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Energy Efficient Lighting Options for Afghanistan

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South Asia Sustainable Development (SASDE)

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Currency Equivalents

(Exchange Rate Effective June 28, 2009)

Currency Unit = AFN
AFN 1.00 = US$ 0.021
US$ 1.00 = AFN 47.30

Abbreviations and Acronyms

%	Percent
AFN	Afghanis
CFL	Compact Fluorescent Lamp
DABM	Da Afghan Breshna Mosases
GLS	General Lighting System
GtZ	Gesellschaft für Technische Zusammenarbeit
IEA	International Energy Agency
IRR	Internal Rate of Return
kW	kilowatt
kWh	Kilowatt hour
LED	Light Emitting Diode
MEW	Ministry of Energy and Water
MH	Metal Halide
MRRD	Ministry of Rural Rehabilitation and Development
NPV	Net Present Value
RE	Renewable Energy
ROI	Return on Investment
SPP	Simple Payback Period
SPV	Solar Photovoltaic
SV	Sodium Vapor
TFL	Tubular fluorescent lamp
USAID	United States Agency for International Development
USD	United States Dollars
W	Watt

Basic Terminology Used in the Lighting Industry[1]

Average rated lamp life

Manufacturer's estimate of the length of time 50 percent of any large number of lamps can be expected to last.

Ballast

An electronic component of every fluorescent fixture. It is used to boost the electric current to start the bulb and to regulate the flow of current to the bulb. Electronic ballast ensures quiet, rapid flicker-free startup and operation. A magnetic ballast, unless has an energy savings rating; may blink on startup, flicker slightly and/or hum during operation.

Color rendering index (CRI), accurate color replication

A measure of how accurately an artificial light source displays colors. CRI is determined by comparing the appearance of a colored object under an artificial light source to its appearance under incandescent light. The higher the CRI of a light source, the more “natural” colors will appear under it. Light source with a low CRI will distort colors. A high CRI (above 80) is preferred in the home.

Color temperature

Light bulbs emit varying colors of light. Lighting color ranges from cool to warm tones, and is known as color temperature. The color temperature of a light source indicates the color of the light emitted measured in degrees Kelvin. Color temperature is not an indicator of lamp heat.

Initial performance values

The photometric and electrical characteristics at the end of the 100-hour aging period

Lamp color

The color characteristics of a lamp as defined by the color appearance and the color rendition

Light output

One of the most important considerations in selecting a light source is how much light it will generate. The unit of measure used for determining light output is the lumen. Light output is measured in lumens at the light source. One lumen equals the amount of light generated by a single standard candle.

Light quality

Having good light quality means using the most efficient light source in a lamp that integrates with the architectural design.

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[1] Source: Natural Resources Canada website: http://oee.nrcan.gc.ca/residential/personal/lighting/terminology.cfm?attr=4

Lumen

A measurement of light output. One lumen is equal to the amount of light emitted by one candle that falls on one square foot of surface located one foot away from the candle.

Lumen maintenance

The luminous flux or lumen output at a given time in the life of the lamp and expressed as a percentage of the initial luminous flux. The mean lumens are the value at 40 percent of rated life.

Power factor

The active power divided by the apparent power (i.e., product of the root mean square [rms] input voltage and rms input current of a ballast). This is a measure of the power efficiency of the lamp.

Rated voltage

The voltage marked on the lamp

Rated wattage

The wattage marked on the lamp, which indicates the energy consumption per second of the lamp when in operation (Watt = Joules (energy)/second)

Rated luminous flux or lumen output

Initial lumen rating (100 hours) declared by the manufacturer

Starting temperature

The minimum and maximum temperatures at which a lamp will reliably start

Starting time

The time needed, after being switched on, for the lamp to start fully and remain lighted

Warranty

A manufacturer's written promise regarding the extent to which defective goods will be repaired or replaced

Watt

A unit of electrical power used to indicate the rate of energy produced or consumed by an electrical device.

Executive Summary

"**People believe the State exists when lights burn"** said Ahmed Rashid, author of the book 'Descent into Chaos {Penguin}'

The Afghan electric power system is currently not able to reach the majority of rural residents, nor is it able to supply enough electricity to meet existing demand on the grid. While the system develops, other options need to be explored that meet this dual need of extending access while not creating even more demand. These options also need to fit within the context of the extreme poverty of Afghanistan and the desire to promote a low carbon growth strategy.

One way to address this set of constraints is to implement energy efficient lighting. Poor consumers often pay a substantial portion of their household earnings on meeting energy needs such as lighting. Therefore the introduction of energy efficient lighting products will help them to reduce these expenditures in the long-run. Coupling energy efficient lighting with off-grid renewable energy sources will expand access to rural residents. Using energy efficient lights in urban, grid-connected areas will also reduce the supply constraint, as well help consumers lower their bills. In both cases, energy efficiency reduces costs because the consumers will be using less electricity. It also reduces pollution and the need to import costly fossil fuels.

This study examines the potential options for implementing an energy efficient lighting program in Afghanistan. It analyzes the range of energy efficient options available in the region and identifies the best choices for specific market segments in off-grid and grid connected areas. Based on this analysis, it is recommended that in rural areas, where grid (local or from main network) is neither available nor likely to be available soon, LED lights coupled with solar PV panels offer the least cost solution for expansion of energy access. In grid-connected areas, compact and tube fluorescent lamps are recommended for existing household connections, as well as community and street lighting. The analysis also shows there are numerous barriers and potential problems with implementing an energy efficiency program in Afghanistan. Therefore a phased implementation program is suggested, with careful oversight of the quality of products entering the market.

Given the difficult electricity situation, the scope of this study extends past providing energy efficient lighting. The deepening of mobile telephone connectivity for the Afghan people is also critically dependent on electricity access. The recommendations for stand-alone efficient lighting systems through solar –backed systems include a feature for charging mobile phones in all home lighting options. Innovative features like dimmers (electronic regulator) to reduce the intensity of light, and to get additional running time in one charge, have also been considered.

Background

Afghanistan, like many other developing countries, is facing a major challenge – of providing access to reliable and affordable electricity services to the large number of people that are currently deprived of it. The sector also faces tremendous other challenges including limited supplies, a damaged electricity infrastructure, transmission and distribution system gaps, high technical and commercial losses, high marginal cost of providing diesel power (both grid and off-grid, primarily in winter), and inadequate exploration of indigenous gas, coal, hydropower, and renewable resources. This report primarily focuses on identifying energy efficient lighting technologies that can be used to improve access to clean energy in off-grid rural areas and then examines the applicability of recommended solutions in grid connected areas. In addition, key policy issues, challenges and barriers to introducing energy efficient lighting initiatives in Afghanistan are identified and development strategies relating to integrating energy efficient and low carbon footprint technologies are recommended. Considering the absence of strong institutional capacity in Afghanistan, the task focused on identifying a few energy-efficient lighting products that have the flexibility to meet the basic needs of critical lighting applications and can be implemented in a short-time frame.

Electricity access in Afghanistan

16% of Afghanistan's population is estimated to have access to the electricity grid.

1. The electricity access rate in Afghanistan is among the lowest in the world, where a mere 16 percent[2] of the population is estimated to have access to the electricity grid. Most of the rural population, and a significant proportion of the urban population, is deprived of electricity. The prevailing service, to the small percentage of the population who has access to electricity through the grid, consists of only a few hours of supply a day. The situation worsens in winter when the generation from hydropower resources, which contributes about 39 percent[3] of power production, drops significantly due to reduced inflow of water, and a corresponding dependence on high cost diesel-based power increases tremendously.

Afghanistan's National Development Strategy (ANDS) include providing electricity to at least 25% of households in rural areas by 2010 and 80% of population lives in rural area.

2. The lack of power supply is a major impediment to the country's development and has been ranked as the most pressing problem faced by the people of Afghanistan today, according to a recent survey of citizens in all 34 provinces of the country. The core targets of Afghanistan's National Development Strategy (ANDS) include providing

[2] Based on the data from the National Risk and Vulnerability Assessment, a major national household-level survey carried out in 2005.

[3] Afghanistan Energy Information Center (AEIC) Annual Production Report, 2008. Source: http://www.afghaneic.org/pdf/Daily%20Statistics%20Report/Yearly%20Report%202008.pdf

electricity *to at least 65 percent of households, 90 percent of non-residential establishments in major urban areas, and at least 25 percent of households in rural areas* by 2010. However, since 80% of Afghanistan's population[4] lives in rural areas, even after the government reaches its target electricity access rates, a large proportion of the population will continue to remain un-served. The provision of providing electricity to meet energy needs is critical for future economic growth in these areas. Unless this occurs, it will not be possible to meet the country's development goals.

3. There is a need to build an energy efficiency agenda into the core development strategy of Afghanistan to evolve sustainable energy solutions to meet these needs. This would also align Afghanistan with the globally recognized priority of following a low carbon – clean energy path for sustainable development. The pollution caused by the most commonly available and used electricity supply sources of diesel generation and kerosene lighting has faced significant criticism even in the Afghan parliament.

4. Lighting is an important requirement that accounts for a significant proportion of electrical load (as covered in next section). Energy-efficient lighting technologies can significantly reduce total energy consumption and operating costs while providing the required illumination levels. This allows limited electricity resources to be stretched across more consumers, which make them an attractive option for Afghanistan. These energy and cost savings are even more significant during times when diesel generators are used to supply grid electricity.

Need for Lighting and Its Share in Electricity Consumption

5. Lighting has evolved as a basic human need that serves as a key input for advancing literacy, safety and productivity. Global energy needs assessments indicate that energy for lighting, cooking, and keeping warm in winter are the three highest priority energy needs for most rural families. This makes lighting one of the primary uses of electricity in rural areas, since cooking needs are often met through the use of locally available firewood and biomass, which also provide warmth in winter. On a global basis, lighting alone accounts for 19% of the electricity consumption[5], and 31% of this is for residential lighting. Electricity requirements for lighting also contribute significantly to the increase in demand during early morning and evening hours.

Globally, lighting accounts for 19% of the electricity consumption, and 31% of this is residential lighting.

6. For indicative baseline information in Afghanistan, the study referenced secondary sources including a study funded by GTZ/Afghanistan and conducted by Altai Consulting, "*Baseline Socio-Economical Survey on Energy Use in Badakhshan (Afghanistan)*", January, 2008.

[4] February 2009 estimates from Central Statistics Office (CSO) of Afghanistan
[5] IPCC: Intergovernmental Panel on Climate Change estimate

7. Kerosene lamps are the major source of lighting in rural communities in Afghanistan, accounting for approximately 86% of lighting[6]. This lighting source is costly, inefficient, polluting and provides poor quality light. Kerosene lighting can create a substantial burden for consumers who often spend 10-15% of their total household income on kerosene[7]. In a recent study in rural Bangladesh[8], when households that used kerosene lamps were compared with households with electric lighting, it was seen that the quality of lighting service obtained from electricity is significantly better than that from kerosene. When compared to energy-efficient lighting such as compact fluorescent lamps, economic assessments show that kerosene lighting costs users 150-times more per unit of useful light[9].

