Lighting Policy

Annotated Bibliography

Articles pertinent to city ordinances, including streetlights and sports lighting Each citation includes an editorial summary of the contents of the paper by Richard OBrien, 2019-2021, v8 (April 2021)

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General Terminology and Overview

ANSI/IES RP-16-17, "Nomenclature and Definitions for Illuminating Engineering"

2017, Approved as an American National Standard July 13, 2017 Addendum 1 was approved by the IES Standards Committee on March 28, 2018, and by the American National Standards Institute on April 25, 2018.

[the ANSI/IES standard definitions no longer contain "fully shielded," "full cutoff," or "semi-cutoff."]

shielding angle

[10.2.5] The angle between a horizontal line through the light center and the line of sight at which the bare source first becomes visible.

[OBrien suggested edit for IDA use: "The angle between a horizontal line through the <u>lowest point of</u> <u>the light source</u> and the line of sight at which the <u>light source</u> first becomes visible."]

OBrien suggested terminology for the IDA

2020, Richard OBrien

light source: a bulb, lamp, reflector (mirrored or white), or translucent cover

This definition is important for "light trespass" and "shielding angle." This definition includes any reflector or translucent cover, which can be the effective light source.

Some luminaires may have asymmetrical shielding, for example a streetlight might have a 60-degree shielding angle toward private property, but a 45-degree shielding angle along the street.

"The first world atlas of the artificial night sky brightness" (2001)

2001, Cinzano, et al, Mon. Not. R. Astron. Soc

"The new world atlas of artificial night sky brightness" (2016)

2016, Falchi, et al, Science Adv.

"Light pollution is one of the most pervasive forms of environmental alteration. It affects even otherwise pristine sites because it is easily observed during the night hundreds of kilometres from its source in landscapes that seem untouched by humans during the day, damaging the nighttime landscapes even in protected areas, such as national parks (for example, the light domes of Las Vegas and Los Angeles as seen from Death Valley National Park)."



Lightpollutionmap.info (dates up to 2020)

Jurij Stare, www.lightpollutionmap.info

An interactive web-based map including "World Atlas 2015 (2016)," and VIIRS data from eight recent years. Users can select between two base maps: "Road" and "Hybrid" (a photo with roads and cities superimposed).

Lighting Ordinances (newest first)

Coverage of Outdoor Lighting Ordinances (2021)

Richard OBrien

Coverage of Outdoor Lighting Ordinances						
Element of the ordinance	Fort Collins (2021)	Crestone (2020)	Model Lighting Ordinance (IDA/IES 2011)	Boulder (2003)		
Plan submission required before building permit	Yes	Yes	Yes	Yes		
Two possible methods to demonstrate compliance	Yes	No	Yes	No		
Existing Lighting: amortization	No	Yes	Yes	Yes		
Streetlights	Not covered	Yes	Exempt	Exempt		
Lighting Zones defined	Yes	No	Yes	No		
Lighting Curfew	Yes	Yes	Yes	No		
Site lumen limit	2.5 lumens / sq. foot (Zone LC2)	Commercial 15,000 lumens/acre Residential 5,000 lumens/acre	Yes	No		
Controls required (shut off or dimming)	Yes	Yes	Yes	No		
Light trespass prohibited, by sight	Yes	Yes	Yes	Yes		
BUG system (shielding and trespass)	Yes	No	Yes	No		
Coordinated Color Temperature limit (degrees K)	3000	2700	No	No		
Illuminated signs	Not covered	Yes	Refers to sign ordinance	Yes		
Flagpole lighting	Not covered	Yes	Not covered	Yes		
Strings of lights	Not covered	Yes	Not covered	Exempt		

City of Fort Collins Municipal Code, 3.2.4, Site Lighting (2021)

Ginny Sawyer, Project and Policy Manager, City of Fort Collins, gsawyer@fcgov.com

Kelly Smith, Senior Environmental Planner, City of Fort Collins, ksmth@fcgov.com

A final draft will be presented to the Fort Collins City Council in March 2021.

draft, Fall 2020

3.2.4 Sight Lighting

(A) Purpose

- (B) General Standard ". . .shall submit for approval a proposed lighting plan. . ."
 - 1. ". . .plan that clearly calculates all exterior lighting being proposed."
 - 2. "...different use areas..."
 - 3. "... utilize "shut off" and dimming controls..."
 - 4. "... style..."
 - 5. [identifies types of property onto which there must be no light spill; Should say: "Demonstrate no light spill onto **any neighboring property**."]
 - 6. [CCT no greater than 3000 Kelvin.]
 - 7. "Light poles shall be anodized. . ."
- (C) Prohibited Lighting
 - 1. "Site lighting that may be confused with warning, emergency or traffic signals."
 - 2. "Mercury vapor lamps."
 - 3. ". . . mounted in a way as to light only towards a property line."
- (D) Lighting Context Areas
 - LC0 No ambient lighting
 - LC1 Low ambient lighting
 - LC2 Moderate ambient lighting
 - LC3 Moderately high ambient lighting.
- (E) Limits to Off-Site Impacts

[Tables give the Backlight, Uplight, and Glare ratings permitted in each Lighting Context Area and mounting position.]

(F) Site lumen limit.

[Gives the limit of total lumens per area allowed for a site.]

(G) Required Lighting Controls – "Lighting systems for non-residential properties shall be shut off or reduced by 50%. . ."

(1) Curfew

- (i) LC0: 8 pm
- (ii) LC1: 8 pm
- (iii) LC2: 10 pm
- (iv) LC3: Midnight
- (v) For Sports Events, one hour after the event ends
- (2) Landscape lighting extinguished by the curfew
- (3) Exceptions to Curfew

(i) Only one luminaire on the site

(ii) Code required lighting (safety)

(H) Alternative Compliance

"the Director may approve an alternative lighting plan. . ."

Definitions.

BUG Candela **Correlated Color Temperature** Footcandle Glare Hardscape Illuminance Light Loss Factor Lumen Luminaire Luminance Luminous Flux Luminous Intensity Mounting Height Vehicle Service Station Visibility



"Who speaks for the night?" (2020)

The regulation of light pollution in the 'Rights of Nature' legal framework 2020, J. C. Barentine, ALAN 2020 presentation

Problems with current legal mechanisms:

- 1. lack of public awareness and/or support, leading to failures of implementation and enforcement
- 2. Western legal approach prioritizes exploitation of natural resources

The "Rights of Nature" (RoN) movement

ANSI/IES RP-8-18 "Design and Maintenance of Roadway & Parking Facility Lighting" (2019)

https://www.ies.org/?s=ANSI%2FIES+RP

Access to the text is restricted to IES members.

https://blog.ansi.org/2019/03/ansi-ies-rp-8-18-design-roadway-lighting/ (summary)

"The benefits of illumination are as clear as the visibility that roadway lighting provides. There is consensus that roadway lighting substantially decreases nighttime automobile collision rates. Furthermore, pedestrians are made safer by lighting, and roadway illumination can correlate with numerous other benefits not associated with driving, including economic benefits, as lighting may draw more people into a commercial area, aesthetics, and even making people feel safer." This is a substantial revision, and aggregates the previous editions of numerous RP-8 standards,

"For example, Chapter 1 of ANSI/IES RP-8-18, which serves as an introduction to roadway lighting, discusses matters like alternatives to lighting, energy conservation, the need for good design, and environmental factors. Similarly, Chapter 2 addresses vision and fundamental concepts, thereby outlining the visible spectrum, the basic principles of vision, the structure of the eye, and various related topics."

