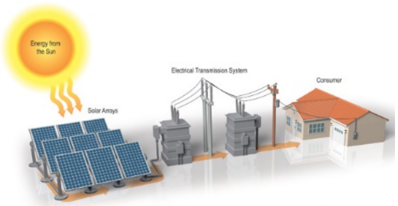
Grid-connected solar systems

Solar panels that harness the sun's power to generate electricity provide clean power for homes, communities and businesses, and help cut global carbon emissions.

Solar photovoltaic (pv) modules generate electricity from sunlight, which can be fed into the mains electricity supply of a building or sold to the public electricity grid. Reducing the need for fossil fuel generation, the growing grid-connected solar PV sector across the globe is helping create jobs, enabling families and businesses to save money, and cut greenhouse emissions.

How grid-connected PV systems work



PV modules use semiconductor materials to generate dc electricity from sunlight. A large area is needed to collect as much sunlight as possible, so the semiconductor is either made into thin, flat, crystalline cells, or deposited as a very thin continuous layer onto a support material. The cells are wired together and sealed into a weatherproof module, with electrical connectors added. Modern modules for grid connection usually have between 48 and 72 cells and produce dc voltages of typically 25 to 40 volts, with a rated output (see box) of between 150 and 350 Wp.

In order to supply electricity into a mains electricity system, the dc output from the module must be converted to ac at the correct voltage and frequency. An electronic inverter is used to do this. Generally, a number of PV modules are connected in series to provide a higher dc voltage to the inverter input, and sometimes several of these ‘series strings’ are connected in parallel, so that a single inverter can be used for 50 or more modules. Modern inverters are very efficient (typically 97%), and use electronic control systems to ensure that the PV array keeps working at its optimum voltage. They also incorporate safety systems as required in the country of use.

How grid-connected PV systems are used

Major grid connected PV systems are installed on frames which are mounted on the suitable land. Ideally the PV faces towards the equator (i.e. South in the northern hemisphere) but the exact direction is not critical. However, it is important to make sure that there is minimal shading of the PV. The inverter is housed inside the building and connected to the mains electrical supply, usually with a meter to measure the kWh generated. The PV electricity production is exported to the grid.

Grid-connected systems do not usually include batteries for storage, because the mains grid can accept or provide power as needed. However, if rechargeable batteries are included, a grid-connected PV system can be used as a standalone ac supply in the event of a power cut, to allow essential loads to keep working.

What are the benefits of grid-connected PV systems?

By reducing the need for fossil-fuel generation, grid-connected PV cuts greenhouse gas emissions (and other air pollution), because no emissions are produced during PV operation.

In the past there has been concern about the greenhouse gases emitted (‘embodied’) in the manufacture of PV systems, particularly in the production of ultra-pure semiconductors. With current production techniques, these embodied greenhouse gases are saved within two to four years of use of grid-connected operation, depending on the amount of sunlight.

PV is the easiest renewable electricity it can be used at any scale – from less than a kWp on an individual home up to MWp scale systems on dedicated sites - and is simple and reliable. Because of this, it is a valuable way to raise awareness of electricity supply and use, and helps highlight the potential for renewable energy.

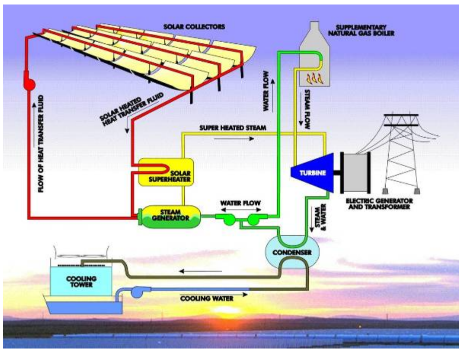
The future

The price of PV modules is decreasing rapidly. For crystalline cells, new ways of processing silicon and increased volume manufacture are driving down prices. The market share of thin film PV is growing rapidly as materials which have been proved in the laboratory go into volume production, and these promise even greater price reductions. However, there is less potential for price reduction in the ‘balance of system’, and these costs will soon dominate the overall system cost.

Because of the decreasing prices, the rapid growth in the market for grid-connected PV is expected to continue even if government support is reduced. The market will really take off when electricity from PV becomes cheaper than other grid sources.

Solar Thermal Generation Plants

Solar thermal power systems use concentrated solar power (CSP)



Solar thermal power generation systems collect and concentrate sunlight to produce the high temperature heat needed to generate electricity. All solar thermal power systems have solar energy collectors with two main components: *reflectors* (mirrors) that capture and focus sunlight onto a *receiver*. In most types of systems, a heat-transfer fluid is heated and circulated in the receiver and used to produce steam. The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity. Solar thermal power systems have tracking systems that keep sunlight focused onto the receiver throughout the day as the sun changes position in the sky.

