Small Off-grid Solar PV Systems Review

A review of available technology and technical design brief

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Introduction

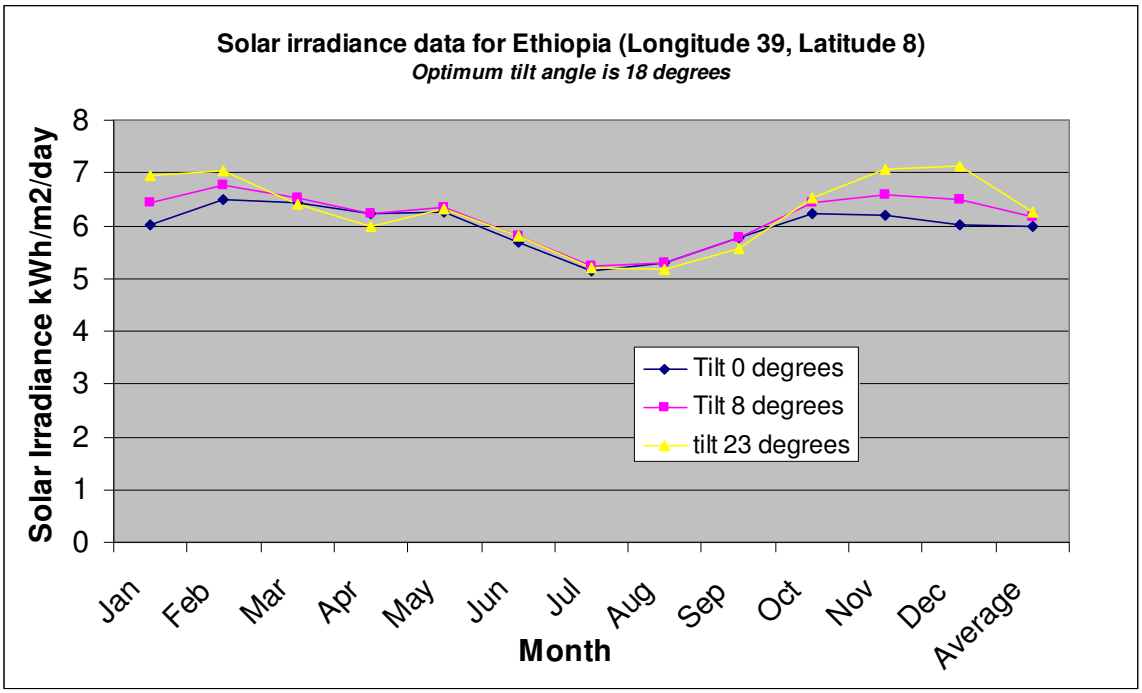
Digital Campus is a not-for-profit organisation working on information communications technology (ICT) for international development. At present they are focusing on Ethiopia. They are looking to supply rural health workers with smart phones and netbook computers with remote connectivity and applications which will allow them to keep better records on patient and house visits.
As these areas are remote, they typically do not have a reliable electricity supply (generally there is no electricity provision). Digital Campus would like to provide some form of portable power supply which can be used to recharge the devices while in the field. Ideally this would be an off-the-shelf unit, but if that is not available then the technical feasibility of such a unit should be discussed.
This report covers an analysis of the load requirements, an overview of products available to do this task and also a basic technical design for a bespoke unit.

Resource available

It was decided that renewable energy should be used, as it would mean there are no on-going fuel costs. Hydro and wind power are very site specific and generally not portable, hence not suitable for a traveling health worker. This leaves solar photovoltaic (PV) technology. While requiring relatively high capital investment, solar PV is reliable, will work is most locations and, depending upon the size of the system, portable.

Location

The system is designed to work within Ethiopia, which has a latitude of 8 degrees N longitude 39 degrees E (this is the central point and the latitude varies from around 4 degrees N to 16 degrees N).
The solar resource data for this location is:



Data from: NASA meteorological surface data (http://eosweb.larc.nasa.gov/cgi-bin/sse/)

The minimum value of around 5 kWh/m2/day (or 5 sun-hours per day) is used to perform any calculations.

Load analysis

There are three main loads to be analysed:

- Smart phone
- Net book computer
- Tablet laptop computer

Smart phone

The phone used is an HTC Hero running Android. While this may not always be the phone used, it has been taken as the benchmark load to supply.
The battery is a 1350mAh 3.7V rechargeable lithium-ion pack. This equates to 1.35Ah x 3.7V = 5Wh. So a full recharge of the battery would require 5Wh.
With 5 sun-hours per day, this would need a 1-2Wp solar panel.

An interesting paper relating to smart phone energy use is available at www.usenix.org/event/usenix10/tech/full_papers/Carroll.pdf

Netbook computer

The model used at present is a Samsung N150. The battery is an 11.1V 44Wh lithium-ion 6-cell battery pack. A full recharge of the battery would require 44Wh.
With 5 sun-hours per day, this would need a 10Wp solar panel.

Tablet computer

At present Digital Campus do not use tablet computers, but the technical design should include these for the future. The iPad 2 computer is used as the design reference. This has a 6930mAh 25Wh lithium-polymer battery. A full recharge of the battery would require 25Wh.
With 5 sun-hours per day, this would need a 6-7Wp solar panel.

