



50 ways
to end
kerosene lighting



renewable
energy
& energy
efficiency
partnership



**Barefoot
Power**

May 2009

ACKNOWLEDGEMENTS

The authors wish to thank the Department of the Environment, Water, Heritage and the Arts (DEWHA - formerly the Australian Greenhouse Office), the Renewable Energy and Energy Efficiency Partnership (REEEP), and the many pioneers who have developed the technologies listed within, to aid in the fight against energy poverty. Many thanks also go to our family, friends, investors and supporters, who continue to provide fantastic support during our mission to help 1 million people gain access to clean, efficient lighting and energy.

DISCLAIMER

The authors have used publicly available website reference information and use of photos, and thank the authors of each and every of these images. The authors have made their best estimates of current expected retail prices of these technologies from publicly available information, but have not contacted the suppliers of each product to confirm pricing. The technical descriptions have also created by the authors, in an attempt to accurately portray the system components, performance, sizing and pricing, but this data should be strictly taken as a guide only. Suppliers of these technologies should be contacted to obtain current and accurate technical specifications and prices.

The reader should not use this guide as the sole basis of commercial decision making, or even the ranking of products. Product information was not verified, and Barefoot Power nor any of its employees make any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of the information provided or represents that its use would not infringe privately owned rights. Furthermore, the listing of products does not represent an endorsement by the authors. In addition, because of the rapidly changing nature of the village lighting and LED industries, the information contained in this document may become outdated, and the list is in no way exhaustive. All errors are wholly those of the authors, and the views and opinions of authors expressed herein do not necessarily state or reflect those of REEEP, the Australian Government or any agency thereof.

Table of Contents

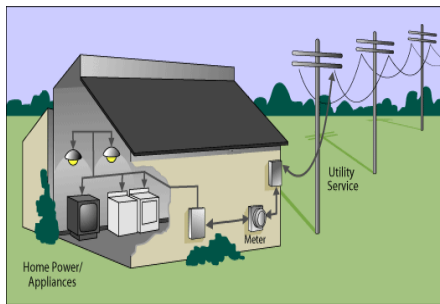
50 ways to eliminate kerosene lighting	page	5
Summary of lighting options	page	6
Wick kerosene lamp	page	8
Hurricane kerosene lamp	page	9
Grid connected CFL	page	10
0.1W solar keyring	page	11
0.1W dynamo torch	page	12
0.18W solar torch	page	13
0.5W solar LED desk lamp	page	14
Non-rechargeable LED desk lamp	page	15
0.5W cranking LED flashlight	page	16
0.5W handcrank LED lantern	page	17
0.7W solar LED torch	page	18
1W solar LED desk lamp	page	19
1W solar LED worktorch	page	20
2W Non-rechargeable bulb torch	page	21
3W LED solar lamp	page	22
3W solar home kit LED	page	23
3W CFL AC lantern	page	24
3W CFL solar lantern	page	25
5W CFL solar lantern	page	26
5W thermoelectric CFL	page	27
6W CFL solar lantern	page	28
7W CFL solar lantern	page	29
10W CFL solar home system	page	30
10W wind CFL home kit	page	31
14W CFL solar home system	page	32
20W fuel cell system	page	33
30W CFL solar home system	page	34
70W pedal power BCS LED	page	35
300W solar BCS CFL	page	36
100W instream hydro CFL BCS	page	37
100W wind CFL home kit	page	38
300W wind BCS CFL	page	39
200W Pico Hydro BCS LED	page	40
200W Pico Hydro BCS LEDs	page	41
200W Pico Hydro AC LEDs	page	42
200W Pico Hydro AC CFLs	page	43
500W Pico Hydro AC LED+CFL	page	44
500W High Head Pico Hydro AC	page	45
1000W Low Head Pico Hydro AC	page	46
1kW solar AC CFL + LEDs	page	47
600W petrol generator BCS-LED	page	48
600W petrol generator BCS-LEDs	page	49
600W petrol generator BCS CFL	page	50
600W petrol generator AC CFL	page	51
1kW Improved Ghatta AC	page	52
1kW Improved Ghatta BCS	page	53
1kW Improved Ghatta BCS-LEDs	page	54
2kW biomass gasifier AC	page	55
2kW biomass steam engine AC	page	56
2kW diesel generator BCS-LEDs	page	57
2kW veg oil generator BCS-LEDs	page	58
3kW Pico Hydro AC	page	59
5kW solar AC CFLs	page	60
Grid extension to one CFL	page	61
Grid extension to tube lights	page	62

50 WAYS TO ELIMINATE KEROSENE LIGHTING

This guide aims to show many different technologies that can be used to eliminate kerosene lighting from households in developing countries. 1.6 billion people in approximately 300 million households still use kerosene lighting, spending around \$10-30 billion/year, or an average of about \$1/week.

There are many technologies available to replace kerosene lighting and some simple measures can be taken to determine if they might be acceptable in the local context. This guide does not seek to give a definitive answer, but just an indication of how an assessment can be made, and what are the options available. Lighting options include white LEDs for 0.1-4W and fluorescent lighting for 4W or more. Power generation options include recharging batteries from the power grid, small diesel or gasoline generators, solar panels, biomass gasifiers, vegetable oil in 'diesel' generators, hand-cranking power and other options.

Power may be used directly in household use, or stored in batteries for later use. Energy may need to be transported from the point of generation to the house - this may be done directly, with poles and wires or underground wires, or it may be done by transporting batteries from a battery charging station to the house.



Grid connected household



Battery charging in Cambodia

Some explanation is required about some of the terminology used in this guide. This guide is primarily focused on improving the service of lighting to the poor, as a first step of improved energy service. Hence it is important to know the basic terms of lighting service, to be able to measure and compare options.

Watt (W)	The unit for measuring power
kilowatt (kW)	One thousand (1000) watts
kilowatt-hour (kWh)	The unit for measuring energy, which is power (in kiloWatt) x time (in hours)
lumen (lm)	The unit for measuring light
lumen-hour (lm.hr)	The unit for measuring lighting service, which is light (in lumen) x time (in hours)
AC	Alternating Current (main or grid power)
BCS	Battery Charging Station
CFL	Compact fluorescent lamp
DC	Direct Current (battery power)
LED	Light emitting diode. White LEDs were invented in the late 1990's and have steadily reduced in price since then.
minigrd	A small powerline + power pole reticulated system for distributing AC power directly from generators to households, operating as a stand-alone, isolated system, separate from the main power grids of the country.

SUMMARY OF LIGHTING OPTIONS

The list below gives a summary of the cost of lighting services from different technologies. The first item shown is the existing situation, a typical kerosene lamp used in a village. Secondly, we compare this to the lighting service that Western consumers enjoy, via a compact fluorescent lamps (CFL). It can be seen that for each dollar spent on lighting, Western consumers enjoy 250 times more service than villagers using kerosene in, say, the Pacific. Seen another way, the poor are spending \$5-20/kWh instead of \$0.15/kWh for their energy services.

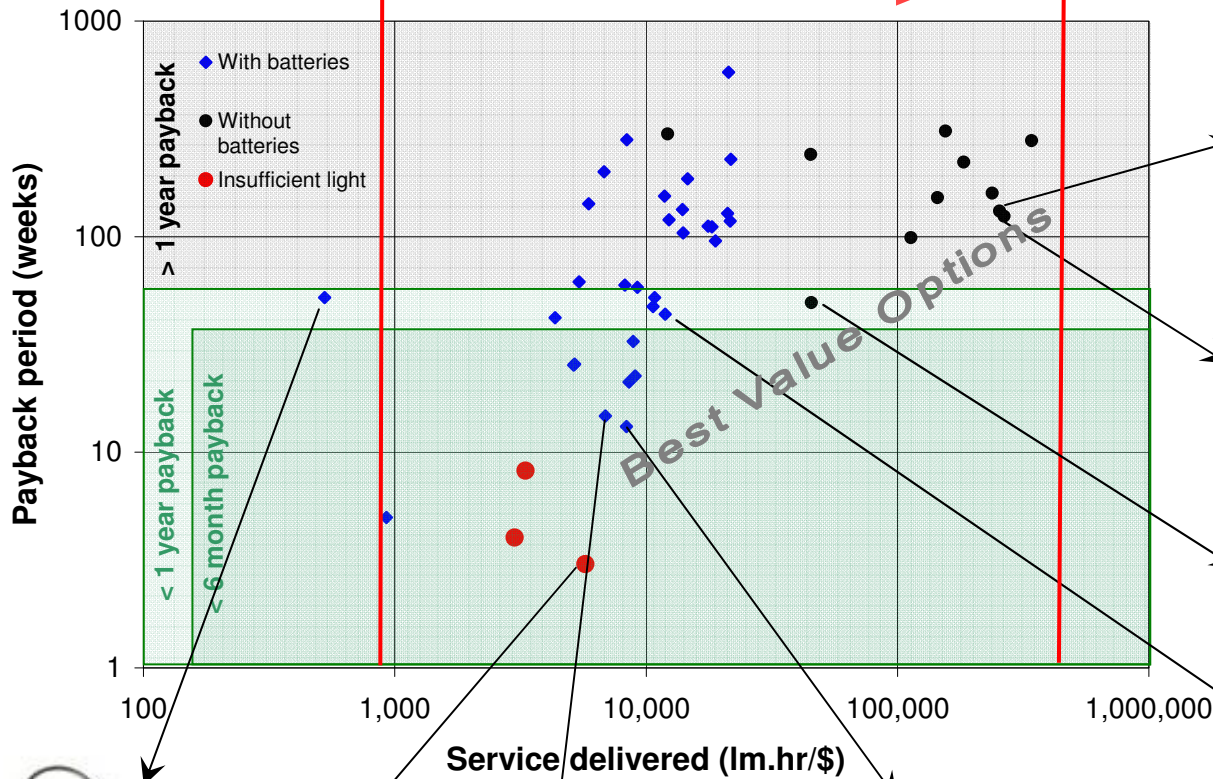
The challenge is to bring cost-effective lighting services to the poor, although this may need to be done through a series of steps. Battery-based technologies can include solar powered desk lamps, rechargeable lanterns and larger-scale battery charging stations, but the cost of storing energy is reflected in the lighting service delivery. This is still 5-15 times better than kerosene and require 6-12 month payback periods, but still less efficient than AC mini-grids that do not require energy storage. Direct AC solutions significantly increase the lighting service efficiency, and can be as efficient as large-scale grid-connected solutions.

