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EU Technical Assistance Facility for the
"Sustainable Energy for All" Initiative

Rural Electrification and the Different Business Models

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THE ENERGY EFFICIENCY CENTER

Outline

1. General introduction to Electricity Access/Rural Electrification

2. Off-grid Stand-alone PV Systems

3. Mini-grid for Rural Electrification

Main Objectives

Participants to be

- **Aware of the fundamentals of electricity access and rural electrification**
- **Familiar with rural electrification schemes (off-grid) and existing business models**

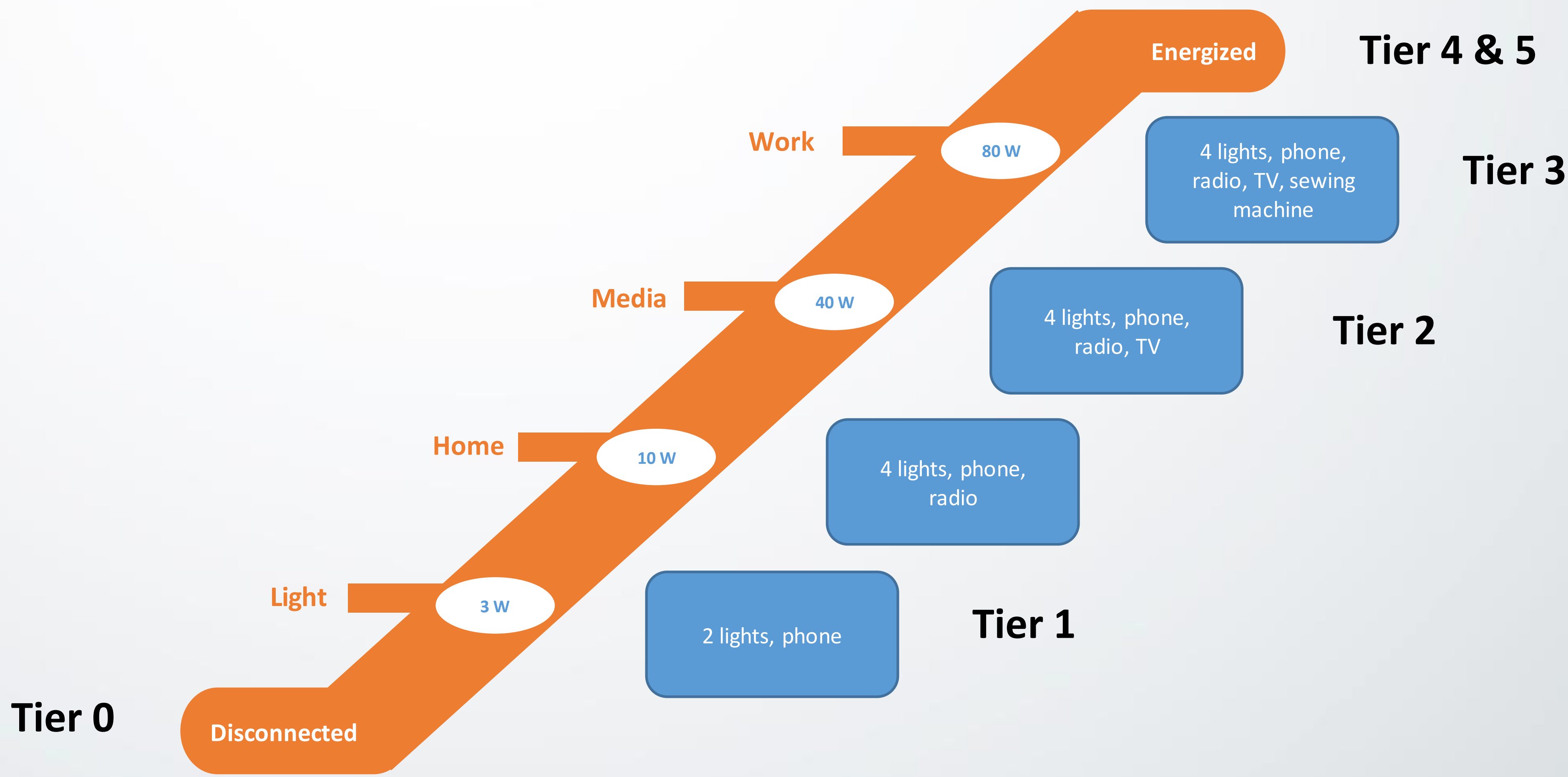
1. Electricity Access & Rural Electrification

Which indicators for electricity access?

- **Electrification rate**: the population with effective access to electricity, compared to the total population (or the total number of households)
- **Electricity access rate**: proportion of population living in electrified localities relative to the total population
- **Electricity coverage ratio**: Number of electrified localities relative to the total number of localities
- **Electricity Service rate or penetration rate**: Population actually having access to electricity compared to the total population of electrified localities.

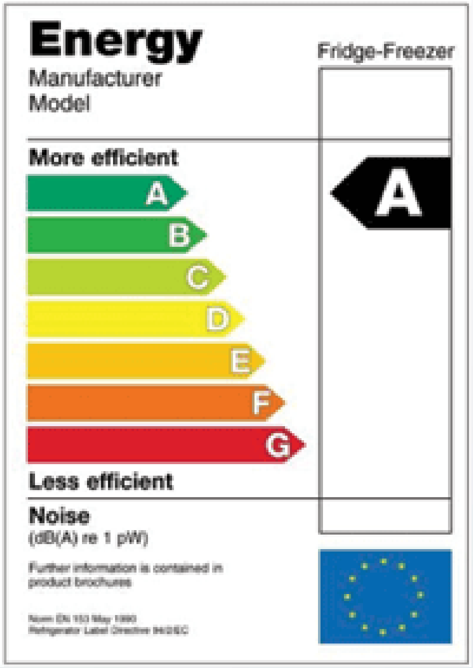
How to get access to electricity?

Access is not a binary state but a process that starts with the basic energy services adapted to the range of affordability

