Distributed and Renewable Energy for the Developing World, **Photovoltaics for a Billion Poor**

Greg P. Smestad, Ph.D.

IEEE Santa Clara Valley Photovoltaic Joint Society

Palo Alto Research Center

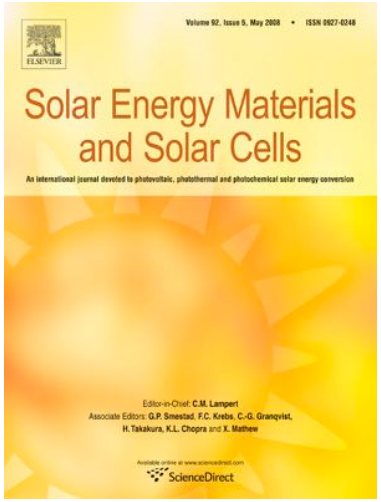
(G.E. Pake Auditorium)

January 15, 2015

Greg P. Smestad, Ph.D.

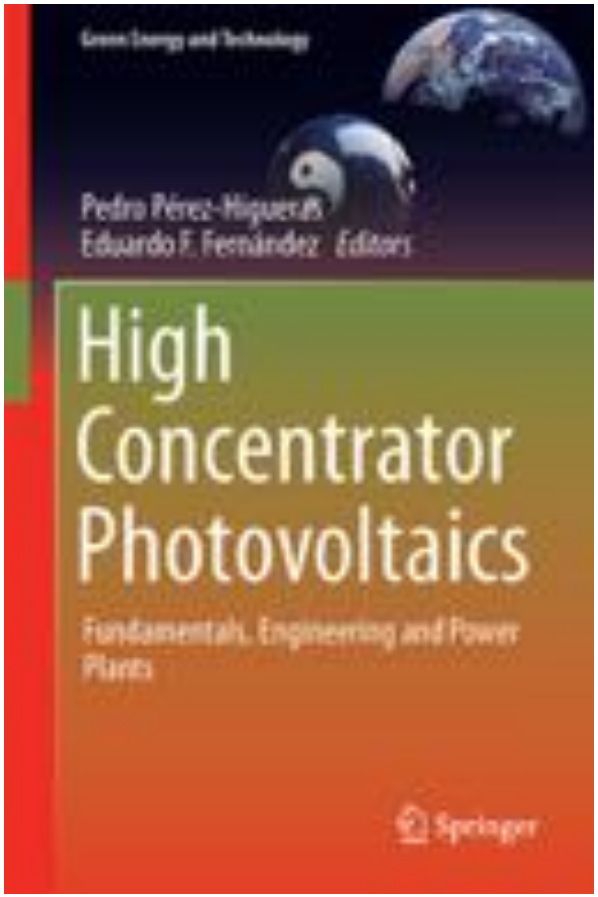
Sol Ideas Technology Development
Solar Energy Materials and Solar Cells
Instructor/Lecturer at SCU

www.solideas.com



Communicate with Prof. Smestad via the web site above or via gsmestad@scu.edu

Current Work (emphasis)



High Concentrator Photovoltaics Fundamentals, Engineering and Power Plants

Series: Green Energy and Technology

Pérez-Higueras, Pedro, Fernández, Eduardo F. (Eds.)

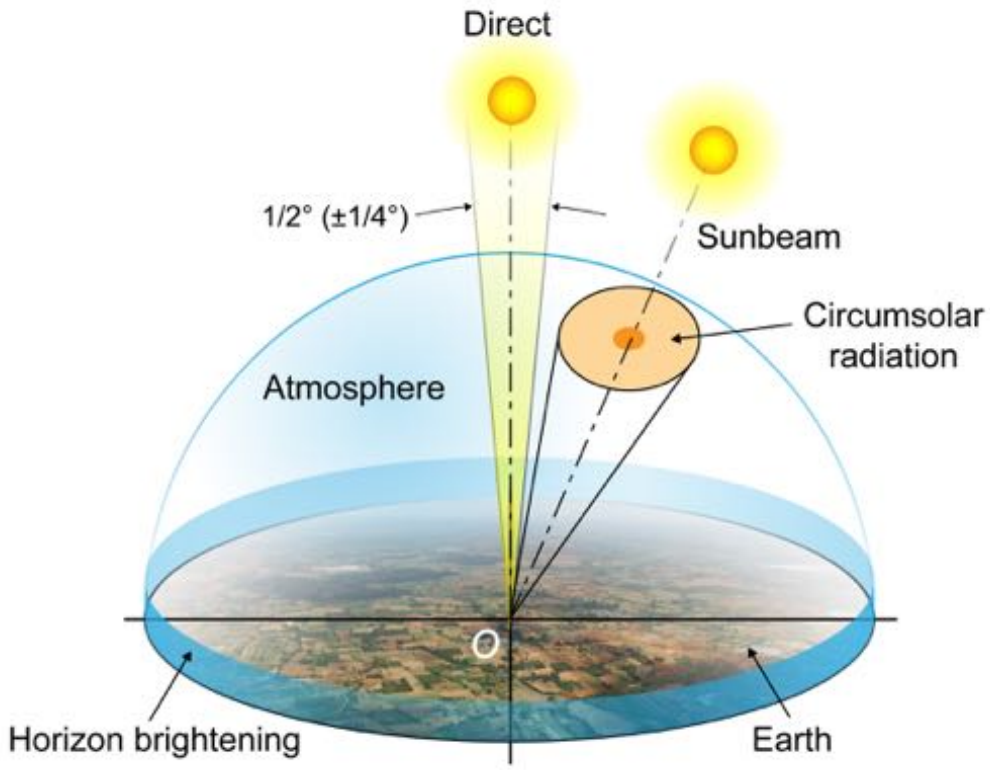
2015, 350 p. 130 illus.

ISBN 978-3-319-15038-3

Release Due: August 7, 2015

http://www.springer.com/energy/renewable+and+green+energy/book/978-3-319-15038-3

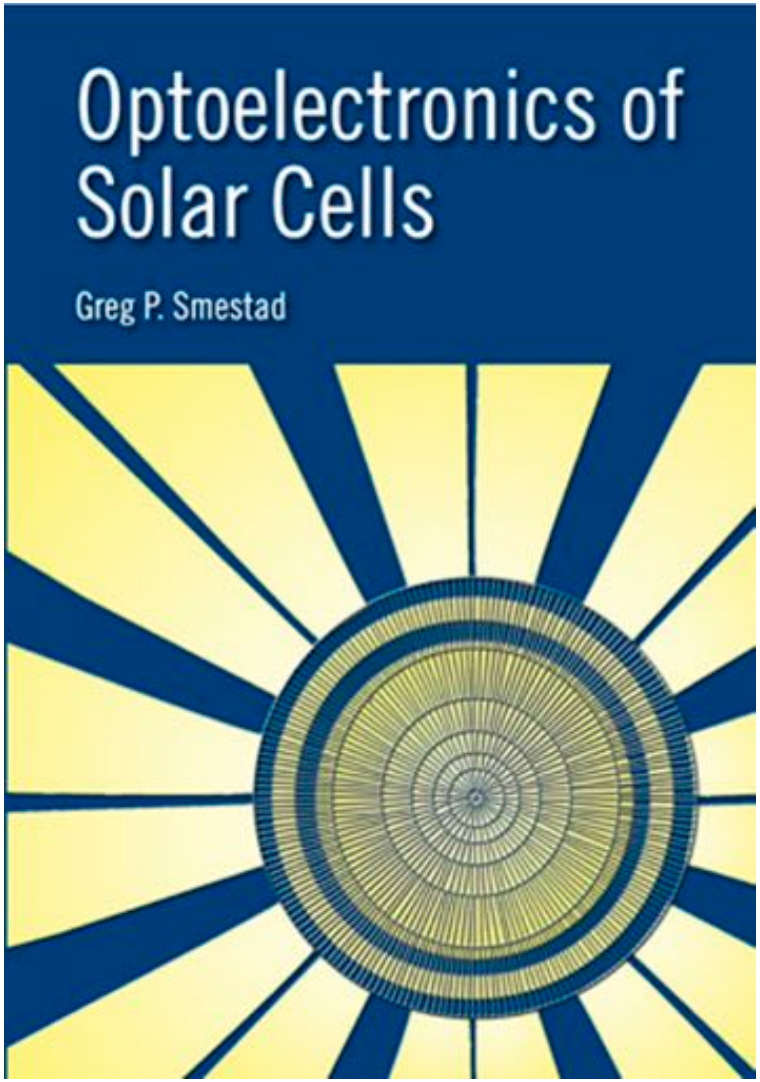
Acceptance Angles for Sensors and Concentrators



Graphic: **Alfred Hicks (NREL)**

Pyrheliometer, theta = 5 degrees

Prior Work



Optoelectronics of Solar Cells
SPIE Monograph PM115,
by Greg P. Smestad
ISBN 0-8194-4440-5
118 pages; Pub. July 2002;
Softcover;
www.solideas.com/
SolarCellBook.html

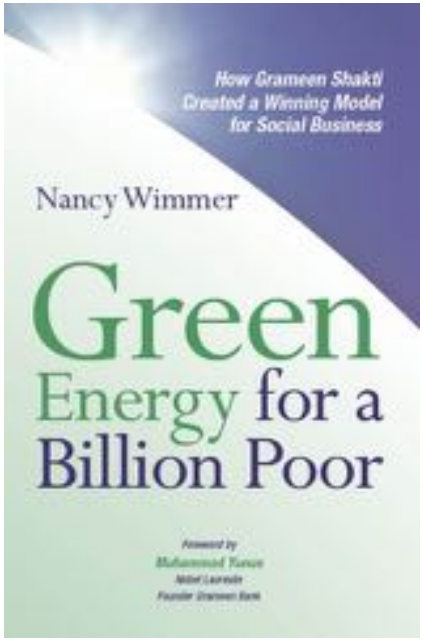
Outline

- Background
- Motivation
- Sources
- Least Developed Nations
- Bangladesh
- Grameen Shakti
  - Technical and Non-Technical approach

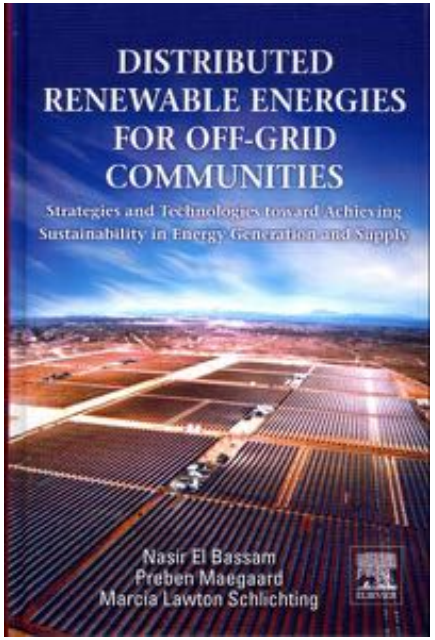
- Conclusion - Understand the context of several case studies and projects, based on strategies being employed within the developing world.