- If a technology can be paid back in less than 6 months, the poor will probably spend cash on it - this is given an "A" rating.
- If a technology can be paid back in 6 to 12 months, this will fit the criteria for microfinance loans, - this is given an "B" rating.
- If a technology takes longer than 12 months to pay back, it may be difficult to implement without large scale investment – resulting in a "C" rating.
- If a technology does not produce as much light (lumen) as a kerosene lamp, it is given a "Z" rating, as this is insufficient light to be a replacement for kerosene."

Battery-based solutions can help to reduce payback periods to a sufficient short period that will allow investment in cash sales or 1-year credit arrangements via microfinance partners. Once the lamps and wiring are installed, and some village capability built up in the management of these systems, subsequent investment may be mobilised, with longer payback periods, to install power generation for AC grids that delivery electricity without the use of batteries. Hence, AC grids can be established once the first battery-based business has repaid the investment - Barefoot Power describes this as 'reversed rural electrification', where lamps are installed first instead of last.



Lighting Map



Lighting Option	Service delivered (lm.hr/\$)	Payback Period (weeks)	Rating
Hurricane kerosene lamp	875		
Grid connected CFL	413,208		
1 0.1W solar keyring	5,734	3	Z
2 0.1W dynamo torch	3,003	4	Z
3 0.18W solar torch	3,320	8	Z
4 0.5W solar LED desk lamp	6,887	15	A
5 Non-rechargeable LED desk lamp	525	52	C
6 0.5W cranking LED flashlight	5,153	25	B
7 0.5W handcrank LED lantern	4,345	42	B
8 0.7W solar LED torch	5,187	26	B
9 1W solar LED desk lamp	8,546	21	A
10 1W solar LED work torch	5,407	62	C
11 2W Non-rechargeable bulb torch	925	5	A
12 3W LED solar lamp	17,633	112	C
13 3W solar home kit LED	5,913	142	C
14 3W CFL AC lantern	8,892	33	B
15 3W CFL solar lantern	10,646	47	B
16 5W CFL solar lantern	6,791	200	C
17 5W thermoelectric CFL	12,338	120	C
18 6W CFL solar lantern	14,016	104	C
19 7W CFL solar lantern	13,936	133	C
20 10W CFL solar home system	14,600	186	C
21 10W wind CFL home kit	11,853	154	C
22 14W CFL solar home system	21,745	228	C
23 20W fuel cell system	1,055	10,140	C
24 30W CFL solar home system	21,292	578	C
25 70W pedal power BCS LED	11,918	44	B
26 300W solar BCS CFL	18,250	111	C
27 100W instream hydro CFL BCS	8,382	281	C
28 100W wind CFL home kit	16,872	2,612	C
29 300W wind BCS CFL	18,887	96	C
30 200W Pico Hydro BCS LED	9,031	23	A
31 200W Pico Hydro BCS LEDs	10,815	52	C
32 200W Pico Hydro AC LEDs	45,506	49	B
33 200W Pico Hydro AC CFLs	265,455	124	C
34 500W Pico Hydro AC LED+CFL	113,206	99	C
35 500W High Head Pico Hydro AC	183,776	221	C
36 1000W Low Head Pico Hydro AC	255,146	131	C
37 1kW solar AC CFL + LEDs	24,796	173	C
38 600W petrol generator BCS-LED	8,341	13	A
39 600W petrol generator BCS-LEDs	8,235	60	C
40 600W petrol generator BCS CFL	21,066	128	C
41 600W petrol generator AC CFL	12,182	299	C
42 1kW Improved Ghatta AC	144,459	152	C
43 1kW Improved Ghatta BCS	21,563	118	C
44 1kW Improved Ghatta BCS-LEDs	9,221	58	C
45 2kW biomass gasifier AC	155,246	309	C
46 2kW biomass steam engine AC	104,500	309	C
47 3kW Pico Hydro AC	238,043	159	C
48 5kW solar AC CFLs	30,423	8,485	C
49 Grid extension to one CFL	45,189	240	C
50 Grid extension to tube lights	341,962	279	C

Product Name Wick kerosene lamp

Description Typical kerosene lamp, smaller style, known as tuki or tadooba



Lumens/Watt	N/A	Estimated retail price	\$0.50
Average Power (W)	N/A	Fuel life (months)	1.0
Battery capacity (Ah)	N/A	Monthly fuel costs	\$1.50
Hours runtime/charge	N/A	Wick life (years)	0.5
Charging hours from flat	N/A	Wick replacement cost	\$0.50
Lumens	10	5-year replacement costs	\$95
Lumen-hours/year @ 4hr/day	14,600	5-year ownership cost	\$96
Service delivered (lm.hr/\$)	764		
Kerosene service (lm.hr/\$)	764		

COMMENTS

The majority of the poor use one to three small kerosene lamps from home-made tins or in glass bottles. In Africa, these are known as "tadooba"; in Nepal, as "tukis". These lamps consume approximately 5-10 mL of kerosene per hour, so a litre of fuel costing around \$1 lasts approximately 100 hours, or 25 nights, per lamp.

SUPPLIERS

Local trade store

Product Name Hurricane kerosene lamp

Description Typical kerosene lamp,
larger style



Lumens/Watt	N/A	Estimated retail price	\$10
Average Power (W)	N/A	Fuel life (months)	1.0
Battery capacity (Ah)	N/A	Monthly fuel costs	\$4.00
Hours runtime/charge	N/A	Wick life (years)	2
Charging hours from flat	N/A	Wick replacement cost	\$0.10
Lumens	30	5-year replacement costs	\$240
Lumen-hours/year @ 4hr/day	43,800	5-year ownership cost	\$250
Service delivered (lm.hr/\$)	875		
Kerosene service (lm.hr/\$)	875		

COMMENTS

This style of kerosene lamp is popular in the Pacific Island countries, with most households owning one to three such kerosene lamps, purchased from trade stores. These lamps consume approximately 10-40 mL of kerosene per hour, so a litre costing around \$1 lasts approximately 40 hours, or 10 nights, per lamp. Adjustable wicks allow the lamp to be turned down and run overnight as a 'security' light. Light levels decrease the glass cover gets dirty.

SUPPLIERS

Local trade store

Product Name Grid connected CFL

Description Cost of lighting service that we enjoy from a CFL lamp in a grid-connected home



Hours/day of service	12	Number of households	1
Lumens/Watt	50	Estimated capital cost	\$14
Average Power (W)	10	Capital works life (years)	2.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$2.00
Hours runtime/charge	N/A	Lamp life (years)	2
Charging hours from flat	N/A	Single lamp replacement cost	\$3.00
Lumens/household	500	5-year replacement costs / house	\$13
Lumen-hours/year/house	2,190,000	5-year ownership cost / house	\$27
Service delivered (lm.hr/\$)	413,208		
Kerosene service (lm.hr/\$)	875		

COMMENTS

Assuming no grid connection cost, this model shows how we enjoy 250 times better lighting service than the poor for each dollar we spend on efficient lighting (assuming lamp are used for 12 hrs/day at \$0.15/kWh). Seen another way, this implies the poor are spending up to \$20/kWh for poor lighting and electricity access. Grid connection capital costs are often high for the poor, and of course powerlines are not extended due to lack of funds.

SUPPLIERS

Local lighting store and power companies

Product Name 0.1W solar keyring
Description Single or multiple LED in keyring, rechargeable battery inside, charged by a 0.1W solar panel



Hours/day of service	7	Number of households	1
Lumens/Watt	40	Estimated retail price	\$3
Average Lamp Power (W)	0.1	Battery life (years)	2.0
Battery capacity (Ah)	0.15	Battery replacement cost	\$0.50
Hours runtime/charge	7	Lamp life (years)	2
Charging hours from flat	7	Lamp replacement cost	\$0.50
Lumens	4	5-year replacement costs	\$3
Lumen-hours/year @ 4hr/day	6,307	5-year ownership cost	\$6
Service delivered (lm.hr/\$)	5,734	Payback in weeks @ \$1/week saved	3
Kerosene service (lm.hr/\$)	872	Rating	Z

COMMENTS

One to three narrow angle LEDs are helpful for task lighting when light is close, but the light is less than a kerosene lamp, and very concentrated, so is not a suitable alternative for room lighting. Payback for kerosene user is rapid, so will interest villagers, but should be marketed with care, due to lower light levels than the kerosene lamp it replaces.

SUPPLIERS

Trade stores, chinese traders

Product Name 0.1W dynamo torch

Description Single LED torch,
charged by shaking
dynamo



Hours/day of service	5-10 times charge time	Number of households	1
Lumens/Watt	40	Estimated retail price	\$4
Average Lamp Power (W)	0.1	Battery life (years)	2.0
Battery capacity (Ah)	N/A	Battery replacement cost	\$0.00
Hours runtime/charge	5-10 times charge time	Lamp life (years)	2
Charging hours from flat	10-20% of runtime	Lamp replacement cost	\$0.50
Lumens	2	5-year replacement costs	\$1
Lumen-hours/year @ 4hr/day	3,154	5-year ownership cost	\$5
Service delivered (lm.hr/\$)	3,003	Payback in weeks @ \$1/week saved	4
Kerosene service (lm.hr/\$)	872	Rating	Z

COMMENTS

30 seconds of shaking gives up to 5 minutes of light. Hence, 3-4 hours of lighting per night would require 20-30 minutes of shaking the torch, adding to manual labour of villagers. In addition, the light given is much lower than kerosene light output, so this is not a scalable solution, but suitable for camping and traveling.

