Resources

1a. American Medical Association. (2016). Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting. Retrieved from http://www.ama-assn.org/sites/default/files/media-browser/public/about-ama/councils/Council%20Reports/council-on-science-public-health/a16-csaph2.pdf Several concerns about the use of LED sources for public lighting are discussed; recommendations to shield outdoor lighting and to use low correlated color temperature (CCT) sources are given.

1b. ASSIST. (2010). *The potential of outdoor lighting for stimulating the human circadian system*. Troy, NY: Lighting Research Center. Retrieved from http://www.lrc.rpi.edu/programs/solidstate/assist/techpaper-outdoorcircadian.asp The International Dark Sky Association has raised concerns about the health effects of outdoor lighting at night. The Lighting Research Center and ASSIST here provide a quantitative analysis of the effects of light at night of different spectral power distributions on the human circadian system. A specific recommendation is made for "a reasonable and conservative working threshold" for exposure to light at night.

1c. Brons, J. A., John D. Bullough, & Rea, M. S. (2008). Outdoor site-lighting performance: a comprehensive and quantitative framework for assessing light pollution. *Lighting Research & Technology*, *40*(3), 201–224. Retrieved from http://lrt.sagepub.com/content/40/3/201 Three different issues regarding outdoor, night-time lighting and light pollution are discussed and evaluated: sky glow, light trespass and glare. The benefits and drawbacks of night-time lighting are discussed and Outdoor Site-Lighting Performance (OSP) is introduced as a useful tool for measuring and quantifying these issues.

1d. Chepesiuk, R. (2009). Missing the Dark: Health Effects of Light Pollution. *Environmental Health Perspectives*, *117*(1), 20–27. Retrieved from http://ehp.niehs.nih.gov/wp-content/uploads/117/1/ehp.117-a20.pdf This article is a high-level review of issues related to light at night. Topics include the mechanisms of sky glow, ecological impacts, and human health impacts such as circadian rhythm disruption and cancer risks.

1e. Illuminating Engineering Society. (2011). *IES TM-15-11: Luminaire Classification System for Outdoor Luminaires* (pp. 1–21). Retrieved from http://www.techstreet.com/products/1800146 As the authors state, "This Technical Memorandum defines a classification system for outdoor luminaires that provides information to lighting professionals regarding the lumen distribution within solid angles of specific interest." TM-15 describes the backlight, uplight, glare, or BUG, classification system.

1f. Illuminating Engineering Society. (2012). *DG-22-12: Design Guide for Sustainable Lighting: An Introduction to the Environmental Impacts of Lighting*. Retrieved from http://www.ies.org/store/product/sustainable-lighting-an-introduction-to-the-environmental-impacts-of-lighting-1265.cfm This Design Guide gives an in-depth look at the environmental impact of lighting in its many applications. The guide discusses sustainability and the challenges and opportunities facing the lighting designers and practitioners of today. Section 2.6 discusses “Reducing Light Pollution.”

1g. Illuminating Engineering Society. (2017). *IES Board Position on AMA CSAPH Report 2-A-16, Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting.* Retrieved from https://www.ies.org/policy/position-statements/ies-board-position-on-ama-csaph-report-2-a-16-human-and-environmental-effects-of-light-emitting-diode-led-community-lighting This position statement outlines several objections to the AMA report on LED public lighting.

1h. International Dark-Sky Association, & Illuminating Engineering Society. (2011). *Model Lighting Ordinance (MLO) with User’s Guide* (p. 44). Retrieved from http://www.darksky.org/wp-content/uploads/bsk-pdf-manager/16_MLO_FINAL_JUNE2011.PDF The Model Lighting Ordinance aims to help communities reduce light pollution in the forms of sky glow, light trespass and discomfort glare through the use of better lighting practice and

technologies. The suggested ordinance is the joint work of the IES of North America and the International Dark Sky Association.

1i. Lighting Research Center. (2016). *Response to the 2016 AMA Report on LED Lighting.* Retrieved from www.lrc.rpi.edu/resources/newsroom/AMA.pdf This report discusses the AMA report on public lighting and describes the appropriate use of lighting metrics to characterize impacts of LED lighting on public health and safety. See also https://youtu.be/2BcfcONrm58 for an LRC webinar presentation summarizing the key issues.

1j. National Institute of Environmental Health Sciences. (2016). *Workshop: Shift Work at Night, Artificial Light at Night, and Circadian Disruption.* Retrieved from https://ntp.niehs.nih.gov/pubhealth/roc/candidates/meetings/workshop_alan.html This workshop was convened to bring scientists together to analyze and discuss impacts of lighting at night and shift work on circadian rhythms in people.

