# Solar Photovoltaic and Biogas Technologies towards Sustainable Rural Development: Research Dimensions

**Dr. Anil Kumar Pandey**
Director, Rahul Multidisciplinary Research Centre, Delhi (India).

## I INTRODUCTION

The hundreds of millions of people in India live in villages in abysmal condition without basic amenities like electricity, sanitation facility, drinking water and cooking gas. According to the Census of India Report 2011: 64 percent of rural population of our country uses firewood, 13 percent crop residue and 12.8 percent use cow dung for cooking and 56 percent of our rural population uses kerosene for lighting. One of the main causes of lack of progress in rural areas is the inadequate and unreliable electricity supply and modern energy services. Energy is a basic human need and is the driver of socio – economic development. The country power installed capacity of 245268MW (Annual Report 2013 -14 of the MNRE, Government of India: This includes 31702 MW of power from renewable energy sources). But a major portion of power is consumed in cities leaving villages with minimal and erratic supply of power.

Sustainable development stands for protecting the environment and avoids depletion of resources. Poverty and the environment are linked in a 'downward spiral' in which people living in poverty are forced to overuse environmental resources for their daily survival thus are impoverished by the degradation of these resources in an unsustainable way. The challenge is to increase per capita availability of energy while ensuring that per capita carbon dioxide emission is kept well within limits so that central climate change related challenges are addressed. The villages do not lack renewable energy resources essential to generate power and change their material condition. Solar power in terms of thermal and photovoltaic power and wind are available in plenty. The cattle dung, human excreta and agricultural waste can be used to generate biogas. The slurry from biogas technology is excellent manure which can stop soil erosion. These sources can supply reliable and affordable energy for rural household needs, the needs of the rural –micro enterprises, irrigation and the needs of the other public services.

An attempt has been made here to identify challenges in developing realistic models of sustainable development based on solar photovoltaic energy and biogas.

## II SOLAR PHOTOVOLTAIC TECHNOLOGY

India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Hence both technology routes for conversion of solar radiation into heat and electricity, namely, solar thermal and solar photovoltaic, can effectively be harnessed providing huge scalability for solar power in India. Solar also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements.

Solar photovoltaic power generation is a method of producing electricity using solar cells. A solar cell converts solar optical energy directly into electrical energy. A solar cell is essentially a semiconductor diode fabricated in a manner which generates a voltage when solar radiation falls on it. Major advantages of solar cells over conventional methods of power generation are[1]: (i) Solar cells convert radiation directly into electricity using photovoltaic effect without going through a thermal process. (ii) Solar cells are reliable, modular, durable, and generally maintenance free. (iii) Solar cells are quite, benign, compatible with almost all environments, respond instantaneously to solar radiation and have lifetime of 20 or more years. Solar modules/panels can be located at the place of use.

Solar photovoltaic technology involves development of systems, based on electrical power generated by the solar cell, for various applications. Due to the statistical nature of the availability of sun systems need to account for this by providing storage capacity inbuilt to the system. As the solar photovoltaic power is statistical in nature power conditioning unit is essential in system design to the monitor and control the storage and supply of power.

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current (DC) electricity using semiconductors that exhibit the photovoltaic effect (see Figure 1).

