*Energypedia webinar*
*Why mini-grid technologies -- biomass, diesel, micro / mini hydro, small wind, and hybrid systems -- need to be differentiated"*

*4th May 2017*

# Rural Solar Micro Grids
# Selected key aspects

**Xavier Vallvé** and **Pol Arranz**

Trama TecnoAmbiental (TTA)

Barcelona - Nairobi - Sao Paulo

# PIONEER EXPERIENCE IN RE RURAL MICRO-GRIDS (MSG)

*Akane (Morocco)*

*Santo Antâo (Cape Verde)*

*3 villages (Chad)*

*Burundi*

*Isla Floreana (Ecuador)*

2016

2015

2013

2012

2009

2007

2006

2005

2002

1997

1994

*Cal Peraire (Spain)*

*Beni Said (Morocco)*


*Las Balsas (Ecuador)*

*Rwanda, Tanzania, Kenya*

*Escuain (Spain)*

*Atouf (Palestine)*

*4 villages (Ghana)*

**1987: Beginning**
*Country house electrification (Spain)*

*La Rambla del Agua (Spain)*

*Diakha Madina (Senegal)*

# Micro-grid with Solar Generation (MSG) - definition -

- Geographical area with multiple clients supplied with electricity services using off grid solar generation
- Electricity generation based on solar PV neration or hybrid (RE + genset)
- Steady village-level electricity service, offering also the possibility to be upgraded to either more capacity, clustering or interconnection
- Capacity to loads from 5 up to 100's kW
- Distribution grid in Low Voltage (no transformers)
- Single or 3-phase grid
- Under one business scheme
- Innovations in billing and payment methods.

*PV Hybrid Micro Grid in West Bank, Palestine*

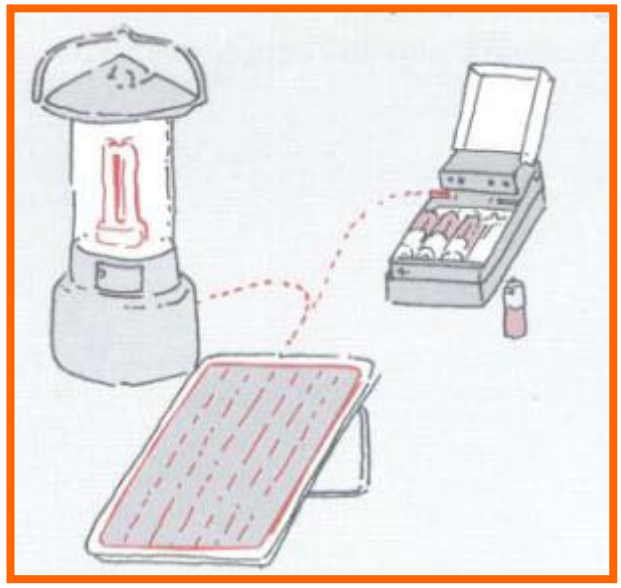
**Challenge: sharing the energy available without conflicts**

➔ **Need comprehensive experience in technical and management levels with multidisciplinary skills**

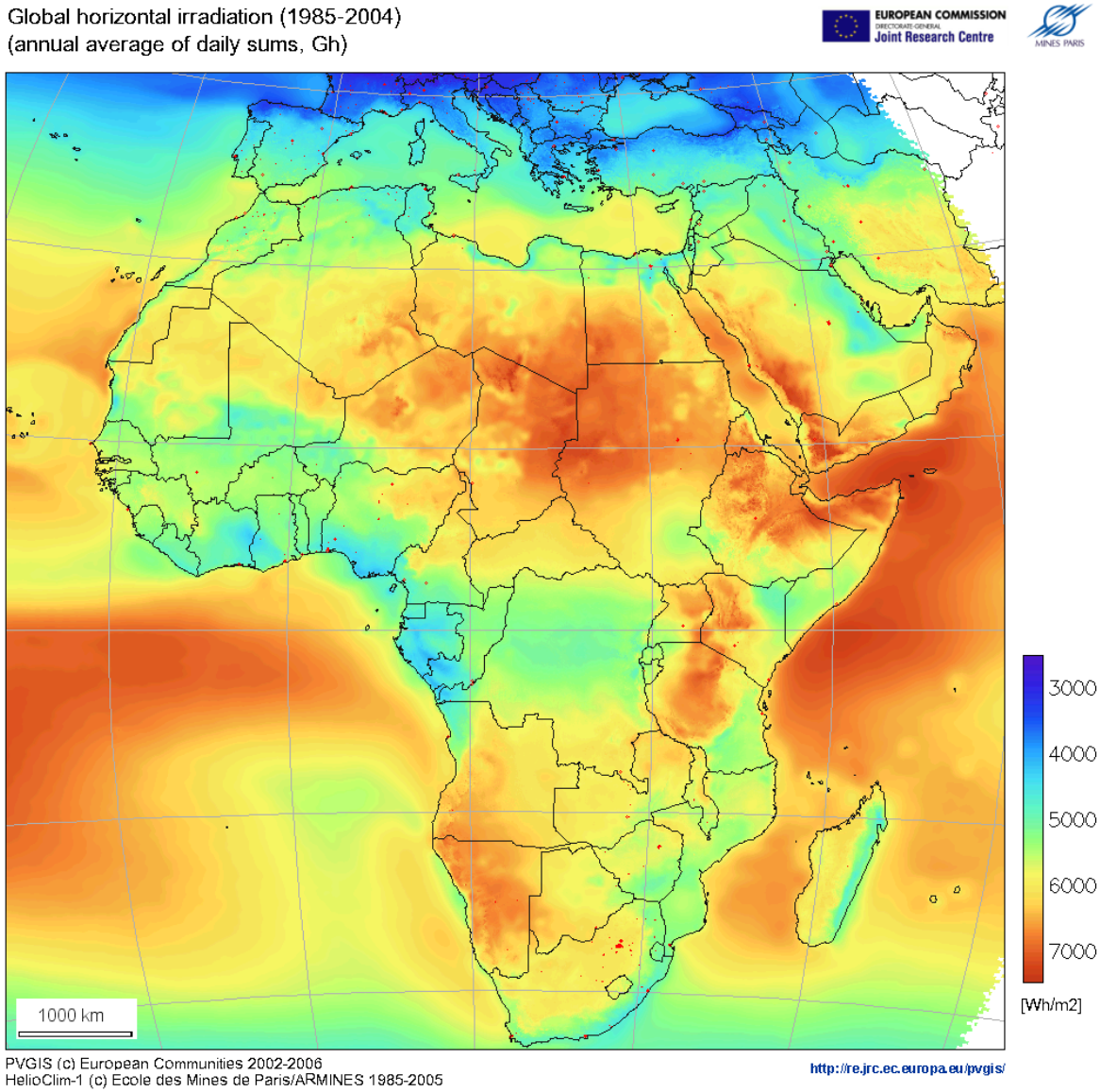
➔ **Need innovative approach to energy distribution and metering!**

# Most outstanding attributes of photovoltaic technology

- Universality of the resource
- Simplicity and modularity
- Reliability
- Social-environmental benefit
- Economic cost-effectiveness