> ***Average Kerosene Use in Rural Households***
> *According to data collected on rural energy projects in India, a rural household consumes an average of 4 liters of kerosene per month for lighting.*
> *At a carbon emission intensity of 2.4kg CO2 per liter of burnt kerosene; this translates to 115,200kg of CO2 for 1000 households per year.*
> ***Source: Akanksha Chaurey, TERI, Lighting A Billion Lives, August 2008***

8. In grid-connected areas in several Afghanistan provinces, there is heavy reliance on electricity sourced through expensive diesel generation, which has gone up to 40 Afghanis per liter (US$0.84)[10] in June 2009, to supplement the limited hours of power supply. This situation becomes even more acute in winter, when generation from indigenous hydro sources reduces considerably. Lighting loads can account for 20 – 40%[11] of electrical load in commercial and large public buildings in urban areas which means that a high proportion of costly and highly polluting diesel generation is supporting lighting alone.

9. Given the importance of lighting in both rural and urban areas and the proportion of electrical load that it accounts for, it becomes critical to look at possible energy-efficient lighting options to meet consumers needs in both off-grid and grid-connected areas.

10. Urban consumers in Kabul (especially poorer consumers), were until recently only receiving a few hours of grid supply every alternative day. Although the availability of power from the grid has improved (18+ hours every day) the additional usage of electricity for meeting lighting and other needs means that these consumers will be paying much higher electricity bills. Energy efficient

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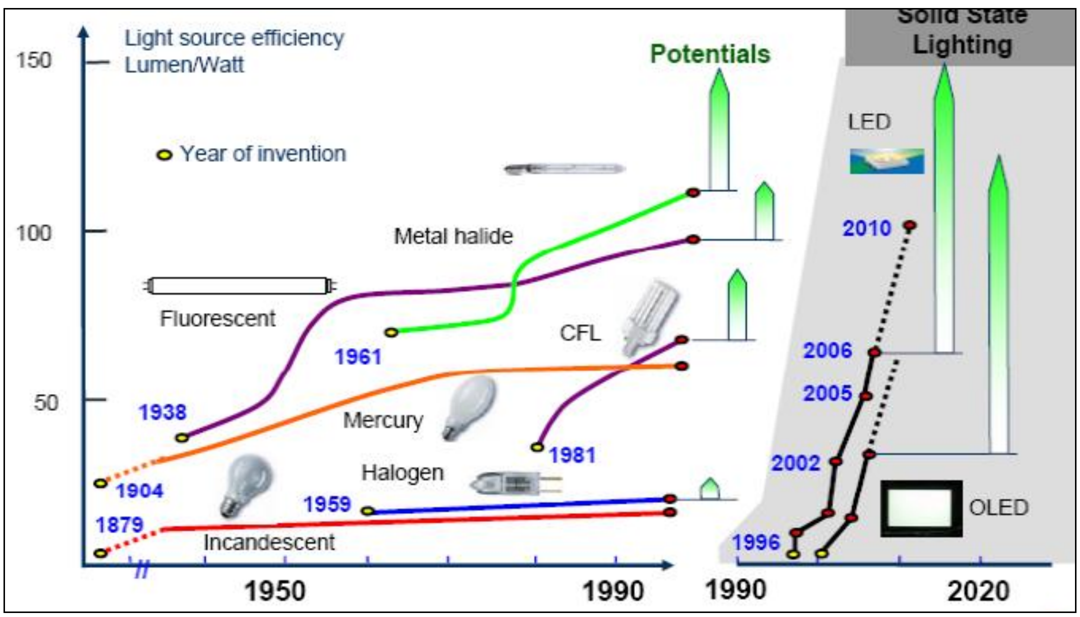
[6] The Afghanistan National Development Strategy, Initial Draft Energy Sector Strategy, 2008 – 2013, October 16, 2007
[7] Conference Proceedings from the Lighting Africa Product Quality Assurance Workshop, October 2007. Source: http://siteresources.worldbank.org/EXTENERGY2/Resources/FINALQAWorkshopProceedingsAug08.pdf?resourceurlname=FINALQAWorkshopProceedingsAug08.pdf
[8] Asaduzzaman, M., Barnes, D., Shahidur, K, March, 2009, Restoring Balance: Bangladesh's Rural Energy Realities
[9] Mills, E., *LEDS offer alternative to polluting, fuel-based lighting,* SCIENCE Magazine, June 2005
[10] Asia Pulse Data, *Fuel prices up, flour and gold down*. Source: http://oilandgas.einnews.com/news/diesel-prices/afghanistan, 28 June 2009
[11] Energy Conservation Building Code Tip Sheet, Building Lighting Design, USAID ECO-III Project, February, 2008

lighting solutions would go a long way to reduce the impact of increased bills for such consumers, in addition to lowering demand on the utility's supply system.

Energy-Efficient Lighting Market and Trends

11. Lighting efficiencies have been increasing consistently as newer lighting options have been introduced. Figure 1 shows the efficiency of a range of lighting options over time. While incandescent bulbs have improved very little in over 100 years, there are other technologies which are still improving. Compact fluorescent lamps (CFL) and tubular fluorescent lamps (TFL) have become the standard energy efficient lights, but they may be overtaken by solid state lighting. Light emitting diodes (LEDs), in particular, have evolved very rapidly in the last decade, exceeding benchmarks for performance (e.g. luminous efficacy, light output) on a regular basis. The next generation of efficient lighting technologies appears to be organic LEDs (OLEDs) and possibly more efficient metal halides, but these technologies are still prohibitively costly, and far from commercialization on a large scale.

Figure 1: Energy Efficiency Progressions and Projections of Lighting Technologies



Source: Wolfgang Gregor, OSRAM (2009)

12. A brief description of various lighting technologies that can be used to meet basic residential, community and street lighting applications are presented in Annex 1. This annex also includes a technical comparison of these lighting technologies based on parameters such as efficacy, lamp life, power factor and quality of light output.

Objectives and Scope

13. The primary objectives of this study are:
    1) To identify suitable energy-efficient lighting solutions for off-grid rural applications and to look at which of these lighting solutions may also be successfully integrated into grid-connected areas ;
    2) To outline key policy issues, challenges and barriers to introducing energy efficient lighting initiatives in Afghanistan; and
    3) To assist Islamic Republic of Afghanistan (IRoA) in integrating energy efficient and low carbon footprint technologies in the core energy sector development strategies.

14. To meet these objectives the energy assessment study sought answers to the following questions:
    - What are the basic needs for consumers in lighting applications?
    - What are appropriate energy efficient lighting options for meeting the needs of off grid/rural consumers?
    - Can these energy efficient lighting options play a role in grid based systems by helping to lower peak demands and/or providing back-up supply alternatives cost effectively?
    - What are the key barriers to introducing and using energy efficient lighting solutions in Afghanistan?
    - What lessons from Bank's other engagements could be integrated into the Afghanistan program?

Study approach

15. Information for this study was collected through discussions with industry players and government counterparts at the Ministry of Energy and Water (MEW) and Ministry of Rural Rehabilitation and Development (MRRD) in Afghanistan and through secondary sources, including internet and research publications. Secondary sources of information used are included in the reference list at the end of this report.

16. The first step of the analysis was to examine the ***lighting needs*** of a typical rural consumer. However, there are significant data gaps and limited information specifically for Afghanistan. Given time constraints it was also not possible to do first-hand surveys within the scope of this assignment. Instead, generalized lessons on rural lighting were gleaned from recent studies for the Lighting Africa program[12] and other similar programs in India, such as the Lighting a Billion Lives (LABL) program[13]. The African example is fitting for Afghanistan because of the similarities in population distribution, level of poverty, and capacity of government institutions.

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[12] Conference Proceedings from the Lighting Africa Product Quality Assurance Workshop, October 2007
[13] Lighting A Billion Lives Website: http://labl.teriin.org/

The experiences from other countries[14] indicate that lighting serves the following priority needs:

- improves quality of life, safety and human health,
- increases education and literacy rates,
- increases the ability for income-generating activities,
- extends the operating hours of businesses that otherwise have to close at dark, and
- enhances the overall quality of life of rural/remote communities.

17. The major lighting application needs of consumers were identified and include:
    - Space/Ambient lighting – a basic minimum amount of illumination for living, and for community lighting applications such as mosques, community halls, rooms, corridors, etc.;
    - Task lighting – a relatively higher illumination level for tasks that require more detailed viewing such as reading, cooking and operating theatres in health centres; and
    - Outdoor lighting – for street lighting, community lighting and security lighting.

    Please refer to Annex 2 for a comparison of lighting technologies that were identified to meet the needs of major lighting applications.

18. Once lighting applications were identified the available ***energy efficient lighting options for meeting these applications*** were examined in more detail. For rural areas, a preliminary step in this process was to identify the possible power supply options for serving the needs of consumers. Lighting loads in off-grid areas could be served by either small community or area based grids, using diesel or renewable based solutions like micro hydro, wind or solar- depending upon the suitability of these options. In more remote and dispersed rural communities, where developing such grids is likely to take a long time, the option of stand-alone solar based lighting solutions has been considered. The solar PV units can be installed and replicated most easily in off-grid areas, as adequate solar radiation levels are available in most areas of Afghanistan, with an average of about 300 days of sunshine per year, and an estimated average solar radiation of 6.5 kWh per square meter per day[15]. Solar PV units are also generally easier to manage and install at individual consumer levels than community based grids.

19. The key criteria used to determine the most appropriate lighting solutions for off-grid areas in Afghanistan include:
    - Efficiency of technology in converting electricity to lighting;
    - Lighting configurations that could provide the required lux levels for the basic rural lighting identified;
    - Flexibility and portability of lighting options to serve the needs of more than one lighting application;

[14] Various World Bank Studies in Bangladesh, Kenya, India

[15] Estimates based on Asian Development Bank estimates of Renewable Energy Potential

- Sustainability criteria - lamp durability and lifetime, low maintenance requirements, modularity and adaptability; and
- Capital and operating costs.

Lessons from earlier implemented lighting programs in Afghanistan and other regions were also examined.

20. The viable options determined by the analysis described above were further narrowed down to a list of a few select energy efficient lighting options - which were found most suitable in fulfilling the basic lighting needs of consumers. In addition, in off-grid areas the financial analysis for energy efficient lighting options considered the associated costs of stand-alone solar PV equipment to support the lighting application as this is the only renewable energy-based technology that can function virtually anywhere in the country without the need for significant infrastructure development. This is critical considering the need to simplify implementation given the challenges associated with weak institutional capacity, the need for sustainable, replicable solutions with low operations and maintenance requirements and the need to reach as many consumers with limited resources.

21. A similar process was used to determine the best energy efficient lighting options for grid-connected customers. In this case the power source was assumed to be a grid connection. However, given the current load shedding, some of the off-grid solutions were also examined to see if they could be used to lower peak demands and/or to provide back-up supply alternatives more cost effectively than the current diesel-generation back-up.

22. As a final step, these results were used to formulate a **broad implementation plan and an assessment of potential risks and mitigating measures** for the Government of Afghanistan. The proposed implementation strategy has been recommended by considering the existing challenges and possible approaches to address these barriers in the context of Afghanistan.

Analysis of lighting options

23. In the context of rural Afghanistan, given the low average household incomes and the low level of electricity load per household the recommended approach would depend on whether or not the community can be served by locally available renewable energy sources economically. The criteria for short-listing these renewable energy sources would include not only cost-effectiveness but also adaptability, flexibility, and maturity of technology.

