University of Strathclyde Engineering

Malawi Community Energy Sustainability Extension

Market Assessment Training

20th – 22nd January 2016

Lilongwe

Community Energy Malawi

Productive Use of Solar PV

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Contents

- Context
- Introduction and Definition
- Benefits of Productive Use
- Restrictions and Challenges
- Examples and Case Studies

Applications of Solar PV, Benefits and Drawbacks

Context – large potential

- 10 million diesel gensets serving base loads in sunny regions of the world

- 2 million villages within 200km of the equator have neither grid nor access to fossil fuels

A large potential for PV stand-alone and hybrid systems

Jon Persson - 2015

PV Applications

- Pico Solar Products
- Solar Home Systems
- Grid Connection

•Vaccine Refrigerators

•Telecommunications

•Power for Schools & Hospitals

•Water Pumping

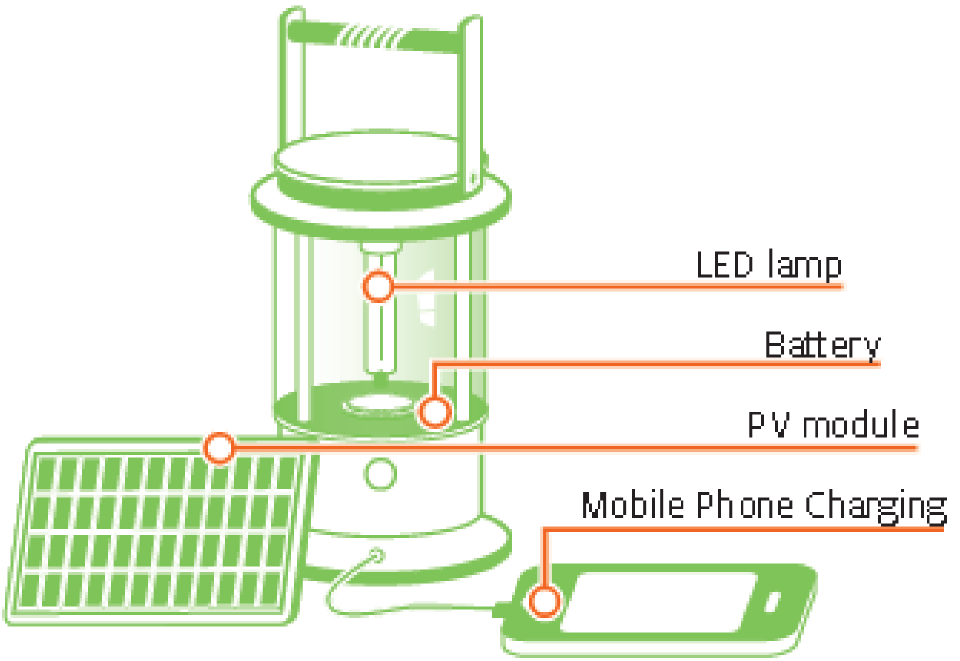
•Street lighting

•Power around the home

- Lighting
- Cooling
- Professional Service

Pico Solar Systems

Typical Power Usages for Pico-Solar Systems

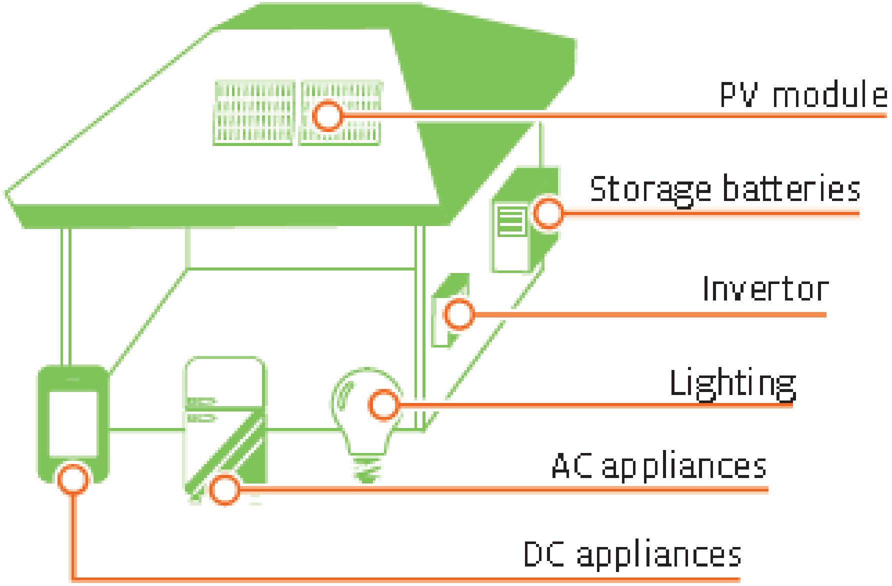


Appliance	Power Use (Watts)
Small LED light (50 lumens intensity)	0.5 W
Radio	0.5 W
Larger LED light (200 lumens)	2 W
Small mobile phone charging to 50% for 2 hours	2 W

Eight19

Solar Home Systems

Typical Power Usages for Solar-Home Systems



Appliance	Power Use (Watts)
Tablet/efficient laptop to charge to 50% in 3 hours	10 W
Small LCD television (DC)	20 W
Ceiling Fan	20 W
Fridge	40 W
Larger LCD television (AC)	100 W
Sewing machine	100 W
Small electric hotplate stove	1000 W

