Societal Benefits of Improved Public Lighting

Annotated Bibliography – Draft for Review

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Painter, K. Farrington, D. The Crime Reducing Effect of Improved Street Lighting: The Dudley Project

This article discusses research conducted by Painter and Farrington in which they seek to "investigate the effects of improved street lighting as a crime prevention technique". First, the authors outline previous research on the relationship between street lighting and crime noting that many of the research projects done prior to theirs have notable flaws. However, to avoid a recurrence of these flaws, present studies are using internal validity measures. The theoretical relationship between street lighting and crime is then discussed and it is pointed out that while "there is no specific body of theory that relates street lighting to crime… explanations of the way street lighting improvements could prevent crime can be found in 'situational' approaches which focus on reducing opportunity and increasing perceived risk, through modification of the physical environment". Previous studies have shown that street lighting provides greater visibility at night which affects offenders' perceptions of the risk of being caught and highlights the importance of lighting investment as it improves "neighborhood conditions as a means of strengthening resident confidence, cohesion and social control". Additionally, improved street lighting signals to residents that positive investments are being made toward improving their neighborhood and shows offenders that crime at that location is more difficult as surveillance and social control has increased. The relationship between visibility, social surveillance and criminal opportunities is a strong theme in the literature and indicates that street lighting plays a role in crime reduction by altering perceptions which in turn changes the behavior of residents and offenders. Then, the methodologies of Painter and Farrington's study are put forth and all findings are presented. On the whole, "the most plausible conclusion from this research is that the improved street lighting was responsible for the decrease in crime". The authors contribute this finding to the fact that more visibility and surveillance on the street led residents to be more optimistic of the level of safety in their community and this community pride increased the perceived level of risk potential offenders had toward committing crimes.

Welsh, B. Farrington, D. Effects of Improved Street Lighting on Crime.

This article outlines a literature review conducted by Welsh and Farrington which aims to "assess the available research evidence on the effects of improved street lighting on crime in public space". The selection criteria used to determine which studies were to be included is discussed and an overview of methodologies used is provided. The authors find that two main explanations can be given as to how street lighting improvements could prevent crime:

1. As a situational crime prevention measure that focuses on reducing opportunity and increasing perceived risk through modification of the physical environment
2. As a method of strengthening informal social control and community cohesion through more effective street use and investment in neighborhood conditions.

The review includes 13 studies (8 from the United States and 5 from the United Kingdom) and finds that 4 of the studies conducted in the USA and 4 of the studies conducted in the UK found that street lighting was effective in crime reduction. The difference found to account for this discrepancy is that both daytime and nighttime crimes were measured in the "effective" evaluations. The results from the meta-analysis of all 13 studies combined shows that crimes decreased by 21% in experimental areas compared with control areas. This may indicate that the theory that street lighting increases community pride and informal social control is more plausible than the theory that crime reduction is from increased surveillance because these studies did not find that nighttime crimes decreased more than daytime crimes. The authors conclude by summarizing the policy implications of research on improved street lighting put forth by Pease (1999). Pease notes that "situational crime prevention involved the modification of environments so that crime needed more effort, more risk, and lower rewards". Additionally, street lighting provides benefits to the whole community and has little to no negative effects and clear benefits for law-abiding citizens.

Raynham, P. Public Lighting in Cities

This paper is a literature review in which over 100 sources of information were reviewed and 30 are cited in the paper. The objective of this paper is to highlight the key issues of the various topics surrounding city lighting. The paper is split into 3 main sections in which city lighting plays an importance role: Human Factors, City Image and Performance. The Human Factors section discusses how city lighting is associated with the needs of the people. In this, lighting provides safe movement, visual orientation, visual comfort, facial recognition and a general feeling of safety for citizens. The City Image section discusses the appearance of a city after dark and how that relates to people's perception of the city. Amenity, planning, aesthetics and iconography are all importance lighting factors that fall into the city image category. The Performance section looks at the practical issues surrounding lighting installation and discusses topics such as energy consumption,

maintenance and the impact on road traffic accidents. The author concludes by reiterating the ability of lighting to provide various public goods to cities, "It can provide a sense of amenity and with careful planning boost the aesthetic qualities of a city and permit the icons of the city landscape to stand out by night as well as the day. Good well-planned lighting can make a city more legible and thus make it easier for people to use it after dark".