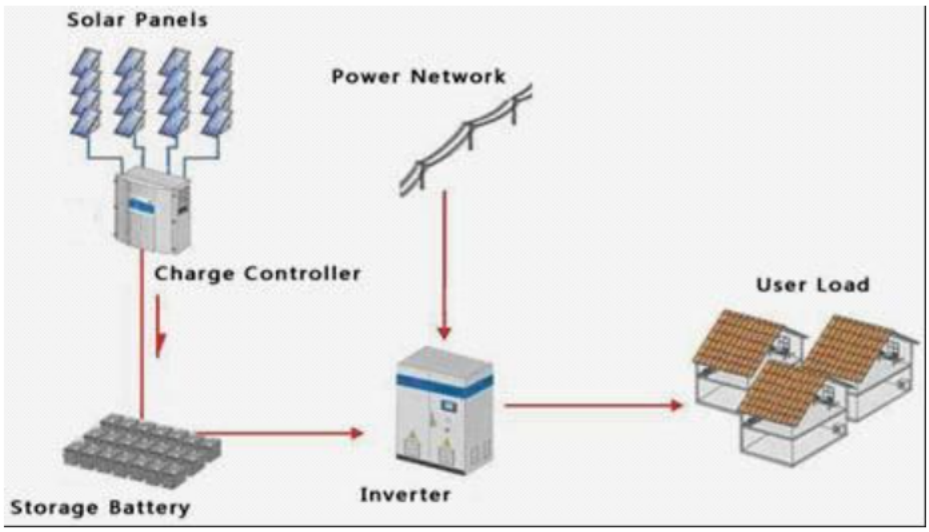


**Fig. 1: A typical off-grid solar photovoltaic system**

It can be seen from the Fig.1 that the power generated from a PV module/panel is influenced by solar irradiance. The irradiance changes during the day and therefore a maximum power point tracking (MPPT) is essential to get the maximum possible power from PV panel, in all conditions. The power conditioning unit is essential to the system. Battery-bank becomes essential for storage of generated power, where the system is not connected directly to the grid.

According to MNRE, Govt. of India renewable energy based systems can be categorized as:-

**(a) Grid Connected Power Systems-** are mainly private investment driven, with favourable tariff policy regimes established by State Electricity Regulatory Commissions (SERC), and almost all-renewable power capacity addition during the year has come through this route.

In addition the ministry is also giving importance to Bio-power. Bio-power:

Four sets of programmes are being implemented with the aim to generate competitively priced bio power and/or heat from agricultural, agro-industrial residues and plantations and urban & industrial wastes. These are:

(i) Biomass power/ bagasse cogeneration
(ii) Non-bagasse cogeneration
(iii) Biomass gasifier
(iv) Urban & Industrial wastes

**(b) Off-Grid Power Systems-** Distributed/decentralized renewable power projects using wind energy, biomass energy, hydro- power and hybrid systems are being established in the country to meet the energy requirements of isolated communities and areas which are not likely to be electrified in near future. Example- Solar PV Roof-top Systems for abatement of diesel for power generation in urban areas.

**(c) Decentralized Systems-** Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to grid-provided power. Over 400 million people in India, including 47.5% of those living in India's rural areas, still had no access to electricity. Because of the remoteness of much of India's un-electrified population, renewable energy can offer an economically viable means of providing connections to these groups. Some of the renewable energy technologies that are used in villages and rural areas as decentralized systems are:

(i) Family-size biogas plants.
(ii) Solar street lighting systems.
(iii) Solar lanterns and solar home lighting systems.
(iv) Solar water heating systems
(v) Solar cookers.
(vi) Standalone solar/ biomass based power generators.
(vii) Akshay Urja / Aditya Solar Shops
(viii) Wind pumps.
(ix) Micro-Hydro plants.

Many of these systems have been found useful in urban and semi urban areas also to conserve the use of electricity and other fossil fuels. Solar water heating systems have helped in demand side management of electricity in various cities and towns during peak hours. Standalone roof top SPV systems are getting popular for day time diesel abatement in areas where power cuts are very high.

So it can be seen that renewable has a vital role to play in shaping the future of the nation.

Apart from these systems another emerging important area of systems is the micro-grids particularly in rural areas. Because of the remoteness of much of India's un-electrified population, renewable energy based micro-grids either based on single source of based on distributed generation can offer an economically viable means of providing connections to these habitats.

Micro-grid is basically a small-scale power supply network that is designed to provide power for a small community. It can-not be used for high-power consuming devices but can be used as an alternative approach to integrate small-scale distributed energy resources into low-voltage electricity systems. Enabling local power generation, it comprises various small power generating sources that make it highly flexible and efficient. Basically, the solution aims to electrify houses that are not directly connected to the electricity board power grid due to their remoteness.

Renewable energy also has a central place in India's 'Action Plan on Climate Change'.

## III RESEARCH, DESIGN AND DEVELOPMENT AREAS

Solar Photovoltaic is a proven technology. Over 4000 MW of power is being generated in the country. But still a lot of RD & D work is still required in this field. Some of the areas are listed below:

**(a)** Conversion efficiency of solar cells is low. Efforts are being made to develop multi- junction solar cells, dye- sensitized solar cells, polymer solar cells and technology based solar cells. All these are major areas off research today.

**(b)** The cost of photovoltaic module has been falling steadily worldwide. But due to the cost of the storage devices (wherever used) like batteries, capacitive storage the system cost is still high. Besides batteries need to be replaced periodically which is inconvenient and add to cost. Researchers the world over are working in this area to reduce cost to make it comparable to the cost of conventional power.

