Workshop

Small Wind Turbines

Increasing awareness of the potential of small/medium wind turbines

Renewable Hybrid Systems

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CIEMAT

Picture: *San Juanico RHS, Mexico*

SWTOMP
Small Wind Turbines Optimization and Market Promotion

SWTOMP Project

Huatulco, Mexico. 25-27 June, 2018

GOBIERNO DE ESPAÑA

MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Layout of the presentation

- Introduction to Renewable Hybrid Systems (RHS)
- Experiences of RHS in LAC
- Types and examples of RHS
- CIEMAT's activities on RHS
- Conclusion

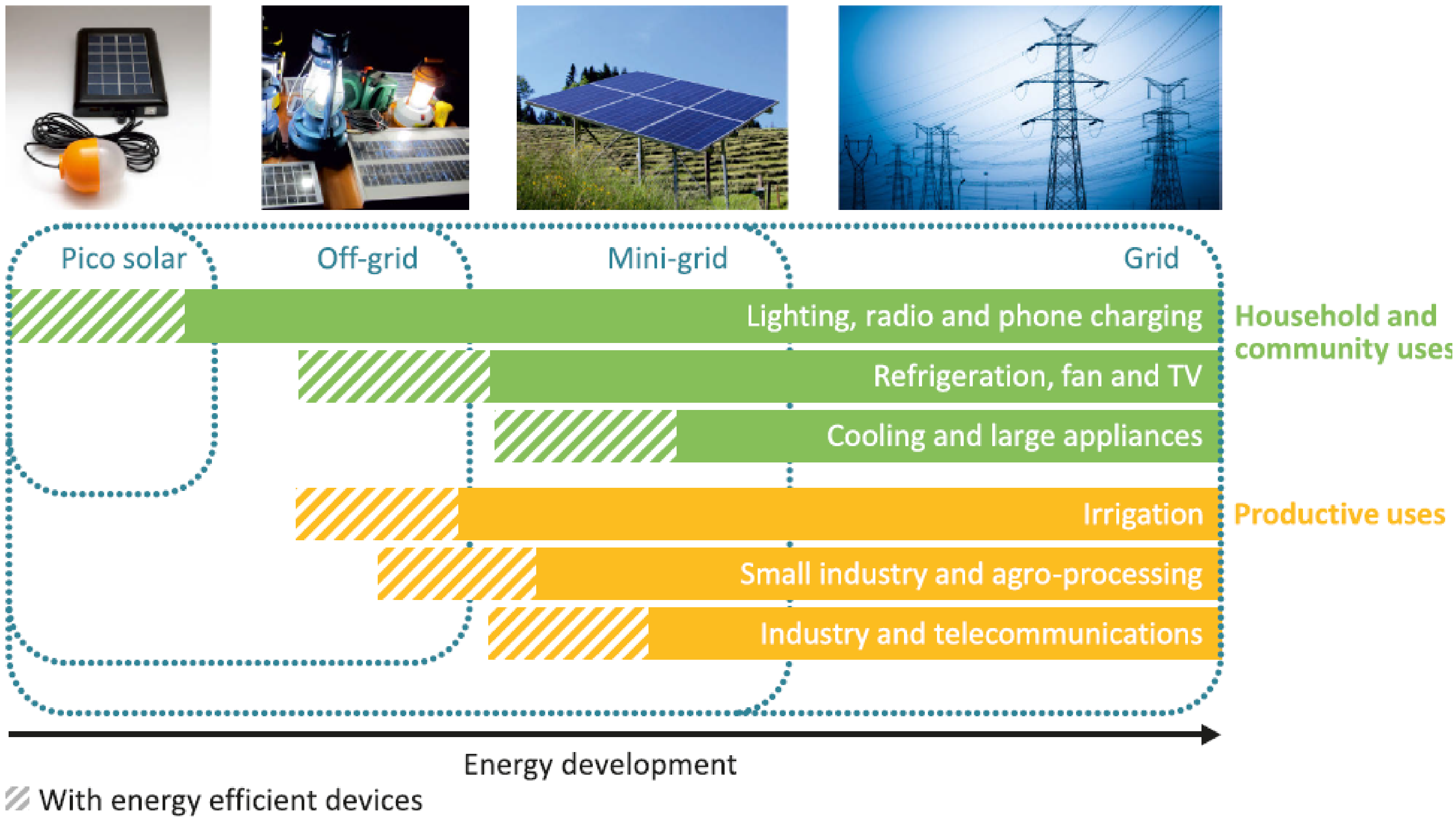
Introduction to Renewable Hybrid Systems (RHS)

- What is a RHS?
- Why RHS?
- What RHS?

What is a RHS?

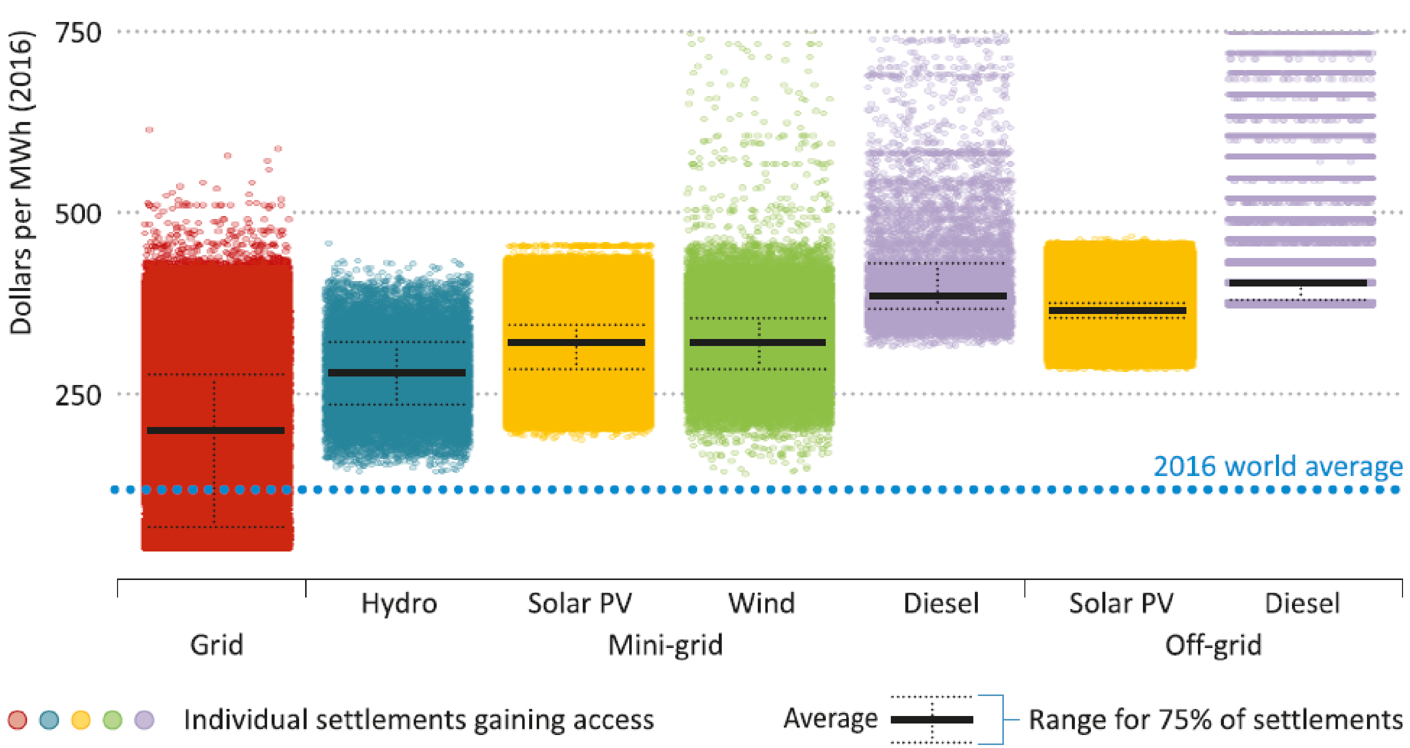
- Electrical generation **systems**
- Including **Renewable Energy** generation
- **Different** generation technologies
- With a common control strategy
- Sharing some electrical equipment

