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SUSTAINABLE STREET LIGHTING:

A Guide on Efficient Public Street Lighting for Lebanon

By:
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Assessment of the Street Lighting in Lebanon

Final Report

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LIST OF ACRONYMS & ABBREVIATIONS

ADT Average Daily Traffic

ANSI American National Standards Institute

BSI British Standards Institute

Cd candela

CDR Council of Development and Reconstruction

CEDRO Community Energy Efficiency & Renewable Energy Demonstration Project for Lebanon

CFL Compact Fluorescent Lamp

EDL Electricite du Liban

$E_{sc,min}$ Minimum semi-cylindrical illuminance

$E_{v,min}$ Minimum vertical illuminance

GLS General Lighting Service

HPMV High Pressure Mercury Vapor

HPS High Pressure Sodium

HPS High Pressure Sodium

HVAC Heating, Refrigerating and Air Conditioning

HZ Hertz

IENSA Illuminating Engineering Society of North America

IES Illuminating Engineering Society

L_{av} Average illuminance over whole of used surface

LCEC Lebanese Center for Energy Conservation

LED Light Emitting Diode

LPMV Low Pressure Mercury Vapor

LPS Low Pressure Sodium

LPS Low Pressure Sodium

MEW Ministry of Energy and Water

MOB Municipality of Beirut

MOIM Ministry of Interior and Municipalities

MPW	Ministry of Public Works
PSL	Public Street Lighting
PV	Photovoltaics
TFL	Tubular Fluorescent Lamp
TI	Threshold increment
TWh	Terawatt Hour (10^9 kWh)
U_0	Uniformity of illuminance

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INTRODUCTION

Public street lighting (PSL) is a major consumer of electricity that is commonly underestimated despite its increasing effect on the national electricity consumption. Being an indispensable need and important factor reducing crime and increasing road safety, there are always limits keeping the governments hands tied when it comes to electricity consumption reduction, yet several internationally recognized and proven technologies and solutions, helped increase the efficiency of public street lighting.

According to the Energy Information Administration of the US, the commercial sector consumed 274 TWh for lighting in 2012, making around 21% of commercial sector electricity consumption. This includes internal lighting as well as public and highway lighting. Data for public street lighting consumption is not available,

In Europe, public street lighting accounts for about 6% of the tertiary sector electricity consumption, varying from a country to another depending on the density of light points and the lamp technologies used, to reach 12% in some countries.

The situation in Lebanon is much worse. With no data available about this sector, so many different players involved, the lack of harmony, and the inefficient use, make it safe to say that PSL definitely shares more than 6% of the national electricity consumption.

There is enough room for improvement in this sector, in fact a lot has already been done by concerned ministries and bodies to reduce PSL consumption through demonstration projects, proposed regulations, and awareness raising.

This is the first deliverable of an assignment aiming at performing an assessment of the existing and the different possible street lighting technologies from technical, financial, and environmental perspectives, for a better understanding prospects and barriers of street lighting solutions for Lebanon.

This first deliverable is a progress report that includes presentation of the stakeholder discussions undertaken by the consultant, and a preliminary table of contents of the final report to be submitted at the end of the consultancy assignment.

WHY STREETLIGHTING?

Being one of the key public services provided by municipalities and other public authorities, public street lighting is with no doubt an important indicator of nation's development and progress levels. Street lighting enhances the appeal of cities and neighborhoods and provides a civilized perspective of communities. It plays a major role in highlighting attractive landmarks and accentuating the ambiance during night.

But the major motive behind street lighting and thus the most important advantage is improving road safety and protecting human life. Proper and well-designed lighting is essential as it contributes to safe roads, reduction of car accidents, and increase in drivers and pedestrians levels of comfort.

As soon as the sun goes down and the lights go off, it becomes essential to light streets and provide motorists, cyclists, and pedestrians with visibility to increase safety levels and avoid night-time road accidents caused by insufficient visibility.

Studies have been conducted to show that pedestrian crashes are reduced by around 50% as a result of proper street lighting [3]. It has become clear that darkness leads to increase number of crashes and fatalities, with research proof estimating pedestrian fatalities to increase by 3 to 6.7 more times in the dark compared to daylight [4], and that lighted intersections and highway interchanges tend to have way less crashes that dark ones [5].

Another important aspect of proper street lighting is its role in reducing crime and vandalism by enhancing the sense of personal safety and improving the security of properties. Street lighting helps in making residents and pedestrians feel safe walking during the night.

BASIC DEFINITIONS

Candela (cd)	Luminous intensity in a given direction (1 cd = a body that emits a monochromatic radiation at 540 x 1012 Hz and has an intensity of radiation in that direction of 1/683 W per steradian)
Color Rendering Index	The ability of a light source to render colors of surfaces accurately. It is based on the accuracy with which a set of test colors is reproduced by the lamp of interest relative to a test lamp, perfect agreement being given a score of 100. Rendering groups and index shown in Table 1.
Color Temperature	The color appearance of the lamp and its light expressed in Kelvin scale (K). It is an indication of how warn, neutral, or cool the light source is. The lower the temperature is, the warmer the lighting source. ***Unit:*** *K*
Glare	Light that either reduces the comfort or directly reduces the vision. Maximum requirements are given for street lighting installations.
Illuminance	The metric unit of measure of illuminate of a surface. It is the average of different lux levels at various points and is equivalent to one lumen per square meter. ***Formula:*** *Lumen / Area* ***Unit:*** *Lux*
Installed Load Efficacy	The average maintained illuminane on a horizontal plan per circuit watt with general lighting of an interior. Installed Load efficacy ratio is the ratio of target load efficacy and installed load. ***Unit:*** *Lux/W/m^2*
Intelligence	Built-in electronics in the luminiare that can measure and control the luminiare and makes two way communication possible and thereby achievement of adaptive lighting, also called intelligent lighting.
Light pollution	Pollution caused by very high levels of lighting. It is defined as the direct or indirect entry of artificial light into the environment. It leads to the degradation of night time ambience and alters the nature of urban areas and environments.
Lumen	The luminous flux emitted within a unit solid angle by a point source with a uniform luminous intensity of one candela. It is the photometric equivalent of the watt, weighted to match the eye response of the "standard observer".

	1 watt = 683 lumens at 555 nm wavelength. It is referred to as the luminous flux per square meter of a sphere with 1 meter radius and a 1 candela isotropic light source at the center. ***Formula:*** 4π × luminous intensity ***Unit:*** *lm*
Luminaire	The lighting unit with all parts and components including lamps as well as support, power supply, light diffusion, positioning, and protection components.
Luminance	Density of reflected or emitted light from a surface in a specific direction, per unit area. It is very important in street lighting ***Unit:*** Cd / m^2
Luminous Intensity (I)	The luminous flux, which falls on each square meter of a sphere one meter in radius when a 1-candela isotropic light source is at the center of the sphere. ***Formula:*** *Lumen* / 4π ***Unit:*** *Candela*
Mounting height	The height of the fixture or lamp above the working plane
Photopic vision	Eye vision under well-lit conditions. It allows color perception, mediated by cone cells, and a significantly higher visual acuity and temporal resolution than available with scotopic vision.
Rated luminous efficacy	The ratio of rated lumen output of the lamp and the rated power consumption.
Room Index	The ratio relating plan dimensions of the room to the height between the working plane and the plane of the fittings.
Scotopic vision	Eye vision under low-lit conditions. It is produced exclusively through rod cells which are most sensitive to wavelengths of light around 498 nm and insensitive to wavelengths longer than about 640 nm.
Target Load Efficacy	The value of Installed load efficacy considered being achievable under best efficiency. ***Unit:*** $Lux/W/m^2$
The Inverse Square Law	The law that defines the relationship between luminance from a point source and distance, with intensity of light per unit area being inversely proportional to the square of distance from source. ***Formula:*** $E = I / d^2$

Uniformity	Relative number that indicates the relation between the lowest luminance level present and the average luminance level present in a defined measuring field. Minimum requirements are given for street lighting installations.
Utilization factor (UF)	The measure of the effectiveness of lighting that is the proportion of the luminous flux of the lamp reaching the working plane.

Table 1: Applications of color rendering groups [7]

Rendering Group	Color Rendering Index (R_a)	Typical applications
1A	$R_a > 90$	Accurate color rendering required (ex. Printing inspection)
1B	$80 < R_a < 90$	Accurate color judgment (ex. Display lighting)
2	60 < Ra < 80	Moderate color rendering required
3	$40 < R_a < 60$	Color rendering little significant but marked distortion unacceptable
4	$20 < R_a < 40$	Color rendering not important at all and marked distortion acceptable

LIGHTING TECHNOLOGIES

The electromagnetic spectrum varies with wavelength from ones in thousands of nanometers to billions. The visible light is a small portion of these electromagnetic waves present in space, located between infrared heat and ultraviolet light.

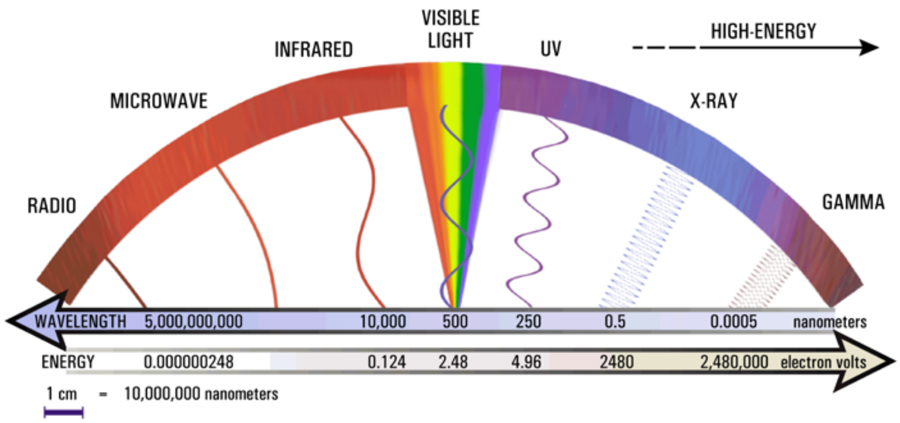


Figure 1: Electromagnetic spectrum and visible radiation [1]

In principle, light is emitted from a body due to one of four phenomena:

1- ***Incandescence:*** by bodies when bodies are heated to temperatures 1000°K

2- ***Electric discharge:*** by atoms and molecules when electric current passes through a gas

3- ***Electro luminescence:*** by bodies like semiconductor when electric current passes through them

4- ***Photoluminescence:*** by solids reemitting absorbed radiation at a different wavelength

Different lighting technologies were utilized using these phenomena, presented in Table 2 and Figure 2.

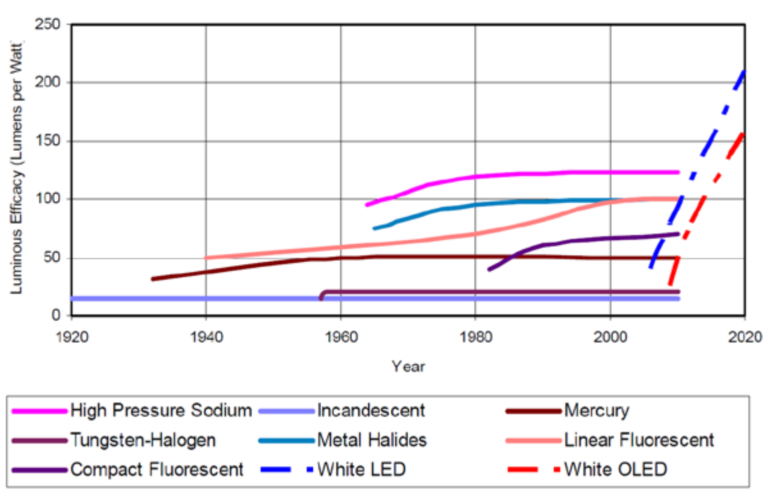


Figure 2: Major lamps development for general lighting [2]

Table 2: Lighting technologies comparative table

Lamp	Lm/Watt	CRI	Lifespan (hrs)	Dimmability	Capex	Opex	Applications
GLS	5-15	✪✪✪✪○	1,000	Excellent	+	✳	General lighting
Tungsten Halogen	12-35	✪✪✪✪○	2,000 – 4,000	Excellent	+	✱	General lighting
Mercury vapor	40-60	✪✪✪○○	12,000	Not possible	*	*	Outdoor lighting
CFL	40-65	✪✪○○○	6,000 – 12,000	Special lamps	+	+	General lighting
Fluorescent Lamp	50-100	✪✪✪○○	10,000 – 16,000	Good	+	+	General lighting
Induction Lamp	60 - 80	✪✪✪○○	60,000 – 100,000	Not possible	✱	+	Difficult maintenance applications
Metal Halide	50 - 100	✪✪✪○○	6,000 – 12,000	Not practical	✱	+	Commercial buildings
HPS (standard)	80-100	✪✪○○○	12,000 – 16,000	Not practical	✱	+	Outdoor street lighting, warehouse
HPS (color improved)	40-60	✪✪✪○○	6,000 – 10,000	Not practical	✱	+	Outdoor, commercial interior lighting
LPS	80-180	○○○○○	10,000 – 18,000	Not practical	✱	+	Outdoor lighting
LED	20-120	✪✪✪○○	50,000 – 100,000	Excellent	✱	+	All in near future

Legend:

○○○○○ Very Poor ✪○○○○ Poor ✪✪○○○ Fair ✪✪✪○○ Good ✪✪✪✪○ Very Good ✪✪✪✪✪ Excellent

+ Low *Moderate ✱High ✳Very high

Energy Efficiency in Lighting

Lighting makes up a huge share of electricity consumption for facilities and buildings, not because of the high power rating, but because of the usage time. In order to reduce the impact of lighting on inflating energy bills without compromising the quality, availability, or convenience of lighting, several methods are being utilized to reduce lighting electricity consumption.

Studies have shown that over a period of 35 years, a typical street lighting operation would incur costs split as 85% for maintenance and operation including power supply, and as low as 15% for capital cost [6]. According to a study conducted by Philips regarding Europe's street lighting switch, the continent could save more than 3 million Euros a year when switching from old to new street lighting technologies. This, according to Philips, saved 45 billion barrels of oil equivalent, avoiding the emittance of 11 million tonnes of CO_2 [3][6].

Natural Daylight

The first thing to start with is to harvest natural lighting and use as much free lighting as possible. In fact, natural lighting offer the highest level of comfort and provides users with a relaxing lighting option.

This option sometimes becomes less convenient in air-conditioned areas where attempts to reduce cooling or heating load is a requirement. Yet, there are modern technologies applied to benefit from natural lighting without having to take the heat that comes with solar rays. This is done through the use of skylight systems that channel the light in tubes and transfer the light to the needed areas.

Some methods used to benefit from natural lighting are:

1- Lighting through windows: This needs to be well designed to avoid glare, and could be incorporated with light shelves to provide disturbance due to glare.

2- Glass strips: This innovative design eliminates glare and allows the harvested light to blend well with the interiors. Glass strips running across the breadth of the roof can provide good uniform lighting most appropriate to industrial applications

3- Skylights: Using skylights with RFP material along with transparent or translucent false ceiling reduces glare and avoids the heat generation that adds to the cooling load.

De-lamping

Over-lighting is a major design issue that leads to enormous electrical energy waste. It doesn't only waste power by lighting more than necessary, but it also reduces the level of comfort among users.

Using a lux meter, and following the standard requirements of lighting levels, the lamping design can be modified to reduce unnecessary lamps especially in industrial and office applications where lighting remains on for more than 10 consecutive hours. De-lamping can happen by reducing the number of lamps, splitting the lighting circuit, and isolating unnecessary fixtures.

High Efficiency Lamps

Some lamps are more efficient than others, offering same levels of lighting but at less electricity consumption. Table 2 presented earlier summarizes the different types of lamps and clearly shows the efficiency levels of different lamps under the column of lumen/Watt. The higher this ration is, the more efficient the lamp is.

Yet it is more than just that, there are several requirements that need to be met. Requirements such as color rendering, cost of retrofit, maintenance requirements, and lifespan of the lamp.

Table 3: Potential savings through lamp retrofit

Original Lamp	Replaced by	Potential Saving (%)
GLS	**CFL**	38 - 75
HPMV	**CFL**	45 - 54
	Tube light (Krypton)	54 – 61
	Metal Halide	37
	HPS	34 – 57
Metal Halide	**CFL**	66
	Tube light (Krypton)	48 - 73
	HPS	35
HPS	**CFL**	66 – 73
	Tube light (Krypton)	48 – 84
	LPS	42
Standard tube light (Argon)	**Slim tube light (Krypton)**	9 – 11
Tungsten Halogen	**Tube light (Krypton)**	31 - 61
Mercury blended lamp	**HPMV**	41
LPM	**HPS**	62
LPS	**HPS**	42

Feeder Voltage Control

It is be possible to reduce energy consumption of lamps by reducing the feeder voltage, but that would also lead to a reduction in lighting output. As long as this reduction is in the acceptable zone, feeder voltage reduction would be a practical solution.

Table 4 shows the effect of feeder voltage variation on power consumption and lighting output for different types of lamps.

Table 4: Feeder voltage variation effect

	10% Lower Voltage		10% Higher Voltage	
	Light reduction	**Power reduction**	**Light increase**	**Power increase**
Fluorescent	9%	15%	8%	8%
HPMV	20%	16%	20%	17%
Mercury blended	24%	20%	30%	20%
Metal halide	30%	20%	30%	20%
HPS	28%	20%	30%	26%
LPS	4%	8%	2%	3%

Electronic Ballasts

In addition to the electrical power needed to light the lamp, the ballast also adds to the consumption as electromagnetic ballasts are used to provide more voltage to start the light, mainly tube light.

The new electronic ballasts reduce electricity consumption by acting as oscillators and converting the frequency to the range of 20 to 30 thousand Hz. This can be applied to fluorescent tube lights, CFLs, LPS, and HPS lamps.

Using electronic ballasts brings in several benefits including:

1. ***Immediate lighting:*** since no starter there anymore, then no more flickering when first turning the lights on
2. ***Improved Efficacy:*** at higher frequencies, tubes have better efficacy and thus lead to additional electricity saving
3. ***Reduced power loss:*** Usually lamps use around 10 to 15 watts using standard electromagnetic ballasts. With electronic ballasts, losses are reduced to as low as 1%

Table 5: Savings using electronic ballast

Lamp	Electromagnetic ballast	Electronic ballast	Power Saving (W)
TFL 40W	51	35	16
LPS 35W	48	32	16
HPS 79W	81	75	6

Occupancy Sensors

In areas of low occupancy, sensors are used to detect presence of people and decide on turning on or off the lamps. Occupancy seniors are usually passive infrared, ultrasonic, or a combination of both.

Passive infrared sensors are based on heat and are designed to react to heat changes within a certain area. This requires an unobstructed view of the covered region. Passive sensors are best used in open areas where doors, stairways, and partitions are not there to block the sensor view.

Ultrasonic sensors are active sensors that transmit sound at a certain level above human hearing levels, and it waits to get the waves back. Based in the time and any pattern breaks noticed by the sensor, the control is activated. These sensors are best used in areas needing 360 degrees coverage.

Several considerations need to be taken when applying occupancy sensors to avoid inconvenience. For example, sometimes the lights might be turned off while people are still in the room, for this it is recommended to include switches for manual control. It is also recommended to keep ultrasonic sensors away from HVAC ducts to avoid vibration caused by these ducts.

Lighting Controls

Lighting control can be used to automatically switch on and off the lights and apply dimming. These controls include manual timers, automatic timers, and photo-sensors.

Timers act as clocks, they are programmed to decide on the dusk to dawn period and arrange for the time to start on the lights, turn them off, and dim them. Timers are conventionally preset manually by the operator based on the season, day length, and other variations. Such an activity is normally done every 3 months and sometimes every 6 months. Newer technologies use pre-programmed timers that automatically change the time everyday based on the variables fed in regarding dusk and dawn time. These reduce maintenance requirements and lead to better results.

Usually there are three time controls being used. The first and most trivial is simple time switch that just uses a preset time. The second is multi-channel time control, which has the ability to control from 4 to 16 dutites. The third is special purpose time control that is used in cycles.

The problem with timers is that they work only based on dusk and dawn, they do not turn on when there is low lighting level caused by fogs, sand storms, or any other environmental factor. Here is where photo-sensors come in handy.

The role of a photo-sensor is to detect the level of lighting available and decide on whether to turn on the lights, dim them or turn them off based on the availability of light. This solves the problem of lighting demand during the day, but also requires further maintenance especially in areas with high levels of dust. The sensor can be covered with dust or other particles and thus reads as low lighting level leading to the lamps to be turned on during unnecessary times.

Maintenance

Keeping the lamps in good shape is important for keeping them efficient. Some lamps age and become a waste of electricity, others get dirty and require cleaning. It is important to take care of the fixture, the lamp, the lenses, and the surrounding area to avoid wasted lighting and unnecessary electricity waste.

Evolution of Street Lighting

Outdoor and street lighting started a few centuries back, even before Edison first introduced his commercial lamp, light was invented and the need for outdoor lighting was identified, passing through different phases and stages until it reached the current efficient model of public street lighting.

Arc Lighting

Based on the concept of carbon rods in a closed electric circuit with carbon separated, the arc lamp was the first lamp ever used. It was then developed in 1876 by Charles Brush who invented the open carbon arc that was the first street lighting lamp ever.

This technology appeared to be effective but didn't seem to get a lot of welcome, especially with the need for trimming and the frequent replacement of electrodes, in addition to the presence of unwanted combustion byproducts.

There were two major types of Arc lights, the first being open arc which was operated with carbon electrodes openly exposed to the atmosphere, while the second was the enclosed arc lights that was developed in the mid-1890s and limited the operating inside a glass globe which played a major role in increasing the electrodes life to reach almost 125 burning hours.

Compared to carbon-filament street lighting that was present in those days, Arc street lighting was considered a blessing in terms of efficiency and color quality.

Incandescent Series Lamps

Arc lighting did not survive that long, especially when tungsten-coiled series street lighting was introduced. In 1912, "Mazda C" the first gas-filled tungsten filament lamp was introduced, offering whiter light, increased efficiency, and improved lamp life. Which led to a rapid vanish of Arc lighting and wide spreading of incandescent for street lighting.

Incandescent lighting passed through various stages throughout the years, developing from a couple of hundred lumens to 6,000 ad 8,000 lumens in the 20th century.

1915 **1920** **1930**

Figure 3: Evolution of incandescent street lights

Incandescent Multiple Lamps

Multiple lamps have significant variations compared to series as they operate directly from the voltage supplied by the utility distribution circuit. Although this method has been there early 1900s, but it wasn't actually given much attention until the late 40s of that century, especially with photo-electric control being introduced and becoming more affordable than ever.

Firstly, multiple fixtures were normally operated by a separate control on the pole, while some were operated in groups from one photo-control that can handle higher amount of current. Then in the 1950s, integral photo-controls started to be more popular especially when becoming less expensive years later.

Mercury Vapor

Mercury vapor was something totally new introduced to street lighting. The concept of mercury lamps is based on an electric discharge tube containing mercury vapor and put under pressure. The vapor density decides on the color output and lamp efficacy, while the first can be modified using different methods such as the use of phosphorous.

Mercury vapor lamps were used extensively for street lighting applications with wattage of 100 and above, but suffered from poor color rendering which required the development of different types of mercury vapor lamps such as phosphorus-coated lamps, yellow mercury lamps, deluxe white lamps, and caution yellow lamps.

Low Pressure Sodium

Being known as sodium illumination before the 1960s when high pressure sodium was introduced, LPS was considered a state-of-the-art technology reaching up to 50 lumen per watt and around 18,000 hours lifespan, such an achievement in those days with double that of incandescent street lights

The 180W 10,000 lumen and the 145W 6,000 lumen LPS lamp were the most widely used street lighting lamp for highways and bridges especially in Europe. The major drawback was the color distortion making things appear a bit yellowish. But LPS remains advantageous in foggy regions because it doesn't scatter light.

Fluorescent Lamps

GE was the leader in manufacturing fluorescent lamps back in the late-1950s, introducing it as a street lighting application that was widely used in those days especially in the United States in the 1960s. They brought in advantages of higher efficiency, increased lifespan, and excellent color rendering.

Fluorescent street lighting didn't last much, by 1980 you could rarely find any of them as they stopped being installed by early 1970s.