**(c)** Whenever the DC power is converted first for transmission and then in the user's applications there is loss of power. R & D work is on to develop low power and low frequency inverters, DC devices like fans, fridge etc. Some of them are already commercialized but much work is still needed in this direction.

**(d)** Powered by solar panels micro-grids are spreading slowly across rural India where over 400 million people live without electricity. Nearly all micro-grids in India are powered by solar photovoltaic panels. Intense technical discussion and development efforts are going on in the areas of both AC and DC grids as each has its own merit and demerit. R & D efforts are also being made to develop distributed generation small micro-grids.

## IV BIOGAS TECHNOLOGY

It is a common knowledge that most of the energy needs, particularly in domestic activities, in rural areas is met through crop residues, cattle dung and burning of wood. This is a matter of grave concern for all those interested in maintenance of soil fertility, higher crop yield and the environment. The animal waste from livestock population in rural India contributes excess nutrients, pathogens, organic matter, solids and odorous compounds to the environment and severely affects the water quality.

The animals consume plant biomass in both dry and green forms. The dry fodder consumed is usually in the form of crop straw, residual cereals, pulses and oilseeds that are obtained after the harvesting of crop produced, while in mountain regions and other places grasses from permanent pastures usually form the feed of these animal. Biogas is obtained from the animal waste after it is subjected to anaerobic digestion in the digesters. Inside the biogas plant, the complex organic polymers, primarily carbohydrates, lipids and proteins in the biomass, are fermented to produce biogas which mainly comprises methane and carbon dioxide.

A biogas plant (Plate-1) is a set –up device that converts fermentable organic matter into a combustible gas and mature organic manure.

**Fig. 2: A Biogas plant installed by Mr. Jay Shankar, Gram- Taiteri, District –Begu Sarai, Bihar**

It works by subjecting the material to microbial decomposition in the absence of air, yielding finally, methane, carbon dioxide and water. This process is called anaerobic decomposition. Biogas obtained through this process is known by several names like the swamp gas, sewer gas, fuel gas, marsh gas or wet gas, and in India, it is more commonly referred to as *gobar gas*.

Biogas production is a biochemical process occurring in stages during which different bacteria act on the organic matter. The three stages involved are hydrolysis, acidification and methane formation.

But biomass and cattle –dung are renewable sources of energy. There are several processes by which power sources are created. These processed are listed below:-

(i) Biological Process - Biogas
- Alcohol Fermentation.

(ii) Thermo –Chemical - Pyrolysis
- Gasification
- Briquetting.

In India cattle dung is the principal substrate used for operating a biogas plant. The combined population of domestic animals in India is about 974.01 million heads, comprising 485 million livestock and 489 million poultry. These animals produce about 1386.23 million tones of animal excreta and dropping annually. Assuming that 75% of the total animal waste is collected and 25% of animal waste is not in usable form due to animal holding pattern and other uses about 693.12 million tones of animal excreta is available per year, which can be used biomethanation. This can generate about 290 x $10^8$ $m^3$ of gas having 188.66 $m^3$ of methane[2]. The energy equivalent of 1 $m^3$ of biogas with 60% methane is equal to 4713 kcal, or 0.714 l petrol, or 4.698 kWh of electricity. So we can get a lot of energy from cattle dung.

Besides the cattle dung, organic waste available in the country can be technically used to generate biogas. Annual production of wheat and rice in the year 1999-2000 was 71.78 million tones and 88.55 million tones, respectively, which paved the way for 258 million tones of straw, accounting for about 70% of the crop residue available in India. About 45 million tones of fruit and vegetable waste accumulates each year. A large portion of this biomass remains unutilized and creates a problem of disposal and leads to environmental pollution. Besides the bulky nature of organic residues, their low thermal efficiencies and profuse release of smoke are the other major limitations in the use of these residues economically. In recent years, a number of advanced biogas designs have been developed for treating these wastes and including wastes from food processing industries, sewage sludge, municipal and industrial waste and so on. If all this biomass is taken into account as feedstock, the potential for biogas generation in the country is virtually unlimited.

In addition to the gas yield, the organic manure produced from the biogas plants can meet a substantial amount of the nutrient requirement in the country. In fact this slurry from the biogas plant can be used for vermin composting (Plate-2 &3).

