



# Solar PV for rural diesel grids

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*Based on draft PVPS report Hybrids, by Grégoire Lena (IED)*

PVPS

9<sup>th</sup> Annual Meeting of the CLUB-ER  
Abidjan, Cote d'Ivoire, 10-14 December 2012





# Hybrid mini-grids in general

- Depending on local situation and availability of energy sources:
- Hybrid diesel mini-grids with hydro, wind, PV or biomass power systems
- (or combinations of sources)
- Focus of this presentation: PV



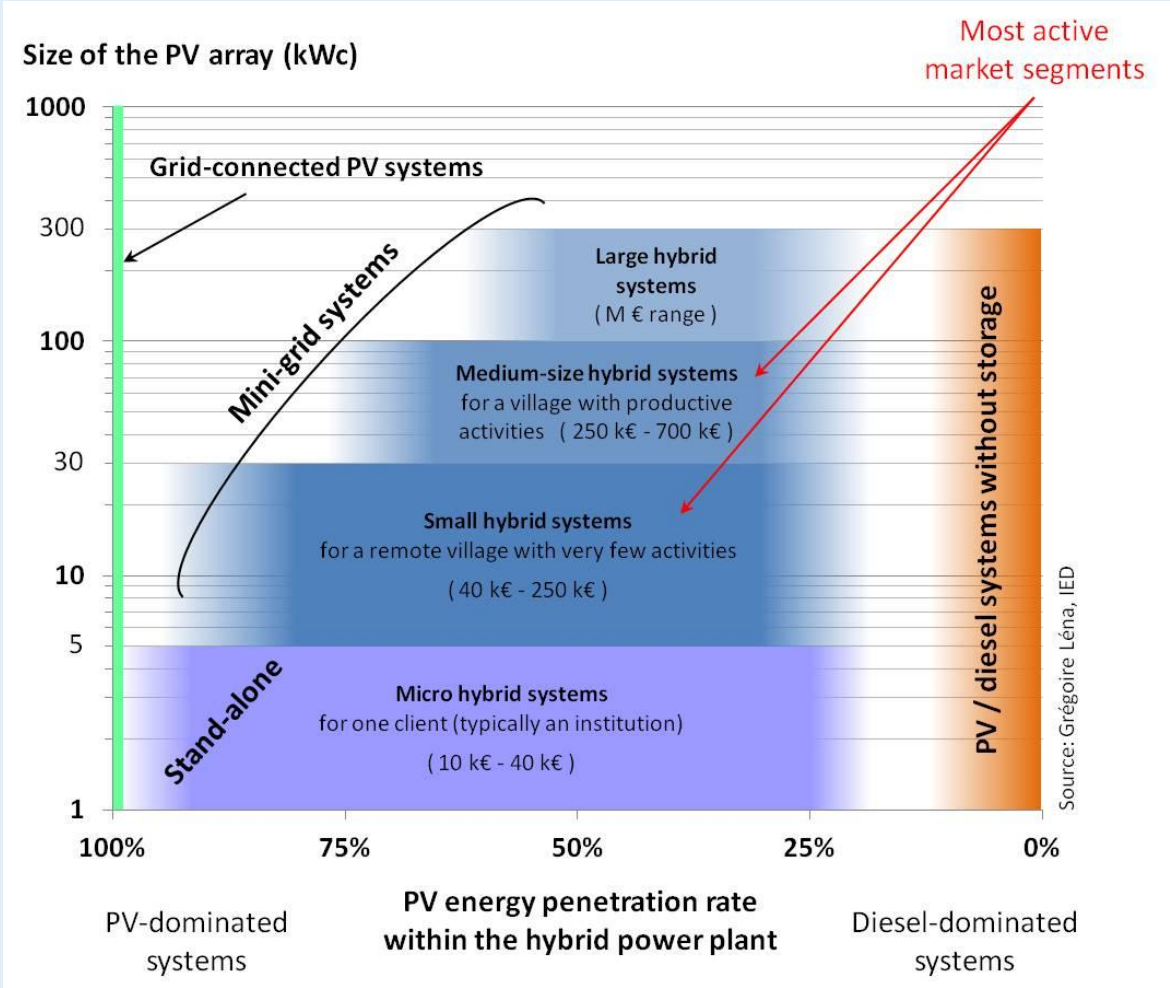
# IEA-PVPS Task 9

## ST4: PV Hybrids for rural electrification

- In collaboration with CLUB-ER: 2 training sessions in French and English were organised in 2011, covering 15 countries, offering the opportunity for assessment of state-of-the-art.
- **Subject of this presentation:** Joint publication with CLUB-ER on the status of the technology and cost, with feedback from CLUB-ER training sessions; ready early 2013
- Integration of earlier work by PVPS Task 11:  
“*PV Hybrid systems within mini-grids*”