Solar thermal power systems may also have a thermal energy storage system component that allows the solar collector system to heat an energy storage system during the day, and the heat from the storage system is used to produce electricity in the evening or during cloudy weather. Solar thermal power plants may also be hybrid systems that use other fuels (usually natural gas) to supplement energy from the sun during periods of low solar radiation.

Types of concentrating solar thermal power plants

There are three main types of concentrating solar thermal power systems:

- Linear concentrating systems, which include parabolic troughs and linear Fresnel reflectors
- Solar power towers

- Solar dish/engine systems

Linear concentrating systems
Linear concentrating systems collect the sun's energy using long, rectangular, curved (U-shaped) mirrors. The mirrors focus sunlight onto receivers (tubes) that run the length of the mirrors. The concentrated sunlight heats a fluid flowing through the tubes. The fluid is sent to a heat exchanger to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror, and linear Fresnel reflector systems, where one receiver tube is positioned above several mirrors to allow the mirrors greater mobility in tracking the sun.

A linear concentrating collector power plant has a large number, or *field*, of collectors in parallel rows that are typically aligned in a north-south orientation to maximize solar energy collection. This configuration enables the mirrors to track the sun from east to west during the day and concentrate sunlight continuously onto the receiver tubes.

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Parabolic trough power plant (Source: Stock photography (copyrighted)

Parabolic troughs
A parabolic trough collector has a long parabolic-shaped reflector that focuses the sun's rays on a receiver pipe located at the focus of the parabola. The collector tilts with the sun to keep sunlight focused on the receiver as the sun moves from east to west during the day.

Because of its parabolic shape, a trough can focus the sunlight from 30 times to 100 times its normal intensity (concentration ratio) on the receiver pipe, located along the focal line of the trough, achieving operating temperatures higher than 750°F.

Parabolic trough linear concentrating systems are used in the longest operating solar thermal power facility in the world, the Solar Energy Generating System (SEGS), which has nine separate plants and is located in the Mojave Desert in California. The first plant, SEGS 1, has operated since 1984, and the last SEGS plant that was built, SEGS IX, began operation in 1990. With a combined electricity generation capacity of 354 megawatts (MW), the SEGS facility is one of the largest solar thermal electric power plants in the world.

In addition to the SEGS, many other parabolic trough solar power projects operate in the United States and around the world. The three largest projects in the United States after SEGS are

- Mojave Solar Project: a 280 MW project in Barstow, California
- Solana Generating Station: a 280 MW project in Gila Bend, Arizona
- Genesis Solar Energy Project: a 250 MW project in Blythe, California

Linear Fresnel reflectors

Linear Fresnel reflector (LFR) systems are similar to parabolic trough systems in that mirrors (reflectors) concentrate sunlight onto a receiver located above the mirrors. These reflectors use the **Fresnel lens** effect, which allows for a concentrating mirror with a large aperture and short focal length. These systems are capable of concentrating the sun's energy to approximately 30 times its normal intensity. The only operating linear Fresnel reflector system in the United States is a compact linear Fresnel reflector (CLFR)—also referred to as a concentrating linear Fresnel reflector—a type of LFR technology that has multiple absorbers within the vicinity of the mirrors. Multiple receivers allow the mirrors to change their inclination to minimize how much they block adjacent reflectors' access to sunlight. This positioning improves system efficiency and reduces material requirements and costs.

Solar power towers (Source: National Renewable Energy Laboratory (NREL)

Solar power towers

A solar power tower system uses a large field of flat, sun-tracking mirrors called heliostats to reflect and concentrate sunlight onto a receiver on the top of a tower. Sunlight can be concentrated as much as 1,500 times. Some power towers use water as the heat-transfer fluid. Advanced designs are experimenting with molten nitrate salt because of its superior heat transfer and energy storage capabilities. The thermal energy-storage capability allows the system to produce electricity during cloudy weather or at night.

Solar dish/engines Solar dish Source: Stock photography (copyrighted)

Solar dish/engine systems use a mirrored dish similar to a very large satellite dish. To reduce costs, the mirrored dish is usually composed of many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to an engine generator. The most common type of heat engine used in dish/engine systems is the Stirling engine. This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power runs a generator or alternator to produce electricity.

Solar dish/engine systems always point straight at the sun and concentrate the solar energy at the focal point of the dish. A solar dish's concentration ratio is much higher than linear concentrating systems, and it has a working fluid temperature higher than 1,380°F. The power-generating equipment used with a solar dish can be mounted at the focal point of the dish, making it well suited for remote locations, or the energy may be collected from a number of installations and converted into electricity at a central point.

Rural Electrification Solution (RES)

Standalone solutions such as low voltage mini/micro-grids, present a clean and low emission solutions for providing high quality light to those who live off-grid. Basic solutions offer minimum services, Pico or Solar Household Solution (SHS) (typically light and a mobile charging point), however, scalability is possible to allow for the provision larger communal loads, such as electricity for local schools, basic health units, or water pumps.