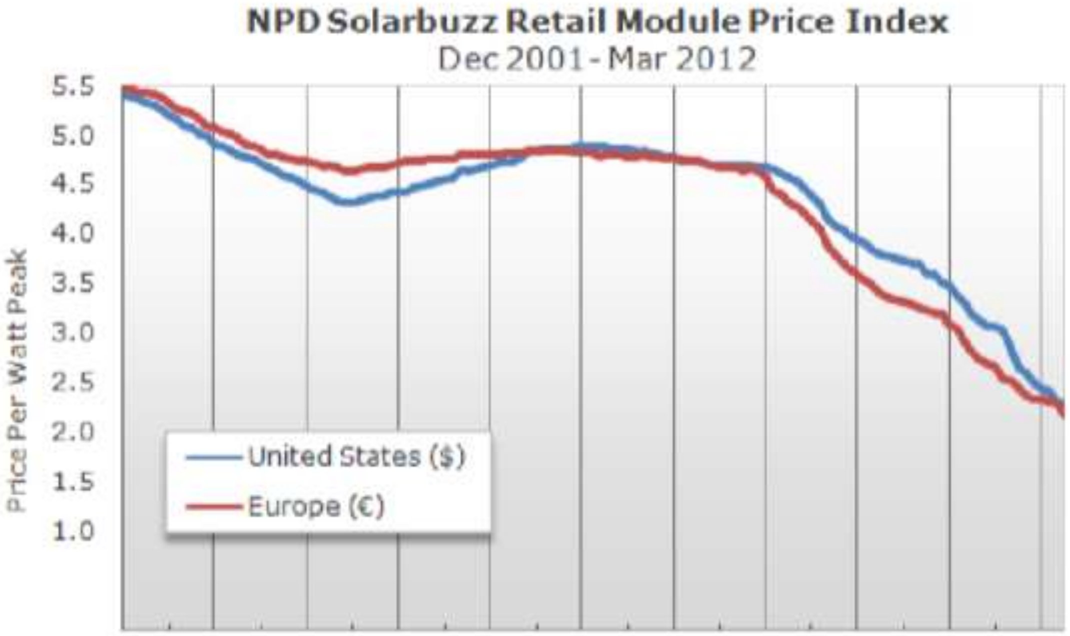
Solar home systems

NREL PIX, credits: Roger Taylor

Benefits of PV

- Modular – scalable
- Good solar resource in Malawi
- Prices reducing
- Low maintenance compared to Wind, Hydro or Diesel
- Low $C0_2$, Low other emissions

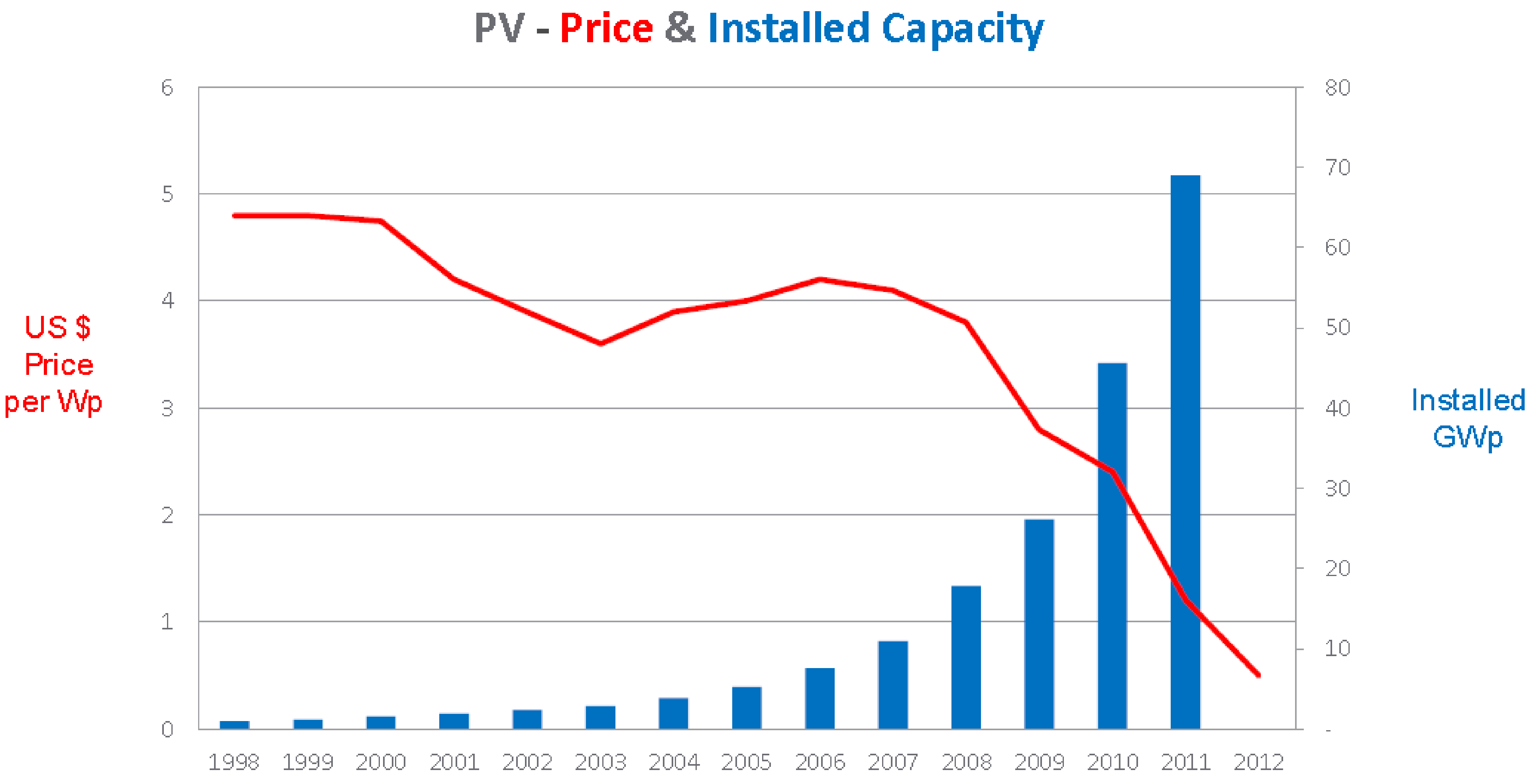
Solar modules are becoming cheaper…



Module Pricing Trends per Watt peak			
United States	$2.29	↘	0%
Europe	€2.17	↘	-5%
Number of Prices <$2.00 or €1.54/Wp	329 (34% of survey)	↗	9%
Lowest Mono-cSi Module Price	$1.1 €0.81	↘ ↓	-8% -11%
Lowest Multi-cSi Module Price	$1.06 €0.78	↘ ↘	-2% -5%
Lowest Thin Film Module Price	$0.84 €0.62	↗ →	4% 0%

