OFF-GRID PHOTOVOLTAIC APPLICATIONS IN REGIONS OF LOW ELECTRIFICATION:

HIGH DEMAND, FAST FINANCIAL AMORTIZATION AND LARGE MARKET POTENTIAL

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Motivation & Purpose of Work

In the world, 1.4 billion people have no access to electricity.[1] More than 80% of people without access to electricity live in rural regions of developing countries, typically showing high solar irradiation. Attractive priced solar home systems (SHS) and pico systems (PS) should enable a fast financial amortization and thus enormously improve local standards of living. In case of high power demand and relatively high income, PV based mini-grid systems become also attractive.

The purpose of the presented work is to analyse the location of people without access to electricity and to give an estimation of the market potential for off-grid PV applications, driven by the fast financial amortization of those systems.

Global Access to Electricity

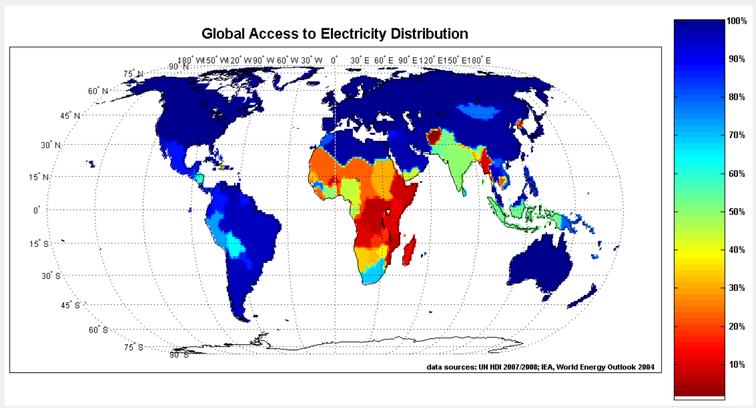

Fig. 1: Global access to electricity in percent of local population.[2,3] Electrification is completed in Europe, Central and East Asia and North America. It is nearly finished in Latin and South America, North Africa and Middle East. People without access to electricity mainly live in sub-Saharan Africa, South Asia and in some countries of the Pacific Rim.

Off-Grid People and Local Irradiation

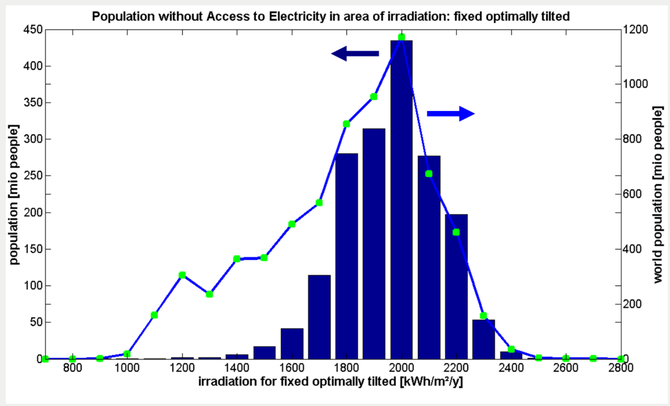

Fig. 2: Population without access to electricity in dependence of local solar irradiation on optimally fixed tilted modules.[4,5] Georeferenced analysis of irradiation of those regions where the people without electricity live confirms that a majority of them has access to excellent solar resources of about 1,800 – 2,200 kWh/m²/y irradiation on the modules.

Electrification and Poverty

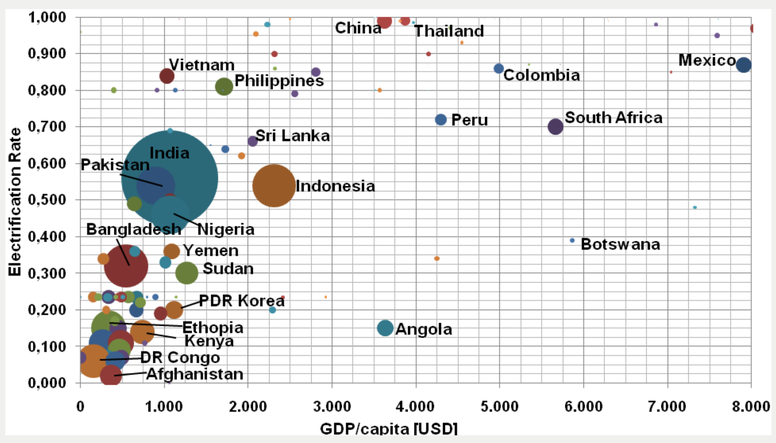

Fig. 3: Electrification rate in dependence of gross domestic product (GDP) per capita for developing countries. The bubble size is according to the quantity of people without access to electricity.