24. In off-grid areas, the potential for introducing community based small decentralized grids has been considered. However, this potential is low in Afghanistan, due to widely dispersed rural communities, difficult terrains, lack of strong institutional arrangements, and additional infrastructure and resources required to support community-based systems. In addition, since the

productive loads in rural communities tend to be low there is typically not much energy efficiency gains in the load duration curve when rural households are grouped together on a single system.

25. The cost-benefit analysis of each lighting technology was performed based on the net present value of the lighting system over a lifetime of 20 years. See Annex 3 (Table 9 and 10) for details on approach and assumptions for financial analysis. Although the options were compared using a least cost analysis, the direct cost per unit is not the only cost parameter to consider. Given the low paying capacity of most rural consumers, flexibility of lighting systems is an important criterion to short-list options that can serve the needs of multiple applications. For example, a light source that is used for reading and cooking indoors should also be able to be carried outside to illuminate a pathway at night. In addition, including additional features that can be supported by the system, such as a single socket for mobile charging, fan, or radio provide increased reach and socio-economic benefits to the rural household.

26. Given the current power shortages in grid-connected areas, and high dependence on diesel back-up, the cost viability of incorporating the off-grid energy-efficient lighting solutions identified above were examined for possible dual-mode operation in grid-connected areas. i.e. PV lighting systems that can be solar charged during daytime and in case of no solar availability, can be charged directly through grid supply.

27. Suitable energy efficient lighting options were selected for meeting basic lighting needs of off-grid areas and for integration in grid-connected areas. This selection was based on the current lighting options in the market and a least cost comparison of technologies. A summary of recommended options determined through this analysis are presented in the table below.

Table 1: Summary of Recommended Solar-Based Energy Efficient Lighting Options

S. No.	Application	Average Recommended lux level	Recommended Lighting	Solar Panel Sizing	Battery Sizing	Daily Usage /Back up	Emergency use /Autonomy	Recommended for ON-Grid or OFF-Grid
1	Residential General Lighting (One Fixed and one portable type)	100	2X5 W LED	20Wp	12 V 20Ah	5-6 hrs	14-16 hrs	Both
		100	2X 9 W CFL non - retrofit	40Wp	12 V 40Ah	5-6 hrs	14-16 hrs	ON GRID*
		100	2X 9 W CFL non - retrofit as portable source and 9W CFL retrofit as a fixed source	60Wp	12 V 60Ah	5-6 hrs	14-16 hrs	ON GRID
2	Residential Task Lighting (Portable type)	100	5 W LED	10Wp	12 V 10Ah	5-6 hrs	14-16 hrs	Both
		100	9 W CFL	20Wp	12V 20Ah	5-6 hrs	14-16 hrs	ON GRID*
3	Street/Outdoor Space Lighting	25	2X14 W T-5	120Wp	12 V 120Ah	12 hrs	3 Days	OFF GRID
4	Community Lighting	100	14 W T-5	30Wp	12 V 30Ah	12 hrs	3 Days	OFF GRID
			20 W CFL retrofit type	40Wp	12 V 40Ah	5-6 hrs	14-16 hrs	ON GRID

* Can be considered for off-grid lighting options as well, although the study analysis indicate LED based systems to be more cost effective over a 20-year lifespan.

Key recommendations

28. Recommendations take into account the cost analysis, Afghanistan context, existing infrastructure, and potential barriers to implementation and hence differ for consumers in off-grid vs. grid-connected areas. Grid-connected consumers include both urban consumers and rural consumers where localized grids exist or are possible, particularly where micro-hydro/wind potential is viable.

Recommendations for off-grid areas

29. Solar PV based energy-efficient lighting options are recommended for supporting basic lighting needs in off-grid areas given the adequate availability of solar radiation. The modular nature of SPV systems, the ease of installation, the short timeframe required for installation, and the low operating and maintenance requirements also make these systems an attractive option for Afghanistan. If localized grids exist or are possible, particularly where micro-hydro/wind potential is viable, the recommendations on efficient lighting solutions are similar to grid based solutions (covered in the next section).

30. High upfront costs of solar-PV based stand-alone lighting systems are lower in comparison with costs for grid extension to smaller areas. A typical home lighting system with two light bulbs per household (one fixed; one portable) was considered, as this is the minimum requirement for a basic lighting system that can meet multiple needs and therefore provides a suitable option for Afghanistan where approximately have the population lives below the poverty level. Based on the analysis (presented in Annex 3) the configuration of 2 x5 W LED will cost USD 130 / (6150 AFN) and if we include installation cost plus the training and maintenance costs; the total cost reaches around USD 180, (8514 AFN) assuming a lifetime of 20 years. On the other hand, just the distribution connection cost of connecting one customer to grid can be as high as USD 1000 (47300 AFN) where over and above the initial costs, power tariffs would need to be billed and collected, and infrastructure maintained at larger operating costs. This clearly indicates huge cost savings potential for the government to provide basic lighting needs to off-grid consumers through solar-backed systems.

31. The table below summarizes the configurations of each of these recommended lighting options for off-grid lighting. Details on the approach and assumptions used in the analysis are provided in Annex 3.

Table 2: Summary of Recommended Energy Efficient Lighting Options for Off-grid Applications

S. No.	Type of Lighting Systems	Home Lighting System	Lantern as task and portable lighting	Street/Space Lighting*	Community Indoor Lighting
	Recommended Product	**2X5 W Solar LED (fixed + portable)**	**5 W Solar LED with PV panel**	**2X14 W Solar T-5**	**14 W Solar T-5**
1	Flexibility	One portable and one fixed type lamp is suggested, so that user can use one fixed type product in one room and a second portable option can be used as a handy solution as per the requirement.	This product can be used in the off- grid areas, with solar PV, and can also be used with AC supply (in case of grid connected applications).	This can be used for two identified applications i.e. Street lighting and outdoor community lighting.	This product is selected to reduce the different types of lamps for different applications and can be used for both street lighting and community indoor lighting applications.
2	Cost	LEDs and T-5s provide significantly higher efficiency in terms of lumens /Watt. Therefore initial capital cost of the system is significantly reduced for PV and batteries. For example, in the case of a 5W LED the capital costs of the solar equipment works out to US$54, as compared to a cost of US$102 for the equivalent light output from a 9W CFL lamp.			
3	Lighting Adequacy	Efficacy in Lumens/Watt is around 100, which is adequate to meet basic lighting needs		Efficacy in Lumens/ Watt is around 80. The standard lux requirement for outdoor streetlight can be fulfilled by this lighting solution.	Efficacy in Lumens/ Watt is around 80. T-5 lamps offer a good amount of light in comparison to incandescent lamps.
4	Ability to expand the applications served through solar backed systems	Solar energy is widely available, therefore additional products can be added and used (at additional cost) as per requirement, by expanding size of solar panels to meet additional needs . The govt. can consider providing subsidized or even free only home lighting solution and consumers can later upgrade with similar systems for use of appliances like TV, etc. and productive loads at their own cost			

*For street lighting applications it is assumed that street lighting poles are 7 meters in height and placed at a distance of 14 meters apart.

32. Despite the relatively nascent nature of LED technology and current higher cost of luminaries, LED lamps were found to be cost effective in meeting the residential lighting needs in stand-alone off-grid areas in Afghanistan due to: 1) the low power requirements, 2) high durability; 3) long lifetime of lamps, and 4) potential for further improvement in efficiency. The higher upfront cost of LEDs is more than compensated by reduced solar panel and battery size requirements. The analysis for the

recommended 2x5W LED home lighting system shows that the associated cost of the solar panel and battery is half of the cost of an equivalent CFL-based lighting system of 2x9W. LEDs have the potential to become even more economical in the long-run, due to further advancements in efficiency levels and light output forecasted over next few years.

Recommendations for grid-connected areas

33. The recommendations for grid areas are further subdivided into best options for new grid-connected consumers, where infrastructure for electricity supply is being developed, and existing grid-connected customers.

New Grid-Connected Consumers

34. In new grid connected systems, energy efficient lighting solutions for residential lighting, community space lighting, and street lighting were examined. The analysis determined that solar-based energy-efficient lighting systems that were identified for off-grid applications also have viability in new grid-connected areas. Please refer to Annex 4 for additional details.

35. For home lighting, use of high power factor Compact Fluorescent Lights (CFLs) is recommended. However, a big challenge in the use of CFLs is competition that is offered from the existing cheap, low quality products that have penetrated the market. Tackling this challenge needs to be strategically handled - by introducing systems and practices to weed out poor quality energy-efficient lighting products, strengthening consumer awareness campaigns, etc. Issues like low power factor, potential harmonics problems for the grid and environmental hazard due to the presence of small quantities of mercury in lamps exist and need to be managed appropriately.

36. It is also found that the use of recommended solar-based stand alone energy-efficient lighting options would be particularly attractive during peak time loads, where the tariff levels are very high or utility/consumers often have to rely on diesel generation costs to provide required electricity needs. These products could be used as back up options for outages during grid supply failure and could run in dual-mode of operation. The benefits would be in term of peak demands shaved, and provide lower cost of operation for consumers over the lifetime of the lighting system. The total costing of the system would reduce as well since the autonomy that needs to be taken into consideration for off-grid systems would be reduced from 3 days to 1.5 days for grid-integrated systems.

Existing Grid-Connected Consumers

37. In existing grid-connected areas the use of energy-efficient lighting technologies would help to reduce the total lighting load requirement. This would benefit both consumers and utilities since there would be a reduction of operating costs for consumers and a reduction of overall electricity demand for utilities. Given this situation, even use of retrofit energy-efficient lighting options that are not backed by renewable energy sources would be beneficial, particularly to commercial and industrial consumers who have larger lighting loads and often rely on diesel generation to meet power needs.

38. The analysis shows that the breakeven point for consumers to switch to energy efficient lights is 16 cents per kWh. If consumers are currently paying this rate or above, it would be rational to switch to energy efficient bulbs even without subsidy. For consumers who pay less than this tariff, subsidies may need to be used to encourage them to switch.

Table 3: Average Tariff Rates for Different Categories of DABM consumers

	Government Consumers/ NGOs	Holy Places	Shops/ Commercial	Registered Factories	Households		
					0-300kWh	301-700kWh	>701kWh
Tariff in Afghanis (AFN)/unit	10.20	9.74	9.47	5.77	2.62	3.94	4.99
Tariff in US cents/unit	21.2	20.23	19.68	11.98	5.44	8.19	10.36

Source: Weighted Average of Tariff Rates of DABM for the 06 Cycle of fiscal year ended 1386

39. At these existing tariff rates energy-efficient lighting technologies would provide an economically viable option for government consumers, NGOs and holy places even with the high upfront costs of these products. For consumers at tariff levels below US 16 cents (7.6 AFN), however, the cost of providing lighting through these energy-efficient lighting technology options would not be economically viable without providing subsidy to off-set the part of higher upfront costs.

40. At present, CFL-based lighting options may be preferable to LED lighting options due to the lower upfront costs and higher penetration and awareness of CFLs in the market. If advancements in LED technologies and associated cost reductions continue at current rates, it could be expected that LED technologies may be a more economical option than CFL options within the next 2-3 years, due to the lower wattage requirements and significantly enhanced lighting efficiencies that are expected of LEDs. This reduces the overall cost reduction potential over the lifetime of the lighting system.