Herbert, D. Modifying the Built Environment: The Impact of Improved Street Lighting

This article begins by outlining the debate surrounding the degree to which crime can be reduced by changes in the built environment. The focus of this paper is on street lighting's ability to influence the built environment and how improved street lighting can influence reduction in crime itself and the fear of crime. The author notes that fear of crime is an important factor in influencing resident's behavior and that there is strong support that "that improved street lighting reduces the fear of crime and enhances feelings of community safety". The paper then outlines studies conducted in both Hull and Cardiff and discusses the methodologies and findings related to each area. The paper concludes by discussing the finding that the effects of changing the street lighting in Cardiff and Hull have been astonishing in that "many more people are willing to be out-of-doors after dark, there is a greater confidence in home and community and a general willingness to see things in a more positive way". The author than puts forth three reasons as to why this could have occurred: "Firstly, street lighting is visible and obvious and its improvement is instantly recognised. Secondly, the installation of new lighting is seen as an act of faith in the future of the local community and this in itself serves to increase confidence. Thirdly, improved street lighting achieves immediate and tangible benefits. There is more light and visibility and the greater surveillance which is often advocated for safe communities (Newman, 1972) is achieved". The author lastly notes that the finding point to an important policy implication in that street lighting can achieve tangible gains and is an important factor in raising the perceptions of safety especially for vulnerable members of society.

Painter, K. Farrington, D. The financial benefits of improved street lighting, based on crime reduction

Painter and Farrington work to compare the financial benefits of improved street lighting programmes with their financial costs. The authors draw on two previously conducted studies, one in Dudley and one in Stoke-on-Trent, in which it was initially determined that the financial savings from reduced crimes in one year more than outweighed the full capital costs of the improved lighting. However, the authors now seek to calculate the financial benefits more accurately as the Home Office produced new estimates of the

financial costs of different types of crime. The article proceeds by outlining the studies done in both Dudley and Stoke-on-Trent. Afterwards, the costs of crime are discussed in which the costs of crime are divided into tangible and intangible costs and the estimates conducted by the Home Office are put forth. Then, a cost-benefit analysis is done for both Dudley and Stoke-on-Trent and it is determined that the savings from crimes prevented more than paid off the full capital cost of the improved lighting in one year. The article concludes by asserting that "it is clear from these calculations that improved street lighting can be extremely cost-effective to the extent that it leads to reductions in crime". Furthermore, given the expensive nature of crime and the relatively cheap cost of lighting, the authors believe their main results are valid in that "improved street lighting can reduce crime and that the financial benefits can enormously outweigh the financial costs".

Ciriminna, R. LED Street Lighting: A Looking Ahead Perspective

Ciriminna's article discusses the ability of LED street lighting to increase energy efficiency and reduce environmental damage. The author first puts forth the advantages of LED street lights which include the prevention of light pollution (due to efficiency of directing light to desired areas), high light output even at low temperatures, longer projected average lifetime and that they "do not contain poisonous mercury and sodium gases, nor toxic lead, lowering the environmental impact and the disposal cost for the owners of damaged street lights". Then, limitations of LED lighting are also discussed which include glare and some new environmental and health problems such as eye strain and fatigue. Afterwards, performance and price is discussed and it is determined that as LED street lamps are adaptive lighting systems there will be a reduction in costs, enhanced visibility and minimized adverse health effects. It is then asserted that decades of trials indicate that cities across the globe that have adopted LED street lighting have achieved energy savings of between 50 % and 70 %. Additionally, the cities can expect a rapid return on investment due to the fall in price of LED lights. In terms of environmental sustainability, "the cutting effect in carbon dioxide emissions can be very important insofar LED lighting reduces the primary energy demand". To conclude, Ciriminna states that the hope is that the overall implications of these findings can be used to assist policy makers "to take into account not only the economic advantages due to reduced energy requirements but also those health, environmental and aesthetic aspects that will allow them to exploit the full potential of LED lighting".

