Centralized vs. distributed power generation in developing countries: what's smarter?

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PV Competitiveness in Village Powers

Strategic Rationale

- Currently off-grid communities in Northern Africa rely mainly on diesel generators to cover electricity demand

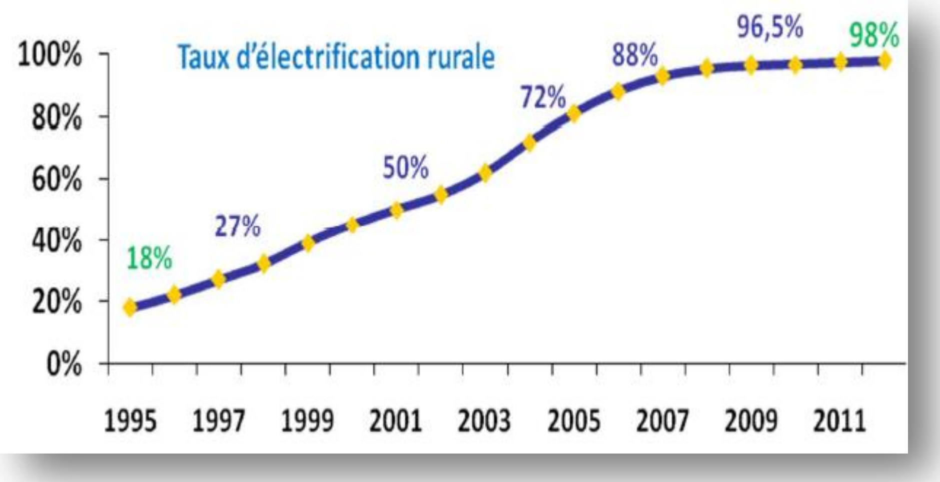
- Diesel generators present several issues:
  - Expensive solution to produce electricity
  - Very low reliability of small generators

- **PV systems** present **several advantages**:
  - **Competitive electricity production** in sites with high solar resource
  - PV panels can **easily be maintained** by local communities thus **enhancing job creation**

PV Competitiveness in Village Powers

Moroccan experience – PERG Solar programme

Morocco is one of the **leading Mediterranean countries** in terms of improving rural electrification rates for millions of consumers through **PV systems**.



- The PERG programme was launched in 1995 to meet growing electricity demand and attain rural electrification targets.
- The electrification rates increased **from 18% in 1995 to 98% in 2011.**
- Since 1995, 12 million Moroccans 35,600 villages have been connected to the grid and **5,600 PV kits have been provided to Moroccan consumers** (3,663 villages)
- 100,000 jobs have been created thanks to the program

Morocco experience already confirmed PV competitiveness in several cases
Hybrid PV systems could be adopted to further increase the security of supply

PV Competitiveness in Village Powers

Phase I : Pre-feasibility study

Objectives:

1. Assess competitiveness of integrated PV+Diesel systems in off-grid villages in North Africa

2. Evaluate potential benefits of storage integration

3. Quantify global potential PV market in off-grid applications

❶ Assess Competitiveness of Integrated PV+Diesel Systems in Off-Grid Villages in North Africa (1/4)

- The business-as-usual way to cover rural villages' electricity demand is **to rely on diesel generators**
- Fuel represents approximately 95% of total cost of diesel generation
- Assuming 1$/l diesel price[1], the levelized cost of electricity (LCOE) would be in the range of **300-500**$/MWh
- Diesel generator **may cover 100%** of the daily village demand

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1) The price 1$/l refers to the full diesel cost, including transport costs

❶ Assess Competitiveness of Integrated PV+Diesel Systems in Off-Grid Villages in North Africa (2/4)

- PV technology has developed rapidly in the last few years with a continuous decrease of overall system cost over time, while efficiency and reliability have significantly improved

- Capex represents approximately 90% of total cost of PV generation

- Assuming 2.0-2.5$/W cost for small sized PV installations, corresponding LCOE would be in the range of **150-250**$/MWh

- PV system without storage **may not cover** the whole daily village demand (i.e. hours without sunlight)

① Assess Competitiveness of Integrated PV+Diesel Systems in Off-Grid Villages in North Africa (3/4)

Case Study results:

System configuration		**Power demand** (MWh/y)	**Diesel % of demand**	**PV % of demand**	**Initial CAPEX** (k$)	**Diesel use** (l/y)	**LCOE** ($/MWh)
Diesel gen.	**PV**						
		234	100%	-	20	90,000	**420**
 +		234	70%	30%	130	60,000	**351**
		234	-	30%	110	-	**188**[2]

