Urban Energy Technical Note

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Solar Home Systems and Solar Lanterns

Globally, approximately 1.5 billion people do not have access to electricity, often living far from the electricity grid. Household solar systems and lanterns allow those consumers access to electricity and replace costly, harmful kerosene lamps and candles. While solar lanterns play an important role in curbing kerosene usage and providing light to students, more sophisticated solar systems have been developed in recent years that provide a range of functions to customers – from mobile charging to television usage. While solar technology has been promoted in developing countries since the 1970s, it is only recently that falling prices and innovative business models have led to more widespread adoption.

A solar home system is a stand-alone system, suitable for residential applications such as home appliances, lighting, phone charging, computers and water pumps. A solar home system is generally designed and sized to supply direct current (DC) and/or alternating current (AC) electrical appliances. It consists of a solar module connected to a solar charge controller, an inverter and a battery. The generated DC power is stored in the battery and converted to AC power for supplying to AC loads.

Solar lanterns and solar home systems (SHS) are helping homes in developing countries that are not connected to the main grid (off-grid) to have access to electricity for the first time.

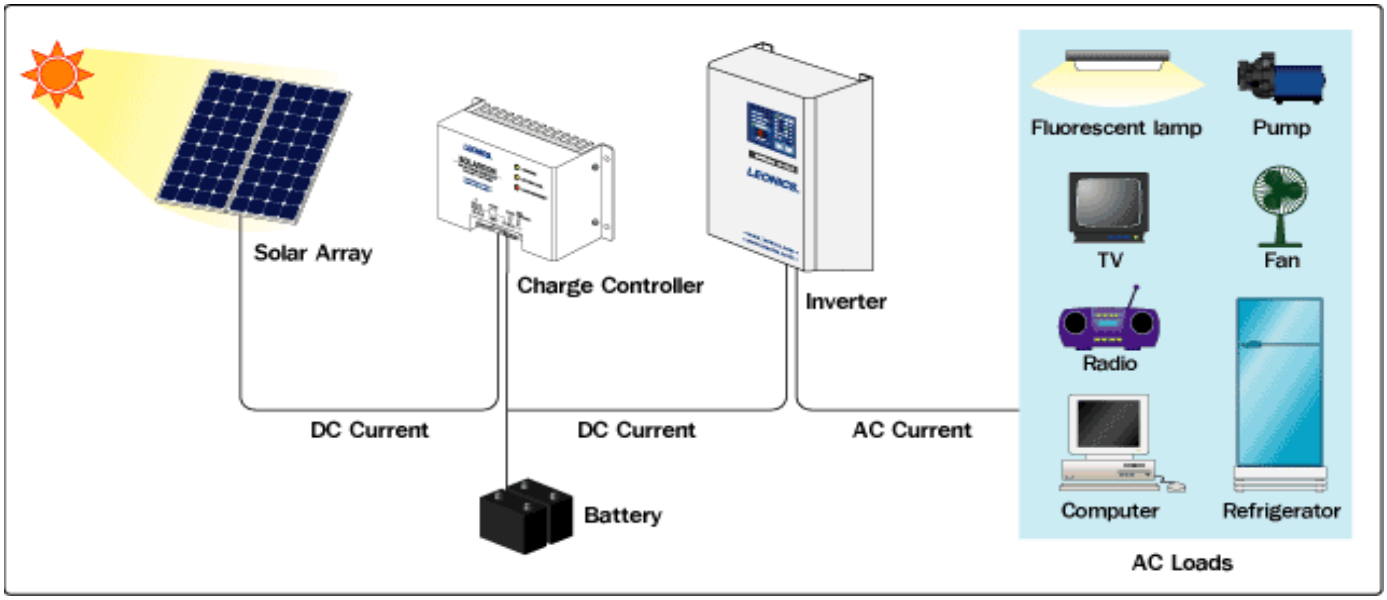
Key facts

- Millions of solar home systems and solar lanterns are in use globally.
- High quality lanterns retail for as little as US$10 each.
- 1 Wp of PV provides enough electricity for a small light and a phone charger.

