOD OUTREACH

The scoping process commenced on August 20, 2019, is discussed in Section 1.5. A copy of the scoping letter and the responses received are provided in Appendix D.

6.2 DISTRIBUTION OF THE DEA

DPW has provided this EA to the parties listed in Table 6.1 and Table 6.3 with a request for review and comment.

Table 6.1 DEA Distribution List

Federal Agencies	**County of Maui**
U.S. Army Corps of Engineers, Honolulu District	Department of Agriculture
U.S. Department of Agriculture	Department of the Corporation Counsel
U.S. Department of Commerce	Department of Environmental Management
U.S. Department of Homeland Security	Department of Finance
U.S. Department of Housing and Urban Development	Department of Fire and Public Safety
U.S. Department of Interior, National Park Service	Department of Housing & Human Concerns
U.S. Department of Transportation – Federal Aviation Administration	Department of Management
U.S. Department of Transportation – Federal Highway Administration	Department of Parks and Recreation
U.S. Environmental Protection Agency, Region 9	Department of Planning
U.S. Fish and Wildlife Service, Pacific Islands Field Office	Department of Public Works
State Agencies	Department of Transportation
Department of Agriculture	Department of Water Supply
Department of Accounting and General Services	Emergency Management Agency
Department of Business, Economic Development, and Tourism (DBEDT)	Office of Climate Change, Resiliency and Sustainability
DBEDT, Hawai‘i Housing and Finance Development Corporation	Police Department
DBEDT, Hawai‘i State Energy Office	**Elected Officials**
DBEDT, Office of Planning and Sustainable Development	U.S Senator Brian Schatz
Department of Defense	U.S. Senator Mazie Hirono
Department of Education	U.S. Representative Kaiali‘i Kahele
Department of Hawaiian Home Lands	U.S. Representative Ed Case
Department of Health (DOH), Clean Air Branch	Governor David Ige
DOH, Clean Water Branch	Mayor Michael P. Victorino
DOH, Environmental Health Services Division	State Senator Stanley Chang
DOH, Wastewater Branch	State Representative Mark J. Hashem
Department of Human Services	

Department of Labor and Industrial Relations	Senator Rosalyn H. Baker
Department of Land and Natural Resources (DLNR)	Senator Lynn DeCoite
DLNR, Division of Forestry and Wildlife	Representative Angus L.K. McKelvey
Department of Transportation, Long Range Planning Branch	Representative Justin H. Woodson
Office of Hawaiian Affairs	Representative Linda Clark
Libraries and Depositories	Alice L. Lee, Council Chair
Hawaiʻi State Library Documents Center	Keani Rawlins-Fernandez, Council Vice-Chair
Kahului Public Library	Tasha Kamaʻaina, Presiding Officer Pro Tempore
Kīhei Public Library	Councilmember Gabe Johnson
Lahaina Public Library	Councilmember Kelly Takaya King
Makawao Public Library	Councilmember Mike Molina
Wailuku Public Library	Councilmember Tamara Paltin
Hana Public and School Library	Councilmember Shane Sinenci
University of Hawaiʻi Maui College Library	Councilmember Yuki Lei Sugimura
Utilities	
Hawaiʻi Gas	
Maui Electric Company	
Hawaiian Telcom	
Media	**Other**
Honolulu Star Advertiser	Earthjustice
Honolulu Civil Beat	Haleakalā Observatory & UH C.E.K. Mees Solar Observatory
The Maui News	
Maui Time Weekly	

Source: Compiled by Planning Solutions, Inc. (2022)

Chapter 7: REFERENCES

Adams, R. (2020a) Expert Disclosure Report of Robert Adams, Ph.D. April 20, 2020.

Adams, R. (2020b) Rebuttal Expert Disclosure Report of Robert Adams, Ph.D. June 18, 2020.

County of Maui

——— (2010). County of Maui 2030 General Plan.

——— (2012). Maui Island Plan.

——— (2015). Lānaʻi Island Plan

——— (2018). Molokaʻi Community Plan.

Chris Hart & Partners, Inc. (2006) *County of Maui 2030 General Plan: Scenic Resources Inventory Report*. June 2006.

Clanton & Associates, Inc. (2010). *Advanced Street Lighting Technologies Assessment Project – City of San Jose*. December 10, 2010.

Curran, J. W. Letter to County of Maui dated May 20, 2020.

Curran, J. W. Letter to County of Maui dated June 29, 2020.

Illuminating Engineering Society of North America (2012). *Technical Memorandum 12 Spectral Effects of Lighting on Visual Performance at Mesopic Lighting Levels*. March 2, 2012.

The International Commission on Illumination (2010). *Recommended System of Mesopic Photometry*. 2010.

Longcore, T., Rodriquez, A., Witherington, B., Penniman, J., Herf, L., and Herf, M. *Rapid Assessment of Lamp Spectrum to Quantify Ecological Effects of Light at Night*. Journal of Experimental Zoology, Vol 1(11), 2018.

OEQC (Office of Environmental Quality Control). (1997). *Guidelines for Assessing Cultural Impacts*, adopted by the Environmental Council of the State of Hawaiʻi on November 19, 1997.

Penniman, J. Expert Disclosure Report. April 30, 2020.

Appendix A. Chapter 201, MC-15, Street Lighting Standards

TITLE MC-15

DEPARTMENT OF PUBLIC WORKS

SUBTITLE 02

STREET LIGHTING STANDARDS

CHAPTER 201

STREET LIGHTING STANDARDS

Subchapter 1 General Provisions

SUBCHAPTER 1

GENERAL PROVISIONS

§15-201-1 Title. The rules in this chapter shall be known as the "Street Lighting Standards". [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-2 Authority. The rules herein are established pursuant to sections 46-1.5(13) and 46-1.5(16) of the Hawaii Revised Statutes. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-3 Purpose. These rules provide standards for outdoor lighting that, while providing a level of safety for vehicular and pedestrian traffic, do not excessively interfere with nighttime viewing and avoid glare and light trespass onto private property. These rules also encourage the conservation of electricity. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-4 Construction. These rules should be read in conjunction with the provisions of Hawaii Revised Statutes, the revised charter of the County of Maui (1983), as amended, and the Maui County Code. In any conflict between the general provisions herein and any other provision, the more restrictive provision shall govern. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-5 Definitions. For the purpose of these rules, unless it is plainly evident from the context that a different meaning is intended, certain words and phrases used herein are defined as follows:

"Agricultural" means areas designated agricultural by the State land use commission and/or zoned agricultural via County ordinance.

"Blue light power content" means the International Dark Sky Association's (IDA) definition of blue light content or the sum of energy between 405-530nm divided by the sum of energy from 380-730nm times the total power output in watts. The blue light power content for HPS is 10w for 100w HPS bulb, 15w for a 150w HPS bulb, and 25w for a 250w HPS bulb.

"CCT" is correlated color temperature expressed in degree Kelvin (K).

"Director" means the director of the department of public works of the County of Maui, or a duly authorized designee.

"Fully shielded" means that the outdoor light fixture is constructed so that all of the light emitted by the fixture is projected below the horizontal plane of the lowest point of the fixture.

"Glare" means the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility.

"LED" means light emitting diode.

"Light trespass" is any form of artificial illumination emanating from a luminaire that penetrates other property other than its intended use.

"Luminaire" means the complete lighting assembly, less the support assembly.

"Partially shielded" means that the outdoor lighting fixture is constructed so that at least ninety percent of the light emitted by the fixture is projected below the horizontal place of the lowest point of the fixture.

"Rural" means areas designated rural by the State land use commission and/or zoned rural by County ordinance.

"S/P ratio" means the proportion of scotopic to photopic output.

"Urban" means areas designated urban by the State land use commission. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-6 Lamp standards. (a) High pressure sodium or LED lamps or other fixtures approved by the director shall be the only allowed lamp on public and/or private right-of-ways; however, existing lamps other than high pressure sodium or LED lamps shall remain until they expire at which time they shall be replaced.

(b) LED lamps shall meet the following requirements:

i) CCT of less than 3000k.

ii) S/P ratio <1.2.

iii) Blue light power content less than the corresponding blue light power content for HPS.

iv) Adaptive controls to allow for dimming.

(c) For roadways within the rural or agricultural areas, the maximum allowable wattage shall be 100W HPS (or equivalent LED wattage) for internal road intersections and 150W HPS (or equivalent LED wattage) for intersections from a project with a major and/or minor collector road.

(d) For roadways within the urban areas, the maximum allowable wattage shall be 150W HPS (or equivalent LED wattage) for internal road intersections and 250W HPS (or equivalent LED wattage) at intersections with a major or minor collector road. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-7 Luminaire standards. Fully shielded luminaires shall be the only allowed fixture on public and/or private right-of-ways. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-8 Light standards (poles). (a) Free standing aluminum light standards and aluminum arms shall continue to be stocked and used for existing lighting within major collector roadways.

(b) Any new subdivision or project that requires street lighting within public roadways, shall use light standards that are non-reflective, such as anodized bronze or any other light standard accepted by the director. Any unusual or project specific requests for non-standard lighting standards shall be reviewed and approved by the director after consultation with the utilities, the public works commission, and applicant.

(c) The maximum height of the light standard, measured from ground level directly below the luminaire to the bottom of the lamp itself, shall be twenty feet. Also, light standards are only required at intersecting streets. Any variation to this height standard will be reviewed and approved by the director after consultation with the public works commission.

(d) Any unusual or project specific requests for non-standard lighting standards shall be reviewed and approved by the director after consultation with the utilities, the public works commission, and applicant. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-9 <u>Installation, illumination, removal, and alteration guidelines.</u> (a) The department may install, illuminate, remove, or alter street lights for:

(1) Locations where the nighttime accident rate exceeds those of the daylight hours.

(2) Intersections, urban or rural, taking into consideration the layout of the intersection, traffic volumes, location of the intersection, concentration of pedestrians, roadside interferences and that channelized intersections and the roadway width may require more lighting.

(3) Any significant change of the roadway alignment, long bridges, tunnels, or any structures that may be hazardous, such as curbs, piers, abutments, or culverts.

(4) Locations along the highway where police reports show crimes are committed, such as theft, rape, and bodily harm cases.

(5) Locations of a highway where traffic turning movements to and from roadside developments threaten public safety.

(6) Subdivision streets, provided that the street has been dedicated to the County and at least fifty percent of the lots on the street are occupied.

(b) Street lights not needed shall be removed. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16), MCC §12.17.030) (Imp: MCC §18.20.060)

§15-201-10 <u>Severability.</u> If any portion of the foregoing rules or the applicability thereof to any person, property or circumstance is held invalid for any reason, that invalidity shall not affect other provisions or applications which can be given effect without the invalid provision or application, and to this end these are declared to be severable. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

S:\CLERICAL\RULES\Public Works\2018-01-27 Chapter 201 Standard Version.docx

ADOPTED this 20th day of November, 2017, at Wailuku, Maui, Hawaii.

DEPARTMENT OF PUBLIC WORKS

DAVID C. GOODE
Director

~~ALAN M. ARAKAWA~~
~~Mayor, County~~ of Maui KEITH A. REGAN
ACTING MAYOR, COUNTY OF MAUI

Approved this 12th day of January, 2018.

APPROVED AS TO FORM
AND LEGALITY:

MICHAEL J. HOPPER
Deputy Corporation Counsel
County of Maui

Received this 17th day of

January, 2018.

DANNY A. MATEO
County Clerk
County of Maui

<u>CERTIFICATION</u>

I, DAVID C. GOODE, Director, Department of Public Works, County of Maui, do hereby certify:

1. That the foregoing is a copy of the amendments to the Rules Pertaining to Street Lighting Standards for the County of Maui, drafted in Ramseyer format, pursuant to the requirements [to] <u>of</u> Section 91-4.1, Hawaii Revised [Statues,] <u>Statutes,</u> which were adopted on the <u>20th</u> day of <u>November</u>, 20<u>17</u>, following a public hearing on <u>November 20, 2017</u>, and filed with the Office of the County Clerk.

2. That the notice of public hearing on the foregoing amendments to the rules was published in The Maui News on the <u>19th</u> day of <u>October, 2017</u>.

DAVID C. GOODE, Director
Department of Public Works

2017-0955
2017-12-07 Amd to Title 15

Appendix B. Maui Electric Street Lighting Study (Demonstration Project Report by Johnson Controls)

Maui Electric

Street Lighting Study

Report Presented by: Johnson Controls

Revised 10/21/2016

Table of Contents

Section I – Executive Summary

Executive Summary

Objective

Johnson Controls is commissioned by Maui Electric to provide an independent product study to evaluate the performance and characteristics for a number of installed light emitting diode (LED) products. The study intent is to provide an unbiased evaluation for each manufacturer product along a stretch of the Maui Lani Parkway. The intent was not to evaluate the effectiveness of the product under the installed application, but rather a product-to-product performance evaluation in regards to operating behaviors and characteristics in relation to other "like" products and the manufacturer published data.

Study Subjects

Maui Electric installed six product groups from three manufacturers along a stretch of Maui Lani Parkway in Kahului, on the island of Maui in Hawaii. A control group of existing conditions (previously installed High Pressure Sodium) was identified to serve as a base for the proposed fixtures. Johnson Controls was requested by Maui Electric representative, Kurt Tsukiyama to isolate the metered fixtures and provide the data for evaluation in regards to color parameters, light output above and below the fixtures, as well as the measurement of EMF above and below the fixture. With Mr. Tsukiyama's assistance, the measurements were executed over three evenings under clear conditions to provide the requested measurements under three light level (dimmed) conditions. Good faith attempts were made to provide measurements free from transient and contributing light sources as well as tree and foliage obstructions. In several cases measurements were performed for two of the same installed product to evaluate variance in the manufacturer's own LED product.

The following groups of test fixtures were installed in sets of (4):

- Cree 3000K
- GE 2700K
- Chips & Wafers (C&W) 3200K
- C&W 2400K

The C&W 3000K were installed in a group of (3), while only one GE 3000K was installed.

Evaluation Criteria and Methodology

For general lighting measurements, JCI utilized an Extech HD400 Heavy Duty Light Meter to take point measurements at ground level in eight major and minor directions in relation to the LED fixture orientation at intervals of five, ten, and fifteen meters where possible. The measurement values were recorded in lux for precision. Light levels were also measured under dimmed conditions.

For color parameter measurement, an UPRtek MK350S Advanced Spectrometer was deployed to determine illumance (lux), color parameters (correlated color temperature - CCT, color rendering index - CRI, C.I.E. chromaticity coordinates), dominate wave length, and the scotopic-to-photopic ratio of the tested LED sources during full brightness, and at controlled 75% and 50% light levels.

For Electromagnetic Field evaluation, JCI utilized an Extech RF EMF Strength Meter model 480836, to measure the Electromagnetic Field Strength in the near-field area of each source to help validate the personal and environmental safety of the emitting sources during operation.

General Illumination (Light Meter)

Measurement Method for Light Levels

Meter Make: Extech

Meter Model: HD400

Measurements were performed by taking instantaneous light level measurements at ground level (six inches) from five, ten, and fifteen meter intervals in eight major and minor directions in relation to the orientation of the studied pole head. In most cases the five, ten, and fifteen meter intervals behind the source was inaccessible due to dramatic terrain changes. To reduce and/or minimize the interference or skewing of results from other light sources, the surrounding area lights were shut off where possible. The moon was waxing and 98% full when readings commenced and 100% full upon conclusion. Every effort was made to block the moon contribution with a human body during the measurements at each point.

The measurement values are recorded and expressed in lux. Foot candles are a broader unit of measure and did not reflect the degree of accuracy needed during this study. Additionally, scotopic values can be arrived at by multiplying the recorded photopic value by the recorded scotopic-to-photopic ratio recorded from the spectrometer.

Color Parameter (Spectrometer)

Measurement Method for Color Parameters

Meter Make: UPRtek

Meter Model: MK350S

Measurements were performed by taking instantaneous measurements from chest level with the site class pointing directly at the light source directly under the light source. The meter records the Spectrum graph and dominant wavelength, CRI (Ra/R1-R15), CCT, CIE 1931 and 1976 chromaticity, and scotopic-to-photopic ratio. In addition to operator recorded values, a raw log file is exported for additional evaluation. To reduce and/or minimize the interference or skewing of results from other light sources, the surrounding area lights were shut off where possible. The moon was waxing and 98% full when readings commenced and 100% full upon conclusion. Every effort was made to block the moon contribution with a human body during the measurement. An additional readings was provided with the use of a bucket truck, one meter above to ensure fixture complied with full cutoff requirements. Additional measurements were provided to determine if there was a significant shift in color due to dimming operations.

Electric Field Strength (RF Meter)

Measurement Method for Electromagnetic Field Strength

Meter Make: Extech

Meter Model: 480836

Measurements were performed by taking the measurement for 10-15 second instantaneous maximum levels from five and ten meter intervals in four major directions in relation to the orientation of the studied pole head. In all cases the ten meter interval directly behind the source was inaccessible. To reduce and/or minimize the interference or skewing of results from other sources, the meter was shielded on all sides by human bodies except from the direction of the target source. Two additional readings were provided, directly under the LED pole head, and with the use of a bucket truck, one meter above.

The measurement values are recorded and expressed in units of volts per meter (V/m). Due to the low detection levels the measurements reflected in the study are recorded as milli-volts per meter (mV/m).

Federal Regulation via the FCC provides safety limits for the general population although its levels are highly disputed. Some independent sources report serious individual health and safety risks are possible for those who are in continuous and prolonged exposure (several hours a day for several months) to EMF levels as low as 10 mV/m. Independent studies have linked exposures to adverse biological effects to serious diseases including cancer. To put the tested sources into perspective, the typical mobile phone produces 10-150 V/m while a Wi-Fi router produces .1-.2 V/m at a range of 5 meters.

Test Environment

A Canon EOS Rebel T6i with a Canon EFS 18-55mm image stabilizer lens used with a RF-UVF58 filter was used to take photographs. Pictures were taken from 3:30am – 5:00am in light traffic conditions. The sky was partly cloudy with temperatures averaging 75 degrees. The moon was 96% full behind the cloud cover. The pavement was partially wet due to timed sprinkler systems. Measurements to be performed would be completed under dry pavement conditions.

Fixture Observations

The baseline lux levels currently meet the AASHTO lux recommendation of 8 with measurement right at 8.3.

The Cree 3000K fixtures have the highest CRI at 95 while the C&W 2400K and 3200K have CRIs in the 50 and 60 range. The remaining three fixtures have a CRI in the 70s.

The C&W 2400K and 3200K fixtures seem to have the lowest levels of blue light content compared to the other fixtures that were measured.

AT 100% levels, the GE 2700K had the highest lux readings at 56, while the Cree 3000K had the lowest at 19. At the 75% and 50% dimmed levels, the GE 2700K remained to perform the strongest with level mirroring one another at 31.5 lux.

The C&W 3000K fixture seemed to produce the highest above fixture reading (1 meter) at 2.4 lux. All other fixtures were in between 1.6 and 1.8.

GE's optics had a high level of performance and control over the lit area as they were specified for the application whereas the other manufacturers used general optics for a general application.

During the dimming test and measurements for the Cree 3000K group, the product had difficulty maintaining stable light levels at 75% and 50% and continued to shift. During the 75% test the pole 42 could not maintain a stable output and had to be lowered to 70%. Additionally pole 42 could not maintain a 50% light level and failed the test.

During the group dimming, it was noted that the GE 2700K seemed to be the least effective with meeting the expected light levels when trimmed to 75%. The C&W 3200K and GE 3000K performed the best with variances at 12% or greater, exceeding the expected lux measurements. In the meantime, the C&W 3000K performed the lowest at 50% while the GE 3000K was the most effective at this level. See Appendix C for further details.

The GE 2700K had the highest variance in EMF strength when compared against the other fixtures. Please see Table A-4 in Appendix A for reference.

The C&W 3200K Pole 23 – EMF readings spiked to 1.5 m/V during the command to pole to dim to 75%. This is an independent test, not all poles were measured for RF spikes during control calls, and is not intended to demonstrate anything but an increase in strength during command calls that would most likely be characteristic of all test subjects.

All fixtures exceed the AASHTO required levels of 8 lux even at 50% dimming levels.

Section II- Map of Test Location

Map of Test Location and Fixtures

Section III – AASHTO Recommendations

AASHTO Recommendations for Roadways:

TABLE 3-5a. Illuminance and Luminance Design Values (English)

Roadway and Walkway Classification	Off-Roadway Light Sources	Illuminance Method						Luminance Method			Additional Values (both Methods)
		Average Maintained Illuminance				Minimum Illuminance	Illuminance Uniformity Ratio	Average Maintained Luminance			Veiling Luminance Ratio
		R1	R2	R3	R4			Lavg	Uniformity		
	General Land Use	(foot-candles) (min)	(foot-candles) (min)	(foot-candles) (min)	(foot-candles) (min)	(foot-candles)	avg/min (max) (6)	cd/m2 (min)	Lavg/Lmin (max)	Lmax/Lmin (max)	Lv(max)/Lavg (max) (3)
Principal Arterials											
Interstate and other freeways	Commercial	0.6 to 1.1	0.6 to 1.1	0.6 to 1.1	0.6 to 1.1	0.2	3:1 or 4:1	0.4 to 1.0	3.5:1	6:1	0.3:1
	Intermediate	0.6 to 0.9	0.6 to 0.9	0.6 to 0.9	0.6 to 0.9	0.2	3:1 or 4:1	0.4 to 0.8	3.5:1	6:1	0.3:1
	Residential	0.6 to 0.8	0.6 to 0.8	0.6 to 0.8	0.6 to 0.8	0.2	3:1 or 4:1	0.4 to 0.6	3.5:1	6:1	0.3:1
Other Principal Arterials (partial or no control of access)	Commercial	1.1	1.6	1.6	1.4	As uniformity ratio allows	3:1	1.2	3:1	5:1	0.3:1
	Intermediate	0.8	1.2	1.2	1.0		3:1	0.9	3:1	5:1	0.3:1
	Residential	0.6	0.8	0.8	0.8		3:1	0.6	3.5:1	6:1	0.3:1
Minor Arterials	Commercial	0.9	1.4	1.4	1.0		4:1	1.2	3:1	5:1	0.3:1
	Intermediate	0.8	1.0	1.0	0.9		4:1	0.9	3:1	5:1	0.3:1
	Residential	0.5	0.7	0.7	0.7		4:1	0.6	3.5:1	6:1	0.3:1
Collectors	Commercial	0.8	1.1	1.1	0.9		4:1	0.8	3:1	5:1	0.4:1
	Intermediate	0.6	0.8	0.8	0.8		4:1	0.6	3.5:1	6:1	0.4:1
	Residential	0.4	0.6	0.6	0.5		4:1	0.4	4:1	8:1	0.4:1
Local	Commercial	0.6	0.8	0.8	0.8		6:1	0.6	6:1	10:1	0.4:1
	Intermediate	0.5	0.7	0.7	0.6		6:1	0.5	6:1	10:1	0.4:1
	Residential	0.3	0.4	0.4	0.4		6:1	0.3	6:1	10:1	0.4:1
Alleys	Commercial	0.4	0.6	0.6	0.5		6:1	0.4	6:1	10:1	0.4:1
	Intermediate	0.3	0.4	0.4	0.4		6:1	0.3	6:1	10:1	0.4:1
	Residential	0.2	0.3	0.3	0.3		6:1	0.2	6:1	10:1	0.4:1
Sidewalks	Commercial	0.9	1.3	1.3	1.2		3:1	Use illuminance requirements			
	Intermediate	0.6	0.8	0.8	0.8		4:1				
	Residential	0.3	0.4	0.4	0.4		6:1				
Pedestrian Ways and Bicycle Ways (2)	All	1.4	2.0	2.0	1.8		3:1				

Notes:

1. Meet either the Illuminance design method requirements or the Luminance design method requirements and meet veiling luminance requirements for both the Illuminance and the Luminance design methods.
2. Assumes a separate facility. For Pedestrian Ways and Bicycle Ways adjacent to roadway, use roadway design values. Use R3 requirements for walkway/bikeway surface materials other than the pavement types shown. Other design guidelines such as IESNA or CIE may be used for pedestrian ways and bikeways when deemed appropriate.
3. Lv(max) refers to the maximum point along the pavement, not the maximum in lamp life. The Maintenance Factor applies to both the Lv term and the Lavg term.
4. There may be situations when a higher level of illuminance is justified. The higher values for freeways may be justified when deemed advantageous by the agency to mitigate off-roadway sources.
5. Physical roadway conditions may require adjustment of spacing determined from the base levels of illuminance indicated above.
6. Higher uniformity ratios are acceptable for elevated ramps near high-mast poles.
7. See AASHTO publication entitled, "A Policy on Geometric Design of Highways and Streets" for roadway and walkway classifications.

AASHTO Requirements for Measured Area

Roadway Type	General Land Use	Road Surface – R3*	Uniformity Ratio
Local	Commercial	0.8	6 to 1

*Road Surface Classification. Please see Table 3-1.

Area Classifications

Commercial. That portion of a municipality in a business development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak traffic or a sustained high pedestrian volume and a continuously heavy demand for off-street parking space during business hours. This definition applies to densely developed business areas outside of, as well as those that are within, the central part of a municipality.

Intermediate. That portion of a municipality which is outside of a downtown area but generally within the zone of influence of a business or industrial development, often characterized by a moderately heavy nighttime pedestrian traffic and a somewhat lower parking turnover than is found in a commercial area. This definition includes densely developed apartment areas, hospitals, public libraries, and neighborhood recreational centers.

Residential. A residential development, or a mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover at night. This definition includes areas with single family homes, townhouses, and/or small apartments. Regional parks, cemeteries, and vacant lands are also included.

TABLE 3-1. Road Surface Classifications

Class	Q_o*	Description	Mode of Reflectance
R1	0.10	Portland cement concrete road surface. Asphalt road surface with a minimum of 12 percent of the aggregates composed of artificial brightener (e.g., Synopal) aggregates (e.g., labradorite, quartzite).	Mostly diffuse
R2	0.07	Asphalt road surface with an aggregate composed of minimum 60 percent gravel [size greater than 1 cm (0.4 in.)]. Asphalt road surface with 10 to 15 percent artificial brightener in aggregate mix. (Not normally used in North America).	Mixed (diffuse and specular)
R3	0.07	Asphalt road surface (regular and carpet seal) with dark aggregates (e.g., trap rock, blast furnace slag); rough texture after some months of use (typical highways).	Slightly specular
R4	0.08	Asphalt road surface with very smooth texture.	Mostly specular

* Q_o 5 representative mean luminance coefficient.
Reprinted from *American National Standard Practice for Roadway Lighting*, ANSI/IES RP-8-00, Illuminating Engineering Society of North America. Used by permission.

Section IV – Pole Results

Baseline High Pressure Sodium (HPS) Pole Results:

Not actual photo of metered area. Example of HPS in the proximity.

Baseline HPS Summary of Results:

Spectroanalysis data*	HPS Pole 47-50 (Metered)	HPS Pole 47-75 (Metered)	HPS Pole 47-100 (Metered)	HPS (Cut sheet)
Lux	N/A	N/A	64.9	N/A
CCT	N/A	N/A	2132	N/A
CRI	N/A	N/A	8.28	N/A
S/P	N/A	N/A	0.614036	N/A

*HPS is not dimmable. Please see Appendix D for more detailed data.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

C&W 3000K Pole Results:

Photo of C&W 3000K LED fixture install

C&W 3000K Summary of Results:

Spectroanalysis data*	C&W 3000K Pole 33-50 (Metered)	C&W 3000K Pole 33-75 (Metered)	C&W 3000K Pole 33-100 (Metered)	C&W 3000K (Cut sheet)
Lux	15	27.3	30.6	N/A
CCT	3144	3113	3104	3000
CRI	78.58713	77.21357	76.71439	N/A
S/P	1.358703	1.330867	1.324717	N/A

*Data above is based upon 50%/75%/100% measurements. Please see Appendix D for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

Cree 3000K Pole Results:

Photo of Cree 3000K LED fixture install

Cree 3000K Summary of Results:

Spectroanalysis data*	Cree 3000K Pole 44-50 (Metered)	Cree 3000K Pole 44-75 (Metered)	Cree 3000K Pole 44-100 (Metered)	Cree 3000K (Cut sheet)
Lux	12.9	20.7	19.1	N/A
CCT	3067	3054	3055	3000 (+/- 175K)
CRI	94.63934	94.89367	95.00991	80
S/P	1.455847	1.442726	1.439812	N/A

* Data above is based upon 50%/75%/100% measurements. Please see Appendix D for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

GE 3000K Pole Results:

Photo of GE 3000K LED fixture install

GE 3000K Summary of Results:

Spectroanalysis data*	GE 3000K Pole 38-50 (Metered)	GE 3000K Pole 38-75 (Metered)	GE 3000K Pole 38-100 (Metered)	GE 3000K (Cut sheet)
Lux	13.3	21.1	27.8	N/A
CCT	3096	3093	3084	3000
CRI	73.1386	72.7588	72.45164	70
S/P	1.235747	1.228611	1.221511	N/A

* Data above is based upon 50%/75%/100% measurements. Please see Appendix D for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

GE 2700K Pole Results:

Photo of GE 2700K LED fixture install

GE 2700K Summary of Results:

Spectroanalysis data*	GE 2700K Pole 39-50 (Metered)	GE 2700K Pole 39-75 (Metered)	GE 2700K Pole 39-100 (Metered)	GE 2700K (Cut sheet)
Lux	31.5	31.5	56.3	N/A
CCT	2792	2781	2789	2700
CRI	71.67072	71.19247	71.23451	N/A
S/P	1.101103	1.09006	1.094674	N/A

* Data above is based upon 50%/75%/100% measurements. Please see Appendix D for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

C&W 2400K Pole Results:

Photo of C&W 2400K LED fixture install

C&W 2400K Summary of Results:

Spectroanalysis data*	C&W 2400K Pole 28-50 (Metered)	C&W 2400K Pole 28-75 (Metered)	C&W 2400K Pole 28-100 (Metered)	C&W 2400K (Cut sheet)
Lux	13.3	20.6	30.6	N/A
CCT	2465	2469	2477	2400
CRI	63.16407	62.77892	64.44673	N/A
S/P	0.797652	0.795536	0.81434	N/A

*Data above is based upon 50%/75%/100% measurements. Please see Appendix D for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

C&W 3200K Pole Results:

Photo of C&W 3200K LED fixture install

C&W 3200K Summary of Results:

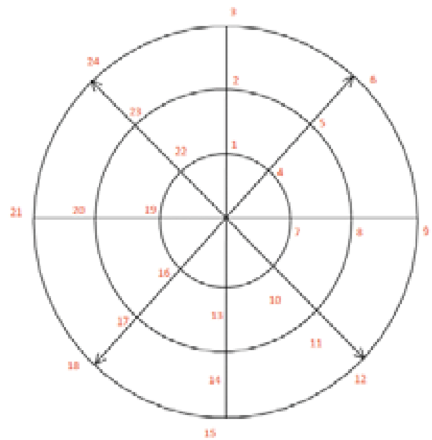
Spectroanalysis data*	C&W 3200K Pole 23-50 (Metered)	C&W 3200K Pole 23-75 (Metered)	C&W 3200K Pole 23-100 (Metered)	C&W 3200K (Cut sheet)
Lux	13.1	19.6	27.1	N/A
CCT	3334	3306	3326	3200
CRI	56.77235	50.72585	52.64069	N/A
S/P	1.018288	0.989286	1.00208	N/A

*Data above is based upon 50%/75%/100% measurements. Please see Appendix A for more detailed data regarding the dimmed readings.

Note: The lux values reflect the field record hand ticket values for the corresponding pole. The lux as measured by the MK350 spectrometer was measured at chest level and disregarded due to the improper method captured. Lux measurements were performed at six inches with the HD300 light meter. Values displayed for CCT, CRI and S/P are from the raw data logs generated from the MK350 Spectrometer and may vary from the field record hand ticket value for the corresponding pole.

Section V – Appendix A – Analysis Tables

Appendix A – Analysis Tables



The following tables compares the lux measurements based off of the reading location chart presented to the left. The data collected compares the baseline HPS against the (6) metered LED fixtures. Please note the data also references the fixtures when dimmed to 50% and 75%. Baseline HPS data was not available for the dimming portion as HPS lamps are not dimmable.

The EMF strength was also compared across all (7) fixtures in Table A-4.

Table A-1: Lux at 100% (not dimmed)

Reading Location	Base HPS	C&W3200	C&W3000	C&W2400	Cree3000	GE2700	GE3000
1	36.1	11.8	18.4	9.4	17.1	11.6	20
2	6	0	0	0	4.9	0.01	0
3	0	0	0	0	0	0	0
4	29	14.9	20.6	16	19.5	38.8	17.3
5	10	4	6.5	1.3	7.9	2	4.3
6	2.1	0	0	0	3.1	0	0
7	21.3	13.7	18.8	14.4	14.9	33.4	6.7
8	11	3.2	4.3	4.4	3.6	10.7	2.3
9	6.4	0	0	0	0	10.6	0
10	16.5	9.1	0	11.3	6.2	12.5	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	4.2	0	4.2	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	9.1	12.7	11.3	5.6	2.7	0
17	0	0	1.6	0	0	0	0
18	0	0	0	0	0	0	0
19	19.9	13.3	21.4	15.1	13.4	32.5	6.4
20	5.4	2.8	10.2	5.6	2.3	8.8	2.1
21	0	0	1.3	0		9	0
22	31.2	15.5	22	14	26.3	35.9	20.2
23	8.7	0	7.2	2.8	8.4	2.3	0
24	1.6	0	0.2	0	2.1	0	0

Table A-2: Lux at 75% dimmed

Reading Location	Base HPS*	C&W3200	C&W3000	C&W2400	Cree3000	GE2700	GE3000
1	0	9.5	13.9	6.3	14.2	10.3	17.3
2	0	0	0	0	2.6	0	0
3	0	0	0	0	0	0	0
4	0	14	17.3	10.3	19.2	28	14.6
5	0	3.2	4.8	0	5.2	0.6	2.7
6	0	0	0	0	1.7	0	0
7	0	12.2	14.8	10.5	11.4	21.4	6
8	0	2.2	1.2	1.6	1.9	6	1.3
9	0	0	0	0	0	5.4	0
10	0	8.2	0	8.6	6.2	7.8	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	3.3	0	3.1	1.5	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	7.5	11.3	8.9	6.6	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	13.7	14.4	11.3	11.9	21.1	5.9
20	0	2.5	5	2.9	2	4.2	1.9
21	0	0	0	0	0	5	0
22	0	12.3	15.1	10.4	19.6	27.4	17.6
23	0	0	3.2	1.5	5.7	2.3	0
24	0	0	0	0	1.3	0	0

*Product is not dimmable

Table A-3: Lux at 50% dimmed

Reading Location	Base HPS*	C&W3200	C&W3000	C&W2400	Cree3000	GE2700	GE3000
1	0	5.5	7.1	3.2	8.3	6	9.2
2	0	0	0	0	1.5	0	0
3	0	0	0	0	0	0	0
4	0	7.2	10	6.1	10.2	15.6	8.5
5	0	1.7	2.4	0	1.5	0	1.2
6	0	0	0	0	0	0	0
7	0	7	6.6	6.7	5.8	13.8	3.8
8	0	2.2	0.2	0.8	0	3.5	0
9	0	0	0	0	0	3	0
10	0	5.1	0	5.6	2.6	4.1	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	1.8	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	5.1	5.4	6.1	2.8	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	7.1	7.7	6.7	6.6	14	3.7
20	0	1.1	2.8	1.6	0	3.5	0
21	0	0	0	0	0	3	0
22	0	7.6	10.2	6.8	13.8	16.1	11.4
23	0	0	2.4	0	4.1	0	0
24	0	0	0	0	0	0	0

*Product is not dimmable

Table A-4: EMF Strength

Reading Location	Base HPS	C&W3200	C&W3000	C&W2400	Cree3000	GE2700	GE3000
1	207.4	131	179.5	125.4	228	315	210.6
2	305.6	100.6	215.8	11.1	297.2	305.4	244.9
3							
4							
5							
6							
7	385.2	104.6	149.2	153.6	129.4	384.3	237.9
8	171.6	352.6	248.1	160.3	106.6	463.2	267.7
9							
10							
11							
12							
13	425.1	507.8	106.2	251.5	142.5	757.8	237
14							
15							
16							
17							
18							
19	203.7	481.8	479.2	250.2	227.8	556.7	298
20	254.3	488.1	309.3	206.6	117.2	231.3	108.6
21							
22							
23							
24							

Section VI – Group Comparison

Appendix B – Group Comparison

The following data represents the variance in lux within each manufacturer group when compared to one another. Please note that a comparison was not available for the GE 3000K fixture.

C&W3200

Pole Number	23	25	
Reading Location	LUX - 100%		Variance
1	11.8	7.2	5.3
2	0	0	0.0
3	0	0	0.0
4	14.9	13.3	0.6
5	4	2	1.0
6	0	0	0.0
7	13.7	12.2	0.6
8	3.2	1.9	0.4
9	0	0	0.0
10	9.1	9.1	0.0
11	0	0	0.0
12	0	0	0.0
13	4.2	3.3	0.2
14	0	0	0.0
15	0	0	0.0
16	9.1	11.5	1.4
17	0	0	0.0
18	0	0	0.0
19	13.3	14.3	0.3
20	2.8	2.7	0.0
21	0	0	0.0
22	15.5	8.7	11.6
23	0	0	0.0
24	0	0	0.0

C&W3000

Pole Number	33	31	
Reading Location	LUX - 100%		Variance
1	18.4	14.7	3.4
2	0	0.6	0.1
3	0	0	0.0
4	20.6	17.8	2.0
5	6.5	5.6	0.2
6	0	0	0.0
7	18.8	14.7	4.2
8	4.3	3.3	0.2
9	0	0	0.0
10	0	8.7	18.9
11	0	0	0.0
12	0	0	0.0
13	0	4	4.0
14	0	0	0.0
15	0	0	0.0
16	12.7	11.4	0.4
17	1.6	0	0.6
18		0	0.0
19	21.4	16.7	5.5
20	10.2	4.8	7.3
21	1.3	0	0.4
22	22	17.8	4.4
23	7.2	3.1	4.2
24	0.2	0	0.0

C&W2400

Pole Number	28	29	
Reading Location	LUX - 100%		Variance
1	9.4	10.4	0.3
2	0	0	0.0
3	0	0	0.0
4	16	13.7	1.3
5	1.3	3.2	0.9
6	0	0	0.0
7	14.4	12.2	1.2
8	4.4	3.1	0.4
9	0	0	0.0
10	11.3	8.9	1.4
11	0	0	0.0
12		0	0.0
13	4.2	4	0.0
14		0	0.0
15		0	0.0
16	11.3	11.6	0.0
17	0	0	0.0
18		0	0.0
19	15.1	14.1	0.3
20	5.6	1.9	3.4
21	0	0	0.0
22	14	15.2	0.4
23	2.8	2.7	0.0
24	0	0	0.0

Cree 3000

Pole Number	44	42	
Reading Location	LUX - 100%		Variance
1	17.1	17.6	0.1
2	4.9	1.7	2.6
3	0	0	0.0
4	19.5	26.3	11.6
5	7.9	6.9	0.3
6	3.1	2.5	0.1
7	14.9	12.3	1.7
8	3.6	2.1	0.6
9	0	0	0.0
10	6.2	6.7	0.1
11	0	0	0.0
12		0	0.0
13	0	4.2	4.4
14		0	0.0
15		0	0.0
16	5.6	8.6	2.3
17	0	0	0.0
18		0	0.0
19	13.4	15.7	1.3
20	2.3	2.3	0.0
21		0	0.0
22	26.3	20.7	7.8
23	8.4	6.3	1.1
24	2.1	1.4	0.1

GE 2700

Pole Number	39	35	
Reading Location	LUX - 100%		Variance
1	11.6	15.3	3.4
2	0.01	0	0.0
3	0	0	0.0
4	38.8	31.9	11.9
5	2	0.6	0.5
6	0	0	0.0
7	33.4	32.9	0.1
8	10.7	9.7	0.3
9	10.6	8.4	1.2
10	12.5	3.2	21.6
11		0	0.0
12		0	0.0
13	0	0	0.0
14		0	0.0
15		0	0.0
16	2.7	2.5	0.0
17		0	0.0
18		0	0.0
19	32.5	28.6	3.8
20	8.8	10.5	0.7
21	9	7.4	0.6
22	35.9	37.6	0.7
23	2.3	1.4	0.2
24	0	0	0.0

Section VII – Group Dimming

Appendix C – Group Dimming Evaluation

Effectual dimming is the expression of how well the product achieved the conceptual light levels when the user selected to dim the controller to 75% and 50% respectively. The following tables outlines the variance between the metered and conceptual data.

C&W3200

100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
11.8	9.5	8.85	7%	5.5	5.9	-7%
0	0	0		0	0	
0	0	0		0	0	
14.9	14	11.175	20%	7.2	7.45	-3%
4	3.2	3	6%	1.7	2	-18%
0	0	0		0	0	
13.7	12.2	10.275	16%	7	6.85	2%
3.2	2.2	2.4	-9%	2.2	1.6	27%
0	0	0		0	0	
9.1	8.2	6.825	17%	5.1	4.55	11%
0	0	0		0	0	
0	0	0		0	0	
4.2	3.3	3.15	5%	0	2.1	
0	0	0		0	0	
0	0	0		0	0	
9.1	7.5	6.825	9%	5.1	4.55	11%
0	0	0		0	0	
0	0	0		0	0	
13.3	13.7	9.975	27%	7.1	6.65	6%
2.8	2.5	2.1	16%	1.1	1.4	-27%
0	0	0		0	0	
15.5	12.3	11.625	5%	7.6	7.75	-2%
0	0	0		0	0	
0	0	0		0	0	
		Effectual Dimming@ 75% :	14%		**Effectual Dimming@ 50% :**	-2%

C&W3000

100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
18.4	13.9	13.8	1%	7.1	9.2	-30%
0	0	0		0	0	
0	0	0		0	0	
20.6	17.3	15.45	11%	10	10.3	-3%
6.5	4.8	4.875	-2%	2.4	3.25	-35%
0	0	0		0	0	
18.8	14.8	14.1	5%	6.6	9.4	-42%
4.3	1.2	3.225	-169%	0.2	2.15	-975%
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
12.7	11.3	9.525	16%	5.4	6.35	-18%
1.6	0	1.2		0	0.8	
0	0	0		0	0	
21.4	14.4	16.05	-11%	7.7	10.7	-39%
10.2	5	7.65	-53%	2.8	5.1	-82%
1.3	0	0.975		0	0.65	
22	15.1	16.5	-9%	10.2	11	-8%
7.2	3.2	5.4	-69%	2.4	3.6	-50%
0.2	0	0.15		0	0.1	
		Effectual Dimming@ 75% :	-8%		**Effectual Dimming@ 50% :**	-32%

C&W2400

100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
9.4	6.3	7.05	-12%	3.2	4.7	-47%
0	0	0		0	0	
0	0	0		0	0	
16	10.3	12	-17%	6.1	8	-31%
1.3	0	0.975		0	0.65	
0	0	0		0	0	
14.4	10.5	10.8	-3%	6.7	7.2	-7%
4.4	1.6	3.3	-106%	0.8	2.2	-175%
0	0	0		0	0	
11.3	8.6	8.475	1%	5.6	5.65	-1%
0	0	0		0	0	
0	0	0		0	0	
4.2	3.1	3.15	-2%	1.8	2.1	-17%
0	0	0		0	0	
0	0	0		0	0	
11.3	8.9	8.475	5%	6.1	5.65	7%
0	0	0		0	0	
0	0	0		0	0	
15.1	11.3	11.325	0%	6.7	7.55	-13%
5.6	2.9	4.2	-45%	1.6	2.8	-75%
0	0	0		0	0	
14	10.4	10.5	-1%	6.8	7	-3%
2.8	1.5	2.1	-40%	0	1.4	
0	0	0		0	0	
		Effectual Dimming@ 75% :	-9%		**Effectual Dimming@ 50% :**	-21%

Cree3000

100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
17.1	14.2	12.825	10%	8.3	8.55	-3%
4.9	2.6	3.675	-41%	1.5	2.45	-63%
0	0	0		0	0	
19.5	19.2	14.625	24%	10.2	9.75	4%
7.9	5.2	5.925	-14%	1.5	3.95	-163%
3.1	1.7	2.325	-37%	0	1.55	
14.9	11.4	11.175	2%	5.8	7.45	-28%
3.6	1.9	2.7	-42%	0	1.8	
0	0	0		0	0	
6.2	6.2	4.65	25%	2.6	3.1	-19%
0	0	0		0	0	
0	0	0		0	0	
0	1.5	0	100%	0	0	
0	0	0		0	0	
0	0	0		0	0	
5.6	6.6	4.2	36%	2.8	2.8	0%
0	0	0		0	0	
0	0	0		0	0	
13.4	11.9	10.05	16%	6.6	6.7	-2%
2.3	2	1.725	14%	0	1.15	
	0	0		0	0	
26.3	19.6	19.725	-1%	13.8	13.15	5%
8.4	5.7	6.3	-11%	4.1	4.2	-2%
2.1	1.3	1.575	-21%	0	1.05	
		Effectual Dimming@ 75% :	9%		**Effectual Dimming@ 50% :**	-18%

GE2700

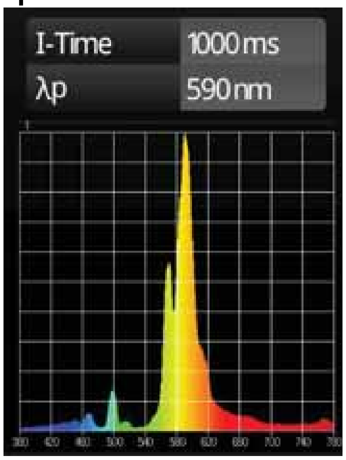
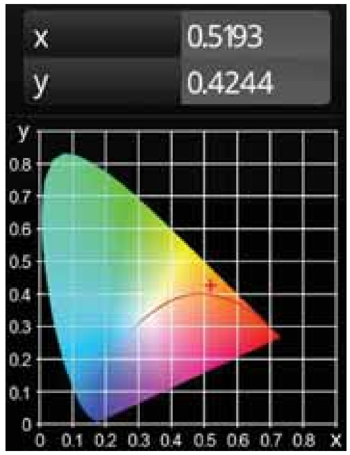
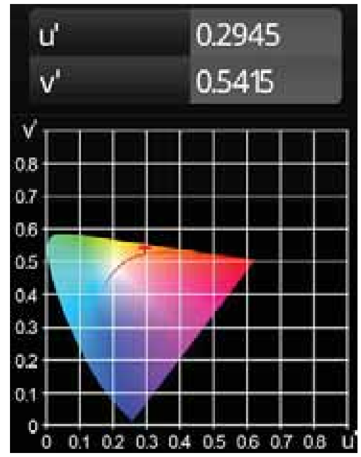
100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
11.6	10.3	8.7	16%	6	5.8	3%
0.01	0	0.0075		0	0.005	
0	0	0		0	0	
38.8	28	29.1	-4%	15.6	19.4	-24%
2	0.6	1.5	-150%	0	1	
0	0	0		0	0	
33.4	21.4	25.05	-17%	13.8	16.7	-21%
10.7	6	8.025	-34%	3.5	5.35	-53%
10.6	5.4	7.95	-47%	3	5.3	-77%
12.5	7.8	9.375	-20%	4.1	6.25	-52%
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
2.7	0	2.025		0	1.35	
0	0	0		0	0	
0	0	0		0	0	
32.5	21.1	24.375	-16%	14	16.25	-16%
8.8	4.2	6.6	-57%	3.5	4.4	-26%
9	5	6.75	-35%	3	4.5	-50%
35.9	27.4	26.925	2%	16.1	17.95	-11%
2.3	2.3	1.725	25%	0	1.15	
0	0	0		0	0	
		Effectual Dimming@ 75% :	-13%		**Effectual Dimming@ 50% :**	-28%

GE3000

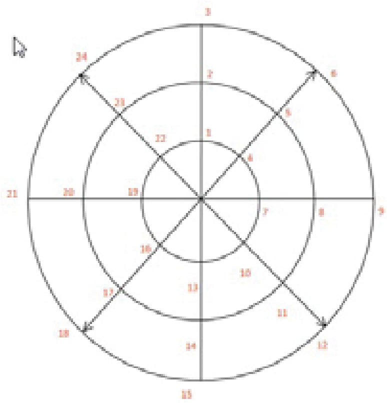
100% Metered	75% Metered	75% Conceptual	Variance	50% Metered	50% Conceptual	Variance
20	17.3	15	13%	9.2	10	-9%
0	0	0		0	0	
0	0	0		0	0	
17.3	14.6	12.975	11%	8.5	8.65	-2%
4.3	2.7	3.225	-19%	1.2	2.15	-79%
0	0	0		0	0	
6.7	6	5.025	16%	3.8	3.35	12%
2.3	1.3	1.725	-33%	0	1.15	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
0	0	0		0	0	
6.4	5.9	4.8	19%	3.7	3.2	14%
2.1	1.9	1.575	17%	0	1.05	
0	0	0		0	0	
20.2	17.6	15.15	14%	11.4	10.1	11%
0	0	0		0	0	
0	0	0		0	0	
		Effectual Dimming@ 75% :	12%		**Effectual Dimming@ 50% :**	-5%

Section VIII – Color Space/Wavelength Charts

Appendix D – Color Space/Wavelength Charts and Spectroanalysis Data

<table>
<tr><td>Baseline HPS Pole 47</td><td></td><td>Baseline HPS Pole 47</td><td></td><td>Baseline HPS Pole 47</td></tr>
<tr><td>Spectrum Chart

</td><td></td><td>CIE 1931

</td><td></td><td>CIE 1976

</td></tr>
</table>

Baseline HPS Pole 47 – Spectroanalysis Data



Pole Number: 47
SL Tag Number: SL102757
Install Date: 7/15/2016

Date of Measurements: 8/17/2016
Time of Measurements: 8:45pm
Weather conditions/visability: Partly Cloudy
Moon phase: 98%
Ground conditions: Dry pavement
Pole Orientation: North East

Measurements By: Neal Phillips
Witnessed By: James Siegrist

Magnetic Compass Orientation

*Readings 1-3:	40	Readings 13-15:	220
Readings 4-6:	85	Readings 16-18:	265
Readings 7-9:	130	Readings 19-21:	310
Readings 10-12:	175	Readings 22-24:	355

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	mV/m**
		2			469

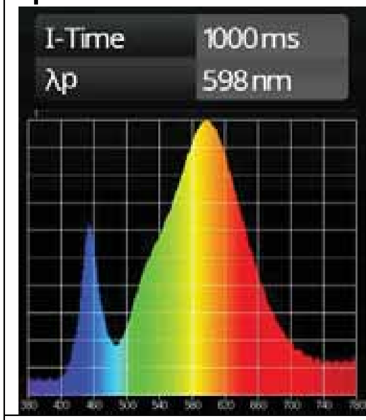
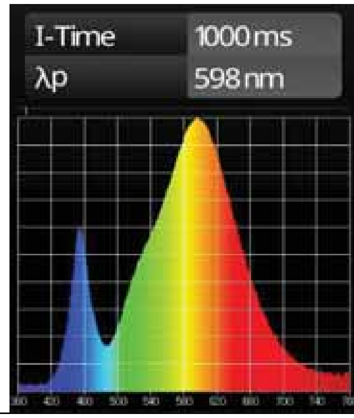
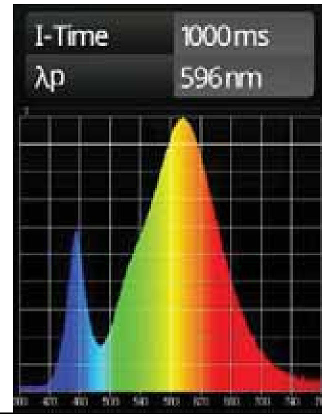
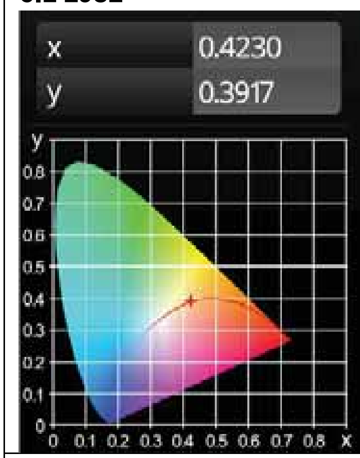
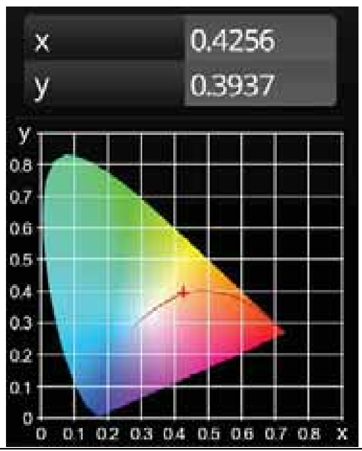
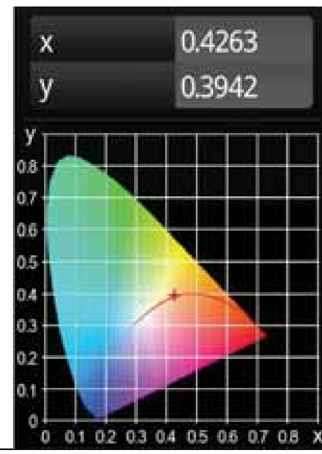
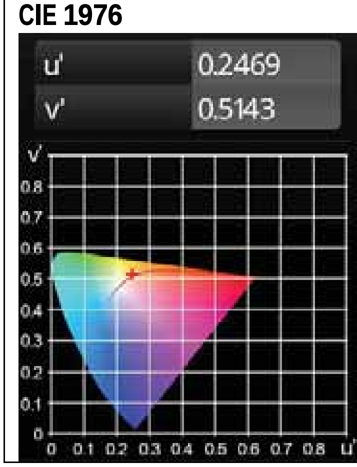
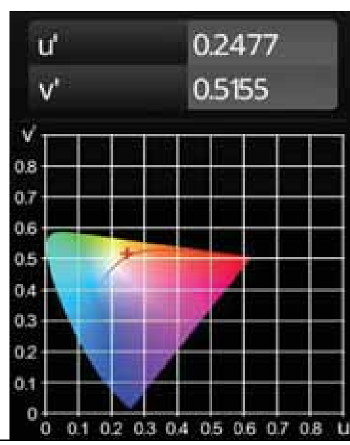
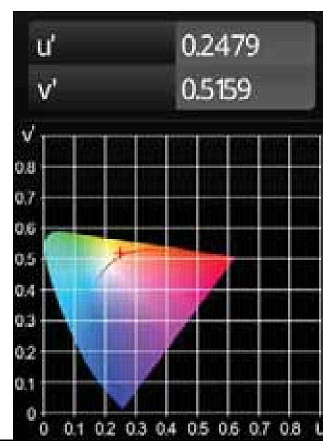
Below fixture reading (Ground level)

	CCT	CRI	LUX	lp	R9	mV/m**
100%	2148	8.3	64.9	590nm	-373.3	183.9
75%						
50%						

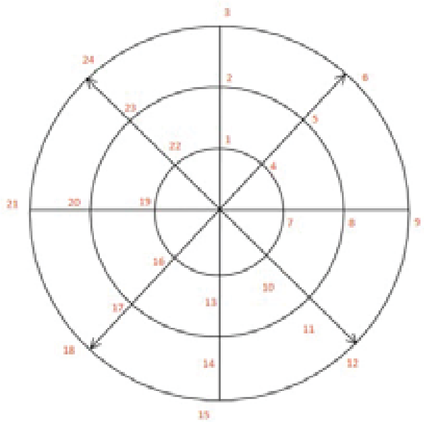
**10 second MAX

Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m**
1	36.1			207.4
2	6			305.6
3	0			
4	29			
5	10			
6	2.1			
7	21.3			385.2
8	11			171.6
9	6.4			
10	16.5			
11				
12				

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	0			425.1
14				
15				
16	0			
17				
18				
19	19.9			203.7
20	5.4			254.3
21	0			
22	31.2			
23	8.7			
24	1.6			

C&W 3000K Pole 33-50		C&W 3000K Pole 33-75		C&W 3000K Pole 33-100
Spectrum Chart 				
CIE 1931 				
CIE 1976 				

C&W 3000K Pole 33 Spectroanalysis Detail



Pole Number:	33
SL Tag Number:	SL102758
Install Date:	6/22/2016

Date of Measurements:	16-Aug	Measurements By:	Neal Phillips
Time of Measurements:	9:15pm HDT	Witnessed By:	James Siegrist
Weather conditions/visability:	Partly cloudy/10mi		
Moon phase:	Full 98%		
Ground conditions:	Dry pavement		
Pole Orientation:	North/North West		

Magnetic Compass Orientation

*Readings 1-3:	310	Readings 13-15:	130
Readings 4-6:	355	Readings 16-18:	175
Readings 7-9:	40	Readings 19-21:	220
Readings 10-12:	85	Readings 22-24:	265

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	mV/m**
		2.4			423.9

Below fixture reading (Ground level)

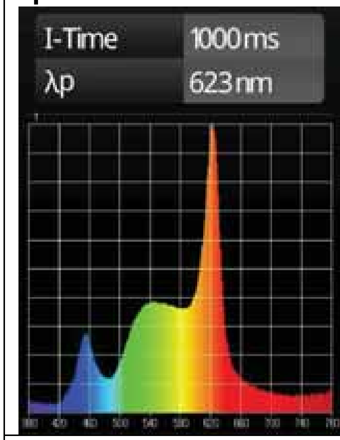
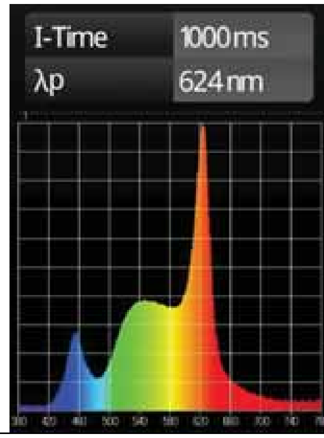
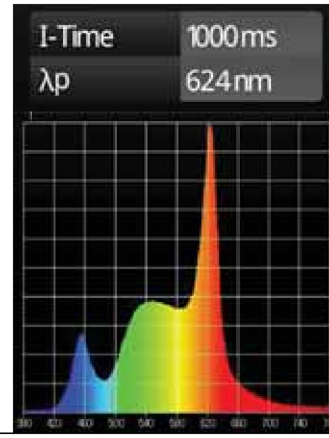
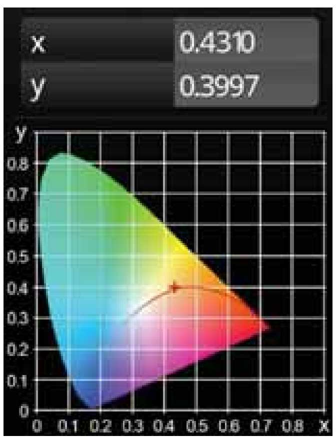
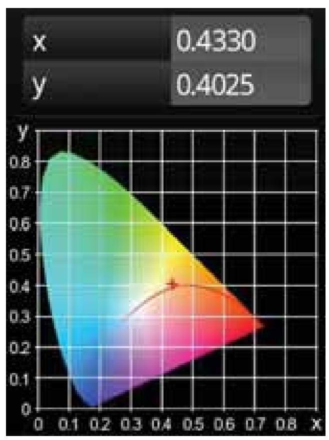
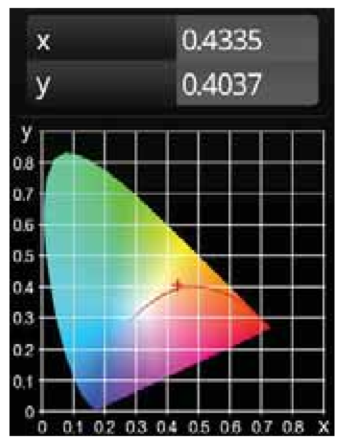
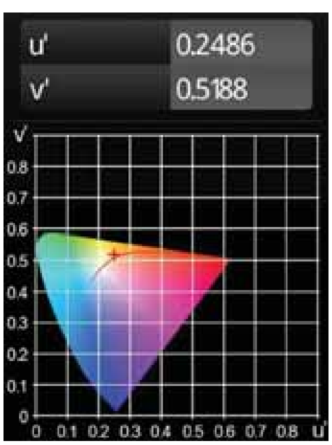
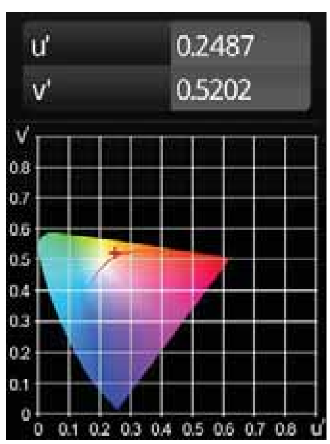
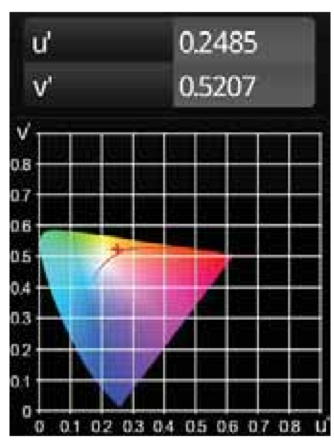
	CCT	CRI	LUX	lp	R9	mV/m**
100%	3104	76.7	30.6	596	-12.1	403
75%	3113	77.2	27.3	598	-9.9	
50%	3144	78.6	15	598	-4.2	

**10 second MAX

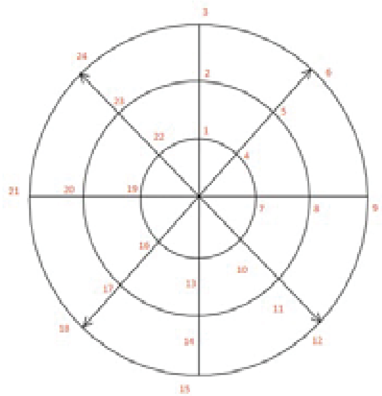
Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m***
1	18.4	13.9	7.1	179.5
2	0	0	0	215.8
3	0	0	0	
4	20.6	17.3	10	
5	6.5	4.8	2.4	
6	0	0	0	
7	18.8	14.8	6.6	149.2
8	4.3	1.2	0.2	248.1
9	0	0	0	
10	0	0	0	
11	0	0	0	
12	0	0	0	

***10 second MAX

	LUX	LUX - 75%	LUX - 50%	mV/m
13	0	0	0	106.2
14	0	0	0	
15	0	0	0	
16	12.7	11.3	5.4	
17	1.6	0	0	
18		0	0	
19	21.4	14.4	7.7	479.2
20	10.2	5	2.8	309.3
21	1.3	0	0	
22	22	15.1	10.2	
23	7.2	3.2	2.4	
24	0.2	0	0	

Cree 3000K Pole 44-50		Cree 3000K Pole 44-75		Cree 3000K Pole 44-100
Spectrum Chart 				
CIE 1931 				
CIE 1976 				

Cree 3000K Pole 44 Spectroanalysis Data



Pole Number: 44
SL Tag Number: SL102641
Install Date: 6/22/2016

Date of Measurements: 8/16/2016 - 8/17/2016
Time of Measurements: 10:04pm / 10:12pm
Weather conditions/visability: Partly cloudy/10mi
Moon phase: Full 98% 100%
Ground conditions: Dry pavement
Pole Orientation: South

Measurements By: Neal Phillips
Witnessed By: James Siegrist

Magnetic Compass Orientation

*Readings 1-3:	200	Readings 13-15:	20
Readings 4-6:	245	Readings 16-18:	65
Readings 7-9:	290	Readings 19-21:	110
Readings 10-12:	335	Readings 22-24:	155

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	mV/m**
		1.7			1.41

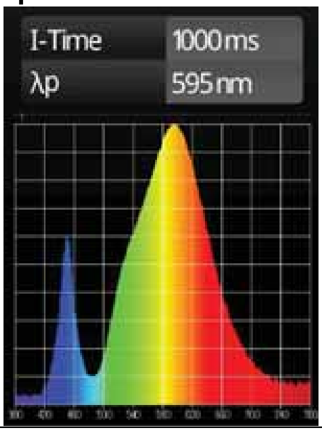
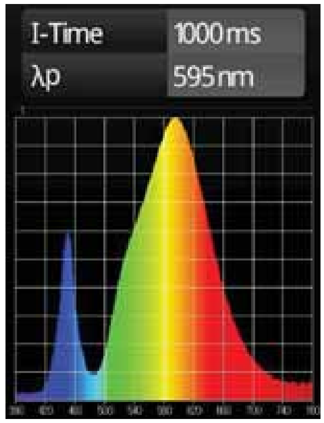
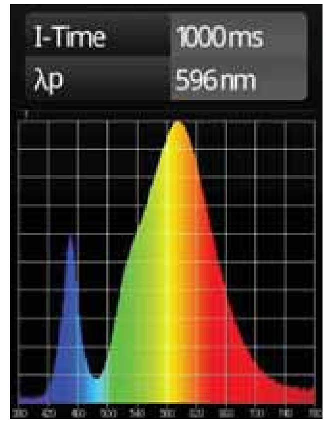
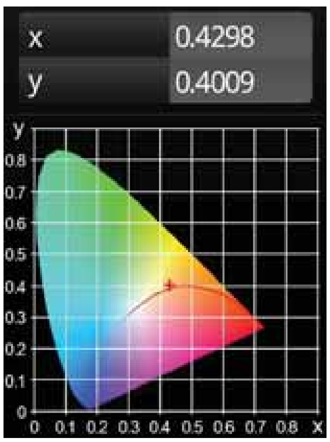
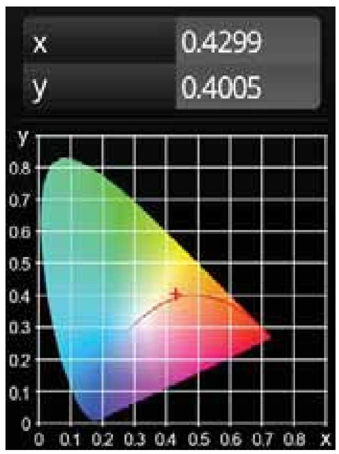
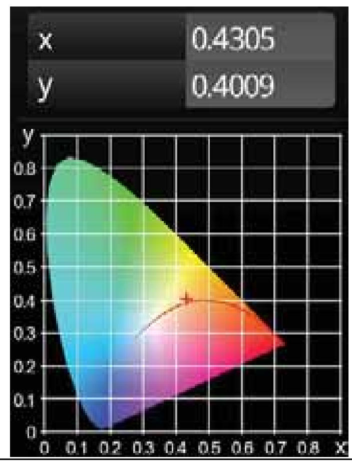
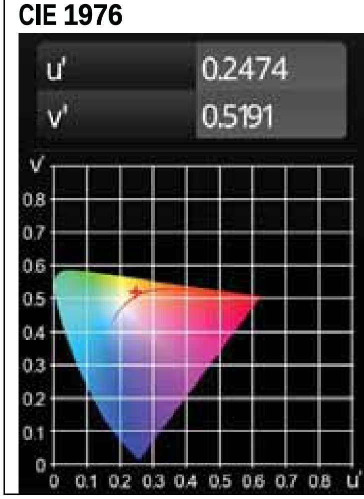
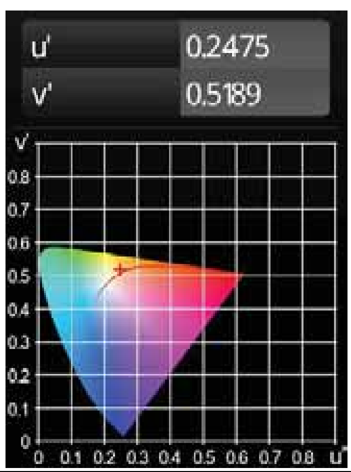
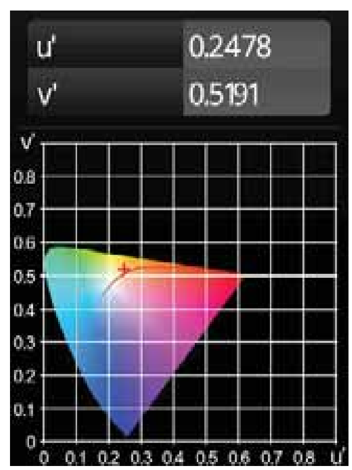
Below fixture reading (Ground level)

	CCT	CRI	LUX	lp	R9	mV/m**
100%	3055	95	19.1	624nm	72.2	451.6
75%	3054	94.9	20.7	624	71.6	
50%	3067	94.6	12.9	623	69.8	

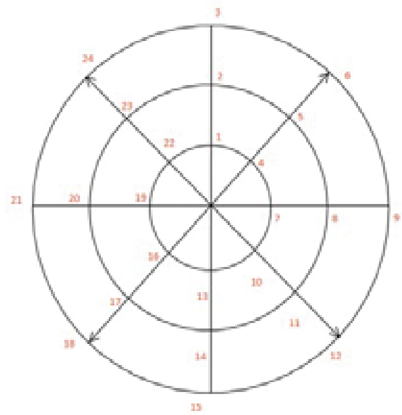
**10 second MAX

Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m**
1	17.1	14.2	8.3	228
2	4.9	2.6	1.5	297.2
3	0	0	0	
4	19.5	19.2	10.2	
5	7.9	5.2	1.5	
6	3.1	1.7	0	
7	14.9	11.4	5.8	129.4
8	3.6	1.9	0	106.6
9	0	0	0	
10	6.2	6.2	2.6	
11	0	0	0	
12		0	0	

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	0	1.5	0	142.5
14		0	0	
15		0	0	
16	5.6	6.6	2.8	
17	0	0	0	
18		0	0	
19	13.4	11.9	6.6	227.8
20	2.3	2	0	117.2
21		0	0	
22	26.3	19.6	13.8	
23	8.4	5.7	4.1	
24	2.1	1.3	0	

<table>
<tr><td>GE 3000K Pole 38-50</td><td></td><td>GE 3000K Pole 38-75</td><td></td><td>GE 3000K Pole 38-100</td></tr>
<tr><td>Spectrum Chart

</td><td></td><td>
</td><td></td><td>
</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CIE 1931

</td><td></td><td>
</td><td></td><td>
</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CIE 1976

</td><td></td><td>
</td><td></td><td>
</td></tr>
</table>

GE 3000K Pole 38 Spectroanalysis Data



Pole Number:	38		
SL Tag Number:	SL102644		
Install Date:	7/15/2016		
Date of Measurements:	8/17/2016	Measurements By:	Neal Phillips
Time of Measurements:	11:01pm	Witnessed By:	James Siegrist
Weather conditions/visability:	Partly cloudy/10mi		
Moon phase:	Full 100%		
Ground conditions:	Dry pavement		
Pole Orientation:	South		

Magnetic Compass Orientation

*Readings 1-3:	160	Readings 13-15:	340
Readings 4-6:	205	Readings 16-18:	25
Readings 7-9:	250	Readings 19-21:	70
Readings 10-12:	295	Readings 22-24:	115

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	V/m**
		1.8			1.76

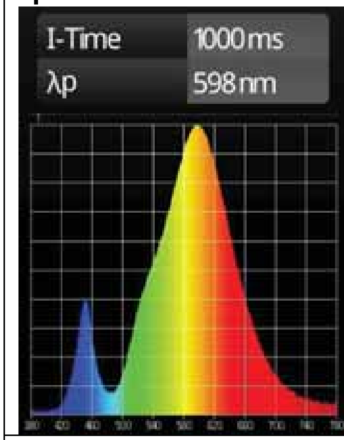
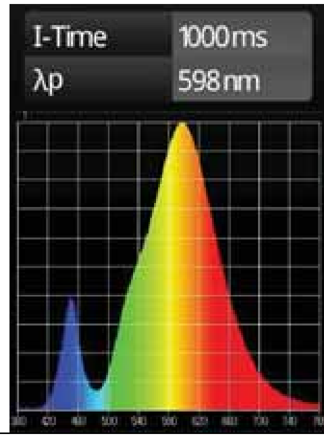
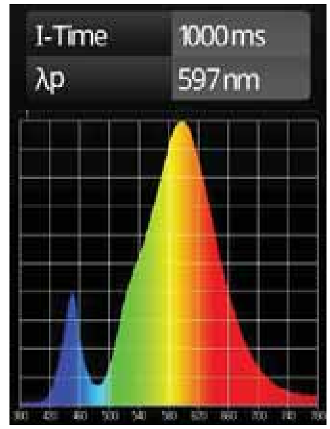
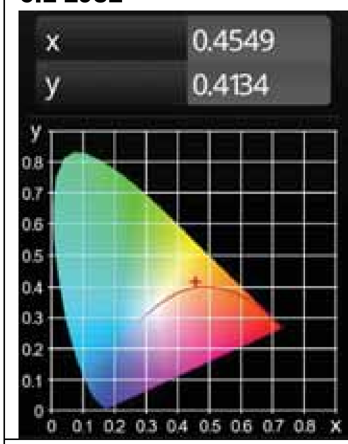
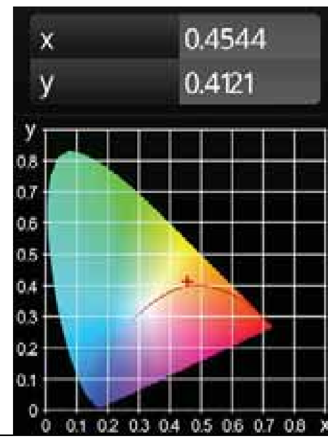
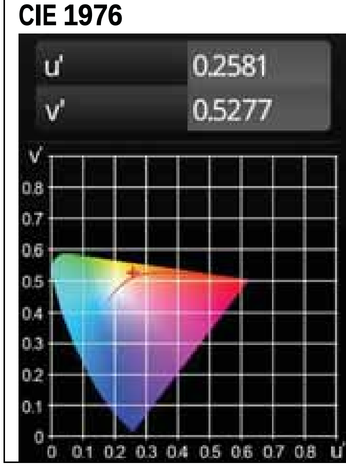
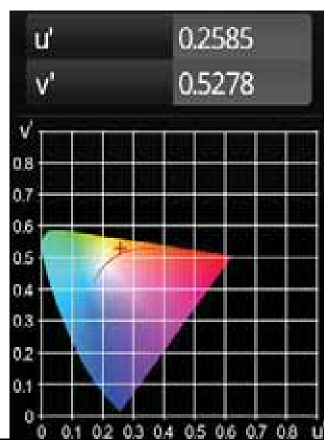
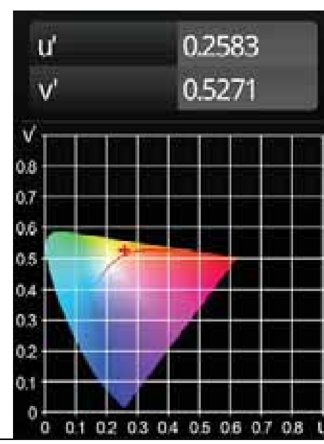
Below fixture reading (Ground level)

	CCT	CRI	LUX	lp	R9	mV/m**
100%	3084	72.5	27.8	596	-22.9	243.2
75%	3093	72.8	21.1	595	-21.7	
50%	3096	73.1	13.3	595	-20.6	

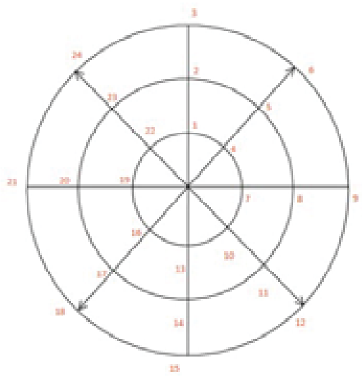
**10 second MAX

Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m***
1	20	17.3	9.2	210.6
2	0	0	0	244.9
3	0	0	0	
4	17.3	14.6	8.5	
5	4.3	2.7	1.2	
6	0	0	0	
7	6.7	6	3.8	237.9
8	2.3	1.3	0	267.7
9	0	0	0	
10	0	0	0	
11	0	0	0	
12	0	0	0	

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	0	0	0	237
14	0	0	0	
15	0	0	0	
16	0	0	0	
17	0	0	0	
18	0	0	0	
19	6.4	5.9	3.7	298
20	2.1	1.9	0	108.6
21	0	0	0	
22	20.2	17.6	11.4	
23	0	0	0	
24	0	0	0	

GE 2700K Pole 39-50		GE 2700K Pole 39-75		GE 2700K Pole 39-100
Spectrum Chart 				
CIE 1931 				
CIE 1976 				

GE 2700K Pole 39 Spectroanalysis Data



Pole Number: 39
SL Tag Number: SL102753
Install Date: 7/15/2016

Date of Measurements: 8/17/2016
Time of Measurements: 10:23pm/10:48
Weather conditions/visability: Partly cloudy
Moon phase: Full 98%
Ground conditions: Dry pavement
Pole Orientation: North

Measurements By: Neal Phillips
Witnessed By: James Siegrist

Magnetic Compass Orientation

*Readings 1-3:	10	Readings 13-15:	190
Readings 4-6:	55	Readings 16-18:	235
Readings 7-9:	100	Readings 19-21:	280
Readings 10-12:	145	Readings 22-24:	325

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	mV/m**
		1.9			372

Below fixture reading (Ground level)

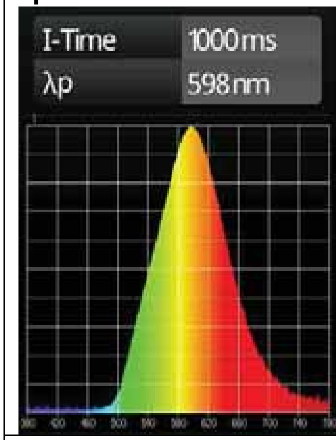
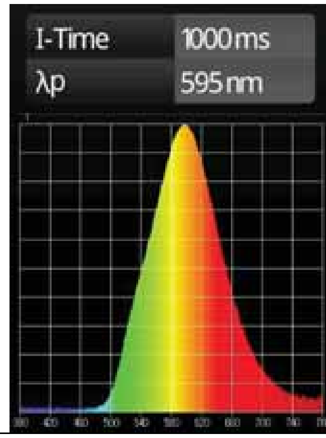
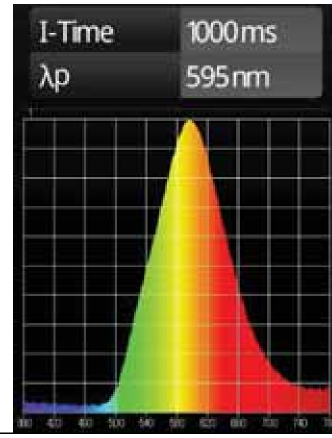
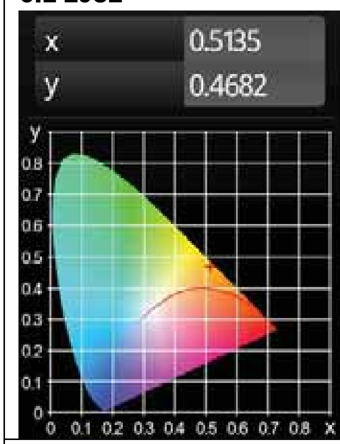
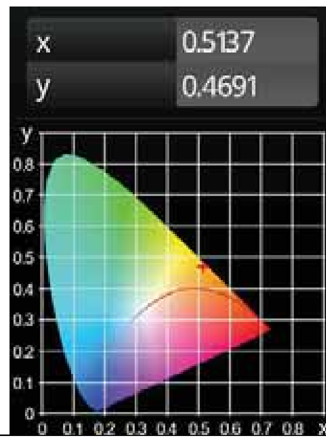
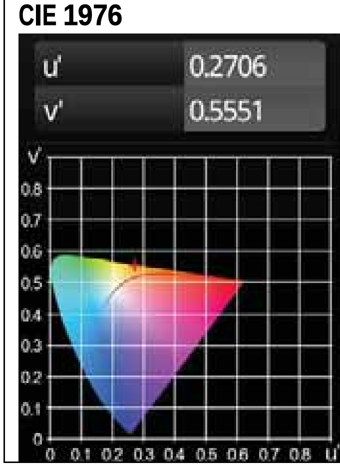
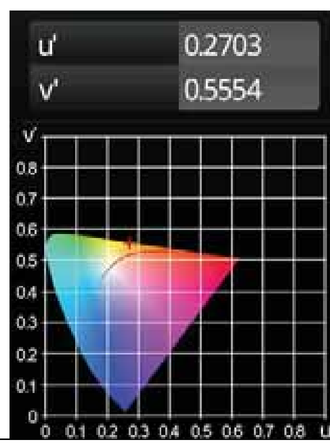
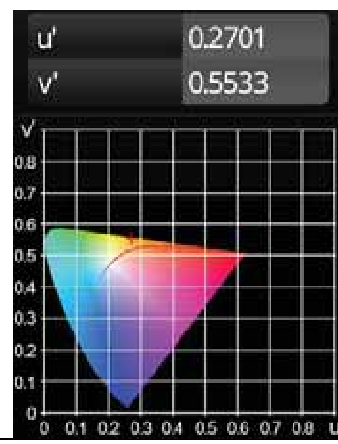
	CCT	CRI	LUX	lp	R9	mV/m**
100%	2789	71.2	56.3	597nm	-28.8	288.4mmV/m
75%	2781	71.2	31.5	598	-29.2	
50%	2781	71.2	31.5	598	-29.2	

**10 second MAX

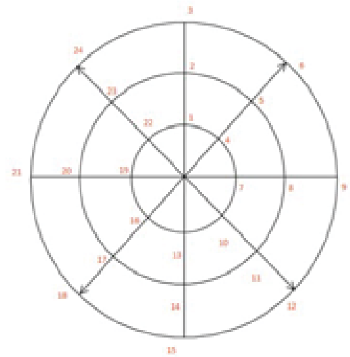
Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m***
1	11.6	10.3	6	315mmV/m
2	0.01	0	0	305.4mmV/m
3	0	0	0	
4	38.8	28	15.6	
5	2	0.6	0	
6	0	0	0	
7	33.4	21.4	13.8	384.3
8	10.7	6	3.5	463.2
9	10.6	5.4	3	
10	12.5	7.8	4.1	
11		0	0	
12		0	0	

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	0	0	0	757.8mmV/m
14		0	0	
15		0	0	
16	2.7	0	0	
17		0	0	
18		0	0	
19	32.5	21.1	14	556.7
20	8.8	4.2	3.5	231.3
21	9	5	3	
22	35.9	27.4	16.1	
23	2.3	2.3	0	
24	0	0	0	

The 50% values for the readings below the fixture for this field record hand ticket appears to duplicate the values recorded for 75% and should be disregarded. The evaluation of CCT, CRI, Lambda P value, and R9 should be reviewed from the MK350 spectrometer log.