Source: www.solarbuzz.com. Retrieved 2013-05-06

...as more are being installed

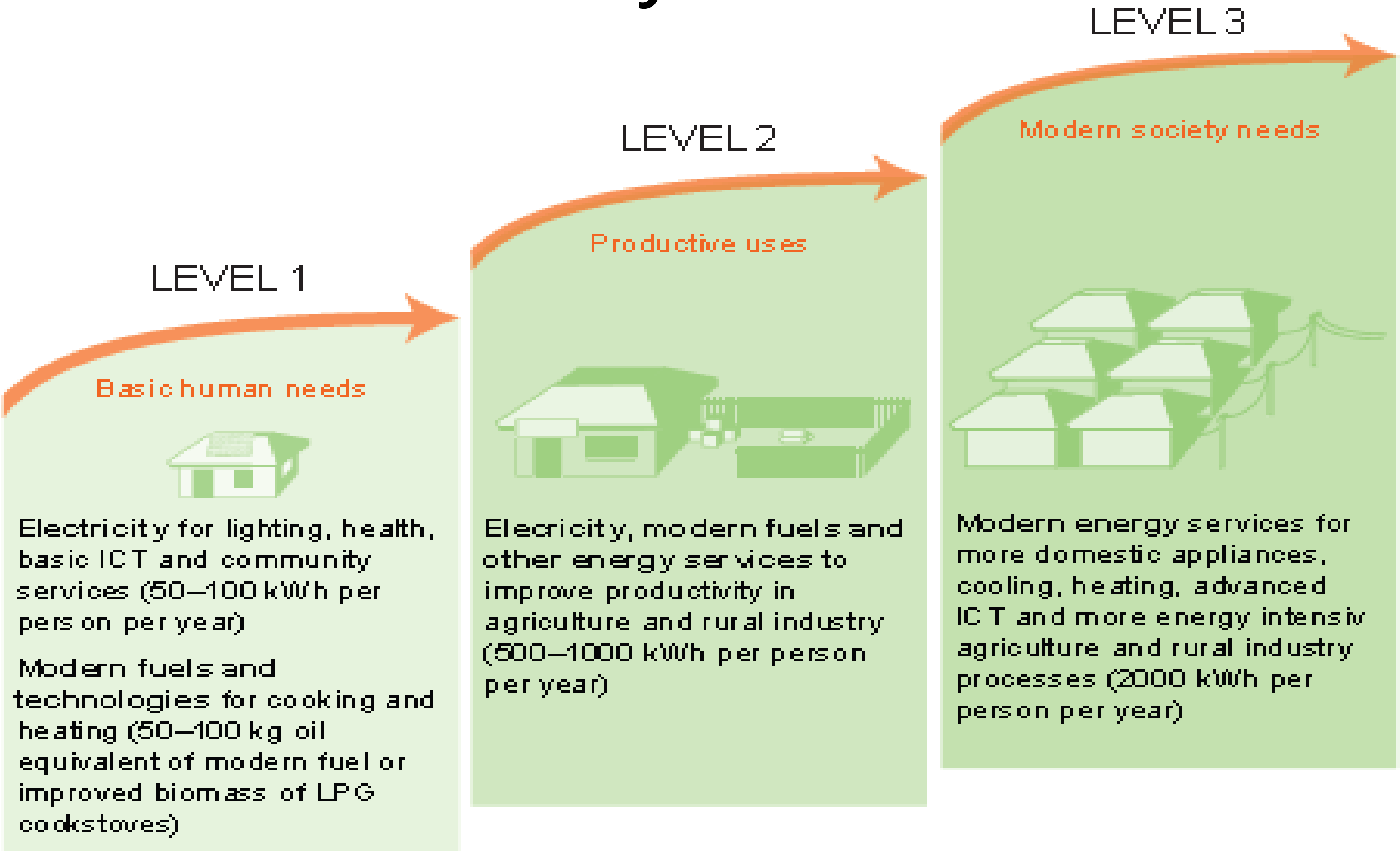


Challenges with PV Deployment

- High upfront costs
- May not be suitable for applications on a largescale (e.g. machines for industrial manufacturing processes), because of the high costs
  - Especially in emerging economies with limited purchasing power and a lack of suitable financial products
- Business models play an important role in all cases.
- Development of a business model is not a simple task but often requires long preparation time and a lot of devotion to details.
- Business models evolve over time and there is a lot of creativity required from entrepreneurs to develop suitable packages for PV products

Productive Use of Energy

Levels of Electricity Use



Productive Use Definition

"one that involves the application of energy derived mainly from renewable resources to create goods and/or services either directly or indirectly for the production of income or value.

The production of income or value is understood to be achieved by selling products or services at greater than their cost of production, resulting in an increase in the net income of the enterprise or the entrepreneur".

https://energypedia.info/images/5/53/Productive_use_of_pv_bangladesh.pdf

Benefits of PUE with Renewable Energy

- Triple Bottom Line Sustainable Business
- Stronger local economy
- Local impact: Jobs & increased purchase power
- Improved health and sanitation:
  - Stronger socio-economic development
- Contribution to SE4All and SDGs: Environment and climate change

Energy Services	Income Generating Value	Renewable Energy Services
Irrigation	Better yields, higher value crops, greater reliability, growing during periods when the market prices are higher	Wind, PV solar, biomass, micro-hydro
Illumination	Reading, extending operating hours	Wind, PV solar, biomass, micro-hydro, geothermal
Grinding, milling, husking	Create value-added product from raw agricultural commodity	Wind, PV solar, biomass, micro-hydro
Drying, Smoking (Preserving with process heat)	Create value-added product, preserve product to enable selling in higher-value markets	Biomass, solar heat geothermal
Expelling	Produce refined oil from seeds	Biomass, solar heat
Transport	Reaching markets	Biomass (biodiesel)
TV, radio, computer, internet , telephone	Entertainment businesses, education, access to market news, coordination with suppliers and distributors.	Wind, PV solar, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end-users (phone charging business)	Wind, PV solar, biomass, micro-hydro, geothermal
Refrigeration	Selling cooled products, increasing the durability of the products	Wind, PV solar, biomass, micro-hydro

Economic and social benefits of PUE

Rural electrification projects with a productive use component are more likely to achieve economic development and sustainability:

- Obtaining financing for Renewable Energy Technologies (RET) may be easier as rural financing agencies might be more willing to provide lending to households that use the provided energy to increase their income.

