Alliance for Rural Electrification

Shining a Light for Progress

Hybrid power systems based on renewable energies:

a suitable and cost-competitive solution for rural electrification

Source: Trama Tecno Ambiental S.L.

This brochure constitutes an informative instrument to raise awareness among the international community, relevant stakeholders and decision makers, of the existence of a compelling solution to provide a cost-competitive and environmentally friendly electricity service to rural communities

Therefore, this is a tool to:

- Gain an immediate access to reliable electricity at any time.
- Avoid long waits for grid extension and permit the connection if it comes.
- Reduce dependency from oil price fluctuations.
- Improve health care and education in rural areas.
- Increase economic productivity and create local employment opportunities.
- Strengthen social cohesion by providing access to electricity for ALL users.
- Fight climate change and poverty.
- Allow for a better use of local natural resources.

THE "POWER" OF ELECTRICITY

For a community to raise itself out of subsistence and into an upward spiral of increased prosperity, certain basic services must be available and affordable. These include drinkable water, health care, education, transportation and communication. Access to reliable electricity is a precondition for the provision of many of these services and an active catalyst for sustainable development.

The provision of electricity has a significant social impact. The improvement of communication and social activities, as well as health and educational services and facilities, clearly boost living standards and, consequently, prevent urban migration, provide a stronger sense of community, reduce mortality and improve gender quality.

Electricity access has also a substantial impact in terms of economic development by increasing productivity and economic growth, as well as local employment The possibility of preserving specific products, having irrigation facilities and powered processing equipment, will increase the production capacity as well as the quantity and quality of the product placed in the market.

RURAL ELECTRIFICATION WITH HYBRID POWER SYSTEMS BASED ON RENEWABLE ENERGIES

A quick glance at the electrification world map will show that rural areas are in great need of affordable and reliable electricity to achieve development.

Likewise, an overview through the most important literature on rural electrification will prove that renewable energies (RES) are one of the most suitable and environmentally friendly solutions to provide electricity within rural areas.

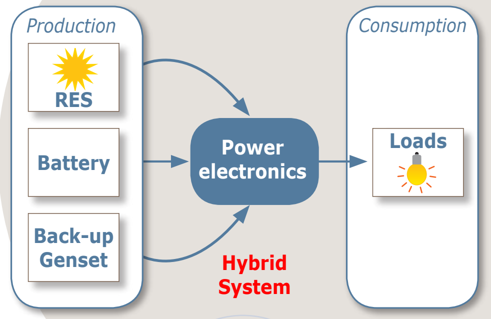
Autonomous decentralized (off grid) rural electrification based on the generation of renewable energy power on site through the installation of stand alone power systems in rural households, and the set up of electricity distribution mini-grids, fed by RES or mixed, have been proven capable of delivering high quality and reliable electricity for lighting, communication, water supply and motive power, among others.

What is a hybrid power system?

Off grid renewable energy technologies satisfy energy demand directly and avoid the need for long distribution infrastructures. A combination of different but complementary energy generation systems based on renewable energies or mixed (RES- with a backup of Liquefied Petroleum Gas (LPG)[1]/diesel/gasoline genset), is known as a hybrid power system ("hybrid system").

Hybrid systems capture the best features of each energy resource and can provide "grid-quality" electricity, with a power range between 1 kilowatt (kW) to several hundred kilowatts. They can be developed as new integrated designs within small electricity distribution systems (mini-grids) and can also be retrofitted in diesel based power systems.

Hybrid systems can provide a steady community-level electricity service, such as **village electrification**, offering also the possibility to be upgraded through grid connection in the future. Furthermore, due to their high levels of efficiency, reliability and long term performance, these systems can also be used as an effective **backup solution to the public grid** in case of blackouts or weak grids, and for **professional energy solutions**, such as telecommunication stations or emergency rooms at hospitals.