C&W 2400K Pole 28-50	C&W 2400K Pole 28-75	C&W 2400K Pole 28-100
Spectrum Chart 		
CIE 1931 		
CIE 1976 		

C&W 2400K Pole 28 Spectroanalysis Data



Pole Number:	28
SL Tag Number:	SL102649
Install Date:	6/22/2016
Date of Measurements:	8/16/2016
Time of Measurements:	10:49pm/11:48
Weather conditions/visability:	Partly cloudy/10mi
Moon phase:	Full 98%
Ground conditions:	Dry pavement
Pole Orientation:	South/South East

Measurements By:	Neal Phillips
Witnessed By:	James Siegrist

Magnetic Compass Orientation

*Readings 1-3:	165	Readings 13-15:	345
Readings 4-6:	210	Readings 16-18:	30
Readings 7-9:	255	Readings 19-21:	75
Readings 10-12:	300	Readings 22-24:	120

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	lp	R9	mV/m**
		1.7			420

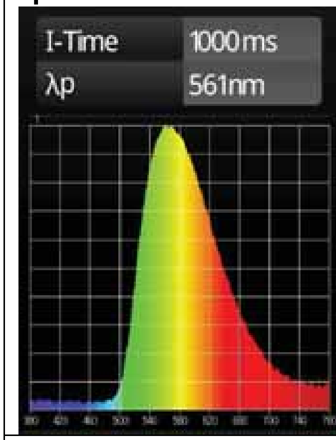
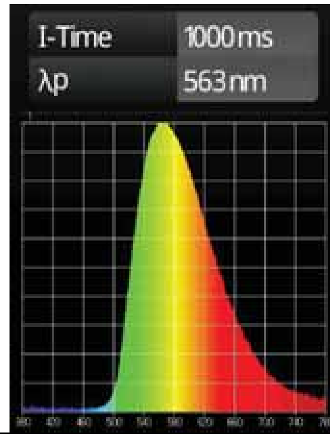
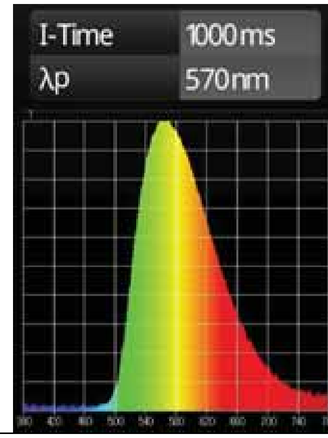
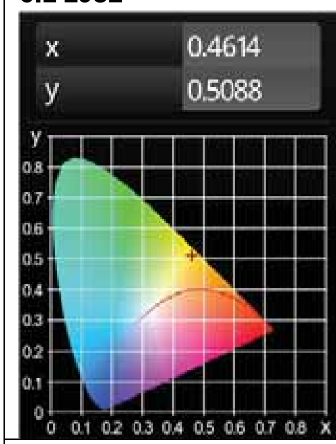
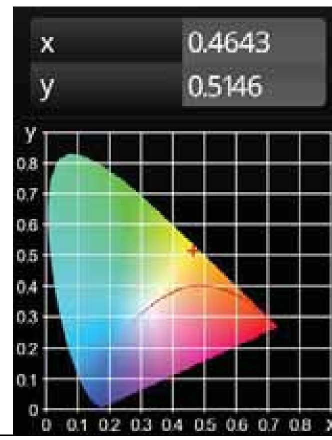
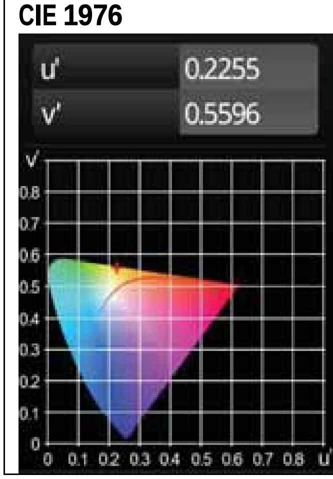
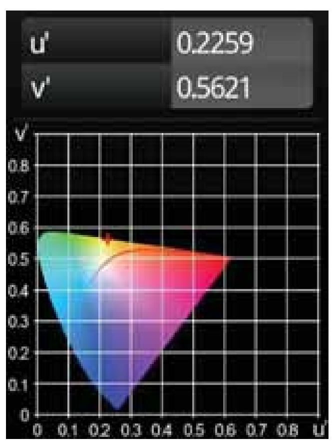
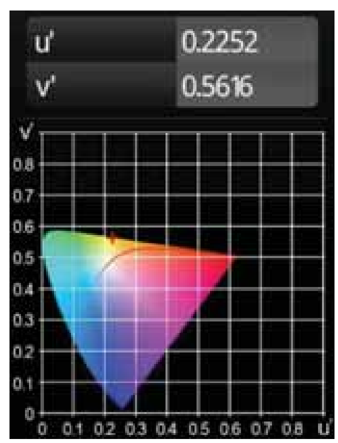
Below fixture reading (Ground level)

	CCT	CRI	LUX	lp	R9	mV/m**
100%	2477	64.4	30.6	595	-46.8	309.21
75%	2469	62.8	20.6	595	-48.9	
50%	2465	63.2	13.3	598	-48.6	

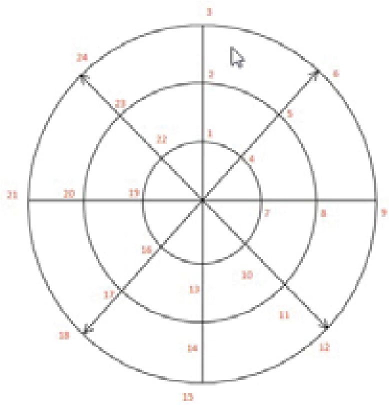
**10 second MAX

Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m***
1	9.4	6.3	3.2	125.4
2	0	0	0	11.1
3	0	0	0	
4	16	10.3	6.1	
5	1.3	0	0	
6	0	0	0	
7	14.4	10.5	6.7	153.6
8	4.4	1.6	0.8	160.3
9	0	0	0	
10	11.3	8.6	5.6	
11	0	0	0	
12		0	0	

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	4.2	3.1	1.8	251.5
14		0	0	
15		0	0	
16	11.3	8.9	6.1	
17	0	0	0	
18		0	0	
19	15.1	11.3	6.7	250.2
20	5.6	2.9	1.6	206.6
21	0	0	0	
22	14	10.4	6.8	
23	2.8	1.5	0	
24	0	0	0	

C&W 3200K Pole 23-50	C&W 3200K Pole 23-75	C&W 3200K Pole 23-100
Spectrum Chart  	 	
CIE 1931  	 	
CIE 1976  	 	

C&W 3200K Pole 23 Spectroanalysis Data



Pole Number:	23
SL Tag Number:	SL102745
Install Date:	6/22/2016
Date of Measurements:	8/17/2016
Time of Measurements:	12:16
Weather conditions/visability:	Partly cloudy/10mi
Moon phase:	Full 98%
Ground conditions:	Dry pavement
Pole Orientation:	North
Measurements By:	Neal Phillips
Witnessed By:	James Siegrist

Magnetic Compass Orientation

*Readings 1-3:	15	Readings 13-15:	195
Readings 4-6:	60	Readings 16-18:	240
Readings 7-9:	105	Readings 19-21:	285
Readings 10-12:	150	Readings 22-24:	330

*Primary Orientation Direction

Above fixture reading (1 meter)

CCT	CRI	LUX	Ip	R9	mV/m**
		1.6			324.5

Below fixture reading (Ground level)

	CCT	CRI	LUX	Ip	R9	mV/m**
100%	3326	56.2	27.1	570	-76.6	160.4
75%	3306	50.7	19.6	563	-76.5	
50%	3334	56.8	13.1	561	-72.7	

**10 second MAX

Reading	LUX - 100%	LUX - 75%	LUX - 50%	mV/m***
1	11.8	9.5	5.5	131
2	0	0	0	100.6
3	0	0	0	
4	14.9	14	7.2	
5	4	3.2	1.7	
6	0	0	0	
7	13.7	12.2	7	104.6
8	3.2	2.2	2.2	352.6
9	0	0	0	
10	9.1	8.2	5.1	
11	0	0	0	
12	0	0	0	

	LUX - 100%	LUX - 75%	LUX - 50%	mV/m
13	4.2	3.3	0	507.8
14	0	0	0	
15	0	0	0	
16	9.1	7.5	5.1	
17	0	0	0	
18	0	0	0	
19	13.3	13.7	7.1	481.8
20	2.8	2.5	1.1	488.1
21	0	0	0	
22	15.5	12.3	7.6	
23	0	0	0	
24	0	0	0	

Section IX – Cut sheets

“We provide innovative solutions to unique problems. The goal is more than lighting up a space; we make every lumen count™.”

DR. BOB ADAMS; PRESIDENT C&W ENERGY SOLUTIONS

INDIVIDUAL LIGHT ENGINE SPECIFICATIONS

Average LED Life (L-70):	>50,000 Hours
LED Source:	Nichia NS9W383
Light Engine Power (W):	24
Ingress Protection:	IP67
Cover Lens:	2V - Star Friendly™ - SF7 Polycarbonate
Safety:	CE, UR, RoHS Compliant

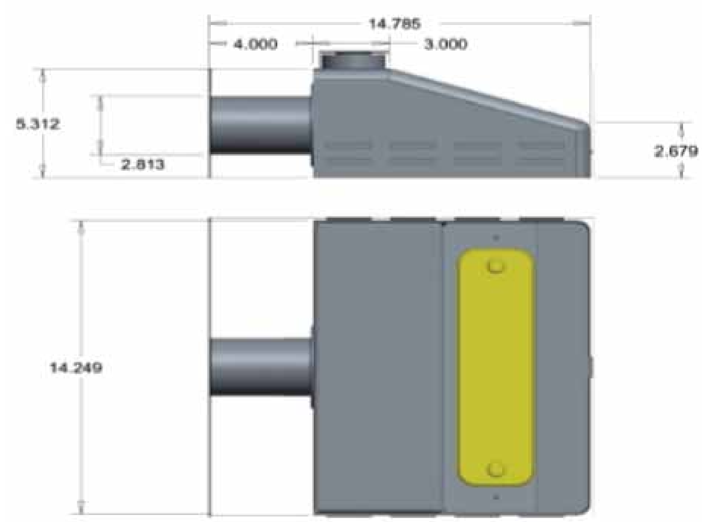
HIB-SLA-74-1-7-UN-GR-OR-2V-PC-SS-BT-EL

Data Sheet for LED Luminaires
Meets County of Hawaii City Ordnance

The CWES HIB Series LED roadway luminaire is a stylized sleek energy efficient LED unit made of powder-coated aluminum that accepts a 1½" – 2 5/8" roadway arm. The fixture is a Type II distribution with full cut-off optics for dark sky and shielded applications. The HIB-SLA-74-1-7 series houses a single light engine that is IP67 rated with a polycarbonate shatter resistant cover. Our entires LED luminaire is RoHS compliant. LED optics and drive circuits are integrated into the light engines. The light engine is designed to suppress >99% of the light emission from 400 nm and 500 nm inclusive to comply with the County of Hawaii lighting ordinances. The HIB-SLA-74-1-7 series luminaire is a replacement for current 90 watt low pressure sodium (LPS) sources.

LUMINAIRE SPECIFICATIONS

X:Y Value:	OR: X=0.522; Y=0.470 - Orange - (2400K)
System Watts:	55 (dimmable 0-10V)
System Efficacy (L/W) @ 700mA:	80
Blue Light Content:	< 1%
Optical Distribution:	IESNA Type II
Input AC Voltage:	90-305
Lumen Output:	4200
Operating Temperature:	-20°C - 50°C
Operating Humidity:	10% - 85%
System Warranty:	10 Years
Weight:	8 lbs
E.P.A.:	0.45



NOTES:

1. L-70: Refers to the estimated time for the LED to reach 70% of the initial lumens. 90,000 hour L-70 is determined by LM80 data from Nachia on the NS9W383 single package at 55°C ambient.
2. X:Y Value: The HIB SLA series luminaire with the SF7 option offers a custom filtered light output that is reference as “Blue Light Content and Traffic Color Compliant”. Blue Light Content is defined as the ratio of the amount of energy emitted by the outdoor light fixture $\Sigma 400 – 500$ nm / $\Sigma 400 – 700$ nm $\leq 1.0\%$, where measurements are taken in one nanometer increments and power measured in mW. “Traffic Color Compliant” means the 1931 CIE X:Y color coordinated of the HIB SLA series luminaire with SF7 option is outside of any of the automotive color boxes as defined by SAE J578.
3. See CWES General Terms and Conditions.

5234 East Hatcher Rd Paradise Valley, Arizona U.S.A
p:480-998-1694 | WWW.CWENERGYUSA.COM

C&W ENERGY SOLUTIONS

> "We provide innovative solutions to unique problems. The goal is more than lighting up a space; we make every lumen count™."
>
> DR. BOB ADAMS; PRESIDENT C&W ENERGY SOLUTIONS

INDIVIDUAL LIGHT ENGINE SPECIFICATIONS

Average LED Life (L-70):	>50,000 Hours
LED Source:	Nichia NS9W383
Light Engine Power (W):	24
Ingress Protection:	IP67
Cover Lens:	2V - Clear Polycarbonate
Safety:	CE, UR, RoHS Compliant

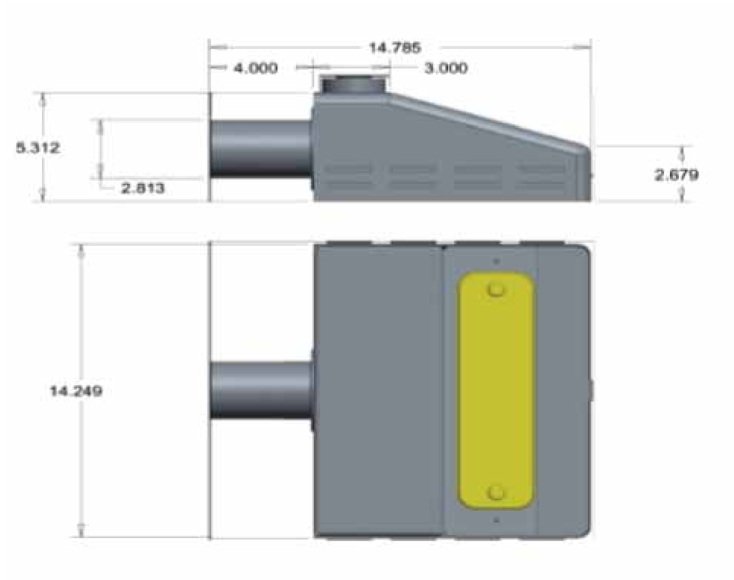
LUMINAIRE SPECIFICATIONS

X:Y Value:	WW: X=0.437 Y=0.405 - Warm White (3000K)
System Watts:	55 (dimmable 0-10V)
System Efficacy (L/W) @ 700mA:	100
Blue Light Content:	< 1%
Optical Distribution:	IESNA Type II
Input AC Voltage:	90-305
Lumen Output:	>5000
Operating Temperature:	-20°C - 50°C
Operating Humidity:	10% - 85%
System Warranty:	10 Years
Weight:	8 lbs
E.P.A.:	0.45

HIB-SLA-74-1-7-UN-GR-WW-2V-PC-SS-BT-EL

Data Sheet for LED Luminaires
Meets County of Hawaii City Ordnance

The CWES HIB Series LED roadway luminaire is a stylized sleek energy efficient LED unit made of powder-coated aluminum that accepts a 1½" – 2 5/8" roadway arm. The fixture is a Type II distribution with full cut-off optics for dark sky and shielded applications. The HIB-SLA-74-1-7 series houses a single light engine that is IP67 rated with a polycarbonate shatter resistant cover. Our entires LED luminaire is RoHS compliant. LED optics and drive circuits are integrated into the light engines. The light engine is designed to suppress >99% of the light emission from 400 nm and 500 nm inclusive to comply with the County of Hawaii lighting ordinances. The HIB-SLA-74-1-7 series luminaire is a replacement for current 90 watt low pressure sodium (LPS) sources.



NOTES:

1. L-70: Refers to the estimated time for the LED to reach 70% of the initial lumens. 90,000 hour L-70 is determined by LM80 data from Nachia on the NS9W383 single package at 55°C ambient.
2. X:Y Value: The HIB SLA series luminaire with the SF7 option offers a custom filtered light output that is reference as "Blue Light Content and Traffic Color Compliant". Blue Light Content is defined as the ratio of the amount of energy emitted by the outdoor light fixture Σ400 – 500 nm / Σ400 – 700 nm ≤ 1.0%, where measurements are taken in one nanometer increments and power measured in mW. "Traffic Color Compliant" means the 1931 CIE X:Y color coordinated of the HIB SLA series luminaire with SF7 option is outside of any of the automotive color boxes as defined by SAE J578.
3. See CWES General Terms and Conditions.

5234 East Hatcher Rd Paradise Valley, Arizona U.S.A
p:480-998-1694 | WWW.CWENERGYUSA.COM

> We provide innovative solutions to unique problems. The goal is more than lighting up a space; **we make every lumen count™.**

DR. BOB ADAMS; PRESIDENT **C&W ENERGY SOLUTIONS**

INDIVIDUAL LIGHT ENGINE SPECIFICATIONS

Average LED Life (L-70):	>50,000 Hours
LED Source:	Nichia NS9W383
Light Engine Power (W):	24
Ingress Protection:	IP67
Cover Lens:	2V - Star Friendly™ - SF7 Polycarbonate
Safety:	CE, UR, RoHS Compliant

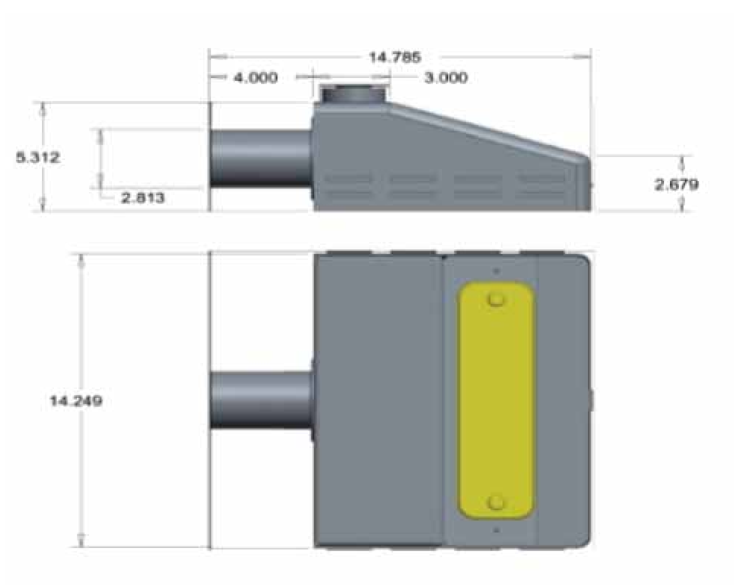
HIB-SLA-74-1-7-UN-GR-YL-2V-PC-SS-BT-EL

Data Sheet for LED Luminaires
Meets County of Hawaii City Ordnance

The CWES HIB Series LED roadway luminaire is a stylized sleek energy efficient LED unit made of powder-coated aluminum that accepts a 1½" – 2 5/8" roadway arm. The fixture is a Type II distribution with full cut-off optics for dark sky and shielded applications. The HIB-SLA-74-1-7 series houses a single light engine that is IP67 rated with a polycarbonate shatter resistant cover. Our entires LED luminaire is RoHS compliant. LED optics and drive circuits are integrated into the light engines. The light engine is designed to suppress >99% of the light emission from 400 nm and 500 nm inclusive to comply with the County of Hawaii lighting ordinances. The HIB-SLA-74-1-7 series luminaire is a replacement for current 90 watt low pressure sodium (LPS) sources.

LUMINAIRE SPECIFICATIONS

X:Y Value:	YL: X=0.473; Y=0.518 - Yellow- (3200K)
System Watts:	55 (dimmable 0-10V)
System Efficacy (L/W) @ 700mA:	90
Blue Light Content:	< 1%
Optical Distribution:	IESNA Type II
Input AC Voltage:	90-305
Lumen Output:	>4500
Operating Temperature:	-20°C - 50°C
Operating Humidity:	10% - 85%
System Warranty:	10 Years
Weight:	8 lbs
E.P.A.:	0.45



NOTES:

1. L-70: Refers to the estimated time for the LED to reach 70% of the initial lumens. 90,000 hour L-70 is determined by LM80 data from Nachia on the NS9W383 single package at 55°C ambient.
2. X:Y Value: The HIB SLA series luminaire with the SF7 option offers a custom filtered light output that is reference as "Blue Light Content and Traffic Color Compliant". Blue Light Content is defined as the ratio of the amount of energy emitted by the outdoor light fixture Σ400 – 500 nm / Σ400 – 700 nm ≤ 1.0%, where measurements are taken in one nanometer increments and power measured in mW. "Traffic Color Compliant" means the 1931 CIE X:Y color coordinated of the HIB SLA series luminaire with SF7 option is outside of any of the automotive color boxes as defined by SAE J578.
3. See CWES General Terms and Conditions.

5234 East Hatcher Rd Paradise Valley, Arizona U.S.A
p:480-998-1694 | WWW.CWENERGYUSA.COM

Cree® RSW Series

LED Street Luminaire

HELLO, MEET THE WARMER SIDE OF COOL

Unrivaled Performance

Featuring WaveMax™ Technology, expect unmatched visual comfort and high-quality lighting without sacrificing performance. The RSW Series delivers both optimized target illumination and industry-leading efficacy to improve overall energy efficiency. Finally, an LED street light that delivers warmer color temperatures and significant reduction in energy costs.

Unexpected Value

No one likes wasting money. Least of all cities and utilities who are charged with being the highest stewards of taxpayer dollars. That's why we created the RSW Series to be an economic solution that delivers a surprisingly rapid payback upfront. And with significantly reduced maintenance cycles and annual energy savings up to 70 percent compared to incumbent technology, the RSW Series can deliver returns for years to come.

Exceptional Reliability

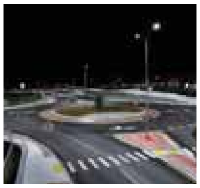
Virtually maintenance-free, the RSW™ LED Street Luminaire is designed to last up to 100,000 hours to L_{70} — eliminating unnecessary truck rolls. The RSW™ luminaire is constructed of high strength, yet lightweight bulk molding compound for long weathering and durability, which is just one of the reasons why we can offer our industry-leading 10-year limited warranty.

REDEFINING THE EXPECTATIONS OF STREET LIGHTING

From uptown to downtown, the RSW Series utilizes WaveMax™ Technology and newly optimized materials to outperform incumbent technology by providing superior illumination, durability, and economic performance for municipalities and utilities, resulting in expedient payback with less than half the wattage and one-third the typical weight of comparable traditional solutions.

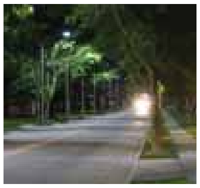
PERFORMANCE SUMMARY
Input Power: 30W or 50W
Efficacy: Up to 115 Lumens per Watt (LPW)
CRI: 80 CRI
CCT: 3000K (+/- 175K); 4000K (+/- 300K)
Input Voltage: 120-277V, 50/60Hz
Weight: 6.5 lbs (2.9kg)
Dimensions: 20.7"L x 9.8"W x 4.7"H (includes NEMA® Receptacle)
Limited Warranty†: 10 years on luminaire

APPLICATIONS



Street Lighting
Virtually maintenance-free, the RSW™ LED Street Luminaire is designed to last 100,000 hours. Now, maintenance crews can focus on more important projects, rather than replacing burnt out lamps.

Campus Street Lighting
Welcome visitors to your site with either a warm 3000K CCT that is comfortable and inviting or choose a cooler, more crisp 4000K CCT that brings out the beauty of the architecture and surrounding areas.



Residential Street Lighting
The RSW Series' 3000K option combined with beautiful light quality helps ensure the transition to LED is a seamless one for residents. Its color is comfortable and familiar while the 115 lumens per watt achieved is too great to ignore.

Intersections
WaveMax™ Technology provides exceptional light quality and distribution to help improve roadway visibility. Improving visibility means drivers see other vehicles and nearby areas better to help avoid unsafe situations, even at busy intersections.

Visit **www.cree.com/lighting** or contact a Cree lighting representative to learn more

info@cree.com | 800.236.6800

 CAT/SSHT-C039 Rev. Date: 01/26/16

CREE

GE
Lighting

Evolve™ LED Roadway Lighting

LED Roadway Luminaire (ERL1-ERLH-ERS1-ERS2)

imagination at work

Product Features

The Evolve™ LED Roadway Luminaire is optimized for customers requiring a LED solution for local, collector and major roadways. GE's unique reflective optics are designed to optimize application efficiency and minimize glare. The modern design incorporates the heat sink directly into the unit for heat transfer to prolong LED life. This reliable unit has a 100,000 hour design life, significantly reducing maintenance needs and expense over the life of the fixture. This efficient solution lowers energy consumption compared to traditional HID fixture for additional operating cost savings.

Applications

- Designed to meet recommended luminance and illuminance requirements for local, collector and major roadway/street classifications.

Housing

- The modern design incorporates Casting-integral heatsink for maximum heat transfer.
- Meets 3G vibration per ANSI C136.31-2010.
- Die Cast Enclosure.

LED & Optical Assembly

- Evolve™ light engine consisting of reflective technology designed to optimize application efficiency and minimize glare.
- Utilizes high brightness LEDs, 70 CRI at 3000K and 4000K typical.
- LM-79 tests and reports in accordance with IESNA standards.

Lumen Maintenance

- Lumen Maintenance per TM21.

Ratings

- UL/cUL listed, suitable for wet locations per UL 1598.
- Std. Optical enclosure rated per ANSI C136.25-2009: ERL1 = IP65, ERS1-2 = IP66, ERLH = IP65.
- Upward Light Output Ratio (ULOR) = 0.
- Compliant with the material restriction requirements of RoHS.

Product ID	Lumen Output	Ambient Rating
ERL1	02-09	-40°C to 50°C
ERLH	10-11	-40°C to 50°C
ERLH	13-15	-40°C to 40°C
ERS1	10-15	-40°C to 50°C
ERS2	16-23	-40°C to 50°C
ERS2	25-28	-40°C to 40°C

Delayed start may be experienced <-35°C.

Mounting

- Slipfitter with +/- 5 degree of adjustment for leveling.
- Integral die cast mounting pipe stop.
- Adjustable for 1.25 in. or 2 in. mounting pipe.

Finish

- Corrosion resistant polyester powder paint, minimum 2.0 mil. thickness.
- Standard colors: Black, Gray and Dark Bronze.
- RAL & custom colors available.
- Optional coastal finish available.

Electrical

- 120-277 VAC and 347-480 VAC.
- System power factor is >90% and THD <20%.*
- Class "A" Sound rating.
- 0-10V dimming standard or DALI dimming available upon request for 120V-277V.
- Surge Protection per ANSI C136.2-2015:
  - Standard: 6kV/3kA "Basic: (120 Strikes)"
  - Optional Secondary: 10kV/5kA "Enhanced: (40 Strikes)"
- EMI: Title 47 CFR Part 15 Class A
- Photo electric sensors (PE) available.

** System power factor and THD is tested and specified at 120V input and maximum load conditions. THD<26% for 347/480V supply with 03 power level.*

Warranty

- 5 Year Standard
- 10 Year Optional

Suggested HID Replacement Lumen Levels

- ~4,000–5,000 lumens to replace 100W HPS Cobra-head
- ~7,000–8,800 lumens to replace 150W HPS Cobra-head
- ~8,500–11,500 lumens to replace 200W HPS Cobra-head
- ~11,500–14,000 lumens to replace 250W HPS Cobra-head
- ~21,000–28,000 lumens to replace 400W HPS Cobra-head

***Note:** Actual replacement lumens may vary based upon mounting height, pole spacing, design criteria, etc.*

Ordering Number Logic

Evolve™ LED Streetlight (ERL1)

E R L 1

____ _ __ __ __ _ ____ ___

PROD. ID	VOLTAGE	LUMEN OUTPUT	DISTRIBUTION	CCT	CONTROLS	COLOR	OPTIONS
E = Evolve **R** = Roadway **L** = Local **1** = Single Module	**0** = 120-277* **1** = 120 **2** = 208 **3** = 240 **4** = 277 **5** = 480 **D** = 347 **H** = 347-480* * Not available with Fusing. Must choose a descreet voltage with F option.	**02*** **03** **04** **05** **06** **07** **08** **09** See Data Table for more information. *120V only, not compatible with 0-10V dimming.	**A1** = Extra Narrow Asymmetric **B1** = Narrow Asymmetric (Medium) **C1** = Asymmetric (Short) **D1** = Asymmetric Forward **E1** = Asymmetric (Medium) **F1** = Asymmetric (Wide) **G1** = Asymmetric (Extra Wide) See Data Table for more information	**30** = 3000K **40** = 4000K	**A** = ANSI C136.41 7-pin **D** = ANSI C136.41 7-pin receptacle with Shorting Cap **E** = ANSI C136.41 7-pin Receptacle with non-Dimming PE Control.* * PE Control Only available for 120-277V or 480V Discrete. Not available for 347-480V or 347V Discrete. **NOTE:** Dimming controls wired for 0-10V standard unless DALI option "U" requested.	**GRAY** = Gray **BLCK** = Black **DKBZ** = Dark Bronze	**A** = 4 Bolt Slipfitter † **F** = Fusing **G** = Internal Bubble Level **I** = IP66 Optical **L** = Tool-Less Entry **R** = Optional Secondary Enhanced Surge Protection (10kV/5kA) **U** = Universal DALI Programmable +^ **X** = Single Package # **Y** = Coastal Finish * **XXX** = Special Options † Contact manufacturer for Lead-Time. # Std Packaging = 20 units per container. * Recommended for installations within 1 mile from the coast. Contact Factory for Lead-Time. + Compatible with LightGrid 2.0 nodes. ^ Not available in 347V, 480V or 347-480V for Lumen Level 07 and 08.

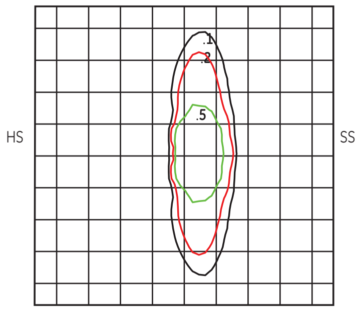
PRODUCT ID	LUMEN OUTPUT	DISTRIBUTION	TYPICAL INITIAL LUMENS 4000K	TYPICAL INITIAL LUMENS 3000K	TYPICAL SYSTEM WATTAGE 120-277V	TYPICAL SYSTEM WATTAGE 347-480V	BUG RATING 4000K	BUG RATING 3000K	IES FILE NUMBER 4000K 120-277V	IES FILE NUMBER 4000K 347-480V	IES FILE NUMBER 3000K 120-277V	IES FILE NUMBER 3000K 347-480V
ERL1	02	A1	1900	1800	15	N/A	B1-U0-G1	B1-U0-G1	ERL1_02A140____-120V.IES	N/A	ERL1_02A130____-120V.IES	N/A
ERL1		B1	1900	1800			B1-U0-G0	B1-U0-G0	ERL1_02B140____-120V.IES	N/A	ERL1_02B130____-120V.IES	N/A
ERL1		C1	2000	1900			B1-U0-G1	B1-U0-G1	ERL1_02C140____-120V.IES	N/A	ERL1_02C130____-120V.IES	N/A
ERL1		D1	1900	1800			B1-U0-G0	B1-U0-G0	ERL1_02D140____-120V.IES	N/A	ERL1_02D130____-120V.IES	N/A
ERL1		E1	2000	1900			B1-U0-G0	B1-U0-G0	ERL1_02E140____-120V.IES	N/A	ERL1_02E130____-120V.IES	N/A
ERL1		F1	2000	1900			B1-U0-G1	B1-U0-G1	ERL1_02F140____-120V.IES	N/A	ERL1_02F130____-120V.IES	N/A
ERL1		G1	2000	1900			B1-U0-G1	B1-U0-G1	ERL1_02G140____-120V.IES	N/A	ERL1_02G130____-120V.IES	N/A
ERL1	03	A1	2800	2700	25	28	B1-U0-G1	B1-U0-G1	ERL1_03A140____-120-277V.IES	ERL1_03A140____-347-480V.IES	ERL1_03A130____-120-277V.IES	ERL1_03A130____-347-480V.IES
ERL1		B1	2900	2800			B1-U0-G1	B1-U0-G1	ERL1_03B140____-120-277V.IES	ERL1_03B140____-347-480V.IES	ERL1_03B130____-120-277V.IES	ERL1_03B130____-347-480V.IES
ERL1		C1	3000	2900			B1-U0-G1	B1-U0-G1	ERL1_03C140____-120-277V.IES	ERL1_03C140____-347-480V.IES	ERL1_03C130____-120-277V.IES	ERL1_03C130____-347-480V.IES
ERL1		D1	2900	2800			B1-U0-G1	B1-U0-G1	ERL1_03D140____-120-277V.IES	ERL1_03D140____-347-480V.IES	ERL1_03D130____-120-277V.IES	ERL1_03D130____-347-480V.IES
ERL1		E1	3000	2900			B1-U0-G1	B1-U0-G1	ERL1_03E140____-120-277V.IES	ERL1_03E140____-347-480V.IES	ERL1_03E130____-120-277V.IES	ERL1_03E130____-347-480V.IES
ERL1		F1	3000	2900			B1-U0-G1	B1-U0-G1	ERL1_03F140____-120-277V.IES	ERL1_03F140____-347-480V.IES	ERL1_03F130____-120-277V.IES	ERL1_03F130____-347-480V.IES
ERL1		G1	3000	2900			B1-U0-G1	B1-U0-G1	ERL1_03G140____-120-277V.IES	ERL1_03G140____-347-480V.IES	ERL1_03G130____-120-277V.IES	ERL1_03G130____-347-480V.IES
ERL1	04	A1	3800	3700	32	35	B1-U0-G1	B1-U0-G1	ERL1_04A140____-120-277V.IES	ERL1_04A140____-347-480V.IES	ERL1_04A130____-120-277V.IES	ERL1_04A130____-347-480V.IES
ERL1		B1	3900	3800			B1-U0-G1	B1-U0-G1	ERL1_04B140____-120-277V.IES	ERL1_04B140____-347-480V.IES	ERL1_04B130____-120-277V.IES	ERL1_04B130____-347-480V.IES
ERL1		C1	4000	3900			B1-U0-G1	B1-U0-G1	ERL1_04C140____-120-277V.IES	ERL1_04C140____-347-480V.IES	ERL1_04C130____-120-277V.IES	ERL1_04C130____-347-480V.IES
ERL1		D1	3900	3800			B1-U0-G1	B1-U0-G1	ERL1_04D140____-120-277V.IES	ERL1_04D140____-347-480V.IES	ERL1_04D130____-120-277V.IES	ERL1_04D130____-347-480V.IES
ERL1		E1	4000	3900			B1-U0-G1	B1-U0-G1	ERL1_04E140____-120-277V.IES	ERL1_04E140____-347-480V.IES	ERL1_04E130____-120-277V.IES	ERL1_04E130____-347-480V.IES
ERL1		F1	4000	3900			B1-U0-G1	B1-U0-G1	ERL1_04F140____-120-277V.IES	ERL1_04F140____-347-480V.IES	ERL1_04F130____-120-277V.IES	ERL1_04F130____-347-480V.IES
ERL1		G1	4000	3900			B1-U0-G1	B1-U0-G1	ERL1_04G140____-120-277V.IES	ERL1_04G140____-347-480V.IES	ERL1_04G130____-120-277V.IES	ERL1_04G130____-347-480V.IES
ERL1	05	A1	4800	4600	41	45	B2-U0-G1	B2-U0-G1	ERL1_05A140____-120-277V.IES	ERL1_05A140____-347-480V.IES	ERL1_05A130____-120-277V.IES	ERL1_05A130____-347-480V.IES
ERL1		B1	4800	4600			B2-U0-G1	B2-U0-G1	ERL1_05B140____-120-277V.IES	ERL1_05B140____-347-480V.IES	ERL1_05B130____-120-277V.IES	ERL1_05B130____-347-480V.IES
ERL1		C1	5000	4800			B2-U0-G1	B2-U0-G1	ERL1_05C140____-120-277V.IES	ERL1_05C140____-347-480V.IES	ERL1_05C130____-120-277V.IES	ERL1_05C130____-347-480V.IES
ERL1		D1	4800	4600			B1-U0-G1	B1-U0-G1	ERL1_05D140____-120-277V.IES	ERL1_05D140____-347-480V.IES	ERL1_05D130____-120-277V.IES	ERL1_05D130____-347-480V.IES
ERL1		E1	5000	4800			B2-U0-G1	B2-U0-G1	ERL1_05E140____-120-277V.IES	ERL1_05E140____-347-480V.IES	ERL1_05E130____-120-277V.IES	ERL1_05E130____-347-480V.IES
ERL1		F1	5000	4800			B2-U0-G1	B2-U0-G1	ERL1_05F140____-120-277V.IES	ERL1_05F140____-347-480V.IES	ERL1_05F130____-120-277V.IES	ERL1_05F130____-347-480V.IES
ERL1		G1	5000	4800			B2-U0-G1	B2-U0-G1	ERL1_05G140____-120-277V.IES	ERL1_05G140____-347-480V.IES	ERL1_05G130____-120-277V.IES	ERL1_05G130____-347-480V.IES
ERL1	06	A1	5700	5500	53	58	B2-U0-G1	B2-U0-G1	ERL1_06A140____-120-277V.IES	ERL1_06A140____-347-480V.IES	ERL1_06A130____-120-277V.IES	ERL1_06A130____-347-480V.IES
ERL1		B1	5800	5600			B2-U0-G1	B2-U0-G1	ERL1_06B140____-120-277V.IES	ERL1_06B140____-347-480V.IES	ERL1_06B130____-120-277V.IES	ERL1_06B130____-347-480V.IES
ERL1		C1	6000	5800			B2-U0-G1	B2-U0-G1	ERL1_06C140____-120-277V.IES	ERL1_06C140____-347-480V.IES	ERL1_06C130____-120-277V.IES	ERL1_06C130____-347-480V.IES
ERL1		D1	5800	5600			B1-U0-G1	B1-U0-G1	ERL1_06D140____-120-277V.IES	ERL1_06D140____-347-480V.IES	ERL1_06D130____-120-277V.IES	ERL1_06D130____-347-480V.IES
ERL1		E1	6000	5800			B2-U0-G1	B2-U0-G1	ERL1_06E140____-120-277V.IES	ERL1_06E140____-347-480V.IES	ERL1_06E130____-120-277V.IES	ERL1_06E130____-347-480V.IES
ERL1		F1	6000	5800			B2-U0-G1	B2-U0-G1	ERL1_06F140____-120-277V.IES	ERL1_06F140____-347-480V.IES	ERL1_06F130____-120-277V.IES	ERL1_06F130____-347-480V.IES
ERL1		G1	6000	5800			B2-U0-G1	B2-U0-G1	ERL1_06G140____-120-277V.IES	ERL1_06G140____-347-480V.IES	ERL1_06G130____-120-277V.IES	ERL1_06G130____-347-480V.IES
ERL1	07	A1	6700	6500	67		B2-U0-G2	B2-U0-G2	ERL1_07A140____.IES		ERL1_07A130____.IES	
ERL1		B1	6800	6600			B2-U0-G1	B2-U0-G1	ERL1_07B140____.IES		ERL1_07B130____.IES	
ERL1		C1	7000	6800			B2-U0-G1	B2-U0-G1	ERL1_07C140____.IES		ERL1_07C130____.IES	
ERL1		D1	6800	6600			B2-U0-G1	B2-U0-G1	ERL1_07D140____.IES		ERL1_07D130____.IES	
ERL1		E1	7000	6800			B2-U0-G1	B2-U0-G1	ERL1_07E140____.IES		ERL1_07E130____.IES	
ERL1		F1	7000	6800			B2-U0-G2	B2-U0-G2	ERL1_07F140____.IES		ERL1_07F130____.IES	
ERL1		G1	7000	6800			B2-U0-G2	B2-U0-G2	ERL1_07G140____.IES		ERL1_07G130____.IES	
ERL1	08	A1	8200	8000	88		B2-U0-G2	B2-U0-G2	ERL1_08A140____.IES		ERL1_08A130____.IES	
ERL1		B1	8300	8100			B2-U0-G1	B2-U0-G1	ERL1_08B140____.IES		ERL1_08B130____.IES	
ERL1		C1	8500	8200			B2-U0-G1	B2-U0-G1	ERL1_08C140____.IES		ERL1_08C130____.IES	
ERL1		D1	8300	8100			B2-U0-G1	B2-U0-G1	ERL1_08D140____.IES		ERL1_08D130____.IES	
ERL1		E1	8500	8200			B2-U0-G1	B2-U0-G1	ERL1_08E140____.IES		ERL1_08E130____.IES	
ERL1		F1	8500	8200			B2-U0-G2	B2-U0-G2	ERL1_08F140____.IES		ERL1_08F130____.IES	
ERL1		G1	8500	8200			B2-U0-G2	B2-U0-G2	ERL1_08G140____.IES		ERL1_08G130____.IES	
ERL1	09	A1	8400	8100	90		B2-U0-G2	B2-U0-G2	ERL1_09A140____.IES		ERL1_09A130____.IES	
ERL1		B1	8500	8200			B2-U0-G1	B2-U0-G1	ERL1_09B140____.IES		ERL1_09B130____.IES	
ERL1		C1	8800	8400			B2-U0-G1	B2-U0-G1	ERL1_09C140____.IES		ERL1_09C130____.IES	
ERL1		D1	8500	8200			B2-U0-G2	B2-U0-G1	ERL1_09D140____.IES		ERL1_09D130____.IES	
ERL1		E1	8800	8400			B2-U0-G1	B2-U0-G1	ERL1_09E140____.IES		ERL1_09E130____.IES	
ERL1		F1	8800	8400			B2-U0-G2	B2-U0-G2	ERL1_09F140____.IES		ERL1_09F130____.IES	
ERL1		G1	8800	8400			B2-U0-G2	B2-U0-G2	ERL1_09G140____.IES		ERL1_09G130____.IES	

Photometrics

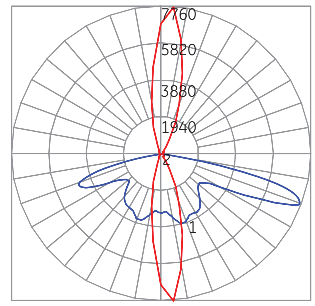
Evolve™ LED Streetlight (ERL1)

ERL1
Extra Narrow Asymmetric (08A1)

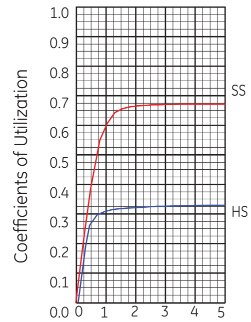
8,200 Lumens
4000K
ERL1_08A140______.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



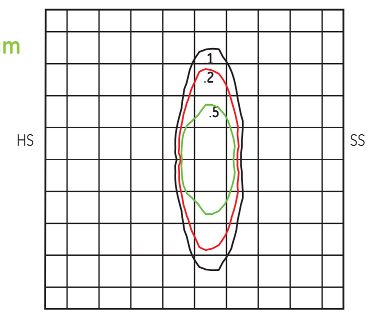
— Vertical plane through horizontal angle of maximum candlepower at 85°
— Vertical plane through horizontal angle of 70°



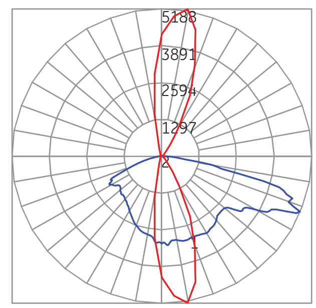
Street Width/Mounting Height

ERL1
Narrow Asymmetric Medium (08B1)

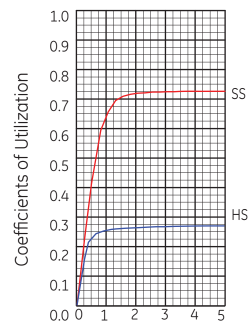
8,300 Lumens
4000K
ERL1_08B140______.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



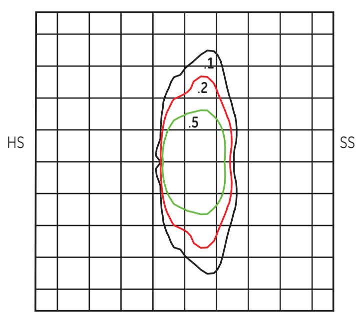
— Vertical plane through horizontal angle of maximum candlepower at 80°
— Vertical plane through horizontal angle of 68°



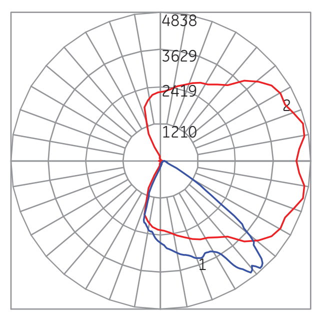
Street Width/Mounting Height

ERL1
Asymmetric Short (08C1)

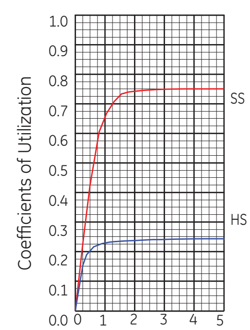
8,500 Lumens
4000K
ERL1_08C140______.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



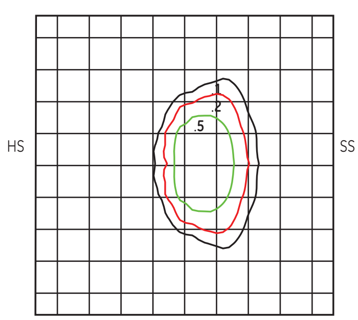
— Vertical plane through horizontal angle of maximum candlepower at 15°
— Vertical plane through horizontal angle of 42°



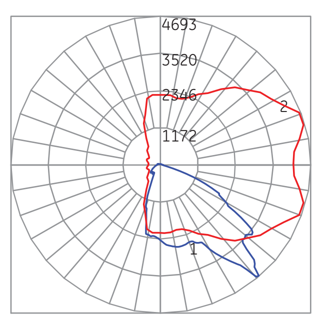
Street Width/Mounting Height

ERL1
Asymmetric Forward (08D1)

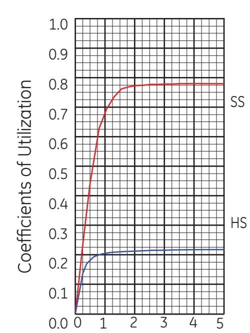
8,300 Lumens
4000K
ERL1_08D140______.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



— Vertical plane through horizontal angle of maximum candlepower at 15°
— Vertical plane through horizontal angle of 42°



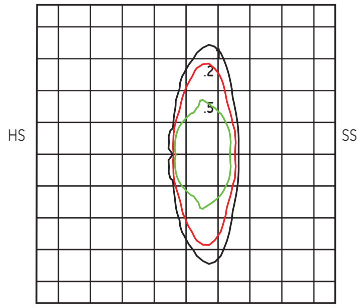
Street Width/Mounting Height

Photometrics

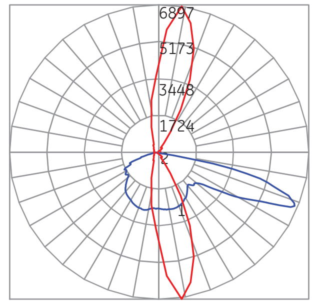
Evolve™ LED Streetlight (ERL1)

ERL1
Asymmetric Medium
(08E1)

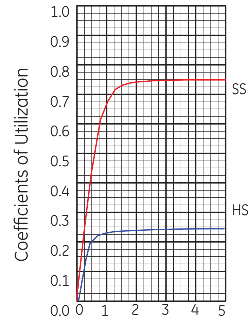
8,500 Lumens
4000K
ERL1_08E140_____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade



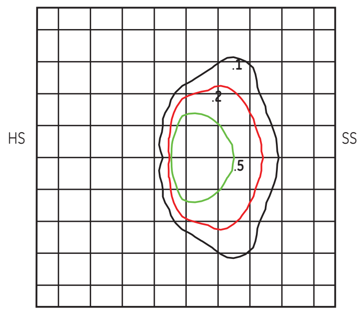
— Vertical plane through horizontal angle of maximum candlepower at 80°
— Vertical plane through horizontal angle of 69°



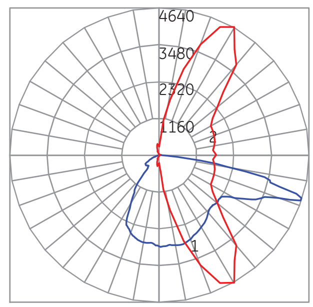
Street Width/Mounting Height

ERL1
Asymmetric Wide
(08F1)

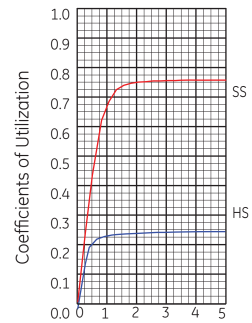
8,500 Lumens
4000K
ERL1_08F140_____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade



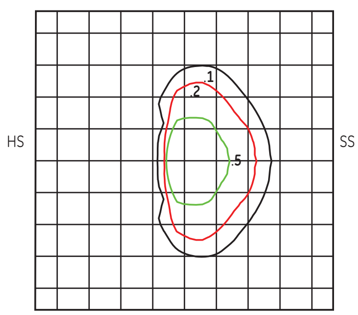
— Vertical plane through horizontal angle of maximum candlepower at 60°
— Vertical plane through horizontal angle of 73°



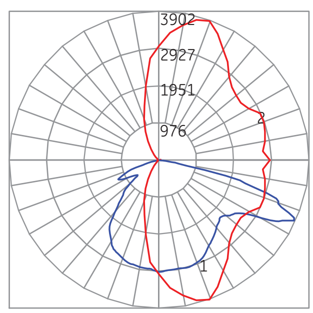
Street Width/Mounting Height

ERL1
Asymmetric Extra Wide
(08G1)

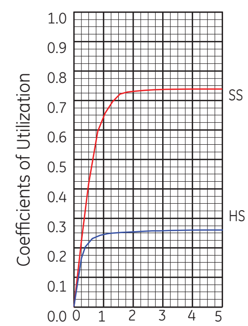
8,500 Lumens
4000K
ERL1_08G140_____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade



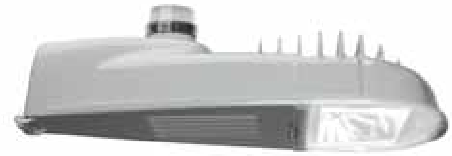
— Vertical plane through horizontal angle of maximum candlepower at 70°
— Vertical plane through horizontal angle of 66°



Street Width/Mounting Height

Ordering Number Logic

Evolve™ LED Streetlight (ERLH)



E R L H

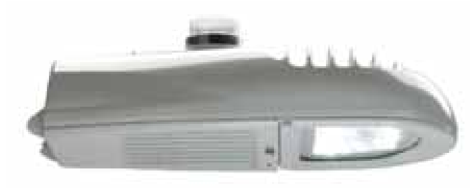
_ _ _ _   _   _ _   _ _   _ _   _   _ _ _ _   _ _ _

PROD. ID	VOLTAGE	LUMEN OUTPUT	DISTRIBUTION	CCT	CONTROLS	COLOR	OPTIONS
E = Evolve **R** = Roadway **L** = Local **H** = High Output	**0** = 120-277* **1** = 120 **2** = 208 **3** = 240 **4** = 277 **5** = 480 **D** = 347 **H** = 347-480* * Not available with Fusing. Must choose a descreet voltage with F option.	**10** **11** **13** **14** **15** See Data Table for more information.	**A1** = Extra Narrow Asymmetric **B1** = Narrow Asymmetric (Medium) **C1** = Asymmetric (Short) **D1** = Asymmetric Forward **E1** = Asymmetric (Medium) **F1** = Asymmetric (Wide) **G1** = Asymmetric (Extra Wide) See Data Table for more information	**30** = 3000K **40** = 4000K	**A** = ANSI C136.41 7-pin **D** = ANSI C136.41 7-pin receptacle with Shorting Cap **E** = ANSI C136.41 7-pin Receptacle with non-Dimming PE Control.* * PE Control Only available for 120-277V or 480V Discrete. Not available for 347-480V or 347V Discrete. **NOTE:** Dimming controls wired for 0-10V standard unless DALI option "U" requested.	**GRAY** = Gray **BLCK** = Black **DKBZ** = Dark Bronze	**A** = 4 Bolt Slipfitter † **F** = Fusing **G** = Internal Bubble Level **I** = IP66 Optical **L** = Tool-Less Entry **R** = Optional Secondary Enhanced Surge Protection (10kV/5kA) **U** = Universal DALI Programmable +^ **X** = Single Package # **Y** = Coastal Finish * **XXX** = Special Options † Contact manufacturer for Lead-Time. # Std Packaging = 20 units per container. * Recommended for installations within 1 mile from the coast. Contact Factory for Lead-Time. + Compatible with LightGrid 2.0 nodes. ^ Not available at 347V, 480V or 347-480V.

PRODUCT ID	LUMEN OUTPUT	DISTRIBUTION	TYPICAL INITIAL LUMENS		TYPICAL SYSTEM WATTAGE	BUG RATING		IES FILE NUMBER	
			4000K	3000K		4000K	3000K	4000K	3000K
ERLH		A1	9500	9100		B3-U0-G2	B3-U0-G2	ERLH_10A140_____.IES	ERLH_10A130_____.IES
ERLH		B1	9800	9500		B3-U0-G1	B2-U0-G1	ERLH_10B140_____.IES	ERLH_10B130_____.IES
ERLH		C1	10000	9600		B2-U0-G1	B2-U0-G1	ERLH_10C140_____.IES	ERLH_10C130_____.IES
ERLH	10	D1	9800	9500	90	B2-U0-G2	B2-U0-G2	ERLH_10D140_____.IES	ERLH_10D130_____.IES
ERLH		E1	10000	9600		B2-U0-G2	B2-U0-G2	ERLH_10E140_____.IES	ERLH_10E130_____.IES
ERLH		F1	10000	9600		B2-U0-G2	B2-U0-G2	ERLH_10F140_____.IES	ERLH_10F130_____.IES
ERLH		G1	10000	9600		B2-U0-G2	B2-U0-G2	ERLH_10G140_____.IES	ERLH_10G130_____.IES
ERLH		A1	10900	10500		B3-U0-G2	B3-U0-G2	ERLH_11A140_____.IES	ERLH_11A130_____.IES
ERLH		B1	11200	10800		B3-U0-G2	B3-U0-G1	ERLH_11B140_____.IES	ERLH_11B130_____.IES
ERLH		C1	11500	11100		B3-U0-G2	B3-U0-G2	ERLH_11C140_____.IES	ERLH_11C130_____.IES
ERLH	11	D1	11200	10800	108	B2-U0-G2	B2-U0-G2	ERLH_11D140_____.IES	ERLH_11D130_____.IES
ERLH		E1	11500	11100		B3-U0-G2	B3-U0-G2	ERLH_11E140_____.IES	ERLH_11E130_____.IES
ERLH		F1	11500	11100		B3-U0-G2	B3-U0-G2	ERLH_11F140_____.IES	ERLH_11F130_____.IES
ERLH		G1	11500	11100		B3-U0-G2	B3-U0-G2	ERLH_11G140_____.IES	ERLH_11G130_____.IES
ERLH		A1	12300	11900		B3-U0-G2	B3-U0-G2	ERLH_13A140_____.IES	ERLH_13A130_____.IES
ERLH		B1	12700	12200		B3-U0-G2	B3-U0-G2	ERLH_13B140_____.IES	ERLH_13B130_____.IES
ERLH		C1	13000	12500		B3-U0-G2	B3-U0-G2	ERLH_13C140_____.IES	ERLH_13C130_____.IES
ERLH	13	D1	12700	12200	125	B3-U0-G2	B2-U0-G2	ERLH_13D140_____.IES	ERLH_13D130_____.IES
ERLH		E1	13000	12500		B3-U0-G2	B3-U0-G2	ERLH_13E140_____.IES	ERLH_13E130_____.IES
ERLH		F1	13000	12500		B3-U0-G2	B3-U0-G2	ERLH_13F140_____.IES	ERLH_13F130_____.IES
ERLH		G1	13000	12500		B3-U0-G2	B3-U0-G2	ERLH_13G140_____.IES	ERLH_13G130_____.IES
ERLH		A1	13300	12800		B3-U0-G3	B3-U0-G3	ERLH_14A140_____.IES	ERLH_14A130_____.IES
ERLH		B1	13700	13200		B3-U0-G2	B3-U0-G2	ERLH_14B140_____.IES	ERLH_14B130_____.IES
ERLH		C1	14000	13500		B3-U0-G2	B3-U0-G2	ERLH_14C140_____.IES	ERLH_14C130_____.IES
ERLH	14	D1	13700	13200	139	B3-U0-G2	B3-U0-G2	ERLH_14D140_____.IES	ERLH_14D130_____.IES
ERLH		E1	14000	13500		B3-U0-G2	B3-U0-G2	ERLH_14E140_____.IES	ERLH_14E130_____.IES
ERLH		F1	14000	13500		B3-U0-G2	B3-U0-G2	ERLH_14F140_____.IES	ERLH_14F130_____.IES
ERLH		G1	14000	13500		B3-U0-G2	B3-U0-G2	ERLH_14G140_____.IES	ERLH_14G130_____.IES
ERLH		A1	14200	13700		B3-U0-G3	B3-U0-G3	ERLH_15A140_____.IES	ERLH_15A130_____.IES
ERLH		B1	14700	14200		B3-U0-G2	B3-U0-G2	ERLH_15B140_____.IES	ERLH_15B130_____.IES
ERLH		C1	15000	14500		B3-U0-G2	B3-U0-G2	ERLH_15C140_____.IES	ERLH_15C130_____.IES
ERLH	15	D1	14700	14200	161	B3-U0-G2	B3-U0-G2	ERLH_15D140_____.IES	ERLH_15D130_____.IES
ERLH		E1	15000	14500		B3-U0-G2	B3-U0-G2	ERLH_15E140_____.IES	ERLH_15E130_____.IES
ERLH		F1	15000	14500		B3-U0-G2	B3-U0-G2	ERLH_15F140_____.IES	ERLH_15F130_____.IES
ERLH		G1	15000	14500		B3-U0-G2	B3-U0-G2	ERLH_15G140_____.IES	ERLH_15G130_____.IES

Ordering Number Logic

Evolve™ LED Streetlight (ERS1)



E R S 1 _ _ _ _   _   _ _   _ _   _   _ _   _   _ _ _ _   _ _ _

PROD. ID	VOLTAGE	LUMEN OUTPUT	DISTRIBUTION	DRIVE CURRENT	CCT	CONTROLS	COLOR	OPTIONS
E = Evolve **R** = Roadway **S** = Scalable **1** = Single Module	**0** = 120-277* **1** = 120 **2** = 208 **3** = 240 **4** = 277 **5** = 480 **D** = 347 **H** = 347-480* * Not available with Fusing. Must choose a descreet voltage with F option.	**10** **11** **13** **14** **15** See Data Table for more information.	**A1** = Extra Narrow Asymmetric **B1** = Narrow Asymmetric (Medium) **C1** = Asymmetric (Short) **D1** = Asymmetric Forward **E1** = Asymmetric (Medium) **F1** = Asymmetric (Wide) **G1** = Asymmetric (Extra Wide) See Data Table for more information	**X** = Not Applicable	**30** = 3000K **40** = 4000K	**A** = ANSI C136.41 7-pin **D** = ANSI C136.41 7-pin receptacle with Shorting Cap **E** = ANSI C136.41 7-pin Receptacle with non-Dimming PE Control.* * PE Control Only available for 120-277V or 480V Discrete. Not available for 347-480V or 347V Discrete. **NOTE:** Dimming controls wired for 0-10V standard unless DALI option "U" requested.	**GRAY** = Gray **BLCK** = Black **DKBZ** = Dark Bronze	**F** = Fusing **G** = Internal Bubble Level **L** = Tool-Less Entry **R** = Optional Secondary Enhanced Surge Protection (10kV/5kA) **T** = 20kV/10kA Surge Protection per IEEE/ANSI C62.41.2-2002 † **U** = Universal DALI Programmable+^ **Y** = Coastal Finish* **XXX** = Special Options * Recommended for installations within 1 mile from the coast. Contact Factory for Lead-Time. + Compatible with LightGrid 2.0 nodes. ^Not available at 347V, 480V or 347-480V.