High Pressure Sodium

GE also led the introduction of high pressure sodium back in the 1960s with the first 400W HPS street lamp. A couple of years later, more wattages were introduced offering more flexibility especially for secondary streets applications.

HPS lamps are characterized with high efficacy, long life, and good color rendering compared to LPS and other technologies used at that time. It is still being considered as one of the most used lighting technologies for street lighting.

Metal Halides

The first commercially available metal halide lamp was introduced in 1965 with a wattage of 400 offering 80 to 90 lumens per watt with around 6,000 hours lifespan.

These lamps are usually enclosed in elliptical envelopes and very similar in appearance to mercury vapor lamps. In order to reduce glare and improve color rendering, some lamps are internally coated with phosphor.

Metal halides are not widely used for street lighting applications, this is mainly due to the presence of high performance HPS lamps that offer better options that metal halides.

Light Emitting Diode

LED lighting is currently the most efficient and widely spreading application for public street lighting due to its improving technology, high lumen per watt ration, and wide variety of shapes and applications.

LED lighting offers higher efficacy and good color rendering compared to other technologies currently used, but much care needs to be taken when designing LED public street lighting applications.

Street Lighting Standards & Requirements

There are several standards and codes followed in the design of street lighting to guarantee energy performance and safety requirements. A number of standards and codes are currently in place, varying from country to another. In principle, these standards consider various variables and influencing parameters that affect light requirements. These variables are:

1. **Speed:** Composition of users in the same relevant area
2. **Geometry:** Type of junctions, intersection density, conflict areas, etc…
3. **Traffic use:** Flow of vehicles and pedestrians, parked vehicles, crime risk, etc…
4. **Environmental** Complexity of visual field, ambient luminance, weather type, color rendition

5. Visual guidance: Including traffic control

The main and most commonly adopted standards are presented in Table 6:

Table 6: Common internationally adopted standards and codes

Standard	Description	By
CIE-115	Lighting of roads for motor and pedestrian traffic,	CIE
CIE 180	Road Transport Lighting for Developing Countries	CIE
BS EN 13201-2:2004	Road lighting. Performance requirements	BSI
ANSI/IESNA RP-8	American national standard practice for roadway lighting	ANSI/IES

CIE 115

The latest version is CIE 115:2010 that is being followed in several countries especially Europe. According to CIE 115:2010, there are different sets of classes applied to lighting namely:

- Class M for motorized traffic
- Class C for conflict areas[1]
- Class P for pedestrian and low speed traffic areas

These classes are described with the influencing parameters in Attachment I: Selection Parameters and Design Factors for Lighting Classes in CIE 115:2010.

CIE 180

CIE 180 standard is developed for developing countries where safety is always at risk. It discusses the night-time value of simple road markings and signs, stressing the importance of retro-reflective materials. This leads to the role of vehicle lighting, with particular emphasis on the need for individual drivers to take responsibility for cleaning and aiming.

A chapter on fixed roadway lighting deals with the basic design of simple installations and explains the many different factors that need to be considered. Because of its importance, maintenance is considered in a separate chapter.

[1] Conflict areas are areas where vehicle streams intersect each other or run into areas frequented by pedestrians, cyclists, or other road users, or when the existing road is connected to a stretch with substandard geometry, such as a reduced number of lanes or a reduced lane or road width

Design requirements for developing countries are presented in Attachment II: Lamination Requirements in CIE 118:2007.

BS EN 13201

The European Norm for Road Lighting (EN13201) provides the basis for specifying lighting quality for a given scheme. It is divided into 3 norms as follows:

- BS EN 13201-2: Performance Requirements
- BS EN 13201-3: Calculation of Performance
- BS EN 13201-4: Methods of Measuring Lighting Performance

The factors of interest in the norm are: ME (Luminance), S (Illuminance) and CE (Conflict areas)

Design requirements are presented in Attachment III: Technical Requirements in EN 31201 Standards.

IESNA RP-8

The standard provides practices for designing new continuous lighting systems for roadways and streets. Roadway and street lighting includes pedestrian and bikeway lighting when it is associated with the public right-of-way.

This standard is adopted in North America. It provides uniformity and veiling luminance ratio for different Road & Pedestrian Conflict Area combinations and considering different pavement classifications (R1, R2, R3, and R4).

Road types are Freeway Class A and Freeway Class B, in addition to Expressway, Major, Collector, and Local with different pedestrian conflict areas (High, Medium, and Low).

Design requirements are presented in Attachment IV: Lamination Requirements in ANSI/IESNA RP-8.

PUBLIC STREET LIGHTING IN LEBANON

Current Trends

Public street lighting in Lebanon is a complex issue that involves a variety of actors and different authorities. There is not much information available about this sector, making it difficult to properly present the current situation in Lebanon, the applied technologies, and the distribution of street lighting loads.

Currently, most newly installed public streetlights use HPS lamps. The rating of the lamp varies by application but is mainly 150 Watts for municipalities and inner roads. As for older technologies that are still being used in certain areas, these street lighting facilities are outdated and therefore highly inefficient. This leads to higher energy and maintenance requirements. In areas using these old technologies, street lighting can account for as much as 30-50% of their entire power consumption.

Stakeholders: Who Does What?

A variety of stakeholders are involved in this sector. Sometimes there is not much coordination between the different parties that the process becomes inefficient and lack of follow-up leads to inadequate operation of the systems. Major stakeholders and are presented in Table 7

Table 7: Major stakeholders involved in the public street lighting sector in Lebanon

Stakeholder	Responsibility	Execution	Ownership	Billing	O&M
MPW	Highways	✓	✓	✓	✓
	Primary roads	✓	✓	✓	✓
CDR	Highways				✓[2]
MOIM	Local Streets		✓	✓	✓
EDL	Billing users				
MEW	Distribution of lamps				
LCEC	RE and EE street lights				
UNDP/CEDRO	RE and EE street lights				

[2] For first year

CDR

The Council for Development and Reconstruction executes highway street lighting projects and delivers to MPW, with a 1-year defect liability period

MPW

The Ministry of Public Works is responsible for major highways including international roads. They are in charge of the operation, maintenance, and bills of public street lights. MPW pays the bills for the electricity consumption of highways and main roads.

MOIM

All internal roads governed by municipalities. The execution, retrofit, operation, and maintenance is done by the municipality's team and with their own budgets. Municipalities fall under the authority of the Ministry of Interior and Municipalities.

MEW

The Ministry of Energy and Water support municipalities in street lighting through a variety of programs such as distributing lamps on annual basis. In principle, the ministry distributes 1,500 HPS to municipalities per year. These 150-W lamps are meant to replace damaged and faulty lamps.

Policies

Until recent years, no major policies or regulations regarding public street lighting have ever been set. In 2010, Minister of Energy and Water Eng. Gebran Bassil published the Policy Paper for the Electricity Sector, outlining the Ministry's strategy to improve the electricity sector and enhance energy efficiency.

Initiative 6 of the policy paper presents demand side management and energy efficiency measures and solutions. Action step d in this imitative targets public street lighting by "encouraging the use of energy saving public lighting"[8].

The National Energy Efficiency Action Plan (NEEAP) prepared by the LCEC and adopted by the government of Lebanon in 2012 discusses public street lighting in Initiative 5: "Design and Implementation of a National Strategy for Efficient and Economic Public Street Lighting in Lebanon". "This initiative aims at the design and implementation of a national strategy for public street lighting in Lebanon in order to offer a safe and energy efficient street lighting with an intelligent monitoring, control, and maintenance procedure."

Street Lighting Standards & Codes

With no identified and officially adopted standards and codes for public street lighting in Lebanon, it is usually the consultant who decide on the design aspects and international standards to be applied. In general, BS EN standards are adopted in the design, operation, and maintenance of public street lights in Lebanon.

As for the technical specifications of street lighting poles, fixtures, and systems, the LCEC and the 3M lamps project implementation unit together with the CEDRO project have developed a technical specification document that was shared with involved authorities to be used in budding processes and strategic planning decisions. A number of issued standards used in street lighting projects are presented in

Support Initiatives

Several support programs and initiatives are in place, some are supporting municipalities replacing damaged lamps, other are for a more efficient operation of systems. Recently, a number of support programs are designed to create a shift towards energy efficient street lighting using LED and renewable energy-powered lighting systems using solar and wind.

Some of these programs are listed in

Table 8: Main support initiatives taking place in Lebanon

Initiative	Technology	Poles	Locations	Year
Photosensor supply & retrofit - MEW/LCEC	Photosensor	~15,000	Distributed	2012-2013
800 PVPSL - MEW to Municipalities	PVPSL - LED	800	Distributed	2012-2013
UNDP/CEDRO	PVPSL – LED	~1,000	Distributed	2010-present
Live Lebanon PSL Support Initiative	PVPSL – LED	89	Sultan Yaacoub (Bekaa) Marjeyoun (South)	2012-2014
UNIFIL Support to South Lebanon Municipalities	PVPSL – LED	~100	South Lebanon	2011- present
MPW Highway Lighting	PVPSL - LED	~1,200	Ras Baalbeck (Bekaa) Hermel (Bekaa)	2010, 2012

The Numbers

There is no count what so ever of installed Public Street lights in Lebanon, this is mainly due to the variety of stakeholders involved. In order to quantify the number of streetlights in Lebanon, data shall be collected for the different categories classified as follows:

Table 9: Categories used for the quantification of PSL number and power load

Category	Description	Available information	Source
(A) Municipal lights	Street lighting poles and load for different municipalities excluding Municipality of Beirut	Number and power available for 254 municipalities	MEW/LCEC
(B) Municipality of Beirut	Street lighting poles and load for Municipality of Beirut	Number of poles	MoB
(C) Highways & main roads	Street lights for international highways and roads that are not under municipality's control	Number of poles	Estimates

The total number of street lighting poles is estimated to be around 645 thousands including the three categories presented in Table 9. The results are presented in Table 10, and the extrapolation methodology is presented in

Table 10: Quantification of PSL number and power load

Category	Lamps	MW
(A) Municipal lights	626,606	145,738
(B) Municipality of Beirut	1,500	338
(C) Highways & main roads	15,200	3,800
Total	643,306	149,877

Lighting Fixture

Street lighting usually use discharge lamps. They are normally classified in accordance to the gas they utilize or the pressure level. Lamps are either mercury or sodium vapor, and either high pressure or low pressure. The properties of each define its applicability and suitability for certain the situation in hand.

Table 11: Classification of street lighting

		Gas	
		Mercury	**Sodium Vapor**
Pressure	**Low**	• Fluorescent	• Low Pressure Sodium
	High	• Mercury Vapor	• High Pressure Sodium

Fluorescent

Fluorescent lamps are usually used in domestic and industrial applications with clear advantages when compared to incandescent in terms of energy saving and lifespan. Applicability in street lighting is not very common, it is only used in domestic lighting and not normally public lighting.

Mercury Vapor

Discharge is produced at high pressure, producing a wide spectrum including considerable amount of ultraviolet radiation, which is highly detrimental to astronomy and the environment. In terms of energy performance, it has low efficiency as compared to other technologies.

There is not much use of mercury vapor in street lighting these days, it is expected to diminish in the coming few years.

High Pressure Sodium

High pressure sodium lamps are characterized with high efficiency and long life reaching around 25,000 hours, in addition to high capacity to contrast objects, making it the most commonly used solar street lamp all over the world as well as Lebanon. Chromatic performance is not high but is enough for most situations.

Low Pressure Sodium

LPS is similar to HPS except that it uses low pressure gas instead of high pressure. It generates higher lumen per watt, probably the highest in market, but with one main drawback which is color rendering. LPS is used in large avenues and boulevards where there is not much need for color reproduction. It has an average lifespan of 23,000 hours. From an astronomical and environmental perspective it is the best.

Metal Halide

A common type of lamp used in street lighting with an average lifespan of 10,000 hours and an average energy performance. Its major advantage is its good capacity for chromatic performance.

Light Emitting Diode (LED)

LED is not a discharge type lamp, they produce no radiant-flux emission. They have great energy performance and offer modularity and flexibility for design.

From an astronomical and environmental perspective, warm color temperature LED with a low blue light content are ideal for ambient use.

Induction

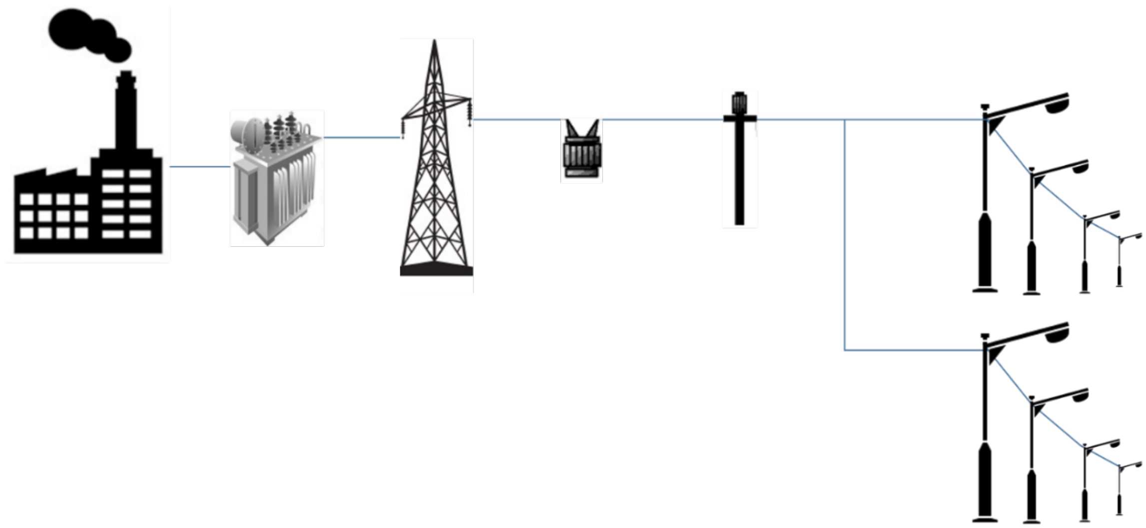
Induction lamps are similar to fluorescent lamps in that they create light by using an electromagnetic field to excite mercury particles mixed in an inert gas. They are relatively large providing a broad, diffuse light, from a large-diameter tube, which is not easily controlled.

As compared to LED, Induction has limited directionality. Its life time is lower and negatively affected by heat.

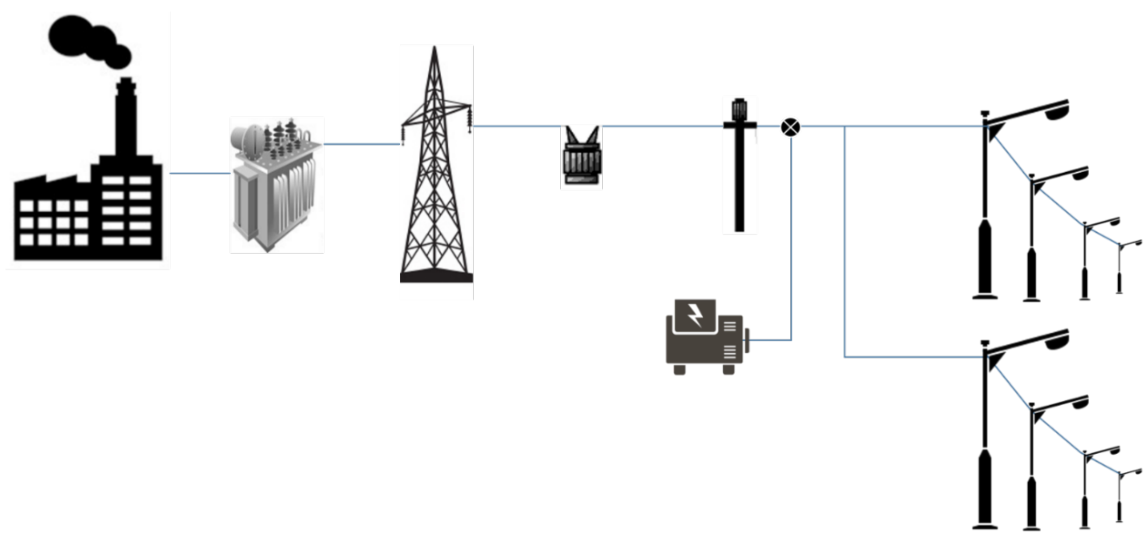
Power Supply

Street lights are commonly powered by the grid, with lines coming from a power substations extending from a pole to another and supplying power to the lamp installed on the pole. Power can be also transported underground through special underground cables.

In this case light availability is completely dependent on grid availability, thus whether there is a need for lights or not, whenever the grid is unavailable there will be no lighting.

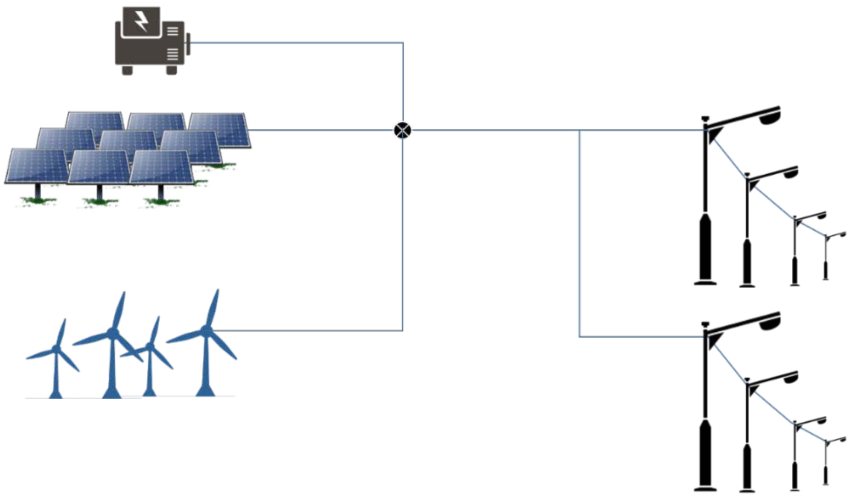


In some cases, especially remote areas where the grid is not available, a private generator is used to supply power to the street lights. This generator can either be powered by fossil fuel or renewable energy. This is an example of alternative centralized power supply.



Hybrid systems are used in centralized systems combining several power sources together based on the grid availability and site available resources.

With the need to have streets lit all night, several authorities are connecting their own private generators to the PSL grid, these generators running on fossil fuel will turn on during electricity cut-off and supply power to the street lighting grid.



Decentralized systems offer stand-alone operation of street lights. They normally utilize renewable energy to power the luminaire. Be it solar, wind, or both together, the panels/turbines are installed together with the luminaire on one pole. Each unit will be independently operating.

Control Systems

Street lights operation and lighting levels can be controlled for optimized energy use and lighting production. These control components are used to do a variety of tasks such as controlling lighting levels and activating the luminaires based on: (1) Available lighting, (2) Time of day/day of year, and (3) Traffic levels.

Photocell

A photocell is installed on the street lighting pole to measure the lux levels and activate the lamp when measured level is low. Photocells play an important role in reducing energy consumption and achieving safety requires.

The advantage of photocells is their ability to activate the lamps during dark days, and thus achieving higher safety levels. The drawback of a photocell is the high maintenance requirements. The cell needs to be frequently cleaned or else it will always read low lux levels and the lamp will be activated when it doesn't really need to.

Timer

A timer uses scheduling to activate and deactivate the lamps. Usually it is based on seasonal sunrise and sunset hours but without any considerations of weather conditions and availability of day light. Scheduling is present by the system operator and applied without frequent interruptions.

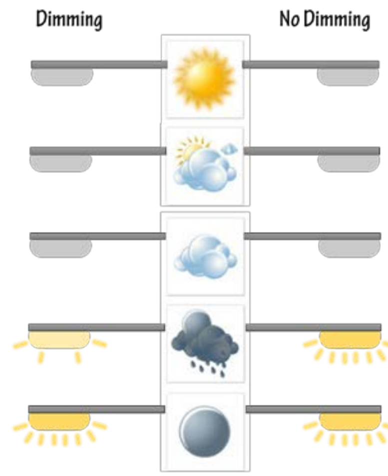
Dimming

Dimming is an option that highly contributes to energy saving. It can be applied with luminaries having the feature of dimmability. Dimming is based on three different inputs:

1- Time: when coupled with a timer
2- Lighting level: when coupled with a photocell
3- Voltage: In Solar PV applications

Time-based dimming control uses a similar scheduling process but also accounting for low traffic after mid-night. The operator will have the option to decide on dimming times and levels.

Lux-based dimming control provides feedback from the photocell to the lamp and adjusts the lighting output according, leading to huge saving potential as compared to other techniques.



Intelligent Control System

The combination of all these controllability options for intelligent and efficient operation of street lighting is called intelligent control system. This system allows for controlling the lighting levels based on a variety of factors including traffic, available light, date and time, weather conditions, etc…

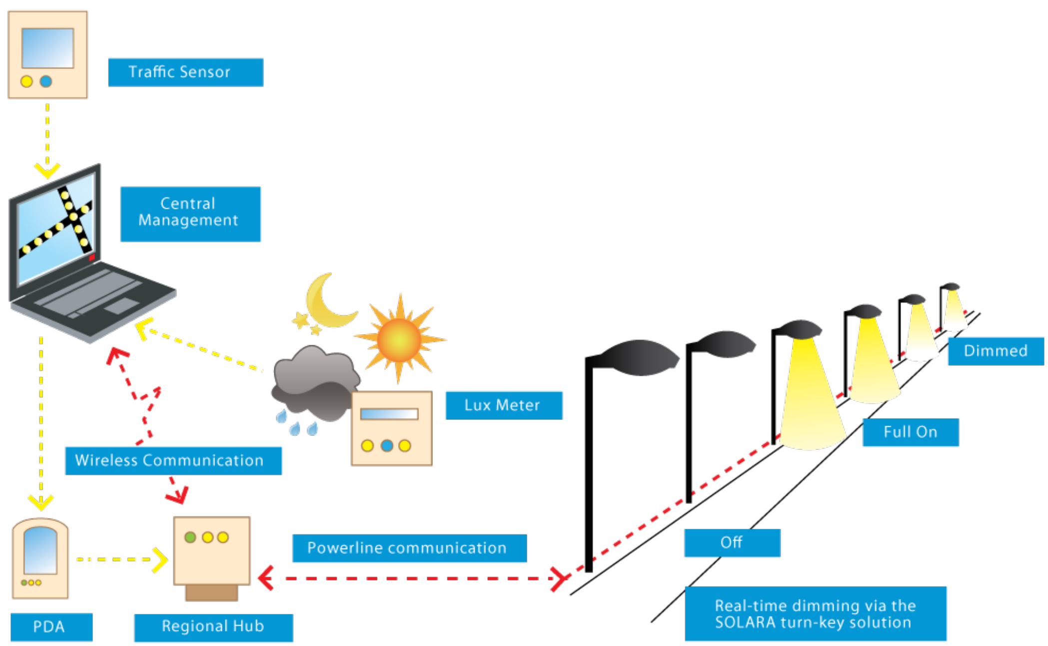


Figure 4: Example of an intelligent control system (by ELSA global energy solutions)

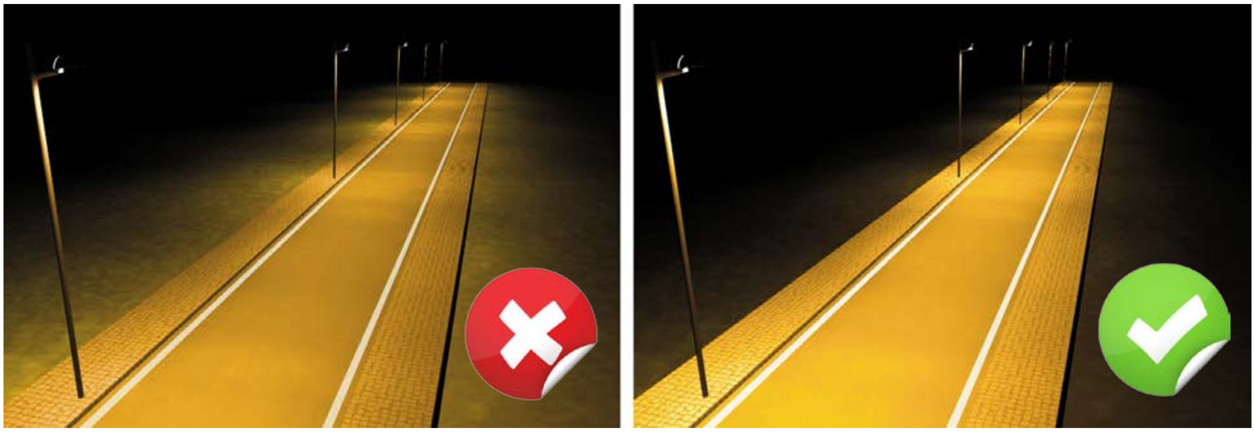
Design Considerations

There are many factors to be considered when designing street lighting to offer proper lighting and reduce environmental impact. A major issue to be thought of is reduction of glare especially in cities and city sides. Other major aspects are energy performance of the lamps, scattering effect, ultraviolet and infrared emissions,

The following should be considered when considering solar street lighting.

