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Solar Off-Grid Lighting: An Optimistic and Pragmatic View Required

Solar lighting systems are solar-powered devices and systems used solely or primarily for lighting. In India, 77 million households do not yet have grid electricity, so these solar-powered lighting systems can prevent these households from being plunged into darkness post-sunset. Some parts of the solar lighting segment have witnessed exponential growth and a range of innovations, signalling interest in the topic. Though these devices have brought light to many households, their role in the larger energy access scenario needs to be viewed pragmatically, keeping in mind their strengths and limitations. This paper outlines the developments in the solar off-grid lighting (SOL) segment and the part it can play in providing sustainable energy access to rural India.

Types of solar off-grid lighting systems

SOL systems typically comprise a photovoltaic (PV) module that converts sunlight into electricity, a battery that stores energy for use in hours post-sunset, and a luminaire, which is usually a CFL (compact fluorescent lamp) or LED (light-emitting diode). SOL includes solar lanterns, solar home-lighting systems, and solar street lights.

- A solar lantern is a portable lighting device that is suitable for both indoor and outdoor lighting. It consists of a PV module, a battery, a lamp, and electronics. The battery, lamp, and electronics are placed in a suitable housing, made of metal or plastic or fibreglass. Lanterns using CFL cover a full range of 360 degrees and some of the new range of LED lanterns are focus type with the solar panel, battery, and light integrated like a torch. While CFL lanterns are priced between $22 and $60 (US), the starting price for an LED focus lantern is $5 to $7.5.
- A solar home-lighting system (SHS) provides a comfortable level of illumination in one or more rooms of a house. The SHS consists of a PV module, control electronics, battery, and luminaire(s). There are several SHS models featuring one, two, or four luminaires. The system could also be used to run a small DC fan or a 12-V DC television in addition to lights. The price of a SHS starts from as low as $40 and goes up to over $400, depending on the capacity and end-use options.
- A stand-alone solar PV street lighting system is an outdoor lighting unit used for illuminating a street or an open area. The solar street lighting system consists of a solar PV module, luminaire, storage battery, control electronics, interconnecting wires/cables, and module mounting pole, including hardware and battery box. The luminaire emits light when an electric current passes through it and is mounted on a pole at a suitable angle to maximize illumination on the ground. The PV module is placed at the top of the pole at an angle facing south so that it receives solar radiation throughout the day without any shadow falling on it. A battery is placed in a box attached to the pole. Electricity generated by the PV module charges the battery during the daytime, which then powers the luminaire from dusk to dawn. The system typically lights up at dusk and switches off at dawn automatically.

>> Highlights

- Solar off-grid lighting (SOL) is an improvement on and can replace kerosene for rural lighting.
- Estimates indicate a market potential of 75 million off-grid households for solar lanterns in India, though this is an ever-reducing market as the grid expands.
- Kerosene subsidies can be channelled to subsidise the SOL market.
- Adequate lighting should be considered a basic minimum need.
- SOL is an important interim step toward full energy access for rural India.
- SOL as a package, with other small-scale decentralised renewable energy technologies like solar pumps, renewable energy-based dryers, and cold-storage systems can provide meaningful energy access for households, communities, and productive applications.

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Solar street lights represent an important renewable energy technology in both rural and urban areas, but the focus of this paper is on solar lanterns and SHS. These lighting systems are emerging as a means for basic lighting (and limited electrification, in the case of SHSs) in millions of Indian households. They primarily replace kerosene, which has long been the principal lighting fuel in unelectrified households and in households that are electrified but do not get electricity when they need it. In fact, our surveys have shown that many households opt out of electrification because they find kerosene more reliable.

SOL systems driven by a number of pull and push factors

SOL has significant advantages over kerosene, which is beset with a number of problems (detailed in Box 1). Apart from the risks associated with kerosene, the cost of kerosene is also an important driver for switching to SOL. By contrast, SOL systems are characterized by 'their ease of use, safety, brighter and cleaner light, long product life, and significantly lower lifecycle costs compared to conventional sources of lighting—mainly kerosene' (IFC, 2012).