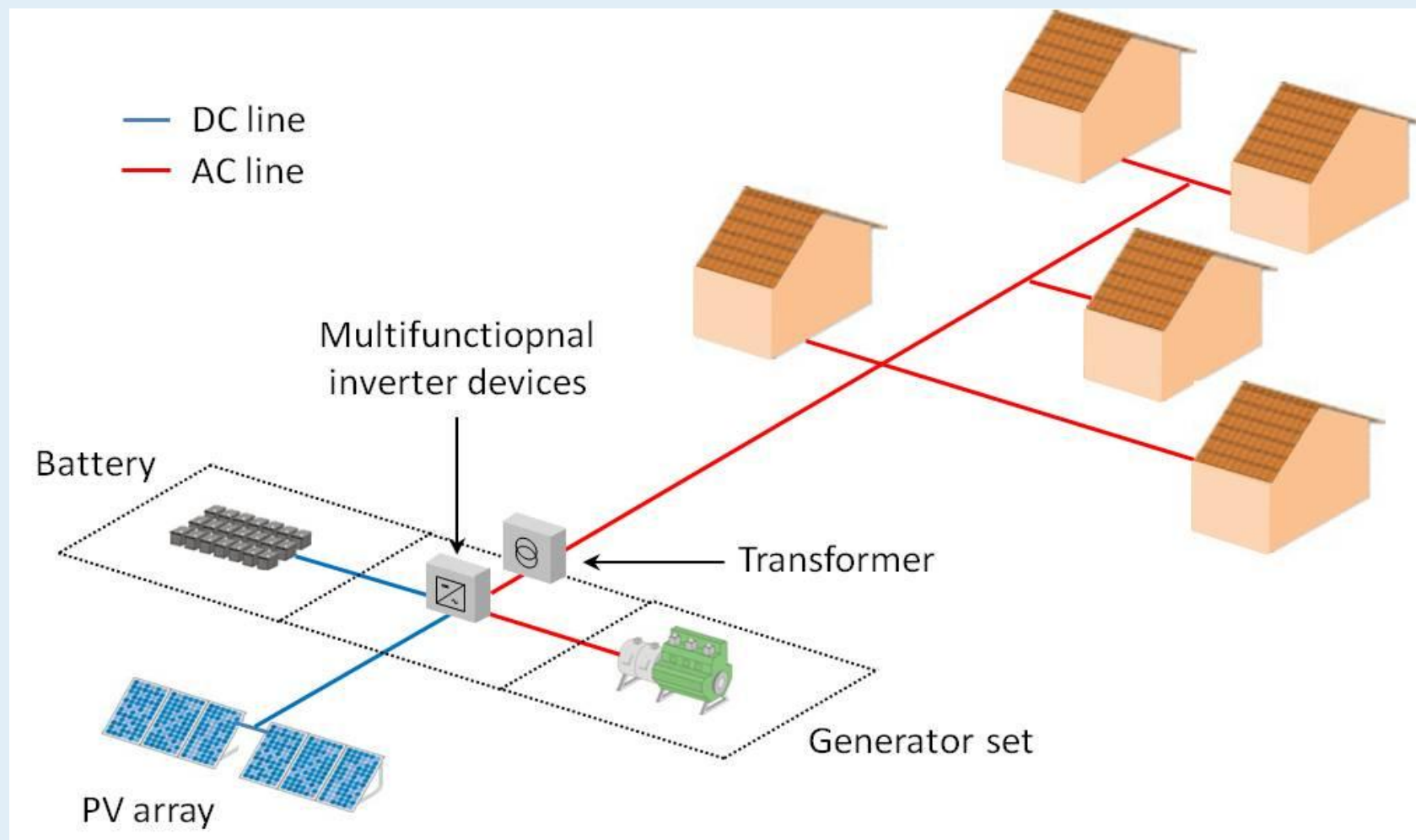
# PV mini grids: between grid connected and isolated stand-alone systems