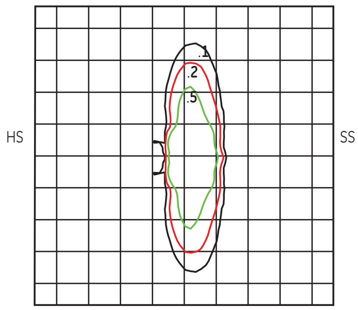
PRODUCT ID	LUMEN OUTPUT	DISTRIBUTION	TYPICAL INITIAL LUMENS		TYPICAL SYSTEM WATTAGE	BUG RATING		IES FILE NUMBER	
			4000K	3000K		4000K	3000K	4000K	3000K
ERS1	10	A1	9500	9200	90	B3-U0-G2	B3-U0-G2	ERS1_10A1X40____.IES	ERS1_10A1X30____.IES
ERS1		B1	9800	9500		B3-U0-G1	B2-U0-G1	ERS1_10B1X40____.IES	ERS1_10B1X30____.IES
ERS1		C1	10000	9600		B2-U0-G1	B2-U0-G1	ERS1_10C1X40____.IES	ERS1_10C1X30____.IES
ERS1		D1	9800	9500		B2-U0-G2	B2-U0-G2	ERS1_10D1X40____.IES	ERS1_10D1X30____.IES
ERS1		E1	10000	9600		B2-U0-G2	B2-U0-G2	ERS1_10E1X40____.IES	ERS1_10E1X30____.IES
ERS1		F1	10000	9600		B2-U0-G2	B2-U0-G2	ERS1_10F1X40____.IES	ERS1_10F1X30____.IES
ERS1		G1	10000	9600		B2-U0-G2	B2-U0-G2	ERS1_10G1X40____.IES	ERS1_10G1X30____.IES
ERS1	11	A1	10900	10500	108	B3-U0-G2	B3-U0-G2	ERS1_11A1X40____.IES	ERS1_11A1X30____.IES
ERS1		B1	11200	10800		B3-U0-G2	B3-U0-G1	ERS1_11B1X40____.IES	ERS1_11B1X30____.IES
ERS1		C1	11500	11100		B3-U0-G2	B3-U0-G2	ERS1_11C1X40____.IES	ERS1_11C1X30____.IES
ERS1		D1	11200	10800		B2-U0-G2	B2-U0-G2	ERS1_11D1X40____.IES	ERS1_11D1X30____.IES
ERS1		E1	11500	11100		B3-U0-G2	B3-U0-G2	ERS1_11E1X40____.IES	ERS1_11E1X30____.IES
ERS1		F1	11500	11100		B3-U0-G2	B3-U0-G2	ERS1_11F1X40____.IES	ERS1_11F1X30____.IES
ERS1		G1	11500	11100		B3-U0-G2	B3-U0-G2	ERS1_11G1X40____.IES	ERS1_11G1X30____.IES
ERS1	13	A1	12300	11900	125	B3-U0-G2	B3-U0-G2	ERS1_13A1X40____.IES	ERS1_13A1X30____.IES
ERS1		B1	12700	12200		B3-U0-G2	B3-U0-G2	ERS1_13B1X40____.IES	ERS1_13B1X30____.IES
ERS1		C1	13000	12500		B3-U0-G2	B3-U0-G2	ERS1_13C1X40____.IES	ERS1_13C1X30____.IES
ERS1		D1	12700	12200		B3-U0-G2	B2-U0-G2	ERS1_13D1X40____.IES	ERS1_13D1X30____.IES
ERS1		E1	13000	12500		B3-U0-G2	B3-U0-G2	ERS1_13E1X40____.IES	ERS1_13E1X30____.IES
ERS1		F1	13000	12500		B3-U0-G2	B3-U0-G2	ERS1_13F1X40____.IES	ERS1_13F1X30____.IES
ERS1		G1	13000	12500		B3-U0-G2	B3-U0-G2	ERS1_13G1X40____.IES	ERS1_13G1X30____.IES
ERS1	14	A1	13300	12800	139	B3-U0-G3	B3-U0-G3	ERS1_14A1X40____.IES	ERS1_14A1X30____.IES
ERS1		B1	13700	13200		B3-U0-G2	B3-U0-G2	ERS1_14B1X40____.IES	ERS1_14B1X30____.IES
ERS1		C1	14000	13500		B3-U0-G2	B3-U0-G2	ERS1_14C1X40____.IES	ERS1_14C1X30____.IES
ERS1		D1	13700	13200		B3-U0-G2	B3-U0-G2	ERS1_14D1X40____.IES	ERS1_14D1X30____.IES
ERS1		E1	14000	13500		B3-U0-G2	B3-U0-G2	ERS1_14E1X40____.IES	ERS1_14E1X30____.IES
ERS1		F1	14000	13500		B3-U0-G2	B3-U0-G2	ERS1_14F1X40____.IES	ERS1_14F1X30____.IES
ERS1		G1	14000	13500		B3-U0-G2	B3-U0-G2	ERS1_14G1X40____.IES	ERS1_14G1X30____.IES
ERS1	15	A1	14200	13700	161	B3-U0-G3	B3-U0-G3	ERS1_15A1X40____.IES	ERS1_15A1X30____.IES
ERS1		B1	14700	14200		B3-U0-G2	B3-U0-G2	ERS1_15B1X40____.IES	ERS1_15B1X30____.IES
ERS1		C1	15000	14500		B3-U0-G2	B3-U0-G2	ERS1_15C1X40____.IES	ERS1_15C1X30____.IES
ERS1		D1	14700	14200		B3-U0-G2	B3-U0-G2	ERS1_15D1X40____.IES	ERS1_15D1X30____.IES
ERS1		E1	15000	14500		B3-U0-G2	B3-U0-G2	ERS1_15E1X40____.IES	ERS1_15E1X30____.IES
ERS1		F1	15000	14500		B3-U0-G2	B3-U0-G2	ERS1_15F1X40____.IES	ERS1_15F1X30____.IES
ERS1		G1	15000	14500		B3-U0-G2	B3-U0-G2	ERS1_15G1X40____.IES	ERS1_15G1X30____.IES

Photometrics

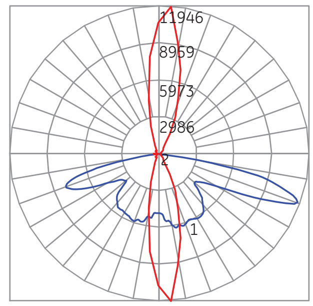
Evolve™ LED Streetlight (ERLH and ERS1)

ERLH and ERS1 Extra Narrow Asymmetric (15A1)

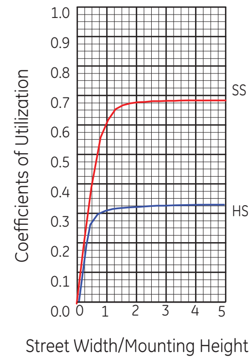
14,200 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

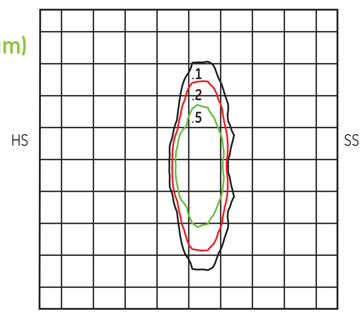


— Vertical plane through horizontal angle of maximum candlepower at 85°
— Vertical plane through horizontal angle of 71°

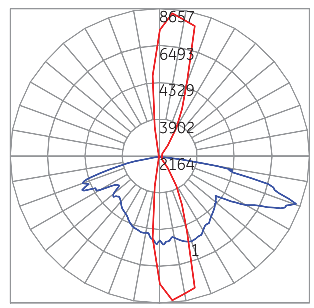


ERLH and ERS1 Narrow Asymmetric (Medium) (15B1)

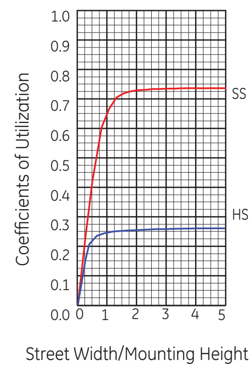
14,700 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

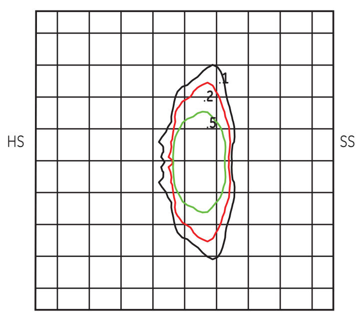


— Vertical plane through horizontal angle of maximum candlepower at 85°
— Vertical plane through horizontal angle of 71°

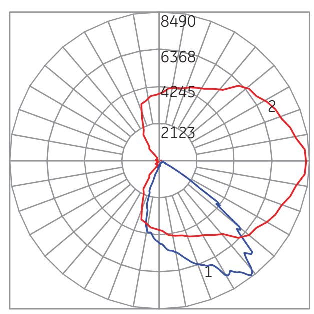


ERLH and ERS1 Asymmetric Short (15C1)

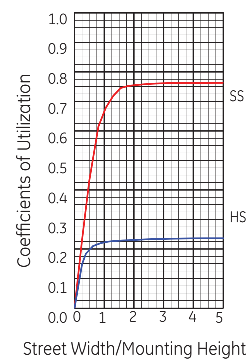
15,000 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

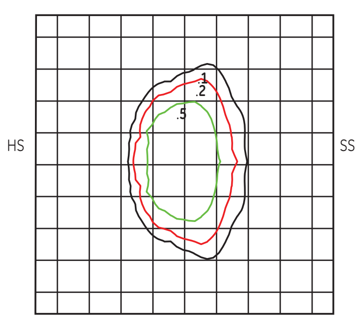


— Vertical plane through horizontal angle of maximum candlepower at 0°
— Vertical plane through horizontal angle of 38°

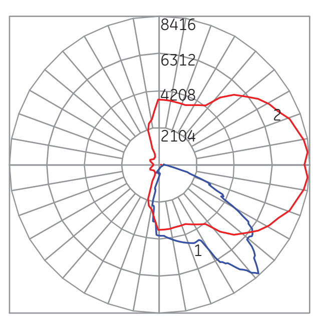


ERLH and ERS1 Asymmetric Forward (15D1)

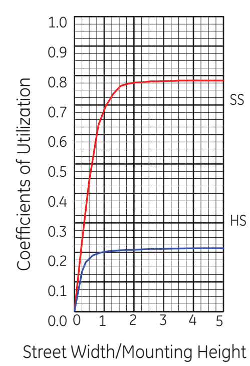
14,700 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



— Vertical plane through horizontal angle of maximum candlepower at 5°
— Vertical plane through horizontal angle of 41°

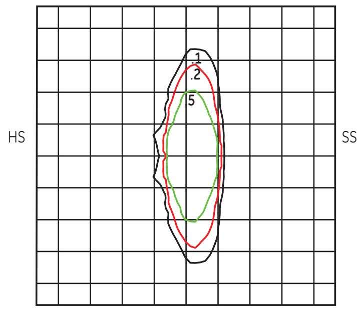


Photometrics

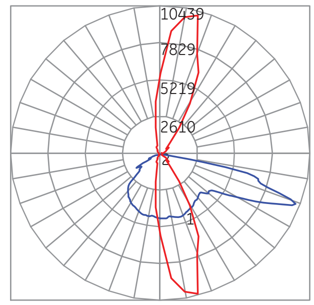
Evolve™ LED Streetlight (ERLH and ERS1)

ERLH and ERS1 Asymmetric Medium (15E1)

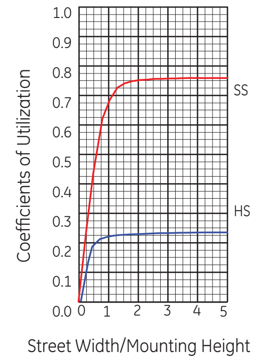
15,000 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

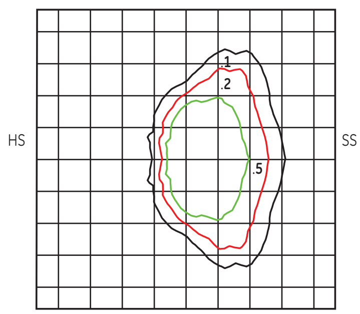


— Vertical plane through horizontal angle of maximum candlepower at 75°
— Vertical plane through horizontal angle of 70°

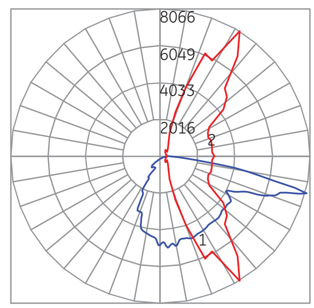


ERLH and ERS1 Asymmetric Wide (15F1)

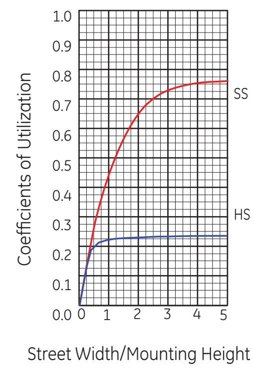
15,000 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

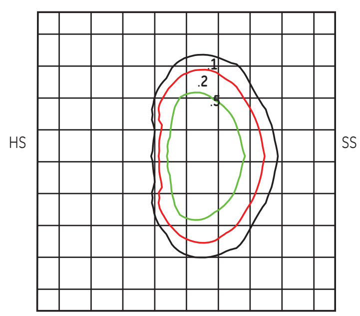


— Vertical plane through horizontal angle of maximum candlepower at 60°
— Vertical plane through horizontal angle of 75°

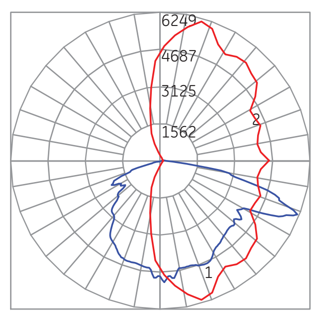


ERLH and ERS1 Asymmetric Extra Wide (15G1)

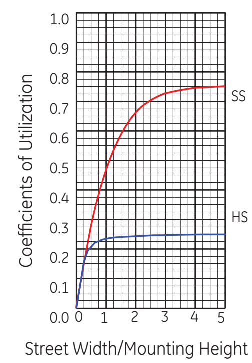
15,000 Lumens
4000K



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



— Vertical plane through horizontal angle of maximum candlepower at 75°
— Vertical plane through horizontal angle of 68°



Ordering Number Logic

Evolve™ LED Streetlight (ERS2)

E R S 2

____ _ __ __ _ __ _ ____ __

PROD. ID	VOLTAGE	LUMEN OUTPUT	DISTRIBUTION	DRIVE CURRENT	CCT	CONTROLS	COLOR	OPTIONS
E = Evolve **R** = Roadway **S** = Scalable **2** = Double Module	**0** = 120-277* **1** = 120 **2** = 208 **3** = 240 **4** = 277 **5** = 480 **D** = 347 **H** = 347-480* * Not available with Fusing. Must choose a descreet voltage with F option.	**16** **18** **19** **21** **23** **25** **27** **28** See Data Table for more information.	**A1** = Extra Narrow Asymmetric **B1** = Narrow Asymmetric (Medium) **C1** = Asymmetric (Short) **D1** = Asymmetric Forward **E1** = Asymmetric (Medium) **F1** = Asymmetric (Wide) **G1** = Asymmetric (Extra Wide) See Data Table for more information	**X** = Not Applicable	**30** = 3000K **40** = 4000K	**A** = ANSI C136.41 7-pin **D** = ANSI C136.41 7-pin receptacle with Shorting Cap **E** = ANSI C136.41 7-pin Receptacle with non-Dimming PE Control.* * PE Control Only available for 120-277V or 480V Discrete. Not available for 347-480V or 347V Discrete. **NOTE:** Dimming controls wired for 0-10V standard unless DALI option "U" requested.	**GRAY** = Gray **BLCK** = Black **DKBZ** = Dark Bronze	**A** = 4 Bolt Slipfitter † **F** = Fusing **G** = Internal Bubble Level **L** = Tool-Less Entry **R** = Optional Secondary Enhanced Surge Protection (10kV/5kA) **T** = 20kV/10kA Surge Protection per IEEE/ANSI C62.41.2-2002 † **U** = Universal DALI Programmable +^ **Y** = Coastal Finish* **XXX** = Special Options † Contact manufacturer for Lead-Time. * Recommended for installations within 1 mile from the coast. Contact Factory for Lead-Time. + Compatible with LightGrid 2.0 nodes. ^ Not available at 347V, 480V or 347-480V.

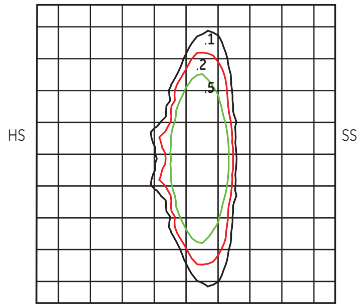
PRODUCT ID	LUMEN OUTPUT	DISTRIBUTION	TYPICAL INITIAL LUMENS		TYPICAL SYSTEM WATTAGE	BUG RATING		IES FILE NUMBER	
			4000K	3000K		4000K	3000K	4000K	3000K
ERS2		A1	15200	14700		B3-U0-G3	B3-U0-G3	ERS2_16A1X40____.IES	ERS2_16A1X30____.IES
ERS2		B1	15700	15100		B3-U0-G2	B3-U0-G2	ERS2_16B1X40____.IES	ERS2_16B1X30____.IES
ERS2		C1	16000	15400		B3-U0-G2	B3-U0-G2	ERS2_16C1X40____.IES	ERS2_16C1X30____.IES
ERS2	16	D1	15700	15100	132	B3-U0-G2	B3-U0-G2	ERS2_16D1X40____.IES	ERS2_16D1X30____.IES
ERS2		E1	16000	15400		B3-U0-G2	B3-U0-G2	ERS2_16E1X40____.IES	ERS2_16E1X30____.IES
ERS2		F1	16000	15400		B3-U0-G2	B3-U0-G2	ERS2_16F1X40____.IES	ERS2_16F1X30____.IES
ERS2		G1	16000	15400		B3-U0-G2	B3-U0-G2	ERS2_16G1X40____.IES	ERS2_16G1X30____.IES
ERS2		A1	17100	16500		B3-U0-G3	B3-U0-G3	ERS2_18A1X40____.IES	ERS2_18A1X30____.IES
ERS2		B1	17600	17000		B3-U0-G2	B3-U0-G2	ERS2_18B1X40____.IES	ERS2_18B1X30____.IES
ERS2		C1	18000	17400		B3-U0-G2	B3-U0-G2	ERS2_18C1X40____.IES	ERS2_18C1X30____.IES
ERS2	18	D1	17600	17000	157	B3-U0-G2	B3-U0-G2	ERS2_18D1X40____.IES	ERS2_18D1X30____.IES
ERS2		E1	18000	17400		B3-U0-G2	B3-U0-G2	ERS2_18E1X40____.IES	ERS2_18E1X30____.IES
ERS2		F1	18000	17400		B3-U0-G3	B3-U0-G2	ERS2_18F1X40____.IES	ERS2_18F1X30____.IES
ERS2		G1	18000	17400		B3-U0-G2	B3-U0-G2	ERS2_18G1X40____.IES	ERS2_18G1X30____.IES
ERS2		A1	18000	17400		B3-U0-G3	B3-U0-G3	ERS2_19A1X40____.IES	ERS2_19A1X30____.IES
ERS2		B1	18600	17900		B3-U0-G2	B3-U0-G2	ERS2_19B1X40____.IES	ERS2_19B1X30____.IES
ERS2		C1	19000	18300		B3-U0-G2	B3-U0-G2	ERS2_19C1X40____.IES	ERS2_19C1X30____.IES
ERS2	19	D1	18600	17900	162	B3-U0-G2	B3-U0-G2	ERS2_19D1X40____.IES	ERS2_19D1X30____.IES
ERS2		E1	19000	18300		B3-U0-G2	B3-U0-G2	ERS2_19E1X40____.IES	ERS2_19E1X30____.IES
ERS2		F1	19000	18300		B3-U0-G3	B3-U0-G3	ERS2_19F1X40____.IES	ERS2_19F1X30____.IES
ERS2		G1	19000	18300		B3-U0-G3	B3-U0-G2	ERS2_19G1X40____.IES	ERS2_19G1X30____.IES
ERS2		A1	20000	19300		B3-U0-G3	B3-U0-G3	ERS2_21A1X40____.IES	ERS2_21A1X30____.IES
ERS2		B1	20600	19900		B3-U0-G2	B3-U0-G2	ERS2_21B1X40____.IES	ERS2_21B1X30____.IES
ERS2		C1	21000	20300		B3-U0-G2	B3-U0-G2	ERS2_21C1X40____.IES	ERS2_21C1X30____.IES
ERS2	21	D1	20600	19900	193	B3-U0-G2	B3-U0-G2	ERS2_21D1X40____.IES	ERS2_21D1X30____.IES
ERS2		E1	21000	20300		B3-U0-G2	B3-U0-G2	ERS2_21E1X40____.IES	ERS2_21E1X30____.IES
ERS2		F1	21000	20300		B3-U0-G3	B3-U0-G3	ERS2_21F1X40____.IES	ERS2_21F1X30____.IES
ERS2		G1	21000	20300		B3-U0-G3	B3-U0-G3	ERS2_21G1X40____.IES	ERS2_21G1X30____.IES
ERS2		A1	21900	21100		B4-U0-G3	B3-U0-G3	ERS2_23A1X40____.IES	ERS2_23A1X30____.IES
ERS2		B1	22500	21700		B3-U0-G3	B3-U0-G2	ERS2_23B1X40____.IES	ERS2_23B1X30____.IES
ERS2		C1	23000	22200		B3-U0-G2	B3-U0-G2	ERS2_23C1X40____.IES	ERS2_23C1X30____.IES
ERS2	23	D1	22500	21700	219	B3-U0-G2	B3-U0-G2	ERS2_23D1X40____.IES	ERS2_23D1X30____.IES
ERS2		E1	23000	22200		B3-U0-G2	B3-U0-G2	ERS2_23E1X40____.IES	ERS2_23E1X30____.IES
ERS2		F1	23000	22200		B3-U0-G3	B3-U0-G3	ERS2_23F1X40____.IES	ERS2_23F1X30____.IES
ERS2		G1	23000	22200		B3-U0-G3	B3-U0-G3	ERS2_23G1X40____.IES	ERS2_23G1X30____.IES
ERS2		A1	23800	23000		B4-U0-G3	B4-U0-G3	ERS2_25A1X40____.IES	ERS2_25A1X30____.IES
ERS2		B1	24500	23600		B4-U0-G3	B3-U0-G3	ERS2_25B1X40____.IES	ERS2_25B1X30____.IES
ERS2		C1	25000	24100		B3-U0-G2	B3-U0-G2	ERS2_25C1X40____.IES	ERS2_25C1X30____.IES
ERS2	25	D1	24500	23600	243	B3-U0-G3	B3-U0-G3	ERS2_25D1X40____.IES	ERS2_25D1X30____.IES
ERS2		E1	25000	24100		B3-U0-G3	B3-U0-G3	ERS2_25E1X40____.IES	ERS2_25E1X30____.IES
ERS2		F1	25000	24100		B3-U0-G3	B3-U0-G3	ERS2_25F1X40____.IES	ERS2_25F1X30____.IES
ERS2		G1	25000	24100		B3-U0-G3	B3-U0-G3	ERS2_25G1X40____.IES	ERS2_25G1X30____.IES
ERS2		A1	25700	24800		B4-U0-G3	B4-U0-G3	ERS2_27A1X40____.IES	ERS2_27A1X30____.IES
ERS2		B1	26500	25600		B4-U0-G3	B4-U0-G3	ERS2_27B1X40____.IES	ERS2_27B1X30____.IES
ERS2		C1	27000	26000		B4-U0-G3	B4-U0-G3	ERS2_27C1X40____.IES	ERS2_27C1X30____.IES
ERS2	27	D1	26500	25600	275	B3-U0-G3	B3-U0-G3	ERS2_27D1X40____.IES	ERS2_27D1X30____.IES
ERS2		E1	27000	26000		B4-U0-G3	B4-U0-G3	ERS2_27E1X40____.IES	ERS2_27E1X30____.IES
ERS2		F1	27000	26000		B4-U0-G4	B4-U0-G3	ERS2_27F1X40____.IES	ERS2_27F1X30____.IES
ERS2		G1	27000	26000		B4-U0-G3	B4-U0-G3	ERS2_27G1X40____.IES	ERS2_27G1X30____.IES
ERS2		A1	26600	25600		B4-U0-G3	B4-U0-G3	ERS2_28A1X40____.IES	ERS2_28A1X30____.IES
ERS2		B1	27400	26400		B4-U0-G3	B4-U0-G3	ERS2_28B1X40____.IES	ERS2_28B1X30____.IES
ERS2		C1	28000	26900		B4-U0-G3	B4-U0-G3	ERS2_28C1X40____.IES	ERS2_28C1X30____.IES
ERS2	28	D1	27400	26400	280	B3-U0-G3	B3-U0-G3	ERS2_28D1X40____.IES	ERS2_28D1X30____.IES
ERS2		E1	28000	26900		B4-U0-G3	B4-U0-G3	ERS2_28E1X40____.IES	ERS2_28E1X30____.IES
ERS2		F1	28000	26900		B4-U0-G4	B4-U0-G3	ERS2_28F1X40____.IES	ERS2_28F1X30____.IES
ERS2		G1	28000	26900		B4-U0-G4	B4-U0-G3	ERS2_28G1X40____.IES	ERS2_28G1X30____.IES

Photometrics

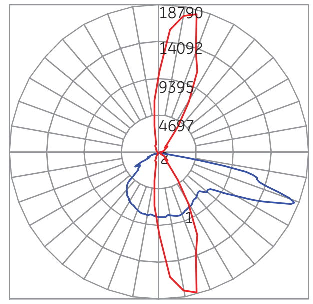
Evolve™ LED Streetlight (ERS2)

ERS2
Asymmetric Medium
(27E1)

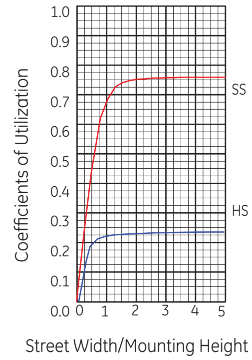
27,000 Lumens
4000K
ERS2_27E1X40____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade

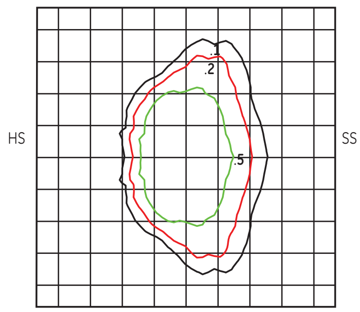


— Vertical plane through horizontal angle of maximum candlepower at 75°
— Vertical plane through horizontal angle of 70°

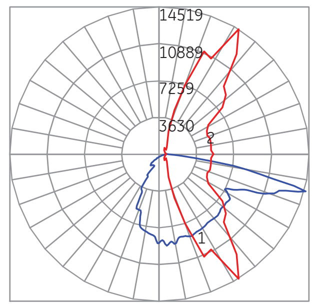


ERS2
Asymmetric Wide
(27F1)

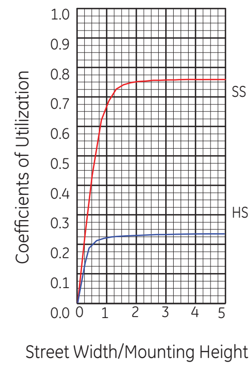
27,000 Lumens
4000K
ERS2_27F1X40____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade

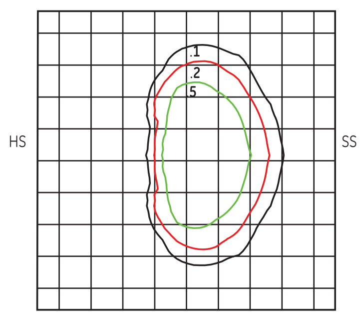


— Vertical plane through horizontal angle of maximum candlepower at 60°
— Vertical plane through horizontal angle of 75°

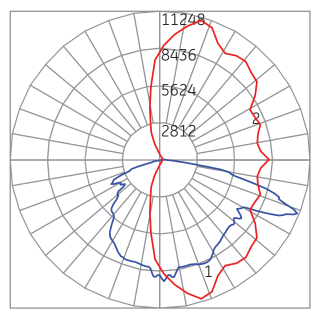


ERS2
Asymmetric Extra Wide
(27G1)

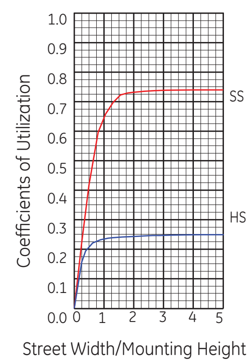
27,000 Lumens
4000K
ERS2_27G1X40____.IES



Grid Distance in Units of
Mounting Height at 30' Initial
Footcandle Values at Grade



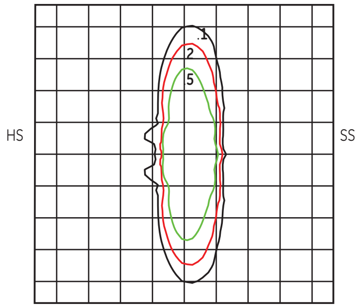
— Vertical plane through horizontal angle of maximum candlepower at 75°
— Vertical plane through horizontal angle of 68°



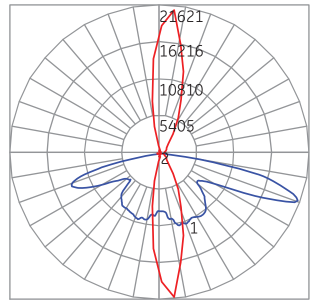
Photometrics
Evolve™ LED Streetlight (ERS2)

ERS2
Extra Narrow Asymmetric (27A1)

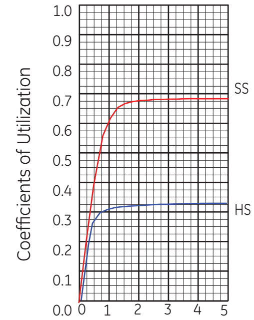
25,700 Lumens
4000K
ERS2_27A1X40____.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



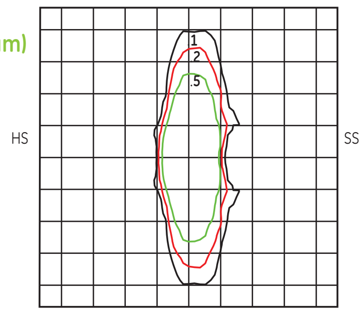
— Vertical plane through horizontal angle of maximum candlepower at 85°
— Vertical plane through horizontal angle of 71°



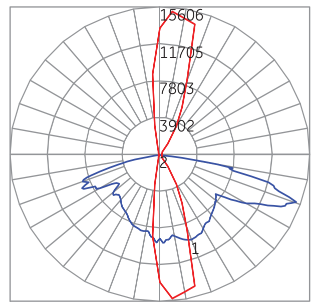
Street Width/Mounting Height

ERS2
Narrow Asymmetric (Medium) (27B1)

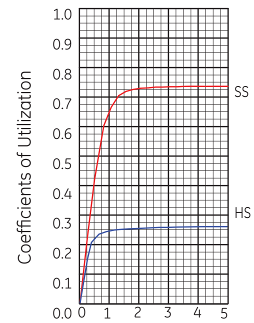
26,500 Lumens
4000K
ERS2_27B1X40____.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



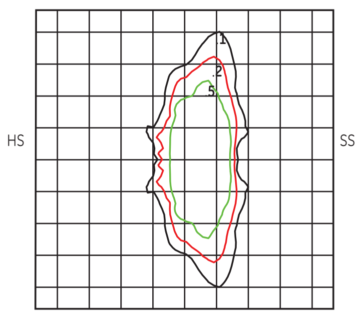
— Vertical plane through horizontal angle of maximum candlepower at 85°
— Vertical plane through horizontal angle of 71°



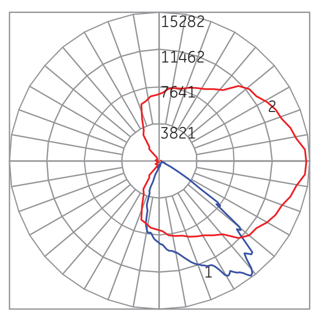
Street Width/Mounting Height

ERS2
Asymmetric Short (27C1)

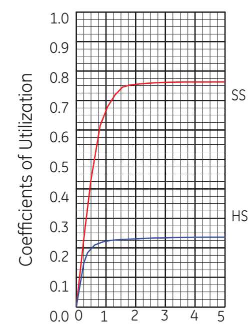
27,000 Lumens
4000K
ERS2_27C1X40____.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



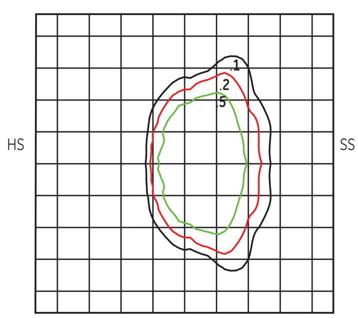
— Vertical plane through horizontal angle of maximum candlepower at 0°
— Vertical plane through horizontal angle of 38°



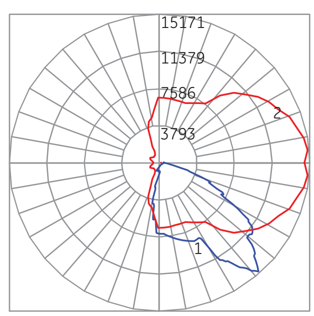
Street Width/Mounting Height

ERS2
Asymmetric Forward (27D1)

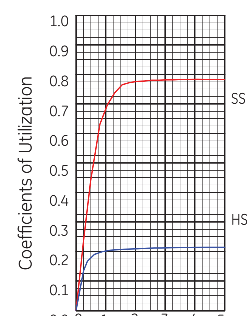
26,500 Lumens
4000K
ERS2_27D1X40____.IES



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



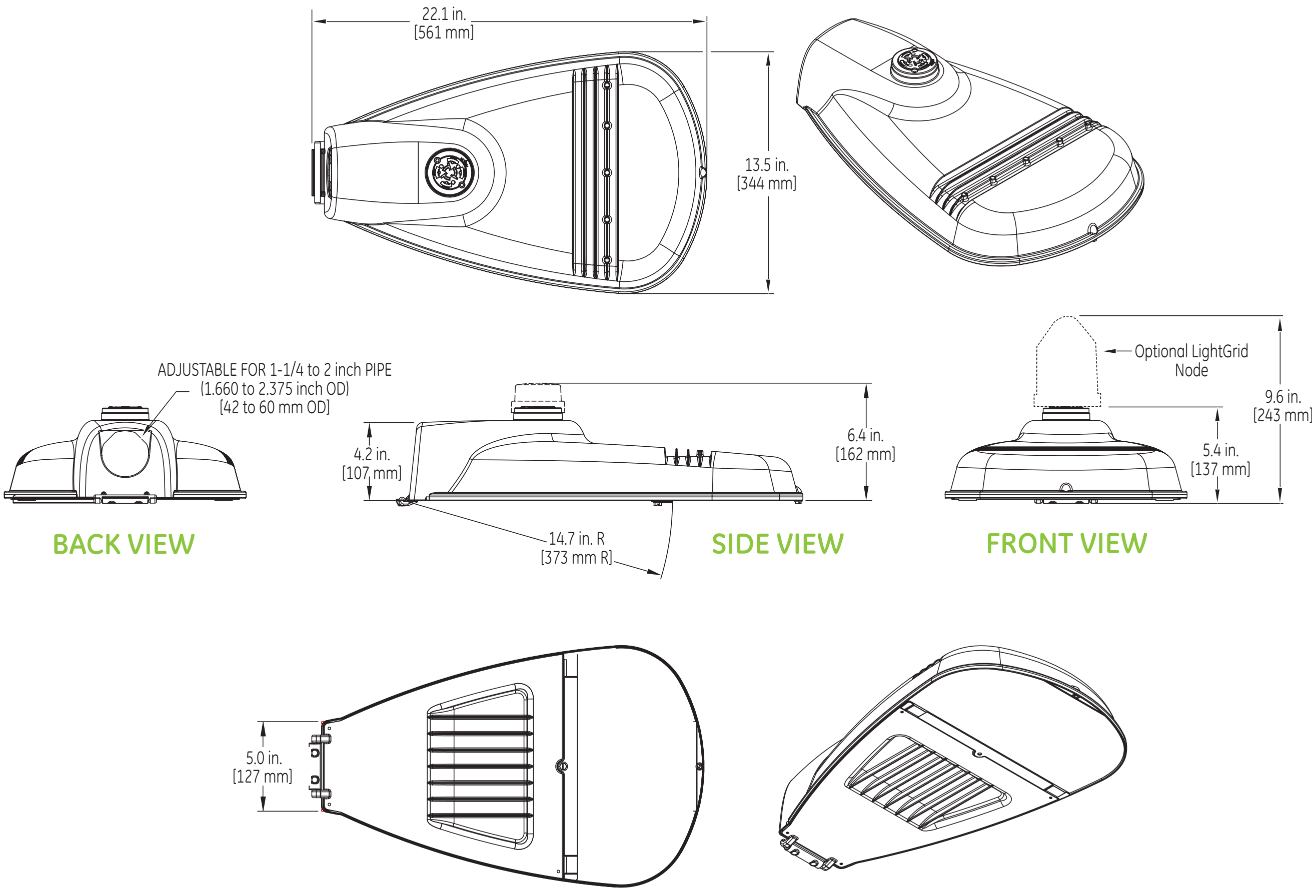
— Vertical plane through horizontal angle of maximum candlepower at 5°
— Vertical plane through horizontal angle of 41°



Street Width/Mounting Height

Product Dimensions

Evolve™ LED Streetlight (ERL1)

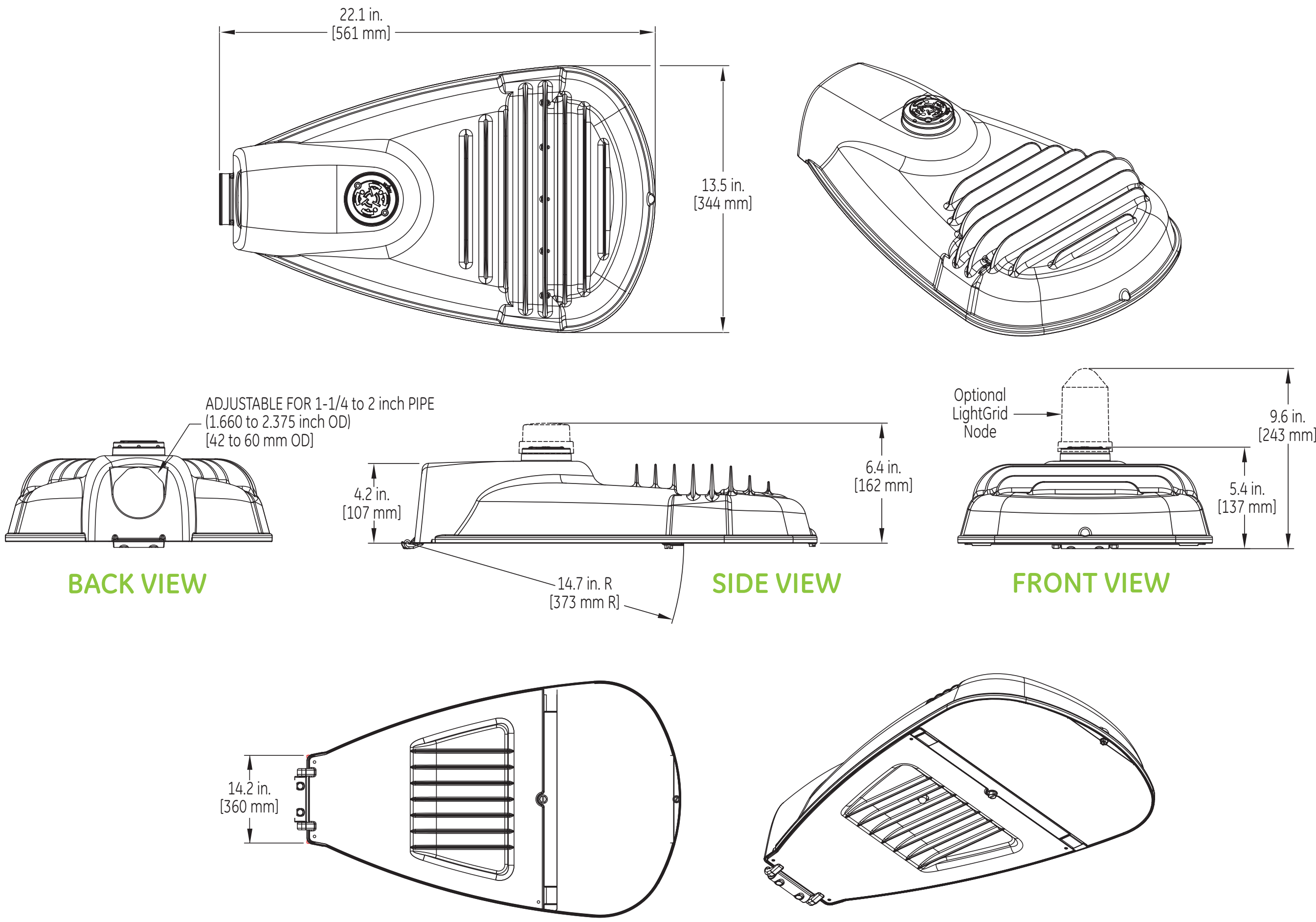


DATA

- Approximate net weight: 12.4 lbs (5.6 kgs) - Without XFMR
- Approximate net weight: 15.5 lbs (7 kgs) - With XFMR
- Effective Projected Area (EPA): 0.5 sq ft max (0.046 sq m)

Product Dimensions

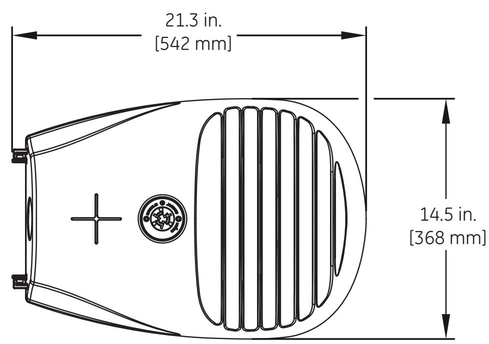
Evolve™ LED Streetlight (ERLH)

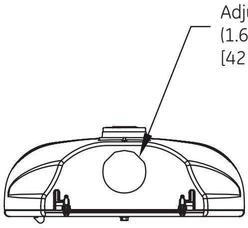


DATA	
	• Approximate net weight: 15.15 lbs (6.9 kgs) - 2 Bolt Slipfitter • Approximate net weight: 15.85 lbs (7.2 kgs) - 4 Bolt Slipfitter • Effective Projected Area (EPA): 0.5 sq ft max (0.046 sq m)

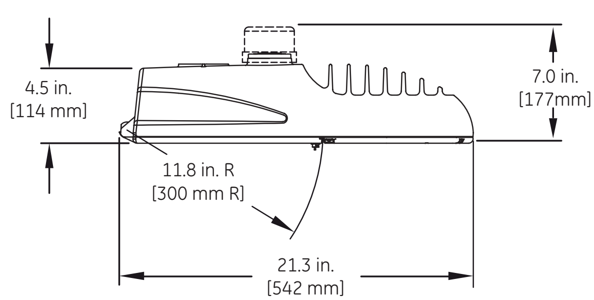
Product Dimensions

Evolve™ LED Streetlight (ERS1)

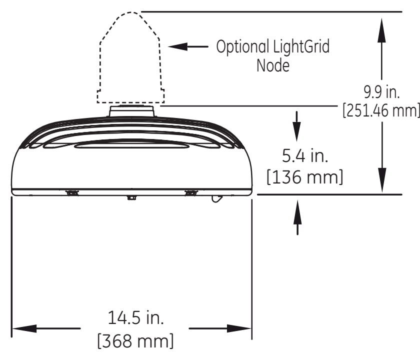




BACK VIEW



SIDE VIEW

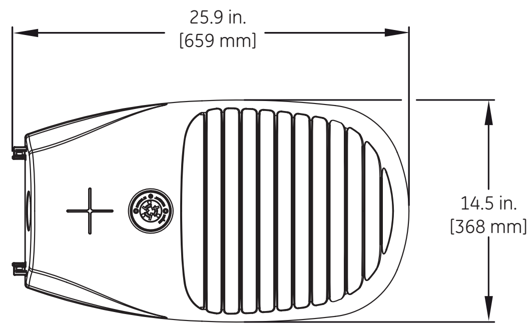


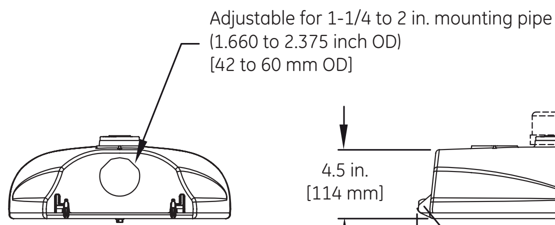
FRONT VIEW

DATA	
	• Approximate net weight: 20 lbs (9.1 kgs) to 25 lbs (11.4 kgs) • Effective Projected Area (EPA): 0.5 sq ft max (0.046 sq m)

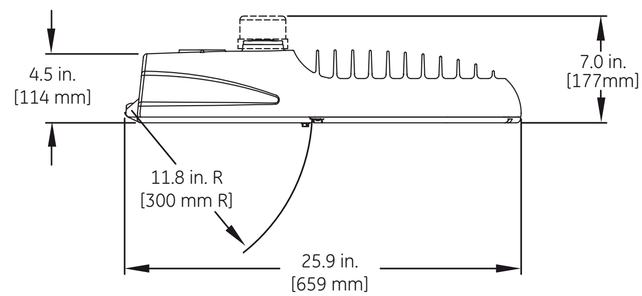
Product Dimensions

Evolve™ LED Streetlight (ERS2)

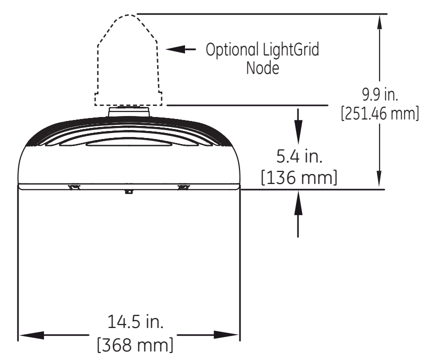




BACK VIEW



SIDE VIEW



FRONT VIEW

DATA

- Approximate net weight: 25 lbs (11.4 kgs) to 29 lbs (13.2 kgs)
- Effective Projected Area (EPA): 0.7 sq ft max (0.065 sq m)

www.gelighting.com

OLP3105 (Rev 04/22/16)

Section X – Glossary of Terms

Glossary of Terms

Illuminance: a measure of how much the incident light illuminates the surface that is typically measured in lux or footcandles.

Electro Magnetic Field (EMF): a physical field produced by electrically charged objects.[1] It affects the behavior of charged objects in the vicinity of the field. The electromagnetic field extends indefinitely throughout space and describes the electromagnetic interaction. It is one of the four fundamental forces of nature (the others are gravitation, weak interaction and strong interaction).

Radio Frequency radiation: any of the electromagnetic wave frequencies that lie in the range extending from around 3 kHz to 300 GHz, which include those frequencies used for communications or radar signals

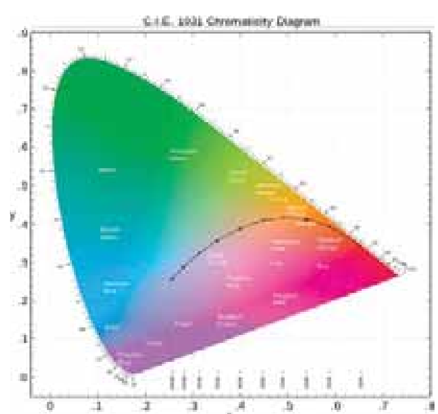
Correlated Color Temperature (CCT): a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K).

Color Rendering Index (CRI): a scale from 0 to 100 percent indicating how accurate a "given" light source is at rendering color when compared to a "reference" light source. The higher the CRI, the better the color rendering ability.

Scotopic: the vision of the eye under low light conditions. In the human eye cone cells are nonfunctional in low light – scotopic vision is produced exclusively through rod cells which are most sensitive to wavelengths of light around 498 nm (green-blue) and are insensitive to wavelengths longer than about 640 nm (red).

Photopic: the vision of the eye under well-lit conditions (luminance level 10 to 10^8 cd/m²). In humans and many other animals, photopic vision allows color perception, mediated by cone cells, and a significantly higher visual acuity and temporal resolution than available with scotopic vision. The human eye uses three types of cones to sense light in three bands of color. The biological pigments of the cones have maximum absorption values at wavelengths of about 420 nm (blue), 534 nm (Bluish-Green), resp. 564 nm (Yellowish-Green). Their sensitivity ranges overlap to provide vision throughout the visible spectrum. The maximum efficiency is 683 lm/W at a wavelength of 555 nm (green).

CIE 1931: the first defined quantitative links between physical pure colors (i.e. wavelengths) in the electromagnetic visible spectrum, and physiological perceived colors in human color vision. The CIE 1931 color space chromaticity diagram rendered in terms of the colors of lower saturation and value than those displayed in the diagram above that can be produced by pigments. The colors are in the scale are from the Munsell color system. This color system is a color space that specifies colors based on three color dimensions: hue, value (lightness), and chroma (color purity).



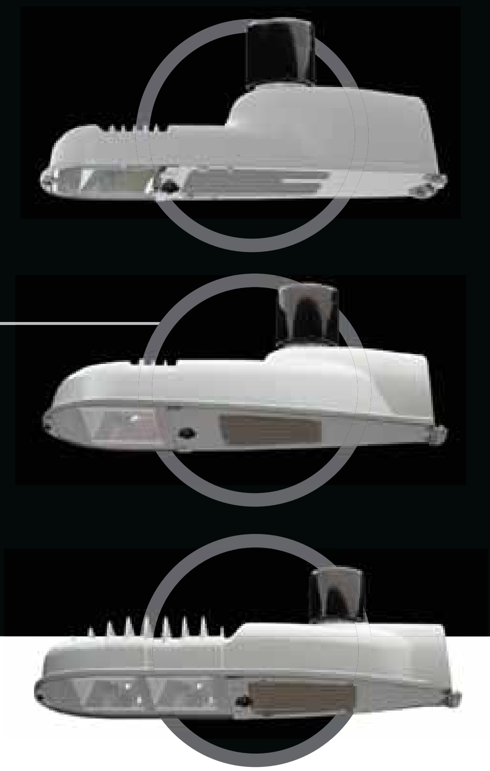
CIE 1976: a color space adopted by the International Commission on Illumination (CIE) in 1976, as a simple-to-compute transformation of the 1931 CIE XYZ color space.

Appendix C. LED Roadway Lighting Cut Sheet

Evolve®

LED Roadway Lighting

ERLC-ERL1-ERL2



GE current
a Daintree company

Evolve® LED Roadway Lighting

Cobra Head (ERL1)

Project Name ______________________

Date ______________ Type ______________

Notes ______________________

The **Evolve**® LED Roadway ERL1 Luminaire is optimized utilizing advanced LED reflective optical system for local, collector and major roadways. The modern design incorporates the heat sink directly into the unit for heat transfer to prolong LED life.

CONSTRUCTION

Housing:	Aluminum die cast enclosure casting integral heat sink for maximum heat transfer
Lens:	Impact resistant tempered glass
Paint:	Corrosion resistant powder paint, ≥ 2.0 mil thickness *(RAL & custom colors available)* Standard = Black, Dark Bronze, Gray, White Optional = Coastal Finish
Weight:	12.4 lbs (5.6 kgs)

OPTICAL SYSTEM

Lumens:	2,000 - 15,700
Distribution:	Type II ,III, IV, Type II Narrow and Type II Enhanced Backlight
Efficacy:	111-140 LPW
CCT:	2700K, 3000K, 4000K and 5000K
CRI:	≥70

ELECTRICAL

Input Voltage:	120-277V or 347-480V
Input Frequency:	50/60Hz
Power Factor:	≥ 90% at rated watts
Total Harmonic Distortion:	≤ 20% at rated watts

SURGE PROTECTION*

Standard	Optional
☐ 10kV/5kA	☐ Secondary 10kV/5kA (R Option) or ☐ Secondary 20kV/10kA (T Option)

*Per ANSI C136.2-2018

LUMEN MAINTENANCE

Projected Lxx per IES TM-21-11 at 25°C

Lumen Codes	Distributions	LXX(10K) @ Hours 25,000 HR	50,000 HR	60,000 HR
02 ,03, 04, 05, 06	A5, B5, C5, D5, E5	L96	L94	L93
07, 08	A5, B5, C5, D5, E5	L99	L98	L98
09	A5, B5, C5, D5, E5	L98	L97	L96
10	A5, B5, C5, D5, E5	L94	L87	L84
11	A5, B5, C5, D5, E5	L93	L85	L82
12	A5, B5, C5, D5, E5	L96	L95	L94
13	A5, B5, C5, D5, E5	L96	L94	L93
14	A5, B5, C5, D5, E5	L95	L92	L91
15	A5, B5, C5, D5, E5	L93	L88	L86
16	A5, B5, C5, D5, E5	L91	L85	L83

Note: Projected Lxx based on LM80 (≥ 10,000 hour testing). Accepted Industry tolerances apply to initial luminous flux and lumen maintenance measurements.

RATINGS

Operating Temp:	-40°C to 50°C
Vibration:	3G per ANSI C136.31-2018
LM-79:	Testing in accordance with IES Standards
EMI:	Title 47 CFR Part 15 Class A
RoHS:	Complies with the material restrictions of RoHS

CONTROLS

Dimming:	Standard-0-10V ☐ Optional-DALI (Option U) ☐
Sensors:	Photo Electric Sensors (PE) available LightGrid Compatible

WARRANTY

☐ 5 Year (Standard) ☐ 10 Year (Optional)

UL 1598 for WET LOCATIONS

IP65 HDR CONTROLS ENABLED

GE current
a Daintree company

Evolve® LED Roadway Lighting

Cobra Head (ERL1)

Catalog Logic

Project Name ______________________

Date ______________ Type ______________

Notes ______________________

E R L 1

_ _ _ _   _   _ _   _ _   _ _   _   _ _ _ _   _ _ _

PROD. ID	VOLTAGE	LUMENS	DISTRIBUTION[3]	CCT	CONTROLS PER ANSI C136.41	COLOR	OPTIONS
E = Evolve	0 = 120-277[1,2]	02[2]	A5 = Type II Narrow	27 = 2700K[4]	A = 7-Pin Receptacle	GRAY = Gray	A = 4 Bolt Slipfitter[5]
R = Roadway	H = 347-480[1]	03	B5 = Type II	30 = 3000K[4]	D = 7-Pin Receptacle with Shorting Cap	BLCK = Black	B = Tether
L = Local	1 = 120	04	C5 = Type III	40 = 4000K	E = 7-Pin Receptacle with non-dimming Long Life PE	DKBZ = Dark Bronze	F = Fusing
1 = Single Module	2 = 208	05	D5 = Type IV	50 = 5000K	**Note:** 0-10V standard	WHTE = White	G = Internal Bubble Level
	3 = 240	06	E5 = Type II Enhanced Back Light				I = Optional IP66 Optical Enclosure
	4 =277	07					L = Tool-Less Entry
	8 = 120-240[1,11]	08					R = Secondary 10kV/5kA SPD
	5 = 480	09					T = Secondary 20kV/10kA SPD
	D = 347	10					U = DALI Programmable[6,7]
		11					V1 = Field Adjustable Module[10]
		12					X = Single Pack[8]
		13					Y = Coastal Finish[9]
		14					XXX = Special Options
		15					
		16					

1 Fusing requires discrete voltage.
2 02 Lumen Level, Voltage options 1, 2, 3 and 8 only
3 Nominal IES Type and classing subject to typical variation, individual units may differ
4 Select 2700K or 3000K CCT for IDA approved units
5 Lead time varies, contact Factory
6 Compatible with LightGrid
7 Not available in 347V, 480V or 347-480V for Lumen Output Levels 08-16
8 Option provides single pack box per fixture. Standard packaging = 23 units per MagnaPak Container
9 Recommended for installations within 750 feet from coast. Lead time varies, check with factory.
10 Not available with DALI "U" option
11 Only available with 02 Lumen Code

SUGGESTED HID REPLACEMENT

Approximately 2,000-3,000 lumens to replace 50W-70W HPS Cobra-head
Approximately 4,000-5,000 lumens to replace 100W HPS Cobra-head
Approximately 7,000-9,000 lumens to replace 150W HPS Cobra-head
Approximately 9,000-12,000 lumens to replace 200W HPS Cobra-head
Approximately 12,000-16,000 lumens to replace 250W HPS Cobra-head

Note: actual replacement lumens may vary based upon mounting height, pole spacing, design criteria, etc.

GE current
a Daintree company

Evolve® LED Roadway Lighting

Cobra Head (ERL1)

Spec Tables

Project Name ______________________

Date ______________ Type ______________

Notes ______________________

LUMEN OUTPUT	DIST.	TYPICAL INITIAL LUMENS			WATTAGE		BUG RATINGS		
		5000K/ 4000K	3000K	2700K	120V 277V	347V 480V	5000K/4000K	3000K	2700K
02	A5	2000	1900	1900	15*	N/A	B1-U0-G1	B1-U0-G1	B1-U0-G1
	B5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	C5						B1-U0-G1	B0-U0-G1	B0-U0-G1
	D5						B0-U0-G1	B0-U0-G1	B0-U0-G1
	E5						B1-U0-G1	B1-U0-G1	B1-U0-G1
03	A5	3000	2900	2800	22	26	B1-U0-G1	B1-U0-G1	B1-U0-G1
	B5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	C5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	D5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	E5						B1-U0-G1	B1-U0-G1	B1-U0-G1
04	A5	4000	3900	3800	29	33	B1-U0-G1	B1-U0-G1	B1-U0-G1
	B5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	C5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	D5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	E5						B1-U0-G1	B1-U0-G1	B1-U0-G1
05	A5	5000	4900	4700	37	39	B1-U0-G1	B1-U0-G1	B1-U0-G1
	B5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	C5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	D5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	E5						B2-U0-G2	B1-U0-G1	B1-U0-G1
06	A5	6000	5800	5700	46	49	B2-U0-G2	B2-U0-G2	B2-U0-G2
	B5						B1-U0-G1	B1-U0-G1	B1-U0-G1
	C5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	D5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	E5						B2-U0-G2	B2-U0-G2	B2-U0-G2
07	A5	7000	6700	6200	50	51	B2-U0-G2	B2-U0-G2	B2-U0-G2
	B5						B1-U0-G2	B1-U0-G2	B1-U0-G1
	C5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	D5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	E5						B2-U0-G2	B2-U0-G2	B2-U0-G2
08	A5	8000	7600	7100	59		B2-U0-G2	B2-U0-G2	B2-U0-G2
	B5						B2-U0-G2	B2-U0-G2	B1-U0-G2
	C5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	D5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	E5						B2-U0-G2	B2-U0-G2	B2-U0-G2
09	A5	9000	8600	8000	68		B2-U0-G2	B2-U0-G2	B2-U0-G2
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	C5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	D5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	E5						B2-U0-G2	B2-U0-G2	B2-U0-G2

NOTE: * 120-240V only

For additional information on ERL1 IES files, please click one of the following links:

Non-Shielded Shielded

GE current
a Daintree company

Evolve® LED Roadway Lighting

Cobra Head (ERL1)

Spec Tables

Project Name ______________________

Date ____________ Type ____________

Notes ______________________

LUMEN OUTPUT	DIST.	TYPICAL INITIAL LUMENS			WATTAGE		BUG RATINGS		
		5000K/ 4000K	3000K	2700K	120V 277V	347V 480V	5000K/4000K	3000K	2700K
	A5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
10	C5	10000	9600	8900	76		B2-U0-G2	B2-U0-G2	B1-U0-G2
	D5						B1-U0-G2	B1-U0-G2	B1-U0-G2
	E5						B3-U0-G3	B2-U0-G2	B2-U0-G2
	A5						B3-U0-G3	B3-U0-G3	B2-U0-G2
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
11	C5	11000	10500	9700	87		B2-U0-G2	B2-U0-G2	B2-U0-G2
	D5						B2-U0-G2	B2-U0-G2	B1-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	A5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
12	C5	12000	11500	11100	93		B2-U0-G2	B2-U0-G2	B2-U0-G2
	D5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	A5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
13	C5	13000	12400	12000	102		B2-U0-G3	B2-U0-G2	B2-U0-G2
	D5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	A5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	B5						B2-U0-G2	B2-U0-G2	B2-U0-G2
14	C5	14000	13400	13000	110		B2-U0-G3	B2-U0-G3	B2-U0-G3
	D5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	A5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	B5						B3-U0-G3	B2-U0-G2	B2-U0-G2
15	C5	15000	14400	13900	121		B2-U0-G3	B2-U0-G3	B2-U0-G3
	D5						B2-U0-G2	B2-U0-G2	B2-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	A5						B3-U0-G3	B3-U0-G3	B3-U0-G3
	B5						B3-U0-G3	B3-U0-G3	B2-U0-G2
16	C5	15700	15000	14600	129		B2-U0-G3	B2-U0-G3	B2-U0-G3
	D5						B2-U0-G3	B2-U0-G3	B2-U0-G2
	E5						B3-U0-G3	B3-U0-G3	B3-U0-G3

For additional information on ERL1 IES files, please click one of the following links:

Non-Shielded Shielded

GE current
a Daintree company

Evolve® LED Roadway Lighting

Cobra Head (ERL1)

Photometric Plots

Project Name

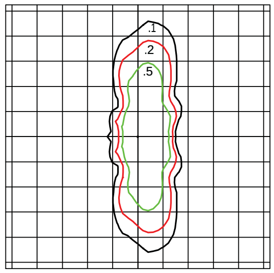
Date Type

Notes

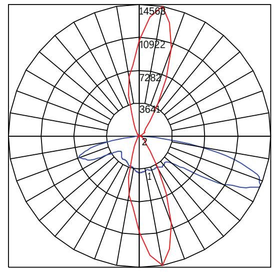
ERL1

Type II Narrow

15700 Lumens
5000K
ERL1_16A550___.IES



- Mounting Height at 30′
- Initial Footcandle at Grade

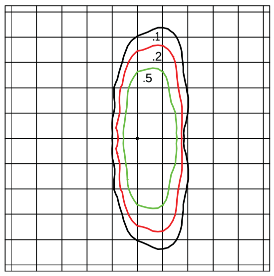


— Vertical plane at max Cd horiz. angle 80°
— Horizontal cone at max Cd vert. angle 68°

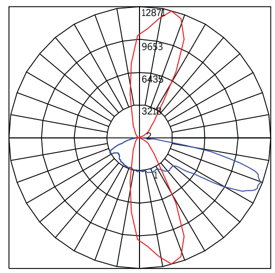
ERL1

Type II Wide

15700 Lumens
5000K
ERL1_16B550___.IES



- Mounting Height at 30′
- Initial Footcandle at Grade

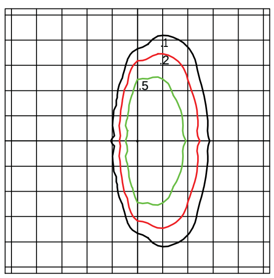


— Vertical plane at max Cd horiz angle 75°
— Horizontal cone at max Cd vert. angle 70°

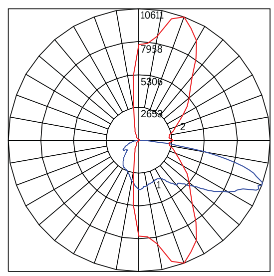
ERL1

Type III

15700 Lumens
5000K
ERL1_16C550___.IES



- Mounting Height at 30′
- Initial Footcandle at Grade

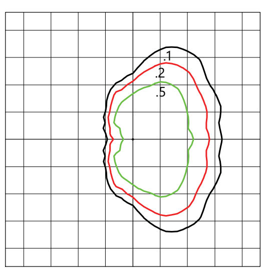


— Vertical plane at max Cd horiz angle 70°
— Horizontal cone at max Cd vert. angle 70°

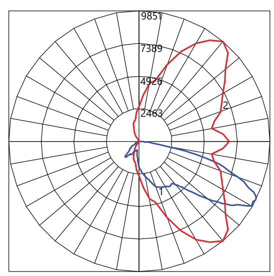
ERL1

Type IV Short

15700 Lumens
5000K
ERL1_16D550___.IES



- Mounting Height at 40′
- Initial Footcandle at Grade

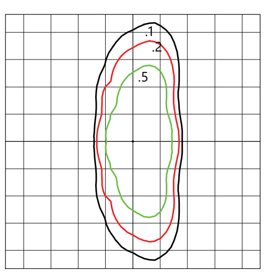


— Vertical plane at max Cd horiz angle 50°
— Horizontal cone at max Cd vert. angle 63°

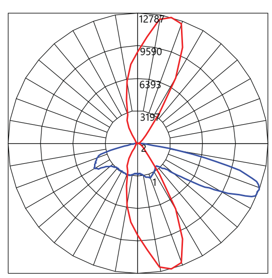
ERL1

Type II Medium

15700 Lumens
5000K
ERL1_16E550___.IES



- Mounting Height at 40′
- Initial Footcandle at Grade



— Vertical plane at max Cd horiz angle 75°
— Horizontal cone at max Cd vert. angle 69°

ISO illuminate diagrams and polar plots are representative of the SKUs illustrated.
Refer to IES files for SKU specific information.

GE current
a Daintree company

Evolve® LED Roadway Lighting

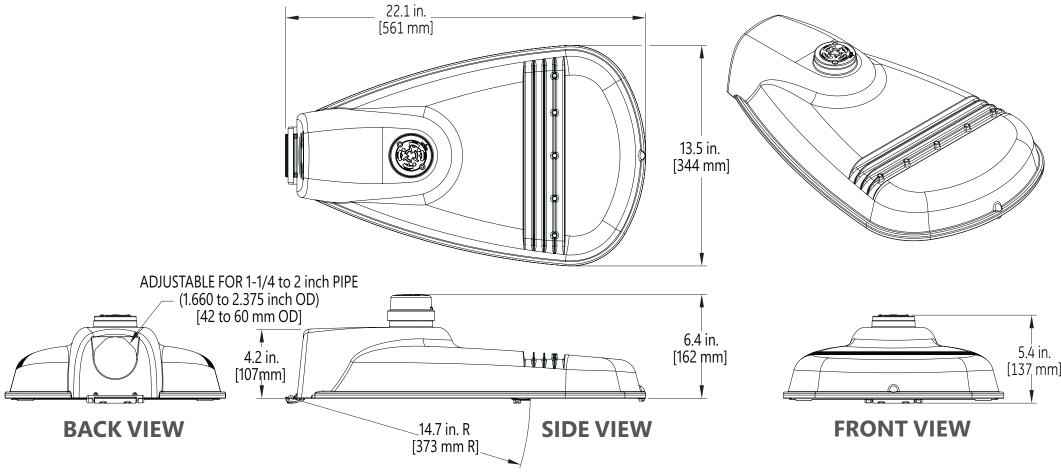
Cobra Head (ERL1)

Mounting & Accessories

Project Name ____________________

Date __________ Type __________

Notes ____________________



MOUNTING

- Adjustable for 1.25 to 2 in. nominal mounting pipe (1.660 to 2.375 inch OD)
- Integral diecast mounting pipe stop
- Slipfitter with +/- 5 degrees of leveling adjustment

EFFECTIVE PROJECTED AREA

- 0.5 sq ft max (0.046 sq m)

WEIGHT

- 12.4 lbs (5.6 kgs)

ACCESSORIES

SAP Number	Part Number	Description
93029237	PED-MV-LED-7	ANSI C136.41 Dimming PE, 120-277V
93029238	PED-347-LED-7	ANSI C136.41 Dimming PE, 347V
93029239	PED-480-LED-7	ANSI C136.41 Dimming PE, 480V
28299	PECOTL	Long Life PE 120-277V
93147530	PECHTL	Long Life PE 347-480V
73251	SCCL-PECTL	Shorting Cap

NETWORK LIGHTING CONTROLS

Current's **LightGrid™** Outdoor Lighting Control System is designed for Street and Roadway Applications. It enables remote monitoring, control, and asset management of a single fixture or a group of fixtures through a web enabled Central Management System.

GE current
a Daintree company

Evolve® LED Cobra Head
Shield Guide

Project Name ______________
Date ______________ Type ______________
Notes ______________

HOUSE SIDE SHIELDS

ERLC SHIELDS

Product Code:	93110037	Description:	ELSHS-ERLC-BLCK
Product Code:	93110038	Description:	ELSHS-ERLC-GRAY

ERL1 SHIELDS

Product Code:	93024487	Description:	ELSHS-ERL1-BLCK
Product Code:	93046386	Description:	ELSHS-ERL1-GRAY
Product Code:	93068998	Description:	ELSHS-ERL1-DKBZ

ERL2 SHIELDS

Product Code:	93070722	Description:	ELSHS-ERL2-BLCK
Product Code:	93085564	Description:	ELSHS-ERL2-GRAY
Product Code:	93096747	Description:	ELSHS-ERL2-DKBZ

STREET SIDE SHIELDS

ERLC SHIELDS

Product Code:	93132372	Description:	ELSFS-ERLC-BLCK-10
Product Code:	93132373	Description:	ELSFS-ERLC-BLCK-15
Product Code:	93134760	Description:	ELSFS-ERLC-BLCK-20

ERL1 SHIELDS

Product Code:	93092595	Description:	ELSFS-ERL1-BLCK-10
Product Code:	93108740	Description:	ELSFS-ERL1-GRAY-10
Product Code:	93092906	Description:	ELSFS-ERL1-BLCK-15
Product Code:	93105144	Description:	ELSFS-ERL1-GRAY-15
Product Code:	93088130	Description:	ELSFS-ERL1-BLCK-20
Product Code:	93088131	Description:	ELSFS-ERL1-GRAY-20

ERL2 SHIELDS

Product Code:	93132955	Description:	ELSFS-ERL2-BLCK-20
Product Code:	93132986	Description:	ELSFS-ERL2-GRAY-20

GE current
a Daintree company

Evolve® LED Cobra Head
Shield Guide

Project Name ______________________

Date ______________ Type ______________

Notes ______________________

SIDE SHIELDS (L&R)

Shipped as a kit - L & R can be used independently

ERLC SHIELDS

Product Code:	93132374	Description:	ELS-ERLC-LEFTRIGHTSIDEKIT-BLCK-10


ERL1 SHIELDS

Product Code:	93118695	Description:	ELS-ERL1H-LEFTRIGHTSIDEKIT-BLCK-10


ERL2 SHIELDS

Product Code:	93132989	Description:	ELS-ERL2-LEFTRIGHTSIDEKIT-BLCK-10


FOOTNOTES:

1) 10 = 1" Shield Depth; 15 = 1.5" Shield Depth; 20 = 2" Shield Depth
2) Black is recommended to reduce potential for glare coming off of the shield
3) Use "House Side" Shield to block light trespass behind the pole
4) Use "Street Side" / Front Shield to block light light trespass across the street

OLP3187 (Rev 04/12/22)

Type: LED Post Top .

GE Evolve™

LED Post Top Lighting

Salem™ Post Top (EPST)

current
powered by GE

Type: LED Post Top .

GE Evolve™

LED Post Top Lighting

Salem™ Post Top (EPST)

The **GE Evolve™ LED Salem™ Post Top** offers energy efficiency and quality of light in a classic, utility carriage look and style. The advanced LED optical system provides improved horizontal and vertical uniformity, reduced glare and improved lighting control. GE's unique optical ring technology effectively aims the light where you need it, while eliminating the unsightly shadow circles commonly seen under other LED post top fixtures.

The Salem post top can yield up to a 60-percent reduction in system energy compared with standard HID systems, depending on applications. This reliable system operates well in cold temperatures and offers more than 20 years of service life to reduce maintenance frequency and expense, based on a 100,000 hour life and 12 hours of operation per day.

Features:

- Optimized photometric distributions.
- **Evolve™** light engine consisting of nested concentric directional reflectors designed to optimize application efficiency and minimize glare.
- 70 CRI at 3000K and 4000K typical
- -40°C to 50°C UL Ambient
- Designed and Assembled in USA

Applications:

- Local Roadways
- Parks and Pathways
- Antique Streetscapes
- University and Business Campuses

To learn more about **GE Evolve EPST Salem Post Top**, go to: **www.currentbyge.com**

Type: LED Post Top .

GE Evolve™

LED Post Top Lighting

Salem™ Post Top (EPST)

Project name ________________

Date ________________

Type ________________

Typical Specifications: EPST

LED & Optical Assembly

- **Output Range:** 2,800 – 8,900 lm
- **Photometric Options:**
  - – Symmetric Type V
  - – Asymmetric Type III
- **System Efficacy:** 99 - 114 LPW
- **CCT:** 3000K, 4000K; High brightness LEDs @ 70 CRI

Lumen Maintenance Table

- Projected Lxx per IES TM-21 at 25 °C for reference:

SKU	Lxx (10k) @ Hours 25,000 hr	50,000 hr	100,000 hr
EPST	L97	L96	L94

Note: Projected Lxx based on LM80 (100,000 hour testing).

Lumen Ambient Temperature Factors:

Ambient Temp (°C)	Initial Flux Factor
10	1.02
20	1.01
25	1.00
30	0.99
40	0.98

Electrical

- **Input Voltage:** 120-277V or 347-480V
- **Input Frequency:** 50/60Hz
- **Power Factor (PF)*:** ≥0.90
- **Total Harmonic Distortion (THD)*:** ≤20%

* *System PF and THD specified at rated watts*

Ratings

- **Safety:** UL/cUL listed per UL1598, suitable for wet locations.
- **Intrusion Protection (IP):** IP65 rated optical enclosure per ANSI C136.25-2009.
- **Sound:** Class "A" rating.
- **Surge Protection:** per ANSI C136.2-2015
  - **(Driver Internal):**
  - – 6kV/3kA "Basic: (40 Strikes)" – Standard
  - **(Additional Secondary SPD):**
  - – 10kV/5kA "Enhanced (40 Strikes)" – Option R
- **Environmental:** Complies with the material restrictions of RoHS
- **EMI:** Title 47CFR Part 15 Class A
- **Vibration:** 2.0G per ANSI C136.41-2010
- LM-79 testing in accordance with IESNA standards.
- **Operating Temperature:** -40 °C to + 50 °C

Construction & Finish

- **Housing:**
  - – Diecast aluminum housing.
  - – Internal heat sink ensuring maximum heat transfer for long LED life.
  - – Cupola compatible with C136.10 PE's and Shorting Caps and LightGrid™ 2.0 node.
- **Lensing:** UV resistant polymer lens
- **Paint:** Corrosion resistant polyester powder paint, minimum 2.0 mils thickness.
  - – Standard colors: Black, Dark Bronze
  - – RAL & custom colors available
- **Weight:** 23 lbs. (10.4 kgs.) – 24 lbs. (10.9 kgs)

Warranty

- **System Warranty:** 5 Year Standard, 10 Year Optional

Controls

(Connected via 7-Pin C136.41 receptacle)

- **Dimming:**
  - – Standard 0-10V
  - – Optional DALI
- **Sensors:**
  - – Photo-electric sensors (PE) available for all voltages
  - – LightGrid™ 2.0 compatible

Mounting

- Post top mounting for 3-inch (76mm) OD by 3-inch vertical tenon secured with three square head set screws.

Type: LED Post Top .

GE Evolve™

LED Post Top Lighting

Salem™ Post Top (EPST)

Project name ________________

Date ________________

Type ________________

Ordering Number Logic

PROD. ID	GENERATION (VERSION)	VOLTAGE	LUMEN OUTPUT	DISTRIBUTION	CCT	CONTROLS ANSI C136.41 7 PIN PE RECEPTACLE	TOP TYPE	COLOR	OPTIONS
EPST	02	0	08	B	30	D	A	BLCK	R
E = Evolve **P** = Post Top **S** = Salem **T** = Traditional	**02** = GEN 2	**0** = 120-277 **5** = 480** **D** = 347** **H** = 347-480** **Not available for 03 thru 06 lumen codes	**03** **04** **05** **06** **07** **08** **09**	**A** = Symmetric Type V **B** = Asymmetric Type III	**30** = 3000K **40** = 4000K	**1** = None **A** = PE Receptacle **D** = PE Receptacle with Shorting Cap **E** = PE Receptacle with non-dimming PE in box* *Must specify discrete voltage	**A** = Salem	**BLCK** = Black **DKBZ** = Dark Bronze	**R** = Secondary 10KV/5KA SPD **U** = DALI* **XXX** = Special Options * Not available for 5, D, & H voltages

DISTRIBUTION CODE	OPTICAL CODE	TYPICAL INITIAL LUMENS		TYPICAL SYSTEM WATTAGE		BUG RATINGS		IES FILE NUMBERS			
								4000K		3000K	
		4000K	3000K	120-277V & 347-480V		4000K	3000K	120-277V	347-480V	120-277V	347-480V
A Symmetric Type V	**03**	3000	2800	27	N/A	B2-U2-G1	B2-U1-G1	EPST02_03A40_-120-277V.IES		EPST02_03A30_-120-277V.IES	
	04	4000	3800	35	N/A	B2-U2-G1	B2-U2-G1	EPST02_04A40_-120-277V.IES		EPST02_04A30_-120-277V.IES	
	05	4900	4600	43	N/A	B3-U2-G1	B3-U2-G1	EPST02_05A40_-120-277V.IES		EPST02_05A30_-120-277V.IES	
	06	6100	5700	54	N/A	B3-U2-G1	B3-U2-G1	EPST02_06A40_-120-277V.IES		EPST02_06A30_-120-277V.IES	
	07	7000	6600	65		B3-U2-G1	B3-U2-G1	EPST02_07A40_.IES		EPST02_07A30_.IES	
	08	7900	7500	74		B3-U2-G2	B3-U2-G1	EPST02_08A40_.IES		EPST02_08A30_.IES	
	09	8900	8400	85		B3-U2-G2	B3-U2-G2	EPST02_09A40_.IES		EPST02_09A30_.IES	
B Asymmetric Type III	**03**	3000	2800	27	N/A	B1-U2-G1	B1-U1-G1	EPST02_03B40_-120-277V.IES		EPST02_03B30_-120-277V.IES	
	04	4000	3800	35	N/A	B1-U2-G1	B1-U2-G1	EPST02_04B40_-120-277V.IES		EPST02_04B30_-120-277V.IES	
	05	4900	4600	43	N/A	B1-U2-G2	B1-U2-G1	EPST02_05B40_-120-277V.IES		EPST02_05B30_-120-277V.IES	
	06	6100	5700	54	N/A	B1-U2-G2	B1-U2-G2	EPST02_06B40_-120-277V.IES		EPST02_06B30_-120-277V.IES	
	07	7000	6600	65		B1-U2-G2	B1-U2-G2	EPST02_07B40_.IES		EPST02_07B30_.IES	
	08	7900	7500	74		B2-U2-G2	B2-U2-G2	EPST02_08B40_.IES		EPST02_08B30_.IES	
	09	8900	8400	85		B2-U2-G2	B2-U2-G2	EPST02_09B40_.IES		EPST02_09B30_.IES	

Type: LED Post Top .