In addition, the Ministry of New and Renewable Energy (MNRE) incentivises solar lanterns, SHS, and solar street lights. The MNRE provides grant subsidies on lanterns that meet their specifications, to households in off-grid villages. The lanterns are disbursed through the State Nodal Agencies as well as exclusive retail outlets known as Akshay Urja Shops.

Estimates indicate a market potential of 75 million off-grid households for solar lanterns in India and consequently, a private SOL industry has developed over the past few years. The policy environment with low import duties and favourable taxation policies has helped, but industry sources claim that these benefits are negated by the large kerosene subsidy. With solar lantern sales of 2–3 million and SHS sales of around 1 million, market penetration is reportedly less than 5%, indicating a huge potential for growth (IFC 2012). Many feel that within SOL, SHS is a fast-growing segment, having doubled in sales in just a decade between 2001 and 2011.

SOL market dominated by small players

Seeing the life-changing potential as well as the market potential of SOL, a number of players have entered this segment, but it is mostly SMEs and social enterprises that are the most active. This is possibly because the target consumers are largely low-income off-grid households in remote rural locations and thus not on the radar of large private enterprises. Commercial business models based on remunerative pricing and profitability are few. Many of the players depend on government subsidies and other grants to make the products affordable. Given that the markets are remote and scattered, transaction costs are also high.

The lighting provision role of solar off-grid systems in unelectrified and under-electrified areas is clearly evident. SOL innovations have a tremendous potential to expand their reach to critical applications. Entrepreneurial ventures and livelihood activities around SOL are also taking shape. There are mixed views about the independent role of these systems as sustainable energy access providers. Nevertheless, SOL can play complementary and intermediate or transient roles in sustainable energy access endeavours. These points are elaborated below.

Facilitating the transition to a kerosene-free India; allowing various options to compete for avoided kerosene subsidies

One of the major impacts of large-scale dissemination of SOL is the reduction in consumption of kerosene for lighting. Gradual eradication of kerosene will benefit the country through avoidance of risks and costs associated with kerosene (as outlined in Box 1). Importantly, it will also free up Rs 30,000 crore annually. This is the sum currently being lost due to under-recovery and subsidies[1] for kerosene

BOX 1: Risks associated with kerosene-based lighting

Kerosene is the most popular fuel used for lighting in India by households that are not electrified or face frequent power outages and voltage fluctuations. Use of kerosene for lighting has serious issues. Kerosene can emit substantial quantities of fine particulate matter. Poisoning from ingestion of kerosene, particularly in children, are unfortunately common in developing countries. The problem is exacerbated by the common practice of insecure storage of small amounts of kerosene in soft-drink bottles without safety closures.

Relative to gasoline or LPG, risks of explosion are low for kerosene. However, kerosene lamps (and stoves) have contributed to major fires and serious, often fatal, burns because the lamps are used in crowded homes with low ventilation and are often placed on the floor where they can be knocked over. Also, the mixing of kerosene with gasoline (often the same container is used for both), can increase the risk of explosion. Manufactured pressure lamps suffer from blocking of nozzles by soot. Attempts to clear the nozzle with a pin or wire can cause a sudden high-pressure release of an air–fuel mixture, resulting in an explosion (Lam *et al.*, 2012).

[1] Under-recovery incurred by the Oil Marketing Companies and subsidy borne by the government is estimated at Rs 32.67 per litre and Rs 0.08 per litre in September 2014. Source: <http://ppac.org.in/WRITEREADDATA/PS_oil_prices.pdf>

distributed below cost through the public distribution system. For several decades, it has been suggested that channelling kerosene under-recoveries and subsidies to SOL will be a win-win for all. This is not a new recommendation, but despite its obvious rationale, this recommendation has not been taken up, possibly because of political ramifications.