Why RHS? – Electricity access options



Source: *Energy Access Outlook 2017, from poverty to prosperity*. OECD/IEA, 2017. International Energy Agency. www.iea.org

Why RHS? – Renewable Energies



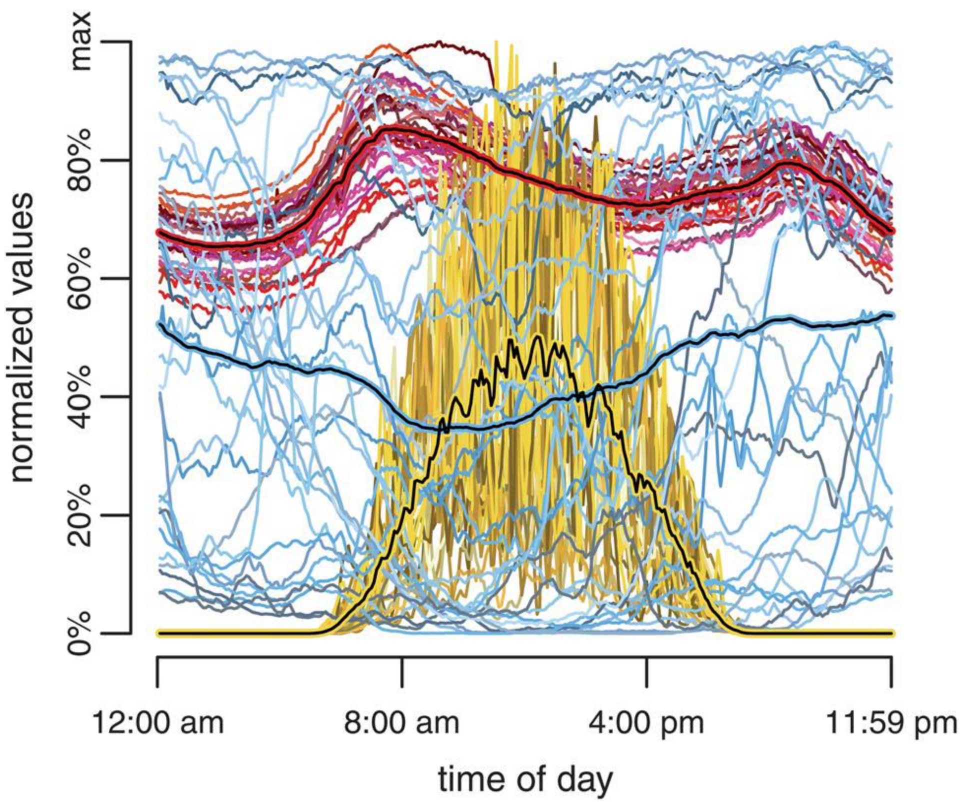
On-grid access provides the lowest-cost pathway to electricity access, but for remote areas, mini-grid and off-grid systems are a cost-effective way to expand access

Notes: Each dot represents an individual settlement. Each settlement represents an area of one square kilometre. The least-cost option for 25 million settlements is presented. 2016 world average represents the average LCOE of the overall electricity supply for residential consumers across regions.

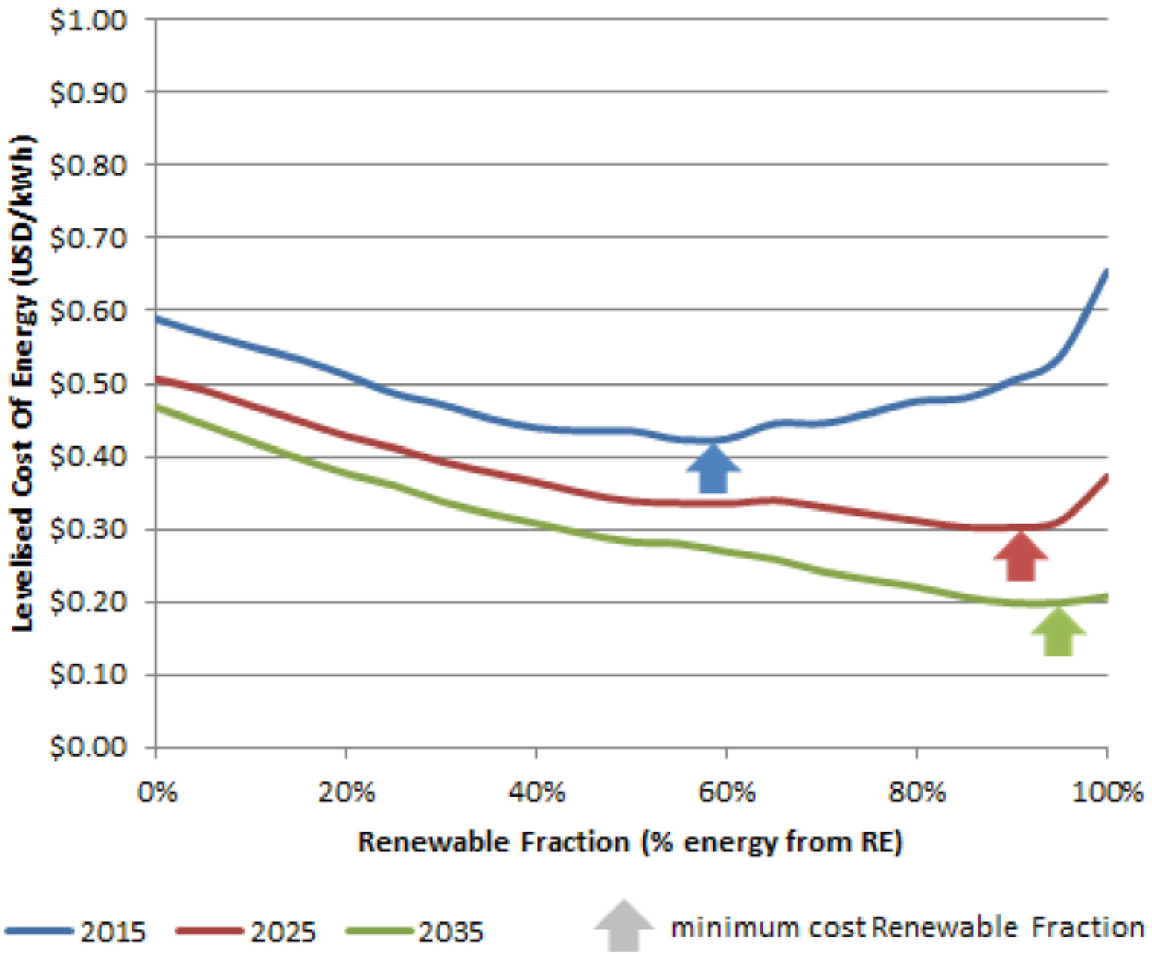
Fuente: *Energy Access Outlook 2017, from poverty to prosperity*. OECD/IEA, 2017. International Energy Agency. www.iea.org