- **What is our motivation?**
- **Where are the markets?**
- **What tools can we use?**

Courtesy: Paola de Cecco



Nancy Wimmer



Nasir El Bassam et al

- **Other Resources:**

http://energymap-scu.org is an interactive web site with many case studies and general information about the energy technologies and relevant business models. There are resources, an interactive world map, profiles and insights.

http://www.solideas.com/bio/TeachingExperienceSCU.html

http://energymap-scu.org/

www.scu.edu/socialbenefit/entrepreneurship/energy/

Internationales Forschungszentrum für Erneuerbare Energien Deutschland (*IFEED*)
International Research Center for Renewable Energy

Prof. Dr. N. El Bassam

IFEED e.V. Fabrikstraße 6, D-38159 Vechelde-Wierthe, Germany
www.ifeed.org/
info@ifeed.org
International Secretary:
m.schlichting@ifeed.org

SolarforPeace

1. S4P uses PV and electrical engineering experts that are familiar with industrial methods.
2. S4P is agnostic to religion, ethnicity, nationality; there is no motive beyond enabling PV.
3. They work with country experts not just ex-pats.
4. PV modules are not grade “A” in appearance; they are grade “A” TÜV Rheinland approved for longevity and performance…

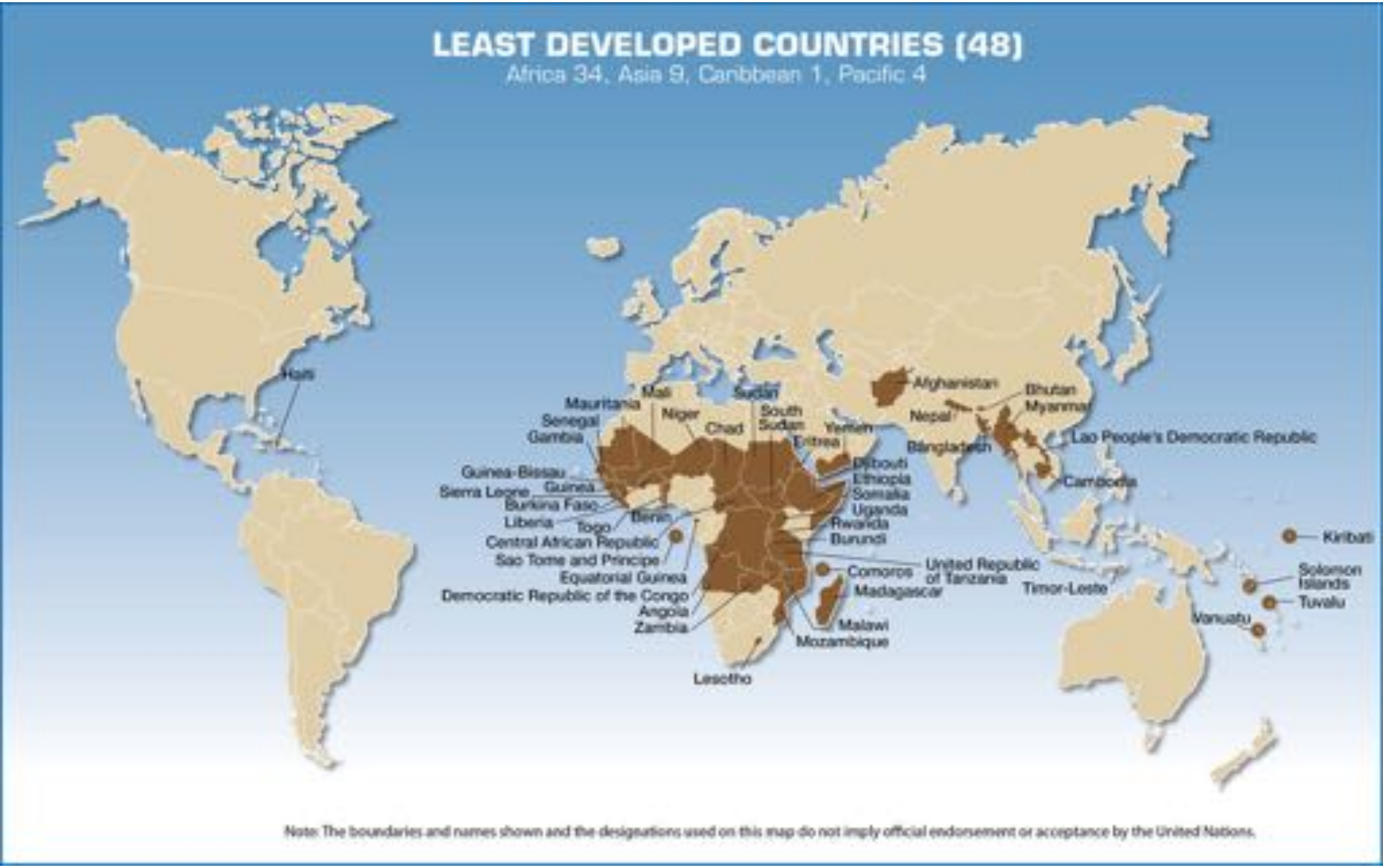
5. info@solarforpeace.org
6. Matthias R. Heinze

Solar for peace

- **The Vatican City received first solar power plant in 2008.**
- **2394 PV Modules,**
- **300 MWh/y, reducing 225 t/y CO_2.**

- **Installation of solar panels on the Paul IV conference hall has saved 89.84 tons of oil equivalent.**

Source: Nasir El Bassam et al



http://www.un.org/en/development/desa/policy/cdp/ldc/ldc_list.pdf

	Country	Date of inclusion on the list		Country	Date of inclusion on the list
1	Afghanistan	1971	25	Madagascar	1991
2	Angola	1994	26	Malawi	1971
3	Bangladesh	1975	27	Mali	1971
4	Benin	1971	28	Mauritania	1986
5	Bhutan	1971	29	Mozambique	1988
6	Burkina Faso	1971	30	Myanmar	1987
7	Burundi	1971	31	Nepal	1971
8	Cambodia	1991	32	Niger	1971
9	Central African Republic	1975	33	Rwanda	1971
10	Chad	1971	34	Sao Tome and Principe	1982
11	Comoros	1977	35	Senegal	2000
12	Dem. Rep of the Congo	1991	36	Sierra Leone	1982
13	Djibouti	1982	37	Solomon Islands	1991
14	Equatorial Guinea[1]	1982	38	Somalia	1971
15	Eritrea	1994	39	South Sudan	2012
16	Ethiopia	1971	40	Sudan	1971
17	Gambia	1975	41	Timor-Leste	2003
18	Guinea	1971	42	Togo	1982
19	Guinea-Bissau	1981	43	Tuvalu	1986
20	Haiti	1971	44	Uganda	1971
21	Kiribati	1986	45	United Rep. of Tanzania	1971
22	Lao People's Dem. Republic	1971	46	Vanuatu[1]	1985
23	Lesotho	1971	47	Yemen	1971
24	Liberia	1990	48	Zambia	1991

http://www.un.org/en/development/desa/policy/cdp/ldc/ldc_list.pdf

List of Landlocked Developing Countries (LLDCs)

Afghanistan
Armenia
Azerbaijan
Bhutan
Bolivia
Botswana
Burkina Faso
Burundi
Central African Republic
Chad
Ethiopia
Kazakhstan
Kyrgyzstan
Lao People's Democratic Republic
Lesotho
Macedonia
Malawi
Mali
Moldova
Mongolia
Nepal
Niger
Paraguay
Rwanda
Swaziland
Tajikistan
Turkmenistan
Uganda
Uzbekistan
Zambia
Zimbabwe

List of Small Island Developing States (SIDS)*

Antigua and Barbuda
Bahamas
Barbados
Cape Verde
Comoros
Dominica
Fiji
Grenada
Jamaica
Kiribati
Maldives
Marshall Islands
Micronesia
Mauritius
Nauru
Palau
Papua New Guinea
São Tomé and Príncipe
Seychelles
Solomon Islands
St Kitts and Nevis
St Lucia
St Vincent and the Grenadines
Timor-Leste
Tonga
Trinidad and Tobago
Tuvalu
Vanuatu

* The UN has never established criteria to determine an official list of SIDS. This unofficial list is used by UNCTAD for analytical purposes only.

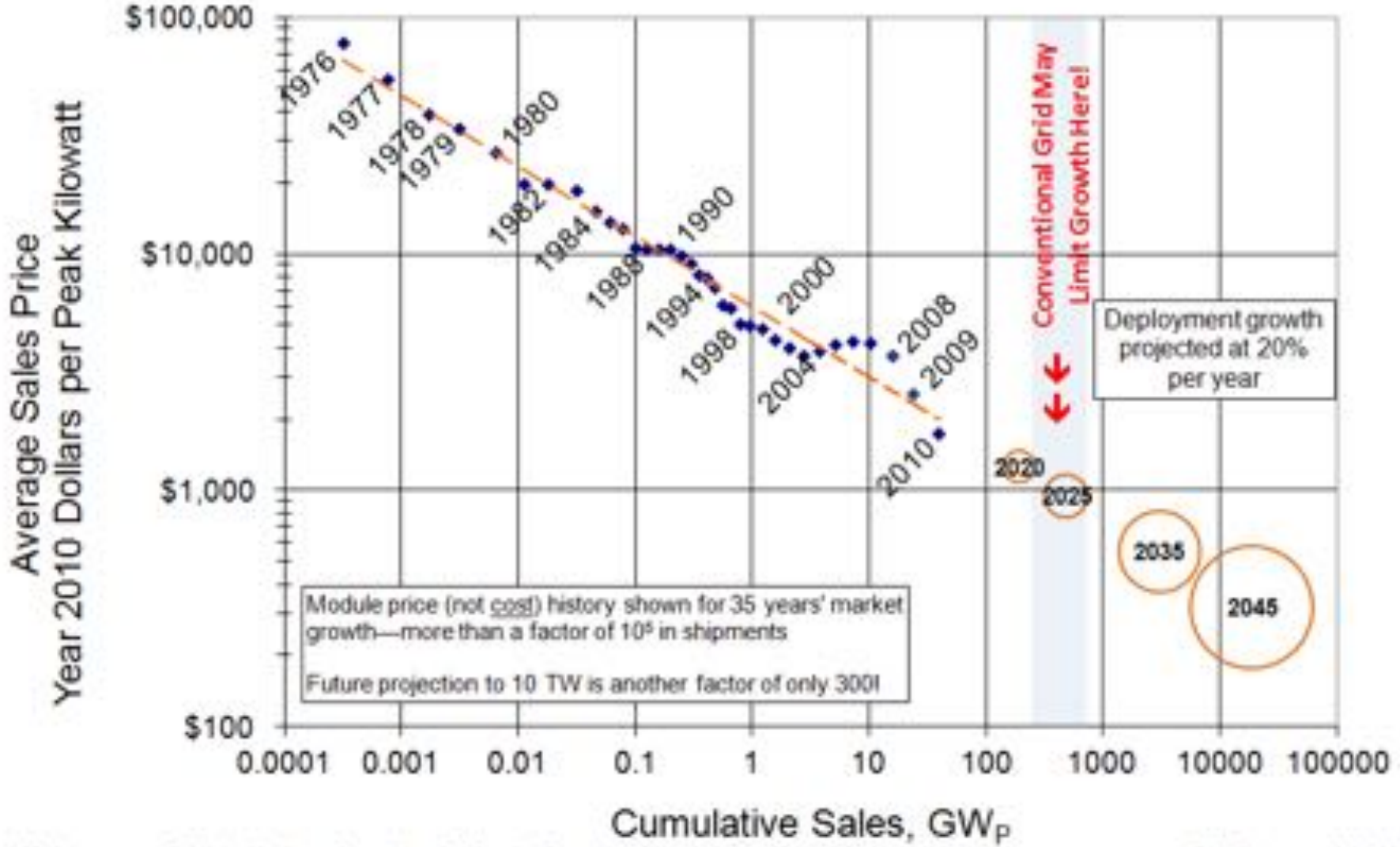
Figure 14.8 - Solar panels power street lights in Fallujah, Iraq.
(U.S Army 2010)
Source: Nasir El Bassam et al