SUPPLIERS

Trade stores, chinese traders

Product Name 0.18W solar torch

Description Typically three 5mm LEDs in solar torch, rechargeable battery inside, charged by a 0.2W solar panel



Hours/day of service	6	Number of households	1
Lumens/Watt	40	Estimated retail price	\$8
Average Lamp Power (W)	0.2	Battery life (years)	2.0
Battery capacity (Ah)	0.35	Battery replacement cost	\$1.50
Hours runtime/charge	6	Lamp life (years)	2
Charging hours from flat	10	Lamp replacement cost	\$1.00
Lumens	6	5-year replacement costs	\$6
Lumen-hours/year @ 4hr/day	9,461	5-year ownership cost	\$14
Service delivered (lm.hr/\$)	3,320	Payback in weeks @ \$1/week saved	8
Kerosene service (lm.hr/\$)	872	Rating	Z

COMMENTS

Three to six narrow angle LEDs are helpful for task lighting when light is close, but the light is less than a kerosene lamp, and very concentrated, so is not a suitable alternative for room lighting. Payback for kerosene user is rapid, so will interest villagers, but should be marketed with care, due to lower light levels than the kerosene lamp it replaces.

SUPPLIERS

Trade stores, chinese traders

Product Name 0.5W solar LED desk lamp

Description Single or multiple LEDs in desk lamp, rechargeable battery inside, charged by a 0.5W solar panel



Hours/day of service	7	Number of households	1
Lumens/Watt	50	Estimated retail price	\$14
Average Lamp Power (W)	0.5	Battery life (years)	2.0
Battery capacity (Ah)	0.65	Battery replacement cost	\$2.00
Hours runtime/charge	7	Lamp life (years)	2
Charging hours from flat	8	Lamp replacement cost	\$3.00
Lumens	25	5-year replacement costs	\$13
Lumen-hours/year @ 4hr/day	36,500	5-year ownership cost	\$27
Service delivered (lm.hr/\$)	6,887	Payback in weeks @ \$1/week saved	15
Kerosene service (lm.hr/\$)	872	Rating	A

COMMENTS

Three 60-degree LEDs are very helpful for task lighting when light is close, or 2 120-degree assist room lighting when placed up high. Payback for kerosene user is quite rapid, and more lumens are produced than a kerosene lamp. A nightlight feature is provided.

SUPPLIERS

Barefoot Power, Australia - www.barefootpower.com

Product Name Non-rechargeable LED desk lamp

Description Single or multiple LEDs in desk lamp, non-rechargeable battery inside, batteries replaced each week



Hours/day of service	10	Number of households	1
Lumens/Watt	40	Estimated retail price	\$5
Average Lamp Power (W)	0.4	Battery life (years)	0.02
Battery capacity (Ah)	0.65	Battery replacement cost	\$0.90
Hours runtime/charge	N/A	Lamp life (years)	3.0
Charging hours from flat	N/A	Lamp replacement cost	\$3.00
Lumens	17	5-year replacement costs	\$235
Lumen-hours/year @ 4hr/day	25,229	5-year ownership cost	\$240
Service delivered (lm.hr/\$)	525	Payback in weeks @ \$1/week saved	52
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Five to ten 60-degree LEDs are very helpful for task lighting when light is close. Becoming easily available in village markets, increasing awareness of LED lighting. However, batteries are not rechargeable, so there is a very high cost for replacement batteries.

SUPPLIERS

Local markets and Chinese trading companies

Product Name 0.5W cranking LED flashlight

Description 7 LEDs in flashlight, rechargeable battery inside, handcrank or 6V 100mA AC charger



Hours/day of service	3	Number of households	1
Lumens/Watt	40	Estimated retail price	\$25
Average Lamp Power (W)	0.5	Battery life (years)	5.0
Battery capacity (Ah)	1.0	Battery replacement cost	\$3.00
Hours runtime/charge	3	Lamp life (years)	3.0
Charging hours from flat	24	Lamp replacement cost	\$5.00
Lumens	20	5-year replacement costs	\$3
Lumen-hours/year @ 4hr/day	29,200	5-year ownership cost	\$28
Service delivered (lm.hr/\$)	5,153	Payback in weeks @ \$1/week saved	25
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

Seven LEDs give very targeted light in a small area. Not suitable for room lighting, better for outdoor applications. At least 40 minutes of hand-cranking required to fully recharge one lamp, which adds to the manual labour of a villager. Internal rechargeable battery often not replaceable. Human powered lamps do not scale well to larger lighting applications, but is a good backup power source for emergency situations.

SUPPLIERS

Freeplay Energy, UK - www.freeplayenergy.com/product/sherpaled

Product Name 0.5W handcrank LED lantern

Description 9 LEDs in a torch (3 wide angle, 6 narrow angle), rechargeable battery inside, charged by a 0.5W solar panel



Hours/day of service	2.5	Number of households	1
Lumens/Watt	50	Estimated retail price	\$42
Average Lamp Power (W)	0.5	Battery life (years)	5.0
Battery capacity (Ah)	0.3	Battery replacement cost	\$0.00
Hours runtime/charge	2.5	Lamp life (years)	5
Charging hours from flat	1	Lamp replacement cost	\$0.00
Lumens	25	5-year replacement costs	\$0
Lumen-hours/year @ 4hr/day	36,500	5-year ownership cost	\$42
Service delivered (lm.hr/\$)	4,345	Payback in weeks @ \$1/week saved	42
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

7 ultra-bright LEDs shine in all directions via reflector, so light at 1m will be lower than light levels from single-direction lamp styles. Single LED nightlight function included. 2 hours runtime with 1 LED after 1 minute of charging, or 70 hours runtime after full charge, implies at least 35 minutes of cranking to full charge, and only gets 2.5 hours of full power light. Hence, human cranking power is useful only for small, occasional uses of light. AC chargeable as well.

SUPPLIERS

Freeplay Energy, UK - www.freeplayenergy.com/product/indigo

Product Name 0.7W solar LED torch

Description 9 LEDs in a torch (3 wide angle, 6 narrow angle), rechargeable battery inside, charged by a 0.7W solar panel



Hours/day of service	5	Number of households	1
Lumens/Watt	50	Estimated retail price	\$25
Average Lamp Power (W)	0.45	Battery life (years)	1.5
Battery capacity (Ah)	0.8	Battery replacement cost	\$2.00
Hours runtime/charge	5	Lamp life (years)	5
Charging hours from flat	10	Lamp replacement cost	\$0.00
Lumens	22.5	5-year replacement costs	\$7
Lumen-hours/year @ 4hr/day	32,850	5-year ownership cost	\$32
Service delivered (lm.hr/\$)	5,187	Payback in weeks @ \$1/week saved	26
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

Six narrow angle LEDs are very helpful for torch lighting, and 3 wide-angle LED assist room lighting when placed up high. Multiple settings are used to extend runtime, at dimmer light settings. Price estimated at \$15 from supplier, from blog posting on 2 for more than \$25, and added 65%.

SUPPLIERS

Sun Night Solar, USA - www.sunnightsolar.com

Product Name 1W solar LED desk lamp

Description Single or multiple LEDs in desk lamp, rechargeable battery inside, charged by a 1W solar panel



Hours/day of service	4	Number of households	1
Lumens/Watt	50	Estimated retail price	\$20
Average Lamp Power (W)	0.8	Battery life (years)	1.5
Battery capacity (Ah)	0.65	Battery replacement cost	\$2.00
Hours runtime/charge	4	Lamp life (years)	2
Charging hours from flat	4	Lamp replacement cost	\$3.00
Lumens	40	5-year replacement costs	\$14
Lumen-hours/year @ 4hr/day	58,400	5-year ownership cost	\$34
Service delivered (lm.hr/\$)	8,546	Payback in weeks @ \$1/week saved	21
Kerosene service (lm.hr/\$)	872	Rating	A

COMMENTS

Broad angle LEDs are very helpful for task lighting when light is close, or room lighting when placed up high. Payback for kerosene user is quite rapid, and more lumens are produced than a kerosene lamp. A nightlight feature is provided.

SUPPLIERS

Barefoot Power, Australia - www.barefootpower.com

Product Name 1W solar LED worktorch

Description Single 1W power LED, rechargeable battery inside, charged by a 2.5W solar panel



Hours/day of service 10

Number of households 1

Lumens/Watt 50

Estimated retail price \$60

Average Lamp Power (W) 1

Battery life (years) 2.0

Battery capacity (Ah) 2.3

Battery replacement cost \$3.00

Hours runtime/charge 10

Lamp life (years) 30

Charging hours from flat 8

Lamp replacement cost \$0.00

Lumens 50

5-year replacement costs \$8

Lumen-hours/year @ 4hr/day 73,000

5-year ownership cost \$68

Service delivered (lm.hr/\$) 5,407

Payback in weeks @ \$1/week saved 62

Kerosene service (lm.hr/\$) 872

Rating C

COMMENTS

Adjustable beam angle from focused to wide angle. Very robust, long runtime, but relatively high initial cost. Adjustable light settings.

SUPPLIERS

Cosmos Ignite, India - www.cosmosignite.com

Product Name 2W Non-rechargeable bulb torch

Description Single incandescent bulb lamp in torch, non-rechargeable D-size batteries inside



Hours/day of service	1.0	Number of households	1
Lumens/Watt	10	Estimated retail price	\$2
Average Lamp Power (W)	2.0	Battery life (years)	0.04
Battery capacity (Ah)	9000	Battery replacement cost	\$1.20
Hours runtime/charge	14	Lamp life (years)	1.0
Charging hours from flat	N/A	Lamp replacement cost	\$0.25
Lumens	20	5-year replacement costs	\$156
Lumen-hours/year @ 4hr/day	29,200	5-year ownership cost	\$158
Service delivered (lm.hr/\$)	925	Payback in weeks @ \$1/week saved	5
Kerosene service (lm.hr/\$)	872	Rating	A

COMMENTS

Traditional torch used by villagers, with disposable D-size batteries. Light very tight beam angle, not suited for indoor lighting, which needs wide angle lighting. Easily available in village markets. However, batteries are not rechargeable, so there is a very high cost for 2-weekly replacement batteries, costing more than kerosene for only 1 hour of light per night. Hence, torches are not typically used for lighting everyday.