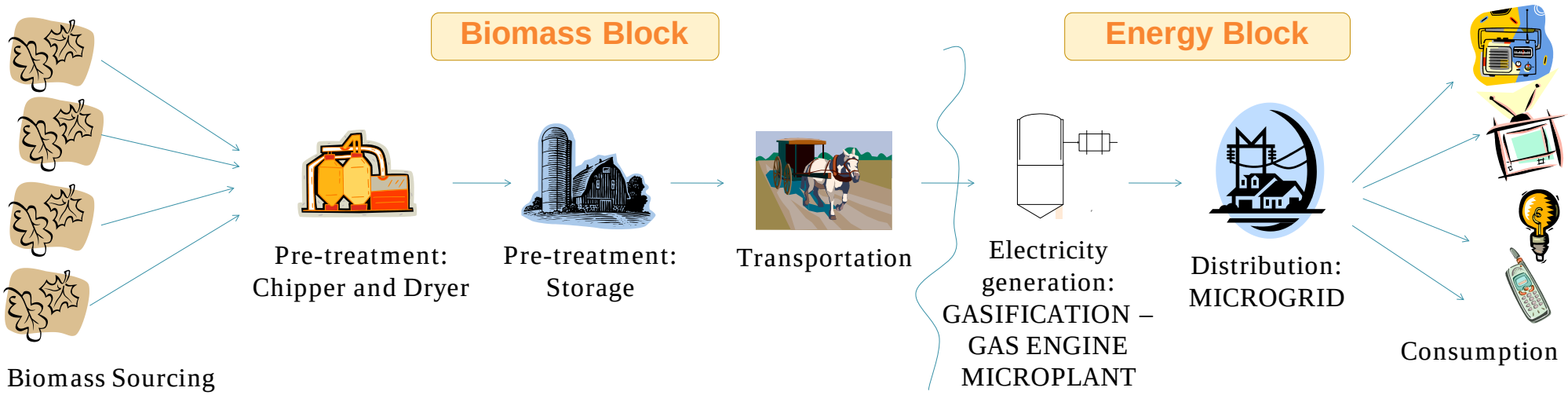


# Universality of the resource




Relatively uniform distribution

# Biomass minigrids: supply chain approach is key




## Key Issues in a biomass to electricity supply chain:

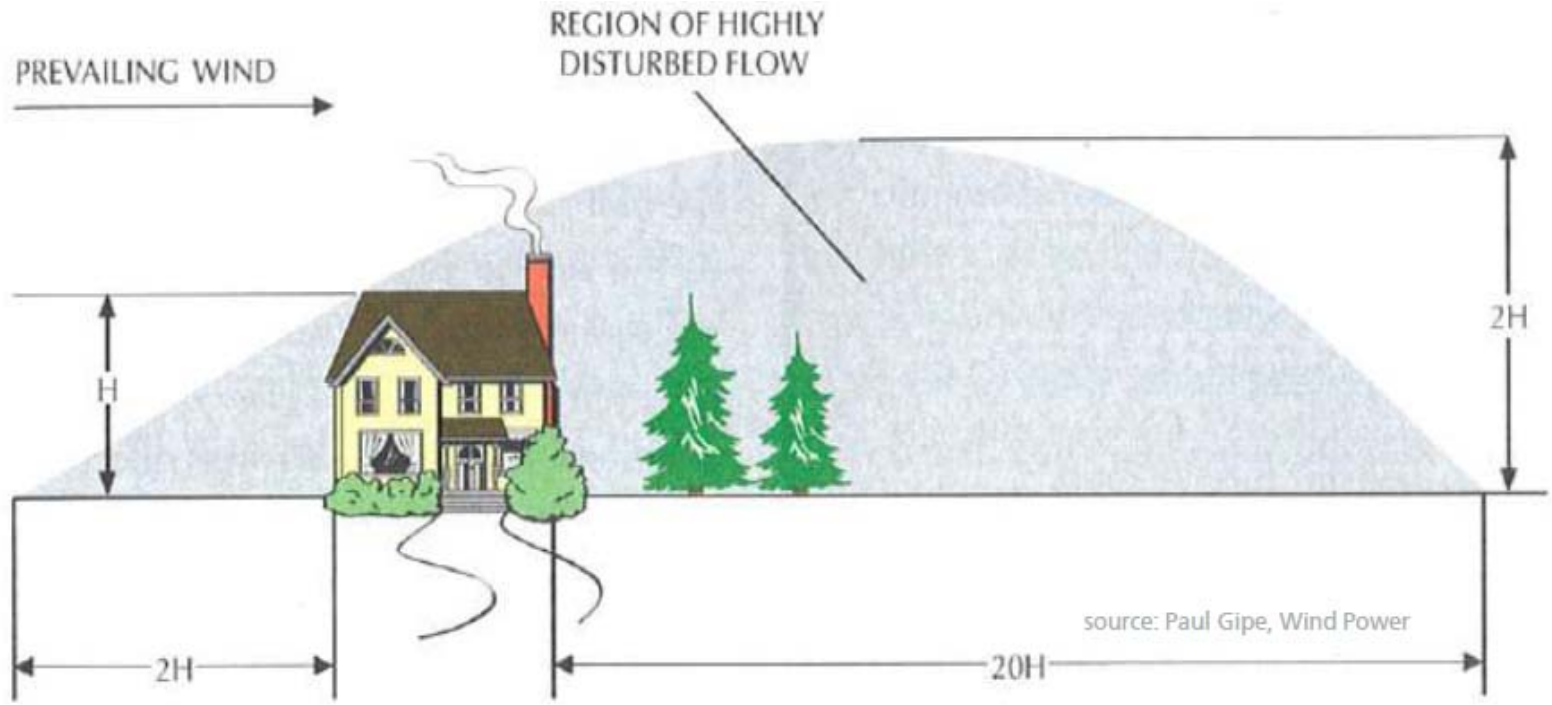
- Flexible enough to react to sudden changes in any of the chain stages
- Feedstock availability, distribution or shipping channels, import duties, etc.
- Professional staff at different levels:
  - Biomass block with local specialists to handle duties, customs and political issues.
  - Energy block with Engineering + M&O&M qualified staff (similar requirements to a Genset based powerhouse)

# Wind turbine minigrids: site specific resource

## Local wind conditions

### Siting and choosing tower height

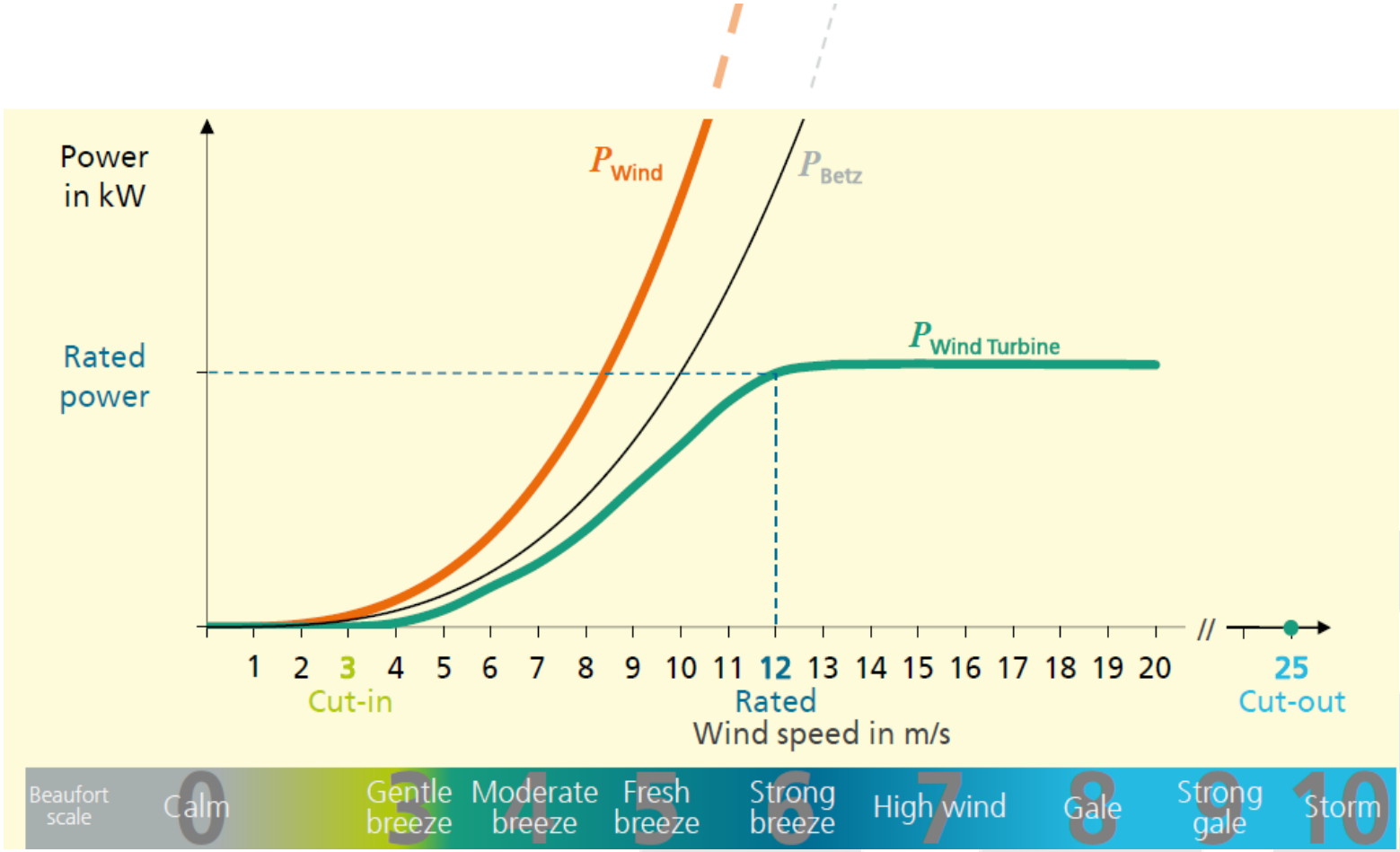
- Siting of small wind turbines:
  - near the place of electricity consumption
  - no wind data available
  - safety, vibration