1- Maximize Coefficient of Utilization

In order to maximize the coefficient of utilization, lamps should not be placed from the target area



2- Prevent direct light upward emission

Emission of direct light upwards and at angles near horizon should be avoided. To do so, reflectors should be used when possible. Luminaires shall not be tilted from their horizontal position.

In addition, asymmetric beam flood lights should be used and adjusted for the target area.

3- Avoid excess lighting levels

With proper codes and regulations in place, lighting levels should be controlled and comply with the requirements. The lighting level should be sufficient to provide proper sight at the target area, yet it should not exceed the required level by more than 20%. The level is determined by the target area requirements, the traffic volume, and the availability of natural lighting.

4- Use adaptive lighting

The occupancy profile and traffic volume varies during the day, even the availability of natural lighting is on the change. Adaptive lighting should be used to reduce unwanted energy consumption and ensure sufficient lighting at all times. Adaptive lighting can be manually or automatically controlled.

5- Avoid wavelengths shorter than 500 nm

It is recommended to avoid lamps with radiant output of wavelengths below 500 nm (no blue light or UV). This is essential to avoid insects and living creatures, causing damages and reducing biodiversity of natural environments.

6- Use proper luminaire distribution design

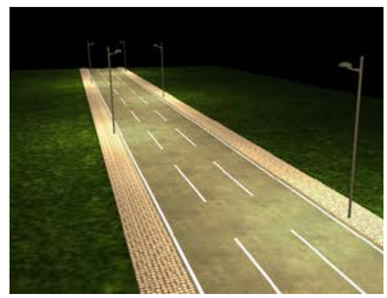
Selection of the proper luminaire distribution is essential to achieve desired lighting output. Four major luminaire distribution designs are followed in street lighting design.

One-sided Distribution

Luminaires are place on the same side of the road. The spacing is determined based on the luminaires specifications and road requirements.

This design is only used when the width of the road is less than the mounting height of the luminaire.

Staggered

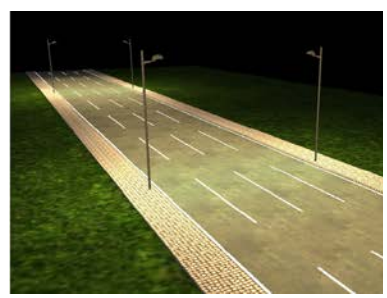


Luminaires are placed on opposite sides of the road with no opposite facing poles.

This design is mainly used when the width of the road is 1 to 1.5 times the mounting.

This design is very critical to avoid lack of uniformity on the road that could cause alternate bright and dark spots.

Opposite Pairing



Luminaires are placed on opposite sides of the road facing each other.

This design is mainly used when the width of the road is 1.5 times the mounting.

Suspended over Middle of Road

Whenever I is tough to place poles on the sides of the roads, luminaires can be installed suspended over the middle of the road

7- Follow proper spacing design

In cross intersections, at least one luminaire, oriented at right angles to the road centerline, shall be provided at each intersection at about the point of tangency of the curb return of the far side of the street from direction of traffic. In T intersections, a luminaire shall be at placed at the center line at the top of the T.

The proper spacing between the poles shall be determined using the following formula:

$$S = \frac{L \times U \times 0.8}{I \times W}$$

Where:

- S: Spacing measured along center line of road (m)
- L: Lamp lumens (lm)
- U: Coefficient of utilization
- I: Minimum required average illumination (lm/m_2)
- W: road width (m)

STREET LIGHTING TECHNOLOGIES REVIEW

Ten street lighting options are studied employing HPS, LED, and induction luminaires. With different control methods and various power supply options.

Each is studied technically, financially, and environmentally compared for five different cases based on a variety of factors such as pole spacing, road width, and mounting height. These classifications are referred to as L1 to L5.

Table 12: Lamping types L1 to L5 specifications

Classification	Ref. HPS	Lumens	Lux/m²
L1	50W	5,000	3.5
L2	70W	7,000	3.5
L3	100W	10,000	3.5
L4	150W	16,000	3.5
L5	250W	33,000	4.5

In order to clearly demonstrate the different options, and be able to compare apples to apples when analyzing the different technologies and lamping options, L1 to L5 are designed as presented in Table 13.

The variations between the different opts are related to the pole details and the road specifications.

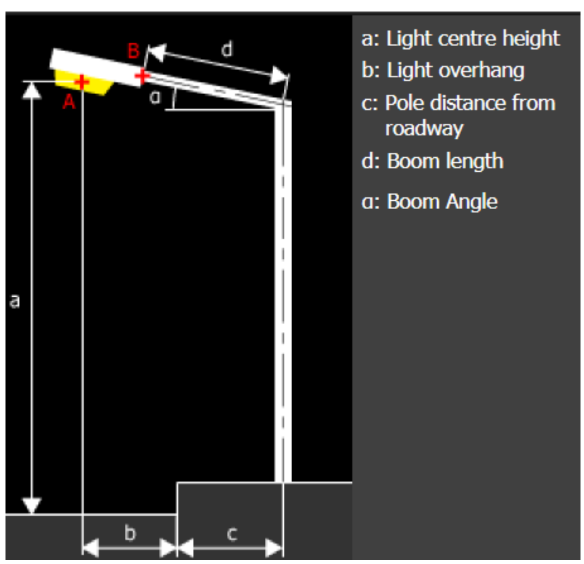
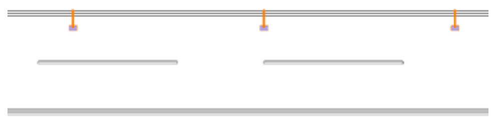
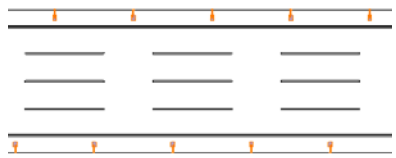
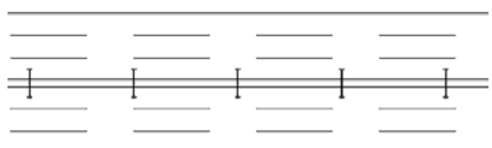
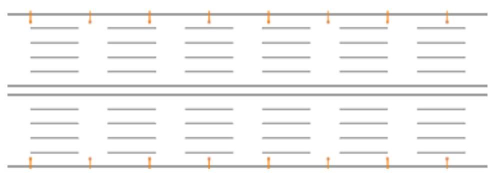


Table 13: Classification design aspects

	Type of Road	Road details	Pole Details
L1		• Ways: 1 • Lanes/Way: 1 • Total Width: 3.5m • Poles type: one-side • Lamps/pole: 1	• a: 4m • b: 1m • c: 0.65m • d: 1.65m • α: 0°
L2		• Ways: 2 • Lanes/Way: 1 • Total Width: 6m • Poles type: one-side • Lamps/pole: 1	• a: 6m • b: 1m • c: 0m • d: 1m • α: 0°
L3		• Ways: 2 • Lanes/Way: 2 • Total Width: 14+4m • Poles type: Staggered • Lamps/pole: 1	• a: 7m • b: 0m • c: 2m • d: 2m • α: 0°
L4		• Ways: 2 • Lanes/Way: 3 • Total Width: 25m • Poles type: Middle • Lamps/pole: 2	• a: 12m • b: 2m • c: 0.5m • d: 2.5m • α: 15°
L5		• Ways: 2 • Lanes/Way: 5 • Total Width: 37m • Poles type: Middle • Lamps/pole: 2	• a: 10m • b: 2m • c: 0.65m • d: 2.65m • α: 15°

Business as usual scenarios are presented in Table 12 for HPS, the choice of LED and Induction lamps alternative was done based on Dialux analysis. Dialux is an internationally used software for lighting design and planning. Lamp specifications are fed into the system and analysis is performed with the restrictions mentioned in Table 11 to obtain the pole spacing requirement for each lamp type and size applying EN13201 standard.

For reference the lamps specifications applied are shown in Table 14.

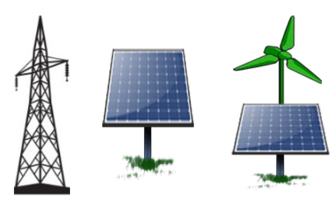
Table 14: Lamps specifications applied in Dialux

Classification	Manufacturer	Wattage range	Product model
HPS	General Electric	50-250 W	Odyssey VC
LED	General Electric	19-91 W	Spinella LED
Induction	Everlast	55-150	EGS-ED

In calculating the energy consumption, sunrise and sunset values for Lebanon are calculated using present weather data, summing to a total of 4,447 hours per year, adding half an hour before sunset and another half after sunrise, the total becomes 4,812. During winter there is a potential of dark days and fog requiring street lighting, this is estimated to lead to an additional 180 hours to reach a total of 4,992 hours per year.

Considering the current electricity supply profile in Lebanon, with a 33% average cutoff rate, the overall PSL operating hours becomes 3,295 hours per year.

Table 15: Analyzed street lighting options

		Control Method		
		On/Off	**Timer & Photocell**	**Intelligent Control**
Lamp Type	**HPS**			
	LED			
	Induction			

High Pressure Sodium (HPS)

High pressure sodium is the most widely used luminaire type n public street lighting worldwide and in Lebanon as well. It offers the highest photopic illumination per watt, but when considering scotopic and photopic light HPS appears to be way behind while light sources. Studies have shown that white light doubles driver peripheral vision and increases driver brake reaction time by 25%.

Comparing HPS to conventional Metal Halide at the same photopic light levels, street scene illuminated at night by a metal halide lighting system was reliably seen as brighter than that illuminated by a high pressure sodium system.

High lumen output per watt, offering energy saving potential when compared to other technologies such as metal halide and mercury vapor. It is among the best luminaire types if considering the lumen per watt ratio.

Although it is always possible to power HPS with solar PV, it is impractical to do so due to the high rating of HPS lamps, requiring larger PV units.

It is not practical to dim HPS that results in of flickering. HPS are affected by a reduction of 50°K to 200°K in color temperature when dimmed.

An HPS lamp would need 10 to 15 minutes to turn on to its full capacity, making it a less attractive solution for on-off operations.

Timer control is possible for HPS. The timer works based on preset schedules varying by season to save on energy consumption of the lamps.

There are some HPS lamps with improved CRI levels, yet they are still low compared to other technologies.

With a lifespan of 12,000 to 16,000 hours, HPS is considered to have an average lifespan of around 3.5 years considering 12 hours of operation per day.

Although mercury is found in limited and nontoxic volumes, it remains an issue to consider when disposing HPS lamps. This is a major issue on the environment that is mainly considered when performing lifecycle environmental analysis.

Grid-powered with On/Off Operation

HPS-G-C0	Unit	L1	L2	L3	L4	L5
Spacing:	m	8	11	17	21	28
Lamp Wattage:	W	50	70	100	150	250
Ballast Wattage:	W	10	14	20	30	50
System Wattage:	W	60	84	120	180	300
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	3,850	3,850	3,850	3,850	3,850
Lamp Lifespan:	hrs	16,000	16,000	16,000	16,000	16,000
Replacement:	yrs	4.2	4.2	4.2	4.2	4.2
Luminaire Cost:	USD	100	115	125	140	160
Control Cost:	USD	0	0	0	0	0
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	10	12	13	14	16
Energy Consumption:	kWh/yr	231	323	462	693	1,155
Electricity Cost:	USD/yr	51	71	102	152	254
CO_2 Emission:	kg/yr	150	210	300	450	751

Sample Road Distance	1	km				
Amount:	nb.	125	91	59	48	36
System Wattage:	W	7,500	7,636	7,059	8,571	10,714
Energy Consumption:	kWh/yr	28,876	29,401	27,177	33,001	41,251
Electricity Cost:	USD/yr	6,353	6,468	5,979	7,260	9,075
CO_2 Emission:	kg/yr	18,769	19,110	17,665	21,450	26,813

Life Cycle Analysis:	20	years				
Investment Cost:	USD	12,500	10,455	7,353	6,667	5,714
Replacement Cost:	USD	63,165	52,501	36,802	33,230	28,360
Maintenance Cost:	USD	25,000	20,909	14,706	13,333	11,429
Electricity Cost:	USD	127,053	129,363	119,579	145,203	181,504
Life Cycle Cost:	USD	227,718	213,228	178,440	198,433	227,007
CO_2 Emissions:	kg	375,383	382,208	353,302	429,009	536,262

Grid-powered with Timer and Photosensor

HPS-G-C1	Unit	L1	L2	L3	L4	L5
Spacing:	m	8	11	17	21	28
Lamp Wattage:	W	50	70	100	150	250
Ballast Wattage:	W	10	14	20	30	50
System Wattage:	W	60	84	120	180	300
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	3,356	3,356	3,356	3,356	3,356
Lamp Lifespan:	hrs	16,000	16,000	16,000	16,000	16,000
Replacement:	yrs	4.8	4.8	4.8	4.8	4.8
Luminaire Cost:	USD	100	115	125	140	160
Control Cost:	USD	40	40	40	40	40
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	12	14	15	17	19
Energy Consumption:	kWh/yr	201	282	403	604	1,007
Electricity Cost:	USD/yr	44	62	89	133	221
CO_2 Emission:	kg/yr	131	183	262	393	654

Sample Road Distance	1	km				
Amount:	nb.	125	91	59	48	36
System Wattage:	W	7,500	7,636	7,059	8,571	10,714
Energy Consumption:	kWh/yr	25,169	25,626	23,688	28,764	35,955
Electricity Cost:	USD/yr	5,537	5,638	5,211	6,328	7,910
CO_2 Emission:	kg/yr	16,360	16,657	15,397	18,697	23,371

Life Cycle Analysis:	20	years				
Investment Cost:	USD	17,500	14,091	9,706	8,571	7,143
Replacement Cost:	USD	55,057	45,761	32,078	28,964	24,719
Maintenance Cost:	USD	30,000	25,091	17,647	16,000	13,714
Electricity Cost:	USD	110,743	112,756	104,228	126,563	158,204
Life Cycle Cost:	USD	213,299	197,699	163,659	180,098	203,780
CO_2 Emissions:	kg	327,194	333,143	307,947	373,936	467,420

Light Emitting Diode (LED)

LEDs are the next big thing. They are becoming a more and more widely used alternative for HPS in outdoor lighting applications with a developing technology with promising future. LED offers great scotopic and photopic illumination per watt.

High lumen output per watt, offering energy saving potential when compared to other technologies. It is among the best luminaire types if considering the lumen per watt ratio.

LED is the best option to be powered by solar PV or other renewable energy sources, its low watt rating and dimming capabilities make it very convenient to renewable energy applications.

LED lamps are perfectly dimmable offering a dimmability range of 1% to 100%. The dimmability options creates an additional room for saving.

No start-up delay exists with LED lamps. The lamp can turn on immediately to its full power.

Timer control is possible for LED. The timer works based on preset schedules varying by season to save on energy consumption of the lamps.

LED offers great CRI levels, making it a suitable option for different applications especially ones requiring face recognition.

With a lifespan of 50,000 to 100,000 hours, LED is considered to have a great lifespan of around 11 to 22 years considering 12 hours of operation per day.

No toxic material or components is used in LED lamps. Recycling is not a major issue.

Grid-powered with On/Off Operation

LED-G-C0	Unit	L1	L2	L3	L4	L5
Spacing:	m	8	11	17	21	28
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	0.95	1.35	2.7	3.4	4.55
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	3,789	3,789	3,789	3,789	3,789
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	13.2	13.2	13.2	13.2	13.2
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	0	0	0	0	0
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	9	11	12	14	15
Energy Consumption:	kWh/yr	76	107	215	271	362
Electricity Cost:	USD/yr	17	24	47	60	80
CO_2 Emission:	kg/yr	49	70	140	176	235

Sample Road Distance	1	km				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	7,560	7,162	11,936	15,031	16,457
Electricity Cost:	USD/yr	1,663	1,576	2,626	3,307	3,621
CO_2 Emission:	kg/yr	4,914	4,655	7,758	9,770	10,697

Life Cycle Analysis:	20	years				
Investment Cost:	USD	30,000	24,333	22,222	25,000	22,727
Replacement Cost:	USD	46,229	37,387	34,103	38,314	34,792
Maintenance Cost:	USD	18,000	14,600	13,333	15,000	13,636
Electricity Cost:	USD	33,262	31,511	52,519	66,135	72,413
Life Cycle Cost:	USD	127,491	107,832	122,178	144,449	143,568
CO_2 Emissions:	kg	98,274	93,102	155,170	195,399	213,946

Grid-powered with Timer and Photosensor

LED-G-C1	Unit	L1	L2	L3	L4	L5
Spacing:	m	8	11	17	21	28
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	0.95	1.35	2.7	3.4	4.55
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	3,295	2,801	3,295	3,295	3,295
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	15.2	17.9	15.2	15.2	15.2
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	40	40	40	40	40
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	15	18	20	23	25
Energy Consumption:	kWh/yr	66	79	187	235	315
Electricity Cost:	USD/yr	14	17	41	52	69
CO_2 Emission:	kg/yr	43	52	121	153	205

Sample Road Distance	1	km				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	6,574	5,293	10,379	13,070	14,311
Electricity Cost:	USD/yr	1,446	1,165	2,283	2,875	3,148
CO_2 Emission:	kg/yr	4,273	3,441	6,747	8,496	9,302

Life Cycle Analysis:	20	years				
Investment Cost:	USD	34,000	27,000	24,444	27,222	24,545
Replacement Cost:	USD	40,199	27,634	29,655	33,316	30,254
Maintenance Cost:	USD	30,000	24,333	22,222	25,000	22,727
Electricity Cost:	USD	28,924	23,291	45,669	57,509	62,967
Life Cycle Cost:	USD	133,123	102,258	121,990	143,047	140,494
CO_2 Emissions:	kg	85,456	68,814	134,930	169,912	186,040

Grid-powered with Intelligent Control

LED-G-C2	Unit	L1	L2	L3	L4	L5
Spacing:	m	10	15	18	18	22
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	1	1	3	3	5
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	2,801	2,801	2,801	2,801	2,801
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	17.9	17.9	17.9	17.9	17.9
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	100	100	100	100	100
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	3.0	3.7	4.0	4.5	5.0
Energy Consumption:	kWh/yr	56	79	159	200	268
Electricity Cost:	USD/yr	12	17	35	44	59
CO_2 Emission:	kg/yr	36	52	103	130	174

Sample Road Distance	**1**	**km**				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	5,587	5,293	8,822	11,110	12,164
Electricity Cost:	USD/yr	1,229	1,165	1,941	2,444	2,676
CO_2 Emission:	kg/yr	3,632	3,441	5,735	7,221	7,907

Life Cycle Analysis:	**20**	**years**				
Investment Cost:	USD	40,000	31,000	27,778	30,556	27,273
Replacement Cost:	USD	34,169	27,634	25,207	28,319	25,716
Maintenance Cost:	USD	6,000	4,867	4,444	5,000	4,545
Electricity Cost:	USD	24,585	23,291	38,818	48,882	53,522
Life Cycle Cost:	USD	104,754	86,792	96,247	112,757	111,056
CO_2 Emissions:	kg	72,637	68,814	114,691	144,425	158,134

PV-powered with Intelligent Control

LED-P-C2	Unit	L1	L2	L3	L4	L5
Spacing:	m	10	15	18	18	22
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	1	1	3	3	5
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.00	0.00	0.00	0.00	0.00
CO_2 Emission Rate:	kg/kWh	0.00	0.00	0.00	0.00	0.00
Operating Hours:	hrs/yr	2,801	2,801	2,801	2,801	2,801
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	17.9	17.9	17.9	17.9	17.9
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	100	100	100	100	100
Power Supply Cost:	USD	279	369	680	785	956
Maintenance Cost:	USD/yr	6	7	8	9	10
Energy Consumption:	kWh/yr	56	79	159	200	268
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Sample Road Distance	1	km				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	5,587	5,293	8,822	11,110	12,164
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Life Cycle Analysis:	20	years				
Investment Cost:	USD	67,930	55,570	65,578	74,189	70,705
Replacement Cost:	USD	34,169	27,634	25,207	28,319	25,716
Maintenance Cost:	USD	12,000	9,733	8,889	10,000	9,091
Electricity Cost:	USD	0	0	0	0	0
Life Cycle Cost:	USD	114,099	92,937	99,673	112,508	105,511
CO_2 Emissions:	kg	0	0	0	0	0

Hybrid-powered with Timer and Photosensor

LED-H-C1	Unit	L1	L2	L3	L4	L5
Spacing:	m	10	15	18	18	22
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	1	1	3	3	5
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.00	0.00	0.00	0.00	0.00
CO_2 Emission Rate:	kg/kWh	0.00	0.00	0.00	0.00	0.00
Operating Hours:	hrs/yr	3,295	2,813	2,949	3,295	3,295
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	15.2	17.8	17.0	15.2	15.2
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	40	40	40	40	40
Power Supply Cost:	USD	335	442	816	942	1,147
Maintenance Cost:	USD/yr	20	24	26	29	33
Energy Consumption:	kWh/yr	66	80	167	235	315
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Sample Road Distance	**1**	**km**				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	6,574	5,316	9,289	13,070	14,311
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Life Cycle Analysis:	**20**	**years**				
Investment Cost:	USD	67,516	56,484	69,804	79,582	76,664
Replacement Cost:	USD	40,199	27,754	26,541	33,316	30,254
Maintenance Cost:	USD	39,000	31,633	28,889	32,500	29,545
Electricity Cost:	USD	0	0	0	0	0
Life Cycle Cost:	USD	146,715	115,871	125,235	145,398	136,463
CO_2 Emissions:	kg	0	0	0	0	0

Hybrid-powered with Intelligent Control

LED-H-C2	Unit	L1	L2	L3	L4	L5
Spacing:	m	10	15	18	18	22
Lamp Wattage:	W	19	27	54	68	91
Ballast Wattage:	W	1	1	3	3	5
System Wattage:	W	19.95	28.35	56.7	71.4	95.55
Electricity Rate:	USD/kWh	0.00	0.00	0.00	0.00	0.00
CO_2 Emission Rate:	kg/kWh	0.00	0.00	0.00	0.00	0.00
Operating Hours:	hrs/yr	2,801	2,801	2,801	2,801	2,801
Lamp Lifespan:	hrs	50,000	50,000	50,000	50,000	50,000
Replacement:	yrs	17.9	17.9	17.9	17.9	17.9
Luminaire Cost:	USD	300	365	400	450	500
Control Cost:	USD	100	100	100	100	100
Power Supply Cost:	USD	335	442	816	942	1,147
Maintenance Cost:	USD/yr	8	9	10	11	13
Energy Consumption:	kWh/yr	56	79	159	200	268
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Sample Road Distance	1	km				
Amount:	nb.	100	67	56	56	45
System Wattage:	W	1,995	1,890	3,150	3,967	4,343
Energy Consumption:	kWh/yr	5,587	5,293	8,822	11,110	12,164
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Life Cycle Analysis:	20	years				
Investment Cost:	USD	73,516	60,484	73,138	82,916	79,391
Replacement Cost:	USD	34,169	27,634	25,207	28,319	25,716
Maintenance Cost:	USD	15,000	12,167	11,111	12,500	11,364
Electricity Cost:	USD	0	0	0	0	0
Life Cycle Cost:	USD	122,685	100,285	109,456	123,734	116,471
CO_2 Emissions:	kg	0	0	0	0	0

Induction

Induction lamps have been there for more than a century now. The technology is mature with not much potential for development. It offers good lighting levels with good saving potential, yet, when compared to LED, induction lamps have limited directionality.