Example of Town Development

- Street Lights
- Qty = 3800
- LED lights for each pole
- equivalent to 60W and at the intersections 90W
- Total Average Power requirement = 68W
- 3800 x 68 W = 2,58 MW Total Power

Courtesy: Attilio Dalvit,
South Africa, MSC ITM, UK, SMSAIEE,
Email: attiliodalvit@gmail.com

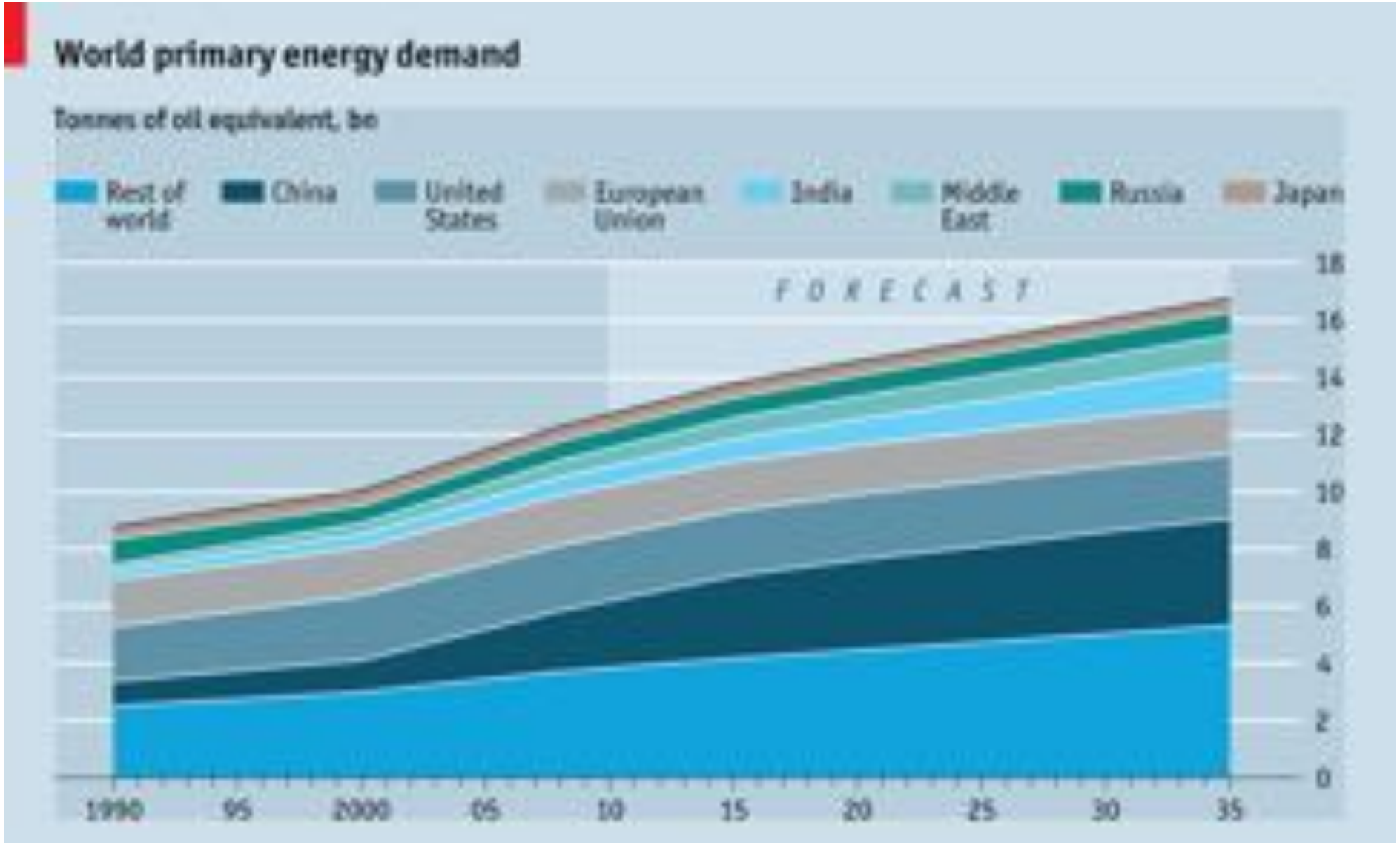
PV Power-Module Global Average Sales Price