[1] The use of LPG as a backup allows to considerably lower the emissions of CO2, NOx, SOx and SPM (suspended particulate matters)

The best replacemet for diesel fuel based power systems

Diesel based power systems will, sooner or later, grow to be a barrier for rural areas due to the operating costs (elevated fuel and transport prices), the high needs of maintenance, their acoustic and environmental polluted nature and the geographical difficulties to deliver the fuel to remote areas. Retrofitting hybrid power systems to the existing diesel based plants will significantly minimize delivery and transport problems and will drastically reduce maintenance and emissions, representing an advantageous and more suitable solution for rural areas

SUCCESSFUL STORIES BASED ON HYBRID SYSTEMS

Successful results have already been obtained with hybrid systems worldwide. Rural communities without hope to be connected to the public grid (at least not in the medium term), lacking resources to keep up with the fuel prices or with unused diesel infrastructures, have found on hybrid systems the most suitable, environmentally friendly and cost competitive solution for power delivery

Photovoltaic/diesel hybrid system

Location:China
Date of Installation: 2006
Performance:
Provides electricity to 55 households
Source/Implementer: SolarWorld AG

Photovoltaic/wind//diesel hybrid system

Location: China
Date of Installation: 2002
Performance:
Provides electricity to 3 villages composed of 500 households, community services (clinic, school, postal office, TV transferring station) and a tourist facility
Source/ Implementer: Bergey

Photovoltaic/diesel hybrid system

Location: Tanzania
Date of Installation: 2006
Performance:
Provides electricity to several households, community services (school, clinic, public lighting), small workshops, cabinetmaking, and technical equipment
Source/Implementer: CONERGY/ Schott Solar

Photovoltaic/diesel hybrid system

Location: Ecuador
Date of Installation: 2006
Performance:
Provides electricity to 20 households and community services (school, public lighting, health centre, community meeting and dining halls)
Source/Implementer: Trama TecnoAmbiental

Photovoltaic/diesel hybrid system

Location: Algeria
Date of Installation:1998-2000
Performance:
Provides electricity to 12 households and community services (school, health centre)
Source/Implementer: CDER

Hydro/PV/Diesel hybrid system

Location: Laos
Date of installation : 2007
Performance:
Provides electricity to 98 households and community services
Source/Implementer: Entec

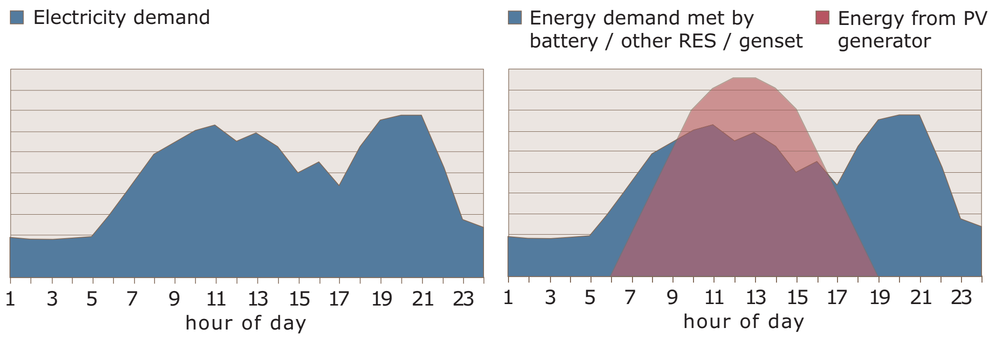
TECHNOLOGICAL CONFIGURATIONS FOR HYBRID SYSTEMS

A typical hybrid system combines two or more energy sources, from renewable energy technologies, such as photovoltaic panels, wind or small hydro turbines; and from conventional technologies, usually diesel or LPG gensets (though biomass fed gensets are also a feasible option, if locally available). In addition, it includes power electronics and electricity storage batteries.

The hybrid system can be designed following different configurations to effectively use the locally available renewable energy sources and to serve ALL power appliances (requiring DC or AC electricity).

The technological configurations can be classified according to the voltage they are coupled with; this is, using DC, AC and mixed (DC and AC) bus lines (cf. next page).

