**5. Outdoor Lighting Demonstrations and LED Technology Comparisons**

The resources listed below describe outdoor lighting installations using LEDs and other lighting technologies, and discuss the primary differences in performance between LED sources and other types of lighting systems. All links below are up-to-date as of January 2020.

Beckwith, D., Smalley, E., Yand, M., Chan, L., & Zhang, X. (2010). LED Streetlight Application Assessment Project Pilot Study in Seattle, WA. In ASCE Green Streets and Highways 2010, American Society of Civil Engineers. Retrieved from <http://dx.doi.org/10.1061/41148%28389%2919> 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.

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.

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.

DesignLights Consortium Qualified Products List. Retrieved from <https://www.designlights.org/search/> 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.

DiLouie, C. (2014). DOE Announces New Energy Efficiency Standards for MH Luminaires | Lighting Controls Association. Lighting Controls Association. Retrieved 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.

Millard, B. (2015). LEDs Make Inroads into Streetlighting. Architectural Lighting. Retrieved from <https://www.archlighting.com/industry/reports/leds-make-inroads-into-streetlighting_o> 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.

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.

New York State Energy Research and Development Authority. (2019). LED Roadway Lighting Benefits and Costs Collaboration, 19-40. Albany, NY: New York State Energy Research and Development Authority. Retrieved from <https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Transportation/19-40-LED-Roadway-Lighting-Benefits.pdf> This report describes a test installation of LED streetlights along a major arterial roadway near Albany, NY. Four different types of LED streetlights were installed and feedback from drivers and pedestrians demonstrated that the visual conditions were improved from the previous HPS lighting.

Radetsky, L. (2010). NLPIP Specifier Reports: Streetlights for Collector Roads. Troy, NY: Lighting Research Center. Retrieved from <https://www.lrc.rpi.edu/programs/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 (in 2010) were up to twice that of the HPS and PSMH streetlights tested.

University Transportation Research Center. (2019). Evaluation of Light Emitting Surface and Light Emitting Diode Roadway Luminaires. New York: University Transportation Research Center. Retrieved from <http://www.utrc2.org/sites/default/files/Final-Report-Evaluation-of-Light-Emitting-Surface.pdf> This report describes measurements and photometric analyses to evaluate the performance of LED and light emitting surface (LES) streetlighting luminaires. Both types provided similar performance for roadway illumination.

U.S. Department of Energy, Energy Efficiency & Renewable Energy. (2013). Gateway Demonstrations: Pedestrian Friendly Outdoor Lighting. 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.

U.S. Department of Transportation, University Transportation Centers Program (2014). Maximizing Pedestrians’ Perceptions of Safety Using Light Source Spectrum. UTC Spotlight. Retrieved from <https://www.transportation.gov/sites/dot.gov/files/docs/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.

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.