1k. Klinkenborg, V. (2008) Light Pollution. *National Geographic*. Retrieved from http://ngm.nationalgeographic.com/2008/11/light-pollution/klinkenborg-text This magazine article summarizes the impacts of light pollution. The effects on birds, bats, and amphibians are discussed.

1l. Maine State Planning Office. *Promoting Quality Outdoor Lighting in Your Community*. Retrieved from http://www.maine.gov/dacf/municipalplanning/docs/lightingmanual.pdf This bulletin discusses the impacts of outdoor lighting, the qualities of outdoor lighting to consider, and means of implementing outdoor lighting standards. The document provides concise, actionable recommendations for policy makers.

1m. Bierman, A. (2012). Will switching to LED outdoor lighting increase sky glow? *Lighting Research and Technology*, *44*(4), 449–458. doi:10.1177/1477153512437147 http://lrt.sagepub.com/cgi/doi/10.1177/1477153512437147 As more and more outdoor lighting systems are switching to LED light sources, concerns are growing regarding the potential for increased sky glow resulting in the subsequent increase in short wavelength radiation from these sources. Atmospheric light scatter from a 6500 K LED source and a 2050 K High Pressure Sodium lamp are compared and it was found that one can expect roughly 10-20% more light scatter attributing to sky glow from the LED source.

1n. Bullough, J. D., Sweater Hickcox, K., & Narendran, N. (2011). *ASSIST recommends: A Method for Estimating Discomfort Glare from Exterior Lighting Systems* (Vol. 9, pp. 1–7). Retrieved from http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-DiscomfortGlare.pdf This report discusses existing mathematical models for predicting discomfort glare and an extension of those models based on new research. Example calculations are provided.

1o. Brons, J., Bullough, J., & Rea, M. (2007). Light Pollution: Thinking Inside the Box. *Lighting Journal*, *72 No 5*, 27–34. Retrieved from http://www.lrc.rpi.edu/researchAreas/pdf/insidetheBox.pdf The Outdoor Site-Lighting Performance (OSP) is a method of calculating light pollution including light trespass, glare, and sky glow. This paper describes the system and provides evaluation data from real-world outdoor lighting installations.

1p. The Chartered Institution of Building Services Engineers (CIBSE). (2012). *Guide to Limiting Obtrusive Light 2012*. CIBSE. Retrieved from http://www.cibse.org/knowledge/cibse-lg/guide-to-limiting-obtrusive-light According to the authors, "this guide outlines the causes and consequences of obtrusive light, and what can be done to minimize obtrusive light generally and in some commonly occurring applications."

1q. CIE. (2003). *Technical Report: Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Applications* (Vol. CIE 150:20). Vienna, Austria: CIE. Retrieved from http://www.techstreet.com/cie/products/1210066 This technical report provides a methodology for the mitigation of the obtrusive effects of outdoor lighting such as light trespass, daytime appearance and glare.

1r. Lighting Research Center. (2003). *Implementation of Decision-Making Tools that Address Light Pollution for Localities Planning Street Lighting* (pp. 1–12). Retrieved from

http://www.lrc.rpi.edu/programs/transportation/pdf/lightPollution/whitePaper.pdf This white paper provides information regarding Connecticut outdoor lighting legislation, light pollution, and best practice for efficient, effective outdoor lighting. According to the authors, the paper "discusses lighting considerations that should be considered before embarking on a lighting project and summarizes good lighting practice and how municipalities can work with designers or planners to ensure that their lighting installation meets the lighting objectives in their community."

1s. Rea, M S; Brons, J; Figueiro, M. F. (2012). Measurement of light at night (LAN) for a sample of female school teachers. *NIH Vesrion - FInal in Chronbiol Int*, *28*(8), 673–680. doi:10.3109/07420528.2011.602198. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3342668/ Past studies have shown links between exposure to light at night (LAN) as well as rotating shift schedules to an increased risk in breast cancer. Some such past studies have used satellite-photometry as well as self-reported bedroom light levels to express this link and have claimed that data from these reports show an increased risk in breast cancer regardless of shiftwork history. The present article investigates the use of satellite-photometry as well as self-reported brightness as a useful way of characterizing light levels at the cornea by studying light levels of a sample of female school teachers working regular day shifts using Daysimeter measurement devices. It was found that there was no known connection between the satellite measured photometric data and the 24-hr light-level exposures of the female school teachers.