\* Solar energy penetration rate:  $PV\ kWh / total\ kWh$



# What is a diesel-PV hybrid system?





# Examples diesel-PV hybrids



IDC, Mwanza, Tanzania  
12 kVA 0,65 kWp 2,4 kWh



Kimprana, Mali  
175 kVA 72 kWp 1185 kWh



Sine Moussa Abdou, Senegal  
8,5 kVA 5,2 kWp 120 kWh



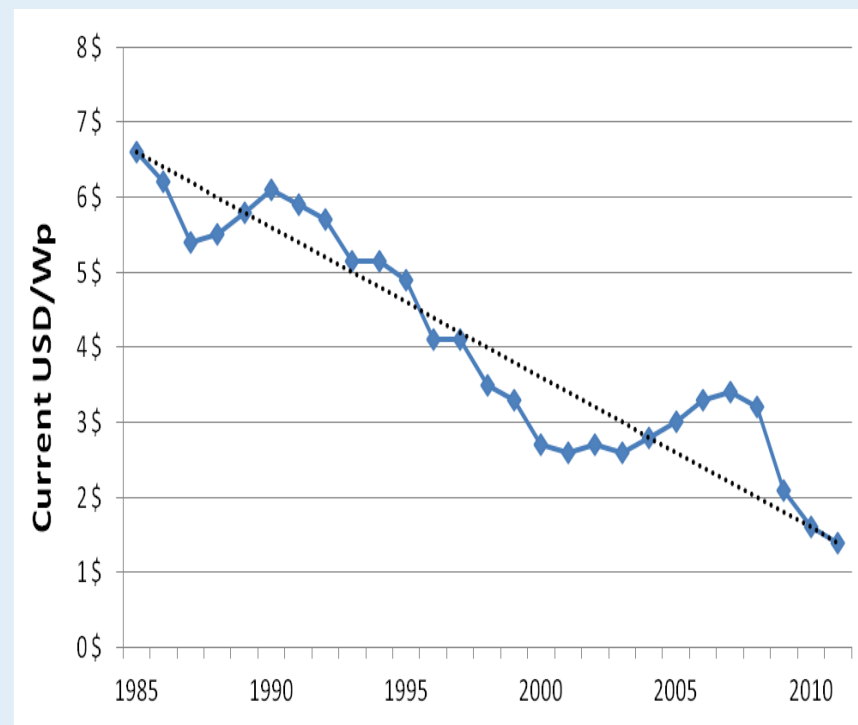
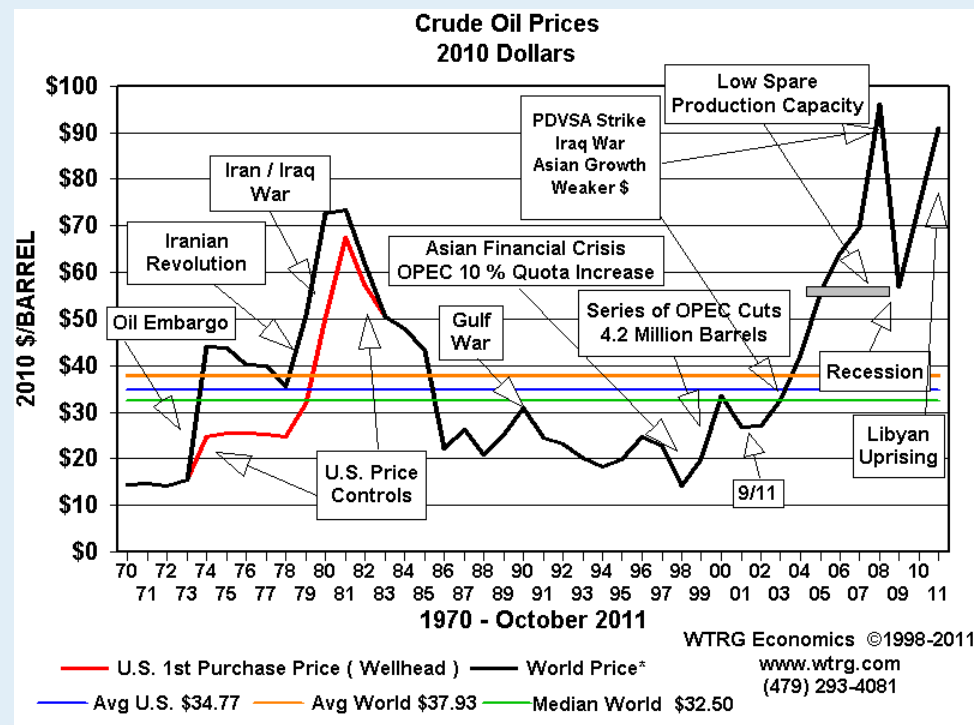
Ouelessebougou, Mali  
2x 275 kVA 216 kWp 1600 kWh







# The opportunity: price oil up, PV down (and transport to rural areas adds to fuel costs)

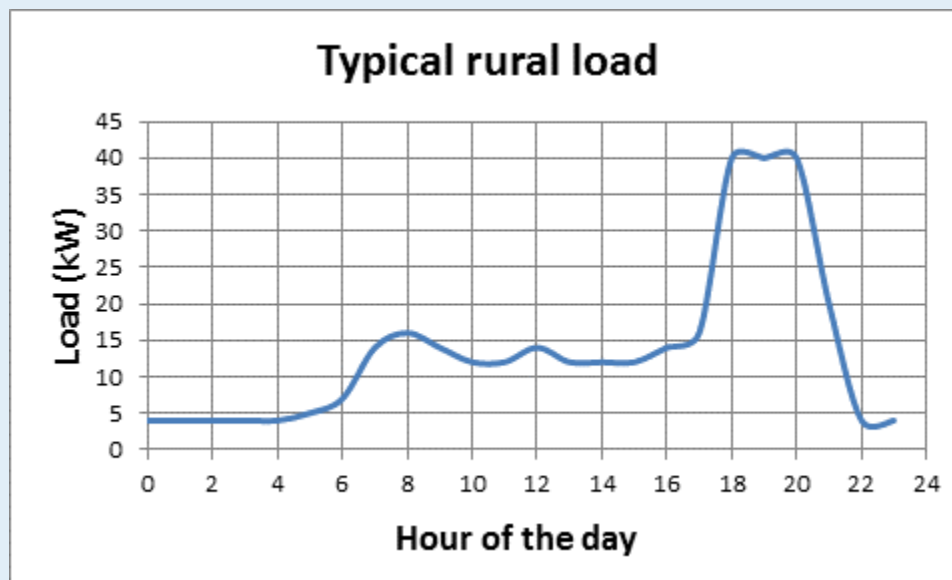
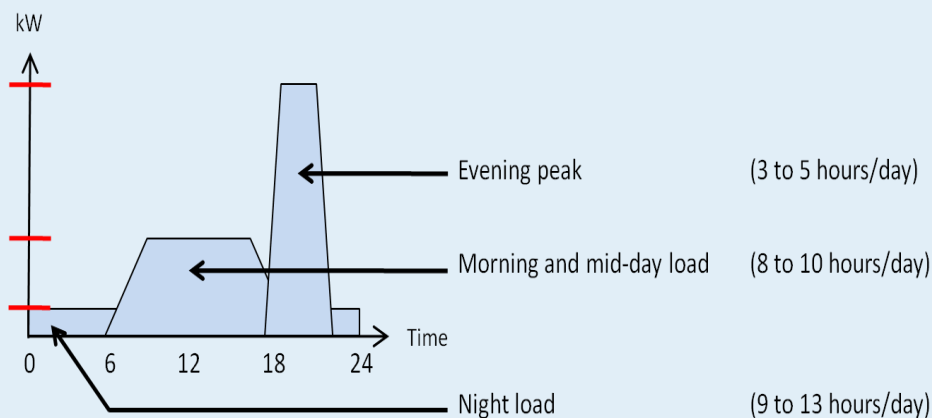