41. The following energy-efficient lighting options are recommended for on-grid applications. A detailed list of energy-efficient options to replace existing lamps, with associated costs and savings is provided in Annex 4. The cost of purchasing the energy efficient lighting products could be greatly reduced if the government procures a bulk supply of CFLs. This has successfully been used in many World Bank energy efficiency programs to bring lamp costs down to well under US$ 1/lamp (47.30 AFN). Further discussion of the Bank energy efficiency programs in other countries are discussed in the section on implementation.

Table 4: Recommended Replacement Options for On-grid Applications (For details, refer Annex 4, Table 13)

S.No.	Application	Average Accepted lux level	Recommended Lighting	Against Replacement of	Initial Investment required in USD	Payback period*
1	Home Lighting	50-100	2X11 W CFL	2x40 W GLS	3.5 (166 AFN)	3-4 months (6 hrs/day)
2	Street/Space Lighting	25-30	2X14 W T-5	70 W SV	28 (1330 AFN)	14 months (12 hrs/day)

*Payback period calculated based on a tariff rate of US 10 cents/unit

Barriers to implementation

42. The table below highlights the primary barriers to adoption of energy efficient lighting and the potential mitigation measures, which could be used to overcome these barriers.

Table 5: Summary of Major Barriers and Possible Mitigation Approaches

S. No	Major Barriers	Possible Mitigation Approaches (including Recent Developments)
1	**Financing and Market** a. High Upfront Costs of energy-efficient lighting b. Since LEDs for general lighting applications is a new technology there are limited suppliers of LED lighting systems and controls	- Subsidy may be needed for consumers who have lower paying capacity. - Accessing funding sources available for low carbon growth strategies to help provide subsidy - Attracting international suppliers through procuring minimum critical volumes. - Enlarging market by promoting similar products in viable grid connected areas.
2	**Institutional Capacity** a. Lack of institutional arrangements to support scaling up programs for energy-efficient lighting b. Lack of good systems to ensure quality of new technologies	- Developing institutional capacity of appropriate ministries/ institutions such as MEW, MRRD and DABS with donors support to implement energy efficient solutions. - Use lessons on institutional arrangements from past experiences from National Solidarity Program and other countries - Appropriate quality assurance and third party testing system need to be implemented with good standards of specs. - training required on energy-efficient lighting

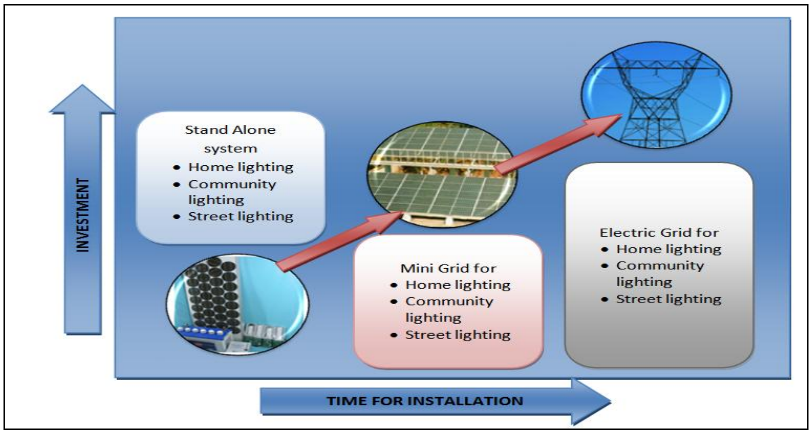
		systems at various levels including government staff and central and local level, implementing agencies, utility service providers, and consumers. - Standardization, keeping adequate spares and maintaining skills for regular operation and maintenance will help in managing this risk.
3	**Lack of Awareness of Energy-Efficient lighting Products** a. Limited consumer awareness on choosing products and understanding benefits and cost savings	- Awareness campaigns targeting consumers and local distributors on the benefits of energy-efficient lighting options - Developing "how-to" manuals and materials that can be easily distributed - Demonstrating the use of energy-efficient lighting in a few areas and then ramping up this awareness to other regions
4	**Sustainability** a. Lack of standards to ensure quality b. Competition from very low initial cost products available in the market c. Operation and maintenance of systems d. Limited distribution and availability e. Fluctuations in availability of renewable energy resource for off-grid lighting systems, due to adverse weather conditions	- Develop minimum technical specifications/standards for performance. - Support development of testing programs/facilities and seek longer guarantee periods in the initial years. - Ensure that products that are supplied for government programs meet certain minimum quality standards - Appropriate training and materials for local staff and consumers on operations and maintenance of systems - Setting up hubs to provide local support, spare parts and technical assistance to ensure operations and maintenance of installed systems - Higher autonomy of lighting systems and innovative features like power output regulators would allow lighting products to function at dimmed levels even if power source is restricted or to consciously reduce lighting load as per consumer demand

Implementation Strategy

43. An energy efficient lighting initiative in Afghanistan that covers both off-grid and grid-connected customers would include: a) considerations for off-grid electricity generating options (solar PV) and b) a light bulb replacement program. In both cases the goal would be to alleviate the current problems and improve the market for energy efficient lighting.

44. Based on previous experiences with energy and lighting projects in Afghanistan and other countries it is recommended that implementation takes place in a phased approach so that limited resources can be used to address the critical lighting needs first and the supporting framework for sustainability can be developed concurrently.

Figure 2: Phasing of Time and Investment for Installation of Energy Efficient Lighting Services



45. The technical specifications for stand-alone solar based lighting systems are attached in Annex 5 for reference. These specifications should help in energy efficient products adhering to international standards. Though additional considerations like higher warranty period, adequate spares, training of personnel and quality assurance mechanism need to be added to the technical specifications as per specific requirement.

46. In developing an appropriate implementation strategy the following would also need to be taken into consideration: current lighting technologies and market trends, key barriers and mitigation measures; institutional capacity for supporting an energy-efficient lighting program; and socio-economic demographics of the beneficiary community. Below is a list of some key factors which could be components of an implemented program.

1. ***Awareness generation***: Awareness campaigns for consumers and local distributors on the benefits of energy-efficient lighting options may prove to be very useful in the present context. Since the project requires a shift from the existing practices, coupled with higher initial investments, it is important to address and influence pre-existing mindsets that may act as a barrier to adoption and use of energy-efficient lighting systems. This is a function that could be carried out by the energy efficiency unit/departments of MRRD; MEW and DABS but would need coordination with local entities to ensure that end-users understand the benefits, capabilities, and costs of these lighting systems.

2. ***Capacity building:*** Appropriate exposure and training on energy-efficient lighting systems should be provided at various levels including government staff, potential suppliers, implementing agencies, service providers, project facilitators and consumers. At the government level exposure drive should be conducted at a broader level, to cover basic technical aspects, benefits and barriers of energy-efficient lighting options, how the use of these lighting technologies can help to meet electrification planning goals, and considerations for implementing lighting programs. Suppliers and project facilitators would benefit from training on marketing and outreach strategies for energy efficient lighting, project procedures and management of a sustainable service delivery model through lessons from past experiences. Consumers would benefit from training on the advantages of energy-efficient lighting options and guidance on choosing and operating appropriate systems that would meet their lighting needs. The implementing ministry could take a lead in developing the required type of training programmes for various stakeholders.

3. ***Quality control for energy-efficient lighting market/products*** Minimum technical/ quality standards should be adopted for energy-efficient lighting products that are used/disseminated as part of a lighting program initiative. This will ensure more effective implementation of the program by eliminating low quality products that could lead to negative perceptions of these new technologies. Selection of supplier of products of standard specifications needs to be identified for the effective implementation of this program. There is also a need for standardization in procurement of energy efficiency lighting products and preparing a listing of available testing facilities.

4. ***Monitoring and evaluation (M&E)*** M&E arrangements have to be strong for programs of this nature as they involve various stakeholders and a large beneficiary base. A monitoring mechanism that helps to capture quantitative information such as available suppliers, products, and testing standards, as well as qualitative information such as successes, barriers, and lessons learnt will be helpful in drawing lessons for future energy efficient lighting programs and scaling up the proposed program. Such a macro level monitoring system could perhaps be put in place by the implementing agency (for e.g. MRRD or MEW)

5. ***Leveraging donor coordination*** Effective leveraging of existing projects or programs would be useful in planning the development of energy-efficient lighting programs/projects. The Government of Afghanistan has undertaken a home lighting system initiative under the multi-donor funded National Solidarity Program (NSP) and a project for the electrification of 100 villages by Central Electronics Ltd. (a Government of India agency). Donor agencies such as World Bank, GTZ, USAID, and Agha Khan Foundation also have experiences from similar programs in other regions. A thorough review of lessons from previous programs and leveraging networks of existing programs in Afghanistan would ensure better success in implementation.

6. ***Rural energy efficiency hubs*** Local hubs or energy efficiency centres could be set up to demonstrate the use of energy efficient lighting products and provide local support, spare parts and technical assistance to ensure operations and maintenance of installed systems. (Ref. TERI case study Annex 8).

7. ***Creating rural enterprise*** Another viable alternative implementation strategy can be to develop one centralized rural enterprise (shop, kiosk) which will provide a facility for a charging station and distribution of solar lanterns without panel base. On one hand, this will help to reduce the unit cost of installation/purchase for the rural consumer and on the other hand, it helps to develop local market and entrepreneurship to sustain such lighting initiatives (refer to Annex 6 for case study examples).

8. ***Government leadership*** It will important for the government to consider the value of introducing energy efficient lighting in their broader strategy. They would need to lead this campaign and can garner required collaboration between different players. .

Next steps

Based on the above analysis, it is clear that energy efficient lighting systems could benefit Afghanistan by extending access to a greater portion of the population, reducing demand on the grid network, and reducing costs for all consumers. The next steps in designing an implementation strategy are a review of delivery models and full economic and financial analysis of the delivery options followed by pilot projects which can be scaled up.

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ANNEXURES

[1-6]

Annex 1: Comparative Analysis of Different Lighting Options[16]

There are six commonly used lighting technologies that were examined as part of this study. Brief descriptions of each of these technologies are presented below followed by a table that compares them on technical parameters such as efficacy life; lighting quality.

Incandescent Lamps

Incandescent light is produced by a tiny coil of tungsten wire that glows when it is heated by an electrical current. Unfortunately, 90-95% of the power consumed in this process is emitted as heat, therefore making this process inefficient from an energy standpoint. Incandescent lamps have the shortest lives of the common lighting types.

Fluorescent Lamps

The light produced by a fluorescent tube is caused by an electric current conducted through mercury and inert gases in a partially evacuated glass tube that is lined with phosphors. Fluorescent lamps need ballasts (devices that control the electricity used) for starting and circuit protection, which means that these lamps do not always start instantly. Fluorescent lighting is about three to four times as efficient as incandescent lighting, although efficiencies vary based on lamp wattage and ballast type (electronic vs. magnetic) and quality. Fluorescent lamps last about 10 times longer than incandescent lamps, but for optimum efficiency, should be installed in places where they remain on for several hours at a time.