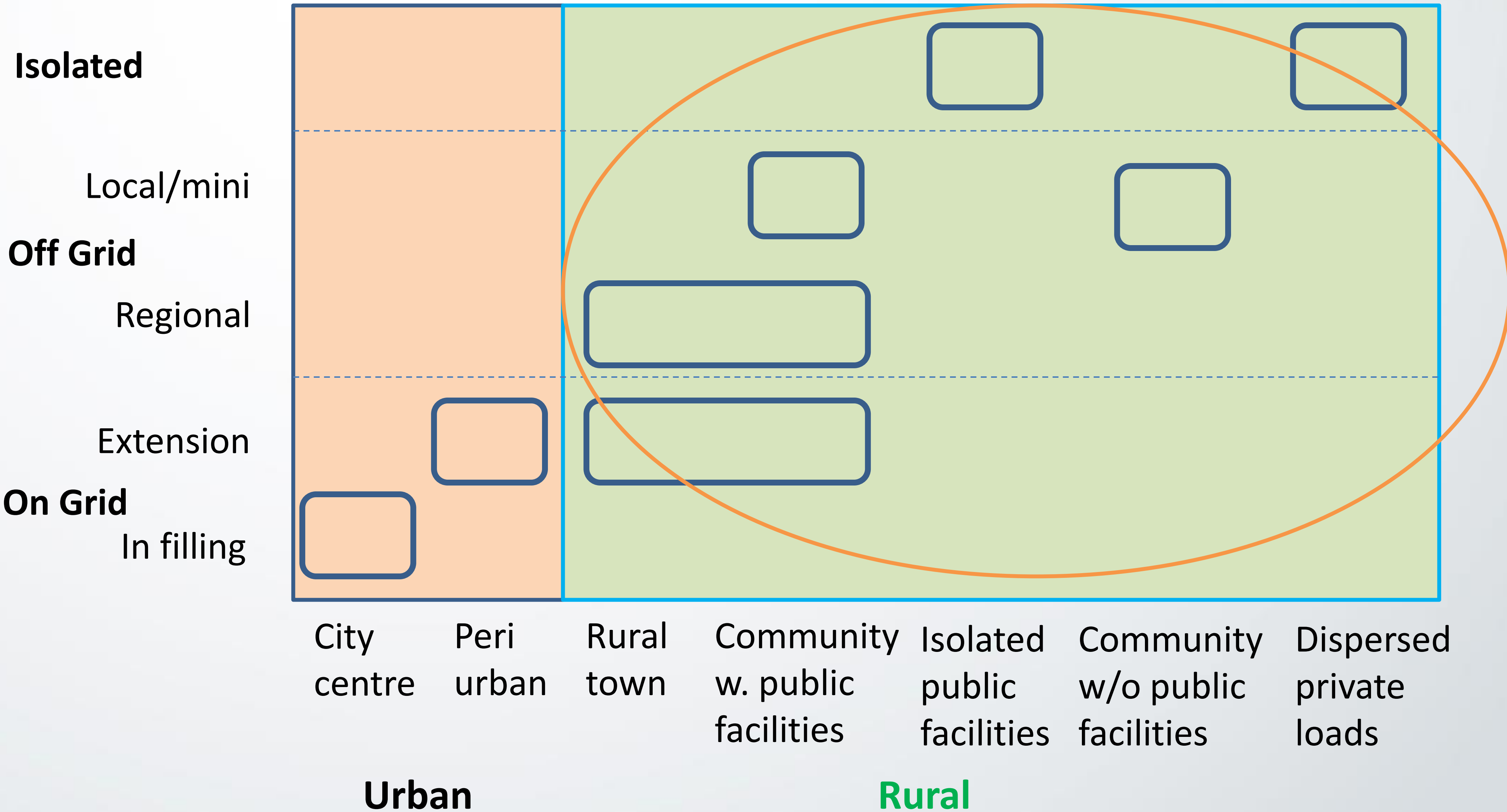


Energy Efficiency unlocks the energy ladder

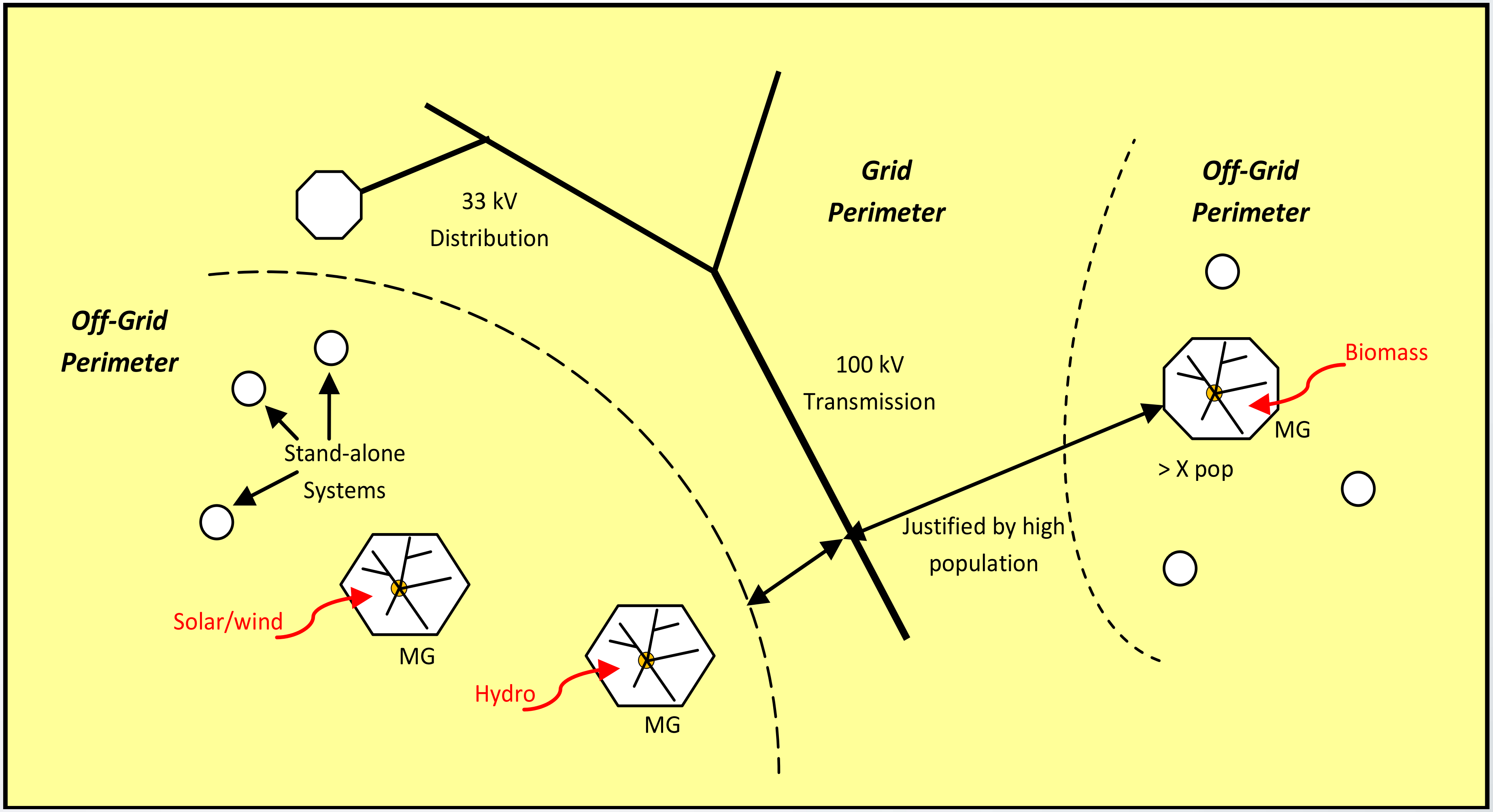
- Replacing incandescent light bulbs with **LED** light bulbs delivers the same energy service for 50-85% less energy
- The most energy efficient **fans** move four to eight times as much air per watt as less efficient fans
- Similar gains possible for **refrigeration**, possibly shared amongst several households
- **Energy efficient appliances (A+)** cost more up front, but cost far less than generating excess power in the long run: Leverage of Energy Efficiency Standards (MEPS) and Labeling (**S&L**)