1t. The Royal Commission on Environmental Pollution. (2009). *Artificial Light in the Environment* (pp. 1–48). Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228832/9780108508547.pdf.pdf An in-depth inquiry into the human-health and environmental effects of light pollution in Great Britain. Glare, light trespass, light clutter, light profligacy, sky glow and an absence of darkness are listed as the different kinds of light pollution and are further analyzed in this publication.

2a. ANSI, ASHRAE, & IES. (2010). *90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings I-P Edition*. Retrieved from https://law.resource.org/pub/us/code/ibr/ashrae.90.1.ip.2010.pdf This standard is referenced by the building codes in many states. Section 9.4.3 covers exterior lighting.

2b. ASSIST. (2011). *ASSIST recommends… Recommendations for Evaluating Street and Roadway Luminaires*. Retrieved from http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/parkinglot.asp This report provides guidance about LED parking lot lighting. A recommendation is made for using Luminaire System Application Efficacy (LSAE) to evaluate the lighting system. An online calculator is provided that performs all of the calculations for LSAE using either standard IES files or an IES file uploaded by the user.

2c. Bullough, J. D. (2012). *New Lighting Technologies and Roadway Lighting: An Informational Brochure* (pp. 1–6). Retrieved from https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-10-14_RoadwayLighting-InformationalBrochure.pdf This brochure provides an introduction to technologies and techniques for roadway lighting. It also provides a list of resources for more in-depth information.

2d. Bullough, J. D., & Radetsky, L. (2014). *Sustainable Roadway Lighting Seminar* (pp. 1–60). Troy, New York. Retrieved from http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Transportation/Sustainable-Roadway-Lighting-Seminars.pdf This report is a summary of material presented at a series of seminars presented by Rensselaer's Lighting Research Center to engineers and others from the New York State Department of Transportation, municipalities, utilities, and engineering firms. The topics include roadway lighting basics, roadway lighting technologies, visibility and safety, economics and benefit/cost analyses, and new approaches to roadway lighting including ecoluminance, pedestrian crosswalk lighting, mesopic vision and brightness appearance.

2e. Illuminating Engineering Society. (2012). *DG-22-12: Design Guide for Sustainable Lighting: An Introduction to the Environmental Impacts of Lighting*. Retrieved from http://www.ies.org/store/product/sustainable-lighting-an-introduction-to-the-environmental-impacts-of-lighting-1265.cfm This Design Guide gives an in-depth look at the environmental impact of lighting in its many applications. The guide discusses sustainability and the challenges and opportunities facing the lighting designers and practitioners of today. Section 2.6 discusses “Reducing Light Pollution.”

2f. Illuminating Engineering Society. (2014). *IES RP-20-14: Lighting for Parking Facilities* (pp. 1–59). Retrieved from http://www.techstreet.com/products/1885587#product This document provides recommendations for designing new lighting systems for parking facilities. Recommendations include interior and exterior lighting, enhancing of personal safety and security, optimizing energy use, and minimizing maintenance.

2g. Moyer, J. L. (2013). *The Landscape Lighting Book: Third Edition* (Third., pp. 1–440). Wiley. Retrieved from http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118073827.html This book is a comprehensive guide to landscape lighting design. According to the publisher, it covers lighting practices, materials including LED products, design applications, preparing lighting drawings, technical specifications, mesopic vision, and lighting controls.

2h. Society, I. E. (2014). *IES RP-8-14: Roadway Lighting (ANSI Approved)* (pp. 1–58). Retrieved from http://www.techstreet.com/cie/products/1883732 This document recommends how to design lighting for new construction of roadways, streets, adjacent bikeways, and pedestrian ways. Recommendations include illuminance and luminance levels and uniformity ratios.

2i. University of Illinois at Urbana-Champaign Facilities and Services (2014). *Adaptive Bi-Level Lighting*. Retrieved from https://www.fs.illinois.edu/docs/default-source/News-Docs/adaptive-bi-level-lighting.pdf This one-page project summary gives an overview of a project to install bi-level lighting at a parking lot.

2j. U.S. Department of Energy Energy Efficiency & Renewable Energy (2013). *Exterior Lighting Control Guidance*. Retrieved from https://www4.eere.energy.gov/alliance/sites/default/files/uploaded-files/exterior-lighting-control-guidance.pdf This guide provides an overview of exterior lighting controls. It discusses strategies, control and light source technologies, installation, commissioning, and examples of installations.

2k. U.S. Department of Energy, Federal Energy Management Program (FEMP), Lawrence Berkeley National Laboratory, & California Lighting Technology Center. (2010). *Exterior Lighting Guide* (p. 38). Retrieved from http://cltc.ucdavis.edu/sites/default/files/files/publication/2010_DOE_FEMP_Exterior_Lighting_Guide.pdf A comprehensive guide for specifying lighting technologies for outdoor applications. Pertinent information is given regarding possible energy savings through the use of more efficient lamps as well as superior control strategies, as well as improved maintenance and quality of light.

