IEA Task 9 : Deployment of PV Services for Regional Development

Sub-Task 4:

Hybrid PV Mini-Grids for Rural Electrification

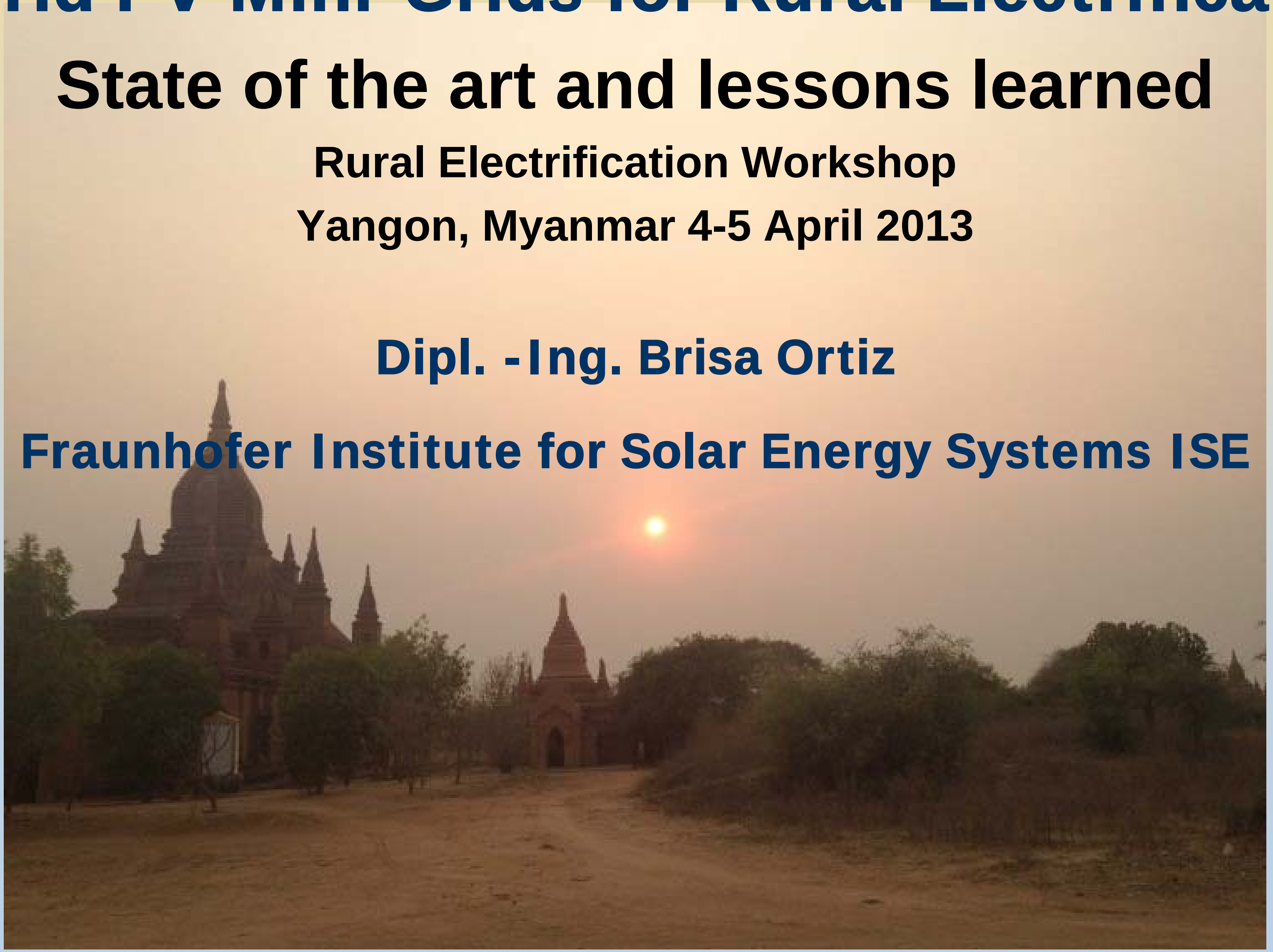
State of the art and lessons learned

Rural Electrification Workshop

Yangon, Myanmar 4-5 April 2013

Dipl. -Ing. Brisa Ortiz

Fraunhofer Institute for Solar Energy Systems ISE



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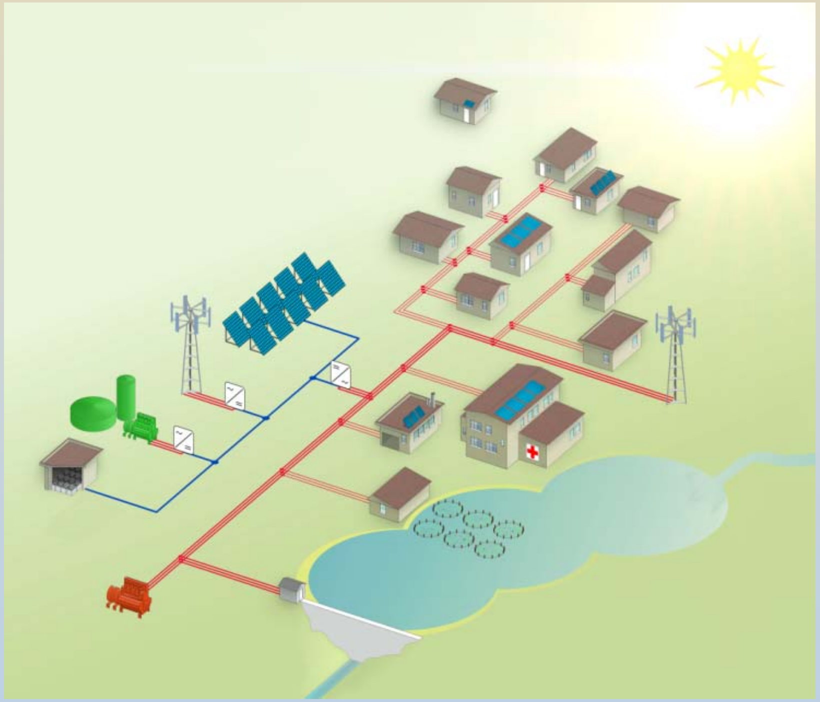
Outline

1. PV Systems for rural electrification providing electricity with Hybrid PV Mini-grids
2. Designing PV Hybrid systems
3. Lessons learned: operating 100% photovoltaic PV Mini-Grids in Mexico
4. Conclusions



Hybrid PV Systems and Mini-Grids
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1. PV Systems for rural electrification providing electricity with Hybrid PV Mini-grids
2. Designing PV Hybrid systems, how to deal with
3. Lessons learned: operating 100% photovoltaic PV Mini-Grids in Mexico
4. Conclusions

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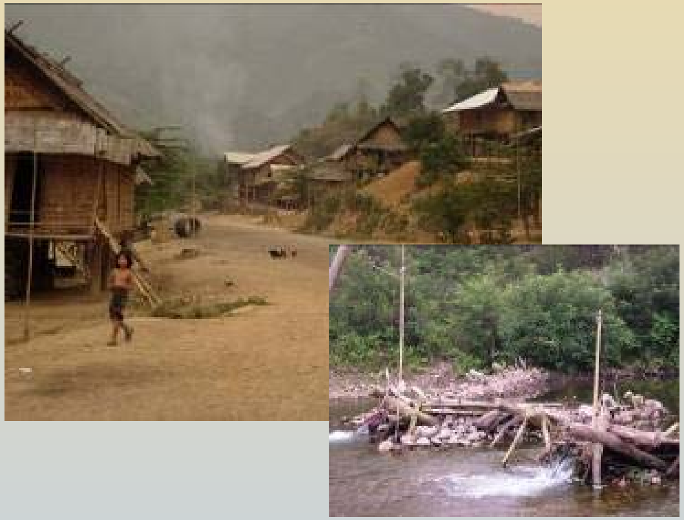
Rural electrification with renewable energies
Off-Grid Systems



Small PV systems

Hydroelectric power stations

Hybrid PV systems

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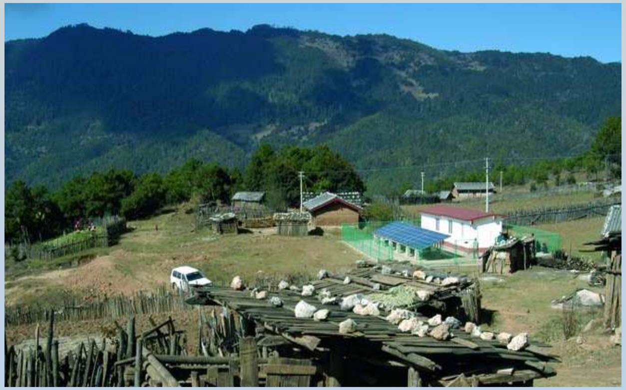
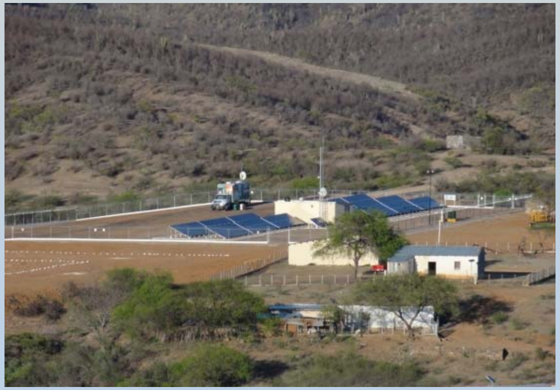
1. Generación fotovoltaica conectada a la red
2. Redes a base de motores diesel con integración fotovoltaica
3. Sistemas domiciliarios (Solar Home Systems)
4. **Redes autónomas híbridas basadas en la tecnología fotovoltaica**

-> Granjas solares …..





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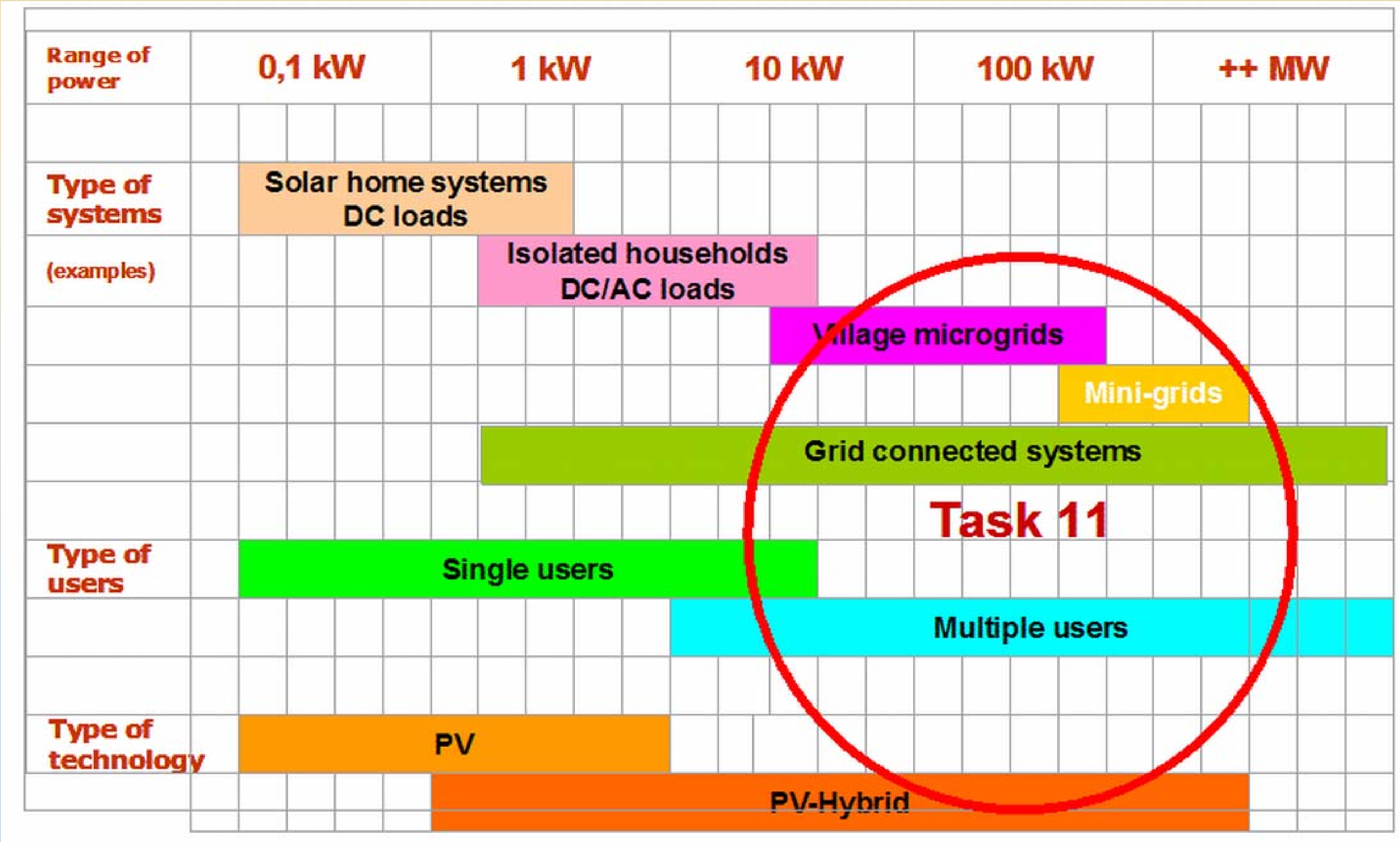
Classifying
IEA PVPS Task 11 - PV Hybrids and Mini Grids