WTRG Economics, 2011

1985-2010 data: Paula Mints, Navigant; 2011: IED



# Typical rural load profiles

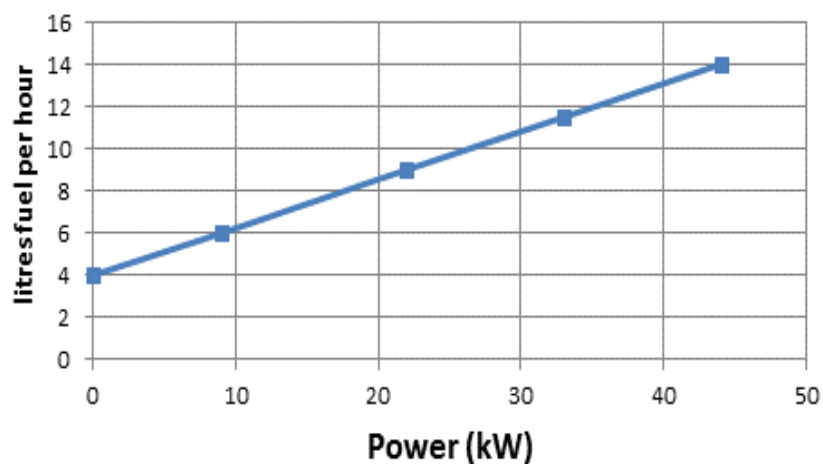




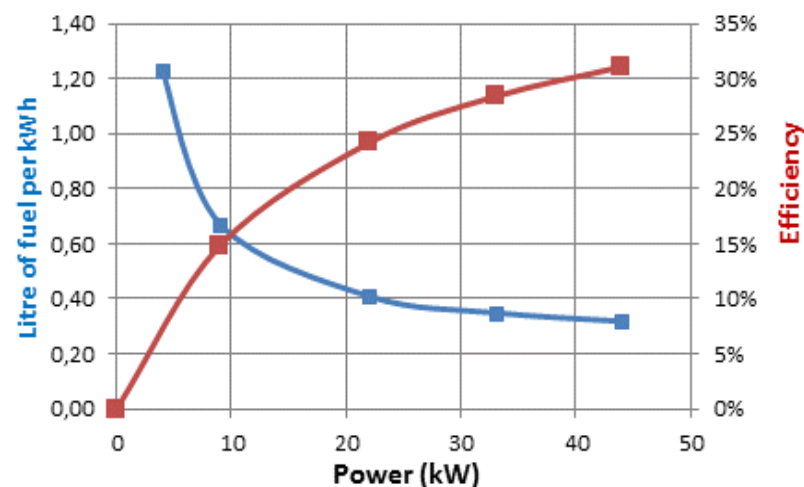


# Typical fuel consumption characteristics diesel genset