AIREC takes a slightly different position on kerosene subsidies and proposes a competition to access the subsidies once they are freed. The subsidy may be recast in the form of a cash transfer to a household, which can then use the money in any of the following ways. Each user household could get an electronic voucher equivalent of a fixed cost (approximately Rs 5,000 per house) as a connection charge. Alternatively, a cash transfer equivalent to the approximate monthly subsidy on kerosene may be made to the household. This monthly transfer (estimated at Rs150 per month, based on the average household expenditure on kerosene) may be used by the household to either service a loan availed for purchasing a SHS, for a pay-per-use for a SHS, or as a service fee to a micro grid operator. Additionally, each customer is entitled to apply for a consumer loan under the RBI's priority sector guideline for over-the-counter purchase of a household renewable energy device.

SOL as providers of energy access: Varying views

Some governments (such as Bangladesh) have incorporated SOL into their electrification plans and have gone so far as to equate the provision of SOL to electrification. The MNRE does not to equate SOL with electrification, but the Jawaharlal Nehru National Solar Mission (JNNSM) goal of deploying 20 million SHSs to serve 100 million people by 2022 reflects the hope vested with this segment, though not much has been achieved yet. While SOL is undeniably a move up the energy access ladder, it would be inappropriate to equate SOL with electrification for a number of reasons:

- Off-grid lighting systems provide DC electricity and therefore can only run DC-compatible appliances, which are less common and typically more expensive. AC appliances will need inverters to operate and the addition of inverters will add to the cost and technological complexity.
- Off-grid lighting systems are smaller and have lower efficiency than micro grids. And because they are operated in the home by numerous family members, operation and maintenance are often suboptimal leading to frequent equipment breakdowns.
- The cost of energy generation in a solar home system is estimated to be as high as Rs 52/kWh.
- An important limitation of a solar home system is that its capacity is low, around 100 watts. These systems typically support only small household loads such as lights, fans, and mobile charging, and adding productive loads is not usually possible.
- Informal estimates indicate that more solar lanterns and home systems have been provided in electrified than in unelectrified villages. This indicates that SOL is not living up to its role of providing first time access to modern energy.[2]
- SOL's contribution to livelihoods is largely limited to increasing work hours due to availability of lighting.

BOX 2: Solar off-hrid Lighting – MYTHS and FACTS

- Are the costs of SOL really coming down? The panel and battery account for 70% of the cost. And while panel costs have been declining, battery costs have not. Therefore, costs of SOL as a whole are unlikely to decline significantly in the near future. If research on batteries/energy storage can bring battery costs down significantly, the SOL segment will witness a significant cost push. There are also now more categories of solar lanterns, in terms of amount of light emitted. Some of the lower cost lanterns are of lower quality and light output than those that were offered earlier at higher prices.
- Is the market really that large? The market for SOL is always equated with the number of unelectrified households. It must be borne in mind that this number is dynamic and declining.
- Are the systems being used to their full life? Among problems that have haunted the performance and reliability of SOL are poor maintenance, regulation, and quality of systems and parts. Installers do little to protect solar panels from obvious threats like monkeys, rats and pigeons, so when systems are damaged, they can become underutilised or in some cases discarded. These issues are not intrinsic to SOL and can be addressed largely through regulation and awareness, but it is important that these issues be flagged. If solar lanterns and SHS are not used to their full potential over their entire lifetime, the economics of these systems will not hold.

[2] Of the 400,000 solar home-lighting systems installed in rural areas up to 2009, about 300,000 are in electrified villages, and of the 670,000 lanterns distributed, 60% are in electrified villages. Source: <http://ekonnect.net/images/stories/rudicon13/shruti%20orf%20presentation%20rudicon13.pdf>

- Micro grids that can potentially work on solar and nonsolar resources offer many advantages, including the ability to add higher loads. A challenge with micro grids, however, has been to provide adequately high base loads.

There are numerous issues that are touted as positive trends but they need more detailed analysis (see Box 2).

Innovative approaches adopted, more needed going forward

Many parallels have been drawn between mobile phones and solar lanterns. Both can potentially change lives, and both have seen rapid declines in cost and increased innovation in product design, services offered, and in business models (see Box 3).