Review of available products

Lighting Africa

www.lightingafrica.org
Lighting Africa are a joint IFC and World Bank program to help develop commercial off-grid lighting markets in Sub-Saharan Africa. They provide market and technical research for lighting products and they rate commercial lighting products for use in projects in Sub-Saharan Africa.
They do not manufacture anything but do have a lot of information on the various products available.
They have produced an interesting report on the Off-Grid Lighting Market in Sub-Saharan Africa.

Glow Star

www.glowstar.net – Cost: GS5 £53, GS7 £75 + solar PV panel cost
Glow Star produced one of the first solar lights designed for international development. There are two versions which have external plug in solar panels (5-30Wp). The Glow Star has a 12V socket which can be used to recharge external devices, such as mobile phones.

- Glow Star GS5: 4.4Ah 12V lead-acid battery and can use 5, 10 or 20Wp solar panels
- Glow Star GS7: 7.2Ah 12V lead-acid battery and can use 10, 20 or 30Wp solar panels

The lantern does not come with a solar panel, which is available separately – their 10Wp solar panel (amophous) is £33 – or you can use any similar specification PV panel.
The Glow Star is manufactured by Sollatek, a UK based company (http://www.sollatek.com/), who may be a useful contact to produce a bespoke solar re-charging unit.

d.light

www.dlightdesign.com – Cost: The S250 is UK £30
d.light make three different solar lighting products – the S250, S10, S1. Only the S250 is designed to have an output to recharge a mobile phone, the others are smaller, lighting-only products. It also has an integrated state of charge indicator. The PV panel is rated at 1.3Wp and the battery pack is comprised of 3 x AA Ni-MH batteries with a capacity of 1.5Ah at 3.6V.

Some of these units have been bought by Digital Campus and are in use at the moment.

Barefoot power

www.barefootpower.com – Cost: AUS $250 for the 5Wp Powapack kit
Barefoot power is an Australian company which produces the firefly lights and Powapack systems:

- Firefly 5: 0.5Wp solar panel (poly), 650mAh battery, can recharge mobile phones
- Firefly 12: 1.5Wp solar panel (poly), 900mAh battery, can recharge mobile phones
- Powapack: from 1.5 to 15Wp solar panels (poly), batteries are either sealed lead-acid or NiCds, depending upon the size. All have ability to recharge phones.

SOLUX e.V.

www.solux.org – LED-50 Euros 33, LED-100 Euros 66, LED-105 Euros 55,
SOLUX is a German charity producing and selling eco-friendly solar lights for developing countries. They produce three main products:

- SOLUX-LED-50: 1.5Wp solar PV panel (poly), 3xAA NiMH batteries, can recharge mobile phones
- SOLUX-LED-100: 2.5Wp solar PV panel (poly), 3xmini NiMH batteries, can recharge mobile phones
- SOLUX-LED-105: 2.5Wp solar PV panel, NiMH batteries, can recharge mobile phones

Greenlight Planet

www.greenlightplanet.com
Greenlight Planet are a US based company producing solar lights. They produce the Sun King solar light. This has a small solar PV panel (poly) of unspecified size. They use a lithium-ion battery pack. There is no provision for mobile phone recharging, hence this product is not useul for this review.

Sun Transfer

www.suntransfer.com – Cost: no details available
Sun Transfer is a German company owned by the owned by the non profit organisation Stiftung Solarenergie - Solar Energy Foundation (www.stiftung-solarenergie.org) who are providing solar PV systems within developing countries (including a training centre within Ethiopia).
They only have one product at present:

- SunTransfer 2: 2Wp solar PV panel (poly), 6V sealed lead acid battery 4.5Ah, USB mobile phone charger socket.

Philips

http://www.lighting.philips.com/af_en/solar_lighting/products/mini_uday_lantern.p

hp?main=af_en&parent=af_en&id=af_en_solar_lighting&lang=en – Cost: no details available
Philips produce a solar light, but this does not have a phone recharging output.
Uday mini: 5Wp solar PV panel (poly), 6V sealed lead acid battery (no capacity details).

Tough Stuff Solar

www.toughstuffonline.com – Cost: £25 (buy one, fund one)
Tough Stuff is a social enterprise producing solar lighting and power products for developing countries. They use a 1Wp 5.7V semi-flexible solar panel. This can be used to recharge a lighting unit (1300mAh NiMH battery pack) or a battery pack unit (2 x AA 1300mAh NiMH batteries). It can also be used to directly recharge a mobile phone.

Cobra Solar Charger POWERplus

www.leafliving.com/store/powerplus-cobra-solar-charger/
- Cost: around £40-50
This is designed for the portable power market. It is a 1.76Wp solar PV panel (poly) with a 1000mAh 3.7V lithium-ion battery pack.

Voltaic

http://www.voltaicsystems.com/generator.shtml – Cost: US$500
This is a 15W solar PV panel (mono) built into a carry case. It includes a battery which can supply 70Wh (technology unknown) at various output voltages.