Compact Fluorescent Lamps

CFLs (compact fluorescent lamps) combine the efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. Although CFLs cost about 10 to 20 times more than comparable incandescent bulbs, they last 10 to 15 times as long. This energy saving and superior longevity makes CFLs one of the best energy-efficient investments available.

High-intensity discharge Lamps

HID (high-intensity discharge) lamps are a suitable alternative to high wattage incandescent lamps, where intense, concentrated light is required. They are commonly used for outdoor lighting, and in large indoor areas. These lamps use an electric arc to produce intense light. They also require ballasts, and take a few seconds to produce light when first turned on because the ballast needs time to establish the electric arc.

The three most common types of HID lamps are mercury vapor, metal halide, and high-pressure sodium. HID lamps and fixtures can save 75%—90% of lighting energy when they replace incandescent lamps and fixtures.

[16] Adapted from Energy Conservation Building Code Tip Sheet, Building Lighting Design, USAID ECO-III Project, February, 2008

a. Mercury vapor

Mercury Vapor (MV) lamps use a high-pressure mercury discharge that directly generates visible light. This is the oldest type of HID lighting, and is used primarily for street lighting. MV lamps have lower efficacy than fluorescent and other HID lamps. Most indoor mercury vapor lighting has been replaced by metal halide lighting, which has better colour rendering and efficiency.

b. Metal Halide

These lamps are similar in construction and appearance to mercury vapor lamps but have the addition of iodides of metals such as thallium, indium, and sodium to the arc tube, which makes them produce a higher quantity and quality of light than MV lamps. However, after a shut down or power interruption these lamps may require as much as 10-15minutes to restart.

c. Sodium Lamps

In sodium vapor lamps, a high frequency, high voltage pulse ionizes a rare gas, such as xenon, in an enclosed tube. This is fast becoming the most common type of outdoor lighting. Sodium lamps vary widely in efficacy and color quality, and performance is very sensitive to the gas pressure inside the tube. Sodium lamps are used in applications where color quality is not as important because they render colors in tones of yellow or grey and improving the quality of light can significantly reduce their efficacy.

Light-Emitting Diodes (LEDs)

LEDs use solid-state electronics to create light. In the past few years, solid-stare lighting in general and Light Emitting Diodes (LEDs) in particular have received more attention than any other lighting technology. Major elements in the packaging of an LED include a heat sink to dissipate the energy that is not converted into light, a lens to direct the light output, and leads to connect the LED to a circuit. LEDs are rapidly increasing in efficacy, light output, and color availability while decreasing in cost. LED products can operate both on AC and DC current. Universal input ranges and the ability to sustain voltage fluctuations make LED products a good option for rural applications. LED lamps, or more specifically white LEDS, are believed to produce nearly 200 times more useful light than a kerosene lamp and almost 50 times the amount of useful light of a conventional incandescent bulb.

Table 6 shows the comparative characteristics of these different lighting technologies.

Table 6: Comparative Analysis of Different Lighting Technologies

Parameter	Conventional Incandescent	TFL	CFL	Mercury Vapor	Metal halide	Sodium Vapor	LED
Efficacy (lumens per Watt)	10-20	40-90	25-70 (incl. ballast losses)	35-65	70-130	50-150	80-120
Lamp Life (hours)	1,000	5,000 (T-12 & T-8) 18,000 (T-8 high lumen & T-5)	6,000-10,000	6,000- 8,000	15,000	12,000-15,000	50,000
Ballast Life (hours)	NA	50,000	10,000	10,000	15,000	15,000	50,000
Lighting quality in terms of CRI on a scale of 100	100	45-89	70	50	75	20	80-89
Distribution of light in terms of spread	✓	✓✓	✓	✓	✓✓	✓✓	✓
Power factor	Not an issue	Ballasts with high power factor are available –but ballasts with low power factor are cheaper and widely available.	Ballasts with high and low power factor are available but some have low power factor.	Ballasts with high power factor are available but some have low power factor.	Ballasts with high power factor are available but some have low power factor.	Ballast with high power factor available but some have low power factor.	Not an issue
Effect of temperature	Minimal	Serious loss of light output above and below optimum lamp temperature of 38°C	Serious loss of light output above and below optimum lamp temperature of 38°C	Minimal loss at temperatures > 30°C	Minimal loss at temperatures > 30°C	Minimal loss at temperatures > 30°C	Performance is not impacted as temperatures drop
Harmonic distortion	None	High distortions occur in cheaper electronic ballasts	CFLs with electronic ballasts have significant harmonic distortions – cheaper CFLs have higher levels than others	Minor if ballasts are magnetic	Minor if ballasts are magnetic	Minor if ballasts are magnetic	Very low
Energy saving potential compared to incandescent lamps	NA	90%	80%	80%	87.50%	90%. However, due to its low CRI, its application is limited.	95%

The different lighting technologies are compared based on lifetime of lamps, CRI, efficacy, and market penetration in the figures below.

Figure 3: Comparison of Lamp Life and CRI for Different Lighting Options

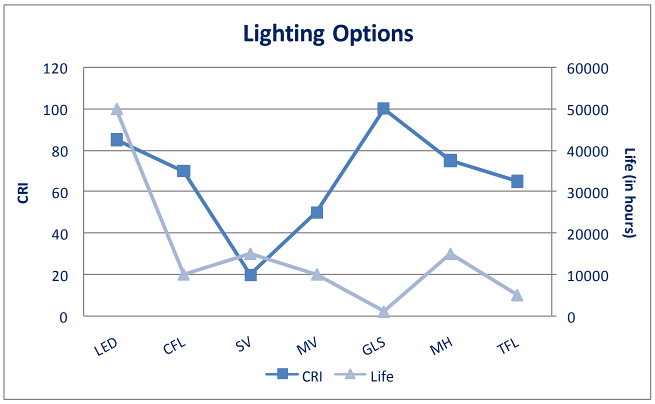


Figure 4: Comparison of Efficacy for Different Lighting Options

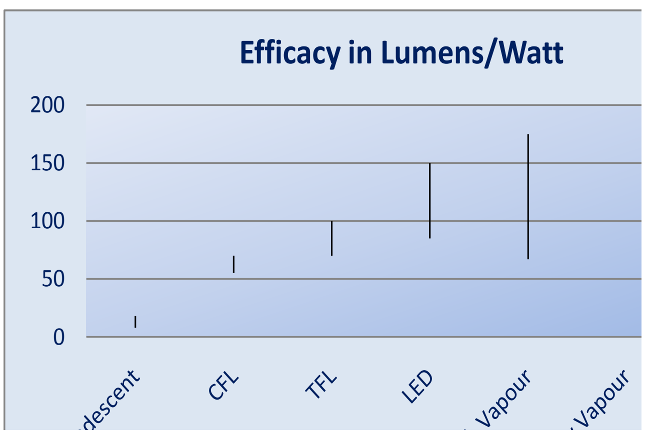
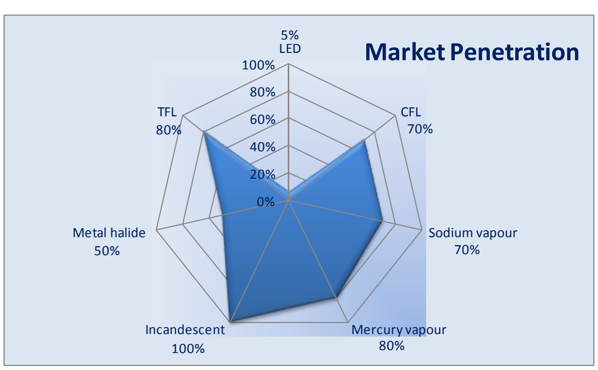


Figure 5: Global Market Penetration of Different Lighting Options*



*Source: Data compiled from various industry sources

Annex 2: Basic Consumer Lighting Applications and Technologies to meet those Needs

The following table presents lighting technology options available and corresponding wattage requirements to meet basic consumer lighting needs.

Table 7: Comparison of Lighting Technologies to Meet Basic Consumer Lighting Applications

Major Group Application	Typical Applications within group	Lux Levels Required	Lighting Technology and Corresponding Wattage Requirement to Meet Lux levels (in Watts)						
			LED	CFL	Sodium Vapor	Mercury Vapor	Metal Halide	TFL	GLS
Residential lighting	Lighting for cooking, reading, general illumination	50 – 150	5-10	9-18	NA	NA	NA	NA	40-80
Outdoor lighting	Street and outdoor area lighting	20-25	75	110	250	400	150	100	1500
Community Lighting (indoor)	Indoor general illumination applications e.g. mosques, community halls	100-200	10-20	36	NA	NA	NA	14-40	200

*NA applies to technologies that cannot produce light at the required lux levels to meet the needs of the corresponding lighting application.

Annex 3: Financial Analysis Energy Efficient Lighting Options in Off-grid Applications

Approach and Assumptions for Financial Analysis

The discounted LCC (Life cycle cost) analysis method was used to calculate the viability of energy-efficient lighting options in off-grid areas. According to the Life Cycle Cost (LCC) analysis method, solar PV-based systems are much more economically viable than alternative sources such as grid and diesel when the electrical loads are smaller and dispersed, as in the case of rural Afghanistan because solar PV systems can be designed to meet the demand required for smaller loads. In the case of diesel generator sets, on the other hand, one has to buy a minimum practical sized generator, which may still be oversized for rural applications. PV System costing is done using the per watt peak cost of the module. There are varying estimates available on the cost contribution of the solar modules, ranging from 42% to 52%. The thumb rule is that the total cost of the PV module is nearly 50% of the system cost. In the BOS (Balance of system), the battery cost is 15% and the cost of charge controllers, inverters, and other electrical equipment is also 15%. The balance 20% consists of the indirect costs, which mainly includes taxes. It is logical to arrive at the best system cost estimates after evaluating a suitable system design. Once the system designing has been completed, one can calculate the approximate cost of the system.