Source: IEA PVPS Task 11 - PV Hybrids and Mini Grids

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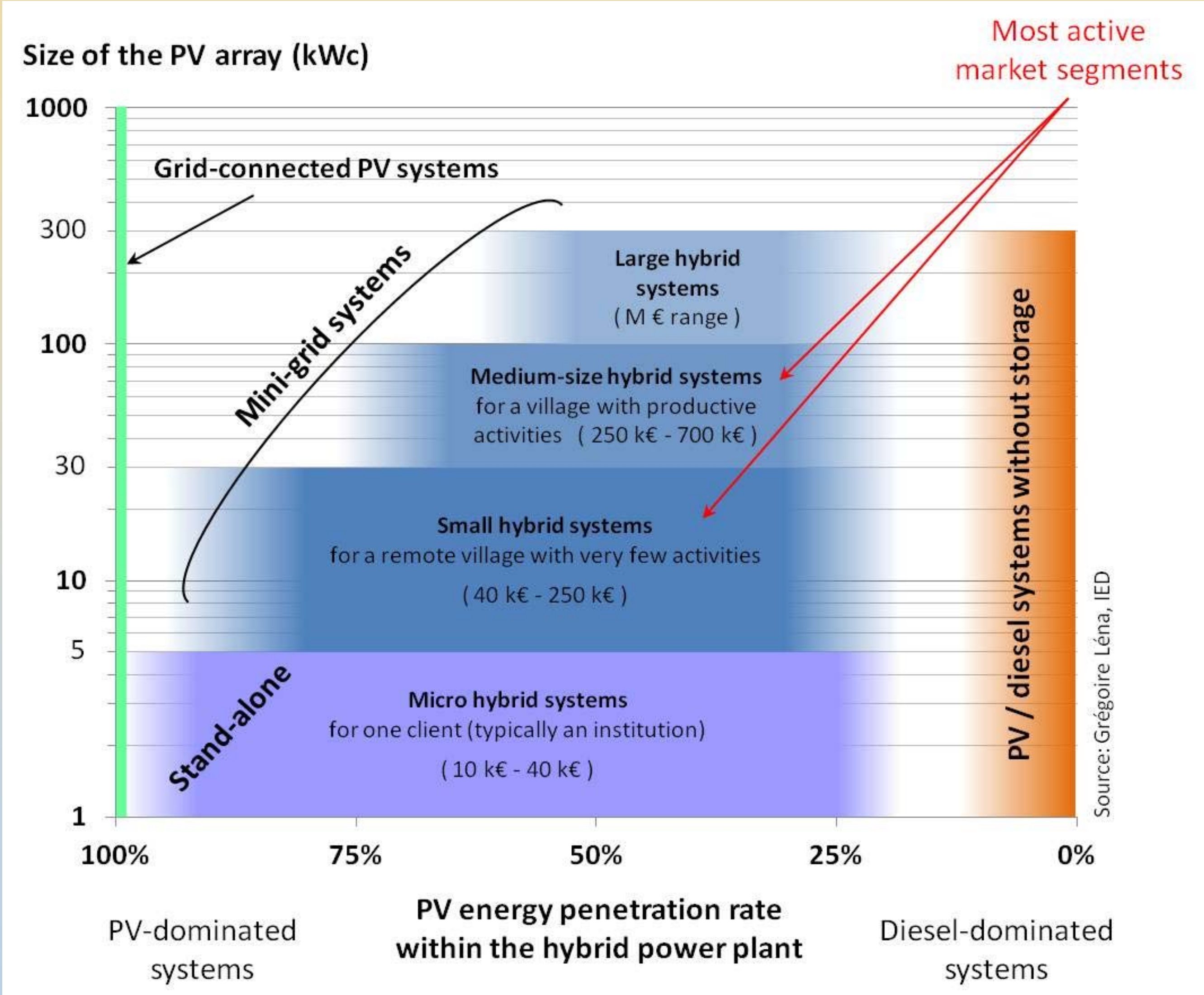
PV Hybrids and Mini Grids

between grid connected and isolated stand-alone systems



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

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PV Systems and Mini-Grids: The inverter as the hearth of the system

Small Single Systems				
		0.1	0.5	kW
		0.6	2	kW
		2.1	5	kW
Hybrid – Mini-Grid Systems				
		2	5	kW
		6	30	kW
		31	70	kW
		71	300	kW

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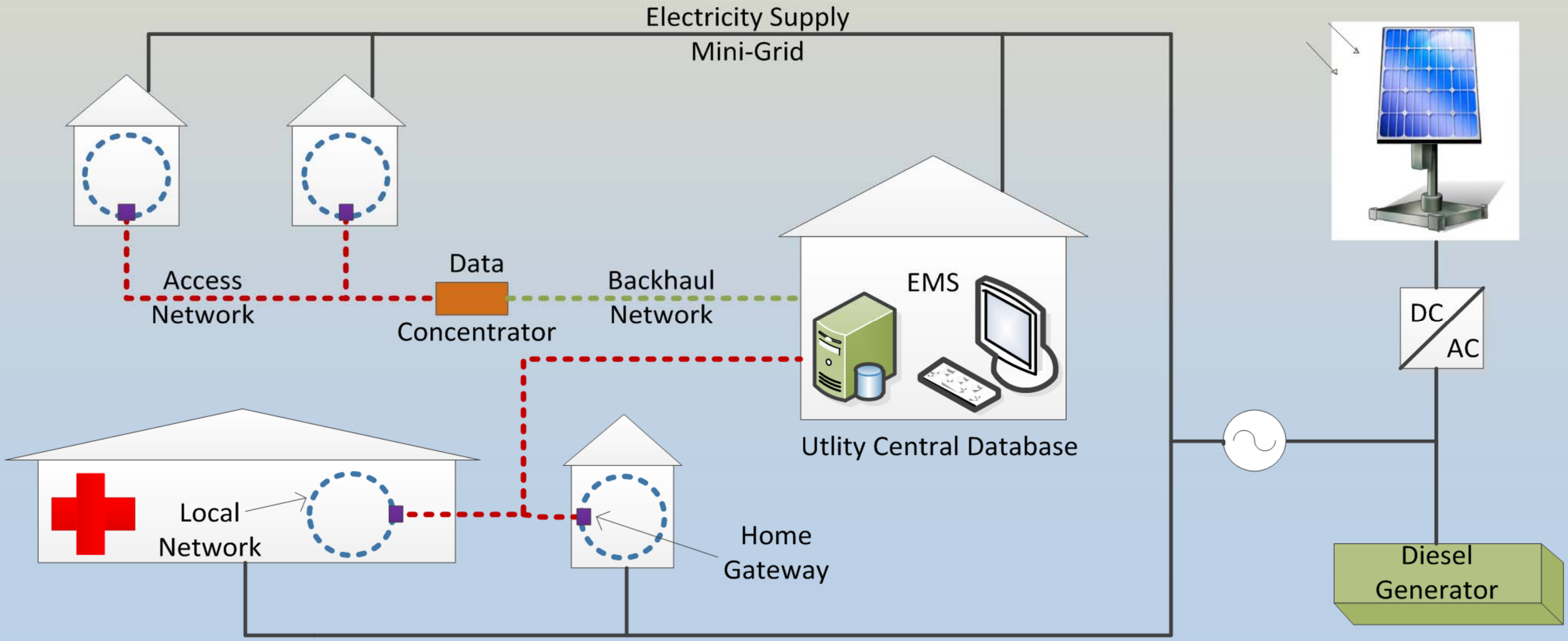
** Solar energy penetration rate: PV kWh / total kWh*

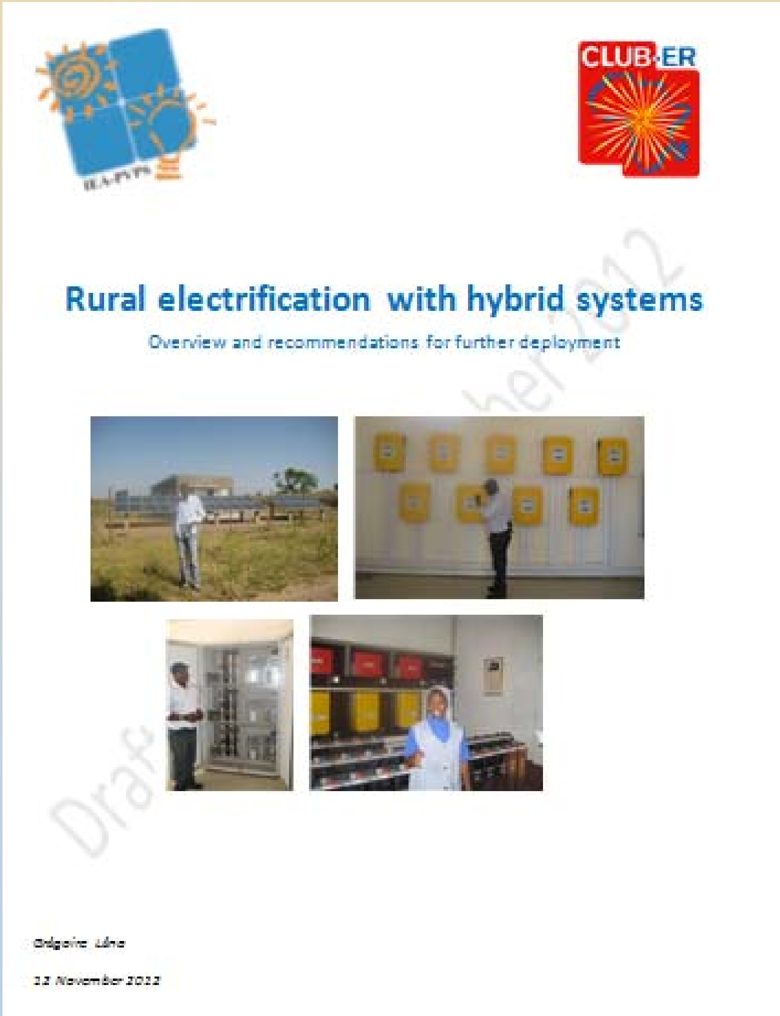
Next generation of PV Hybrid Mini-grids New components the need of intelligence

- Creation and Implementation of new local operating models includes:
  - Economic models
  - Involvement of third party energy services providers
  - Control and operation and management for in-situ and remote solutions