One major concern of induction lamps that remains unresolved is the radio interference they casue.

High lumen output per watt, offering energy saving potential when compared to other technologies such as metal halide and mercury vapor. It is among the best luminaire types if considering the lumen per watt ratio.

Induction lamps are compatible with renewable energy applications such as wind and solar PV.

Dimmability is possible from 50 to 100%.

Induction lamps might witness delay in turn-on in cold weather. Reaching full capacity might take a few minutes.

Timer control is possible. The timer works based on preset schedules varying by season to save on energy consumption of the lamps.

Induction lamps offer great CRI levels, making it a suitable option for different applications especially ones requiring face recognition.

With a lifespan of 50,000 to 100,000 hours, induction lamps is considered to have a great lifespan of around 11 to 22 years considering 12 hours of operation per day.

Induction lamps use a power couple to energize solid mercury inside the lamp bulb. Mercury is a toxic material that needs to be well-handled.

Grid-powered with Timer and Photosensor

IND-G-C1	Unit	L1	L2	L3	L4	L5
Spacing:	m	11	11	10	11	10
Lamp Wattage:	W	55	70	80	100	150
Ballast Wattage:	W	4.125	5.25	6	7.5	11.25
System Wattage:	W	59.125	75.25	86	107.5	161.25
Electricity Rate:	USD/kWh	0.22	0.22	0.22	0.22	0.22
CO_2 Emission Rate:	kg/kWh	0.65	0.65	0.65	0.65	0.65
Operating Hours:	hrs/yr	3,307	2,801	2,949	3,295	3,295
Lamp Lifespan:	hrs	100,000	100,000	100,000	100,000	100,000
Replacement:	yrs	30.2	35.7	33.9	30.3	30.3
Luminaire Cost:	USD	220	245	280	300	360
Control Cost:	USD	40	40	40	40	40
Power Supply Cost:	USD	0	0	0	0	0
Maintenance Cost:	USD/yr	15	17	20	21	25
Energy Consumption:	kWh/yr	196	211	254	354	531
Electricity Cost:	USD/yr	43	46	56	78	117
CO_2 Emission:	kg/yr	127	137	165	230	345

Sample Road Distance	1	km				
Amount:	nb.	91	91	100	91	100
System Wattage:	W	5,375	6,841	8,600	9,773	16,125
Energy Consumption:	kWh/yr	17,776	19,160	25,362	32,201	53,132
Electricity Cost:	USD/yr	3,911	4,215	5,580	7,084	11,689
CO_2 Emission:	kg/yr	11,554	12,454	16,485	20,931	34,536

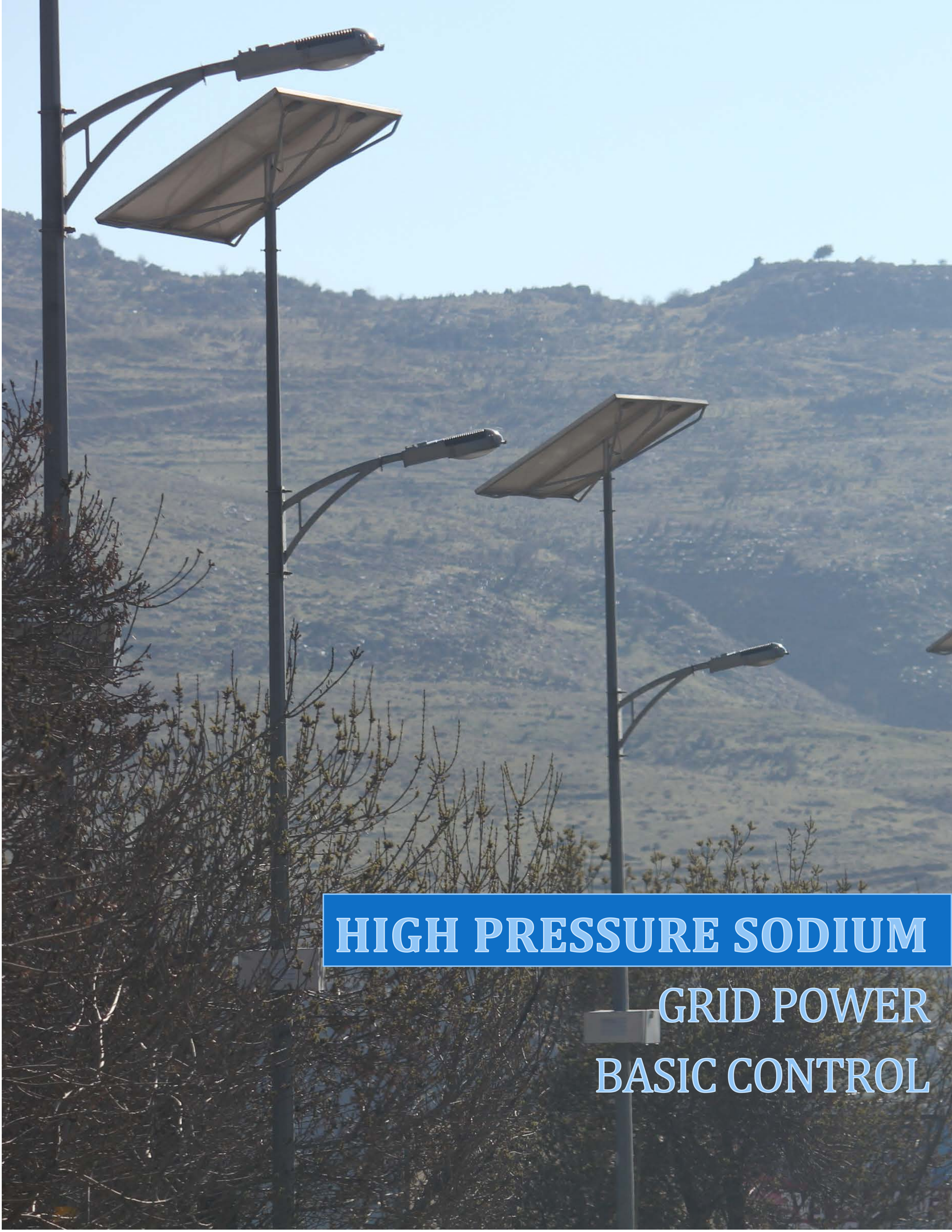
Life Cycle Analysis:	20	years				
Investment Cost:	USD	23,636	25,909	32,000	30,909	40,000
Replacement Cost:	USD	13,529	12,731	16,809	18,272	24,054
Maintenance Cost:	USD	28,000	31,182	39,200	38,182	50,400
Electricity Cost:	USD	78,214	84,303	111,591	141,685	233,780
Life Cycle Cost:	USD	143,380	154,124	199,601	229,048	348,234
CO_2 Emissions:	kg	231,088	249,076	329,701	418,615	690,714

PV-powered with Control

IND-P-C2	Unit	L1	L2	L3	L4	L5
Spacing:	m	11	11	10	11	10
Lamp Wattage:	W	55	70	80	100	150
Ballast Wattage:	W	4.125	5.25	6	7.5	11.25
System Wattage:	W	59.125	75.25	86	107.5	161.25
Electricity Rate:	USD/kWh	0.00	0.00	0.00	0.00	0.00
CO_2 Emission Rate:	kg/kWh	0.00	0.00	0.00	0.00	0.00
Operating Hours:	hrs/yr	2,961	2,961	2,961	2,961	2,961
Lamp Lifespan:	hrs	100,000	100,000	100,000	100,000	100,000
Replacement:	yrs	33.8	33.8	33.8	33.8	33.8
Luminaire Cost:	USD	220	245	280	300	360
Control Cost:	USD	120	120	120	120	120
Power Supply Cost:	USD	828	978	1,032	1,183	1,613
Maintenance Cost:	USD/yr	10	11	13	14	16
Energy Consumption:	kWh/yr	175	223	255	318	477
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Sample Road Distance	**1**	**km**				
Amount:	nb.	91	91	100	91	100
System Wattage:	W	5,375	6,841	8,600	9,773	16,125
Energy Consumption:	kWh/yr	15,916	20,257	25,466	28,939	47,749
Electricity Cost:	USD/yr	0	0	0	0	0
CO_2 Emission:	kg/yr	0	0	0	0	0

Life Cycle Analysis:	**20**	**years**				
Investment Cost:	USD	106,159	122,114	143,200	145,682	209,250
Replacement Cost:	USD	12,114	13,460	16,879	16,421	21,617
Maintenance Cost:	USD	18,000	20,045	25,200	24,545	32,400
Electricity Cost:	USD	0	0	0	0	0
Life Cycle Cost:	USD	136,273	155,619	185,279	186,648	263,267
CO_2 Emissions:	kg	0	0	0	0	0



HIGH PRESSURE SODIUM

GRID POWER
BASIC CONTROL

PROJECT DETAILS

Project Description	HPS lamps are originally installed in almost all streets in Lebanon. In order to reduce electricity consumption through reducing operating hours, the Ministry of Energy and Water distributed photocells and timers to municipalities in to be installed with existing HPS streetlights.
Road Type	Municipal
Year	2011-2013
Implemented By	Ministry of Energy and Water – LCEC
Location	All over Lebanon
Lamp Type	HPS (existing)
Control	Timer + Photocell
Budget	$500,000
Owner	Municipalities

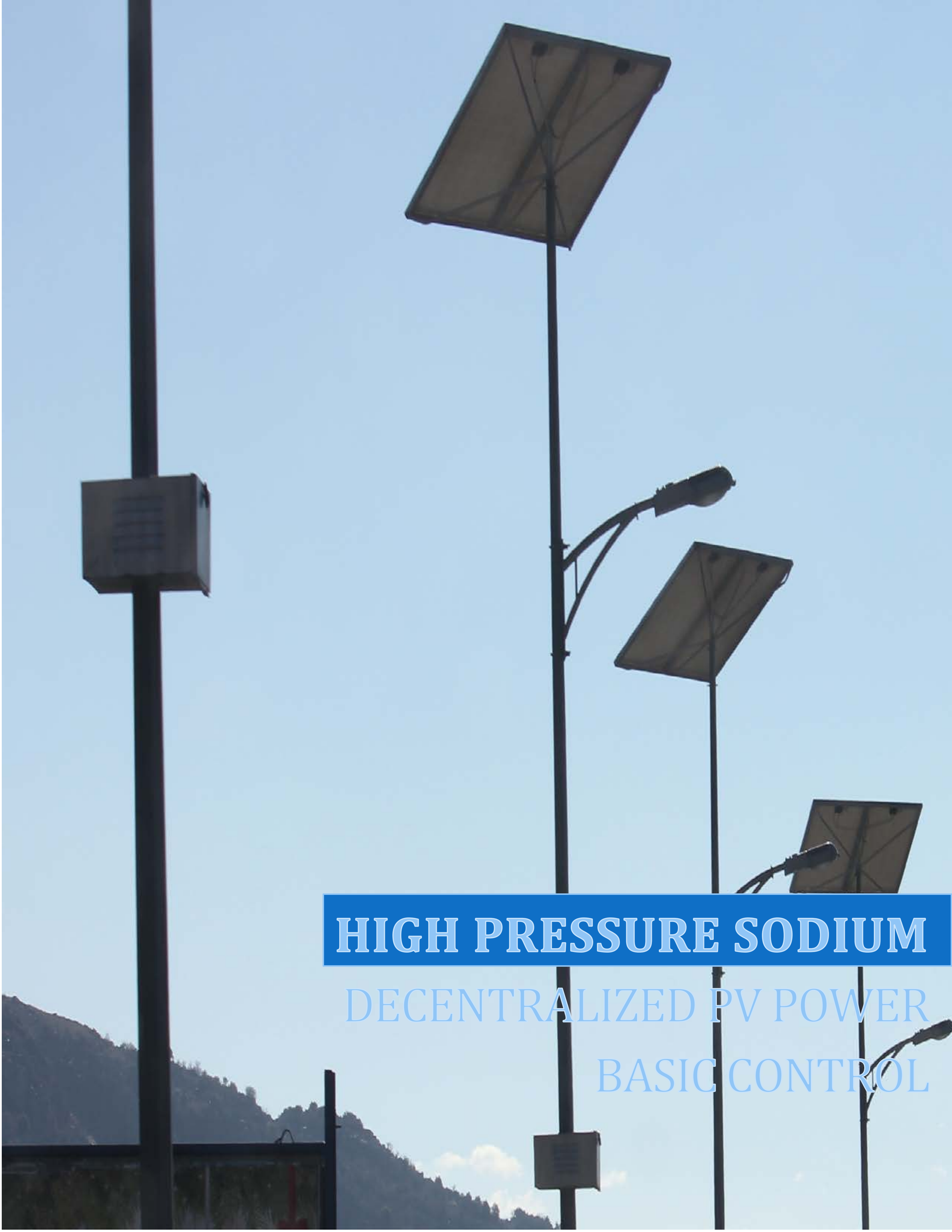
PERFORMANCE

Saving Method	Reduction of operating hours
Energy Saving	15%
Reported Problems	• Photocell requires frequent cleaning
User Feedback	• *High maintenance requirement* • *Not always effective* • *Cost is still high*

PROJECT PARTNERS

LEBANESE REPUBLIC MINISTRY OF ENERGY AND WATER

L.C.E.C.
Lebanese Center for Energy Conservation



HIGH PRESSURE SODIUM

DECENTRALIZED PV POWER

BASIC CONTROL

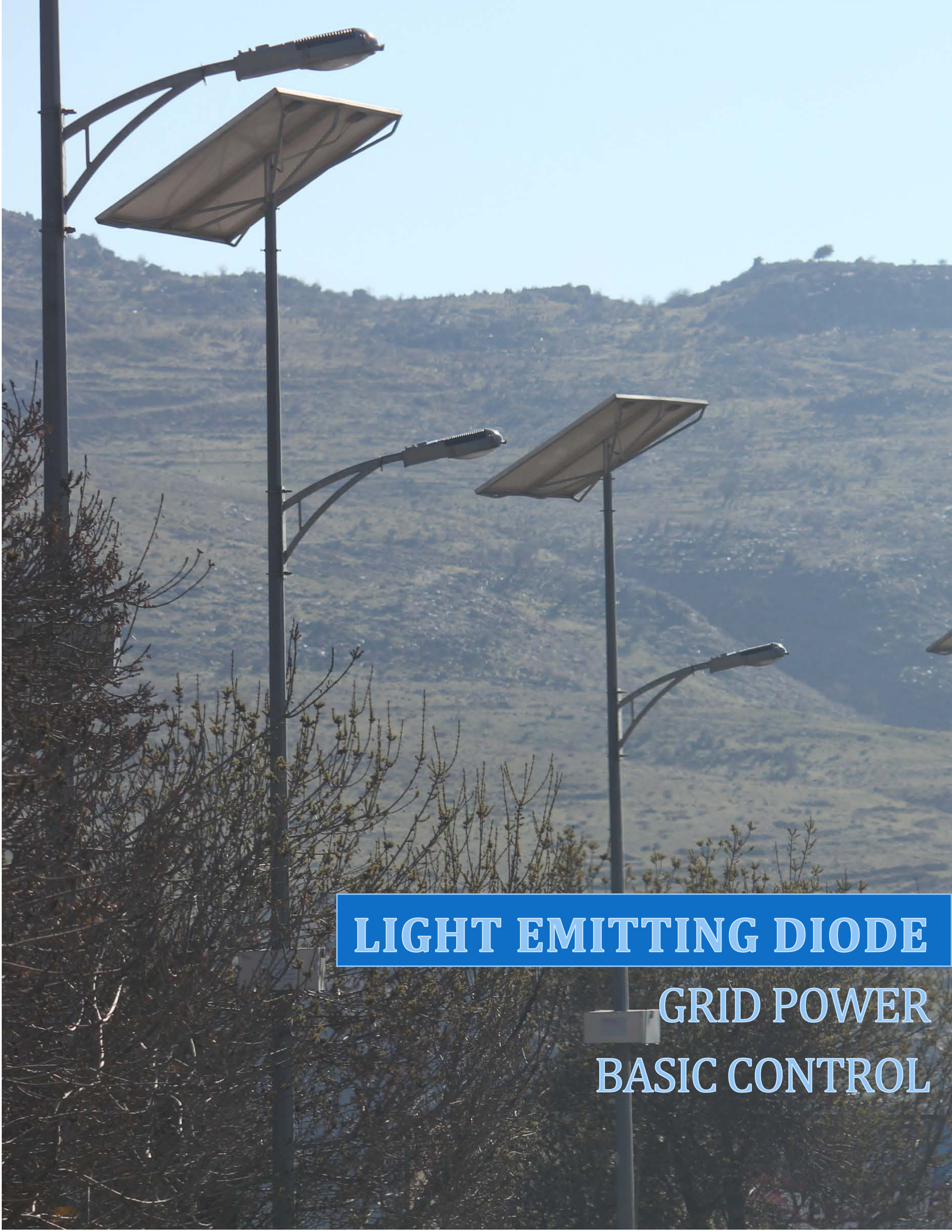
PROJECT DETAILS

Project Description		
Road Type		
Year		
Implemented By		
Location		
Lamp Type		
Control		
Budget		
Owner		

PERFORMANCE

Saving Method	
Energy Saving	
Reported Problems	•
User Feedback	•

PROJECT PARTNERS



LIGHT EMITTING DIODE

GRID POWER

BASIC CONTROL

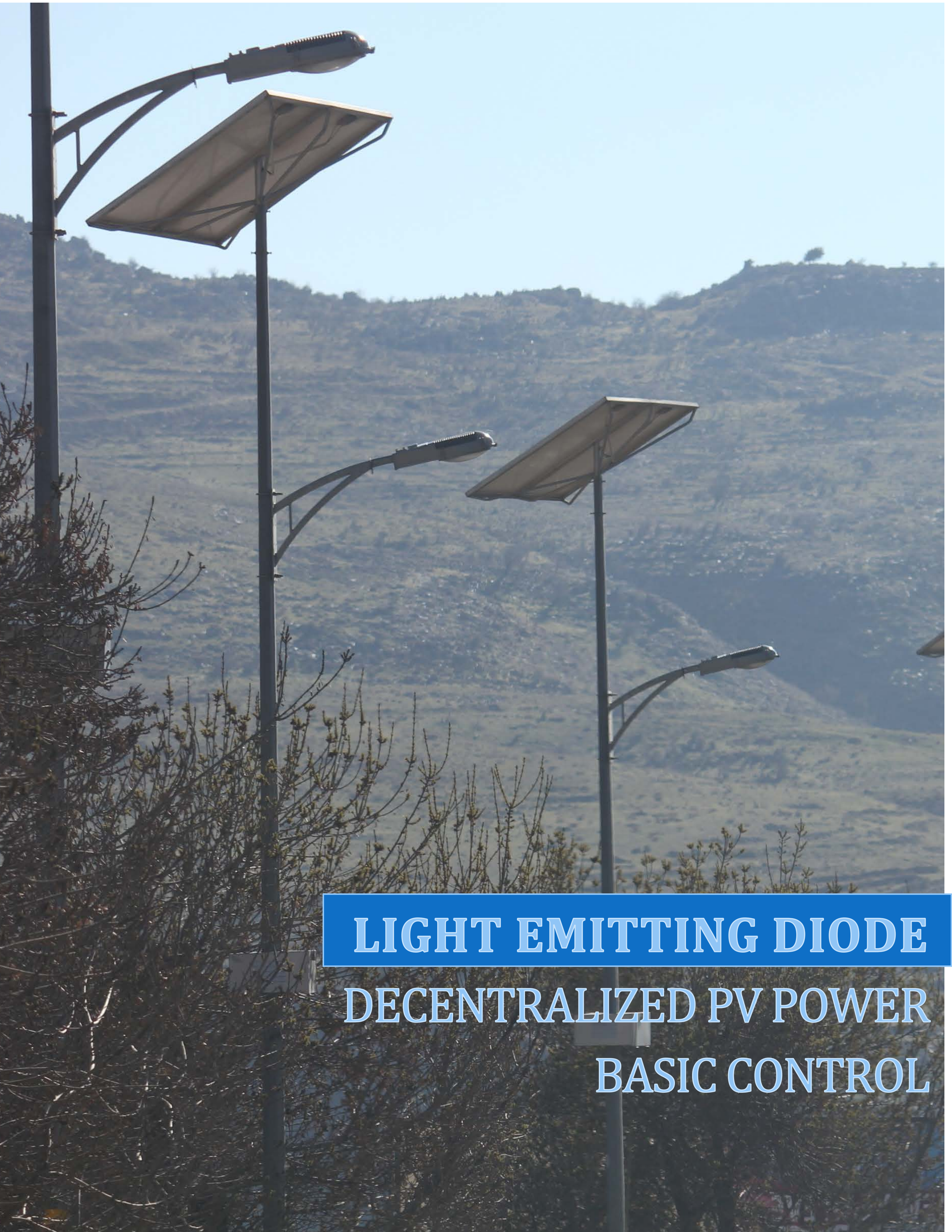
PROJECT DETAILS

Project Description		
Road Type		
Year		
Implemented By	CEDRO-UNDP	
Location		
Lamp Type	LED	
Control	Timer + Photocell	
Budget		
Owner		

PERFORMANCE

Saving Method	Operating hours & power load
Energy Saving	
Reported Problems	•
User Feedback	•

PROJECT PARTNERS



LIGHT EMITTING DIODE

DECENTRALIZED PV POWER

BASIC CONTROL

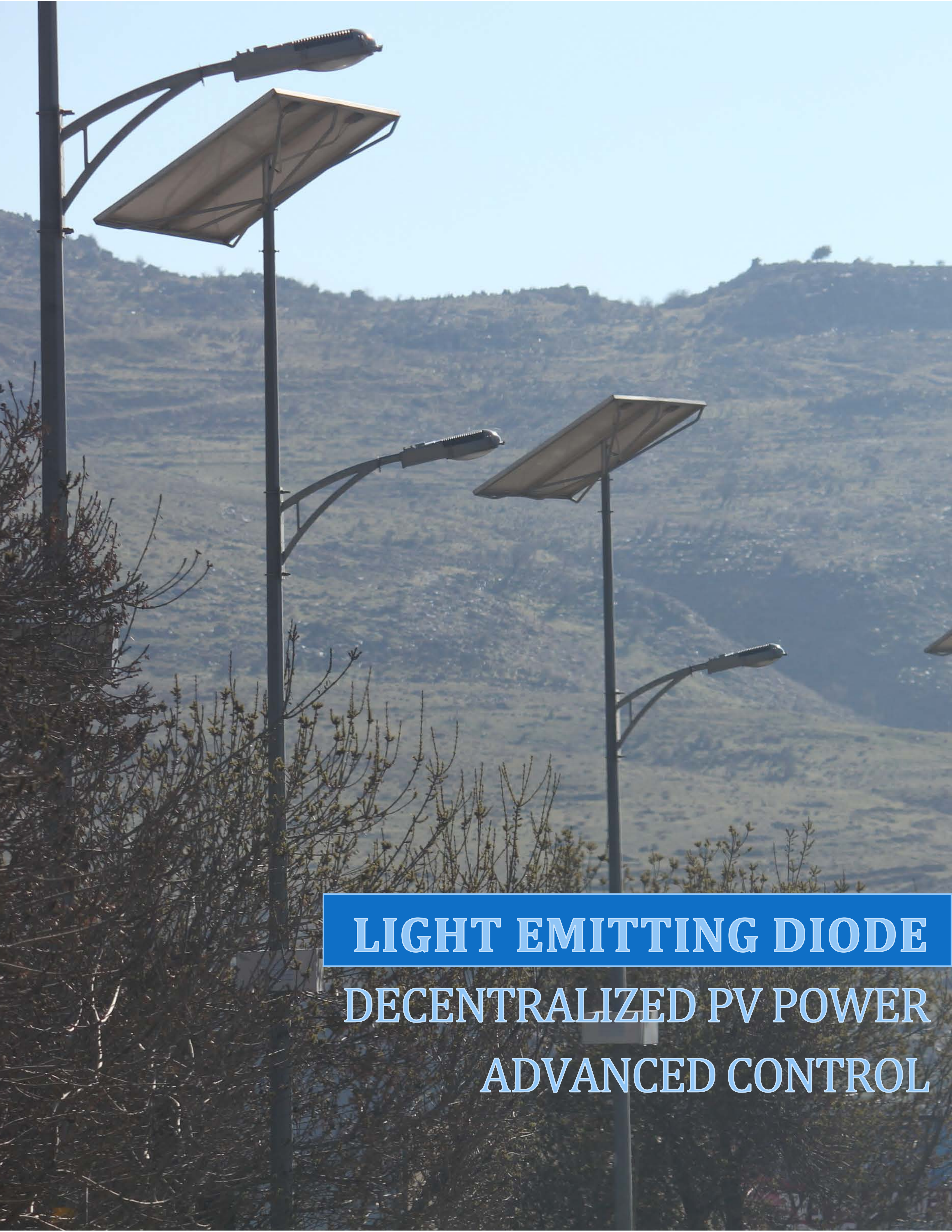
PROJECT DETAILS

Project Description		
Road Type	Municipal	
Year		
Implemented By	CEDRO-UNDP	
Location		
Lamp Type	LED	
Control	Timer + Photocell	
Budget		
Owner	Municipalities	