**Fig. 3 : Vermi Composting at Gram- Tetari, District –Begu Sarai, Bihar**

**Fig. 4 : Vermi compost in final form made at Gram- Tetari, District –Begu Sarai, Bihar**

According to some estimates the cattle dung to vermin compost yield is in the ratio of 3:1. In cost terms 1 Kg of Cattle dung could be priced at 10 paise and 1 Kg of Vermi compost at Rs. 7 to 10. The cost of biogas plant can thus be recovered by sale of vermin compost and biogas may be in two years times or so.

Thus, biogas technology has the potential to address the pressing social, environmental and economic problems in rural areas. It can mitigate drudgery of women and stop soil erosion. The vermin compost in the field results in better nitrogen fixation and water retention and thus preserve the nutrients in the soil. Better environment ensure better health and reduced loss of man hours. The water borne diseases are also drastically reduces due to the availability of clean water. Rain water harvesting could be resorted to and thus protecting the ground water resource. Therefore biogas technology offers a wide scope in rural areas of India.

## V RESEARCH, DESIGN AND DEVELOPMENT AREAS

Though biogas is a well proven technology and has found wide acceptance special at family level. However a number of issues are attracting attention of the scientists and technocrats alike. Some of the areas of research, design and development are listed below.

**(a)** Improvement in process in terms of yield.

**(b)** Continuous availability of fixed amount of gas,

**(c)** Reducing the biomethanation time by use chemical methods adopting technologies like genetics engineering and nanotechnologies etc.

**(d)** Development of Efficient and easy filtering processes,

**(e)** Scaling up the technology to community level plants and development of technologies for storage like bottling and setting up demonstration plants.

**(f)** Microbiological studies for use biogas slurry for production of fish.

**(g)** System design and application biogas for *Atta Chakki* and irrigation pump to make village diesel free.

Under the provisions of technology demonstration MNRE, Government of India took up bottling of biogas to demonstrate on Integrated Technology Package in Entrepreneurial mode on medium size mixed –feed biogas fertilizer plant (BGFP) for generation, purification/enrichment, bottling and piped distribution of biogas[3].

## VI RESEARCH & DEVELOPMENT BY THE MINISTRY OF NEW AND RENEWABLE EERGY (MNRE), GOVERNMENT OF INDIA

MNRE supports R & D towards technology development and demonstration leading to commercialization apart from strengthening the capacity of R & D/ academic institution and industry for taking up advanced research for technology development. The ultimate goal is to reduce the cost and improve the efficiency in near future.

A Research, Design & Development Project Appraisal Committee (RDPAC) has been constituted under the chairmanship of Secretary, MNRE for the purpose of giving guidance to the overall direction of RD&D effort in new and renewable energy. This Committee also elicits RD&D proposals, appraises them, and recommends financial support wherever required.

## VII SUSTAINABLE RURAL DEVELOPMENT

Energy is an essential input to economic development. India is basically an agricultural country where it's 60% population lives. However the agricultural sector consumes only 14% percent of electrical energy generated in the country. This results in inefficient use energy resources and use of diesel both of which cannot reduce poverty and result in environment degradation.

Further, increased population demands increased production which requires mechanization and hence energy consumption. Therefore, the major challenge for sustainable rural development is energy sustainability. The National Committee of Science and Technology on Fuel and Power indicates the large towns and cities with population of 500000 and more accommodate only 6% of India's total population but consume about 50% of the total commercial energy produced in the country. Therefore, energy demand in rural areas met through renewable energy in an efficient manner alone can ensure sustainable development and solar photovoltaic and biogas are the two such major technologies.

## VIII CONCLUSION

Solar power and Biogas technologies hold promise of transforming the rural India and provide sustainable development. Faculty members and students of universities R & D institutions and industry can play a role in this effort by way of their research, design and development efforts. This will also help the country in reducing the emission of greenhouse gases, conserve resources and sustain socio –economic growth.

## REFERENCES


[1] Solar Energy: Fundamentals and Applications by H P Garg and J Prakash.

[2] Biogas Technology: Towards Sustainable Development by R S Khoiyangbam, Navindu Gupta and Sushil Kumar, TERI, New Delhi, publication 2011, pages 5-6.

[3] MNRE Annual Report 2013-14; 1.22 & 23