SUPPLIERS

Local markets and Chinese trading companies

Product Name 3W LED solar lamp

Description Single or multiple power LED lantern with rechargeable battery and 2.5W solar panel



Hours/day of service	5.0	Number of households	1
Lumens/Watt	90	Estimated retail price	\$112
Average Lamp Power (W)	3.0	Battery life (years)	5.0
Battery capacity (Ah)	3500	Battery replacement cost	\$5.00
Hours runtime/charge	4	Lamp life (years)	10.0
Charging hours from flat	N/A	Lamp replacement cost	\$5.00
Lumens	270	5-year replacement costs	\$0
Lumen-hours/year @ 4hr/day	394,200	5-year ownership cost	\$112
Service delivered (lm.hr/\$)	17,633	Payback in weeks @ \$1/week saved	112
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Camping-style lantern that emits light in all directions. Should be noted that when brought close for reading, half the light shines in opposite direction, so more of an area light than task light. High quality and long lifetime, but with high capital cost that requires financing to be affordable for most households. Well suited to donor projects where capital costs are subsidized and minimal operational costs are required, though local partners must assemble lamp themselves to get lowest prices.

SUPPLIERS

Solux, Germany - www.solux.org

Product Name 3W solar home kit LED

Description 2 x 1.5W highest quality powerLEDs, rechargeable 7Ah battery + 5W solar panel and controller



Hours/day of service	5	Number of households	1
Lumens/Watt	50	Estimated retail price	\$90
Average Lamp Power (W)	3	Battery life (years)	1.0
Battery capacity (Ah)	7	Battery replacement cost	\$12.00
Hours runtime/charge	18	Lamp life (years)	10.0
Charging hours from flat	10	Lamp replacement cost	\$8.00
Lumens	150	5-year replacement costs	\$95
Lumen-hours/year @ 4hr/day	219,000	5-year ownership cost	\$185
Service delivered (lm.hr/\$)	5,913	Payback in weeks @ \$1/week saved	142
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Very robust, top quality LED lamps with dimming function, available from the pioneer of LED lighting in villages, Light Up The World Foundation. High initial cost results in relatively long payback period - requires microfinancing to gain maximum uptake and lifetime benefits.

SUPPLIERS

Light Up The World, Canada - www.lutw.org

Product Name 3W CFL AC lantern
Description Single 4W CFL, rechargeable, charged by AC charger, on grid



Hours/day of service	3	Number of households	1
Lumens/Watt	35	Estimated retail price	\$25
Average Lamp Power (W)	3	Battery life (years)	1.0
Battery capacity (Ah)	4	Battery replacement cost	\$5.00
Hours runtime/charge	3	Lamp life (years)	4.0
Charging hours from flat	10	Lamp replacement cost	\$4.00
Lumens	105	5-year replacement costs	\$61
Lumen-hours/year @ 4hr/day	153,300	5-year ownership cost	\$86
Service delivered (lm.hr/\$)	8,892	Payback in weeks @ \$1/week saved	33
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

Light from a lantern may be a similar strength at 1m from the lantern as smaller LED lamps, as not all the light goes in one direction. Light strength not adjustment, no night light function. Both solar and AC charge modes available.

SUPPLIERS

TATA BP Solar, India - www.tatabpsolar.com

Product Name 3W CFL solar lantern

Description Single 3W CFL, rechargeable battery, charged by a 3.3W solar panel



Hours/day of service	3	Number of households	1
Lumens/Watt	35	Estimated retail price	\$42
Average Lamp Power (W)	3	Battery life (years)	1.0
Battery capacity (Ah)	4	Battery replacement cost	\$5.00
Hours runtime/charge	3	Lamp life (years)	4
Charging hours from flat	10	Lamp replacement cost	\$4.00
Lumens	105	5-year replacement costs	\$30
Lumen-hours/year @ 4hr/day	153,300	5-year ownership cost	\$72
Service delivered (lm.hr/\$)	10,646	Payback in weeks @ \$1/week saved	47
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

Light from a lantern may be a similar strength at 1m from the lantern as smaller LED lamps, as not all the light goes in one direction. Light strength not adjustment, no night light function. Both solar and AC charge modes available.

SUPPLIERS

TATA BP Solar, India - www.tatabpsolar.com

Product Name 5W CFL solar lantern

Description Single 5-7W CFL, rechargeable lead-acid 4-7Ah battery, charged by a 5-10W solar panel



Hours/day of service	5	Number of households	1
Lumens/Watt	40	Estimated retail price	\$150
Average Lamp Power (W)	5	Battery life (years)	1.0
Battery capacity (Ah)	4.4	Battery replacement cost	\$12.00
Hours runtime/charge	5	Lamp life (years)	4
Charging hours from flat	7	Lamp replacement cost	\$4.00
Lumens	200	5-year replacement costs	\$65
Lumen-hours/year @ 4hr/day	292,000	5-year ownership cost	\$215
Service delivered (lm.hr/\$)	6,791	Payback in weeks @ \$1/week saved	200
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

One of the original lanterns to try and address low wattage lighting, Glowstar solar lantern was developed by ITDG and then commercially manufactured by Sollatek, both in the UK. A large investment was made by donors to design a lantern specifically for the poor, but the end price made it unaffordable for cash for the majority. A very high quality solution that can charge radios and phones, but is not affordable for cash purchase - available in 5W, 7W and 9W versions, and 5/10/20W solar panels

SUPPLIERS

Sollatek - www.glowstar.net

Product Name 5W thermoelectric CFL

Description Single 5W CFL, rechargeable battery, charged by a 5-10W thermoelectric pot/stove



Hours/day of service	4	Number of households	1
Lumens/Watt	45	Estimated retail price	\$108
Average Lamp Power (W)	5	Battery life (years)	3.0
Battery capacity (Ah)	7	Battery replacement cost	\$12.00
Hours runtime/charge	11	Lamp life (years)	4
Charging hours from flat	7	Lamp replacement cost	\$4.00
Lumens	225	5-year replacement costs	\$25
Lumen-hours/year @ 4hr/day	328,500	5-year ownership cost	\$133
Service delivered (lm.hr/\$)	12,338	Payback in weeks @ \$1/week saved	120
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Thermoelectric modules convert waste heat to electricity, with an efficiency of 3-5% but a cost similar to solar power. Two examples are available, though there are possible no pro-poor products in mass production - Ukraine and China manufacturers make pots that, when boiling water, can generate 5-10W of power, to run a CFL or series of LEDs. In Nepal, STARIC won a Mondialogo award for combining an improved cookstove with a thermoelectric module, to reduce fuelwood consumption and indoor air pollution whilst providing power.

SUPPLIERS

STARIC, Nepal - www.staric.com.np
 Taihuaxing Thermoelectric, China - www.thermonamic.com

Product Name 6W CFL solar lantern

Description Single 6W CFL, rechargeable battery, charged by a 7W solar panel



Hours/day of service	5	Number of households	1
Lumens/Watt	40	Estimated retail price	\$90
Average Lamp Power (W)	6	Battery life (years)	2.0
Battery capacity (Ah)	7	Battery replacement cost	\$12.00
Hours runtime/charge	5	Lamp life (years)	4
Charging hours from flat	10	Lamp replacement cost	\$4.00
Lumens	240	5-year replacement costs	\$35
Lumen-hours/year @ 4hr/day	350,400	5-year ownership cost	\$125
Service delivered (lm.hr/\$)	14,016	Payback in weeks @ \$1/week saved	104
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Well designed lantern style, can hang upside down for room lighting, but at 2-year payback, very expensive, even with a microfinance loan.

SUPPLIERS

Philips, Netherlands - www.philips.com
 Logic Electronics, Netherlands - www.le.nl

Product Name 7W CFL solar lantern

Description Single 7W CFL, rechargeable battery, charged by a 10W solar panel



Hours/day of service	3	Number of households	1
Lumens/Watt	45	Estimated retail price	\$100
Average Lamp Power (W)	7	Battery life (years)	1.0
Battery capacity (Ah)	7	Battery replacement cost	\$12.00
Hours runtime/charge	8	Lamp life (years)	4
Charging hours from flat	7	Lamp replacement cost	\$4.00
Lumens	315	5-year replacement costs	\$65
Lumen-hours/year @ 4hr/day	459,900	5-year ownership cost	\$165
Service delivered (lm.hr/\$)	13,936	Payback in weeks @ \$1/week saved	133
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

MK3 has 7W CFL, 12V 7Ah battery. MK4 has 5W CFL, 6V 4Ah battery. No adjustment, no nightlight, and only 2 hours of light for MK4 version. Due to short runtime, battery replacement costs could be very high.

SUPPLIERS

TATA BP Solar, India - www.tatabpsolar.com

Product Name 10W CFL solar home system

Description Two 5W CFLs, 12V 7Ah battery, charged by a 10W solar panel



Hours/day of service	5	Number of households	1
Lumens/Watt	40	Estimated retail price	\$150
Average Lamp Power (W)	10	Battery life (years)	2.0
Battery capacity (Ah)	7	Battery replacement cost	\$15.00
Hours runtime/charge	5	Lamp life (years)	2.0
Charging hours from flat	7	Lamp replacement cost	\$5.00
Lumens	400	5-year replacement costs	\$50
Lumen-hours/year @ 4hr/day	584,000	5-year ownership cost	\$200
Service delivered (lm.hr/\$)	14,600	Payback in weeks @ \$1/week saved	186
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Typical small-scale solar home system from China, various quality levels available, for 1-2 lamps, as used in the largest rural solar electrification project in the world, the China Renewable Energy Development Project (CREDP). If loans are available from banks or microfinance partners, over 3-5 years at around 10% p.a., the cost can reduce to around \$1/week. Batteries are typically undersized for load (5 hours for 2 lamps, 10 hours for 1 lamp), and LED lamps are of poor quality, if available at all, and wiring may require skill to install.