Example of load profile: village electrification



Hybrid systems with a backup genset run with minimal fuel consumption because the genset is brought on line only to assist in periods of high loads or low renewable power availability. This results in a large reduction in fuel consumption as compared to a genset only powered system.

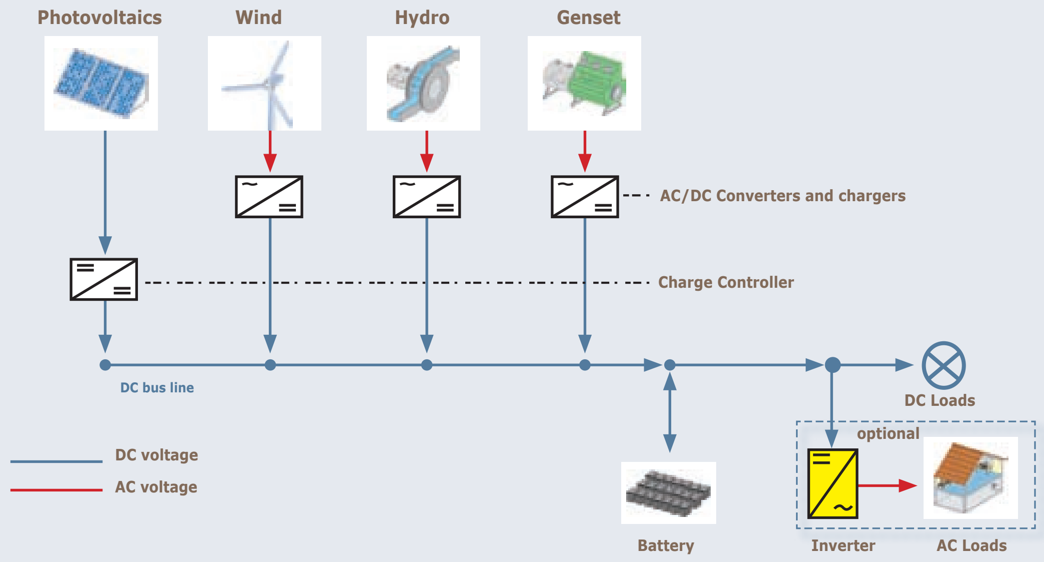
PRINCIPLE TECHNOLOGICAL CONFIGURATIONS FOR HYBRID SYSTEMS

1. Electricity generation coupled at DC bus line

All electricity generating components are connected to a DC bus line from which the battery is charged. AC generating components need an AC/DC converter. The battery, controlled and protected from over charge and discharge by a charge controller, then supplies power to the DC loads in response to the demand. AC loads can be optionally supplied by an inverter.

Hybrid system (DC coupled)

Source/Implementer: STECA (Greece)