Why RHS? - Hybrids

- RE generation depends on **Time** distribution of
  - Resources
  - Loads
- Usually, RE will need a back-up source

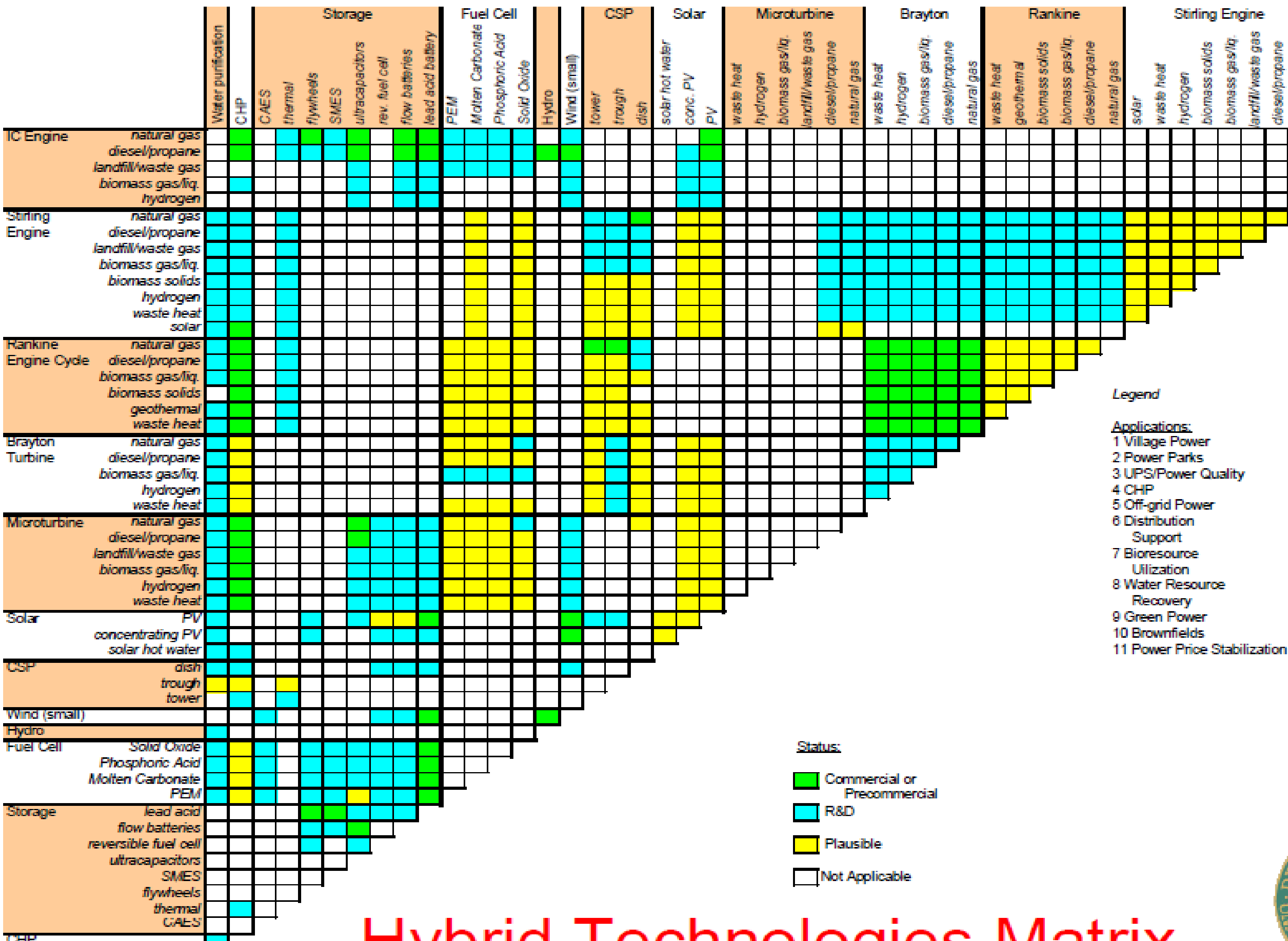


Why RHS? - Economics



Source: "**IRENA (2016), Innovation Outlook: Renewable Mini-grids", International Renewable Energy Agency, Abu Dhabi.**

What RHS? – Difficult to cope with



Hybrid Technologies Matrix

What RHS? – For this presentation:

- Those including wind generation
  - Small Wind Turbines (SWT), less than 100 kW
  - And Medium Wind Turbines, up to MW scale
- And from those, mainly:
  - Hybridized with
    - Photovoltaics (PV)
    - Diesel generators
  - In Latin-American Countries (LAC)
  - Off-grid

Experience of RHS for rural electrification in LAC

- Mexico in the 90s
- Chile: Chiloé archipelago
- Venezuela 48 wind-PV-Diesel
- Chile: El Toqui mine
- Ecuador: San Cristóbal Island
- Bonnaire Island
- …

Experiences of RHS for rural electrification in LAC: Mexico in the 90s

Ubicación del Proyecto	Año de Instalación	Potencia Fotovoltaica (kW)	Potencia Eólica (kW)	Generador Diésel (kW)	Población servida
Ma. Magdalena	1991	4.3	5	18	168
Nva. Victoria	1991	8.6	-	28	355
Oyamello	1991	0.76	5	4	-
X-Calak	1992	11.2	60	125	232
El Junco	1992	1.6	10	-	250
La Gruñidora	1992	1.2	10	-	230
I. Allende	1992	0.8	10	-	140
Calabazal	1992	0.8	10	-	130
Agua Bendita	1993	12.4	20	48	250
Villas Carrousel	1995	0.15	0.5	-	-
Isla Margarita	1997	2.25	15	60	200
San Juanico	1999	17	70	85	400

Types of RHS – According to IEC

Tipo de generador		Clasificación de sistemas asociados	
		Individual	Colectivo
Solo ER, híbrido o no	SIN Almacenamiento	T_1, I	T_1, C
Solo ER, híbrido o no	CON Almacenamiento	T_2, I	T_2, C
ER + grupo, híbrido o no	SIN Almacenamiento	T_3, I	T_3, C
ER + grupo, híbrido o no	CON Almacenamiento	T_4, I	T_4, C
Grupo solo	SIN Almacenamiento	T_5, I	T_5, C
Grupo solo	CON Almacenamiento	T_6, I	T_6, C

Notación: ER = Energías Renovables; Grupo = Grupo electrógeno; T_i, I = Sistema individual, tipo i; T_i, C = Sistema Colectivo, tipo i