PERFORMANCE

Saving Method	Operating hours, power load, & EDL electricity
Energy Saving	
Reported Problems	•
User Feedback	•

PROJECT PARTNERS


LIGHT EMITTING DIODE
DECENTRALIZED PV POWER
ADVANCED CONTROL

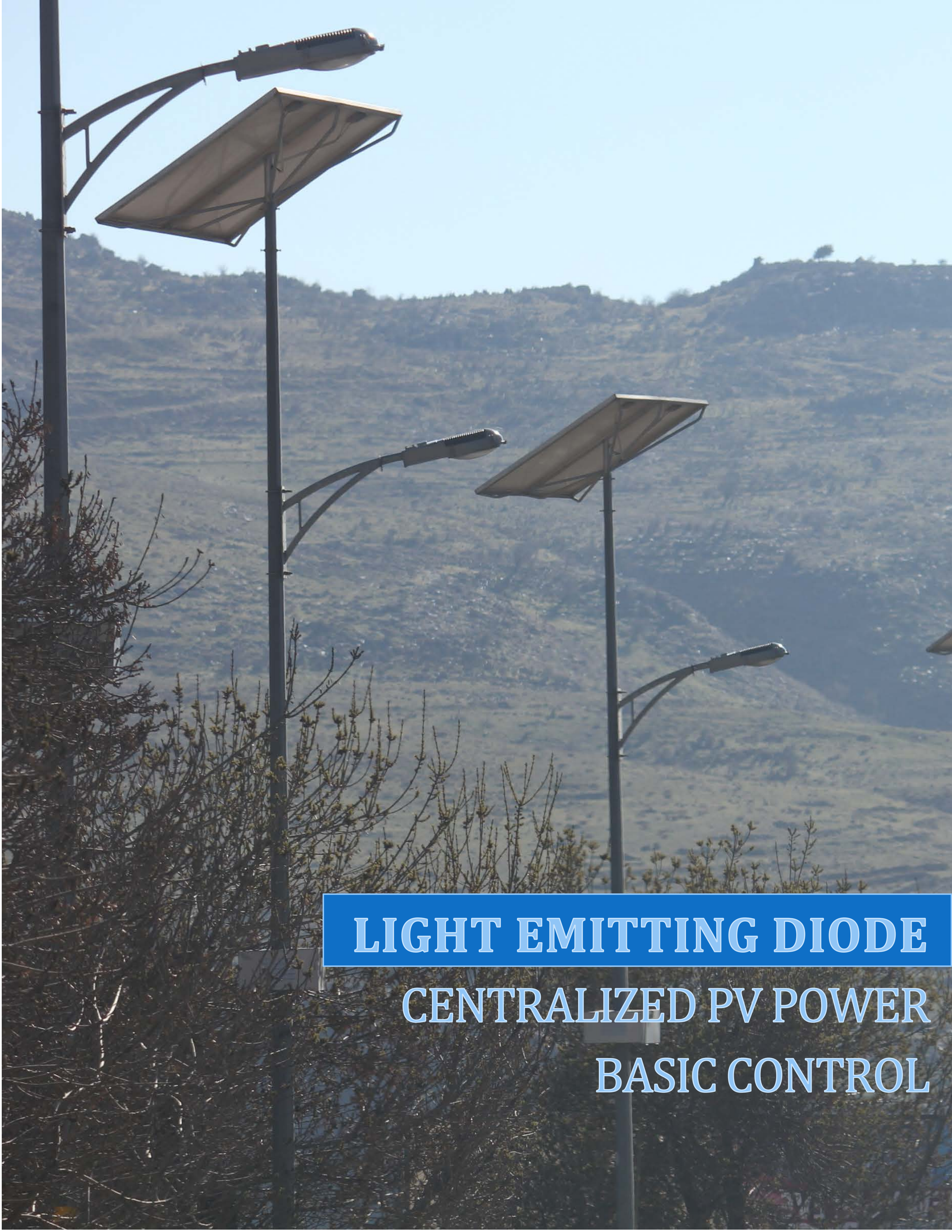
PROJECT DETAILS

Project Description	
Road Type	
Year	
Implemented By	Ministry of Energy and Water – LCEC
Location	
Lamp Type	LED
Control	Timer + Photocell + Adaptive control
Budget	
Owner	

PERFORMANCE

Saving Method	Operating hours, power load, & EDL electricity
Energy Saving	
Reported Problems	•
User Feedback	•

PROJECT PARTNERS



LIGHT EMITTING DIODE

CENTRALIZED PV POWER

BASIC CONTROL

PROJECT DETAILS

Project Description		
Road Type		
Year		
Implemented By	Ministry of Public Works	
Location	Chekka	
Lamp Type		
Control		
Budget		
Owner		

PERFORMANCE

Saving Method	Operating hours, power load, & EDL electricity
Energy Saving	
Reported Problems	•
User Feedback	•

PROJECT PARTNERS

Life Cycle Cost Analysis

Lifecycle cost analysis is performed to assess the cost of each of the analyzed solutions, considering investment cost, operation cost, replacement cost, and other cost such as maintenance, etc… this is done for a distance of 1km over a period of 20 years.

The results of the LCC are shown in Table 16. The applications compared are:

- HPS-G-C0: High Pressure Sodium, Grid Power, No Control
- HPS-G-C1: High Pressure Sodium, Grid Power, Basic Control
- LED-G-C0: Light Emitting Diode, Grid Power, No Control
- LED-G-C1: Light Emitting Diode, Grid Power, Basic Control
- LED-G-C2: Light Emitting Diode, Grid Power, Advanced Control
- LED-P-C2: Light Emitting Diode, PV Power, Advanced Control
- LED-H-C1: Light Emitting Diode, Hybrid Power, Basic Control
- LED-H-C2: Light Emitting Diode, Hybrid Power, Advanced Control
- IND-G-C1: Induction Lamp, Grid Power, Basic Control
- IND-P-C2: Induction Lamp, PV-Powered, Advanced Control

Table 16: LCA results in USD

	L1	L2	L3	L4	L5
HPS-G-C0	227,718	213,228	178,440	198,433	227,007
HPS-G-C1	213,299	197,699	163,659	180,098	203,780
LED-G-C0	127,491	107,832	122,178	144,449	143,568
LED-G-C1	133,123	102,258	121,990	143,047	140,494
LED-G-C2	104,754	86,792	96,247	112,757	111,056
LED-P-C2	114,099	92,937	99,673	112,508	105,511
LED-H-C1	146,715	115,871	125,235	145,398	136,463
LED-H-C2	122,685	100,285	109,456	123,734	116,471
IND-G-C1	143,380	154,124	199,601	229,048	348,234
IND-P-C2	136,273	155,619	185,279	186,648	263,267

Environmental Analysis

Over the same period of 20 years, environmental impact is also performed resulting in Table 17.

Table 17: Environmental iumpact results in kg CO_2

	L1	L2	L3	L4	L5
HPS-G-C0	375,383	382,208	353,302	429,009	536,262
HPS-G-C1	327,194	333,143	307,947	373,936	467,420
LED-G-C0	98,274	93,102	155,170	195,399	218,946
LED-G-C1	85,456	68,814	134,930	169,912	186,040
LED-G-C2	72,637	68,814	114,691	144,425	158,134
LED-P-C2	0	0	0	0	0
LED-H-C1	0	0	0	0	0
LED-H-C2	0	0	0	0	0
IND-G-C1	231,088	249,076	329,701	418,615	690,714
IND-P-C2	0	0	0	0	0

Retrofit Financial Analysis

The results have shown three solutions to have an attractive impact on the national energy consumption. These options are:

- LED-G-C1: Light Emitting Diode, Grid Power, Basic Control
- LED-G-C2: Light Emitting Diode, Grid Power, Advanced Control
- LED-P-C2: Light Emitting Diode, PV Power, Advanced Control

Investment cost and impact is performed against the business as usual scenario (HPS-G-C0: High Pressure Sodium, Grid Power, No Control), with a power rating of 150 Watts on a roadway of 1 km length. Two scenarios are considered, the first being a complete retrofit of an existing street light and the second being the adoption of these technologies for a new street lighting installation. Cash flow, ROI, IRR, and NPV analysis are performed.

Detailed cash flows for the different options are presented in Attachment VI: Detailed cash flow for different solutions.

L1

Table 18: Financial analysis input data for L1 solutions

	HPS-G-C1	LED-G-C1	LED-G-C2	LED-P-C2
Investment per Pole	$140	$340	$400	$679
Poles per km	125.0	100.0	100.0	100.0
Total Investment	$17,500	$34,000	$40,000	$67,930
Investment Difference	$0	$16,500	$22,500	$50,430
O&M Expenses	$7,037	$2,946	$1,529	$600
O&M Saving	$0	$4,091	$5,508	$6,437
Replacement Cost	$17,500	$34,000	$40,000	$40,000
Replacement Period	4.8	15.2	17.9	17.9

Table 19: NPV and IRR for L1 solutions

	Retrofit		New Installation	
	NPV	IRR	NPV	IRR
LED-G-C1	$2,996.77	8%	$20,496.77	23%
LED-G-C2	$6,515.96	10%	$24,015.96	23%
LED-P-C2	($11,569.56)	4%	$5,930.44	9%

L2

Table 20: Financial analysis input data for L1 solutions

	HPS-G-C1	LED-G-C1	LED-G-C2	LED-P-C2
Investment per Pole	$155	$405	$465	$834
Poles per km	90.9	66.7	66.7	66.7
Total Investment	$14,091	$27,000	$31,000	$55,570
Investment Difference	$0	$12,909	$16,909	$41,479
O&M Expenses	$6,892	$2,381	$1,408	$487
O&M Saving	$0	$4,511	$5,484	$6,406
Replacement Cost	$14,091	$27,000	$31,000	$31,000
Replacement Period	4.8	17.9	17.9	17.9

Table 21: NPV and IRR for L1 solutions

	Retrofit		New Installation	
	NPV	**IRR**	**NPV**	**IRR**
LED-G-C1	$16,621.95	15%	$30,712.86	35%
LED-G-C2	$17,930.67	16%	$32,021.58	32%
LED-P-C2	$3,120.07	8%	$17,210.98	13%

L3

Table 22: Financial analysis input data for L1 solutions

	HPS-G-C1	LED-G-C1	LED-G-C2	LED-P-C2
Investment per Pole	$165	$440	$500	$1,180
Poles per km	58.8	55.6	55.6	55.6
Total Investment	$9,706	$24,444	$27,778	$65,578
Investment Difference	$0	$14,739	$18,072	$55,872
O&M Expenses	$6,094	$3,395	$2,163	$444
O&M Saving	$0	$2,699	$3,931	$5,649
Replacement Cost	$9,706	$24,444	$27,778	$27,778
Replacement Period	4.8	15.2	17.9	17.9

Table 23: NPV and IRR for L1 solutions

	Retrofit		New Installation	
	NPV	**IRR**	**NPV**	**IRR**
LED-G-C1	$633.26	7%	$10,339.14	16%
LED-G-C2	$5,644.85	10%	$15,350.74	20%
LED-P-C2	($13,947.24)	3%	($4,241.36)	6%

L4

Table 24: Financial analysis input data for L1 solutions

	HPS-G-C1	LED-G-C1	LED-G-C2	LED-P-C2
Investment per Pole	$180	$490	$550	$1,335
Poles per km	47.6	55.6	55.6	55.6
Total Investment	$8,571	$27,222	$30,556	$74,189
Investment Difference	$0	$18,651	$21,984	$65,617
O&M Expenses	$7,128	$4,125	$2,694	$500
O&M Saving	$0	$3,003	$4,434	$6,628
Replacement Cost	$8,571	$27,222	$30,556	$30,556
Replacement Period	4.8	15.2	17.9	17.9

Table 25: NPV and IRR for L1 solutions

	Retrofit		New Installation	
	NPV	**IRR**	**NPV**	**IRR**
LED-G-C1	$1,481.81	8%	$10,053.24	14%
LED-G-C2	$7,378.25	11%	$15,949.68	18%
LED-P-C2	($13,010.54)	4%	($4,439.11)	6%

L5

Table 26: Financial analysis input data for L1 solutions

	HPS-G-C1	LED-G-C1	LED-G-C2	LED-P-C2
Investment per Pole	$200	$540	$600	$1,556
Poles per km	35.7	45.5	45.5	45.5
Total Investment	$7,143	$24,545	$27,273	$70,705
Investment Difference	$0	$17,403	$20,130	$63,562
O&M Expenses	$8,596	$4,285	$2,903	$455
O&M Saving	$0	$4,311	$5,693	$8,141
Replacement Cost	$7,143	$24,545	$27,273	$27,273
Replacement Period	4.8	15.2	17.9	17.9

Table 27: NPV and IRR for L1 solutions

	Retrofit		New Installation	
	NPV	**IRR**	**NPV**	**IRR**
LED-G-C1	$18,538.10	16%	$25,680.96	24%
LED-G-C2	$24,964.72	19%	$32,107.58	28%
LED-P-C2	$7,475.99	9%	$14,618.85	10%

Recommendations

ATTACHMENTS

Attachment I: Selection Parameters and Design Factors for Lighting Classes in CIE 115:2010

Class M

Table 28: Motorized traffic lighting classification system (CIE)

Class	**Dry**			**Wet**[3]	**TI**	**SR**
	L_{av} (cd/m²)	**U_O**	**U_L**	**U_O**		
M1	2.00	0.40	0.70	0.15	10%	0.5
M2	1.50	0.40	0.70	0.15	10%	0.5
M3	1.00	0.40	0.60	0.15	10%	0.5
M4	0.75	0.40	0.60	0.15	15%	0.5
M5	0.50	0.35	40	0.15	15%	0.5
M6	0.30	0.35	0.40	0.15	20%	0.5

[3] Applicable in addition where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available

Table 29: Selection of category M lighting class with example illustrated

Parameter	Options	Weighting Value	Check	Value
Speed	High	1	✓	**1**
	Moderate	0		
Traffic Volume	Very High	1		**0**
	High	0.5		
	Moderate	0	✓	
	Low	-0.5		
	Very Low	-1		
Traffic composition	Mostly non-motorized	1		**0**
	Mixed	0.5		
	Motorized only	0	✓	
Separation of ways	No	1		**0**
	Yes	0	✓	
Intersection density	High	1	✓	**1**
	Moderate	0		
Parked vehicles	Present	1	✓	**1**
	Not present	0		
Ambient luminance	Very high	1	✓	**1**
	High	0.5		
	Moderate	0		
	Low	-0.5		
	Very low	-1		
Visual guidance, traffic control	Poor	0.5		**0**
	Good	0	✓	
	Very good	-0.5		
			Total	**4**
			Class	**M2[4]**

[4] Class = 6 - Total

Class C

Table 30: Conflict areas traffic lighting classification system (CIE)

Class	L_{av} (lx)	U_0	TI[5]	
			High & moderate speed	Low & very low speed
C1	50	0.40	10%	15%
C2	30	0.40	10%	15%
C3	20	0.40	10%	20%
C4	15	0.40	10%	20%
C5	10	0.40	15%	25%

[5] Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) are of importance

Table 31: Selection of category C lighting class with example illustrated

Parameter	Options	Weighting Value	Check	Value
Speed	High	2	✓	**2**
	Moderate	1		
	Low	0		
Traffic Volume	Very High	1		**0.5**
	High	0.5	✓	
	Moderate	0		
	Low	-0.5		
	Very Low	-1		
Traffic composition	Mostly non-motorized	1	✓	**1**
	Mixed	0.5		
	Motorized only	0		
Separation of ways	No	1		**0**
	Yes	0	✓	
Ambient luminance	Very high	1		**-0.5**
	High	0.5		
	Moderate	0		
	Low	-0.5	✓	
	Very low	-1		
Visual guidance, traffic control	Poor	0.5		**0**
	Good	0	✓	
	Very good	-0.5		
			Total	**3**
			Class	**C3** [6]

[6] Class = 6 - Total

Class P

Table 32: Pedestrian and low speed traffic areas lighting classification system (CIE)

Class	L_{av} (lx)	L_{min} (lx)	TI[7]	Additional Requirements for facial recognition	
				$E_{v,min}$	$E_{sc,min}$
P1	15	3.0	20%	5.0	3.0
P2	10	2.0	25%	3.0	2.0
P3	7.5	1.5	25%	2.5	1.5
P4	5.0	1.0	30%	1.5	1.0
P5	3.0	0.6	30%	1.0	0.6
P6	2.0	0.4	35%	0.6	0.4

[7] Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) and conflict areas (C classes) are of importance

Table 33: Selection of category M lighting class with example illustrated

Parameter	Options	Weighting Value	Check	Value
Speed	Low	1		**0**
	Very low	0	✓	
Traffic Volume	Very High	1		**0**
	High	0.5		
	Moderate	0	✓	
	Low	-0.5		
	Very Low	-1		
Traffic composition	Pedestrians, cyclists & motorized	1		**0**
	Pedestrians & motorized	0.5		
	Pedestrians & cyclists	0.5		
	Cyclists	0		
	Pedestrians	0	✓	
Parked vehicles	Present	0.5	✓	**1**
	Not present	0		
Ambient luminance	Very high	1	✓	**1**
	High	0.5		
	Moderate	0		
	Low	-0.5		
	Very low	-1		
Facial recognition	Necessary	Add. requirements		
	Not necessary	No add. requirements	✓	
			Total	**2**
			Class	**P4**[8]

[8] Class = 6 - Total

Attachment II: Lamination Requirements in CIE 118:2007

Table 34: Lamination requirements in developing countries (CIE)

Class	L_{avg}	Uo
Residential areas, pedestrians & many non-motorized vehicles	1-2 lux	0.2
Largely residential, but some motorized vehicles	4-5 lux	0.2
Major access roads, distributors and minor main roads	8 lux	0.4
Important rural and urban traffic routes	15 lux	0.4
High-speed roads, dual carriageways	25 lux	0.4

Attachment III: Technical Requirements in EN 31201 Standards

Table 35: Recommended specifications for ME classes in BS EN

Class	Luminance of road surface in dry condition			
	L_{av} (cd/m^2)	Uo	Ul	TI
ME1	2.0	40%	70%	10%
ME2	1.5	40%	70%	10%
ME3a	1.0	40%	70%	15%
ME3b	1.0	40%	60%	15%
ME3c	1.0	40%	50%	15%
ME4a	0.75	40%	60%	15%
ME4b	0.75	40%	50%	15%
ME5	0.5	35%	40%	15%
ME6	0.3	35%	40%	15%

Table 36: Selection of ME lighting classes for traffic routes

Type	Description	Detailed description	ADT	Class
Motorway	Limited Access	Routes for fast long distance traffic. Fully grade-separated and restrictions on use		
		• Main carriageway in complex interchange areas	≤ 40,000	ME1
			> 40,000	ME1
		• Main carriageway with interchanges <3km	≤ 40,000	ME2
			> 40,000	ME1
		• Main carriageway with interchanges ≥3km	≤ 40,000	ME2
			> 40,000	ME2
		• Emergency lanes	-	M4a
Strategic Route	Trunk and some principal “A” roads between primary destinations	Routes for fast long distance with little pedestrian traffic. Speed limits in excess of 65 km/h with few junctions. Pedestrian crossings segregated or controlled, parked vehicles prohibited		
		• Single carriageways	≤ 15,000	ME3a
			> 15,000	ME2
		• Dual carriageways	≤ 15,000	ME3a
			> 15,000	ME2

Main Distributor	Major urban network and inter-primary links Short- to medium- distance traffic	Routes between strategic routes & linking urban centres to strategic network with limited frontage access. In urban areas speed limits usually 65 km/h or less, parking restricted at peak times with positive measures for pedestrian safety reasons.		
		• Single carriageways	≤ 15,000	ME3a
			> 15,000	ME2
		• Dual carriageways	≤ 15,000	ME3a
			> 15,000	ME2
Secondary distributor	Classified Road (B and C class) and unclassified urban bus route, carrying local traffic with frontage access and frequent junctions	Rural areas (Zone E1/2d) These roads link larger villages to strategic and Main Distributor Network.	≤ 7,000	ME4a
			> 7,000 ≤15,000	ME3b
			>15,000	ME3a
		Urban areas (Zone E3d) Speed limits 48 km/h, high pedestrian activity, crossing facilities, unrestricted parking except for safety	≤ 7,000	ME3c
			> 7,000 ≤15,000	ME3b
			>15,000	ME2
Link road	Road linking between Main and Secondary Distribution Network with frontage access and frequent junctions local traffic with frontage access and frequent junctions	Rural areas (Zone E1/2d) Linking smaller villages to distributor network. Vary in width, not always capable of carrying two-way traffic.	Any	ME5
		Urban areas (Zone E3d) Residential or industrial interconnecting roads, 48 km/h speed limits, random pedestrian movements, uncontrolled parking	Any	ME4b or S2
			Pedestrian traffic	S1

Attachment IV: Lamination Requirements in ANSI/IESNA RP-8

Table 37: Lamination requirements in different roads (ANSI/IESNA)

Road & Pedestrian Conflict Area		Pavement Classification (lx)			U_O	$L_{v,max}/L_{avg}$
Road	**Pedestrian conflict**	**R1**	**R2 & R3**	**R4**		
Freeway Class A	N/A	6	9	8	3.0	0.3
Freeway Class B	N/A	4	6	5	3.0	0.3
Expressway	High	10	14	13	3.0	0.3
	Medium	8	12	10	3.0	0.3
	Low	6	9	8	3.0	0.3
Major	High	12	17	15	3.0	0.3
	Medium	9	13	11	3.0	0.3
	Low	6	9	8	3.0	0.3
Collector	High	8	12	10	4.0	0.4
	Medium	6	9	8	4.0	0.4
	Low	4	6	5	4.0	0.4
Local	High	6	9	8	6.0	0.4
	Medium	5	7	6	6.0	0.4
	Low	3	4	4	6.0	0.4

Attachment V: Extrapolation methodology to quantify PSL in Lebanon

Table 38: Extrapolation for municipal PSL

Available Data				Extrapolation		
District	**Municip.**	**Lamps**	**Watts**	**Municip.**	**Lamps**	**Watts**
North	43	42,418	9,362,925	100	98,647	21,774,244
South	44	19,155	4,718,950	200	87,068	21,449,773
Beirut	0	0	0	0	-	-
Mount Lebanon	81	24,965	6,384,835	500	154,107	39,412,562
Nabatieh	9	6,640	1,687,500	300	221,333	56,250,000
Bekaa	74	32,528	6,387,244	200	87,914	17,262,822
Baalbeck	3	727	162,450	200	48,467	10,830,000
TOTAL	**254**	**126,433**	**28,703,904**	**1,500**	**697,535**	**166,979,400**

Attachment VI: Detailed cash flow for different solutions

L1				

LED-G-C1	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($34,000)	$0	($34,000)	($34,000)
1	$0	$4,091	$4,091	($29,909)
2	$0	$4,091	$4,091	($25,818)
3	$0	$4,091	$4,091	($21,727)
4	$0	$4,091	$4,091	($17,636)
5	$0	$4,091	$4,091	($13,545)
6	$0	$4,091	$4,091	($9,454)
7	$0	$4,091	$4,091	($5,363)
8	$0	$4,091	$4,091	($1,272)
9	$0	$4,091	$4,091	$2,819
10	$0	$4,091	$4,091	$6,909
11	$0	$4,091	$4,091	$11,000
12	$0	$4,091	$4,091	$15,091
13	$0	$4,091	$4,091	$19,182
14	$0	$4,091	$4,091	$23,273
15	($17,500)	$4,091	($13,409)	$9,864
16	$0	$4,091	$4,091	$13,955
17	$0	$4,091	$4,091	$18,046
18	$0	$4,091	$4,091	$22,137
19	$0	$4,091	$4,091	$26,228
20	$0	$4,091	$4,091	$30,319
	NPV	$2,996.77	IRR	8%