"However, ANSI/IES RP-8-18 covers much more than this background information. In all, the standard exists to improve motorist visual quality, provide quality light and increased contrast for seeing hazards, illuminate conflict areas, minimize environmental impacts of light at night, and employ lighting systems that are easily maintained and minimize energy use. To meet these objectives, ANSI/IES RP-8-18 addresses numerous matters integral to the design of lighting systems. For example, Chapter 3 covers calculations; Chapter 5 confronts the planning and design process; Chapter 6 deals with system components; and Chapter 9 outlines maintenance and operations. In all, throughout its nearly-500 pages, the ANSI/IES RP-8-18 document contains 19 chapters and 10 annexes for assuring

quality roadway lighting solutions."

part of RP-8-18 includes the previous TM-10-10

"The European Union Adopts New Guidance On Roadway Lighting Installations" (2018)

John Barentine, International Dark-sky Association

https://www.darksky.org/eu-gpp-2018/

"EU Green Public Procurement Criteria for Road Lighting and Traffic Signals (GPP)"

"Lighting installations must be compatible with the use of active dimming controls . . ."

"... must be equipped with controls that allow dimming to at least 50% of the maximum light output"

"... must be rated as 0% RULO, meaning that they emit no light above the horizontal plane."

"... the color temperature of lighting must be less than 3000 Kelvins in residential areas."

Addendum A for IES TM15-11: "Backlight, Uplight, and Glare (BUG) Ratings" (2015)

Illuminating Engineering Society

https://www.ies.org/store/errata-addenda/

This gives a full explanation of the BUG rating system, which is used in the Model Lighting Ordinance. An example shows how the rating system can be applied to a luminaire.

"Classifying Outdoor Luminaires: The Limits of BUG" (2012)

Ian Ashdown, Lighting Analysts, Inc.

Recommends that the Joint IDA-IES Model Lighting Ordinance Task Force clarify that a zero Uplight rating is NOT based on photometric measurements, but on visual inspection. This should be included in city outdoor lighting ordinances.

"Model Lighting Ordinance" (IDA/IES 2011)

2011, a joint project of the IES and IDA

[problem: the model was not widely adopted; the language was written by specialists, and was difficult for a general audience to understand. A new MLO is in progress.]

Has side-by-side ordinance text and notes

Lighting Zones

- LZ0 No ambient lighting
- LZ1 Low ambient lighting
- LZ2 Moderate ambient lighting
- LZ3 Moderately high ambient lighting
- LZ4 High ambient lighting

Requirements

Exempt:

streetlights, lighting for public monuments and statuary temporary lighting for performance areas and construction sites underwater lighting in water features and swimming pools seasonal lighting, provided that lamps are less than 70 lumens emergency lighting low-voltage landscape lighting with automatic controls, in LZ2, 3, and 4 lighting specified in a specific use permit lighting required by laws or regulations illuminated signs regulated by the sign ordinance

Lighting Control Requirements

automatically extinguish all lighting when sufficient daylight is available except: under canopies, in tunnels, parking garages, and similar

curfew

lumens reduced by at least 30%

except:

landscape lighting, residential areas with no common area only one luminaire

code requirements

motion activated lighting

special use permit

businesses that operate on a 24-hour basis

Non-residential Lighting

Either of two methods: prescriptive method and performance method

A. Prescriptive Method

B. Performance Method

a lighting designer needed more flexible than the Prescriptive Method

uses the BUG system (Backlight, Uplight, and Glare)

Residential Lighting

". . .all outdoor luminaires shall be fully shielded and shall not exceed the allowed lumen output in Table G, row 2."

a number of exceptions

Lighting by Special Permit Only

Existing Lighting

Amortization – date

Enforcement - Reserved - individual jurisdictions will vary

Tables

- A. Allowed lumens per site, non-residential, per parking space method
- B(1). Allowed lumens per site, non-residential, hardscape area method
- B(2). Lumen allowances, in addition to base allowance
- C-1. Maximum Backlight
- C-2. Maximum Uplight
- C-3. Maximum Glare
- D. Performance Method total site lumens
- E. Performance Method additional luminaire lumen allowances
- F. Maximum Vertical Illuminance at the property line
- G. Residential Lighting Limits

Definitions

including "Fully Shielded Luminaire," now depracated

Vertical Illuminance – calculated in a plane perpendicular to the property line

Optional streetlight ordinance

Definitions

Master Lighting Plan

goals

safety and security

environment, by Lighting Zone

energy use

curfews

Warranting

to determine whether lighting is needed Shielding – no light emitted above 90 degrees

City of Boulder Municipal Code, 9-9-16, Lighting, Outdoor (2003).

https://library.municode.com/co/boulder/codes/municipal_code?nodeId=TIT9LAUSCO_CH9DEST_9-9-16LIOU

Conents and notes, with amendments that are recent [and editorial suggestions in square brackets.]

9-9-16. Lighting, Outdoor

- (a) Purpose
- (b) Legislative History [must conform by 2018]
- (c) Scope [change to include all lights visible from outside]

[need to add section:

(c2) Definitions

Definitions that appear in Chapter 16, Definitions, appear in **bold type.** For convenience, some key definitions are also given here.

Light Source - Any bulb, lamp, reflector, and/or translucent cover

Light Trespass - The light source is visible from a neighboring property [include illustration]

Lighting Zones 0-4 - Lighting zones 0-4 shall be defined as an overlay to existing Use Zones.