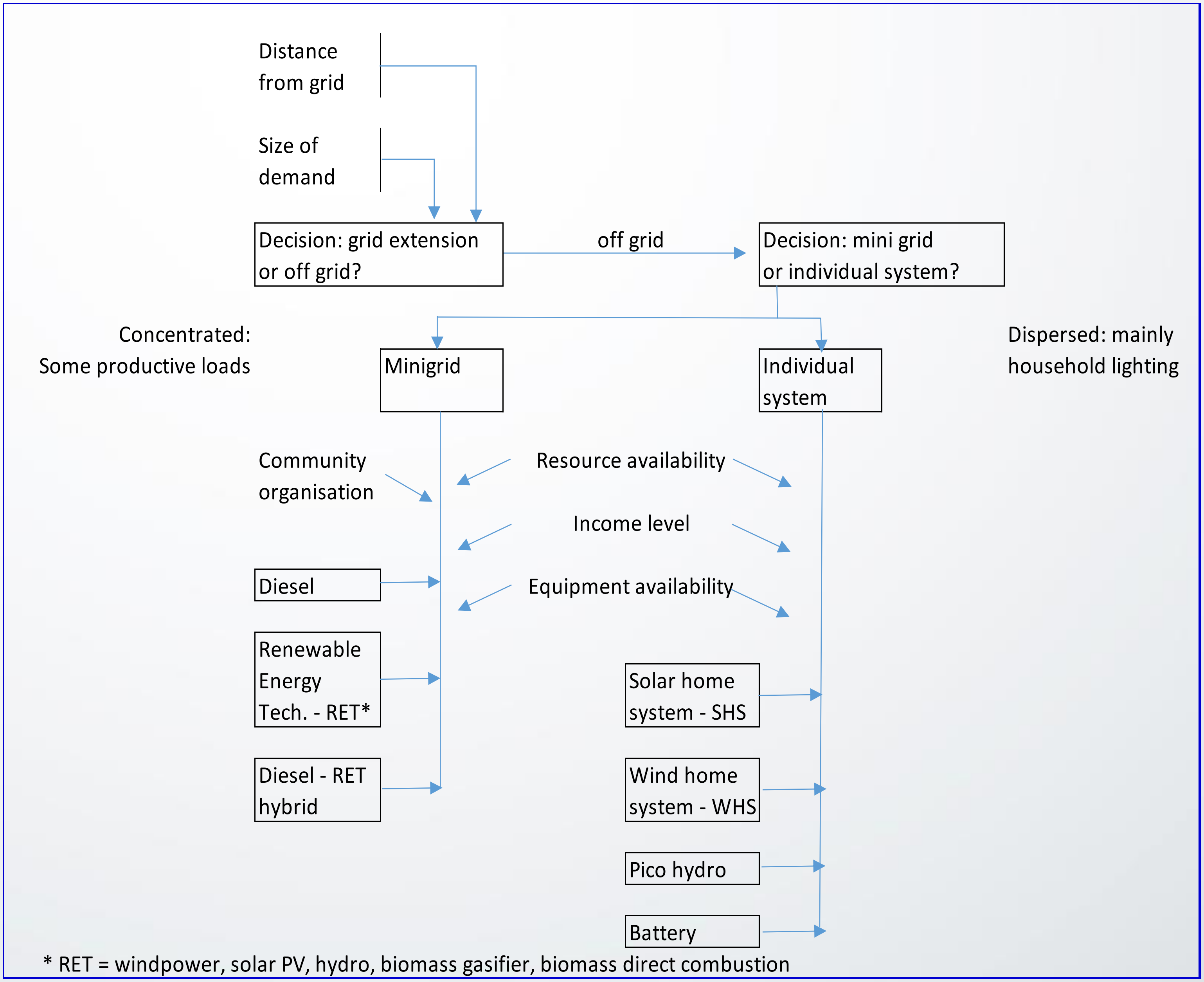
What is Rural Electrification?



Which options for Rural Electrification?



Least cost decision making process for Rural Electrification



Electricity access solutions up the energy ladder

Continuous Spectrum of improving Electricity supply Attributes

Attributes	Tier 0	Tier 1	Tier 1	Tier 1.5	Tier 2	Tier 2.5	Tier 3	Tier 3	Tier 4	Tier 5
Service Description	Kerosene lighting	Task lighting and phone charging (or radio)	Task lighting and phone charging (or radio)	4 lights, phone charging and radio	General lighting and TV or fan (if needed)	General lighting and TV and fan (if needed)	Tier 2 and any low power applicances	Tier 2 and any low power applicances	Tier 3 and any medium power applicance	Tier 3 and any high power applicances
Peak available capacity (W)	-	1	5	10	20	50	200	500	2000	2000
Duration (hours/day)	-	4	4	4	4	4	8	8	16	22
Evening supply (hours/day)	-	2	2	2	2	2	2	2	4	4
Average annual consumption per household										
Load factor		17%	17%	17%	17%	17%	18%	20%	20%	25%
annual consumption (kWh/year)		1,5	7,3	14,6	29,2	73	315	876	3504	4380
Price of electricity (US$/kWh)		5,0	4,8	4,0	4,0	3,0	1,0	0,50	0,30	0,25
annual cost (US$/year)		7,3	35	58	117	219	315	438	1051	1095
Average costs (US$/household)										
Least cost		70	110	166	288	500	1800	3200	1600	1600
Likely electricity supply technology	**None**		**Solar lanterns**		**Stand-alone home systems**			**Mini grid**	**on grid**	

2. Off-grid Stand-alone PV systems

Rationale for Stand-alone electrification

- Off-grid solutions are proposed by **central planners** to priority loads and neighbouring dense population clusters that are distant from main grid
- The electrification of populations in isolated areas not close to a **priority load** may be delayed by many years and even decades
- In isolated services areas (e.g. that are distant from the main grid – e.g. over 10 km) where loads are fairly distant of each other or are in limited number (less than 20 customers), the **universal access** policy may be implemented by the market with private operators

→ **Solar PV products** are **cheaper, brighter, more efficient, healthier** than kerosene lamps, candles or dry cell flashlights and offer additional important functionalities such as mobile phone charging outlets.
Also simpler (plug & play)

Solar Portable Lights (SPL)

- Single light source with/without mobile phone charging outlet
- Entry level products with solar (PV) panels of 0.2-2 W
- Price range: $20-$60

d.light S20
dlight.com

Little Sun
littlesun.com

Pico PV Systems (PPS)

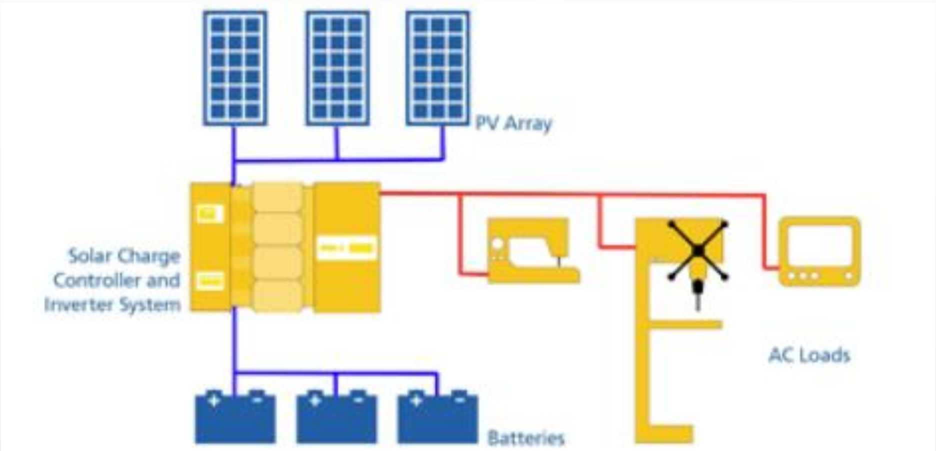
- Multi-lights source applications with mobile phone charging outlet made of a kit of components
- Power range: 2-10 W
- Price range: $150-$200

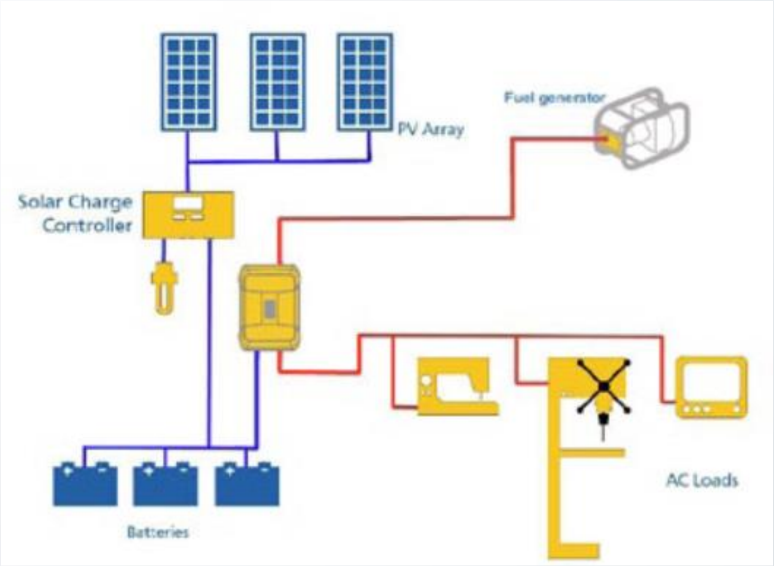
Solar Home Systems (SHS)