SUPPLIERS

Solar Season - www.solarseason.com

SinoStar - www.sinostar.com

Product Name 10W wind CFL home kit

Description 10W wind turbine to power 1x7W CFL



Hours/day of service 5
Lumens/Watt 45
Average Lamp Power (W) 7
Battery capacity (Ah) 5
Hours runtime/charge 6
Charging hours from flat 5
Lumens/household 315
Lumen-hours/year @ 4hr/day 459,900

Number of households 1
Estimated capital cost \$97
Capital works life (years) 5.0
Operation & Maintenance costs \$19
Lamp life (years) 4.0
Single lamp replacement cost \$4.00
5-year replacement costs / house \$98
5-year ownership cost / house \$194

Service delivered (lm.hr/\$) 11,853
Kerosene service (lm.hr/\$) 872

Payback in weeks @ \$1/week saved 154
Rating C

COMMENTS

Over 100,000 small wind turbines are used in Mongolia and China, by nomadic villagers. Some international companies also offer small wind turbines, though at higher capital cost. A 100W turbine is popular, costing around \$250, but a few companies are offering tiny 10W turbines, which can power LED or CFL lamps. A 5Ah \$8 battery stores the power for later use, and approximately 10m of wiring is required, as well as a 3A charge controller. Maintenance cost, including labour, are estimated at 20%, and includes battery replacement. However, many villagers build houses behind hills, protected from the wind, so some length of wiring may be required.

SUPPLIERS

Shanghai Aeolus Windpower Technology - www.sawt.com.cn/products.html

Product Name 14W CFL solar home system

Description Two 7W CFLs or 6W tube lights, 12V 15-35Ah battery, charged by a 14W solar panel



Hours/day of service	4	Number of households	1
Lumens/Watt	50	Estimated retail price	\$180
Average Lamp Power (W)	14	Battery life (years)	4.0
Battery capacity (Ah)	25	Battery replacement cost	\$40.00
Hours runtime/charge	12	Lamp life (years)	4.0
Charging hours from flat	15	Lamp replacement cost	\$4.00
Lumens	700	5-year replacement costs	\$55
Lumen-hours/year @ 4hr/day	1,022,000	5-year ownership cost	\$235
Service delivered (lm.hr/\$)	21,745	Payback in weeks @ \$1/week saved	228
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Typical small-scale solar home system in various World Bank projects, for 1-2 lamps. Loans are available from banks in India, Sri Lanka and other countries, over 5 years at around 10% p.a., reducing this cost to around \$1/week - short loan periods increase this cost per week. 15% deposits of \$25-30 can be a barrier.

SUPPLIERS

Umeme Jua, Tanzania - www.umemejua.com
 SELCO, India - www.selco-india.com
 Sundaya, Indonesia - www.sundaya.com

Product Name 20W fuel cell system

Description 20W fuel cell distributes to 3 LEDs per house via 12-24V minigrd of a several nearby households.



Hours/day of service	4	Number of households	5
Lumens/Watt	40	Estimated retail price	\$585
Average Lamp Power (W)	3	Battery life (years)	0.1
Battery capacity (Ah)	208	Battery replacement cost	\$4.00
Hours runtime/charge	150	Lamp life (years)	4.0
Charging hours from flat	N/A (20 mins warm up)	Lamp replacement cost	\$4.00
Lumens	120	5-year replacement costs	\$245
Lumen-hours/year/house	175,200	5-year ownership cost	\$830
Service delivered (lm.hr/\$)	1,055	Payback in weeks @ \$1/week saved	10,140
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Occasionally people ask if fuel cells can be used for villages. Technically this is possible - a fuel cell needs a 2500 Wh methanol and water replaceable cartridge every month, if it to served 3W of power to 5 household each month. The original fuel cell would cost hundreds of dollars (estimated at \$15/W, so \$300), and the fuel cartridges would generate high operational costs, even if only \$4 (likely to be much higher). It is not likely this will be a cost-effective alternative within 10 years, and is currently no more cost-effective than kerosene.

SUPPLIERS

Ultracell, USA - www.ultracellpower.com

Product Name 30W CFL solar home system

Description Four 7W CFLs or 6W tube lights, 12V 30-50Ah battery, charged by a 30Wp solar panel



Hours/day of service	4	Number of households	1
Lumens/Watt	50	Estimated retail price	\$400
Average Lamp Power (W)	28	Battery life (years)	4.0
Battery capacity (Ah)	40	Battery replacement cost	\$60.00
Hours runtime/charge	9	Lamp life (years)	4.0
Charging hours from flat	15	Lamp replacement cost	\$4.00
Lumens	1400	5-year replacement costs	\$80
Lumen-hours/year @ 4hr/day	2,044,000	5-year ownership cost	\$480
Service delivered (lm.hr/\$)	21,292	Payback in weeks @ \$1/week saved	578
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Typical medium-scale solar home system in various World Bank projects, for 3-4 lamps, fan and/or phone recharging. Loans are available from banks in India, Sri Lanka and other countries, over 5 years at around 10% p.a., reducing this cost to around \$2/week - short loan periods increase this cost per week.

SUPPLIERS

Umeme Jua, Tanzania - www.umemejua.com

SELCO, India - www.selco-india.com

Sundaya, Indonesia - www.sundaya.com

Product Name 70W pedal power BCS LED

Description 70W pedal generator shared in village, charging batteries for 2x1W LED lamps



Hours/day of service	4	Number of households	30
Lumens/Watt	50	Estimated capital cost	\$1,205
Average Lamp Power (W)	2	Capital works life (years)	5.0
Battery capacity (Ah)	7	Operation & Maintenance costs	\$121
Hours runtime/charge	27	Lamp life (years)	4.0
Charging hours from flat	3	Single lamp replacement cost	\$4.00
Lumens/household	100	5-year replacement costs / house	\$21
Lumen-hours/year @ 4hr/day	146,000	5-year ownership cost / house	\$61
Service delivered (lm.hr/\$)	11,918	Payback in weeks @ \$1/week saved	44
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

Pedal generators have been developed in Canada, Nepal and China, to turn pedaling energy into DC battery-charging electricity. When there is no solar, wind or other resources nearby, this can be one of the only options left, especially for villages located many days walk from a road. A 7Ah battery is recharged, often 2 at a time, with several amps of power, and this can be used directly for LEDs, or to recharge lower voltage rechargeable desk lamps. A human can generate around 70W for an hour, or about 6Ah, so after losses, this can generate 1A for 5 hours of light, or 12W of light per household. Hence, pedal power can scale to a maximum of one CFL lamp, but is more typically used for multiple 1W \$5 LED lamps. Recharging twice a week and 1 hour per household, one generator can serve 30 houses.

SUPPLIERS

Ecosystems Nepal, Nepal - www.ecosystemsnepal.com/ecopower.php

Light Up The World Foundation, Canada - www.lutw.org

Windstream Power, USA - www.windstreampower.com

Product Name 300W solar BCS CFL
Description 300W solar centralized battery charging station, with exchangeable 7W CFL lanterns



Hours/day of service	3	Number of households	50
Lumens/Watt	45	Estimated capital cost	\$5,000
Average Lamp Power (W)	7	Capital works life (years)	10.0
Battery capacity (Ah)	7	Operation & Maintenance costs	\$250
Hours runtime/charge	8	Lamp life (years)	4.0
Charging hours from flat	7	Single lamp replacement cost	\$4.00
Lumens/household	315	5-year replacement costs / house	\$26
Lumen-hours/year @ 4hr/day	459,900	5-year ownership cost / house	\$126
Service delivered (lm.hr/\$)	18,250	Payback in weeks @ \$1/week saved	111
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

The Tata Energy Research Institute has initiated the Light a Billion Lives campaign, which utilizes a centralized battery charging station with a 300W solar panel. This recharges 50 portable CFL lanterns for 50 households, via a fee-for-service model. This system may or may not use a lantern exchange system (like gas bottles). Fees charged are \$0.30-\$1/week, resulting in a 2-4 year payback period for each charging station. To reach 200 million households in India, TERI estimate it will cost US\$18 billion, a very capital intensive challenge.

SUPPLIERS

Light a Billion Lives Campaign, TATA / TERI - labl.teriin.org

Product Name 100W instream hydro CFL BCS

Description 100W instream picohydro generator at centralized battery charging station, with 7W CFL lanterns



Hours/day of service	3	Number of households	15
Lumens/Watt	45	Estimated capital cost	\$2,850
Average Lamp Power (W)	7	Capital works life (years)	5.0
Battery capacity (Ah)	7	Operation & Maintenance costs	\$250
Hours runtime/charge	8	Lamp life (years)	4.0
Charging hours from flat	7	Single lamp replacement cost	\$4.00
Lumens/household	315	5-year replacement costs / house	\$84
Lumen-hours/year @ 4hr/day	459,900	5-year ownership cost / house	\$274
Service delivered (lm.hr/\$)	8,382	Payback in weeks @ \$1/week saved	281
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Yachts occasionally use submersible hydro generators to recharge batteries. The same technology can be used for villages with fast flowing streams (>3m/s) in relatively flat areas. There is a risk of damage to the turbine during floods. In a few areas, tidal flows in and out of streams near the sea can provide sufficient current - increased flows are often found under small bridges. The power is DC output, so is used to charge batteries - in this case, 100W produces 5-8A of current, which charges an intermediate 50Ah battery before charging smaller CFL lanterns. Should China or India become involved in producing such turbines, prices would surely decrease, but for now, this option is expensive.

SUPPLIERS

Ampair, UK - www.ampair.com/ampair/waterpower.asp

DuoGen, UK - www.duogen.co.uk

Product Name 100W wind CFL home kit

Description 100W wind turbine to power 3x10W CFL lights (+ often TV and other appliances)



Hours/day of service 5
Lumens/Watt 50
Average Lamp Power (W) 30
Battery capacity (Ah) 50
Hours runtime/charge 13
Charging hours from flat 5
Lumens/household 1500
Lumen-hours/year @ 4hr/day 2,190,000

Number of households 1
Estimated capital cost \$432
Capital works life (years) 5.0
Operation & Maintenance costs \$43
Lamp life (years) 4.0
Single lamp replacement cost \$4.00
5-year replacement costs / house \$217
5-year ownership cost / house \$649

Service delivered (lm.hr/\$) 16,872
Kerosene service (lm.hr/\$) 872

Payback in weeks @ \$1/week saved 2,612
Rating C

COMMENTS

Over 100,000 small wind turbines are used in Mongolia and China, by nomadic villagers. Some international companies also offer small wind turbines, though at higher capital cost. A 100W turbine is popular, costing around \$250. A 50Ah \$75 battery stores the power for later use, and approximately 30m of wiring is required, as well as a 10A charge controller. Maintenance cost, including labour, are estimated at 10%, and includes battery replacement. However, many villagers build houses behind hills, protected from the wind, so some length of wiring may be required.