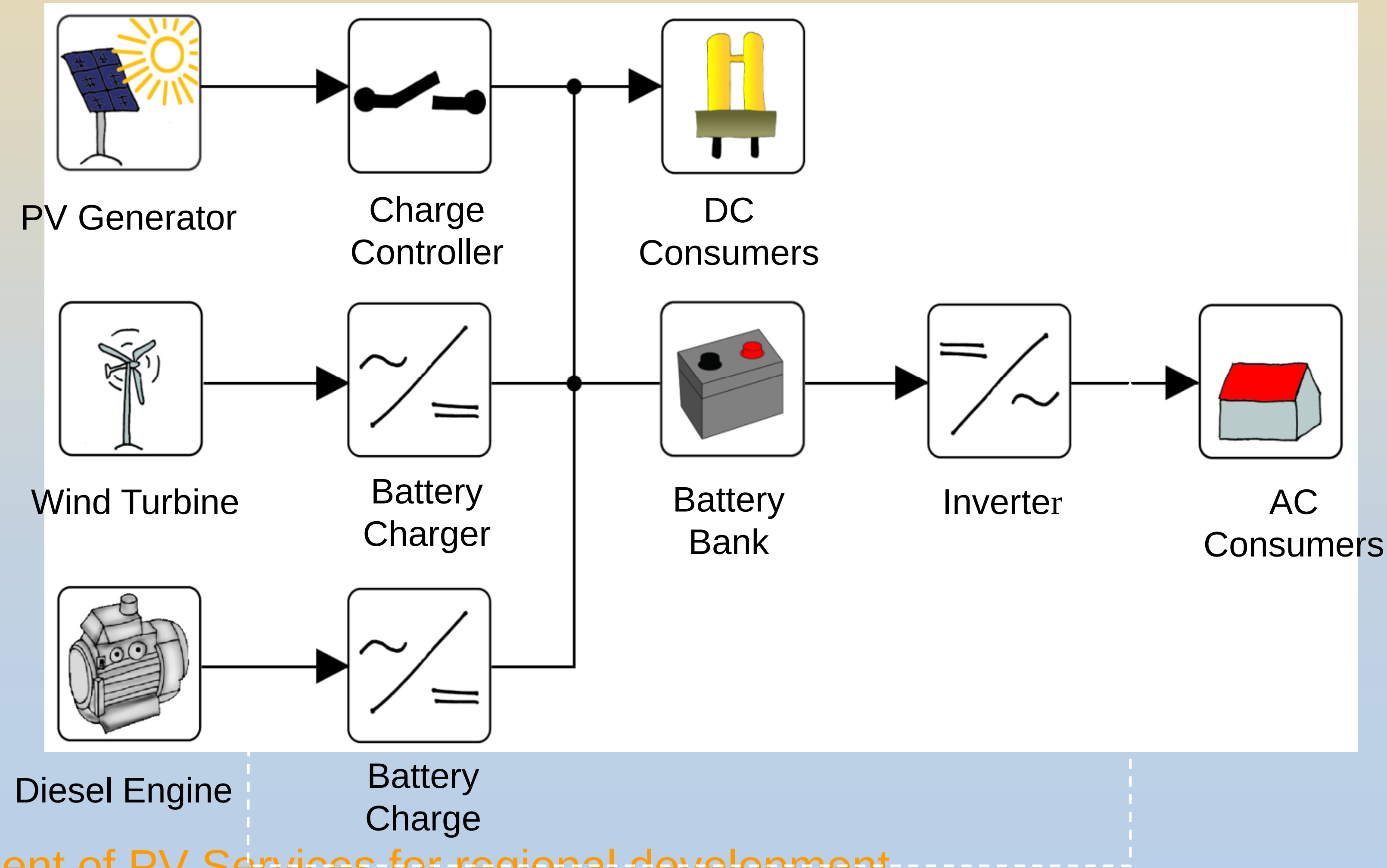


IEA Task 9 Deployment of PV Systems for regional development

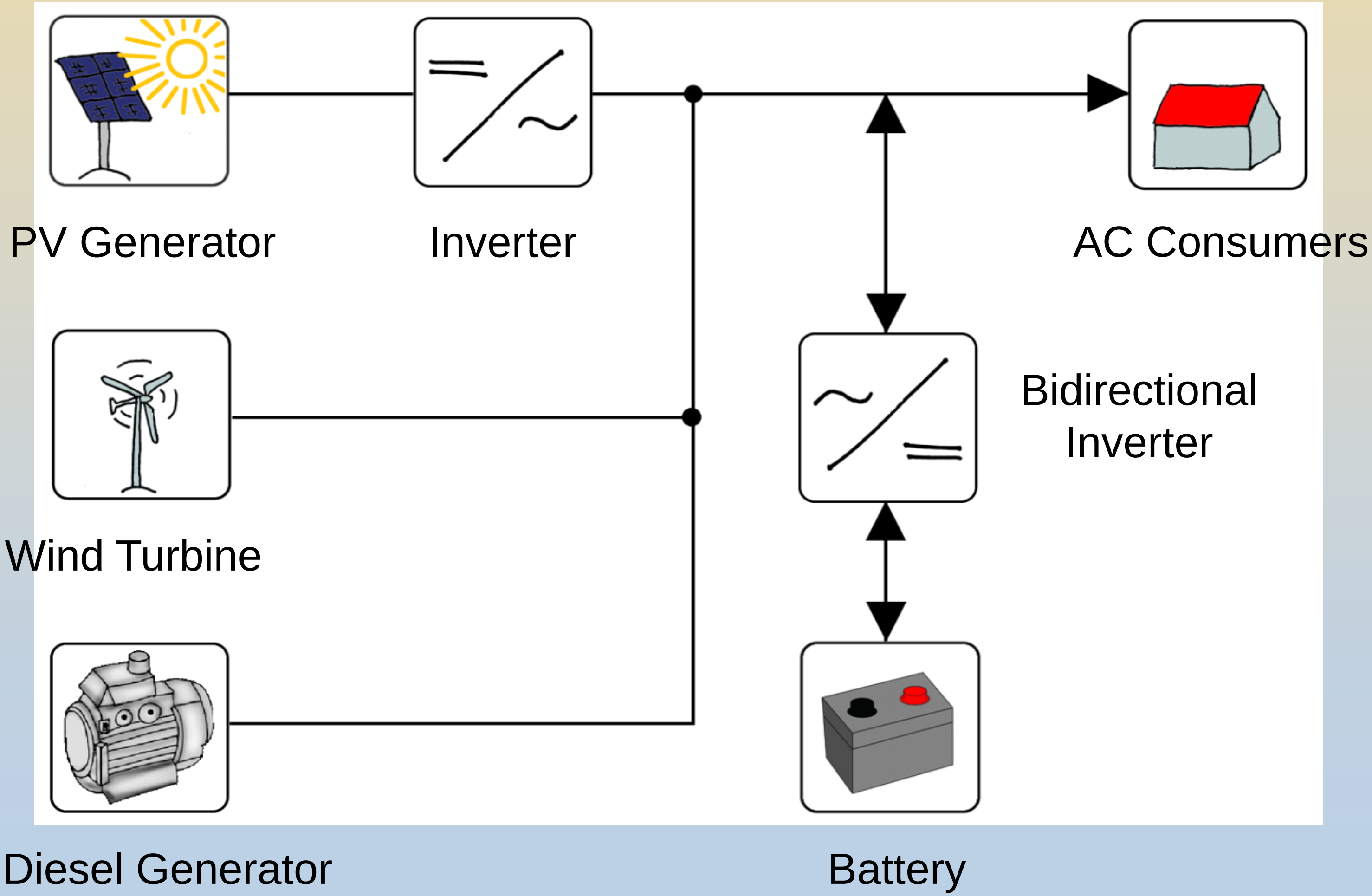
3. Sub-Task4: Hybrid PV Mini-Grids for Rural Electrification (phase 2)
   3. Main activities/Content
      - Coordination with IED, approaching “all in” PV Hybrids
      - Contribution to the Training Workshops
      - Collection of information
      - Members and non members contribution follow up (options selection)
      - Milestones and activities’ outputs
      - Resources & Activities 1, 2, 3
      - Next meetings
   4. Deliverables
      - A **paper report**: Review on **Simulation tools** for designing PV Hybrid Systems
      - **Handbook**: Designing PV Hybrid Systems and Mini Grids


IEA-PVPS
CLUB-ER
Rural electrification with hybrid systems
Overview and recommendations for further deployment
Draft November 2012
Grégoire Léna
12 November 2012

Principal design of a hybrid system with DC Bus



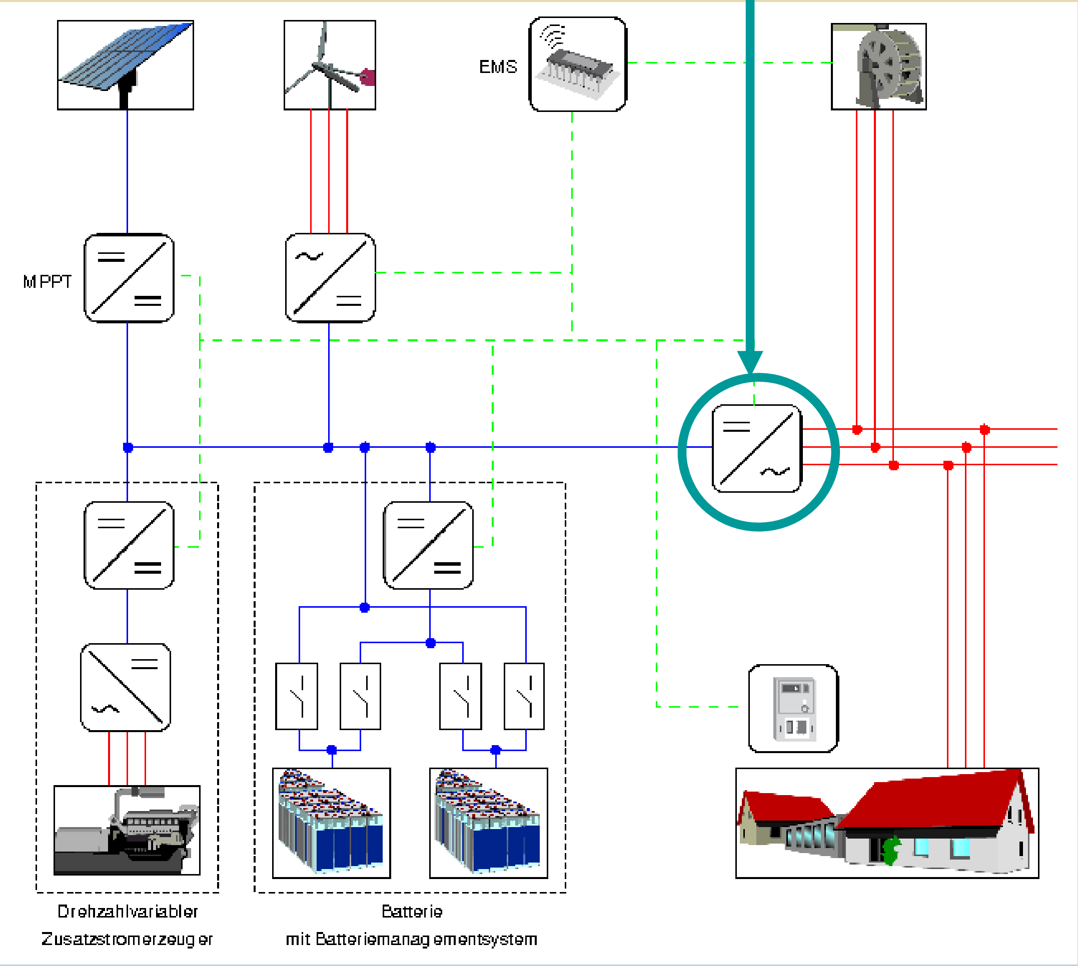
Principal design of a hybrid system with AC Bus



Next generation of PV Hybrid Mini-grids

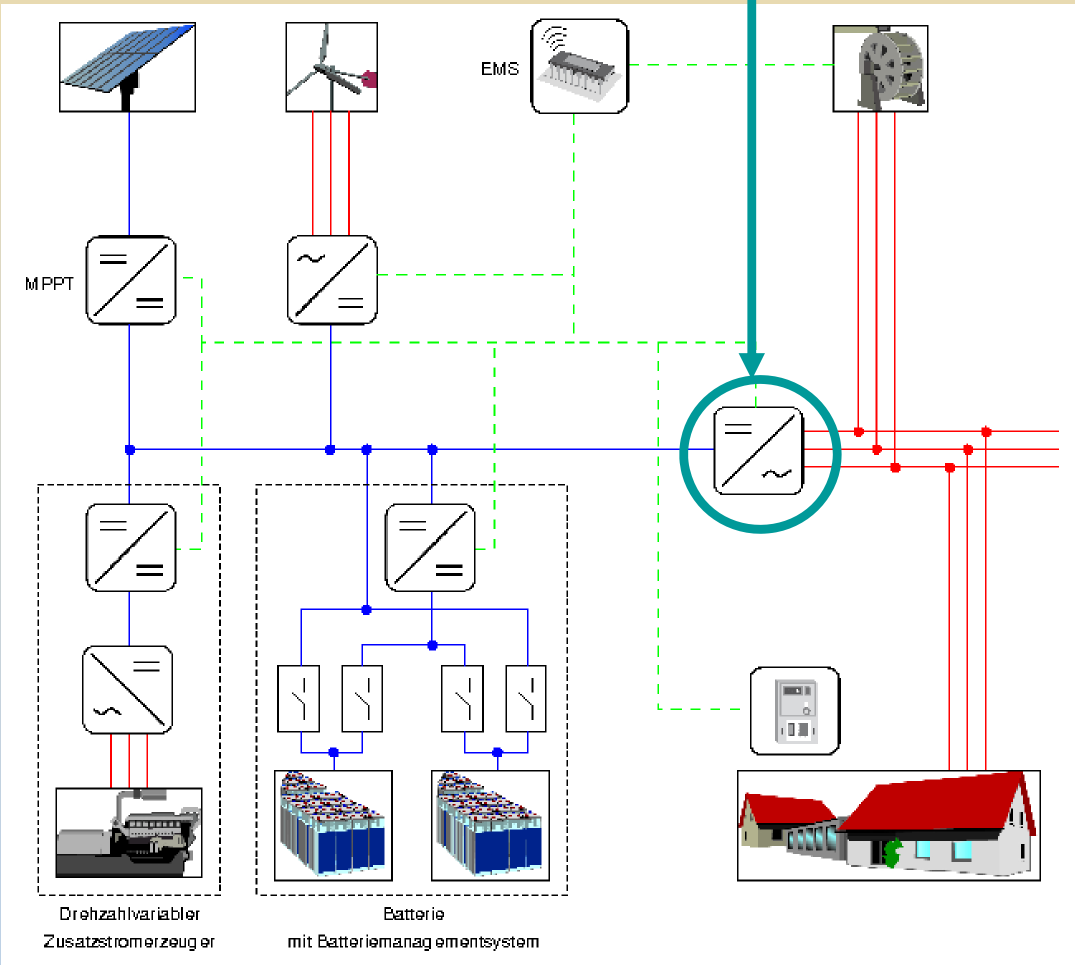
- Hybrid battery system (lead acid and lithium) with integrated battery management system
- Development of an Energy management system
- Standardized communication infrastructure