- As people's incomes rise through the productive use of energy, their demand for energy services is likely to rise too. This creates attractive market conditions for RET dealers and vendors

How to support productive use of electricity?

The provision of electricity alone does not necessarily lead to its productive application
The most important preconditions for productive applications of electric energy in developing countries:

- **Knowledge and skill** by small and micro-business, households and farmers on how to use new-found electrical and motive power for profitable enterprise.
- **Technical and financial management** capacity of small and micro-business, house-holds and farmers, including availability of credit and micro-credit to finance productive tools and equipment.

Where one or several of these factors are nonexistent, productive use of electricity may be hampered significantly.

How to support productive use of electricity?

- **A policy and institutional environment** conducive to business development, willingness to promote decentralized services, etc.
- **Access to markets** for additional or new products produced or services offered as a result of new electrical, heat or motive power
- Availability of a minimum of other complementary **infrastructure services**, such as transport, water supply and ICT services.

Where one or several of these factors are nonexistent, productive use of electricity may be hampered significantly.

Case Studies and Examples

Case Study: Phaesun GmbH Horn Renewables
Business Opportunities with Solar Systems in Somaliland

Project description

- Solar mobile phone charging stations were developed and set-up in different locations in Somaliland.
- LED lamps with integrated battery (lithium lamps) were rented to be charged again at the charging station.
  - lighting in private households,
  - illumination of salt fields in coastal communities, (where people usually after sundown)
- Solar cooling and freezing kits based on the solar fridge Steca PF 166 were introduced.
  - In 2013, shop and kiosk owners bought refrigeration kits to improve their businesses.
- Refrigeration kits also introduced for fishermen to produce ice to cool their fish and subsequently transport them in cooling boxes to the cities.
  - Fishermen achieved higher margins because they were now able to sell fresh fish in the cities

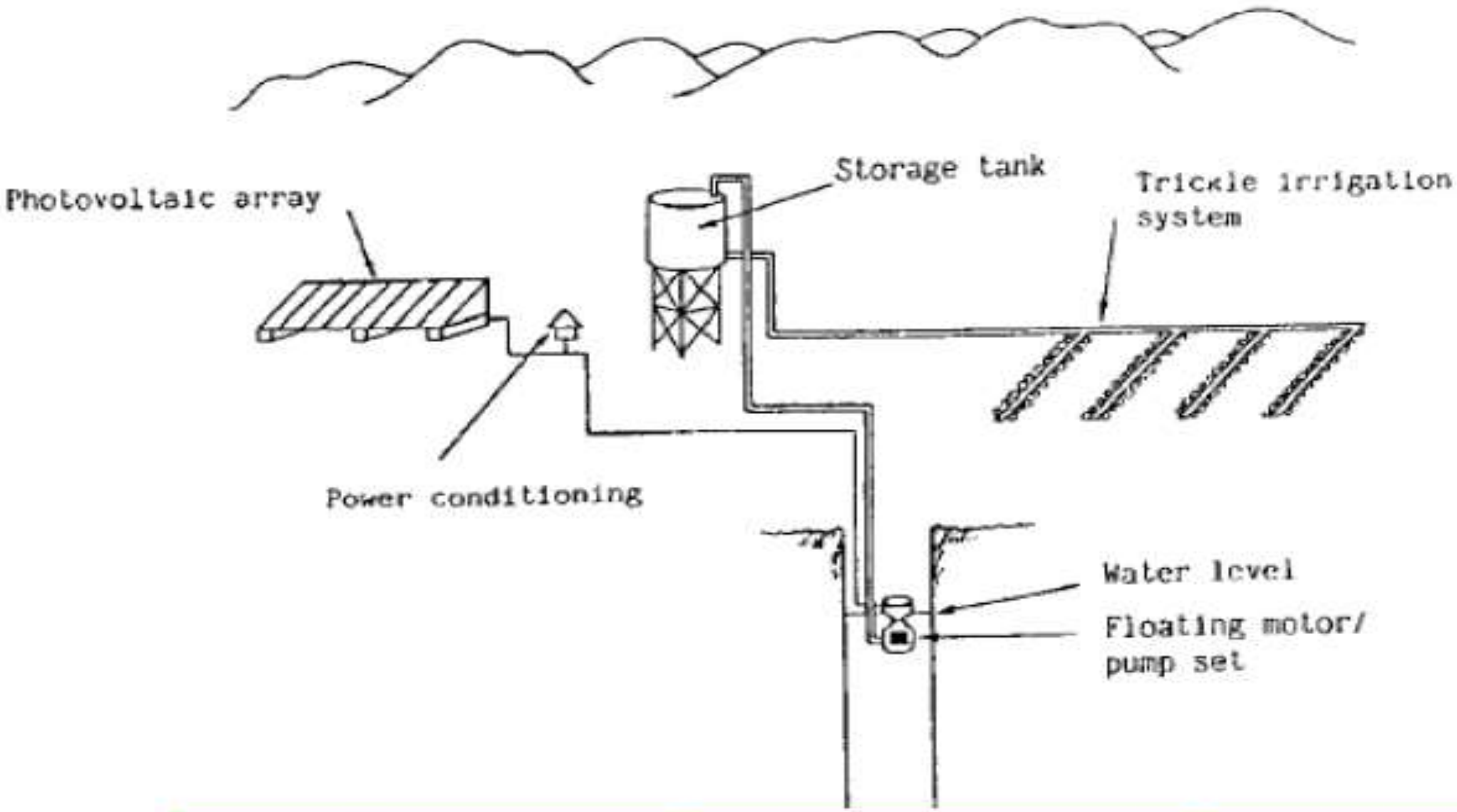
Milk cooling tank in Fukeni (Tanzania)

Keeping fresh longer, or increasing quality on diary production.

Vaccine refrigerators are available as DC or AC versions.

Very important to have a well functioning cooling chain.