# Wind turbine minigrids: site specific resource

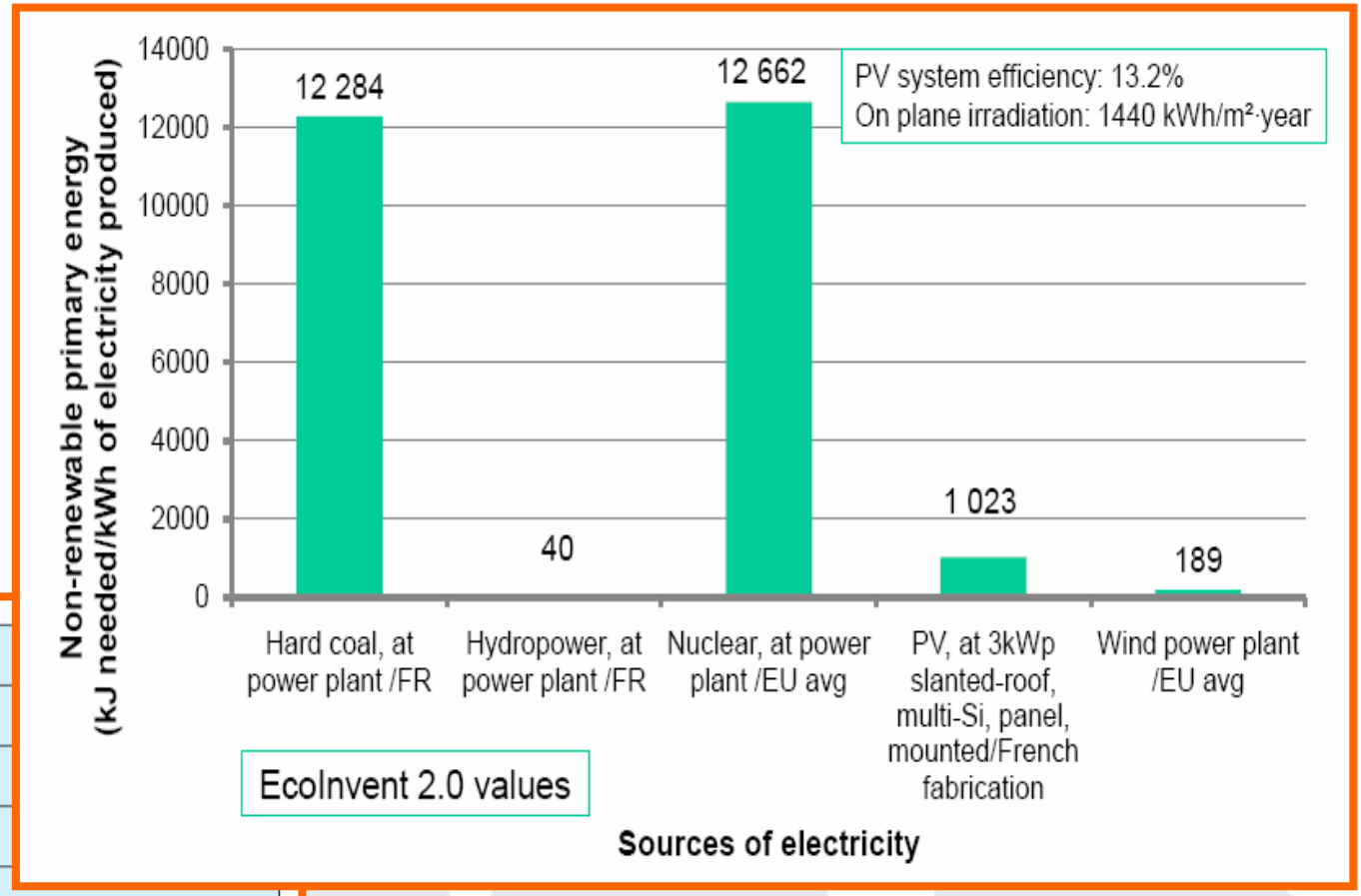
## How much power is in the wind?