SUPPLIERS

Bergey Windpower - www.bergey.com/Dealers & Resellers

Product Name 300W wind BCS CFL
Description 300W wind centralized battery charging station, with exchangeable 7W CFL lanterns



Hours/day of service	3	Number of households	50
Lumens/Watt	45	Estimated capital cost	\$4,025
Average Lamp Power (W)	7	Capital works life (years)	5.0
Battery capacity (Ah)	7	Operation & Maintenance costs	\$403
Hours runtime/charge	8	Lamp life (years)	4.0
Charging hours from flat	7	Single lamp replacement cost	\$4.00
Lumens/household	315	5-year replacement costs / house	\$41
Lumen-hours/year @ 4hr/day	459,900	5-year ownership cost / house	\$122
Service delivered (lm.hr/\$)	18,887	Payback in weeks @ \$1/week saved	96
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

The Tata Energy Research Institute has initiated the Light a Billion Lives campaign, which utilizes a centralized battery charging station with a 300W solar panel. Should a 300W wind turbine be used instead, similar to that used in Mongolia, lower capital costs may be possible. The wind turbines would recharge 50 portable CFL lanterns for 50 households, via a fee-for-service model.

SUPPLIERS

Light a Billion Lives Campaign, TATA / TERI - labl.teriin.org
 Liten Wind Power Company, China - www.wind-turbine.cn/300w-wind-turbine-generator.htm

Product Name 200W Pico Hydro BCS LED

Description Low head (2m) pico hydro turbine, for 150 households with 1 x 1W LED each, via 4V 4Ah battery charging



Hours/day of service	4	Number of households	150
Lumens/Watt	40	Estimated capital cost	#####
Average Lamp Power (W)	1	Capital works life (years)	5.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$290
Hours runtime/charge	31	Lamp life (years)	4.0
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	40	5-year replacement costs / house	\$11
Lumen-hours/year @ 4hr/day	58,400	5-year ownership cost / house	\$32
Service delivered (lm.hr/\$)	9,031	Payback in weeks @ \$1/week saved	23
Kerosene service (lm.hr/\$)	872	Rating	A

COMMENTS

Pico hydro refers to 3kW or less. Low head turbines costing about US\$50-200 can be purchased from Vietnam, China and other Asian countries. Due to the low vertical drop required for the water ("head"), civil works costs are low and can use local materials. Instead of connecting each household with wiring, each house has a 4V 4Ah battery, recharged twice a week. 20 \$8 batteries are charged per day, 6 hrs/charge in 2 shifts, via 1A 6V chargers.

SUPPLIERS

Power Pal, Vietnam - www.powerpal.com
 Lotus Energy, Nepal - www.lotusenergy.com
 Video from Palang Thai - www.youtube.com/watch?v=fuz7KMx8dJc
 Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 200W Pico Hydro BCS LEDs

Description Low head (2m) pico hydro turbine, for 60 households with 3 x 1W LEDs each, via 3-5Ah battery charging



Hours/day of service	4	Number of households	50
Lumens/Watt	40	Estimated capital cost	\$2,250
Average Lamp Power (W)	3	Capital works life (years)	5.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$330
Hours runtime/charge	10	Lamp life (years)	4.0
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$36
Lumen-hours/year @ 4hr/day	175,200	5-year ownership cost / house	\$81
Service delivered (lm.hr/\$)	10,815	Payback in weeks @ \$1/week saved	52
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Pico hydro refers to 3kW or less. Low head turbines costing about US\$50-200 can be purchased from Vietnam, China and other Asian countries. Due to the low vertical drop required for the water ("head"), civil works costs are low and can use local materials. Instead of connecting each household with wiring, each house has a 3-5Ah battery, recharged twice a week. 20 \$8 batteries are charged per day, 6 hrs/charge in 2 shifts, via 0.5-1A chargers.

SUPPLIERS

Power Pal, Vietnam - www.powerpal.com
 Lotus Energy, Nepal - www.lotusenergy.com
 Video from Palang Thai - www.youtube.com/watch?v=fuz7KMx8dJc
 Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 200W Pico Hydro AC LEDs

Description Low head (2m) pico hydro turbine, meeting demands of 50 households with 3 x 1W of LEDs



Hours/day of service	16	Number of households	50
Lumens/Watt	40	Estimated capital cost	\$2,150
Average Lamp Power (W)	3	Capital works life (years)	5.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$310
Hours runtime/charge	N/A	Lamp life (years)	4.0
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$34
Lumen-hours/year/house	700,800	5-year ownership cost / house	\$77
Service delivered (lm.hr/\$)	45,506	Payback in weeks @ \$1/week saved	49
Kerosene service (lm.hr/\$)	872	Rating	B

COMMENTS

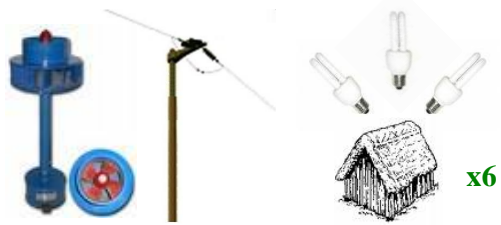
Pico hydro refers to 3kW or less. Low head turbines costing about US\$50-200 can be purchased from Vietnam, China and other Asian countries. Due to the low vertical drop required for the water ("head"), civil works costs are low and can use local materials (see video). Approximately 100m of wiring is required to connect the households + 10-15m inside each house. Mechanical energy is not available for agro-processing.

SUPPLIERS

Power Pal, Vietnam - www.powerpal.com
Lotus Energy, Nepal - www.lotusenergy.com
Video from Palang Thai - www.youtube.com/watch?v=fuz7KMx8dJc
Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 200W Pico Hydro AC CFLs

Description Low head (2m) pico hydro turbine, meeting demands of 6 households with 3 x 10W of CFLs



Hours/day of service	16	Number of households	6
Lumens/Watt	50	Estimated capital cost	\$522
Average Lamp Power (W)	30	Capital works life (years)	5.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$90
Hours runtime/charge	N/A	Lamp life (years)	4.0
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$78
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$165
Service delivered (lm.hr/\$)	265,455	Payback in weeks @ \$1/week saved	124
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Pico hydro refers to 3kW or less. Low head turbines costing about US\$50-200 can be purchased from Vietnam, China and other Asian countries. Due to the low vertical drop required for the water ("head"), civil works costs are low and can use local materials.

SUPPLIERS

Power Pal, Vietnam - www.powerpal.com

Lotus Energy, Nepal - www.lotusenergy.com

Video from Palang Thai - www.youtube.com/watch?v=fuz7KMx8dJc

Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 500W Pico Hydro AC LED+CFL

Description Low head (2m) picohydro turbine, meeting demands of 35 households with 1x10W CFLs, 2x1W LEDs



Hours/day of service	16	Number of households	35
Lumens/Watt	45	Estimated capital cost	\$2,595
Average Lamp Power (W)	12	Capital works life (years)	5.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$435
Hours runtime/charge	N/A	Lamp life (years)	4.0
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	540	5-year replacement costs / house	\$65
Lumen-hours/year/house	3,153,600	5-year ownership cost / house	\$139
Service delivered (lm.hr/\$)	113,206	Payback in weeks @ \$1/week saved	99
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Pico hydro refers to 3kW or less. High head turbines costing about US\$500-1000 can be purchased from Vietnam, Nepal, China and other Asian countries. High head sites require up to 50m of 2-4 inch water pipe (\$200). Approximately 100-300m of wiring is required to connect the households + 10-15m inside each house. Surveys indicate acceptance of CFL for main room, LEDs for minor rooms. Mechanical energy is not available.

SUPPLIERS

REDCO, Sri Lanka - www.redcoenergy.com

Video from Palang Thai - www.youtube.com/watch?v=OzmZa0kEv0o&feature=channel_page

List of Nepali manufacturers - aepc.gov.np/index.php?option=com_content&task=view&id=71&Itemid=38

Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 500W High Head Pico Hydro AC

Description Low head (2m) pico hydro turbine, meeting demands of 6 households with 3 x 10W of CFLs



Hours/day of service	16	Number of households	15
Lumens/Watt	50	Estimated capital cost	\$1,855
Average Lamp Power (W)	30	Capital works life (years)	5.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$335
Hours runtime/charge	N/A	Lamp life (years)	4.0
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$115
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$238
Service delivered (lm.hr/\$)	183,776	Payback in weeks @ \$1/week saved	221
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Pico hydro refers to 3kW or less. High head turbines costing about US\$500-1000 can be purchased from Vietnam, Nepal, China and other Asian countries. High head sites require up to 50m of 2-4 inch water pipe (\$200). Approximately 100-300m of wiring is required to connect the households + 10-15m inside each house. Mechanical energy is not available for agro-processing.

SUPPLIERS

REDCO, Sri Lanka - www.redcoenergy.com

Video from Palang Thai - www.youtube.com/watch?v=OzmZa0kEv0o&feature=channel_page

List of Nepali manufacturers - aepc.gov.np/index.php?option=com_content&task=view&id=71&Itemid=38

Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 1000W Low Head Pico Hydro AC

Description Low head (2-3m) pico hydro turbine, meeting demands of 30 households with 3 x 10W of CFLs



Hours/day of service	16	Number of households	30
Lumens/Watt	50	Estimated capital cost	\$2,710
Average Lamp Power (W)	30	Capital works life (years)	5.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$470
Hours runtime/charge	N/A	Lamp life (years)	4.0
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$81
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$172
Service delivered (lm.hr/\$)	255,146	Payback in weeks @ \$1/week saved	131
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

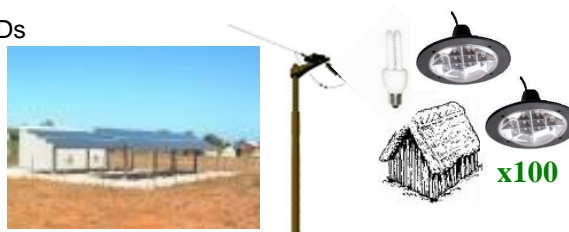
Pico hydro refers to 3kW or less. Low head turbines costing about US\$1000 can be purchased from Vietnam, China and other Asian countries. Civil works costs to divert the water may require some concrete (\$300). Approximately 100-300m of wiring is required to connect the households + 10-15m inside each house. Mechanical energy is not available for agro-processing.