## Fuel consumption

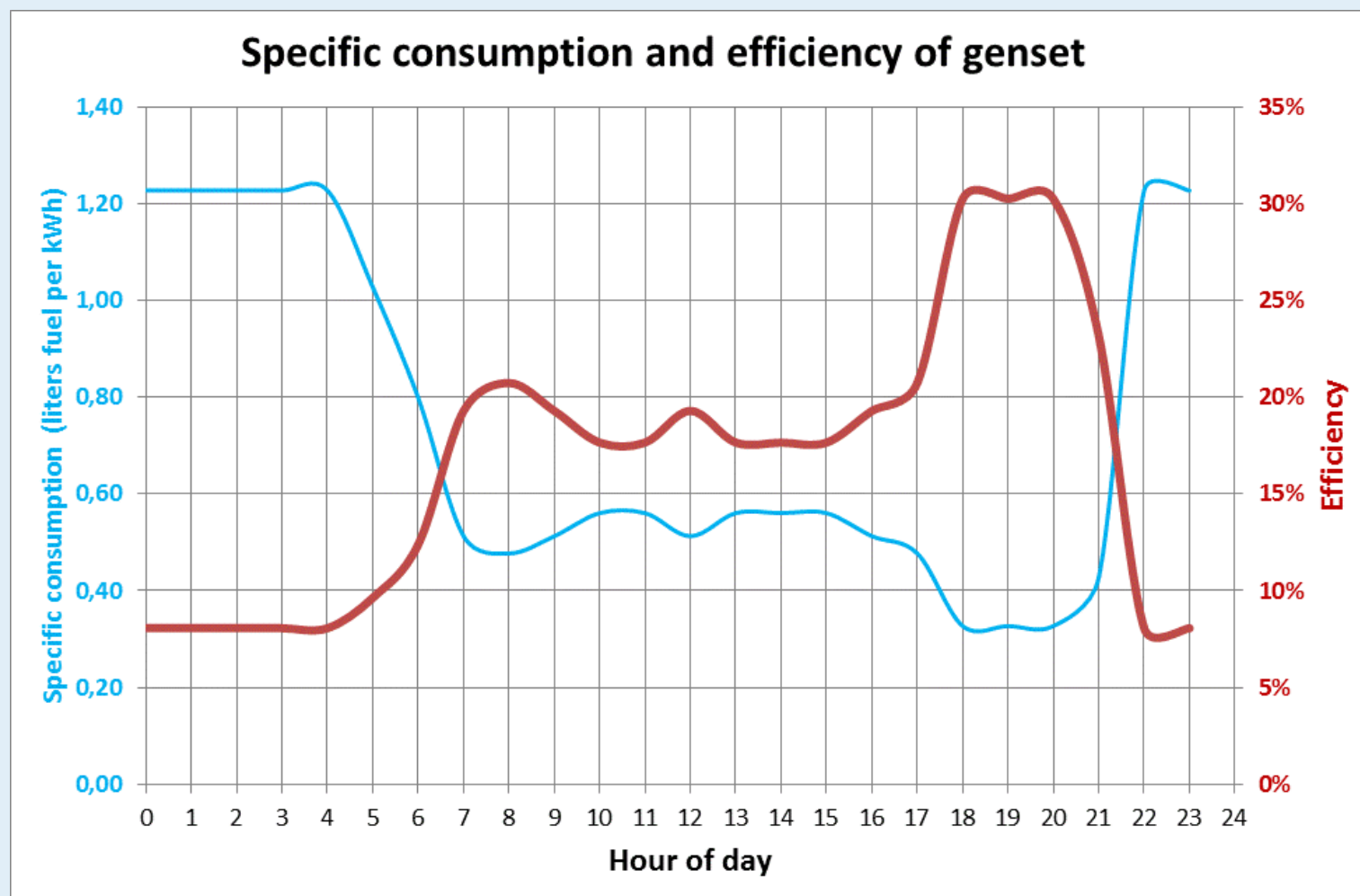


## Specific consumption and efficiency





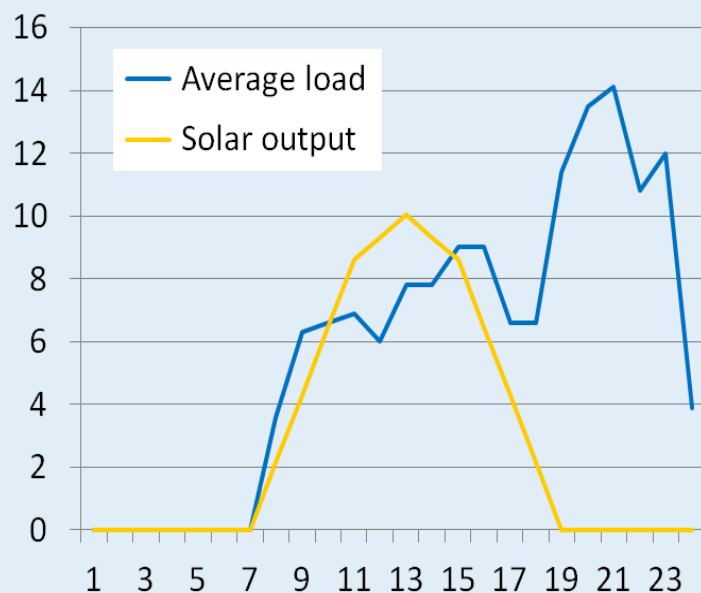
Specific diesel consumption varies per hour if one single genset covers such load variations