LED-G-C1	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($16,500)	$0	($16,500)	($16,500)
1	$0	$4,091	$4,091	($12,409)
2	$0	$4,091	$4,091	($8,318)
3	$0	$4,091	$4,091	($4,227)
4	$0	$4,091	$4,091	($136)
5	$0	$4,091	$4,091	$3,955
6	$0	$4,091	$4,091	$8,046
7	$0	$4,091	$4,091	$12,137
8	$0	$4,091	$4,091	$16,228
9	$0	$4,091	$4,091	$20,319
10	$0	$4,091	$4,091	$24,409
11	$0	$4,091	$4,091	$28,500
12	$0	$4,091	$4,091	$32,591
13	$0	$4,091	$4,091	$36,682
14	$0	$4,091	$4,091	$40,773
15	($17,500)	$4,091	($13,409)	$27,364
16	$0	$4,091	$4,091	$31,455
17	$0	$4,091	$4,091	$35,546
18	$0	$4,091	$4,091	$39,637
19	$0	$4,091	$4,091	$43,728
20	$0	$4,091	$4,091	$47,819
	NPV	$20,496.77	IRR	23%

LED-P-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($67,930)	$0	($67,930)	($67,930)
1	$0	$6,437	$6,437	($61,493)
2	$0	$6,437	$6,437	($55,056)
3	$0	$6,437	$6,437	($48,619)
4	$0	$6,437	$6,437	($42,182)
5	$0	$6,437	$6,437	($35,744)
6	$0	$6,437	$6,437	($29,307)
7	$0	$6,437	$6,437	($22,870)
8	$0	$6,437	$6,437	($16,433)
9	$0	$6,437	$6,437	($9,996)
10	$0	$6,437	$6,437	($3,559)
11	$0	$6,437	$6,437	$2,878
12	$0	$6,437	$6,437	$9,316
13	$0	$6,437	$6,437	$15,753
14	$0	$6,437	$6,437	$22,190
15	$0	$6,437	$6,437	$28,627
16	$0	$6,437	$6,437	$35,064
17	$0	$6,437	$6,437	$41,501
18	($40,000)	$6,437	($33,563)	$7,938
19	$0	$6,437	$6,437	$14,375
20	$0	$6,437	$6,437	$20,813
	NPV	($11,569.56)	IRR	4%

LED-P-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($50,430)	$0	($50,430)	($50,430)
1	$0	$6,437	$6,437	($43,993)
2	$0	$6,437	$6,437	($37,556)
3	$0	$6,437	$6,437	($31,119)
4	$0	$6,437	$6,437	($24,682)
5	$0	$6,437	$6,437	($18,244)
6	$0	$6,437	$6,437	($11,807)
7	$0	$6,437	$6,437	($5,370)
8	$0	$6,437	$6,437	$1,067
9	$0	$6,437	$6,437	$7,504
10	$0	$6,437	$6,437	$13,941
11	$0	$6,437	$6,437	$20,378
12	$0	$6,437	$6,437	$26,816
13	$0	$6,437	$6,437	$33,253
14	$0	$6,437	$6,437	$39,690
15	$0	$6,437	$6,437	$46,127
16	$0	$6,437	$6,437	$52,564
17	$0	$6,437	$6,437	$59,001
18	($40,000)	$6,437	($33,563)	$25,438
19	$0	$6,437	$6,437	$31,875
20	$0	$6,437	$6,437	$38,313
	NPV	$5,930.44	IRR	9%

LED-G-C2	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($31,000)	$0	($31,000)	($31,000)
1	$0	$5,484	$5,484	($25,516)
2	$0	$5,484	$5,484	($20,031)
3	$0	$5,484	$5,484	($14,547)
4	$0	$5,484	$5,484	($9,062)
5	$0	$5,484	$5,484	($3,578)
6	$0	$5,484	$5,484	$1,907
7	$0	$5,484	$5,484	$7,391
8	$0	$5,484	$5,484	$12,876
9	$0	$5,484	$5,484	$18,360
10	$0	$5,484	$5,484	$23,845
11	$0	$5,484	$5,484	$29,329
12	$0	$5,484	$5,484	$34,814
13	$0	$5,484	$5,484	$40,298
14	$0	$5,484	$5,484	$45,782
15	$0	$5,484	$5,484	$51,267
16	$0	$5,484	$5,484	$56,751
17	$0	$5,484	$5,484	$62,236
18	($31,000)	$5,484	($25,516)	$36,720
19	$0	$5,484	$5,484	$42,205
20	$0	$5,484	$5,484	$47,689
	NPV	**$17,930.67**	**IRR**	**16%**

LED-G-C2	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($16,909)	$0	($16,909)	($16,909)
1	$0	$5,484	$5,484	($11,425)
2	$0	$5,484	$5,484	($5,940)
3	$0	$5,484	$5,484	($456)
4	$0	$5,484	$5,484	$5,029
5	$0	$5,484	$5,484	$10,513
6	$0	$5,484	$5,484	$15,998
7	$0	$5,484	$5,484	$21,482
8	$0	$5,484	$5,484	$26,967
9	$0	$5,484	$5,484	$32,451
10	$0	$5,484	$5,484	$37,936
11	$0	$5,484	$5,484	$43,420
12	$0	$5,484	$5,484	$48,904
13	$0	$5,484	$5,484	$54,389
14	$0	$5,484	$5,484	$59,873
15	$0	$5,484	$5,484	$65,358
16	$0	$5,484	$5,484	$70,842
17	$0	$5,484	$5,484	$76,327
18	($31,000)	$5,484	($25,516)	$50,811
19	$0	$5,484	$5,484	$56,296
20	$0	$5,484	$5,484	$61,780
	NPV	**$32,021.58**	**IRR**	**32%**

L2

LED-G-C1	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($27,000)	$0	($27,000)	($27,000)
1	$0	$4,511	$4,511	($22,489)
2	$0	$4,511	$4,511	($17,978)
3	$0	$4,511	$4,511	($13,467)
4	$0	$4,511	$4,511	($8,955)
5	$0	$4,511	$4,511	($4,444)
6	$0	$4,511	$4,511	$67
7	$0	$4,511	$4,511	$4,578
8	$0	$4,511	$4,511	$9,089
9	$0	$4,511	$4,511	$13,600
10	$0	$4,511	$4,511	$18,111
11	$0	$4,511	$4,511	$22,622
12	$0	$4,511	$4,511	$27,134
13	$0	$4,511	$4,511	$31,645
14	$0	$4,511	$4,511	$36,156
15	$0	$4,511	$4,511	$40,667
16	$0	$4,511	$4,511	$45,178
17	$0	$4,511	$4,511	$49,689
18	($14,091)	$4,511	($9,580)	$40,109
19	$0	$4,511	$4,511	$44,621
20	$0	$4,511	$4,511	$49,132
	NPV	$16,621.95	IRR	15%

LED-G-C1	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($12,909)	$0	($12,909)	($12,909)
1	$0	$4,511	$4,511	($8,398)
2	$0	$4,511	$4,511	($3,887)
3	$0	$4,511	$4,511	$624
4	$0	$4,511	$4,511	$5,135
5	$0	$4,511	$4,511	$9,647
6	$0	$4,511	$4,511	$14,158
7	$0	$4,511	$4,511	$18,669
8	$0	$4,511	$4,511	$23,180
9	$0	$4,511	$4,511	$27,691
10	$0	$4,511	$4,511	$32,202
11	$0	$4,511	$4,511	$36,713
12	$0	$4,511	$4,511	$41,224
13	$0	$4,511	$4,511	$45,736
14	$0	$4,511	$4,511	$50,247
15	$0	$4,511	$4,511	$54,758
16	$0	$4,511	$4,511	$59,269
17	$0	$4,511	$4,511	$63,780
18	($14,091)	$4,511	($9,580)	$54,200
19	$0	$4,511	$4,511	$58,711
20	$0	$4,511	$4,511	$63,223
	NPV	$30,712.86	IRR	35%

LED-P-C2	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($55,570)	$0	($55,570)	($55,570)
1	$0	$6,406	$6,406	($49,164)
2	$0	$6,406	$6,406	($42,759)
3	$0	$6,406	$6,406	($36,353)
4	$0	$6,406	$6,406	($29,947)
5	$0	$6,406	$6,406	($23,542)
6	$0	$6,406	$6,406	($17,136)
7	$0	$6,406	$6,406	($10,730)
8	$0	$6,406	$6,406	($4,325)
9	$0	$6,406	$6,406	$2,081
10	$0	$6,406	$6,406	$8,487
11	$0	$6,406	$6,406	$14,892
12	$0	$6,406	$6,406	$21,298
13	$0	$6,406	$6,406	$27,704
14	$0	$6,406	$6,406	$34,110
15	$0	$6,406	$6,406	$40,515
16	$0	$6,406	$6,406	$46,921
17	$0	$6,406	$6,406	$53,327
18	($31,000)	$6,406	($24,594)	$28,732
19	$0	$6,406	$6,406	$35,138
20	$0	$6,406	$6,406	$41,544
	NPV	**$3,120.07**	**IRR**	**8%**

LED-P-C2	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($41,479)	$0	($41,479)	($41,479)
1	$0	$6,406	$6,406	($35,073)
2	$0	$6,406	$6,406	($28,668)
3	$0	$6,406	$6,406	($22,262)
4	$0	$6,406	$6,406	($15,856)
5	$0	$6,406	$6,406	($9,451)
6	$0	$6,406	$6,406	($3,045)
7	$0	$6,406	$6,406	$3,361
8	$0	$6,406	$6,406	$9,766
9	$0	$6,406	$6,406	$16,172
10	$0	$6,406	$6,406	$22,578
11	$0	$6,406	$6,406	$28,983
12	$0	$6,406	$6,406	$35,389
13	$0	$6,406	$6,406	$41,795
14	$0	$6,406	$6,406	$48,200
15	$0	$6,406	$6,406	$54,606
16	$0	$6,406	$6,406	$61,012
17	$0	$6,406	$6,406	$67,417
18	($31,000)	$6,406	($24,594)	$42,823
19	$0	$6,406	$6,406	$49,229
20	$0	$6,406	$6,406	$55,634
	NPV	**$17,210.98**	**IRR**	**13%**

L3				

LED-G-C1	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($24,444)	$0	($24,444)	($24,444)
1	$0	$2,699	$2,699	($21,745)
2	$0	$2,699	$2,699	($19,046)
3	$0	$2,699	$2,699	($16,347)
4	$0	$2,699	$2,699	($13,648)
5	$0	$2,699	$2,699	($10,948)
6	$0	$2,699	$2,699	($8,249)
7	$0	$2,699	$2,699	($5,550)
8	$0	$2,699	$2,699	($2,851)
9	$0	$2,699	$2,699	($151)
10	$0	$2,699	$2,699	$2,548
11	$0	$2,699	$2,699	$5,247
12	$0	$2,699	$2,699	$7,946
13	$0	$2,699	$2,699	$10,645
14	$0	$2,699	$2,699	$13,345
15	($9,706)	$2,699	($7,007)	$6,338
16	$0	$2,699	$2,699	$9,037
17	$0	$2,699	$2,699	$11,736
18	$0	$2,699	$2,699	$14,436
19	$0	$2,699	$2,699	$17,135
20	$0	$2,699	$2,699	$19,834
	NPV	**$633.26**	**IRR**	**7%**

LED-G-C1	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($14,739)	$0	($14,739)	($14,739)
1	$0	$2,699	$2,699	($12,039)
2	$0	$2,699	$2,699	($9,340)
3	$0	$2,699	$2,699	($6,641)
4	$0	$2,699	$2,699	($3,942)
5	$0	$2,699	$2,699	($1,242)
6	$0	$2,699	$2,699	$1,457
7	$0	$2,699	$2,699	$4,156
8	$0	$2,699	$2,699	$6,855
9	$0	$2,699	$2,699	$9,554
10	$0	$2,699	$2,699	$12,254
11	$0	$2,699	$2,699	$14,953
12	$0	$2,699	$2,699	$17,652
13	$0	$2,699	$2,699	$20,351
14	$0	$2,699	$2,699	$23,050
15	($9,706)	$2,699	($7,007)	$16,044
16	$0	$2,699	$2,699	$18,743
17	$0	$2,699	$2,699	$21,442
18	$0	$2,699	$2,699	$24,141
19	$0	$2,699	$2,699	$26,841
20	$0	$2,699	$2,699	$29,540
	NPV	**$10,339.14**	**IRR**	**16%**

L3				

LED-G-C1	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($24,444)	$0	($24,444)	($24,444)
1	$0	$2,699	$2,699	($21,745)
2	$0	$2,699	$2,699	($19,046)
3	$0	$2,699	$2,699	($16,347)
4	$0	$2,699	$2,699	($13,648)
5	$0	$2,699	$2,699	($10,948)
6	$0	$2,699	$2,699	($8,249)
7	$0	$2,699	$2,699	($5,550)
8	$0	$2,699	$2,699	($2,851)
9	$0	$2,699	$2,699	($151)
10	$0	$2,699	$2,699	$2,548
11	$0	$2,699	$2,699	$5,247
12	$0	$2,699	$2,699	$7,946
13	$0	$2,699	$2,699	$10,645
14	$0	$2,699	$2,699	$13,345
15	($9,706)	$2,699	($7,007)	$6,338
16	$0	$2,699	$2,699	$9,037
17	$0	$2,699	$2,699	$11,736
18	$0	$2,699	$2,699	$14,436
19	$0	$2,699	$2,699	$17,135
20	$0	$2,699	$2,699	$19,834
	NPV	**$633.26**	**IRR**	**7%**

LED-G-C1	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($14,739)	$0	($14,739)	($14,739)
1	$0	$2,699	$2,699	($12,039)
2	$0	$2,699	$2,699	($9,340)
3	$0	$2,699	$2,699	($6,641)
4	$0	$2,699	$2,699	($3,942)
5	$0	$2,699	$2,699	($1,242)
6	$0	$2,699	$2,699	$1,457
7	$0	$2,699	$2,699	$4,156
8	$0	$2,699	$2,699	$6,855
9	$0	$2,699	$2,699	$9,554
10	$0	$2,699	$2,699	$12,254
11	$0	$2,699	$2,699	$14,953
12	$0	$2,699	$2,699	$17,652
13	$0	$2,699	$2,699	$20,351
14	$0	$2,699	$2,699	$23,050
15	($9,706)	$2,699	($7,007)	$16,044
16	$0	$2,699	$2,699	$18,743
17	$0	$2,699	$2,699	$21,442
18	$0	$2,699	$2,699	$24,141
19	$0	$2,699	$2,699	$26,841
20	$0	$2,699	$2,699	$29,540
	NPV	**$10,339.14**	**IRR**	**16%**

LED-P-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($65,578)	$0	($65,578)	($65,578)
1	$0	$5,649	$5,649	($59,928)
2	$0	$5,649	$5,649	($54,279)
3	$0	$5,649	$5,649	($48,630)
4	$0	$5,649	$5,649	($42,980)
5	$0	$5,649	$5,649	($37,331)
6	$0	$5,649	$5,649	($31,682)
7	$0	$5,649	$5,649	($26,033)
8	$0	$5,649	$5,649	($20,383)
9	$0	$5,649	$5,649	($14,734)
10	$0	$5,649	$5,649	($9,085)
11	$0	$5,649	$5,649	($3,435)
12	$0	$5,649	$5,649	$2,214
13	$0	$5,649	$5,649	$7,863
14	$0	$5,649	$5,649	$13,513
15	$0	$5,649	$5,649	$19,162
16	$0	$5,649	$5,649	$24,811
17	$0	$5,649	$5,649	$30,461
18	($27,778)	$5,649	($22,128)	$8,332
19	$0	$5,649	$5,649	$13,982
20	$0	$5,649	$5,649	$19,631
	NPV	($13,947.24)	IRR	3%

LED-P-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($55,872)	$0	($55,872)	($55,872)
1	$0	$5,649	$5,649	($50,223)
2	$0	$5,649	$5,649	($44,573)
3	$0	$5,649	$5,649	($38,924)
4	$0	$5,649	$5,649	($33,275)
5	$0	$5,649	$5,649	($27,625)
6	$0	$5,649	$5,649	($21,976)
7	$0	$5,649	$5,649	($16,327)
8	$0	$5,649	$5,649	($10,677)
9	$0	$5,649	$5,649	($5,028)
10	$0	$5,649	$5,649	$621
11	$0	$5,649	$5,649	$6,271
12	$0	$5,649	$5,649	$11,920
13	$0	$5,649	$5,649	$17,569
14	$0	$5,649	$5,649	$23,219
15	$0	$5,649	$5,649	$28,868
16	$0	$5,649	$5,649	$34,517
17	$0	$5,649	$5,649	$40,167
18	($27,778)	$5,649	($22,128)	$18,038
19	$0	$5,649	$5,649	$23,687
20	$0	$5,649	$5,649	$29,337
	NPV	($4,241.36)	IRR	6%

LED-G-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($27,778)	$0	($27,778)	($27,778)
1	$0	$3,931	$3,931	($23,847)
2	$0	$3,931	$3,931	($19,917)
3	$0	$3,931	$3,931	($15,986)
4	$0	$3,931	$3,931	($12,055)
5	$0	$3,931	$3,931	($8,125)
6	$0	$3,931	$3,931	($4,194)
7	$0	$3,931	$3,931	($263)
8	$0	$3,931	$3,931	$3,667
9	$0	$3,931	$3,931	$7,598
10	$0	$3,931	$3,931	$11,528
11	$0	$3,931	$3,931	$15,459
12	$0	$3,931	$3,931	$19,390
13	$0	$3,931	$3,931	$23,320
14	$0	$3,931	$3,931	$27,251
15	$0	$3,931	$3,931	$31,182
16	$0	$3,931	$3,931	$35,112
17	$0	$3,931	$3,931	$39,043
18	($27,778)	$3,931	($23,847)	$15,196
19	$0	$3,931	$3,931	$19,126
20	$0	$3,931	$3,931	$23,057
	NPV	$5,644.85	IRR	10%

LED-G-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($18,072)	$0	($18,072)	($18,072)
1	$0	$3,931	$3,931	($14,141)
2	$0	$3,931	$3,931	($10,211)
3	$0	$3,931	$3,931	($6,280)
4	$0	$3,931	$3,931	($2,349)
5	$0	$3,931	$3,931	$1,581
6	$0	$3,931	$3,931	$5,512
7	$0	$3,931	$3,931	$9,442
8	$0	$3,931	$3,931	$13,373
9	$0	$3,931	$3,931	$17,304
10	$0	$3,931	$3,931	$21,234
11	$0	$3,931	$3,931	$25,165
12	$0	$3,931	$3,931	$29,096
13	$0	$3,931	$3,931	$33,026
14	$0	$3,931	$3,931	$36,957
15	$0	$3,931	$3,931	$40,887
16	$0	$3,931	$3,931	$44,818
17	$0	$3,931	$3,931	$48,749
18	($27,778)	$3,931	($23,847)	$24,902
19	$0	$3,931	$3,931	$28,832
20	$0	$3,931	$3,931	$32,763
	NPV	$15,350.74	IRR	20%

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LED-G-C1	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($27,222)	$0	($27,222)	($27,222)
1	$0	$3,003	$3,003	($24,220)
2	$0	$3,003	$3,003	($21,217)
3	$0	$3,003	$3,003	($18,214)
4	$0	$3,003	$3,003	($15,211)
5	$0	$3,003	$3,003	($12,209)
6	$0	$3,003	$3,003	($9,206)
7	$0	$3,003	$3,003	($6,203)
8	$0	$3,003	$3,003	($3,201)
9	$0	$3,003	$3,003	($198)
10	$0	$3,003	$3,003	$2,805
11	$0	$3,003	$3,003	$5,808
12	$0	$3,003	$3,003	$8,810
13	$0	$3,003	$3,003	$11,813
14	$0	$3,003	$3,003	$14,816
15	($8,571)	$3,003	($5,569)	$9,247
16	$0	$3,003	$3,003	$12,250
17	$0	$3,003	$3,003	$15,252
18	$0	$3,003	$3,003	$18,255
19	$0	$3,003	$3,003	$21,258
20	$0	$3,003	$3,003	$24,260
	NPV	**$1,481.81**	**IRR**	**8%**

LED-G-C1	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($18,651)	$0	($18,651)	($18,651)
1	$0	$3,003	$3,003	($15,648)
2	$0	$3,003	$3,003	($12,645)
3	$0	$3,003	$3,003	($9,643)
4	$0	$3,003	$3,003	($6,640)
5	$0	$3,003	$3,003	($3,637)
6	$0	$3,003	$3,003	($635)
7	$0	$3,003	$3,003	$2,368
8	$0	$3,003	$3,003	$5,371
9	$0	$3,003	$3,003	$8,374
10	$0	$3,003	$3,003	$11,376
11	$0	$3,003	$3,003	$14,379
12	$0	$3,003	$3,003	$17,382
13	$0	$3,003	$3,003	$20,384
14	$0	$3,003	$3,003	$23,387
15	($8,571)	$3,003	($5,569)	$17,818
16	$0	$3,003	$3,003	$20,821
17	$0	$3,003	$3,003	$23,824
18	$0	$3,003	$3,003	$26,826
19	$0	$3,003	$3,003	$29,829
20	$0	$3,003	$3,003	$32,832
	NPV	**$10,053.24**	**IRR**	**14%**

LED-G-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($30,556)	$0	($30,556)	($30,556)
1	$0	$4,434	$4,434	($26,122)
2	$0	$4,434	$4,434	($21,688)
3	$0	$4,434	$4,434	($17,253)
4	$0	$4,434	$4,434	($12,819)
5	$0	$4,434	$4,434	($8,385)
6	$0	$4,434	$4,434	($3,951)
7	$0	$4,434	$4,434	$483
8	$0	$4,434	$4,434	$4,917
9	$0	$4,434	$4,434	$9,351
10	$0	$4,434	$4,434	$13,785
11	$0	$4,434	$4,434	$18,219
12	$0	$4,434	$4,434	$22,653
13	$0	$4,434	$4,434	$27,087
14	$0	$4,434	$4,434	$31,521
15	$0	$4,434	$4,434	$35,955
16	$0	$4,434	$4,434	$40,389
17	$0	$4,434	$4,434	$44,823
18	($30,556)	$4,434	($26,122)	$18,701
19	$0	$4,434	$4,434	$23,135
20	$0	$4,434	$4,434	$27,569
	NPV	$7,378.25	IRR	11%

LED-G-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($21,984)	$0	($21,984)	($21,984)
1	$0	$4,434	$4,434	($17,550)
2	$0	$4,434	$4,434	($13,116)
3	$0	$4,434	$4,434	($8,682)
4	$0	$4,434	$4,434	($4,248)
5	$0	$4,434	$4,434	$186
6	$0	$4,434	$4,434	$4,620
7	$0	$4,434	$4,434	$9,054
8	$0	$4,434	$4,434	$13,488
9	$0	$4,434	$4,434	$17,922
10	$0	$4,434	$4,434	$22,356
11	$0	$4,434	$4,434	$26,790
12	$0	$4,434	$4,434	$31,224
13	$0	$4,434	$4,434	$35,658
14	$0	$4,434	$4,434	$40,092
15	$0	$4,434	$4,434	$44,526
16	$0	$4,434	$4,434	$48,960
17	$0	$4,434	$4,434	$53,394
18	($30,556)	$4,434	($26,122)	$27,273
19	$0	$4,434	$4,434	$31,707
20	$0	$4,434	$4,434	$36,141
	NPV	$15,949.68	IRR	18%