GE Evolve™

LED Post Top Lighting

Salem™ Post Top (EPST)

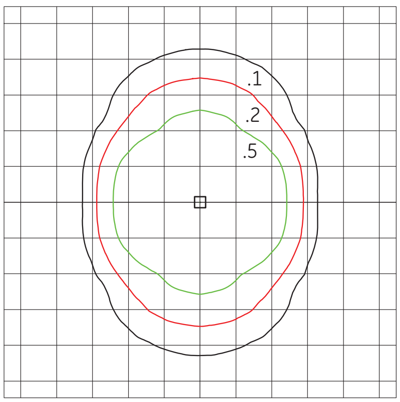
Project name ______________

Date ______________

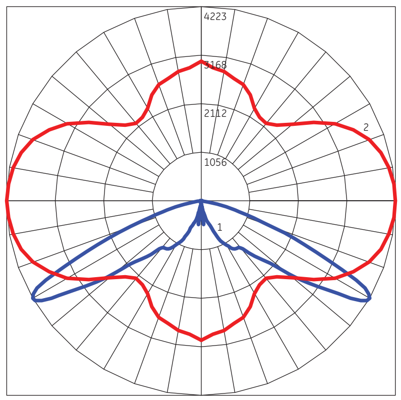
Type ______________

Photometrics

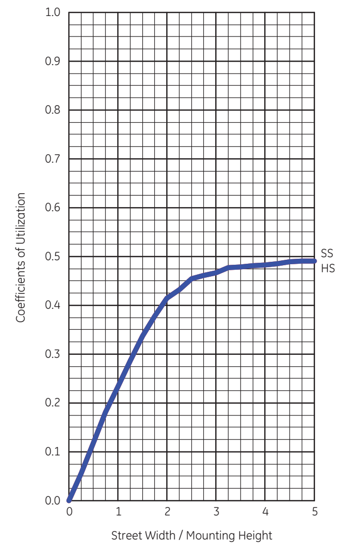
EPST02*A40 – Symmetric (Type V)**
8,900 Lumens, 4000K



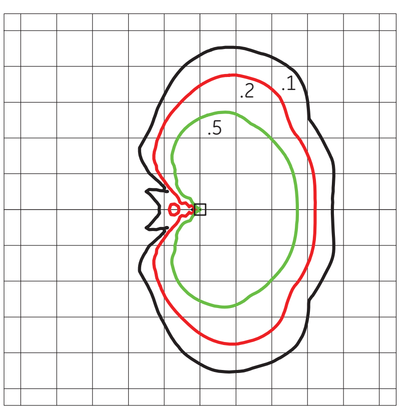
Grid Distance in Units of Mounting Height at 16'
Initial Footcandle Values at Grade



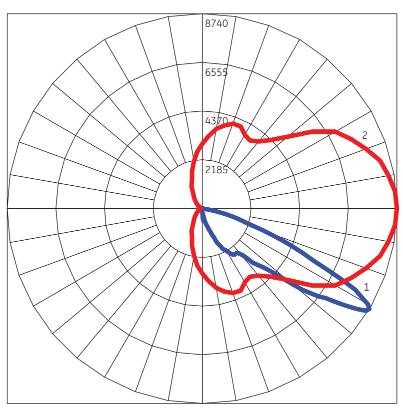
Vertical plane through horizontal angle of Max. Cd at 0°
Horizontal cone through vertical angle of Max. Cd at 60°



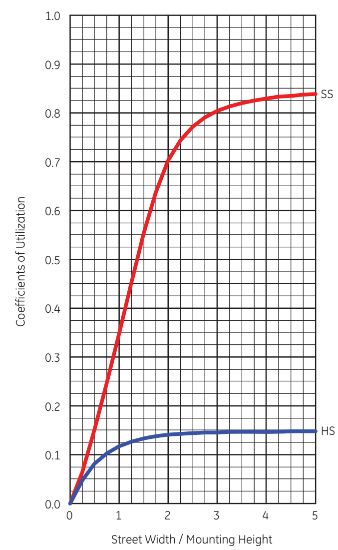
EPST02*B40 – Asymmetric (Type III)**
8,900 Lumens, 4000K



Grid Distance in Units of Mounting Height at 16'
Initial Footcandle Values at Grade

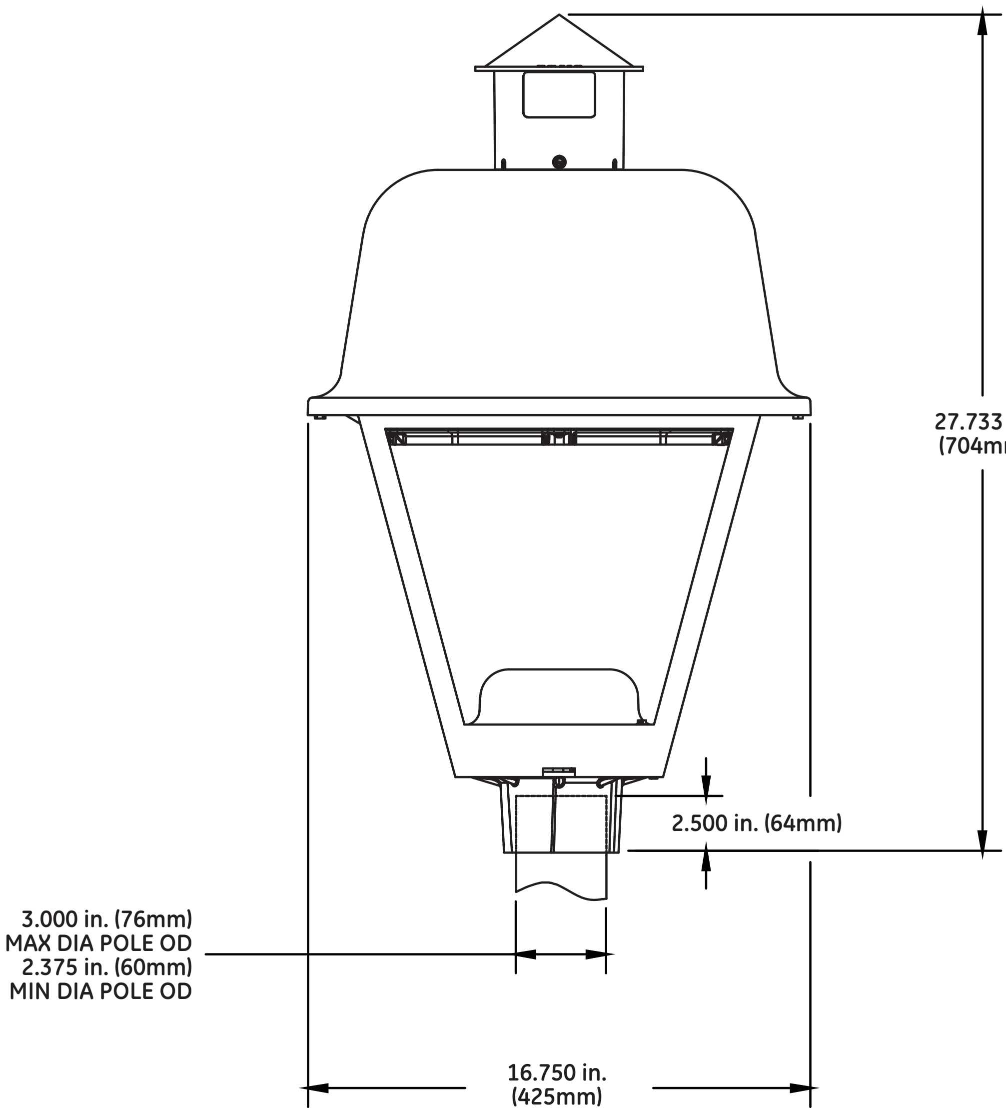


Vertical plane through horizontal angle of Max. Cd at 0°
Horizontal cone through vertical angle of Max. Cd at 59°



Type: LED Post Top .

Product Dimensions



DATA

- Approximate Net Weight: 23 lbs (10.4 kgs) - 24 lbs (10.9 kgs)
- Suggested Mounting Height: 8-16 ft max (2.5-5 m)
- Effective Projected Area (EPA): 1.6 sq ft max (0.15 sq m)

Appendix D. Scoping Letter and Responses

MICHAEL P. VICTORINO
Mayor

ROWENA M. DAGDAG-ANDAYA
Director

STEPHEN M. WELLING, P.E.
Deputy Director

GLEN A. UENO, P.E., L.S.
Development Services Administration

RODRIGO "CHICO" RABARA, P.E.
Engineering Division

JOHN R. SMITH, P.E.
Highways Division

Telephone: (808) 270-7845
Fax: (808) 270-7955

COUNTY OF MAUI
DEPARTMENT OF PUBLIC WORKS
200 SOUTH HIGH STREET, ROOM 434
WAILUKU, MAUI, HAWAII 96793

August 20, 2019

Ms. Michelle Bogardus, Island Team Leader
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawaii 96850

Dear Ms. Bogardus:

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, MAUI COUNTY, HAWAII DPW PROJECT NO.: 18-34

The County of Maui Department of Public Works (DPW) seeks your advice and input regarding the County's proposal to replace all existing County-owned High Pressure Sodium (HPS) streetlight fixtures located within Maui County roadway rights-of-way with Light Emitting Diode (LED) fixtures. This project would utilize existing poles while replacing streetlight fixtures (bulbs) throughout Maui County. County funds are intended to be utilized for this project.

This early consultation letter is being sent in support of an upcoming environmental assessment being conducted by the DPW pursuant to Hawaii Revised Statutes (HRS), Chapter 343, and Hawaii Administrative Rules (HAR), Title 11, Chapter 200.1.

The County of Maui is following the other Counties and the State of Hawaii Department of Transportation (HDOT) in converting its streetlights to LED fixtures. They have all completed or are completing their streetlight conversions (Hawaii County: approximately 10,000 fixtures; Kauai County: approximately 3,500 fixtures; City & County of Honolulu: approximately 52,000 fixtures; HDOT: approximately 20,000 fixtures statewide). On Maui, the HDOT completed its LED streetlight conversion in 2018.

PROJECT DESCRIPTION

In comparison to the HPS fixtures proposed to be replaced, LED fixtures have a better color rendering index which means colors and objects will have better visibility and objects will be sharper, which maintains the safety of the roadway, drivers, pedestrians, and bicyclists.[1] Initial public outreach and scoping included a pilot LED streetlight study, which Maui Electric Company and the DPW collaboratively developed and launched in 2016. The two (2)-month pilot involved the installation of 24 LED streetlight fixtures along Maui Lani Parkway in Kahului to test and evaluate various types of LED lights. The pilot provided opportunities for the public, law enforcement representatives, and community organizations to share feedback on the characteristics of the different types of LED lighting, such as glare and visual acuity. The LED fixtures that were determined to be the preferred alternative following the 2016 pilot study are 2700K bulbs made by General Electric. Specifications for the General Electric LED lights can be found using the following link: https://products.currentbyge.com/sites/products.currentbyge.com/files/documents/document file/OLP3128-GE-LED-Evolve-Roadway-Data-Sheet.pdf.

The project involves the replacement of approximately 4,800 streetlight fixtures located along County roadways on Maui, Molokai, and Lanai islands. These fixtures are owned and maintained by Maui Electric Company. Work includes the removal and disposal of existing HPS streetlight fixtures and the installation of new LED streetlight fixtures. Work would be completed during normal business hours of 8:00 a.m. to 5:00 p.m. and would not require the closure of any roadways or the diversion of traffic. The project is anticipated to cost approximately $4 million and is expected to begin within six (6) months of the completion of this environmental review with project completion approximately 12 months later.

The project is proposed to be completed in two (2) phases:

Phase 1 includes approximately 1,889 fixtures in the following districts:

- Kahakuloa-Waiehu-Wailuku-Kahului (1,687 fixtures);
- Kailua-Hana (49 fixtures); and
- Olowalu-Napili (153 fixtures).

Phase 2 includes approximately 2,931 fixtures in the following districts:

- Lahaina-Napili (369 fixtures);
- Ma'alaea-Makena: (957 fixtures);

[1] https://www.mauielectric.com/community-and-education/led-streetlight-installation/led-streetlight-installation-faq

- Ulupalakua-Kula-Pukalani-Makawao-Haiku-Kuau-Spreckelsville: (1,098 fixtures);
- Moloka'i: (365 fixtures); and
- Lana'i: (142 fixtures).

The project will implement a wireless adaptive control system which will allow the County of Maui, HDOT, and Maui Electric Company to remotely manage the operation of the streetlight infrastructure in real-time and at the individual fixture level. This technology allows for dimming/brightening of individual or groups of lights, and also includes remote system monitoring which provides notification when a fixture is burnt out and needs replacement. The project will also include GPS mapping of the streetlights.

PROJECT NEED AND PURPOSE

The purpose of the project is to increase roadway safety and visibility while simultaneously reducing energy consumption and County of Maui operating expenses. LEDs will provide better service reliability, lower maintenance costs, lower operating costs, and reduced carbon emissions due to their lifespan being about four (4) times that of an HPS lamp and their energy consumption being less than 50% of comparable HPS fixtures. The reduced energy consumption alone is estimated to result in savings of approximately $650,000 per year in electricity cost for the County of Maui.

The proposed LED fixtures have been designed to provide an improved distribution of light, increasing visibility in dark spots between streetlight poles, rather than solely projecting light directly below streetlight fixtures as the HPS luminaires do. The LEDs are also designed to reduce the amount of light that spills back behind the streetlight pole and onto adjacent properties. The LEDs allow colors to appear more natural at night, improving color rendering and visibility compared to the current HPS bulbs, improving safety for both pedestrians and vehicles.

We are soliciting your comments and applicable agency requirements for the project to assist us in completing this environmental review. We greatly appreciate your cooperation in providing us with written comments by Friday, September 20, 2019, addressed to the County of Maui, Department of Public Works at the address shown above.

Should you have any questions regarding this matter, please call me at (808) 270-7845.

Sincerely,

ROWENA M. DAGDAG-ANDAYA
Director of Public Works

RMDA/MJB/KW:jso
cc: Brian Bilberry, Deputy Corporation Counsel (electronic)
DPW Traffic Section (electronic)
S:\PWADMIN\Jso\Rowena\LED Early Env Consultation Review Mail Merge Ltr.doc

MICHAEL P. VICTORINO
Mayor

LORI TSUHAKO
Director

LINDA R. MUNSELL
Deputy Director

DEPARTMENT OF HOUSING
& HUMAN CONCERNS
COUNTY OF MAUI
2200 MAIN STREET, SUITE 546
WAILUKU, MAUI, HAWAI'I 96793
PHONE: (808) 270-7805

August 22, 2019

Rowena M. Dagdag-Andaya, Director
Department of Public Works
200 S. High Street
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya:

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, MAUI COUNTY, HAWAII DPW PROJECT NO.: 18-34

The Department is in receipt of your request for an Early Environmental Consultation for the above subject project. Based on our review, the department has no comments to offer.

Sincerely,

LORI TSUHAKO, LSW, ACSW
Director of Housing and Human Concerns

xc: Brian Bilberry, Deputy Corporation Counsel
DPW Traffic Section

MICHAEL P. VICTORINO
Mayor

DAVID C. THYNE
Fire Chief

BRADFORD K. VENTURA
Deputy Fire Chief

DEPARTMENT OF FIRE & PUBLIC SAFETY
COUNTY OF MAUI
200 DAIRY ROAD
KAHULUI, HI 96732

August 26, 2019

RECEIVED
2019 AUG 2? PM 12: 0?
COUNTY OF MAUI
PUBLIC WORKS

Rowena Dagdag-Andaya, Director
Department of Public Works
200 South High St., Room No. 434
Wailuku, HI 96793

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSATION PROJECT, MAUI COUNTY, HAWAII DPW PROJECT NO.: 18-34

Dear Director Dagdag-Andaya,

The Department of Fire & Public Safety has had the opportunity to review the early consultation request for the subject above and do not have any concerns at this time.

If you have any questions, please feel free to contact our office at (808) 270-7561.

Sincerely,

DAVID C. THYNE
Fire Chief

DAVID Y. IGE
GOVERNOR

RECEIVED

2019 SEP -9 PM 4:00

COUNTY OF MAUI
PUBLIC WORKS

ARTHUR J. LOGAN
MAJOR GENERAL
ADJUTANT GENERAL

KENNETH S. HARA
BRIGADIER GENERAL
DEPUTY ADJUTANT GENERAL

734

RUSH

STATE OF HAWAII
DEPARTMENT OF DEFENSE
OFFICE OF THE ADJUTANT GENERAL
3949 DIAMOND HEAD ROAD
HONOLULU, HAWAII 96816-4495

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR							
DEPUTY DIR.							
FISCAL ANALYST	✓						✓
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ____________ Due ____________
By: ____________

September 5, 2019

Ms. Rowena M. Dagdag-Andaya
Director of Public Works
Department of Public Works
200 South High Street, Room 434
Wailuku, Maui, Hawaii 96793

Dear Ms. Dagdag-Andaya:

Thank you for your letter dated August 20, 2019, subject: Early Environmental Consultation Review Maui County Light Emitting Diode (LED) Streetlight Conversion Project, Maui County, Hawaii DPW Project No. 18-34.

The Office of Homeland Security has no projects that would impact the subject project. We do appreciate the opportunity to review and comment.

The Federal Emergency Management Agency requires all Homeland Security funding to have an Environmental Historical Preservation review (EHP). Therefore, we would request that a copy of the environmental assessment and any decisions/approvals be made available to the Maui Emergency Management for future reference.

Thank you for the opportunity to review. If you have further questions, please have your staff contact me by email at dolores.m.cook@hawaii.gov.

Sincerely,

Dolores Cook

Dolores M. Cook
Homeland Security Administrator

c. Herman Andaya, Administrator, Maui Emergency Management Agency

DAVID Y. IGE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
MAUI DISTRICT HEALTH OFFICE
54 HIGH STREET
WAILUKU, HAWAII 96793-3378

BRUCE S. ANDERSON, Ph.D.
DIRECTOR OF HEALTH

LORRIN W. PANG, M.D., M.P.H.
DISTRICT HEALTH OFFICER

RECEIVED
2019 SEP -9 PM 2:26
COUNTY OF MAUI
PUBLIC WORKS

RUSH 732

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR	✓						
DEPUTY DIR.							
FISCAL ANALYST	✓						✓
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

September 5, 2019

Ms. Rowena M. Dagdag-Andaya
Director
Department of Public Works
County of Maui
200 South High Street, Room 434
Wailuku, HI 96793

Dear Ms. Dagdag-Andaya:

Subject: Early Environmental Consultation Review
Maui County Light Emitting Diode (LED) Streetlight
Conversion Project, Maui County, Hawaii
DPW Project No.: 18-34

Thank you for the opportunity to review this project. We have no comments to offer.

Should you have any questions, please contact me at 808 984-8230 or email me at patricia.kitkowski@doh.hawaii.gov.

Sincerely,

Patti Kitkowski

Patti Kitkowski
District Environmental Health Program Chief

DAVID Y. IGE
GOVERNOR

CURT T. OTAGURO
COMPTROLLER

AUDREY HIDANO
DEPUTY COMPTROLLER

RECEIVED
2019 SEP -9 PM

COUNTY OF MAUI
PUBLIC WORKS

STATE OF HAWAII
DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES

P.O. BOX 119, HONOLULU, HAWAII 96810-0119

(P)19.192

☐ RUSH

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR							
DEPUTY DIR.							
FISCAL ANALYST							
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ______ Date ______
By: ______ Date ______

SEP 6 2019

Ms. Rowena M. Dagdag-Andaya, Director
County of Maui
Department of Public Works
200 South High Street, Room 434
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya:

Subject: Early Environmental Consultation Review
Maui County Light Emitting Diode (LED) Streetlight
Conversion Project, Maui County, Hawaii
DPW Project No.: 18-34

Thank you for the opportunity to review the information regarding the subject project. The project does not impact any of the Department of Accounting and General Services' projects or existing facilities and we have no comments to offer.

If you have questions your staff may call Ms. Dora Choy of the Public Works Division at 586-0488.

Sincerely,

CURT T. OTAGURO
Comptroller

c: Mr. Wade Shimabukuro, DAGS, MDO

MICHAEL P. VICTORINO
Mayor

ERIC A. NAKAGAWA, P.E.
Director

SHAYNE R. AGAWA, P.E.
Deputy Director

MICHAEL P. RATTE
Solid Waste Division

SCOTT R. ROLLINS, P.E.
Wastewater Reclamation Division

TAMARA L. FARNSWORTH
Environmental Protection &
Sustainability Division

RECEIVED
2019 SEP 10 PM 3:18
COUNTY OF MAUI
PUBLIC WORKS

DEPT. OF PUBLIC WORKS | INFO | ACTION | SEE ME | COMMENTS | COPY | SCAN | FILE
DIRECTOR, DEPUTY DIR., FISCAL ANALYST, PERSONNEL, DSA, ENGR., HWY, SECTY

RUSH 743

COUNTY OF MAUI
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
2050 MAIN STREET, SUITE 2B
WAILUKU, MAUI, HAWAII 96793

September 10, 2019

MEMO TO: ROWENA DAGDAG-ANDAYA, DIRECTOR OF PUBLIC WORKS

FROM: ERIC A. NAKAGAWA, DIRECTOR OF ENVIRONMENTAL MANAGEMENT

SUBJECT: **MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, DPW PROJECT NO. 18-34 EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY, HAWAII**

We reviewed the subject application and have the following comments:

1. Solid Waste Division comments:

    a. All applicable federal, state, and local regulations regarding disposal of mercury-containing bulbs are to be followed.

2. Wastewater Reclamation Division (WWRD) comments:

    a. None.

If you have any questions regarding this letter, please contact Shayne Agawa at 270-8230.

MICHAEL P. VICTORINO
Mayor

ERIC A. NAKAGAWA, P.E.
Director

SHAYNE R. AGAWA, P.E.
Deputy Director

MICHAEL P. RATTE
Solid Waste Division

SCOTT R. ROLLINS, P.E.
Wastewater Reclamation Division

TAMARA L. FARNSWORTH
Environmental Protection &
Sustainability Division

RECEIVED
2019 AUG 30 PM 3: 22
COUNTY OF MAUI
PUBLIC WORKS

RUSH

COUNTY OF MAUI
DEPARTMENT OF
ENVIRONMENTAL MANAGEMENT
2050 MAIN STREET, SUITE 2B
WAILUKU, MAUI, HAWAII 96793

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR	✓						
DEPUTY DIR.							
FISCAL ANALYST	✓						✓
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ______ Due ______
By: ______ Date: ______

August 26, 2019

Ms. Rowena M. Dagdag-Andaya
Director of Public Works
County of Maui
200 South High Street, Room 434
Wailuku, Maui, Hawaii 96793

Dear Ms. Dagdag-Andaya:

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, MAUI COUNTY, HAWAII DPW PROJECT NO.: 18-34

This letter responds to your request for advice and input regarding the County's proposal to replace all existing County-owned High Pressure Sodium (HPS) streetlight fixtures located within Maui County roadway rights-of-way with Light Emitting Diode (LED) fixtures. All applicable federal, state, and local regulations regarding disposal of mercury-containing bulbs are to be followed.

If you have any questions, please call the Solid Waste Division at (808) 270-7875.

Sincerely,

Shayne R. Agawa

for ERIC A. NAKAGAWA, P.E.
Director of Environmental Management

cc: Robert Schmidt, Acting Chief, Solid Waste Division

DAVID Y. IGE
GOVERNOR

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

JADE T. BUTAY
DIRECTOR

Deputy Directors
LYNN A.S. ARAKI-REGAN
DEREK J. CHOW
ROSS M. HIGASHI
EDWIN H. SNIFFEN

RECEIVED
2019 SEP 13 PM 2:11
COUNTY OF MAUI

IN REPLY REFER TO:
DIR 0888
STP 8.2747

RUSH

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR							
DEPUTY DIR.							
FISCAL ANALYST							
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ______ Due ______ Date ______

September 12, 2019

Ms. Rowena M. Dagdag-Andaya
Director of Public Works
County of Maui
Department of Public Works
200 South High Street, Room 434
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya:

Subject: Maui County Light Emitting Diode (LED) Streetlight Conversion Project
Early Environmental Consultation Review
Maui, Hawaii
TMK: (2) Various

The State Department of Transportation (DOT) understands the County proposes to replace all existing County-owned High-Pressure Sodium streetlight fixtures located within Maui County roadway rights-of-way on Maui, Lanai, and Molokai with LED fixtures. DOT's comments are as follows.

The Draft Environmental Assessment should address how the project complies with the county and state's dark night sky protection policies. A discussion should be included of the potential for seabird light attraction fallout, especially in areas in close proximity to DOT facilities, such as the commercial ports in Kaunakakai, Kaumalapau, and especially Kahului.

If there are any questions, please contact Mr. Blayne Nikaido of the DOT Statewide Transportation Planning Office at (808) 831-7979 or via email at blayne.h.nikaido@hawaii.gov.

Sincerely,

JADE T. BUTAY
Director of Transportation

MICHAEL P. VICTORINO
Mayor

MICHELE CHOUTEAU MCLEAN, AICP
Director

JORDAN E. HART
Deputy Director

RECEIVED

2019 SEP 23 PM 2:48

COUNTY OF MAUI
PUBLIC WORKS

RUSH

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR	✓						
DEPUTY DIR.							
FISCAL ANALYST	✓						✓
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

DEPARTMENT OF PLANNING
COUNTY OF MAUI
ONE MAIN PLAZA
2200 MAIN STREET, SUITE 315
WAILUKU, MAUI, HAWAII 96793

September 17, 2019

Rowena M. Dagdag-Andaya, Director
Department of Public Works
200 South High Street, Room 434
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya:

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW OF MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, MAUI COUNTY, HAWAII, DPW PROJECT NO: 18-34 (RFC 2019/0084)

The Department of Planning (Department) has received your letter dated August 20, 2019 asking for comment regarding the above referenced project. The Department is in support of the project and has no further comment.

Should you have any questions, please feel free to contact Paul Fasi, staff planner by email at paul.fasi@mauicounty.gov or by phone at (808) 270-7814.

Sincerely,

MICHELE MCLEAN, AICP
Planning Director

xc: Paul F. Fasi, Staff Planner (PDF)
Project File
MCM:PFF:lk
K:\WP_DOCS\PLANNING\RFC\2019\0084_DPWProjectNo.18-3\RFC2018-0085Reply.docx

DAVID Y. IGE
GOVERNOR

DR. CHRISTINA M. KISHIMOTO
SUPERINTENDENT

RECEIVED
2019 SEP 18 PM 2:08
COUNTY OF MAUI
PUBLIC WORKS

STATE OF HAWAI'I
DEPARTMENT OF EDUCATION
P.O. BOX 2360
HONOLULU, HAWAI'I 96804

OFFICE OF FACILITIES AND OPERATIONS

September 12, 2019

Rowena Dagdag-Andaya, Director
Department of Public Works
200 South High Street, Room 434
Wailuku, Hawaii 96793

Re: Early Environmental Consultation Review Maui County Light Emitting Diode (LED) Streetlight Conversion Project, Maui County, Hawaii DPW Project No.: 18-34

The Hawaii State Department of Education (HIDOE) has the following comments for the proposed Street Light Conversion Project (Project). According to the information provided, Maui County will replace approximately 4,800 street light fixtures located along County roadways on Maui, Molokai, and Lanai.

HIDOE facilities maybe affected by the Project. In order for HIDOE to identify which facilities will be affected, a map or maps of County roadways will be required.

Thank you for the opportunity to comment. Should you have questions, please contact Robyn Loudermilk, School Lands and Facilities Specialist of the Facilities Development Branch, Planning Section at 784-5093 or via email at robyn.loudermilk@k12.hi.us.

Respectfully,

Kenneth G. Masden II
Public Works Manager
Planning Section

KGM:rll

RUSH TM

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR	✓						
DEPUTY DIR.							
FISCAL ANALYST	✓						✓
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ______ Date ______
By: ______

POLICE DEPARTMENT
COUNTY OF MAUI

MICHAEL P. VICTORINO
MAYOR

55 MAHALANI STREET
WAILUKU, HAWAII 96793
(808) 244-6400
FAX (808) 244-6411

TIVOLI S. FAAUMU
CHIEF OF POLICE

DEAN M. RICKARD
DEPUTY CHIEF OF POLICE

OUR REFERENCE

YOUR REFERENCE

RECEIVED
2019 SEP 20 PM 12: 48
COUNTY OF MAUI
PUBLIC WORKS

RUSH 185

DEPT. OF PUBLIC WORKS
DIRECTOR
DEPUTY DIR.
FISCAL ANALYST
PERSONNEL
DSA
ENGR.
HWY.
SECTY.
Return to ______ Date ______
By ______ Date ______

September 19, 2019

Ms. Rowena Dagdag-Andaya
Director
County of Maui
Dept. of Public Works
200 South High Street
Wailuku, Hawaii 96793

SUBJECT: EARLY ENVIRONMENTAL CONSULTATION REVIEW MAUI COUNTY LIGHT EMITTING DIODE (LED) STREETLIGHT CONVERSION PROJECT, MAUI COUNTY, HAWAII DPW JOB NO. 18-34

Dear Ms. Dagdag-Andaya:

This is in response to your letter dated August 20, 2019, requesting comments on the above subject.

In reviewing the submitted documents, concerns from the police perspective are upon the safety of pedestrian and vehicular movement. Light Emitting Diodes (LED) lighting is recommended in Crime Prevention Through Environmental Design (CPTED) practices and is the preferred lighting source to utilize. The LED's will provide better visibility by eliminating dark spots, reducing energy consumption, lower maintenance and operating costs while improving safety for both pedestrians and vehicular traffic. This project to convert High Pressure Sodium (HPS) fixtures to LED lighting will greatly benefit the County of Maui by enhancing and maintaining the safety of the roadway for drivers and pedestrians in allowing colors and objects to have better visibility and appear sharper.

Thank you for giving us the opportunity to comment on this environmental review.

Sincerely,

AC Jakubczak

Assistant Chief John Jakubczak
for: TIVOLI S. FAAUMU
Chief of Police

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawaii 96850

In Reply Refer To:
01EPIF00-2019-TA-0468

September 20, 2019

Ms. Rowena M. Dagdag-Andaya
Director of Public Works
County of Maui
200 South High Street, Room 434
Wailuku, Maui, Hawaii 96793

Subject: Technical Assistance for Maui County LED Streetlight Conversion Project, Maui County, Hawaii

Dear Ms. Dagdag-Andaya:

Thank you for your August 20, 2019, letter requesting our recommendations as you develop an environmental assessment for the replacement of existing high-pressure sodium streetlights with LED light bulbs. Approximately 4,800 LED lights with warm (2,700 kelvin) color would be installed on existing Maui County streetlights. We reviewed the proposed project pursuant to the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Based on information you provided, and information in our files including data compiled by the Hawaiʻi Biodiversity and Mapping project, we are concerned the proposed streetlights change poses a increased risk to Hawaiian seabirds, including the endangered Hawaiian petrel (*Pterodroma sandwichensis*), band-rumped petrel (*Oceanodroma castro*) and the threatened Newell's shearwater (*Puffinus newelli*), and sea turtles, including the endangered Hawksbill sea turtle (*Eretmochelys imbricata*), and the threatened Green sea turtle (*Chelonia mydas).* In addition, project risks to the following endangered species should be included in your environmental assessment: Blackburn's sphinx moth (*Manduca blackburni*) and Hawaiian hoary bat (*Lasiurus cinerus semotus*). Designated critical habitat for the Blackburn's sphinx moth is in the vicinity of the project areas.

Biological effects of artificial light to animals may include altered behavior and physiological changes such as alterations in cortisol production and immune function. The following general measures, in addition to the species-specific measures detailed below, should be implemented island-wide to minimize impacts of outdoor lighting to threatened and endangered species:

- Install lights and use lighting only when and where necessary for human safety;
- use the lowest lumens necessary;
- Fully shield all outdoor lights so the bulb, lamp, and glowing lens can only be seen from below bulb height and ensure light does not spill horizontally into areas where it is not needed;
- Position lights as low to the ground as possible to reduce ambient lighting;

- Position light so they do not shine on water, where the reflected light may increase light pollution;
- Ensure that direct lighting is not visible from any ocean-side shoreline and limit overall ambient lighting along shorelines;
- All lighting changes should continue to fulfill all requirements outlined in the Maui County Outdoor Lighting Ordinance (Chapter 20.35; http://mauico-hi.elaws.us/code/coor_title20_ch20.35);
- Implement the use of automatic motion-sensor switches and controls on all lights or otherwise ensure all light fixtures are turned off when the lit area is not occupied by a vehicle or pedestrian.

***Hawaiian seabirds* (Hawaiian petrel, Newell's shearwater and band-rumped storm petrel)**
Hawaiian seabirds traverse the project areas at night during the breeding, nesting and fledging seasons (March 1 to December 15). Outdoor lighting, including fully-shielded LED lighting, is known to result in seabird disorientation, fallout, and injury or mortality. These night-flying seabirds are attracted to artificially lighted areas and after circling the lights they become exhausted and collide with nearby wires, buildings, or other structures or they may land on the ground. Downed seabirds are vulnerable to being struck by vehicles, starvation, and predation by dogs, cats, and other predators. Young birds (fledglings) traversing the project areas between September 15 and December 15, are the most vulnerable to light attraction.

***Sea turtles* (hawksbill sea turtle and green sea turtle)**
Green sea turtles may nest on any sandy beach area in the Pacific Islands. Hawksbill sea turtles exhibit a wide tolerance for nesting substrate (ranging from sandy beach to crushed coral) with nests typically placed under vegetation. Green sea turtle nests have been documented across multiple beaches across Maui, and the highest concentration of hawksbill nests is known to occur along the south shore beaches from Maalaea to Makena Beach. Both species exhibit strong nesting site fidelity. Nesting occurs on beaches from May through September, peaking in June and July, with hatchlings emerging through November and December.

Optimal sea turtle nesting habitat is a dark beach. Direct and ambient light pollution is known to disorient hatchlings or deter female turtles from nesting. Nesting turtles may be deterred from approaching or laying eggs on lighted beaches. Nesting females may become disoriented by artificial lighting, leading to exhaustion and placement of a nest in an inappropriate location (such as at or below the high tide line). Hatchlings that emerge from nests may be attracted onto also be disoriented by artificial lighting. Inland areas visible from the beach should be sufficiently dark to allow for successful navigation to the ocean.

In addition to the general measures outlined above, we recommend you implement the following measures to minimize impacts to sea turtles:

- Use only bulbs with wavelength of 560 nm or greater (such as LED light bulbs with red, orange, or amber colored diodes; low pressure sodium, red or orange internally phosphor-LED fluorescent tubes) in any areas that are near ocean-side shorelines or otherwise contribute to ambient lighting that can be seen from the shoreline;

- To further reduce light impacts to beaches, we recommend you replace lights on poles with low-profile, low-level lamps, and plant or improve vegetation buffers between the light source and the beach to screen light from the beach.

We recommend you include a comprehensive analysis of project risks to sea turtles in your biological assessment.

Blackburn's sphinx moth
The Blackburn's sphinx moth may be in the vicinity of the proposed project area. Adult moths feed on nectar from native plants, including beach morning glory (*Ipomoea pes-caprae*), iliee (*Plumbago zeylanica*), and maiapilo (*Capparis sandwichiana*); larvae feed upon non-native tree tobacco (*Nicotiana glauca*) and native aiea (*Nothocestrum* sp.). To pupate, the larvae burrow into the soil and can remain in a state of torpor for up to a year (or more) before emerging from the soil. Soil disturbance can result in death of the pupae.

If the project will involve the installation of new poles or any associated ground disturbance, we offer the following survey recommendations to assess whether the Blackburn's sphinx moth is within the project area:

- A biologist familiar with the species should survey areas of proposed activities for Blackburn's sphinx moth and its larval host plants prior to work initiation.
  - Surveys should be conducted during the wettest portion of the year (usually November-April or several weeks after a significant rain) and within 4-6 weeks prior to construction.
  - Surveys should include searches for eggs, larvae, and signs of larval feeding (chewed stems, frass, or leaf damage).
  - If moths or the native aiea or tree tobacco over 3 feet tall are found during the survey, please contact the Service for additional guidance to avoid take.

If no Blackburn's sphinx moth, aiea, or tree tobacco are found during surveys, it is imperative that measures be taken to avoid attraction of Blackburn's sphinx moth to the project location and prohibit tree tobacco from entering the site. Tree tobacco can grow greater than 3 feet tall in approximately 6 weeks. If it grows over 3 feet, the plants may become a host plant for Blackburn's sphinx moth. We therefore recommend that you:

- Remove any tree tobacco less than 3 feet tall.
- Monitor the site every 4-6 weeks for new tree tobacco growth before, during and after the proposed ground-disturbing activity.
  - Monitoring for tree tobacco can be completed by any staff, such as groundskeeper or regular maintenance crew, provided with picture placards of tree tobacco at different life stages.

Hawaiian hoary bat
The Hawaiian hoary bat roosts in both exotic and native woody vegetation across all islands and will leave young unattended in trees and shrubs when they forage. If trees or shrubs 15 feet or taller are cleared during the pupping season, there is a risk that young bats could inadvertently be harmed or killed since they are too young to fly or may not move away. Additionally, Hawaiian

hoary bats forage for insects from as low as 3 feet to higher than 500 feet above the ground and can become entangled in barbed wire used for fencing.

If the project will involve the installation of new poles or any associated ground disturbance, we recommend you incorporate the following applicable measures into your project description:

- Do not disturb, remove, or trim woody plants greater than 15 feet tall during the bat birthing and pup rearing season (June 1 through September 15).
- Do not use barbed wire for fencing.

Compliance with the Endangered Species Act

Although implementation of light minimization measures is known to significantly reduce the likelihood of impacts to endangered species, existing Maui County streetlights and facilities have previously resulted in documented take of listed seabirds and sea turtles. The ESA and Hawaii Revised Statutes (HRS) §195D prohibit the “take”, including “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect” of all endangered species. If take of endangered species cannot be fully avoided, we recommend Maui County would need to obtain an incidental take permit pursuant to 10(a)(1)(B) of the ESA. In addition, an incidental take license would be required from the State of Hawaii DLNR pursuant to HRS §195D. An application for incidental take permit requires the preparation of a Habitat Conservation Plan (HCP) outlining the measures you will implement to minimize and mitigate take of endangered species. The draft EA should include an analysis of existing streetlight impacts to endangered species on Maui, as well as an analysis of the likely change in impacts associated with project implementation. U.S. Fish and Wildlife Service and the Hawaii Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW) staff are available to provide additional technical assistance.

Thank you for participating with us in the protection of our endangered species. If you have any further questions, please contact John Vetter, Fish and Wildlife Biologist, 808-792-9400, e-mail: John_Vetter@fws.gov. Official correspondence relating to this project or future projects can be sent directly to pifwo_admin@fws.gov. When referring to this project, please include these reference numbers: ***01EPIF00-2019-SL-0468.***

Sincerely,

Michelle Bogardus
Island Team Manager
Maui Nui and Hawaii Islands

CC: Keith Swindle, Resident Agent in Charge, USFWS Office of Law Enforcement
David G. Smilth, DLNR-DOFAW Administrator
Scott Fretz, DLNR - DOFAW Maui Branch Manager

MICHAEL P. VICTORINO
Mayor

KARLA H. PETERS
Director

JOHN L. BUCK III
Deputy Director

RECEIVED
2019 SEP 19 PM 5:39
COUNTY OF MAUI
PUBLIC WORKS

183

DEPT. OF PUBLIC WORKS	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR							
DEPUTY DIR.							
FISCAL ANALYST							
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ______
By ______

DEPARTMENT OF PARKS AND RECREATION

700 Hali'a Nakoa Street, Unit 2, Wailuku, Hawaii 96793
Main Line (808) 270-7230 / Facsimile (808) 270-7942

September 19, 2019

Rowena Dagdag-Andaya, Director
Department of Public Works
200 South High Street, Room 434
Wailuku, HI 96793

Dear Ms. Dagdag-Andaya:

SUBJECT: Early Consultation Request for the Proposed Maui County Light Emitting Diode (LED) Streetlight Conversion Project; Maui County, Hawaii; DPW Project No.: 18-34

Thank you for the opportunity to review and comment on the subject project. The Department of Parks & Recreation is in support of the project, however, would like to request more information about the locations of the proposed streetlights included in the conversion project that are currently owned and maintained by Maui Electric Company and located within County park properties. In addition to the physical identification of affected streetlights out in the field, we would appreciate the inclusion of maps that identify the locations of the streetlights.

We would also like to recommend that within County park properties, the converted streetlights provide sufficient light to ensure public safety.

Please feel free to contact me or Cheryl Akiona, Acting Chief of Planning and Development, at cheryl.akiona@co.maui.hi.us or (808) 270-7388, should you have any questions.

Sincerely,

KARLA H. PETERS
Director of Parks & Recreation

c: Kaeo Ah Sau, Chief of Recreation
Chris Kinzle, Maintenance Superintendent
Cheryl Akiona, Acting Chief of Planning and Development

KHP:csa

Institute for Astronomy
Office of the Director

UNIVERSITY of HAWAIʻI
MĀNOA

RECEIVED
2019 SEP 27 PM 2:33
COUNTY OF MAUI
PUBLIC WORKS

RUSH 799

September 23, 2019

DEPT. OF PUBLIC WORKS

	INFO	ACTION	SEE ME	COMMENTS	COPY	SCAN	FILE
DIRECTOR							
DEPUTY DIR.							
FISCAL ANALYST							
PERSONNEL							
DSA							
ENGR.							
HWY.							
SECTY.							

Return to ________ Date ________
By: ________ Date ________

Via U.S. mail and email:

County of Maui Department of Public Works
200 South High Street, Room 434
Wailuku, HI 96793

Attention: Rowena Dagdag-Andaya, Director

Re: Early Environmental Consultation Review
Maui County LED Streetlight Conversion Project
DPW aProject No.: 18-34

Dear Ms. Dagdag-Andaya:

Thank you for the opportunity to comment on the proposed Maui County LED Streetlight conversion.

The University of Hawaiʻi Institute for Astronomy (IfA) conducts research in astronomy using telescopes located on Haleakalā and Maunakea and operated by IfA and our partner institutions. Both Haleakalā and Maunakea are among the best sites in the world for astronomical facilities because of their elevation, clear skies, favorable atmospheric conditions, and low levels of light pollution. Hawaiʻi-based observatories have played major roles in the advancement of astronomy and astrophysics for over 50 years and are well positioned to remain at the forefront of astronomical research for decades to come.

Because of the outstanding quality and productivity of these facilities, IfA is acutely concerned about negative impacts on astronomy from increased light pollution. Our work to combat light pollution has also brought us into contact with others concerned about light pollution for other reasons, including impacts on wildlife (particularly seabirds) and on human health.

With that background, we offer the following comments:

Conversion of high-pressure sodium lights to lights with a different spectral energy distribution can adversely affect observations on Haleakalā. In particular, use of lighting that has higher blue content than high-pressure sodium will result in increased sky background at the observatory, and negatively impact our observations. Observations presently being performed on Haleakalā include a major search for Near-Earth Objects with the Pan-STARRS telescopes. This search is acutely affected by increased sky background, and increasing the sky background will result in loss of discovery of potentially hazardous asteroids. Astronomy is acutely affected by increases in blue light because of Rayleigh scattering by nitrogen and oxygen molecules in Earth's atmosphere. This scattering occurs in a manner that is inversely proportional to the 4th power of the wavelength of the light. Shorter wavelength blue light is scattered much more readily than longer wavelength yellow, amber or red light.

For this reason, we urge the County to follow its own Street Lighting Standards (copy enclosed), and specifically follow section 15-201-6 (b)(iii) by selecting LEDs that have a blue light content less than the corresponding blue light content for HPS. By following this standard, we believe that negative impact on astronomy can be avoided. We note that similar protocols to this have been successfully implemented in the County of Hawai'i, and on the Island of La Palma in the Canary Islands.

We specifically note that 2700 K LEDs have higher blue content (15-21% depending on manufacturer) than high pressure sodium (10%). This makes them unsatisfactory.

We also note that the present lamps standards outlined in 15-201-6 (d) result in unnecessary over lighting, energy waste, and damage to the night sky at Haleakalā Observatory. Many streets in Maui County have been lit to higher levels than recommended by the Illuminating Engineering Society. For example, most residential roadways in the City and County of Honolulu were lit by 70 Watt high-pressure sodium lamps (before LED conversion), compared to 150 Watt high-pressure sodium being used in Maui County. As a result, approximately twice as much light (and energy) as is necessary/recommended is being used.

Therefore, we also recommend that the proposed streetlight conversion is properly engineered to use no more than the recommended amount of light. This will result in major energy/cost saving to the County, and result in decreased artificial sky brightness at Haleakalā Observatory. Including appropriate dimming (for later at night) in the streetlight conversion will result in further energy savings, and further reduce the impact of the streetlights on astronomy on Haleakalā.

Finally, we note that there is a strong need for further dialog with the University regarding light pollution on Maui, and a strong need for revision of the present lighting ordinance to properly address the impacts of changes in lighting technology including LED lighting.

Attached are two papers published in peer reviewed scientific journals that directly affect the choice of lighting for Maui County. Both papers strongly suggest that blue-deficient LED lighting should be selected.

Thank you for your consideration of these comments and attention to IfA's concerns. If you have questions or need further detail regarding these comments, please do not hesitate to contact the undersigned or Richard Wainscoat (rjw@hawaii.edu).

Very truly yours,

Robert McLaren
Interim Director

DEPARTMENT OF PUBLIC WORKS

COUNTY OF MAUI

Adoption of Chapter 201
Street Lighting Standards

SUMMARY

Chapter 201, entitled "Street Lighting Standards", is adopted.

TITLE MC-15

DEPARTMENT OF PUBLIC WORKS

SUBTITLE 02

STREET LIGHTING STANDARDS

CHAPTER 201

STREET LIGHTING STANDARDS

Subchapter 1 General Provisions

SUBCHAPTER 1

GENERAL PROVISIONS

§15-201-1 Title. The rules in this chapter shall be known as the "Street Lighting Standards". [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-2 Authority. The rules herein are established pursuant to sections 46-1.5(13) and 46-1.5(16) of the Hawaii Revised Statutes. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-3 Purpose. These rules provide standards for outdoor lighting that, while providing a level of safety for vehicular and pedestrian traffic, do not excessively interfere with nighttime viewing and avoid glare and light trespass onto private property. These rules also encourage the conservation of electricity. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-4 Construction. These rules should be read in conjunction with the provisions of Hawaii Revised Statutes, the revised charter of the County of Maui (1983), as amended, and the Maui County Code. In any conflict between the general provisions herein and any other provision, the more restrictive provision shall govern. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-5 Definitions. For the purpose of these rules, unless it is plainly evident from the context that a different meaning is intended, certain words and phrases used herein are defined as follows:

"Agricultural" means areas designated agricultural by the State land use commission and/or zoned agricultural via County ordinance.

"Blue light power content" means the International Dark Sky Association's (IDA) definition of blue light content or the sum of energy between 405-530nm divided by the sum of energy from 380-730nm times the total power output in watts. The blue light power content for HPS is 10w for 100w HPS bulb, 15w for a 150w HPS bulb, and 25w for a 250w HPS bulb.

"CCT" is correlated color temperature expressed in degree Kelvin (K).

"Director" means the director of the department of public works of the County of Maui, or a duly authorized designee.

"Fully shielded" means that the outdoor light fixture is constructed so that all of the light emitted by the fixture is projected below the horizontal plane of the lowest point of the fixture.

"Glare" means the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility.

"LED" means light emitting diode.

"Light trespass" is any form of artificial illumination emanating from a luminaire that penetrates other property other than its intended use.

"Luminaire" means the complete lighting assembly, less the support assembly.

"Partially shielded" means that the outdoor lighting fixture is constructed so that at least ninety percent of the light emitted by the fixture is projected below the horizontal place of the lowest point of the fixture.

"Rural" means areas designated rural by the State land use commission and/or zoned rural by County ordinance.

"S/P ratio" means the proportion of scotopic to photopic output.

"Urban" means areas designated urban by the State land use commission. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-6 <u>Lamp standards.</u> (a) High pressure sodium or LED lamps or other fixtures approved by the director shall be the only allowed lamp on public and/or private right-of-ways; however, existing lamps other than high pressure sodium or LED lamps shall remain until they expire at which time they shall be replaced.

(b) LED lamps shall meet the following requirements:

i) CCT of less than 3000k.

ii) S/P ratio <1.2.

iii) Blue light power content less than the corresponding blue light power content for HPS.

iv) Adaptive controls to allow for dimming.

(c) For roadways within the rural or agricultural areas, the maximum allowable wattage shall be 100W HPS (or equivalent LED wattage) for internal road intersections and 150W HPS (or equivalent LED wattage) for intersections from a project with a major and/or minor collector road.

(d) For roadways within the urban areas, the maximum allowable wattage shall be 150W HPS (or equivalent LED wattage) for internal road intersections and 250W HPS (or equivalent LED wattage) at intersections with a major or minor collector road. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-7 <u>Luminaire standards.</u> Fully shielded luminaires shall be the only allowed fixture on public and/or private right-of-ways. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-8 <u>Light standards (poles).</u> (a) Free standing aluminum light standards and aluminum arms shall continue to be stocked and used for existing lighting within major collector roadways.

(b) Any new subdivision or project that requires street lighting within public roadways, shall use light standards that are non-reflective, such as anodized bronze or any other light standard accepted by the director. Any unusual or project specific requests for non-standard lighting standards shall be reviewed and approved by the director after consultation with the utilities, the public works commission, and applicant.

(c) The maximum height of the light standard, measured from ground level directly below the luminaire to the bottom of the lamp itself, shall be twenty feet. Also, light standards are only required at intersecting streets. Any variation to this height standard will be reviewed and approved by the director after consultation with the public works commission.

(d) Any unusual or project specific requests for non-standard lighting standards shall be reviewed and approved by the director after consultation with the utilities, the public works commission, and applicant. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

§15-201-9 Installation, illumination, removal, and alteration guidelines. (a) The department may install, illuminate, remove, or alter street lights for:

(1) Locations where the nighttime accident rate exceeds those of the daylight hours.

(2) Intersections, urban or rural, taking into consideration the layout of the intersection, traffic volumes, location of the intersection, concentration of pedestrians, roadside interferences and that channelized intersections and the roadway width may require more lighting.

(3) Any significant change of the roadway alignment, long bridges, tunnels, or any structures that may be hazardous, such as curbs, piers, abutments, or culverts.

(4) Locations along the highway where police reports show crimes are committed, such as theft, rape, and bodily harm cases.

(5) Locations of a highway where traffic turning movements to and from roadside developments threaten public safety.

(6) Subdivision streets, provided that the street has been dedicated to the County and at least fifty percent of the lots on the street are occupied.

(b) Street lights not needed shall be removed. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16), MCC §12.17.030) (Imp: MCC §18.20.060)

§15-201-10 Severability. If any portion of the foregoing rules or the applicability thereof to any person, property or circumstance is held invalid for any reason, that invalidity shall not affect other provisions or applications which can be given effect without the invalid provision or application, and to this end these are declared to be severable. [Eff 3/23/00; am and comp 01/27/18] (Auth: HRS §§46-1.5(13), (16)) (Imp: MCC §18.20.060)

S:\CLERICAL\RULES\Public Works\2018-01-27 Chapter 201 Standard Version.docx

ADOPTED this 20th day of November, 2017, at Wailuku, Maui, Hawaii.

DEPARTMENT OF PUBLIC WORKS

DAVID C. GOODE
Director

~~ALAN M. ARAKAWA~~
~~Mayor, County of Maui~~ KEITH A. REGAN
ACTING MAYOR, COUNTY OF MAUI

Approved this 12th day of January, 2018.

APPROVED AS TO FORM
AND LEGALITY:

MICHAEL J. HOPPER
Deputy Corporation Counsel
County of Maui

Received this 17th day of January, 2018.

Danny A. Mateo

DANNY A. MATEO
County Clerk
County of Maui

<u>CERTIFICATION</u>

I, DAVID C. GOODE, Director, Department of Public Works, County of Maui, do hereby certify:

1. That the foregoing is a copy of the amendments to the Rules Pertaining to Street Lighting Standards for the County of Maui, drafted in Ramseyer format, pursuant to the requirements [to] <u>of</u> Section 91-4.1, Hawaii Revised [Statues,] <u>Statutes,</u> which were adopted on the <u>20th</u> day of <u>November</u>, 20<u>17</u>, following a public hearing on <u>November 20, 2017</u>, and filed with the Office of the County Clerk.

2. That the notice of public hearing on the foregoing amendments to the rules was published in The Maui News on the <u>19th</u> day of <u>October, 2017</u>.

DAVID C. GOODE, Director
Department of Public Works

2017-0955
2017-12-07 Amd to Title 15

Received: 15 December 2017 | Revised: 30 April 2018 | Accepted: 1 May 2018

DOI: 10.1002/jez.2184

RESEARCH ARTICLE

WILEY JEZ-A ECOLOGICAL AND INTEGRATIVE PHYSIOLOGY

Rapid assessment of lamp spectrum to quantify ecological effects of light at night

Travis Longcore[1] | Airam Rodríguez[2] | Blair Witherington[3] | Jay F. Penniman[4] | Lorna Herf[5] | Michael Herf[5]

[1]University of Southern California, Los Angeles, California

[2]Estación Biológica de Doñana CSIC, Sevilla, Spain

[3]Disney's Animals, Science and Environment, Lake Buena Vista, Florida

[4]Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Honolulu, Hawaii

[5]f.lux Software LLC, Los Angeles, California

Correspondence
Travis Longcore, University of Southern California, Watt Hall 204, Los Angeles, CA 90089, USA.
Email: longcore@usc.edu

Abstract

For many decades, the spectral composition of lighting was determined by the type of lamp, which also influenced potential effects of outdoor lights on species and ecosystems. Light-emitting diode (LED) lamps have dramatically increased the range of spectral profiles of light that is economically viable for outdoor lighting. Because of the array of choices, it is necessary to develop methods to predict the effects of different spectral profiles without conducting field studies, especially because older lighting systems are being replaced rapidly. We describe an approach to predict responses of exemplar organisms and groups to lamps of different spectral output by calculating an index based on action spectra from behavioral or visual characteristics of organisms and lamp spectral irradiance. We calculate relative response indices for a range of lamp types and light sources and develop an index that identifies lamps that minimize predicted effects as measured by ecological, physiological, and astronomical indices. Using these assessment metrics, filtered yellow-green and amber LEDs are predicted to have lower effects on wildlife than high pressure sodium lamps, while blue-rich lighting (e.g., K ≥ 2200) would have greater effects. The approach can be updated with new information about behavioral or visual responses of organisms and used to test new lighting products based on spectrum. Together with control of intensity, direction, and duration, the approach can be used to predict and then minimize the adverse effects of lighting and can be tailored to individual species or taxonomic groups.

KEYWORDS
action spectrum, behavioral response, light pollution, phototaxis

1 | INTRODUCTION

It has long been known that artificial night lighting affects wildlife through attraction and disorientation (Allen, 1880), and recent research has documented the extent of the adverse consequences of artificial night lighting to include, for example, plant phenology (Somers-Yeates et al., 2016), predator–prey relations (Minnaar, Boyles, Minnaar, Sole, & McKechnie, 2015), circadian rhythms (Dominoni, 2015), and nocturnal rest and recovery (Gaston, Bennie, Davies, & Hopkins, 2013). Importantly, light attraction and disorientation results in direct mortality of many groups of insects (Eisenbeis & Hänel, 2009), birds (Longcore et al., 2012), including seabirds (Rodríguez et al., 2017b), and sea turtles (Salmon, 2003), contributing to species decline (Fox, 2013; Wilson et al., 2018). The degree of influence of outdoor electric lighting is determined by the direction, intensity, duration, and spectrum of the lights (Gaston, Davies, Bennie, & Hopkins, 2012; Longcore and Rich, 2017). For many years, only a handful of lamp types were economically viable for widespread deployment and their spectral characteristics were limited. For example, low pressure sodium lamps, with nearly all emissions in the yellow/orange at 589 nm became the lamp of choice around astronomical observation sites and near sea turtle nesting beaches because both night sky observation and sea turtle orientation benefit from a narrow-band light in the longer wavelengths (Witherington, 1992). Other lamps were similarly deployed in different situations and consequently most studies of ecological effects are on these types—low-pressure sodium, high-pressure sodium, metal halide, and mercury vapor (although this lamp type has largely been phased out) (Eisenbeis & Eick, 2011; Rich and Longcore, 2006). In the past decade, however, light-emitting diode (LED) lamps have become economically viable, bringing a range of new spectral characteristics to the marketplace (Boyce, Fotios, & Richards, 2009; Gaston, 2013) along with concerns about their differential effects on wildlife species (Davies, Bennie, Inger, de Ibarra, & Gaston, 2013; Gaston, 2013).

In the early days of commercial LEDs for outdoor lighting, full spectrum light was achieved through coating a blue LED with a phosphor, which produced light across the visual spectrum (Hecht, 2012). These lamps had a high correlated color temperature (CCT), indicating a high proportion of blue and violet in the emissions, as a result of the underlying blue LED. This blue hue became more dramatic as the phosphor aged. Many in the general public and scientific community may have developed the perception that all light from LEDs was a "cool" white (high CCT) at this time. Technological innovation in the LED industry has, however, been rapid, because the energy savings from LEDs are so attractive that replacement lamp types that address a range of color spectrum specifications have been developed (Dudley, Erkintalo, & Genty, 2015). While earlier efforts to develop LEDs with lower color temperatures came with a penalty of less efficiency, by 2015, LEDs at 2700 K and 3000 K were commercially available that matched the energy efficiency of 5000 K lamps. Furthermore, the development of different colors of LEDs and different filtering technologies has led to a range of different spectral signatures for lamps that are all economically competitive in terms of energy efficiency.

Conservation scientists need to keep up with the changing array of outdoor lighting options to provide guidance to officials and managers around the world who are faced with the obvious economic choice of switching to high-efficiency lighting such as LEDs (Hecht, 2016). Such a switch can be catastrophic for the effects on other species, or it can be a benefit, depending on the spectrum, duration, direction, and intensity of the new lamps (Gaston et al., 2012; Longcore et al., 2015; Rodríguez, Dann, & Chiaradia, 2017a). The same applies to sky glow (Kinzey et al., 2017). Some ecologists have voiced generic concerns about LEDs in general, questioning whether they pose a risk across the board (Pawson and Bader, 2014; Stone, Jones, & Harris, 2012), and noting the unfortunate "rebound effect" in which more efficient lighting leads to deployment of even more light (Kyba et al., 2017; Kyba, Hänel, & Hölker, 2014). Similar concerns about the adverse effects of the rapid spread of full spectrum LED lighting are voiced by dark sky advocates (Bierman, 2012). The spectrum of light used will greatly affect the amount of scattering of light at different distances from a source (Kinzey et al., 2017). The extent of these effects depends in part on the spectral characteristics of the LEDs used, and many opportunities are available to evaluate the performance of the wide array of LED spectral configurations, such as investigating multiple spectral configurations of 2700 K LEDs to reduce attraction of flying insects (Longcore et al., 2015) or comparing LEDs of different color temperatures (Eisenbeis & Eick, 2011).

Differences between the spectral response curve for human vision (both photopic and scotopic) and the visual sensitivity and measured behavioral responses of animals indicate an opportunity to configure outdoor lighting that avoids sensitive regions of the spectrum while providing needed visibility for humans. For example, many insects are attracted to shorter wavelengths (blue, violet, and ultraviolet) more than longer wavelengths (Eisenbeis, 2006; Eisenbeis & Hänel, 2009). Light sources that have low blue and shorter wavelength emissions attract fewer insects (Cleve, 1964; Eisenbeis & Eick, 2011; Eisenbeis & Hänel, 2009; Menzel & Greggers, 1985) and consequently, fewer bats that forage on insects (Stone, Harris, & Jones, 2015). The lower behavioral response of hatching sea turtles to longer wavelengths of light (Witherington, 1992) has become the basis to limit the permissible spectral characteristics of lights on and near nesting beaches in many jurisdictions. Such regulations to minimize adverse effects of lighting on nature are always compromises and usually driven by the species or species group with regulatory protection in a particular situation.

The current challenge for conservationists is that assessing the effects of different spectral distributions on wildlife in experimental or field situations is time consuming and an increasing number of lamp types are being developed, while jurisdictions are making decisions about replacement of aging fixtures every day (Hecht, 2016). Once such decisions are made, new lamps will be in place for years to come. Tools are therefore needed to assess the potential adverse effects of newly developed lights compared with existing technologies in a rapid manner and in a way that allows tradeoffs between adverse effects on wildlife and human needs to be compared. In this paper, we assemble a series of spectral response curves from the literature and a series of spectral emission curves for established and new outdoor lighting sources, develop a standardized index that weights the spectral output by the response curves, provide a matrix of lighting performance measures (e.g., color rendering index, correlated color temperature, Star Light Index), and present these results on a website that can be periodically updated to serve as a clearinghouse for this information.

2 | METHODS

We obtained spectral power distribution curves for a wide range of lamp types and calculated indices representing the degree of overlap with a series of spectral response curves for different organisms. Following recommendations of the Bureau International des Poids et Mesures (BIPM), action spectra are dimensionless, while spectral irradiance is measured in $\mu W \cdot cm^{-2} \cdot nm^{-1}$, from which we calculate the weighted sum across wavelengths (BIPM, 2006, Appendix 3, Section 2). We treat spectral response curves like action spectra even if they do not meet the high standards for a true action spectrum (Björn, 2015). Species response curves were converted from photons to spectral power ($\mu W \cdot cm^{-2} \cdot nm^{-1}$) because organismal responses are dependent on the number of photons, not the energy of the light (Johnsen, 2012) while light is frequently measured with power units.

Spectral power distributions were obtained in $\mu W \cdot cm^{-2} \cdot nm^{-1}$ and resampled to 1 nm increments from 350 nm (well in the ultraviolet, which is still the visual spectrum for some insects) (Menzel & Greggers, 1985) through 780 nm to encompass the full range of vision for organisms. Spectral response curves were normalized to 1 at the maximal value, and multiplied by the emissions at each wavelength and then summed over all wavelengths, yielding three metrics.

1. A standard "effective irradiance" metric, computed by multiplying spectral irradiance at each wavelength by the spectral response ("actinic power"). (BIPM, 2006, Appendix 3 and CIE, 2007)

$$E_{eff} = \int E_\lambda S_i(\lambda)\, d\lambda,$$

where E_λ represents the source spectral irradiance and S_i is the actinic spectrum.

2. The actinic power per lux (the human photopic response, $V(\lambda)$):

$$E_{lux} = \frac{\int E_\lambda S_i(\lambda)\, d\lambda}{\int E_\lambda V(\lambda)\, d\lambda}.$$

The resulting measurement is thereby standardized in terms of the effect on each species per lux produced by the lamp and can be referred to as the taxonomic (e.g., turtle, salmon) action factor of the light source (CIE, 2014).

3. To allow comparison across species, we scaled the action factor relative to the response that would be elicited by daylight.

$$a_{D65} = \frac{E_{lux}(E)}{E_{lux}(D65)}.$$

The resulting values indicate the increase of effects on species relative to sunlight for each additional lux. A metric indexed to daylight allows actinic response metrics to be compared across species, even when the "shape" of the action spectra varies.

This approach allows comparison across lamp types and for different intensities by isolating the effect of spectrum. These methods follow the overall approach of Aubé, Roby, and Kocifaj (2013) and the recommendations of the BIPM (2006) and CIE (2014).

We used measured spectral distributions for mercury vapor, metal halide, high pressure sodium, low pressure sodium, incandescent, phosphor-coated amber LED, and 3000 K LED from Elvidge, Keith, Tuttle, and Baugh (2010). We also obtained spectral power distributions for three filtered LED systems (warm white LED with integrated filter) from C&W Energy Solutions, a filtered LED from LED Living Technology (LLT) and three lamps used in an experiment with attraction of shearwaters to light (Rodríguez et al., 2017a; Table 1; Figure 1).

For the species responses, we used spectral response curves developed for a range of organisms, including insects, sea turtles, and birds (Table 2). Some response curves represent behavioral responses to light of different wavelengths (e.g., moths and hatchling sea turtles) while others represent the visual sensitivity of the eyes of the organisms or physiological response (photosynthesis). For visual sensitivity curves, we used $\log_{10}$ transformed values, which were then normalized, because perceptual responses to visual cues are widely seen to be on a log scale as suggested by Stevens' power law (Stevens, 1961) and its application to sensory phenomena in insects (Ruchty, Roces, & Kleineidam, 2010).

To evaluate the potential effect of each lamp on night sky pollution, we calculated the Star Light Index proposed by Aubé et al. (2013) using the spreadsheet provided as an electronic supplement, which tracks human scotopic vision. We also calculated indices to evaluate the effect of spectrum on Rayleigh scattering, which would be prevalent near cities, and Mie scattering, which would predominate in indirect skyglow >80 km from city centers (Aubé, 2015; Luginbuhl, Boley, & Davis, 2014; see Figure 2).

Finally, we calculated photometric indices for each light source that are important to lighting engineers and end users. These include the correlated color temperature (CCT), color rendering index (CRI), and M/P ratio (melanopic/photopic ratio), using the spreadsheet from Lucas et al. (2014).

TABLE 1 Lamps and spectral output curves included in study, by type, correlated color temperature (CCT), and color rendering index (CRI)

Lamp/Standard	Type	CCT	CRI
D65 (Daylight)	Natural	6504	100
CIE Illuminant A	Lighting Standard	2856	100
Kerosene Oil	Combustion	1913	99
Full moon	Natural	4134	98
Philips TL950	Fluorescent	4684	96
SORAA Vivid	LED	4965	93
CFL Greenlite 13 W	Fluorescent	2892	81
Philips AmbientLED	LED	2601	81
LLT Telescope Light	Filtered LED	1908	81
3000K LED	LED	3262	80
OCTRON 32 W	Fluorescent	4012	79
Metal Halide 70W	Metal Halide	3071	79
LSG Good Night 2016	LED	2266	76
LEDway Streetlight CW 54W	LED	6270	75
City of Los Angeles Streetlight	LED	4310	73
LED VBLFL-855-4-40	LED	4663	70
Cosmopolis 60W	Metal Halide	2879	66
Yard Blaster	LED	4164	64
PC Amber Cree	PC Amber LED	1717	59
AEL 75W	PC Amber LED	1743	58
CWES 74 WW CW7	Filtered LED	2448	54
Iwasaki 60W	Mercury Vapor	3757	53
MH MASTER HPI-T Plus 400W/645 E40 1SL	Metal Halide	3808	51
CWES 74 WW CW10	Filtered LED	2096	49
CWES Anna's Light	Filtered LED	1193	26
HPS SON-T 400W/220 E40 1SL	High Pressure Sodium	1947	18
150 W HPS	High Pressure Sodium	2059	17
18 W LPS	Low Pressure Sodium	1810	−44

We then calculated the ratio of the actinic power of each lamp per lux of output compared to a D65 standard. This measurement compares the effect on each species response or light pollution metric of an additional lux of each lamp type, compared with an additional lux of daylight (the D65 standard). We also calculated ratio of the actinic power of each lamp compared with the total power of the lamp. This measurement indicates how much of the energy output of the lamp will affect each species or light pollution metric.

To illustrate the tradeoffs between minimizing effects on different groups of wildlife and optimizing performance for outdoor lighting, we calculated mean values for each lamp, consisting of: 1) animal response by taxonomic group (insect mean, sea turtle mean, Newell's

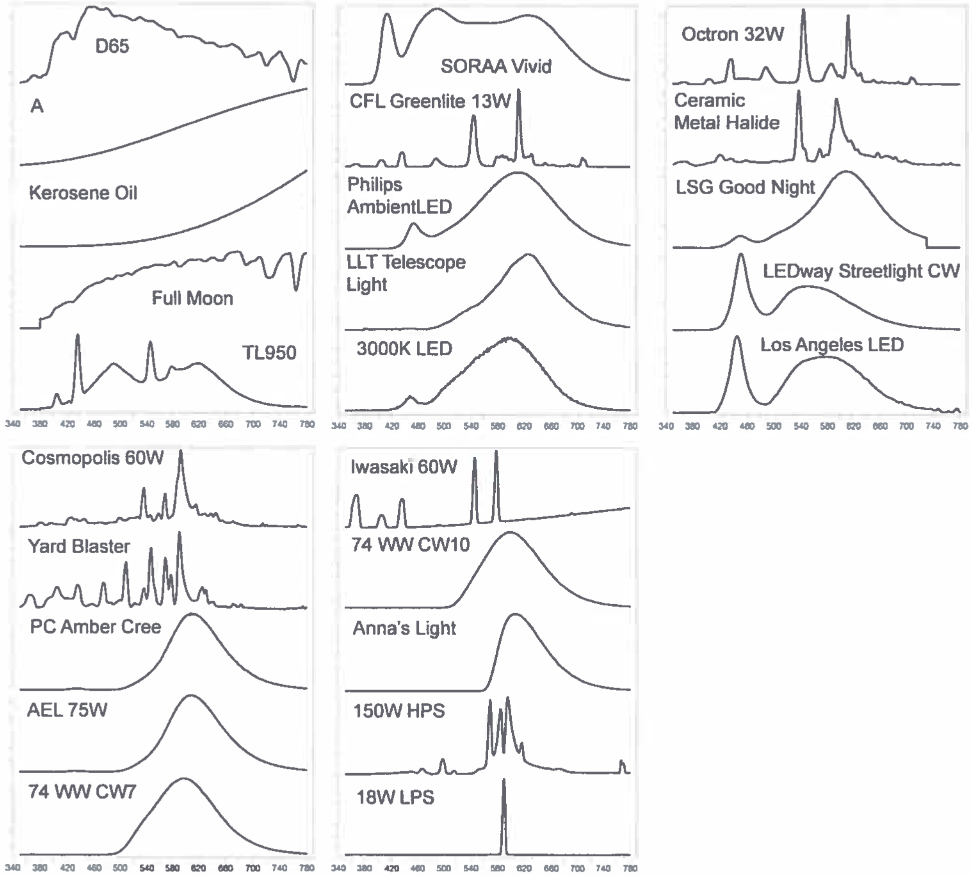


FIGURE 1 Spectral power distributions of light sources investigated. The five panels are in order of decreasing CRI from top left to lower middle

TABLE 2 Organismal response spectra

Taxon	Response	Format	Notes and Source
Moths (Lepidoptera)	Behavioral	Digitized by CIE	(Cleve, 1964)
Bee (Hymenoptera)	Behavioral	Digitized by CIE	(Menzel & Greggers, 1985)
Insects (Class Insecta)	Behavioral	Modeled	Composite metric for all Insecta (Donners et al., 2018)
Green turtle hatchlings (*Chelonia mydas*)	Behavioral	Digitized	(Witherington, 1992)
Green turtle adults (*Chelonia mydas*)	Visual sensitivity	Digitized	(Midolo, 2011) See also (Levenson, Eckert, Cognale, Deegan, & Jacobs, 2004)
Loggerhead hatchlings (*Caretta caretta*)	Behavioral	Digitized	(Witherington, 1992)
Juvenile Atlantic salmon (*Salmo salar*)	Visual sensitivity	Digitized	(Hawryshyn, Ramsden, Betke, & Sabbah, 2010)
Newell's shearwater (*Puffinus newelli*)	Visual sensitivity	Digitized	(Reed, 1986)
Photosynthesis (Plantae)	Physiological	Digital	(DIN, 2016)

shearwater, juvenile salmon, or the mean of all four), 2) Star Light Index, 3) melatonin suppression, and 4) visual performance. For visual performance, we assumed that CRI greater than 75 was acceptable and assigned values as follows:

$$\text{If}\begin{pmatrix} \text{CRI} > 75 \Rightarrow 1 \\ \text{else} \quad \Rightarrow \quad 1 - \dfrac{(75 - \text{CRI})}{150} \end{pmatrix}.$$

This approach is necessary to account for the −44 CRI of low pressure sodium lamps so that all values of the index range 0–1. We calculated which lamps performed best as an average of the four categories, running the average once for each of the organismal responses (to match a scenario where that species or species group was most important) and for all organismal responses with a weight of 1 for each of the major taxonomic groups. For comparison with a ranking that considers only environmental factors, we

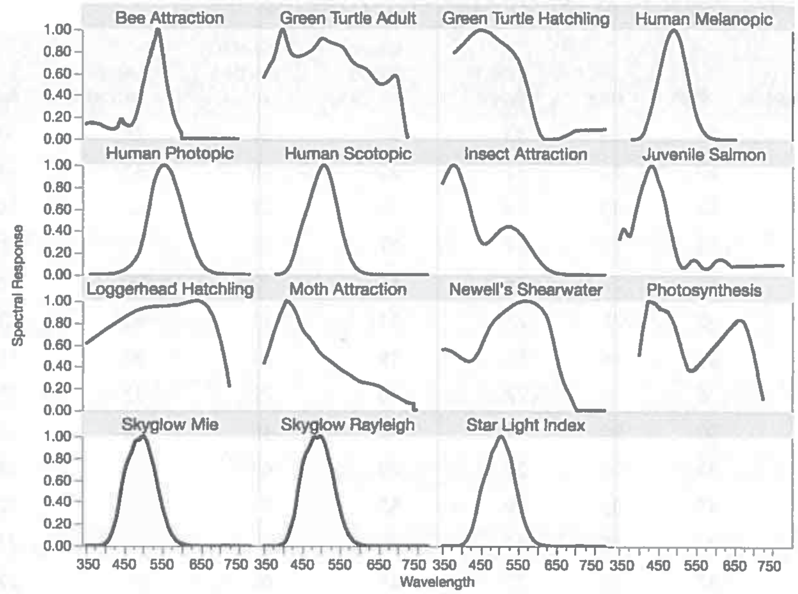


FIGURE 2 Response curves that can be used to estimate influence of light sources [Color figure can be viewed at wileyonlinelibrary.com]

calculated performance for each lamp in the same manner but without incorporating CRI.