# How to match the load curve? Solar + battery + genset

## Example in Mauritania

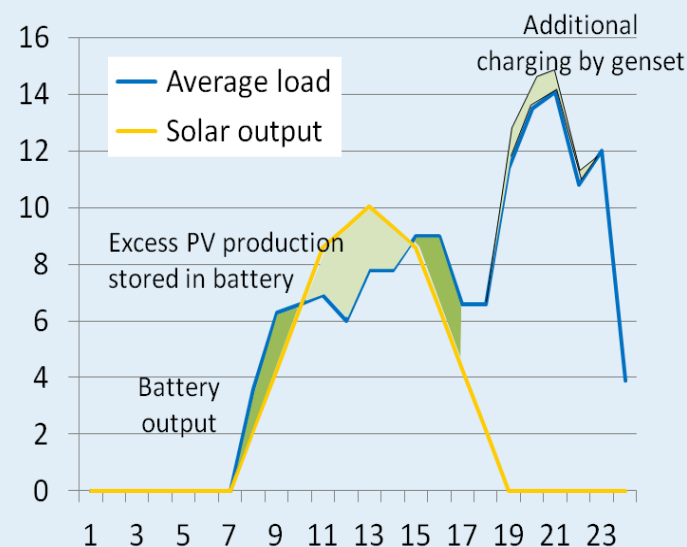
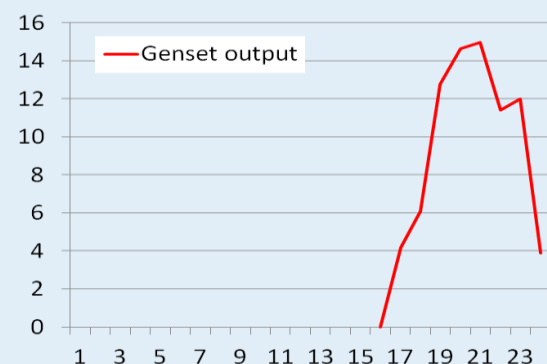


Source: IED

Genset: 55 kVA

PV system: 16 kWp

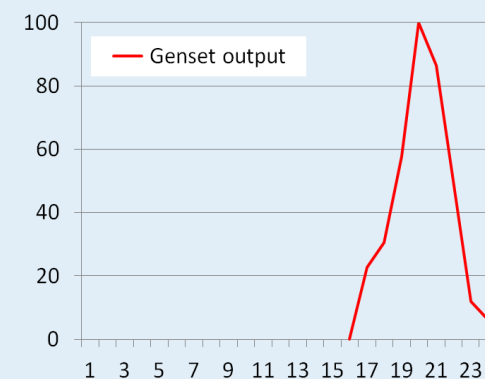
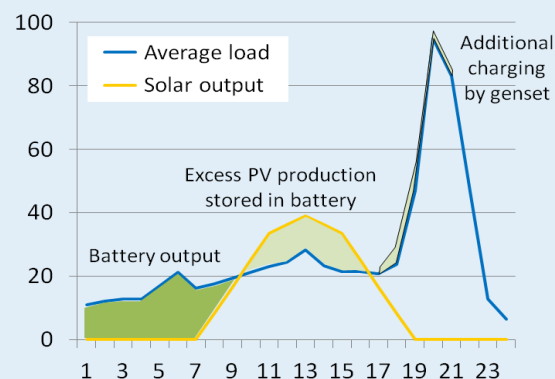
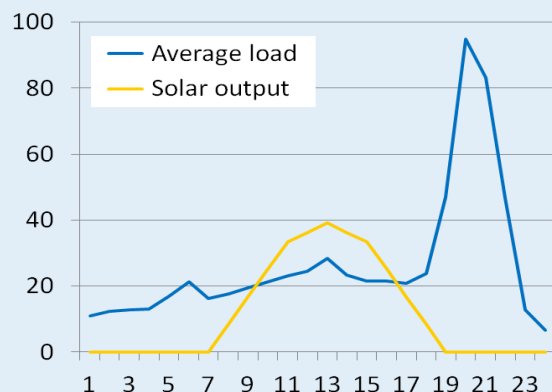
Battery: 120 kWh



Annual PV penetration rate: 35%



# Example: Cambodia



- Gensets: 73 + 125 + 175 kVA
- PV system: 70 kWp
- Battery: 600 kWh
- PV penetration rate: 45%