125 kVA – 500 kVA



Next generation of PV Hybrid Mini-grids New components the need of intelligence

125 kVA – 500 kVA



- Hybrid battery system (lead acid and lithium) with integrated battery management system
- Development of an Energy management system
- Standardized communication infrastructure

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Main information about the site

- „Off-Grid Questionnaire"
- Essential information about local conditions
- Mandatory for system design
- Rough system design (These steps are
- only a first estimate and no final system design)

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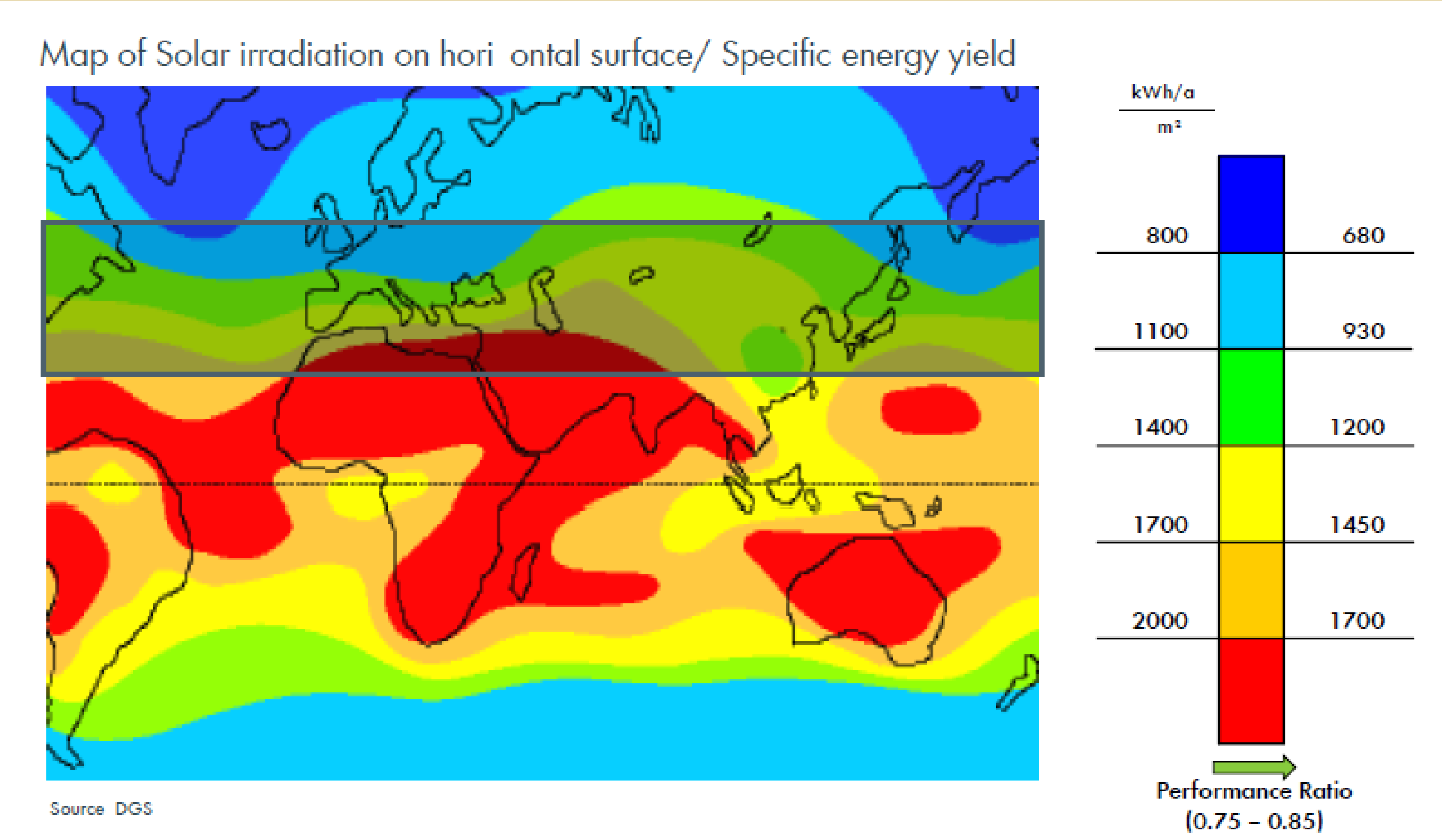
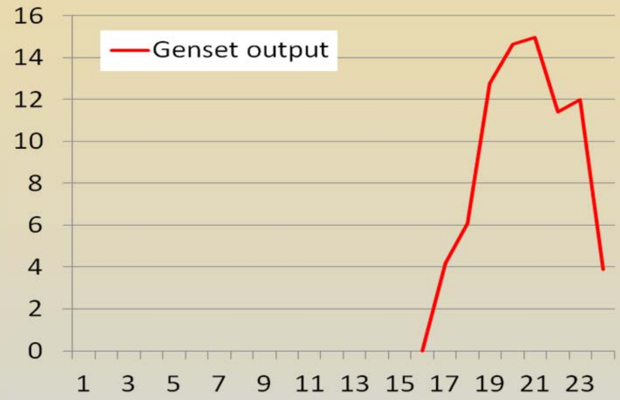
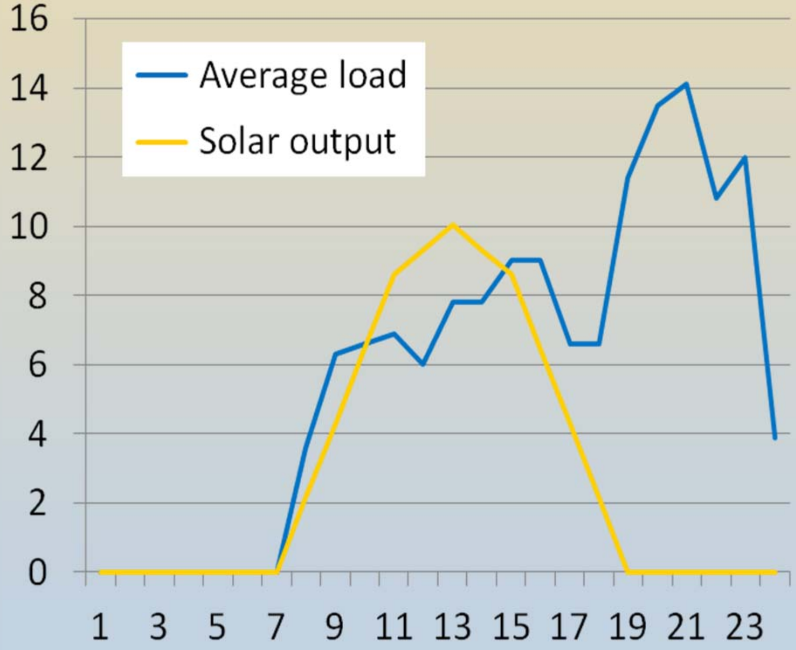
Solar radiation
How to match the load curve?
Solar + battery + genset



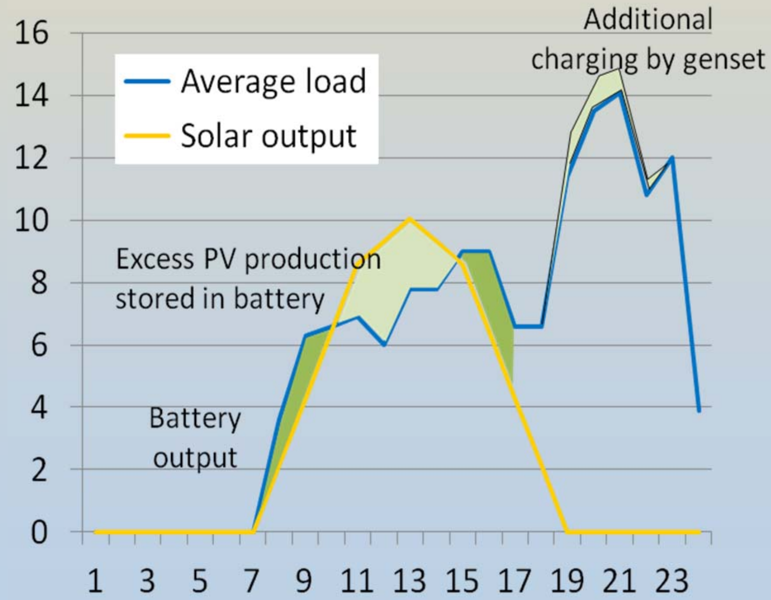
The Load
How to match the load curve?
Solar + battery + genset



Example in Mauritania



Source: IED



Genset: 55 kVA

PV system: 16 kWp

Battery: 120 kWh

Annual PV penetration rate: 35%

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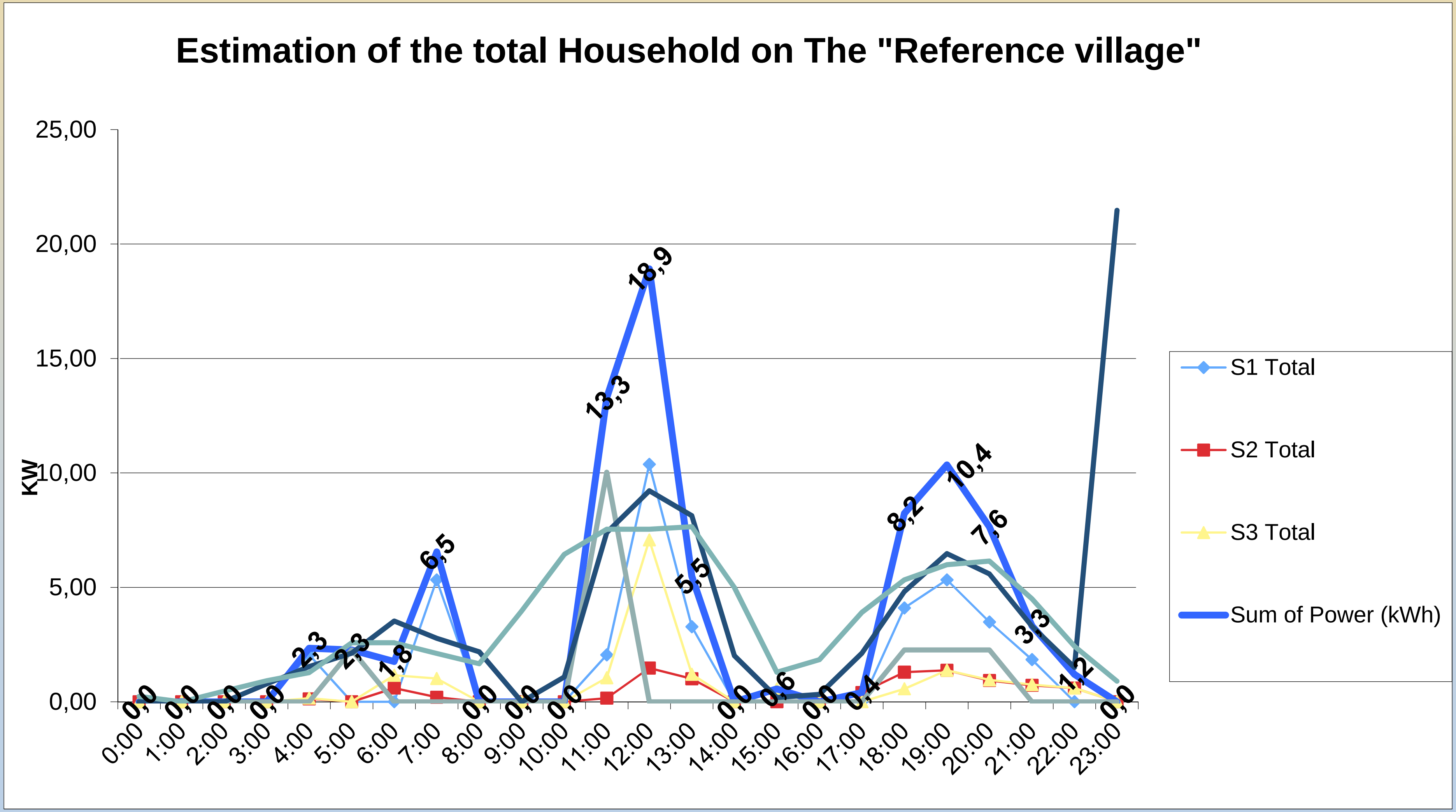
The Load
How to match the load curve?
Solar + battery + genset