LED-P-C2	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($74,189)	$0	($74,189)	($74,189)
1	$0	$6,628	$6,628	($67,561)
2	$0	$6,628	$6,628	($60,933)
3	$0	$6,628	$6,628	($54,304)
4	$0	$6,628	$6,628	($47,676)
5	$0	$6,628	$6,628	($41,048)
6	$0	$6,628	$6,628	($34,420)
7	$0	$6,628	$6,628	($27,792)
8	$0	$6,628	$6,628	($21,164)
9	$0	$6,628	$6,628	($14,536)
10	$0	$6,628	$6,628	($7,907)
11	$0	$6,628	$6,628	($1,279)
12	$0	$6,628	$6,628	$5,349
13	$0	$6,628	$6,628	$11,977
14	$0	$6,628	$6,628	$18,605
15	$0	$6,628	$6,628	$25,233
16	$0	$6,628	$6,628	$31,861
17	$0	$6,628	$6,628	$38,490
18	($30,556)	$6,628	($23,927)	$14,562
19	$0	$6,628	$6,628	$21,190
20	$0	$6,628	$6,628	$27,818
	NPV	**($13,010.54)**	**IRR**	**4%**

LED-P-C2	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($65,617)	$0	($65,617)	($65,617)
1	$0	$6,628	$6,628	($58,989)
2	$0	$6,628	$6,628	($52,361)
3	$0	$6,628	$6,628	($45,733)
4	$0	$6,628	$6,628	($39,105)
5	$0	$6,628	$6,628	($32,477)
6	$0	$6,628	$6,628	($25,849)
7	$0	$6,628	$6,628	($19,220)
8	$0	$6,628	$6,628	($12,592)
9	$0	$6,628	$6,628	($5,964)
10	$0	$6,628	$6,628	$664
11	$0	$6,628	$6,628	$7,292
12	$0	$6,628	$6,628	$13,920
13	$0	$6,628	$6,628	$20,548
14	$0	$6,628	$6,628	$27,177
15	$0	$6,628	$6,628	$33,805
16	$0	$6,628	$6,628	$40,433
17	$0	$6,628	$6,628	$47,061
18	($30,556)	$6,628	($23,927)	$23,134
19	$0	$6,628	$6,628	$29,762
20	$0	$6,628	$6,628	$36,390
	NPV	**($4,439.11)**	**IRR**	**6%**

L5

LED-G-C1	Retrofit			
Year	**Investment**	**O&M Saving**	**Net Cash Flow**	**Net Cumulative**
0	($24,545)	$0	($24,545)	($24,545)
1	$0	$4,311	$4,311	($20,234)
2	$0	$4,311	$4,311	($15,923)
3	$0	$4,311	$4,311	($11,612)
4	$0	$4,311	$4,311	($7,301)
5	$0	$4,311	$4,311	($2,990)
6	$0	$4,311	$4,311	$1,321
7	$0	$4,311	$4,311	$5,633
8	$0	$4,311	$4,311	$9,944
9	$0	$4,311	$4,311	$14,255
10	$0	$4,311	$4,311	$18,566
11	$0	$4,311	$4,311	$22,877
12	$0	$4,311	$4,311	$27,188
13	$0	$4,311	$4,311	$31,500
14	$0	$4,311	$4,311	$35,811
15	($7,143)	$4,311	($2,832)	$32,979
16	$0	$4,311	$4,311	$37,290
17	$0	$4,311	$4,311	$41,601
18	$0	$4,311	$4,311	$45,913
19	$0	$4,311	$4,311	$50,224
20	$0	$4,311	$4,311	$54,535
	NPV	**$18,538.10**	**IRR**	**16%**

LED-G-C1	New Installations			
Year	**Investment**	**O&M**	**Net Cash Flow**	**Net Cumulative**
0	($17,403)	$0	($17,403)	($17,403)
1	$0	$4,311	$4,311	($13,091)
2	$0	$4,311	$4,311	($8,780)
3	$0	$4,311	$4,311	($4,469)
4	$0	$4,311	$4,311	($158)
5	$0	$4,311	$4,311	$4,153
6	$0	$4,311	$4,311	$8,464
7	$0	$4,311	$4,311	$12,775
8	$0	$4,311	$4,311	$17,087
9	$0	$4,311	$4,311	$21,398
10	$0	$4,311	$4,311	$25,709
11	$0	$4,311	$4,311	$30,020
12	$0	$4,311	$4,311	$34,331
13	$0	$4,311	$4,311	$38,642
14	$0	$4,311	$4,311	$42,954
15	($7,143)	$4,311	($2,832)	$40,122
16	$0	$4,311	$4,311	$44,433
17	$0	$4,311	$4,311	$48,744
18	$0	$4,311	$4,311	$53,055
19	$0	$4,311	$4,311	$57,367
20	$0	$4,311	$4,311	$61,678
	NPV	**$25,680.96**	**IRR**	**24%**

LED-G-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($27,273)	$0	($27,273)	($27,273)
1	$0	$5,693	$5,693	($21,580)
2	$0	$5,693	$5,693	($15,888)
3	$0	$5,693	$5,693	($10,195)
4	$0	$5,693	$5,693	($4,503)
5	$0	$5,693	$5,693	$1,190
6	$0	$5,693	$5,693	$6,882
7	$0	$5,693	$5,693	$12,575
8	$0	$5,693	$5,693	$18,267
9	$0	$5,693	$5,693	$23,960
10	$0	$5,693	$5,693	$29,652
11	$0	$5,693	$5,693	$35,345
12	$0	$5,693	$5,693	$41,037
13	$0	$5,693	$5,693	$46,730
14	$0	$5,693	$5,693	$52,422
15	$0	$5,693	$5,693	$58,115
16	$0	$5,693	$5,693	$63,807
17	$0	$5,693	$5,693	$69,500
18	($27,273)	$5,693	($21,580)	$47,920
19	$0	$5,693	$5,693	$53,612
20	$0	$5,693	$5,693	$59,305
	NPV	$24,964.72	IRR	19%

LED-G-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($20,130)	$0	($20,130)	($20,130)
1	$0	$5,693	$5,693	($14,437)
2	$0	$5,693	$5,693	($8,745)
3	$0	$5,693	$5,693	($3,052)
4	$0	$5,693	$5,693	$2,640
5	$0	$5,693	$5,693	$8,333
6	$0	$5,693	$5,693	$14,025
7	$0	$5,693	$5,693	$19,718
8	$0	$5,693	$5,693	$25,410
9	$0	$5,693	$5,693	$31,103
10	$0	$5,693	$5,693	$36,795
11	$0	$5,693	$5,693	$42,488
12	$0	$5,693	$5,693	$48,180
13	$0	$5,693	$5,693	$53,873
14	$0	$5,693	$5,693	$59,565
15	$0	$5,693	$5,693	$65,258
16	$0	$5,693	$5,693	$70,950
17	$0	$5,693	$5,693	$76,643
18	($27,273)	$5,693	($21,580)	$55,062
19	$0	$5,693	$5,693	$60,755
20	$0	$5,693	$5,693	$66,447
	NPV	$32,107.58	IRR	28%

LED-P-C2	Retrofit			
Year	Investment	O&M Saving	Net Cash Flow	Net Cumulative
0	($70,705)	$0	($70,705)	($70,705)
1	$0	$8,141	$8,141	($62,563)
2	$0	$8,141	$8,141	($54,422)
3	$0	$8,141	$8,141	($46,281)
4	$0	$8,141	$8,141	($38,139)
5	$0	$8,141	$8,141	($29,998)
6	$0	$8,141	$8,141	($21,856)
7	$0	$8,141	$8,141	($13,715)
8	$0	$8,141	$8,141	($5,574)
9	$0	$8,141	$8,141	$2,568
10	$0	$8,141	$8,141	$10,709
11	$0	$8,141	$8,141	$18,850
12	$0	$8,141	$8,141	$26,992
13	$0	$8,141	$8,141	$35,133
14	$0	$8,141	$8,141	$43,274
15	$0	$8,141	$8,141	$51,416
16	$0	$8,141	$8,141	$59,557
17	$0	$8,141	$8,141	$67,698
18	($27,273)	$8,141	($19,131)	$48,567
19	$0	$8,141	$8,141	$56,708
20	$0	$8,141	$8,141	$64,850
	NPV	$7,475.99	IRR	9%

LED-P-C2	New Installations			
Year	Investment	O&M	Net Cash Flow	Net Cumulative
0	($63,562)	$0	($63,562)	($63,562)
1	$0	$8,141	$8,141	($55,420)
2	$0	$8,141	$8,141	($47,279)
3	$0	$8,141	$8,141	($39,138)
4	$0	$8,141	$8,141	($30,996)
5	$0	$8,141	$8,141	($22,855)
6	$0	$8,141	$8,141	($14,714)
7	$0	$8,141	$8,141	($6,572)
8	$0	$8,141	$8,141	$1,569
9	$0	$8,141	$8,141	$9,710
10	$0	$8,141	$8,141	$17,852
11	$0	$8,141	$8,141	$25,993
12	$0	$8,141	$8,141	$34,134
13	$0	$8,141	$8,141	$42,276
14	$0	$8,141	$8,141	$50,417
15	$0	$8,141	$8,141	$58,559
16	$0	$8,141	$8,141	$66,700
17	$0	$8,141	$8,141	$74,841
18	($27,273)	$8,141	($19,131)	$55,710
19	$0	$8,141	$8,141	$63,851
20	$0	$8,141	$8,141	$71,993
	NPV	$14,618.85	IRR	10%

APPENDICES

Appendix A: Technical specifications used in various initiatives

CEDRO, with energy efficiency on our mind

Contents

TECHNICAL SPECIFICATIONS

A- Solar Street-Lighting Systems- LVD Lamp

Typical operating condition is from down to dusk with optional dimming possibility for 50% of the time to save energy. The system must be able to operate for a maximum of 2 nights even with an overcast weather of consecutive 2 days. The system is composed of the following items:

- Solar panels
- Charger/controller
- Gel battery(s)
- Equipment storage housing
- Wire harness
- Mounting brackets (must allow variable orientation and inclination of the PV module)

The existing wooden poles are to be used due to harsh costal environment. All the poles are already installed in the harbor area. The locations of the poles are subject year round to salty environment. The poles can be in direct contact with sea water during rough weather days.

All components should be sea water resistant or located in housings that are water tight and sea water resistant. It is recommended to locate all the components on tope of the poles to minimize the exposure. If a different location is proposed valid explanation must be presented. Due the project location the following criteria applies to the installed system:

Environment requirements:

- Water resistance
- Corrosion resistance
- Wind resistance up to 130Km/h
- Operating temperature up to 55°C

Manufacturing: All items should be manufactured in plants that are ISO 9001:2000 certified. Preferably manufactured in Europe, North America or Japan.

In case some of the proposed equipments are not located on the top of the poles they must be designed to be vandal resistance.

Total system weight should be inferior to 120 Kg (Electronic components)

Where needed all metallic part should be powder painted unless they are in stainless steel or aluminum alloy.

General Specifications:

Solar Energy street lamp with highly efficient mono crystal or multi crystal silicon solar panels for power supply

- Working Voltage : 12 / 24V DC

- Lighting Time : 8 to 12 hours per day depending on the season
- Advanced charging, discharging and lighting control circuit with reliable performance
- High lighting efficiency, great brightness
- Easy installation
- Safe, reliable, energy saving, economic, environmental protection

Lamp spec:

- Lamp technology: LVD (Induction light)
- Power Rating: 40W
- Life span: > 100,000 hours
- Mean lumen : 6,800
- Mean pupil lumen : 11,000
- CRI > 80
- Color temperature: 2700, 2500 or 4100K (based on client's decision for type of color)

Lamp fixture spec:

Different lamp fixture designs can be proposed. The final choice will depend on the architectural effect on the harbors antique character. The fixture must include the following components:

- Reflector
- Closed housing
- Electronic Ballast
- Mounting brackets

Details of the proposed fixtures should be submitted with both clear designs, cut sheets and photometric performances.

PV module spec:

Type: Multi or Mono crystalline technology

Conversion Efficiency: > to 15%

Manufacturing tolerance on rated power: ≤ 3%

Module Voltage: 12V

Environment: See general description for environment requirements

Connector type: Multi Contact type possibility

Total weight: ≤ 20 KG

Cell protection: The cells should be protected by a tempered glace

Batteries spec:

The following are the minimum requirements for the battery(s):

- Maintenance free
- Gel type batteries
- No leakage
- 12V type
- Deep discharge capacity
- Expected life span over 8 years in normal operating condition

Charger controller spec:

The charger controller should be located close to the battery(s) and it should need minimum maintenance. This unit can include the automatic dusk/down switch and the dimmer/timer module. The controller should have the following protections:

- Overcharging
- Over discharging
- Overload
- Rivers current
- Thunder

B- Solar-Powered Street Lighting Systems- LED Lamp

Stand-alone photovoltaic lighting systems with highly- efficient monocrystalline or polycrystalline silicon solar panels for power supply:

- Systems to be installed on new poles
- Working Voltage: 12/24V DC
- Lighting Time: 12 hours per day
- Advanced charging, discharging and lighting control circuit with reliable performance
- High lighting efficiency, great brightness
- Easy installation
- Safe, reliable, energy saving, economic, environmental protection

The system is composed of the following items:

- Street lighting pole
- Solar panels
- Lamp

- Diming System
- Charger/ Controller
- Gel batteries
- Equipment storage casing
- Wire harness
- Mounting brackets (must allow variable orientation and inclination of the PV module)
- Protection

- The typical operating conditions are from dawn to dusk. The system must be able to operate for a maximum of 2 nights even with an overcast weather of 2 consecutive days.
- Total system weight should be inferior to 120Kg.
- The system should have a wind resistance of 120 km/s.
- IP ratings: IP65

<u>Street Lighting Pole:</u>

- Height of 6 m
- The pole must be water and corrosion resistant and have a conical shape with 30cm base
- Poles must a have a minimum thickness of 4mm
- A concrete base for the pole of $1m^3$ is required

<u>Photovoltaic Modules:</u>

The PV modules must meet the following:

- Type: Mono or Poly crystalline technology
- Rated Power: 2 x 100W (or equivalent)
- Conversion Efficiency: greater than 13%
- Module Voltage: 12 V
- PV generators shall withstand wind up to 120 km/h
- Cell Protection: cells should be protected by tempered glass
- Warranty: 5 years on material and manufacturing, and 20 years 80% power output warranty
- Product shall be tested, CE certified, ISO9000 registered

<u>Lamps:</u>

- Type of lighting: high power Light Emitting Diode LED fixture should be suitable for road lighting application, including integrated, high-efficiency LED driver
- Power Rating: 60W- 70W as long as it meets the required luminous flux
- Life Span: 50,000 hours
- Luminous Flux: minimum of 6400 lm
- Illuminance level on ground surface: 15-27 lux
- Color Temperature: between 2300-4000K
- Beam angle of 120°
- Environmental conditions: the LED fixture must work with an environmental temperature of

-10 °C to 45 °C and with a relative humidity of 50% to 95%.

- Lamp to be placed right underneath the PV panels.
- Luminous Maintenance: minimum 80% of initial lumen output after 50,000hours
- Color Rendering Index: greater or equal to 75
- Materials and Finishing: Fixture; die cast aluminum corrosion resistant parts, grey powder coat finish. LED light to be protected by clear acrylic lens, or approved equivalent
- Ingress Protection Rating: IP65
- Warranty: minimum 3 years
- Product shall be tested, CE certified, ISO9000 registered

Controller:

- Voltage and Current: 24V, 20A
- Feature: automatic dusk/ dawn switch and timer module
- Protections: overcharging, over discharging, overload, reverse current and thunder
- Product shall be tested, CE certified, ISO9000 registered
- Warranty: 2 years

Battery:

- Battery: 2 x 150 Ah, 12 V, maintenance free, gel type battery, no leakage, expected life span of 5 years in normal operating conditions
- Deep discharge capacity: 75%
- Product shall be tested, CE certified, ISO9000 registered
- Warranty: 2 years

Protection Circuit:

- Fuses should be provided for short-circuit conditions
- All electronic components must take into consideration temperature compensation issues
- Full protection against open circuit, accidental short circuit and reverse polarity should be provided
- Lightening protection circuits must be added to each system

C- LED Fixture Retrofit

- **Type of lighting:** high power Light Emitting Diode LED fixture should be suitable for road lighting application, including integrated, high-efficiency LED driver
- **Supply Source**: 220-240 volt AC. However, conditions for voltage fluctuations should be considered and the system should be robust enough to withstand such variation in supply source
- **Lamp Lifetime**: The minimum lamp life will be at least 50,000 hours of functioning.
- **Environmental conditions**: the LED fixture must work with an environmental temperature of -10 °C to 45 °C and with a relative humidity of 50% to 95%.

- **Wattage:** 90- 100W
- **Luminous Flux:** minimum 7000 lumens
- **Illuminance Level on road surface (existing poles height 8m.):** average of 10 lux. Maximum of 27lux
- **Beam Angle:** horizontal axis 120°; vertical axis 60°
- **Usage Hours:** around 10 hours per day
- **Power Factor:** greater than 0.9
- **Efficiency at Nominal Power:** greater than 0.9
- **Total Harmonics Distortion:** less than 20% based in ANSI C82
- **Frequency:** 50 Hz, ± 0.5 %.
- **Luminous Maintenance:** minimum 80% of initial lumen output after 50,000hours
- **Color Rendering Index:** greater or equal to 75
- **Correlated Color temperature:** Warm White, temperature equal to 4,000°K at nominal intensity.
- **Materials and Finishing:** Fixture; die cast aluminum corrosion resistant parts, grey powder coat finish. LED light to be protected by clear acrylic lens, or approved equivalent.
- **Ingress Protection Rating:** IP65
- **Package of the lamps**: the packages will be in English, name of the model, origin, factory, nominal voltage, lifetime, luminous flux, color temperature, color rendering.
- **Warranty**: minimum 2 years
- **Standards Required**:
- Photobiological safety of lamps according to IEC 62471
- Safety testing for LED according to EN 61347-2-13:2006
- Safety of LED: ANSI/UL 8750
- Luminaries' safety testing according to EN 60598-1 and EN 60598-2
- Harmonics: EN61000-3-2
- RoHS compliance Testing

لائحة الاسعار لاشغال انارة عامة في قضاء بنت جبيل.

رقم	تعريف الاشغال	السعر بالليرة
١	- تقديم ونقل وتركيب جهاز إنارة كامل من النوع الخارجي للإنارة العامة المعد لحمل مصباح كهربائي على الصوديوم بقدرة ١٥٠ وات للعمل بتوتر ٢٢٠ فولت. ومن النوع المحمي ضد الصدأ والمجهز بغطاء من البلاستيك أو الزجاج وذلك وفقاً للمواصفات الفنية العالمية (ISO 9001) AP65 وما فوق مصدقة حسب الاصول، وموافق عليه من قبل اللجنة الفنية في مصلحة التجهيز الكهربائي، وأن يكون العاكس الشعاعي للضوء مصنع من معدن لامع غير قابل للصدأ بما فيه : ١ – مصباح كهربائي على الصوديوم لون أصفر بقدرة ١٥٠ وات. ٢ – أجهزة التحويل والمكثف ضمن الجهاز نفسه وجميع اللوازم للتركيب والتثبيت والوصل للعمل بتوتر ٢٢٠ فولت. صناعة أوروبية. ٣ – سلك نحاسي معزول من الترموبلاستيك قطر ٢ x ٣،٥ ملم٢ الواصل بين الجهاز والذائب في علبة الوصل. يدفع ثمن الجهاز الواحد فقط ليرة لبنانية لا غير.	
٢	– تقديم ونقل وتركيب ذراع قطر إنش ونصف مزيبق لحمل جهاز الإنارة، إنحنائه ٢٠ درجة عن الخط العامودي طول إجمالي متر ونصف، وذلك وفقاً لجميع المواصفات الفنية المرفقة بما فيه تقديم ونقل وتركيب : - حدائد التثبيت على الأعمدة الحديدية أو الخشبية والحديدة المبسطة طول ١٥ سم. لتثبيت علبة الوصل الخارجية. - سلك ألترموبلاستيك مقطع ٢ x ٢،٥ ملم٢ الواصل بين علبة الوصل والشبكة الهوائية. يدفع ثمن الذراع الواحد فقط ليرة لبنانية لا غير.	
٣	– تقديم ونقل وتركيب علبة وصل للأذرع من النوع الخارجي ضد الصدأ مع غطاء محكم لمنع تسرب المياه وبحجم كاف لإيواء المعدات الملحوظة لجهاز الإنارة وفقاً لجميع المواصفات الفنية المعتمدة بما فيه: - التوصيلات اللازمة ضمن العلبة. - تقديم ونقل وتركيب ضاغطات تثبيت على مدخل ومخارج العلبة. يدفع ثمن العلبة الواحدة فقط ليرة لبنانية لا غير.	
رقم	تعريف الاشغال	**السعر بالليرة**

/

رقم	تعريف الاشغال	السعر بالليرة
٤	- تقديم ونقل وتركيب علبة تحكم كاملة بأجهزة الإنارة بقوة ١٥٠ وات لما يقارب الخمسين جهازاً لكل من الإتجاهين، مصنوعة من المعدن بقياس ٤٠ x ٦٠ سم. معزولة ومحكمة الإغلاق لمنع تسرب المياه، مع جميع القطع والتوصيلات اللازمة بما فيه : - مصهر (Fuse) قدرة ٦٠ أمبير مع القاعدة. - ماسة (Contacteur) بقدرة ٦٠ أمبير. - قاطع (Disjoncteur) (آحادي الأطوار) بقدرة ٦٠ أمبير. - قاطع (Disjoncteur) عدد اثنان (آحادي الأطوار) بقدرة ٣٠ أمبير. - العين السحرية (Photocell.) المثبتة خارج علبة التحكم. - كابل معزول للتوصيل من وإلى علبة التحكم وخطوط التغذية والإنارة. - الأسلاك والقطع اللازمة للتوصيل والتثبيت. يدفع ثمن العلبة الواحدة فقط ليرة لبنانية لا غير.	

نظمه
المهندس
أكرم حسيكي

دققه
رئيس مصلحة التجهيز الكهربائي
المهندس نزار ابو درويش

وافق
المدير العام للموارد المائية والكهربائية
د. فادي جورج قمير

صدق
وزير الطاقة والمياه
آلان طابوريان

١ تموز ٢٠٠٩

الجمهورية اللبنانية
وزارة الطاقة والمياه
المديرية العامة للموارد المائية والكهربائية

كشف تقديري لاشغال انارة عامة في قضاء بنت جبيل.

الرقم	نوع الاشغال	الوحدة	الكمية	السعر الافرادي ل.ل.	السعر الاجمالي ل.ل.
١	تقديم ونقل وتركيب جهاز انارة عامة ١٥٠ وات – صوديوم – تـوتر ٢٢٠ فولت.	عدد	٥٠٠		
٢	تقديم ونقل وتركيب ذراع حديدي طول ١٥٠ سم ١,٥ انش مزيبق.	عدد	٥٠٠		
٣	تقديم ونقل وتركيب علبة وصل نـوع خارجي.	عدد	٥٠٠		
[illegible]	تقديم ونقل وتركيب علبة تحكم باجهزة الانارة.	عدد	٢٠		
			المجموع		
			TVA		
			المجموع العام		

نظمــه

المهندس

د. أكرم حسيكي

دققــه

رئيس مصلحة التجهيز الكهربائي

المهندس نزار ابو درويش

وافــق

المدير العام للموارد المائية والكهربائية

د. فادي جورج قمير

١١ تموز ٢٠٠٩ **صـدق**

وزير الطاقة والمياه

آلان طابوريان

TERMS OF REFERENCE (TOR)
SOLAR PV PUBLIC STREET LIGHTING

Item	SCOPE OF WORK	PRICE (L.L)

1	**Part One – PV Module**
	
	Interested companies are asked to quote the supply, delivery, and installation of solar photovoltaic panels with a minimum production capacity of **1.8 kW** including a self-support framework made of aluminum according to the following specifications:
	- Nominal Voltage: 12V
	- Module efficiency > 15%
	- Power tolerance < 3%
	- Nominal Operating Cell Temperature NOCT shall be 47°C ±2°C
	- Photovoltaic array nominal voltage 48V achieved via connection of 4 modules in series
	- Performance warranty on power output minimum 80% over 20 years
	- PV Junction Box shall have a minimum protection rating of IP65
	- PV module to conform with the following international standards:
	    - ISO 9000
	    - ISO 14001
	    - IEC 61215 ed 2
	    - IEC 61730 Safety Class 2
	- International Laboratory Tests should be submitted from either one of the following laboratories:
	    - TÜV Rheinland
	    - Fraunhofer Institute for Solar Energy Systems (ISE)
	    - Arsenal Research
	    - CENER
	    - Photovoltaic Testing Laboratory – PTL
	    - European Solar Test Installation (ESTI)
	    - Underwriters Laboratory (UL)
	- Manufacturer's warranty on modules 2 years.
	