Table 8: Typical Lifespan of Solar PV Components

Component	Years
Module	25
Charge Controller	15
Inverter	5-15
Batteries (solar)	4-6
Wiring	> 10

Source: From Sunlight to Electricity, A Practical Handbook on Solar Photovoltaic Applications, TERI, 2008

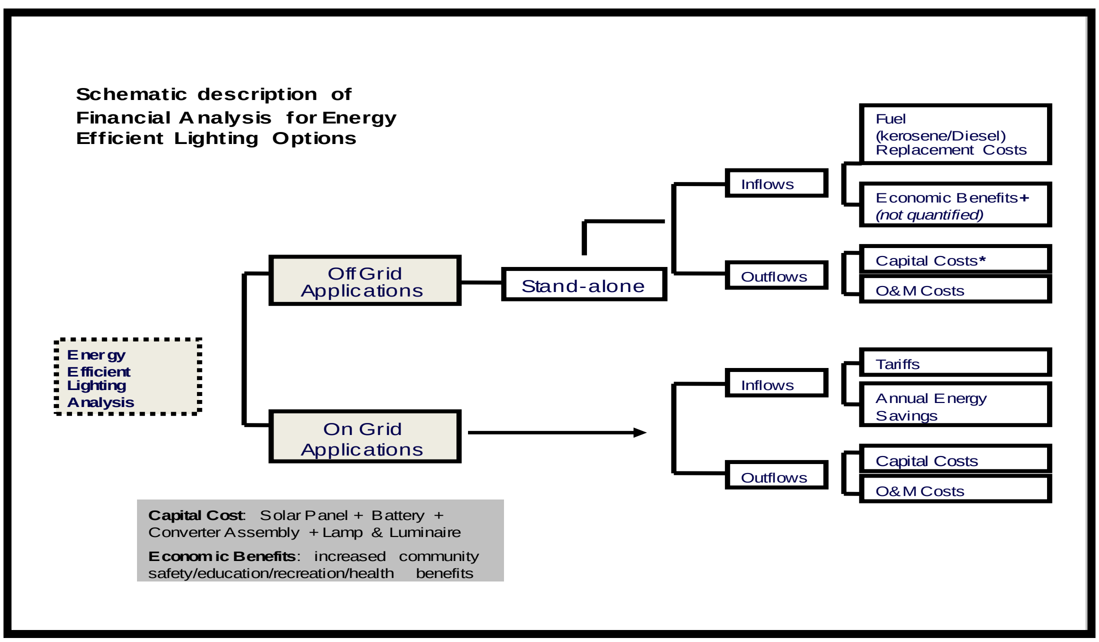
The key assumptions used in the financial analysis for stand-alone solar PV lighting systems are included below:

1. 20 year lifecycle for system; 365 days of use in a year;
2. 6 hours of operation for residential and community lighting applications;
3. 12 hours of operation for street/outdoor lighting applications;
4. 3 days of redundancy/autonomy built-in;
5. Net Present Value (NPV) using a discount rate of 12%;
6. Battery life of five years*
7. Operations and Maintenance (O&M) assumed to be 10% of battery and converter assembly costs

*Sensitivity analysis was done assuming a battery life of 3 years, and it was determined that the recommended options still appeared to be the most viable in all cases.

In calculating the NPV of each of the energy efficient lighting options the costs associated with the inflows and outflows were determined on the parameters outlined in the schematic diagram below:

Figure 6: Schematic description of financial cost calculations



Framework for Financial Analysis for Off-grid Lighting Applications

An LCC analysis was undertaken for the eight energy efficient options that were short-listed for off-grid applications. The analysis revealed that generally the unit cost of generation associated with LEDs is lower than that of CFL. However, per day expenditure over a 20 year lifetime is lower for LEDs compared to CFLs. It is evident from the above analysis that for the solar PV based lighting systems; LED based lighting solutions provide better economics over 20-year life cycle. Thus, the study recommends LED based energy efficient lighting products. For community lighting and street lighting applications, however, T-5 FTLs have been found to be the most viable option. A comparison of unit costs of generation and per day expenditures for LEDs, TFLs, and CFLs are provided in the figures below.

Figure 7: Unit Cost of Generation (USD) For Solar-Based Energy Efficient Lighting Options

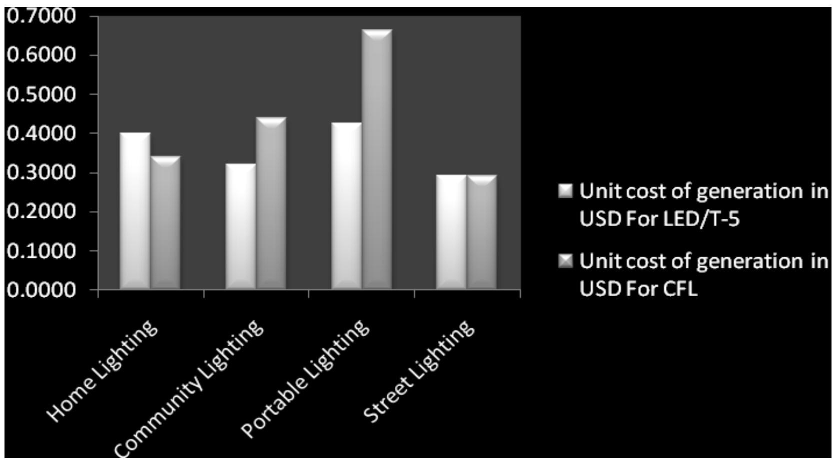
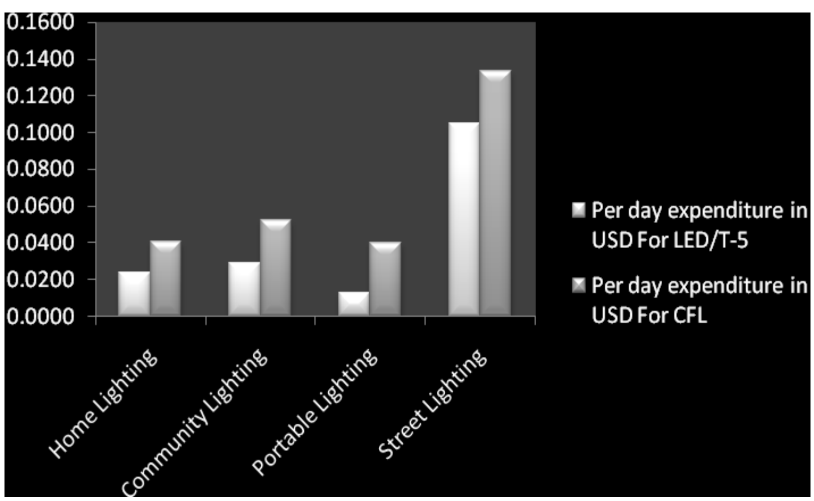
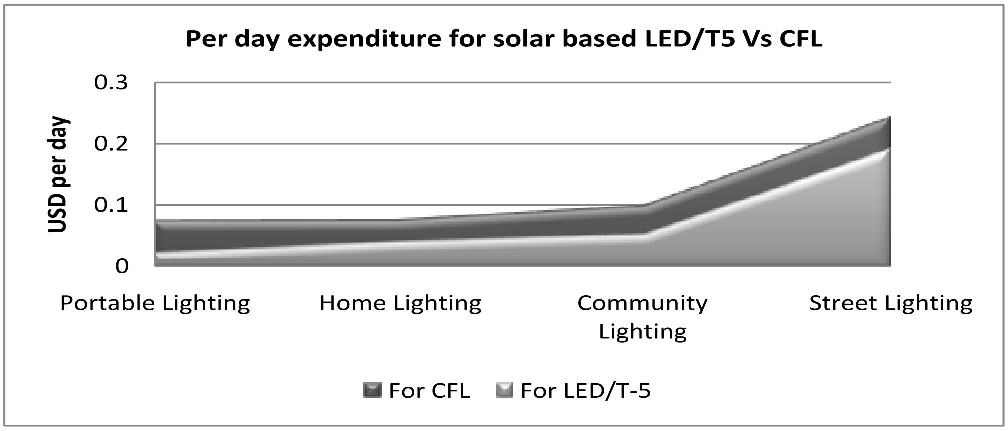


Figure 8: Per day Expenditure (USD) For Solar-Based Energy Efficient Lighting Options
(assuming a 20 year lifetime)





Indicative Calculations For Typical Configuration(s):

Indicative cost calculations for a 5W LED portable lights and 14W T-5 light, based on the analysis conducted are presented in tables 9 and 10 below.

5 W LED portable light

The total number of hours in a year for which LED will be used is 2190 hrs (@ 365X6 hrs/day). One 5W LED system will generate 10.95 KWh (2190 X 5 hrs)/1000) each year. Computed cost per unit equals 0.4259 USD (NPV divided by total investment i.e. 93.28/219 at annual discount rate of 12%). For a 5 W LED this will imply a cost of 0.0212 $ ((0.42 $ X 5)/1000) per hour. Use of this device for 6 hrs each day will entail a cost of 0.12 $ (0.0212X6) (5.69 AFN).

Table 9: Cost Calculation for Solar Portable Light (5 W LED) in USD

Year	Capital Investment									Total Capital cost	Total annual generation in units
	For Generation Equipments for 5 W					For 5 W LED					
	Solar panel	Battery	Converter assembly	Annual O&M Cost	Sub-total	Luminaire	Lamp	Annual O&M cost	Sub-total		
0	34 (1608.20 AFN)	12 (567.60 AFN)	8 (378.40 AFN)	0	54 (2554.20 AFN)	8 (378.40 AFN)	12 (567.60 AFN)	0	20	74 (3500.30 AFN)	0
1	0	0	0	2	2	0	0	0	0	2	10.95
2	0	0	0	2	2	0	0	0	0	2	10.95
3	0	0	0	2	2	0	0	0	0	2	10.95
4	0	0	0	2	2	0	0	0	0	2	10.95
5	0	0	0	2	2	0	0	0	0	2	10.95
6	0	12	0	2	14	0	0	0	0	14	10.95
7	0	0	0	2	2	0	0	0	0	2	10.95
8	0	0	0	2	2	0	0	0	0	2	10.95
9	0	0	8	2	10	0	0	0	0	10	10.95

Table 9: Cost Calculation for Solar Portable Light (5 W LED) in USD (contd.)

Year	Capital Investment									Total Capital cost	Total annual generation in units
	For Generation Equipments for 5 W					For 5 W LED					
	Solar panel	Battery	Converter assembly	Annual O&M Cost	Sub-total	Luminaire	Lamp	Annual O&M cost	Sub-total		
10	0	0	0	2	2	0	0	0	0	2	10.95
11	0	12	0	2	14	0	0	0	0	14	10.95
12	0	0	0	2	2	0	0	0	0	2	10.95
13	0	0	0	2	2	0	0	0	0	2	10.95
14	0	0	0	2	2	0	0	0	0	2	10.95
15	0	0	0	2	2	0	0	0	0	2	10.95
16	0	12	0	2	14	0	0	0	0	14	10.95
17	0	0	8	2	10	0	0	0	0	10	10.95
18	0	0	0	2	2	0	0	0	0	2	10.95
19	0	0	0	2	2	0	0	0	0	2	10.95
20	0	0	0	2	2	0	0	0	0	2	10.95
Total investment on generation for 20 years					**146 (6905.80)**	**Total investment of lamp & Luminaire**			**20**	**166** (7,851.80 AFN)	**219**
						NPV for 20 years				**93.28** (4412.14 AFN)	

Table 10: Cost Calculation for 14 W T-5 Community Lighting System

Year	Capital Investment									Total Capital cost	Total annual generation in units
	For Generation Equipments for 15 W					For 14 W T-5					
	Solar panel	Battery	Converter assembly	Annual O&M Cost	Sub-total	Luminaire	Lamp	Annual O&M cost	Sub-total		
0	102 (4824.60 AFN)	36 (1702.80 AFN)	12 (567.60 AFN)	0	150 (7095.00 AFN)	6 (284.70 AFN)	2 (94.90 AFN)	0	8	158 (7502.20 AFN)	0
1	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
2	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
3	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
4	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
5	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
6	0	36	0	4.8	40.8	0	0	0	0	40.8	32.85
7	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
8	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
9	0	0	12	4.8	16.8	0	0	0	0	16.8	32.85
10	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
11	0	36	0	4.8	40.8	0	0	0	0	40.8	32.85

Table 10: Cost Calculation for 14 W T-5 Community Lighting System (contd.)