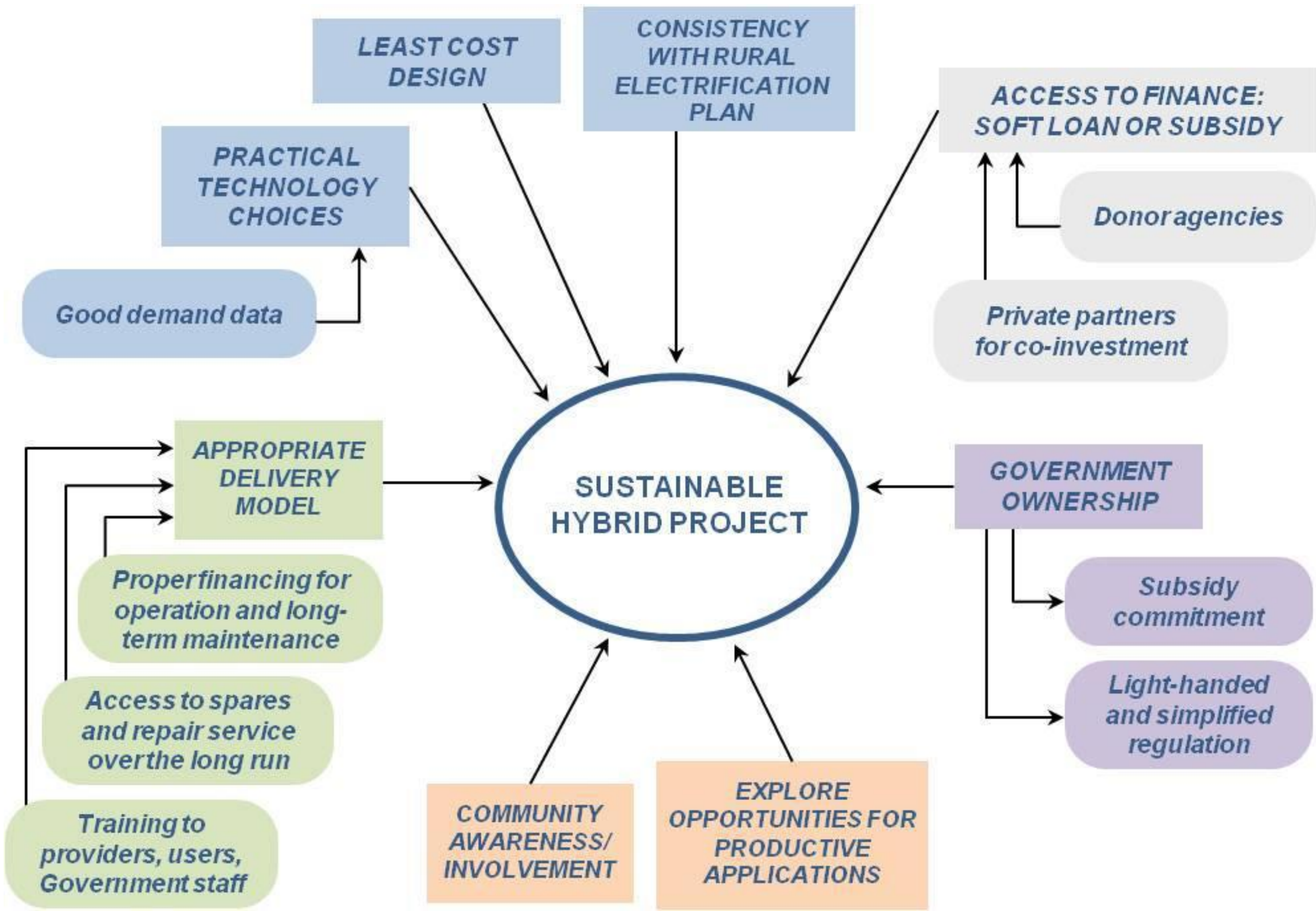
Fuente: IEC 62257, 2005, " *Recomendaciones para sistemas de pequeña potencia e híbridos con energías renovables en aplicaciones de electrificación rural*"

Criteria

1. RE
2. Hybrid
3. Storage
4. Genset
5. Users

12 different types

Other non-technical issues



Issues: **Rural Electrification with PV Hybrid Systems;** Overview and Recommendations for Further Deployment.
Report IEA-PVPS T9-13:2013

Types of RHS – According to the master type

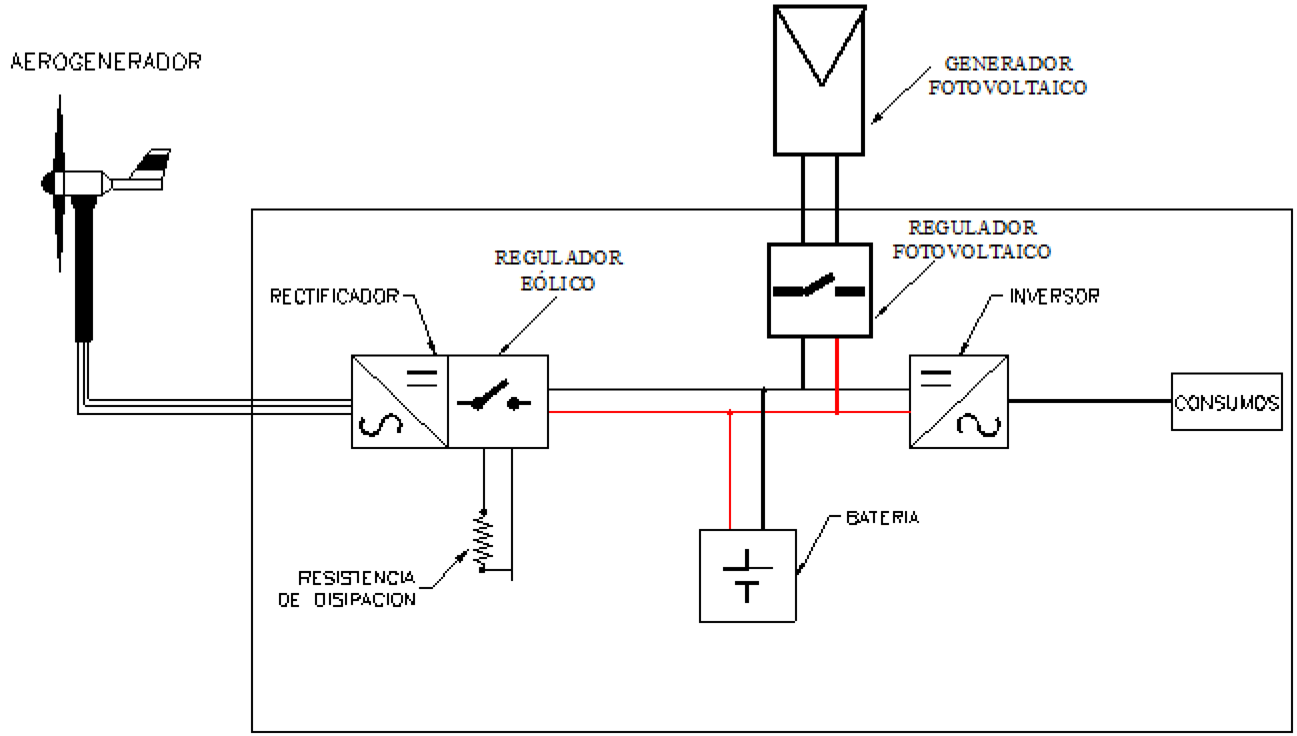
- Inverter dominated
  - Single fixed master (unidirectional inverter)
  - Changing fixed master (bidirectional inverter)
  - Multimaster (distributed inverters)
- Diesel dominated
  - low RE percentage
  - medium RE percentage
  - high RE percentage