Assumptions: village dimension of ca. 1,000 inhabitants with a 234MWh/year electricity demand and an average load profile containing 45%[1] consumption during daily hours

Introduction of PV systems would allow a 15-20% reduction of total electricity cost, while increasing security of supply

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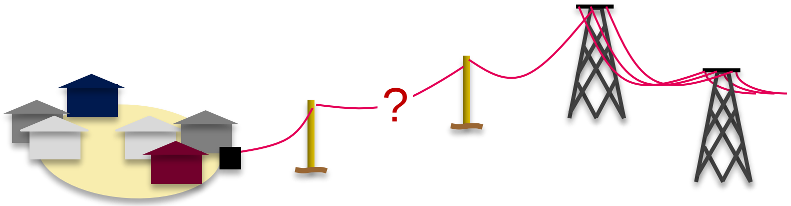
1) 45% of daily average load is concentrated between 10 a.m. and 7 p.m.

2) 100% PV LCOE and CAPEX refer to a PV plant, optimized in capacity to reduce LCOE, producing 30% of total demand with a 10% lost production due to mismatch with load profile. 188€/MWh LCOE is referred exclusively to PV production

❶ Assess Competitiveness of Integrated PV+Diesel Systems in Off-Grid Villages in North Africa (4/4)

Wouldn't it be cheaper to extend the distribution network?



Key Assumptions

Power demand: 234 MWh/y

Grid power price: 80$/MWh

Village Power LCOE: 351$/MWh (corresponding to Diesel+PV supply mix)

MV line CAPEX: 45k$/km + 40k$ transformers

Diesel price: 1$/l

Period of the analysis: 20 years

A medium voltage line extension represents the cheapest solution for power supply <u>only up to a 15km</u> distance of the village from the grid

Methodology: compare grid extension and grid electricity costs vs. Diesel+PV LCOE over a time span of 20 years.

❷ Evaluate potential benefits of storage integration

- Recently battery storage systems are being analyzed as a potential solution against the issue of renewables production variability

- In the case study analyzed, a PV plant designed to supply 30% of total annual demand, minimizes the LCOE. The **introduction of batteries will increase the demand coverage**.

- If the PV system capacity size is well dimensioned vs. peak load, the **introduction of batteries will not reduce average LCOE**

Introduction of batteries in a PV system remains too expensive to justify the replacement of diesel generation

❸ Global PV Market Potential in Rural Electrification

Potential PV market in off-grid applications worldwide can be quantified as follows:

A ▶ Reduction of **current off-grid diesel use** (estimated at 150GW[1])

in order to obtain the optimal share of PV production covering 30% of total demand, about **200GW PV** should be integrated in existing off-grid diesel powered systems

B ▶ According to IEA, achievement of **universal electricity access** (estimated at 1.3 billion people with no electricity today) by 2030 would imply

additional **840TWh/y** of global electricity consumption, of which **170TWh/y** could be produced by solar off-grid and mini-grid[2] applications **(100-150GW of PV)**

Over 300GW of potential PV capacity in off-grid applications worldwide by 2030

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1) Only small diesel gensets (under 500kW) for off-grid power generation considered

2) Mini-grids provide centralized generation at a local level. They operate at a village or district network level, with loads of up to 500kW. Isolated off-grid solutions include small capacity systems, such as solar home systems, micro-hydro systems, wind home systems and biogas digester

Source: IEA – WEO 2011, Dec 2011; BNEF, Power to the People? PV and batteries for the 150 GW Diesel market, Dec 2011; EGP estimates

