Alliance for
Rural
Electrification

Shining a Light for Progress

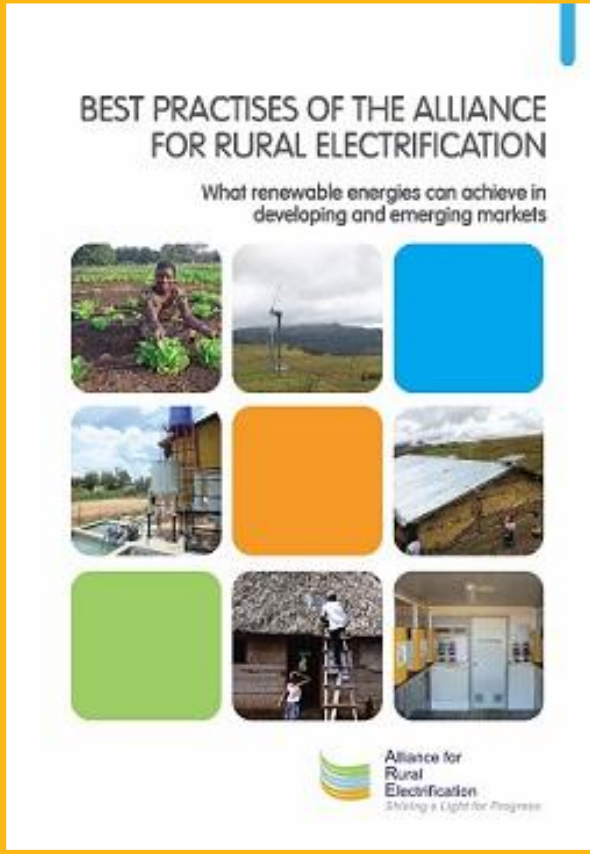
PV Systems and Storage
for Off-Grid Solutions

Who we are, what we do

- International business association representing the **decentralised energy sector** working towards the integration of renewables into **rural electrification markets in developing and emerging countries**

- Enabling improved energy access through business development support for more than 80 members along the whole value chain for off-grid technologies by **targeted advocacy** and facilitating **access to international and regional funding**

- Global platform **for sharing knowledge and best practices** to provide for rapid implementation of available and advanced RE technologies and services



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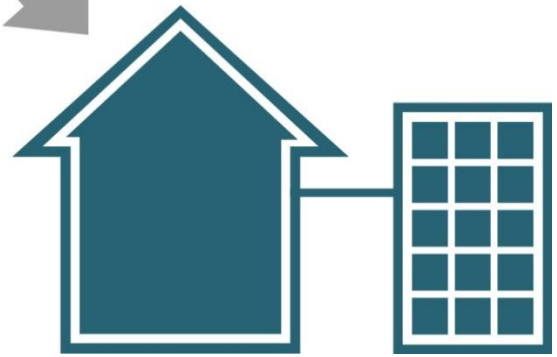
Members from industry, academia and public sector