Hember, A. Sjoberg, S. Wallerstrom, C. Smart street lighting: The advantages of LED Street Lighting and a smart control system in Uppsala municipality

This report seeks to determine the benefits of replacing the street lights in the municipality of Uppsala to LED and installing a smart control system. The report discusses thoroughly the details of the research such as methodologies and limitations. Afterwards, the findings of the research are presented and the main conclusions are put forth. The effects of replacing all street lighting to LED armatures connected to a stand-alone system or a smart control system proved to have both environmental and economic benefits. In the discussion, it is stated that "the energy savings for the two scenarios compared to the energy consumption today are approximately 73.5 % and 79.2 %, thus it is profitable to invest in LED technology". The authors contribute much of this success to the smart control system as it "gives an overview of the energy consumption and the errors in the street light system. The smart control system also enables the flexibility to adjust the intensities of the light in different parts of the municipality since the armatures are possible to regulate individually". Additionally, it is stated that the energy consumption has the potential to be lower than calculated in the report as the municipality could have taken further advantage of the flexibility in the smart control system. Next, the authors discuss the economic benefits in which it is determined that savings in maintenance costs when using a smart control system indicate the economic efficiency of this system as reduction of maintenance costs is a big part of annual savings. In the conclusion, it is noted that LED lights also provide benefits in terms of personal safety and comfort. Overall, the authors determine that "installing LED and a smart control system decreases the energy consumption and CO2-e extensively, and the economic consequences are beneficial".

Murry, A. Feng, X. Public street lighting service standard assessment and achievement

Murray and Feng work to develop a framework for assessing public street lighting based on location modeling. In this, the aim of their work is to contribute to informed planning and management. The authors determine that nighttime lighting is an instrumental public service in terms of impacting human activities and promoting transportation and pedestrian safety. However, it is also clear that these services can have negative economic and environmental outcomes. Thus, delivery of these services must be assessed due to sustainability concerns. The authors find that "a significant problem with existing urban infrastructure systems is that they have evolved over time using rule-of thumb planning standards associated with the locational placement street lights". This has resulted in inefficiencies and requires enhanced spatial efficiency of infrastructure. It is concluded that street lighting has compelling benefits such as reduced criminal behavior, reduced fear of crimes, increased surveillance potential and perpetrator detection and can reduce the chance of pedestrian, bike and vehicle accidents. Furthermore, "lighting enhances

community pride, neighborhood cohesiveness, and informal social control". Thus, it is necessary municipalities maintain standards associated with the provision of public street lighting such that costs and environmental impacts are kept to a minimum.

Green, J. Perkins, C. Steinbach, R. Edwards, P. Reduced street lighting at night and health: A rapid appraisal of public views in England and Wales

This article works to determine the relationship between reduced street lighting and health. Ethnographic data, a household survey and documentary sources are utilized in the appraisal of eight areas of England and Wales. In recent years, local authorities have reduced street lighting at night to reduce costs and carbon emissions under the Climate Change Act 2008. This reduction raised public and media concern, centering on crime, fear of crime, perceptions of safety, and road safety which are all directly related to health and well-being. The report further investigates these perceptions with the overall aim of the paper being "to explore public understanding of the possible pathways through which street lighting might impact on health and wellbeing, and how reductions in street lighting were understood as impacting on health and wellbeing outcomes". The article finds that reduction in street lighting at night affected health and well-being both directly and indirectly. The direct positive implications were improved sleep, existential capital from being able to see the night sky while the direct negative implications were anxiety from fear of crime and constraints on mobility at night. It must also be noted that while the public emphasized negative impacts, these implications for personal wellbeing were balanced against other health determinants such as "carbon emission reduction and divesting resources to spend on other services, which might accrue from reduced energy expenditure". The study concludes by suggesting that, in order to achieve sustainability gains without compromising personal wellbeing, that "attention should also be paid to the more symbolic effects of street light reductions as well as the direct health impacts".