Enterprises linked with SOL delivery and services

Easy, over-the-counter sales of batteries, panels, luminaires, and spare parts will facilitate sustained use of SOL. In fact, a hybrid system of over-the-counter sales and leasing could improve access to both the product and the services. This, along with the solar charging stations described in Box 2, could create livelihoods around SOL. These could also be tied in with the innovative kerosene subsidy-linked financing mechanisms described above.

Lighting as a basic service, linkage with energy to be provided through DC metering

There is a proposal to raise access to modern lighting to the level of a 'basic minimum need,' along with access to food, drinking water, education, and sanitation. The criteria for lighting could be a minimum number of lux per home with a minimum number of points, rather than based on wattage.

A typical rural household needs light of varying intensities at multiple locations such as the kitchen, living room, courtyard, bathroom, and stable/animal shed, in addition to a portable light. A home has needs for reading (50 lux), cooking (30 lux), general lighting (30 lux), and portable lighting (10 lux),[4] and would need 4-point lighting using 3 watt, 2 watt, and

Box 3: Innovations in SOL

The SOL segment has seen considerable interest and there has been a lot of research on products and services offered. The luminaires have evolved from CFLs to LEDs and batteries have moved from lead acid to the longer-lasting nickel-metal-hydride and lithium-ion batteries. SHS services have increased from just lighting to mobile charging, fans, radios, night lights, and even projectors. Also, hybrid systems have been developed with solar-cum-AC charging.

A useful innovation has been the solar-powered midwives' headlamps designed by the Solar Electric Light Company (SELCO) and the Self Employed Women's Association (SEWA). The headlamps allow midwives to perform deliveries at night.

There has also been innovation in institutional arrangements for distribution, servicing, and financing. Manufacturers have attempted to enter into institutional arrangements with agencies that have a strong rural presence. SELCO, an AIREC member, has teamed up with SEWA Bank for financing and distributing SHS. Some manufacturers have attempted to set up their own branches, but these have proven to be expensive and cumbersome, given the large number of branches required.

In a demonstration programme developed by the National Bank for Agriculture and Rural Development (NABARD) to work with Regional Rural Banks for finance-backed dissemination of SHS, the Aryavart Gramin Bank, an AIREC member, led the way with over 80% sales in Uttar Pradesh.

Solar charging stations are a SOL innovation that has now grown into a separate scheme under the JNNSM. Each charging station with a PV module capacity of 300 Wp can charge 50 lanterns and 5–10 mobiles. The charging stations not only provide off-grid lighting, but also livelihoods as the stations are managed by local entrepreneurs or self-help groups that run a fee-for-service or rental model (typically for solar lanterns). Larger systems can also be rented for certain occasions like weddings.

Another model of distribution is available in Bangladesh through the Infrastructure Development Company Limited (IDCOL)[3] where a service provider is a local NGO or a franchisee who receives a small subsidy and a loan to be distributed to the end user. This programme is the world's fastest growing SHS programme and has already been responsible for installing over 2 million systems in homes.

[3] Source: http://www.iorec.org/iorec1/pdf/1_Session%203.pdf

[4] All lux measurements are at ground level from a down lighter hanging 2 metres above ground.

1 watt high efficiency LED lights. Along with fixed lights, a sturdy unbreakable portable lantern would complete the basic functional lighting needs of a rural household. The total consumption of 48 Whrs can be met with a 10 Wp solar home system. A system of 20 Wp can provide multiple-point lighting and mobile charging, while a 50 Wp systems can handle multiple lights, a portable light, mobile charging, and a radio/MP3 player. An 80 Wp system can provide for multiple lights, entertainment, mobile charging, and a DC fan.

To improve the understanding of SOL in terms of energy consumption, it is recommended that low-power DC energy meters be developed for monitoring SHS. Keeping in mind a minimum level of light to be provided, it may be useful for the SHS to be configured to trip when the lighting (in lux or lumen) is below the required minimum.