Phaesun Company Profile

Phaesun®

Solar components & sales



Solar systems & projects

Content

1. Technical overview: Batteries for Off-Grid systems

Comparison of technologies

2. Storage for specific Off-Grid applications

Off-Grid systems for households

Off-Grid systems in the commercial sector

Off-Grid systems for industrial use

3. Global Potential for Renewable Energy Storage Systems on Islands

1. Technical overview

Comparison of battery technologies

VLRA batteries	**Gel** batteries	**Nickel** batteries	**Lithium** batteries

Comparison of battery technologies

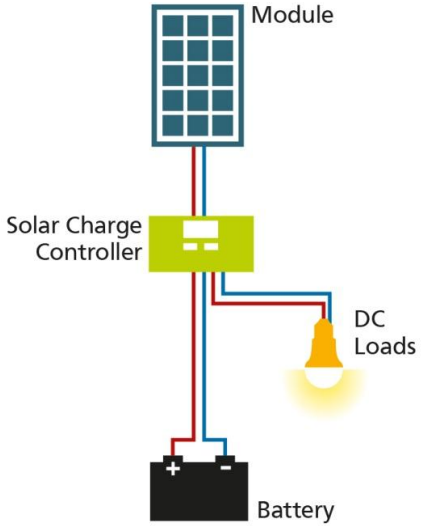
		VLRA batteries		**Gel** batteries	**Nickel** batteries			**Lithium** batteries	
	units	**Pb-Bloc**	**Pb OPzS**	**PB OPzV**	**NiCd**	**NiMH**	**NiFe**	**Li-Ion**	**LiFePO4**
Energy density	Wh/kg	20~35	20~35	20~35	30~50	50~60	18~25	110~190	95~140
Operating life	years	5~6	7~8	12~15	5~15	< 5	>20	5~10	5~10
Cycle @ DOD80%	numbers	600	1500	2200	1500	1000	1500	3000	2500
Self discharge	%	5%	3%	3%	10~20%	20~30%	3%	3%	1%
Efficiency Wh	Wh_{in}/Wh_{out}	85%	85%	85%	75%	85%	90%	90%	95%
Temperature range		-10~40°C	-10~40°C	-10~40°C	-20~50°C	-20~50°C	-20~60°C	-20~55°C	-20~55°C
Captial cost	€	141	211	295	633		450	1.661	675
Energy cost	€/kWh	0,35	0,21	0,20	0,70		0,52	0,71	0,34
Safety		+	+	+	+	+	+	-	+
Environment		-	-	-	---	+	+	+	++

2. Storage for specific Off-Grid applications

Rural households (1)

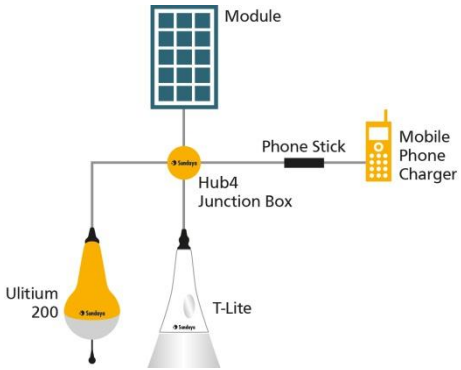
Conventional SHS:

- Individually designed
- Central VRLA-battery
- Use in Asia, Africa, Eurc
- 1980s~now



PicoPV:

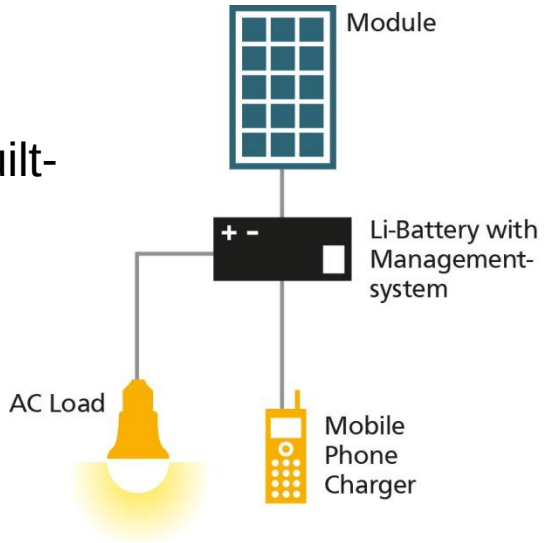
- Complete kits for lighting, mobile phone charging
- With Ni or Li battery
- Limited capacity
- Since 2008



Rural households (2)

Energy Comfort Kits:

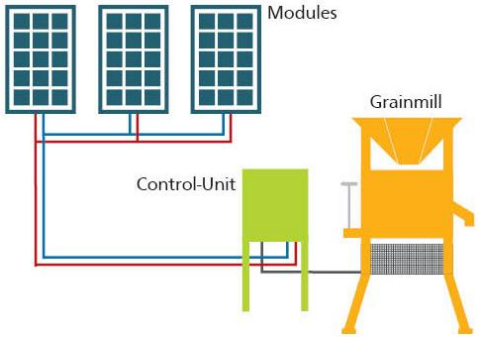
- Central Li-Battery with built-in management system
- Lighting and other individual loads
- Since 2013