To test this approach with experimental data, we compared the results of the light hazard for shearwaters in an experiment comparing light attraction of short-tailed shearwaters for metal halide, high pressure sodium, and 4536 K LED lamps (Rodríguez et al., 2017a). We modeled relative attraction using the same approach of generalized linear mixed models with night as a random factor and actinic power, lamp type, brightness, and CCT each in separate models as an independent factor. We compared models using Akaike's Information Criterion and visualized the fit using scatterplots. Pearson Product-Moment Correlation between responses and photometric indices, and all other statistics were calculated using JMP Pro 13 (SAS, Inc., Cary, NC).

All of the calculations and visualization of the intersection of light spectrum and human and animal response curves can be viewed at a website (https://github.com/herf/ecological) that will be updated with new lamp spectra and response curves and will allow users to submit spectra for analysis.

3 | RESULTS

Actinic power as a percent of total power describes the amount of energy from each lamp spectrum that affects the various species and photometric indices. For some lamps this proportion is relatively high for most action spectra, and for some species responses the proportion is high for most lamps (Table 3). For example, a high proportion of the power from all lamp types is calculated to influence loggerhead hatchlings, while few lamps concentrate their power in the areas of the spectrum most attractive to juvenile salmon (Table 3).

Actinic power per lux compared with daylight calculates the effect on species of increasing or decreasing illumination (in lux). For example, each additional lux of light from a low pressure sodium lamp has 20% of the effect on moths as would an additional lux of daylight, while an additional lux of a mercury vapor lamp would have 72% of the effect of an additional lux of daylight (Table 4).

The tested lamp types ranged in CRI from −44 (low pressure sodium) to 99, and CCT from 1193 (Anna's light) to 6270 (LEDway Streetlight). CCT and CRI were significantly but not strongly correlated (95% CI = 0.10–0.73). The variation in relative actinic power for lamps varied most for juvenile salmon (range, 0.15–1), substantially for insects (range, 0.33–1.16) and sea turtles (range, 0.38–1.02), and least for Newell's shearwaters (range, 0.65–1). For three of the four species groups tested, narrow band lamps with restricted emissions in the shorter wavelengths had the lowest actinic power relative to daylight. Only for Newell's shearwater did one narrow spectrum lamp (CWES Anna's Light) score higher than full spectrum lamps (Figure 3).

Composite assessments that gave equal weight to a wildlife group response, melatonin suppression, and Star Light Index showed lowest effects for lamps with low emissions in the shorter wavelengths (Figure 4a), with low pressure sodium showing the lowest impacts. When CRI was included as a factor, low pressure sodium lamp did not perform as well (Figure 4b), despite low actinic power for wildlife, because of its low CRI. Instead, PC Amber and two filtered LEDs scored lowest overall.

Correlations between photometric values for lamps and resulting light pollution effects were positive and strongest for CCT and both melanopic effect and Star Light Index, positive but weak for CRI and other metrics and modestly strong and positive for CCT and equally weighted wildlife effects (Table 5). Most importantly to our approach, although CCT has a high correlation with the aggregate wildlife effects (95% CI = 0.57–0.90), the correlation between CRI and wildlife effects is lower (95% CI = 0.43–0.86). The same is true for nearly all of the individual responses; CCT predicts wildlife effects more than CRI, with higher CCT values more likely to have higher effects on the wildlife assessed in this study than higher CRI values.

TABLE 3 Actinic power as a percent of total power for each of the taxonomic-specific responses

Light source	Photosynthesis	Moth	Bee	Insect index	Green turtle behavior	Green turtle visual	Loggerhead behavior	Salmon	Shearwater
D65	56	43	22	30	50	66	78	30	60
A	44	22	12	11	23	45	62	14	41
Kerosene Oil	34	13	4.9	4.6	12	31	47	10	25
Full moon	53	31	19	19	37	57	74	20	54
TL950	65	42	27	26	52	72	90	26	75
SORAA Vivid	65	43	25	27	51	71	88	27	70
LLT Telescope Light	61	26	14	13	19	61	90	11	69
CFL Greenlite 13 W	58	38	30	27	40	72	91	22	81
Philips AmbientLED	61	30	20	17	31	65	90	15	72
3000K LED	57	35	25	24	39	67	87	18	73
OCTRON 32 W	62	43	32	29	52	74	91	28	81
Metal Halide 70W	56	37	25	27	39	68	87	22	73
Ceramic Metal Halide 70 W	56	37	25	27	39	68	87	22	73
LSG Good Night 2016	62	30	18	17	27	66	93	13	75
LEDway Streetlight CW 54W	65	45	32	28	61	75	91	31	79
Los Angeles LED	64	41	29	26	51	72	91	27	77
Cosmopolis 60W	58	38	24	27	41	70	90	21	79
Yard Blaster	56	47	28	37	53	75	87	29	76
PC Amber Cree	61	25	12	13	17	61	92	11	73
AEL 75W	61	25	12	13	17	61	91	10	72
CWES 74 WW CW7	58	28	23	18	27	66	93	10	80
Iwasaki 60W	41	30	17	24	29	51	65	20	48
CWES 74 WW CW10	59	27	18	16	22	64	93	10	78
CWES Anna's Light	64	23	3.8	8.7	8.4	59	92	10	71
150 W HPS	57	30	15	19	29	65	89	14	82
LPS 18 W	55	28	13	20	25	68	95	8.7	97

The reanalysis of shearwater grounding data shows that actinic power per lux provides at least an equally valid model (AICc 546.83, effect 95% CI 3.69–61.84) as a categorical analysis with lamp type (AICc 547.59, LED effect 95% CI −1.07 to 0.45, MH 95% CI 0.20–1.72) (Figure 5). The model for CCT had a higher AICc (549.13) with an effect 95% CI intersecting 0, while the model for brightness had a still higher AICc (551.44) and a 95% CI for effect also intersecting 0.

4 | DISCUSSION

Our effort extends the approach presented by Aubé et al. (2013) to develop a method to calculate indices for any organismal response to lighting spectrum assuming equal visual light intensity to humans. These calculations can be easily repeated and updated with additional organismal response curves or with additional lighting products. We included the ultraviolet part of the spectrum because many other light sources do include ultraviolet and it is important for animal responses, although it is not a significant issue for most LEDs used for outdoor lighting.

The approach described here establishes appropriate units for measuring ecological responses to light that are consistent with international standards and thereby provides a basis for comparison that is replicable and testable. Quantification of actinic power can be used to develop hypotheses to test in the field, such as the comparison of lamp types undertaken by Rodríguez et al. (2017a) that we revisited. Furthermore, it allows the rapid and easily updatable comparison of new lamp types so that the most promising spectral configurations for a particular situation can be identified and tested in the field.

Our approach is, however, only as accurate as the action spectra and as applicable as the number of different species groups for which action spectra are available. These response curves are scatted in the literature and although many physiological response curves could be calculated from, for example, peak opsin sensitivities (Davies et al., 2013), behavioral response curves derived from field and laboratory tests are more rare. In at least one instance (loggerhead sea turtle hatchlings) there may be behavioral response differences between

TABLE 4 Actinic power per lux of each lamp type, compared with a lux of daylight (D65)

Light source	Photosynthesis	Moth	Bee	Insect index	Green turtle behavior	Green turtle visual	Loggerhead behavior	Salmon	Shearwater
D65	1	1	1	1	1	1	1	1	1
A	1	0.639	0.681	0.482	0.588	0.865	1.010	0.587	0.867
Kerosene Oil	1.360	0.673	0.494	0.340	0.558	1.050	1.340	0.754	0.924
Full moon	0.922	0.704	0.821	0.597	0.72	0.841	0.917	0.642	0.874
TL950	0.827	0.691	0.858	0.611	0.736	0.774	0.815	0.618	0.876
SORAA Vivid	0.927	0.793	0.891	0.711	0.822	0.860	0.894	0.720	0.920
LLT Telescope Light	0.772	0.425	0.458	0.306	0.275	0.660	0.818	0.259	0.812
CFL Greenlite 13 W	0.573	0.487	0.746	0.490	0.445	0.606	0.648	0.410	0.748
Philips AmbientLED	0.716	0.464	0.593	0.375	0.408	0.648	0.756	0.33	0.785
3000K LED	0.647	0.522	0.714	0.515	0.497	0.655	0.714	0.392	0.778
OCTRON 32 W	0.632	0.573	0.847	0.556	0.599	0.648	0.670	0.534	0.773
Metal Halide 70W	0.656	0.568	0.732	0.576	0.512	0.673	0.723	0.481	0.788
Ceramic Metal Halide 70 W	0.656	0.568	0.732	0.576	0.512	0.673	0.723	0.481	0.788
LSG Good Night 2016	0.696	0.431	0.526	0.343	0.343	0.625	0.743	0.284	0.779
LEDway Streetlight CW 54W	0.715	0.645	0.900	0.574	0.748	0.697	0.713	0.629	0.800
Los Angeles LED	0.688	0.579	0.782	0.510	0.614	0.657	0.700	0.545	0.771
Cosmopolis 60W	0.603	0.519	0.644	0.518	0.485	0.622	0.668	0.415	0.764
Yard Blaster	0.646	0.701	0.821	0.783	0.686	0.729	0.717	0.624	0.816
PC Amber Cree	0.718	0.387	0.361	0.273	0.223	0.613	0.768	0.232	0.792
AEL 75W	0.711	0.383	0.366	0.274	0.225	0.609	0.762	0.229	0.785
CWES 74 WW CW7	0.542	0.342	0.539	0.309	0.283	0.530	0.624	0.178	0.695
Iwasaki 60W	0.771	0.731	0.806	0.822	0.613	0.817	0.869	0.715	0.827
CWES 74 WW CW10	0.581	0.342	0.446	0.285	0.246	0.540	0.653	0.186	0.715
CWES Anna's Light	0.876	0.414	0.131	0.221	0.129	0.681	0.898	0.266	0.898
150 W HPS	0.529	0.368	0.365	0.335	0.307	0.517	0.593	0.243	0.705
LPS 18 W	0.375	0.254	0.221	0.254	0.193	0.393	0.462	0.112	0.615

populations of the same species (Fritsches, 2012), meaning that caution should be used in universally applying action spectra. The emergence of highly configurable outdoor lighting demonstrates the need for research to produce more action spectra and to compile them in a repository. This is a central research need from experimental zoologists to provide the information necessary for lighting designers and especially regulators to act quickly in response to new lighting technologies. Peak opsin sensitivity provides a first pass on behavioral responses, and indeed, behavioral response curves can be calibrated from opsin response curves (Donners et al., 2018). Workers in the field and with captive animals should, however, prioritize research to obtain behavioral response information for sensitive species and to test the generalizable patterns in responses within clades where visual systems are conserved.

We are aware of the limitations of using spectral information that may only be applicable within a certain range of intensity values. Some species respond to spectrum differently depending on its intensity (Wiltschko, Stapput, Thalau, & Wiltschko, 2010). Also, mitigation schemes that depend on spectrum can be undermined by brightness. Any approach to reduce ecological effects of lights must keep intensity to a minimum and can then perhaps further reduce adverse effects through tuning of the spectrum used.

We also note that the influence of lamps of different spectra will be affected by atmospheric conditions that influence the amount and nature of reflection and scattering of light (Aubé, Kocifaj, Zamorano, Lamphar, & de Miguel, 2016; Kyba, Ruhtz, Fischer, & Hölker, 2011). Our wildlife response assessments do not include any shifts in spectral distribution of light that would result from scattering in the atmosphere and therefore are most relevant to situations where direct effects are being evaluated (e.g., local attraction and disorientation). Additional calculations could be added to our approach to address different propagation patterns of light under varying weather conditions.

Our use of CRI as a metric for performance of lamps for human vision should not be taken as a blanket endorsement of CRI as an excellent metric, which it is not (Galadí-Enríquez, 2018). It is, however, widely understood and used in the lighting design community and therefore provides a means to incorporate human design preferences into a composite metric of lighting performance. Furthermore,

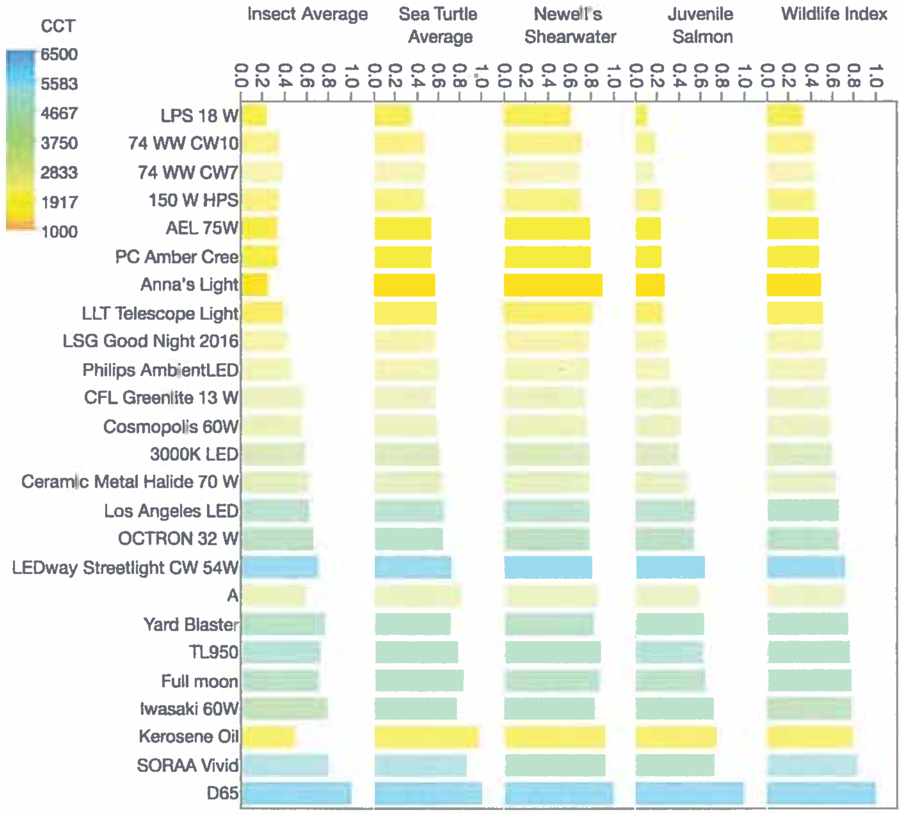


FIGURE 3 Relative modeled impact on insects, sea turtles, shearwaters, and juvenile salmon per additional lux from different light spectra compared with a D65 (6500 K) standard. Colors indicate CCT from low (orange) to high (blue) [Color figure can be viewed at wileyonlinelibrary.com]

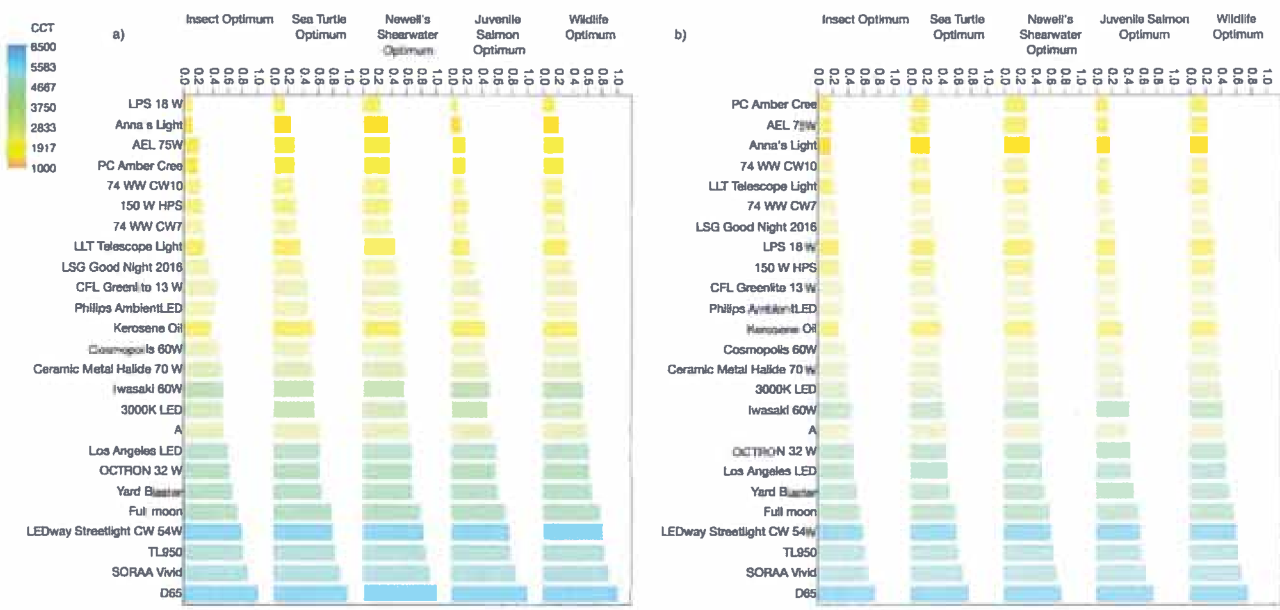


FIGURE 4 Nighttime light performance index balancing Star Light Index, melatonin suppression, and a wildlife impact score (a) and incorporating CRI (b) for equal lux from different light spectra compared with a D65 (6500K) standard. Lower values indicate lower predicted impacts and greater CRI. Colors indicate CCT from low (orange) to high (blue) [Color figure can be viewed at wileyonlinelibrary.com]

this approach can be updated to use other metrics as desired by an end user.

As a conservation tool, our assessments assume that it is a valuable approach to minimize the intersection between the wavelengths that affect sensitive wildlife species and the output of lamps and that it is worthwhile to balance those adverse effects against desirable characteristics of outdoor lighting for human use. Lamps that perform well in this assessment would represent a conservation compromise—no light on a sea turtle nesting beach, on a penguin colony, or on the route a fledgling seabird takes to the sea would be optimal, but if there is

TABLE 5 Pearson's product moment correlation between CCT, CRI, Star Light index, Melanopic response, and average wildlife response. Above diagonal, correlation estimates. Below diagonal, 95% confidence intervals

	CCT	CRI	Star light index	Melanopic	Wildlife
CCT	–	0.48	0.94	0.94	0.78
CRI	0.10–0.73	–	0.64	0.67	0.71
Star Light Index	0.87–0.97	0.40–0.84	–	1.00	0.85
Melanopic	0.87–0.97	0.33–0.83	0.99–1.00	–	0.85
Wildlife	0.57–0.90	0.43–0.86	0.69–0.93	0.69–0.93	–

to be a light nearby, minimizing the wavelengths in the part of the spectrum to which turtles or seabirds are most sensitive is preferable (Rodríguez et al., 2017b, 2018), so long as intensity is also minimized. Such hierarchical minimizing approaches might ignore other more complete solutions such as embedded roadway lighting, which provides guidance to drivers and virtually no light on nearby beaches (Bertolotti & Salmon, 2005), but they do provide guidance for reducing adverse effects from existing lighting infrastructure, which will be replaced with full-spectrum lights in the absence of guidance from ecologists and consideration of wildlife responses.

Given the rapid pace of replacement of street and other outdoor lighting motivated by energy savings (Hecht, 2016), an approach to minimize the adverse effects of lighting through choice of spectrum that is endorsed by conservation scientists is desperately needed. Laws available to reduce the ecological effects from light pollution that are in place around the world are focused predominantly on the direction and intensity of lighting; very few legislators saw the dramatic change in color on the technological horizon. Those jurisdictions that have taken steps to use energy efficient lighting with a spectrum designed to minimize adverse environmental effects have been motivated mostly by particular species protection laws (e.g., the Endangered Species Act in the United States) and by the economic considerations associated with astronomical observatories.

The State of Florida requires that new coastal construction limit lighting near beaches to sources that emit wavelengths only greater than 560 nm to protect sea turtles. Our calculations suggest that several of the filtered LEDs that we assessed would be less attractive to hatchling sea turtles than existing HPS lamps, but none of the filtered

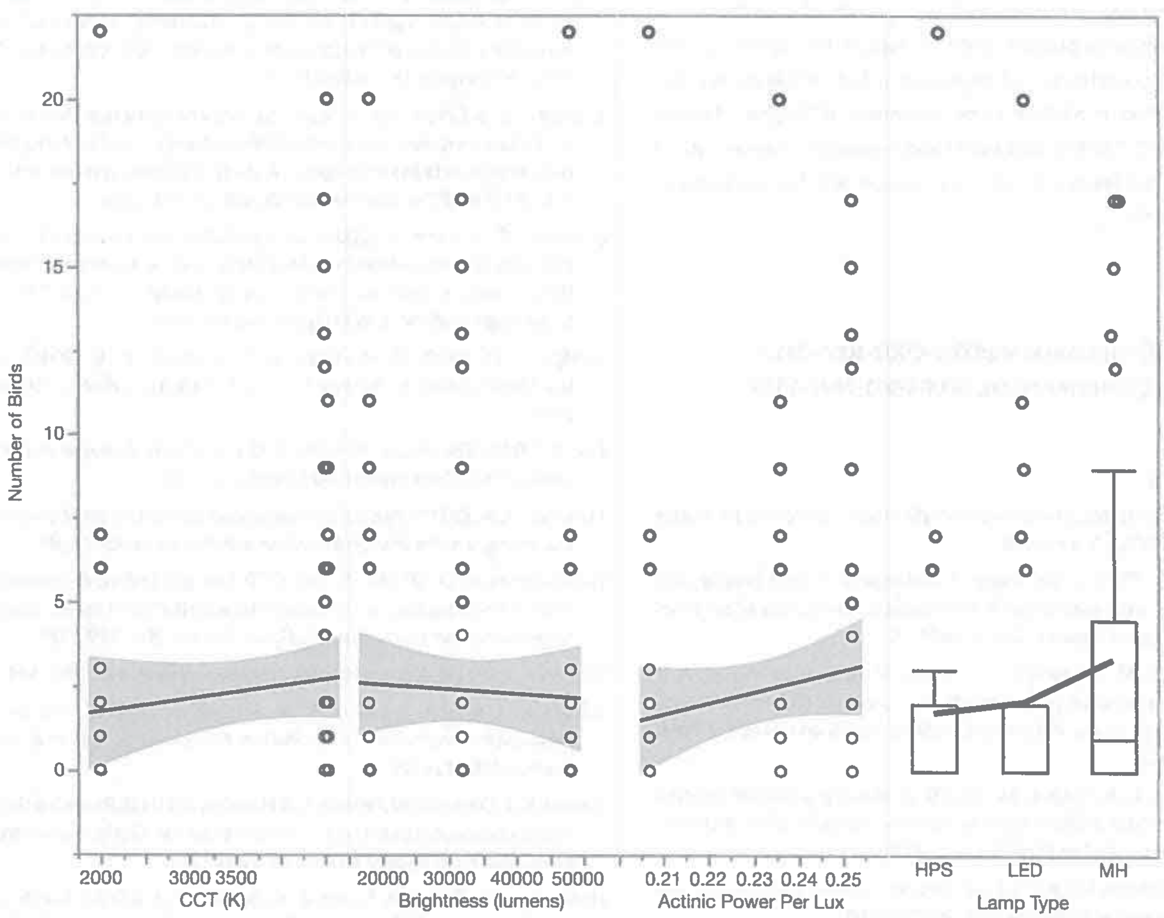


FIGURE 5 Analysis of birds grounded from Rodríguez et al. (2017a), comparing Actinic Power per Lux with CCT, brightness, and lamp type as explanatory variables

lamps meets the 560 nm cutoff. This raises the interesting regulatory question of whether it might be acceptable to modify the strict 560 nm cutoff in favor of a whole-spectrum assessment that we have proposed here, which would lead to approving lamps for street and outdoor lighting (e.g., at ports) that we predict would be less disruptive to turtles, increase color rending when replacing existing HPS, and save significant energy. Of course, to fully address outdoor light management, additional techniques to control light intensity, direction, and duration would need to be employed (Longcore and Rich, 2017), such as use of shields, baffles, and louvers to reduce spill light (Mizon, 2002).

Decision-making power for new lighting types is often vested in street lighting agencies and departments of transportation. When regulations exist to control lighting to reduce harms to certain species, these agencies must comply with relevant laws. They also answer to public opinion on the aesthetics of lighting, as has been shown for many LED projects around the USA that have raised the ire of local residents because the high CCT lamps produce significant glare and were displeasing to residents (Hecht, 2016). For those governmental actors trying to balance considerations for wildlife, the night sky, and safety, clear advice on spectrum is needed to navigate the many available choices. This information is also necessary for regulators facing these issues.

ACKNOWLEDGMENTS

CW Energy Systems provided seed funding for this investigation but did not have any part in the research or reporting of the results. We thank Tim Robinson for productive discussions of this approach and B. M. Seymoure for constructive comments on a draft of this manuscript. AR was supported by a Marie Curie International Outgoing Fellowship (330655 FP7-PEOPLE-2012-IOF) and a Juan de la Cierva contract from the Spanish Ministry of Economy, Industry and Competitiveness (IJCI-2015-23913).

ORCID

Travis Longcore http://orcid.org/0000-0002-1039-2613
Airam Rodríguez http://orcid.org/0000-0001-7882-135X

REFERENCES

Allen, J. A. (1880). Destruction of birds by light-houses. *Bulletin of the Nuttall Ornithological Club*, *5*, 131–138.

Aubé, M. (2015). Physical behaviour of anthropogenic light propagation into the nocturnal environment. *Philosophical Transactions of the Royal Society B Biological Sciences*, *370*, 20140117.

Aubé, M., Kocifaj, M., Zamorano, J., Lamphar, H. A. S., & de Miguel, A. S. (2016). The spectral amplification effect of clouds to the night sky radiance in Madrid. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *181*, 11–23.

Aubé, M., Roby, J., & Kocifaj, M. (2013). Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility. *PLoS One*, *8*, e67798.

Bertolotti, L., & Salmon, M. (2005). Do embedded roadway lights protect sea turtles? *Environmental Management*, *36*, 702–710.

Bierman, A. (2012). Will switching to LED outdoor lighting increase sky glow? *Lighting Research & Technology*, *44*, 449–458.

BIPM. (2006). *The international system of units (SI)*. Sèvres, France: Bureau International des Poids et Mesures.

Björn, L. O. (2015). Action spectroscopy in biology. *Photobiology* (pp. 85–96). New York, NY: Springer.

Boyce, P., Fotios, S., & Richards, M. (2009). Road lighting and energy saving. *Lighting Research & Technology*, *41*, 245–260.

CIE. (2014). Technical Note: Relating photochemical and photobiological quantities to photometric quantities. *CIE TN* 02:2014. Vienna, Austria: International Commission on Illumination.

Cleve, K. (1964). Der Anflug der Schmetterlinge an künstliche Lichtquellen. *Mitteilungen der Deutschen Entomologischen Gesellschaft*, *23*, 66–76.

Davies, T. W., Bennie, J., Inger, R., de Ibarra, N. H., & Gaston, K. J. (2013). Artificial light pollution: Are shifting spectral signatures changing the balance of species interactions? *Global Change Biology*, *19*, 1417–1423.

DIN. 2016. DIN 5031-10: Optical radiation physics and illuminating engineering - Part 10: Photobiologically effective radiation, quantities, symbols and action spectra. Berlin, Germany: Author [German Institute for Standardization].

Dominoni, D. M. (2015). The effects of light pollution on biological rhythms of birds: An integrated, mechanistic perspective. *Journal of Ornithology*, *156*, 409–418.

Donners, M., van Grunsven, R. H. A., Groenendijk, D., van Langevelde, F., Bikker, J. W., Longcore, T., & Veenendaal, E. M. (2018). Colours of attraction: A general model for insect phototaxis. *Journal of Experimental Zoology A*, https://doi.org/10.1002/jez.2188

Dudley, J. M., Erkintalo, M., & Genty, G. (2015). Environment, Wildlife and LED Illumination. *Optics and Photonics News*, *26*, 42–47.

Eisenbeis, G. (2006). Artificial night lighting and insects: Attraction of insects to streetlamps in a rural setting in Germany. In C. Rich & T. Longcore (Eds.), *Ecological consequences of artificial night lighting* (pp. 281–304). Washington, D.C.: Island Press.

Eisenbeis, G., & Eick, K. (2011). Studie zur Anziehung nachtaktiver Insekten an die Straßenbeleuchtung unter Einbeziehung von LEDs [Attraction of nocturnal insects to street lights—A study of lighting systems, with consideration of LEDs]. *Natur und Landschaft*, *86*, 298–306.

Eisenbeis, G., & Hänel, A. (2009). Light pollution and the impact of artificial night lighting on insects. In M. J. McDonnell, A. K. Hahs, & J. Breuste (Eds.), *Ecology of cities and towns: A comparative approach* (pp. 243–263). Cambridge, England: Cambridge University Press.

Elvidge, C. D., Keith, D. M., Tuttle, B. T., & Baugh, K. E. (2010). Spectral identification of lighting type and character. *Sensors*, *10*, 3961–3988.

Fox, R. (2013). The decline of moths in Great Britain: A review of possible causes. *Insect Conservation and Diversity*, *6*, 5–19.

Fritsches, K. A. (2012). Australian loggerhead sea turtles do not avoid yellow. *Marine and Freshwater Behaviour and Physiology*, *45*, 79–89.

Galadí-Enríquez, D. (2018). Beyond CCT: The spectral index system as a tool for the objective, quantitative characterization of lamps. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *206*, 399–408.

Gaston, K. J. (2013). A green light for efficiency. *Nature*, *497*, 560–561.

Gaston, K. J., Bennie, J., Davies, T. W., & Hopkins, J. (2013). The ecological impacts of nighttime light pollution: A mechanistic appraisal. *Biology Reviews*, *88*, 912–927.

Gaston, K. J., Davies, T. W., Bennie, J., & Hopkins, J. (2012). Reducing the ecological consequences of night-time light pollution: Options and developments. *Journal of Applied Ecology*, *49*, 1256–1266.

Hawryshyn, C., Ramsden, S., Betke, K., & Sabbah, S. (2010). Spectral and polarization sensitivity of juvenile Atlantic salmon (*Salmo salar*): Phylogenetic considerations. *Journal of Experimental Biology*, *213*, 3187–3197.

Hecht, J. (2012). Changing the lights: Are LEDs ready to become the market standard? *Optics and Photonics News*, *23*, 44–50.

Hecht, J. (2016). The early-adopter blues. *IEEE Spectrum*, *53*, 44–50.

Johnsen, S. (2012). *The optics of life: A biologist's guide to light in nature*. Princeton, England: Princeton University Press.

Kinzey, B., Perrin, T. E., Miller, N. J., Kocifaj, M., Aubé, M., & Lamphar, H. S. 2017. *An investigation of LED street lighting's impact on sky glow*. Richland, Washington: U.S. Department of Energy (Contract DE-AC05-76RL01830).

Kyba, C., Hänel, A., & Hölker, F. (2014). Redefining efficiency for outdoor lighting. *Energy & Environmental Sciences*, *7*, 1806–1809.

Kyba, C. C. M., Kuester, T., de Miguel, A. S., Baugh, K., Jechow, A., Hölker, F., ...Guanter, L. (2017). Artificially lit surface of Earth at night increasing in radiance and extent. *Science Advances*, *3*, e1701528.

Kyba, C. C. M., Ruhtz, T., Fischer, J., & Hölker, F. (2011). Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. *PLoS One*, *6*, e17307.

Levenson, D. H., Eckert, S. A., Cognale, M. A., Deegan, II, J. F., & Jacobs, G. H. (2004). Photopic spectral sensitivity of green and loggerhead sea turtles. *Copeia*, *2004*, 908–914.

Longcore, T., Aldern, H. L., Eggers, J. F., Flores, S., Franco, L., Hirshfield-Yamanishi, E., ...Barroso, A. M. (2015). Tuning the white light spectrum of light emitting diode lamps to reduce attraction of nocturnal arthropods. *Philosophical Transactions of the Royal Society B Biological Sciences*, *370*, 20140125.

Longcore, T., & Rich, C. 2017. Artificial Night Lighting and Protected Lands: Ecological Effects and Management Approaches (Revised August 2017). Natural Resource Report NPS/NRSS/NSNS/NRR—2017/1493. Fort Collins, Colorado: National Park Service. 1–51.

Longcore, T., Rich, C., Mineau, P., MacDonald, B., Bert, D. G., Sullivan, L. M., ...Drake, D. (2012). An estimate of avian mortality at communication towers in the United States and Canada. *PLoS One*, *7*, e34025.

Lucas, R. J., Peirson, S. N., Berson, D. M., Brown, T. M., Cooper, H. M., Czeisler, C. A., ...O'Hagan, J. B. (2014). Measuring and using light in the melanopsin age. *Trends in Neurosciences*, *37*, 1–9.

Luginbuhl, C. B., Boley, P. A., & Davis, D. R. (2014). The impact of light source spectral power distribution on sky glow. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *139*, 21–26.

Menzel, R., & Greggers, U. (1985). Natural phototaxis and its relationship to colour vision in honeybees. *Journal of Comparative Physiology A*, *157*, 311–321.

Midolo, N. (2011). The suggested effect of lighting on green turtles based on a proposed V(λ) curve. *Lighting Magazine*, *31*, 36–41.

Minnaar, C., Boyles, J. G., Minnaar, I. A., Sole, C. L., & McKechnie, A. E. (2015). Stacking the odds: Light pollution may shift the balance in an ancient predator–prey arms race. *Journal of Applied Ecology*, *52*, 522–531.

Mizon, B. (2002). *Light pollution: Responses and remedies*. London, England: Springer.

Pawson, S., & Bader, M.-F. (2014). LED lighting increases the ecological impact of light pollution irrespective of color temperature. *Ecology Applications*, *24*, 1561–1568.

Reed, J. R. (1986). Seabird vision: Spectral sensitivity and light-attraction behavior [Dissertation]. Madison, WI: University of Wisconsin. 1–190

Rich,C. & Longcore,T. (2006). *Ecological consequences of artificial night lighting* (pp. 458). Washington, D.C.: Island Press.

Rodríguez, A., Dann, P., & Chiaradia, A. (2017a). Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters. *Journal of Nature Conservation*, *39*, 68–72.

Rodríguez, A., Holmes, N. D., Ryan, P. G., Wilson, K-J., Faulquier, L., Murillo, Y., ...Corre, M. L. (2017b). Seabird mortality induced by land-based artificial lights. *Conservation Biology*, *31*, 986–1001.

Rodríguez, A., Holmberg, R., Dann, P., & Chiaradia, A. (2018). Penguin colony attendance under artificial lights for ecotourism. *Journal of Experimental Zoology Part A Ecology and Integrative Physiology*. https://doi.org/10.1002/jez.2155

Ruchty, M., Roces, F., & Kleineidam, J. (2010). Detection of minute temperature transients by thermosensitive neurons in ants. *Journal of Neurophysiology*, *104*, 1249–1256.

Salmon, M. (2003). Artificial night lighting and turtles. *Biologist*, *50*, 163–168.

Somers-Yeates, R., Bennie, J., Economou, T., Hodgson, D., Spalding, A., & McGregor, P. K. (2016). Light pollution is associated with earlier tree budburst across the United Kingdom. *Proceedings. Biological Sciences*, *283*, 20160813.

Stevens, S. S. (1961). To honor Fechner and repeal his law. *Science*, *133*, 80–86.

Stone, E. L., Harris, S., & Jones, G. (2015). Impacts of artificial lighting on bats: A review of challenges and solutions. *Mammalian Biology*, *80*, 213–219.

Stone, E. L., Jones, G., & Harris, S. (2012). Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats. *Global Change Biology*, *18*, 2458–2465.

Wilson, J. F., Baker, D., Cheney, J., Cook, M., Ellis, M., Freestone, R., ...Hodgers, D. (2018). A role for artificial night-time lighting in long-term changes in populations of 100 widespread macro-moths in UK and Ireland: A citizen-science study. *Journal of Insect Conservation* , 1–8. https://doi.org/10.1007/s10841-018-0052-1

Wiltschko, R., Stapput, K., Thalau, P., & Wiltschko, W. (2010). Directional orientation of birds by the magnetic field under different light conditions. *Journal of the Royal Society Interface*, *7*, rsif20090367.

Witherington, B. E. (1992). Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica*, *48*, 31–39.

How to cite this article: Longcore T, Rodríguez A, Witherington B, Penniman JF, Herf L, Herf M. Rapid assessment of lamp spectrum to quantify ecological effects of light at night. *J Exp Zool*. 2018;1–11. https://doi.org/10.1002/jez.2184

ROYAL ASTRONOMICAL SOCIETY
MNRAS 478, 1776–1783 (2018) doi:10.1093/mnras/sty1143
Advance Access publication 2018 May 17

Modelling the effects of phosphor converted LED lighting to the night sky of the Haleakala Observatory, Hawaii

M. Aubé,[1★] A. Simoneau,[2] R. Wainscoat[3] and L. Nelson[2]

[1] Cégep de Sherbrooke, 475, rue du Cégep, Sherbrooke, Québec J1E 4K1, Canada
[2] Bishop's University, 2600 rue College, Sherbrooke, Québec J1M 1Z7, Canada
[3] Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr, Honolulu, HI 96822, USA

Accepted 2018 April 28. Received 2018 April 27; in original form 2018 February 27

ABSTRACT

The goal of this study is to evaluate the current level of light pollution in the night sky at the Haleakala Observatory on the island of Maui in Hawaii. This is accomplished with a numerical model that was tested in the first International Dark Sky Reserve located in Mont-Mégantic National Park in Canada. The model uses ground data on the artificial light sources present in the region of study, geographical data, and remotely sensed data for (1) The nightly upward radiance, (2) The terrain elevation, and 3) The ground spectral reflectance of the region. The results of the model give a measure of the current state of the sky spectral radiance at the Haleakala Observatory. Then, using the current state as a reference point, multiple light conversion plans are elaborated and evaluated using the model. We can thus estimate the expected impact of each conversion plan on the night sky radiance spectrum. A complete conversion to white light emitting diodes (LEDs) with correlated colour temperature of 4000 and 3000 K are contrasted with a conversion using phosphore-convertred amber LEDs. We include recommendations concerning the street lamps to be used in sensitive areas like the cities of Kahului and Kihei, and suggest best lighting practices related to the colour of lamps used at night.

Key words: radiative transfer – light polution.

1 INTRODUCTION

The evaluation of the night sky spectral radiance under clear conditions is a complex task given the large number of dependant variables. Indeed, Aubé (2015) showed that the sky radiance is a non-trivial function of the aerosol and molecular atmospheric content along with the geographical distribution of anthropogenic light sources on the ground and their relationship with the nearby optical and geometrical properties like the underlying ground spectral reflectance, the topography, and the presence of small to medium size blocking obstacles (e.g. trees and buildings). Many factors are variable with time like ground reflectance, tree foliage, aerosol concentration and composition profiles, sports lighting, ornamental lights, and car headlights. The large variance in some of the key variables has been noted by many authors (Dobler et al. 2015; Meier 2018), and this results in a large variance in the inferred sky brightness data (Aubé 2007; Patat 2008; Falchi 2011; Pun & So 2012; Aubé et al. 2014; Puschnig, Posch & Uttenthaler 2014; Pun et al. 2014; Kyba et al. 2015; Sánchez de Miguel 2015; Sánchez de Miguel et al. 2017). This variation in the driving variables makes it difficult to identify the origin of the sky radiance fluctuations because one should record at the same time many other quantities such as the aerosol optical depth (AOD) and Angstrom coefficient α (or the concentration, chemical composition, and size distribution of aerosols). Another factor affecting observations is that low-altitude clouds below the observer sometimes block and suppress artificial light from ground based sources (Pedani 2004; Ribas et al. 2016). Our analysis assumes the more common case of clear sky without low-altitude clouds.

One other way to evaluate the evolution of the sky radiance is the use of a radiative transfer model that allows the selection of diverse values of the key variables identified above, hence allowing them to be maintained at some predefined fixed values. Many night sky brightness models have been constructed since the 1980s. Some are based on homogeneous or simplistic geographical descriptions of the key variables like the Garstang model (Garstang 1986). According to this paper, a city can be modelled as a perfect circle of constant ground level light flux, ground reflectance, and angular emission function. Moreover, the topography is flat and the second-order of scattering is not explicitly calculated. Some improvements of the Garstang model have been proposed (Luginbuhl et al. 2009; Cinzano & Falchi 2012) to minimize these limitations. Recent models take account of the complexity of the environment and hence

★ E-mail: martin.aube@cegepsherbrooke.qc.ca

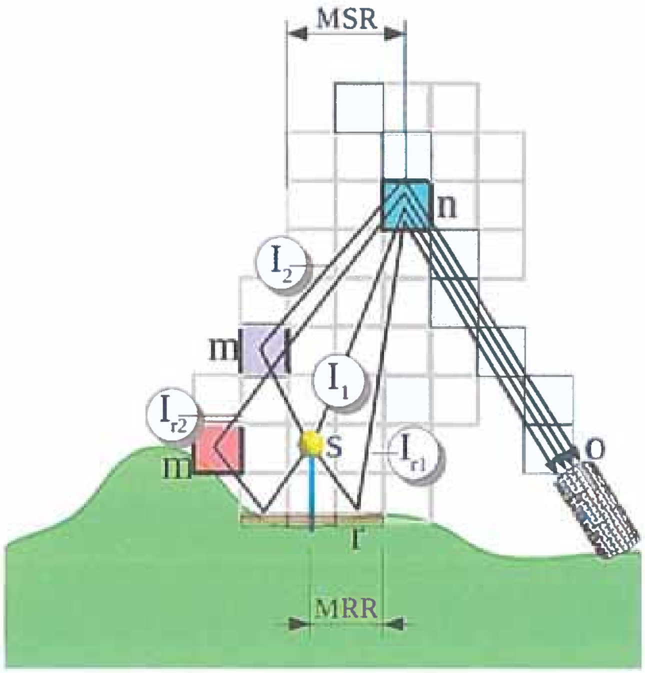


Figure 1. Optical path considered in the calculation of the artificial sky radiance in the Illumina model. 'o' is the virtual observer, 'n' a voxel in the line of sight, 's' a cell containing a light source, 'm' are voxels where second-order scattering occurs, and 'r' is a voxel where light reflects off the ground. 'MRR' is the maximal reflection radius, the distance within which light can reflect off the ground, and 'MSR' is the maximal scattering radius, the distance within which second-order scattering is being considered (Aubé 2007).

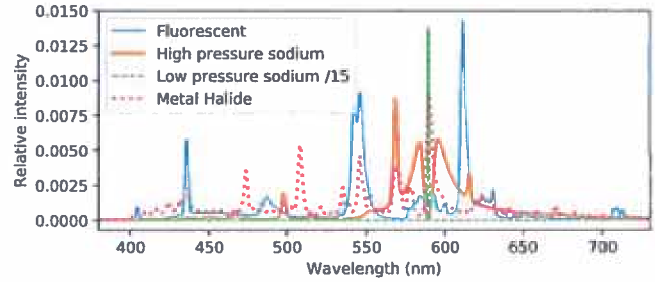


Figure 2. Photopic normalized spectra of high-intensity discharge lamps. The LPS spectrum has been reduced by a factor 15 for scale.

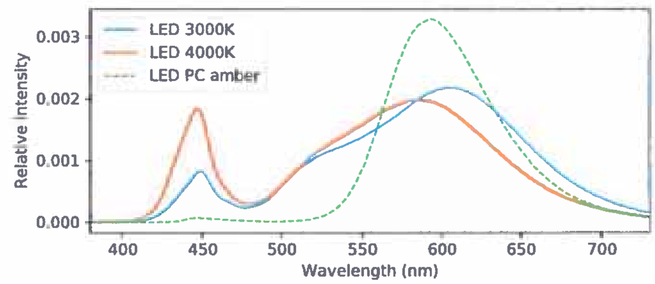


Figure 3. Photopic normalized spectra of LED lamps.

are more realistic with regards to real situations (Baddiley 2007; Kocifaj 2007; Luginbuhl et al. 2009; Cinzano & Falchi 2012; Aubé 2015; Falchi et al. 2016; Aubé & Simoneau 2018).

2 DATA

The model used in this study is called Illumina (Aubé et al. 2005; Aubé 2015; Aubé & Simoneau 2018). The model simulates the reading of a virtual spectrometer by using ray-tracing techniques along with statistical selection of tracing photons. A virtual instrument or observer is located on the voxel based simulation domain characterized by a radiant flux map of the light sources on the territory, by the angular photometry and spectral power distribution (SPD) of these light sources, and by a description of the environment's physical properties. The position and direction of observation of the observer defines a line of sight along which any scattered light can propagate towards the virtual instrument and hence be detected. The model calculates a statistically selected set of possible optical paths from the light sources in the domain to every point on the line of sight, taking into account multiple scatterings and reflections along the way *(See Fig. 1)*. By adding the contribution of every optical path, the total artificial sky brightness is obtained.

Some assumptions are made to facilitate the calculations. Due to the fact that a cell covers an area of one square kilometre, the variations in the angular light output pattern (LOP) with the azimuthal angle are neglected since an area of this size is expected to contain many light sources and that their orientation can vary greatly depending on the way the streets are designed. To the best of our knowledge, an in-dept analysis of the validity of that assumption has not yet been made. Based on some estimates made prior to the model design, only four kinds of optical paths are worth considering when trying to attain a ≈1 per cent precision. Actually, Aubé (2015) showed that for low aerosol loadings (AOD ≈ 0.1), the contribution of the second-order of scattering is generally lower inside the city perimeter (≈7 per cent), but this percentage increases rapidly when exiting the city. The maximum contribution of the second-order of scattering is obtained near the city limit, where it can reach 38 per cent without the blocking effect generated by obstacles. Previous modelling experiments we conducted showed that for moderate distance to the source (<30 km) the contribution of the third order of scattering is lower than 1 per cent of the total. This result is confirmed by Kocifaj (2018a) who stated that higher order of scattering are negligible up to 30 km from the source for blue light and up to 60 km for red light. Since our main light sources are located within 30 km of the observatory, we can neglect higher scattering orders. For that reason, only first and second-order scattering with and without a reflection from the ground underneath the light source are computed.

The basic SPDs used in this study are presented in Figs 2 and 3. The base LOPs are presented in Fig. 4.

2.1 Modelling domain characteristics

The domain is a 500 x 400 km rectangle centred on (20.306N, 156.442W) in the spatial reference system NAD83(HARN)/UTM zone 04N (EPSG:3750). This envelopes most of the Hawaii archipelago, with the exclusion of Kauai island. The virtual observer is located at the Haleakala observatory on the Island of Maui (20.708N, 156.257W) looking at 20° of elevation and with an azimuthal angle of 292°. This is actually pointing towards Honolulu.

Fig. 5 shows the terrain visible by an observer located 20 ft above the Haleakala observatory in direct line of sight, meaning that it is not blocked by the topography. To produce the maps we took into

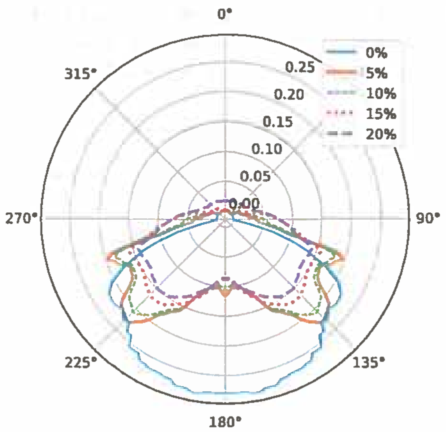


Figure 4. LOPs used by the model. The percentage represents the ULOR of the lamp.

account the Earth's curvature. One can see that most of Honolulu is in the shadow. The main cities on Big Island are also completely in the shadow. However, closer to the observatory on Maui island, both the cities of Kihei and Kahului are in the direct line of sight, with Kahului being the most illuminated. Both cities are near the observatory within a distance of 30 km.

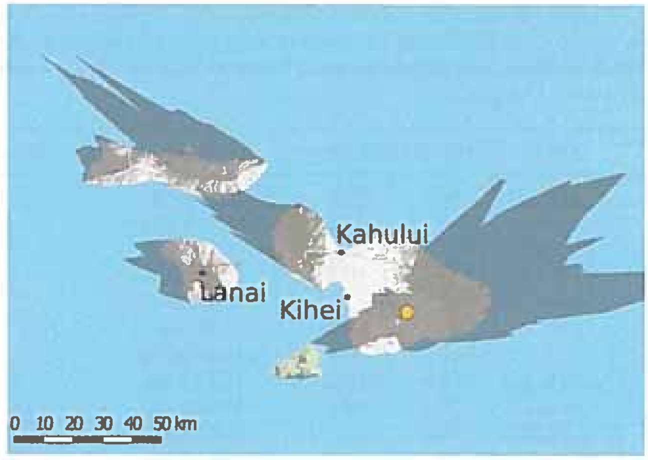
In those cities, most buildings are single story structures with few trees. All of this makes it so that the public light sources are typically above everything else, with very few obstacles blocking the light from directly escaping the city.

The average obstacle height, distance, and filling factor as well as the average height of the light sources were estimated by random sampling and are shown in Table 1. We mostly focused on the brightest city, Honolulu, and the closest one, Kahului. The sampling was done using Google Earth to estimate the obstacles separation and Google StreetView for the rest. These parameters were chosen to be uniform throughout the territory due to the small variation observed in the city of Kahului and the fact that this city is the main source of light pollution, as can be inferred from Fig. 5.

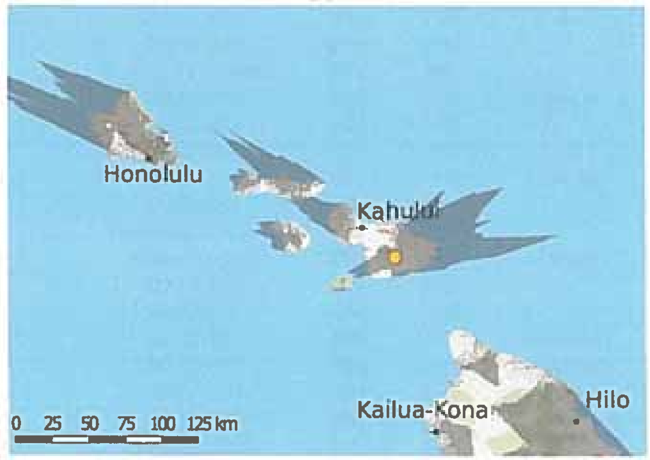
The filling factor of the obstacles is the opacity of the obstacles to light, that is to say the ratio of the light rays that can pass through or between the obstacles. A better approach would be the one described by Kocifaj (2018b), where one takes into account multiple rows of buildings instead of a single one in addition to various other improvements. This may be included in our model in the future. The value 0.5 was estimated using Google StreetView, while considering mainly Kahului for the reasons mentioned above. Second-order scattering was calculated whitin 4 km of the main optical path (MSR in Fig. 1).

2.2 Estimation of the Hawaii lighting infrastructure

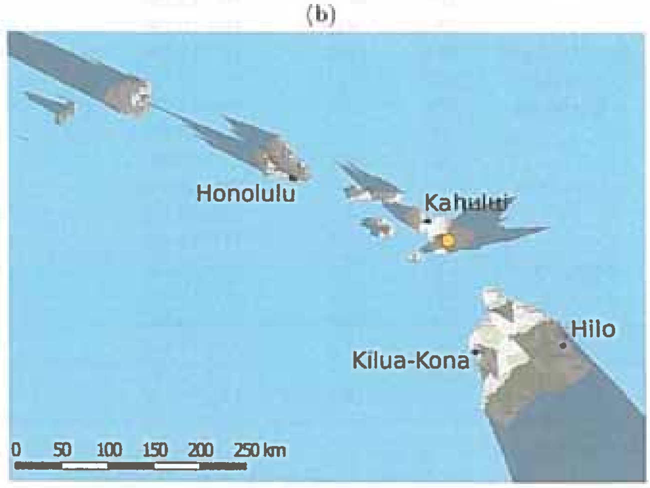
Many parameters were estimated for different circular regions of the modelling domain (see Fig. 6). When two or more regions overlap, the one with the higher index takes precedence. Each region was defined assuming a relative uniformity of their lamps and obstacles characteristics. Table 1 contains the lamps and obstacle characteristics for each region. To estimate the mean lamp and obstacle heights, we used the 3D model available on Google Earth as well as the views from Google StreetView. We estimated the lamps upward light output ratio (ULOR) and SPD according to our knowledge of the islands' lighting infrastructure.



(a)



(b)



(c)

Figure 5. Viewshed from the Haleakala Observatory. The shaded regions correspond to regions that are not visible in the direct line of sight from 20 ft (approx. 6.1 m) above the observatory (yellow dot). *Determined using data from heywhatsthat.com.*

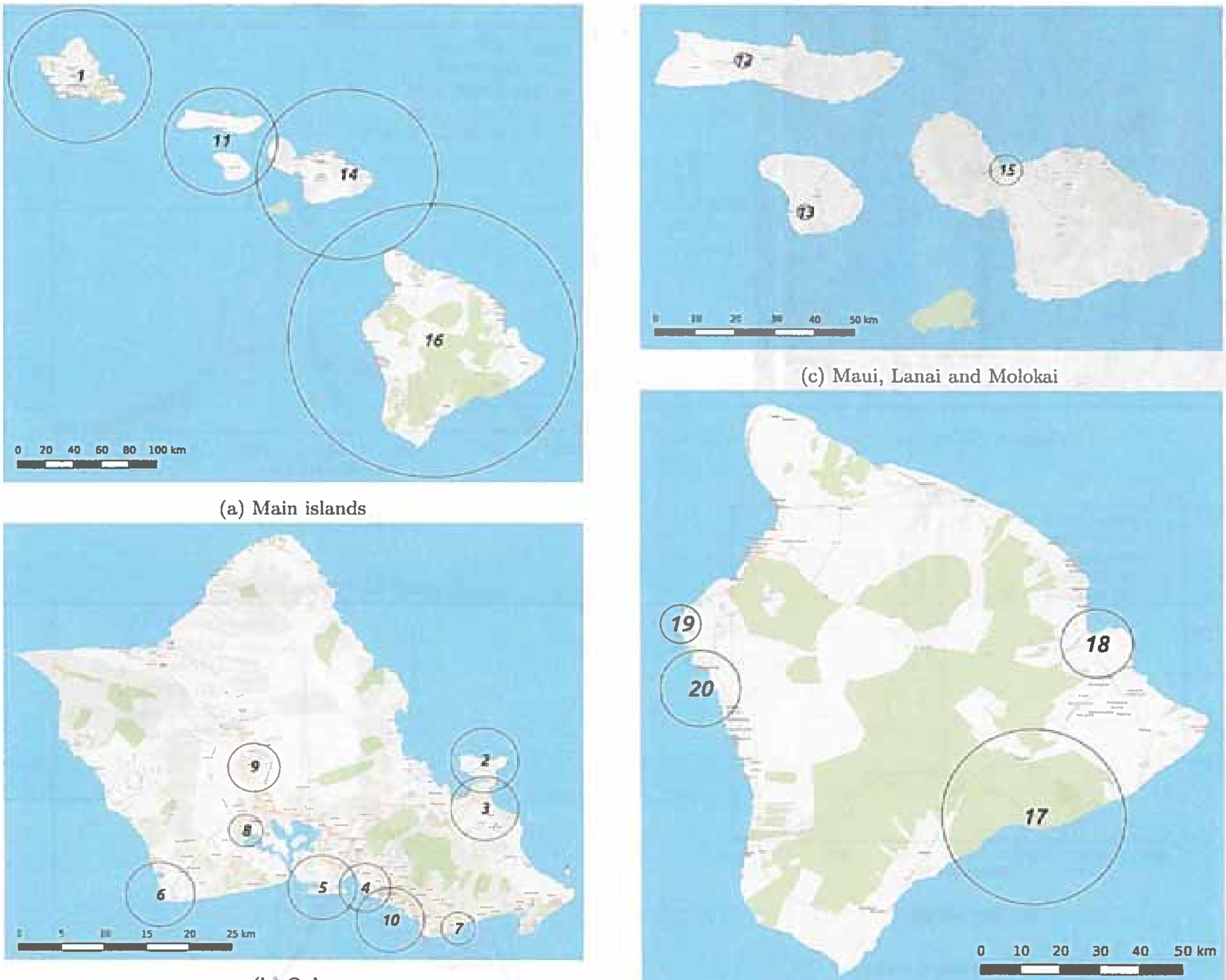
2.3 Other input data and modelling parameters

The ground reflectance is obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) MYD09A1 data set (Kaufman & Tanré 1998) for the period ranging from 2014 May 17 to

Table 1. Lighting infrastructure and obstacle characteristics estimated with Google StreetView. Cobraheads are characterized with 5 per cent ULOR, athletic facilities to 10 per cent ULOR, and full shielding to 0 per cent ULOR. 'Per cent' represent the relative amount (in per cents) of the light from the region that is coming from the associated characteristics. The technology used are low-pressure sodium (LPS), high-pressure sodium (HPS), metal hallide (MH), and compact uorescent lamps (CFLs).

#	Zone	Per cent	Technology	Shielding	Lamp height	Obstacle height	Obstacle distance	Obstacle filling factor
1.	Oahu	90%	HPS	Cobrahead	7 m	5 m	25 m	0.5
		10%	MH	Athletic facilities				
2.	MCBH	35%	CFL	5% ULOR	7 m	5 m	25 m	0.5
		65%	HPS	20% ULOR				
3.	Kailua	50%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		40%	HPS	Cobrahead				
		10%	MH	Athletic facilities				
4.	Honolulu port	100%	HPS	10% ULOR	7 m	5 m	25 m	0.5
5.	Airport /	70%	HPS	10% ULOR	7 m	5 m	25 m	0.5
	Hickam AFB	30%	MH	10% ULOR				
6.	Industrial area	80%	HPS	20% ULOR	7 m	5 m	25 m	0.5
		20%	MH	20% ULOR				
7.	Kahala	50%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		40%	HPS	Cobrahead				
		10%	MH	Athletic facilities				
8.	Waipahu	50%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		40%	HPS	Cobrahead				
		10%	MH	Athletic facilities				
9.	Mililani	50%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		40%	HPS	Cobrahead				
		10%	MH	Athletic facilities				
10.	Waikiki	40%	HPS	Fully shielded	7 m	5 m	25 m	0.5
		40%	HPS	10% ULOR				
		20%	MH	20% ULOR				
11.	Molokai	90%	HPS	Cobrahead	7 m	5 m	25 m	0.5
	and Lanai	10%	MH	10% ULOR				
12.	Molokai airport	100%	HPS	15% ULOR	7 m	5 m	25 m	0.5
13.	Lanai airport	100%	HPS	15% ULOR	7 m	5 m	25 m	0.5
14.	Maui	72%	HPS	Fully shielded	7 m	5 m	25 m	0.5
		18%	HPS	10% ULOR				
		10%	MH	10% ULOR				
15.	Kahului airport	95%	HPS	10% ULOR	7 m	5 m	25 m	0.5
	and port	5%	MH	10% ULOR				
16.	Big Island	87%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		8%	HPS	10% ULOR				
		5%	MH	5% ULOR				
17.	Lava lakes	– %	—	Volcano lava	– m	– m	– m	—
18.	Hilo	70%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		30%	HPS	15% ULOR				
19.	Kona airport	85%	HPS	10% ULOR	7 m	5 m	25 m	0.5
		10%	LPS	10% ULOR				
		5%	MH	20% ULOR				
20.	Kona	70%	LPS	10% ULOR	7 m	5 m	25 m	0.5
		20%	HPS	15% ULOR				
		10%	MH	15% ULOR				

May 24, which has a resolution of 500 m but was resampled to 1 km, and is presented at Fig. 7. The digital elevation model used comes from the Shuttle Radar Topography Mission (SRTM) data (Farr et al. 2007) and is presented in Fig. 8 which has a native horizontal resolution of 3 arcsec (about 90 m) but is also being resampled to 1 km. The radiant flux map is derived using steps presented in Aubé & Simoneau (2017) using satellite imagery at night from the visible infrared imaging radiometer suite day/night band (VIIRS-DNB) VCMSLCFG data set (Elvidge et al. 2017) for the month of 2014 May resampled to 1 km from the original 15 arcsec presented in Fig. 9. Our estimate of the lighting infrastructure consider all light detected with VIIRS being emitted either by sport fields or by streetlights but we know that a substantial part of it is coming from other sources like outdoor private lighting, buildings windows, and car headlights. A number of studies aimed to estimate the relative contribution of the streetlight to the total artificial light at night. Streetlights contribution was estimated to lie between 30 per cent and 50 per cent of the total artificial light at night (Lockwood, Thompson & Floyd 1990; Hiscocks & Gudmundsson 2010; Kuechly et al. 2012). The absolute values that we obtain with the model are certainly overestimated but we do not know the actual percentage of light coming exclusively from streetlights in Hawaii. This should not be an important issue when we are looking to ratios between scenarios but it is certainly a problem for the absolute values (e.g. Fig. 10). In the latter case, one must consider the values as more or less proportional to what would be observed with



(a) Main islands

(b) Oahu

(c) Maui, Lanai and Molokai

(d) Big Island

Figure 6. Approximative zones used for the simulation. In case of overlap, the zone with the higher index takes precedence.

Table 2. Atmospheric parameter used, based on data from Holben et al. (2001). τ_a is for a reference wavelength of 500 nm while α is derived from AERONET bands 440, 500, 675, and 870 nm.

P_0	α	τ_α	R_H	Aerosol type
101.3 kPa	0.70	0.11	70	Maritime

P_0 : ground air pressure.
α : Angstrom exponent.
τ_α : aerosol optical depth.
R_H : relative humidity.

only streetlights and sports fields on. Another caveat is that we do not know anything about the spectral and angular characteristics of other lighting but streetlights.

Eventually, the model will be able to make use of data from VIIRS-DNB for the intensity of the light sources but also use data from the International Space Station to evaluate the SPD of the sources (Sánchez de Miguel 2015) and the approach developed by Kocifaj (2018b) to find the net emission function. In that way we will be able to fully take into account all the

Figure 7. MODIS MYD09A1 RGB composite imagery for the month of 2014 May. [*R = band 1 (645 nm), G = band 4 (555 nm) and B = band 3 (469 nm)]* Each band fluctuates between 0 and 1.

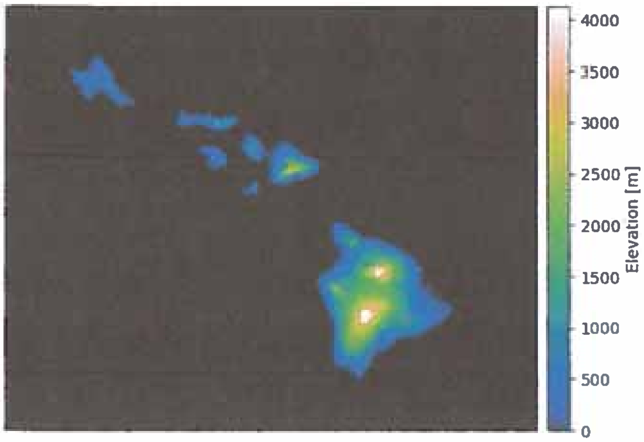
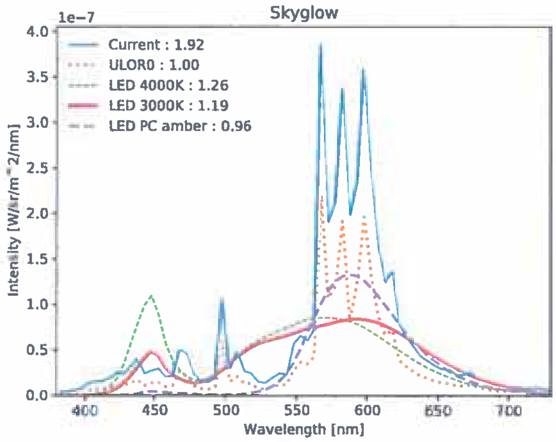
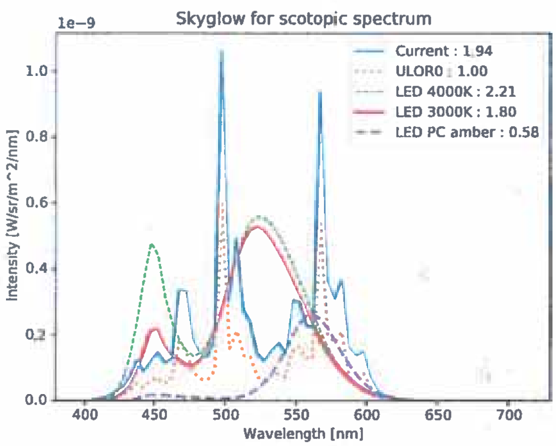


Figure 8. SRTM data.



(a) Raw skyglow

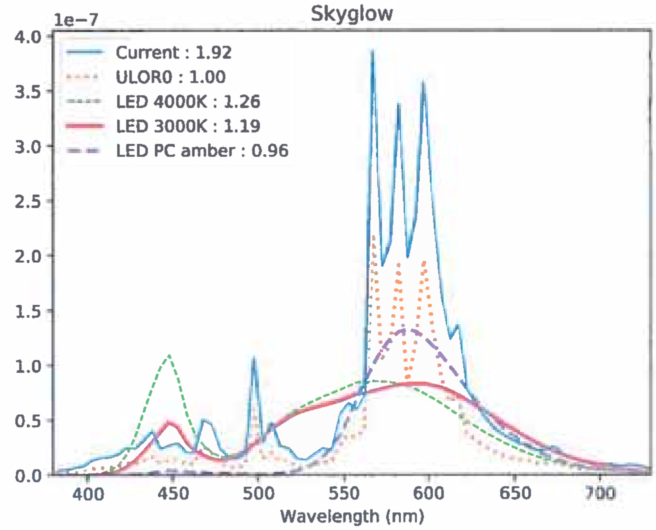


(b) Scotopic skyglow

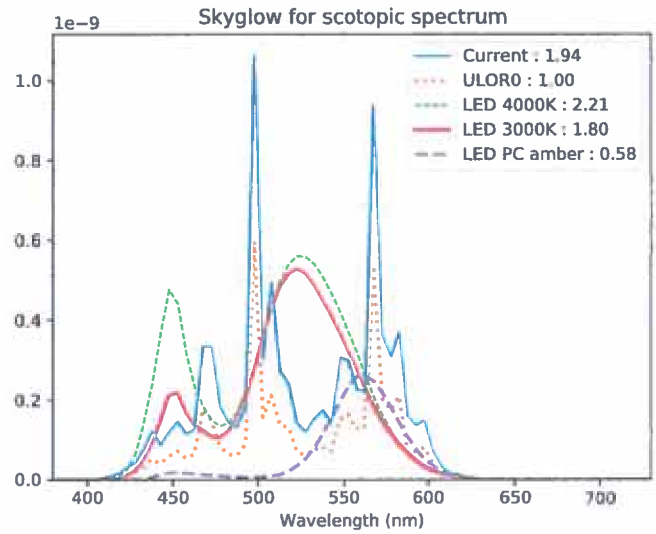
Figure 9. VIIRS-DNB data (logscale).

light sources present in the domain and not restrict ourselves to streetlights.

The AOD or τ_a and Angstrom exponent α shown in Table 2 come from Holben et al. (2001), whose climatology is based on the average of the Aerosol Robotic Network (AERONET) (Holben et al. 1998) data for 38 clear days in May between the years 1995



(a) Raw skyglow



(b) Scotopic skyglow

Figure 10. Sky radiance spectra (a) for different lighting scenarios and its skyglow impact on the scotopic vision (b). The numbers given in the legend of each panel are equal to the ratio of the integral of the associated curve to the integral of 'ULOR0'. Panel 10a is the raw spectra without any weighting and is the most useful one for professional astronomy.

and 1999 for the site of Lanai, HI. The AOD is for a reference wavelength $\lambda_0 = 500$nm while α is derived from AERONET bands 440, 500, 675, and 870 nm using a linear regression. The AOD values for other wavelengths are extrapolated from theses values and Mie's power law, where

$$\frac{\tau_\lambda}{\tau_{\lambda_0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-\alpha} . \quad (1)$$

3 RESULTS AND DISCUSSION

The model was run for ninety 5 nm-wide spectral bands equally spaced between 380 and 830 nm. The model output for different lighting scenarios, namely 'Current', representing the most accurate estimate of the current situation on the archipelago, 'ULOR0' being the same spectral mix as the current scenario but with every lamp head replaced by a full cut-off (0 per cent ULOR). This allows us to isolate the effect of the uplight on the sky radiance spectrum. Then 'LED 4000 K', 'LED 3000 K', and 'LED PC amber' are estimated with a full conversion to these respective technologies with full cut-off heads while keeping the installed lamp's luminous flux constant. The reference spectra are shown in Figs 2 and 3, while the LOPs are shown in Fig. 4.

The model also outputs a map of the contribution of the lights sources to the sky radiance, which can be integrated over the zones described in Figure 6. We obtain a scotopic weighted contribution of 2.1 per cent for Ohau, 1.1 per cent for Molokai and Lanai, 96.3 per cent for Maui and 0.3 per cent for Big Island. This shows that Kahului, the main city of the island of Maui, is the main source of the light seen at the observatory and that Honolulu can be neglected when considering the impact of conversion plans.

Fig. 10 shows the spectral radiance data obtained for the different simulated scenarios. It also shows the spectra when weighted by the nighttime vision (scotopic) sensitivity curve (Wyszecki & Stiles 1982). Please note that any conclusion drawn from Fig. 10 is only valid for this particular site, where the most contributing source, Kahului, has obstacles that are lower than the light sources and is in direct line of sight of the observatory. Note also that obstacles characteristics where chosen to be uniform over the whole territory because other important light sources are relatively far away and have a negligible contribution. A more precise description should include a more detailed definition of the subgrid obstacles. Other configurations, especially when obstacles are higher than light fixtures for nearby sources, may lead to very different results and thus new modelling procedures should be implemented.

By looking at Fig. 10(a), which is the most interesting one for professional astronomy since it is not weighted by the scotopic sensitivity, the impact of reduced uplight is obvious. This is especially clear for the current and current w/o uplight curves, where we can see that removing the uplight while keeping the same luminous flux reduces the sky radiance by an average factor of ≈ 2. On that figure, the numbers indicated in the legends represent the spectral integration reported to the value of the current mix of lamps spectra but without uplight while keeping the same flux (ULOR0.) Both 3000 and 4000 K LEDs produce an averaged radiance greater than ULOR0 indicating that both 4000 and 3000 K LEDs produce a higher level of sky radiance when not considering the change in uplight and keeping the same luminous flux.

The scotopic brightness however, presented in Fig. 10(b), shows clearly the impact of the colour temperature of the LED on the perceived radiance as seen by the dark adapted human eye. Both 4000 and 3000 K LEDs have an average scotopic weighted impact relatively close to the current situation (inside 14 per cent of deviation). Meaning that the brightness reduction provided by the absence of upward light emission for the LEDs is compensated by scotopic brightness associated to the blue content of LEDs. On the other hand, the scotopic brightness generated by PC amber LEDs, is about one third of the scotopic brightness of the current situation. This is due to their low blue light content and their absence of upward light emission. 4000 and 3000 K LEDs have an average scotopic weighted impact about twice the ULOR0 scenario.

The night sky in the 400–550 nm region of the spectrum (blue-green) is naturally extremely dark when the moon is down, or only a thin crescent is illuminated. This is a precious region of the sky for astronomy, and is almost untouched by sodium light sources. At 555 nm, there is a bright yellow-green oxygen line, and astronomers have designed a filter system that avoids this line (with the *g* filter encompassing the blue-green colours short of this wavelength, and the *r* filter encompassing the yellow-red visible light to the red). To the red from 555 nm, are natural sodium and oxygen atmospheric emission lines. The night sky is naturally brighter in the yellow-red wavelengths than in the blue-green wavelengths. Conversion to white LED lighting inevitably moves artificial light into the blue-green part of the spectrum. Use of Amber LEDs greatly minimizes damage to the naturally dark blue-green region of the spectrum. Filtered LEDs, where a filter removes blue LED light emission (such as those in use on the Island of Hawaii), are another alternative to white LEDs that lessen damage to the blue-green part of the night sky spectrum.

4 CONCLUSIONS

The results of this study show that sky radiance for the site of Halaekala observatory in the particular observation direction of 20° of elevation and with an azimuthal angle of 292° (towards Honolulu) is highly sensitive to uplight, largely due to the direct line of sight between the observatory and some nearby cities. For the raw/astronomical impact as well as for the scotopic weighted skyglow, removing the uplight reduces the impact by a factor of approximately two. The county lighting ordinance already requires that all lights are fully shielded, but there remain many cases of unshielded lights. Sports lighting is exempted from this shielding requirements and is particularly damaging.

Because of the effect of the uplight, the current scenario (HPS and MH mix with uplight) produces an impact similar to 4000 and 3000 K LEDs, when looking at the averaged scotopic impact. It can also be seen that the colour temperature for LED lighting has a huge influence on the observed sky radiance, with 4000 K LEDs producing a scotopic brightness nearly four times greater than that for PC amber LEDs. Even 3000 K LEDs produce a scotopic brightness that is three times greater than the PC amber when the conversion is made at constant (installed) luminous flux. Any scenario of LED installation without complete elimination of unshielded lights will result in degradation of the sky brightness.

Although skyglow seems to be very sensitive to uplight, it is important to remember that this is due to the particular geography and cityscape of the region (no blocking by terrain towards nearby cities and obstacles lower than lamps). But when there is no upward light emission, both 4000 and 3000 K LEDs produce skyglow greater than the ULOR0 scenario, which is mainly high-pressure sodium and a few metal halide lamps. The PC amber LEDs, however, produce significatively less skyglow than every other technology tested. For that reason, PC amber LEDs should always be preferred over 3000 and 4000 K LEDs when considering light conversion plans which aim to restrict the sky brightness.