MNRE specifications should not curb innovation

MNRE specifications currently focus on size of solar panel, capacity of battery, and type of enclosure. The fixation on materials rather than on output or service provided can curb innovation. For instance, new types of lanterns like LED focus lights are forced out of the purview of subsidy because they do not meet certain material specifications, even though they clearly meet a certain lighting service requirement. The focus of specifications should shift from materials to performance-based standards like the intensity of light on the ground from 2 metres height, the frequency of charge required and discharge cycle of the batteries, the breakability of enclosures, and the sturdiness of solar module mounts. The standards should also offer a wider selection to consumers so that varying needs, affordability, and aspirational aspects can be catered to.

The role of SHS in a step-by-step approach to energy access

Appreciating the benefits of the SOL segment, while also recognising their limitations, the various types of SOL need to be differentiated.

Differentiate between solar lanterns and SHS

As providers of energy, it is important to segregate solar lanterns from SHS, given that the latter are considerably wider in terms of their application potential. Therefore their relevance must be understood and the ecosystems that they need to operate in must also be appreciated.

Solar lanterns provide lighting (and mobile charging in few models) and are portable, similar to torches. They can be used for outside of home activities such as farmers, fishers, and herders working at night. Solar lanterns (along with and similar to solar street lights) also provide safety for movement outside during dark hours and during power outages, even after the grid arrives. Social security and security from harm such as snake bites is an important function that solar lanterns serve. The clear role of solar lanterns, then, is as devices with specific uses, and they must not be seen as a substitute for electricity access.

Unlike lanterns, SHSs that can be used for lights, fans, and mobile charging, could represent a basic minimum level of energy access, but should also not be treated as equivalent to electrification.

Further, it has been observed that the functionality of solar lanterns after one year goes down to 60% and in two years it reduces further to 40%. While a SHS, on the other hand, maintains a functionality rate of more than 80% for the first three years.

A good quality product with efficient distribution, maintenance, and financing can ease the reliability challenges. Some of the Ashden Award winners like D-Light, Noble Energy, Barefoot College and SELCO have proven that large-scale reliable deployment of solar lanterns and SHSs is achievable and can change lives significantly.

SHSs and other DRE packages as an interim energy access solution

SHSs, along with other decentralised renewable energy (DRE) technologies for productive uses and community applications, can act as important energy access packages. DRE-powered technologies for applications such as milk chilling, horticulture product cold storage, powering of small machines like food processors, drying of vegetables, spices and fish, and cold storage of medicines must be disseminated along with SHSs. This will ensure clean energy access for rural livelihoods and development activities along with basic household energy enduses. In this way, SHS can be an integral part of interim renewable energy-based energy access solutions until such time that renewable energy-based micro grids or the conventional grid can be possible.

While the SHS has the distinct advantage of giving the user full ownership and control over the device, it also transfers the risk of operations to the customer and limits the extent of energy availability to specific uses. By contrast, micro grids are operated by entrepreneurs and users merely have to pay for the electricity or the service. Ownership and management of micro grids is always a challenge, but a well-run micro grid has the potential to

provide reasonably reliable energy access (though expecting 24/7 energy access could be unrealistic), and in the case of grid-tied systems, makes it possible to feed electricity into the grid as well. Beyond DRE packages, including SHS, the next logical step up the energy ladder appears to be through renewable energy-powered micro grids, followed then by the aspirational reliable grid electricity.

In conclusion, SOL—both solar lanterns and SHS—have their own separate roles in the provision of lighting. SOL is undeniably a relatively quick solution to provision of reliable lighting and is fast emerging as a consumer durable segment. However, a step-by-step approach ensures that energy access provision is meaningful and goes beyond just household lighting. Solar off-grid lighting systems are rightly viewed as an important innovation, but it is important that we integrate them into a larger energy access transition plan that caters to the aspirations of the energy poor. It is essential that we consider a transition from darkness to not just light, but a move away from darkness to holistic development.

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