ASP data source: P. Mints, Navigant Consulting PV Service Practice

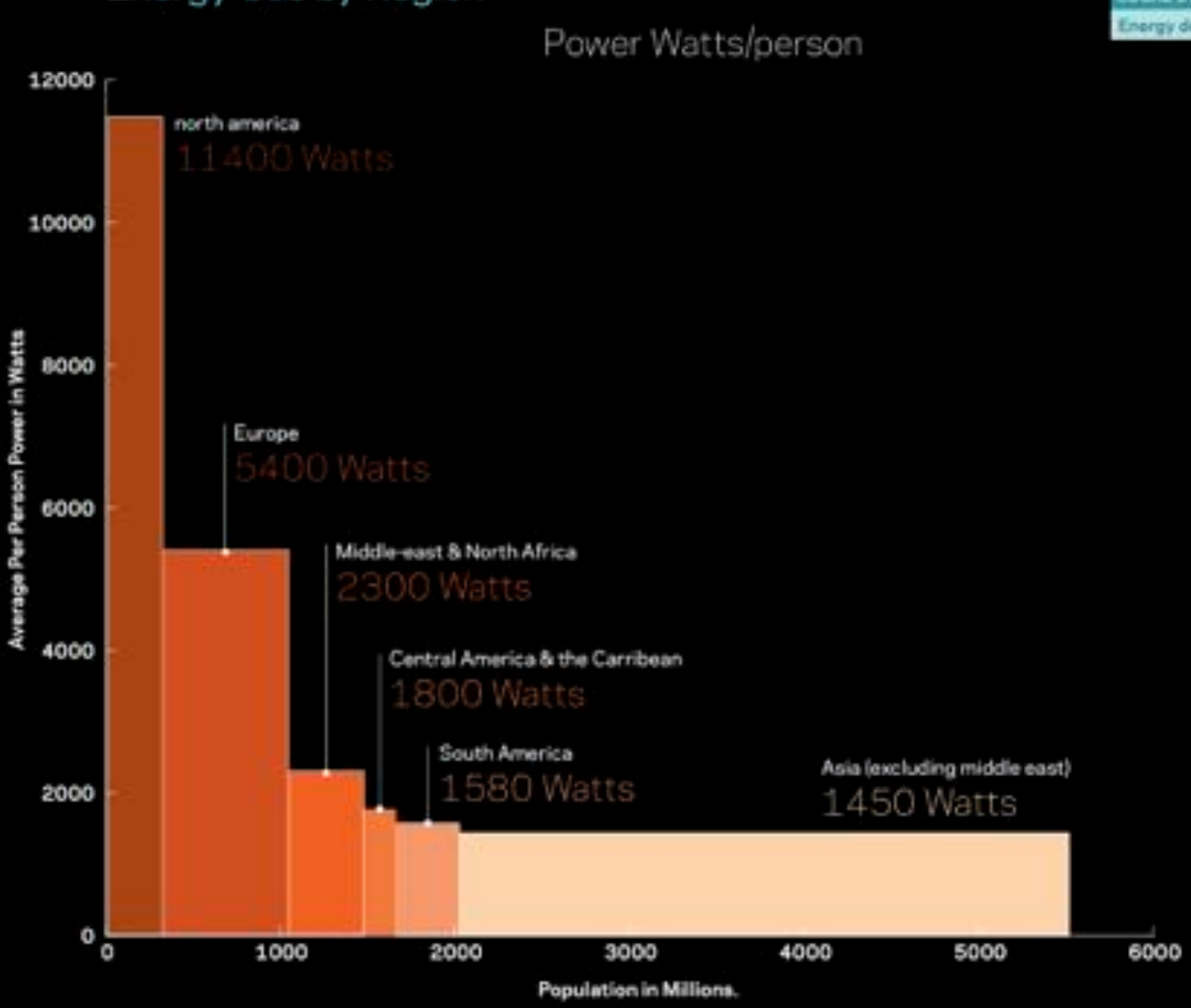
T.M. Peterson 10/28/11

Lighting



http://www.economist.com/blogs/dailychart/2010/11/energy_demand

Energy Use by Region



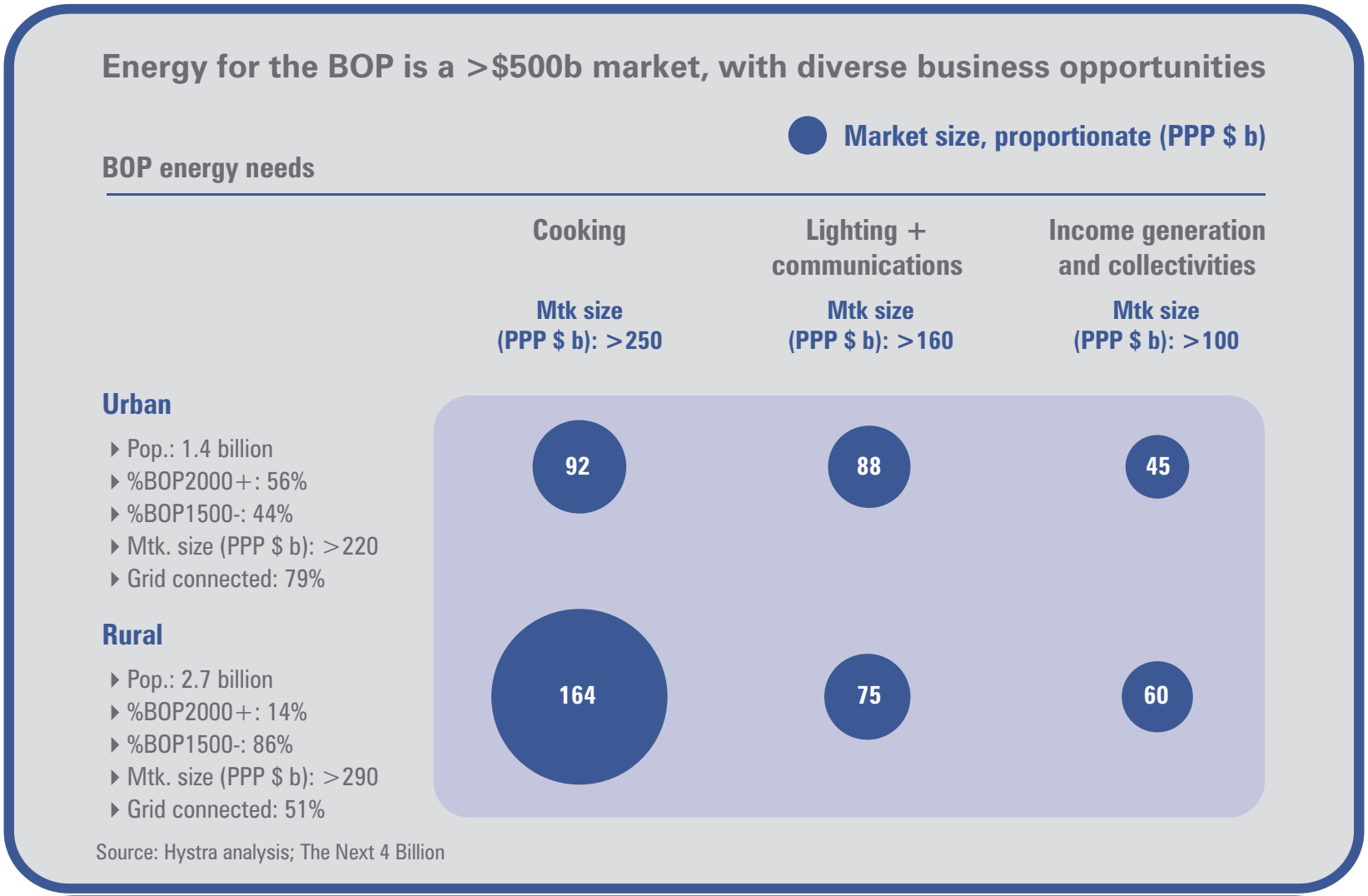
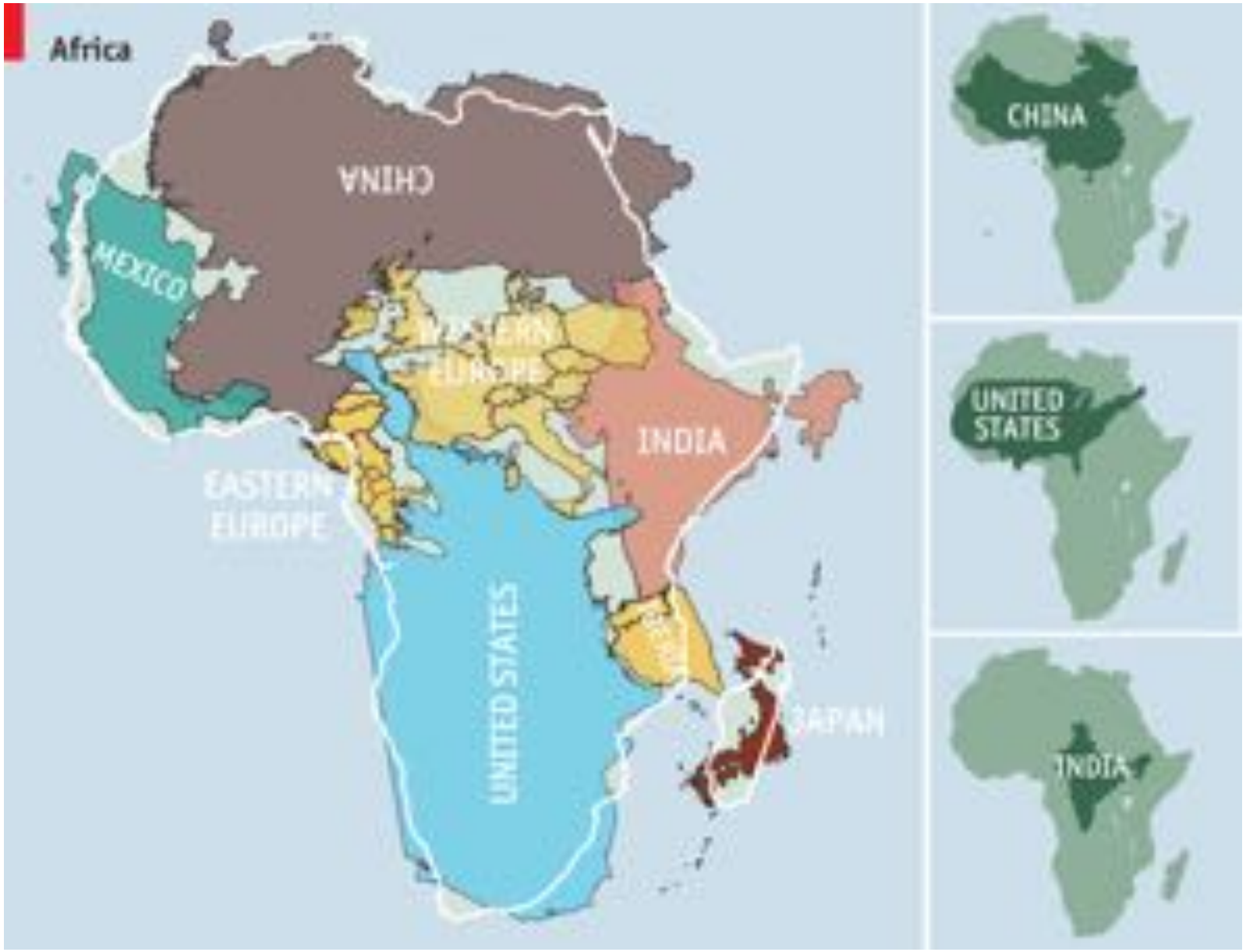


Figure 3 *Energy market for BOP customers*

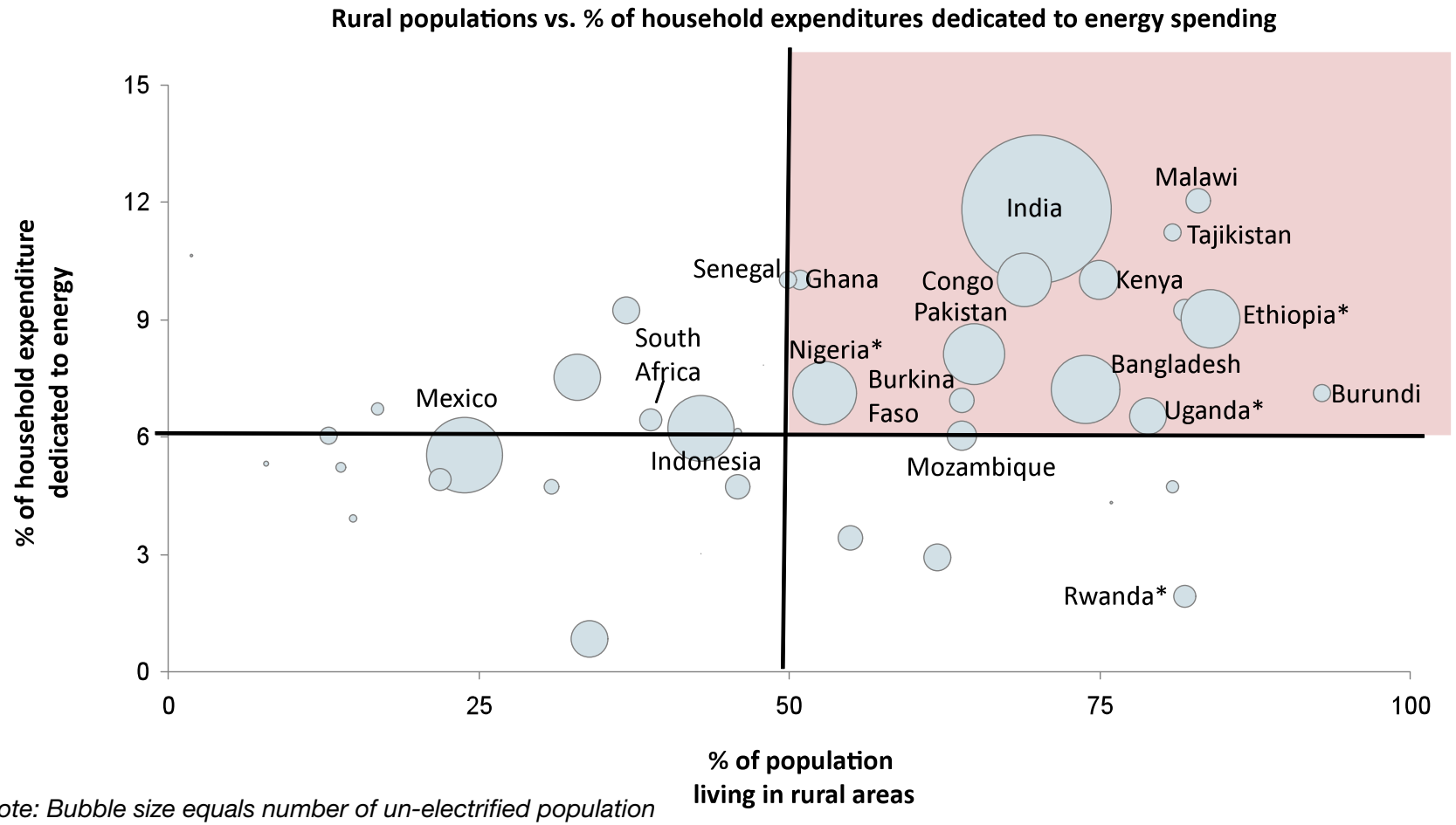
Source: Access to Energy for the Base of the Pyramid. Hystra, 2009.