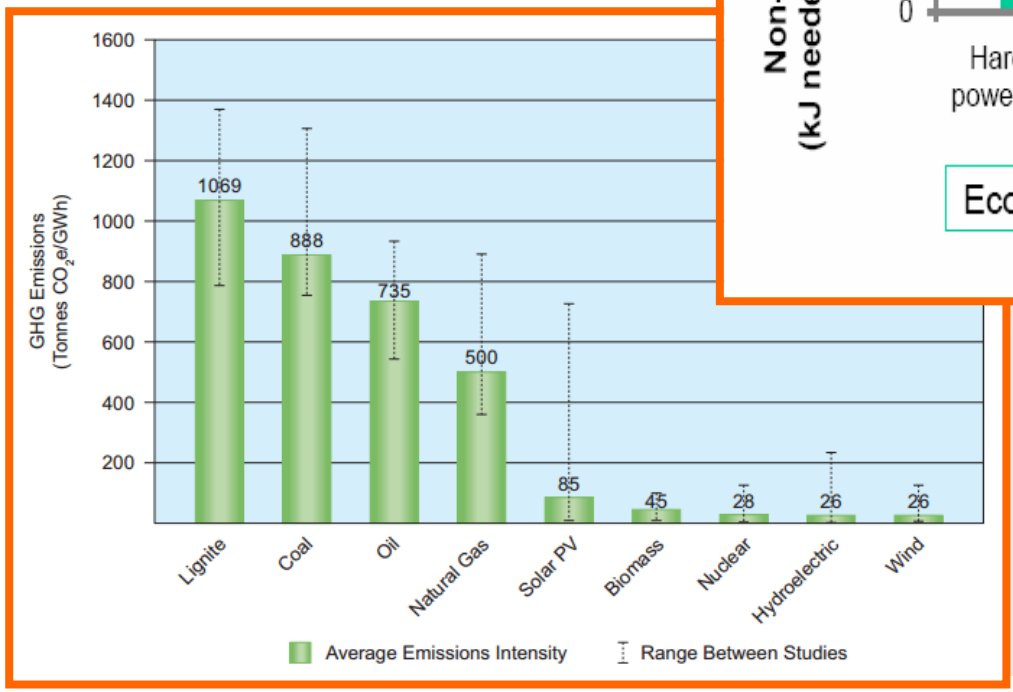
**Power curve and wind speed**



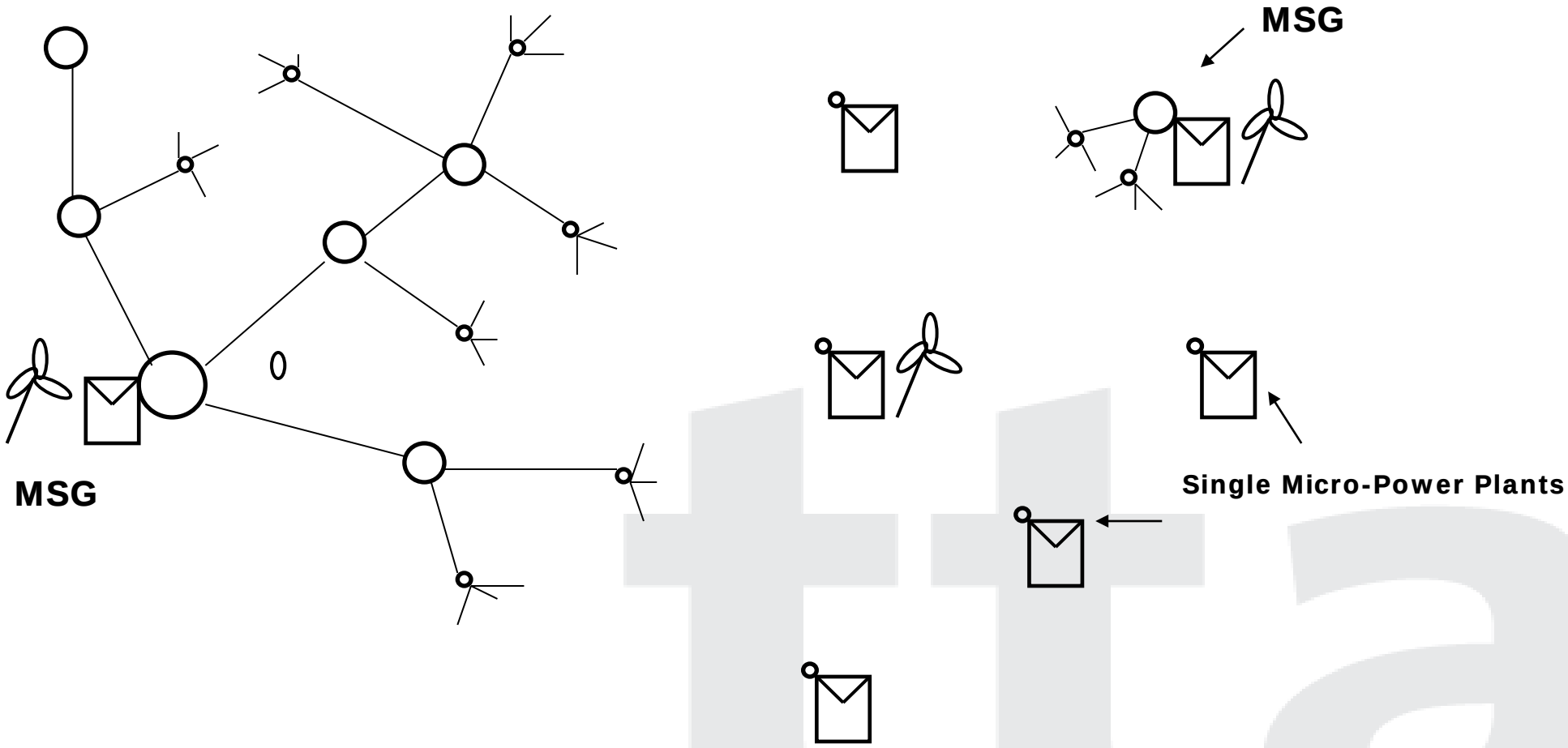

Ghana Microgrids Electricity Services

# Environmental impact

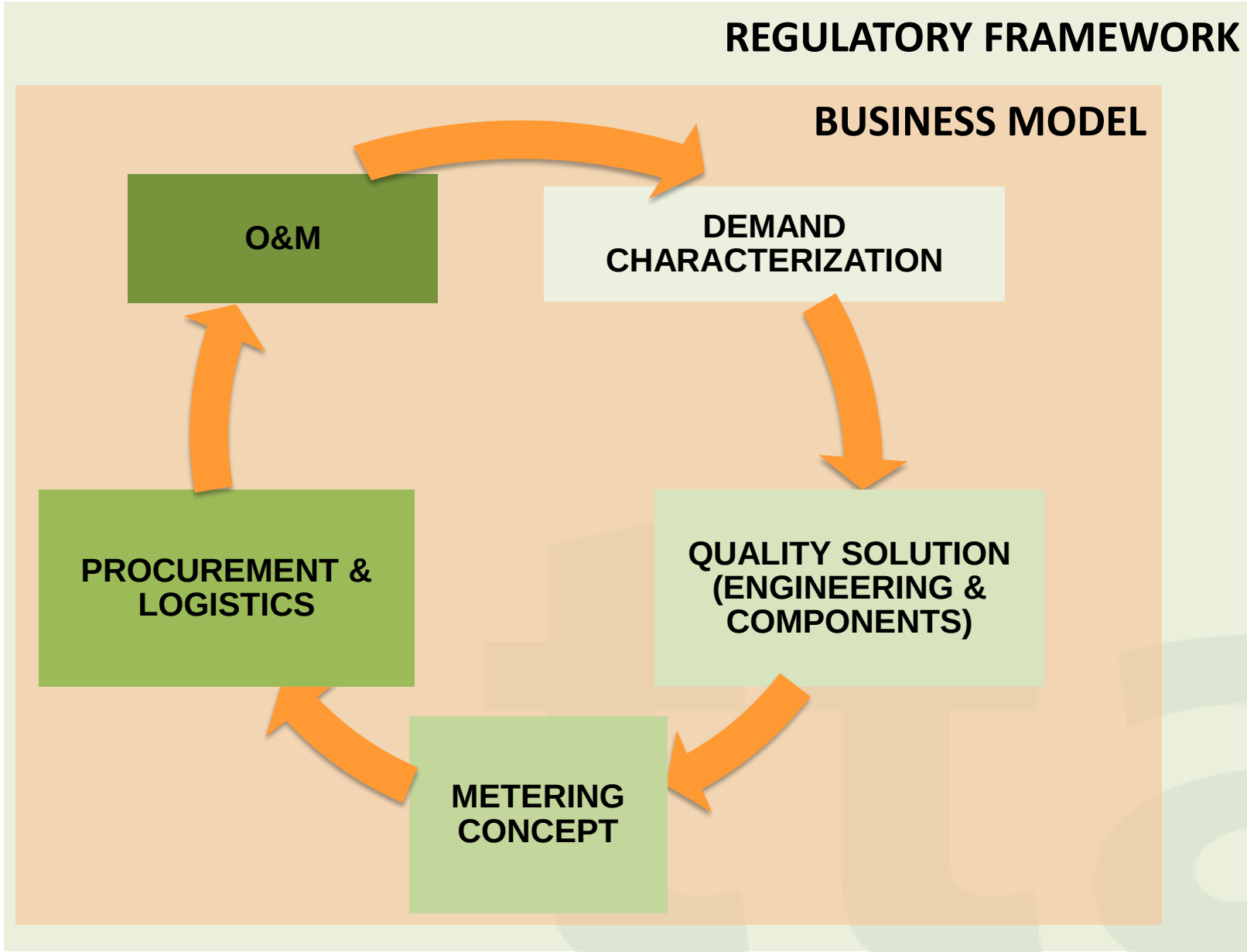


# VISION: Universal electrification with single plants and micro grids in one service area



# CRITICAL SUCCESS FACTORS



# **Demand Segmentation** (used by TTA since 2004)

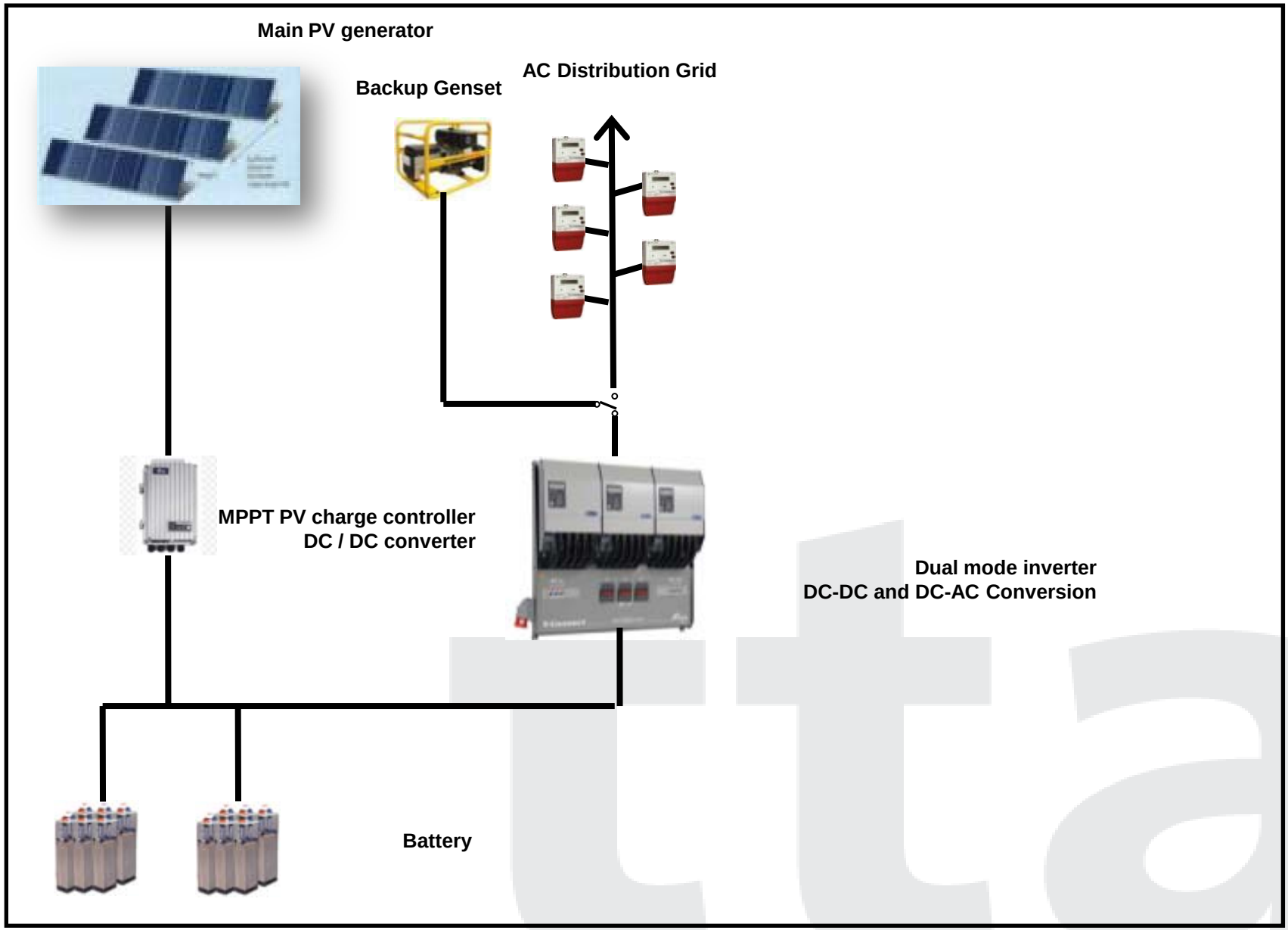
Consumers grouping according to energy daily demand and service category

| | **Category A** | **Category B** | **Category C** | **Category MSG** |
|---|---|---|---|---|
| **Type of use** | Individual basic "very low and low energy consumption" (lighting and audio/video). | Individual medium services (same as category 1 + freezer or refrigerator and appliances)<br>Or community services (health care centre: lighting and freezer, etc.) | Individual high services<br>(same as category 2<br>+ washing machine, vacuum cleaner, odd jobs, etc.)<br>Or public lighting | Multi-user micro grid with aggregate of individual and community loads of category A, B and C |
| **Essential consumption Characteris-tics** | • Low number of receivers<br>• Low power of receivers<br>• Slim rigid load profile (P1) | • Medium number of receivers<br>• Receivers more powerful<br>• Slim rigid and base load profiles (P1+P2+P3)<br>• or Multiple basic users (P1+P1+ .. n) | • High number of receivers<br>• Some receivers are powerful<br>• High instantaneous power inrush<br>• "Variable" load profile (P1+P2+P4+P5)<br>• or Multiple users (P1+P1+P2+ .. N) | • Powerful receivers<br>• High instantaneous power inrush<br>• Many users some with "Variable" load profile (P1+P2+P4+P5) |
| **Probable needed power** | $P \leq 100$ W | 0,1 kW < $P$ < 1,5 kW | 0,5 kW ≤ $P$ < 3 kW | $P \geq 3$ kW |
| **Average energy over 24h** | $E \leq 1000$ Wh/d | $E \leq 2$kWh/d | 2,2 kWh/d < $E$ < 5 kWh/d | $E < 50$ kWh/d |