- Multi lights source applications with mobile phone charging outlet
- Sources can power devices such as radio and TV
- Power range: 10 W-250 W
- Price range: $150-$400

Residential Home Systems (RHS)

- 12V systems replace diesel generators or car batteries, 12V systems can power multiple lighting points and devices such as TV and fridges
- Power range: 250 W-1,000 W
- Price range: $400-$1,500





→ Can be combined with **Solar Water Heaters** (SWH)

3 main trends drive the Solar PV market

1. Decreasing Solar PV products cost
   - By 6% per annum over 2012-2020
   - Performance and production cost will continue to improve
   - Key costs improvement from PV, batteries, LED and chips
2. Increasing kerosene cost
   - By 4% per annum over 2012-2020
   - Kerosene price grows in line with the oil price
   - Price premium for rural customer must be considered
3. Increasing mobile penetration
   - By 8% per year in Caribbean region (2012)
   - Mobile communication is key facilitator for rural development
   - Mobile charging functionality of accelerates development

Solar PV products market is becoming more established with proven business models

- Up-front payment to installments: **Pay-to-own**
  - System activation through a code on scratch card
  - Unit remotely turned off upon late payment
  - Once fully paid, unit is permanently turned on and owned by customer
- Products sales to services supply: **Pay-as-you-go**
  - Customer takes home Solar PV product after initial deposit
  - Embedded SIM card enable further payment through mobile platform
  - **Modularized** systems that can be extended

Coverage of value chain by key players

	Manufacturers		Distributors and retailers				Consumers
	Design and engeeneering	Production	International distribution	National distribution	Retailing	After sales	Consumer financing
d. light / Barefoot power	Active	Active	Active	Active	Active	Active	Partially active
Azuri / Mobisol	Active	Active (1)		Active	Active	Active	Active (2)
Off-grid:Electric / M Kopa	Active	Active		Active	Active	Active	Active (2)
Fenix / Lumos	Active	Active		Active	Active	Active	Active (2)
Philips	Active	Active (1)	Active				
Osram	Active	Active (1)	Active (3)			Active	Partially active
NIWA	Active	Active (1)					
Fosera	Active	Active (1)					
Prosonergy			Active	Active			
Total			Active	Active	Active	Active	Active
Sunnymoney			Active	Active	Active	Active	
SunTransfer			Active	Active	Active	Active	Active
Solar Sisters / ARTI				Active	Active		
KIVA / Local MFIs						Partially active	Active

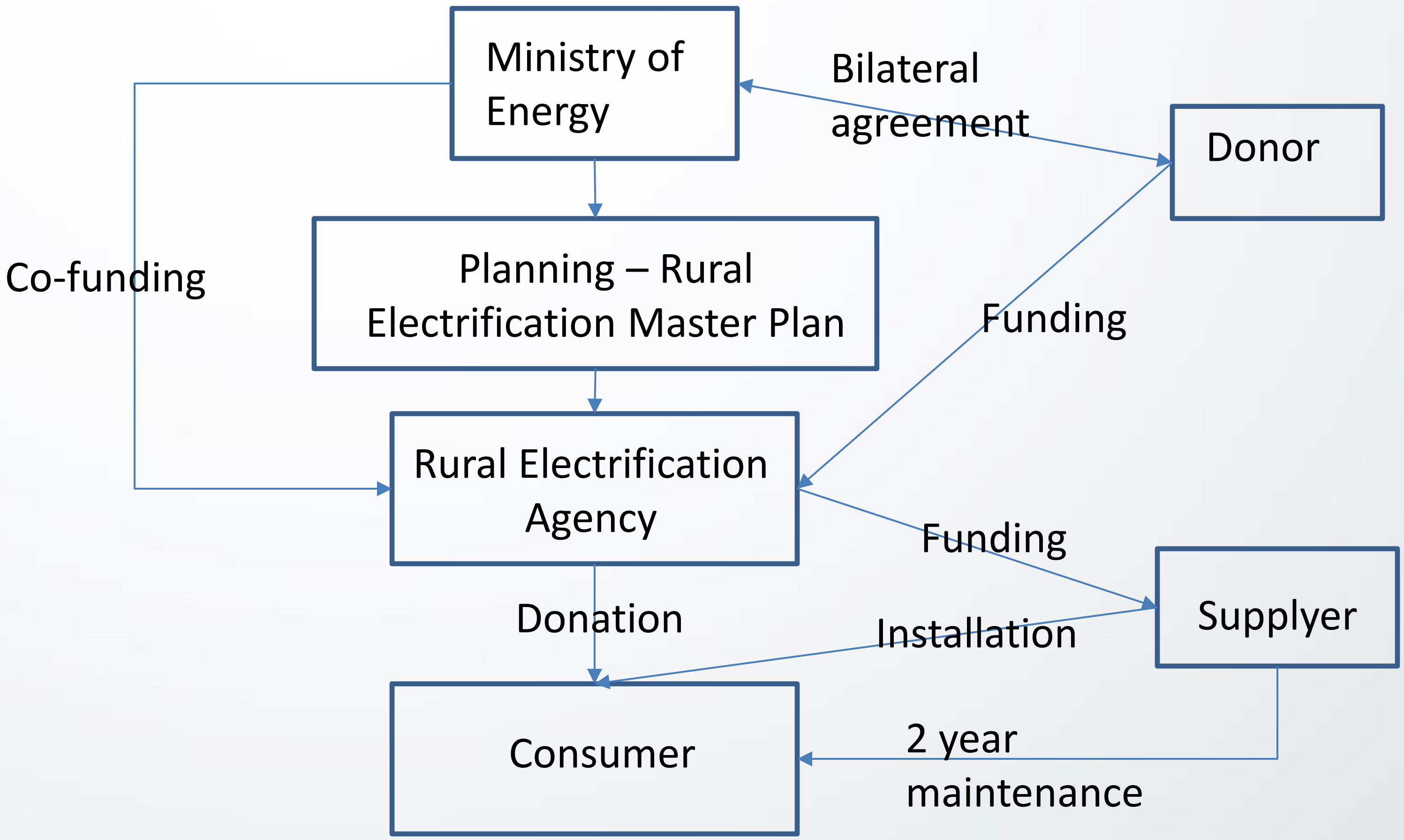
Legend: Active; Partially active

Notes
1. Manufacturing certain components at own factories
2. Implementing pay-as-you-go solutions
3. Distributing only in own projects