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RES4MED RENEWABLE ENERGY SOLUTIONS FOR THE MEDITERRANEAN

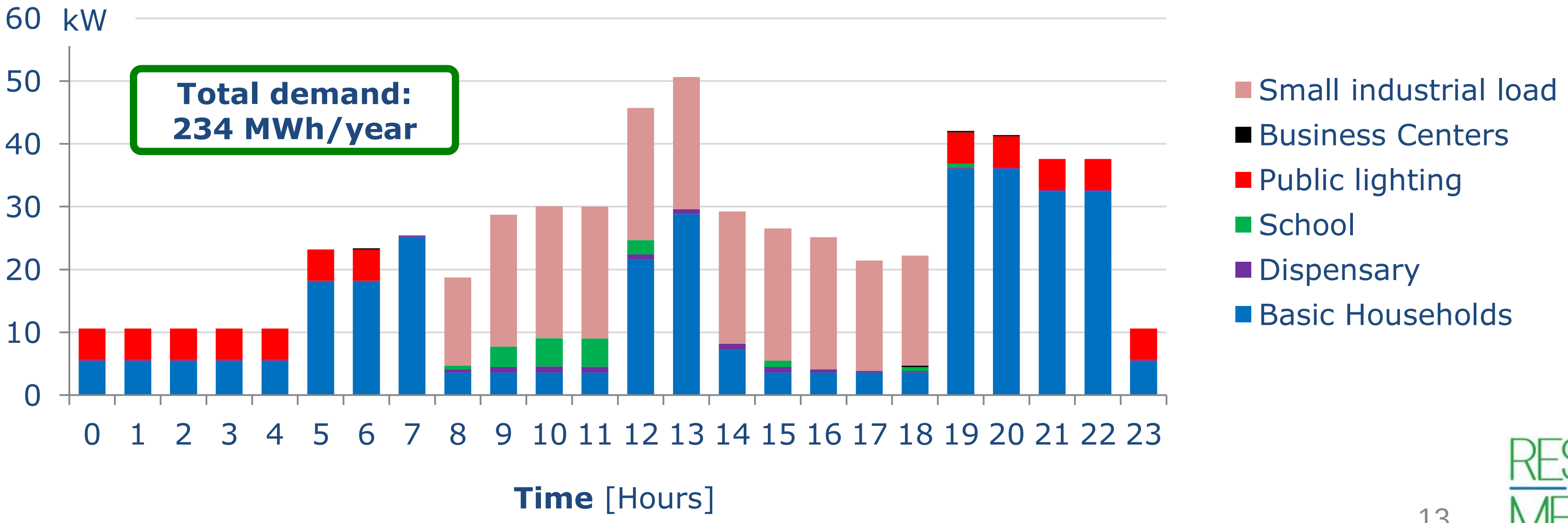
Backup

Major Assumptions of the Analysis

Demand Estimation

- Village characteristics:
    - 1,000 inhabitants, 200 houses
    - one primary school, one dispensary, 20 small shops, 20 cell phone charging centres, 2 water pumps and 2 milling machines
    - 5 km road with street lights
- Seasonal increase of load profile takes into account higher utilization of cooling appliances such as refrigerators, air conditioners and fans

Load Profile in normal season (kW)



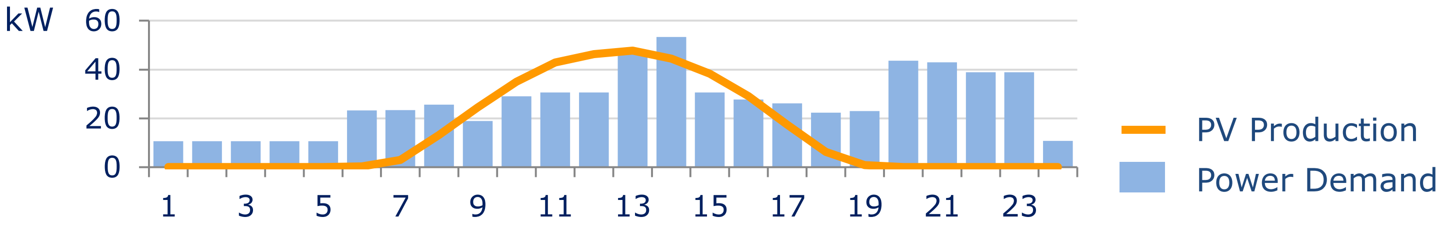
Total demand: 234 MWh/year

Source: Politecnico di Milano estimates

Load Profile and PV Production

- The **coverage of the load curve by PV production** highly affects PV economics

PV production and load curve (30% of annual PV penetration)



PV Generation LCOE after lost production ($/MWh)

		WACC		
		5%	**8%**	**12%**
Excess Production	**0 %**	139	169	215
	10 %	154	$\boxed{188}$	239
	20 %	173	212	232

☐ Base case

- At **PV penetration of 30% PV lost production due to mismatch with load profile** is assumed to be up to **20%** of total production
- PV LCOE after lost production would be approx 10% higher
- **Base case** assumed at **188$/MWh**

For the LCOE calculation the following assumptions were used: inflation rate 2%, EOH 1,600, CAPEX fixed at 2.3$/W, 20 years life, no taxes
Source: EGP estimates