Source: http://www.economist.com/blogs/dailychart/2010/11/cartography

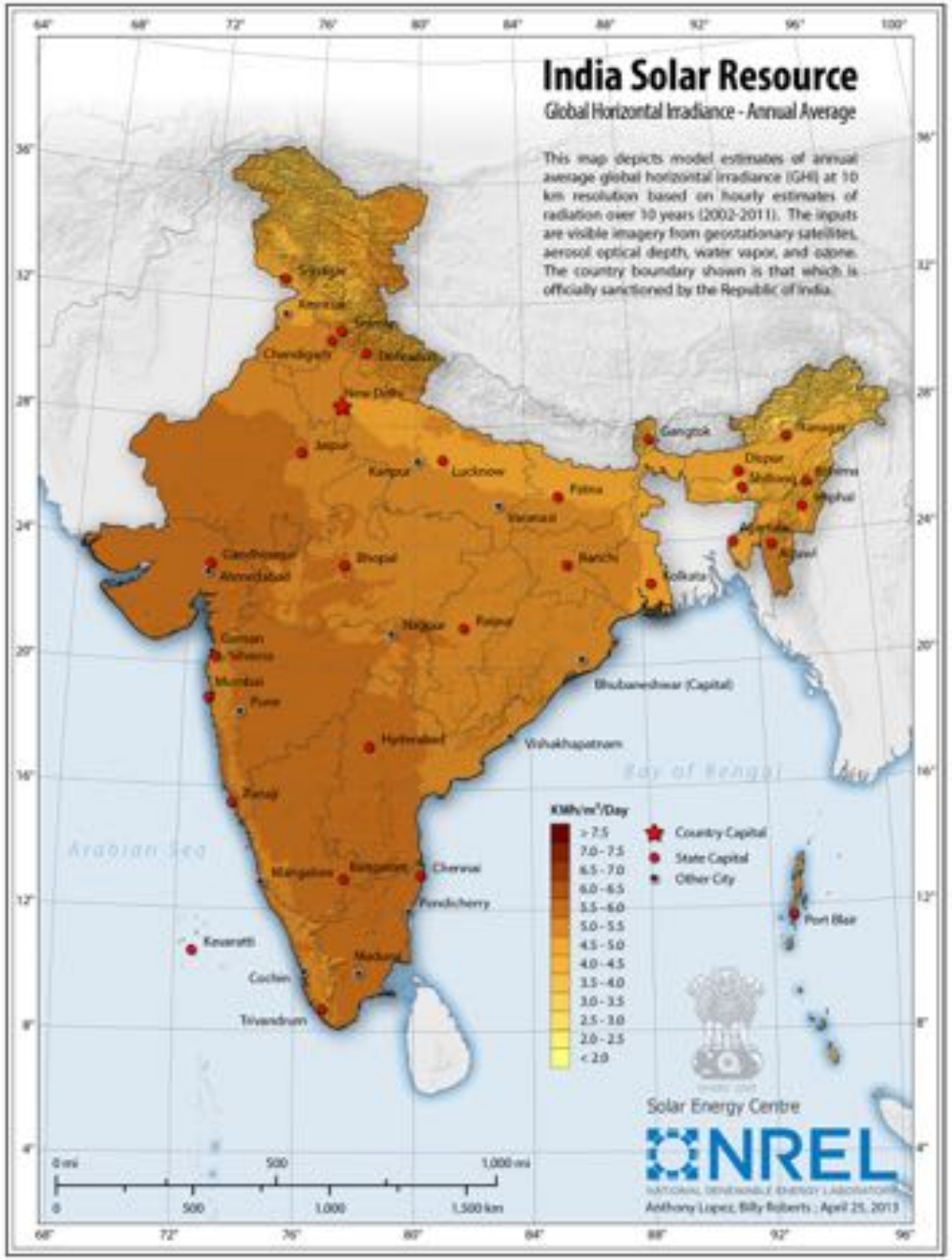
Opportunity

African countries are the priority given high energy spend and large rural off-grid populations



Note: Bubble size equals number of un-electrified population

*Rural vs. Urban mix based on 2003 WB data
Source: World Resources Institute; Dalberg analysis



Solar Resource

Source:
http://www.nrel.gov/international/ra_india.html

Focus in on Bangladesh

Bangladesh

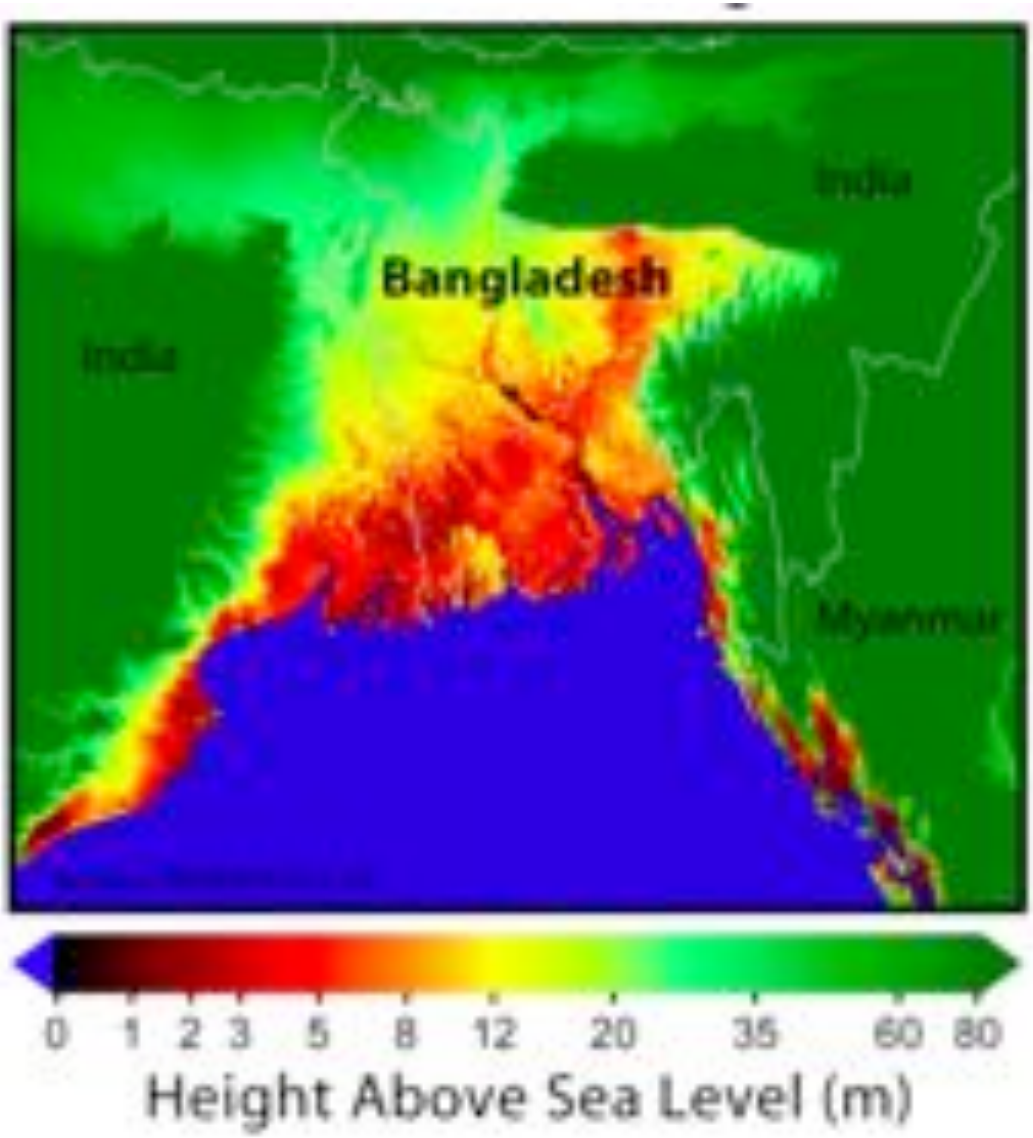
- Approximately 150 million people inhabit Bangladesh, which has a land area of 55,598 square miles, slightly smaller than the size of Iowa.

- This seventh most populous nation is one of the most crowded countries in the world, ranked fifth in population density.

- During the monsoon season from June to October, between 30% and 70% of the country is under water due to flooding of rivers.

Source: travel.state.gov/travel/cis_pa_tw/cis/cis_1011.html

Waterways



http://www.globalwarmingart.com/wiki/Sea_Level_Rise_Maps_Gallery

Rural Environment

farmers
fishermen
merchants
craftsmen

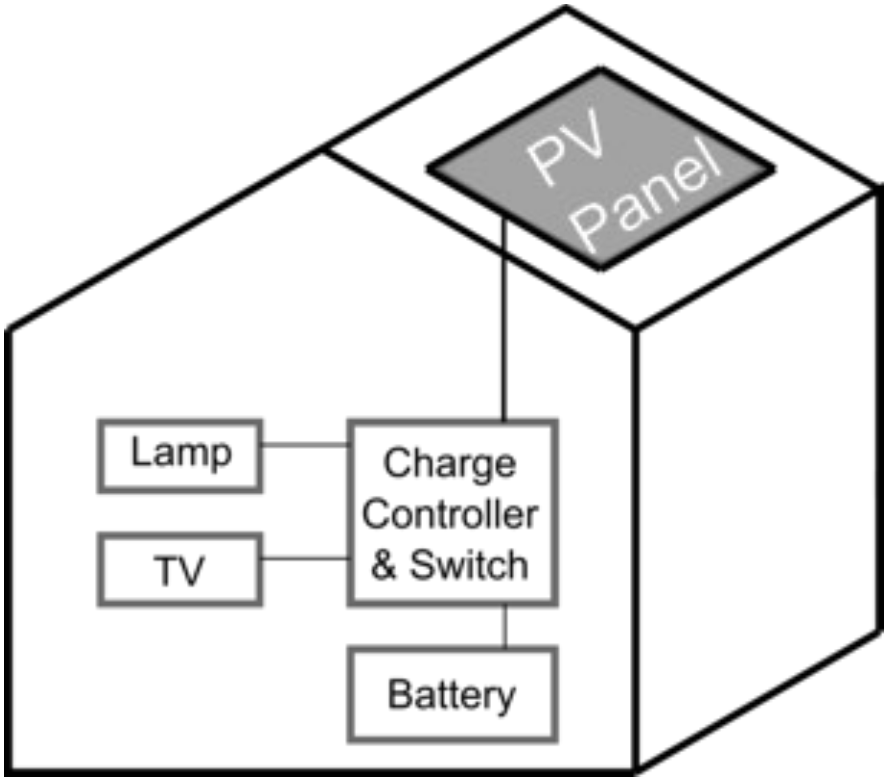
Courtesy: Nancy Wimmer

peculiarities of rural business

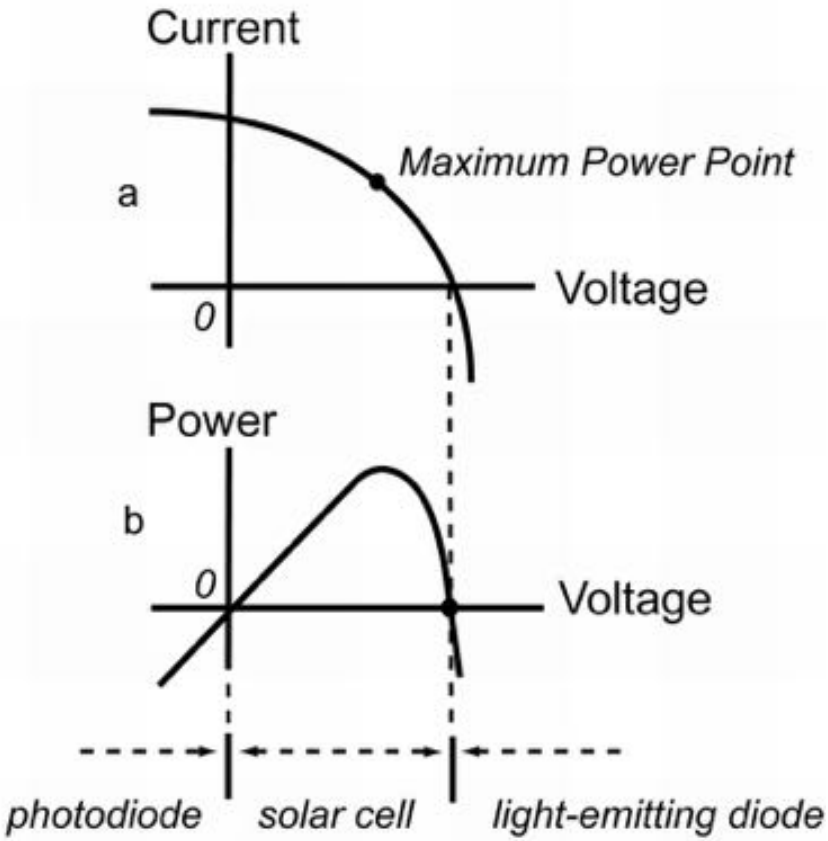
rural presence	startup strategy	things to avoid	social ecology	carbon credits	**production & procurement**
	full service		synergy of services		
		engineers	product packaging		
			training & auditing		
			customer financing	**growth funding**	
networking of branches	HR management	funds management	risk management	IT management	**product ownwership**