2l. ANSI, ASHRAE, IES, & USGBC. (2014). *ANSI/ASHRAE/IES/USGBC Standard 189.1, Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*. Retrieved from https://www.ashrae.org/resources--publications/bookstore/standard-189-1 Standard 189.1 provides sustainability guidance for designing, building, and operating high-performance green buildings. Section 5.3.3 discusses exterior lighting requirements for reducing light pollution and energy use. This standard provides baseline requirements that align with LEED prerequisites.

2m. Leslie, R and Rodgers, P. (1996). *The outdoor lighting pattern book*. New York: McGraw-Hill. Retrieved from http://www.lrc.rpi.edu/publicationdetails.asp?id=100 This book presents many lighting patterns for typical outdoor residential, commercial, institutional, industrial, and public spaces, including walkways and areas adjoining apartment houses, alleys, quick-stop shopping, pedestrian malls, city business districts, office parks, parking garages, loading docks, school yards, playgrounds, public parks, and waterfront walks. Although it was written before LED products were available, the lighting design recommendations are still appropriate.

2n. New York State Energy Research and Development Authority. (2002). *NYSERDA How-to Guide to Effective Energy-Efficient Street Lighting* (p. 1-32). Retrieved from http://www.lrc.rpi.edu/programs/transportation/pdf/how-to-officials.pdf This is a guide to the effective implementation of outdoor street lighting with energy efficiency and application efficacy in mind. The two sections of the guide explain what the benefits of energy-efficient and effective outdoor lighting are, and the process that should be followed to define the project design goals and limitations as well as to communicate these principles with design professionals, vendors and city officials and residents.

3a. ASSIST. (2009). *ASSIST recommends... Outdoor Lighting: Visual Efficacy* (Vol. 6, p. 14). Troy, NY. Retrieved from http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-VisualEfficacy-Jan2009.pdf This report describes how to apply the unified system of photometry (sometimes referred to as mesopic vision) developed at Rensselaer's Lighting Research Center. Using this system, outdoor lighting can be designed that reduces energy use but maintains visual performance.

3b. Bullough, J. D., & Rea, M. S. (2008). *Innovative , Energy-Efficient Lighting for New York State Roadways: Opportunities for Incorporating Mesopic Visibility Considerations Into Roadway Lighting Practice* (p. 55). Retrieved from http://ntl.bts.gov/lib/27000/27000/27037/Innovativelighting.pdf This report discusses the potential to use the unified system of photometry (also called mesopic vision) developed at Rensselaer's Lighting Research Center to outdoor lighting practices for roundabouts, mid-block crossings, and work-zone lighting as well as new opportunities for better lighting practices to reduce operating cost and improve energy efficiency at roadways in urban and rural communities.

3c. Rea, M., Bullough, J., & Akashi, Y. (2009). Several views of metal halide and high-pressure sodium lighting for outdoor applications. *Lighting Research & Technology*, *41*(4), 297–320. doi:10.1177/1477153509102342 http://lrt.sagepub.com/content/41/4/297 Quality comparisons were performed to better understand the differences between Metal Halide and High Pressure Sodium light sources for nighttime outdoor lighting applications. In general, at equal illuminance levels, Metal Halide sources were viewed as brighter than the High Pressure Sodium sources, however, differences between the lighting systems for facial recognition, eyewitness identification and acceptability for social interaction were not as clear.

3d. U.S. Department of Energy Energy Efficiency & Renewable Energy. (2013). *Gateway Demonstrations: Pedestrian Friendly Outdoor Lighting* (p. 68). Retrieved from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2013_gateway_pedestrian.pdf An in-depth look at the criteria for pedestrian lighting and how they differ from general area outdoor lighting and street lighting applications. A series of mockups were performed for two different pedestrian-scale projects with data collected from surveys of pedestrians and neighborhood residents. One of the focuses was exploring some of the possible benefits of using solid state lighting for these applications.

3e. U.S. Department of Transportation, University Transportation Centers Program (2014). Maximizing Pedestrians' Perceptions of Safety Using Light Source Spectrum. *UTC Spotlight*. Retrieved from http://www.rita.dot.gov/utc/sites/rita.dot.gov.utc/files/utc_spotlights/pdf/spotlight_0714.pdf This brief synopsis summarizes the results of experiments that found that the spectrum of outdoor lighting influences perceptions of brightness, safety, and security.