Solar irrigation



Distribution method	Typical application efficiency	Typical head	Suitability for use With solar pumps
Open Channels	50-60%	0.5-1m	Yes
Sprinkler	70%	10-20m	No
Trickle/drip	85%	1-2m	Yes
Flood	40-50%	0.5m	No

Small wind turbine construction

Assembly and balancing






Rural settlement in Handew

Electrification of a local shop

Rural settlement in Handew

Electrification of a local shop

The grid in rural areas

- Power cuts for 1 or 2 hours per day
- Lack of appropriate transformers
- Electrification only of major towns

Off-grid electrification system

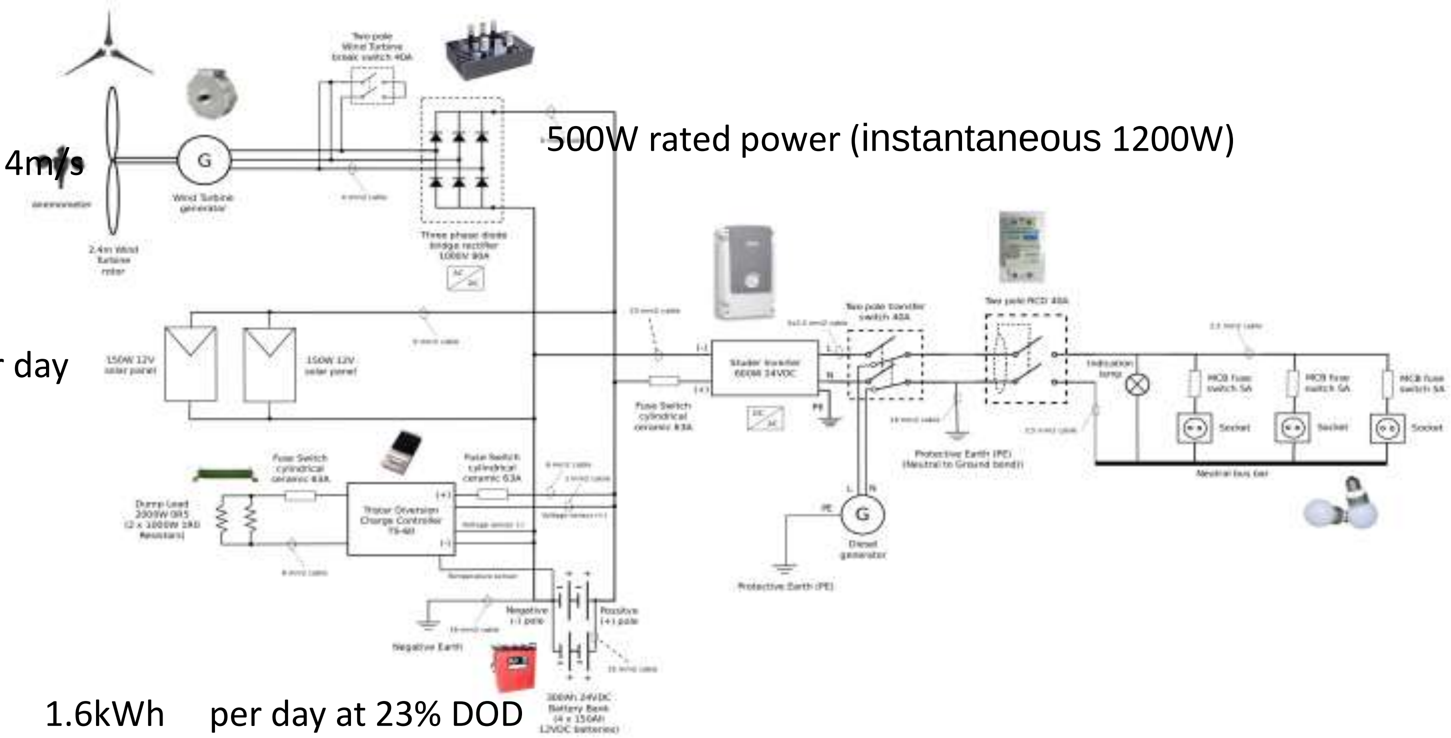
System loads and electrical diagram

Load Type	Equipment Rating (W)	Number of Equipment	Running Time(Hrs/day)	Daily Energy (KWh)
Lighting (CFL)	11	3	5	165
Mobile charging station	3	15	17	765
Refrigerator	70	1	8	560
Radio	18	1	8	144
TOTAL				**1.634**

2.3kWh per day at 4m/s

500W rated power (instantaneous 1200W)

1.3kWh per day



1.6kWh per day at 23% DOD

Jijiga - Jan 2015

Small wind turbine

Preparation for erection





Small wind turbine

3m rotor diameter at 12m hub height

Photovoltaic panels

2 x 150W polycrystalline panels 24VDC



Installation of off-grid system

Batteries, diversion load charge controller, inverter, data logger




Case Study: Neu-Ulm University of Applied Sciences (HNU) Applied Entrepreneurship Education Programme (AEEP), Ethiopia

Project description

The project focuses on entrepreneurial education with the objective to create job opportunities. Micro entrepreneurs were trained to build and maintain prototypes for diverse kind of businesses such as for productive use of energy businesses.

8 Business Opportunities with Solar Systems (BOSS) models were developed and constructed

1) barber shop,
2) cafeteria,
3) charging station and
4) ice cream shop were developed
5) mobile city photography shop
6) ICT training center
7) rural mobile photograph

Project financing and costs

Funded by German Federal Ministry of Cooperation and Development. The program has a financial revolving mechanism. Micro entrepreneurs get materials for building the prototypes and are obligated to pay back all costs including a small extra fee within 2 years to the Arba Minch University, so the university can refinance the program with the repayments.