Sources United Nations Foundation; A.T. Kerney analysis; TAF

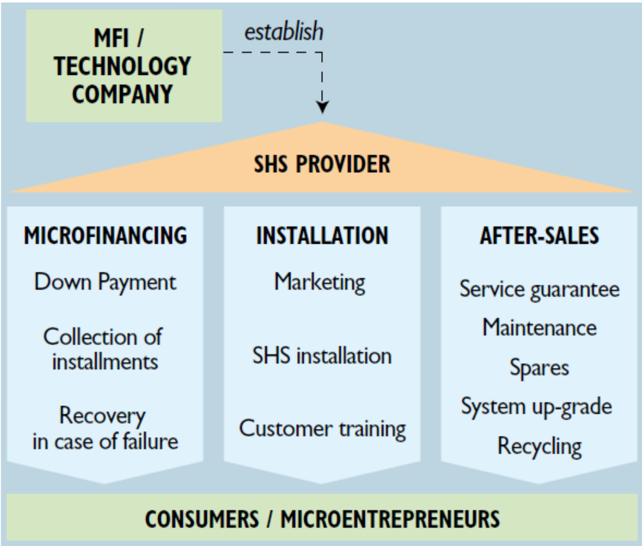
Business models for off-grid

1) Traditional public business model

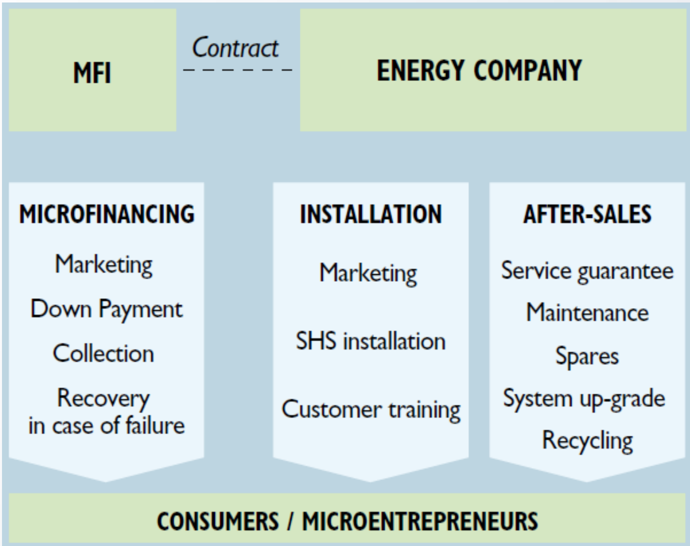


2) Private market driven business models

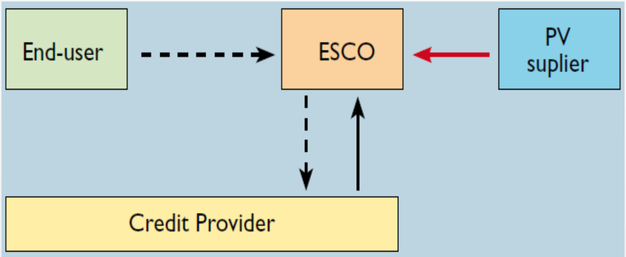
One hand business model



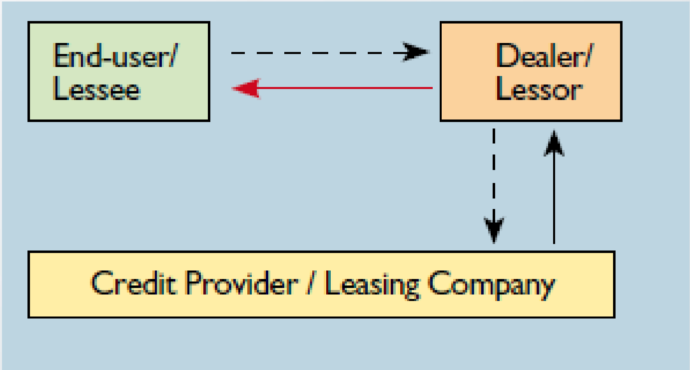
Two hand business model



Fee for service or pay as you go business model



Lease /hire purchase business model



The top market barrier is access to finance

1. **Access to finance** for solar firms
   - Access to working capital
   - Long-term growth financing
2. **Policy issues**
   - Regulatory uncertainties
   - Tax and duty on quality off grid lighting products
   - Subsidy on kerosene or LPG
   - Phase out of fuel based lighting
3. **Poor product quality**
   - Low quality players
   - Technical specifications and standards & labelling
   - Installer certification

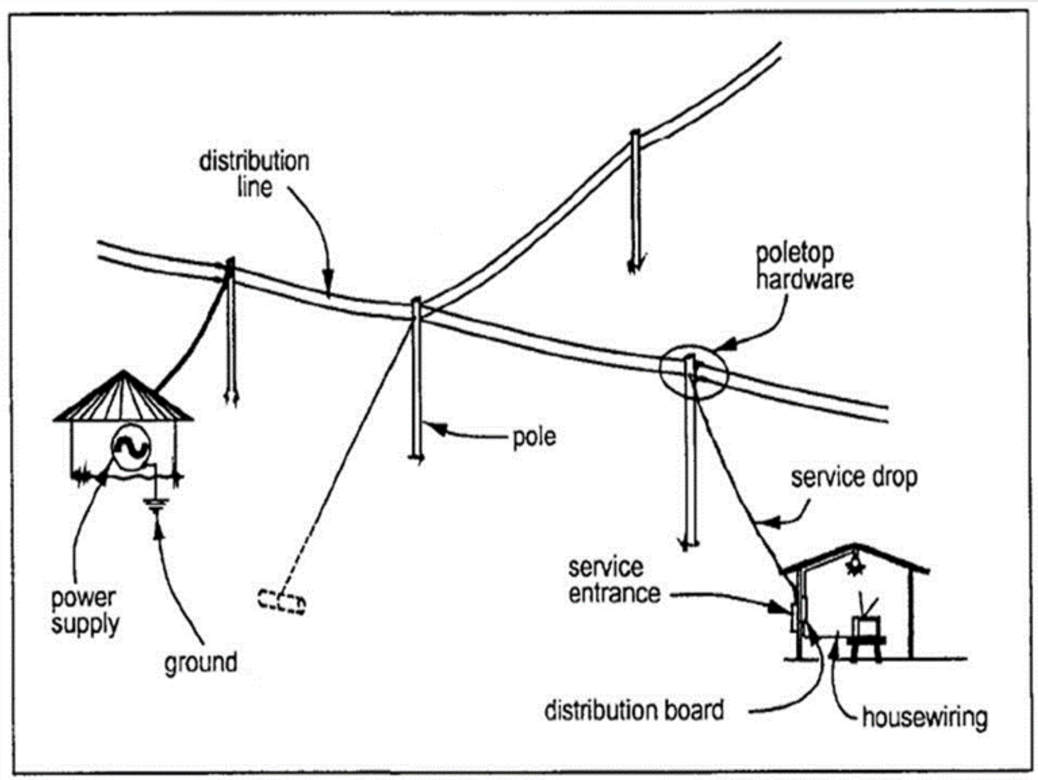
Key Questions for Stand-alone electrification

1. Is the cost (up-front or annual) per household acceptable?
2. How and who will operate & maintain the stand-alone systems?
3. What will happen when batteries reach their end of technical life?

3. Mini-grid for Rural Electrification

Main components of a mini-grid

- Small scale generators (diesel, RE)
- Medium voltage distribution line
- MV/LV distribution lines and LV distribution lines to supply load at a limited distance of distribution substation
- Service drop line that links the distribution LV line and the meter of the consumer
- Service entrance system including the distribution board with protection and in-house wiring that connect the appliances.