The following sets out the basis for the foundation of a project to design, build and install scalable mini/micro-grid system through scale economies allowing for the provision of communal loads, in addition to the provision of basic electrification to communities & individual households.

In line with this rationale, a project will work on:

(a) eliciting the demand for such a service, and study changes in consumer willingness to pay based on their experience with the technology and
(b) analyze the potential effects of basic electrification to these off-grid communities.
(c) consider incorporating existing generating units to create a **Hybrid** system.

Electrification would lower fuel costs and relax the day-light constraint on productive hours. Second, data on both the supply and demand side will allow a guide policy to be developed determining an opium solution for efficient route for rural electrification. The project will require engagement of relevant government agencies and provide them with material to support the changes in legislation should it be required. This activates will assist in creating a micro-energy economy with a viable, scalable and profitable mini/micro-grid model providing opportunities new sources of employment.

For a project a full-scale study, will be required estimated through a randomized control trial.:

Design and cost a decentralized high voltage DC mini/micro-grid, which can provide for a communal load of up to:

Pico System (SHS) 3000 VA (apparent power)
Nano grids 5000 VA, (apparent power) 10 to 20 households clustered together
Micro grids 500,000 VA, (apparent power) 50 to a few hundred households
Mini grids 1000,000 VA, (apparent power) more than 200 households

in addition to providing basic electrification to households in a rural settlement.
Conduct a survey in a village cluster containing both off-grid and Semi-Electrified Rural (SER) settlements, to provide an estimate of the demand for such services.

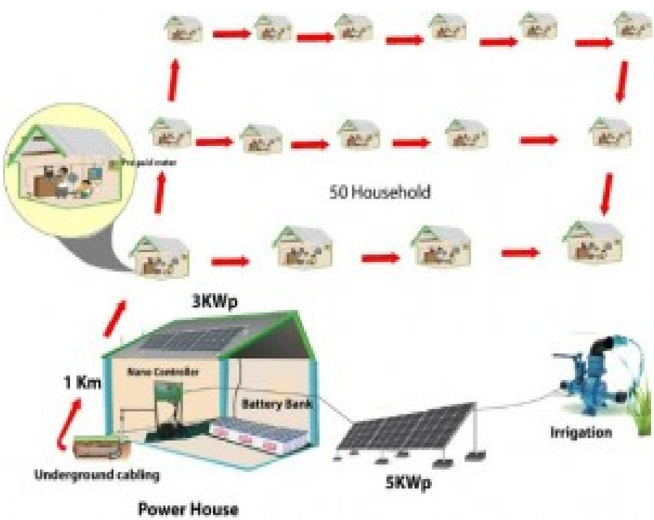
The outcome of this project will lead to a low-cost decentralized power delivery through solar energy without significant overheads from Government agencies.

Recently, after the worldwide success of the SHS in off-grid, isolated regions, new concepts and basic design systems are emerging to scale up the SHS, maintaining their low cost while at the same time addressing some of their limitations.

The main limitation of a SHS is its inability to serve a community to support small-scale economic activities that require power. Consequently, it is proposed that a system between 3 to 5kW could be a very effective solution for a community of 10-20 households clustered together, providing some excess energy for small-scale economic activities. The size is smaller than a predefined 'micro-grid' and consequently the named 'nano-grid'.

The differences between the types of systems are tabled below:

Mini/Micro Grids	Nano Grids	Pico (SHS) Solar House Solution
Power generated at a central location	Connections from central PV installation to end user	PV installed to household
50 – few hundred households	Less than 50 households	Designed for single household
Transmission and distribution lines	No transmission or distribution lines required, therefore cost saved including cost of protection systems as accidental hazards unlikely	No transmission or distribution lines required, therefore cost saved including cost of protection systems as accidental hazards unlikely
Current generated as direct current DC	Not applicable	Not applicable
Current transmitted as alternating current AC	Current transmitted as DC	Current transmitted as DC
Need of a DC/AC inverter	No DC/AC inverter required	No DC/AC inverter required
Coverage ranges from a few hundred meters to 1-2 kilometers	Coverage ranges less than 100 metres	Coverage range less than 20 metres



Overall, the proposed nano-grids are very flexible in design. For example, in a village of clustered households, there can be more than one nano-grid to supply power to the community and in case of increased need, new PV panels can be installed and the existing nano-grids can be interconnected to form a larger distributed PV system. Then, if the national grid arrives at the locality, the nano-grid PV systems can be hooked up to the main grid.

Expected Outcomes from RES

- Longer Vendor Hours
- Perishable goods can be refrigerated
- Improved agriculture
- Schools set and used for adult education literacy courses followed by higher number of beneficiaries and different community activities implemented at night time.
- Medical facilities 24/7 electrification
- Release of woman to work **decision-making positions filled by women**
- Better Health no more breathing kerosene or candle fumes
- And so, on so many benefits