Case Studies

- 2 more needed (4 in total) for Reporting
- Need to get more information on specific costs and implementation plans
- Which are suitable in Malawi?
- Which are suitable in specific CBOs?
- Ideally have some feasibility studies with implementation strategies.
- Need to get Load Profiles

Example Energy Consumption (Small and Micro Enterprises)

Customer Type		Total Consumption (kWh/day)	Total Consumption per customer (kWh/day)
Retail & repair shops	64	82.96	1.30
Grain Mills	3	72.28	24.09
Petrol stations and welding garages	7	43.53	6.22
Bars, lodgings and hotels	5	39.43	7.89
Carpentry workshops	2	18.07	9.04
Small tea/ food café	20	9.86	0.49
(sub)total	101	266.13	

Example Energy Consumption (Appliances)

ENERGY USE (HOUSEHOLD-LEVEL)

Sources: energyusecalculator.com and nvenergy.com

Appliance	Average energy use (kWh/day)
CFL lightbulab	0.07
Incandescent lightbulb	0.3
22" LCD/LED Display	0.15
CRT display monitor	0.38
Desktop computer	0.60
Laptop	0.36
Wi-Fi router	0.14
Printer	0.01
Cell phone charger	0.01
Electric furnace (central heating system)	36
Space heater	7.5
Water heater	12
Central air conditioner	10.5
Air conditioner	3
Washing machine	0.75
Clothes dryer	3
Electric cooking stove top	3
Oven	2.4
Dishwasher	1.8
Freezer (stand-alone)	4.8
Refrigerator	4.32
Coffee maker	0.26
Microwave	0.6
Electric iron	0.28
Sewing machine	0.075
Vacuum	0.35
Ceiling fan	0.22

Supply Options and Costs

ELECTRICITY SUPPLY OPTIONS TO GENERATE 5 KWH/DAY

Sources: Based on USAID n.d. and Practical Action (2013)

Technology	System size	Capital (US$)	Operating cost (US$/year)
Solar PV system with batteries	1,200 W panels 20 kWh batteries	$12,000 system $2,000 batteries	$500
Wind turbine with batteries	1,750 W turbine 20 kWh batteries	$10,000 system $2,000 batteries	$600
Diesel engine generator	2.5 kW	$2,000	$1,400
Hybrid system	1,200 W panels 10 kWh batteries 500 W engine	$12,000 system $1,000 batteries $500 generator	$450
Grid extension	n/a	$10,000+ per mile	$200

Market Research for PUSPV

Productive Use Survey

Household Survey

For the following services, how willing would you be to pay for the following services?

Extremely	Very	Somewhat	Not very	Not at all
5	4	3	2	1

Business Survey

Make it clear we not offering any funding for new businesses

How successful do you think the following businesses would be if established in this area? By successful we mean profitable.

Extremely	Very	Somewhat	Not very	Not at all
5	4	3	2	1

PU Survey Options

Battery charging

Tailoring - Electric sewing machines,

Dressmaking

Cold drinks refrigeration (coke, beer)

Agricultural Refrigeration (Fish, meat, milk)

Entertainment – TV and Music

Mobile phone charging

Barbershop

Electronic Repair

Electric Fencing

Maize Mill

Water pumping for irrigation

Water pumping for potable water

Chicken incubation

Internet café and IT services

Printing services (photo printing, photocopying, document printing)

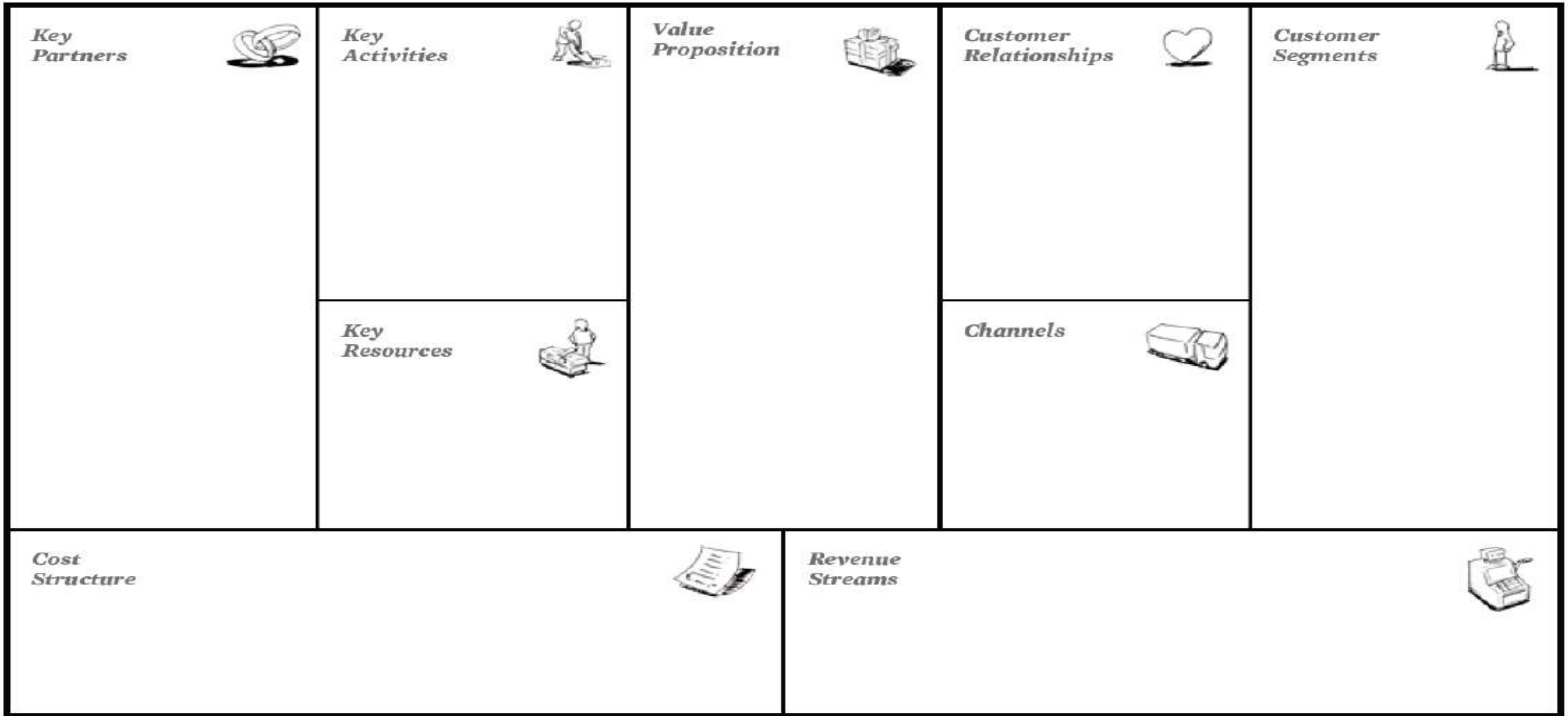
Wood workshop (Carpentry, furniture making)