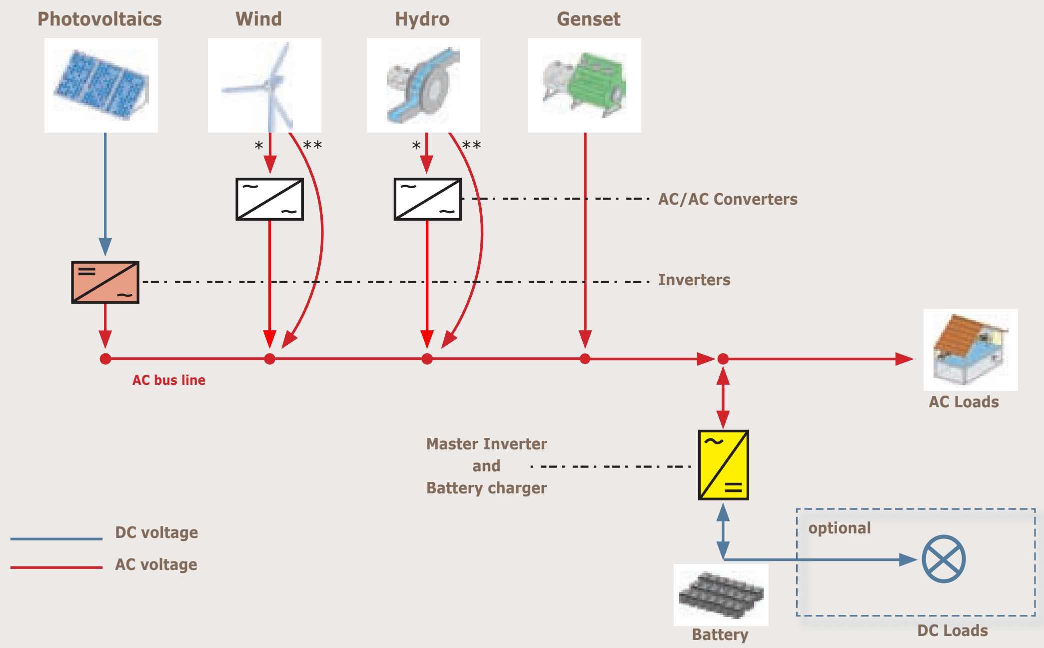


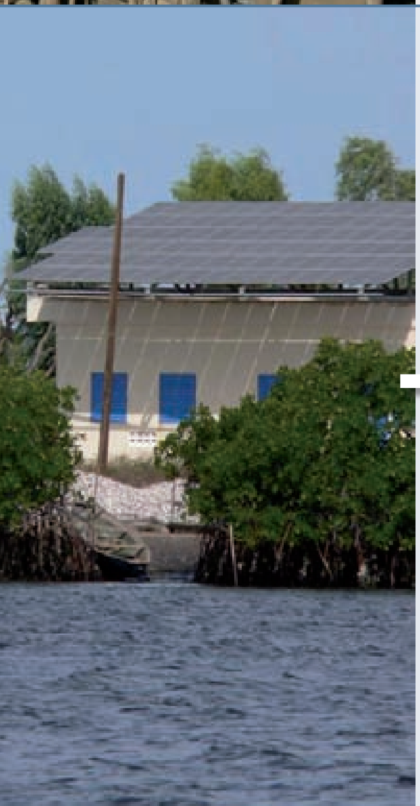
2. Electricity generation coupled at AC bus line

All electricity generating components are connected to an AC bus line. AC generating components may be directly connected to the AC bus line (**) or may need a AC/AC converter to enable stable coupling of the components (*). In both options, a bidirectional master inverter controls the energy supply for the AC loads and the battery charging. DC loads can be optionally supplied by the battery.

Hybrid system (AC coupled)

Source/Implementer: SMA (China)





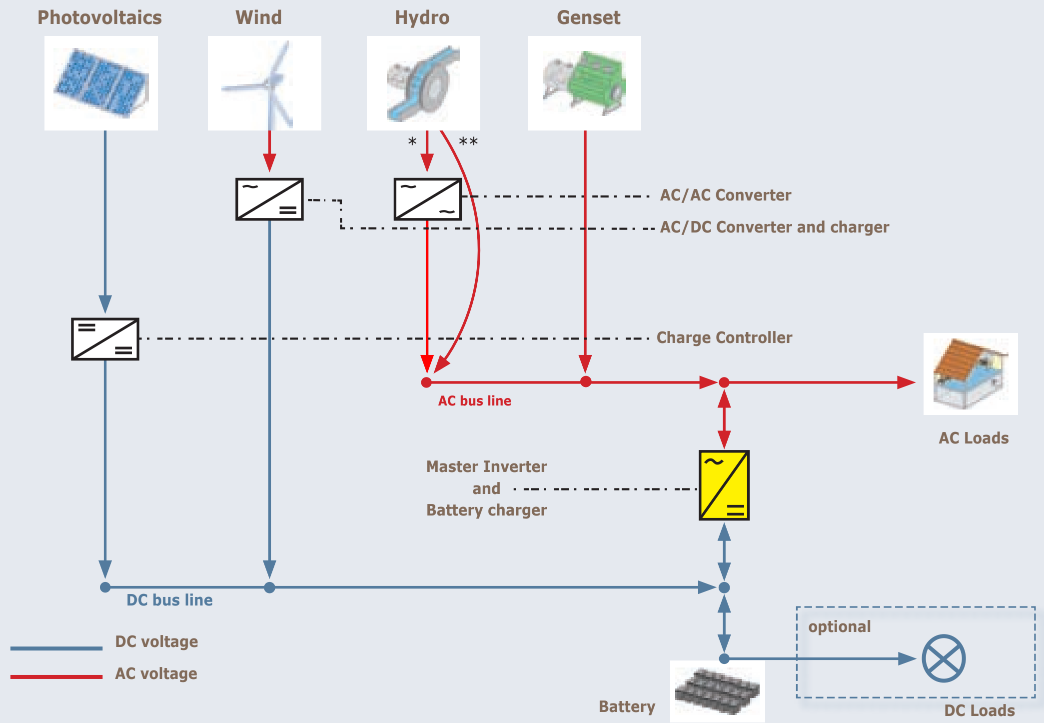
3. Electricity generation coupled at AC/DC bus lines