However, one needs to take into account that when such a conversion to LEDs occurs, the luminous flux is often reduced by 30–50 per cent because of the better concentration of the light on the street surface that can generally be achieved with LEDs (Kinzey et al. 2017). In such cases the impacts shown in the previous figures need to be multiplied by a factor 0.5–0.7. But since this reduction is only caused by better optics and not by a better luminous efficiency of LEDs, it would, in principle, be possible to develop HPS lamps with good optics that would produce the same flux reduction because of a better concentration of the light. This is due to the fact that lighting professionals generally want to keep the same illuminance level on the ground while reducing the total luminous flux. It is, however, true that the design of such optics is far easier with

LEDs due to their relative size. LED can also be operated efficiently at low power. But these benefits are true for all LEDs, including PC amber LEDs. Therefore, this is not an argument to favour 4000 and 3000 K LEDs lights.

Lower CCT LEDs, such as 2700 K, are now becoming more common. These were not discussed in detail in this paper, but their impact on astronomy can be inferred by interpolation between the cases on 3000 K and PC amber. In cases where white light is necessary, 2700 K (or lower CCT) should always be chosen over higher CCT LEDs. In cases where white light is not necessary, PC amber LEDs should be used; LEDs that are filtered to remove blue light may also be considered.

ACKNOWLEDGEMENTS

We applied the sequence-determines-credit approach (Tscharntke et al. 2007) for the sequence of authors. Some computations were carried out on the Mammouth Serial II cluster managed by Calcul Québec and Compute Canada. The operation of these supercomputers is funded by the Canada Foundation for Innovation (CFI), NanoQuébec, Réseau de Médecine Génétique Appliquée, and the Fonds de recherche du Québec – Nature et technologies (FRQNT). MA thanks the FQRNT for financial support through the Research program for college researchers . AS thanks the Centre de Recherche d'Astrophysique du Quebec (CRAQ) and FRQNT for financial support. LN thanks the Natural Sciences and Engineering Research Council (Canada) for financial support through the Discovery Grants program.

REFERENCES

Aubé M., Proceedings of Starlight 2007 conference, La Palma, Spain, 2007
Aubé M., 2015, Phil. Trans. R. Soc. B, 370
Aubé M., Simoneau A., 2018, J. Quant. Spectrosc. Radiat. Transfer, 211, 25
Aubé M., Franchomme-Fossé L., Robert-Staehler P., Houle V., 2005, Proc.SPIE, San Diego, California, US, 5890, p. 589012
Aubé M., Fortin N., Turcotte S., García B., Mancilla A., Maya J., 2014, PASP, 126, 1068
Aubé M., Simoneau A. 2017, Illumina Users Guide, available at: http://cegepsherbrooke.qc.ca/~aubema/index.php/Prof/IlluminaGuide2016
Baddiley C., 2007, Starlight: A Common Heritage, La Palma, Spain
Cinzano P., Falchi F., 2012, MNRAS, 427, 3337
Dobler G. et al., 2015, Inf. Syst., 54, 115
Elvidge C. D., Baugh K., Zhizhin M., Hsu F. C., Ghosh T., 2017, Int. J. Remote Sens., 38, 5860
Falchi F., 2011, MNRAS, 412, 33
Falchi F. et al., 2016, Sci. Adv., 2
Farr T. G. et al., 2007, Rev. Geophys., 45
Garstang R., 1986, PASP, 98, 364
Hiscocks P. D., Gudmundsson S., 2010, J. R. Astron. Soc. Can., 104, 190
Holben B. N. et al., 1998, Remote Sens. Environ., 66, 1
Holben B. et al., 2001, J. Geophys. Res.: Atmos., 106, 12067
Kaufman Y. J., Tanré D., 1998, NASA MODIS Algorithm Theoretical Basis Document, Vol. 85, Goddard Space Flight Center, p. 3
Kinzey B., Perrin T. E., Miller N. J., Kocifaj M., Aubé M., Lamphar H. S., Carlson T., 2017, US Depatment of Energy, US
Kocifaj M., 2007, Appl. Opt., 46, 3013
Kocifaj M., 2018a, J. Quant. Spectrosc. Radiat. Transfer, 206, 260
Kocifaj M., 2018b, J. Quant. Spectrosc. Radiat. Transfer, 205, 253
Kuechly H. U., Kyba C. C., Ruhtz T., Lindemann C., Wolter C., Fischer J., Hölker F., 2012, Remote Sens. Environ., 126, 39
Kyba C. C. et al., 2015, Sci. Rep., 5
Lockwood G., Thompson D., Floyd R., 1990, PASP, 102, 481
Luginbuhl C. B., Duriscoe D. M., Moore C. W., Richman A., Lockwood G. W., Davis D. R., 2009, PASP, 121, 204
Meier J. M., 2018, Int. J. Sustainable Light., 19, 142
Patat F., 2008, A&A, 481, 575
Pedani M., 2004, New Astron., 9, 641
Pun C. S. J., So C. W., 2012, Environ. Monit. Assess., 184, 2537
Pun C. S. J., So C. W., Leung W. Y., Wong C. F., 2014, J. Quant. Spectrosc. Radiat. Transfer, 139, 90
Puschnig J., Posch T., Uttenthaler S., 2014, J. Quant. Spectrosc. Radiat. Transfer, 139, 64
Ribas S. J., Torra J., Paricio S., Canal-Domingo R., 2016, Int. J. Sustainable Light., 18, 32
Sánchez de Miguel A., 2015, PhD thesis, Univ. Complutense de Madrid
Sánchez de Miguel A., Aubé M., Zamorano J., Kocifaj M., Roby J., Tapia C., 2017, MNRAS, 467, 2966
Tscharntke T., Hochberg M. E., Rand T. A., Resh V. H., Krauss J., 2007, PLoS Biol., 5, e18
Wyszecki G., Stiles W. S., 1982, Colour Science Vol. 8. Wiley, New York

This paper has been typeset from a TEX/LATEX file prepared by the author.

Maui Nui Seabird Recovery Project
868 Hali'imaile Road, Makawao, HI 96768
808.572-3500 – mauinuiseabirds@gmail.com
www.mauinuiseabirds.org

RECEIVED
2019 OCT 15 AM 7: 31
COUNTY OF MAUI
PUBLIC WORKS

RUSH 863

DEPT. OF PUBLIC WORKS — INFO / ACTION / SEE ME / COMMENTS / COPY / SCAN / FILE
DIRECTOR RMDA
DEPUTY DIR.
FISCAL ANALYST
PERSONNEL
ENGR.
HWY
SECTY.
Return to ______ Due ______

October 15, 2019

Ms. Rowena M. Dagdag-Andaya
Department of Public Works
200 South High Street, Room 434
Wailuku, Hawaiʻi 96793

Subject: **Early environmental consultation review. Maui County light emitting diode (LED) streetlight conversion project, Maui County, Hawaiʻi. DPW Project no.: 18-34**

Aloha Director Dagdag-Andaya,

Thank you for the opportunity to comment on the proposed conversion of The County of Maui streetlights from HPS to LED. We support the proposal to convert to LED for many of the reasons listed in the early consultation letter. However, the short wave length content of the previously selected, and partially installed product, is an increase from what the HPS content was and is well above what we believe is healthy for humans, wildlife, and astronomy. We believe that filtered light emitting diodes (FLED) provide all the benefits of LED and reduce the negative impacts of short wave length light or blue light at night (BLAN).

Artificial light at night (ALAN) is an extremely recent development in the evolution of life on planet earth. Humans, wildlife, plant communities, and near shore coral reef communities all developed over millennia and require darkness for optimal health. There is an increasing volume of literature reflecting the undesirable effects of BLAN on everything from human health, wildlife distraction, and agricultural crop suppression to coral reef ecology.

We expect that a thorough environmental review will identify and apply the lessons of the research that is available. Outdoor lighting should be used only to provide light where it is needed in the minimum intensity to provide for safety and visibility. Lighting should be provided with motion detectors and timers wherever possible. Lights should be down directed, and shielded to further control light trespass. FLED that reduces the energy content of 400-500nm to less than 2% is the standard that has the best potential to reduce or eliminate the deleterious effects of BLAN.

The two month pilot project on Maui Lani Parkway provided FLED options that were effective in providing good color rendering and minimal glare. The option that the Public Works Department chose has excessive glare and increases the BLAN by approximately 3% over the replaced HPS.

We look forward to participating in the development of the environmental assessment and working with Public Works and the county council to arrive at new outdoor lighting standards that recognize the most recent science in protecting our resident's and visitor's health, our wildlife and the valuable darkness of the night for all beings.

Jay F. Penniman
Manager, Maui Nui Seabird Recovery Project
808-280-4114 (Mobile)

OFFICE OF PLANNING
STATE OF HAWAII

DAVID Y. IGE
GOVERNOR

MARY ALICE EVANS
DIRECTOR
OFFICE OF PLANNING

235 South Beretania Street, 6th Floor, Honolulu, Hawaii 96813
Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804

Telephone: (808) 587-2846
Fax: (808) 587-2824
Web: http://planning.hawaii.gov/

September 30, 2019

Ms. Rowena M. Dagdag-Andaya
Director of Public Works
County of Maui
200 South High Street, Room 434
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya:

Subject: Early Consultation Review, Maui County Light Emitting Diode Streetlight Conversion Project, DPW Project No. 18-34

Thank you for the opportunity to provide comments on the early consultation request for the preparation of a Draft Environmental Assessment (Draft EA) on the proposed light emitting diode (LED) streetlight conversion project for Maui County.

It is our understanding that the project involves the replacement of approximately 4,800 streetlight fixtures along County roadways on Maui, Molokai, and Lanai. Work includes the removal and disposal of existing halogen streetlight fixtures and the installation of the new LED fixtures. It is anticipated that the project will result in improved roadway safety and visibility while simultaneously reducing energy consumption, and operating expenses. LED lights are expected to provide greater reliability, lower maintenance costs, and reduce carbon emissions.

The Office of Planning (OP) has reviewed the transmitted material and has the following comment to offer:

Impact of Exterior Lighting

In enacting Act 224, Session Laws of Hawaii 2005, the legislature found that:

[l]Light pollution in Hawaii's coastal areas and artificial lighting illuminating the shoreline and ocean waters can be disruptive to avian and marine life. Light pollution in these areas has been documented as causing the death of hatching sea turtles, fledgling shearwaters, nocturnal flying sea birds, and migratory birds.

Pursuant to HRS §§ 205A-30.5(b)(2) and 205A-71(b), for artificial lighting provided by a government agency or its authorized users for government operations, security, public safety, or navigational needs, a government agency or its authorized users shall make reasonable efforts to properly position or shield lights to minimize adverse impacts.

The Draft EA should therefore assess potential impacts from the proposed activity and discuss reasonable efforts to properly shield these lights to minimize adverse impacts.

If you have any questions regarding this comment letter, please contact Joshua Hekekia of our office at (808) 587-2845.

Mahalo,

Mary Alice Evans

Mary Alice Evans
Director

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE
MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

September 20, 2019

County of Maui
Department of Public Works
Attn: Ms. Rowena M. Dagdag-Andaya — via email: public.works@mauicounty.gov
200 South High Street, Room 434
Wailuku, Hawaii 96793

Dear Ms. Dagdag-Andaya :

SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** within Maui County; Islands of Maui, Molokai, and Lanai (DPW Project No. 18-34)

Thank you for the opportunity to review and comment on the subject matter. In addition to our previous comments dated September 19, 2019, enclosed are comments from the Division of Aquatic Resources on the subject matter. Should you have any questions, please feel free to contact Darlene Nakamura at (808) 587-0417 or email: darlene.k.nakamura@hawaii.gov. Thank you.

Sincerely,

Russell Y. Tsuji
Land Administrator

Enclosures
cc: Central Files

DAVID Y. IGE
GOVERNOR OF HAWAII

RECEIVED
LAND DIVISION
SEP 19 AM 10:55
DEPT. OF LAND & NATURAL RESOURCES
STATE OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

RECEIVED
AUG 30 2019
Division of Aquatic Resources
DAR 6007

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

August 28, 2019

MEMORANDUM

TO: **DLNR Agencies:**
X Div. of Aquatic Resources
X Div. of Boating & Ocean Recreation
X Engineering Division
X Div. of Forestry & Wildlife
X Div. of State Parks
X Commission on Water Resource Management
X Office of Conservation & Coastal Lands
X Land Division – Maui District
X Historic Preservation

FROM: Russell Y. Tsuji, Land Administrator
SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** (DPW Project No. 18-34)
LOCATION: Maui County; Islands of Maui, Molokai, and Lanai
APPLICANT: County of Maui, Department of Public Works

Transmitted for your review and comment is information on the above-referenced subject matter. Please submit any comments by **September 18, 2019.**

If no response is received by this date, we will assume your agency has no comments. If you have any questions about this request, please contact Darlene Nakamura at 587-0417 or by email at darlene.k.nakamura@hawaii.gov. Thank you.

( ) We have no objections.
( ) We have no comments.
(X) Comments are attached.

Signed:
Print Name: Brian Neilson
Date: 9/17/19

Attachments
cc: Central Files

DAVID Y. IGE
GOVERNOR OF
HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
FIRST DEPUTY

M. KALEO MANUEL
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF AQUATIC RESOURCES
1151 PUNCHBOWL STREET, ROOM 330
HONOLULU, HAWAII 96813

Date: 09/10/2019
DAR # 6007

MEMORANDUM

TO: Brian J. Neilson
DAR Administrator

FROM: Russell Sparks, Aquatic Biologist

SUBJECT: Early Environmental Consultation Review of the Proposed Maui County Light Emitting Diode (LED) Streetlight Conversion Project.

Request Submitted by: Russell Y. Tsuji, Land Administrator

Location of Project: Maui County, Islands of Maui, Molokai, and Lanai

Brief Description of Project:

The county of Maui is seeking comments as part of an early environmental consultation process relating to their efforts to replace existing High Pressure Sodium (HPS) street lights with more efficient Light Emitting Diode (LED) light fixtures. This consultation is in support of an upcoming environmental Assessment (EA) process being conducted by the county Department of Public Works (DPW).

Comments:
☐ No Comments ☒ Comments Attached

Thank you for providing DAR the opportunity to review and comment on the proposed project. Should there be any changes to the project plan, DAR requests the opportunity to review and comment on those changes.

Comments Approved: _______________ Date: 9/17/19
Brian J. Neilson
DAR Administrator

DAR# ____________

Comments

The Division of Aquatic Resources is concerned with the known and unknown impacts of lighting on sensitive marine and coastal marine animals and ecosystems. There is documented concerns with the effects high levels of lighting can have on nesting sea turtles, newly hatched sea turtles and on many species of sea birds. All these animals can be easily disoriented by lights and this often results in high levels of mortality to these animals during critical periods of their life histories. There is also, very likely less obvious impacts that occur to coastal ecosystems and to nearshore marine habitats that are not as well documented and understood. Therefore, we suggest extreme caution be exercised during the planning and conversion to these new LED fixtures. LED fixtures need to be filtered to make sure that they release no more than 2% of short wave length light (light wave lengths less than 550nm). This standard is especially critical anywhere near sensitive coastal or marine habitats. However, the technology to filter these lights is widely available and been shown to have a low impact on light efficiency. DAR suggests, therefore, that these filtered lights be the standard used everywhere.

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

September 19, 2019

County of Maui
Department of Public Works
Attn: Ms. Rowena M. Dagdag-Andaya
200 South High Street, Room 434
Wailuku, Hawaii 96793

via email: public.works@mauicounty.gov

Dear Ms. Dagdag-Andaya :

SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** within Maui County; Islands of Maui, Molokai, and Lanai (DPW Project No. 18-34)

Thank you for the opportunity to review and comment on the subject matter. The Land Division of the Department of Land and Natural Resources (DLNR) distributed or made available a copy of your request pertaining to the subject matter to DLNR's Divisions for their review and comments.

At this time, enclosed are comments from the (a) Engineering Division, (b) Division of State Parks, and (c) Land Division – Maui District on the subject matter. Should you have any questions, please feel free to contact Darlene Nakamura at (808) 587-0417 or email: darlene.k.nakamura@hawaii.gov. Thank you.

Sincerely,

Russell Y. Tsuji
Land Administrator

Enclosures
cc: Central Files

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

August 28, 2019

MEMORANDUM

'19 AUG 29 AM10:35 ENGINEERING

~~TO:~~ FROM

DLNR Agencies:
X Div. of Aquatic Resources
X Div. of Boating & Ocean Recreation
X Engineering Division
X Div. of Forestry & Wildlife
X Div. of State Parks
X Commission on Water Resource Management
X Office of Conservation & Coastal Lands
X Land Division – Maui District
X Historic Preservation

~~FROM:~~ TO
Russell Y. Tsuji, Land Administrator

SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** (DPW Project No. 18-34)

LOCATION: Maui County; Islands of Maui, Molokai, and Lanai

APPLICANT: County of Maui, Department of Public Works

Transmitted for your review and comment is information on the above-referenced subject matter. Please submit any comments by **September 18, 2019.**

If no response is received by this date, we will assume your agency has no comments. If you have any questions about this request, please contact Darlene Nakamura at 587-0417 or by email at darlene.k.nakamura@hawaii.gov. Thank you.

( ) We have no objections.
(✓) We have no comments.
( ) Comments are attached.

Signed: ______

Print Name: Carty S. Chang, Chief Engineer

Date: 9/3/19

Attachments
cc: Central Files

57894

DAVID Y. IGE
GOVERNOR OF HAWAII

RECEIVED
LAND DIVISION

2019 SEP -4 AM 10:56

RECEIVED
DEPT. OF LAND & NATURAL RESOURCES
STATE OF HAWAII

'19 AUG 30 AM 10:32

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

DEPT OF LAND & NATURAL RESOURCES

August 28, 2019

MEMORANDUM

TO: **DLNR Agencies:**
X Div. of Aquatic Resources
X Div. of Boating & Ocean Recreation
X Engineering Division
X Div. of Forestry & Wildlife
X Div. of State Parks
X Commission on Water Resource Management
X Office of Conservation & Coastal Lands
X Land Division – Maui District
X Historic Preservation

FROM: Russell Y. Tsuji, Land Administrator
SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** (DPW Project No. 18-34)
LOCATION: Maui County; Islands of Maui, Molokai, and Lanai
APPLICANT: County of Maui, Department of Public Works

Transmitted for your review and comment is information on the above-referenced subject matter. Please submit any comments by **September 18, 2019.**

If no response is received by this date, we will assume your agency has no comments. If you have any questions about this request, please contact Darlene Nakamura at 587-0417 or by email at darlene.k.nakamura@hawaii.gov. Thank you.

( ) We have no objections.
(✓) We have no comments.
( ) Comments are attached.

Signed: [signature]

Print Name: CURT COTTRELL

Date: 8.30.19

Attachments
cc: Central Files

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

RECEIVED
LAND DIVISION
2019 SEP 13 AM 8:18
DEPT. OF LAND & NATURAL RESOURCES
STATE OF HAWAII

August 28, 2019

MEMORANDUM

2019 SEP -3 PM 3:56

TO: **DLNR Agencies:**
X Div. of Aquatic Resources
X Div. of Boating & Ocean Recreation
X Engineering Division
X Div. of Forestry & Wildlife
X Div. of State Parks
X Commission on Water Resource Management
X Office of Conservation & Coastal Lands
X Land Division – Maui District
X Historic Preservation

FROM: Russell Y. Tsuji, Land Administrator
SUBJECT: Early Environmental Consultation Review of the Proposed **Maui County Light Emitting Diode (LED) Streetlight Conversion Project** (DPW Project No. 18-34)
LOCATION: Maui County; Islands of Maui, Molokai, and Lanai
APPLICANT: County of Maui, Department of Public Works

Transmitted for your review and comment is information on the above-referenced subject matter. Please submit any comments by **September 18, 2019.**

If no response is received by this date, we will assume your agency has no comments. If you have any questions about this request, please contact Darlene Nakamura at 587-0417 or by email at darlene.k.nakamura@hawaii.gov. Thank you.

( ) We have no objections.
( ) We have no comments.
(X) Comments are attached.

Signed:

Print Name: Daniel Ornellas

Date: 9/12/19

Attachments
cc: Central Files

Suggest they consult with DOFAW + USFWS to determine Best Management Practices related to shielding of ambient light using shields.

Appendix E. *Maui County's LED Street Light Conversion Wildlife Technical Report for an Environmental Assessment* report prepared by Hamer Environmental LP

Maui County's LED Street Light Conversion
Wildlife Technical Report for an Environmental Assessment


Prepared for:

County of Maui
Public Works - Engineering Division
200 South High Street
Wailuku, Hawaii 96793

Prepared by:

Hamer Environmental LP
P.O Box 256
Mount Vernon, WA 98273

April 22, 2022

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

CCT	Correlated Color Temperature
CRI	Color Rendering Index
DLNR	Department of Land and Natural Resources
DPS	Distinct Population Segment
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FFS	French Frigate Shoals
FONSI	Finding of No Significant Impact
GRST	Green Sea Turtle
HAPE	Hawaiian Petrel
HAR	Hawai'i Administrative Rule
HAST	Hawksbill Sea Turtle
HCP	Habitat Conservation Plan
HEPA	Hawai'i Environmental Policy Act
HPS	High-Pressure Sodium
HWF	Hawai'i Wildlife Fund
IDSA	International Dark Sky Association
IES	Illuminating Engineering Society
ITP	Incidental Take Permit
K	Kelvin
KSHCP	Kauai Seabird Habitat Conservation Plan
LED	Light Emitting Diode
LPS	Low Pressure Sodium
MBTA	Migratory Bird Treaty Act
MEC	Maui Electric Company
MHI	Main Hawaiian Islands
MNSRP	Maui Nui Seabird Recovery Project
NESH	Newell's Shearwater
NFP	Natal Foraging Philopatry
nm	Nanometer
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWHI	Northwestern Hawaiian Islands
PE	Photo Electric (Sensors)
PMRF	Pacific Missile Range Facility
SOS	Save Our Shearwaters
USFWS	U.S. Fish and Wildlife Service
WTSH	Wedge-tailed Shearwater

1. Introduction

The County of Maui, for purposes of this report, encompasses the islands of Maui, Moloka'i, and Lāna'i. All three islands contain streetlight infrastructure owned by the County of Maui. The Maui County Streetlight Conversion Project (hereafter, project) proposes to replace all existing County-owned High-Pressure Sodium (HPS) streetlight fixtures with Light Emitting Diode (LED) fixtures. The project involves the replacement of a total of 4,820 streetlight fixtures located along County of Maui roadways on the island of Maui (4,313), the island of Moloka'i (365), and the island of Lāna'i (142). The purpose of the project is to increase roadway safety and visibility while simultaneously reducing energy consumption and County of Maui operating expenses.

Hawai'i Wildlife Fund (HWF) and the Conservation Council for Hawai'i represented by the organization Earthjustice filed a lawsuit in February 2019 contending that the County of Maui (County) did not fully comply with HRS Chapter 343 prior to proceeding with the project (Earth Justice 2020). Representatives from these groups have stated the project would disorient sea turtles and seabirds among other nocturnal species. Specifically, four species federally protected under the Endangered Species Act (ESA) could be potentially impacted: threatened Newell's Shearwater (*Puffinus newelli* [NESH]), endangered Hawaiian Petrel (*Pterodroma sandwichensis* [HAPE]), endangered Hawksbill Sea Turtle (*Eretmochelys imbricata* [HAST]) and the threatened Distinct Population Segment of the Hawaiian Green Sea Turtle (*Chelonia mydas*, [GRST]). Negative impacts caused to federally protected species or critical habitats constitutes "take" under the ESA.

1.1 Scope

The scope of this Technical Report is to provide technical information in support of an Environmental Assessment (EA). This report focuses on comparing aspects of HPS and LED lighting fixtures and evaluating available information to assess potential impacts to the four ESA-listed species resulting from the project and to propose measures to reduce and/or avoid those impacts. This report considers the:

- Regulatory framework for streetlights and light emittance standards: Federal, State, and County;
- Biological, ecological, physiological, behavioral and population aspects unique to the four ESA species (NESH, HAPE, HAST, and GRST) among the islands of the County of Maui;
- General description of the County of Maui nighttime environment in terms of artificial light;
- Nation-wide streetlight conversion projects in several states including Hawai'i; and
- Differences between the existing streetlight fixture type (GE 2100 Kelvin (K) HPS) and the proposed light fixture type (GE 2700K LED).

1.2 Regulatory Framework

Regulatory compliance is appliable to the project on federal, state and county levels. The following regulations referenced in this technical report are listed and briefly summarized.

1.2.1 Endangered Species Act (ESA)

The purpose of the ESA is to protect and recover endangered and threatened species and the ecosystems upon which they depend. Section 9 of the ESA and Federal regulation pursuant to Section 4(d) of the ESA prohibit the "take" of endangered and threatened species without special exemption. Under the ESA, "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (16 USC § 1532(19)). Further, "harm" includes significant habitat modification or degradation that results in death or injury to a listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). "Incidental take" means take that is incidental to, and not the purpose of, the conduction of an otherwise lawful activity. Section 7(a)(2) of the ESA requires Federal agencies to ensure that actions, including the issuance of permits, do not jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat. "Jeopardize the continued existence of…" pursuant to 50 CFR 402.2, means to engage in an action that would be expected, directly or indirectly, to appreciably reduce the likelihood of the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

1.2.2 Federal Migratory Bird Treaty Act (MBTA)

The MBTA of 1918, as amended (16 USC § 703-712), prohibits the take of migratory birds and makes it unlawful to pursue, hunt, take, capture, kill, possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product without proper authorization. Pursuant to U. S. Fish and Wildlife (USFWS) policy, an Incidental Take Permit (ITP) also constitutes a Special Purpose Permit under 50 CFR § 21.27 for the take of ESA-listed migratory bird species so long as the permit holder maintains compliance with the ITP terms and conditions. Under those circumstances, the take of ESA-listed migratory birds would not be considered a violation of the MBTA.

1.2.3 HRS Chapter 343, the "Hawai'i Environmental Policy Act" and HAR Chapter 200.1

The origin of the National Environmental Protection Act provided a model for the development of HRS Chapter 343 in 1974; it is commonly referred to as the "Hawaiʻi Environmental Policy Act" or HEPA. HEPA's implementing regulations are contained in Hawaiʻi Administrative Rule (HAR) Title 11, Chapter 200.1. HEPA established environmental policies and guidelines for state and county agencies. HEPA mandated environmental assessments for all state and county projects and some private projects. State and county projects may comply with HEPA via an exemption, an EA and Finding of No Significant Impact (FONSI), or an Environmental Impact Statement (EIS). The EA will contain: a "general description of the action's technical, economic, social, cultural, historical and environmental characteristics," "identification and analysis of impacts and alternatives considered," and "proposed mitigation measures," among other minimum contents.

1.2.4 HRS Chapter 195D

Chapter 195D of the HRS defines the State's responsibilities, with respect to species listed as endangered or threatened, to protect and conserve native wildlife and their habitats including species federally listed as endangered or threatened. Under the provisions of HRS Chapter 195D, species listed as endangered or threatened pursuant to the ESA are also listed as endangered or threatened by the State of Hawai'i law (HRS §195D-4). Section 195D-2 defines "take" similarly to the Federal ESA. Section 195D-3 expressly prohibits, except as permitted by rules, any person to take, possess, transport, transplant, export, process, sell, offer for sale, or ship any species that the Department of Land and Natural Resources (DLNR) has deemed in need of protection (see also §195D-4(e)).

The ESA and Hawai'i Revised Statutes (HRS) §195D prohibit take of endangered species. If take is unavoidable, the County would need to obtain an incidental take permit pursuant to 10(a)(1)(B) of the ESA and an incidental take license from the State of Hawai'i DLNR pursuant to HRS §195D. The latter requires a Habitat Conservation Plan (HCP) be completed outlining mitigation measures to implement to minimize and mitigate take of endangered species.

1.2.5 Hawai'i State House Bill HB 155 CD1

The State lighting ordinance H.B. 155 (State of Hawai'i 2007) went into effect in July 2007, and requires most light sources to be fully shielded, such that light is directed downward only, emitting no uplight (light placed or designed to throw illumination upward above the horizon). The regulations "focus on requiring streetlights and some commercial lighting to be "shielded," preventing glare from shining into the night sky."

1.2.6 County of Maui Ordinance 3430

Chapter 20.35 *Outdoor Lighting* of Maui County Ordinance 3430 establishes standards for the type and use of outdoor lights to protect against excess light capable of degrading "the night visual environment." In 2015, the County's Outdoor Lighting Standards Committee amended regulations to set deadlines for bringing all county lights installed prior to January 2007 into compliance with current shielding requirements and usage restrictions (Council of the County of Maui 2015).

2. Methods

A desktop analysis was performed of available online sources for information relevant to the project with an emphasis on the four federally listed species and their populations on each of the County's islands. Data was gathered on each species to provide pertinent details on population status and trends, breeding behaviors, breeding locations, differences among age classes, and habitat use. A fifth species, a seabird that is a Migratory Bird Treaty Act (MBTA) protected species, is briefly addressed (see Section 2.1). Data was also gathered on nighttime light sources, aspects of light pollution and impact to wildlife (specifically seabirds and sea turtles), and aspects related to the vision of these nocturnal animals. Lighting information was received from the County regarding fixtures and product specification sheets provided by the lighting company from which the existing HPS and new LED lights were purchased. Documents from federal, state, and county agencies pertaining to outdoor lighting requirements, endangered species protection measures, and regulatory codes were incorporated into the report. Articles and reports citing case studies of metropolitan cities and residential neighborhoods that have undergone light conversions were included along with conservation efforts and measures taken to reduce light-induced adverse effects on nocturnal species (specifically seabirds and sea turtles).

Information and data were compiled and organized based on the technical scope of work outlined in the Statement of Work for the project. Methods for analyzing level of potential project impact considered:

- the four ESA-listed species potentially affected,
- characteristics and differences in visual capabilities between humans and these four species,
- County of Maui nighttime environment, and
- the differences between the existing county light sources (HPS) and the proposed light sources (LED).

2.1 Seabirds

Sources for both NESH and HAPE regarding population status, flyway use, flight behaviors, breeding colony locations, post-fledging behavior, and tracking population trends comes from research involving ornithological radar throughout the Main Hawaiian Islands (MHI) (Brandt et al. 1995; Cooper and Day 1995, 1998, 2003; Day and Cooper 1995, 2002; Day et al. 2003a; Day et al. 2003b; Day et al. 2005; Deringer 2009; Deringer et al. *in prep-a;* Deringer et al. 2011a; Gall and Obritschkewitsch 2019).

Additional information was provided during scoping of the Kaua'i Seabird Habitat Conservation Plan, habitat conservation plans with a seabird component on Maui, and published or publicly available studies assessing the effect of different light spectra on nocturnal seabirds, vision in nocturnal birds, and migratory navigation cues (magnetic, olfactory, visual, etc.) used by nocturnal seabirds (Bastos et al. 2020; Bingman and MacDougall-Shackleton 2017; Bonadonna and Gagliardo 2021; Brandt et al. 1995; Cruz and Lindner 2011; Griesemer and Holmes 2011; Hu et al. 2001; Martin and Osorio 2010; Nevitt et al. 1995; Penniman and Duffy 2021; Pollonara et al. 2015; Syposz et al. 2021a; Syposz et al. 2021b; Taylor et al. 2020; Telfer et al. 1987; Troy et al. 2013; Tyagi and Bhardwaj 2021; USFWS 2005; Van Doren et al. 2017).

Sources for NESH are primarily from Kaua'i where nesting numbers are the highest in the world. Information on population status and long-term trend tracking has been conducted using direct and indirect measures of breeding activity. Direct measures, such as physically monitoring nest success within a known colony, are difficult to obtain given the bird's discrete breeding activity and remote colony locations. Therefore, indirect measures of breeding activity are also used, including ornithological radar, audio, and visual survey methods; compiling seabird salvage data (recovery of birds found on the ground); and conducting spatial auditory and visual surveying techniques at known colonies.

Information for this report included direct observations during a cross-fostering experiment (1980-1984) where 90 eggs were taken from a colony and raised by Wedge-tailed Shearwaters (Byrd et al. 1984; Telfer 1986), a breeding study (1993-1994) (Ainley et al. 1997b), and detailed observations of two pairs (likely cross-foster progeny) at Kilauea Point National Wildlife Refuge since 1997 and 2001 (Zaun 2009). Timing of fledging was determined from island-wide 'fallout' of fledglings, birds fallen victim to light attraction or collision with artificial structures (Telfer et al. 1987) and collected by members of the public as part of Save Our Shearwaters (SOS) program (n=29,359; 1979-2008) (State of Hawaiʻi 2009). Further, information on salvaged birds that were subsequently rehabilitated, banded, and released was used (Raine et al. 2020), along with research on the post dispersal of fledglings (Joyce et al. 2010; Raine et al. 2018). Additional sources included auditory monitoring at Moalepe, a site located in the Makaleha Mountains approximately 1.2 km from a known breeding colony (Deringer 2009; KESRP 2009b), at-sea observations of bird density (1984-1994) (Spear et al. 1995; Spear et al. 1999), intra-seasonal variation in radar passage rates (Day and Cooper 1995, 2008; Deringer 2009; King and Gould 1967; Sincock and Swedberg 1969), and historical observations (King and Gould 1967; Sincock and Swedberg 1969). Relevant research regarding population status, breeding colony locations, and known effects of light pollution were also used (Griesemer and Holmes 2011; Holmes et al. 2011; Holmes et al. 2009; Newell's Shearwater Working Group 2005; Podolsky et al. 1998; Reed 1987; Reed et al. 1986; USFWS 2009b; Vanzandt et al. 2014).

For HAPE, phenology described from studies and monitoring efforts in the Haleakalā National Park colony on east Maui remains the most detailed information available. Richardson and Woodside (1954) provided initial observations, with greater detail from Simons (1985) during breeding studies (1979-1981), and later updated within the Birds of North America species account (Simons and Natividad Hodges 1998). Further information was from predator trapping efforts, assessing conservation fencing of colonies (1981-1994) (Hodges and Nagata 2001), visual and auditory surveys in 2005 (Natividad Bailey 2009b), and records of island-wide fallout as a proxy for fledging between 1996-2007 (n=99 east, n=12 west) (Natividad Bailey 2009a).

Sources for HAPE on remaining islands were less detailed. From Kaua'i, direct breeding observations were used from Upper Limahuli Preserve (north shore, 2006-2009) (Holmes 2006; Holmes and Joyce 2009), observations of island-wide fallout and visual surveys of birds on the north shore (1993-1994) (Ainley et al. 1997a; Ainley et al. 1997b; State of Hawaiʻi 2009), and intra-seasonal variation in radar passage rates (north and east shores, 2008) (Day and Cooper 1995; Deringer 2009), with timing of fledging determined from island-wide fallout (n=282, 1979-2008, (State of Hawaiʻi 2009)). On Lāna'i, where population information is limited, phenology is estimated from evidence of breeding activity (2006-2007) observed by Penniman and Duval (2008) within a colony discovered in 2006 (MNSRP 2022) and further investigated by VanZandt et al. (2014) and auditory detections in 1976 and 1977 (Hirai 1978). Genetic information and fossil evidence supporting population structure was also incorporated (Burg and Martin 2012; Olson and James 1982a, 1982b; Olson and James 1991). Background and conservation information for HAPE came from management, habitat, and mitigation plans (Holmes et al. 2011; USFWS 2009a; USFWS and State of Hawaiʻi 2011).

The Wedge-tailed Shearwater (WTSH) (*Ardenna pacifica)* is listed under the MBTA of 1918 and not addressed in this report along with the ESA-listed NESH and HAPE. The WTSH is a burrow-nesting seabird that is found globally in the tropics and subtropics (Warham 1996). Overall global populations of this species are either stable or on a downward trend and estimated at over 5 million birds with approximately 40,000 to 60,000 pairs breeding in the MHI (HDLNR 2015). The WTSH differs from NESH and HAPE in some respects. WTSH utilizes different nesting habitats, preferring coastal shores and offshore islets, the latter providing predator-proof security, but can use upland volcanic slopes as well. The fledglings of coastal-nesting WTSH would not have to traverse over inland artificial lights but could be affected by coastal lighting. The timing of the synchronous breeding cycle is similar to NESH and HAPE in that nesting can extend from colony arrival in March to fledging in late November to mid-to-late December; this fledging period coincides with WTSH fallout on Maui Island (Penniman 2022). Limited studies on WTSH in a region of O'ahu provide evidence that the species would not be affected by the proposed LED streetlight conversion project (no change in impact) (Urmston et al. 2020; Friswold et al. 2020; Idle et al. 2021;

Hyrenbach et al. 2022). That WTSH is the most prevalent species of all fallout species collected on Maui Island would suggest this species colonizes there in higher numbers than either NESH or HAPE. Avoidance and minimization measures presented in Chapter 7, especially those for coastal areas (sea turtles), would also benefit WTSH.

2.2 Sea Turtles

Sources were used to describe population status, breeding behaviors, location of nesting beaches, locations of resting and foraging areas, and tracking population trends in the MHI (Arthur and Balazs 2008; Balazs 1980, 1994; Balazs et al. 1987; Balazs et al. 1994; Balazs et al. 2015a; Balazs et al. 2015b; Bowen et al. 1992; Brunson et al. 2017; Katahira et al. 1994; King 2015; King et al. 2004; NOAA Fisheries 2011a, 2011b, 2017; Nurzia-Humburg and Hargrove 2008; Owens 1980; USFWS 2015, 2016; Whittow and Balazs 1982).

Sea Turtle Recovery Plans, Habitat Conservation Plans, and agency reports with information on nesting success trends, stock assessments, salvage/stranding numbers, and conservation management issues were used, including impacts from artificial nighttime light pollution (Balazs et al. 1992; Brei et al. 2019; Cutt and Martin 2019, 2020; NMFS and USFWS 1998a, 1998c, 1998b, 2007; NOAA Fisheries 2017; Salmon 2003).

Since 2010, the Pacific Islands Region Marine Turtle Management and Conservation Program has supported monitoring and conservation activities of the Hawai'i Hawksbill Recovery Project in Maui via the non-governmental organization, HWF. The Hawksbill Recovery Project monitors nesting activity, tags nesting females, collects data on foraging (individuals, relative threats, and foraging substrate) by swimming transects, and direct observations (Seitz et al. 2012; Van Houtan and Kittinger 2014). Further, the project mitigates threats to turtles, nests and hatchlings through invasive predator and exotic vegetation removal, protects nesting habitats by promoting no driving of vehicles on beaches, promotes light impact reduction from hotels and residences, coordinates marine debris beach cleanup efforts, and provides extensive community outreach and education to support.

2.3 Assessment

Assessing impacts to rare and endangered species is often difficult given their low numbers, low detection probability and the difficulties in making direct observations. Information gathered on each of the potentially affected species (Chapter 3) was pooled and evaluated in tandem with nighttime lighting attributes. Assessing light attributes incorporated information such as product specification sheets, applicable government regulations, aspects of large-scale streetlight conversion projects, characteristics and properties of light, various ways to reduce light pollution, and vision in humans and the four potentially affected species.

Individual pieces of information that were reviewed were represented in varying formats (text, maps, graphs, etc.). Further, the metrics presented in reports and studies also varied. Assessment of the diversity of information gathered accounted for this heterogeneity in data.

3. Potentially Affected Species

3.1 SEABIRDS

Two federally protected seabird species potentially affected are the Hawaiian Petrel (HAPE) and Newell's Shearwater (NESH). Adults of both species only come ashore each year to breed, laying a single egg in an underground burrow or within rock crevices, and cooperatively raise a single chick to fledging. They have synchronized flight patterns during the breeding season and are nocturnal when coming ashore. Adults fly ashore after sunset and fly seaward pre-sunrise. The young of both species fledge from their burrow and fly to the ocean in complete darkness; during this maiden flight they are susceptible to negative impacts associated with artificial lights.

Both NESH and HAPE nest exclusively in the MHI. For NESH, breeding occurs primarily on Kaua'i with smaller populations on Maui, Hawai'i and possibly Moloka'i (Cluett Pactol 2018) and O'ahu (Young et al. 2019). HAPE, once found on all the MHIs, primarily nest near the summit of Haleakalā Crater on Maui, the higher slopes of Lānaʻihale on Lāna'i, and remote areas of Kaua'i, with smaller numbers on Moloka'i and Hawai'i. Both HAPE and NESH share similar and specific behaviors during their breeding cycle and throughout their nesting range. However, differences exist between the species and by island. For example, the breeding cycle between HAPE and NESH differ slightly in timing, and HAPE exhibit both inter- and intra-island differences in synchronous colony behavior.

During nocturnal flights, these seabirds can become confused around, or blinded by, certain bright artificial light sources and, should this happen, may circle the lighted area until colliding with structures or becoming exhausted (Ainley et al. 1997a; Ainley et al. 1997b; Podolsky et al. 1998). In either case, birds that "fallout" of the sky and land on the ground are unable to take off, making them susceptible to predation, dehydration, starvation, and being hit by cars.

3.1.1 NEWELL'S SHEARWATER

The NESH is a medium-sized shearwater, endemic to Hawai'i and listed as threatened under the Endangered Species Act of 1973 (Harrison 1990; USFWS 2009b). The International Union for Conservation of Nature (IUCN) Red List consider NESH as endangered (IUCN 2017). Approximately 90% of the global population of the species breeds on Kaua'i, therefore, what is mostly known about this species in Hawai'i is based on data collected from that island's populations. Information on NESH from Kaua'i has come from long-term (37 years), large-scale (island-wide), and multiple studies using different methods of data collection.

3.1.1.1. POPULATION STATUS AND DISTRIBUTION

The population of NESH throughout the State of Hawai'i was estimated to be 84,000 birds including 14,600 breeding pairs in the 1990's (Ainley et al. 1997b; Cooper and Day 1995; Spear et al. 1995). Population estimates in 2014 were 27,011 birds, including 16,000-19,000 breeding pairs (BirdLife International 2021). Based on population monitoring on Kaua'i there was a drastic decline in NESH numbers between 1993 and 2013. Radar surveys from 1993 to 2013 and the number of SOS salvaged fledglings from 1979 to 2015 indicate a 94% decline (Else 2018; KESRP 2009a, 2009b; Raine et al. 2017), occurring at an average rate of approximately 13% per year during the period analyzed (Raine et al. 2017). Researchers believe NESH numbers are likely being underestimated and eminent population collapse is predicted without intervention and management (Griesemer and Holmes 2011; Raine et al. 2017).

The population status of NESH in the County of Maui, specifically Maui, Lāna'i and Moloka'i Islands is not known. An estimate by Cooper and Day (2003) using ornithological radar put the number of NESH coming ashore on the island of Maui during June 2001 at ≥ 140 birds (≥ 51 in the west; ≥ 89 in the east).

3.1.1.2. Breeding Phenology

These are extremely discrete, burrow-nesting birds; chicks are raised by both parents and remain below ground with their first flight out of the colony each fall occurring in the dark of night. While juvenile birds remain at sea for years after fledging, individuals that have reached sexual maturity (adult breeders and sub-adult pre-breeding birds) come ashore to attempt to nest April through November. The yearly breeding cycle of NESH on Kaua'i is about 30 to 32 weeks (Figure 1), from colony arrival in April until the fledging of chicks in October to November. On Kaua'i, arrival of individuals begins in the first two weeks of April, when birds return to prospect for nest sites. A pre-laying exodus from the colony by females follows in late April and May and flyway activity decreases noticeably. A highly synchronized egg-laying, where pairs produce one egg, occurs in early and June continues through the early part of July; the peak of fledging occurs late October into early November.

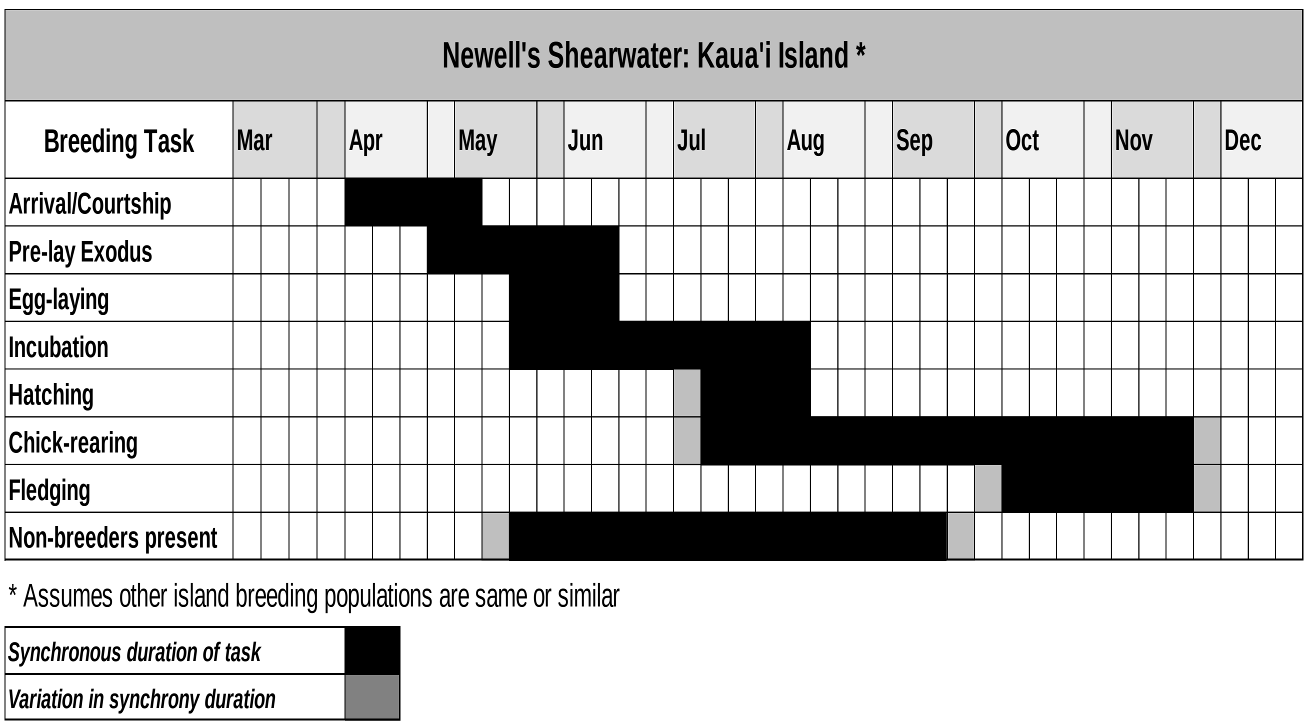


Figure 1. Breeding phenology for NESH on Kaua'i Island where the species primarily nests and has been extensively studied during the breeding season (Deringer et al. *in prep-b*). Sources also listed in Methods 2.1 Seabirds.

3.1.1.3. Breeding Colonies

NESH are a colonial nesting seabird (Warham 1990). Most colonies on Kaua'i occur between 160 and 1,200 m (525–3,936 ft) elevation on steep, densely vegetated terrain. However, birds also nest on the dry, sparsely vegetated cliffs of the Nā Pali coast and on Lehua Islet (Wood and Biley 2008).

On Maui Island, NESH occurrence studied in June 2001 using ornithological radar showed a higher proportion of NESH-like targets in west Maui than in east Maui (Cooper and Day 2003). One NESH nest was discovered in the mountains of east Maui in 2004 at 1,950 m (6,397 ft.) elevation (Figure 2) (Wood and Biley 2008). In 2019, the ongoing Makamaka'ole NESH social attraction project in west Maui (H.T. Harvey & Associates 2022) reported visitation by NESH in 22 nest boxes (Spencer et al. 2020).

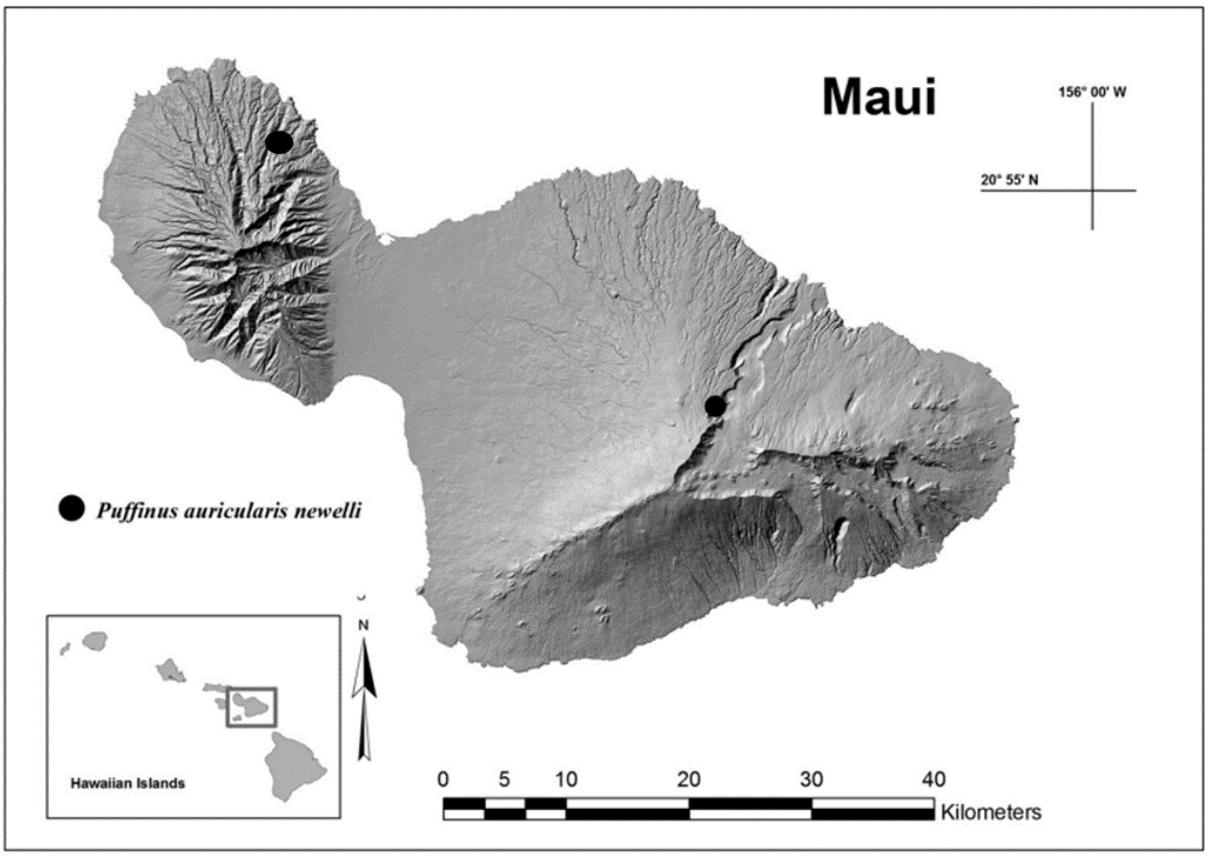


Figure 2. Known NESH nests on Maui Island; a social attraction project in the west mountains with artificial burrows (left) and a single nest found in the east (right) (Spencer et al. 2020; Wood and Biley 2008).

Nests have also been documented on Moloka'i (Cooper and Day 2003; Day et al. 2003a; VanderWerf et al. 2007); Day and Cooper (Day and Cooper 2002) detected radar targets that were considered NESH because of the timing of movement after sunset at Wai'ale'ia Valley, Kalaupapa Pali, and Waikolu/ Wai'ale'ia Valleys (Figure 3). The authors suspect that NESH may occur in all eight of the main valleys surveyed in northeastern Moloka'i with the Pelekunu and Wailau valleys having the greatest potential for nesting birds. The status of NESH breeding on Lāna'i Island is unknown but suspected (KIUC 2011).

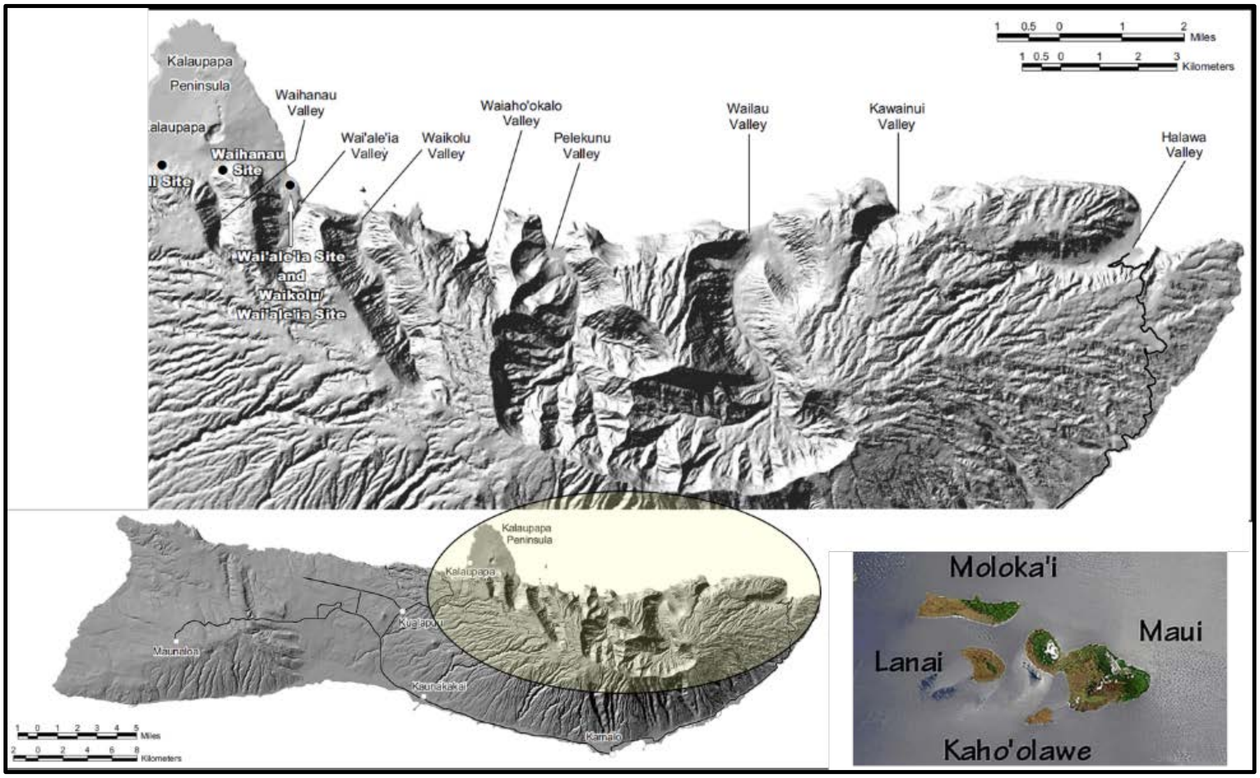


Figure 3. Moloka'i Island (bottom, left) and a close up of its eight major valleys in the northeast (top) surveyed with ornithological radar in June 2002 (Day and Cooper 2002).

3.1.1.4. Timing of Activity

On Kaua'i, NESH were found to exhibit almost no movement until after complete darkness, whereupon they moved inland in a wave that peaked from 40 to 60 minutes after sunset (Day and Cooper 1995; Deringer 2009). After that peak, the rate of movement decreases steadily until 90 minutes after sunset, after which few NESH are detected (Figure 4). In the morning, NESH begin moving to sea approximately 40 minutes before the first measurable light and movement rates increase rapidly, peaking just before measurable light at dawn (Day and Cooper 1995). Interpreting the timing of movement rates regardless of the type of data (visual observations, radar target, auditory calls) must account for the location of the study, for example measuring when birds come ashore at the coast will differ from those measured at high elevation inland colonies.

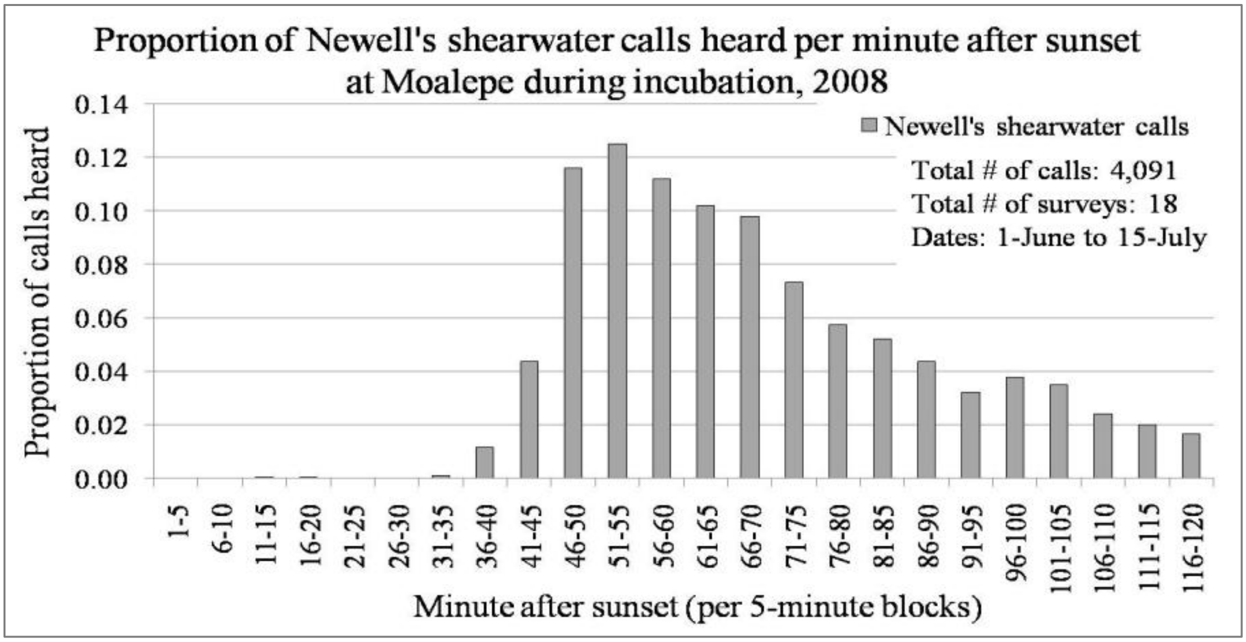


Figure 4. Timing of evening calling activity of Newell's shearwaters at the Moalepe colony, Kaua'i, during incubation based on auditory surveys (Deringer 2009).

3.1.1.5. Artificial Light Fallout

Fallout data collected over the years by SOS on Kaua'i has revealed many aspects of the NESH fledging period. For example, the duration of the fledging period has been defined. While the annual peak of fledging on Kaua'i is normally during the last 2 weeks of October and the first week of November, a few fledglings begin to depart colonies around the last week of September and usually less than a dozen or fewer stragglers are downed by bright lights in early December (State of Hawaiʻi 2009; Telfer 1979; Telfer et al. 1987).

There is a significant effect of moon phase on peak fallout (State of Hawaiʻi 2009; Telfer et al. 1987). Fallout for NESH fledglings is lowest when the annual peak occurs around the full moon and highest when the annual peak occurs around the new moon. Further, the moon cycle shapes the temporal distribution; only a single fallout peak is observed in years when the new moon coincides with the annual peak fledging period, but two separate fallout peaks occur in years when a full moon coincides with the peak of fledging (Telfer et al. 1987). Overall, fewer groundings are reported when the full moon coincides with the period of peak fledging (Ainley et al. 2001).

Long-term trend analysis shows annual changes in fallout numbers. These changes show negative and positive impacts on the species in relation to urban nighttime lighting; negative impact (increase fallout with increase urban development and artificial lighting), and positive impact (light shielding decreases fallout numbers) (Joyce et al. 2010; Troy et al. 2011; Troy et al. 2013). Additionally, from a management perspective, the extremely high number of fledgling mortalities caused by fallout alone makes the threat from artificial nighttime light extremely important to manage for the species to stay extant (Griesemer and Holmes 2011).

In the County of Maui, 8 NESH fledgling fallout have been collected over an 11-year period (2009-2019). Unlike on Kaua'i, the fallout data on Maui does not have other data giving insight on populations to compare with, such as radar data from the same time period, and therefore has little context to make determinations on how these small numbers of NESH fallout affects population numbers in Maui County overall.

3.1.2 Hawaiian Petrel

The HAPE is a large gadfly petrel endemic to Hawai'i. Prior to the arrival of Polynesians, sub-fossil evidence indicates the Hawaiian Petrel was common throughout the MHIs (Olson and James 1982b). The species was federally listed as endangered in 1967 (USFWS 1983). Like NESH, this species is a pelagic seabird and highly adapted to ocean environments. Populations of HAPE on Kaua'i between 2010 and 2015 are estimated to have declined by 78% (at an average rate of ~6% per year); fallout numbers have been relatively constant, however, since the year 2000 (Raine et al. 2017).

3.1.2.1. Population Status and Distribution

State-wide population estimates of HAPE over the years have ranged broadly from 3,000 to 34,000 birds based on at-sea observations, inland counts of birds on Kaua'i, and estimates from known colonies on Maui and Hawai'i Islands (Sources listed in Chapter 2.1). In the early 1990s, the State's estimate was approximately 20,000 individuals, including 4,500 breeding pairs (KESRP 2019). A population estimate by Cooper and Day (2003) using ornithological radar put the number of HAPE coming ashore on Maui Island during the June 2001 incubation period at $\geq$ 1,038 breeding birds ($\geq$ 79 Hawaiian Petrels in the west; $\geq$ 959 in the east). The County of Maui harbors approximately one-third of the HAPE population known to breed in the State of Hawai'i (HPR 2022) or approximately 1,500 adult and subadult birds. Approximately 450 to 600 breeding pairs exist on Maui Island (MNSRP 2022).

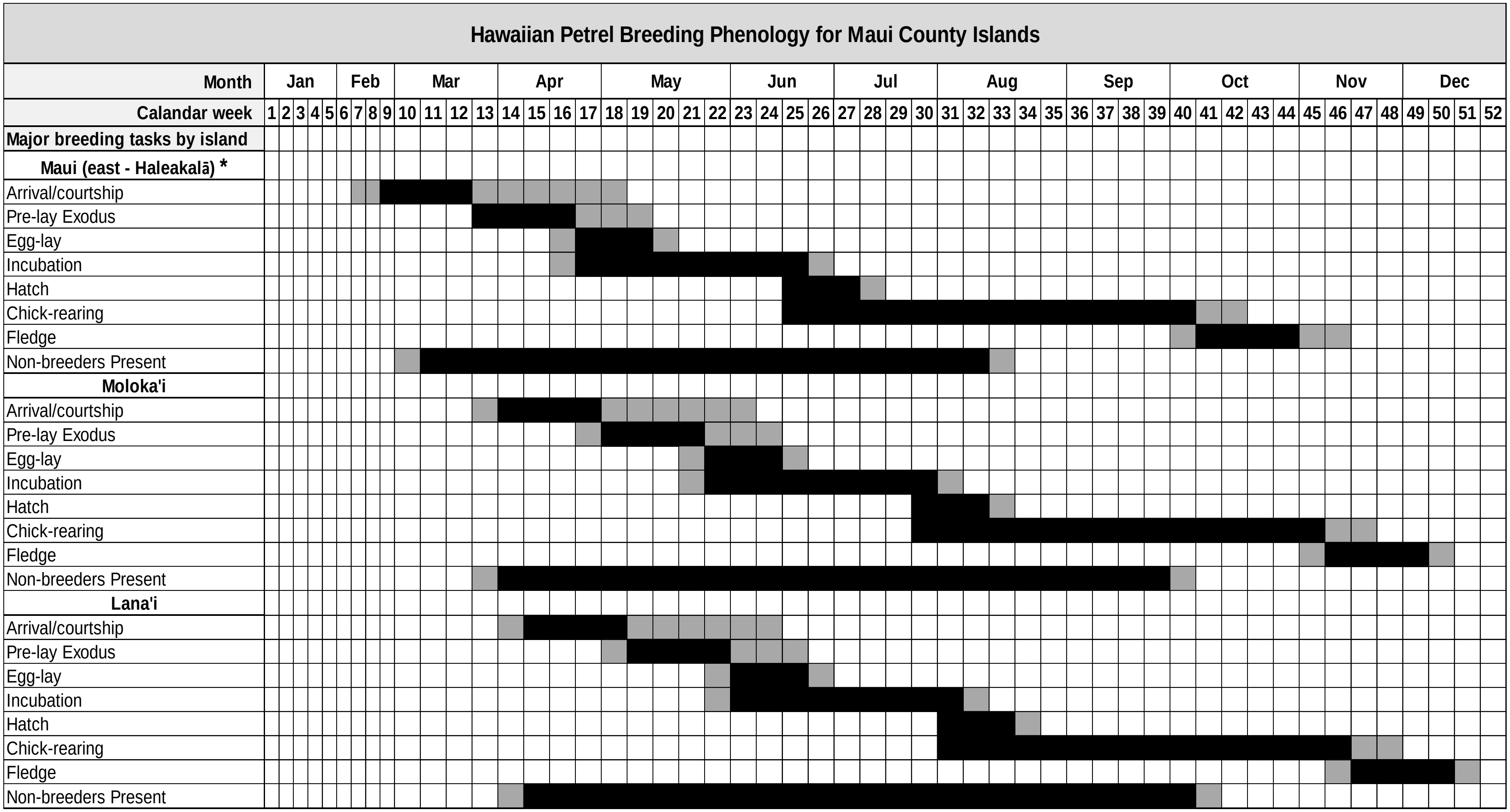
Genetically, HAPE of O'ahu, Moloka'i, and Lāna'i have an unusual degree of similarity (Welch et al. 2011). The proposed hypothesis is that HAPE moved from O'ahu and Moloka'i to Lāna'i around 100-200 years ago as their breeding sites on O'ahu and Moloka'i became threatened (Casey 2020; Welch et al. 2010; Welch et al. 2012; Welch et al. 2011). Study results by Morra et al. (2018) further indicate that each HAPE breeding colony among the different Hawaiian Islands are ecologically distinct. The authors base their results on feather isotope analyses to suggest that different but consistently used foraging areas among colonies and even among individuals in a single colony, allow for the coexistence of colonies and may aid in keeping the species extant.

3.1.2.2. Breeding Phenology

This species nests in colonies and will excavate underground burrows in high elevation rock crevices or wet, dense forests for nesting. Breeding phenology of HAPE varies among colonies in the MHIs and among colonies of the same island, for example between east and west Maui Island populations. This variation is evident from direct observations of breeders and from indirect evidence of the timing and duration of the fledging period (Figure 5).

In east Maui, birds in the Haleakalā colonies begin breeding four to six weeks prior to birds in west Maui (based on salvage data), as well as those on Lāna'i (based on direct observations), Kaua'i, and Hawai'i

Islands (Volcanoes National Park populations). In east Maui HAPE arrive to colonies beginning in late February; in west Maui arrival is approximately mid-March and early April. Females are absent from the colonies during the 3- to 4-week pre-laying exodus and return for egg-laying. Incubation is 8 weeks and at about 16 weeks chicks fledge (MNSRP 2022; Simons 1985). Most of the non-breeding birds abandon the Haleakalā colony in late July, leaving only breeding adults making flights to and from their nest (Simons 1985).



*** Phenology of West Maui matches that of Moloka'i and Lāna'i**

Synchronous duration of task

Variation in synchrony duration

Figure 5. Breeding phenology for HAPE in Maui County. Note the difference in timing of breeding of Maui Island colonies between east and west populations (Deringer et al. *in prep-b*). Sources also listed in Methods, 2.1. Seabirds.

The difference in the commencement of breeding may be a consequence of nesting elevation; east Maui nesting areas are located between elevations of 2,500 and 3,000 m (8,202-9,842 ft.), making Haleakalā one of the highest colonies of nesting seabirds in the world. Breeders of high-elevation colonies may need to lay eggs earlier, thereby fledging earlier to avoid winter conditions in December (Figure 6). Further, the duration of each breeding stage (i.e., arrival, courtship, egg laying, fledging) on other islands in the County of Maui is only presumed to match that of east Maui Island populations (Simons 1985), but inter-island differences are likely. For example, incubation durations in east Maui may be influenced by adaptations of the egg to high-altitude nesting, (Simons and Natividad Hodges 1998; Warham 1990, 1996; Whittow 2002). The synchrony of breeding tasks of HAPE on Lāna'i appears to match Kohala Mountain populations of northeast Hawai'i Island (Deringer 2009) but are not consistent with that seen on Kauai'i (Deringer 2013; Deringer et al. *in prep-a;* Deringer et al. 2011a; Deringer et al. *in prep-b;* Judge 2011).

Based on fledgling fallout (Figure 6) and burrow monitoring on Kaua'i, it is estimated that fledging peaks there in November. Fledging from monitored burrows on Lāna'i Island, where breeding occurs at a similar elevation as Kaua'i, is also known to peak in November (Deringer 2009). Based on burrow monitoring on Maui, it is known that fledging from high altitude burrows peaks in October (Figure 5). On Kaua'i, fledgling fallout has occurred as early as the third week of October, indicating that some portion of the fledglings originated from high elevation colony sites, most likely from east Maui (Deringer 2009).

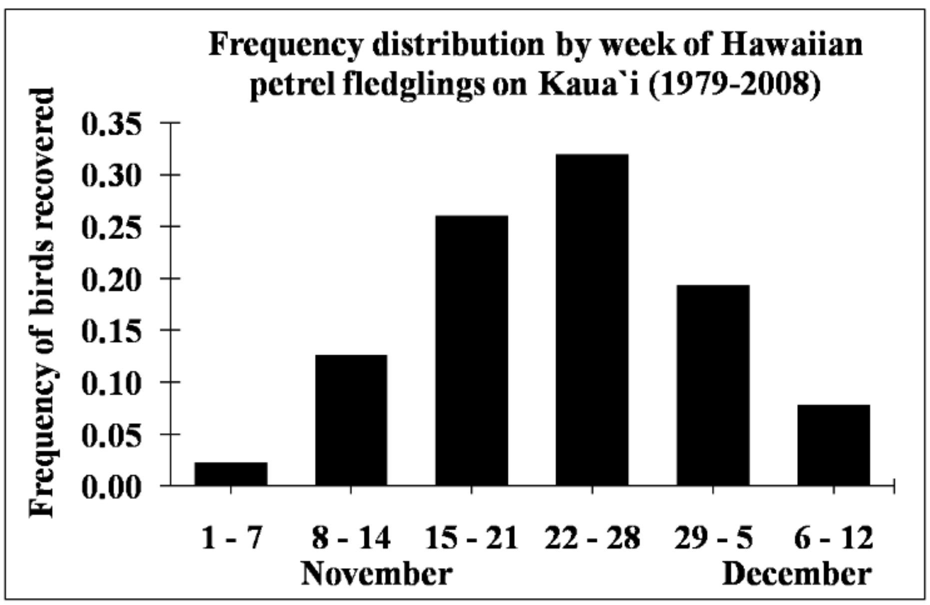


Figure 6. Primary fledging season for HAPE on Kaua'i based on fallout from 1979 to 2008 (Deringer 2009).

3.1.2.3. Breeding Colonies

Known breeding colonies exist on Maui and Lāna'i, and auditory and radar data suggest HAPE may still breed on the island of Moloka'i (Day and Cooper 2002; Simons and Natividad Hodges 1998). On Kaua'i, HAPE colonize steep slopes of interior forests and on Hawai'i Island, Kohala populations colonize areas similar to that found on Kaua'i, but HVNP populations primarily use rock crevices on lava rock habitat (Deringer 2013; Deringer et al. 2011a; Deringer et al. 2011b; Judge 2010; University of Hawai'i 2019).

On Maui, the colonies of Haleakalā are known to exist in the crater (Day et al. 2005; Hu et al. 2001; Natividad Bailey 2009b, 2009a, 2011) and near its summit (Gall and Obritschkewitsch 2019; MNSRP 2022); these latter colonies are known as Nakula/Kahikinui (Figure 7).

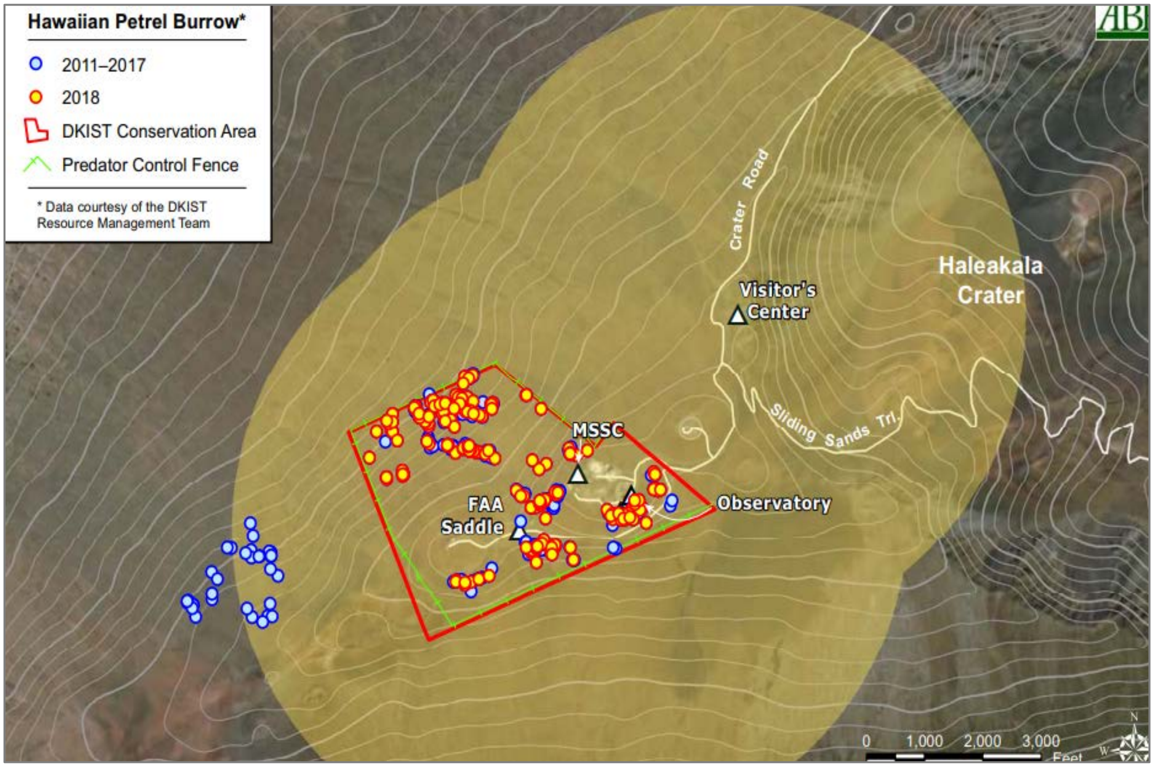


Figure 7. HAPE burrows located near summit of Haleakalā on Maui Island (Gall and Obritschkewitsch 2019).