- LZ0 open space areas
- LZ1 city parks and low-density residential zones
- LZ2 light commercial [list specific Boulder use zones], public ballfields, and highdensity residential zones
- LZ3 larger commercial and industrial zones [list specific Boulder use zones]
- LZ4 zones where another authority sets the standards (university campus, airport, etc.) [note that the ordinance previously had standards for "Public Zoning District" which could be LZ0, LZ1, LZ2, or LZ4]
- **Shielding Angle** The angle below horizontal through which the light source is not visible [include illustration]

:end of added section]

(d) Design Standards

(1) Maximum Light Levels at the Property Line

(A)

(B)

- (2) White Light Source Required [combine with (d)(13)]
- (3) Use of High Pressure Sodium Lamps [delete]
- (4) Architectural Lighting of Building Facades
 - (A) ["Upward aimed building facade lighting shall not exceed **a total** of nine hundred lumens". . . . "fully shielded"
 - (B) ["exceeding **a total** of nine hundred lumens . . ."
 - (C) [delete]
 - (D)
- (5) Unshielded Lighting (sic) [change to "Shielded Lighting Required"]
 - [add: "all light fixtures must have shielding sufficient to prevent **light trespass**." Add bolding for "light trespass."]
 - (A) [move to (B)]
 - (B) [revise and move to (A)]
 - [replace diagram with photos]

[add language to exempt certain low-intensity lighting from shielding; was (i)(1)]

- (6) Signs
- (7) Standards for Lights Adjacent to Residential . . .

[insert "shielded to prevent **light trespass**"--delete most other language]

- (8) Canopy Lighting
- (9) Flagpoles [poles of 20 feet or less can have lights on the ground pointing up; taller poles may only have lights at the top pointing down]
- (10) Strings of Lights
 - (A)
 - (B)
- (i) "The string . . . only low-wattage low-intensity bulbs . . .
- (ii)
- •••
- (v)

[add language from (i)(2) and (i)(5)]

- (11) Parking Lot Lights and Trees
- (12) Full Cutoff Fixtures (sic)

[delete "Full Cutoff Fixtures: Full cutoff fixtures" Replace with "Installation: All fixtures shall be installed in a horizontal position as designed to provide shielding to prevent **light trespass** and glare."

- (13) Color Temperature
- (e) Maximum Light Standards

Table 9-11, maximum levels for Residential Zones, Commercial Zones, and Public Zones

[move to top: "Maximum lumen rating for a partially shielded fixture"

[change columns to "Lighting Zone 0," "Lighting Zone 1," "Lighting Zone 2," etc.] Table 9-12, Special Use Requirements

for parking structures, private recreation, public recreation, and special commercial uses (Service Stations, Auto Dealerships, Drive-Thru Windows)

[add an "Outdoor Lighting Curfew"

LZ0 and LZ1 - all lighting extinguished by 11 pm (motion detectors suggested)

LZ3 and LZ4 - lighting reduced by 30% by 11 pm (or an hour after closing if later)

the 30% reduction might mean 1/3 of the lights shut off, or all lights dimmed by 30%

streetlights shall be dimmed by 30% at 11 pm

(f) Prohibitions

- (1)
 - (2) [delete]

•••

- (8) ["Any lamp, bulb, **reflector and/or translucent cover (except seasonal displays and lowintensity lighting as permitted elsewhere)** which is visible beyond the property line"]
- (9) [modify] "Any lamp or bulb **installed** after November 15, 2018 with a correlated color temperature (CCT) that exceeds three thousand degrees Kelvin."
- (g) Lighting Plans Required
- (h) Final Inspection and Certification: Prior to . . . [delete] . . . the issuance of a certificate of occupancy . . .

[replace existing language with "a city inspector will confirm that the outdoor lighting as installed complies . . ."]

- (i) Exceptions [delete entire section]
 - (1) Ornamental Lighting [delete "Low voltage" and add a lumen cap; move to]
 - (2) Strings of Light [move to (d)(10)]
 - (3) Aviation Lighting
 - (4) Right-of-Way Lighting [delete, add section on streetlights]
 - (5) Seasonal Lighting Displays [combine with (d)(10)]
 - (6) Ballfields [delete, add section on sports lighting]
- (j) Variances and Exemptions
 - (1)
 - (2)
 - (3)

(4)

- (k) Amortization: All . . . brought into conformance no later than November 15, 2018
 - (1)

• • •

- (4) Exempt From Amortization Requirements [what does this mean?]
 - (A) Existing high pressure sodium and metal halide . . .
 - (B) Existing high pressure sodium and metal halide . . .
 - (C) Existing high pressure sodium and metal halide . . .
- (l) Immediate Compliance Required

[Significant re-writing is needed, including replacing obsolete terminology.]

IESNA TM-10-10: "Addressing Obtrusive Light In Conjunction With Roadway Lighting" (2010)

from the summary of this 2010 version:

"Misdirected or misapplied outdoor lighting is a concern for aesthetic, environmental and energy management reasons. Roadway lighting has been estimated to account for approximately 30 percent of sky glow and light trespass. While the concerns and solutions for stray light problems associated with roadway lighting can be described in several different ways, this Technical Memorandum addresses three components: sky glow, light trespass, and glare. It then suggests lighting design solutions, which can be used as the basis for lighting ordinances or regulations. Following some brief introductory statements, this Technical Memorandum contains four major sections: stray light defining the major components (sky glow, light trespass, and glare) and giving some historical perspective on related problems/concerns; community ordinances and regulations providing the rationale for creating uniform ordinances based on scientific principles rather than political pressure; methods for measuring and evaluating stray light summarizing methods advocated by the Commission Internationale de l'Eclairage (CIE) and describing a simple non-technical method for measuring light trespass using a light meter from the Light Trespass Research Report published in March, 2000; and solutions and mitigation giving alternative approaches for dealing with existing sky glow and light trespass problems through prevention and remedial modification. The impact of roadway lighting upon animal or plant life is outside the scope of this Technical Memorandum, but should not be ignored by designers and engineers responsible for outdoor lighting."

The four sections of TM-10-10

- 1. Defining the major components (sky glow, light trespass, glare)
- 2. Community ordinances
- 3. Methods for measuring stray light
- 4. Solutions and mitigation

Streetlight Case Study: Tucson

"Tucson street light project"

2019, telephone conversation with Jessie Sanders, Project Manager, 4/30/2019.

The IDA recommended 3000 degrees K and dimming; the city adopted that recommendation. The project meets recommendations from the IDA, the AMA, and the IES. Hired Chris Monrad as contractor. Dimming schedule: most areas dimming at midnight; some areas later. The "full" setting is at 90% power; the "dimmed" setting is 60%. Streetlights are networked, and are centrally-controlled (part of the "Smart City" environment).

"City of Tucson Investment Grade Audit"

LED Lighting Conversion Project 2016, Ameresco, January 2016

Total implementation cost: \$14.8 million Savings and rebates: \$4.6 million per year Payback: 5.3 years

reduce electric consumption by 22 million kWh per year

"Skyglow changes over Tucson . . . resulting from a municipal LED . . . conversion"

2018, John Barentine, Constance Walker, et al, Journal of Quantitative Spectroscopy and Radiative Transfer, vol. 212, June 2018, 10-23. also Christian Monrad, Monrad Engineering, Inc.

Measurements of skyglow before and after change about 18,000 luminaires were changed to LED Some evidence . . . that dimming LED lights reduced skyglow "the city's upward-directed optical radiance detected from Earth orbit decreased by approximately 7%."