Rationale for mini-grid electrification

- When a mini-grid is built in a village, all **rural households**-even those who do not have the financial resources to afford electricity in their own homes can enjoy its benefits: drinking or irrigation water, street lighting, improved educational and health services, agroprocessing
- Residual cost of a mini-grid, after deduction of subsidies, is **shared** between all connected customers
- **Its quality of electricity supply** is constrained by the original design and affordability criteria
- A mini-grid implies a **generation license** and a **distribution license** (managed to some extent at local level)

Reference costs of a mini-grid

Technology -based MG	Size range (kW)	Power plant investment ($/kW)	LCOE ($/kWh)	Operating time (h/yr)
Diesel genset	5 – 300	500 – 1500	0.3 – 0.6	On demand
Hydro	10 – 1000	2000 – 5000	0.1 – 0.3	3000 – 8000
Biomass-gasifier	50 – 300	2000 – 3000	0.1 – 0.3	3000 – 6000
Wind hybrid	1 – 100	2000 – 6000	0.2 – 0.4	2000 – 2500
Solar hybrid	1 – 150	5000 – 10000	0.4 – 0.6	1000 – 2000
MV distribution	*33kV*	*13,000 - 15,000*	*$/km (site specific)*	
LV distribution	*380V*	*5,000 – 8,000 $/km*	*A rough estimate of the required length is 30 customers per km.*	
Connection costs	*Ideally $350 per customer (but Capex/customer varies $350-3500)*			

Hybridizing a diesel generator

Diesel Configuration (n x kW)		1 x 20 kW	1 x 60 kW	1 x 100 kW
Diesel installed capacity (kW)		20	60	100
Wind configuration (n x kW)		1 x 10 kW	2 x 20 kW	1 x 80 kW
Nb of modules		1	2	1
Wind installed capacity (kW)		10	40	80
PV configuration (n x kW)		1 x 10 kW	1 x 10 kW	1 x 25 kW
Nb of modules		1	1	1
PV installed capacity (kW)		10	10	25
Fixed Cost				
Capital (2007$ thousand)		147	344	539
Capital (2007$/kW)		7358	5736	5395
Diesel ($/kW)		2300	1550	1381
Wind ($/kW)		5000	5000	3839
PV ($/kW)		5116	5116	3768
Capital (2007€/kW)		5371	4187	3938
Solar availability factor		18%	18%	18%
Wind availability factor		20%	20%	20%
Diesel availability factor		90,00%	90,00%	90,00%
Outage Adjustment		1,1111	1,1111	1,1111
Adjusted Annual Fixed Cost hybrid scheme ($/kW,yr)		2898	1867	1516
Adjusted Annual Fixed Cost diesel only ($/kW,yr)		1 968	1 154	948
Variable Cost				
Fuel Price scenario ($/litre)		1,9	1,9	1,9
SRMC diesel only (UScts/kWh)		61,5	56,8	54,7
Summary of generation costs for a decentralized diesel wind solar power plant				
Total Annual Fixed Cost ($/kW/yr)		2 608	1 680	1 364
SRMC (UScts/kWh)		49,8	47,5	43,5
LRMC (UScts/kWh)		82,9	68,8	60,8

Business models for Mini-grids

Business Models	Borrower	Owner Asset	Remark
Utility based	1 Existing Utility	Utility	Known by most FIs
Franchise	1 Franchisee possibly backed by Franchiser	Franchisee	Management performance enforced by Franchiser
A-B-C Business Model with Anchor Loads	1 New Private Utility	A-B-C Company	Anchor-load based
Clustering Model	1 New Energy Service Company	Energy Service Company	Existing client based; economies of scale
Local Entrepreneur Model	1 Existing entrepreneur	Entrepreneur	Well established social network
Private ESCO Contractor	1 New Energy Service Company	N civilians	Weak creditor base - unproven
Private Concessionaire	1 New IPP	Concessionaire	Contract-based. Ongoing investment obligations
Generator – IPP Model	1 New Generator	IPP	Contract-based
Private Distributor	1 New Distributor	Distributor	Weak creditor base – unproven
Community based	1 New Community	N civilians	Weak creditor base - unproven

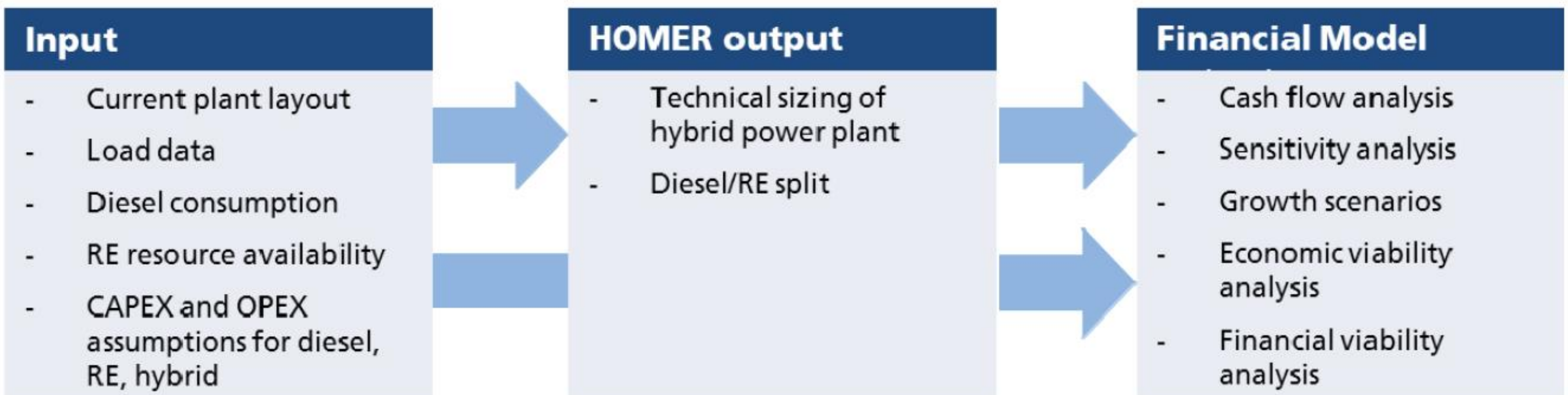
Questions for mini-grid electrification

1. Is the project developer reliable and creditworthy?
2. Does the Mini-Grid Business Model comply with legal framework?
3. Is the proposed Mini-Grid project technically & financially viable?
4. Is the tariff affordable to most customers? How do electricity bills are recovered? By whom?
5. What happens if the mini-grid scheme is connected to main grid?

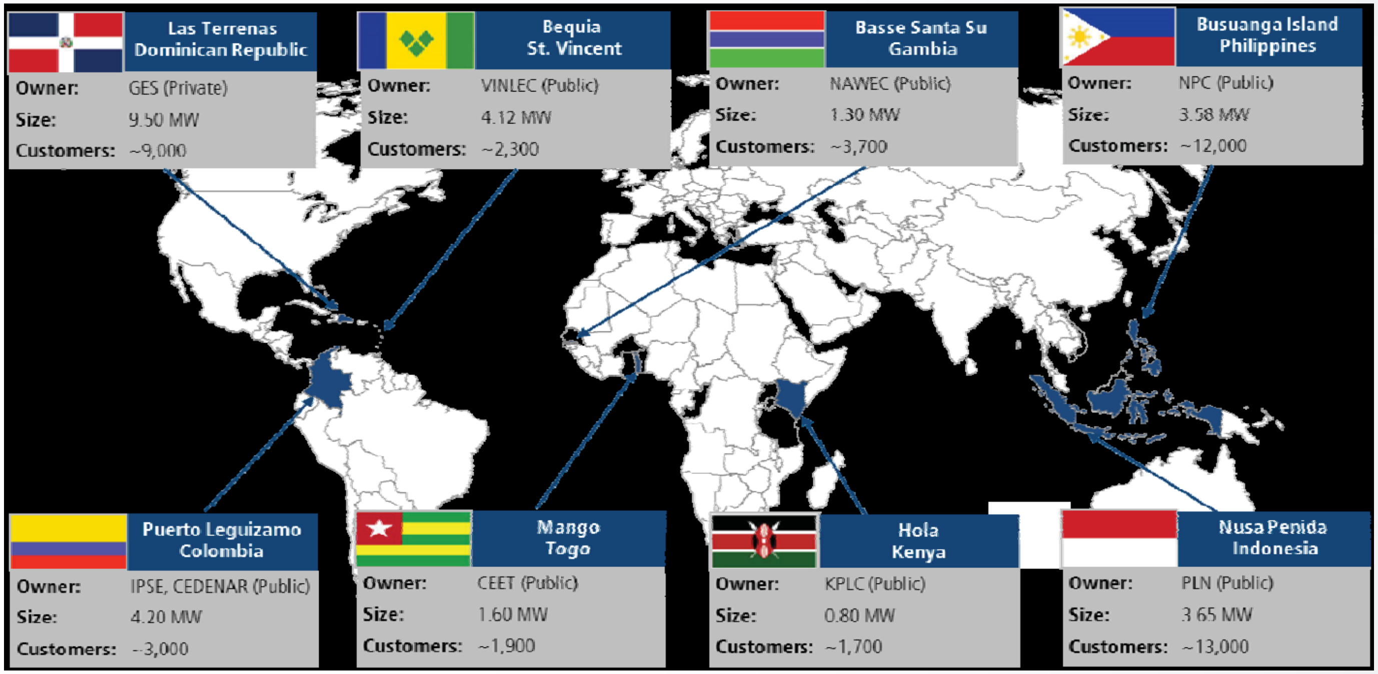
Examples of Mini-grid hybrid diesel/RE projects in the LAC region