Inverter dominated

- Based on long-term storage, usually electrochemical (Li-ion or Lead-acid)
- Diesel genset is optional, as a back-up
- Great opportunities for the inclusion of RE
- Systems configuration remains nearly constant with size
- Supervisory control may be very simple

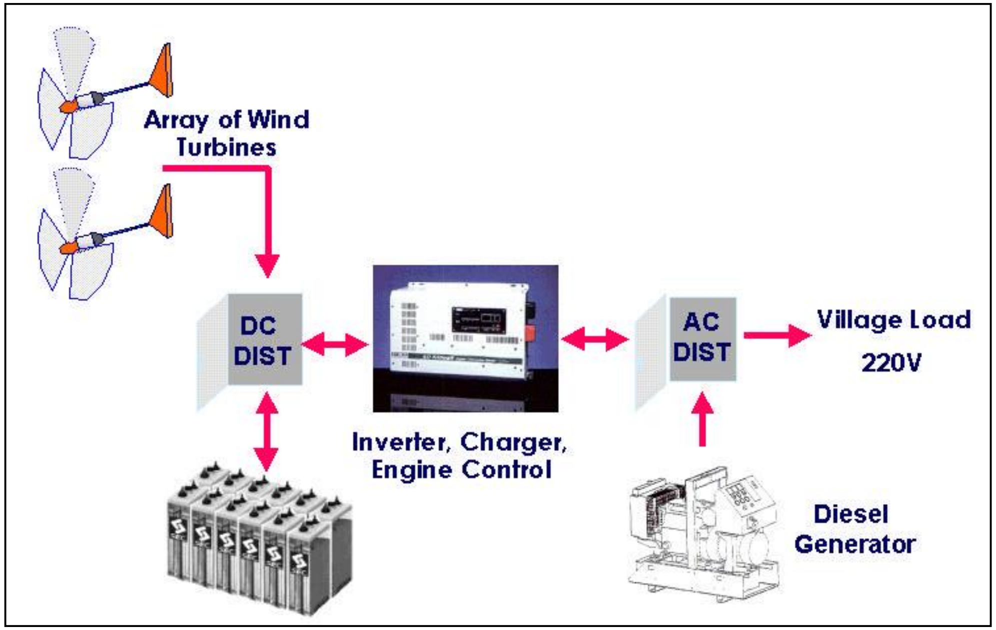
Inverter dominated

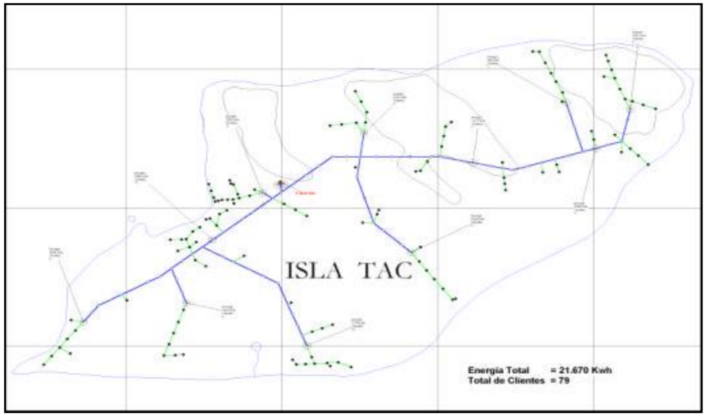
Single fixed master (unidirectional inverter)



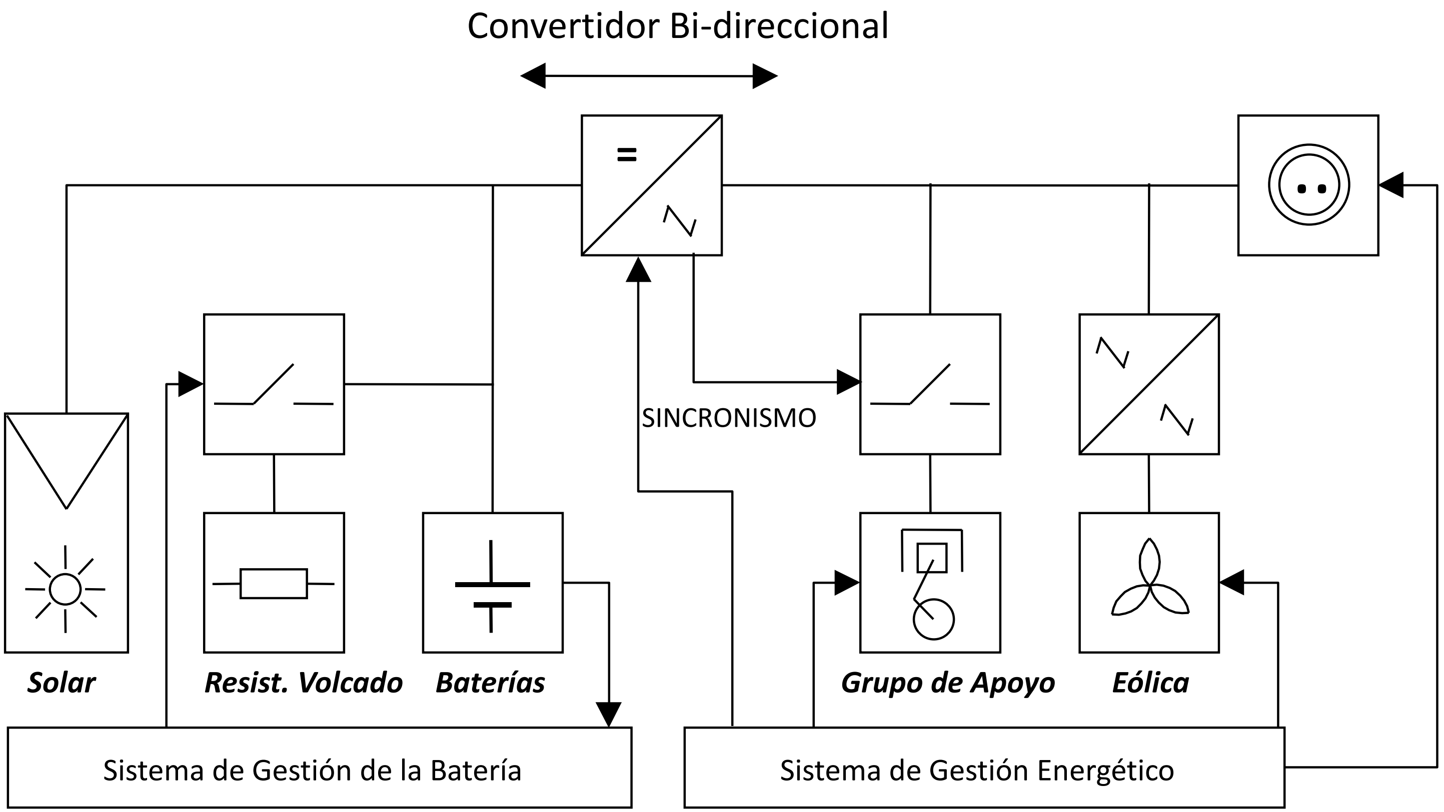
Example: unidirectional inverter dominated