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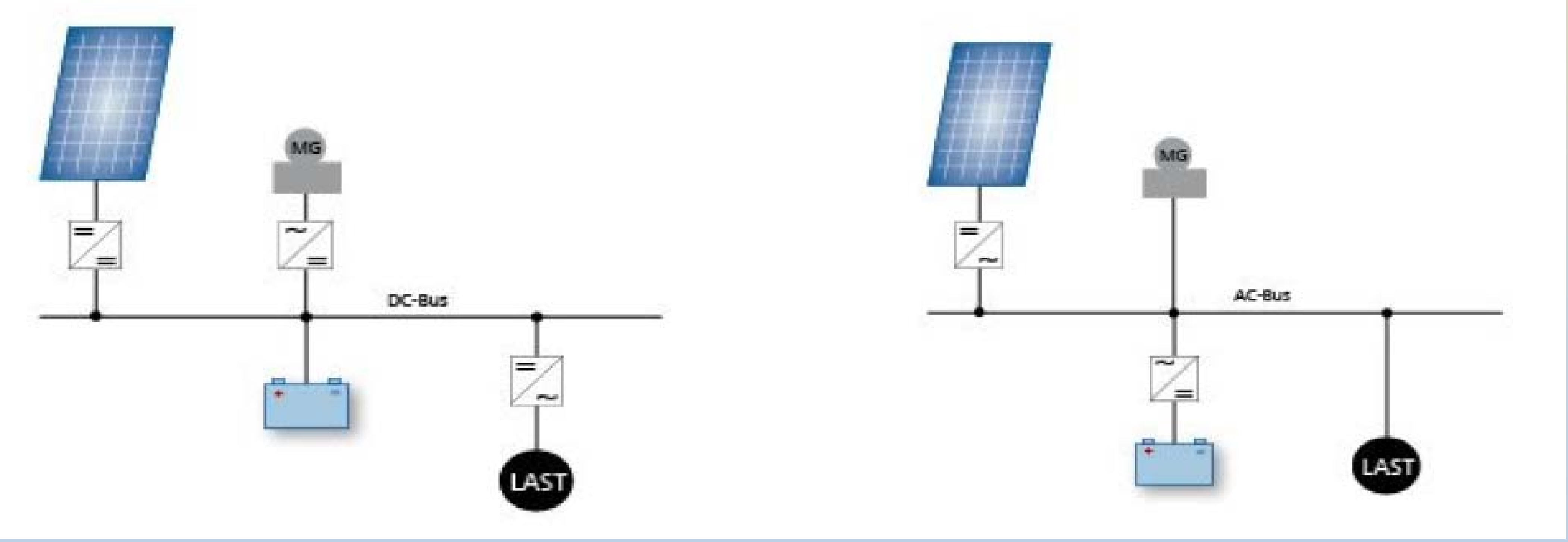
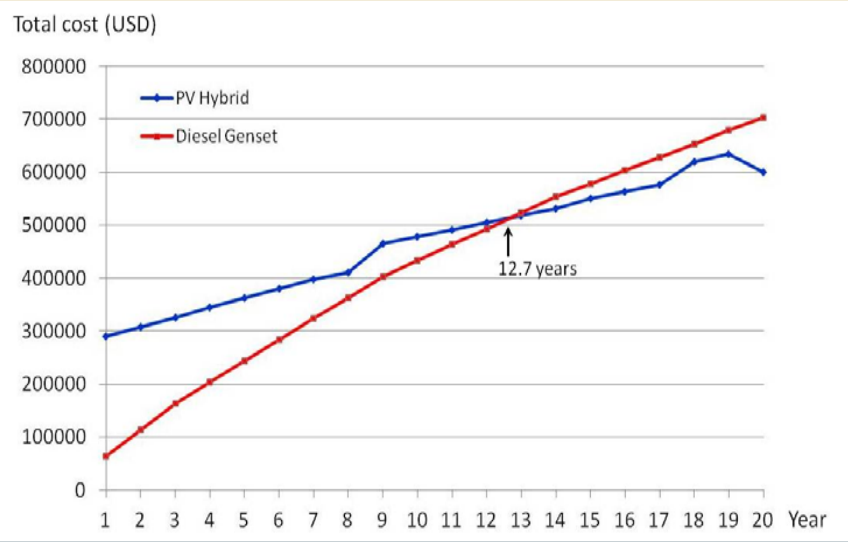
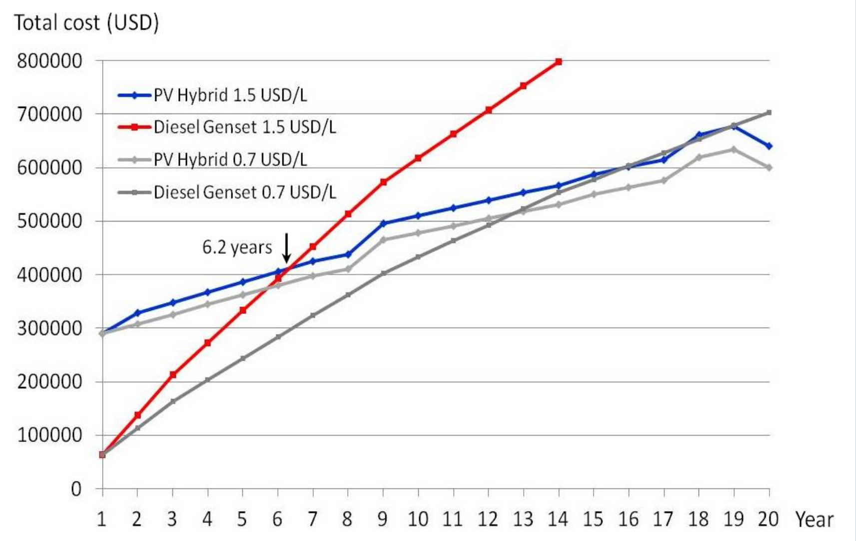
Principal design of a hybrid PV system DC and AC Bus



Life cycle costs: payback period beyond 12 years

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



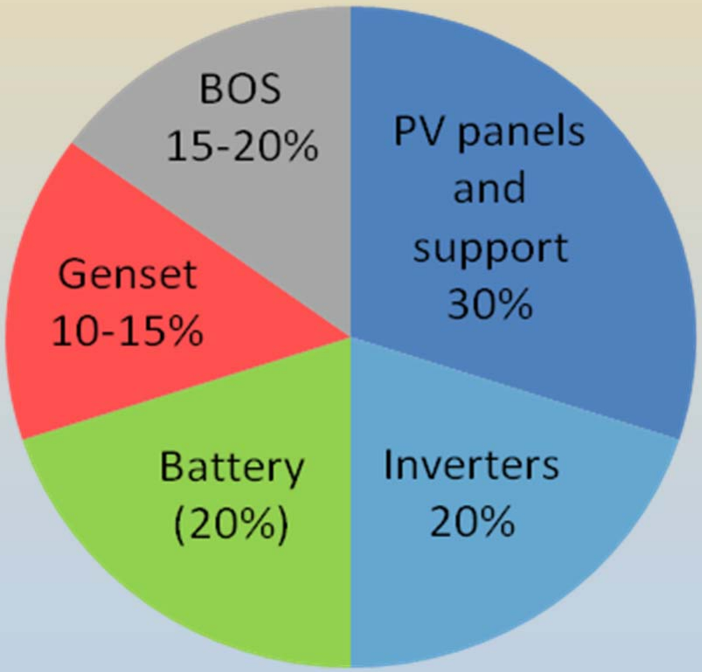


Source: IED

Cost structure hybrid system

challenge: cost reduction electronics and batteries

Location		
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		



The case in Mexico
Operating 100% PV Systems

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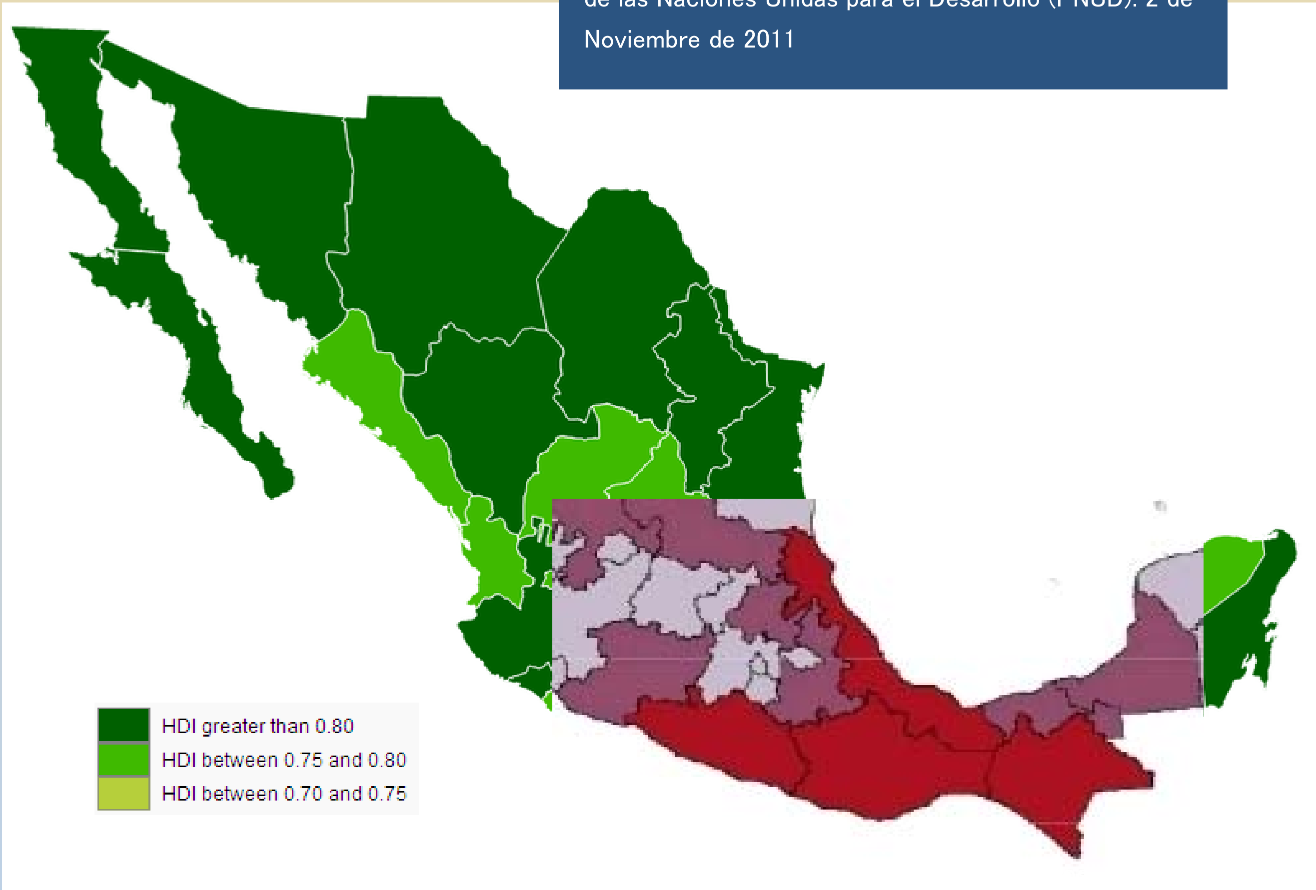
El caso de México: el acceso a la electrificación y el desarrollo social

- Entre 2 y 7 % de la población no tiene acceso a la electricidad
- Directa relación con extrema pobreza
- La meta del Gobierno de México es electrificar 100% a la población
- En directa cooperación con el Edo. de Campeche se quiere proveer servicios integrales de energía en las comunidades rurales con redes autónomas fotovoltaicas
- Mejora de las condiciones de la población en las áreas rurales
  - Que tecnologías?
  - Que servicios?
  - Es sustentable?