Metal Workshop (grinding, drilling, welding, locksmith, blacksmith)

Shop lighting

Other (please specify)

Business Model Canvas



Key recommendations for PURE:

- **Raise awareness for PURE, which is the least cost option over its life cycle**, through communication campaigns, with a particular focus on the return on investment generated by renewable energy installations based on sustainable business models;

- **Facilitate access to finance for small and medium-scale PURE project**s – which could be replicated and scaled up – by increasing the overall budgets available for this and in particular for upfront investments, allowing small ticket sizes and stimulating the bundling of projects where appropriate, also taking the gender bias into account;

- Stimulate clean rural electrification through PURE projects in particular with a **clear, efficient and supportive policy and regulatory framework**; behavioural change requires at least a level playing field for RETs and is further facilitated if incentives are more attractive;

- **Facilitate private sector investment** in small and medium-scale PURE projects, by helping to reduce the (perceived) risks on the regulatory, technological, political and market development level, as well as by taking part in financing e.g. through grants and soft loans;

Key recommendations:

• Support local **capacity building** and training, especially to start and run a business, as well as to work with the renewable energy installation;

• Highlight the importance of **sharing experience and best practices** both on the political-institutional and the industry level, and work with established sector partners and stakeholders;

• **Engage with the local community** and NGOs when developing programmes targeting the spread of PURE to better understand and support local needs and increase local acceptance, whilst integrating the feedback into a holistic approach to stimulate local economic development;

• Consider a more systematic and **market-near approach** by facilitating the understanding of the local energy market and its outlook for potential market participants, and avoiding the distribution of energy systems without any reciprocal commitment in order to focus on quality and cost-effective renewable energy solutions.

Further Reading

Productive Use of Energy – PRODUSE
A Manual for Electrification Practitioners

euei pdf
energy for development

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

The Productive Use of Renewable Energy in Africa

Africa-EU Energy Partnership

Innovative Business Models and
Financing Mechanisms for
PV Deployment in Emerging Regions

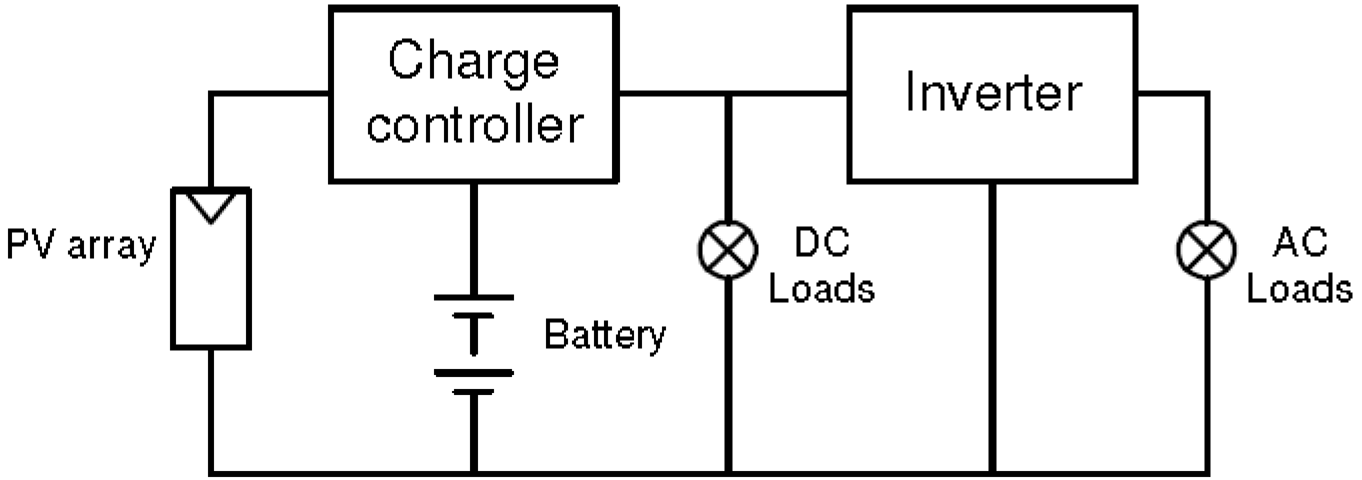
PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T9-14:2014

System Design

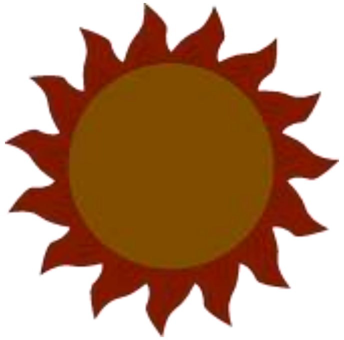
System Diagram

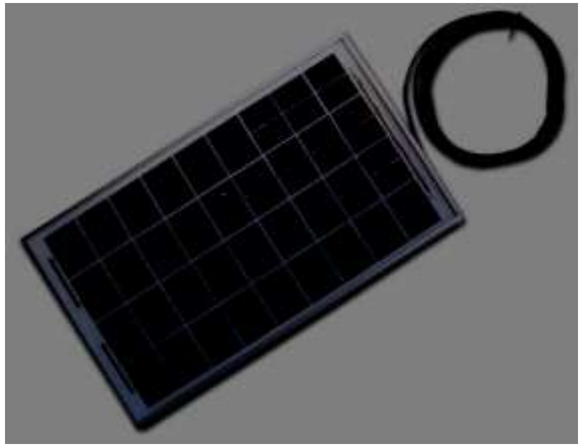
System with inverter



- Wider choice of loads
- Inverter standing losses and inefficiency
- Motor starting problems
- Increased cost

Elements of a Standalone System





PV Array

Charge Controller

Inverter

Battery

DC Loads

AC Appliances

Sizing a standalone PV system

Energy supply >= Energy demand

Worst month peak sun hours x array power >= Power of each load x the number of hours it's used

Sizing a standalone PV system

Energy supply >= Energy demand

Worst month peak sun hours x array power x ? >= Power of each load x the number of hours it's used

1. Are the batteries 100% efficient?
2. Are the PV's operating at their maximum power point?
3. What do we do if this year's "worst month" is worse than the average published "worse month"

Sizing a standalone PV system

Energy supply >= Energy demand

Worst month peak sun hours x array power × ? >= Power of each load x the number of hours it's used

1. batteries 100% efficient?
2. PV's operating at their maximum power point?
3. What do we do if this year's "worst month" is worse than the average published "worse month"

1. 80%
2. 80% - different for mppt controllers
3. 80% to 100%

Total .64 to .51

It's not an ideal world.
We need to add some system inefficiencies

$$DailyUsefulEnergy(Wh) = PeakSunHours \times P_{peak} \times \zeta_{BAT} \times PR$$

$$P_{peak} = \frac{DailyUsefulEnergy}{PeakSunHours \times \zeta_{BAT} \times PR}$$

Sizing the array.