3f. Washington State University Extension Energy Program. Mesopic Lighting for Street Lighting. *Energy Efficiency Emerging Technology Program Database.* Retrieved from http://e3tnw.org/ItemDetail.aspx?id=25 This technology summary discusses the benefits and uses of tuning outdoor lighting for the best visibility under moderately low (mesopic) light levels. Energy savings potential and costs are discussed.

3g. Boyce, P. R., Eklund, N. H., Hamilton, B. J., & Bruno, L. D. (2000). Perceptions of safety at night under different lighting conditions. *Lighting Research and Technology*, *32*(2), 79–91. Retrieved from http://lrt.sagepub.com/content/32/2/79 This paper presents the results of a series of studies on the perception of safety and security in parking lots in Albany, NY and New York City. The authors found that "an average horizontal illuminance on a parking lot surface or street sidewalk of about 30 Ix provides enough light to ensure that perceptions of safety are close to what they are in daylight. The light spectrum is a minor factor relative to illuminance."

3h. Bullough, J. D., Sweater Hickcox, K., & Narendran, N. (2011). *ASSIST recommends: A Method for Estimating Discomfort Glare from Exterior Lighting Systems* (Vol. 9, pp. 1–7). Retrieved from http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-DiscomfortGlare.pdf This report discusses existing mathematical models for predicting discomfort glare and an extension of those models based on new research. Example calculations are provided.

3i. Bullough, J. D., Radetsky, L., & Besenecker, U. (2013). *Leveraging Brightness from Transportation Lighting Systems through Light Source Color: Implications for Energy Use and Safety for Traffic and Pedestrians* (p. 30). Retrieved from http://www.utrc2.org/sites/default/files/pubs/Final-LRC-Light-Source-Color_1.pdf This report presents the findings of a laboratory study that explored brightness perception using various color light sources. This has implications for using "yellowish" high pressure sodium lamps vs. "white" light sources such as LED in areas where brightness perception is important, such for perceptions of safety and security by pedestrians.

3j. Fotios, S., Unwin, J., & Farrall, S. (2014). Road lighting and pedestrian reassurance after dark: A review. *Lighting Research and Technology*. doi:10.1177/1477153514524587 http://lrt.sagepub.com/cgi/doi/10.1177/1477153514524587 This article looks into road lighting for pedestrian reassurance and safety. A more thorough and focused research approach is proposed to validate the 10 lux suggested optimum illuminance level as well as desirable spectral power distributions.

3k. Fotios, S., Uttley, J., Cheal, C., & Hara, N. (2014). Using eye-tracking to identify pedestrians' critical visual tasks, Part 1. Dual task approach. *Lighting Research and Technology*. doi:10.1177/1477153514522472 http://lrt.sagepub.com/cgi/doi/10.1177/1477153514522472 The visual fixations and critical visual tasks of pedestrians were examined using eye-tracking technology. It was found that under daylight conditions and for long distance visual tasks, other pedestrians were the most frequent point of fixation, while for close distances, the pathway itself was the most frequent visual fixation. At night, the pathway was the most frequent visual fixation for any relative distance.

3l. Rea, M. S. (2001). The road not taken. *The Lighting Journal*, *66*(1), 18. This paper discusses the importance of peripheral vision when designing roadway lighting. Topics include the background physiology and considerations for intensity and spectral power distributions of light sources. This paper is currently not available online.

3m. Rea, M., Bullough, J., Freyssinier-Nova, J., & Bierman, A. (2004). A proposed unified system of photometry. *Lighting Research \& Technology*, *36*(2), 85. Retrieved from http://lrt.sagepub.com/cgi/content/abstract/36/2/85 This paper describes a unified system of photometry that predicts visual performance (reaction times) at all light levels. This model incorporates what is sometimes called "mesopic vision." Predicted visual performance is based on both photopic luminance and the ratio of scotopic to photopic lumens for a particular light source.

3n. Rea, M., Bullough, J., & Zhou, Y. (2010). A method for assessing the visibility benefits of roadway lighting. *Lighting Research and Technology*, *42*(2), 215–241. doi:10.1177/1477153509360855 http://lrt.sagepub.com/cgi/doi/10.1177/1477153509360855 This study used photometrically accurate lighting software and a mathematical model of visual performance to evaluate roadway lighting, a methodology that can be duplicated by others. Three conclusions were reached: That "low-speed and high-speed intersections should be illuminated; older drivers particularly benefit from high illumination levels on high-speed roadways; and lighting from sources other than fixed roadway lighting systems are important for driving, implying photosensors might be more strategically used to save public funds."