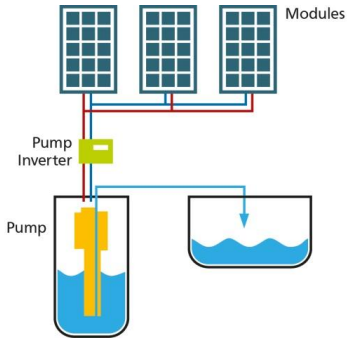
Commercial sector

Off-Grid systems for income generation without storage:

- Solar grain mill



- Solar irrigation

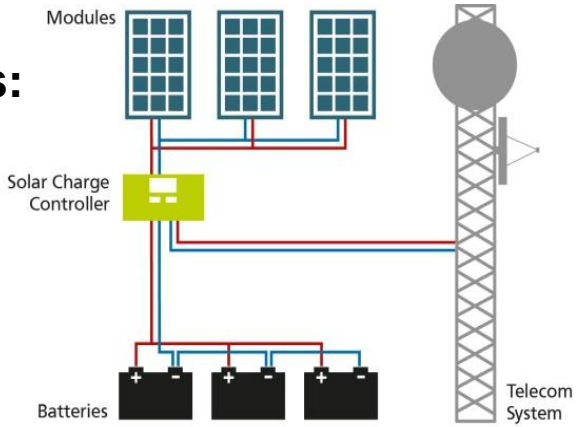


- Solar cooling

Industrial use

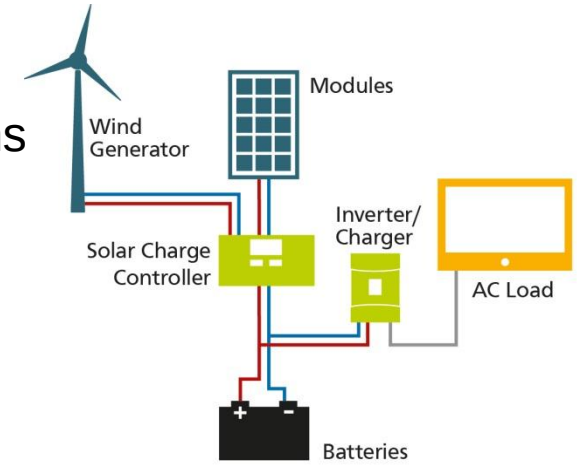
Telecommunication stations:

- Continous power need far from the grid
- With Ni or VLRA
- Often in combination with Diesel



Measuring stations:

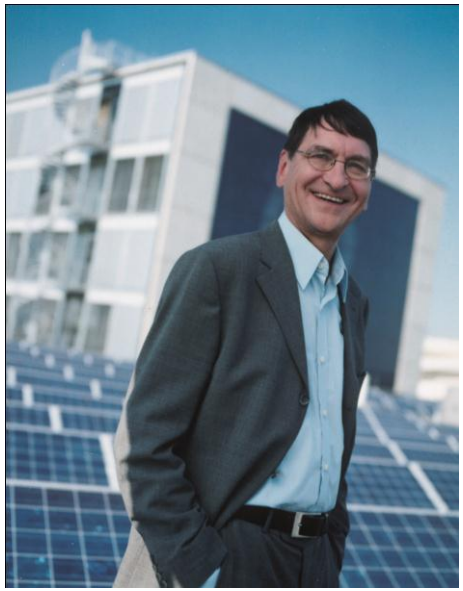
- Extreme weather conditions
- Increasing use of Li-batteries



3. Global Potential for Renewable Energy Storage Systems on Islands

Reiner Lemoine Institut

- **Renewable Energy Mobility**
  - Mobility concepts based on RE
- **Renewable Energy Technology**
  - Small wind power applications
  - Technical integration of RE
- **Renewable Energy Systems**
  - Optimization of energy systems
  - Energy transition processes
  - Off-grid energy systems



Reiner Lemoine
Initiatior of the Reiner Lemoine-Foundation and Institute

Scientific research and support for a transition towards 100 % renewable energies