How Solar Home Systems and Solar Lamps Work

Solar home systems and lamps use photovoltaic (solar-electric or PV) cells and rechargeable batteries to provide electrical power away from the mains grid. Lamps provide a single light (and sometimes phone charging) and are portable. Solar home systems are fixed in a home and can supply several lights, phone charging and other small appliances.
PV cells are made from semiconductor materials, such as silicon, and generate direct current electricity from sunlight. A number of cells can be connected together and sealed in a weatherproof casing to form a PV module.

Fig. 01: **Components Solar Home System**



Layout of Solar Home System

Solar PV cells and modules are specified by their 'watt-peak' (Wp) rating, which is the power generated under standard conditions, equivalent to bright sun in the tropics although they can still work at lower light levels. Solar home systems use between about 5 and 100Wp of PV, solar lanterns between about 0.5 and 2Wp.

The rechargeable batteries store electricity, so that it is available at night and on cloudy days, as well as when the sun is bright, and they also provide a stable voltage for the appliances that use the electricity. Larger solar home systems normally use lead-acid batteries designed specifically for solar use – standard car batteries do not last long with the deep levels of discharge needed in a solar system. Nickel-cadmium and nickel-metal-hydride batteries have been used in lanterns and smaller systems because they are easier to make portable and in small sizes. But lithium-ion batteries are rapidly becoming the most popular because, with good electronic controllers, they last longer.

An electronic charge-controller protects the battery from being overcharged (when it is very sunny) or over-discharged (when people try to get too much electricity from the system). Other features can also be built into the controller, like different brightness settings for lamps.

Appliances that are powered directly must operate at the DC voltage of the battery but an inverter (DC to AC converter) can be included in a larger system so that standard mains-voltage equipment can be used.

One advantage with solar energy technologies is that they are modular, i.e. they can be tailored to the power needs of individual applications such as electric calculators, small radios, televisions, computers, lights or electric pumps. Solar electric systems can be expanded easily by adding more modules and batteries.

Fig. 02: **Solar Home System Design for Home Applications**

Description	Application
SHS 30Wp	2 bulbs of 9W compact fluorescent lamp for 7hr use
SHS 50Wp	9W compact fluorescent lamp for 12hr use
SHS 100Wp	2 bulbs of 9W compact fluorescent lamp for 12hr use
SHS 130Wp	2 tubes of 10W fluorescent lamp + radio or 21" TV. Approximate energy produced 400Wh per day
SHS 400Wp	3 tubes of 18W fluorescent lamp + radio+ TV + fan, 20L fridge. Approximate energy produced 1kWh per day (suitable for small size home)
SHS 2000Wp	Fluorescent lamp + radio+ TV + fan, large size fridge + water pump. Approximate energy produced 6kWh per day (suitable for medium size home)
SHS 4000Wp	Any appliances except air conditioner. Approximate energy produced 12kWh per day (suitable for general home)

How solar home systems and solar lanterns are used

The PV module of a solar home system should be fixed in a position that collects as much sunlight as possible, ideally on an unshaded roof – this also reduces the risk of theft. Ideally, how much a surface should be tilted towards the sun depends on the latitude and what time of year most solar collection is required. If a surface is tilted at an angle equal to the latitude, it will be perpendicular to the sun's rays at midday. The battery is kept indoors with the terminals covered so that they cannot be touched accidentally. The PV, battery, lights and sockets for appliances are wired to the charge-controller.

Customers usually buy solar systems based on the service that they provide (for example: 'charge one phone and run two lights for six hours each day'). It is up to the supplier to make sure that there is sufficient PV capacity to provide this service throughout the year, and sufficient battery capacity to keep the supply running even when there are several cloudy days in a row. It pays to use the most efficient lights and appliances, so LED lights are now most commonly used, although larger systems also use fluorescent lights.

In a solar lamp, the LED light, battery and charge controller are all in a casing which is easy to carry and can stand on a table, or hang from the ceiling. Some have small plug-in PV modules, like solar home systems, but others have the PV cell mounted on the casing. This cuts the cost, but has the disadvantage that the whole lamp has to be out in the sun to recharge the battery.

Solar-home-systems and lamps can be very reliable and need little maintenance, although in many countries there are cheap, poor quality products on the market as well. Users must be trained to check the battery, keep the PV module clean and make sure that connectors are secure. Even with careful use, batteries deteriorate and need to be replaced every few years.

