

SOLAR PV SYSTEM DESIGN

A solar PV system design can be done in four steps:

- Load estimation
 - Estimation of number of PV panels
 - Estimation of battery bank
 - Cost estimation of the system.
 - Base condition: 2 CFLs (18 watts each), 2 fans (60 watts each) for 6hrs a day.
- ▶ The total energy requirement of the system (total load) i.e Total connected load to PV panel system
= No. of units $\times$ rating of equipment = $2 \times 18 + 2 \times 60 = 156$ watts
- ▶ Total watt-hours rating of the system
= Total connected load (watts) $\times$ Operating hours = $156 \times 6 = 936$ watt-hours
- ▶ Actual power output of a PV panel = Peak power rating $\times$ operating factor
= $40 \times 0.75 = 30$ watt
- ▶ The power used at the end use is less (due to lower combined efficiency of the system)
= Actual power output of a panel $\times$ combined efficiency
= $30 \times 0.81 = 24.3$ watts (VA)
= 24.3 watts
- ▶ Energy produced by one 40 Wp panel in a day
= Actual power output $\times$ 8 hours/day (peak equivalent)
= $24.3 \times 8 = 194.4$ watts-hour
- ▶ Number of solar panels required to satisfy given estimated daily load :
= (Total watt-hour rating (daily load))/(Daily energy produced by a panel)
= $936/194.4 = 4.81 = 5$ (round figure)
- ▶ Inverter size is to be calculated as :
 - Total connected load to PV panel system = 156 watts
 - Inverter are available with rating of 100, 200, 500 VA, etc.
 - Therefore, the choice of the inverter should be 200 VA.

COST ESTIMATION OF A PV SYSTEM

- (a) Cost of arrays = No. of PV modules $\times$ Cost/Module
= 5×8000 (for a 40 Wp panel @ Rs.200/Wp) = Rs.40000
- (b) Cost of batteries = No. of Batteries $\times$ Cost/Module
= $1 \times 7500 =$ Rs.7500

(c) Cost of Inverter = No. of inverters $\times$ Cost/Inverter = 1×5000
 $= 1 \times 5000 = \text{Rs.}5000$

Total cost of system = A + B + C = $40000 + 7500 + 5000 = \text{Rs.}52500$

[Additional cost of wiring may be taken as 5% of total system cost]

ASSUMPTIONS TAKEN FOR DESIGN

:

- ❖ Inverter converts DC into AC power with efficiency of about 90%.
- ❖ Battery voltage used for operation = 12 volts
- ❖ The combined efficiency of inverter and battery will be calculated as :
combined efficiency = inverter efficiency $\times$ battery efficiency = $0.9 \times 0.9 = 0.81 = 81\%$
- ❖ Sunlight available in a day = 8 hours/day (equivalent of peak radiation.
- ❖ Operation of lights and fan = 6 hours/day of PV panels.
- ❖ PV panel power rating = 40 Wp (Wp, meaning, watt (peak), gives only peak power output of a PV panel)
- ❖ A factor called ‘ operating factor’ is used to estimate the actual output from a PV module.
[The operating factor between 0.60 and 0.90 (implying the output power is 60 to 80% lower than rated output power) in normal operating conditions, depending on temperature, dust on module, etc.]

DESIGN OF BIOGAS PLANT

Biogas system design for cooking for a family of six members is considered here. The system design includes the estimation of total gas required, amount of feedstock (or dung), required and the number of animals required to have feedstock of a given amount.

Following assumptions are made for the design:

- ▶ About 350-450 litres of biogas required per day per person for cooking (in engine about 450 litres/hp/hour of biogas is required)
- ▶ **Average production of dung per animal per day:**
 - Cow– 10 kg/day
 - Bullock – 14 kg/day
 - Buffalo – 15 kg/day
- ▶ **Other biomass night soil, sugar cane bagasse, maize straw, etc. can also be used)**
 - 1000 litres of gas is equivalent to 1 m³ of gas.
 - Average gas production from dung is about 40 litres/kg of fresh dung.
 - Retention period of dung slurry in digester is 50 days.

AMOUNT OF GAS REQUIRED PER DAY

- I. Number of family members = 6 (adult). Considering 400 litre/day/person for cooking, total gas required = $6 \times 400 = 2400$ litres/day or about 2.4 m³ gas/day.
- II. Number of animals required to fulfil daily gas requirement = Amount of gas produced from a kg of fresh dung = 40 litre/kg.
- III. Total amount of dung required = Total gas required/Gas per kg of dung
 $= 2400/40 = 60$ kg.
- IV. Thus, in order to have 60 kg of dung no. of cows required = in order to have 60 kg of dung no. of cows required = $60/10 = 6$ cows.

DESIGN OF DIGESTER AND GAS HOLDER

In order to make slurry, water should be added to equal amount of dung.