Small islands as market for RE storage systems

- Dependent on expensive diesel power generation
- High diesel fuel transportation costs
- Renewable resources abundant on most islands
- No major power generation infrastructure (< 100,000 inhabitants)

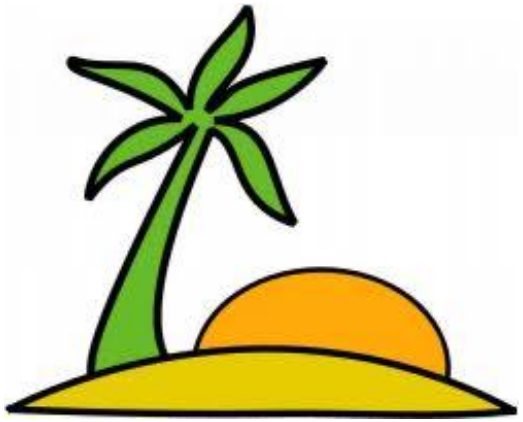


Table: Overview on global small island landscape (1,000 to 100,000 inhabitants).

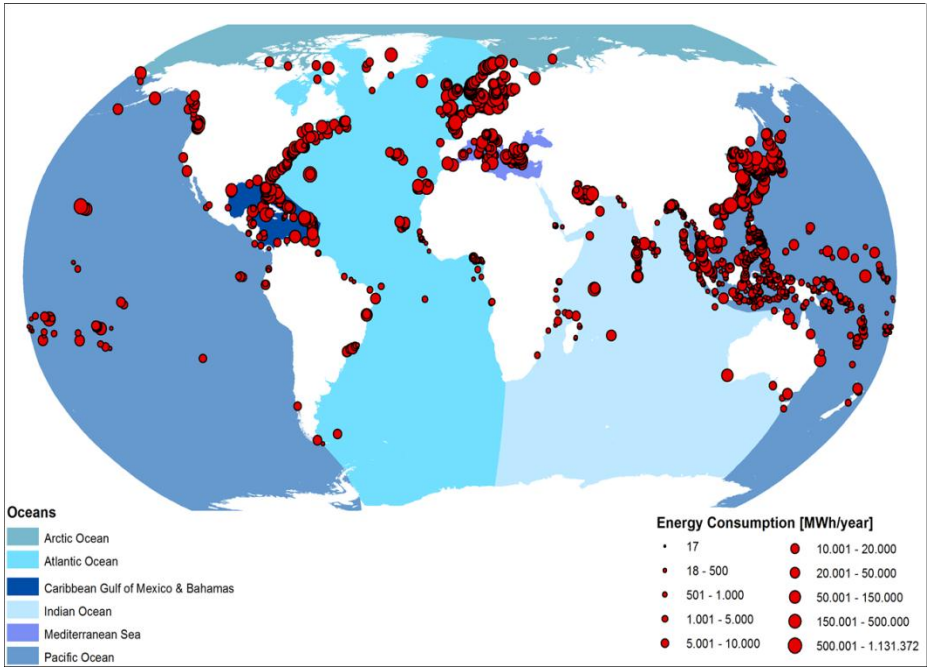
Region	Number of Islands	Population (av.)	Population (sum)	GDP (av.) [EUR/cap]
Atlantic+ Arctic Ocean	416	9,985	4,150,000	18,200
Caribbean + Gulf of Mexico	105	16,160	1,700,000	14,600
Indian Ocean	232	12,210	2,830,000	2,960
Mediterranean Sea	104	10,540	1,100,000	23,500
Pacific Ocean	1,199	9,690	11,620,000	8,660
Total	**2,056**	**10,410**	**21,400,000**	**14,300**

Energy consumption on small islands

Table: Overview on global small island landscape (1,000 to 100,000 inhabitants).