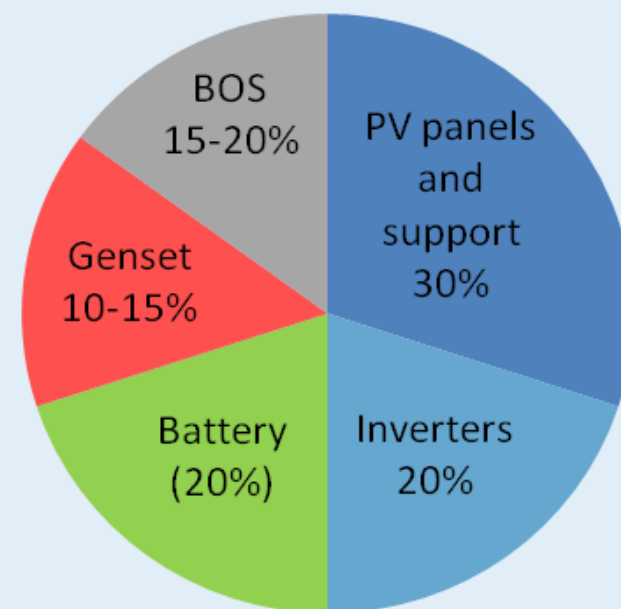
Source: IED



# Cost structure hybrid system

## challenge: cost reduction electronics and batteries

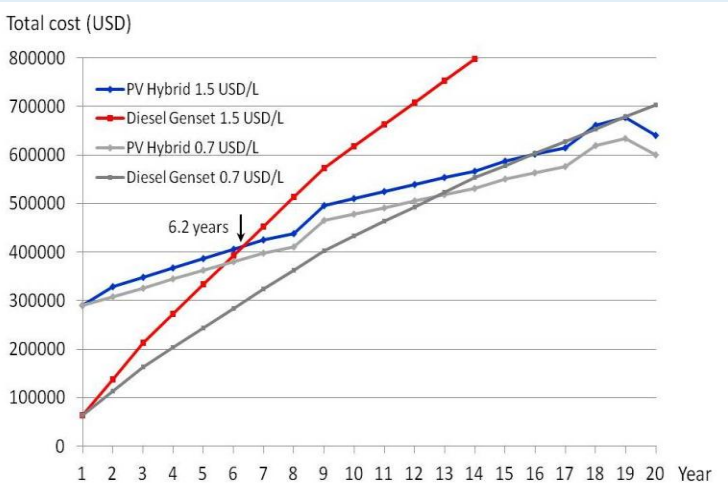
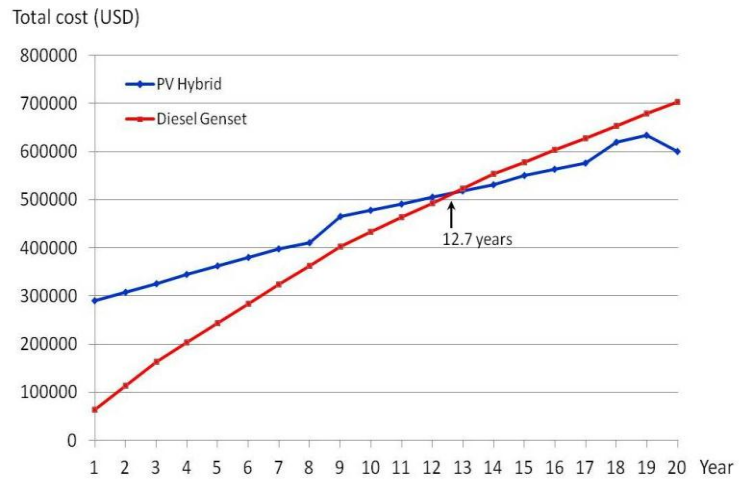
Location	Senegal	Cambodia
PV array capacity	30 kWp	70.8 kWp
PV panels and support structure	56,600 €	141,700 €
Inverters	42,700 €	93,600 €
Battery bank	29,800 €	122,600 €
Genset	21,400 €	84,600 €
BOS (including civil works)*	24,000 €	98,400 €
Total	174,500 €	540,900 €
Total / kWp PV	5,820 €	7,640 €
*Cost does not include any MV or LV grid.Sources: GIZ, IED		





# Life cycle costs: payback period remains beyond 12 years at current prices (example Ecuador)

Energy data		
Solar resource	6	kWh/m2/day
Energy demand	266	kWh/day
Peak load	26	kW
Fuel cost (1)	0,7	USD/litre
Fuel cost (2)	1,5	USD/litre
Costs of components		
Genset (30 kVA)	400	USD/kW
PV system (60 kWp)	2822	USD/kWp
Battery	225	USD/kWh
Converter	1445	USD/kW
Lifespan		
Genset	25000	hours
Battery	8	years