	Payment for the PV Module Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L

1
 	
2
	Part Two – Support Structure
	
	Interested companies are asked to quote the supply, delivery, and installation of the galvanized steel structure type:
	- G90 type (Galvanization 20 microns equivalent to 275g/m^3) or Hot Dip Galvanized or Aluminum
	- Tilt Angle: fixed at 45° ±5°
	- Elevation above the ground: 1 meter minimum to account for snow at altitude
	- Wind Speed: 150Km/hr
	- PV panels shall be fixed on PV mountings using PV clamps made of at least Hot Dip Galvanized construction.
	- Bidder must provide all the equipment, labor and installation of the systems, including all costs and profits
	
	Payment for Integrated Unit (Only LBP)
	
	Concrete strips to be designed and built by the contractor.
	- Dimensions:
	  - Length: 3m
	  - Width: 0.6m
	  - Depth: 0.6m
	- The following technical specifications should apply per cubic meter:
	  - Cement: 250 Kg
	  - Sand: 0.400 m3
	  - Crushed Stone: 0.800 m3
	  - Iron: 100 Kg/ m3
	- Anchorage: footplate with mechanical anchorage in concrete (using anchor bolts)
	
	The bidder must provide a design analysis and calculation on the support structure. The bidder must provide all the equipment, labor and installation of the systems, including all costs and profits.
	
	Payment for Support Structure Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
1	**Part Three – Solar Charge Controller** Interested companies are asked to quote the supply, delivery, and installation of the mandatory type PWM regulator with a microprocessor control system for photovoltaic generators: **Electrical Specifications**: - Nominal Voltage of 48 V	

	- Photovoltaic module current up to 55A - Photovoltaic current achieved with no more than 1 charge controller - Admissible load current: 55A - Multistage Charging Technology - Maximum Self consumption:15mA **Mechanical Specifications**: - Minimal efficiency of 96% - Operating temperature range between -10°C to 60°C - Minimum Enclosure Type: IP65 **Features:** - LCD screen indicating output parameters - Temperature compensation via External Temperature sensor connected to the batteries **Electronic Protection Function:** - Overcharge Protection - Deep Discharge protection - Reverse polarity protection of load and module - Short circuit protection of load and module - Reverse polarity protection by internal fuse - Automatic electronic fuse - Overvoltage protection at module input - Open circuit protection without battery - Over temperature and overload protection - Battery overvoltage shutdown **Certifications:** - ISO 9001 - ISO 14001 - DIN IEC 68 - CE MARK - EN 60730-1:2000 - EN 55022:1998 + A1: 2001 - EN 60730-2-11: 1993 - EN 55022:1998 + A2:2003 - EN 60730-2-11:/A1:1997 - EN 61000-6-2:2001 Payment for the Solar Charge Controller Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
1	**Part Four – Batteries** Interested companies are asked to quote the supply, delivery, and installation of solar batteries 2 Vdc with the following criteria: - ISO 9001 - ISO 14001 - IEC 60896-11	

	- IEC 61427:2005 Batteries manufacturing date should not be older than six (6) months at the time of installation. Battery specifications – Design and Requirements - Cycle life: Minimum of 1500 cycles at 80% depth of discharge and minimum 6250 cycles at 20% depth of discharge - Nominal Capacity: Capacity at 120 hr rate, 25°C, 1.85Vdc; minimum capacity of 430Ah. - Nominal Block Voltage: 2 Vdc - Battery set voltage: 48Vdc - Tubular plates: - Electrolyte: Diluted sulfuric acid with specific gravity of 1.240 +/- 0.010 at 25°C. Large electrolyte reserve to minimize topping up. - Vent Plugs: Safety plugs equipped with flame arrestors. - Terminals: Lead alloy leakproof pole with brass insert. - Intercell connectors: Fully insulated, solid copper inter-cell connectors - Warranty: Minimum 2 years Payment for Batteries (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
1	**Part Five – PV Junction Box** Interested companies are asked to quote the supply, delivery, and installation of the **PV Junction Box** with the following criteria: - Junction box shall be made of PVC - Protection rating: Minimum IP65 - Required to connect Photovoltaic strings in parallel - String fuses must be installed for protection of individual strings. Fuse rating shall be 16A - Cable entry into junction box shall be via cable glands. - Location: Fixed on PV mountings The bidder must provide all the equipment, labor and installation of the systems, including all costs and profits.	

	Payment for PV Junction Box (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
1	**Part Six – LED** Interested companies are asked to quote the supply, delivery and installation of the **Light Source LED** with the following criteria: - High power Light Emitting Diode LED Lamp - Single or multiple diodes - Light output should be at least 6000 lumens at ground level from an altitude of 6m of the lamp. - Power Factor should be above 0.95. - Total Harmonic Distortion should be less than 20% based on ANSI C82. - The lamp should be housed in an assembly suitable for outdoor use. - Minimum view angle of 120°. - The lamp's efficiency must exceed 70 lm/W when measured luminaire as whole. - The Luminous output must maintain at least 80% of its initial lumen output after 50,000hours - The duty cycle of the system must be of at least two nights based on a 12 hours functioning per night. - Light color should be within the interval 4500 K- 6500 K. - All system's components must be water resistant. - All system's components must be corrosion resistant. - The system must have a wind resistance up to 120Km/h. - Operating temperature between -10°C and 55°C. - The use of LED with UV emissions is not permitted. - Color Rendering Index: greater or equal to 75 - Ingress Protection Rating: IP65 - Warranty: minimum 2 years - Product shall be tested, CE certified, ISO9000 registered The bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for the LED Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
	Part Seven – PV Module for Standalone PV Street Lighting System	

1	Interested companies are asked to quote the supply, delivery and installation of the **PV Module for Standalone PV Street Lighting System** with the following criteria: - Monocrystalline or Polycrystalline technologies. - 200 Wp panel (s). - Conversion efficiency >15%. - Module voltage 12V. - Manufacturer tolerance on rated power: ≤ 3%. - The cells should be protected with a tempered glace. - Shall withstand wind up to 120Km/h. - Product must be tested, CE certified, ISO 9000 registered. - 20 years 80% power output warranty. - Warranty: 2 years on material and manufacturing. The bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for PV Module Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
	Part Eight - Back up Batteries for Standalone PV Street Lighting System	
1	Interested companies are asked to quote the supply, delivery and installation of the **Back up Batteries for Standalone PV Street Lighting** with the following criteria: - DC voltage output of 12V. - Gel type batteries. - Batteries must be sealed maintenance free. - Batteries' enclosure must be sealed to avoid theft and manipulation. - No leakage. - Deep discharge capacity > 75%. - Minimum lifetime of 5 years guaranteed in normal operating conditions. - Batteries should have a capacity of 2*150Ah or more. - Batteries manufacturing date should not be older than one year at the time of installation. - Product shall be tested, CE certified, ISO 9000 registered - Warranty: 2 years The bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits.	

	Payment for Batteries Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
1	**Part Nine – Charger Controller for Standalone PV Street Lighting System** Interested companies are asked to quote the supply, delivery and installation of the **Charger Controller for Standalone PV Street Lighting System** with the following criteria: - Voltage and Current: 24V, 20A. - Feature: automatic dusk/ dawn switch and timer module. - Protections: overcharging, over discharging, overload, reverse current and thunder. - Product shall be tested, CE certified, ISO 9000 registered. - Warranty: 2 years. The bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for Charger Controller Unit (Only LBP) **Part Ten – Protection Circuit** Interested companies are asked to quote the supply, delivery and installation of the **Protection Circuit** with the following criteria: - Fuses should be provided for short-circuit conditions. - Blocking diode for reverse flow of current through PV panels must be added in case it is not provided in the panels. - All electronic components must take into consideration temperature compensation issues. - Full protection against open circuit, accidental short circuit and reverse polarity should be provided. - Lightning protection circuits must be added to each system. Bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for Protection Circuit Unit (Only LBP)	

NBR	SCOPE OF WORK	PRICES L.L
	Part Eleven – PSL Pole	
1	Interested companies are asked to quote the supply, delivery and installation of the 8 meters **PSL Pole** with the following criteria: - Height of 8m. - Lamp fixture at 6m. - The PSL pole must be equipped with mounting brackets that allow variable orientation and inclination of the PV module. - The pole must be water and corrosion resistant. - Poles must have an octagonal shape with a 30cm at the base going to a 15cm diameter on top. - Poles must a have a minimum thickness of 4mm. Price includes drilling and pour of concrete base measuring 80x80 cm, deep 120 cm, fixing the pole by a metal base by four screws each of 120 cm length and 18 mm diameter. Bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for each eight (8) meters PSL pole (Only LBP)	
2	Interested companies are asked to quote the supply, delivery and installation of the 6 meters **PSL Pole** with the following criteria: - Height of 6m. - Lamp fixture at 4.5m. - The PSL pole must be equipped with mounting brackets that allow variable orientation and inclination of the PV module. - The pole must be water and corrosion resistant. - Poles must have an conical/octagonal shape with a 30cm at the base going to a 15cm diameter on top. - Poles must a have a minimum thickness of 4mm. Price includes drilling and pour of concrete base measuring 80x80 cm, deep 120 cm, fixing the pole by a metal base by four screws each of 120 cm length and 18 mm diameter. Bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for each six (6) meters PSL pole (Only LBP)	
3	Interested companies are asked to quote the supply, delivery and installation of the **Decorative PSL Pole** with the following criteria:	

	- **Decorative Pole** with Height of 6m. - Lamp fixture at 4.5m. - The PSL pole must be equipped with mounting brackets that allow variable orientation and inclination of the PV module. - The pole must be water and corrosion resistant. - Poles must have a conical shape with a 30cm at the base going to a 15cm diameter on top. - Poles must a have a minimum thickness of 4mm. Price includes drilling and pour of concrete base measuring 80x80 cm, deep 120 cm , fixing the pole by a metal base by four screws each of 120 cm length and 18 mm diameter. Bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for each decorative PSL (Only LBP) **Part Twelve – Light Source**	
1	Interested companies are asked to quote the supply, delivery and installation of the **Linear LED strip** with the following criteria: - Flexible LED strip lighting module - LED Spacing: approximately 16.5 mm on center - Power Consumption: 5 to 9 W/m at full output, steady state - Lamp life: 50,000 Hours - Distribution Type: Nominal 130 deg beam angle) - Waterproof: Dry/ Damp/ Wet Location, IP 66 Rating - Temperature Rating: - 40° to + 50° C - Input Voltage: 12 Vdc, 24 Vdc, or 48 Vdc via included power supply - Can be cut at marked predefined intervals. - Certifications: CE or any equivalent (CCC, RoHS, UKAS) - The luminous output must maintain at least 80% of its initial lumen output after 50,000 hours. - Warranty: Minimum 2 years Payment for linear LED Strip (Only LBP)	
2	Interested companies are asked to quote the supply, delivery and installation of the **Flashlight LED** with the following criteria: - Beam Angle 8°	

	- Input Voltage: 12 Vdc, 24 Vdc, or 48 Vdc via included power supply - Power Consumption 50 W maximum at full output, steady state - Housing Die-cast aluminium, powder-coated finish - Lens Tempered glass - Fixture Connections Unified power cable with three flying leads - Operating Temperature: - 40° C to + 50° C - Humidity 0 – 95%, non-condensing - Certification UL / cUL, CE - LED Class 2 LED product - Environment Dry / Damp / Wet Location, IP66 - Warranty: Minimum 2 years The bidder must provide all the equipment, labor and installation of the implementation with the best technical standards including all costs and profits. Payment for Light Source (Only LBP)	

TERMS OF REFERENCE (TOR)

A. OBJECTIVES

On March 10, 2010, the Council of Ministers (CoM) of Lebanon approved the plan of the Ministry of Energy and Water (MEW) regarding the implementation of energy conservation measures in three different areas (energy efficient lighting, solar water heaters, and public street lighting). The CoM committed to invest a total budget of 9 Million USD in achieving the objectives of this initiative.

One major part of this initiative is to set a national action plan towards an energy efficient utilization of public street lighting systems. The plan consists in supporting municipalities and other involved parties in the development of a well structured approach for the repair and maintenance of public street lighting systems. In addition, the plan consists in the preparation of standardized technical specifications for new public street lighting systems. The plan also includes the marketing of lighting systems based on photovoltaic technologies.

Finally, the action plan includes the purchase of photo-sensors and timers to replace damaged ones in the different public street lighting systems all over Lebanon. The Ministry of Energy and Water is planning to procure these systems based one lot as per the following table:

Lot	Number of Photo-Sensors and Timers
Lot 1	Purchase of 1,500 systems including accessories

Interested bidders can submit the offers for. A major criterion in the selection of the winning bidder is the date of delivery.

The current "terms of reference" document is for the procurement of 1,500 photo-sensors, 1,500 timers, and 12,000 m of cables including all needed accessories. The products are to be delivered to the main warehouse (to be located in Greater Beirut area).

B. SCOPE OF WORK

Interested companies are asked to quote the supply and delivery of 1,500 photo-sensors and 1,500 timers including all needed accessories. The products are to be delivered to the main warehouse (to be located in Greater Beirut area) according to the requirements and specifications mentioned hereafter.

C. GLOSSARY OF TERMS

Manual Switch	The basic and simplest option consists of manually turning on and off the Public Street Lighting (PSL) sectors in order to illuminate the roads at night and switch off the lights during the day. This option requires the presence of personnel that operate the switches and is constraint to the personnel accuracy.
Photo-Sensor	The photo-sensor is a photo-sensing device that can measure daylight intensity providing a signal when the daylight threshold intensity is reached. This information is valuable for controlling PSL sectors since it can tell when the daylight is fading in order to activate the public street lights. The PSL sector could be controlled directly through the Photo-sensor or through a contactor activated by the photo-sensor. This latter is the preferable solution in order to limit the intensity flowing in the photo-sensor and get an external override commands on the contactor in order to switch on and off the lights on special occasions or for special purposes. The system may include some feature like: » Override switch from the lighting controller; » Override control from a PSL management unit; » Controllers with calibrated set points. PSL sensors shall be mounted at a good elevation and pointed upwards in order to get a clear vision towards the northern sky. The sensor is usually a photo diode sensor with a focus on the work area and can be calibrated from 1 to the maximum light level required for the application.
Timer	Timers may be used to control the on/off sequence of the street lighting sectors. In this section, timers are simple electric devices that operate a contactor based on a predefined schedule. The basic timers can be programmed on daily or weekly basis and thus can't account for the actual daylight intensity.
Programmable Controller and Timer	Programmable controllers and timers are electric controllers that operate without photoelectric cell and calculate sunrise and sunset times according to their geographic position. Having the sunlight calendar embedded, they can be programmed to perform any on/off

	scenario throughout the year and thus can be used to switch on and off the lights several times in a single night.
Photo-sensor coupled to programmable controllers	It is possible to couple a photo-sensor to a controller; the result is a fully automated system with possible overrides that can take any scenario that suits the application. The advantage of such a system relative to the programmable timer is the ability to turn on the lights during the day if the daylight intensity drops below the threshold because of the weather (clouds, blizzard, etc.) or Sun eclipse. A main requirement for the controller is its ability to get a manual control and a terminal for remote override switches. The controller shall be completely adjustable to cover all foot candle set points. The "ON" and "OFF" set points shall be protected with a preset "dead-bang" setting from 2 to 30%.Pilot lights shall be provided for "ON" and "OFF" status of each control setting. It is of importance to get/select: » Input levels (actual foot candle readings); » Set point levels for "ON" and "OFF"; » HID timer (i.e 0-30 minutes); » Cloud filter (i.e 0 to 5 minutes); » Override timer (i.e 0 to 120 minutes); » Simulation scheme; » Pulse or maintained mode; » Sensor calibration (i.e 500, 1000, 5000, 10000, foot candles); » Number of control levels; However, several options are available to complete the system as for example: » Override remote pushbuttons with (i.e 0 to 120 minutes) automatic "ON" adjustable delay timers; » Time clock interface (time clock-on / photo diode-off or photo diode-on / time clock-off); » Remote H-O-A (Hand -Off- Auto Switch) and pilot light indicators.

D. TECHNICAL SPECIFICATIONS

The technical specifications consist of the description included herein. This section includes the following items:

1. Scope:

The works under this project shall consist of the supply and delivery of 1,500 photo-sensors, 1,500 timers and 12,000 m of cables (3x1.5 mm^2) including all needed accessories. The products are to be delivered in good condition to the main warehouse (to be located in Greater Beirut area).

2. Minimum Requirements:

The photocells must have the minimum technical specifications:

- Sensor type: Photodiode
- Supply Voltage: 230 V AC +/- 15%
- Frequency: 50 Hz
- Cut phase output: Relay 16A
- Operating temperature: -20^0c °c↔ 50
- Protection index: IP 54
- Relay type: electromagnetic/semi-conductor
- Switch-on level: Dusk (55 to 70 lux)
- Switching diff: Dawn (ratio 1 : 1.5)
- Enclosure material: corrosion resistant
- Power consumption: ≤ 2 W
- Tripping delay: from 1 to 120 s
- Mounting: pole
- Electrical connection: 1.5 to 4 mm^2
- Conformity to European regulations (CE) or ANSI C136.10 “Physical and Electrical Interchangeability and Testing”

The timers must have the minimum technical specifications:

- Supply Voltage: 230 V AC +/- 15%
- Frequency: 50/60 Hz
- Power reserve: ≥ 72 Hours
- Protection Index: IP 20 (EN 60 529)
- Power consumption: ≤2.5 VA
- Cut phase Outputs: Relay 16A
- Accuracy of operation: ± 1s/Day
- Operating temperature: -10^0c °c↔ 50
- Connection by cage terminals, section of conductors: 1.5 to 4 mm^2

- Contact material: Hard Silver
- Housing and isolation material: High temperature resistant thermoplastic
- Protection class: 2
- Minimum switching interval: 30 min
- Dielectric Strength: Input to contact: 2500 VAC; Between Open Contact: 1000 VAC
- Mounting: on DIN rail
- Conformity to European regulations (CE)

The 3x1.5 mm^2 cables must be NYM type copper wire or equivalent, 3x1.5 mm^2 for external use, to be supplied by Cables du Liban or equivalent products.

As soon as the winning bidder receives MEW's instruction to initiate the work, but before Contract signature, the Supplier has to secure a prior written and signed approval on the quantity of the systems to be supplied and the date of delivery.

3. Delivery Date
The winning bidder must commit to deliver all products in a period of no more than 4 weeks after signing the contract. The other acceptable alternative would be to deliver half the quantity (750 systems) in a period of no more than 4 weeks after signing the contract, while the other half (750 systems) could be delivered in a period of no more than 8 weeks after signing the contract.

All delivery dates must clearly stated in the bidders' offer.

4. Delivery Location
The winning bidder must commit to deliver the products to the main warehouse (to be located in Greater Beirut area).

E. TERMS OF EXECUTION

- **Timeframe:** The start date of the contract is immediate. The overall term of execution of this contract is spread over 3 months, effective from contract signature date. This includes the delivery of the products to sites.

- **Delivery:** The awarded party is responsible for clearing, including payment of custom clearance, delivered equipments from Beirut port. The products delivered to the selected site shall be considered under the supplier's responsibility until the final hand-over of the photocells and timers. It may be noted that the road conditions may be adverse and the packing shall therefore protect the equipment thoroughly from moisture and vibrations.

- **Defected Products:** The supplier has to replace all the defected products within a two-month time frame after the installation and upon the request of MEW.

F. EVALAUATION CRITERIA

The evaluation of the proposal will be based, on a two-step process:

- In the first stage: Compliance with the evaluation criteria of the Technical quality of the product. If one of the mandatory criteria requested failed, the whole offer will be declined.

- In the Second Stage: The price proposal of all suppliers, who have passed the technical evaluation, will be compared. The contract will be awarded to the Contractor offering the lowest price.

Financial Proposal:

Item	Description	Total Quantity	Unit Price in USD (Exc. VAT)	Total Price in USD (Exc. VAT)
1	Photo-Sensor	1,500 pieces		
2	Mechanical Time Switch	1,500 pieces		
3	Cables- 3x1.5 mm^2	12,000 meters		
TOTAL				
TOTAL (after Applying Special Discount)				

Appendix B: CEDRO PSL projects in Lebanon

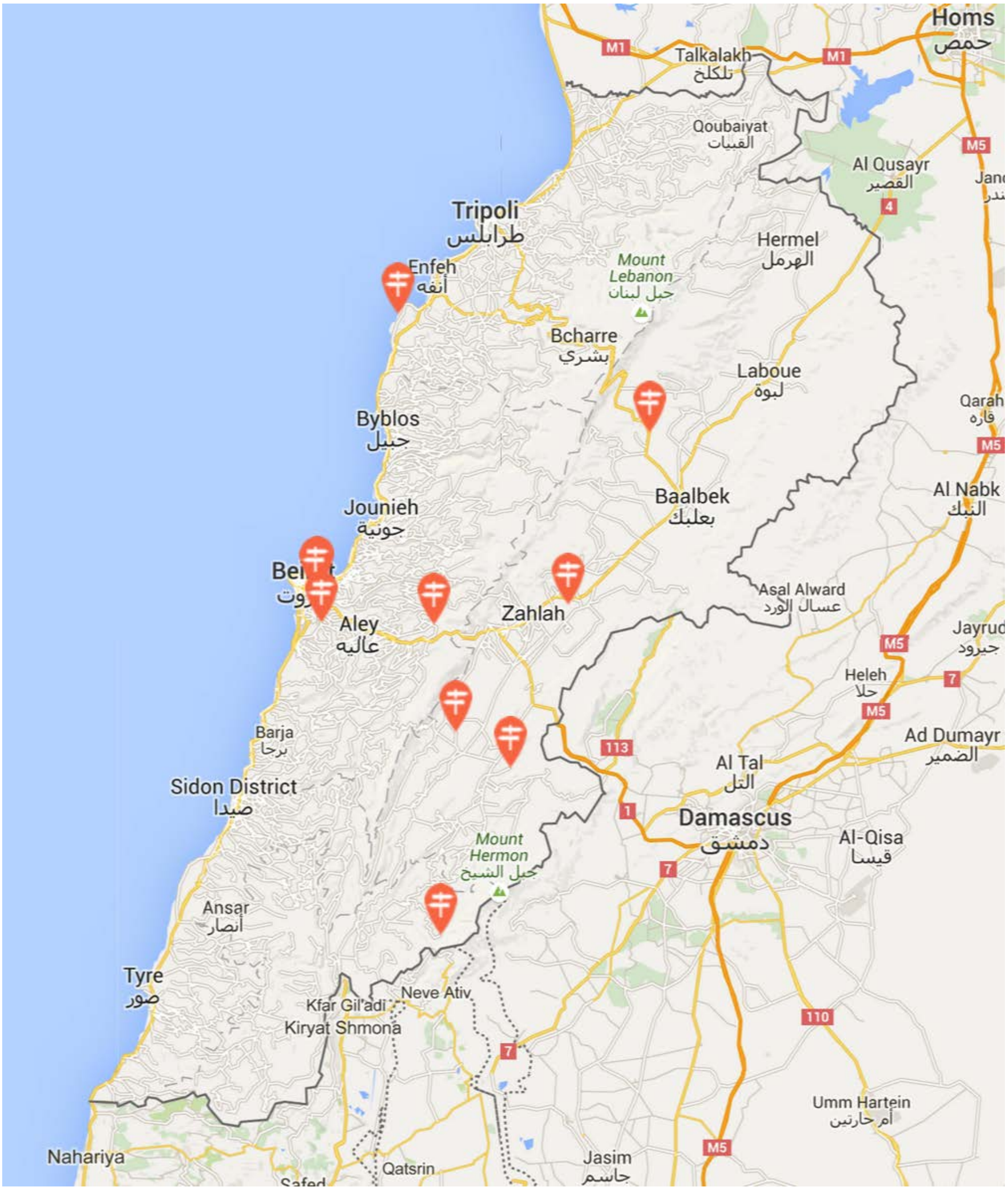

Figure 5: CEDRO PSL projects distribution in Lebanon

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