Year	Capital Investment									Total Capital cost	Total annual generation in units
	For Generation Equipments for 15 W					For 14 W T-5					
	Solar panel	Battery	Converter assembly	Annual O&M Cost	Sub-total	Luminaire	Lamp	Annual O&M cost	Sub-total		
12	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
13	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
14	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
15	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
16	0	36	0	4.8	40.8	0	2	0	2	42.8	32.85
17	0	0	12	4.8	16.8	0	0	0	0	16.8	32.85
18	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
19	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
20	0	0	0	4.8	4.8	0	0	0	0	4.8	32.85
Total investment on generation for 20 years					**378 (17948)**	**Total investment of lamp & Luminaire**			**10**	**388** (18,352.40 AFN)	**657**
						NPV for 20 years				209.57 (9912.66 AFN)	

One 14W (T-5) system will entail a cost of 0.28$/day (13.2 AFN/day).

Annex 4: Financial Analysis for Energy Efficient Lighting Options in Grid-Connected Areas

The analysis for grid-connected areas was further subdivided into best options for new grid-connected consumers, where infrastructure for electricity supply is being developed, and existing grid-connected customers. As a result, two types of analysis were undertaken for grid-connected consumers:

a. Financial viability of integrating recommended energy-efficient lighting options identified for off-grid applications into grid-connected areas so that back-up can be provided through solar generation vs. diesel-based generation; and
b. Costs and energy savings associated with replacement of existing fixtures with energy efficient lighting options.

Dual-Mode Energy-Efficient Lighting Options

The table below presents a summary of recommended options for grid-integrated energy-efficient lighting options, backed by solar PV.

Table 11: Dual-Mode Energy-Efficient Lighting Options for Grid connected consumers

Application	Average Recommended lux level	Recommended Lighting options (solar based)	Against Replacement of	Total Investment required in 20 years in USD	Total O&M Cost in USD in 20 years	Cost of Energy at which proposed lighting system is viable in USD cents/unit (AFNs/unit)
Grid Based LED and T-5 options						
Home Lighting	100	2X5 W LED	2x40 W GLS	184.8	43.40	**14.17 (670)**
Portable Lighting	100	5 W LED	40 W GLS	101.4	27.7	**15.35 (726)**
Street/ Outdoor Space Lighting	25	2X14 W T-5	70 W SV	819.80	190.40	**34.85 (1646.04)**
Community Lighting	100	14 W T-5	100 W GLS	218.20	59.10	**13.30 (629.09)**
Grid-based CFL options						
Home Lighting	100	2X9 W CFL*	2x40 W GLS	452.20	120.20	46.24 (2187)
Portable Lighting	100	9 W CFL	40 W GLS	157.20	43.40	26.42 (1249)
Community Lighting	100	20 W CFL*	100 W GLS	563.60	153.60	48.13 (2276.55)
Street/space Lighting	25	36 W CFL	70 W SV	1000.48	237.80	55.3 (2615.69)

* Power factor of 0.5. Please note that portable lights come with a non-retrofit CFL hence power factor (PF) is around 0.8 and above.

It was found that LED based lighting options are cost viable over 20-year period compared to CFL based options. However, CFLs with high power factor (>0.85) are a competitive alternative. CFLs currently available in the Afghanistan market are typically of low power factor i.e. 0.5 and below.

Recommended Energy Efficient Lighting Options for Replacement of Existing Lamps[17]

Cost calculations for replacement of existing lamps with energy efficient lighting options were considered based on the methodology presented in the table below:

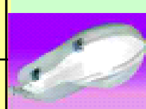
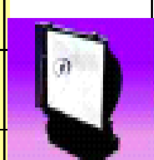
Table 12: Sample Cost Calculation Methodology for Replacement

1. Application	:	Replacing existing lamp (e.g. conventional incandescent) with more energy efficient lighting technology (e.g. CFL)
2. Existing type of lamp and wattage	:	(a) 100 W incandescent
3. Proposed lamp and wattage	:	(b) 20 W CFL
4.Average hours of use per day	=	(c) 6 hrs
5. No. of days per year		(d) 365 days
6.Savings per light fitting	=	a - b watts = (e) 100-20 = 80W
6.Total energy saving per year	= =	c x d x e /1000 units (f) 80W x 6hrs x 365days /1000 = 175.2kWh or units
7. Annual Cost Savings @ USD per unit (h)	=	(g) = 175.2kWh x 0.1 {power tariff (USD per unit)} = US$ 17.5 (827.75 AFN)
Investment (cost of fixture)	=	(h) US$ 2 (94.6 AFN)
Simple Payback period	=	(h/g) 0.114years (less than 2 months)

Cost calculations, energy saving potential and approximate pay-back period for various energy efficient lighting options are considered in the table below for existing residential, street, and outdoor community lighting applications.

[17] All cost calculations were based on a tariff assumption of 10 US cents/unit (~ 4.73 AFN/unit)

Table 13: Recommended Energy Efficient Lighting Options for Replacement of Existing Lamps

S.No.	Replace	Picture of Conventional Light	With	Picture of Energy Efficient Lighting	Energy saving Per lamp in Watts	Estimated Cost per Fitting	Approximate Pay-back Period
GENERAL RESIDENTIAL LIGHTING							
1	T-12 with electro-magnetic choke		T-5 with Electronic choke		55 – 30 = 25	12 USD (567 AFN)	Around Twenty Six months @ 6hrs working/day
2	100 W Incandescent		20 W CFL		100- 20 = 80	2 USD (94.6 AFN)	Less than 2 months @ 6hrs working/day
3	100 W Incandescent		10W LED		100-10 = 90	40 USD (1,892 AFN)	Two years @ 6hrs working/day
4	60 W Incandescent		15W CFL		60- 15 = 45	1.8 USD (85.14 AFN)	2 to 3 months @ 6hrs working/day
5	40 W Incandescent		11W CFL		40-11= 29	1.7USD (80.41 AFN)	3 to 4months @ 6hrs working/day
6	40 W Incandescent		5W LED		40-5 =35	20USD (946 AFN)	Around Two and a half years @ 6hrs working/day
7	25 W Incandescent		5W CFL		25-5 = 20	1.6 USD (75.68 AFN)	4-5 months @ 6hrs working/day
STREET LIGHTING							
8	250W Sodium Vapor		3 x 36 W CFL		280-110= 170	100 USD (4,730 AFN)	16-17 months @ 12hrs working/day
9	150W Sodium Vapor		4 x 14W T-5		175 – 60 =115	90 USD (4,257 AFN)	21-22 months @ 12hrs working/day
10	70W Sodium Vapor		36W CFL with electronic ballast		85- 38 = 47	20 USD (946 AFN)	Around 11 months @ 12hrs working/day
11	40W FTL having copper choke		2 X 11 W CFL with electronic ballast		55- 24= 31	18 USD (851 AFN)	15-16 months @ 12hrs working/day
12	40W FTL		28W T-5		55- 30 = 25	18 USD (851 AFN)	Around 20 months @ 12hrs working/day
COMMUNITY OUTDOOR LIGHTING							
13	400W Mercury Vapor		7 x 24 W T-5		440 – 174 =266	130 USD (6149 AFN)	13-14 months @ 12hrs working/day
14	150W MH		3 X 36W CFL		175 – 110 = 65	100 USD (4730 AFN)	Around Three and Half years @ 12hrs working/day
15	250W MH		5x 36W CFL		280 – 180 = 100	130 USD (6149AFN)	Around 3 years @ 12hrs working/day

Note : The pay back period above is calculated on the basis of 365 days working and a power tariff of 0.1USD per kwh or Unit

Annex 5: Sample Technical Specifications for Recommended Lighting Products[18]

1. Technical specifications of 5 W led portable light source for residential applications

Figure 9: Solar portable 5 W LED Light

Key features

- Portable, Lightweight, All-weather durable and easy to use.
- Super bright white LED with 60,000 hour life expectancy gives a lovely ambient lighting.
- Manual On/OFF with automatically switching through dusk/dawn.
- High capacity Lead Acid Battery (Sealed Maintenance Free).
- Output for Mobile charging – *As most of the people are using mobiles in Afghanistan, therefore mobile charging option is provided for their convenience and ease*
- Rugged and dependable.
- Silent operation.
- Omni directional light.
- ABS plastic body in attractive colour.
- Suitable for AC as well as DC charging – *To increase the product flexibility, user can use it with Solar PV i.e. DC charging and in case of Grid Area , user can use it with AC charging i.e. Grid Power*
- Cut off provision for at 30% DOD
- Dimmer is to be provided so that a user can use the lantern at lower wattage and can get more back up time. In case if he needs lower light output he can reduce it or if he wants higher light output than he can increase it as per his requirement by using a dimmer.

[18] Sources of Specifications: Ministry of New and Renewable Energy (Govt. of India) , OSRAM, PHILIPS , TATA BP SOLAR , G.S. Enterprises and website of pvgap.org (Photo Voltaic Global Approval Program)

PV Modules

For the Crystalline Module the relevant PVGAP standard is PVRS2" Crystalline silicon terrestrial photovoltaic modules "The applicable international standard for modules IEC 61215:1993 crystalline silicon terrestrial modules design qualification and design approval. The PV modules must be warranted to retain at least 90% of its rated capacity measured at STC for at least ten years.

- Highly resistant to rain, water, abrasion and hail impact.
- Anodized aluminum frame with pre-drilled mounting holes.
- High impact resistant, toughened glass.

Batteries

The relevant PVGAP standard is PVRS5 "Lead Acid batteries for solar voltaic energy system (modified automotive batteries)". The applicable international standards for batteries IEC 61427 IEC 2001 Ed2, secondary cells and batteries for Solar Photovoltaic Energy system (PVES) – General requirement and Methods of test. Deep Cycles batteries are preferred.

- Protected from overcharging, deep discharge and reverse polarity.
- Battery cut off at Minimum depth of discharge
- Life of the battery: 5 years and sensitivity analysis done for 3 yrs.
- LEDs for "Battery Charging" and deep discharge protection

Note: reverse polarity means if the battery connections are wrongly done or interchanged.

Table 14: Technical specifications of module and battery for solar portable light

BATTERY	12v / 10 Ah @ C/20, Max Do D 70%
DAILY USE	5-6 HRS (in case if he uses at 5w full load)
EMERGENCY USE	14-16 HRS (in case if he uses at 5w full load)
PROTECTION	Reverse Polarity , Low Volt short circuit , Overload
SPV MODULE	10wp measured at 16.4 V as V load Module Voc minimum of 21 V

Note: Illumination angle is also an important parameter in the choice of lamp technology. For general lighting, CFLs are the best choice, but if the lighting is for reading or doing handicraft work that requires only a limited illumination area, then LED-based lamps can be a good choice as they have high luminous efficacy and very long lamp life. The costs of LED lamps are still falling, while the efficiencies are improving. In the future they are likely to be a sensible choice for household lighting.

3. Technical Specifications for 2X5 W LED Home Lighting System with one fixed and one portable light source

Figure 10: 2X5 W LED Home Lighting System

Home lighting system

Two lamps sources are provided. One movable type i.e. Lantern and other is Fixed type. In a two room house, one fixed type fixture can be installed on wall in one rooms and other movable i.e. Lantern Type can be kept in the other room. The Movable type is suggested for the purpose of providing greater flexibility of use.