Skyglow v.5 - publicly available - http://skyglow.sav.sk/#simulator Tucson: 18 light-emitting areas that share common physical properties city chose 90% of maximum power, 37.6% reduction from pre-retrofit also used Sky Quality Meter ("SQM-L") - 4 devices Dark Sky Meter iPhone app luminance-calibrated all-sky digital imagery estimates of the naked-eye limiting magnitude (NELM) using both the Loss of the Night app for Android and the Globe at Night reference charts

SQM-L devices use magnitude per square arcsecond, a non-SI unit (the SI unit is candela per square meter)

for SQM-L readings: discarded the initial reading in each set (known problem)

all-sky imagery: Canon T5i DSLR body, Sigma 4 mm circular fisheye lens, apparent field of view 180°

30-second exposures at f/2.8, ISO 1600

study apparently did not consider the dimming at midnight, nor discuss the centralized control due to the networking of the streetlights

"How the Tucson . . . LED Conversion Improved the Quality of the Night"

Nov. 2019, International Dark-sky Association

https://www.darksky.org/nights-over-tucson/?eType=EmailBlastContent&eId=bd2ec59b-be0f-49f9b43c-bd38a2fa844a

Convert nearly 20,000 streetlights from high-pressure-sodium to LED with adaptive controls projected savings \$180,000 per month early evening: 90% power midnight: 60% power

approved by Tucson city council Feb. 2016 completed in 2018 total lumen output from streetlighting was reduced from ~\$481 million lumens to ~\$181 million lumens

results ~\$2.2 million in annual savings expected lifetime 25 years (from 8 years) 63% reduction in total lumens emitted by streetlights blue light emissions reduced by ~\$34% 7% reduction in "total light emissions from the Tucson metro area"

Tucson's project manager, Jessie Sanders, told IDA, "The cost savings and the dimming capability – which also saves money on electrical usage – should be enough for any jurisdiction to consider LED conversion with dimming."

Streetlight Case Study: Kozushima

"Report from Tokyo: The Great Achievement of a Small Island"

2020, Nobuaki Ochi, IDA Tokyo (on darksky.org)

Kozushima Island, 180 km south of Tokyo, Village of Kozushima the only town with 1,900 people some places on the island reach 21.9 mag/sq. arc sec. Tokyo prefecture; from Tokyo, 30 min. by plane or four hours by boat

more than 400 streetlights upgraded warm color, less glare, few complaints see photos

"Outlying island, Kozushima, recognized as a Dark Sky Park"

2020, on darksky.org

Kozushima Island named as International Dark Sky Park (a Dark Sky Island) the second Dark Sky Place in Japan

a single municipality, Kozushima Village, has worked toward Dark Sky Island designation for all of island

Kozushima Village upgrade notes

2020

Iwasaki Electric Co., Ltd. Yoshitsuna Ito, CEO https://www.eye.co.jp/ 1,873 employees https://www.eye.co.jp/contact2/fixtures/webapp.php/inquiry/form

USA

EYE Lighting International of North America, Inc. 9150 Hendricks Rd. Mentor, OH 44060, USA Tel: +1-440-350-7000 Fax: +1-440-350-7001 E-mail: <u>sales@eyelighting.com</u> • eyelighting.com

Contact EYE Lighting National Sales Manager John Fisher <u>440-358-4745</u> <u>John.Fisher@eyelighting.com</u>

Illumination Systems Kimberly Clayton <u>303-295-2900</u> <u>quotes@illumsys.com</u>

Dark-Sky Promotion Agency (DPA) – consultant, prepared application Nobuaki Ochi, Takahiro Ueno, also of IDA Tokyo

Nobuaki Ochi



Takahiro Ueno



Plan to achieve 100% LMP compliance by March 2023 now 75.3% of fixtures are LMP compliant

Outdoor lighting maintained by two governmental bodies: Tokyo Metropolitan Government Kozushima Village

Adopted by the Tokyo Metropolitan Government:

Iwasaki Electric

E71258-0/2700K + WLE80V750M1/24-1 LED 6300lm 2700K Upward luminous flux 0% Installation by horizontal angle 0° Applying for IDA's Fixture Seal of Approval



adopted by Kozushima Village:

Iwasaki Electric E70061SAN9/2700K + NL501 (Louver) LED 700lm 2700K Upward luminous flux 0% Installation by horizontal angle 0° Applying for IDA's Fixure Seal of Approval Joint development between the manufacturer and the Village

Iwasaki Electric developed a special louver, horizontal installation, and measured the light distribution data





Before and After photos

2020 (date photos were published on darksky.org)





After – no reflection on the ocean

Before





After – shielded from above



Before

Before



After – shielded from street level



Before



After – shielded from street level



Before

After – color, intensity, and shielding

Sports Lighting

"IDA-Criteria for Community-Friendly Outdoor Sports Lighting v1.0" (2018)

International Dark-sky Association, March 2018

- 1. Complance with all applicable Codes and Standards (e.g. Underwriter Laboratories, CEC, National Building Codes with Local Amendments)
- 2. Target illumination IES RP-6-15 Sports and Recreational Area Lighting
- 3. Backlight, Uplight, and Glare
 - a. Backlight
 - no more than 15% of the total lumens outside a 33 foot offset
 - spill illuminance not to exceed 2.0 lux at 150' beyond the edge of the field
 - b. Uplight
 - no light emitted above horizontal
 - c. Glare

less than 250 lumens in the "Very High" glare zone

- 4. Lighting Zoning
 - LZ1 LZ4 only (no LZ0)
- 5. Application Efficiency
 - minimum of 70 lumens per watt
- 6. Controls
 - a. automatic and/or remote, shut off not later than 11:00 PM
 - b. each field separate controls
 - c. variable adaptive illumination levels (25% 100%)
 - d. formal policy on light levels for specific activities
- 7. Color
 - less than 5700 degrees K
- 8. Other Lighting

parking, concession, etc., illuminated by separate luminaires

ANSI/IES RP-6-15, "Sports and Recreational Area Lighting" (2015)

IES standard, RP-6-15

Impacts on Human Health: High-colortemperature Light

"Action on the AMA House of Delegates 2016 Annual Meeting ... Recommendations Adopted ..."

CSAPH Rep. 2-A-16

Three AMA recommendations:

- 1. Support conversion to LED; reduced energy consumption
- 2. Use the lowest emission of blue light possible
 - ("... using the lowest emission of blue light possible")
- 3. 3000 K or less, shielded, dimmable

"LED Streetlights Bring Cost Savings, And Headaches, To Colorado Cities" (2016)

https://www.cpr.org/news/story/led-streetlights-bring-cost-savings-and-headaches-to-colorado-cities

2016, Grace Hood, CPR, Sept. 15, 2016

Denver: \$2 Million to replace streetlights on 13-block 16th Street Mall

AMA Guidelines

3000 K or less shielding to reduce glare and light trespass dimmable

Nancy Clanton (Boulder): LEDs in Anchorage, San Jose, San Diego, Denver 16th Street Mall

Ouray

2009 installed LEDs first in the state

Fort Collins

about 1/3 of its streetlights to LED by 2017 and 2018 different intensities and color temperatures

Impacts on Nature: Ecologically Sensitive Sites

"Methods for Monitoring of Light Pollution around Ecologically Sensitive Sites" (2019)

J. C. Barentine, Journal of Imaging

"Simple Summary: Imaging and photometric techniques are used to characterize the brightness of nighttime conditions in protected areas in support of conservation efforts."