3o. Rea, M. S., Radetsky, L. C., & Bullough, J. D. (2011). Toward a model of outdoor lighting scene brightness. *Lighting Research and Technology*, *43*(1), 7–30. Retrieved from http://lrt.sagepub.com/content/43/1/7.abstract A series of experiments was used to create a model of brightness perception of outdoor scenes. Brightness perception is important for pedestrians' sense of safety and security.

4a. Bullough, J. D., Donnell, E. T., & Rea, M. S. (2013). To illuminate or not to illuminate: roadway lighting as it affects traffic safety at intersections. *Accident Analysis & Prevention*, *53*, 65–77. doi:10.1016/j.aap.2012.12.029 http://www.ncbi.nlm.nih.gov/pubmed/23377085 This study correlated the lighting with crash frequency at intersections in Minnesota. A model of relative visual performance was used to characterize the lighting at the intersections. The results allow engineers to quantify the expected safety improvements at an intersection from installing a particular lighting system. "Overall, the presence of roadway intersection lighting was found to be associated with an approximately 12% lower night-to-day crash ratio than unlighted intersections."

4b. Bullough, J. D. (2014). Roadway Lighting and Safety : An Integrated Approach. *Lighting Research Center*. Retrieved November 24, 2014, from http://www.lrc.rpi.edu/programs/transportation/lightingsafety.asp This web page provides links to articles on roadway lighting and safety. Specific topics include safety, visibility, synthesis, and cost benefits.

4c. Clarke, R. V. (2008). *Problem-Oriented Guides for Police Improving Street Lighting to Reduce Crime in Residential Areas* (p. 50). Retrieved from http://cops.usdoj.gov/Publications/e1208-StreetLighting.pdf This guide provides insights to communities wishing to use improved outdoor street lighting as a method of reducing crime. Lighting techniques are suggested and the costs and benefits of improved lighting are weighed and considered. Some benefits include improved perception of safety, less actual crime and disorder and the overall improvement of appearance of outdoor areas.

4d. Hanford, D.J. (2011). Exterior Lighting: Use Best, Not Brightest. *Building Operating Management*. Available at http://www.facilitiesnet.com/lighting/article/Outdoor-Lighting-Strategy-Can-Balance-Safety-Security-and-Environmental-Stewardship-Facilities-Management-Lighting-Feature--12857 This article discusses lighting for safety vs. security, appropriate light levels, and lighting controls. It also provides a case study from Walmart.

4e. Illuminating Engineering Society (2015). The Value Proposition: At the Crossroads of Intersections. *LD+A e-report*. Retrieved from http://www.ies.org/LDA/e-newsletter/2015/SALC/2015_SALC-crossroads.cfm This brief article discusses recent research on the value of lighting roadway intersections and how the results might be used to decide when and where to light intersections.

4f. Rea, M. S., Bullough, J. D., Fay, C. R., Brons, J. A., Van Derlofske, J., & Donnell, E. T. (2009). *Review of the safety benefits and other effects of roadway lighting* (pp. 1–61). Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP05-19_LitReview.pdf A summarization of studies performed as part of the National Cooperative Highway Research Program (NCHRP) is provided to take an in-depth look at the effects of nighttime lighting on roadway crashes, pedestrian perceptions of safety and security, street crime, economic development and light pollution. Wide variations in findings likely stemming from biases and analysis techniques are seen to exist, however, there is nevertheless a connection found to exist between effective outdoor lighting and the reduction of street crime and roadway accidents.

4g. Donnell, E. T., Porter, R. J., & Shankar, V. N. (2010). A framework for estimating the safety effects of roadway lighting at intersections. *Safety Science*, *48*(10), 1436–1444. doi:10.1016/j.ssci.2010.06.008 http://linkinghub.elsevier.com/retrieve/pii/S0925753510001670 The methods for evaluating the safety effects of intersection lighting are proposed. The methods are used to evaluate Minnesota intersection crash data; benefits were found to be lower than previously published research suggested, but consistent with estimates in Highway Safety Manual research.

4h. Boyce, P. R., Eklund, N. H., Hamilton, B. J., & Bruno, L. D. (2000). Perceptions of safety at night under different lighting conditions. *Lighting Research and Technology*, *32*(2), 79–91. Retrieved from http://lrt.sagepub.com/content/32/2/79 This paper presents the results of a series of studies on the perception of safety and security in parking lots in Albany, NY and New York City. The authors found that "an average horizontal illuminance on a parking lot surface or street sidewalk of about 30 Ix provides enough light to ensure that perceptions of safety are close to what they are in daylight. The light spectrum is a minor factor relative to illuminance."