# **Demand Segmentation** (recent evolutions)

| ALL | | Average % of tariffs connection per Use Type | | | NREL MGS Tier kWh: | BGFZ/SWEDEN Tier kWh | NREL MGS Tier W: |
|---|---|---|---|---|---|---|---|
| EDA (Wh/day) | Maximum Power/connection type (W) | Household | Institution | Productive | | | |
| 275 | 500 | 2,2% | 0,0% | 0,0% | | Tier H3 | Level 3 |
| 550 | 500 | 28,4% | 2,7% | 8,7% | Level 2 | Tier P4, I1 | |
| 1100 | 500 | 10,9% | 2,3% | 11,6% | | | |
| 1200 | 500 | 0,0% | 0,0% | 0,1% | | | |
| 1650 | 500 | 6,6% | 0,5% | 5,8% | | | |
| 2200 | 1000 | 0,3% | 0,5% | 5,3% | | | Level 4 |
| 2750 | 1000 | 3,4% | 0,3% | 4,0% | | | |
| 3300 | 1000 | 0,0% | 0,2% | 0,5% | Level 3 | Tier P5, I2 | |
| 3850 | 1500 | 0,0% | 1,1% | 1,5% | | | |
| 4400 | 1500 | 0,2% | 0,5% | 0,9% | | | |
| 5500 | 1500 | 0,0% | 0,3% | 0,8% | | | |
| 6600 | 1500 | 0,0% | 0,0% | 0,7% | | | |
| 7600 | 2000 | 0,0% | 0,0% | 0,1% | Level 4 | | |
| 13400 | 2000 | 0,0% | 0,0% | 0,0% | | Tier P6, I3 | |
| 14850 | 2000 | 0,0% | 0,0% | 0,0% | | | |
| 30625 | 5000 | 0,0% | 0,0% | 0,2% | | | Level 5 |
| 53350 | 5000 | 0,0% | 0,0% | 0,1% | Level 5 | | |

# PV plant typical configuration



# PV plant typical configuration

- RE Generation PV is more universal; may be hybridized with genset, wind, biomass if available.
- Operation through converters and energy management units
- Small to medium plants with battery 1 to 300 kWh, designers prefer ELV (12,24,48 V) for intrinsic safety
- MWh configurations are different and under commercial development

# Battery handling

- Transportation difficulties in accessibility of sites

# Tariff Schemes for energy management

**Financial Sustainability :**

• Tariffs designed to ensure enough revenues to cover its M&O&M, replacement and unforeseen costs and, including or not, pay-back of investment

**Tariff schemes:**

-Flat subscription

-Power-based

-Energy-based

-Service-based subscription

-Combination of above (ie Energy Daily Allowance)

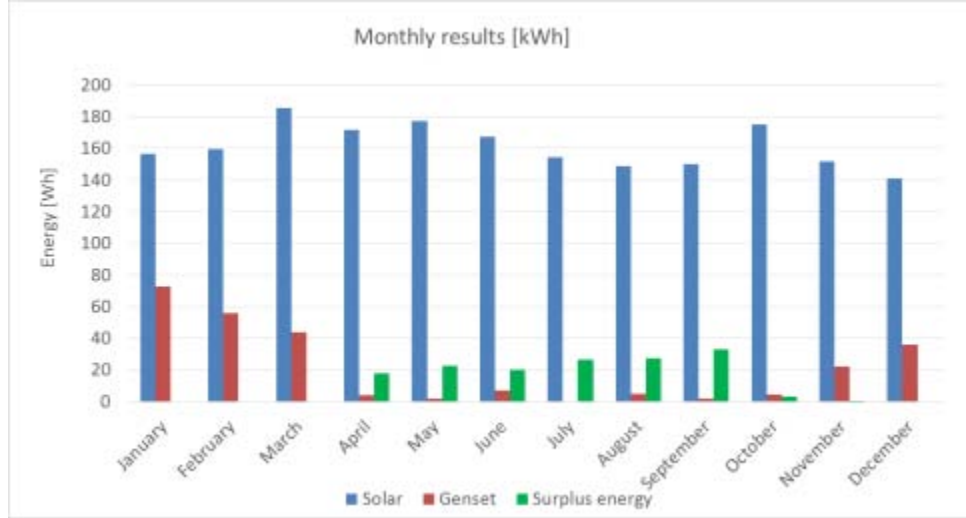
Pre-payment or post-payment

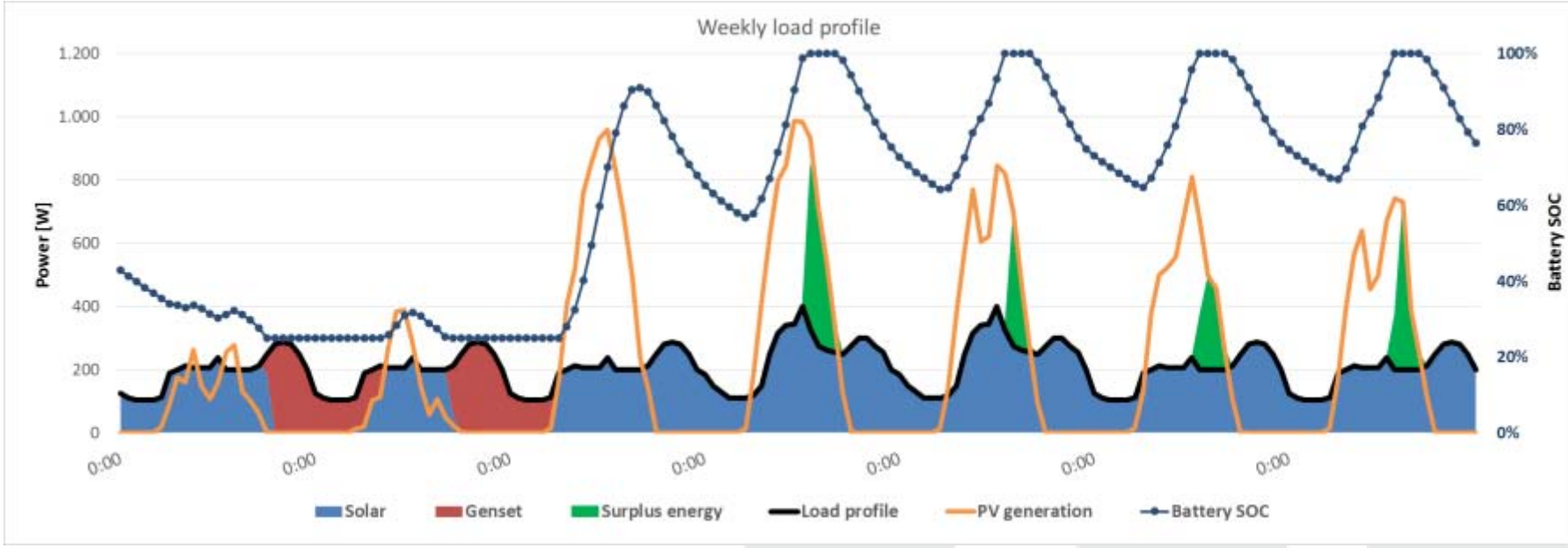
**Linked to the quality of service:**

| Service duration | Service disruption | Technical factors |
|---|---|---|
| 24/7 | < 1% | Voltage drop |
| 18/24, 12/24, … | < 10%, < 15%, … | Frequency variation |
| Weekends | On demand | |
| Seasonal | … | Harmonic Distortion |

# Real time price signal

- Productive use and load management



# Factors affecting PV hybrid microgrid costs (< 1 MW)

- Grid connected to weak grids vs fully autonomous
- Economies of scale
- Demand, load profile and RE sources => engineering design
- Quality of service – ie service categories (hrs/day; power; energy; voltage)
- Market maturity
- PV fraction:

| Category | Indicative PV annual energy fraction | Indicative PV rated capacity/load ratio | Characteristics |
|---|---|---|---|
| Low | < 20% | < 50% | No batteries<br>No control |
| Medium | 20%-50% | > 50% | Batteries with autonomy 1-2 days<br>Large genset |
| High | > 50% | > 150% | Batteries with autonomy > 2 days<br>Small gensets |