Gutierrez-Escolar, A. A Study to Improve the Quality of Street Lighting in Spain

This article outlines a case study conducted in Spain in which the aim was to analyze the various devices that influence energy consumption in order to better understand their performance and in turn, optimize energy consumption. The devices analyzed were lamps, ballasts, street lamp globes, control systems and dimmable lighting systems. An analysis of all these elements was conducted in the article as the authors believe this was a necessary task in obtaining an understanding of how each component affects the final energy consumption. In terms of street lamps, it is suggested that by replacing common bulbs with energy-saving LED lamps Spain can reduce energy consumption by up to 80%. Once each component was analyzed, the case study concluded that there was much room for improvement in Spanish street lighting systems and the article puts forth suggestions

policies and technologies that could be incorporated into the Spanish Standards to improve the quality of street lighting.

New York State Energy Research and Development Authority, How-to Guide Effective Energy Efficiency Street Lighting

NYSERDA sets out to provide the municipalities of New York State with guidance for effective energy-efficient street lighting systems. The main aim of the report is "to provide municipalities with additional information on how to combine photometrics, design, and energy-saving performance of street lighting installations". The report states that the methods provided will enable municipalities with the tools needed to specify efficient products while maintaining aesthetically pleasing installations. In doing so, street lighting systems can provide efficiency and economic benefits as a result of increased commercial activity in New York State's urban areas. The guide seeks to equip cities with the tools needed to identify important elements of energy-efficiency in street lighting and to gain the knowledge needed to make informed street lighting procurement decisions. After the aims of the report have been discussed, the opportunities of effective street lighting are explored. The opportunities identified by NYSERDA are: returns on investment through energy savings, capital cost savings, maintenance cost savings, improved sense of security, evenly lit roads and sidewalks, reduced glare and improved visibility, aesthetically pleasing areas and economic development. Then, guidelines for how municipalities can implement more efficient street lighting systems are presented and the considerations that need to be taken into account to do so are listed. Rationale is then provided for the criteria put forth and guidance for selection of lamps and luminaires is given. The article concludes by stating that street lighting can create added value for the public, business community, public safety officials and those interested in energy savings and environmental concerns.

Bodhani, A. Built Environment: Connected LED Street Lights Cut Council Costs

This is a news article that discusses the integration of Ericsson technology into Phillips lighting hardware which turned lighting poles into mini mobile base stations. The scheme was designed to provide improved network performance and broadband coverage and high-quality energy-efficient public lighting. Energy consumption and lack of available capital in the city's operating budget means city's need to reduce consumption costs in the most efficient way possible. This 'lighting as a service model' is expected to "accelerate the payback time for renovated lighting".

Gunjan, P. LED Streetlights Brightening India's Sustainability Plans

This article discussed how LED streetlights will play an important role in the Indian government's plan to develop 100 smart cities. In India, it is projected that LED streetlights will soon be widely disseminated across the country to meet India's needs for energy conservation. The implementation of LED streetlights is part of the Indian government's plan to develop 100 smart cities in India and different cities across India will soon begin replacing sodium vapour lamps and incandescent bulbs with LED lights. To meet the requirements of efficiency, long life span and energy conservation, the product development of LED street lights focused on "efficiency, wherein the lumens output, longevity, thermal management and control systems are key". Additionally, intelligent streetlight controllers (SLC) enable more effective streetlight management: "Lights can be controlled over the Web and mobile, with longitude/latitude based switching on/off, energy tracking and planning, and monitoring of the energy consumed. The user can monitor faulty streetlights and implement an effective fault repair and servicing system". Government requirements and the desire of corporations and other institutions to embrace sustainability means the demand for energy-saving products has increased across India and will likely continue to grow as the country develops further.