DC and AC electricity generating components are connected at both sides of a master inverter, which controls the energy supply of the AC loads. DC loads can be optionally supplied by the battery.

On the AC bus line, AC generating components may be directly connected to the AC bus line (**) or may need a AC/AC converter to enable stable coupling of the components (*).

Hybrid system (AC/DC coupled)

Source/Implementer: ISOFOTON (Senegal)



The most appropriate technological configuration

Any combination *of renewable energy technologies with an optional back up with LPG, gasoline or diesel genset* ***is possible***

The way to determine the most appropriate technological solution for hybrid systems implies always a feasibility study based on gathering field data for each specific site and on a life cycle cost analysis.

Technical, economic, financial, and socio-cultural considerations must all be included in the decision process to ensure the appropriate choice of technologies and operational and ownership scheme. Location, resource evaluation and load analysis are among the basic criteria to be considered to design an optimal power solution.

Once the most appropriate system configuration has been chosen, a carefully and responsible selection of components should be carried out considering: quality (reliability), yield, regular maintenance requirements, after sales service availability, cost of servicing, warranty, spare parts availability and price

THE BEST SERVICE FOR AN OPTIMAL USE OF ELECTRICITY

The use of electricity should not stop in the delivery of power but lead also to sustainable development and stimulate market growth. Therefore, the technological solution provided for a given community should permit the development of "productive uses" of electricity.

By definition, a "productive use" involves the application of energy/electricity for the generation of income or value. Usually, productive uses of electricity are only linked to direct income generating activities (ex: motive power for agricultural, industrial and commercial uses) but the truth is that the productive uses of electricity are already present by the simple fact of providing electricity. Access to electricity will automatically generate a surplus within the domestic economies (saving up money otherwise spent in expensive candles, kerosene or disposable batteries) and will also promote micro-enterprise development (ex basket making, handcraft, sewing, etc) The enhancement of education activities, the improvement of health services or the facilitation of information and communication technologies, play also a very important role in the economic development of a rural community. Educated and healthy people will possess greater potential for income generation!

Therefore, the use of electricity to extend the total numbers of productive hours available (beyond daylight hours), to enable the access to information (to make business decisions), to increase life expectancy or to develop higher literacy rates, should also be considered a productive use. Together with the possibility of establishing hotels, restaurants, repair shops, retail stores or communication centers, the delivery of electricity will certainly contribute to the sustainable development of rural communities.

Hybrid systems allow for ALL productive uses of electricity (domestic, public and income-generating uses), permitting the scaling up of productive applications and rural development.

Energy efficiency and renewable energies

A combination of energy efficiency measures with the use of renewable energies will not only reduce electricity consumption and peak demand, thereby increasing the electricity service, but also reduce the production of conventional energy and greenhouse emissions from the combustion of fossil fuels

Hybrid systems based on RES can meet every energy demand!