A review of techniques used to measure nighttime sky brightness. Included are upward radiance as measured from satellites and photographs from the International Space Station, single-channel radiometry using a Sky Quality Meter (both handheld and data logging), calibrated all-sky imagery using photography, drone-based aerial imaging, interpolated single-channel detector maps, and temporal monitoring (comparing the evolution of sky brightness).

Examples of each type:

- upward radiance "A first-order guess. . ." VIIRS-DNB radience from satellites, fed into a model (as on lightpollutionmap.info)
- single-channel radiometry Sky Quality Meter

calibrated all-sky imagery – NPS all-sky "false color" imagery

drone-based aerial imaging – photos from Girona, Catalonia showing daytime and nighttime aerial photos

interpolated single-channel detector maps - combining many SQM readings distributed throughout an area to create a map of zenithal night sky brightness – South Downs National Park, England temporal monitoring – data-logging Sky Quality Meter; NPS all-sky imagery from different years

"Skyglow extends into the world's Key Biodiversity Areas" (2019)

J. K. Garrett, et al, Animal Conservation

"We show that of the world's Key Biodiversity Areas (KBAs), less than a third have completely pristine night-time skies, about a half lie entirely under artificially bright skies and only about a fifth contain no area in which night-time skies are not polluted to the zenith."

"Skyglow is often envisaged as an exclusively urban issue. However, both modelling and ground measurements have shown it to be very widespread, often being propagated over long distances from sources (Kyba *et al.*, <u>2015</u>; Falchi *et al.*, <u>2016</u>)."

"Global climate change and invariable photoperiods" (2019)

Ecology and Evolution, August 2019, Walker, W., et al.

https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.5537

Abstract:

"The Earth's surface temperature is rising, and precipitation patterns throughout the Earth are changing; the source of these shifts is likely anthropogenic in nature. Alterations in temperature and precipitation have obvious direct and indirect effects on both plants and animals. Notably, changes in temperature and precipitation alone can have both advantageous and detrimental consequences depending on the species. Typically, production of offspring is timed to coincide with optimal food availability; thus, individuals of many species display annual rhythms of reproductive function. Because it requires substantial time to establish or re-establish reproductive function, individuals cannot depend on the arrival of seasonal food availability to begin breeding; thus, mechanisms have evolved in many plants and animals to monitor and respond to day length in order to anticipate seasonal changes in the environment. Over evolutionary time, there has been precise fine-tuning of critical photoperiod and onset/offset of seasonal adaptations. Climate change has provoked changes in the availability of insects and plants which shifts the timing of optimal reproduction. However, adaptations to the stable photoperiod may be insufficiently plastic to allow a shift in the seasonal timing of bird and mammal breeding. Coupled with the effects of light pollution which prevents these species from determining day length, climate change presents extreme evolutionary pressure that can result in severe deleterious consequences for individual species reproduction and survival. This review describes the effects of climate change on plants and animals, defines photoperiod and the physiological events it regulates, and addresses the consequences of global climate change and a stable photoperiod."

from the IDA summary:

"Although it has been suspected for years that light pollution influenced climate change because of the energy waste it represents, until recently we did not understand how exposure to the light itself can further harm wildlife already stressed by climate change. This fascinating study shows how light pollution is disrupting natural biological behaviors of plants and animals, such as sleep and breeding.

Light pollution is evidently impacting the global ecology itself, making many plants and animals less resilient to the effects of climate change. As the authors put it, "coupled with the effects of light pollution which prevents these species from determining day length, climate change presents extreme evolutionary pressure that can result in severe deleterious consequences for individual species reproduction and survival." This observation underscores the seriousness of concerns about light pollution globally, showing that it can no longer be thought of as only harming individual species."

Impacts on Nature: Migratory Birds (newest first)

"The influence of artificial light at night and polarized light on bird-building collisions" (2020)

S. Lao, et al, Biological Conservation

https://www.sciencedirect.com/science/article/abs/pii/S0006320719312339

"Lighting area had a stronger effect on collisions than any glass variables measured."

"Collisions with buildings annually kill up to 1 billion birds in the United States."

Study included collisions with 48 facades of 13 buildings in Minneapolis. They found that "... the area of glass emitting ALAN was the most important factor influencing collisions ..." "... this result provides strong support for turning off lights at night to reduce bird-building collisions."

"Mapping out rest stops for migrating birds" (2020)

U. of Delaware, summary in Science Daily

"The stopover-to-passage ratio is an indicator of the number of migrants that stop to rest during migration and those that continue heading north or south, depending on the season. The ratio varies from site to site,"

"A place to land: spatiotemporal drivers of stopover habitat use by migrating birds" (2020)

E. B. Cohen, et al, Ecology Letters

"American Skyscrapers Kill an Estimated 600 Million Migratory Birds Each Year" (2019)

Dapcevich, EcoWatch: Environmental News for a Healthier Planet and Life https://www.ecowatch.com/birds-killed-skyscrapers-light-pollution-2634222993.html

"During the spring, billions of birds fly through the central U.S. between the Rocky and Appalachian Mountain ranges, with cities in the center of these areas being particularly deadly."

"Study Names Top Cities Emitting Light that Endangers Migratory Birds" (2019)

Cornell Lab of Ornithology

https://mailchi.mp/cornell/release-study-lists-top-cities-where-lights-endanger-migratory-birds-1314385

top cities for danger for spring and fall migration:

- 1. Chicago
- 2. Houston
- 3. Dallas

"Careful design solutions can ensure that birds [can see] the stars during migration" (2019)

Illuminating Engineering Society.

"We are at the onset of light addiction, with LEDs so small they can be put almost anywhere, making once acceptably bright places seem dark again in contrast. While the Model Lighting Ordinance serves as a starting point, it is necessary to continue developing a cohesive model for lighting. As LEDs proliferate, lighting regulation must be developed simultaneously."

"Bright lights in the big cities: migratory birds' exposure to artificial light" (2019)

Horton, et al, Frontiers in Ecology and the Environment

web-only PDF tables:

WebTable 1. Who migrates and when do they migrate? Avian migratory classification of North American terrestrial species

WebTable 2. Seasonal artificial light at night (ALAN) exposure rankings of the 125 largest urban areas in the continental US

"Urban areas affect flight altitudes of nocturnally migrating birds" (2019)

Journal of Animal Ecology

"Migration Science: Phenology of nocturnal avian migration has shifted" (2019)

Farnsworth, et al, BirdCast.info

"How animals follow the stars" (2018)

Proceedings. Biological Sciences

"High-intensity urban light installation dramatically alters nocturnal bird migration" (2017)

Horton, et al, US National Academy of Science.