- Total mass of slurry – Dung+ Water = $60+60 = 120$ kg.
- Volume of slurry per day (specific gravity of slurry is about 1090 kg/m³)
 $= \frac{\text{Total mass of slurry}}{\text{Specific gravity}}$
 $= \frac{120}{1090} = 0.11$ m³
- Retention period of slurry = 50 days. Total volume of the digester = per day volume of slurry $\times$ retention period = $0.11 \times 50 = 5.5$ m³ ~ 6 m³.
- Dimensions of the digester : Depth to diameter ratio should be between 1 and 1.3
- Gas holder tank dimension : The volume of the gas holder tank should be about 60% of the per day gas volume.
- Various possible costs incurred in manufacturing of a biogas plant is given below:

<i>Component</i>	<i>Capital cost (Rs.)</i>
1. Gas holder and frame	5500
2. Piping and stove	1750
3. Civil engineering construction	12000
Total cost of biogas plant	19250

SAVING DUE TO USE OF BIOGAS PLANT

Assuming that biogas is replacing the use of LPG in a household, following calculations can be done to calculate the amount savings.

- The amount of LPG required is about 2kg/per person/month
- Total LPG required for 6 people for a month is $6 \times 2 = 12$ kg/month
- Cost of LPG per kg is about Rs. 24.
- Total cost of LPG (if used in place of biogas) = $12 \times 24 = \text{Rs.}288$ per month (this amount is monthly saving.)
- Total yearly savings = $288 \times 12 = \text{Rs.}3456$ per year
- Therefore, the simple payback period is = Total cost of biogas plant/yearly savings
= $19250/3456 = 5.5$ years

ESTIMATION OF REQUIRED WIND TURBINE POWER RATING

Assume that annual energy requirement of an industry is 20000 kWh ,we calculate that what will be the size of wind turbine that is required to be installed to meet the energy requirement.

Following assumptions are taken into account for estimation:

- Annual energy requirement – 20000 kWh
- Propeller type wind machine is used
- Coefficient of performance – 0.40
- Wind speed at 15 metre height is 5 metre/sec (if the turbine hub is placed at the height other than 15 metre, the wind speed should be estimated as shown in ‘vertical’ wind speed variation section’.
- Density of air – 1 kg/m³
- Capacity factor – 0.30 (i.e. 30% of the time, wind machine is producing energy at rated power)
- Number of hours in a year 8760 hours.

The power density of wind (power per unit area)

$$= \frac{1}{2} \times \text{air density} \times (\text{velocity})^2$$

$$= 0.5 \times 1 \times (5 \times 5 \times 5)$$

$$= 62.5 \text{ watt/m}.$$

Actual power density that will be converted to useful energy

$$= C_p \times \text{transmission loss} \times \text{generator loss}$$

Considering losses

- Coefficient of performance $C_p = 0.40$
- Transmission losses (rotor to generator) = 0.90
- Generator losses = 0.90
- **Overall loss factor**
 $= 0.40 \times 0.90 \times 0.90$
 $= 0.324$
- **Actual power density**
 $= 62.5 \times 0.324$
 $= 20.25 \text{ W/m}^2$
- **Annual energy density (useful)**
 $= \text{power density} \times \text{number of hours per year}$
 $= 20.25 \times 8760 = 177.39 \text{ kWh/m}^2$

- **The rotor size and turbine power rating estimation:**

$$= \frac{\text{Total annual energy required}}{\text{Useful energy density}} = \frac{20000}{177.39} = 112.75 \text{ m}^2.$$

- **Radius of the rotor blade, (R)**

$$\pi R^2 = 112.75$$

$$R = 5.91 \text{ metre.}$$

- **Power rating of the turbine**

$$= \text{Actual power density} \times \text{area of the rotor}$$

$$= 20.25 \times 112.75$$

$$= 2.28 \text{ kW}$$

- **Actual rated power of the turbine rating should be**

$$= \text{power rating} / \text{capacity factor}$$

$$= 2.28 / 0.30$$

$$= 7.6 \text{ kW} \sim 8 \text{ Kw}$$

Thus, a 8 kW rated power wind turbine will provide desired annual energy under given situation.

The cost of a wind turbine of per kW basis runs between Rs.30000 and Rs.50000. For the above calculation a 8 kW wind turbine would cost about $8 \times 40000 = \text{Rs.}320000$.

Assumption made:

[The above power rating is based on the assumption that wind speed of 5 metre/sec will be available throughout the year, 8760 hours, which is not the case, therefore we have taken the capacity factor into account.]

ORGANISATION OF POWER SECTOR IN INDIA

The subject Power is the concurrent list of Indian Constitution. As such, the responsibility of power development lays both with the central and state governments.