The locations where fallout occurs combined with results from radar studies indicate the west side of Maui Island harbors some colonies of HAPE, primarily on the northeast slopes of the West Maui Mountains and specifically concentrated in the upper 'Iao and Waihe'e Valleys (Figure 8) (Natividad Bailey 2009a; Penniman and Duvall 2008).

The HAPE in east Maui appear to use multiple routes to and from their colonies (Gall and Obritschkewitsch 2019). Access to the crater bowl is through the Ke’anae Valley if birds followed the valley upward and crossed through the Ko’olau Gap; HAPE at Hana appear to access the crater summit directly; birds at Waiho’i Valley appear to fly directly up that valley; and birds at Ohe’o Gulch appear to fly directly up the Kipahulu Valley. However, birds at Nu’u Bay, Mokuia Point, and to some extent, Kaupo, primarily headed westward, rather than northwestward toward the crater summit.

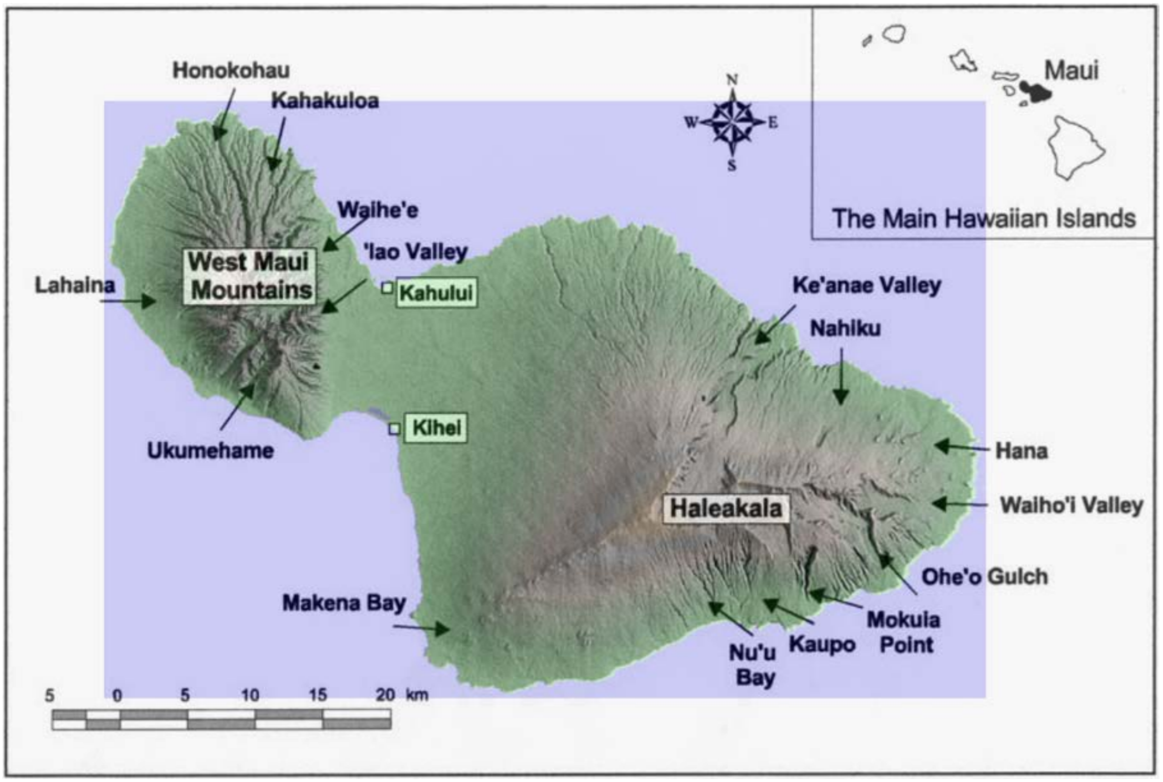


Figure 8. Direct observations of HAPE at coastal points occurred at all nine radar/visual study sites in east Maui, and at radar/visual sites at Kahakuloa and Waihe'e in the West Maui Mountains (Day et al. 2005)

On Lāna'i, over 80 nests are being directly observed within the Lāna'ihale colony discovered in 2006 and located in a valley of the island's windward side (Figure 9) (Penniman and Duvall 2008; Vanzandt et al. 2014). The colony location is near Lanai City (~2-3 miles flight line). Based on increases in auditory detections during annual surveys (HPR 2022) and indirect measurements using new technology and equipment (unmanned all-terrain vehicle and satellite imagery), the colony population appears to be growing (MNSRP 2022).

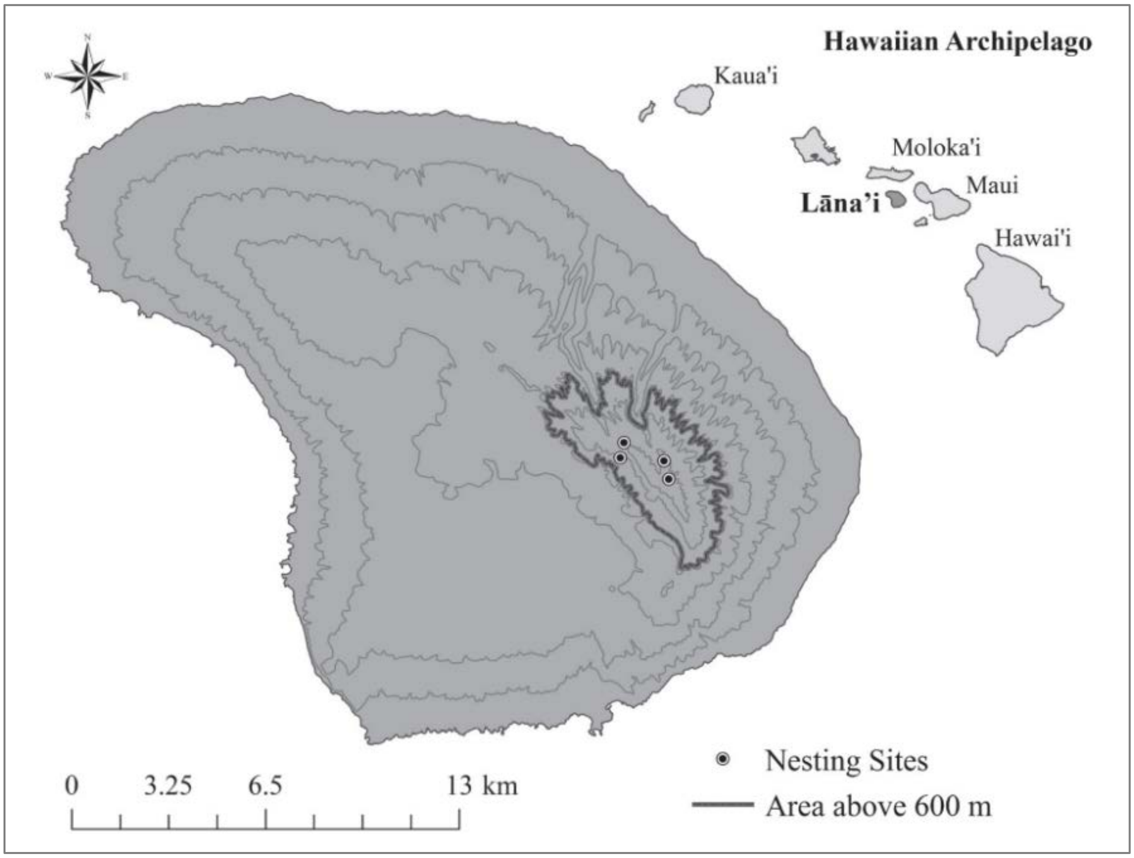


Figure 9. Known colony of HAPE nesting on Lāna'i (Vanzandt et al. 2014).

Ornithological radar surveys on Moloka'i (Day and Cooper 2002), indicate that HAPE are likely breeding on the island in most, if not all, of the eight major valleys on the northeast shore (Figure 3).

3.1.2.4. Timing of Activity

Visual observations of HAPE on Kaua'i detected inland flights beginning 10 minutes after sunset, when there is still light in the western sky (Figure 10). This early movement indicates some individuals are crepuscular, heading inland with enough light to be detected by predators but typically flying at extremely high altitudes as they come ashore (Deringer 2009). Individuals continued inland flights to, and past the point of complete darkness (about 30 min after sunset). Radar movements detected peak activity of radar targets occurs just before the point of complete darkness which occurs at 20 minutes after sunset, but a substantial number of radar targets also fly inland at 30–50 min after sunset, with some movement occurring even later (Cooper and Day 2003). Following this peak, the rate of movement decreases drastically.

In the morning, HAPE begin moving to sea in numbers while it is still completely dark, increasing in numbers rapidly and peaking just after the point of complete darkness had been crossed. After sunrise, only a few HAPE are headed offshore as late as 30 min after sunrise (Day and Cooper 1995).

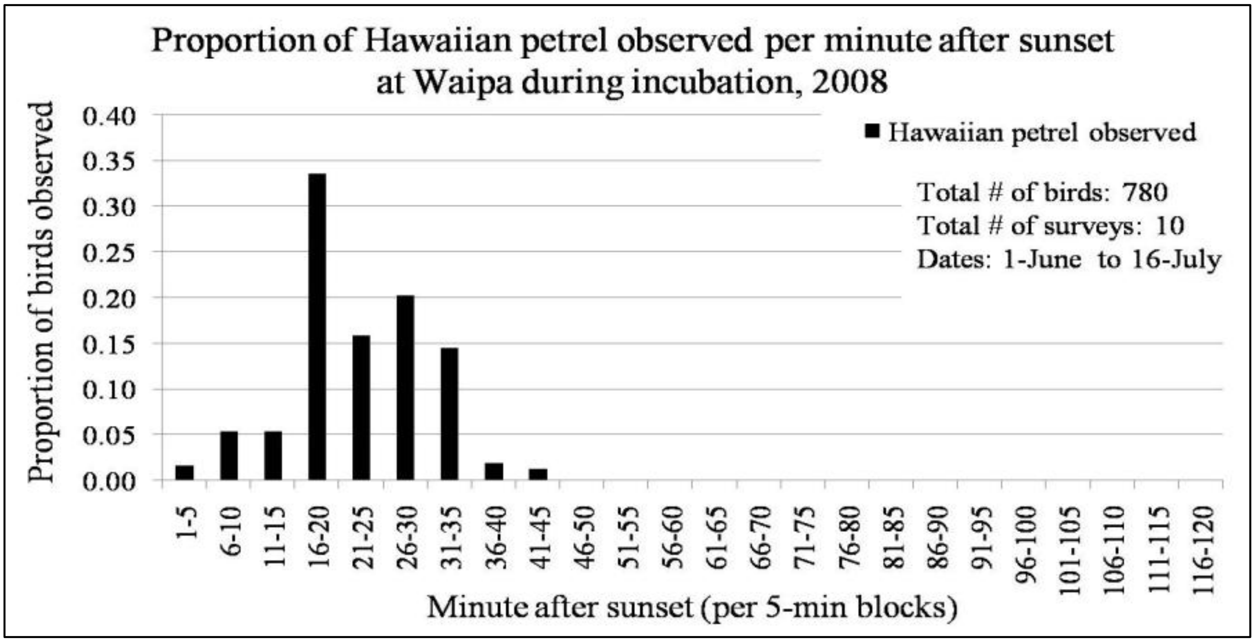


Figure 10. Visual observations recorded per minute after sunset of HAPE in at Waipa (Kaua'i Island) during synchronous evening inland flights from June to mid-July 2008. Point of complete darkness (lux=0) occurred around 20 minutes after sunset (Deringer 2009).

3.1.2.5. Artificial Light Fallout

As with NESH, HAPE fledglings are most susceptible to impact from artificial nighttime light when they make their first flight from the burrow to the ocean, primarily between 15-September and 15-December each year. For HAPE, fallout is more likely to occur on overcast or moonless nights (Deringer 2009; Telfer et al. 1987). Over 11 years (2009-2019), MNSRP documented fallout of 220 HAPE on the island of Maui and an additional 16 on the island of Lāna'i (Penniman 2020). Two HAPE were salvaged in Kahului within the first 3 weeks of the 2020 fledging period in locations where new LED lights have been installed (Penniman 2020). While this is notable, HAPE fallout occurred in this area when the streetlights were HPS and, furthermore, there are many other artificial light sources in the area.

3.2. Sea Turtles

Two federally protected sea turtle species that occur in the project area that are potentially affected are the Hawksbill Sea Turtle and the Distinct Population Segment (DPS) of Hawaiian Green Sea Turtle. The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and the USFWS share responsibility for management and recovery of sea turtle species listed under the ESA that are found in waters and on lands under U.S. jurisdiction. NMFS is responsible for addressing activities that affect sea turtles in the marine environment, while USFWS is responsible for addressing activities that affect sea turtles in the terrestrial environment (NMFS and USFWS 1998a, 1998c, 1998b, 2007; NOAA Fisheries 2011a, 2011b, 2017; USFWS 2017).

Adults of both species come ashore over multiple nights each year during the nesting season. They crawl up the beach past the high tide line to dig a cavity in beach sand where they deposit their eggs. After laying, they cover the nest with their hind flippers and then crawl back to the water. Multiple nests are laid during a breeding season; in between laying stints, turtles remain in nearshore waters during the day. The GRST population has increased significantly in past decades in the MHI and in the Northwestern Hawaiian Islands (NWHI) while HAST numbers remain precariously low for unknown reasons.

3.2.1. Hawksbill Sea Turtle

Hawksbill sea turtles (*Eretmochelys imbricata*) have been protected under the ESA since 1970 and became listed as critically endangered globally by IUCN in 1996 (Brunson et al. 2017). This species inhabits waters of the East and West Pacific and of the Central Pacific, the latter solely composed of the Hawaiian Archipelago population. The HAST population found in the MHIs is a candidate for DPS listing; there is no evident genetic connectivity to other HAST in the Pacific Ocean (Gaos et al. 2020). With little to no post-hatching dispersal behavior exhibited, juveniles in this population typically migrate between islands, remain in offshore waters of the island archipelago, and utilize nearshore waters of the MHIs all their lives.

3.2.1.1 Population Status

Globally, the species is declining throughout its known range. The adult population in Hawai'i remains on the brink of extirpation due to natural and anthropogenic threats, including historical harvest for their shell. Nesting observations, foraging studies, and satellite tracking have shown that the Hawaiian HAST population is confined to short interisland migrations.

Monitoring the number of females that come ashore to nest is the most logistically and economically feasible method to evaluate sea turtle populations (Balazs and Chaloupka 2004). Estimated counts from various sources suggest only about 50 to 100 mature females are nesting at 20 beaches around the State, primarily on Hawai'i Island (Brunson et al. 2017). Between 1991-2014 nine nesting females had been documented and banded on Maui Island. Long-term data collection on nesting HAST on Maui Island for the last 21 years indicates nesting numbers remain precariously low despite continual research and conservation efforts (Brunson et al. 2017; NOAA Fisheries 2017; Van Houtan et al. 2012). While it appears that only a small number of HAST currently nest in Hawai'i, it is unclear whether the species has suffered a major decline compared to historical numbers, or if it has always persisted at relatively low levels in the region (but perhaps higher than current levels) (Brunson et al. 2017).

3.2.1.2. Nesting Season

Nesting season can begin as early as mid-May, with hatching events from July to as late as early January, for a nearly eight-month nesting activity window (King 2015). Only breeding adult females come ashore at night to nest. Nesting success depends upon several factors including human-related impacts such as pedestrian traffic on beaches, campfires, vehicle headlights, and flashlights, and stochastic events such as storms, high/king tides, and chronic beach erosion.

3.2.1.3. Nesting Beaches

HAST nest mainly along the Ka'ū Coast (southeast shoreline) of Hawai'i Island, as well as on Maui and the eastern coast of Moloka'i (i.e., Halawa beach). There is speculation that occasional nesting may occur on the northern coast of Lāna'i (e.g., Shipwreck Beach) but no nests have been documented to date on the island (Nurzia-Humburg and Hargrove 2008).

Throughout the tropical oceans of the world, HAST utilize both low- and high-energy nesting beaches. They appear to prefer nesting sites with steep beaches and coarse sand (NOAA Fisheries 2011b). Not all sites are active every year and the annual level of nesting activity for each site can fluctuate substantially (Seitz et al. 2012). For example, in the 27 years of monitoring, no HAST nests were documented on Maui Island in 2003, 2007, 2013, and 2019 (HWF 2020). Most importantly, nesting beaches that are dark and quiet are preferred by HAST adults and nests on those beaches tend to have higher nest success (Sundquist and Bernard 2018; Sundquist et al. 2017).

On Maui Island, from 1991 to 2014 a total of 78 nests and 63 false crawls[1] were recorded on eight different beaches: Kealia, Kalepolepo, Kawililipoa, Oneloa, Little Beach, Hāna Bay, Koki, and Hāmoa (Table 1). Annually, from June 1st through September 30th, a community group of volunteers organized by the USFWS and carried out by HWF staff document nesting activity along Maui's four known southern nesting beaches (Kealia, Kalepolepo, Kawililipoa, and Oneloa) and have initiated monitoring at beaches in the south (Oneloa and Little Beach), and on the north shores of the island's isthmus where the species is known to nest; although there have been sporadic nesting events in Hāna, there is no organized monitoring there (Figure 11).

Table 1. Known Maui Island beaches used by HAST (HWF 2020).

Coast	Hawaiian/Main Beach Name	Other Known Name
South (Mā'alaea to Mākena)	Kealia Beach	Sugar Beach
	Kawililīpoa Beach	Waipu'ilani/Uluniu Road
	Kalepolepo Beach	
	Pālau'ea Beach	White Rock
	Pu'u Ōla'i	Little Beach
	Oneloa Beach	Mākena/Big Beach
East (Hāna area)	Hāna Bay	
	Koki Beach	
	Hāmoa Bay	

[1] A false crawl is when an adult turtle crawls up the beach in a manner consistent with egg laying but does not lay any eggs.

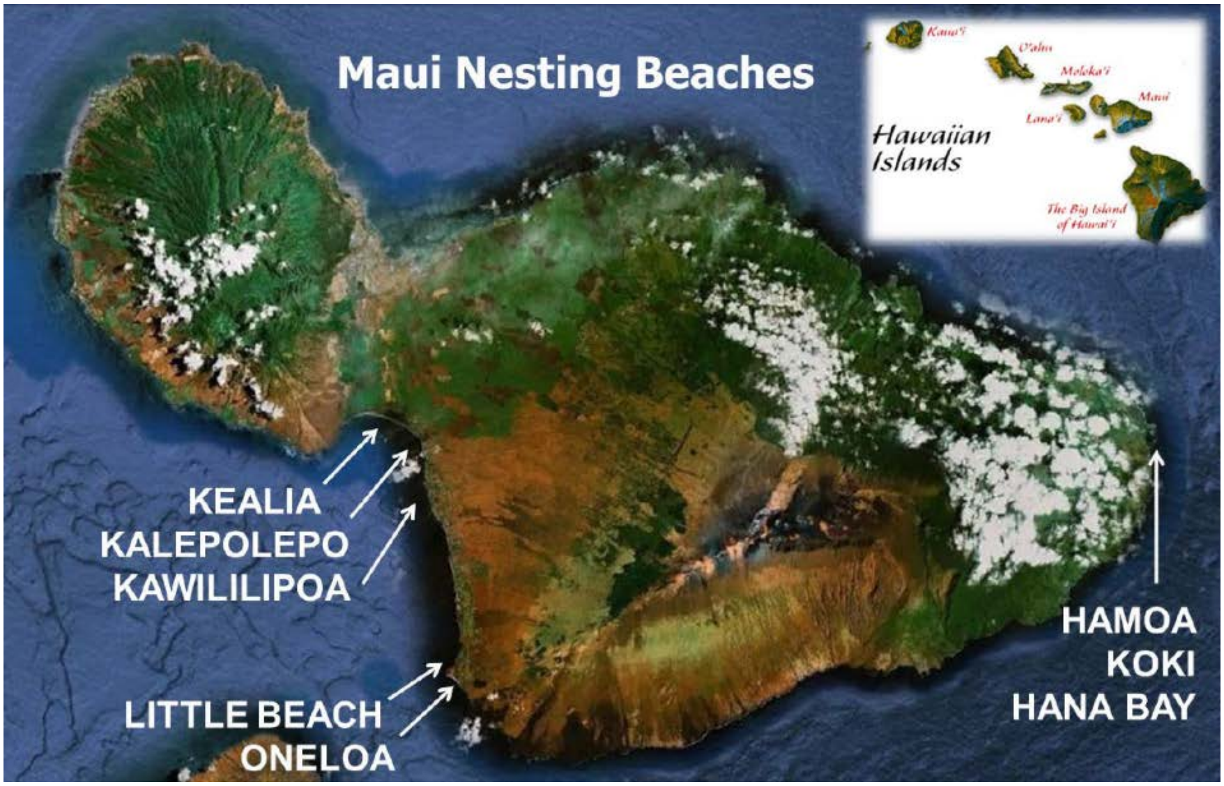


Figure 11. Nesting locations of HAST on Maui Island (King et al. 2004).

The HWF is aware of HAST nesting activity on Moloka'i but does not currently monitor nesting activity there or on Lāna'i (Penniman 2020). There is limited nesting along the eastern coast of Moloka'i (i.e., Halawa beach) and speculation that occasional nesting occurs on north Lāna'i (e.g., Shipwreck Beach) but no nests have been documented to date on the island. Not all sites are active every year and the annual level of nesting activity for each site can fluctuate substantially (Seitz et al. 2012).

Maui Island's beaches are the most erosional of the three islands based on average rates and percent of eroding transects (77%, long-term). All regions of Maui are dominantly erosional in the long and short-term (Romine et al. 2013). The HAST nesting beaches along Maui's southwest shores are prone to erosion, especially near the isthmus between west and east Maui. Nesting beaches include:

- **Oneloa Beach** is a wide, sandy beach in a state park, separated from car traffic and closed to the public at night, with no commercial development and minimal artificial light;
- **Kawililipoa Beach** runs along the center of the town of Kihei, where the coastline has been developed for residential, tourist and recreational uses during the day and night with artificial light;
- **Kealia Beach** is a narrow beach running along the highway north of Kihei, with heavy traffic. HAST females appear to heavily favor Kealia for nesting but hatching success at this beach is extremely rare. Since HAST activity was first documented at Kealia in 1991, it has remained the most frequently utilized beach on Maui, with 28 nests by over 4 turtles over 13 seasons (King 2015).
- **Hana Bay** is located on the northeastern windward coast. It differs from the above three beaches in its location on Maui. In 2001 only, hatchlings were reported but no nest cavity was found when the beach was searched. Due to Hana Bay's remote location, limited resources and the isolated report of

hatchlings, this beach was not regularly checked by HWF volunteers during turtle nesting seasons (1996 to 2003). Although it is not currently considered primary HAST nesting habitat, the community has been provided with contact instructions on what to do if there are any future indications of nesting. In 2004, light pollution was considered a major threat at this beach (King et al. 2004).

3.2.1.4. Nesting Success

Nest success for HAST depends upon, among other important factors, beach habitat being dark and quiet at night. Distant point sources of light and urban glow are more likely to affect hatchlings but can impact adult females (Salmon et al. 1992). When coming ashore to nest, adult females use a "straight ahead" method to select a nest site and tend to be affected by bright lights in front of them upon emerging from the sea (Salmon 2003; Witherington 1992a). Artificial lights can cause HAST females to abandon nesting efforts, resulting in a false crawl or a nesting attempt where the female fails to deposit eggs (Witherington 1992a) or returns to water and inadvertently sheds her eggs at sea (Witherington and Martin 2000). In addition, light pollution may cause some turtles to use sub-optimal nesting habitat causing a reduced number of hatchlings to be produced, hatchling survivorship compromised, and hatchling sex ratios altered.

Once hatchlings emerge from the nest cavity, they are highly sensitive to disorientation by artificial lights. Hatchlings are equipped with rudimentary essentials to survive; regardless of the nesting beach, their crawls seldom deviate more than ± 20˚ from a heading directly toward the sea (Salmon 2003). Emerging from the nest, hatchlings tend to orient toward the brightest direction. When attracted to artificial lights, they wander in directions counter to their natural behavior – out to sea (Salmon 2003; Witherington and Martin 2000). Those that are disoriented may either travel along a consistent course away from the ocean and toward an artificial light source or are unable to establish a particular course and wander aimlessly.

3.2.1.5. Foraging and Resting Behavior and Habitats

In Hawai'i, HAST are specialist sponge carnivores (Vicente 1994). Coral reef habitat supplies HAST with many food items including sponges, which need solid substrates for attachment. The ledges and caves of the reef provides turtles shelter for resting both during the day and at night. The HAST is also found around rocky outcrops and high energy shoals that are optimum sites for sponge growth (Meylan and Redlow 2006; Seitz et al. 2012; Vicente 1994).

The tendency of HAST in Hawai'i to use foraging habitats in the vicinity of their natal nesting colony (i.e., natal foraging philopatry (NFP), implies that mortality at foraging habitats would have a direct impact on local nesting populations and similarly, threats at nesting beaches would have direct impacts on nearby foraging habitats (Brunson et al. 2017; Gaos et al. 2020)). Numerous sightings have been reported at foraging habitats along west Maui due in large part to efforts by conservation organizations and collaborators in the area (King 2015). The potential impacts for HAST around the Hawaiian Islands are heightened given the isolation of the archipelago and that it represents the only significant and genetically distinct HAST nesting colony in the Central Pacific Ocean.

3.2.1.6. Mortality

There have been two known occurrences of HAST hatchling mortality events from artificial nighttime light sources on Maui Island (Rick 2012). In 2009 near the vicinity of 575 S. Kihei Road, two unmarked nests of

HAST hatchlings emerged, were immediately attracted to car lights, and were killed crossing Kihei Road. In a second event that same year, only 16 hatchlings were rescued from an entire clutch in an area of Kealia Beach; hatchling deaths at Kealia Beach has initiated HWF to implement measures such as fencing and education to minimize future mortality (Cerizo 2021).

Adults disoriented by lights can get stuck on land and succumb to dehydration and exhaustion easily, especially since they are gravid when coming ashore. In 1993 and again in 1996 adult HAST became light attracted and were killed crossing North Kihei Road (Bernard 2020).

3.2.2. Green Sea Turtle

In 1978, the Hawaiian subpopulation of GRST was listed as threatened under the ESA (NOAA Fisheries 2011a; NMFS and USFWS 2007; USFWS 2016). Additional protective regulations are enforced throughout all areas within U.S. jurisdiction to conserve and restore marine turtle populations to their former levels of abundance (NMFS and USFWS 2007; NOAA Fisheries 2011a; USFWS 2016). Inclusion of GRST into the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), made it illegal to trade any products made from this species in the U.S. and 130 other countries.

Of the five species of sea turtles that are known to occur in the Hawaiian Archipelago, the GRST is the most abundant year-round resident (Balazs and Chaloupka 2004; Chaloupka and Balazs 2007; Chaloupka et al. 2008). Their reproductive lifespan is uncertain, but some individuals have been observed nesting for at least 38 years (NOAA Fisheries 2011a).

3.2.2.1. Population status

Worldwide populations of the GRST have seriously declined as a direct result of overharvesting of turtles and eggs (Parsons 1962; Van Houtan and Kittinger 2014). Conversely, the DPS Hawaiian GRST population has increased significantly since being protected (Balazs et al. 2015a; Balazs et al. 2015b). Within the Hawaiian archipelago, this species nests almost exclusively in the NWHI, mainly at French Frigate Shoals (FFS), however, GRST nests have been observed on the MHI (Balazs 1994; Balazs and Chaloupka 2004; Balazs et al. 1987).

A study by Frey et al. (2013) was able to reconstruct genotypes for nesting females from hatchling profiles and estimated that 15 different females were responsible for all nesting on the MHI. Further, their study's results suggest that the nesting population at the MHI may be the result of a few founders that originated from the FFS breeding population, facilitated by captive rearing and release of FFS juveniles locally from O'ahu. In terms of population status, due to the loss of significant nesting habitat in FFS in 2018 from Hurricane Walaka, the nesting habitat of the MHI may be even more important for this species in Hawai'i.

3.2.2.2. Nesting Season

The GRST in Maui begin to mate in March and lay eggs on sandy beaches between April and September. One turtle will lay about 100 eggs in a clutch that incubates in the sand for about 60 days. The hatchlings dig out of the sand at night. In FFS, where 96% of the GRST population nests, a single female may deposit as many as six clutches during one season, but the mean in the MHI is 1.8 (NOAA Fisheries 2011a; Tanji 2021a). The interval between oviposition in turtles that nest more than once averages 13 days and ranging from II to 18 days (Balazs et al. 1994).

3.2.2.3. Nesting Beaches

In the County of Maui, nesting occurs on all three islands. On Maui Island, nesting is primarily on west and north coast beaches (Table 2). The primary threat to GRST nesting beaches on Maui is human presence and coastal infrastructure (HWF 2020).

Table 2. Maui Island Beaches used by GRST (HWF 2020).

Coast	Hawaiian/Main Beach Name	Other Known Name
South (Mā'alaea to Mākena)	Kawililīpoa Beach	Waipu'ilani/Uluniu Road
West (Mā'alaea to Kapalua)	Hanaka'ō'ō Beach	Canoe Beach
	Kamehameha Iki	Park 505 Front Street/ Shark Pit
	Ka'anapali Beach	Kahekili Beach/ Black Rock
	Oneloa Beach	Ironwood/ D.T. Fleming
North (Waihe'e to Ho'okipa)	Waihe'e Beach	Wai'ehu Beach
	Ka'ehu Beach Nehe Point	Nehe Point
	Kanahā Beach	Kite Beach
	Spreckelsville Beach	Stable Road
	Baldwin Beach	
	Pā'ia Bay	
	Hāmākuapoko Beach	Maliko Bay
	Ho'okipa Beach	
East (Hāna area)	unnamed black sand beach	

On Moloka'i, the Mo'omomi Preserve is the most intact coastal sand dune ecosystem in the MHI. Protected since 1988, it provides significant GRST nesting habitat along the island’s NW coast (TNC 2012). From May to November annually, GRST nests are monitored by volunteers along Kawa'aloa Bay, which is located just outside the preserve’s western boundary. Turtle protection measures put in place include a pass-key system for restricted access (by people/by season) from the Preserve to the Kaiehu Point area above Kawa'aloa Bay where most turtles nest (TNC 2012). Mostly, restrictions are in place to specifically “prevent artificial lights from disorienting or disturbing the turtles while in the water or nesting on shore” (TNC 2012). There are no County streetlights within three miles of the preserve or Kawa'aloa Bay.

Polihua beach on the northwest shore of Lāna'i was once a prolific GRST nesting site (Balazs 1976, 1985). In 2008, a GRST nest was documented on the southwestern end of Polihua beach. This was the first confirmed marine turtle nest at this location in several decades (Nurzia-Humburg and Hargrove 2008). Due to limited access to many of the coastal areas of Lāna'i and fewer people utilizing the coast, there is little current information available on marine turtle activity on Lāna'i. A lack of information, however, does not necessarily indicate a lack of marine turtle activity. There are no County streetlights within four miles of any shoreline on Lānaʻi.

3.2.2.4. Nesting Success

Like HAST, nesting success depends upon several factors including human-related impacts and stochastic events. Nesting by GRST is highly variable on Maui Island's north shore. In 2019, only 5 nests from one female were observed and monitored at Ho'okipa Beach Park (HWF 2020). Typically, in the area, 0-3 females will lay 0-5 nests per year. Ho'okipa Beach Park continues to have high nest success and adequate beach habitat where nests can be deposited at least 100 m (33 ft.) from the surf and tidal effects; in 2019, all four nests hatched successfully (HWF 2020). On Moloka'i, results from the 2020 nesting season at Kawa'aloa Bay suggest that only two adults attempted to nest multiple times and only three of nineteen nests likely hatched (Powell 2020).

3.2.2.5. Foraging and Resting Behavior and Habitats

Foraging and resting habitat exist on each of the three islands (Cutt and Martin 2020). GRST that reside in shallow benthic habitats are primarily post-pelagic juveniles (sub-adults) and adults (Balazs 1994). Subadult and adult turtles in nearshore benthic environments are almost completely herbivorous; feeding primarily on macroalgae and seagrasses (HDLNR 2015; Mitchell et al. 2005). Resting/feeding areas typically have a "cleaning station" and food sources (Losey et al. 1994; Nurzia-Humburg and Hargrove 2008), as well as other aspects like protected or semi-protected waters around coral reefs and coastal areas (Balazs 1985; Balazs 1994), shelter from predators such as tiger sharks, and clean waters (Balazs 1994). Key foraging habitat can be found around most of the MHI, but this species often returns to the same foraging areas after the breeding season.

The GRST utilizes beaches on all shores of Maui Island (Table 3) (Cutt and Martin 2020). Marine tourism offers tourists regular sightings of GRST that emerge from the ocean to rest on the sand at Ho'okipa Beach Park. In no other location in Hawai'i do the GRST rest so consistently and in the highest numbers as they do at Ho'okipa Beach, drawing many tourists (Black 2018). At the south end of Ka'anapali Beach just south of the Hyatt Regency hotel, many turtles swim around rocks close to shore at Hanakao'o Beach Park. Foraging habitat for GRST is degraded at Ma'alaea Bay, Kihei, and Lahaina (HDLNR 2015; Mitchell et al. 2005). The GRST also forages at Maluaka Beach and at Turtle Town – the name given to the general area between Makena's One'uli Black Sand Beach and Nahuna Point. Olowalu Reef in Lahaina is a popular snorkel destination where GRST occur at a known cleaning station (Black 2018). In Kahului Bay, the nearshore waters of Hobron Point, where warmwater discharges from the power plant built in 1947, GRST congregating at the outfall showed no aversion to the plant's shoreline lighting (floodlights) suggesting the turtles preferred the thermal advantage over other, darker areas in the bay (Balazs 1985; Balazs et al. 1987).

Table 3. GRST basking reports by region and age class during (Jan-Dec) 2020 on Maui Island (Cutt and Martin 2020).

Region	Juvenile	Sub-adult	Adult	Unknown
North	1	7	26	0
Central	1	1	9	0
South	3	12	56	2
West	2	10	35	1

On Moloka'i, the area of Pala'au is a coastal reef along the island's south-central shoreline where GRST forage and rest (Balazs et al. 1987; Zardus and Balazs 2007).

On Lāna'i, no basking activity has been reported on Polihua beach; however, basking is known to occur on the northeast shore of the island. However, Polihua beach is suitable substrate for basking and relatively close to known basking areas (Nurzia-Humburg and Hargrove 2008).

3.2.2.6. Mortality

No data was found regarding GRST hatchling disorientation and subsequent mortality on beaches in the County of Maui. One incident reported on O'ahu at the James Campbell Wildlife Refuge where a light source far inland and high on a ridgeline was responsible for the disorientation and mortality of hatchling GRSTs on the coast (HPR 2021). This points to the necessity to assess lighting characteristics other than solely proximity of light sources to nesting beaches.

4. How and Why Artificial Light Can Adversely Affect Nocturnal Species

Describing and measuring light is difficult partly because of the many parameters associated with different types of light sources but also due to discrepancies in how light value is presented (Bretschneider 2018). Artificial light sources are usually evaluated based on their lumen output. Lumen is a measure of flux, or how much light energy a light source emits (per unit time). The lumen measure does not include all the energy the light source emits but only the energy with wavelengths capable of affecting the human eye (Cruz and Lindner 2011; Longcore and Rich 2004; Longcore et al. 2018). Therefore, the lumen metric is defined in such a way as to be weighted by the (bright adapted) human eye spectral sensitivity.

LED lighting products can be designed to emit almost any spectrum of light visible to the human eye. This versatility makes LEDs widely useful in myriad applications, especially for producing white light. White light of equal appearance to the human eye can be created with different spectral power distributions, with the brightest, purest white light created when all wavelengths are represented in equal parts across the spectrum of visible light. A spectral power distribution describes the energy emitted by a power source. Visible light are those wavelengths between ultraviolet and infrared (Figure 12).

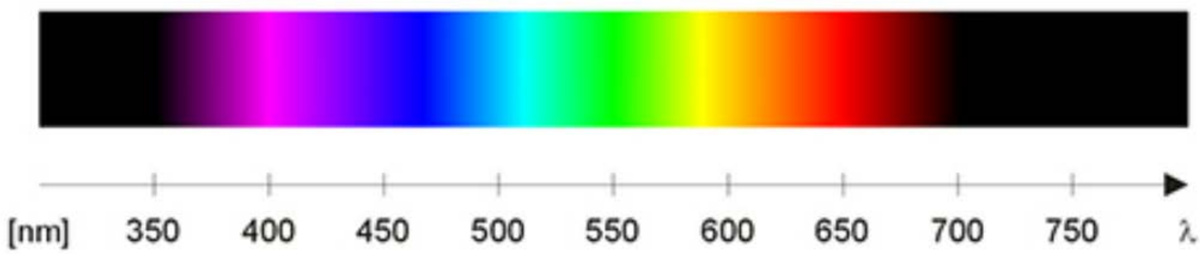


Figure 12. The spectral distribution of light energy: Ultraviolet < 380 nm, visible light (to humans) 380-700 nm, and infrared (> 700 nm) wavelengths in nanometers (nm).

The spectral power distributions for four different light sources, including phosphor coated and red-green-blue color-mixed LED products, can be created to all produce white light (perceived white to the human eye) (USDOE 2016). Conversely, two different sources of LED light with the same nominal Correlated Color Temperature (CCT) (for example, 3000 K) can appear very dissimilar due to spectral power distribution differences. In this way, the source's CCT rating does not directly correlate to how much of each color light is emitted. LEDs that produce "white" light can emit various amounts of spectral wavelengths between approximately 380 nm and 500 nm (range of wavelengths considered "blue"); the CCT only provides a proxy for this blue light content (described in Section 4.1). Therefore, consideration should be given to the spectral characteristics (spectral power distribution curve) of the lighting source.

4.1. Vision, Wildlife, and Artificial Light

Vision is critical for survival in most species of wildlife by providing cues animals use to orient themselves in their environment, find food, avoid predation, communicate, and mate (Nelson and Herron Baird 2002). Understanding wildlife sensitivity to different light wavelengths is critical to assessing potential effects from artificial lights. To manage light appropriately for wildlife, it is critical to consider how the characteristics of different artificial light-producing products are perceived by wildlife (Bretschneider 2018; Lima et al. 2016; Longcore and Rich 2004; Longcore et al. 2018; Workforce Services 2019).

In any light source producing a "white" light, even daylight, the color spectrum being perceived by humans is composed of various wavelengths, from short (in the human visible range of indigo and blue) to long (what humans perceive as yellow and red). Short wavelengths scatter more readily than long. Also, most nocturnal wildlife species are more sensitive to short wavelength light (including blue light) than humans (Figure 13) (Commonwealth of Australia 2020).

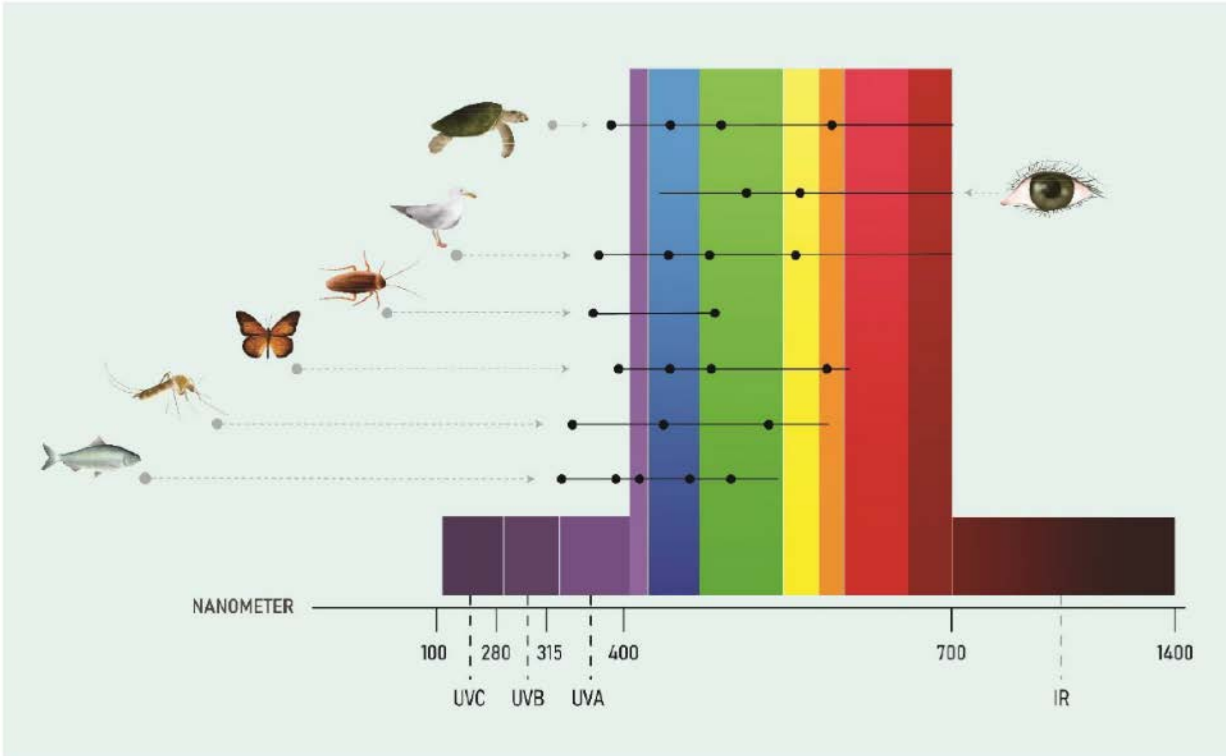


Figure 13. Ability to perceive different wavelengths of light – humans and wildlife – shown with horizontal black lines and dots representing peak sensitivities (Commonwealth of Australia 2020).

Understanding photopic and scotopic vision is important when selecting the color (spectral wavelength composition) and intensity (spectral power distribution) of a light source. Both humans and wildlife detect light using photoreceptor cells in the eye called cones and rods. Color differentiation occurs under bright light conditions (daylight) because bright light activates the cones. Cones allow the eye to see color; this is known as photopic vision. Under low light conditions (dark adapted vision), light is detected by cells in the eye called rods. Rods only perceive light in shades of grey (i.e., no color); this is known as scotopic vision, and it is more sensitive to shorter wavelengths of light than photopic vision. The variation in the number and types of cells in the retina means wildlife and humans do not perceive light, and hence color, in the same way. In wildlife, being 'sensitive' to light means the animal is acutely perceiving light within that spectral wavelength composition (Tosini et al. 2016).

4.2. Vision in Nocturnal Species

Species like sea turtles and seabirds can detect and process the same type of light (identical in spectral power distribution, CCT, and wavelength composition) differently, despite their shared nocturnal habits when coming ashore. Marine turtles view light on the horizon between 0° and 30° vertically and integrate across 180° horizontally, so it is important to consider light in this part of the sky when monitoring for the effects on hatchling orientation during sea-finding (Salmon 2003; Salmon et al. 1992; Witherington 1992a, 1992b; Witherington and Martin 2000). In contrast, fledging shearwaters on their first flight view light in three planes (vertically (at right angles from the horizon), from below, and above) as they ascend into the sky. Overhead sky glow (zenith) measurements are important when trying to avoid glare contamination by point sources of light low on the horizon (Commonwealth of Australia 2020). Quantifying the whole of sky glow is important when measuring the effects of cloud cover, which can reflect light back to illuminate an entire beach or wetland (Aubé et al. 2018; Commonwealth of Australia 2020).

4.2.1. Vision in Nocturnal Seabirds

The design of a nocturnal seabird's eye is to provide good vision in darkness, daylight, under water, and in flight. For NESH and HAPE, tasks like ocean foraging and finding their nesting burrows are likely done visually in combination with olfactory cues, as shown for similar species like the Manx Shearwater (*Puffinus puffinus*) and Leach's Storm-petrel (*Oceanodroma leucorhoa*) (Martin and Brooke 1991; Sin et al. 2021). Manx Shearwaters and NESH were formerly considered conspecific (Brooke 1990; King and Gould 1967; Perrins et al. 1973; Sincock and Swedberg 1969). Both species delay coming ashore during the breeding season until well after sunset and point of complete darkness. The eyes and vision capabilities of Manx Shearwaters have been studied (Martin and Brooke 1991) and this information is here used to make inferences about NESH.

Manx Shearwaters have eyes adapted for high sensitivity which allows for improved nocturnal vision at the cost of high-resolution diurnal vision. Further, the retina in their eyes resembles a cat's retina, whereby a uniquely structured and arranged area of neural cells exists and, depending upon the field of view being visually sampled, can become highly activated (i.e., triggers higher sensitivity) (Hayes et al. 1991). For Manx, it is this area of their retina that interprets images when they use binocular view that is focused below the bill (Martin 2007), such as during foraging and chick rearing. This retinal area is not fully understood but "it may function in the detection of objects on the sea surface and/or be concerned with the detection of the actual sea surface as a bird flies low over it" (Hayes et al. 1991).

It is unknown if the nocturnal vision capabilities are similar between adult NESH transiting low over coastal points and of fledglings leaving burrows on maiden ocean-bound flights. Both can be negatively impacted over brightly lit areas like dense urban areas but without knowing the differences among age classes in eye design and optical capabilities it is impossible to pinpoint the mechanism(s) causing the difference in impact. Some difference must exist based on the higher fallout occurrence of fledglings compared to adults (State of Hawaiʻi 2009).

4.2.2. Vision in Sea Turtles

Sea turtle vision is most acute under water and shortsighted otherwise (Salmon 2003). Sea turtles and humans perceive light quite differently (Figure 13). Like seabirds, a sea turtle's eyes contain oil droplets dispersed in both the rods and cones that help to filter incoming spectral wavelengths. The type and distribution of pigments, or lack of pigmentation, within the numerous oil droplets of each eye is likely what allows for vision in the ultraviolet spectrum of GRST (Liebman and Granda 1971; Mathger et al. 2007). While the vision of sea turtles operates in near-ultraviolet, violet, blue-green, and yellow light wavelengths there is less sensitivity to light in the orange to red range of the (human) visible spectrum (Witherington 1992a). The high sensitivity of sea turtles to short wavelengths would be expected since they live in a medium (ocean water) that selectively filters out long wavelength colors (Salmon 2003).

Hatchling sea turtles can be attracted to long wavelength red light at very high intensities. For example, a light source emitting a single wavelength yellow light is unattractive or only weakly attractive to hatchlings whereas another source that also appears yellow to humans but contains both green and red spectral components can be attractive to hatchlings (Witherington 1992a; Witherington and Martin 2000). Studies have shown that hatchling sea turtles use primarily visual cues to find the ocean post hatching (Van Rhijn 1979; Witherington and Martin 2000) with other factors such as beach slope having less of an influence (Witherington 1992b). Both color (wavelength) and brightness of light sources can influence sea-finding capabilities (Salmon et al. 1992; Witherington 1992b; Witherington and Martin 2000), but light has other properties like directivity, motion, shape, and periodicity that can affect hatchling orientation (Witherington 1992b).

In addition to their spectral sensitivity, hatchling sea turtles also are sensitive to the directional component of light. The way hatchlings appear to integrate light stimulus implies that information is gathered from a broad, cone-like view (Ecological Associates 1998; Ehrenfeld 1968). Whereas adult sea turtles coming ashore to nest are most negatively impacted by light sources in direct line of sight, hatchlings combine visual cues from various directions which can lead to confusion when other light sources are present; such sources can include streetlights, beach campfires, or vehicle headlights. Hatchlings have been observed to respond to artificial light up to 18 km (11 mi.) away during sea finding (Commonwealth of Australia 2020). At the James Campbell National Wildlife Refuge on O'ahu Island a hatchling mortality event was caused by lights far from the nesting beach atop an inland ridgeline (HPR 2021).

4.2.3. Newell's Shearwater and Green Sea Turtle Response to Blue Light

The International Dark Sky Association (IDSA) defines blue light content (as a percentage) as the sum of energy between 405-530 nm divided by the sum total of energy from 380-730 nm. Using the IDSA definition, a “blue light calculation” would include spectral wavelengths that would appear green to the human eye (495-570 nm).

All lights that make light which appears white emit blue light, including the LED streetlight selected by the County of Maui. HPS, which generally appear yellowish, also emit blue light (Figure 14). One way to assess whether the spectral content of a light source is appropriate for use near sensitive wildlife is to consider the light’s spectral output and the species’ response curve (Figures 14-15).

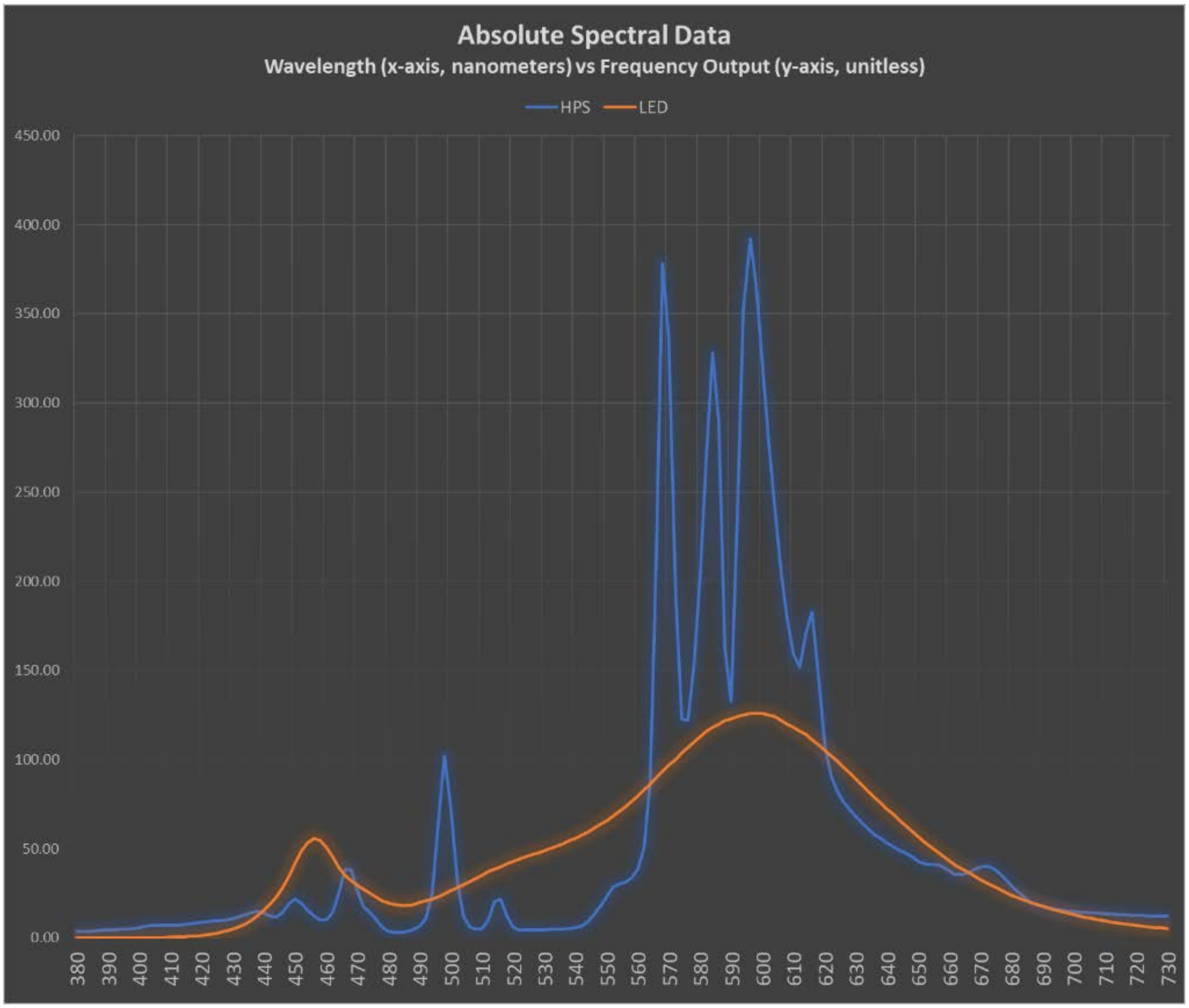


Figure 14. Relative spectral curves plotted for the 100-watt HPS streetlight used by the County of Maui and the LED streetlight selected by the County of Maui to replace the 100-watt HPS, both operated at 100-percent power output. Source: PSI/Maui County Data (Longcore et al. 2018).

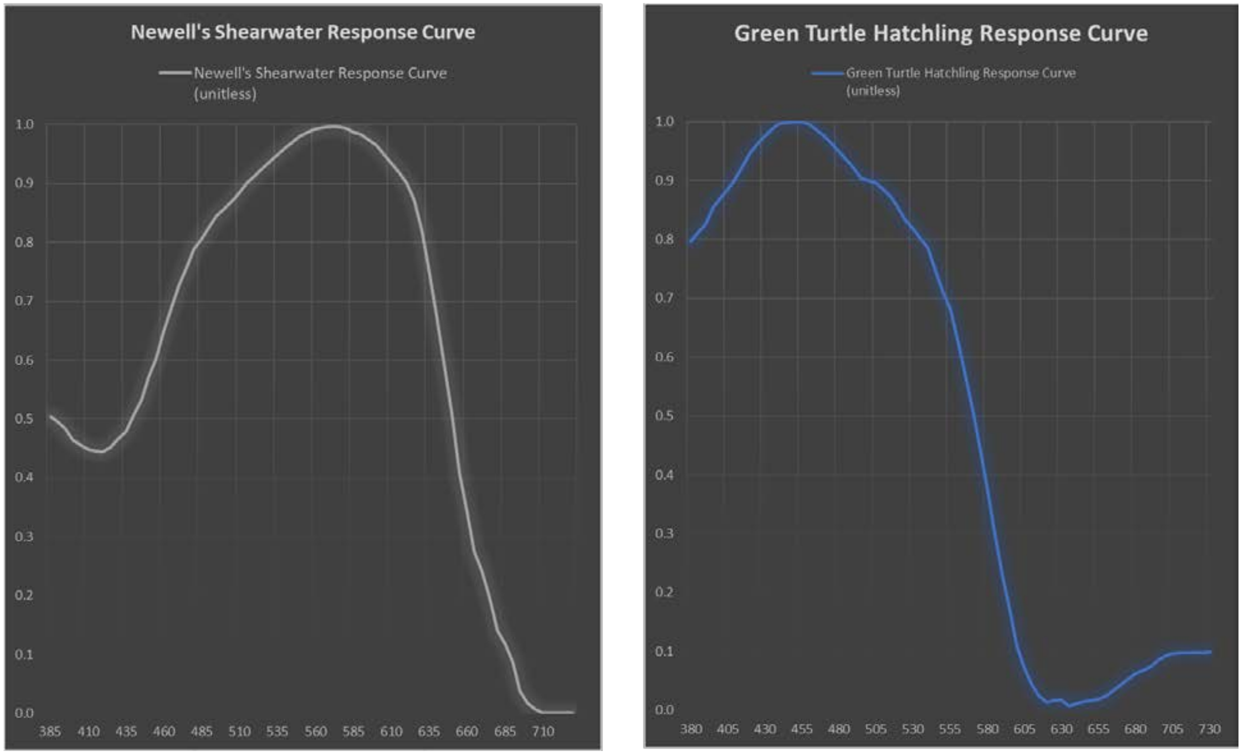


Figure 15. Response curves of NESH (fledgling, left graph) and GRST (hatchling, right graph) to spectral wavelengths (x-axis) (Longcore et al. 2018).

For NESH, response to spectral wavelengths occurs in the UV range and decreases to around 425 nm. Response then increases through the blue and green portions of the spectrum until approximately 570 nm (in the yellow portion of the spectrum, similar to where human eye response peaks) before gradually declining to around 620 nm (near the start of the red portion of the spectrum) and then drastically declining to about 690 nm. For GRST, the response to spectral wavelengths begins in the UV range increasing to about 450 nm (in the blue portion of the spectrum) before declining steadily through the blue, green, and yellow portions of the spectrum until bottoming out at about 615 nm in the orange portion of the spectrum; a response is also evident in the red spectral wavelengths $\geq$ 660 nm.

5. Light Environment

The IDSA defines light pollution as "any adverse effect of artificial light, including sky glow, glare, light trespass, light clutter, and over illumination" (Lima et al. 2016). Most types of light pollution can be broken down into one of five types:

- **Skyglow** is any illumination of the night sky or parts of it; skyglow can be light pollution from artificial light accumulating into a vast glow that can be seen from miles away and from high in the sky. Light is refracted into the surrounding atmosphere and scattered due to a phenomenon known as Rayleigh Scattering. Skyglow is generally greater where unshielded exterior lights are prevalent and reduced when shielded exterior lights are employed. Shielded lights also contributes to skyglow by reflecting off low clouds, and surfaces like buildings, windows, and pavement. However, Luginbuhl et al. (2009) found that even a small fraction of direct upward emission from non-shielded fixtures on dark skies exerts greater impact on skyglow than reflection off the ground.

- **Glare** occurs when stray light is introduced to the human eye. If intense enough, disability glare can occur, which reduces the ability of the eye to resolve spatial detail and impairs visual performance. Intraocular (in the eye) light scatter blankets the retina with a luminance (called Veiling Luminance) that effectively reduces the contrast of images formed on the retina, greatly impairing a person's nighttime driving visibility (Poot et al. 2008). Glare can be dangerous for drivers, cyclists and pedestrians and can also affect human health.
- **Light trespass** occurs when light shines outside of the area it is intended to illuminate. A common light trespass problem occurs when a strong light enters the window of one's home from outside, causing problems such as sleep deprivation or the blocking of an evening view. Several U.S. cities and elsewhere in the world have developed and implemented outdoor lighting standards to protect the rights of their citizens against light trespass (Pace 2000).
- **Light clutter** is the grouping of lights that can collectively generate too much light. While this may pertain to individual homes or business properties, mostly it relates to municipal lighting, especially streetlights (Gibbons et al. 2014; Hiscocks and Guðmundsson 2010). Bright and excessive groupings of lights can distract drivers and others like cyclists and pedestrians. Roadway lighting guidelines have been established that many agencies use to inform their streetlight design, avoid light clutter, and not distract or confuse drivers.
- **Over illumination** includes first, the "more is better" attitude of lighting spaces and second, is having lights turned on that don't need to be. Both aspects waste energy and money. Streetlights turning on too early or using bulb types and/or lighting fixtures that create too much light for the space needing illumination are light pollution. Further, the wasted light output produced from over illumination of night lights can create glare.

5.1. Maui County Nighttime Environment

Maui County's light infrastructure encompasses three inhabited islands in the MHI: Maui, Moloka'i, and Lāna'i. Urban areas tend to be the primary contributors to most significant sources of light pollution and skyglow that affects sensitive natural areas and dark sky reserves (Lima et al. 2016; State of Hawaiʻi 2011). On Maui Island, a high percentage of nighttime light visibility coincides with urban cities and coastal stretches of condominiums, resorts, and neighborhoods (red color, Figure 16). The topography and prominent land features of the island affect light visibility levels in areas of both west and east Maui (orange and yellow colors, Figure 16). The west Maui mountains (height ~1,764 m (5,787 ft.)) and in the east Haleakalā (height ~3,055 m (10,023 ft.)) create sufficient barriers that protect inland high elevation areas of the island from artificial light sources that exist on their flanks (black areas of Figure 16). The east and west mountains of Maui are connected by a flat isthmus known as the Central Valley.

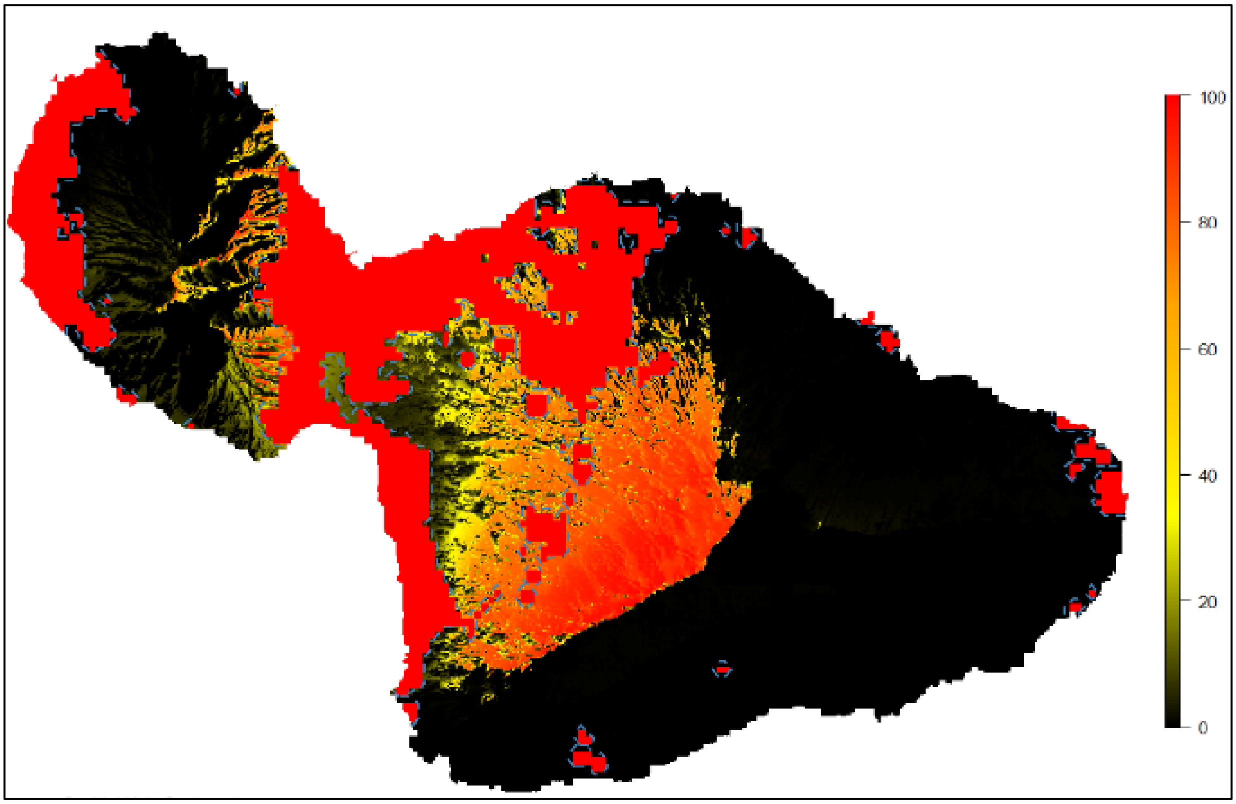


Figure 16. Light visibility on Maui Island. Coloring denotes intensity of nighttime light emittance on a scale from 0 (black) to 100 (red) (Young et al. 2021).

On Moloka'i Island (Figure 17), nighttime light emittance that occurs coastally is primarily along a portion of the south-central shoreline (Kaunakakai), with a small portion of northwest shoreline (Kepuhi Beach), and even smaller portions scattered on shorelines of the eastern half of the island (northshore, Kalaupapa; southeast shore, Ualapue). Non-coastal lighting is centrally located on the island (Kualapuu and Hoolehua) and present in the southwest (Maunaloa). For L āna'i, nighttime light visibility maps were not available, but light emittance is likely associated with populated interior areas of Lāna'i City, the Airport, and the south coast (Hulopoe Bay).

Figure 17. Light visibility on Moloka'i Island. Coloring denotes intensity of nighttime light emittance on a scale from 0 (black) to 100 (red) (Young et al. 2021).

5.2. Street Lighting Characteristics

As mentioned above, streetlighting is generally designed to comply with guidelines that have been established by IDSA or other entities to avoid light clutter, create evenly lit areas, and provide a safe vehicle and pedestrian environment. Nevertheless, street lighting can easily become excessive or cluttered whereby groupings of light sources create a bright and confusing environment for both humans and wildlife. Best Management Practices to eliminate or reduce light pollution include the use of lighting only where it is needed, when it is needed, and as bright as needed (Workforce Services 2019). Management of light sources can include use of timers, motion sensors and dimmer switches and turning lights off when not in use. Using LED light sources can alleviate some light pollution problems. An LED is a semiconductor light source that is highly efficient at converting electricity into visible light, with a high optical efficiency (how much light reaches target areas compared to how much light is produced by the fixture), and a versatile range of CCTs.

Before LED-type lights, measuring a bulb's brightness was by wattage. The higher the wattage, the brighter the light. To specify a bulb's brightness now, reference is made to its output in lumens. Lumen is simply the unit of measurement for the light's brightness as perceived by the human eye. Watts measure the amount of energy required to light products, whereas lumens measure the amount of light produced. The more lumens in a light source, the brighter the light to humans.

The color wavelengths in a light source produce heat, measured in Kelvins (K) and referred to as CCT. The lower range of CCT produces a warm light (approximately 1,000–3,500K) and the higher range provides a cool light (approximately 6,500–10,000K) (Wood et al. 2019). Often, lighting designers will describe light "warm" or "cool" in relation to the light's color; warm lights are rich in yellow and orange where cool lights produce more light in the blue spectrum. Importantly, CCT does not give any information about the color rendering ability of the LED.

The Color Rendering Index (CRI) rating for a light source is on a scale from 1 to 100, where 100 represents the highest ability of the light produced to allow for humans to discern colors accurately. LEDs CRI ratings typically range between 70 and 80, while HPS lights rate between 20 and 30 (USDOE 2016). The light produced by an LED is typically whiter and cooler than that produced by HPS (Figure 18). LED lights can improve nighttime visibility and impair it because of such effects as eye strain and fatigue (Gibbons et al. 2014; Hiscocks and Guðmundsson 2010; Thurairajah 2015).

Figure 18. A comparison between lighting sources; HPS sources (left) and LED (right) (Bilsten et al. 2013).

5.3. Light Shielding and Lenses

In the past, streetlights commonly had a "drop lens" that resulted in a portion of the light produced being directed above the horizontal (uplight). As discussed at the top of Chapter 5, uplight generates skyglow. Streetlights in Maui are now required to be "fully shielded" so that no light is directed above the horizontal. Shielding can be used regardless of the light source type (e.g., HPS or LED) being used. Shields are often used with outdoor lighting fixtures to improve the focus of the light source and to block the pattern of illumination so that it stays below the horizontal plane of the light fixture, thereby increasing the ability to direct light downward, projecting it only where it is needed. Additional shields or hoods (metal or dark plastic shield below the lens) may be added to light fixtures to further reduce stray light and avoid light trespass (Figure 19). Figure 20 shows an example of how shielding affects the lighting environment.

“Drop lens” streetlight	“Fully shielded” streetlight	Fully shielded streetlight with "Additional Shielding”
		

Figure 19. Streetlight “Drop Lens” and “Fully Shielded” Designs and example of Additional Shielding.

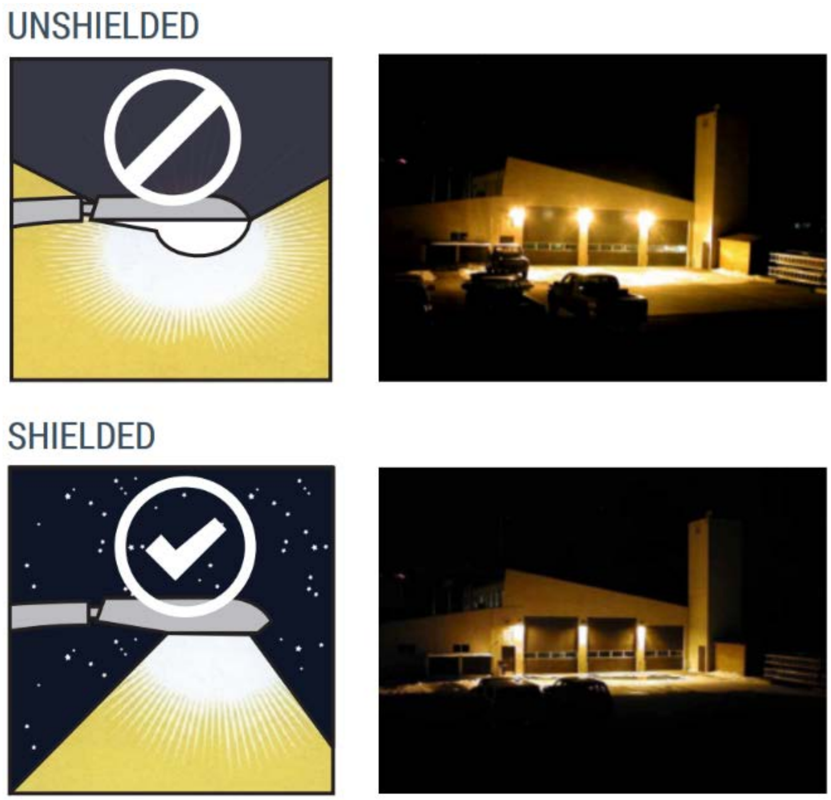


Figure 20. Examples of unshielded and shielded light sources in eliminating light from being projected upward above the horizontal plane of the fixture (Workforce Services 2019).

Many commercially available streetlights can be obtained with a variety of lenses. The lens directs the light in specific directions. For example, one lens type creates a linear lighted area that is appropriate to straight segments of roadway and another lens type creates a circular lighted area that is appropriate to cul-de-sacs or intersections.

6. Streetlight Conversion Projects

6.1 Nation-wide Streetlight Conversion Projects

Most major cities and towns across the United States have converted to roadway lighting using LED fixtures for improved visual (human) acuity, low cost, high efficiency, and low maintenance (Holly 2021). In addition to using less energy, a single LED light has four times the lifespan of a single HPS light, making

LEDs a preferred choice for long-term cost savings (City of San José 2016). Seeing successfully implemented LED street lighting programs that significantly cut annual utility bills and energy emissions has increased the attractiveness and accessibility of streetlight retrofits, regardless of region or utility structure.

The myriad conversion projects nationwide have shed light on the importance of having a thorough knowledge of the area's municipal needs and by working with a lighting planning expert pre- and post-installation. For example, many municipalities simply use illumination guidelines established by the Illuminating Engineering Society (IES) to set lighting levels in their ordinance. However, standards set forth by the IDSA are stricter than IES standards. The City of Boston converted 64,000 electric streetlights (42,000 mercury vapor lamps and 22,000 HPS lamps) to LED lights (City of San José 2016). Several lessons were learned from the Boston light conversion project. Following the project, the city realized that during the design phase of their streetlight conversion project, lighting specifications needed to be highly refined to include more details on aspects such as:

- Pavement type,
- Luminaire height above roadway,
- Luminaire spacing,
- Setbacks,
- Defined uniformity, and
- Defined light loss factor.

The city of Ashville, North Carolina, served by Duke Energy Progress, converted 8,000 streetlights city-wide to LED fixtures (Bilsten et al. 2013). They received 120 complaints that resulted in 40 fixtures receiving shields and 20 fixtures removed altogether. The top complaint was that the LED lights were too bright (Bilsten et al. 2013; Wolf 2015). In the city of Algona, Iowa, 447 LED lights were installed by the Algona Municipal Utilities under the guidance of a lighting expert. Post installation of the new lights, the city stated that their project's success resulted from having extensive knowledge of municipal energy consumption and working with a lighting designer that was able to answer individual technical questions for the city's working group (Bilsten et al. 2013; Wolf 2015).

The City of Las Vegas conducted an extensive study on light pollution following a streetlight conversion project (City of Las Vegas 2013). The study determined that LED light patterns were more controllable, and once light was directed where it needed to be, there was less spillage (light trespass) onto adjacent properties and the sky (skyglow), as shown in other post conversion projects (Figure 21). The City of Las Vegas found that after a period during which final adjustments were made to fixtures, there was a decrease in requests by citizens for the City of Las Vegas to deal with unwanted light on their property.

Figure 21. Aerial views of Mount Wilson, outside of Los Angeles, California, from 2002 (left) prior to LED conversion and in 2012 (right) post LED installation, that the City of Las Vegas used to justify that their conversion project would reduce light pollution (City of Las Vegas 2013).

6.2 Streetlight Conversion Projects in the Hawaiian Islands

The State of Hawai'i joined the nation-wide movement over ten years ago to switch to LED lighting sources for cost-saving purposes and to improve roadway safety throughout its Counties.

6.2.1 Kaua'i County

Kaua'i County was first in the state to retrofit their streetlights to LED. In 2010, prior to the streetlight conversion, the County of Kaua'i faced violations of the ESA by taking (killing and wounding) federally protected species due to nighttime light pollution, with NESH fledglings primarily being impacted. The County of Kaua'i paid fines totaling $720,000 for not shielding any of its lights, preparing a Habitat Conservation Plan (HCP), or applying for a permit to authorize the take of a protected species (USDOJ 2010).

The conversion project began in 2016 and took a year to complete. All streetlights on state and county roadways (3,482 fixtures) have been converted from HPS lights to fully shielded LED lights in a joint project between the County and Kaua'i Island Utility Cooperative (KIUC). Electronic controls are used with this system and lights can be adjusted based on time of day and seasonality, which results in additional energy efficiency. The project was expected to save the county approximately $400,000 annually (HFP 2017).

6.2.2 City and County of Honolulu

The City and County of Honolulu completed its 2-year LED Streetlight Conversion project in the fall of 2019, replacing a total of more than 53,000 city streetlights with “energy-efficient” LEDs, saving as estimated roughly $3 million per year (HFP 2019). LEDs with different CCT values are used throughout the island: 4000 K on arterial streets and some mixed commercial districts and 3000 K in residential areas and Waikīkī, the latter making up approximately 90 percent of the new LED streetlights. A networked control management system allows Honolulu to adjust individual or groups of lights at different times of the day and provided options for dimming and completely shutting off when not in use (Mendoza 2016).

6.2.3 Hawai'i County

The County of Hawai’i has one of the strictest dark sky ordinances in the world due to the world-class observatories present on Mauna Kea. LED streetlight fixtures manufactured to filter out blue light have been used throughout Hawai'i Island since 2012 to comply with Hawai'i County's outdoor lighting standards, which require LED roadway lighting to have less than 2% blue-light content (1988, Ord. No. 88-122, sec. 3). Product specification sheets, corresponding testing reports, and shielding for two models of LED streetlight fixtures manufactured to filter out blue light and being used on Hawai'i Island are found in the County's Department of Public Works, Traffic Division, Street Light Standards notice for new and replacement of streetlights (Hawaii County Code§ 14-55, Table 14-A) (County of Hawai'i 2021).