Informe sobre Desarrollo Humano 2011 del Programa de las Naciones Unidas para el Desarrollo (PNUD). 2 de Noviembre de 2011



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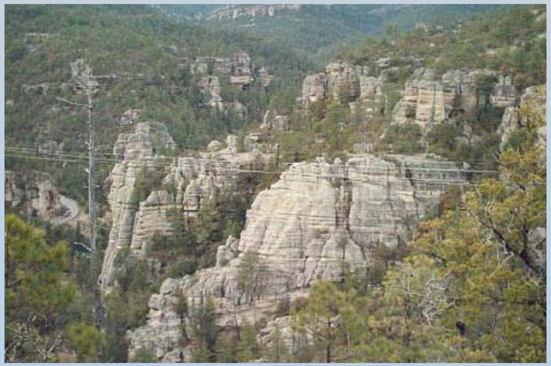
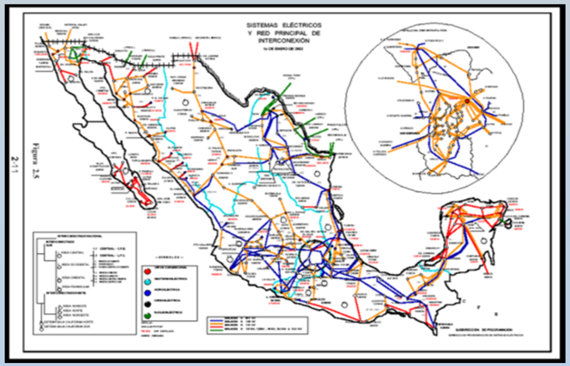
Technology options

1. Conexión a la red
2. Mini-Redes a base de motores diesel
3. Sistemas domiciliarios (Solar Home Systems)



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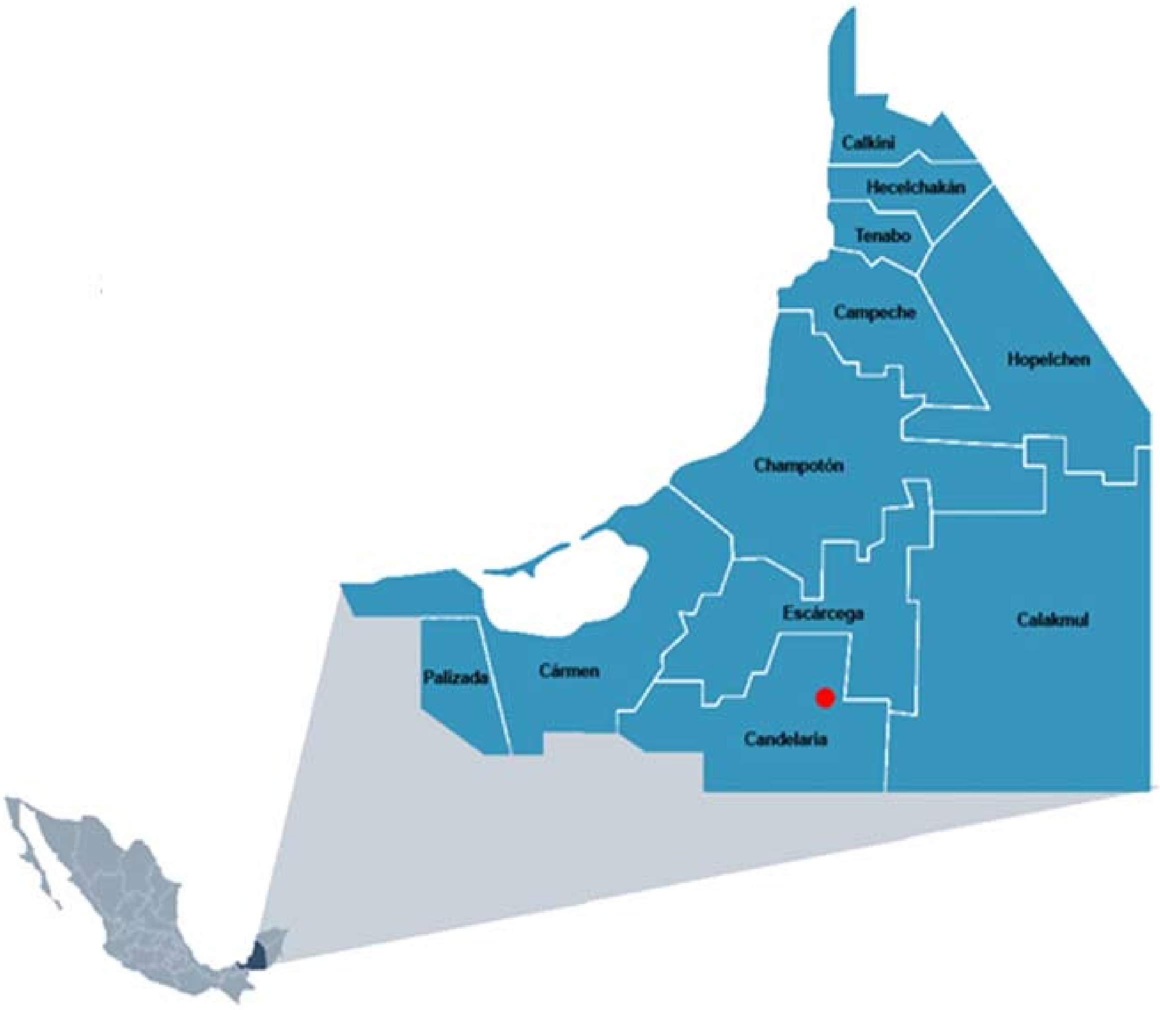
Descripción del sitio

- Curi se encuentra cercano a la red eléctrica de distribución pública (5 Km. aprox.)
- La red pública existente provisiona energía a comunidades cercanas como Rio Caribe/Tablón (16/22 Km. aprox.)
- Se estima que alrededor de 30% la de la población visita las comunidades mas cercanas.



Datos geográficos y meteorológicos del sitio

Ubicaión	**Unidades**	**Valor**	**Datos**	**Fuente**
Latitud	grad	18° 24’ N	Lic. Antonio Glez. Curi	Google maps
Longitud	grad	90° 55’ W	Lic. Antonio Glez. Curi	Goggle maps
Altitud	m	82	Lic. Antonio Glez. Curi	Goggle maps
Radiación Solar Global	**kWh/m²/d**	**5.31**	Promedio anual	Meteonorm
Max. Radiación Solar Global	kWh/m²/d	6.35	Valor máximo	Meteonorm
Min. Radiación Solar Global	kWh/m²/d	4.04	Valor mínimo	Meteonorm
Promedio pluvial	mm/M	6.62	Valor promedio mensual	Meteonorm
Promedio de la velocidad del viento	m/s	2.70	Valor promedio mensual a 10 m sobre el nivel de la tierra.	Meteonorm

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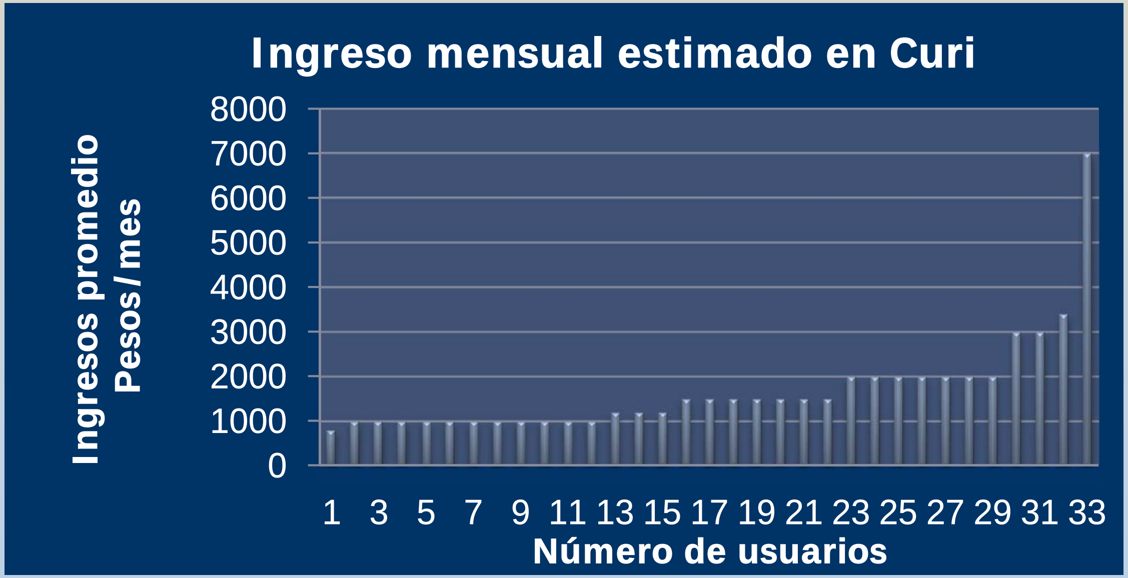
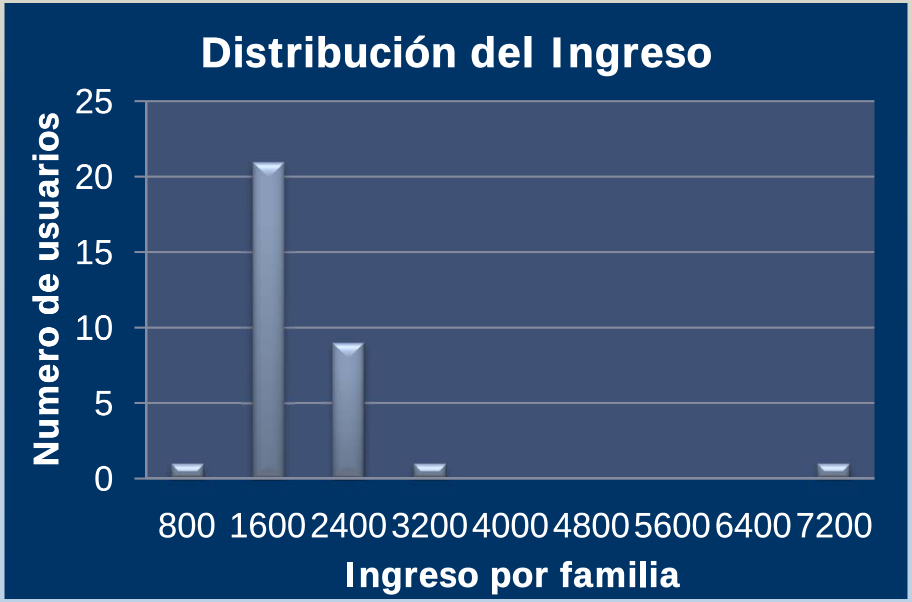
Willness to pay and ability to pay

> Determinar el consumo de energía esperado
> Potencial de crecimiento

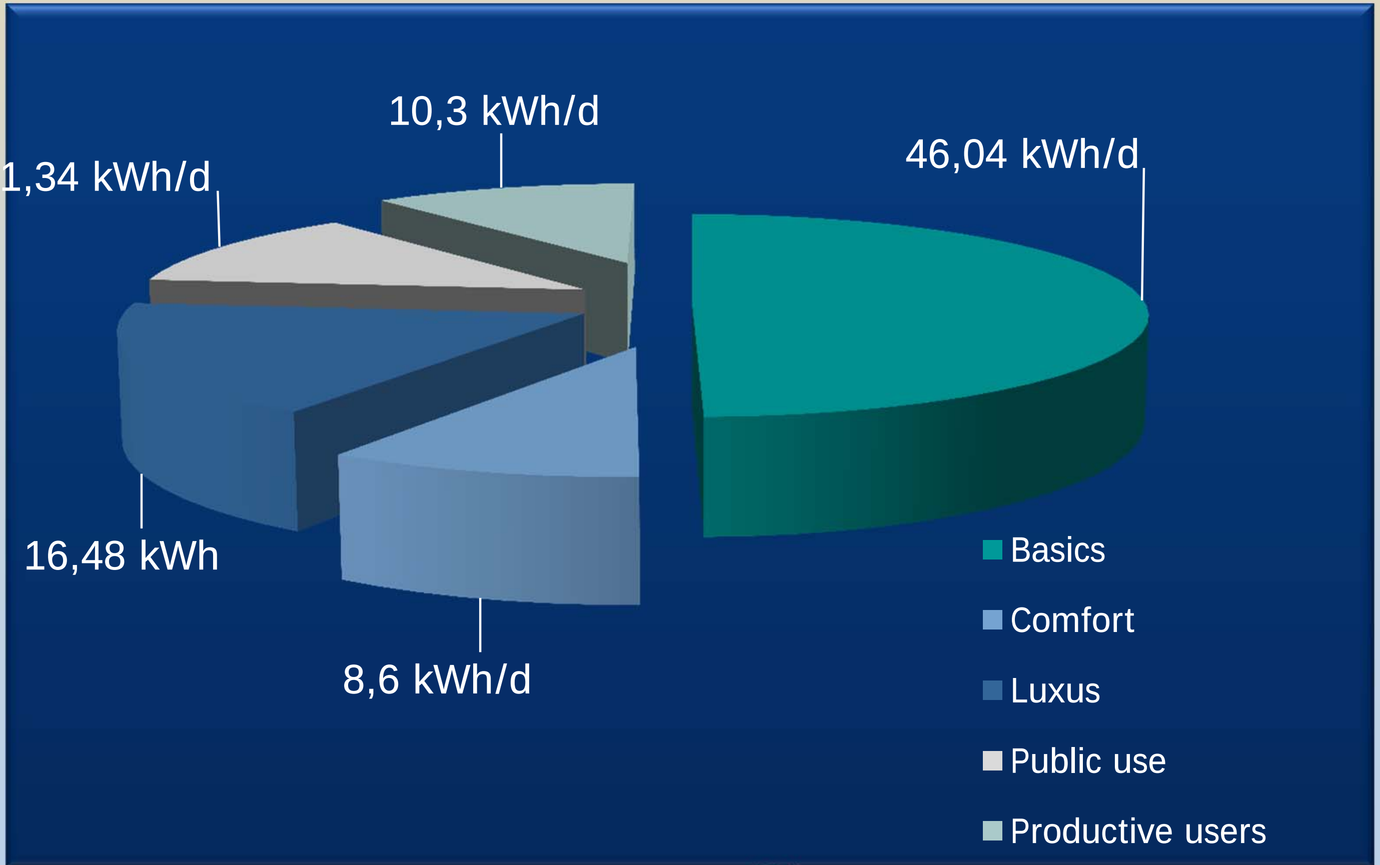




Definición de niveles de servicio

> Servicios de energia esperados y a ser contratados por los usuarios

- Diferentes tarifas??
- Usos públicos: alumbrado público, escuela nocturna, cancha de futbol?