# Financial – Economic component → Viability!

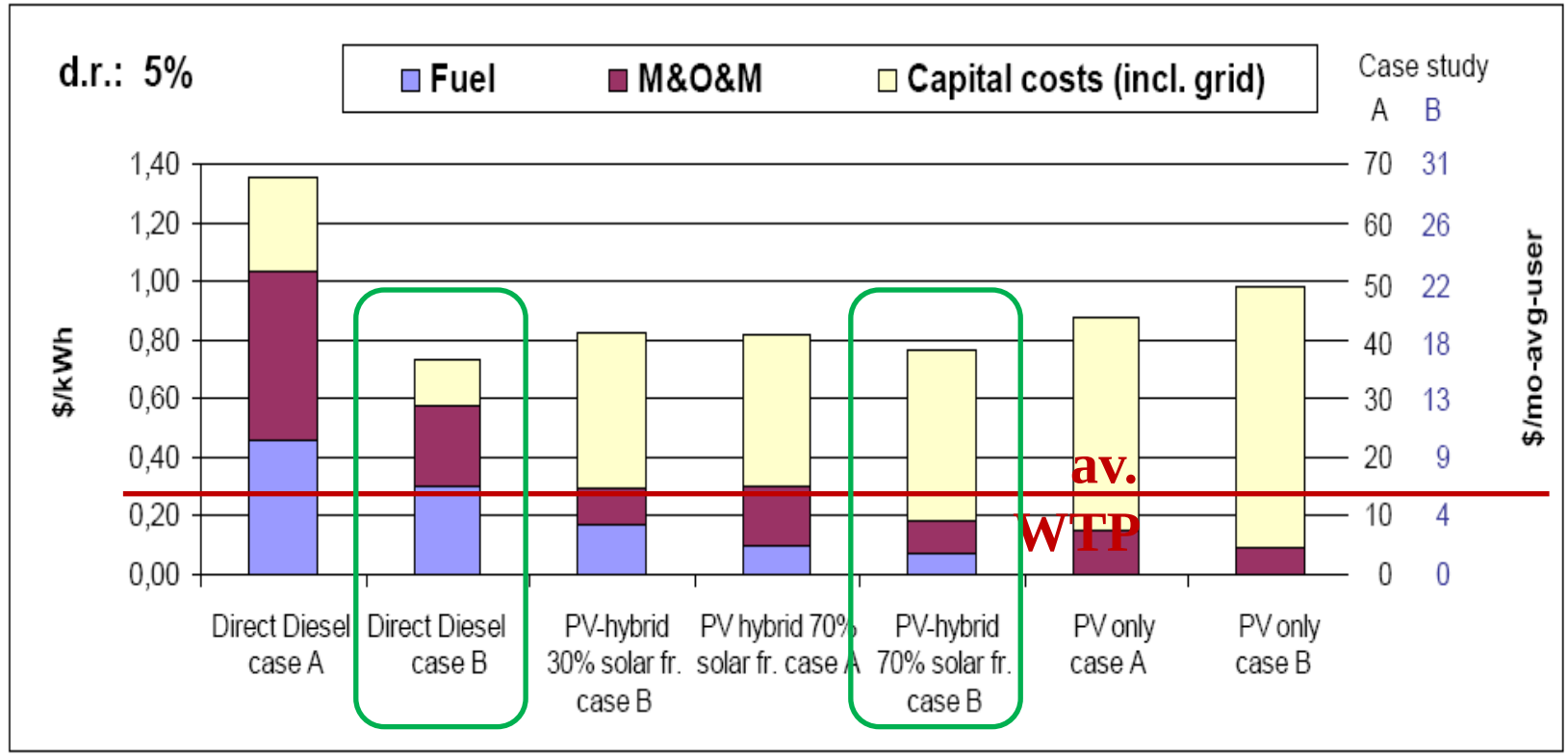
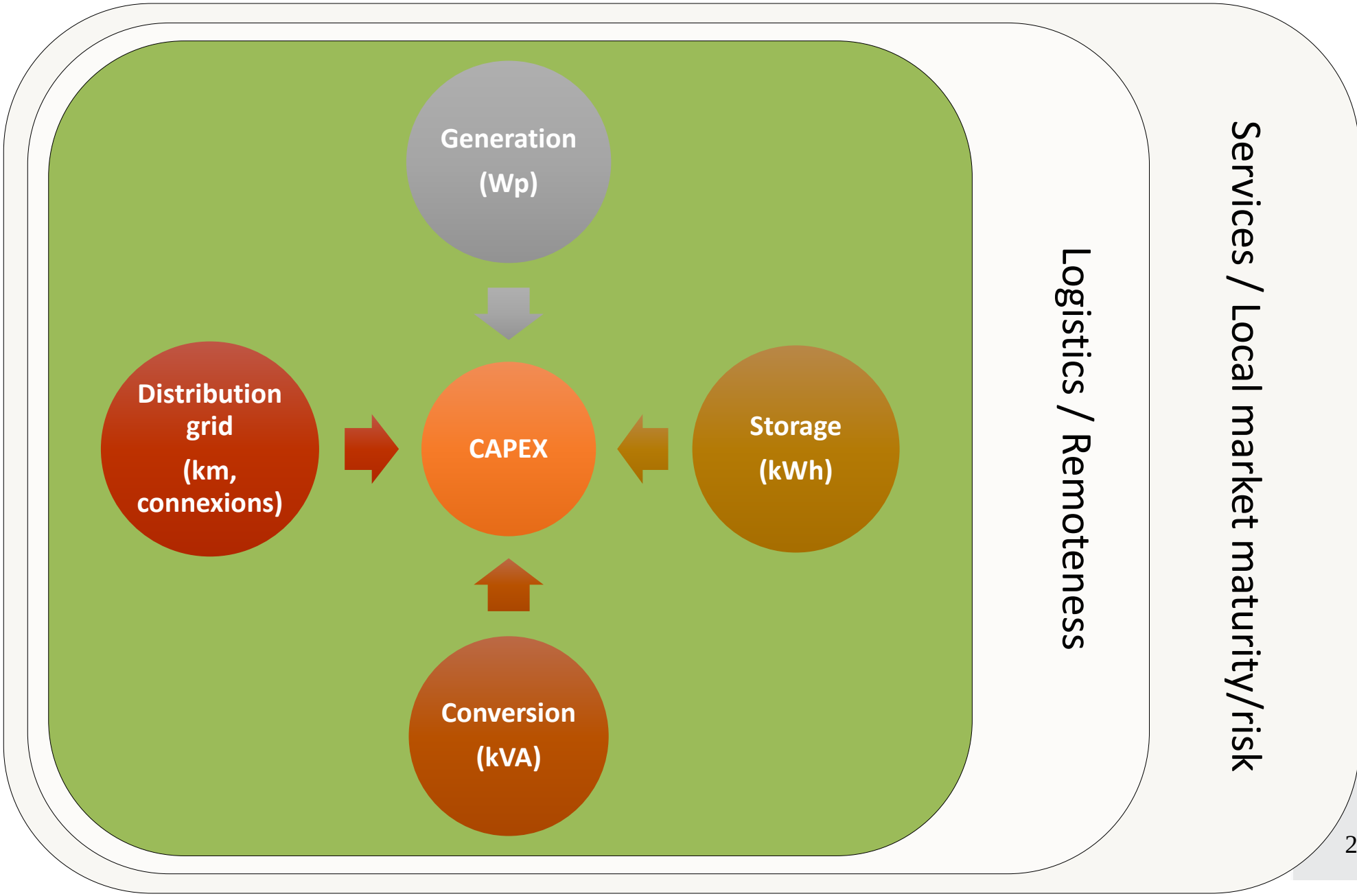


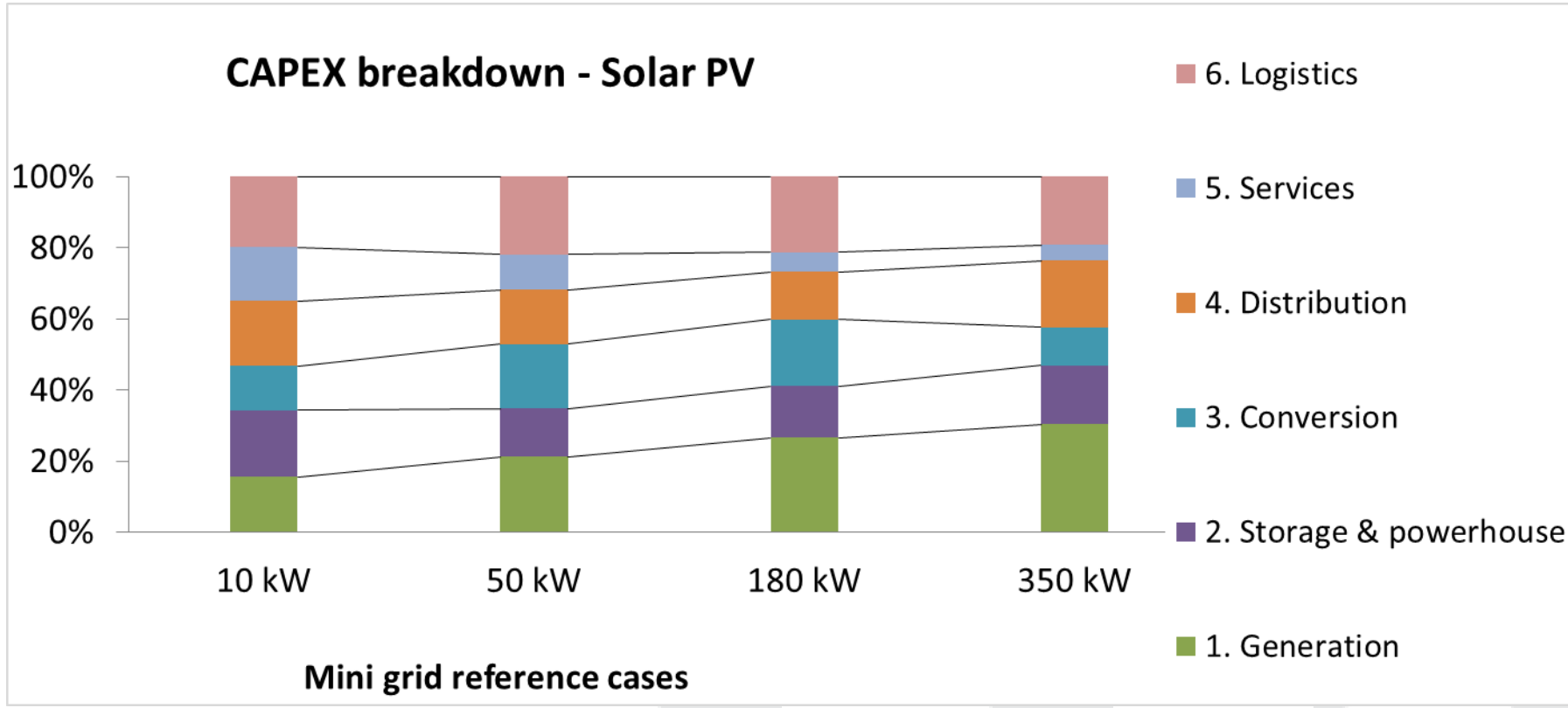

**Figure 3**.- Breakdown of levelized energy costs in Floreana (case A) and Padre Cocha (case B) at 10% and 5% discount rates. Average kWh cost are acceptable to compare different solutions for one application, but for different systems for different locations and small demands, transaction costs, local management, etc, represent a high fraction of the service costs, and the cost per user must also be assessed.