"Here we report that an iconic urban light installation dramatically altered multiple behaviors of nocturnally migrating birds—but these effects disappeared when lights were extinguished. We recommend selective removal of light pollution during nights with substantial bird migration to mitigate negative effects on birds, in particular collisions with lighted structures."

"We Finally Know How Bright Lights Affect Birds Flying at Night" (2017)

Audubon

"Nearly 400 Migratory Birds Were Killed by One Texas Building in a Single Night." (2017)

Audubon

"Does light pollution affect birds?" (2013)

Max Planck Research School

"Wings Over the Great Plains: Bird Migrations in the Central Flyway" (book; 2012)

Paul A. Johnsgard

"Bird Migration" (book; 2010)

Ian Newton

"Artificial night lighting . . . songbirds" (2010)

Science Digest

"Bird Migration and Global Change" (book; 2010)

G. W. Cox

"The book is a review, synthesis, and interpretation of recent scientific literature on migratory birds and their responses to changing climate."

"The Migration of Birds: Seasons on the Wing" (book; 2009)

Janice Hughes

"Polarized light cues underlie compass calibration in migratory songbirds" (2006)

Science

"Saving Migrant Birds" (book; 2003)

J. Faaborg

Includes material on the "Partners in Flight" program

"Collision course: The hazards of lighted structures and windows to migrating birds" (1996)

Ogden, et al.

"Bright moonlight . . . can hinder the use of stars" (1957)

Sauer

"Some notes on the astronomical method of studying bird migration" (1950)

W. A. Rense, Popular Astronomy

"Migration of Birds" (1935-1998)

1935-1998, Lincoln, et al, US Dept. of the Interior Circular 16

Impacts on Nature: Nocturnal Pollinators

"Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review"

2014, Callum Macgregor et al

Reviewed a number of studies various species of nocturnal pollinators. Concluded that this should be studied further.

"Lights at Night Turn Nocturnal Pollinators Off"

https://www.darksky.org/lights-at-night-turn-nocturnal-pollinators-off/

2017, Based on the 2017 study by Knop et al.

"Artificial light at night as a new threat to pollination"

2017, Eva Knop, et al, Nature, 2017

plant: cabbage thistle62% fewer insect visits to the lit meadows13% fewer fruits on the cabbage thistle plants"This loss of night time pollinators cannot be compensated by diurnal pollinators."

"Quantifying the attractiveness of broad-spectrum street lights to aerial nocturnal insects"

2018, Wakefield, et al, 2018 Journal of Applied Ecology 55:714-722

LED and HPS do not differ in attractiveness to nocturnal insects.

"Switching off street lights saves energy and helps ecosystems"

https://www.naturalnews.com/2019-05-05-switching-off-street-lights-saves-energy-and-helpsecosystems.html 2019, Edsel Cook, Natural News

"When street lights are turned off for part of the night, they do not just save on the electricity bill. Researchers from the U.K. said that the energy-conserving practice also <u>benefits moths and other</u> <u>nocturnal insects</u> by helping to restore the animals' original behavior before artificial light pollution intruded upon the night."

"Ecological benefits of part-night lighting revealed"

2019, Newcastle University - ScienceDaily www.sciencedaily.com/releases/2019/01/190121103411.htm

"Study shows there is no difference in pollination success between part-night lighting and full darkness, highlighting the ecological benefit of switching off our street lights even for short periods in the night."

"Effects of street lighting technologies on the . . . pollination in a nocturnally pollinated plant"

2019, Callum Macgregor et al. Ecosphere

"Lighting directly affects plants, but . . . pollen transport by moths is disrupted by lighting." "Contrary to our predictions, flowers under FN [full night] lighting had higher pollination success than flowers under PN [part night] lighting or unlit controls"

"These findings lend further support to previous studies suggesting that PN lighting regimes may provide the best solution to reducing the influence of artificial night lighting on nocturnal wildlife (Azam et al. 2015) and mitigating its ecological impacts. While our study, based on a single plant species, appears to suggest that plants may benefit from being situated under FN lighting, comparing this unexpected result to Knop et al. (2017) demonstrates the potential for ALAN to disrupt pollination systems across the community of plants, disproportionately strengthening some interactions and weakening others (Macgregor et al. 2015). Community-level studies would be valuable to identify potential winners and losers from lighting, to determine the exact mechanisms underpinning the effects we have identified, and to understand how best to mitigate negative impacts."

"Pollinators: switch street lights off at midnight to help moths and nocturnal wildlife"

2019, Macgregor

https://www.darksky.org/pollinators-switch-street-lights-off-at-midnight-to-help-moths-and-nocturnalwildlife/

A general-audience blog post considering various studies, including Macgregor's 2019 study in Ecosphere.

"Surprisingly, this wasn't just a partial improvement. We found no significant difference between rates of pollination in part-night lighting treatments and in natural darkness, and this suggests that turning lights off at or after midnight may allow nocturnal ecosystems to function as normal in the second half of the night."

"These results are quite encouraging. Local authorities can save money and energy from street lighting and help nocturnal ecosystems recover from light pollution at the same time."

"Light pollution is key 'bringer of insect apocalypse'"

2019, The Guardian, November 2019, <u>https://www.theguardian.com/environment/2019/nov/22/light-pollution-insect-apocalypse</u>

"Artificial light at night can affect every aspect of insects' lives, the researchers said, from luring moths to their deaths around bulbs, to spotlighting insect prey for rats and toads, to obscuring the mating signals of fireflies."

"However, unlike other drivers of decline, light pollution was relatively easy to prevent, the team said, by switching off unnecessary lights and using proper shades. "Doing so could greatly reduce insect losses immediately," they said."

from the IDA summary:

"The rapid global decline in insect populations, and especially among pollinating insects, is one of the most dramatic environmental stories of the past decade. <u>Ecologists are concerned</u> that the disappearance of so many insect species threatens a catastrophic collapse of nature's ecosystems. <u>An initial study in 2018</u> showed a 75% decline in the biomass of flying insects in the 27-year study period. The study pointed to light pollution as a possible cause of the issue. After reviewing more than 150 reports on the issue, researchers confirmed this year that light pollution is the "key bringer of the insect apocalypse." But scientists actually consider this good news, because light pollution is the easiest driver of insect decline to prevent."