SUPPLIERS

- Exmork, China - www.exmork.com
- Power Pal, Vietnam - www.powerpal.com
- Video from Palang Thai - www.youtube.com/watch?v=fuz7KMx8dJc
- Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 1kW solar AC CFL + LEDs

Description 1kW centralized solar generation plus battery, inverter from DC to AC, and distribution to houses



Hours/day of service	5	Number of households	100
Lumens/Watt	50	Estimated capital cost	\$15,000
Average Lamp Power (W)	10	Capital works life (years)	10.0
Battery capacity (Ah)	2,000	Operation & Maintenance costs	\$600
Hours runtime/charge	18	Lamp life (years)	4
Charging hours from flat	17	Single lamp replacement cost	\$4.00
Lumens/household	500	5-year replacement costs / house	\$34
Lumen-hours/year/house	912,500	5-year ownership cost / house	\$184
Service delivered (lm.hr/\$)	24,796	Payback in weeks @ \$1/week saved	173
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

A 1kW centralized solar system stores electricity in a centralized battery bank. This DC power is converted to AC with an inverter, and reticulated around the village, at a cost of \$30/household. Each household has one 7W CFL and 3 LEDs for 10W of power access, for 5 hours per day. Solar panels cost US\$6000/kW fully installed, and the cost of the battery and inverter doubles this cost. Distribution costs are included at an estimate of \$30/household. These "mini" centralized solar systems are very capital intensive, and payback periods are 3-5 years for non-subsidized costs replacing kerosene lighting alone.

SUPPLIERS

Bushlight Program, Australia - www.bushlight.org.au
Barefoot Power - www.barefootpower.com

Product Name 600W petrol generator BCS-LED

Description 600-900W “camping” 2-stroke generator is used to charge 4V 4Ah batteries for use of 1 x 1W LEDs



Hours/day of service	4	Number of households	300
Lumens/Watt	40	Estimated capital cost	\$3,600
Average Lamp Power (W)	1	Capital works life (years)	2.0
Battery capacity (Ah)	1.5	Operation & Maintenance costs	\$661
Hours runtime/charge	15	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	40	5-year replacement costs / house	\$23
Lumen-hours/year/house	58,400	5-year ownership cost / house	\$35
Service delivered (lm.hr/\$)	8,341	Payback in weeks @ \$1/week saved	13
Kerosene service (lm.hr/\$)	872	Rating	A

COMMENTS

Tens of thousands of low cost (~\$100) generators are flooding villages from China. Some have reasonable lifespan. Instead of mini grid reticulated wiring, each house has a 1.5Ah battery, recharged twice a week. 100 batteries are charged per day, 6 hours per day, via 1A 6V chargers. Fuel consumption is poor, about 0.9 L/kW/hour, and fuel is assumed to cost US\$1.50/L

SUPPLIERS

Example OEM supplier of 2-stroke gensets - www.alibaba.com/product-gs/200543464/gasoline_generator.htm
 Often available from nearby trade stores
 Recharging kits and lighting from Barefoot Power - www.barefootpower.com

Product Name 600W petrol generator BCS-LEDs

Description 600-900W “camping” 2-stroke generator is used to charge 3-5Ah batteries for use of 3 x 1W LEDs



Hours/day of service	4	Number of households	150
Lumens/Watt	40	Estimated capital cost	\$6,850
Average Lamp Power (W)	3	Capital works life (years)	2.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$1,461
Hours runtime/charge	15	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$61
Lumen-hours/year/house	175,200	5-year ownership cost / house	\$106
Service delivered (lm.hr/\$)	8,235	Payback in weeks @ \$1/week saved	60
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Tens of thousands of low cost (~\$100) generators are flooding villages from China. Some have reasonable lifespan. Instead of mini grid reticulated wiring, each house has a 3-5Ah battery, recharged twice a week. 50 batteries are charged per day, 6 hours per day, via 0.5-1 A chargers. Fuel consumption is poor, about 0.9 L/kW/hour, and fuel is assumed to cost US\$1.50/L

SUPPLIERS

Example OEM supplier of 2-stroke gensets - www.alibaba.com/product-gs/200543464/gasoline_generator.h
 Often available from nearby trade stores
 Recharging kits and lighting from Barefoot Power - www.barefootpower.com

Product Name 600W petrol generator BCS CFL

Description 600-900W “camping” 2-stroke generator is used to charge 12Ah batteries for use of 1 x 10W CFL + 2 x 1W LEDs



Hours/day of service	4	Number of households	100
Lumens/Watt	45	Estimated capital cost	\$7,100
Average Lamp Power (W)	12	Capital works life (years)	2.0
Battery capacity (Ah)	12	Operation & Maintenance costs	\$2,083
Hours runtime/charge	15	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	540	5-year replacement costs / house	\$116
Lumen-hours/year/house	788,400	5-year ownership cost / house	\$187
Service delivered (lm.hr/\$)	21,066	Payback in weeks @ \$1/week saved	128
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Tens of thousands of low cost (~\$100) generators are flooding villages from China. Some have reasonable lifespan. Instead of mini grid reticulated wiring, each house has a 12Ah battery, recharged twice a week. 20 batteries are charged per day, 6 hours per day, via 2-3 A chargers. Fuel consumption is poor, about 0.9 L/kW/hour, and fuel is assumed to cost US\$1.50/L

SUPPLIERS

Example OEM supplier of 2-stroke gensets - www.alibaba.com/product-gs/200543464/gasoline_generator.ht
 Often available from nearby trade stores
 Recharging kits and lighting from Barefoot Power - www.barefootpower.com

Product Name 600W petrol generator AC CFL

Description 600-900W “camping” 2-stroke generator is used to power households via an AC minigrid, for use of 3 x 7W CFLs



Hours/day of service	4	Number of households	60
Lumens/Watt	45	Estimated capital cost	\$4,450
Average Lamp Power (W)	10	Capital works life (years)	4.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$2,202
Hours runtime/charge	N/A	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	450	5-year replacement costs / house	\$196
Lumen-hours/year/house	657,000	5-year ownership cost / house	\$270
Service delivered (lm.hr/\$)	12,182	Payback in weeks @ \$1/week saved	299
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Low cost generators can be found in many villages in developing countries already. Sometimes, they connect nearby households in an informal minigrid using extension cables. This can be formalized using insulated aerial cables, and conversion from AC to DC at bush huts can be advisable for safety. Approximately 100-300m of wiring is required to connect 10-30 households + 10-15m inside each house. Mechanical energy is not available for agro-processing.

SUPPLIERS

Example OEM supplier of 2-stroke gensets - [www.alibaba.com/product-gs/200543464/gasoline_generator.](http://www.alibaba.com/product-gs/200543464/gasoline_generator/)
 Often available from nearby trade stores
 AC cabling and lighting available from Barefoot Power - www.barefootpower.com

Product Name 1kW Improved Ghatta AC

Description Low head improved grinding mill, meeting demands of 25 households with 3 x 10W of CFLs each, direct AC reticulated power



Hours/day of service	10	Number of households	25
Lumens/Watt	50	Estimated capital cost	\$2,469
Average Lamp Power (W)	30	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$434
Hours runtime/charge	N/A	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$91
Lumen-hours/year/house	5,475,000	5-year ownership cost / house	\$190
Service delivered (lm.hr/\$)	144,459	Payback in weeks @ \$1/week saved	152
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Tens of thousands of traditional water mills can be found in the Himalayas. These can be upgraded with higher efficiency turbine blades, and an electric generator can be added. The civil works are largely already in place, and hence considerable cost savings can be made. 20% O&M cost assumed. Mechanical energy is available for improved agro-processing (eg. making flour), creating additional income and reducing the payback period.

SUPPLIERS

Centre for Rural Technology, Nepal - www.crtnepal.org

Product Name 1kW Improved Ghatta BCS

Description Low head improved grinding mill for 100 households with 1 x 10W CFLs + 2 x 1W LEDs each, via 12Ah battery charging



Hours/day of service	4	Number of households	100
Lumens/Watt	40	Estimated capital cost	\$8,125
Average Lamp Power (W)	12	Capital works life (years)	10.0
Battery capacity (Ah)	12	Operation & Maintenance costs	\$1,385
Hours runtime/charge	8	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	480	5-year replacement costs / house	\$81
Lumen-hours/year/house	700,800	5-year ownership cost / house	\$163
Service delivered (lm.hr/\$)	21,563	Payback in weeks @ \$1/week saved	118
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Uses a traditional Himalayan water mill, upgraded with higher efficiency turbine blades and an electric generator added at \$1000/kW. Instead of connecting each household with wiring, each house has a 12Ah battery, recharged twice a week. 30 batteries are charged per day, 6 hours per day, via 2-3 A chargers.

SUPPLIERS

Centre for Rural Technology, Nepal - www.crtnepal.org
Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 1kW Improved Ghatta BCS-LEDs

Description Low head improved grinding mill for 300 households with 3 x 1W LEDs each, via 3-5Ah battery charging



Hours/day of service	4	Number of households	300
Lumens/Watt	40	Estimated capital cost	\$14,250
Average Lamp Power (W)	3	Capital works life (years)	10.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$2,130
Hours runtime/charge	10	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$48
Lumen-hours/year/house	175,200	5-year ownership cost / house	\$95
Service delivered (lm.hr/\$)	9,221	Payback in weeks @ \$1/week saved	58
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Uses a traditional Himalayan water mill, upgraded with higher efficiency turbine blades and an electric generator added at \$1000/kW. Instead of connecting each household with wiring, each house has a 3-5Ah battery, recharged twice a week. 100 batteries are charged per day, 6 hours per day, via 0.5-1 A chargers.