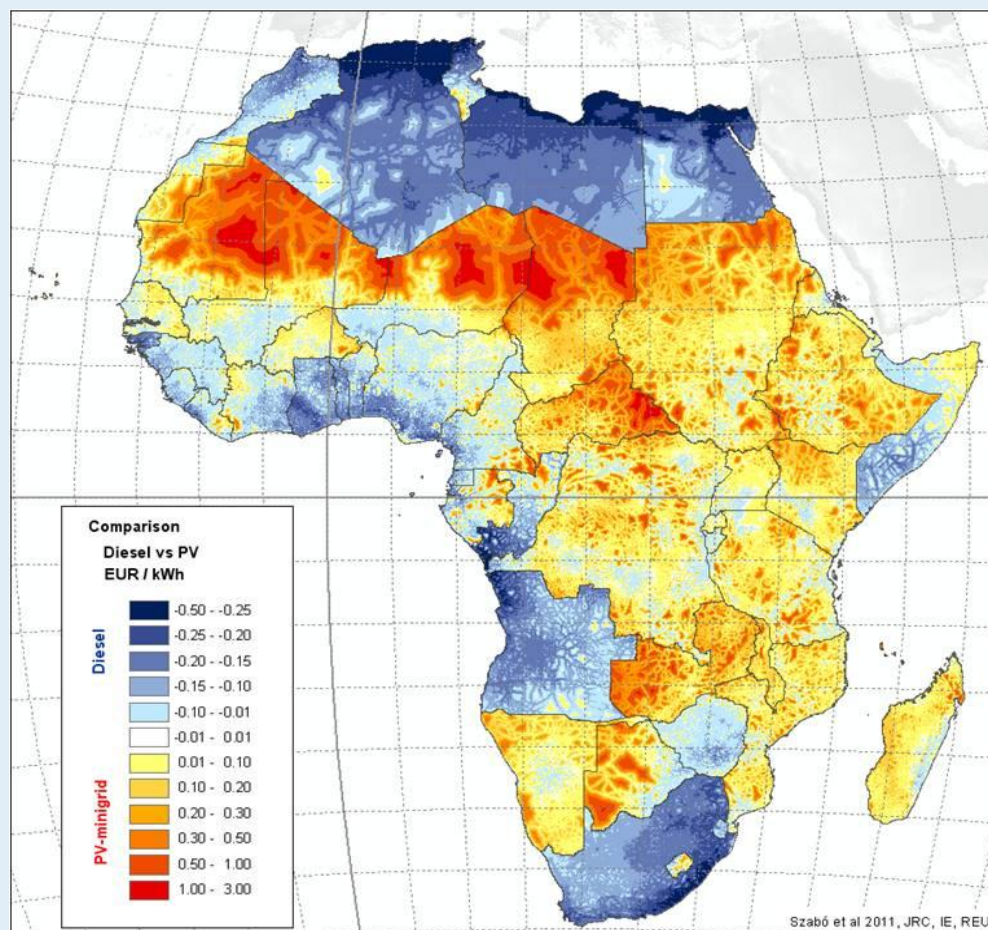




# Solar resource + expensive fuel

The kWh cost of the hybridised system directly depends on the local solar resource (which determines the cost of kWh generated by a PV system of a given cost) and on local diesel fuel cost (including transport cost to the site).

At 2012 costs of PV systems and real cost of diesel, the areas where hybridization makes sense are limited to places where the solar resource is very high or where fuel transport is very expensive.







# Barriers: costs and risks

- At current prices of specific equipment for hybrid systems (electronics, batteries, panels) the demonstrated reduction of the levelized kWh cost of about 15% will appear insufficient to a private investor to cover the potential causes of long term cost overruns without substantial public support.
- **This calls for a strong public-private partnership to mitigate and share risks**
- Upfront cost sharing / financial support as is the case for all rural infrastructure is required from public authorities to then let a private operation run sustainably
- Engagement of the private sector by way of capacity building, ensuring high level of maintenance and quality
- Public sector engagement for a programme approach, and to build skills and to develop the market, with sufficient volume

Remote village with very few activities    Peak load 30-60 kW    150-300 kWh/day    low growth rate

**Small hybrid systems ( 3kWp to 30 kWp PV )**

Option	Key figures for economic / financial analysis				Level of service	Required operating skills
Grid extension	distance to grid	MV line cost 8-13 k€ / km	yearly sales 55 to 110 MWh / yr	timeline for grid extension	full service	no
Diesel-based power plant	initial investment (incl. 1 genset) 40-70 k€	actual cost of diesel fuel  kWh tariff	-if mandatory subsidy on diesel: for a total of 55 to 110 MWh / yr (Ex: 8 to 16 k€/yr)*  -yearly O&M costs	genset lifespan	limited service schedule (no base load)	basic local skills (genset maintenance)
Hybrid-based power plant (Exemple: 30 kWp PV)	initial investment 180-250 k€  + battery renewal (8 years) 35-50 k€	accessible penetration rate > 40%  kWh tariff	-reduced mandatory subsidy on diesel: @40% PV penetration: 30-65 MWh / yr (Ex: 3 to 7 k€/yr)**  -reduced O&M costs	-payback period -long lasting PV investment (25yrs) -battery lifespan -increased genset lifespan	24-hour service possible	training required for operator + distant support

Investment data shown for comparing options does not include cost of the local MV / LV grid or minigrid.

Initial investment and battery renewal cost for the PV / diesel hybrid option are based on a 30 kWp system as an example.

\*Based on a 30% subsidy on 1.00 €/L fuel price and genset consumption 0.5 L/kWh

\*\*Based on improved genset consumption: 0.35 L/kWh



# Key issues for decision makers

- Additional technical skills of operators and installers required
- New opportunities for local distributors of equipment created.
- Comprehensive approach needed: capacity building, training, promotion of the technology and support to local equipment and service providers.
- Electronics in the system are not (yet) failure proof: management and availability of spare parts is fundamental in ensuring continuity of service
- As most rural electricity is subsidised this implies a displacement of the public subsidy from the operating costs side (diesel) to the initial investment side (PV system). This is a significant change for the public authorities involved.



# Conclusions

- Costs of PV systems continue to decrease
- Fuel costs tend to increase
- PV will play increasing role in both urban grids and rural mini-grids
- Battery breakthroughs expected



# Recommendations

- Be prepared: gather information, train personnel, carry out demonstrations
- Be aware of risks: quality, complexity, prices,
- Develop sound investment + business models
- Future grid connection to be considered in design of mini-grids



THANK YOU

for your attention