Source: Arranz-Piera, P. Vallvé, X., González, S. (2006)

# Cost structure – investment costs



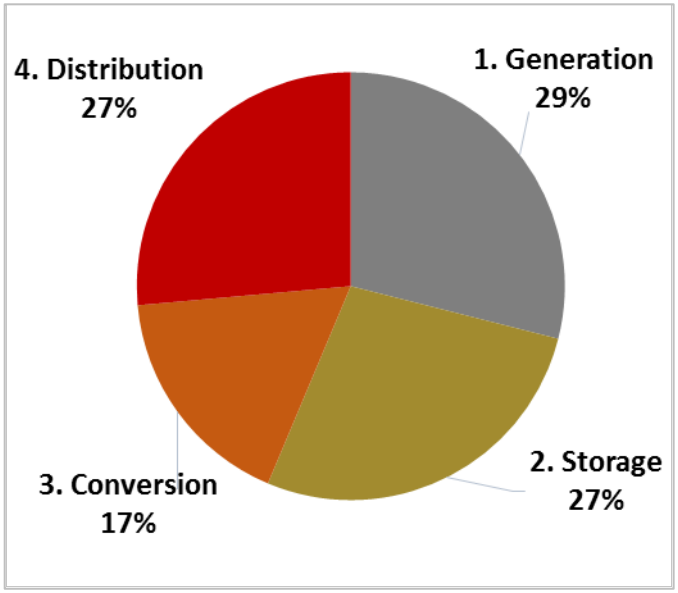
# Investment costs and capacity




Source: ECA, TTA, Access Energy, 2014

# Case study – Pediatorkope (Ghana)

**Investment costs**




**Logistics**

€5 per mile of maritime

€61 per km of terrestrial

**Services**

Project management and engineering: 10% CAPEX

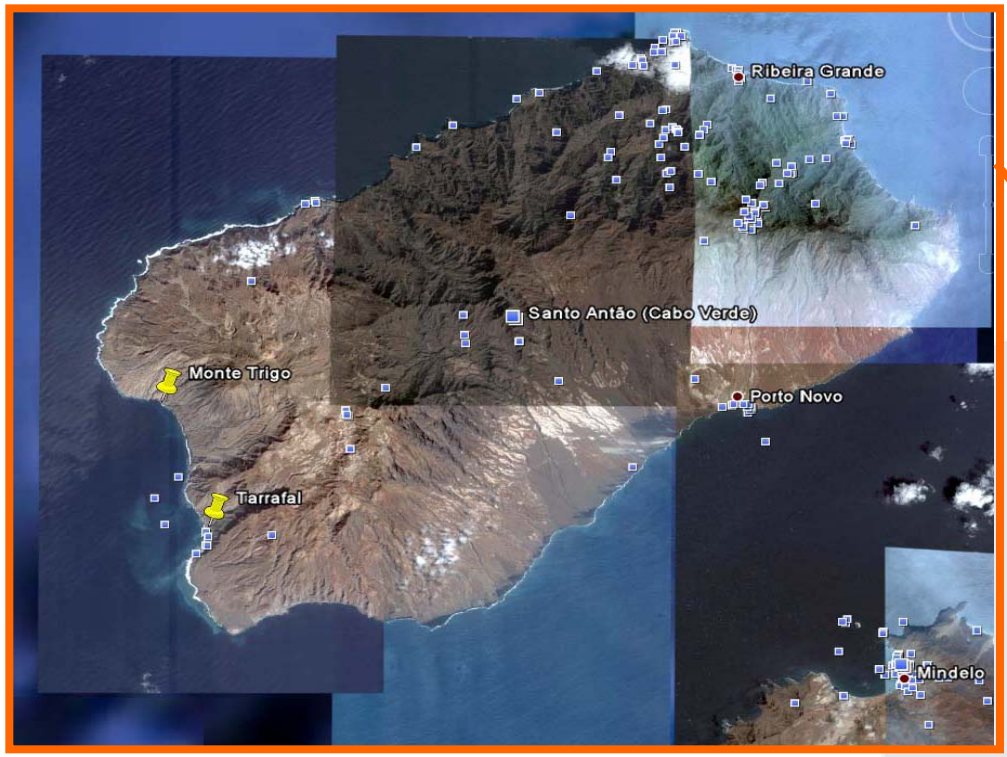
Capacity building & Training: 3% CAPEX

**Low maturity market**

***Not per kWp!***

# Example MSG

## Monte Trigo, Cape Verde



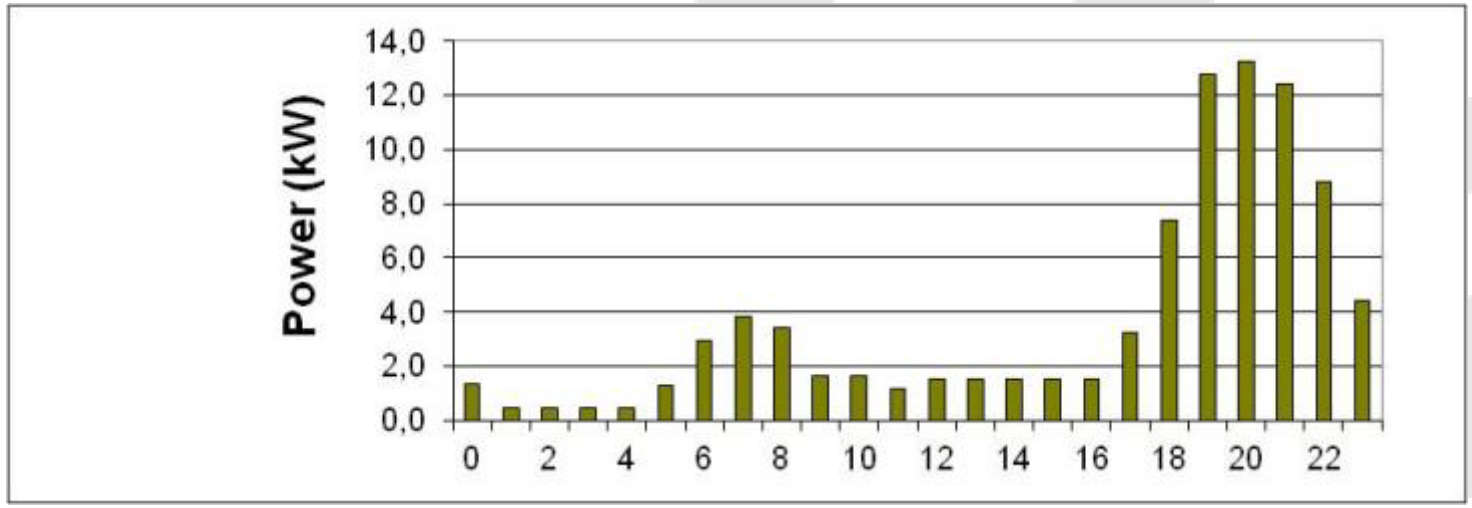

Site: Monte Trigo, 17º01'N , 25º19'O , 00 m s.l.

# Demand characterization

- **Monte Trigo community:**
  - 56 families
  - 1 school
  - 1 health center
  - 1 street lighting
  - 1 periodical deferrable load: ice machine

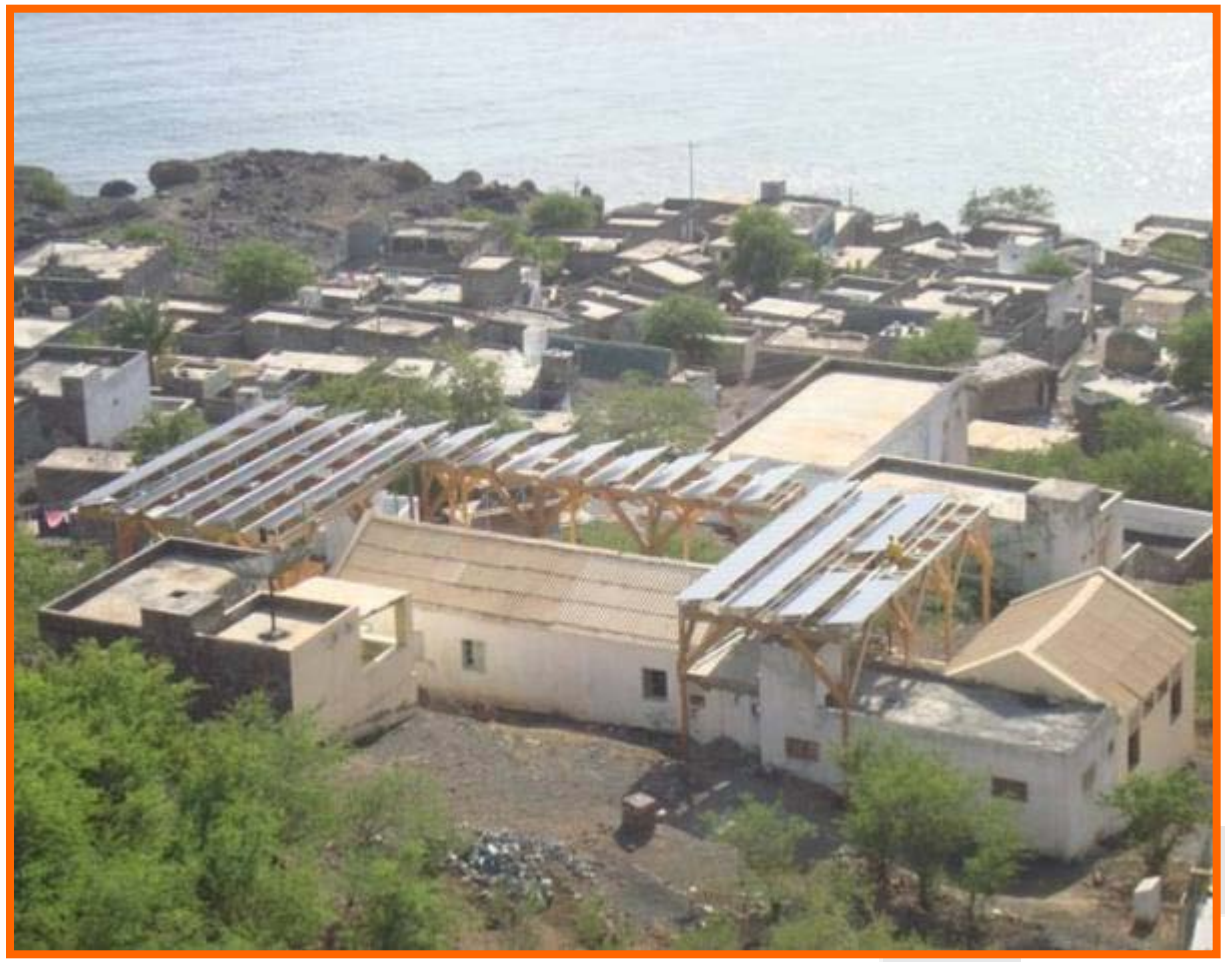
| Category | EDA [Wh] | Power Limit [kW] | Max. "store" Capacity (EDA) | Recommended Monthly Fee [€] |
|---|---|---|---|---|
| **T0301** | 825 | 0,55 | 6 | 11,52 |
| **T0401** | 1.100 | 0,55 | 6 | 14,58 |
| **T0602** | 1.650 | 1,1 | 6 | 21,12 |
| **T0802** | 2.200 | 1,1 | 6 | 27,64 |
| **T1203** | 3.300 | 1,65 | 6 | 40,30 |