In the central government, the 'Ministry of Energy' looks after the development of electric energy and lays down policies regarding generation, transmission, distribution and conservation of electric energy. Under the Electric Supply Act, the Central electricity Authority (CEA) and State Electricity Boards have been set up.

The functions of CEA are :

- (1) Development of national power policy, formulations and coordination of plans of power development,
- (2) Techno-economic appraisal of projects, monitoring the implementation of projects,
- (3) Ensuring efficient operation of power system, arbitration in certain matters promotion and coordination of research and design activities in the power sector, providing assistance to state governments and electricity boards, collection and publication of statically information relating to power supply industry.
- (4) Design and consultancy services and development of training program for power engineers.
- (5) Regional electricity boards were set up in 1964 in each of the five regions for development of integrated operation, initially between the states of the region with the ultimate aim of forming a National grid. The five regional electricity boards are :
 1. Northern Regional Electricity Board covering Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, UP Uttaranchal and Delhi, (head office New Delhi)
 2. Western Regional Electricity Boards covering Gujrat, Madhyapradesh Chhatisgarh, Maharastra, Goa, Daman, Diu, Dadra and Nagar Havellu (head office Bombay).
 3. Southern Regional electricity boards covering Andra Pradesh, kanrantaka, Kerala, Tamil Nadu, and Pondicherry (head Office Bangalore)
 4. Eastern Regional boards covering Bihar, Jharkhand, Orissa West Bengal (head office Calcutta)
 5. North Eastern Regional Electricity Boards covering Assam, Manipur Meghalaya, Nagaland, Tripura, Arunachal Pradesh and Mizoram (head office Shillong).

Regional load dispatch centres have been established to coordinate the activities of state load dispatch Centre so as to ensure optimum utilization of generation and transmission facilities in the regions. State Electricity Boards were set up in 18 states. These boards are mainly responsible for generation, transmission and distribution of electricity in their respective states. These boards are mainly responsible for generation, transmission and distribution of electricity in their respective states. In the remaining states viz. Manipur, Tripura, Sikkim, Nagaland, Goa, Mizoram, Arunachal Pradesh and all Union territories, there are no electricity boards and the generation, transmission and distribution of electricity is looked after by state Electricity Departments. Now the

state electricity boards have been converted into corporations. The Central Government has also set up many public sector undertakings for planning and setting up power projects.

- ❖ The national Thermal Power Projects corporation (NTPC) was set up in 1975 for planning, execution and operation of large pithead power stations and associated transmission networks.
- ▶ NTPC has set up many super thermal power station at Singrauli (UP), Korba (MP), Ramagundem (AP), Faraka (WB), Vindhyachal (MP) and Rihand (UP).
- ▶ The 2000 MW units at Korba and some 219 MW units at other plants have been commissioned. 500 MW units at Rihand and three 500 MW at Farakka have also been commissioned.
- ❖ The National Hydro Power Corporation (NHPC) was set up in 1975 to construct central sector hydroelectricity projects, transmission lines and ancillary works. NHPC has set up Baira Siul and Salal hydroelectricity project (J& K), Chamera Hydro Project (HP) and Deighat Hydroelectric Project (Nepal).
- ❖ The national Project and construction Corporation was set up in 1957 as joint venture of central and state Governments for the execution of multipurpose river valley projects, power projects and other project and other heavy engineering projects.
- ❖ The north Eastern Power Corporation (NEEPCO) was set up in 1976 to develop and set up power projects in north-eastern region. It is setting up 150 MW Kopili hydroelectric project.
- ❖ The Damodar Vally Corporation (DVC) was set up in 1948 for proper development of Damodar Vally in Bihar and West Bengal.
- ❖ The Bhakra Beas Management Board (BBMB) was established in 1966 to manage Bhakra and Beas projects in Northern region.
- ❖ The Nuclear Power Corporation was set up in 1987 to look after the development of nuclear power. A target of 20 GW of nuclear capacity by the year 2025 has been set.
- ❖ The Rural electrification Corporation (REC) was set up in 1969 to promote and financial rural electrification projects in the country. A large number of villages have been electrified in each state and some states have achieved 100% rural electrification.
- ❖ Power Grid Corporation of India (earlier known as National Power Transmission Corporation) was set up in 1990 to look after the development and operation of EHV transmission system in the country.
- ❖ The ministry of Non-conventional energy sources looks after and promotes the research and development of new and renewable sources of energy.

APPLICATION OF NON-CONVENTIONAL ENERGIES THROUGH WBREDA

The West Bengal Renewable Energy Development Agency (WBREDA) continues to implement one of the country's largest broad-spectrum programmes covering the whole range of Renewable Energy (RE) sources. The Programme cover providing of electricity to remote unelectrified rural areas of the state which are mostly located in Islands of Sundarbans, Forest areas of West Midnapur and Bankura, hilly areas of Darjeeling.