Painter, K. The Influence of Street Lighting Improvements on Crime, Fear and Pedestrian Street Use, After Dark

This paper assesses the impact of upgraded street lighting in improving crime and fear of crime on three urban streets. A substantial number of people avoid going out after dark as a precaution against becoming a victim of crime however, there is evidence that this fear of crime of often out of proportion. Research has found that this disproportional fear is often a result of "darkness, disorder and finding oneself alone or in the presence of others who are perceived to be threatening". Thus, it becomes clear that to increase perceptions of safety and nighttime activity, city's must create city centers that facilitate "a greater density of pedestrian traffic, a variety of facilities which people would want to use and clear visibility over long distances". In this, improved street lighting is a cost-effective way of creating a sense of public safety, improving the built environment and increasing the number of people on the streets after dark. The paper proceeds by discussing the design and results of a demonstration project designed to test the feasibility of street lighting as a crime and fear reducing measure. The results of the research project demonstrate that while it is unrealistic to assume that any single strategy can fix crime and fear problems in all contexts, there is "consistent evidence that lighting improvements have a powerful capacity to reduce crime, incivilities and fear at night". Additionally, the research indicates that improved lighting can in fact increase street use after dark which would likely translate into enhanced economic activity.

Ebrahimian, E., Changing our Glow for Efficiency: Municipal Solid State Lighting Consortium – LED Workshop

This presentation begins by highlighting key statistics relevant to Los Angeles and the capacity of it's street lighting bureau. Afterward, operational challenges facing the bureau were discussed and the mentality behind the LED Program is presented which discussed the goal of reducing energy consumption, maintenance costs and carbon emissions. Then, the details of the program are put forth such as the conversion of 140,000 streetlights to LED, the installation of remote monitoring systems, the cost and the timeline. After more program specifics and testing methods were discussed, important lessons learned from the implementation of the LED program were mentioned. Overall, the benefits of the LED program in Los Angeles were energy savings of 68,000,000 KWH/year and $7.5 million/year, maintenance savings of $2.5 million/year, the reduction of 40,500 tons of CO2/year and the enhanced perception of improved lighting/visibility/dimming capability.

Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies

This report begins first by stating the two main reasons cities are implementing public lighting programs; "First, public lighting promotes community safety: studies have shown that public lighting can reduce crime by up to 20 percent, and can reduce the number of fatal traffic accidents by 35 percent. Second, public lighting supports economic growth by increasing the amount of time that people can spend on economic activities such as "entertainment and meals away from home at night". Then, it is discussed why LED lighting technology has become popular within these programs, reasons include: LED electricity consumption tends to be 40 to 60 percent lower, operation and maintenance costs tend to be lower because LED luminaires last at least four times longer than traditional bulbs, the lifetime costs for LED can be lower than for less efficient lighting options and LED lighting is generally perceived as of better quality than traditional lighting because it has a higher color rendering index. The report then goes on to present six case studies in which six different delivery models were utilized by six different cities :energy service company (ESCO), super-ESCO, joint procurement, public-private partnership (PPP), lease-to-own, and municipal financing. Afterwards, the benefits and challenges of public lighting are put forth with the key benefits being fostering economic growth, improving safety by reducing crime and traffic accidents and enhancing city aesthetics by accenting monuments, fountains, and landmarks. Then, the benefits and challenges of LED lighting are discussed with the main benefits being lower lifetime costs, less electricity consumption, longer lifespan, fewer luminaire replacements and less maintenance. Next, summaries of the case studies are presented and "key cross-cutting findings" are discussed such as financial barriers, the role of national governments, private sector partnerships, engaging with stakeholders and flexible implementation.