3 steps approach:

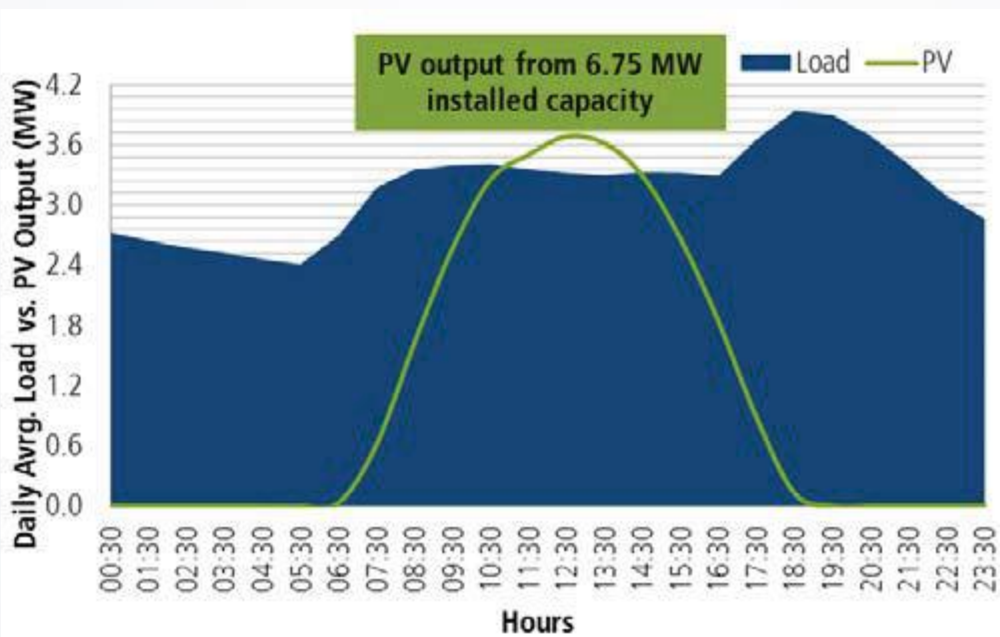
Figure 1: Technical and financial modelling approach

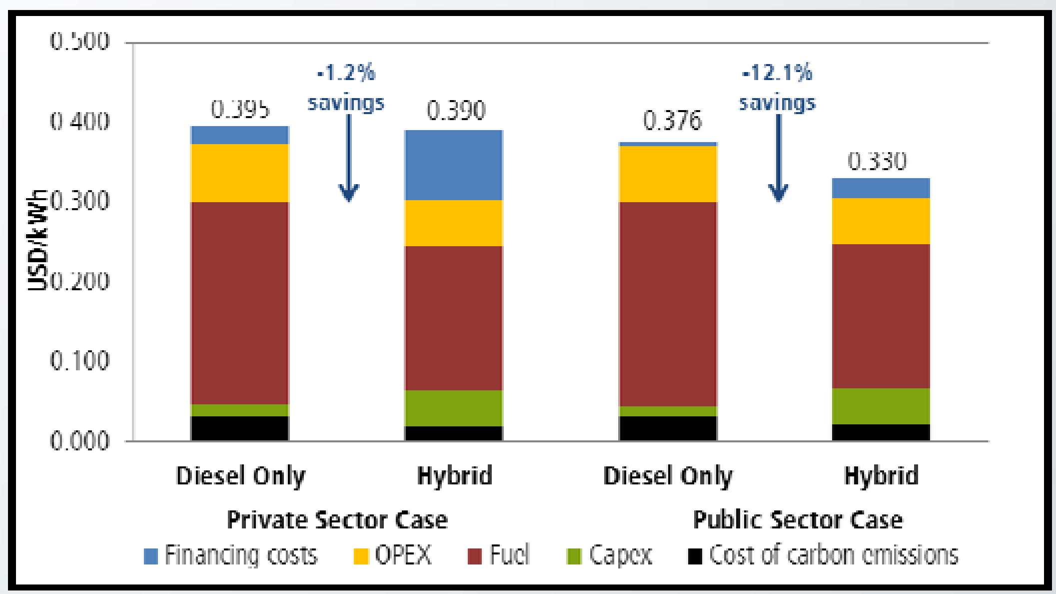


Source: "*Renewable energy in hybrid mini-grids and isolated grids: Economic benefits and business cases*" Frankfurt School- UNEP Collaborating Centre for Climate and Sustainable Energy Finance (December 2014).