Hybrid Systems in Chiloé Archipelago, in Chile





Inverter dominated
Changing fixed master (bidirectional inverter)



Bidirectional inverter example: Venezuela

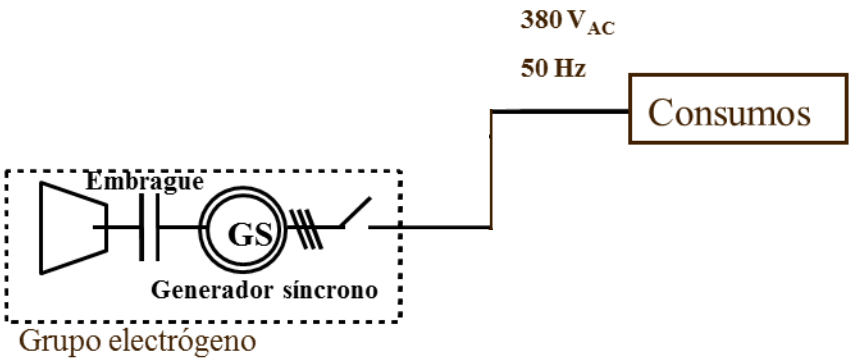
Nº de viviendas	Potencia Fotovoltaica (kW)	Potencia Eólica (kW)	Baterías (C10, Ah)	Inversor (kW)	Generador Diésel (kVA)
10	3	3	800	10	10
20	5.4	6	2x800	10	15
30	8.4	6+3	2x1200	15	20
40	10.8	2x6	4x800	30	25

Diesel dominated

- Diesel genset is one of the most commonly used options for rural electrification (> 500 GW gensets installed)
- Great opportunities for the inclusion of RE
- Storage (short / long term) is optional
- Supervisory control may be complex
- Analysis of transients due to RE quick variations is needed
- Systems configuration depends strongly on RE penetration
  - Instantaneous penetration
  - Average penetration