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Description	Units	Values	Comments
Estimations of Energy Consumption			
Residential use			
Basics	kW	12.7	Based on pondered power factor correction
	kWh	46.04	one hour ventilator 1.12 kWh/HH, 33.7 kWh/HH/M,) (two hours ventilator 1.33kWh/HH, 39.78 kWh/HH/M, 54.67 kWh/d)
Comfort	kW	2.5	
	kWh	8.6	
Luxus	kW	11.43	
	kWh	16.48	
Public users			
Public lighting	kW	2.27	42 (poles) LED Lamps@ 54 W
	kWh/d	11.34	Estimated 5 hours of daily consumption)
Productive users			
Carpenter shop + Water Pump	kW	10.3	(7.5 kW WP, 2.53 kW CS)
	kWh/d	10.3	(7.5 kWh, 2.53 kWh, 1 hr/d. of use)
Estimated max. consumption			
Estimated maximum peak demand	kW	13.5	(expected around 13:00)
Estimated maximum peak demand	kW	11.2	(expected around 19:00
Estimated max. energy consumption	kWh/d	92.79	

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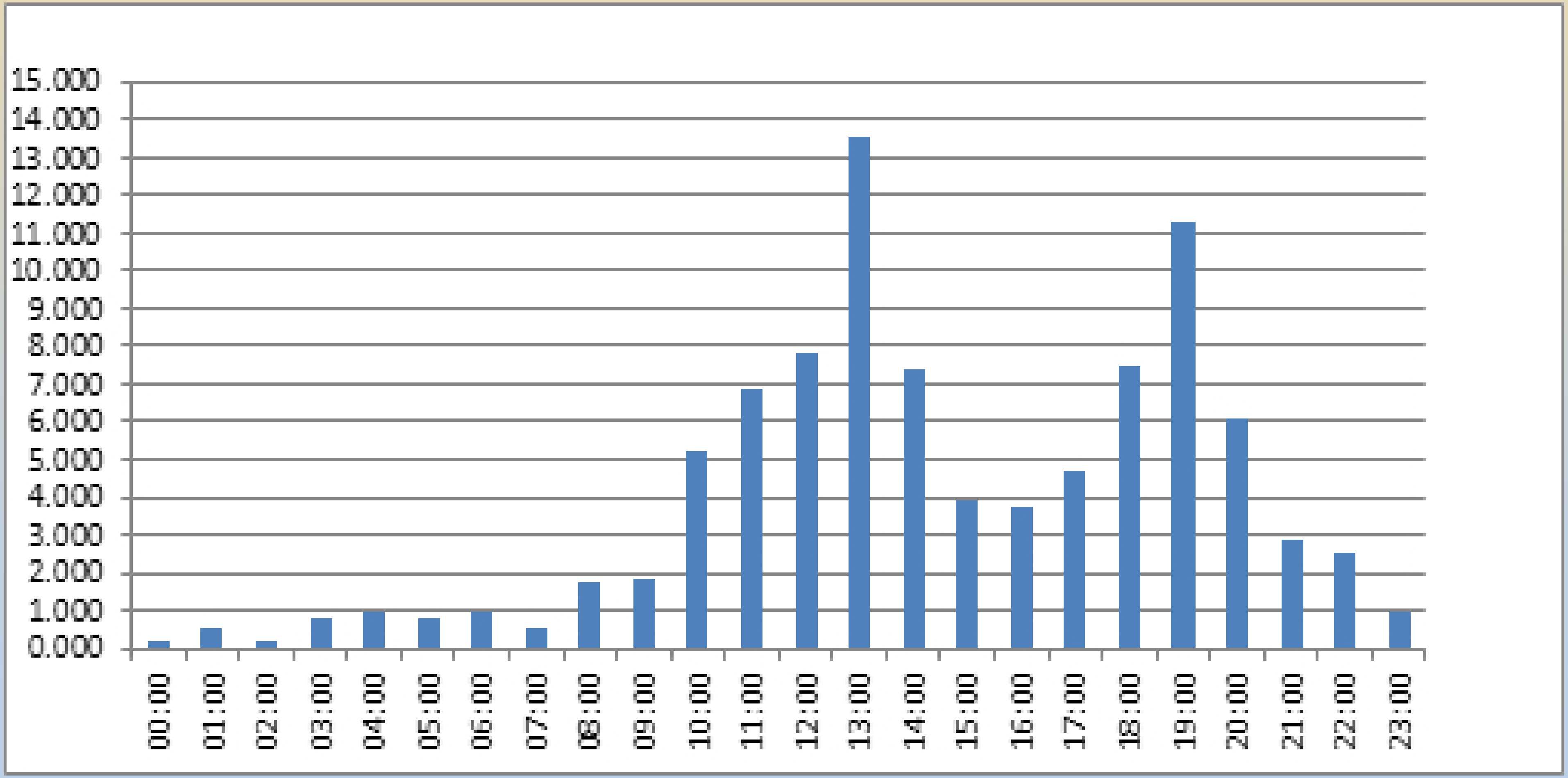
Perfil de la demanda esperada

> Estimación del uso de energía durante el dia y durante la noche!



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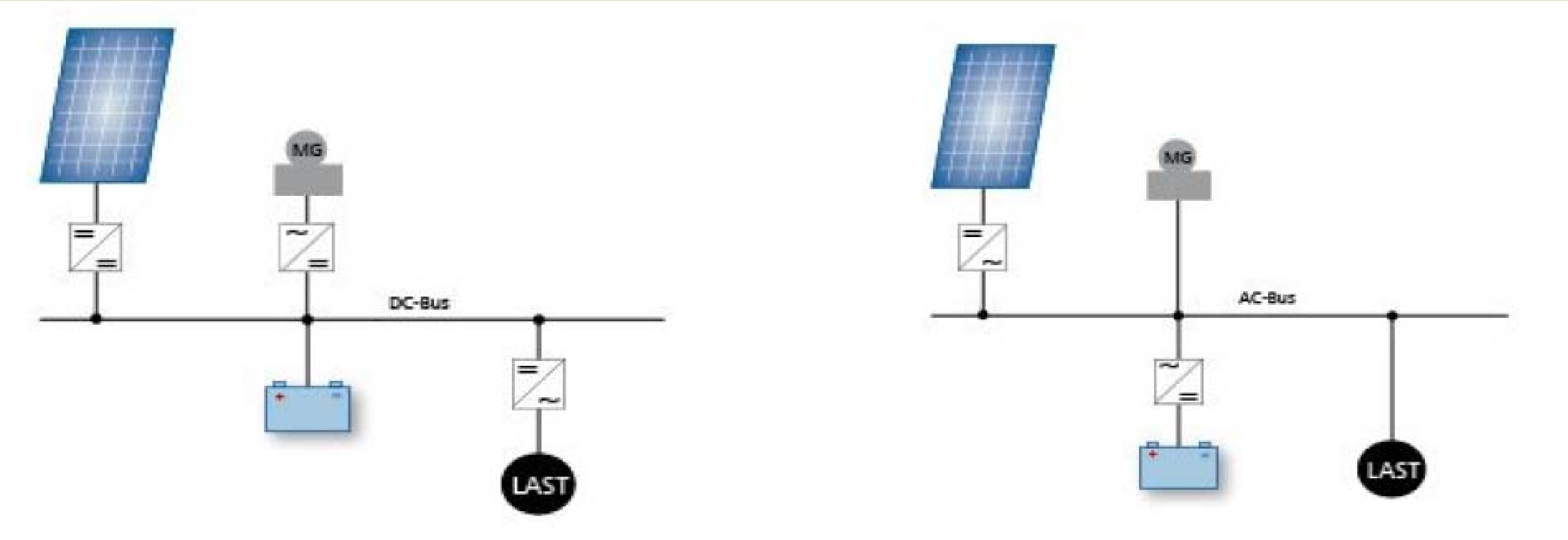
Principal design of a hybrid PV system DC and AC Bus



El diseño de la red fotovoltaica

Description	Units	Values	Comments
PV HYBRID DESIGN			
PV power generator	kW	32.4	135 Modules von Q.Cells Model Q.PRO – G2 230 240 Wp p/Module . Nominal power @ STC
AC inverter max. power	kW	30	3 Sunny boys 10000 TLRP @ 208 V
Number of modules per string	No.	15	15 Module per String and 3 Strings per Inverter
Parallel strings	No.	3	Per each inverter
BATTERY INVERTER			
Battery inverter max. power	kW	30	6 Sunny Island 5048US
Battery bank	kWh	157,4	Two strings of 24 each. BAE Secura PVV solar Model: 12 PVV 2280 1,640 Ah @ C_{10}/1.80 V
Diesel	kW	22	Proposed Diesel Engine 12 kW
Fuel Consumption	Litre/a	2173	Dependency on efficiency. With 72 kWh battery bank, the Diesel consumption would be 8807 L/a. A Diesel engine with 12 KW will consume 1395 litres per year and with a 72 kWh battery bank, the diesel consumption would be 5337 L/a.

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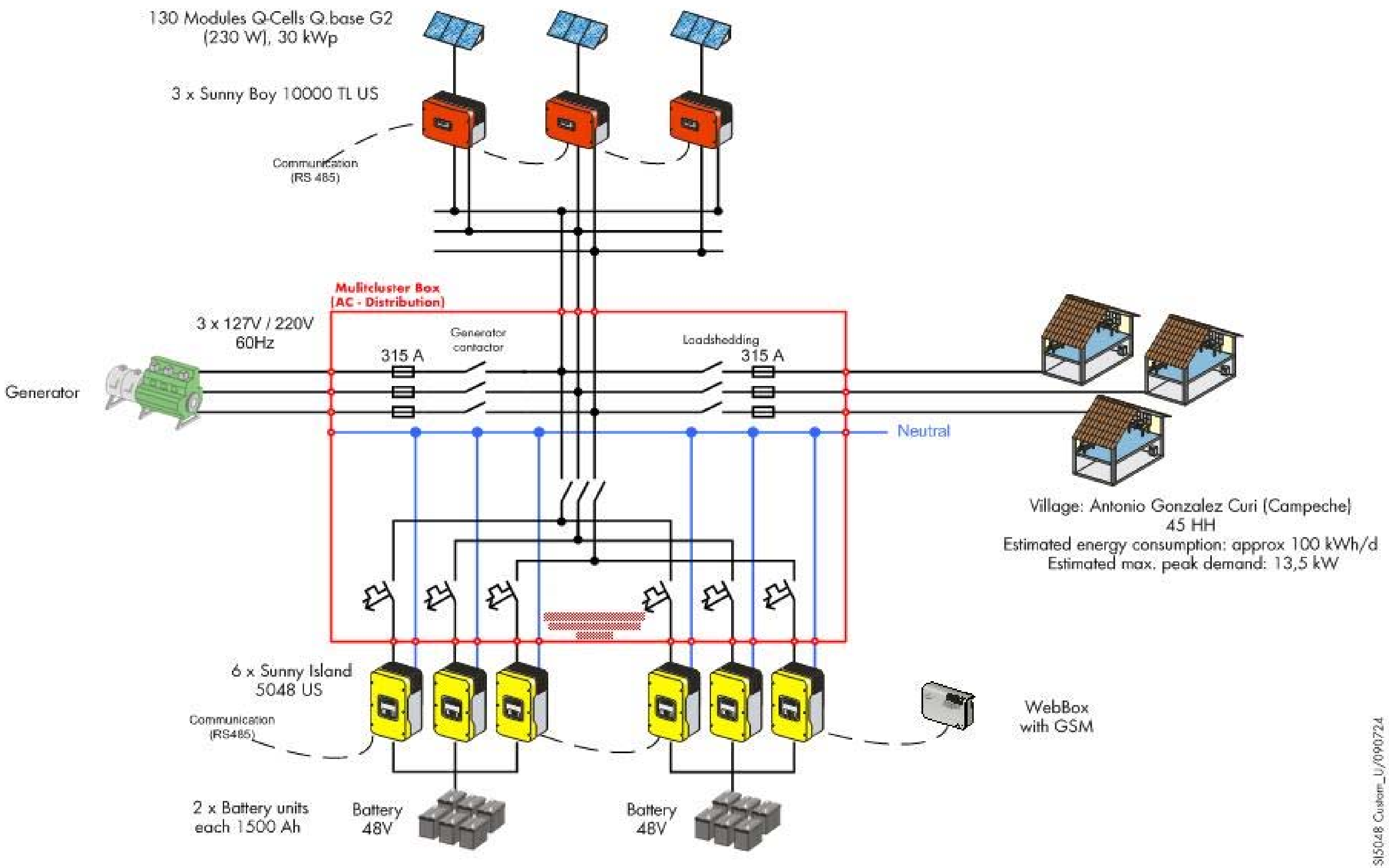
Multicluster Sunny Island 5048U