- Most people without access to electricity live in developing countries of GDP per capita of less than 2,500 USD.
- A large majority of them lives in India (~530 mio.), Bangladesh (~110 mio.), Indonesia (~110 mio.), Nigeria (~85 mio.), Pakistan (~85 mio.) and Ethiopia (~70 mio.).

Local Energy Prices

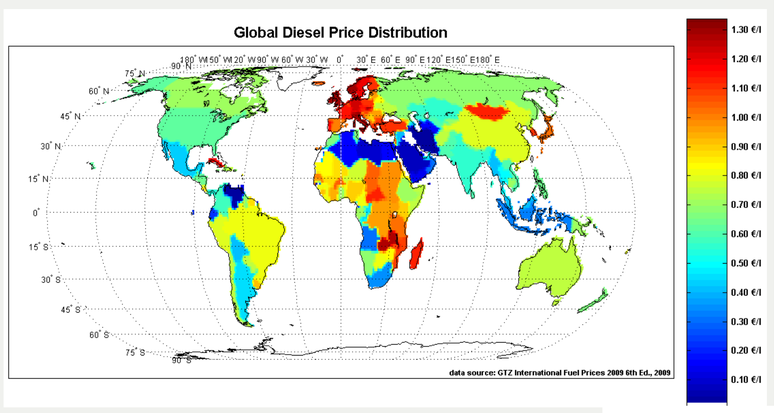

Fig. 4: Global distribution of diesel prices.[6] Blue colour coding represents subsidised diesel price, turquoise colour is equal to true cost of diesel at a crude oil price of about 80 USD/barrel, whereas dark red is an indication for high taxation. Diesel prices are used for estimating local cost for kerosene lamps.

Financial Amortization of Small PV

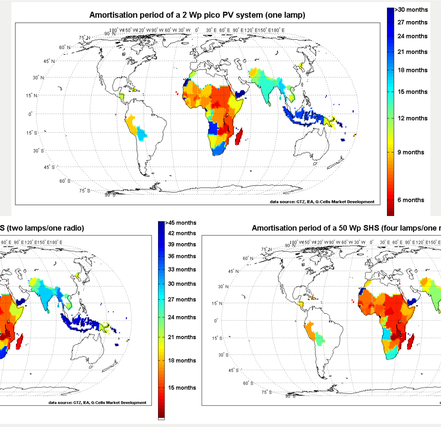

Fig. 5: Amortization period for 2 Wp pico PV system (PS) (top), 10 Wp SHS (bottom, left) and 50 Wp SHS (bottom, right). Coloured countries show electrification rates of less than 80%. Economics are based on assumptions in Table 1 and Fig. 4 plus inflation of 10% and a real interest rate of 3%.
Amortization of complete PV systems ranges between 6 - 18 months (PS) and 12 – 36 months (SHS) but strongly depending on local energy consumption patterns.

		PS	SHS	SHS
system size	[Wp]	2	10	50
system cost	[€/Wp]	23	23	8
reinvest				
battery	[€/Wp]	3.15	3.15	0.96
	[y]	4	4	4
charge controller	[€/Wp]	4.30	4.30	0.80
	[y]	10	10	10
LED	[€/Wp]	2.85	2.85	0.64
	[y]	7	7	7
energy need				
kerosene	[l/month]	5	10	20
radio battery	[€/month]	-	1.70	1.70
tape rec battery	[€/month]	-	-	3.40

Table 1: Economic assumptions for small PV applications and local conventional energy needs. Prices are in the range of international market conditions and are provided by the authors, Gabler [7] and Breyer et al. [8].