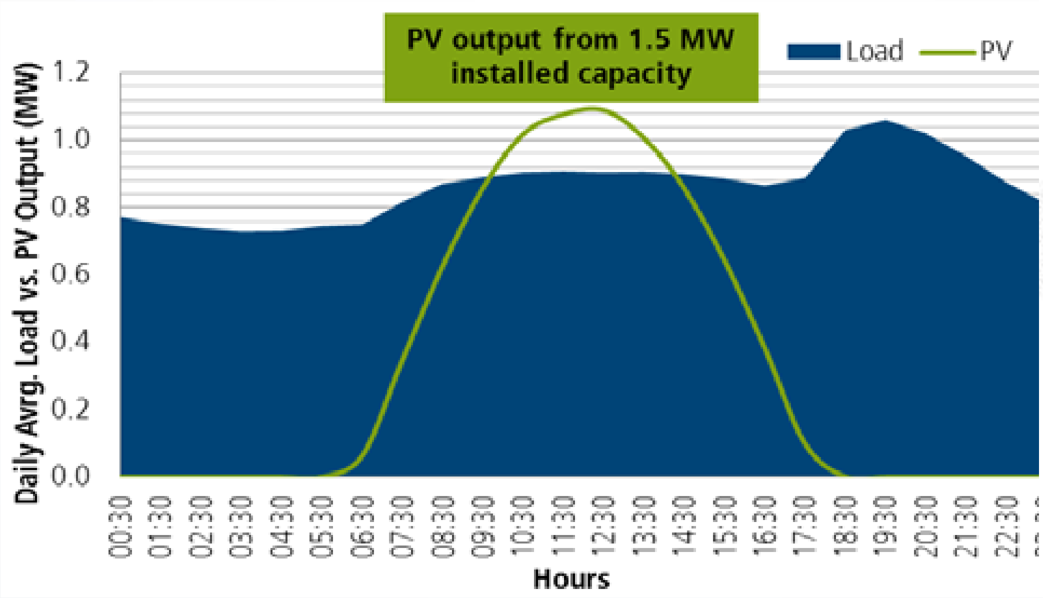
Las Terrenas, Dominican Republic

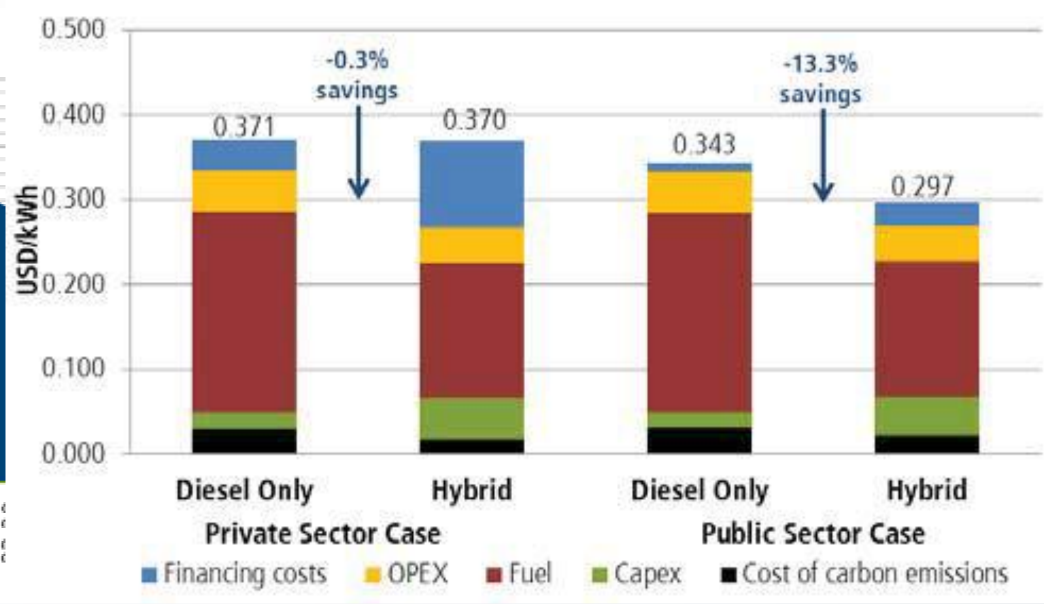




Mini hybrid grid/LAC (3)

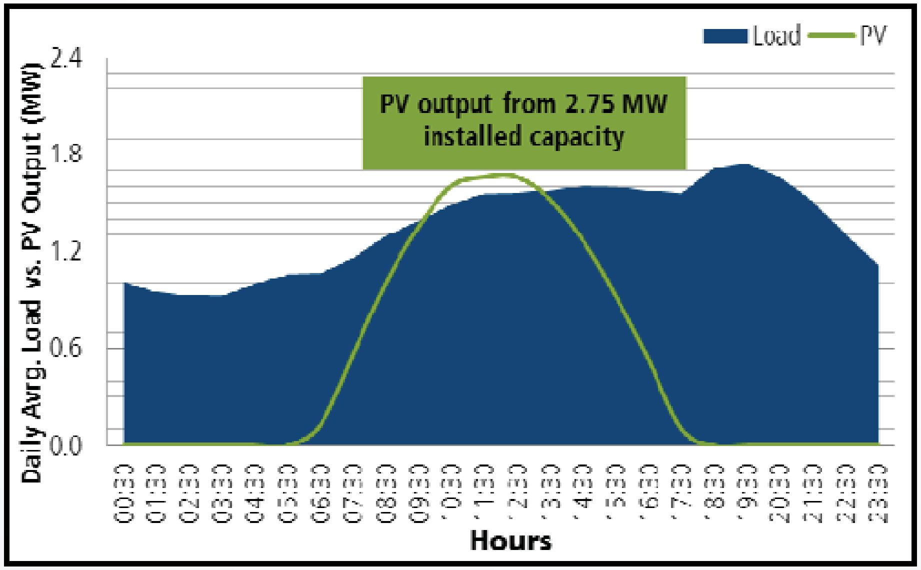
Bequia, St. Vincent & the Grenadine

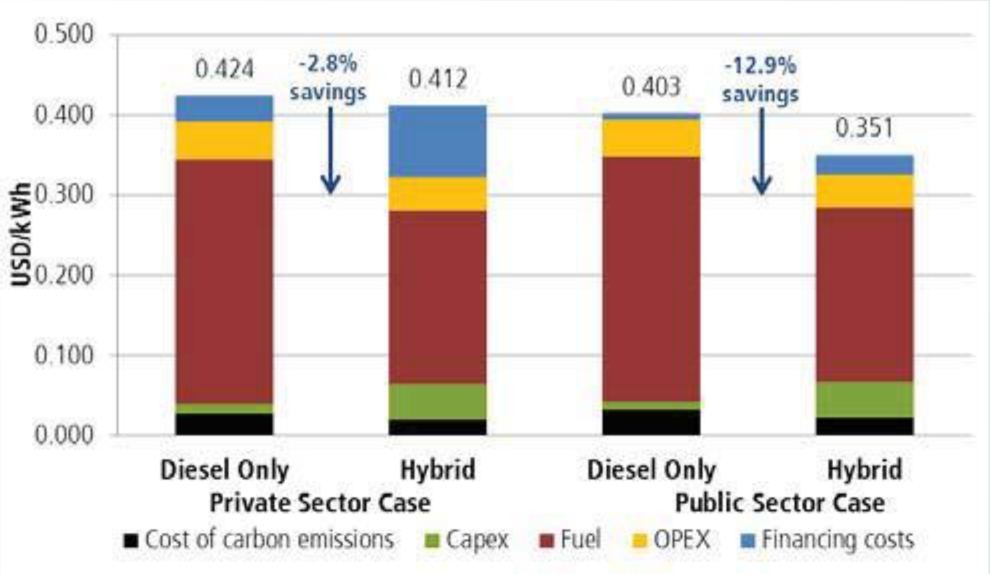




Mini hybrid grid/LAC (4)

Puerto Leguizamo (Putumayo), Colombia





Mini hybrid grid/LAC (4)

Site	Population /Power Customers (in th.) -% of low income)	Main Economic Activity	Power Demand (Average/peak in MW)	Current Electricity Supply Situation (generating costs, reliability)	Utility Ownership (Generation & Distribution)	PV Option (MW and % of Load)	Diesel Consumption Savings (%)	Cost Savings of Hybrid Solution/IRR (%)
Las Terrenas, Dominican Republic	19/9-62%	Services, mostly tourism	3.2/5.8	0.38/frequent power cuts	Two private utilities (G & D)	6.7/31%	30%	12%/13%
Bequia, St. Vincent & Grenadine	4.3/2.3-NA	Services, mostly tourism	0.9/1.5	0.34	One public utility (G & D)	1.5/34%	32%	13%/13%
Puerto Leguizamo (Putumayo), Colombia	31/3-NA	Services	1.4/2.2	0.40/frequent power cuts	Two public utilities (G & D)	2.7/31%	29%	13%/13%

References

1. Initiatives

- Caribbean Renewable Energy Development Programme (CREDP)- www.credp.org
- REGSA - Promoting Renewable Electricity Generation in South America (EuropeAid): http://regsa-project.eu
- Alliance for Rural Electrification (ARE): www.ruralelec.org

2. Trainings

- Clean Energy Solutions Center: Clean Energy in Island Settings (Training Webinar) -https://cleanenergysolutions.org/training/renewable-energy

2. Publications

- ARE (2012-2014)
    - Rural Electrification with Renewable Energy
    - Green light for renewable energy in developing countries
    - Potential of Small Hydro for Rural Electrification-Focus: Latin America
    - Hybrid Mini-grids for Rural Electrification: Lessons Learned
    - Best Practices of the ARE: What renewable energies can achieve in developing and emerging markets
    - The potential of small and medium wind energy in developing countries-A guide for energy sector decision-makers
- Renewable energy in hybrid mini-grids and isolated grids: Economic benefits and business cases (Frankfurt School-UNEP Collaborating Centre for Climate and Sustainable Energy Finance, Dec. 2014, 85 pages)
- Mini-Grid Policy Toolkit (European Union Energy Initiative Partnership Dialogue Facility, EUEI PDF/GIZ/ARE, 2014)

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