Courtesy: Nancy Wimmer

Solar Home System



Courtesy: Nancy Wimmer



Device Electrical Characteristics

$$I(V) = I_{SC} - I_0 \left[\exp\left(\frac{qV}{\gamma kT} \right) - 1 \right]$$

Courtesy: SunPower

Courtesy: Alexis de Vos

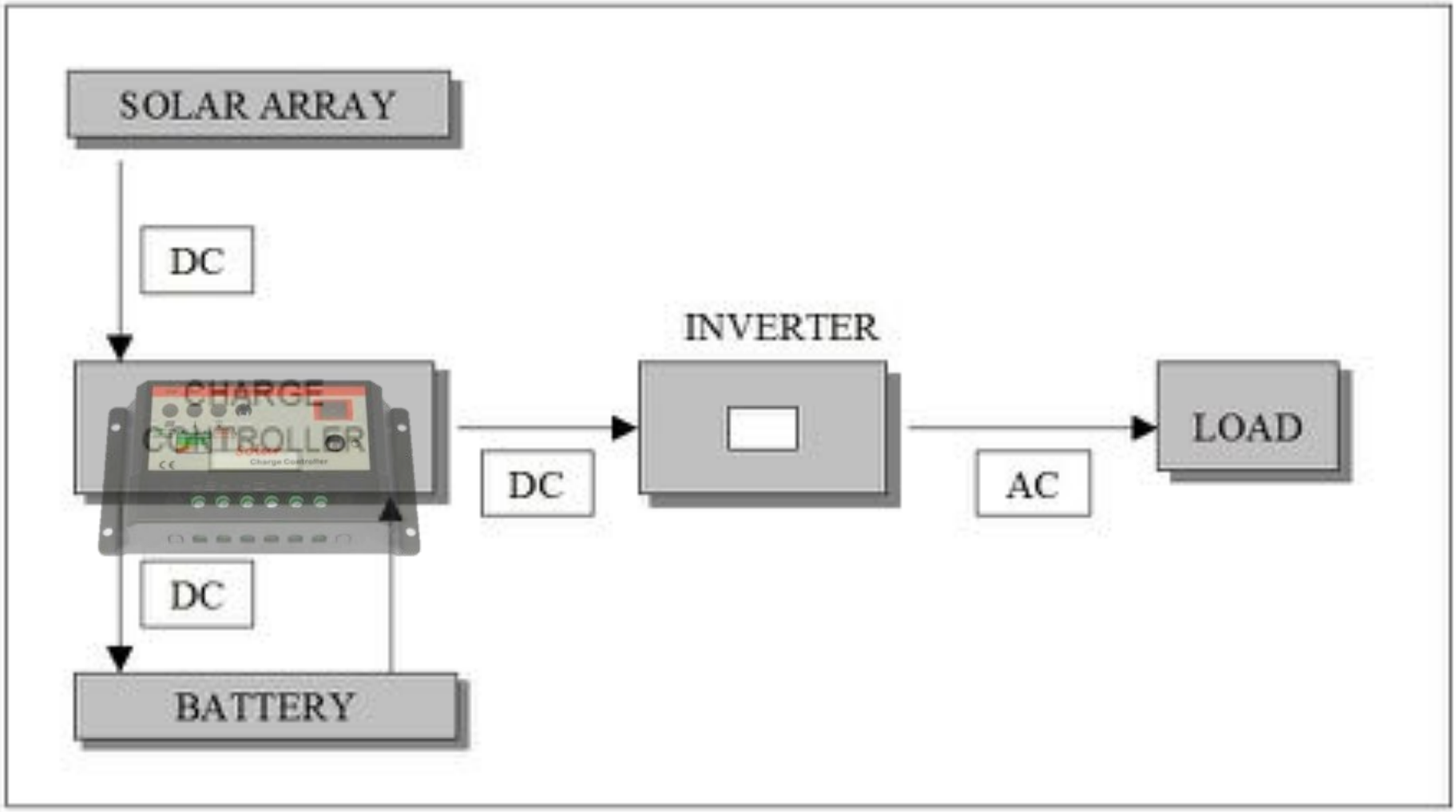


Figure 5.7 Flowchart of the main structure of a PV system.

Source: Nasir El Bassam et al

CHARGE CONTROLLER / REGULATOR

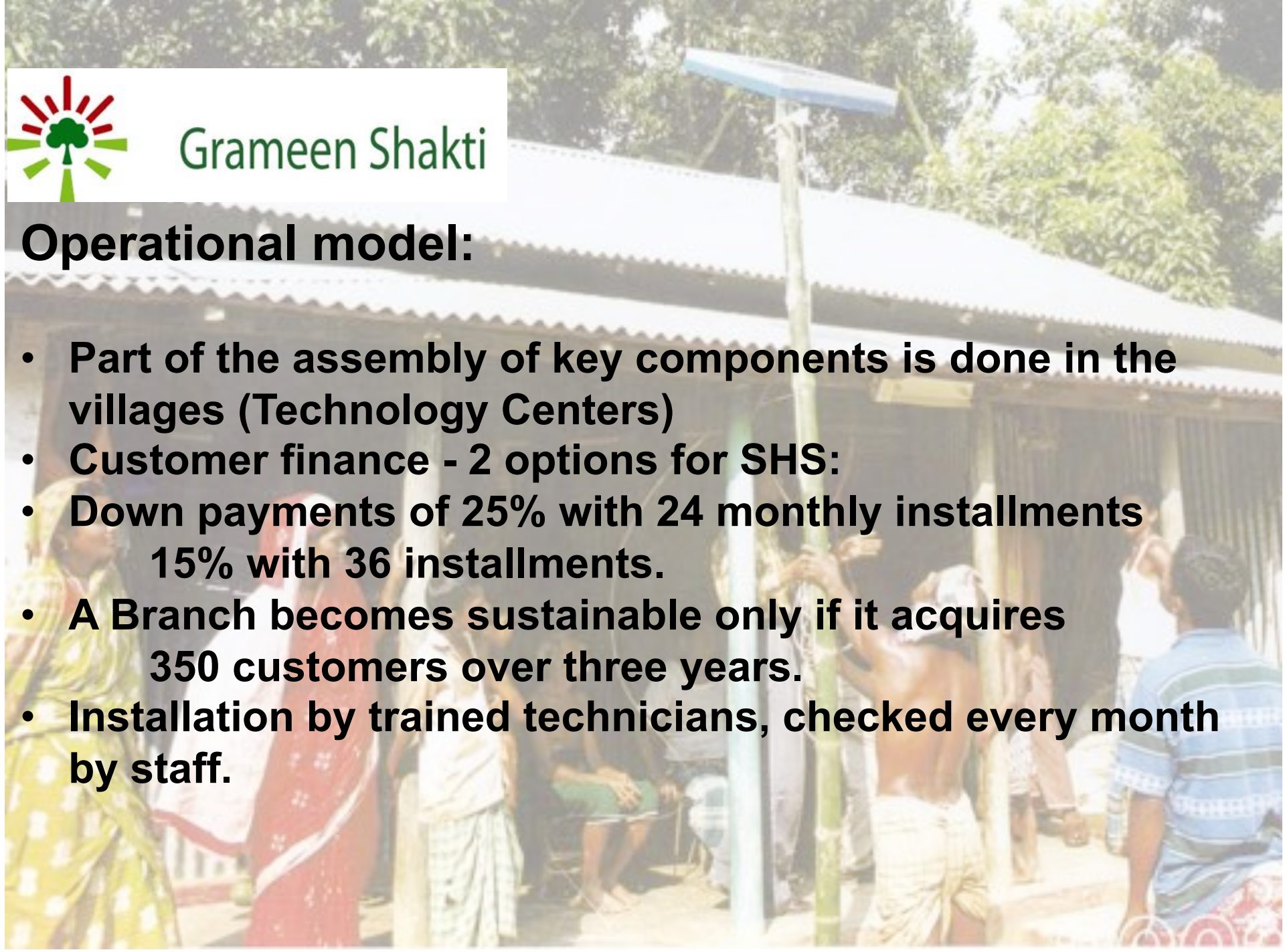
- A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from batteries.
- PV systems that utilize batteries require a solar charge controller.
- It optimizes (via MPP or Shunt) the power going from the solar panels to the batteries.
- A solar charge controller avoids overcharging and extends battery life significantly.

Grameen Shakti

11,000 employees

In over 1,500 branches

Courtesy: Nancy Wimmer



Grameen Shakti

Operational model:

- Part of the assembly of key components is done in the villages (Technology Centers)
- Customer finance - 2 options for SHS:
- Down payments of 25% with 24 monthly installments
  15% with 36 installments.
- A Branch becomes sustainable only if it acquires
  350 customers over three years.
- Installation by trained technicians, checked every month by staff.

Sustainability: The SHS system is well-designed, with a 5 year guarantee on the battery and a 20 year guarantee on the PV panel