ENERGY SERVICES	APPLICATION	BENEFITS
Lighting	Household lighting Public lighting Community lighting	Improvement of health care and education
Communication	Internet/Telephone TV Broadcast/Video/ Cinema Radio-telephone communication capabilities	Facilitation of security/safety and emergency assistance
Refrigeration	Refrigeration of medicines Cold storage Ice making	Reduction of marginalization Increase of employment
Water supply	Drinking water Irrigation Purification Desalination	Enhancement of social life/cohesion Empowerment of women
Motivepower /processing	Drying and food preservation Sugar and silk production Textile dyeing and weaving Crop processing (ex. Coconut fibre)	Generation of added value products Increase of productivity
Health services	Sterilization of medical equipment Electric diagnosis and medical treatment equipment	

THE LEAST COST OPTION (on a life cycle basis)

For a given community, the costs of different electricity supply alternatives will vary depending on specific local conditions, such as load size and distribution, renewable resource availability, fuel price and transportation network.

A combination of improved technology and economies of scale has pushed down the costs of renewable energy technologies. Unlike most conventional energy sources, the cost of producing electricity from renewable energy sources will decrease significantly in the future, given the necessary conditions.

However, despite the favorable trends of renewable energy sources, they are still perceived as high cost options. The reasons can be found within the benefits enjoyed by the conventional energy systems such as favorable policy frameworks and public financing advantages, giving as a result low capital costs, though leaving the evidence of significant operating costs. Renewable energy systems seldom enjoy direct or indirect subsidies, because of their environmental benefits.

Still, renewable energy technologies are already the least cost electrification option in rural areas, even without internalizing environmental costs. The initial high capital costs are offset by the low operation and maintenance costs, the on site production (fuel delivery cost can exceed the wholesale fuel price), as well as the inexistent or little fuel expense (which is the single largest cost on a life cycle basis), the increased reliability and the longer expected useful life of renewable energy technologies.

The uncertainty of oil based solutions

A critical factor of the oil based solutions is the development of the crude oil price and, consequently the price of fuel on a national level. The drastic rises of crude oil and the continuing depletion of this resource are leading to long-term constrains on the economic development worldwide.

Hybrid systems based on RES are independent from oil price fluctuations and increases. Even if these systems may include LPG/diesel genset as a backup, still renewable energy will supply, at least, between 60 and 90% of the energy, with gensets providing as little as 10% of the energy.

Better than candles, kerosene, disposable batteries and car batteries, which are costly, unreliable and harmful for the environment and human health *Hybrid systems based on RES will improve quality of electricity service, displace harmful emissions (like paraffin poison), increase luminosity and quality of light (up to 200 times brighter than kerosene lamps), provide for income-enhancing opportunities (ex. keeping shops open or carrying out activities such as basket weaving or sewing for a few extra- hours, charging cellular phones) and save time and effort involved in hauling acid-filled, short-lived car batteries to battery charging stations every few weeks.*

The unsuitability of grid extension

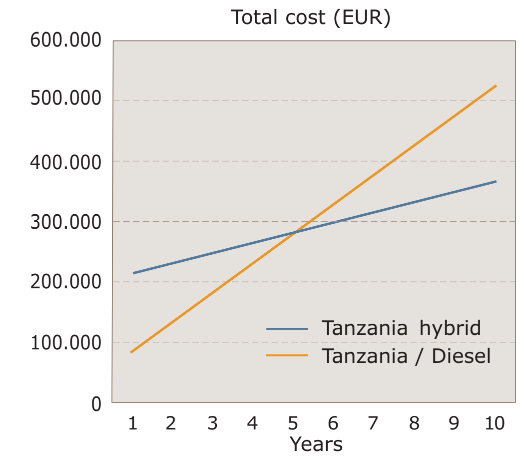
The main key variables in determining the cost of grid extension -comprising installation of high or medium-voltage lines, substation(s) and a low-voltage distribution- are the size of the load to be electrified, the distance of the load from an existing transmission line, and the type of terrain to be crossed. Due to the lack of critical mass, the low potential electricity demand and the, usually, long distances between the existing grid and the rural area, the costs of electrifying small communities through grid extension are very high and therefore, not economically viable. The lack of local technical and management personnel and the high transmission losses are also deterring factors playing against this solution.