By 2012, the County of Hawai'i had installed 100 new, lime-green LED streetlights in Waimea and 500 in Hilo, with plans to install the remaining 400 in Kailua-Kona. The County Department of Public Works' Traffic Division drafted an amendment to the lighting code to allow this conversion of streetlights to continue on all county roads, with energy savings of around 60% compared to the low-pressure sodium (LPS) lights used by the County of Hawaiʻi (Sur 2012).

In 2017, the County of Hawai'i launched a streetlight improvement program, with savings from the 2012 conversion allowing the county to further improve the island's lighting infrastructure (Hawai'i Tribune Herald 2017). The improvement program has three-phases to address lighting inadequacies regarding the type and placement of lighting and number of lights used. The first phase was completed in September 2020 with 1,500 lights replaced on main connector roads in south Hilo and north Kona areas (County of Hawai'i 2019). Part of the streetlight improvement program involved a pilot study using "new smart technology" to monitor streetlights in Hilo, on Kapiʻolani Street, in 2019. The smart lights were remotely monitored by computer, which reduced the cost of sending road crews to visually inspect the lights. Based on the results of the County's pilot program, the new smart streetlights are planned for installment island-wide in Phases Two and Three.

6.2.4 Maui County

Maui County has already purchased and began installation of the LED lighting fixtures for the project. The selected LED product is the Evolve™ LED Roadway Light manufactured by General Electric. Per the product's specification sheet, applications for this fixture include local roadways, collector roadways, and major roadways/streets. Similar to the other counties in the State, the County of Maui's converted streetlights are equipped with a wireless remote-control system. The system allows the County to dim or turn off individual or groups of streetlights.

Features of the Maui County LED fixture being used are listed on the product sheet:

- Product specifications give a pole mounting height of 27 to 40 feet,
- Optimizable roadway photometric distributions capabilities **(zero light trespass, lower output needed)**,
- Evolve™ light engine (reflective technology) designed to increase brightness yet minimize glare,
- **70 CRI at 2700K** (i.e., high ability for humans to discern colors under a warm spectral colored light source), and
- Upwards Light Output Ratio (ULOR) ULOR = 0 (i.e., **zero uplight**).

Chapter 7. Conclusion

7.1 Assessment of Project Impacts

The full effects to seabirds and sea turtles from artificial nighttime light sources are difficult if not impossible to fully quantify. Given the documented sensitivity of NESH, HAPE, HAST, and GRST to artificial nighttime light sources, an impact of some degree, either adverse or beneficial, would be expected when changes are made to the streetlight system. Information known about these species, their breeding habits and habitats, and their nocturnal behaviors, can be used in planning so that potential adverse impacts are minimized, potential beneficial effects are realized, and any unexpected impacts can be quickly addressed and eliminated or minimized.

7.1.1 Seabirds

Both NESH and HAPE, adults and fledglings, exhibit harmful and fatal behaviors in the presence of brightly lit white light at night like that typically found in dense urban areas and at outdoor sports fields (USFWS 2019). These deleterious behaviors have also been exhibited in localized areas where a small but significant bright light source and/or upward reflective light exists (Raine et al. 2017; State of Hawaiʻi 2009; Tanji 2021b).

Each year, during a known period in the fall, fledglings of both species are attracted to and impacted by artificial sources of nighttime lighting in the County of Maui (see Section 3.1.1.5). The County plans to continue converting streetlights in areas where seabird fallout has been documented (Figure 22). The County will have (previously unavailable) means to control aspects of individual and groups of streetlights such as dimming and turning them off. Utilizing this control system to reduce artificial light during the fledging season (September 15 through December 15) each year in known flyways and along coastal shores has the potential to reduce impact to both species, especially NESH. Control of the streetlights could be extended to include consideration of the moon phase, the importance of which is discussed in Section 3.1.1.5.

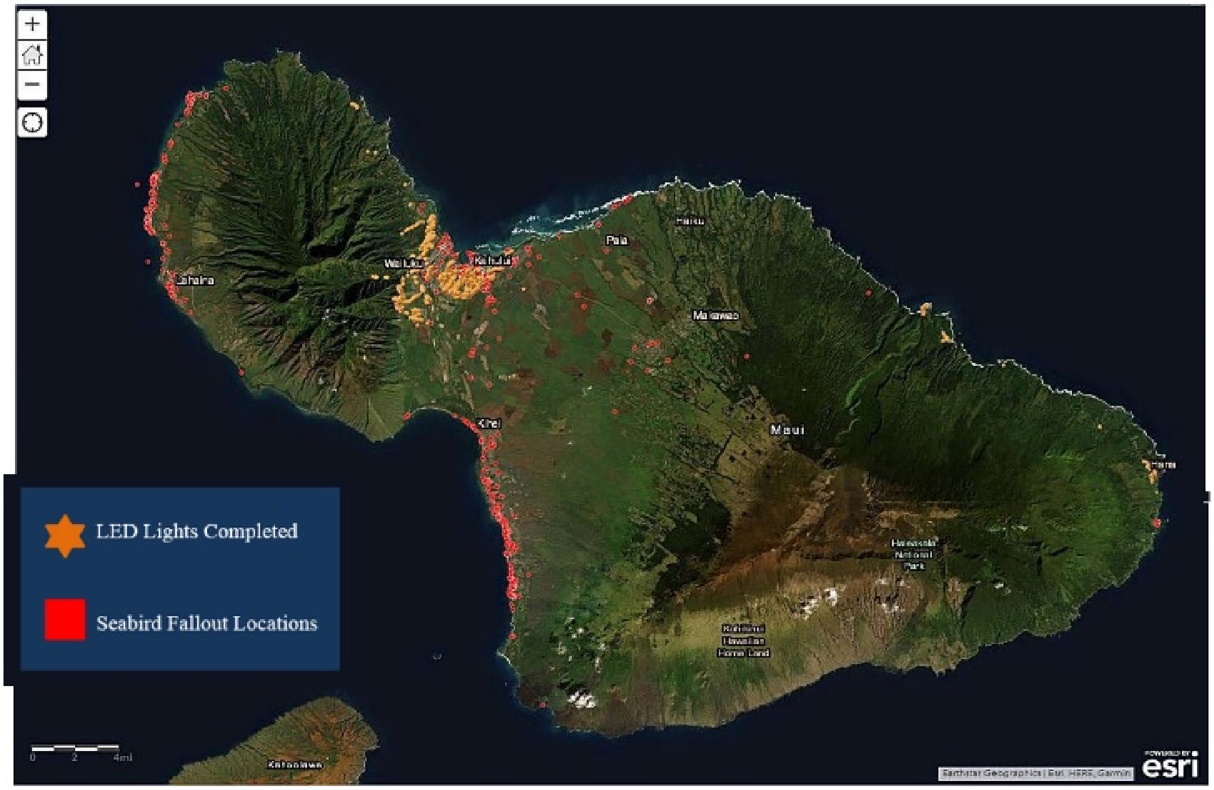


Figure 22. Map of Maui Island showing seabird fallout locations (red square) in relation to areas of high light emittance, and the current extent of LED lights installed for the project (orange star) along the north and east portions of the island (Penniman 2020).

Being dependent upon their scotopic (low light) vision, NESH and HAPE become more sensitive to the scattering of blue light, either directly from a light source or in reflective illumination, which increases perceived sky glow. While the product's specification sheet reports zero ULOR, this only refers to sky glow that will be eliminated through the fixture's fully shielded design but not its illuminance reflected upward from the ground. While some LED sources may emit higher proportions of blue light than HPS sources, the design and output factors for LED luminaires (e.g., full shielding) and a decrease in light output (e.g., dimming capability) can offset some negative impacts potentially caused by the blue light (Wood et al. 2019). Additional measures including turning off lights earlier during peak fallout periods may be needed to fully negate the effect of upward reflective illumination.

Based on our assessment, the conversion of streetlights from HPS to LED as proposed by the County could have negative impacts on NESH and HAPE assuming no avoidance or minimization measures are employed (see Section 7.2). Implementing avoidance and minimization recommendations would greatly reduce the potential negative effects to seabirds. The following provide points regarding how the LED streetlights were selected (and can be managed) to adhere to County regulations and reduce the potential for adverse effects to nocturnal seabirds:

- The lights will be fully shielded. The lamps selected by the County of Maui emit zero uplight.

- The LED light fixtures are better at focusing light on the roads and result in less light trespass than HPS. Glare on road surfaces, localized skyglow, and additional dimming and shielding may need to be addressed for individual or groups of lights through adaptive management practices post LED installation/conversion.
- On Kaua'i, the HCP concluded that shielding lights without also controlling the color spectrum and power output of the light failed to adequately reduce seabird attraction, and hence, take (State of Hawai'i 2020). These three factors are addressed by the County of Maui by using an LED with a low CCT (2700K), at the low end of the CRI scale (70) and having dimming capabilities (not available with HPS lights).
- Factoring in the seabird's eye response, the brightness of the 100W HPS and the selected LED are essentially identical (LED is 0.2% dimmer than HPS). Therefore, it is expected that no change or an improved change in impact would occur.

7.1.2 Sea Turtles

Nighttime artificial lighting is known to disturb emerging adult sea turtles attempting to nest and emerging hatchlings orienting to the sea. Based on the compiled information on use areas, a small population of breeding adults of each species nests in Maui County, primarily on Maui Island, and both species of all age classes use nearshore waters for resting and foraging (Figure 23). Accounting for the increased documented use of beaches and nearshore areas by sea turtles during recent periods of little to no human visitation (state beach and resort closure periods during COVID pandemic), it would be prudent to view all beaches throughout the county as potential nesting beaches and all nearshore areas containing the necessary elements turtles need for feeding and loafing as foraging/resting areas for HAST and GRST.

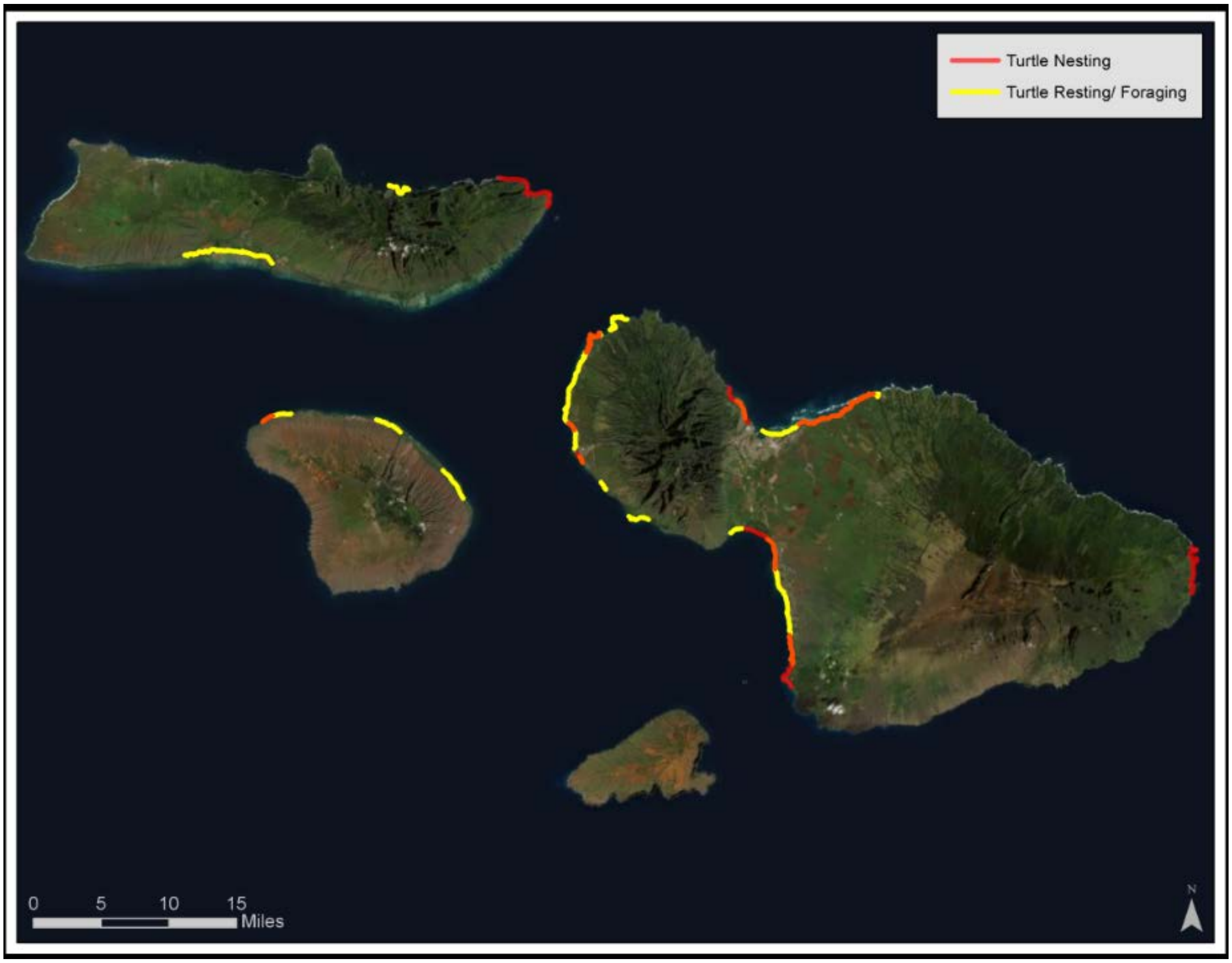


Figure 23. Coastal areas of Maui County used by HAST and GRST from compiled literature resources (see Chapter 2.2). Red denotes areas of known turtle nesting activity, yellow denotes known resting/foraging areas, and orange denotes areas with both activities (Sources listed in Methods 2.2 Sea Turtles).

To assess the potential impact of coastal lighting on sea turtles an analysis of all Phase I (1,847) and Phase II (2,771) LED lights to be installed by the County of Maui was conducted in relation to shoreline setbacks ranging in 100 ft. increments from 300 to 700 ft. (Table 4).

Table 4. Percentages and representative number (in parentheses) of County of Maui coastal lights occurring at 100-foot intervals from the shoreline of Maui Island.

Shoreline Setback (100-ft increments)	Percent of Phase 1 Lights (total = 1,847)	Percent of Phase 2 Lights (total = 2,771)	Total Lights (total = 4,681)
300 feet	1.4% (26)	3.5% (96)	2.6% (122)
400 feet	2% (37)	6.3% (175)	4.5% (212)

Shoreline Setback (100-ft increments)	Percent of Phase 1 Lights (total = 1,847)	Percent of Phase 2 Lights (total = 2,771)	Total Lights (total = 4,681)
500 feet	2.6% (49)	8.3% (231)	6.0% (280)
600 feet	3.7% (70)	9.9% (274)	7.3% (344)
700 feet	5.2% (96)	11% (305)	8.6% (401)

Results were derived primarily using Phase II lights because of the higher number of lights located close to the coast within this data set. There is a substantial difference in the number of lights captured within the 400 ft. setback compared with the 500 ft. setback. However, extending setbacks out to 600 ft. is less significant. Those streetlights within 500 ft. of the shoreline represent most of the lights that have a potential to impact sea turtles.

It is important to note that these measurements are based off a coastline shapefile. Actual ground measurements would likely differ to some degree. For example, given the quality of the imagery, it was difficult to decipher if in some areas the analysis captured all or only portions of a beach. Also, any annual beach erosion (where turtles would be forced further up a beach to nest) were not factored into the analysis. This analysis also does not consider if each streetlight is visible from the beach or if intervening topography, structures, or vegetation results in the streetlight not being visible from the beach.

Further, this analysis does not consider streetlights further from the beach even though, in rare instances, inland light sources at higher elevations have caused disorientation in hatchlings depending upon the angle of light hitting a beach. County-wide ground-truthing from the beaches would be required to assess if streetlights in exposed upland areas represent potential hazards to sea turtles.

Based on our assessment, the conversion of streetlights from HPS to LED as proposed by the County could have negative impacts on HAST and GRST assuming no avoidance or minimization measures are employed (see Section 7.2). The risk for impact is higher for HAST given that this small population in Hawai'i potentially represents a DPS and primarily occurs throughout Maui and Hawaii counties making these populations vulnerable to stochastic events. However, GRST populations in the state are also vulnerable given the loss of nests and nesting habitat at FFS in NWHI from Hurricane Walaka in 2018; the subsequent long-term effects, if any, on GRST productivity numbers from this event remain unknown.

Implementing avoidance and minimization recommendations (see Section 7.2) would greatly reduce the potential negative effects. The following provide points regarding how the LED streetlights were selected (and can be managed) to adhere to County regulations and reduce the potential for adverse effects to sea turtles:

- The streetlights will be fully shielded, with light focused on the roads to reduce light trespass.
- Where streetlights occur within 500-feet of the shoreline, a post-installation assessment should be made to determine if additional shielding or dimming are required.

- Localized skyglow and additional dimming and shielding may need to be addressed for individual or groups of lights through adaptive management practices post installation/conversion in regions of high light emittance (see Section 5.1).

- Post-conversion assessment of targeted areas of seabird and sea turtle sensitive areas (salvage hotspots and coastal beaches, respectively) to optimize adjustments to streetlight timing and dimming options during known breeding periods.

7.2 Recommendations to Avoid and Minimize Potential for Adverse Impacts

For species protection to occur, regulatory compliance must be met in combination with species-specific needs being addressed. Meeting regulatory compliance would eliminate some, but not all, of the factors known to negatively impact these species. Laws that regulate the blue light content of a light source and a light's use are applicable to human health and safety but often neglect to factor in nocturnal species adequately. At a minimum, all lighting changes must comply with the requirements outlined in the Maui County Outdoor Lighting Ordinance (Council of the County of Maui 2015).

Three primary issues the County of Maui can address to reduce the potential for take to seabirds and sea turtles are:

1. Some streetlights occur too close to the shoreline (sea turtles).
2. At targeted seabird/sea turtle sensitive areas (inland salvage hotspots and coastal shores), conduct post-conversion assessment to ensure lights are optimized for wildlife.
3. Ensure the mounting heights of LED fixtures meet the minimum 27-foot specifications provided by GE (for accurate representing the light's properties/behaviors) (General Electric Company 2021).

Recommended Measures:

- In cases where white light is necessary in sensitive wildlife areas, 2700 K or lower CCT (optimal $\leq$ 2500 K) should always be chosen over higher CCT LEDs. In cases where white light is not necessary, PC amber LEDs should be used. LEDs that are filtered to completely remove blue light may also be considered (Aubé et al. 2018).

- Reduce and/or eliminate unexpected light pollution aspects (skyglow, glare, light trespass, light clutter, and over illumination) by using a light planning specialist and wildlife expert throughout the LED conversion project to:

  - Ensure conformance with state and county ordinances for periods of lights off at night where applicable.

  - Determine the temporal and seasonal light setting adjustments for lights located near known hotspots associated with annual events of seabird fledging and sea turtle hatching.

  - Determine changes in skyglow reflectivity of lights under various weather conditions like low cloud ceiling.

  - Determine where additional shielding of lights is needed for any light that may cause light trespass, over illumination, or through dimming or reduction of light clusters to alleviate clutter.

- Employ seasonal dimming of lights for seabirds during fall fledging (15 September to 15 December).

  - Consider the moon phase during the fledging period and adjust the lights as appropriate.
- Employ seasonal dimming of lights for sea turtles during nesting and hatching periods.
  - May to September for adult female nesting.
  - August through October for hatchlings (emerging as late as December).
- Provide additional shielding of lights within 500 ft. of shoreline in the vicinity of sandy beaches for sea turtles (see Figure 19 for example of additional shielding).
- Adjust the height and/or shielding aspects of streetlights in the vicinity of sandy beaches for turtles so that they are not near the horizon when viewed from the beach.
- Employ adaptive management post-LED light conversion to reduce or eliminate unforeseen potential impacts to seabirds and sea turtles.
- Coordinate with wildlife organizations and agencies following the conversion project, as appropriate, to identify problematic streetlights, if any, and take appropriate actions.

7.3 Summary

The best take-away from nation-wide LED streetlight conversion projects is to employ a lighting consultant for both the pre-planning and post LED light installation fine-tuning stages. Ground truthing post LED installation would ensure accurate light measurements are obtained. By project implementation of avoidance and minimization measures, including those recommended in Section 7.2, The County of Maui's LED light conversion project is unlikely to impact nocturnal seabirds NESH and HAPE or sea turtles HAST and GRST any more than existing HPS lighting.

References

Ainley, D.G., R.R. Podolsky, L. deForest, and G.A. Spencer. 1997a. "New insights into the status of the Hawaiian Petrel on Kauaʻi." *Colonial Waterbirds* 20 (1): 24–30.

Ainley, D.G., R.R. Podolsky, N. Nur, L. DeForest, and G.A. Spencer. 2001. "Status and population trends of the Newell's Shearwater on Kaua`i: A model for threatened petrels on urbanized tropical oceanic islands." *Studies in Avian Biology* 22 (108-123): 108.

Ainley, D.G., T.C. Telfer, and M.H. Reynolds. 1997b. *Townsend's (Puffinus auricularis) and Newell's Shearwater (Puffinus auricularis newelli)*. In *Birds of North America Online*, ed A. Poole. Ithaca, NY: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://micro189.lib3.hawaii.edu:2705/bna/species/297.

Arthur, K.E., and G.H. Balazs. 2008. "A comparison of immature green turtle (*Chelonia mydas*) diets among seven sites in the Main Hawaiian Islands." *Pac. Sci.* 62: 205-217.

Aubé, M., A. Simoneau, R. Wainscoat, and L. Nelson. 2018. "Modelling the effects of phosphor converted LED lighting to the night sky of the Haleakala Observatory, Hawai'i." *Monthly Notices of the Royal Astronomical Society* 478: 1776-1783.

Balazs, G. 1976. "Green turtle migrations in the Hawaiian Archipelago." *Biological Conservation* 9: 125-140.

---. 1985. "History of sea turtles at Polihua Beach on northern Lana'i." *'Elepaio* 46 (1): 1-3.

Balazs, G.H. 1980. *Synopsis of biological data on the green turtle in the Hawaiian Islands.* (U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-7. 141 pp.).

---. 1994. "Homeward bound: satellite tracking of Hawaiian green turtles from nesting beaches to foraging pastures." Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation.

Balazs, G.H., and M. Chaloupka. 2004. "Thirty-year recovery trend in the once depleted Hawaiian green sea turtle stock." *Biol. Conserv.* 117: 491-498.

Balazs, G.H., R.G. Forsyth, and A.K.H. Kam. 1987. *Preliminary assessment of habitat utilization by Hawaiian green turtles in their resident foraging pastures.* (U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-71. 107 pp.).

Balazs, G.H., H. Hirth, P. Kawamoto, E. Nitta, L. Ogren, R. Wass, and J. Wetherall. 1992. *Interim Recovery Plan for Hawaiian Sea Turtles.* (Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI; Southwest Fish. Sci. Cent. Admin. Rep. H-92-01. 76 pp.).

Balazs, G.H., R.K. Miya, and M.A. Finn. 1994. "Aspects of Green Turtles in their Feeding, Resting, and Cleaining Areas Off Waikiki Beach." Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation, Jekyll Island, GA. https://www.researchgate.net/profile/Charles-Caillouet-Jr/publication/297732301_Incidental_catch_of_Kemp's_ridley_sea_turtles_Lepidochelys_kempi_by_hook_and_line_along_the_Texas_coast_1980-1992/links/5829ae7b08ae825cda7ef9f1/Incidental-catch-of-Kemps-ridley-sea-turtles-Lepidochelys-kempi-by-hook-and-line-along-the-Texas-coast-1980-1992.pdf#page=26.

Balazs, G.H., P. Parker, J. Gorman, J. Luecke, and J. Pawloski. 2015a. "Settling Down in Hawaii: Adaptation of Captive-bred Green Turtles (*Chelonia mydas*) Released from the Maui Ocean Center." The Marine Turtle Newsletter. Accessed http://www.seaturtle.org/mtn/archives/mtn145/mtn145-5.shtml Sept 14 2021.

Balazs, G.H., K.S. Van Houtan, S.A. Hargrove, S.M. Brunson, and S.K.K. Murakawa. 2015b. "A review of the demographic features of Hawaiian green turtles (*Chelonia mydas*) " *Chelonian Conserv. Biol.* (14): 119−129.

Bastos, R., B. Martins, J.A. Cabral, F.R. Ceia, J.A. Ramos, V.H. Paiva, A. Luís, and M. Santos. 2020. "Oceans of stimuli: an individual-based model to assess the role of olfactory cues and local enhancement in seabirds' foraging behaviour." *Animal Cognition* 23 (4): 629-642. https://doi.org/10.1007/s10071-020-01368-1. https://doi.org/10.1007/s10071-020-01368-1.

Bernard, H. 2020. *Expert Disclosure Report.* Hawai'i Wildlife Fund (Hawai'i Wildlife Fund. et al.. v. Department of Public Works. County of Maui. et al.. Civ. No. 19-1-0053(1) (RILL)).

Bilsten, J., M. Ullman, and G. Cooper. 2013. *DOE Solid-State Lighting Webinar.* Municipal Solid-State Lighting Consortium (U.S. Department of Energy).

Bingman, V.P., and S.A. MacDougall-Shackleton. 2017. "The avian hippocampus and the hypothetical maps used by navigating migratory birds (with some reflection on compasses and migratory restlessness)." *Journal of Comparative Physiology A* 203 (6): 465-474. https://doi.org/10.1007/s00359-017-1161-0. https://doi.org/10.1007/s00359-017-1161-0.

BirdLife International. 2021. "Species factsheet: *Puffinus newelli*. Downloaded from http://www.birdlife.org on 06/09/2021." Accessed September 2021. http://datazone.birdlife.org/species/factsheet/newells-shearwater-puffinus-newelli/text.

Black, C.A. 2018. "The Impact of the Terrestrial Basking Event of Hawaiian Green Sea Turtles on Visitors at Ho'okipa, Maui." Bachelor of Tourism Management, Department of Tourism Management, Thompson Rivers University.

Bonadonna, F., and A. Gagliardo. 2021. "Not only pigeons: avian olfactory navigation studied by satellite telemetry." *Ethology Ecology and Evolution* 33 (3): 273-289. https://hal.archives-ouvertes.fr/hal-03324963/file/Corr-AB-Bonadonna-Gagliardo%20FB%202.pdf.

Bowen, W., A.B. Meylan, J.P. Ross, C.J. Limpus, G.H. Balazs, and J.C. Avise. 1992. "Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny." *Evolution* 46 (4): 865-881.

Brandt, C.A., J.K. Parrish, and C.N. Hodges. 1995. "Predictive approaches to habitat quantification: Dark-rumped Petrels on Haleakalā, Maui." *Auk* 112 (3): 571-579. http://www.jstor.org/stable/4088674.

Brei, M., A. Pérez-Barahona, and E. Strobl. 2019. "Protecting Species through Legislation: The Case of Sea Turtles." *American Journal of Agricultural Economics* 102 (1): 300-328.

Bretschneider, B. 2018. "A Reality Check on Blue Light Exposure." Research. Posted By Joe Wood On September 25, 2018,. Accessed Dec 12. https://www.ies.org/fires/a-reality-check-on-blue-light-exposure/print/.

Brooke, M.D.L. 1990. *The Manx Shearwater*. San Diego, CA: Academic Press Inc.

Brunson, S., K.S. Van Houtan, S. Hargrove, G.H. Balazs, and T. Work. 2017. "Population threats to Hawaiian hawksbill sea turtles revealed from three decades of strandings." 37th Annual Symposium on Sea Turtle Conservation and Biology, Las Vegas, Nevada.

Burg, T.M., and A.B. Martin. 2012. "No island hopping for Hawaiian petrels." *Heredity* 109 (1): 4-5. https://doi.org/10.1038/hdy.2012.5. https://pubmed.ncbi.nlm.nih.gov/22453513

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3375408/.

Byrd, V.G., J.L. Sincock, T.C. Telfer, D.I. Moriarty, and B.G. Brady. 1984. "A cross-fostering experiment with Newell's race of Manx Shearwater." *Journal or Wildlife Management* 48: 163–168.

Casey, D. 2020. "Ecologically Distinct Populations of Hawaiian Petrel (*Pterodroma sandwichensis*): Quantitative Isotopic Analysis to Explore the Uniqueness of Foraging Habits in Kauai and Hawaii Populations." Honors Research Projects, Population Biology Commons, The University of Akron (1046). https://ideaexchange.uakron.edu/cgi/viewcontent.cgi?article=2378&context=honors_research_projects.

Cerizo, K. 2021. "Endangered turtles near road face risk of Kealia area traffic: Nonprofit urges community to protect special fence line." *The Maui News*, 2021, The Local News.

Chaloupka, M., and G. Balazs. 2007. "Using Bayesian state-space modelling to assess the recovery and harvest potential of the Hawaiian green sea turtle stock." *Ecol Model* 205: 93-109.

Chaloupka, M., T.M. Work, G.H. Balazs, M. S.K.K., and R. Morris. 2008. "Cause-specific temporal and spatial trends in green sea turtle strandings in the Hawaiian Archipelago (1982–2003)." *Marine Biology* 154: 887–898. https://doi.org/DOI 10.1007/s00227-008-0981-4. https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/about/pdfs/turtle_stranding.pdf.

City of Las Vegas. 2013. *Evaluation of L.E.D. Street Lighting Implementation; Las Vegas, Nevada: .* (Las Vagas, Nevada).

City of San José. 2016. *Public Streetlight Design.* City of San José.

Cluett Pactol, C. 2018. "Drawing a Seabird Map." *The Molokai Dispatch*, 2018. https://themolokaidispatch.com/drawing-a-seabird-map/.

Commonwealth of Australia. 2020. National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds. edited by Department of the Environment and Energy. Department of Biodiversity, Conservation, and Attractions: Government of Western Australia.

Cooper, B.A., and R.H. Day. 1995. *Kauaʻi endangered seabird study volume 1: Interactions of Dark-rumped Petrels and Newell's Shearwaters with utility structures on Kauaʻi, Hawaiʻi.* Electric Power Research Inst. (Palo Alto, California).

---. 1998. "Summer behavior and mortality of Dark-rumped Petrels and Newell's Shearwaters at power lines on Kauaʻi." *Colonial Waterbirds* 21 (1): 11–19.

---. 2003. "Movement of the Hawaiian petrel to inland breeding sites on Maui Island, Hawai'i." *Waterbirds* 26 (1): 62-71.

Council of the County of Maui. 2015. A Bill for an Ordinance Amending Section 2.40.030, repealing Chapter 12.17, and amending Title 20, Maui County Code, Relating To Outdoor Lighting Standards. Infrastructure and Environmental Management Committee.

County of Hawai'i, 2019, "County Launching New Streetlight Improvement Program," https://www.hawaiicounty.gov/Home/Components/News/News/1236/.

---. 2021. Streetlight Standards. edited by Department of Public Works. Hilo, Hawai'i: Traffic Division.

Cruz, M.S., and R. Lindner. 2011. Insect Vision: Ultraviolet, Color, and LED Light. University of Georgia Department of Entomology.

Cutt, T., and J. Martin. 2019. *Sea Turtle Stranding Response & Rescue 2019 Summary of Results, Maui, Hawaiʻi.* Marine Institue Maui Ocean Center. https://mocmarineinstitute.org/wp-content/uploads/2021/05/2019-Sea-Turtle-REport_Final.pdf.

---. 2020. "Sea Turtle Conservation Program 2020 Annual Report." Marine Institue Maui Ocean Center. Accessed Sept 16 2021. https://mocmarineinstitute.org/swimfree/sea-turtle-rescue/.

Day, R.H., and B.A. Cooper. 1995. "Patterns of Movement of Dark-Rumped Petrels and Newell's Shearwaters on Kauaʻi." *Condor* 97 (4): 1011–1027. http://www.jstor.org/stable/1369540.

---. 2002. *Petrel and shearwater surveys near Kalaupapa, Molokaʻi Island, June 2002.* Pacific Islands Network, National Park Service.

---. 2008. *Results of Endangered Seabird and Hawaiian Hoary Bat Surveys on Northern Oahu Island, Hawaiʻi, October 2007 and July 2008, for FirstWind, LLC.* Prepared by ABR, Inc., Forest Grove, OR and Fairbanks, AK.

Day, R.H., B.A. Cooper, and R.J. Blaha. 2003a. "Movement patterns of Hawaiian petrels and Newell's shearwaters on the Island of Hawaiʻi." *Pacific Science* 57 (2): 147–159.

Day, R.H., B.A. Cooper, and T.C. Telfer. 2003b. "Decline of Townsend's (Newell's) Shearwaters (*Puffinus auricularis newelli*) on Kauaʻi, Hawaiʻi." *Auk* 120 (3): 669–679.

Day, R.H., A.E. Gall, R.M. Burgess, J.P. Parrett, and B.A. Cooper. September 2005. *Movements of Hawaiian Petrels near USAF facilities near the summit of Haleakala, Maui Island, Fall 2004 and Spring 2005.* ABR Environmental, Inc. (Kihei, Hawai`i).

Deringer, C.V. 2009. "Breeding phenology of Hawaiian Petrels (*Pterodroma sandwichensis*) and Newell's Shearwaters (*Puffinus auricularis newelli*) on Kauaʻi, Hawaiʻi, using ornithological radar, auditory, and visual surveys." Tropical Conservation Biology and Environmental Sciences, M.S. Thesis, University of Hawaiʻi.

---. 2013. Auditory surveying for Hawaiian Petrels and Newell's Shearwaters in Puʻu O ʻUmi Natural Area Reserve, Hawaiʻi Island. Final Report to the State of Hawaiʻi, Department of Land and Natural Resources, Division of Forestry and Wildlife. Kamuela, HI. 24pp.

Deringer, C.V., R.H. Day, B.A. Cooper, and W.C. Pitt. *in prep-a*. Evidence of a population change in Hawaiian Petrel and Newell's Shearwater in Kohala Mountain, Hawaiʻi. Hilo, Hawaiʻi.

Deringer, C.V., E. Haber, B. McFarland, O. Johnson, and M.L. VanZandt. 2011a. Audio-visual Surveying for Hawaiian Petrels and Newell's Shearwaters in Puʻu O ʻUmi, Natural Area Reserves System, Hawaiʻi Island. edited by USDA-APHIS-WS-NWRC. Hilo, HI. 24 pp.

Deringer, C.V., N.D. Holmes, and S. Judge. *in prep-b*. "Interisland differences in the breeding phenology of Hawaiian Petrel and Newell's Shearwater in Hawai'i." *Kauai Endangered Seabird Recovery Project and University of Hawai'i at Hilo*.

Deringer, C.V., M.L. VanZandt, and W.C. Pitt. 2011b. Ornithological Radar Surveying for Hawaiian Petrels and Newell's Shearwaters in Waipiʻo and Pololū Valleys, Kohala Mountain, Hawaiʻi. edited by USDA-APHIS-WS-NWRC. Hilo, Hawaiʻi.

Ecological Associates. 1998. *Coastal Roadway Lighting Manual.* Florida Power & Light Company (Jensen Beach, Florida). https://myfwc.com/media/15867/coastal_roadway_lighting_manual.pdf.

Ehrenfeld, D.W. 1968. "The role of vision in the sea-finding orientation of the green turtle (Chelonia mydas). 2. Orientation mechanism and range of spectral sensitivity." *Animal Behaviour* 16 (2): 281-287. https://doi.org/https://doi.org/10.1016/0003-3472(68)90010-9. https://www.sciencedirect.com/science/article/pii/0003347268900109.

Else, J. 2018. "Shearwaters in the Sky." *The Garden Island*, 2018. https://www.thegardenisland.com/2018/09/17/hawaii-news/shearwaters-in-the-skies/.

Frey, A., P.H. Dutton, and G.H. Balazs. 2013. "Insights on the demography of cryptic nesting by green turtles (*Chelonia mydas*) in the main Hawaiian Islands from genetic relatedness analysis." *Journal of Experimental Marine Biology and Ecology* 442: 80-87. https://doi.org/https://doi.org/10.1016/j.jembe.2013.01.030. https://www.sciencedirect.com/science/article/pii/S0022098113000543.

Friswold, B., K. Swindle, K.D. Hyrenbach, and M. Price. 2020. "Wedge-tailed Shearwater (*Ardenna pacifica*) fallout patterns inform targeted management." *Marine Ornithology* 48: 245-254.

Gall, A.E., and T. Obritschkewitsch. 2019. *Movements of Hawaiian Petrels Near the Daniel K. Inouye Solar Telescope and the Summit of Haleakalā, Maui Island, Summer 2019.* ABR, Inc.—Environmental Research and Services (Fairbanks, AK). https://dkist.nso.edu/sites/atst.nso.edu/files/docs/NHPA/20190930-ABR_Haleakal%C4%81%20Avian%20Study_FINAL.PDF.

Gaos, A.R., E.L. LaCasella, L. Kurpita, G. Balazs, S. Hargrove, C. King, H. Bernard, T.T. Jones, B. Peter, and P.H. Dutton. 2020. "Hawaiian hawksbills: a distinct and isolated nesting colony in the Central North Pacific Ocean revealed by mitochondrial DNA." *Conservation Genetics* Printed Online: https ://doi.org/10.1007/s1059 2-020-01287 -1: 14.

General Electric Company. 2021. "Installation Guide: Evolve™ LED Roadway Light. GEH6064 | 99003695" Current Lighting Solutions, LLC.

Gibbons, R.B., F. Guo, A. Medina, T.N. Terry, J. Du, P.J. Lutkevich, and Q. Li. 2014. Design Criteria for Adaptive Roadway Lighting. edited by USHDOT Federal Highway Administration. Virginia Tech Transportation Institute: McLean, Virginia.

Griesemer, A.M., and N.D. Holmes. 2011. *Newell's Shearwater population modeling for Habitat Conservation Plan and Recovery Planning.* The Hawaiʻi-Pacific Islands Cooperative Ecosystem Studies Unit and Pacific Cooperative Studies Unit, University of Hawaiʻi, Honolulu, HI.

H.T. Harvey & Associates. 2022. "Seabird Conservation Program on Maui Island." First Wind Energy, LLC. https://www.harveyecology.com/first-wind. Accessed Jan 5.

Harrison, C.S. 1990. *Seabirds of Hawai'i: natural history and conservation*. Ithaca, N.Y.: Cornell University Press.

Hawai'i Tribune Herald. 2017. "Streetlight savings pay for traffic signal upgrades." https://www.hawaiitribune-herald.com/2017/08/01/hawaii-news/streetlight-savings-pay-for-traffic-signal-upgrades/.

Hayes, B., G.R. Martin, and M.d.L. Brooke. 1991. "Novel Area Serving Binocular Vision in the Retinae of Procellariiform Seabirds." *Brain, Behavior and Evolution* 37 (2): 79-84. https://doi.org/10.1159/000114348. https://www.karger.com/DOI/10.1159/000114348.

HDLNR. 2015. *Hawaiʻi's State Wildlife Action Plan. Prepared.* (Honolulu, Hawaiʻi). https://dlnr.hawaii.gov/wildlife/files/2020/07/HI-SWAP-2015-FINAL.pdf.

HFP, 2017, "Streetlights: Kaua'i First to Complete LED Conversion."

---, 2019, "City completes installation of 53,000 streetlights to energy-saving LEDs," http://www.hawaiifreepress.com/Articles-Main/ID/24252/City-completes-installation-of-53000-streetlights-to-energy-saving-LEDs.

Hirai, L.T. 1978. "Possible Dark-rumped Petrel colony on Lanaʻi, Hawaiʻi." *ʻElepaio* 38: 71–72. https://libsausage.unm.edu/sites/default/files/journals/wb/v09n02/p0071-p0078.pdf.

Hiscocks, P.D., and S. Guðmundsson. 2010. "The contribution of street lighting to light pollution." *J. Roy. Astron. Soci. Can.* 104: 190-196.

Hodges, C.S., and R.J. Nagata, Sr. 2001. "Effects of predator control on the survival and breeding success of the endangered Hawaiian Dark-rumped petrel." *Studies in Avian Biology* 22 (308-318): 308.

Holly, D. 2021. "LED Lighting Wave: DOE predicts 100 percent street light changeover by 2030." *Rural Electric Magazine*.

Holmes, N., H. Freifeld, F. Duvall, J. Penniman, M. Laut, and N. Creps. 2011. *Newell's Shearwater and Hawaiian Petrel recovery: A five year action plan.* Unpublished document to U.S. Fish and Wildlife Service and Hawaiʻi Division of Forestry and Wildlife.

Holmes, N.D. 2006. *Kaua`i Endangered Seabird Recovery Project trip repost. Upper Limahuli Preserve. 11-14 August 2006.* Kaua`i Endangered Seabird Recovery Project (Waimea).

Holmes, N.D., and T. Joyce. 2009. *Report on observations of Hawaiian Petrel in Upper Limahuli Preserve, Kauaʻi, Hawaiʻi (2006–2009).* Kauaʻi Endangered Seabird Recovery Project.

Holmes, N.D., J.R. Troy, and T.W. Joyce. 2009. "Status and conservation of Newell's Shearwaters on Kauaʻi, Hawaiʻi. Reduction in breeding range and developments towards protecting colonies. Spoken paper." 36th Pacific Seabird Group Annual Meeting, Hakodate, Japan.

HPR, "Bright artificial lights disorient, cause death of seabirds and hatchling sea turtles alike," 2021, in *The Conversation*, 7:16.

---, "'Ua'u populations on Lānaʻi are on the rebound, conservationists say," 2022, in *The Conversation*, 7:08, https://www.hawaiipublicradio.org/the-conversation/2022-01-05/uau-populations-on-lanai-are-on-the-rebound-conservationists-say.

Hu, D., C. Glidden, J.S. Lippert, L. Schnell, J.S. MacIvor, and J. Meisler. 2001. "Habitat use and limiting factors in a population of Hawaiian Dark-rumped Petrels on Mauna Loa, Hawai`i." *Studies in Avian Biology* 22: 234–242.

HWF. 2020. *Annual Permit Report 2019 Nesting Season.* Hawaiʻi Wildlife Fund.

Hyrenbach, K.D., J. Urmston, and K. Swindle. 2022. "Road surveys detect unusually high Wedge-tailed Shearwater fallout in SE O'ahu during the 2011 fledging season " *ʻElapiao* 82 (1): 1-5. https://www.pelagicos.net/Reprints/2022/Hyrenbach_et_al._2022_Elepaio82.1.pdf.

Idle, J., C. Wilhite, K. Harmon, B. Friswold, and M. Price. 2021. "Wedge-tailed Shearwater (*Ardenna pacifica*) nesting success in human-dominated coastal environments." *PeerJ* 9: e12096. https://doi.org/10.7717/peerj.12096.

IUCN. 2017. "The IUCN Red List of Threatened Species." Accessed 27 Sept 2017.

Joyce, T., N. Holmes, and R.A. Phillips. 2010. "Post-breeding season dispersal of Newell's Shearwaters." Hawaii Conservation Conference 2010, Honolulu, HI.

Judge, S. 2010. "Hawaiian Petrel decline in Hawai`i Volcanoes National Park on Mauna Loa, personal communication."

---. 2011. "Interisland Comparison of Behavioral Traits and Morphology of the Endangered Hawaiian Petrel: Evidence for Character Differentiation." Master of Science, Tropical Conservation Biology and Environmental Sciences, University of Hawaiʻi at Hilo (Chapter 2. Interisland Comparison of Hawaiian Petrel Breeding Phenology).

Katahira, L.K., C.M. Forbes, A.H. Kikuta, G.H. Balazs, and M. Bingham. 1994. "Recent findings and management of hawksbill turtle nesting beaches in Hawaii." Proc. of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-351, 323 pp.

KESRP. 2009a. *Annual monitoring of Hawaiian Petrels and Newell's Shearwaters on Kauaʻi, Hawaiʻi, using ornithological radar. Unpublished database.* State of Hawaiʻi, Division of Forestry and Wildlife.

---. 2009b. *Auditory surveys of Newell's Shearwaters on Kauaʻi, Hawaiʻi.* Kauaʻi Endangered Seabird Recovery Project (Waimea, Hawaiʻi).

---. 2019. "The Birds: Hawaiian Petrel." Kauaʻi Endangered Seabird Recovery Project. Accessed March 2022. https://kauaiseabirdproject.wordpress.com/hawaiian-petrel/.

King, C.S. 2015. *Initial Report of Nesting Beaches Throughout Greater Maui and Historical Nesting Records (1991-2014).* https://georgehbalazs.com/wp-content/uploads/2020/02/2014MauiNestingReportCKing.pdf.

King, C.S., W.G. Gilmartin, S. Hau, H.J. Bernard, S.M. Canja, G. Nakai, M.J. Grady, S. Williams, and A.G. Hebard. 2004. "Nesting Hawksbill Turtles (*Eretmochelys imbricata*) on the Island of Maui, Hawaiʻi from 1996-2003." https://www.wildhawaii.org/wp-content/uploads/2020/12/Nesting-Hawksbill-Turtles-Maui-Hawaiifrom-1996-2003.pdf.

King, W.B., and P.J. Gould. 1967. "The status of Newell's Shearwater race of the Manx Shearwater." *Living Bird* 6: 165-186.

KIUC. 2011. *Kaua'i Island Utility Cooperative System Short-term Habitat Conservation Plan.* State of Hawai'i Board of Land and Natural Resources and U.S. Fish and Wildlife Service.

Liebman, P.A., and A.M. Granda. 1971. "Microspectrophotometric measurements of visual pigments in two species of turtle, Pseudemys scripta and Chelonia mydas." *Vision Research* 11 (2): 105-114. https://doi.org/https://doi.org/10.1016/0042-6989(71)90227-6. https://www.sciencedirect.com/science/article/pii/0042698971902276.

Lima, R.C., J. Pinto da Cunha, and N. Peixinho. 2016. "Light Pollution: Assessment of Sky Glow on two Dark Sky Regions of Portugal." *Journal of Toxicology and Environmental Health, Part A*: 1-13. http://dx.doi.org/10.1080/15287394.2016.1153446.

Longcore, T., and C. Rich. 2004. "Ecological light pollution." *Frontiers in Ecology and the Environment* 2: 191–198.

Longcore, T., A. Rodríguez, B. Witherington, J. Penniman, L. Herf, and M. Herf. 2018. "Rapid assessment of lamp spectrum to quantify ecological effects of light at night." *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology* 329. https://doi.org/10.1002/jez.2184.

Losey, G.S., G.H. Balazs, and L.A. Privitera. 1994. "Cleaning Symbiosis between the Wrasse, Thalassoma duperry, and the Green Turtle, Chelonia mydas." *Copeia* 1994 (3): 684-690. https://doi.org/10.2307/1447184. http://www.jstor.org/stable/1447184.

Luginbuhl, C.B., C.E. Walker, and R. Wainscoat. 2009. "Lighting and Astronomy." *Phys. Today* 62: 32-37.

Martin, G.R. 2007. "Visual fields and their functions in birds." *Journal of Ornithology* 148 (2): 547-562. https://doi.org/10.1007/s10336-007-0213-6. https://doi.org/10.1007/s10336-007-0213-6.

Martin, G.R., and M.d.L. Brooke. 1991. "The eye of a procellariiform seabird, the Manx shearwater, Puffinus puffinus: visual fields and optical structure." *Brain Behav Evol* 37 (2): 65-78. https://doi.org/10.1159/000114347.

Martin, G.R., and D. Osorio. 2010. *Vision in Birds*. Vol. 1.*The senses: A comprehensive reference*. Elsevier Inc.

Mathger, L.M., L. Litherland, and K.A. Fritsches. 2007. "An Anatomical Study of the Visual Capabilities of the Green Turtle, *Chelonia mydas*." *Copeia* 1: 169-179. https://www.paludarium.net/uploads/4/4/1/8/4418601/an_anatomical_study_of_the_visual_capabilities_of_the_green_turtle.pdf.

Mendoza, J. 2016. "City moves ahead with plan to convert streetlights to LED." *Hawai'i News Now*, 2016. https://www.hawaiinewsnow.com/story/32827261/city-moving-ahead-again-with-streetlight-conversion/.

Meylan, A.B., and A. Redlow. 2006. "*Eretmochelys imbricata* – Hawksbill Turtle." *Biology and Conservation of Florida Turtles,* edited by P.A. Meylan, 105-127Chelonian Research Monographs 3.

Mitchell, C., C. Ogura, D.W. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard, and A. McClung. 2005. *Hawaiʻi's comprehensive wildlife conservation strategy.* (Honolulu, HI: Department of Land and Natural Resources).

MNSRP. 2022. "Acoustic Studies, Burrow Searching and Monitoring, Banding, and Tracking Endangered Hawaiian Seabirds." Our Work: Research. https://mauinuiseabirds.org/lanaihale/. Accessed Jan 5.

Morra, K.E., A.E. Wiley, H.F. James, A. Dutcher, and P.H. Ostrom. 2018. "Influence of Feather Selection and Sampling Protocol on Interpretations of Hawaiian Petrel (*Pterodroma sandwichensis*) Nonbreeding Season Foraging Habits from Stable Isotope Analysis." *Waterbirds* 41 (1): 93-100. https://www.researchgate.net/profile/Kaycee-Morra/publication/324116114_Influence_of_Feather_Selection_and_Sampling_Protocol_on_Interpretations_of_Hawaiian_Petrel_Pterodroma_sandwichensis_Nonbreeding_Season_Foraging_Habits_from_Stable_Isotope_Analysis/links/5b8577a94585151fd139253c/Influence-of-Feather-Selection-and-Sampling-Protocol-on-Interpretations-of-Hawaiian-Petrel-Pterodroma-sandwichensis-Nonbreeding-Season-Foraging-Habits-from-Stable-Isotope-Analysis.pdf.

Natividad Bailey, C.S. 2009a. *Haleakalā National Park Service database: Hawaiian Petrel fallout on Maui.* U.S. National Park Service unpublished (Makawao).

---. 2009b. *Seabird inventory at Haleakalā National Park, Maui, Hawaiʻi.* University of Hawaiʻi at Manoa, Department of Botany (Honolulu, Hawaiʻi).

---. 2011. "Observations of Hawaiian Petrel breeding activity at Haleakalā National Park, Maui, Hawaiʻi, Personal communication."

Nelson, J.B., and P. Herron Baird. 2002. "Seabird communication and displays." In *Biology of Marine Birds*, edited by E. A. Schreiber and J. Burger, In Marine Biology, 308-357. Boca Raton: CRC Press.

Nevitt, G.A., R.R. Veit, and P. Kareiva. 1995. "Dimethyl sulphide as a foraging cue for Antarctic procellariiform seabirds." *Nature* 376: 680–682.

Newell's Shearwater Working Group. October 2005. *Newell's Shearwater five-year work plan. Newell's Shearwater Working Group.* Kauaʻi Endangered Seabird Recovery Project.

NMFS and USFWS. 1998a. Recovery plan for the US Pacific populations of green turtles (*Chelonia mydas*). National Marine Fisheries Service and U.S. Fish and Wildlife Service: Silver Spring, MD and Portland, OR. 84 pp.

---. 1998b. Recovery plan for U.S. Pacific populations of the East Pacific green turtle (*Chelonia mydas*). United States National Marine Fisheries Service: Silver Spring, MD.
---. 1998c. *Recovery Plan for U.S. Pacific Populations of the Hawksbill Turtle (Eretmochelys imbricata).* Silver Spring, MD (National Marine Fisheries Service).
---. 2007. *Green Sea Turtle (Chelonia mydas) 5-year Review: summary and analysis.* Silver Springs, MD and Jacksonville, FL. 102 pp. (National Marine Fisheries Service, Office of Protected Resources and U.S. Fish and Wildlife Service).
NOAA Fisheries. 2011a. *Green Turtle (Chelonia mydas).* Silver Spring, MD (Office of Protected Fisheries).
---. 2011b. *Hawksbill Turtle (Eretmochelys imbricata).* Silver Spring, MD (Office of Protected Fisheries).
---. 2017. "Protected Resources: Sea Turtles; Stock Assessment/Estimated Breeding Population." NOAA Fisheries Pacific Islands Regional Office (PIRO). Accessed Mar 7. http://www.fpir.noaa.gov/PRD/prd_hawksbill.html.
Nurzia-Humburg, I., and S. Hargrove. 2008. *Special Report on Marine Turtle Beach Use in the Areas of South-East Oahu and North-West Lanai.* Issued 29 December 2008. https://georgehbalazs.com/wp-content/uploads/2020/03/IR-08-034_SEOahuNWLanai.pdf.
Olson, S.L., and H.F. James. 1982a. "Fossil birds from Hawaiian Islands: Evidence for wholesale extinction by man before western contact." *Science* 217: 633–635.
---. 1982b. "Prodromus of the fossil avifauna of the Hawaiian Islands." *Smithsonian Contibutions to Zoology* 365.
Olson, S.L., and H.F. James. 1991. "Descriptions of thirty-two new species of birds from the Hawaiian Islands: Part I. Non-passeriformes." *Ornithological Monographs* (45): 1-88. http://www.jstor.org/stable/40166794.
Owens, D.W. 1980. "The comparative reproductive physiology of sea turtles." *Am. Zool.* 20 (3): 549-563.
Pace, A. 2000. "Guidelines for the reduction of light pollution." *Light Pollution Awareness Group*: http://www.maltastro.org/lpag/index.htm.
Parsons, J. 1962. *The Green Turtle and Man.* Gainesville, FL (University of Florida Press).
Penniman, J. 2020. *Expert Disclosure Report Presented to the County of Maui.* Maui Nui Seabird Recovery Project (Hawaiʻi Wildlife Fund, et al. v. Department of Public Works, County of Maui, et al., Civ. No. 19-1-0053(1) (RILL)).
---. 2022. "Seabird fallout numbers for Maui Island (2021-2022)." Personal Communication on March 24.
Penniman, J., and F. Duvall. 2008. *Lanaʻihale database. Observations within an Hawaiian Petrel colony on Lanaʻi.* Unpublished Database.
Penniman, J.F., and D.C. Duffy. 2021. *Best Management Practices to Protect Endangered and Native Birds at Solar Installations in Hawaiʻi.* University of Hawaiʻi at Manoa (Honolulu, HI). https://scholarspace.manoa.hawaii.edu/bitstream/10125/79131/1/v203.pdf.
Perrins, C.M., M.P. Harris, and C.K. Britton. 1973. "Survival of Manx Shearwaters *Puffinus puffinus*." *Ibis* 115: 535-548.
Podolsky, R., D.G. Ainley, G. Spencer, L. Deforest, and N. Nur. 1998. "Mortality of Newell's Shearwaters caused by collisions with urban structures on Kauai." *Colonial Waterbirds* 21 (1): 20-34.
Pollonara, E., P. Luschi, T. Guilford, M. Wikelski, F. Bonadonna, and A. Gagliardo. 2015. "Olfaction and topography, but not magnetic cues, control navigation in a pelagic seabird: displacements with shearwaters in the Mediterranean Sea." *Scientific Reports* 5 (16486): 10. https://www.nature.com/articles/srep16486.pdf.
Poot, H., B.J. Ens, H. deVries, M.A.H. Donners, M.R. Wernand, and J.M. Marquenie. 2008. "Green Light for Nocturnally Migrating Birds." *Ecology and Society* 13 (2): 15. https://www.jstor.org/stable/pdf/26267982.pdf.
Powell, N. 2020. *2020 Green Sea Turtle Monitoring Report.* The Nature Conservancy. https://georgehbalazs.com/wp-content/uploads/2021/03/2020_TNC_TurtleMonitoringReport.pdf.

Raine, A., T. Anderson, M. Vynne, S. Driskill, H. Raine, and J. Adams. 2020. "Post-release survival of fallout Newell's shearwater fledglings from a rescue and rehabilitation program on Kaua'i, Hawai'i." *Endangered Species Research* 43: 39-50.

Raine, A.F., N.D. Holmes, M. Travers, B.A. Cooper, and R.H. Day. 2017. "Declining population trends of Hawaiian Petrel and Newell's Shearwater on the island of Kauai, Hawaii, USA." *The Condor: Ornithological Applications* 119: 405-415.

Raine, A.F., M. Vynne, T. Anderson, S. Driskill, H. Raine, and J. Adams. 2018. *Pilot Project: Assessing the Effectiveness of the SOS Rehabilitation Program: YEAR 3.* Kaua'i Endangered Seabird Recovery Project. https://dlnr.hawaii.gov/wildlife/files/2020/05/A10-Pilot-Project_Assessing-the-effectiveness-of-the-SOS-rehabilitation-project-YEAR-3_2018.pdf.

Reed, J.R. 1987. "Polarizing filters fail to reduce light attraction in Newell's Shearwaters." *Wildlife Society Bulletin* 15: -598.

Reed, J.R., J.P. Hailman, and J.L. Sincock. 1986. *Final report on seabird light modification study.*

Richardson, F., and D.H. Woodside. 1954. "Rediscovery of the nesting of the Dark-rumped Petrel in the Hawaiian Islands." *Condor* 56: 323–327.

Rick, C. 2012. "The Turtles of Sugar Beach." Maui Manini. https://mauimanini.wordpress.com/tag/turtle/. Accessed Oct 2021.

Romine, B.M., C.H. Fletcher, M.M. Barbee, T.R. Anderson, and L.N. Frazier. 2013. "Are beach erosion rates and sea-level rise related in Hawaii?" *Global and Planetary Change* 108: 149-157.

Salmon, M. 2003. "Artificial night lighting and sea turtles." *Biologist* 50: 163-168.

Salmon, M., J. Wyneken, E. Fritz, and M. Lucas. 1992. "Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues." *Behaviour* 122: 56–77.

Seitz, W.A., K.M. Kagimoto, B. Luehrs, and L. Katahira. 2012. *Twenty Years of Conservation and Research Findings of the Hawai'i Island Hawksbill Turtle Recovery Project, 1989 - 2009.* Universtity of Hawai`i at Manoa (The Hawai`i-Pacific Islands Cooperative Ecosystem Studies Unit & Pacific Cooperative Studies Unit). https://scholarspace.manoa.hawaii.edu/bitstream/10125/33196/v178.pdf.

Simons, T.R. 1985. "Biology and behavior of the endangered Hawaiian Dark-rumped Petrel." *Condor* 87: 229–245.

Simons, T.R., and C.S. Natividad Hodges. 1998. *Dark-rumped Petrel (Pterodroma phaeopygia)*, ed A. Poole. Ithaca, NY: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online. http://micro189.lib3.hawaii.edu:2705/bna/species/297.

Sin, S.Y.W., A. Cloutier, G.A. Nevitt, and S.V. Edwards. 2021. "Olfactory receptor subgenome and expression in a highly olfactory procellariiform seabird." *Genetics*. https://doi.org/10.1093/genetics/iyab210. https://doi.org/10.1093/genetics/iyab210.

Sincock, J.L., and G.E. Swedberg. 1969. "Rediscovery of the nesting grounds of Newell's Manx Shearwater (*Puffinus puffinus newelli*), with initial observations." *Condor* 71: 69–71.

Spear, L.B., D.G. Ainley, N. Nur, and S.N.G. Howell. 1995. "Population size and factors affecting at-sea distributions of four endangered Procellariids in the tropical Pacific." *Condor* 97: 613–638.

Spear, L.B., D.G. Ainley, and P. Pyle. 1999. "Seabirds in Southeastern Hawaiian Waters." *Western Birds* 30: 1–32.

Spencer, G., B. Yuen, and D. Ainley. 2020. "Establishing a New Breeding Colony of the ESA Threatened Newell's Shearwater on Maui." 47th Annual Meeting of the Pacific Seabird Group, Feb 12–15.

State of Hawai'i. 2009. Save Our Shearwaters (SOS) Seabird Recovery Database for Kaua'i (1979–2008). Department of Land and Natural Resources, Division of Forestry and Wildlife.

---. 2011. Report to the Twenty-sixth Legislature Regular Session of 2012 relating to the Natural Area Reserves System, Natural Area Partnership Program, and the financial condition of the Natural Area reserve fund. In Response to Section 195-6.6, Hawai'i Revised Statutes. edited by Department of Land and Natural Resources Division of Forestry and Wildlife. Honolulu, HI.

Sundquist, L., and H. Bernard. 2018. "Factors in Historical Hatchling Production and Implications for Nesting Hawksbill Sea Turtles (*Eretmochelys imbricata*) on Maui." 38th International Sea Turtle Symposium, Kobye, Japan.

Sundquist, L., S. Canja, H. Bernard, and B. Gilmartin. 2017. "Long-term monitoring and protection of a rare nesting population of hawksbill sea turtles (*Eretmochelys imbricata*) on Maui: trends and developments from 21 years of research." 2017 International Sea Turtle Symposium, Las Vagas, Nevada.

Sur, P. 2012. "To the future: County moves ahead with LED streetlight conversion." *West Hawai'i Today*, 2012. https://www.westhawaiitoday.com/2012/11/28/hawaii-news/to-the-future-county-moves-ahead-with-led-streetlight-conversion/.

Syposz, M., O. Padget, J. Willis, B.M. Van Doren, N. Gillies, A.L. Fayet, M.J. Wood, A. Alejo, and T. Guilford. 2021a. "Avoidance of different durations, colours and intensities of artificial light by adult seabirds." *Scientific Reports* 11 (1): 18941. https://doi.org/10.1038/s41598-021-97986-x. https://doi.org/10.1038/s41598-021-97986-xhttps://www.nature.com/articles/s41598-021-97986-x.pdf.

Syposz, M., O. Padget, J. Wynn, N. Gillies, A.L. Fayet, and T. Guilford. 2021b. "An assay to investigate factors influencing initial orientation in nocturnally fledging seabirds." *Journal of Avian Biology* Nordic Society Oikos (Published by John Wiley & Sons Ltd.): 11. https://onlinelibrary.wiley.com/doi/pdf/10.1111/jav.02613.

Tanji, M. 2021a. "Green Sea Turtle Strandings Nearly Double in 2020." *The Maui News, https://www.mauinews.com/news/local-news/2021/04/green-sea-turtle-strandings-nearly-double-in-2020/*, September 14, 2021a, Local News.

---. 2021b. "Groups threaten to sue hotel over protected seabirds." *The Maui News*, 2021b. https://www.mauinews.com/news/local-news/2021/09/groups-threaten-to-sue-hotel-over-protected-seabirds/.

Taylor, B.K., K.J. Lohmann, L.T. Havens, C.M.F. Lohmann, and J. Granger. 2020. "Long-distance transequatorial navigation using sequential measurements of magnetic inclination angle." *The Royal Society* 18 (174). https://doi.org/https://doi.org/10.1098/rsif.2020.0887.

Telfer, T.C. 1979. "Successful Newell's Shearwater salvage on Kaua'i." *'Elepaio* 39: 71.

Telfer, T.C. 1986. *Newell's Shearwater nesting colony establishment study on the island of Kaua'i. (1980–1985). Final Report, Statewide Pittman-Roberston Program.* State of Hawai'i Department of Land and Natural Resources, (Honolulu, HI).

Telfer, T.C., J.L. Sincock, G.V. Byrd, and J.R. Reed. 1987. "Attraction of Hawaiian seabirds to lights: conservation efforts and effects of moon phase." *Wildlife Society Bulletin* 15: 406–413.

Thurairajah, U. 2015. "A holistic roadway lighting design approach makes a vital contribution to the visibility, operational efficiency, health and safety of the motorists and public." 10th Biennial Joint Meeting and Technical Conference of the CNC/CIE and CIE/USA and celebration of the IYL2015, Impact Center, University of Toronto, October 10-20, 2015.

TNC. 2012. *Mo'omomi Preserve Long-Range Management Plan.* The Nature Conservancy. https://dlnr.hawaii.gov/ecosystems/files/2013/07/C-FW-Submittals-C4.pdf.

Tosini, G., I. Ferguson, and K. Tsubota. 2016. "Effects of blue light on the circadian system and eye physiology." *Molecular vision* 22: 61-72. https://pubmed.ncbi.nlm.nih.gov/26900325 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4734149/.

Troy, J.R., N.D. Holmes, and M.C. Green. 2011. "Modeling artificial light viewed by fledgling seabirds." *Ecosphere* 2 (10): 109.

Troy, J.R., N.D. Holmes, J.A. Veech, and M.C. Green. 2013. "Using observed seabird fallout records to infer patterns of attraction to artificial light." *Endangered Species Research* 22: 225-234. https://www.int-res.com/articles/esr2014/22/n022p225.pdf.

Tyagi, T., and S.K. Bhardwaj. 2021. "Orientation cues and mechanisms used during avian navigation: A review." *Journal of Applied and Natural Science* 13 (2): 627 - 640. https://doi.org/10.31018/jans.v13i2.2684. http://journals.ansfoundation.org/index.php/jans/article/view/2684.

University of Hawaiʻi. 2019. "After 50 years of silence, endangered seabird heard on Maunakea." Research. Accessed Sept 16 2021. https://www.hawaii.edu/news/2019/05/15/endangered-seabird-heard-on-maunakea/.

Urmston, J., K.D. Hyrenbach, S. Carstenn, and K. Swindle. 2020. "Quantifying environmental and anthropogenic drivers of Wedge-tailed Shearwater fallout on a coastal highway on east Oahu." Pacific Seabird Group 47th Annual Meeting, Portland, Oregon, 2 - 15 February 2020.

USDOE. 2016. *LED Color Characteristics.* U.S. Department of Energy.

USDOJ. 2010. *Hawaiian County Agrees to Pay Restitution and Modify Operations to Resolve Endangered Species Act & Migratory Bird Treaty Act Violations.* Office of Public Affairs, (https://www.justice.gov/opa/pr/hawaiian-county-agrees-pay-restitution-and-modify-operations-resolve-endangered-species-act).

USFWS. 1983. Hawaiian Dark-rumped Petrel and Newell's Manx Shearwater Recovery Plan. Portland, OR.

---. 2005. Regional Seabird Conservation Plan, Pacific Region. U.S. Fish and Wildlife Service, Migratory Bird and Habitat Programs, Pacific Region. Portland, Oregon.

---. 2009a. "Endangered species in the Pacific Islands: Hawaiian Petrel (*Pterodroma sandwichensis*). Pacific Islands Fish and Wildlife Office." http://www.fws.gov/pacificislands/fauna/uau.html.

---. 2009b. "Endangered species in the Pacific Islands: Newell's shearwater (*Puffinus auricularis newelli*). Pacific Islands Fish and Wildlife Office." http://www.fws.gov/pacificislands/fauna/newellsshearwater.html.

---. 2015. "Hawksbill Sea Turtle nests of >200 eggs." USFWS North Florida Ecological Services Office (NFESO). Accessed Mar 7.

---. 2016. "Final rule to list eleven distinct population segments of the green sea turtle (*Chelonia mydas*)." *Federal Register* 81 (66): 20058-20090.

---. 2017. "Fact Sheet: Green Turtle (*Chelonia mydas*)." Midway Atoll National Wildlife Refuge and Battle of Midway National Memorial. Last Modified Feb 9 2017. Accessed Mar 7. https://www.fws.gov/refuge/Midway_Atoll/wildlife_and_habitat/Green_Turtle.html.

---. 2019. *Final Environmental Assessment for the Proposed Memorandum of Understanding with the County of Kauaʻi for the Nighttime Operation of Football Facilities.* U.S. Fish and Wildlife Service (https://www.fws.gov/pacificislands/documents/EA_County_of_Kauai_2019_MOU_Final_Combined_signed.pdf). https://www.fws.gov/pacificislands/documents/EA_County_of_Kauai_2019_MOU_Final_Combined_signed.pdf.

USFWS, and State of Hawaiʻi. 2011. DRAFT Newell's Shearwater and Hawaiian Petrel Recovery: 5-year Action Plan.

Van Doren, B.M., K.G. Horton, A.M. Dokter, H. Klinck, S.B. Elbin, and A. Farnsworth. 2017. "High-intensity urban light installation dramatically alters nocturnal bird migration." *Proceedings of the National Academy of Sciences* 114 (42): 11175-11180. https://doi.org/10.1073/pnas.1708574114. https://www.pnas.org/content/pnas/114/42/11175.full.pdf.

Van Houtan, K.S., and J.N. Kittinger. 2014. "Historical commercial exploitation and the current status of Hawaiian green turtles." *Biol Conserv* 170: 20-27.

Van Houtan, K.S., J.N. Kittinger, A.L. Lawrence, C. Yoshinaga, V.R. Born, and A.D. Fox. 2012. "Hawksbill Sea Turtles in the Northwestern Hawaiian Islands." *Chelonian Conservation and Biology* 11 (1): 117-121. https://doi.org/10.2744/ccb-0984.1. https://doi.org/10.2744/CCB-0984.1.

Van Rhijn, F.A. 1979. "Optic orientation in hatchlings of the sea turtle, chelonia mydasI. Brightness: Not the only optic cue in sea-finding orientation." *Marine Behaviour and Physiology* 6 (2): 105-121. https://doi.org/10.1080/10236247909378558. https://doi.org/10.1080/10236247909378558.

VanderWerf, E.A., K.R. Wood, C. Swenson, M. LeGrande, H. Eijzenga, and R.L. Walker. 2007. "Avifauna of Lehua Islet, Hawai'i: Conservation Value and Management Needs." *Pacific Science* 61 (1): 39-52. http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=23218618&site=ehost-live.

Vanzandt, M., D. Delparte, P. Hart, F. Duvall, and J. Penniman. 2014. "Nesting Characteristics and Habitat Use of the Endangered Hawaiian Petrel (*Pterodroma sandwichensis*) on the Island of Lanai." *Waterbirds* 37. https://doi.org/10.1675/063.037.0107.

Vicente, V.P. 1994. "Spongivory in Caribbean hawksbill turtles, *Eretmochelys imbricata*: Data from stranded specimens." Thirteenth Annual Symposium on Sea Turtle Biology and Conservation, NOAA Tech Memo. NMFS-SEFSC-341, Jekyll Island, GA.

Warham, J. 1990. *The petrels: their ecology and breeding systems*. San Diego, CA: Academic Press, Inc.

---. 1996. *The behaviour, population biology and physiology of the petrels*. San Diego, CA: Academic Press Inc.

Welch, A.J., R.C. Fleischer, and H.F. James. 2010. "Genetic divergence among extant and extirpated colonies of an endangered pelagic seabird, the Hawaiian petrel." December 01, 2010. https://ui.adsabs.harvard.edu/abs/2010AGUFM.B11H..07W.

Welch, A.J., R.C. Fleischer, H.F. James, A.E. Wiley, P.H. Ostrom, J. Adams, F. Duvall, N. Holmes, D. Hu, J. Penniman, and K.A. Swindle. 2012. "Population divergence and gene flow in an endangered and highly mobile seabird." *Heredity* 109 (1): 19-28. https://doi.org/10.1038/hdy.2012.7. https://doi.org/10.1038/hdy.2012.7.

Welch, A.J., A.A. Yoshida, and R.C. Fleischer. 2011. "Mitochondrial and nuclear DNA sequences reveal recent divergence in morphologically indistinguishable petrels." *Molecular Ecology* 20 (7): 1364–1377.

Whittow, G.C. 2002. "Seabird reproductive physiology and energetics." In *Biology of Marine Birds*, edited by E.A. Schreiber and J. Burger, In Marine Biology Series, 409-431. Boca Raton, FL: CRC Press.

Whittow, G.C., and G.H. Balazs. 1982. "Basking behavior of the Hawaiian green turtle (*Chelonia mydas*)." *Pac. Sci.* 36: 129-139.

Witherington, B.E. 1992a. "Behavioral responses of nesting sea turtles to artificial lighting." *Herpetologica* 48: 31-39.

---. 1992b. "Sea-finding behavior and the use of photic orientation cues by hatchling sea turtles." PhD dissertation, University of Florida.

Witherington, B.E., and R.E. Martin. 2000. *Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches.* St. Petersburg, Florida (Florida Marine Research Institute).

Wolf, C. 2015. *Streetlights Report.* Univeersity of Iowa (Iowa City, IA). www.iisc.uiowa.edu/.

Wood, J.W., A. Black, and G. Isoardi. 2019. *Assessment of Blue Light Hazards and Correlated Colour Temperature for Public LED Lighting.* Queensland, Australia (Queensland University of Technology).

Wood, K.R., and P. Biley. 2008. "Vegetation description of a nesting site for Newell’s Shearwater (puffinus auricularis newelli), Piʻinaʻau Stream, east Maui, Hawaiʻi." *ʻElepaio* 66: 63–68.

Workforce Services. 2019. Dark Sky Assessment Guide: Evaluation Methods, Tools, and Resources. Utah Community Development Office,: https://www.darksky.org/wp-content/uploads/bsk-pdf-manager/2019/06/Dark-Sky-Assessment-Guide-Update-6-11-19.pdf.

Young, L.C., E.A. VanderWerf, M. Laut, A. Vorsino, J. Penniman, H. Nevins, A. Wang, N. Agorastos, K. Misajon, and M. McKown. 2021. Hawai'i-wide surveys for Newell's Shearwater, Hawaiian Petrel, and Band-rumped Storm Petrels. Hawai'i Department of Land and Natural Resources: Honolulu, HI.

Young, L.C., E.A. VanderWerf, M. McKown, P. Roberts, J. Schlueter, A. Vorsino, and D. Sischo. 2019. "Evidence of Newell’s Shearwaters and Hawaiian Petrels on Oahu, Hawaii." *The Condor: Ornithological Applications* 121 (1): 1-7. https://pacificrimconservation.org/wp-content/uploads/2019/05/Young-et-al-2019-NESH-HAPE-Oahu.pdf.

Zardus, J.D., and G.H. Balazs. 2007. "Two previously unreported barnacles commensal with the Green Sea Turtle in Hawai'i and a comparison of their attachment modes." *Crustaceana* 80 (11): 1303-1315. http://www.seaturtle.org/PDF/ZardusJD_2007_CrustacIntJCrustacRes.pdf.

Zaun, B. 2009. "Breeding of Newell's Shearwaters at Kilauea Point National Wildlife Refuge, Kaua‘i, Hawai‘i." Kilauea.