Diesel dominated: **Starting point**

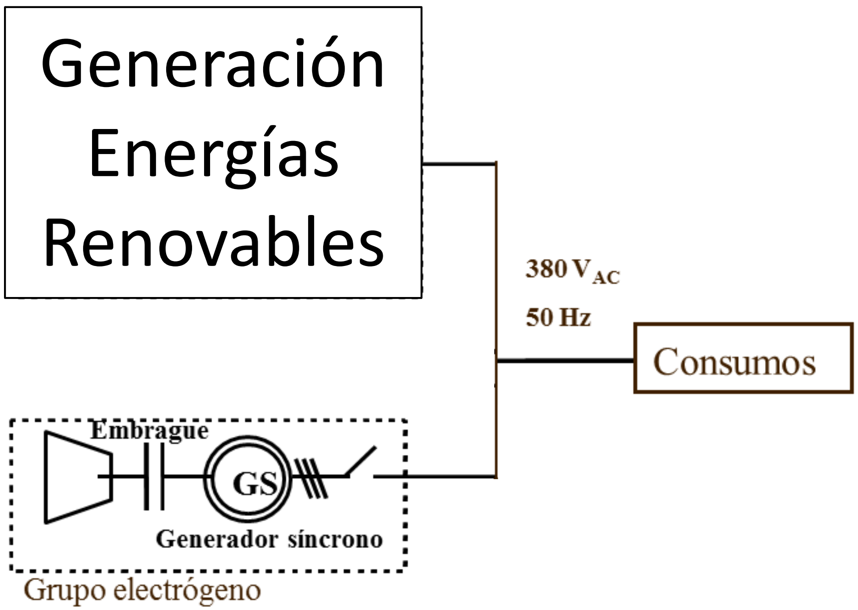
0



Existing Diesel Power Plant

Diesel dominated: low RE percentage

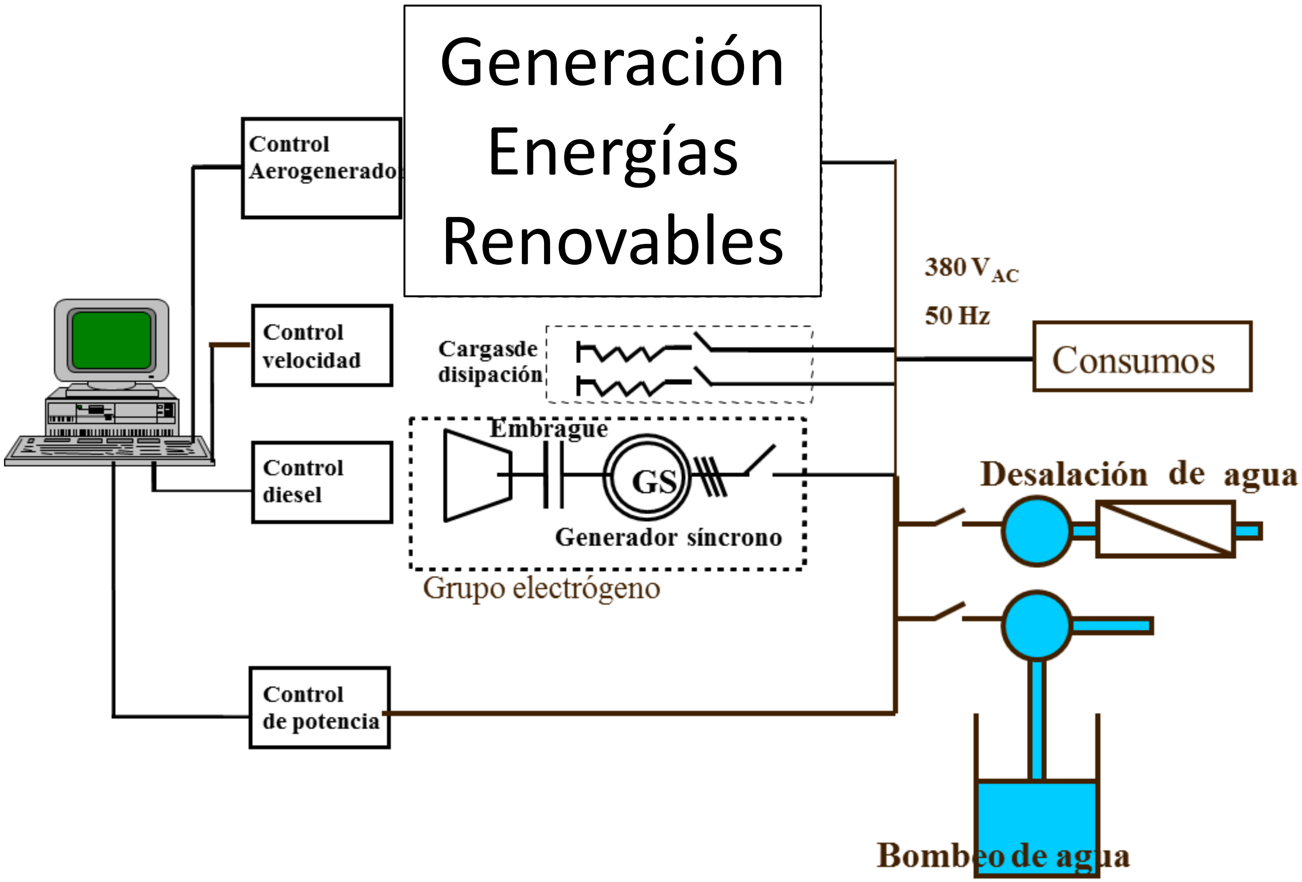
1



- RE Power < Minimum Allowable Load

Diesel dominated: medium RE percentage

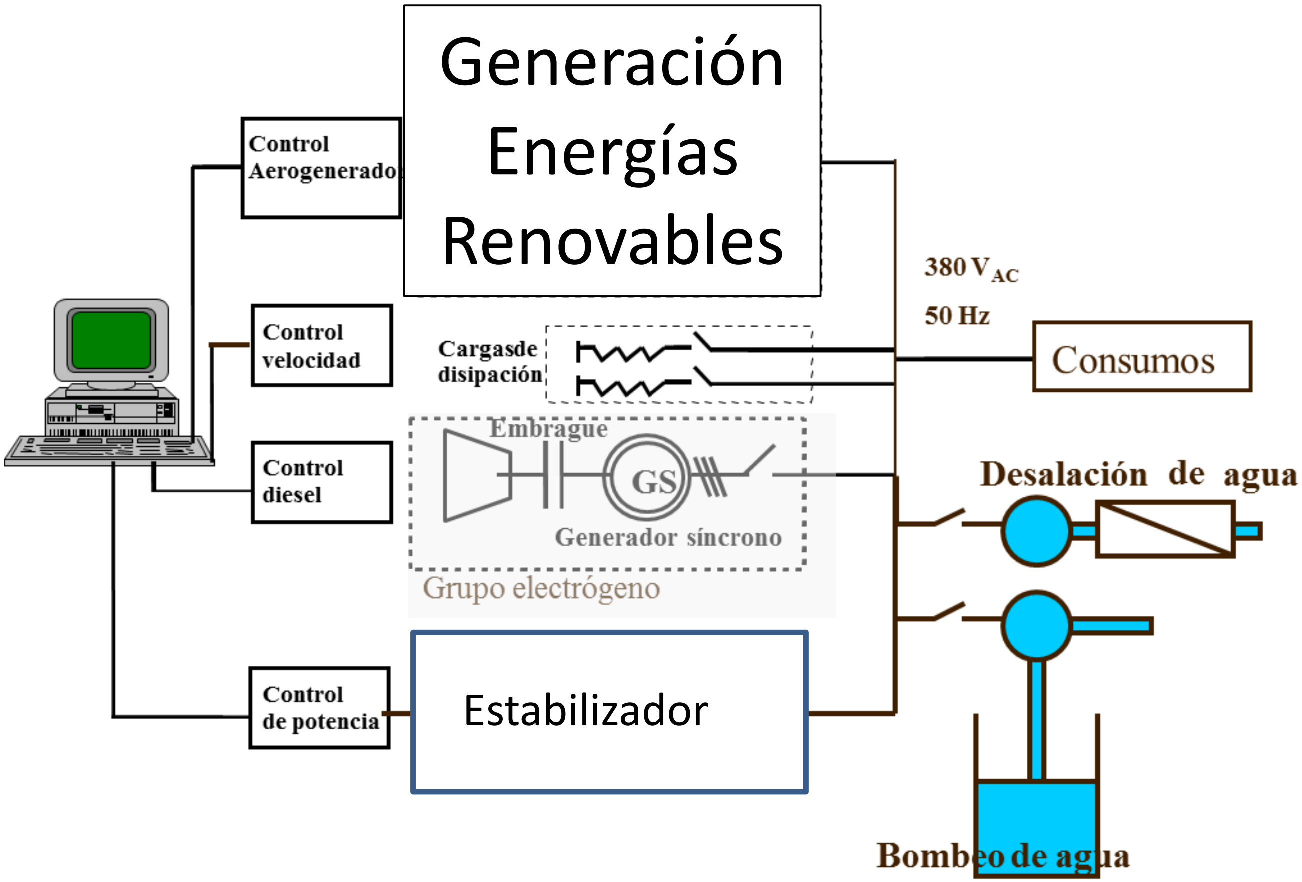
2



- RE Power may be higher than Minimum Allowable Load
- Diesel engine is always ON

Diesel dominated: **high RE percentage**

3



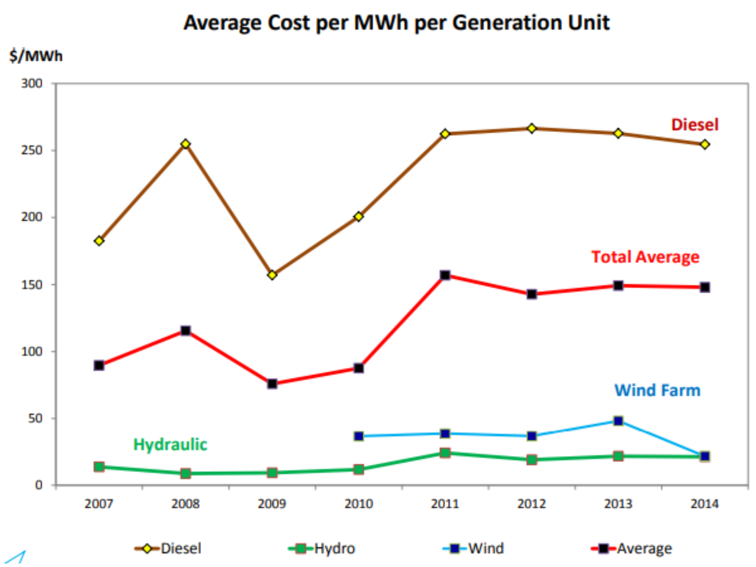
- System can work with Diesel ON or OFF

Example: low RE percentage

Wind Diesel system in El Toqui zinq-gold mine, Chile

1

- **Stage 0:** 5,6 MW Diesel, 2,3 MW Hydro
- **Stage 1:** 6 x 230 kW WT
- **Stage 2:** 1,9 MW Hydro

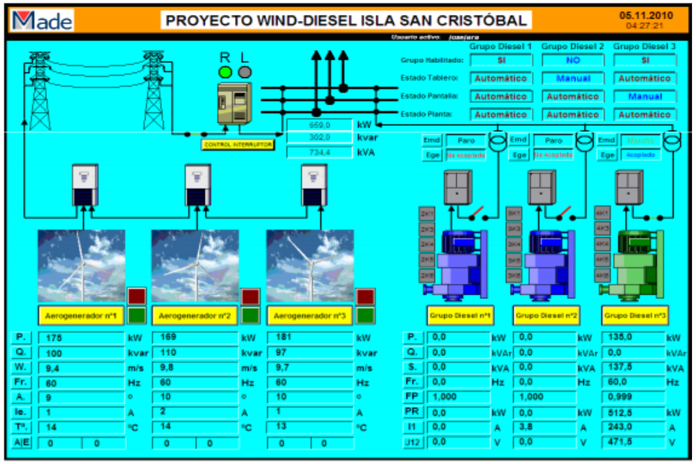


Example: **medium RE percentage**

Wind Diesel system in San Cristobal Island, Galápagos

2

- **Diesel Power Plant:** 3 x 650 kW
- **Wind Power Plant:** 3 x AE59, MADE, variable pitch and variable speed, 800 kW each
- **Control:** SCADA + Diesel
- **Minimum allowable load:** 25%
- **Load profile:** Residential