The NotePower

http://www.greenoptions.com/products/sierra-solar-systems-notepower-solar-laptop-carrier – Cost: 15W is US$240
15W or 22W versions available. Fold out solar panel. No battery storage so not really suitable for this application.

Apple Juicz

http://www.quickertek.com/products/mbasolar_exb.php – Cost: US$800
This has a 27W foldable solar panel and a lithium-ion polymer battery.

Powergorilla

http://www.powergorilla.com/ - Cost: UK £120
A 3Wp solar PV panel (poly) encased in a rugged unit with a 9000mAh 5V lithium-ion polymer battery. This includes outputs for mobile phones and also a high-current output for an iPad. This includes a maximum power point tracker.

Review of available products

There are a number of interesting solar PV power products available. The majority of them would be useful for recharging small loads such as the smart

phone. Having an integral light might be useful, although is does mean a lot of the solar energy may be used up for lighting.

The following factors must be taken into account:

- Robust
- Reliable
- Replaceable batteries – lithium-ion batteries would be very hard to replace, unlike AA NiMH battries.
- External solar panel – perhaps mounted on roof
- Security – how to ensure the unit is not stolen?

The Glow Star is a robust unit which can use external solar panels. I would suggest this as a good unit when used with a larger (20 or 30Wp) solar panel for recharging smart phones and net-book computers. The main negative is the high cost of this unit, although it would not be as expensive as a bespoke unit.

Technical design specifications

Although the off-the-shelf products are available to recharge the relatively low load of a smart phone, I do not think any of the units above are suitable for reliable day-to-day charging of a netbook or tablet computer. Here I propose two system designs – one to power a phone, one to power a netbook computer.

Disclaimer: These are very initial designs and this would need much more research and product development to get to the situation where this could be used 'in the field'.

Smart phone only system

Load requirements: To provide at least 5Wh per day
With 5 sun-hours per day and an 80% inefficiency factor this requires: (5Wh / 5 sun-hrs) x (100/80) = 1.25Wp
Minimum size solar panel: 1.25Wp – suggest larger than this for reliable operation.
Minimum sized battery storage: with 4 days autonomy, 80% battery inefficiency and 50% maximum depth of discharge: 5Wh x 4 days x (100/50) x (100/80) = 50Whs
Battery capacity: in Ah with a 12V system: 50Whs / 12 = 4.2Ah

Item	Cost range	Quantity	Total
5Wp crystalline solar PV panel	£15-40	1	£15-40
Charge regulator with low voltage disconnect	£15-30	1	£15-30
Battery (12V 5Ah)	£15-20	1	£15-20
Connectors and cable	£20		£20
Enclosure (maybe not required)	£10	1	£10
Labour for wiring (UK?)	£20-40	1	£20-40
Other costs (at 20%)	£19-32	1	£19-32
		Total:	**£114-192**

Netbook/tablet computer system

Load requirements: To provide at least 50Wh per day
With 5 sun-hours per day and an 80% inefficiency factor this requires: (50Wh / 5 sun-hrs) x (100/80) = 12.5Wp
Minimum size solar panel: 12.5Wp, suggest larger than this – 20Wp
Minimum sized battery storage: with 4 days autonomy, 80% battery inefficiency and 50% maximum depth of discharge: 50Wh x 4 days x (100/50) x (100/80) = 500Whs
Battery capacity: in Ah with a 12V system: 500Whs / 12 = 42Ah

Item	Cost range	Quantity	Total
20Wp crystalline solar PV panel	£80-150	1	£80-150
Charge regulator with low voltage disconnect >3A	£20-40	1	£20-40
Battery (12V 40Ah)	£50-100	1	£50-100
Connectors and cable	£20-40		£20-40
Enclosure (perhaps not needed)	£20-40	1	£20-40
Labour for wiring	£20-60		£20-60
Other costs (at 20%)	£42-86		£42-86
		Total:	**£252-516**

Conclusion

For a smart phone recharging system it is recommended that a commercial off-the-shelf unit is used. The Glow Star along with a 5Wp or 10Wp solar panel is recommended. The d.light is a less expensive solution, but would only just capture enough solar energy per day to power the smart phone, meaning the user could not use the light without adversely affecting the recharging of the phone. Also the battery bank is much smaller (5.4Wh, compared to 52.8Wh for the GlowStar), hence it is not able to store energy over a longer period.

For a larger system to recharge a netbook or tablet computer I would suggest a bespoke system, comprised from a number of quality components. The larger of the Glow Star products could be used, if an 'off-the-shelf' product is required, although I think the battery size is not appropriate for this sized load.

For both systems some recommendations are made:

- Ensure adequate training for the people using the systems.
- They must have some ownership or responsibility for the system.
- Do not use amorphous solar panels.
- Batteries will be the main maintenance issue and will need to be replaced.
- Ensure there are funds for operation and maintenance for the lifetime of the project.

Disclaimer: This is a proposed design and as such is provided with no guarantee. This report has been provided as an initial starting point only. Details provided were correct at time of writing but are subject to change. Numerous parameters will affect specific projects including: local access to parts, materials and labour, available water supply, local terrain etc.