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INVERSORES
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PROPIOS
SMA
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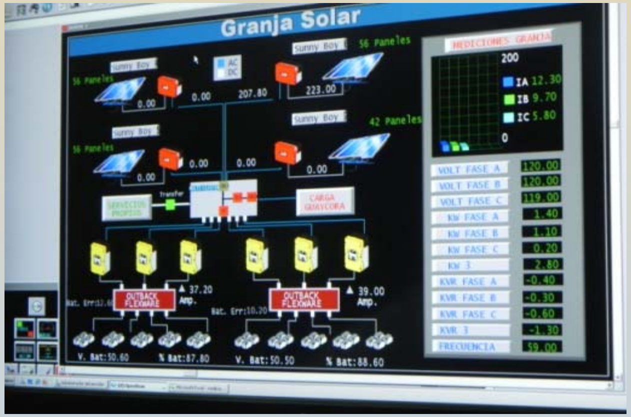
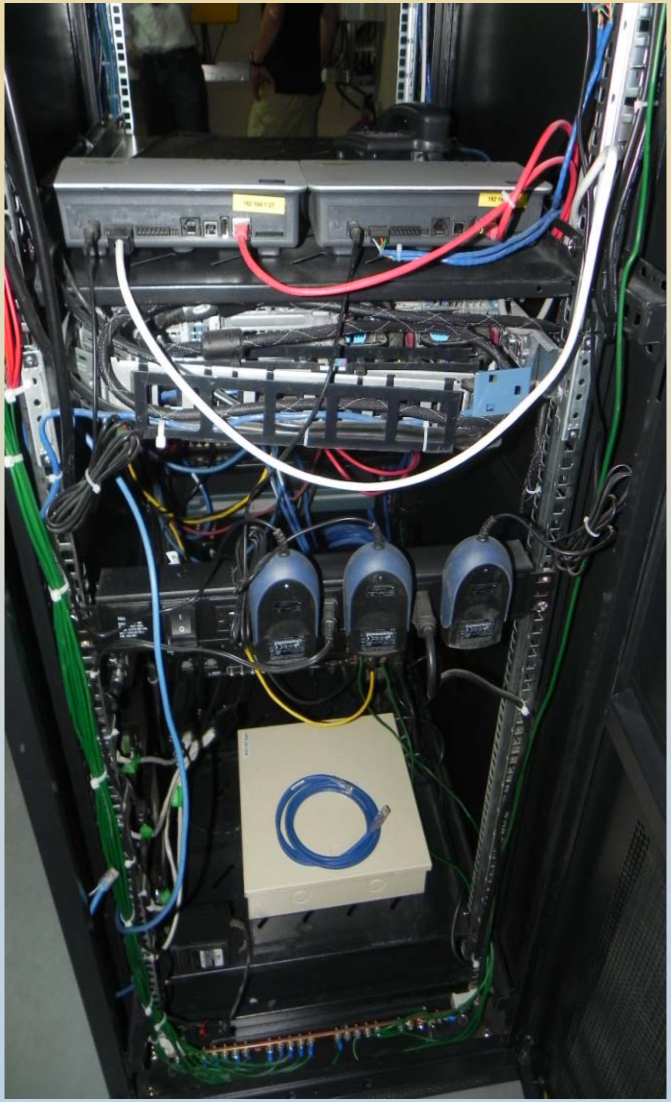
Trojan
L16RE-2V
2 VOLT
Trojan
L16RE-2V
2 VOLT
Trojan
L16RE-2V
2 VOLT
L16RE-2V
2 VOLT


FUEGO/FIRE

Redes inteligentes: automatización, comunicación y manejo de datos

- Confiabilidad del sistema





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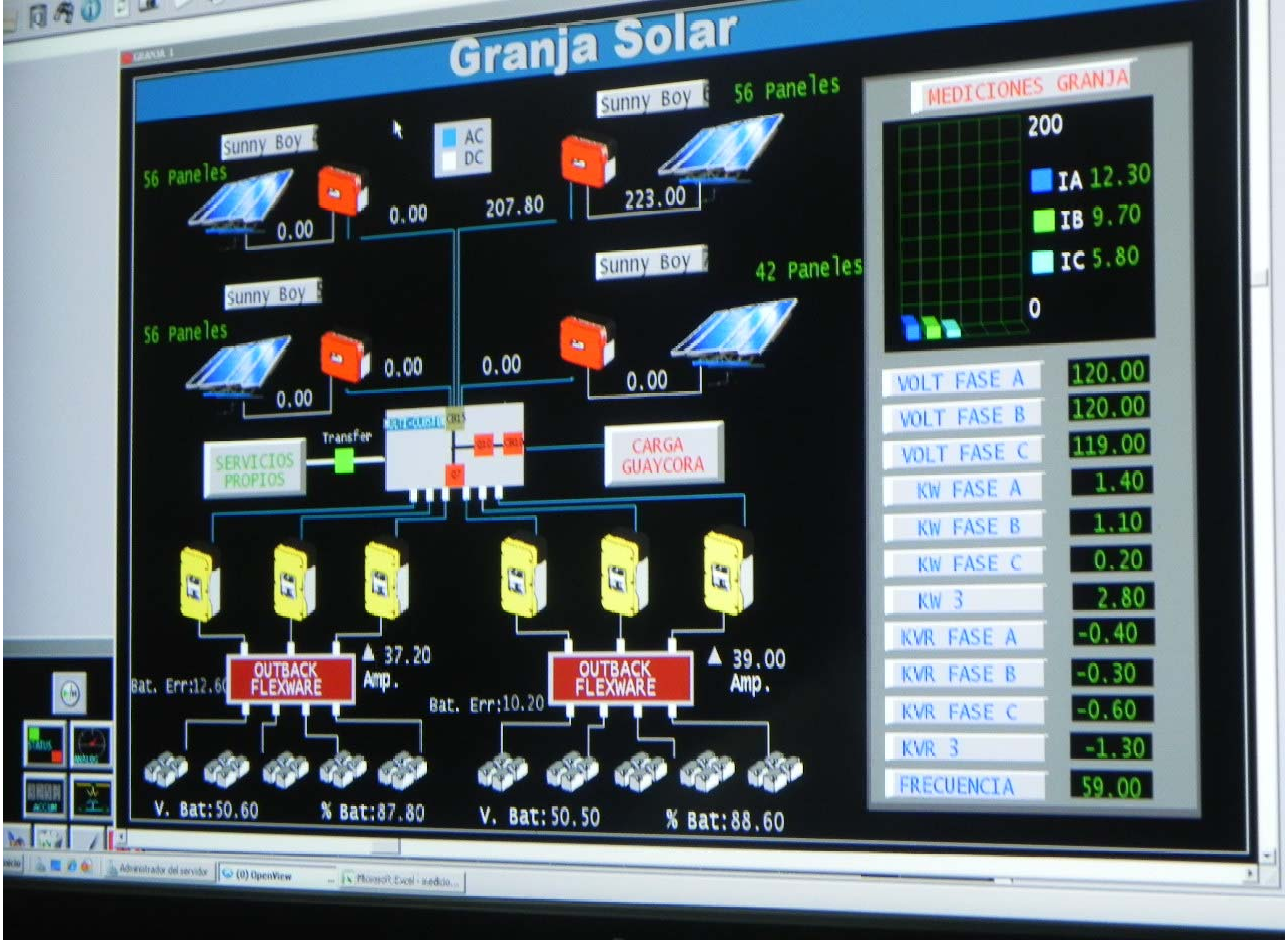

Granja Solar
Sunny Boy
56 Paneles
0.00
0.00
207.80
Sunny Boy
56 Paneles
223.00
AC
DC
Sunny Boy
56 Paneles
0.00
0.00
0.00
Sunny Boy
42 Paneles
0.00
Transfer
SERVICIOS PROPIOS
CARGA GUAYCORA
OUTBACK FLEXWARE
37.20 Amp.
Bat. Err:12.60
OUTBACK FLEXWARE
39.00 Amp.
Bat. Err:10.20
V. Bat:50.60
% Bat:87.80
V. Bat:50.50
% Bat:88.60
MEDICIONES GRANJA
200
IA 12.30
IB 9.70
IC 5.80
0
VOLT FASE A 120.00
VOLT FASE B 120.00
VOLT FASE C 119.00
KW FASE A 1.40
KW FASE B 1.10
KW FASE C 0.20
KW 3 2.80
KVR FASE A -0.40
KVR FASE B -0.30
KVR FASE C -0.60
KVR 3 -1.30
FRECUENCIA 59.00
Administrador del servidor
(0) OpenView
Microsoft Excel - medicio...

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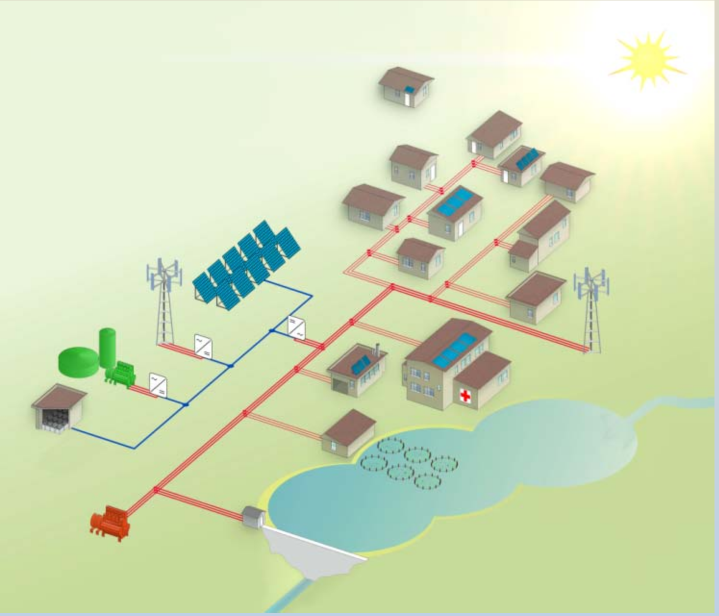

Hybrid PV Systems and Mini-Grids
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- Improve local capacity and access to services
  - Power and distribution (voltage, phases, Grid quality, etc.)
  - Availability (24 hours, day-time only, etc.)
  - Capability for demand-side management
  - Human and financing resources

- Operation and maintenance programs for the long-term run

- To achieve overall "acceptance" and overcome regulatory hurdles

- Need to develop further compelling "best practices" for rural autonomous PV Hybrid Island Grids

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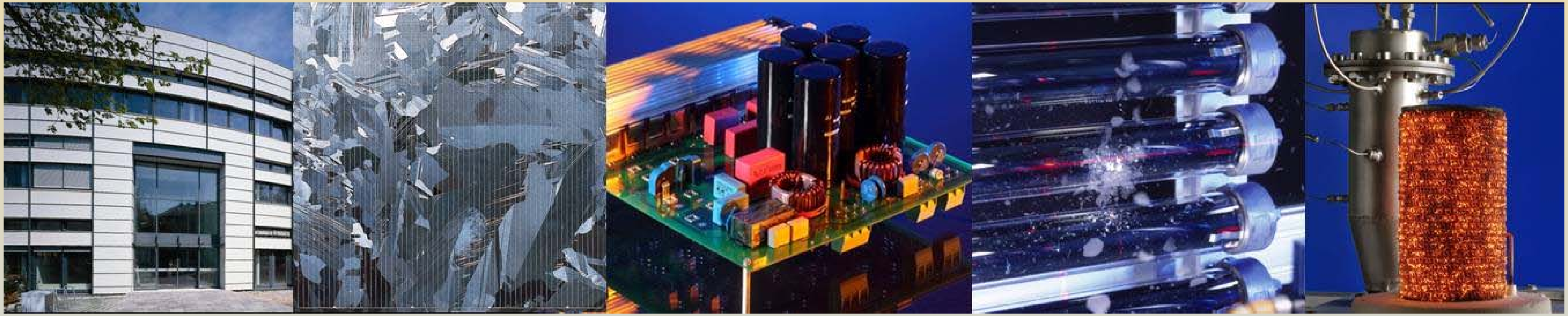
Thank you for your attention!



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Typical fuel consumption characteristics diesel genset