The electrification with hybrid systems based on RES provides in this case a cheaper and less polluting alternative. The increased reliability of these systems, the insignificant power transmission losses, the potential consumer involvement (through an adequate operation scheme) and the optimal use of indigenous resources, play in favor of this decentralized solution.

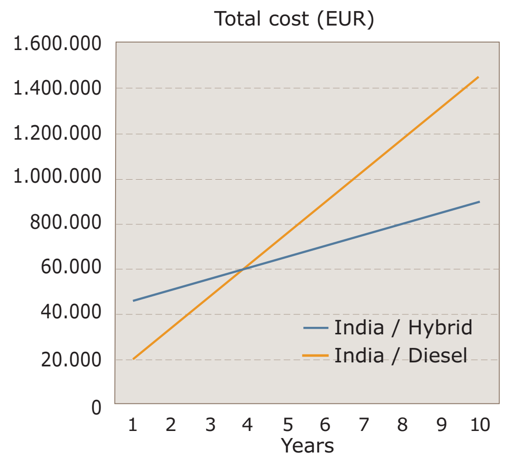
The cost effectiveness of hybrid systems

A number of studies and simulations have been carried out that show the comparative costs of renewable energy systems as well as their competitiveness with conventional energy options, including diesel based power systems and the extension to the grid, as it is shown below:

Economical comparison: diesel vs. hybrid systems (life cycle costs)



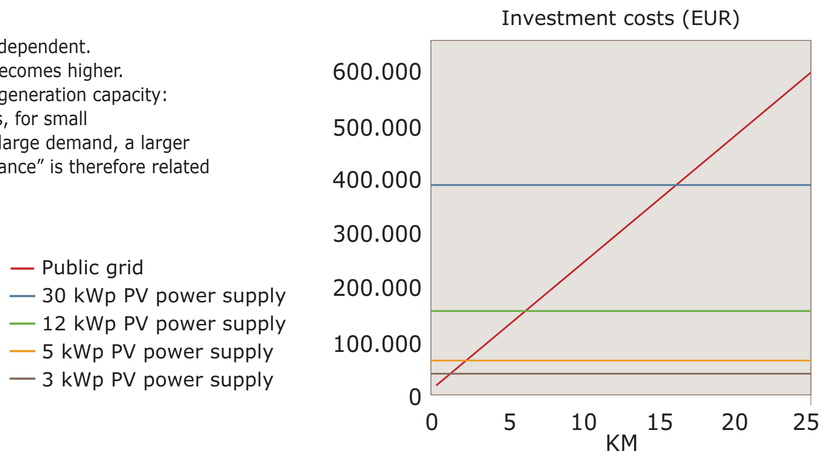
Location: Tanzania
Application: Village power supply
System configuration PV/Diesel hybrid: 30kVA hybrid inverter; 30kWp solar generator; 25kVA diesel generator 240kWh battery
System configuration diesel: 25kVA diesel generator



Location: India
Application: Village power supply
System configuration PV/wind Hybrid: 100kVA hybrid inverter; 40kWp PV generator; 10kW wind generator; 276kWh battery
System configuration diesel: 100kVA diesel generator

Economical comparision: grid extension vs. hybrid systems (investment costs)

Grid extension costs are primarily distance dependent.
If the site is further away, the investment becomes higher.
PV Hybrid costs are related to the required generation capacity:
that depends on the required demand. Thus, for small
demand, a small investment is needed, for large demand, a larger
investment is needed. The break even "distance" is therefore related
to the demand.