4i. Leslie, R.P., Rodgers, P. A. (1996). *The outdoor lighting pattern book*. New York: McGraw-Hill. Retrieved from http://www.lrc.rpi.edu/publicationdetails.asp?id=100 This book presents many lighting patterns for typical outdoor residential, commercial, institutional, industrial, and public spaces, including walkways and areas adjoining apartment houses, alleys, quick-stop shopping, pedestrian malls, city business districts, office parks, parking garages, loading docks, school yards, playgrounds, public parks, and waterfront walks. Although it was written before LED products were available, the lighting design recommendations are still appropriate.

5a. Beckwith, D., Smalley, E., Yand, M., Chan, L., & Zhang, X. (2010). LED Streetlight Application Assessment Project Pilot Study in Study Area and Test Sites. In *Westernite 2010* (pp. 1–10). San Francisco, CA: Western District of the Institute of Transportation Engineers. Retrieved from http://www.westernite.org/annualmeetings/sanfran10/Papers/Session 6_Papers/ITE Paper_6B-Beckwith.pdf LED streetlights were evaluated in this study in Seattle Washington in order to determine the viability and potential energy-savings, distribution and light output benefits of using LED technology instead of existing HPS and Metal Halide lamp technologies. New control technologies were also evaluated to explore further energy savings opportunities. It was found that not all LED luminaires met the specified illuminance levels and uniformity ratios required and but that in most cases, longer life could be expected and that general feedback was supportive of the new technology and public satisfaction levels were generally high.

5b. Bullough, J. (2010). *NLPIP Lighting Answers: Dynamic Outdoor Lighting* (Vol. 11, p. 20). Troy, NY. Retrieved from http://www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=928&type=2 Dynamic outdoor lighting varies light level (or other characteristics) automatically and precisely in response to factors such as vacancy or the type of use of an outdoor space. This report discusses dynamic outdoor lighting in terms of its potential energy savings, environmental benefits, cost reductions and possible liabilities and other potential drawbacks. This document also describes the technologies and strategies for implementation of dynamic outdoor lighting for parking garages, walkways and streets.

5c. Bullough, J. D. (2012). *New Lighting Technologies and Roadway Lighting: An Informational Brochure* (pp. 1–6). Retrieved from https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-10-14_RoadwayLighting-InformationalBrochure.pdf This brochure provides an introduction to technologies and techniques for roadway lighting. It also provides a list of resources for more in-depth information.

5d. Bullough, J. D., & Radetsky, L. C. (2013). *Analysis of New Highway Lighting Technologies*. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(305)_FR.pdf This study includes a review of published literature and an analysis roadway lighting of various light sources, including LEDs. The results suggest "that LED technologies, while still rapidly developing, are viable for specifying energy efficient and visually effective roadway lighting systems." The report discusses suggested evaluation metrics.

5e. DesignLights Consortium Qualified Products List. https://www.designlights.org/QPL This website lists LED products that have met the DesignLights Consortium's specifications under various product categories, including outdoor lighting. Results can be filtered by product category and other specifications.

5f. Dilouie, C. (2013). Exterior Lighting Control Strategies. *Lighting Controls Association*. Retrieved November 24, 2014, from http://lightingcontrolsassociation.org/exterior-lighting-control-strategies/ Lighting control strategies are discussed for varying outdoor lighting applications and code compliance. The use of occupancy sensors and time-clock control is described as being an essential element of energy efficient and effective outdoor lighting and these technologies are described in some depth.

5g. DiLouie, C. (2014). Outdoor Lighting Controls : The State of the Art. *Lighting Controls Association*. Retrieved November 24, 2014, from http://lightingcontrolsassociation.org/outdoor-lighting-controls-the-state-of-the-art/ Over time outdoor lighting controls have become more sophisticated and technologically complex in response to new building energy efficiency codes as well as the controllability of new LED technology. This article explains some of the available outdoor lighting control technologies and outlines some of the potential benefits associated with integrating these options into new installations.

5h. Massachusetts Metropolitan Area Planning Council. (2013). *Buy Back Streetlights from Utility* (pp. 1–5). Retrieved from http://www.mapc.org/system/files/bids/Buy Back Streetlights from Utility.pdf This documents provides a strategy for municipalities to purchase back streetlights from its utility. The authors say that "30-60% of street lighting costs can be saved just by purchasing streetlights from utilities."