Impacts on Safety: Traffic Collisions

ANSI/IES RP-8-14, "Recommended Practice for Roadway Lighting"

2014

contains standards

US DOT – RP8-14 <u>https://safety.fhwa.dot.gov/roadway_dept/night_visib/roadwayresources.cfm</u> <u>https://webstore.ansi.org/Standards/IESNA/ANSIIESNARP14</u>

roadway type, pedestrian interaction

Access to this document requires IES membership or a payment.

[a new version has now been published, ANSI/IES RP-8-18]

"Guidelines for the Implementation of Reduced Lighting on Roadways"

US Department of Transportation, Federal Highway Administration, FHWA-HRT-14-050 <u>https://safety.fhwa.dot.gov/roadway_dept/night_visib/roadwayresources.cfm</u> 2014, Gibbons R., Guo F., Medina A., Terry T., Du J., Lutkevich P., Corkum D., Vetere P., Virginia Tech Transportation Institute, June 2014

Abstract: "This report provides guidelines for the implementation of an adoptive lighting system for roadway lighting. . . . "

"The philosophy behind adaptive lighting is to provide lighting only when and where it is needed . . ."

"The obvious and primary benefit of adaptive lighting is the reduction of energy use . . ."



Figure 1. Illustration. General structure of a lighting control system.

Quotation (screen capture) from the document:

The final component of the adaptive system involves negotiation with the electrical utility. Most lighting systems are either owned by the electrical utility or are charged at a flat rate to the roadway agency when connected to an unmetered source such as the utility secondary feeders. To reap the financial benefits of an adaptive lighting system, the roadway agency must negotiate with the utility for a reduced rate or a rate based on metering of the electrical usage by the lighting system. Some control systems provide utility-grade metering that can be used for this purpose. However, it is vital that this aspect of the adaptive lighting system be negotiated before the system is implemented.

"Traffic Safety Facts: 2017 Data, Pedestrians"

National Highway Traffic Safety Administration, DOT HS 812 681 2018 https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812681

The 2017 data show 75% of pedestrian deaths in the dark.



"Safety"

2019

http://www.pedbikeinfo.org/factsfigures/facts_safety.cfm US Department of Transportation

"Pedestrian and bicyclist fatalities increased by 31 percent in the ten-year period between 2008 and 2017. During that same time period, total traffic fatalities decreased by 0.8 percent."

There is likely a large increase in the number of pedestrians and bicyclists in traffic, which could account for some of the increase. But in contrast to the decrease in total traffic fatalities, this is alarming.

"NHTSA proposes to legalize 'matrix' adaptive LED headlights in the US"

2018

https://www.cnet.com/roadshow/news/nhtsa-proposal-matrix-adaptive-led-headlights/

October 12, 2018

"The National Highway Traffic Safety Administration on Thursday issued a notice of proposed rulemaking, <u>Bloomberg reports</u>, seeking to adjust the Federal Motor Vehicle Safety Standard to permit the use of "adaptive driving beam headlighting systems," otherwise known as "matrix" headlights."

"Are European-style self-dimming and glare-free headlights coming to the U.S.?"

2018, Digital Trends, Bruce Brown

https://www.digitaltrends.com/cars/nhtsa-self-dimming-matrix-headlights-proposal/

As seen in the image below from Osram, the headlights would illuminate the lower body of pedestrians and vehicles, but the LED that would shine in people's eyes would shut down.



"Glare from Headlamps and other Front Mounted Lamps"

1998 Federal Motor Vehicle Safety Standard No. 108; Lamps, Reflective Devices, and Associated Equipment National Highway Traffic Safety Administration (NHTSA), Department of Transportation.

https://one.nhtsa.gov/cars/rules/rulings/glare.html

"Technical Report: Drivers' Perceptions of Headlight Glare..."

2004, PDF, 1021.77 KB

https://www.nhtsa.gov/document/technical-report-dr... January 1, 2004

"Adaptive Driving Beam . . . Glare Assessment"

2015, PDF, 5.07 MB

https://www.nhtsa.gov/document/adaptive-driving-be...

National Hightway Transportation Safety Administration

1.2 Adaptive Driving Beam

Automatic adjustment of the headlamp beam pattern can be accomplished through advanced front lighting systems, including "Adaptive Driving Beam," or ADB. According to the Society of Automotive Engineers, ADB is a "long-range forward visibility beam that adapts to the presence of opposing and preceding vehicles by modifying portions of its beam pattern to avoid glare above lower beam photometry levels to the drivers of opposing and preceding vehicles" [1]. The goal of the system is to improve long-range visibility for the driver without causing discomfort, distraction, or glare to other road users. The automatic adaptation of the beam pattern may not only serve as a convenience feature for drivers, but could result in increased, safety-beneficial upper beam use.

 Overall in these tests, ADB was shown to have the ability to dynamically adapt the headlamp beams to shade oncoming and preceding vehicles. However:

 In some cases, tested ADB systems did not succeed in shading other vehicles to lower beam illuminance levels derived from the current static test requirements in FMVSS No. 108.

"Seeing with Headlights"

2004

Gene Farber, consultant

NHTSA Workshop on Headlamp Safety Metrics

Quotation (screen capture) from the document:

- Pedestrian visibility distance night: 150 - 250 feet day: 1000's of feet
- Distance required to respond and stop from 55 mph: 265 feet

"Physiology of glare and readaption (including age differences)"

Kent Higgins

2004, NHTSA Workshop on Headlamp Safety Metrics: Balancing Visibility and Glare, 2004

Quotation (screen capture) from the document:

When lighting changes, eyes begin to adapt. Conventional ...

- Light adaptation (going from dark room into bright sunlight) is relatively fast (2-3 min.)
- Dark adaptation (entering dark room from bright sunlight) relatively slow, cones requiring 5-10 min. and rods requiring 30-45 min.
- <u>The point</u>: Time course of both measured in minutes



Figure 9-8 Unseen pedestrians stand on the pavement beside four approaching cars on low beams. The camera cars low beams do not reveal the presence of the hazard.

"Investigation of Safety-Based . . . Forward-Lighting Concepts to Reduce Glare"

2008

https://www.nhtsa.gov/document/investigation-safet... September 1, 2008

Quotations (screen captures) from the document:

16. Abstract

This two-part report addresses the feasibility of two approaches for using adaptive forward-lighting systems (AFS) to reduce headlamp glare under different conditions. AFS approaches involve dynamically changing headlamp beam patterns that respond in real time to different surrounding conditions such as roadway geometry, ambient lighting, or the presence of other drivers. In the first part, four field studies are described that investigated interactions between roadway lighting and vehicle headlamps, to determine whether dimming headlamps can be a suitable AFS strategy when roadway lighting is present. The studies found that glare impairs drivers' forward visibility and produces feelings of discomfort, even when street lighting is present, and that in lighted areas, it is possible to dim headlamps (potentially via AFS). reducing glare to oncoming and preceding drivers, without significantly impairing drivers' performance with respect to detection distance. In the second part, another AFS approach was investigated. This approach involved use of a "prime beam" optimized for forward visibility as the main beam pattern, subtracting portions of light when needed to reduce glare to oncoming or preceding drivers. A prototype system using a prime beam was developed, evaluated for visibility and glare in field tests in comparison with conventional low and high beam patterns, and demonstrated on a moving vehicle. The prime beam approach appears to be a promising one to ensure adequate forward visibility under a wide range of conditions while controlling glare to other drivers, and for studying characteristics of lighting as they pertain to visual performance and safety.