Table 1 - Benefits of Improved Public Lighting

Benefits of Improved Public lighting		
Benefits	**Quotes and Quantifiable Findings**	**Source**
Reduced Crime	"The authors determine that nighttime lighting is an instrumental public service in terms of impacting human activities and promoting transportation and pedestrian safety". (1)	Murry, A. Feng, X. Public street lighting service standard assessment and achievement (1)
	"it is clear from these calculations that improved street lighting can be extremely cost-effective to the extent that it leads to reductions in crime". (2)	Painter, K. Farrington, D. The financial benefits of improved street lighting, based on crime reduction (2)
	"The results from the meta-analysis of all 13 studies combined shows that crimes decreased by 21% in experimental areas compared with control areas". (3)	Welsh, B. Farrington, D. Effects of Improved Street Lighting on Crime. (3)
	"the most plausible conclusion from this research is that the improved street lighting was responsible for the decrease in crime". (4)	Painter, K. Farrington, D. The Crime Reducing Effect of Improved Street Lighting: The Dudley Project (4)
	"reduce crime by up to 20%" (5)	Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies (5)

Benefits of Improved Public lighting		
Benefits	**Quotes and Quantifiable Findings**	**Source**
Enhanced public perception of safety	"improved street lighting reduces the fear of crime and enhances feelings of community safety". (1) The relationship between visibility, social surveillance and criminal opportunities is a strong theme in the literature and indicates that street lighting plays a role in crime reduction by altering perceptions which in turn changes the behavior of residents and offenders. (2) Improved street lighting is a cost-effective way of creating a sense of public safety (3)	Herbert, D. Modifying the Built Environment: The Impact of Improved Street Lighting (1) Painter, K. Farrington, D. The Crime Reducing Effect of Improved Street Lighting: The Dudley Project (2) Painter, K. The Influence of Street Lighting Improvements On Crime, Fear And Pedestrian Street Use, After Dark (3)
Financial Savings	"the financial savings from reduced crimes in one year more than outweighed the full capital costs of the improved lighting" (1) "the benefits of the LED program in Los Angeles were energy savings of 68,000,000 KWH/year and $7.5 million/year, maintenance savings of $2.5 million/year" (2) the lifetime costs for LED can be lower than for less efficient lighting options (3)	Painter, K. Farrington, D. The financial benefits of improved street lighting, based on crime reduction (1) Ebrahimian, E., Changing our Glow for Efficiency: Municipal Solid State Lighting Consortium – LED Workshop (2) Energy Sector Management Assistance Program, Proven Delivery

Benefits of Improved Public lighting		
Benefits	**Quotes and Quantifiable Findings**	**Source**
		Models for LED Public Lighting: Synthesis of Six Case Studies (3)
Enhanced nighttime economic activity	"many more people are willing to be out-of-doors after dark, there is a greater confidence in home and community and a general willingness to see things in a more positive way". (1) "Good well-planned lighting can make a city more legible and thus make it easier for people to use it after dark". (2) "The research indicates that improved lighting can in fact increase street use after dark which would likely translate into enhanced economic activity". (3) "Public lighting supports economic growth by increasing the amount of time that people can spend on economic activities such as "entertainment and meals away from home at night". (4)	Herbert, D. Modifying the Built Environment: The Impact of Improved Street Lighting (1) Raynham, P. Public Lighting in Cities (2) Painter, K. The Influence of Street Lighting Improvements on Crime, Fear and Pedestrian Street Use, After Dark (3) Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies (4)