SUPPLIERS

Centre for Rural Technology, Nepal - www.crtnepal.org

Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 2kW biomass gasifier AC

Description Biomass (wood, rice husk, husks) are burned in gasifier, and gas released is cleaned and fed into modified diesel generator



Hours/day of service	16	Number of households	50
Lumens/Watt	50	Estimated capital cost	\$7,000
Average Lamp Power (W)	30	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$1,381
Hours runtime/charge	24	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$142
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$282
Service delivered (lm.hr/\$)	155,246	Payback in weeks @ \$1/week saved	309
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Operation & Maintenance cost assumes \$0.10/dry kg of fuel, 0.9 kWh / kg of fuel, 35% utilization of the power plant, and labour/management costs are 10% of capital cost. \$3500/kW cost includes \$2500/kW for power + \$1000/kW for the distribution network. Can be used for co-generation of electricity and heat – the latter is good for drying.

SUPPLIERS

Ankur Scientific, India - www.ankurscientific.com

Product Name 2kW biomass steam engine AC

Description Biomass is burned in an externally combusted steam engine, which runs a generator, then power is distributed to households



Hours/day of service	16	Number of households	50
Lumens/Watt	50	Estimated capital cost	\$9,750
Average Lamp Power (W)	30	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$2,201
Hours runtime/charge	24	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$224
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$419
Service delivered (lm.hr/\$)	104,500	Payback in weeks @ \$1/week saved	1,414
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Operation & Maintenance cost assume \$0.10/dry kg of fuel, 0.5kWh / kg of fuel, 35% utilization of the power plant, and labour/management costs are 10% of capital cost. \$6500/kW cost includes \$5500/kW for power + \$1000/kW for the distribution network. Can be used for co-generation of electricity and heat. This technology is under development, but is important, as it has the low cost potential of a gasifiers, can deliver 24-hour power, but has the added benefit of silent operation, which gasifiers (that use a 'diesel' engine) do not.

SUPPLIERS

Pritchard Power Systems, Australia - www.pritchardpower.com.au

Product Name 2kW diesel generator BCS-LEDs

Description 2-3 kW efficient diesel generator is used to charge 3-5Ah batteries for use of 3 x 1W LEDs



Hours/day of service	4	Number of households	300
Lumens/Watt	40	Estimated capital cost	\$13,850
Average Lamp Power (W)	3	Capital works life (years)	5.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$2,401
Hours runtime/charge	15	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$52
Lumen-hours/year/house	175,200	5-year ownership cost / house	\$98
Service delivered (lm.hr/\$)	8,922	Payback in weeks @ \$1/week saved	58
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Low cost (~\$600) diesel generators have been rural “workhorses” in Asia for years. Many have reasonable lifespan. Instead of mini grid reticulated wiring, each house has a 3-5Ah battery, recharged twice a week. 50 batteries are charged per day, 6 hours per day, via 0.5-1 A chargers. Fuel consumption is good, about 0.35 L/kW/hour, and fuel is assumed to cost US\$1.50/L

SUPPLIERS

Changfa, China - www.changfa.com
 Lighting kits from Barefoot Power - www.barefootpower.com

Product Name 2kW veg oil generator BCS-LEDs

Description 2-3 kW efficient diesel generator is used to charge 3-5Ah batteries for use of 3 x 1W LEDs



Hours/day of service	4	Number of households	300
Lumens/Watt	40	Estimated capital cost	\$14,350
Average Lamp Power (W)	3	Capital works life (years)	5.0
Battery capacity (Ah)	4	Operation & Maintenance costs	\$2,541
Hours runtime/charge	15	Lamp life (years)	4
Charging hours from flat	6	Single lamp replacement cost	\$4.00
Lumens/household	120	5-year replacement costs / house	\$54
Lumen-hours/year/house	175,200	5-year ownership cost / house	\$102
Service delivered (lm.hr/\$)	8,573	Payback in weeks @ \$1/week saved	60
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

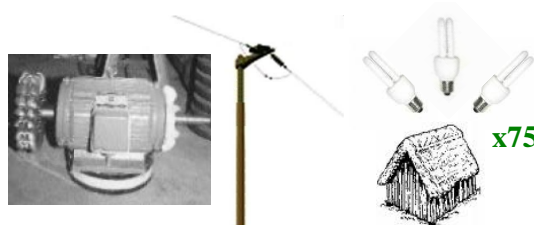
Low cost (~\$600) diesel generators can be run on coconut oil, hand-grated and hand-pressed, then filtered. Instead of mini grid reticulated wiring, each house has a 3-5Ah battery, recharged twice a week. 50 batteries are charged per day, 6 hours per day, via 0.5-1 A chargers. Fuel consumption is good, about 0.45 L/kW/hour, and the coconut oil is assumed to cost US\$1.30/L, but this money stays locally, displacing imported fossil fuels.

SUPPLIERS

Microscale coconut oil processing equipment – Project Support Services PNG – www.psspng.com
 Diesel generators suited for vegetable oil – Changfa, China – www.changfa.com

Product Name 3kW Pico Hydro AC

Description High head pico hydro turbine, meeting demands of 75 households with 3 x 10W of CFLs



Hours/day of service	16	Number of households	75
Lumens/Watt	50	Estimated capital cost	\$9,000
Average Lamp Power (W)	30	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$900
Hours runtime/charge	24	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	1500	5-year replacement costs / house	\$64
Lumen-hours/year/house	8,760,000	5-year ownership cost / house	\$184
Service delivered (lm.hr/\$)	238,043	Payback in weeks @ \$1/week saved	159
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

Pico hydro refers to 3kW or less. Power can be diverted in batteries, and mechanical grinding power, and also income, can be included. US\$3000/kW cost includes US\$1000-1500/kW for power generation, and another \$1000-2000/kW for the transmission line to connect the households. Mechanical energy is available for agro-processing, which can generate additional income, reducing the payback period.

SUPPLIERS

Nigel Smith - www.eee.nottingham.ac.uk/picohydro/docs/NepalCaseStudy_2.pdf

Product Name 5kW solar AC CFLs

Description 5kW centralized solar generation plus battery, inverter from DC to AC, and distribution to houses



Hours/day of service	24	Number of households	36
Lumens/Watt	50	Estimated capital cost	\$70,000
Average Lamp Power (W)	30	Capital works life (years)	10.0
Battery capacity (Ah)	11,000	Operation & Maintenance costs	\$1,400
Hours runtime/charge	36	Lamp life (years)	4
Charging hours from flat	18	Single lamp replacement cost	\$4.00
Lumens/household	1,500	5-year replacement costs / house	\$200
Lumen-hours/year/house	13,140,000	5-year ownership cost / house	\$2,160
Service delivered (lm.hr/\$)	30,423	Payback in weeks @ \$1/week saved	8,485
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

In remote areas of developed countries like Australia, power is made from solar or hybrid systems, for 10-100 households. Power is stored in batteries, and then an inverter changes the power from DC to AC. The system is large enough to power far more than lighting. Solar panels cost US\$6000/kW fully installed, and the cost of the battery and inverter doubles this cost. Distribution costs are included at an estimate of \$300/household. Centralized solar is very capital intensive, and while this service is a good end point to aim for, payback periods are long for non-subsidized costs replacing kerosene lighting alone, and still 5-15 years with higher realized savings.

SUPPLIERS

Bushlight Program, Australia - www.bushlight.org.au

Product Name Grid extension to one CFL

Description Cost of extending grid 5 km to medium sized village. Power generation capital cost not included.



Hours/day of service	12	Number of households	200
Lumens/Watt	50	Estimated capital cost	\$43,300
Average Lamp Power (W)	10	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$873
Hours runtime/charge	N/A	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	500	5-year replacement costs / house	\$26
Lumen-hours/year/house	2,190,000	5-year ownership cost / house	\$242
Service delivered (lm.hr/\$)	45,189	Payback in weeks @ \$1/week saved	240
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

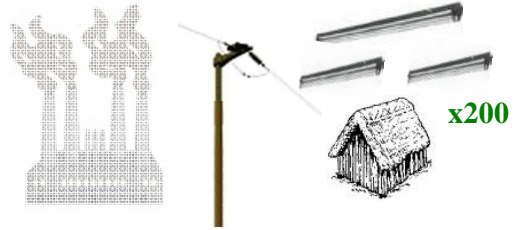
If households live near the grid, extending the grid to the village is an option. The cost of the power generation is not included. Costs vary, but are typically \$4000/km for 1-11kV distribution. It is assumed there is 25m between households, and this distribution costs \$2000/km. 10m of wiring is required inside each household, plus a \$30 meter (preferably a pre-pay meter) and a single \$4 CFL. Operation costs include power purchase and 2% maintenance. Payback periods are typically 5-10 years so power companies and villages are reluctant to invest.

SUPPLIERS

National / State power company

Product Name Grid extension to tube lights

Description Cost of extending grid 5 km to medium sized village. Power generation capital cost not included.



Hours/day of service	12	Number of households	200
Lumens/Watt	60	Estimated capital cost	\$49,360
Average Lamp Power (W)	72	Capital works life (years)	10.0
Battery capacity (Ah)	N/A	Operation & Maintenance costs	\$1,035
Hours runtime/charge	N/A	Lamp life (years)	4
Charging hours from flat	N/A	Single lamp replacement cost	\$4.00
Lumens/household	4320	5-year replacement costs / house	\$30
Lumen-hours/year/house	18,921,600	5-year ownership cost / house	\$277
Service delivered (lm.hr/\$)	341,962	Payback in weeks @ \$1/week saved	279
Kerosene service (lm.hr/\$)	872	Rating	C

COMMENTS

If households live near the grid, extending the grid to the village is an option. The cost of the power generation is not included. Costs vary, but are typically \$4000/km for 1-11kV distribution. It is assumed there is 25m between households, and this distribution costs \$2000/km. 30m of wiring is required inside each household to connect 3 lamps, plus a \$30 meter, 1x36W fluorescent tube lamp + 2x18W, at \$8-12 each. Operation costs include power purchase and 2% maintenance. Payback periods are typically 5-10 years so power companies and villages are reluctant to invest.

SUPPLIERS

National / State power company