- To reduce glare without significantly impairing forward visibility, dimming forward lighting to 50 percent of the initial intensity may be most appropriate for most mounting heights and angular directions within the beam.
- Headlamps with a high mounting height (1200 mm) must be dimmed further to reduce discomfort. Removing glare in these cases may be difficult without impairing drivers' forward visibility. A sophisticated AFS may resolve this difficulty by appropriately controlling headlamp beams in the near future.



Figure I-16. Mean detection distances comparing glare and no-glare conditions.

"Assessment of Headlamp Glare and Potential Countermeasures"

Survey of Advanced Front Lighting System (AFS)

2005, National Highway Traffic Safety Administration Research and Technology PDF, 2.84 MB https://www.nhtsa.gov/search? keywords=Assessment+of+Headlamp+Glare+and+Potential+Countermeasures %3A+Survey+of+Advanced+Front+Lighting+System+%28AFS%29

Quotation (screen capture) from the document:

Conclusions From Oncoming Glare Study

The results of the oncoming-glare study suggested that detection distance can be reduced by up to 30 m with oncoming glare. Oncoming glare can impair drivers detecting peripheral targets even when street lighting is present. In most cases, forward headlamps cannot help drivers improve peripheral target visibility. This suggested the importance of reducing oncoming headlamp intensity to ease glare and therefore improve the forward visibility. However, the experimental results also suggested that forward headlamps may have a small effect in helping drivers detect targets located in the most intense parts of the beam distribution and/or located away from the glare source. This implies that some care is required for those areas when controlling headlamp distribution through AFS.

16. Abstract

The goal of advanced front lighting systems (AFS) is to actively control headlamp beam patterns to meet the dynamic requirements of changing roadway geometries and visibility conditions. AFS is being rapidly introduced worldwide due to its attractive styling aspects and potential safety benefits. However, before AFS becomes more aggressively implemented, it is



Figure 2.1. Proposed AFS beam patterns (from http://visteon.wieck.com/image_database).

Town beam

Can dimming forward headlamps minimize glare to oncoming vehicles without impairing drivers' visibility?

A town forward lighting beam pattern is one that becomes shorter and wider in response to high ambient, low speed conditions. A review paper in the 1970s identified the appropriate luminous intensity range for town beams, suggesting it should be higher than 20 cd and lower than 100 cd. However, since this review paper did not show background data describing how those luminous intensity values were identified, it is still necessary to discuss appropriate luminous intensity distribution of town beams and conduct field studies on real roadways by using town beam prototypes. Recent controlled field studies conducted by the LRC have provided positive answers to this question. The first study proved that it is possible to dim forward headlamps without impairing drivers' forward visibility in lit areas. The second study showed that oncoming headlamp glare impairs drivers' forward visibility in such a way that detection distance was 20 m longer with oncoming headlamp glare than without glare. The third study suggested that dimming forward lighting is effective to reduce glare to oncoming vehicles in lit areas.

"Do brighter, whiter street lights improve road safety?"

2019, Paul Marchant, Significance: Royal Statistical Society

Australian roads

<u>Abstract</u>

Several years ago, the Australian government received a pitch from an association of public works professionals to spend A\$1 billion to upgrade the country's street lights to white light (typically LEDs). That is a sizeable price tag, but the "Roadmap" document made the claim that if an 8% reduction in night-time road traffic collisions (RTCs) was achieved by adding white light, it would generate cost savings of more than A\$500 million per year (<u>bit.ly/2a3qcgm</u>).

The theoretical cost savings assume that brighter, whiter street lights lead to fewer crashes, deaths and injuries, and thus a reduction in cost to the public purse. But is this assumption correct? Does brighter street lighting lead to fewer accidents at night?

Evidence for the claim comes from a 2013 study by Jackett and Frith (JF), which reported substantial reductions in RTCs arising from greater illumination.¹ But the JF study has several issues.

from the IDA summary:

"For decades, public safety proponents have touted the value of lighting up the world's streets and highways to enable better visibility and reduce the risk of traffic accidents and resulting fatalities. Certainly evidence exists that when properly targeted and carefully applied, outdoor lighting can make streets safer at night for motorists, pedestrians and bicyclists. But a key question remains unanswered: does the ability of light to render colors correctly to human observers further influence the safety benefits of roadway lighting? British statistician Paul Marchant looked into claims based on research carried out in New Zealand suggesting that an eight percent reduction in nighttime road traffic collisions could be achieved if governments opted for light with a greater fraction of blue emissions when they transitioned from earlier lighting technologies to white LED lighting. Marchant's analysis pointed out flaws in the assumptions underlying the New Zealand study, finding that once again correlation and causation are different things that are not always related, and that "a large sample size may simply give a false sense of certainty while yielding an incorrect conclusion." Arguing that the issue is too important to leave to chance, Marchant concludes that the best approach moving forward is caution and more careful study of this question."

Impacts on Safety: Crime

"The Chicago Alley Lighting Project: Final Evaluation Report"

2000, Morrow, et al. Illinois Criminal Justice Information Authority

City of Chicago began a plan to reduce crime through improved street and alley lighting. One part: boost lighting levels in alleys

past: 90-watt lights; plan: 250-watt bulbs

study: two similar neighborhoods, one control and one with increased lighting

"number of reported incidents . . . an increase of 21%"

each of the three crime categories increased: violent offenses: increase of 14% property offenses: increase of 20% other offenses: increase of 24%

"These findings indicate . . . with the increased lighting came an increase in crime"

"Lighting, Crime and Safety"

c. 2018

https://www.darksky.org/light-pollution/lighting-crime-and-safety/

"There is no clear scientific evidence that increased outdoor lighting deters crimes. It may make us feel safer, but has not been shown to make us safer."

"The effect of reduced street lighting on road casualties and crime in England and Wales"

2015, Steinbach et al, Journal of Epidemiology and Community Health

"This study found little evidence of harmful effects of switch off, part-night lighting, dimming, or changes to white light/LEDs on road collisions or crime in England and Wales."

strategies studied:

switch off - permanently off part-night lighting - reduced number of hours of lighting dimming - reducing the power output of lamps changes to white light/LEDs - over high-pressure-sodium lights

"Preventing crime: what works, what doesn't, what's promising"

1997, Sherman, et al, report to Congress; U. of Maryland for the National Institute of Justice

"We can have very little confidence that improved lighting prevents crime."