Benefits of Solar Home Systems and Solar Lanterns

The amount of electricity provided by solar home systems and lamps is surprisingly small: the 20 Wp module supplies about 50 watt-hours (0.05 kWh) per day, and the cell on a small lamp only about one watt-hour (0.001 kWh). However, the benefits can be huge.

The main use of a solar home system is to provide better lighting. Many homes without access to grid electricity use kerosene lamps, which are dangerous, producing health-damaging fumes and a constant risk of fires. Children are particularly at risk, so Ashden winner SolarAid has focused on selling solar study lamps, which can be used on a table for

homework. Even these smallest solar lamps give more light than a kerosene lamp. And it is not just studying that is easier and safer with better light. Housework is faster, midwives can deliver babies more safely, shopkeepers can display goods, cattle can be tended and farm produce sorted and packed.

Mobile phones keep people in touch with family and friends, and give access to information, entertainment and mobile money. Being able to charge a mobile phone at home with solar power enables people in off-grid homes to stay connected to the world, without the cost and effort of sending phones to be charged in town. Solar systems can also power radios, providing entertainment and information, and larger systems run televisions as well.

Cost

Costs of solar home systems and lamps vary between countries, and have come down rapidly over the past decade. In 2014, it would cost approximately US$150 to buy a 20 Wp Barefoot Power kit including five LED lights and a phone charger in East Africa, or to have a 20 Wp system with three lights and phone charger installed on your home by Grameen Shakti in Bangladesh. Even though many families spend more than US$150 on kerosene and phone charging in a year, it is a large amount to pay in one instalment and the up-front cost can be prohibitive. In South Asia, micro finance has been used successfully for many years to make solar home systems affordable. More recently there has been growing interest in providing systems on a 'pay-as-you-go' basis, with businesses like Off Grid Electric in Tanzania encouraging customers to pay with their mobile phones.

Dissemination of Solar Home Systems

There are probably more than ten million solar home systems in use. Over three million homes have been supplied through the IDCOL programme in Bangladesh, in which Ashden Award-winners Grameen Shakti and Rahimafrooz Renewable Energy are major partners. The work of the REDP led to the installation of over 400,000 systems in rural China. Kenya is the largest market for solar home systems in Africa, with a large number of independent businesses involved and about 350,000 systems in use.

The Lighting Africa and Lighting Global initiatives have helped to improve the quality of solar lamps and small plug-and-play systems, and sales have grown rapidly over the past five years. Ashden winner d.light has sold over 6 million solar lamps, helped by SolarAid in Africa.

Important applications of solar home systems include:

- Rural electrification (lighting and power supply for buildings, power supply to remote locations, potable water for nomadic herdsmen);
- Water pumping and treatment;
- Health care (for storing vaccines and medicines in PV refrigerators);
- Communication (PV-powered remote radio telephones or repeaters);
- Agriculture (solar pumps for water pumping);
- Transport and navigation aids (PV-powered navigation and signal lights);
- Security (PV-powered security lights);
- Corrosion protection;
- Household and office appliances (ventilation and air conditioners, calculators, watches, path lights, emergency power and battery chargers).

Financing Options for Solar Home Systems

The solar home system market is a fast developing area of the energy access sector, and companies in this sector have pioneered some of most innovative financing mechanisms and distribution strategies. M-KOPA Solar in Kenya has partnered with Safaricom, the country's largest mobile network provider; to launch mobile payment enabled pay-as-you-go solar service using technology from d.light design.

Off.Grid Electric in Tanzania allows its customers to prepay for energy generated from their solar systems using a mobile payment-enabled subscription service, reducing the up-front cost burden M-KOPA's systems. Systems developed by Azuri Technologies allow customers to top-up by purchasing scratch-cards.

Each of these business models has the potential to unlock vast segments of the market that were previously without electricity due to the high up-front costs of the systems themselves. The development of leapfrog technologies in these countries, such as mobile money, have allowed businesses to access hundreds of thousands of customers by reducing the burden of up-front costs and transitioning to "energy as a service" rather than selling products whose full cost remains out-of-reach.