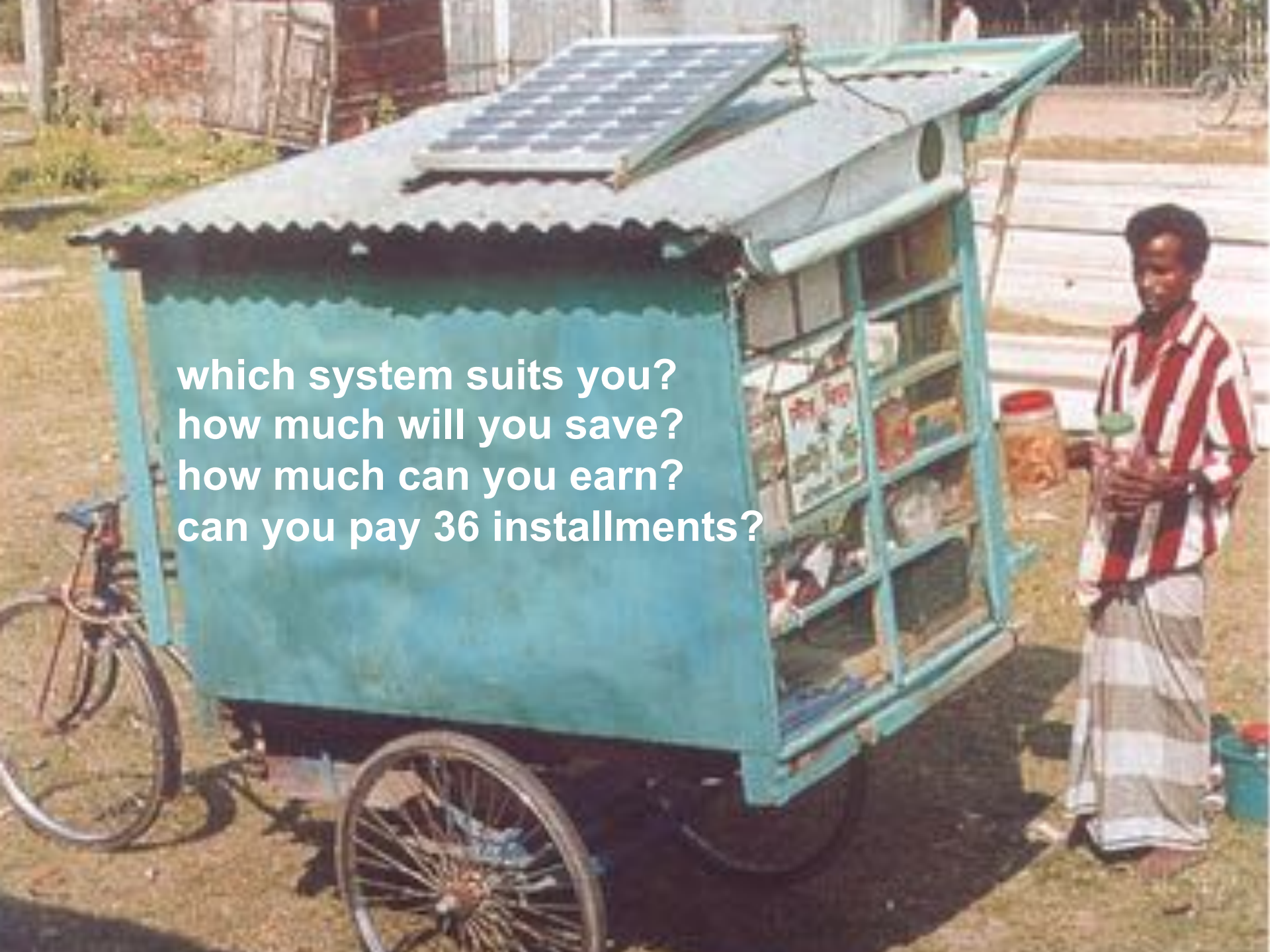
Photos Courtesy: Nancy Wimmer


One Stop Service
finance
installation
maintenance
repair
training

Young engineers

- run branches
- master technology
- train staff
- fix daily problems
- assess the market
- discover new business
- take part in village life
- improve products
- counsel customers

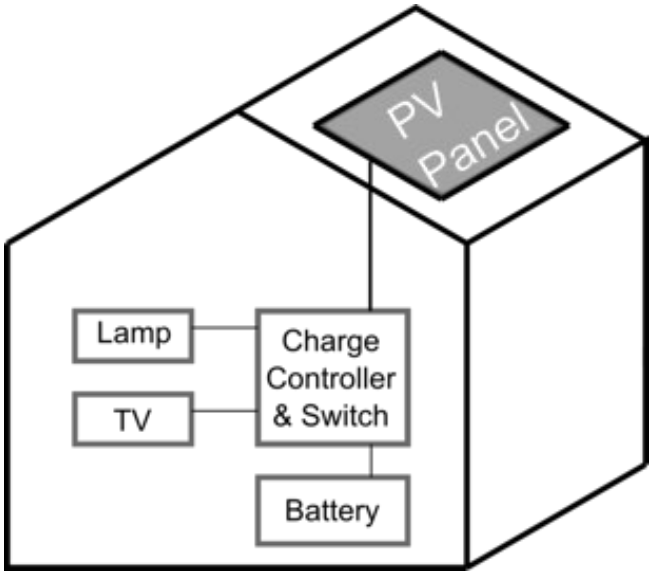
Courtesy: Nancy Wimmer


which system suits you?
how much will you save?
how much can you earn?
can you pay 36 installments?

Pricing (early stages):

SHS priced at

- $140 for 10 W
- $412 for 50 W
- $1,000 for 130 W



Courtesy: Nancy Wimmer

Biogas Plants starting from USD 187 for a 1.6 m^3 plant to $422 for a 4.8 m^3 plant

Improved Cook Stoves at $11.76

Woman engineers & managers run rural technology centers

Courtesy: Nancy Wimmer

This engineer

Courtesy: Nancy Wimmer

serves woman customers

trains woman entrepreneurs

This Entrepreneur

Courtesy: Nancy Wimmer

works in her village home

This Entrepreneur

Courtesy: Nancy Wimmer

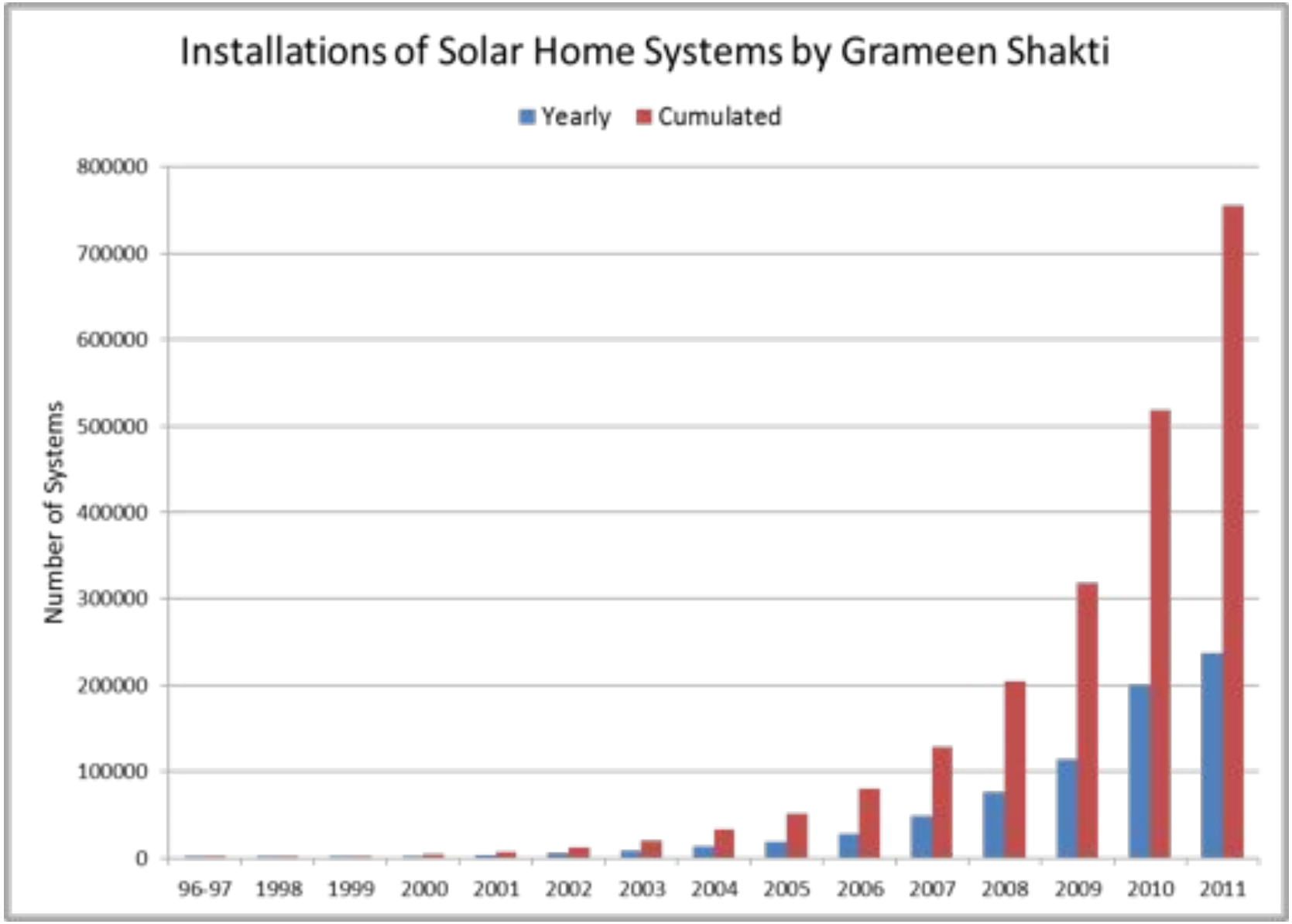
sells, installs, maintains

Energy-Entrepreneurs

Courtesy: Nancy Wimmer

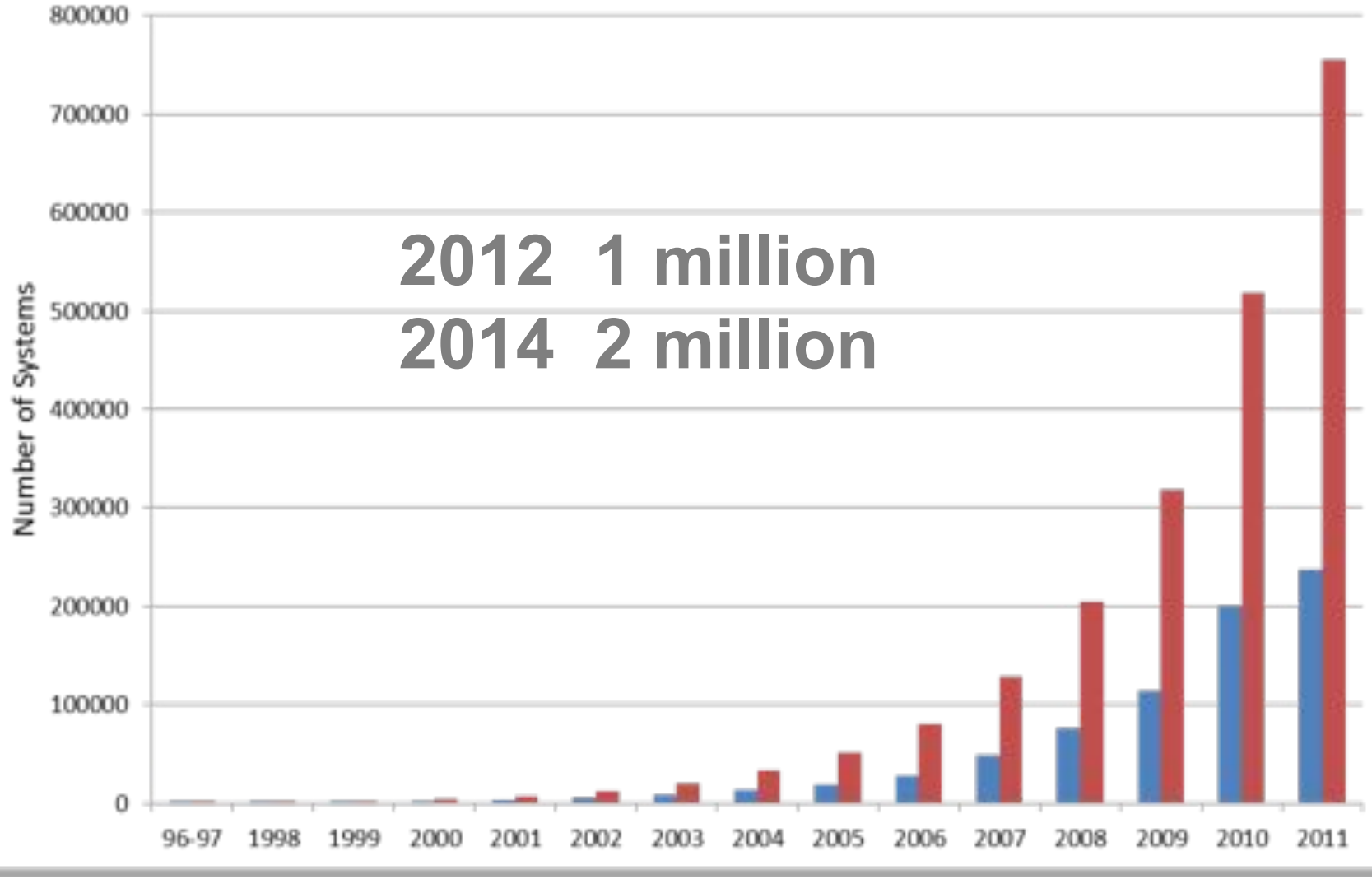
- Rely on Grameen Shakti for training, supply, loans, quality control, brand name,
- Simplify logistics, cut cost & **enable growth**