The state of West Bengal is generating about 30 MW power through primary fuel – biomass, wind, solar, mini hydel and a small portion of diesel.

MAJOR SOLAR ENERGY APPLICATIONS OF WBREDA

- Installation of Solar Water Heaters
- Building Integrated Photovoltaic System
- Energy Recovery from Municipal Solid Waste
- Installation of Solar Street Light in city roads

Over 50 MW of Renewable power generation capacities have been added in the state of West Bengal so far. More than half a million people in the remote areas of the State are enjoying the benefits of electricity which is highest in the country.

On an average, West Bengal receives **Solar Energy** to the tune of 1600kWh per sq. meter per year.

Solar Photo voltaic System	Category of beneficiaries
Solar Lantern	Individual Beneficiaries
Solar PV Street Lighting System	All categories of non-commercial institutions and organizations and also for community use.
Solar PV home lighting system	Individual Beneficiaries
Stand-alone Solar PV power plant	Community use for village Electrification
Grid-Interactive solar PV power plant	Institutional use for peak shaving and partial demand catering.
SPV pump for irrigation and drinking Water supply	Individual or community Use

BIOGAS PROGRAM OF WBREDA

Biogas is a clean and convenient source of fuel generated from biomass, such as cow dung, human waste etc through anaerobic fermentation process. 55% - 70% of this gas can be burnt in specially designed stoves for cooking and in silk mantle for lighting purpose. It can also be used in fuel engines.

The state of West Bengal has a potential to produce 1.5 million cubic meter of biogas every day through digester route. Accordingly to estimate more than 200 MW power can be generated in the state from digester gas and land fill gas.

Recently, **WBREDA** in association with **MNRE** and **USAID**, installed 2 X 30 kW biogas operated micro turbine in Purulia District of West Bengal. The plant is under operation for last couple of months. Micro turbines are highly reliable and almost noiseless with very low emission.

West Bengal Renewable Energy Development Agency and **WBSEB** have jointly set up 3MW Mungpoo-Kalikhola Small Hydel Project. The project site is located at Ranju valley in Darjeeling Hills, 100kms from Siliguri. Of the total cost 50% has been subsidized by MNES, Govt. of India. The project has been completed in 2003.

SALIENT FEATURES OF MUNGPPOO-KALIKHOLA PROJECT

- ❖ Installed capacity : 3x 1000Kw
- ❖ Name of the river : Kalikhola
- ❖ Water discharge : 20 cusecs
- ❖ Location : Namring Tea Estate
- ❖ Gross head : 718.3 M
- ❖ Pen – stock length : 1768 M
- ❖ Pen – stock material : Mild Steel
- ❖ Type of turbine : Pelton Wheel system
- ❖ Power evaluation : 33 k V system at Teesta Bazar
- ❖ Estimated Cost : Rs. 15.95 crores

WIND ENERGY PROGRAM OF WBREDA

➔ Wind Mapping Project

District	Area of Installation
➤ Darjeeling	Kurseong
➤ Coochbehar	Sitalkuchi
➤ Jalpaiguri	Hamiltongunj, Chalsa
➤ Uttar Dinajpur	Islampur, dalkhola, Raigunj
➤ Murshidabad	Salar, Bhagwangola
➤ South 24 Parganas	Sagar, Frasergunj

➔ Wind Monitoring Stations

- | | |
|---------------------|-----------------|
| 1.Frasergunj island | 8. Digha |
| 2.Sagar island | 9.Dadanpatrabar |
| 3.Purulia | |
| 4.Haldia | |

- 5.Nijkasba
- 6.Tiger hills
- 7.Delo hills

→ Wind Diesel Hybrid Project at Sagar Island.

There are about 700 Consumers in the power plant. The duration of power supply is for 6 hours during night time and varies according to local climatic conditions. For local management of the consumer services and for capacity building, West Bengal Renewable Energy Development Agency formed a local Beneficiary Society entitled “Sagar Island Wind Diesel Hybrid Power Plant Beneficiary Society”.

DG sets are very common in India for generation of electricity in distributed mode. However, with the high cost of diesel, DG sets are losing its importance. In order to make DG sets economically viable, WBREDA has installed one unique project in the country in the year 2003.

- The project comprises of diesel generator coupled through intelligent controller.
- It has been observed in windy season about 40% diesel could be saved. An intelligent controller operates the project.
- At present more than 2500 consumers are getting electricity from the project. Recently, one 150 kW Biomass Gasifier has been added into the project.
- Presently, diesel savings has been observed up to 85%.

→ Other Distributed Generation Projects working in West Bengal.

- Biomass Gasifier Project – 500 kW at Gosaba.
- Small Hydel Project at Darjeeling [capacity - 500 kW]