CONCLUSIONS: BEST SERVICE AT LEAST COST

Reaching the non electrified rural population is currently not possible through the extension of the grid, since the connection is neither economically feasible, nor encouraged by the main actors. Further, the increases in oil prices and the unbearable impacts of this energy source on the users and on the environment, are slowly removing conventional energy solutions, such as fuel genset based systems, from the rural development agendas.

Therefore, infrastructure investments in rural areas have to be approached with **cost competitive, reliable and efficient tools** in order to provide a sustainable access to electricity and to stimulate development.

Renewable energy sources are currently one of the most, if not the only, suitable option to supply electricity in fragmented areas or at certain distances from the grid. Indeed, renewables are already contributing to the realization of important economic, environmental and social objectives by the enhancement of security of energy supply, the reduction of greenhouse gases and other pollutants and by the creation of local employment which leads to the improvement of general social welfare and living conditions.

Hybrid systems have proved to be the best option to deliver "high quality" community energy services to rural areas at the lowest economic cost, and with maximum social and environmental benefits. Indeed, by choosing renewable energy, developing countries can stabilize their CO_2 emissions while increasing consumption through economic growth

This brochure presents **a sustainable and powerful technological solution** based on renewable energies (RES) to increase access to modern electricity services in rural areas and beyond.

The technological configurations proposed in this brochure are field proven and have already been successfully implemented worldwide. A careful design of the hybrid system to meet requirements of the community at stake, and a responsible choice of system components, together with the training to operate and maintain the system, are currently offered by a number of system integrators and technology providers.

But, achieving sustainable economic and widespread use of hybrid systems will only be possible if local management schemes, effective policies, meaningful finance and international cooperation with industrialized countries are put in place! Though the private sector's role in rural electrification is growing somewhat, governments and the donor community are still very much needed to provide not only initial start-up financing but the appropriate infrastructures and energy models, as well as a continuous engagement in some fashion.

Let's make it happen!

THE ALLIANCE FOR RURAL ELECTRIFICATION

The Alliance of Rural Electrification (ARE) was founded in 2006 in response to the need to provide sustainable electricity to the developing world, and to facilitate the involvement of its members in the emerging rural energy markets.

The greatest strength of ARE is its robust industry-based approach, coupled with the ability to combine different renewable energy sources in order to provide more efficient and reliable solutions for rural electrification.

ARE´s main objectives are to:

- Increase awareness of the potential of renewable energy in the fight against climate change and poverty.
- Accelerate the deployment and use of renewable energy technologies within developing countries.
- Generate financial resources for rural electrification.
- Promote and support the development of healthy decentralized energy markets.

ARE is developing a number of communication tools and materials to carry out these objectives, including the creation of different Working Groups to assess the services and technologies currently supplied to rural areas; to support the creation of suitable financing instruments, adapted to these technologies and to push forward the off grid markets for rural electrification.

Working Group: Technological Solutions

The Working Group on Technological Solutions is composed by experts coming from different renewable energy sectors that have agreed to work together in order to provide suitable technological solutions for rural electrification already adapted to market needs.

The first assignment of this Group was to identify suitable technological configurations for hybrid power systems based on renewable energies, including O&M, training and transfer of technology.
A Working Plan has been defined accordingly together with a set of deliverables to be produced by the Group.

The first deliverable of this Working Group introduces the principal technological configurations for hybrid power systems based on renewable energies as one of the most cost-competitive and suitable solutions for rural electrification.

With the support off:

Alliance for Rural Electrification
Shining a Light for Progress

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- **European Biomass Industry Association (Eubia)**
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  www.eubia.org
- **European LPG Association**
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  www.aegpl.com
- **European Photovoltaic Industry Association (EPIA)**
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- **European Small Hydropower Association (ESHA)**
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- **European Wind Energy Association (EWEA)**
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- **Powerpal**
  Manufacturer
- **solar23 GmbH**
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  www.solar23.com
- **Schott Solar**
  Manufacturer
  www.schott.com
- **SMA Technologie AG**
  Manufacturer
  www.SMA.de
- **Steca GmbH**
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  www.stecasolar.com
- **Trama TecnoAmbiental S.L.**
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