Fig. 03: **Solar Home Systems**

LEFT: M-KOPA Solar Home System comprise: 2 LED lights with switches and multiple brightness settings; 1 LED portable solar torch light; Phone charging USB with 5 standard connections; Portable solar radio; 8W high quality solar panel. (Source: m-kopa.com)

RIGHT: Students using a solar portable light (Source: offgrid-electric.com).

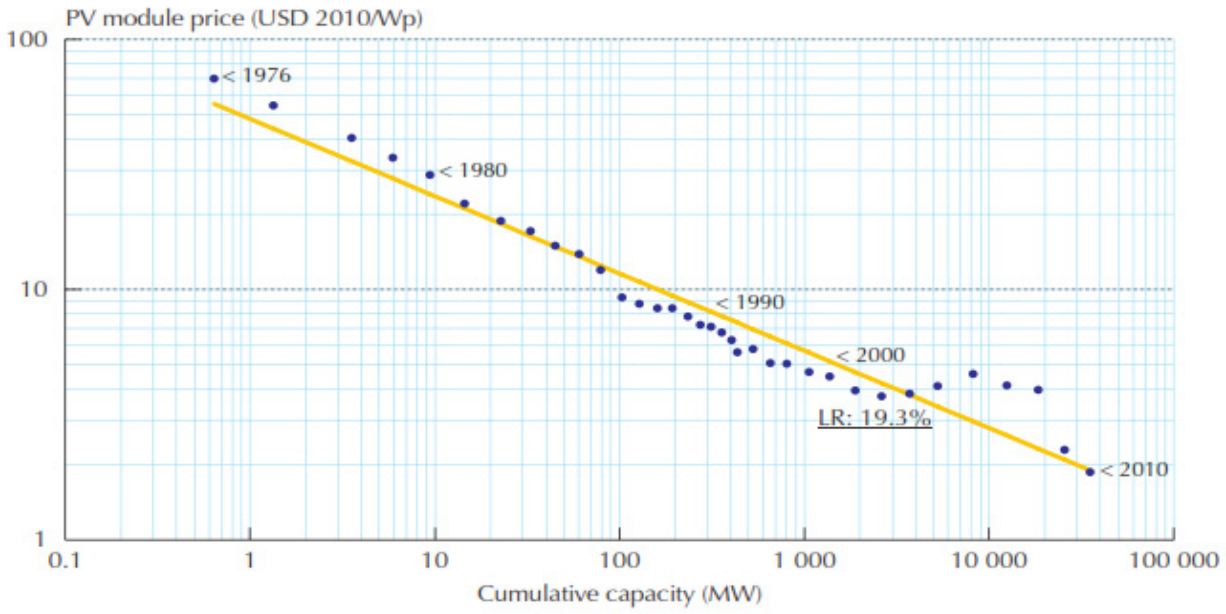
While much of the entrepreneurial activity in East Africa has been focused on delivering solar kits and solar home systems, many companies continue to make strides developing distribution channels to sell solar lights which reduce the need for kerosene and improve the ability to charge mobile phones. SunnyMoney, the social enterprise owned by United Kingdom charity SolarAid, has recently sold its millionth light in sub-Saharan Africa. The company sells a range of lights through promotions in partnership with schools in a number of countries, including market leading products such as Greenlight Planet's SunKing Pro, d.light design's S2, and Barefoot Power's Firefly.

Future of Solar Home Systems & Solar Lanterns

As earlier stated, approximately 1.5 billion people in the world do not have access to electricity, most of them in developing countries. For example, in Tanzania less than 15% of the population are connected to the mains electric grid. Even in India where three quarters of the population have grid power within reach, the supply is unreliable with frequent and lengthy power cuts in many places. Solar home systems do not provide the level of power that the grid offers i.e. they cannot run a refrigerator or power tools on 50Wp of PV – but they have huge potential to provide reliable access to electric lighting, communications and mobile money. System costs will decrease as the global PV market continues to grow, and the improving efficiency of lights and appliances will provide increasing better services (Fig. 04).

Projections indicate that by the year 2030, Africa will still have a non-electrified population of 698 million, compared to around 809 million people in Asia without electricity. the UN Millenium Development Project has set out targets for providing clean efficient energy for reading light and for illuminating schools and health facilities. The target for household lighting consumption is a minimum requirement.

Fig. 04: **Solar Home Systems Learning Curve**



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