- **Daily aggregate load profile:**

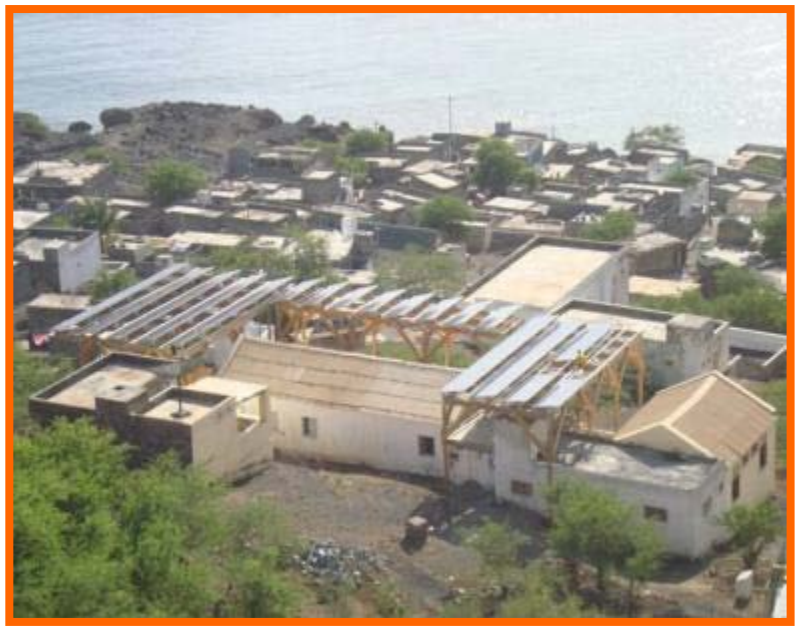


| RURAL RE MICROGRID ( 75 kWh/day) | |
|---|---|
| **PV GENERATOR** | |
| Installed PV capacity | 27 300 Wp |
| Module type | 130 Wp 36 cell – mono crystalline |
| Number of modules | 210 |
| Inclination / orientation | 15º / +20º S |
| **PV CHARGE CONTROLLER** | |
| Rated power | 2x12 000 Wp |
| Control algorithm | MPPT - Boost |
| **BACK UP GENSET** | |
| Rated power | 20 kVA 3- phaseS |
| Fuel | Diesel |
| **BATTERY** | |
| Number of elements (voltage) | 24 (48V)X2 |
| Type | Lead acid OPzS tubular |
| Capacity (C100) | 3 850 Ah – 370 kWh |
| Autonomy | 4 days |
| **INVERTER** | |
| Voltage input / output | 48 V DC / 230 V AC |
| Rated power | 2 X 8 000 W |
| Harmonic distortion | < 2,5% |
| **DATA LOGGER** | |
| Type of data | Energy, voltage, radiation, etc. |
| **ELECTRICITY DISPENSER – METER** | |
| Input | 230 V AC 50 Hz |
| Maximum current | Configurable |
| Algorithm | Configurable Energy Daily Allowance |
| **DISTRIBUTION LINE AND STREET LIGHTING** | |
| Line Length | 800m |
| Number of lamps | 20 |
| Type | 70 W hp Na / 2 level electronic ballast |
| **INDIVIDUAL LOADS** | |
| Households 825 Wh/day | 20 |
| Households 1100 Wh/day | 18 |
| Households 1650 Wh/day | 14 |
| Households 2200 Wh/day | 6 |
| School 1650 Wh/day | 1 |
| Ice machine 4200 Wh/day | 1 |

# Added value solution: PV pergola

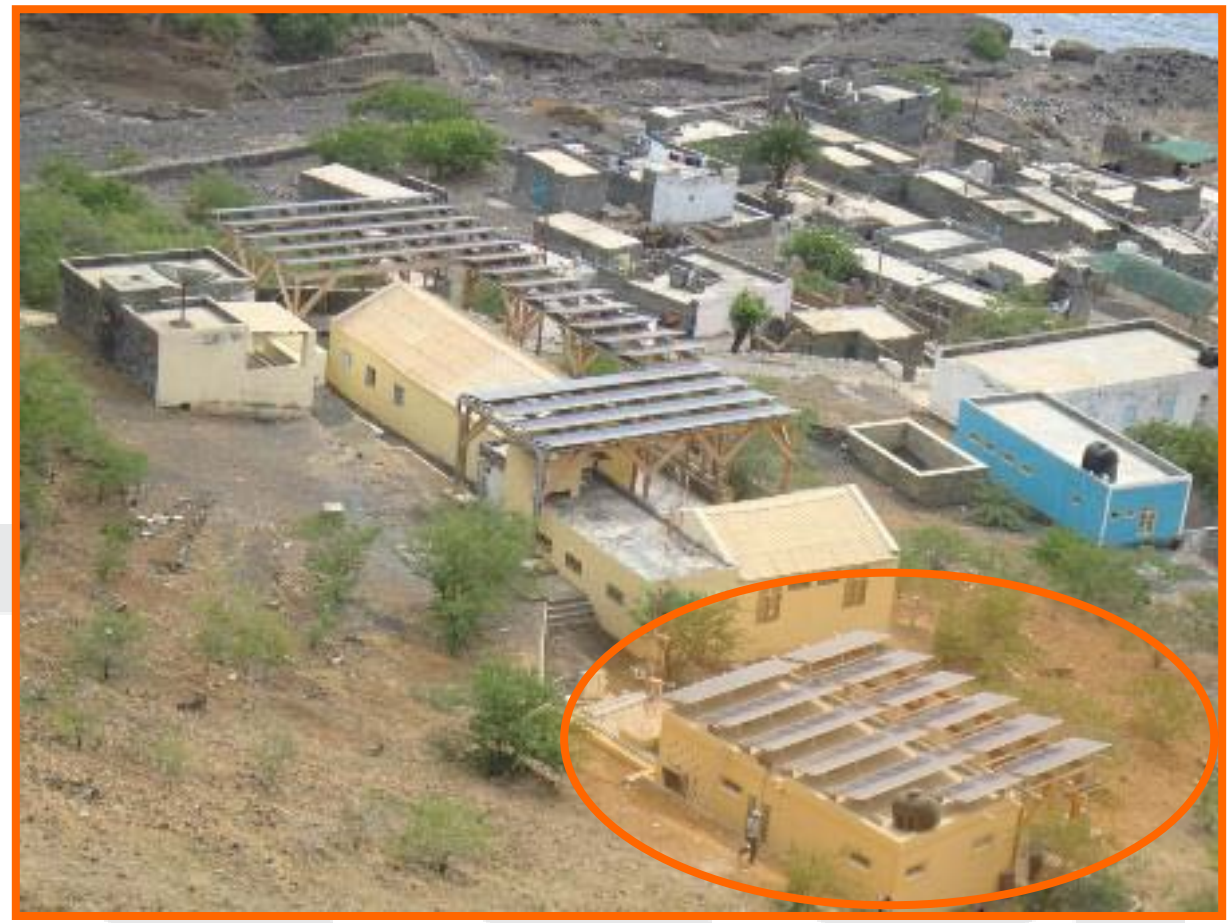


# Added value solution: Scalable



2012

2013



# Added value solution: deferrable consumptions

## Community income generation activity

# Added value solution: Engage the users

# Technical solution: mechanical room

# Technical solution – Single phase LV distribution

# Sustainability: Users and up keepers training


THANK YOU!
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