Hybrid Mini-Grid Attractiveness

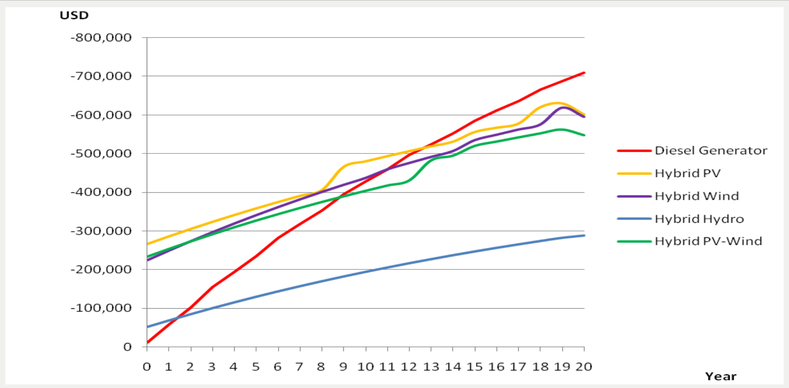

Fig. 6: Total cost of hybrid renewable mini-grid alternatives for an Ecuadorian village. In the long-term the diesel generator is typically the most expensive option, however the least cost option in the beginning. Micro-hydro would be the most cost competitive solution, if the hydro resource were available. In case of good solar and good wind resource availability, the hybrid PV-Wind mini-grid is typically the financial optimum.

Important prerequisites are: power demand >3 kW and annually >300 kWh/user, connected households for village supply >15, no scattered building structure, access to long-term financing and no grid connection within the next 15 – 20 years.

Market Potential of Off-Grid PV

The market for the 1.4 billion people without access to electricity might be evenly addressed by:

- small PV systems of the average size of **30 Wp for very poor regions** accounting for about **2 GWp** representing a market potential of about **20 bn€**,
- larger scale small PV systems of an average size of about **100 Wp for less poor** regions accounting for about **6 GWp** representing a market potential of about **60 bn€**,
- **mini-grid applications** providing annually about **300 kWh/user** account for about **16 GWp** representing a market potential of about **250 bn€**.

Most well emerging and developed countries in the world show a **residential** fraction of total final electricity consumption of roughly one third. Thus, **commercial**, industrial and **public** consumption is two times higher than the residential one. Therefore, the commercial and public (schools, health centres, lanterns, water pumping, telecommunication, etc.) small PV and mini-grid off-grid market might be two times higher than the residential one.

Based on enormous demand for sustainable energy supply, the **global market potential** for **small PV applications** is expected to be in the order of **80 bn€** (residential – 8 GWp) up to **240 bn€** (residential, commercial and public – 24 GWp) plus **PV based mini-grid** solutions of about **250 bn€** (residential – 16 GWp) up to **750 bn€** (residential, commercial and public – 48 GWp).

This enormous economic market potential is in vast contrast to the global market for rural PV off-grid applications in developing countries estimated to about 50 MW in 2007 [7] but growing on a roughly 20% growth rate.

Conclusions

- people without access to electricity live mainly in India, South Asia, the Pacific Rim and sub-Saharan Africa
- the majority of non electrified people has access to excellent solar irradiation
- nearly all people having no electricity live in regions of GDP less then 2,500 USD/capita
- fuels for kerosene lamps are high in cost at almost all regions of low electrification
- amortization periods for pico systems (PS) are 6 – 18 months and for SHS 12 – 36 months
- small PV applications are the least cost option for people without access to electricity in rural areas
- PV based hybrid mini-grids become attractive in case of non subsidized diesel, access to finance and signi-ficantly more energy demand compared to small PV
- total economic market potential for the 1.4 billion not electrified people is estimated to be in the range of about 24 GWp and 240 bn€ (small PV) plus about 48 GWp and 750 bn€ (mini-grids).
- two third of the off-grid PV market potential is due to mini-grid applications, however two third of the not electrified people will get access to electricity by small PV solutions like PV pico systems or solar home systems

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