Region	El. cons. (sum) [GWh/year]	El. cons. (av.) [MWh/year]	El. cons. (av. per cap.) [kWh/year* cap]	LCOE Diesel only (av.) [EURct/kWh]
Atlantic+ Arctic Ocean	18,270	43,930	4,400	36.6
Caribbean + G. o. Mex.	5,730	54,550	3,370	34.2
Indian Ocean	2,240	9,670	790	38.0
Mediterranean Sea	3,680	35,390	3,345	33.2
Pacific Ocean	22,770	18,990	1,960	39.3
Total	**52,690**	**25,630**	**2,462**	**38.0**

Figure: Energy consumption of small islands (1,000 to 100,000 inhabitants). Energy consumption [MWh/year]



- Energy consumption per island is derived from national energy consumption level scaled by the local GDP
- Load profile per island is influenced by climate conditions and a national tourism factor

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Energy Systems Modelling

- For given input parameters a cost optimized energy system configuration (out of diesel generator, PV module, wind power generator & battery) is computed in hourly time steps over one reference year
- Local input parameters are diesel costs, solar and wind resources, and load profiles
- Energy flows of components and resulting costs form the baseline for calculating power generation costs

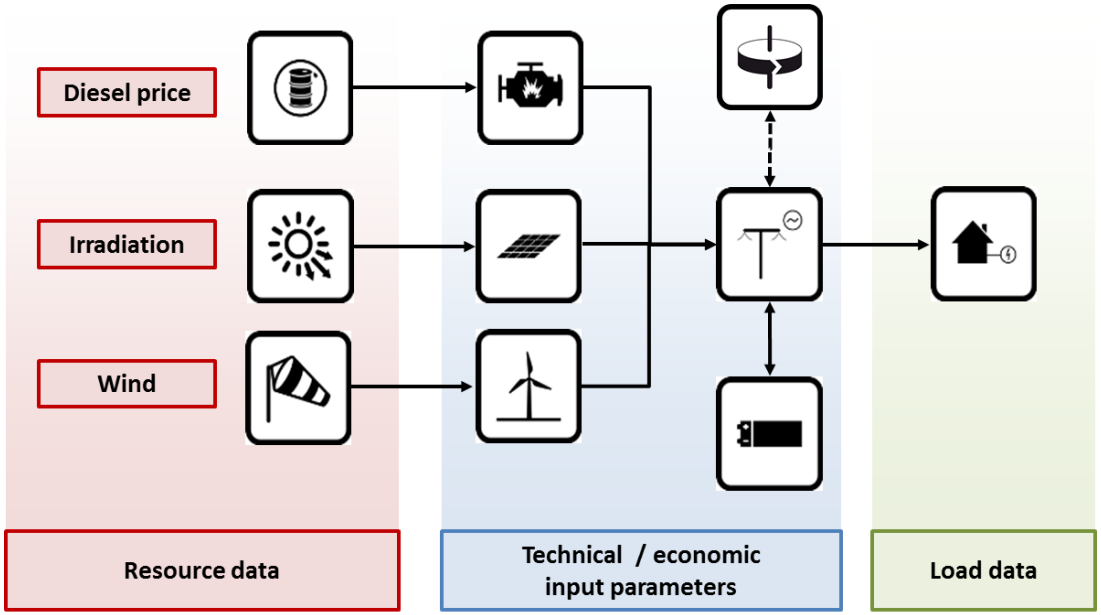

Figure: Simulation design and input parameter of a hybrid mini-grid.

Comparison of RE potential w/o storage

- Scenario I is without battery storage, Scenario II is with battery storage (lead acid), results for Scenario II are in relation to Scenario I in percent.

Table: Results for techno-economic optimization of hybrid island energy supply systems.

Region	Scenario	PV (sum) [MWp]	Wind (sum) [MW]	Storage (sum) [MWh]	LCOE (av.) [EURct/kWh]	RE share (av.)
Atlantic+ Arctic Ocean	Scen I	930	5,320	n/a	26.3	48.0%
	Scen II	+21%	-1%	930	-1.7%	58.2%
Caribbean + G. o. Mex.	Scen I	550	770	n/a	25.8	47.0%
	Scen II	+10%	-1%	230	-1.1%	55.0%
Indian Ocean	Scen I	910	1,210	n/a	24.4	53.9%
	Scen II	+9%	-2%	360	-2.1%	64.9%
Mediterranean Sea	Scen I	420	370	n/a	29.7	44.0%
	Scen II	+74%	-30%	1,240	-6.7%	79.9%
Pacific Ocean	Scen I	3,390	5,090	n/a	30.2	43.8%
	Scen II	+19%	-5%	2,550	-7.1%	70.9%
Total	**Scen I**	**6,200**	**12,760**	**n/a**	**30.2**	**45.8%**
	Scen II	**+21%**	**-4%**	**5,310**	**-6%**	**70.9%**