GOLDEN RULE
business does well
if the village does well

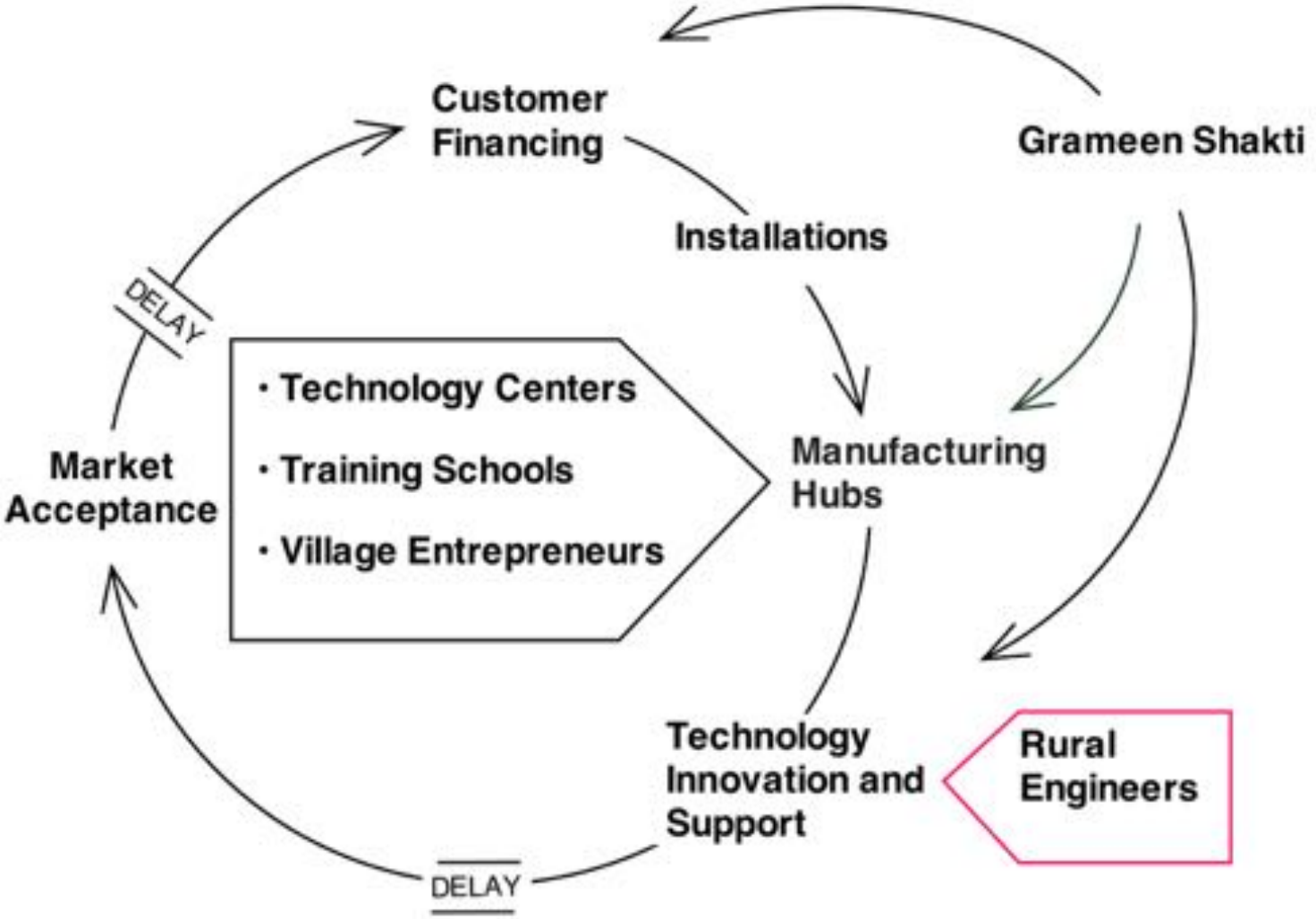


Courtesy: Nancy Wimmer

…A spectacular success



Systems Diagram



Source: Prof. Greg Smestad

Most of the charge controllers currently used under the IDCOL solar program are locally assembled.

Major assemblers are:

- **Innovative Technologies,**
- **Grameen Shakti,**
- **Easy Electronics,**
- **Technosol,**
- **CMES,**
- **Energypac**

In terms of cost, 85% of the raw materials are imported. On an average, 40% on the import value of charge controller components need to be paid as custom duty, supplementary duty, AIT and ATV.

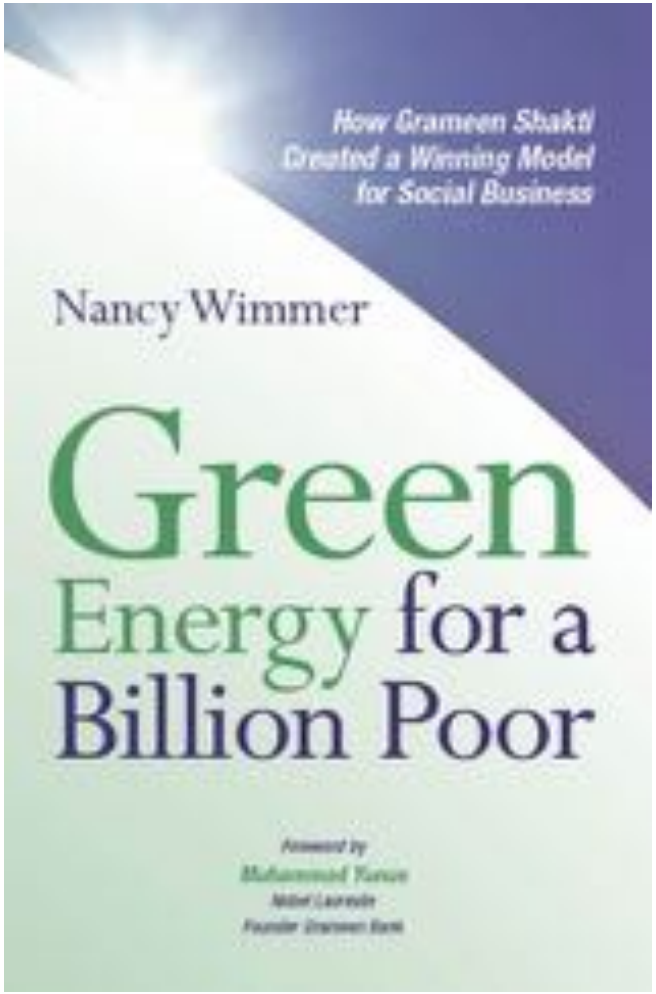
Source: Sajed Kamal, Journal of Bangladesh Studies, Volume 10, Number 1, The Untapped Energy Mine: The Revolutionary Scope of Renewable Energy for Bangladesh, 2008, http://www.bdiusa.org/journals/all-journals

Partners involved

Infrastructure Development Company Limited (IDCOL),
Kyocera Japan,
Grameen Bank's success and network

Courtesy: Nancy Wimmer

Want More Info.?

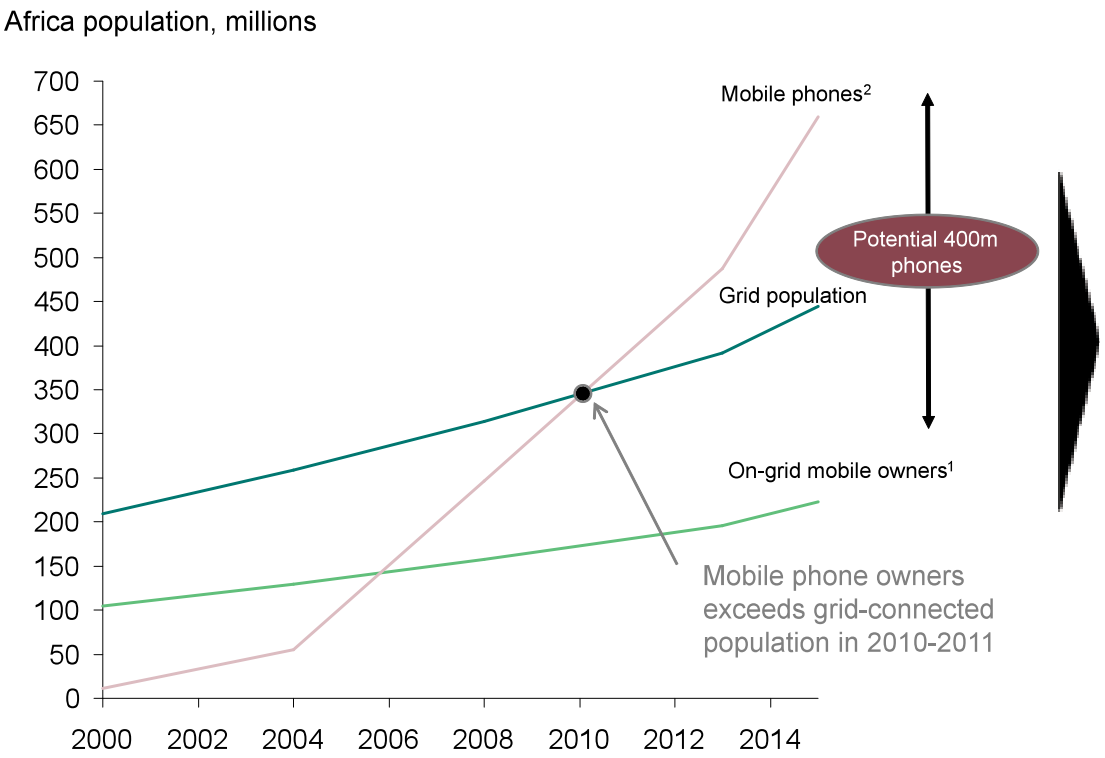


www.microsolar.com

Frau Nancy Wimmer

Phones and Solar

Mobile penetration is outgrowing Africa's grid, and this growing gap will drive demand for off-grid charging solutions



- African mobile phone penetration has outgrown the grid and the gap is growing rapidly
- By 2015 there will be 200MM+ more African mobile phone owners than grid users and a total of ~400MM off-grid phone owners across Africa[2]
- An average off-grid phone user can pay between $2 - $15 per month for phone charging

1 Mobile phone users estimated at 75% of mobile subscribers for developing mobile markets (Wireless Intelligence and LINK Centre)

2 Assumes that ~50% of on-grid individuals own a mobile phone; consistent with GSMA and Wireless Intelligence estimate that 30% of off-grid are phone owners

Source: ICT, World Bank, Pyramid Group, Dataxis, IEA, various gov't electrification authorities, Dalberg analysis

Phones and Solar

Figure 14.35 Solar charging unit for mobile phones in Africa. (Rolf-Peter Owsianowski 2011, Loccum Protestant Academy, Germany).

Greg P. Smestad, Ph.D.

Sol Ideas Technology Development

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SANTA CLARA UNIVERSITY 1851

http://energymap-scu.org/