Key features

- Portable, Lightweight, All-weather durable and easy to use.- Lanterns
- Super bright white LED with 60,000 hour life expectancy gives a lovely ambient lighting.
- Manual On/OFF with automatically switching through dusk/dawn.
- High capacity Lead Acid Battery (Sealed Maintenance Free).
- Output for Mobile charging – As most of the people are using mobiles in Afghanistan , therefore mobile charging option is provided for their convenience and ease

- Rugged and dependable.
- Silent operation.
- Omni directional light. In case of portable type product and aesthetically beautiful luminarie for wall mounting application for fixed use having acrylic cover and beautiful plastic side caps.
- ABS plastic body in attractive color.
- Suitable for AC as well as DC charging – To reduce the no of options; product should be capable to use with AC as well as DC charging. In case of Non grid Areas , user can use it with Solar PV ie DC charging and in case of Grid Area , user can use it with AC charging i.e. Grid Power
- Cut off provision for at 30% DOD
- Dimmer is to be provided so that a user can use the lantern at lower wattage and can get more back up time. In case if he needs lower light output he can reduce it or if he wants higher light output than he can increase it as per his requirement by using a dimmer. Note: Generally in case of Afghanistan people are using candles or kerosene bulbs. In comparison with the existing sources of lighting a lower wattage products are suitable (which are generally available in the market) but products are suggested and selected in such a way that user should feel that they have got products having value addition

PV Modules:

Crystalline Module are required and the relevant PVGAP standard is PVRS2"Crystalline silicon terrestrial photovoltaic modules "The applicable international standard for modules IEC 61215:1993 crystalline silicon terrestrial modules design qualification and design approval. The PV modules must be warranted to retain at least 90% of its rated capacity measured at STC for at least ten years.

- Highly resistant to rain, water, abrasion and hail impact.
- Anodized aluminum frame with pre-drilled mounting holes.
- High impact resistant, toughened glass.

Batteries :

The relevant PVGAP standard is PVRS5 "Lead Acid batteries for solar voltaic energy system (modified automotive batteries). The applicable international standards for batteries IEC 61427 IEC 2001 Ed2, secondary cells and batteries for Solar Photovoltaic Energy system (PVES) – General requirement and Methods of test. Deep Cycles batteries are preferred.

- Protected from overcharging, deep discharge and reverse polarity.
- Battery cut off at Minimum depth of discharge
- Life of the battery: 5 years and sensitivity analysis done for 3 yrs.

Note: REVERSE POLARITY means if the battery connections are wrongly done or interchanged.

Indications:-

- LEDs for "Battery Charging" and deep discharge protection

Technical specifications of module and battery

Table 15: Technical specifications of module and battery for 2x5W LED Home Lighting System

Type of lamp	Battery	Solar Module	Operation	Emergency use
2 X 5W LED	12V , 20Ah @ C/20, Max Do D 70%	20Wp measured at 16.4 V as load Module Voc minimum of 21 V	5-6 Hrs /day	14- 16 hrs

Note: Sources of Specifications are Govt. of India, OSRAM, PHILIPS, TATA BP SOLAR, G.S.Enterprises and website of pvgap.org (Photo Voltaic Global Approval Program)

2. Technical specifications for 14 W T-5 Lighting for indoor community applications

Figure 11: 14 W T-5 Light

Housing:

Energy efficient Tube light assembly made up of PVC extrusion body (For stand alone application) complete within built electronic ballast and lamp

Specifications of Ballasts:

1. Operating Voltage	:	150 VAC to 300 VAC
2. Minimum Voltage at which lamp starts	:	150 VAC
3. Power Factor	:	> 0.95
4. Lamp start	:	Pre heat time less than 2 seconds
5. Rated Life of electronics	:	50000 burning hours
6. Operating temperature	:	Up to 60 degree Centigrade
7. Protections	:	Input over current
	a. Open Circuit	
	b. Deactivated lamp	
	c. Cathode Open	
8. Supply Current Harmonics	: Conforming to IEC 1000 -0-2	
THD	:	< 10%
9. System consumption	:	14w

Lamps:

1 Rated Life	:	10,000 burning hours
2. Lumen	:	1200 lumens per lamp

PV Modules:

Crystalline Module are required and the relevant PVGAP standard is PVRS2"Crystalline silicon terrestrial photovoltaic modules "The applicable international standard for modules IEC 61215:1993 crystalline silicon terrestrial modules design qualification and design approval. The PV modules must be warranted to retain at least 90% of its rated capacity measured at STC for at least ten years.

- Highly resistant to rain, water, abrasion and hail impact.

- Anodized aluminum frame with pre-drilled mounting holes.
- High impact resistant, toughened glass.

Batteries:

The relevant PVGAP standard is PVRS5 "Lead Acid batteries for solar voltaic energy system (modified automotive batteries) ". The applicable international standards for batteries IEC 61427 IEC 2001 Ed2, secondary cells and batteries for Solar Photovoltaic Energy system (PVES) – General requirement and Methods of test. Deep Cycles batteries are preferred.

- Low self-discharge, highly reliable, low maintenance tubular battery
- Protected from overcharging, deep discharge and reverse polarity.
- Battery cut off at Minimum depth of discharge
- Life of the battery: 5 years and sensitivity analysis done for 3 yrs.

Note: REVERSE POLARITY means if the battery connections are wrongly done or interchanged.

Indications

- LEDs for "Battery Charging", "Battery Low" and "Battery Overcharge"

Table 16: Technical Specifications of solar module and battery for 14W T-5 Solar Community Light

S.No.	ITEM	SPECIFICATION	Value
1	Solar Module	Crystalline	30 Wp measured at 16.4 V as V load Module Voc minimum of 21 V
2	Battery	Lead-Acid	12V, 30 Ah @ C/20, Max Do D 70%
3	Charge Controller	Microprocessor based PWM Charger	Provided
4	Daily use	Working Hours	5-6 hrs a day
5	Emergency Use	Working Hours	14- 16 hrs
6	Module Structure, Battery Box etc.	Galvanized M.S. angle Iron structure suitable for SPV Module and Battery Box with Acid Resistant paint	Provided

4. Technical specifications of 2 x 14w T-5 Solar Street light for outdoor community/street application

Figure 12: 2 x 14w T-5 Solar-Based Street light

Streetlight luminaries suitable for T5 lamps (14 W) with suitable ballasts; complete with housing, lamps, high quality reflector as per following specifications:

Housing:

1. Body made up of Aluminum housing
2. All electrical accessories such as electronic ballasts, lamp holders etc., are pre-wired to a terminal block and mounted on an easily detachable gear plate.
3. Hinging arrangement for cover (bowl).
4. High purity aluminum brightened anodized reflector fitted inside.
5. Stainless toggles for fixing UV stabilized acrylic bowl for housing
6. Conformance to IP 65 Ingress Protection.

Ballasts :

1. Operating Voltage	:	150 VAC to 300 VAC
2. Minimum Voltage at which lamp starts	:	150 VAC
3. Power Factor	:	> 0.95
4. Lamp start	:	Pre heat time less than 2 seconds
5. Rated Life of electronics	:	50000 burning hours
6. Operating temperature	:	Up to 60 degree Centigrade
7. Protections	:	Input over current
		a. Open Circuit
		b. Deactivated lamp
		c. Cathode Open
8. Supply Current Harmonics	:	Conforming to IEC 1000 -0-2
THD	:	< 10%
9. System consumption	:	30w

Lamps :

1 Rated Life : 15,000 burning hours
2. Lumen : 1200lumens per lamp

PV Modules:

Crystalline Module are required and the relevant PVGAP standard is PVRS2"Crystalline silicon terrestrial photovoltaic modules "The applicable international standard for modules IEC 61215:1993 crystalline silicon terrestrial modules design qualification and design approval. The PV modules must be warranted to retain at least 90% of its rated capacity measured at STC (Standard test conditions) for at least ten years.

- Highly resistant to rain, water, abrasion and hail impact.
- Anodized aluminum frame with pre-drilled mounting holes.
- High impact resistant, toughened glass.

Batteries:

The relevant PVGAP standard is PVRS5 "Lead Acid batteries for solar voltaic energy system (modified automotive batteries). The applicable international standards for batteries IEC 61427 IEC 2001 Ed2, secondary cells and batteries for Solar Photovoltaic Energy system (PVES) – General requirement and Methods of test. Deep Cycles batteries are preferred.

- Low self-discharge, highly reliable, low maintenance tubular battery
- Protected from overcharging, deep discharge and reverse polarity.
- Battery cut off at Minimum depth of discharge
- Life of the battery: 5 years and sensitivity analysis done for 3 yrs.

Note: REVERSE POLARITY means if the battery connections are wrongly done or interchanged .

Indications:

- LEDs for "Battery Charging", "Battery Low" and "Battery Overcharge"

Electronics:

- PWM type MOSFET version inverter
- Dusk to dawn operation, automatic switch ON and OFF
- Temperature compensated battery charging

Features:

- Low maintenance; One time installation; High reliability and durability; Suitable up to 6meters pole height

Table 17: Technical Specifications of solar module and battery for 2 x 14W T-5 Solar Street light

S.No.	ITEM	SPECIFIATION	Value
1	Solar Module	Crystalline	120 Wp measured at 16.4 V as V load Module Voc minimum of 21 V
2	Battery	Lead-Acid	12V, 120 Ah C/20, Max Do D 70%
3	Charge Controller	Microprocessor based PWM Charger	Provided
4	Operation	Working Hours at night	Dusk to Dawn
5	Emergency Use	Working Hours at night	3nights
6	Module Structure, Battery Box etc.	Galvanized M.S. angle Iron structure suitable for SPV Module and Battery Box with Acid Resistant paint	Provided

Annex 6: Sample Case Study

TERI Case Study

Project name: Lighting a Billion Lives - http://labl.teriin.org/

Implementing agency: The Energy and Resources Institute (TERI)

Key program highlights: The project aims to distribute 200 Million solar lanterns to 1 billion rural people in India (where kerosene is the predominant fuel for lighting), and create local entrepreneur driven delivery channels for distribution and servicing of solar lanterns.

It is being implemented through Campaign Anchors/Implementation Partners (could be grass-roots level organizations -NGO sector/local government units). Modular solar charging stations for 50 lanterns in identified villages are set up.

As far as financing is concerned, cost of implementing in one village includes hardware cost for the charging station with solar panels and 50 lanterns; transportation of material at site; labour charges for installing the station; selection, training, hand-holding of entrepreneurs; and operations and maintenance (O&M) of the charging station and the lanterns. Coordination and monitoring starts at grass-roots level where the charging station entrepreneur keeps records of daily operations of his/her charging station. These records are compiled on a monthly basis by the Campaign anchor and sent to TERI which maintains a detailed Monitoring Information System (MIS). This program has been implemented in 9 Indian states and in 100 villages**.**

Lessons for Afghanistan

In the immediate time frame, Govt. of Islamic Republic of Afghanistan can adopt similar approach and in the 1st phase undertake effective distribution of solar home lighting and portable lighting systems, in addition to community and street lighting systems. As local entrepreneurship is developed over time; TERI model of common charging station can be adopted – which can potentially lower the per user cost of the lighting system and also provide incentive to increase productive load per community. Another significant advantage of this model is ready availability of O&M services to the off-grid consumer.