The array is sized by ensuring that the useful energy generated each day of the design month matches the energy required. Allowance has to be made for inefficiencies of the battery and the mismatch between the battery charging voltage, called the "performance ratio".

Assessing System Loads

Load	No (1)	Power (2)	Time Hours (3)	AC/DC	Inverter Loss (4)	Energy (Wh) (1x2x3x4)
Lights	4	12	4	DC	1	192
Hoover	1	500	0.5	AC	1.2	300
Total						492

Inverter Loss

Load	No (1)	Power (2)	AC/DC	Inverter Loss (3)	Power (W) (1x2x3)
Lights	4	12	DC	1	48
Hoover	1	500	AC	1.2	600
Total					648
System Voltage	12	Maximum Battery Current (Max Power/System Volts)			54 Amps

Resource Data

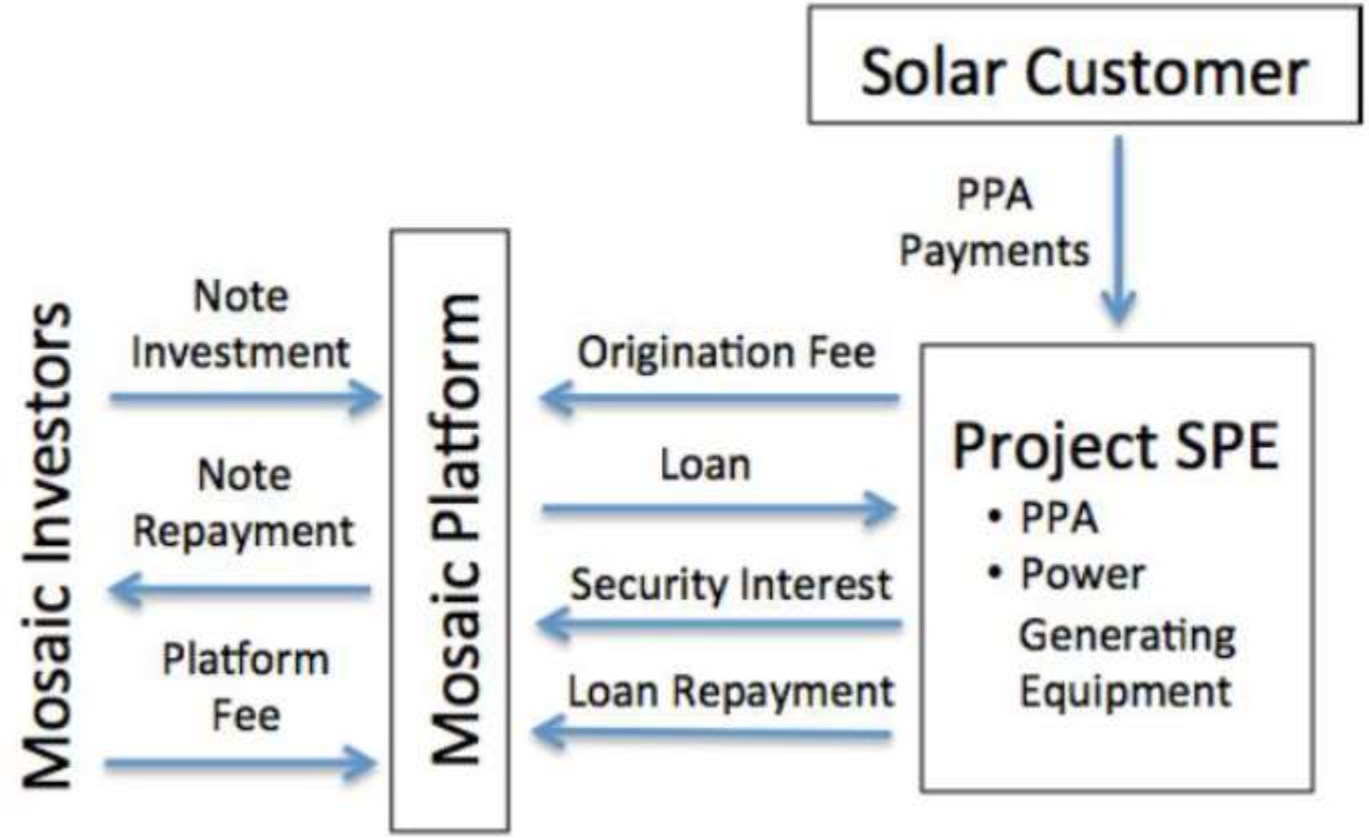
Irradiance data at a tilt angle to optimise the energy capture during the worst case or "design month" is required. This is most easily obtained from the internet. A recommended web site is for Europe and Africa is: http://re.jrc.ec.europa.eu/pvgis.

Financing PUSPV – Case Study: Mosaic

online solar marketplace connecting investors with solar projects in need of financing
Interested people can create an account which allows them to browse through a list of investment projects
Once the projects are operational and generate revenues the investors are being paid back their capital over a certain period plus interest.
Interests achieved are in the range of 4.5 to 6.5% annually.
The minimum investment is US$25.
The project sizes range from less than 50kW to more than 1MW.
The information on the webpage informs about the interest people can get and the term of investment.
Currently only for projects in USA but could be a good option for Malawi

"people enjoy that they can invest in projects that they can see, which is giving them a good feeling to have invested their money in something useful and environmentally friendly. If they want, they can even visit the locations. Many investors are excited about the transparency, tangibility and social and environmental impact."

Financing PUSPV – Case Study: Mosaic



joinmosaic.com