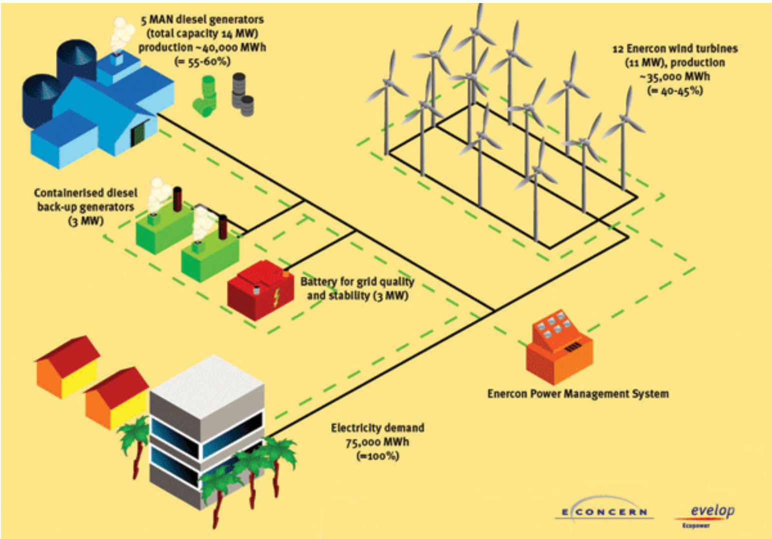


Example: high RE percentage

Wind Diesel system in Bonaire Island

3

- **Stage 0:** 14 MW Diesel
- **Stage 1:** 1 x 300 kW WT
- **Stage 2:** 11 MW Wind, 3 MW/0,1 MWh Battery
- **Stage 3:** Biodiesel from algae

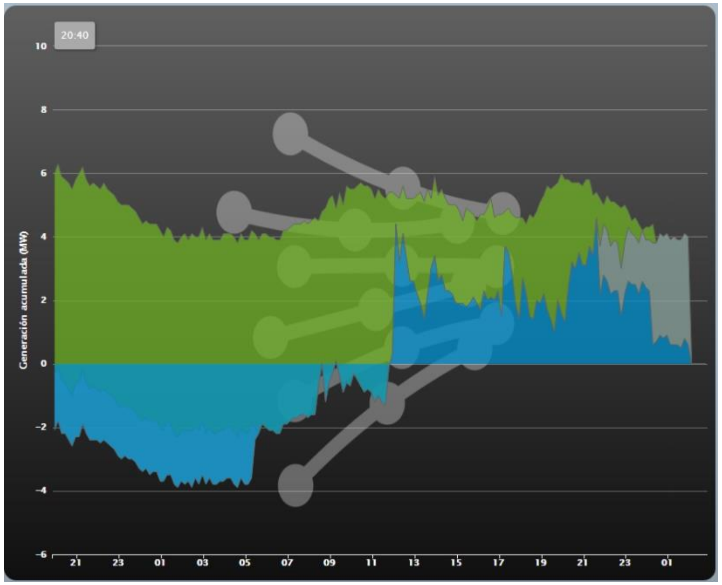


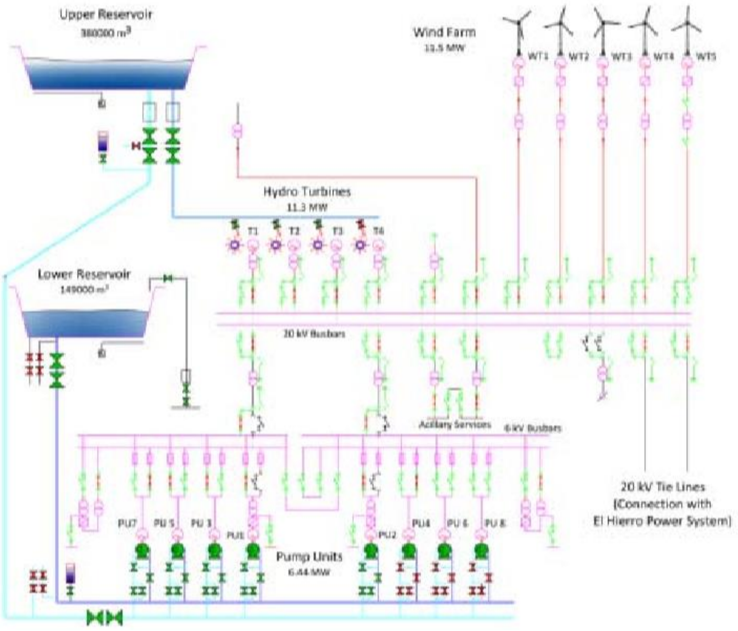
Example: high RE percentage

Wind Diesel system in El Hierro Island

3

- 7 MW peak load (Diesel)
- 11 MW Wind
- Hydraulic storage:
  - 6,5 MW Pumps
  - 11,3 MW Turbines





Experiencia/Capacidades CIEMAT:

Sistemas Híbridos y Miniredes

- Simulación y Dimensionado de sistemas
- Ensayo (CICLOPS 1 & 2) y desarrollo (CICLOPS 2)
- Sistemas de control y supervisión (SEDUCTOR)
- Sistemas Eólico/Diésel (Fuerteventura, SEDUCTOR...)
- Mini-redes y generación distribuida (SINTER, GEBE...)
- Desalación de agua de mar con energía eólica (WINDOSMOSIS, GREEN-MVC, WindRO)

Planta de ensayo de sistemas híbridos y miniredes del CIEMAT-CEDER en . Soria (ESPAÑA)

DERlab

International Energy Agency Photovoltaic Power Systems Programme

PROGRAMA IBEROAMERICANO CYTED CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO

Participación en iniciativas de I+D relevantes:

- IEA R&D WIND Tarea 8: Estudio de aplicaciones descentralizadas para energía eólica (finalizada)
- IEA R&D PVPS: Sistemas híbridos FV en Mini-redes.
- Norma IEC-62257 Pequeños sistemas híbridos con energías renovables
- Proyectos CYTED: ELECSOLRURAL, ECOTUR-Renova
- Mini-redes y generación distribuida: DERlab, FUTURED

Conclusions

- Renewable Hybrid Systems can be a competitive solution for all types of electrical supply
- Depending on the type of system, there are different technical options
- Wind and PV appear as the most common RE technologies to take into account, though hydro can also be a good option when available
- As the size increase, the generation costs get lower, both for RE and conventional technologies

Zhangbei National Wind and Solar Energy Storage and Transmission Demonstration Project, China

100 MW Wind, 40 MW PV, 36 MWh Li-Ion

Picture: I. Cruz - CIEMAT

THANK YOU VERY MUCH FOR YOUR ATTENTION

Acknowledgements

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