5i. Massachusetts Metropolitan Area Planning Council. (2013). *Retrofit Streetlights with LEDs* (pp. 1–18). Retrieved from http://www.mapc.org/system/files/bids/Retrofit Streetlights with LEDs.pdf This guide provides insight and

guidance into the planning process of switching exterior lighting installations to LED technologies. The guide discusses how to develop a scope of work, lighting design, fixture selection, project implementation, procurement, and financing.

5j. Millard, B. (2015). LEDs Make Inroads into Streetlighting. *Architectural Lighting*. Retrieved from http://www.archlighting.com/lighting/leds-make-inroads-into-streetlighting_o.aspx This article provides an overview of the increasing use of LED streetlights in the U.S. It compares the performance of LED streetlights with the incumbent technology, discusses the applications for which LEDs are best suited, provides the energy and cost savings results from several cities that have installed them, and calls for a new business model for streetlight ownership and operation.

5k. Minnesota Department of Commerce. *Energy Efficient Street Lighting Benefits Documented in Conservation Applied Research & Development Report*. Retrieved from http://www.cleanenergyresourceteams.org/sites/default/files/LED-Streetlighting-Factsheet.pdf This is a brief summary of a study of the cost benefit of upgrading roadway lighting. It discusses the study's findings about payback periods of LED streetlights, the results of a pilot installation project, energy savings results, and a list of steps to complete when considering LED streetlights.

5l. Municipal Solid-State Street Lighting Consortium. (2014). *MSSLC Model Specification for LED Roadway Luminaires: Version 2.0* (pp. 1–21). Retrieved from http://www1.eere.energy.gov/buildings/ssl/docs/msslc_model-luminaire-spec_v2.docx This model/template solid-state outdoor lighting specification is meant to aid municipalities, site owner etc. in defining the criteria that need to be met by the LED roadway lighting installation they wish to implement. This sample is meant to be a guideline and should not be considered a rigid set of rules as every lighting design will have different requirements and each municipality or locality may have differing desires.

5m. Bullough, J. D. (2012). *Guide for Optimizing the Effectiveness and Efficiency of Roadway Lighting* (p. 38). Retrieved from https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C10-14_Final Report.pdf This is a simple guide for understanding and implementing lighting replacement installations for roadway applications using new technologies for improved efficacy and energy efficiency. Energy savings of 7-50% are deemed possible by switching from High Pressure Sodium to LED or induction fluorescent technologies. Using these technologies in conjunction with growing understanding of driver and pedestrian night-time vision can improve energy efficiency and effectiveness of lighting installations.

5n. Bullough, J. D., Skinner, N. P., & Brons, J. A. (2015). *Analysis of Energy Efficient Highway Lighting Retrofits*. Retrieved from https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-14-12-Final%20Report_June%202015.pdf This report describes technical and economic analyses comparing LED to existing high pressure sodium road lighting along expressways and major arterial highways, and documents the potential for energy and economic savings.

5o. Dilouie, C. (2014). DOE Announces New Energy Efficiency Standards for MH Luminaires | Lighting Controls Association. *Lighting Controls Association*. Retrieved November 24, 2014, from http://lightingcontrolsassociation.org/doe-announces-new-energy-efficiency-standards-for-mh-luminaires/ The Department of Energy (DOE) has recently implemented new efficiency standards for Metal Halide lamp ballasts which may affect the availability of 50-1000W Metal Halide luminaires in the future. This article discusses the implications of this new standard.

5p. Radetsky, L. (2010). *NLPIP Specifier Reports: Streetlights for Collector Roads*. (Vol. 13, pp. 1–48). Troy, NY: Lighting Research Center. Retrieved from http://www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=927&type=1 The National Lighting Product Information Program (NLPIP) at Rensselaer Polytechnic Institute's Lighting Research Center tested 14 roadway lighting fixtures of various light sources. Results showed that while LED streetlights could result in energy savings, "on average, the LED streetlights and the induction streetlight could be spaced only about one half the distance of the HPS and PSMH streetlights and still meet the RP-8 lighting criteria." As a result of needing additional fixtures per mile, "life cycle cost of the LED streetlights tested for this study were up to twice that of the HPS and PSMH streetlights tested."

5q. Southern California Edison. (2011). *CALIFORNIA EXTERIOR OCCUPANCY SURVEY PHASE 1 - METHODOLOGY*. Retrieved from http://www.etcc-ca.com/sites/default/files/reports/ET08SCE1050%20-%20CA%20Exterior%20Occupancy%20Survey_Final.pdf The methodology detailed in this document are intended to be used to complete a field study that will determine appropriate incentives for installing adaptive exterior lighting. Topics include sensor types, data collection, and survey costs.