Benefits of Improved Public lighting		
Benefits	**Quotes and Quantifiable Findings**	**Source**
Energy conservation	"it is suggested that by replacing common bulbs with energy-saving LED lamps Spain can reduce energy consumption by up to 80%" (1) "the energy savings for the two scenarios compared to the energy consumption today are approximately 73.5 % and 79.2 %, thus it is profitable to invest in LED technology".(2) LED electricity consumption tends to be 40 to 60 percent lower (3)	Gutierrez-Escolar, A. A Study to Improve the Quality of Street Lighting In Spain (1) Hember, A. Sjoberg, S. Wallerstrom, C. Smart street lighting: The advantages of LED Street Lighting and a smart control system in Uppsala municipality (2) Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies (3)
Reduced glare and improved visibility	"The authors contribute this finding to the fact that more visibility and surveillance on the street led residents to be more optimistic of the level of safety in their communities" (1) "The opportunities identified by NYSERDA are: reduced glare and improved visibility" (2) LED lighting is generally perceived as of better quality than traditional lighting because it has a higher color rendering index. (3)	Painter, K. Farrington, D. The Crime Reducing Effect of Improved Street Lighting: The Dudley Project (1) New York State Energy Research and Development Authority, How-to Guide Effective Energy Efficiency Street Lighting (2) Energy Sector Management Assistance Program, Proven Delivery

Benefits of Improved Public lighting		
Benefits	**Quotes and Quantifiable Findings**	**Source**
		Models for LED Public Lighting: Synthesis of Six Case Studies (3)
Increased surveillance potential and perpetrator detection	"There is more light and visibility and the greater surveillance which is often advocated for safe communities is achieved". (1)	Herbert, D. Modifying the Built Environment: The Impact of Improved Street Lighting (1)
Reduced chance of pedestrian, bike and vehicle accidents.	"lighting provides safe movement, visual orientation, visual comfort, facial recognition and a general feeling of safety for citizens" (1) "reduce fatal traffic accidents by 35%" (2)	Raynham, P. Public Lighting in Cities (1) Murry, A. Feng, X. Public street lighting service standard assessment and achievement Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies (2)
Reduced environmental damage	" LED lights do not contain poisonous mercury and sodium gases, nor toxic lead, lowering the environmental impact and the disposal cost for the owners of damaged street lights". (1) "the benefits of the LED program in Los Angeles were…the reduction of 40,500 tons of CO2/year and the enhanced perception of improved lighting/visibility/dimming capability." (2)	Ciriminna, R. LED Street Lighting: A Looking Ahead Perspective (1) Ebrahimian, E., Changing our Glow for Efficiency: Municipal Solid State Lighting Consortium – LED Workshop (2)

Table 2 – Additional Benefits of Connected Street Lighting Systems

Benefits of Connected Street Lighting Systems		
Benefits	**Quotes and Quantifiable Findings**	**Source**
More effective streetlight management	"(the smart control system) gives an overview of the energy consumption and the errors in the street light system. The smart control system also enables the flexibility to adjust the intensities of the light in different parts of the municipality since the armatures are possible to regulate individually". (1) "Lights can be controlled over the Web and mobile, with longitude/latitude based switching on/off, energy tracking and planning, and monitoring of the energy consumed. The user can monitor faulty streetlights and implement an effective fault repair and servicing system". (2)	Hember, A. Sjoberg, S. Wallerstrom, C. Smart street lighting: The advantages of LED Street Lighting and a smart control system in Uppsala municipality (1) Gunjan, P. LED Streetlights Brightening India's Sustainability Plans (2)
Reduction of maintenance costs	"economic efficiency of this system as reduction of maintenance costs is a big part of annual savings" (1) "the benefits of the LED program in Los Angeles were …$7.5 million/year, maintenance savings of $2.5 million/year (2) operation and maintenance costs tend to be lower because LED luminaires last at least four times longer than traditional bulbs (3)	Hember, A. Sjoberg, S. Wallerstrom, C. Smart street lighting: The advantages of LED Street Lighting and a smart control system in Uppsala municipality (1) Ebrahimian, E., Changing our Glow for Efficiency: Municipal Solid State Lighting Consortium – LED Workshop (2)

		Energy Sector Management Assistance Program, Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies (3)
Decreased energy consumption/CO2	"installing LED and a smart control system decreases the energy consumption and CO2-e extensively, and the economic consequences are beneficial". (1)	Hember, A. Sjoberg, S. Wallerstrom, C. Smart street lighting: The advantages of LED Street Lighting and a smart control system in Uppsala municipality (1)

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