- The studied islands posses over a very high potential for RE technologies (6 GWp PV & 12 GW wind)

- The introduction of RE technologies leads to LCOE cost reductions even without impelmenting storage technologies

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Potential for storage technologies on islands

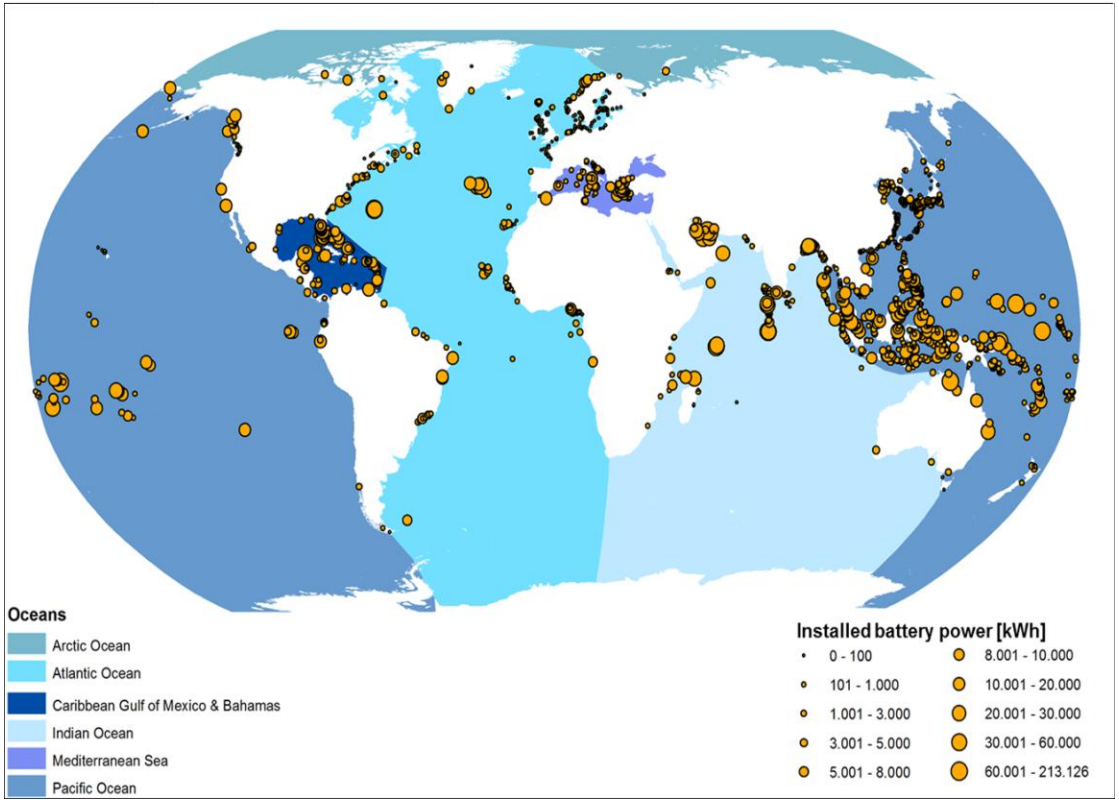

Figure: Installed battery power of small islands (1,000 to 100,000 inhabitants) for optimized hybrid systems. Installed battery power [kWh].

- With storage technologies LCOEs can be further reduced by 6%
- By introducing storage technologies average RE shares rise from 46 % to 70%
- Potential for wind power decreases in favor of PV power by introducing storage solutions
- Paper available at Science Direct:
  Blechinger et al. (2014): Assessment of the Global Potential for Renewable Energy Storage Systems on Small Islands

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