# A Study on Commercial Viability of Solar Power Systems

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**Abstract**

The role and importance of Solar Photovoltaic (PV) power generation increases rapidly all over the world. Investment in this sector grows along with its public interest. Being a purely technical matter, public has less awareness about its technology and economics, hence misguided or even cheated in the present scenario. In this paper, the researcher analyses the commercial viability of various solar PV systems in order to increase the public awareness in this matter.

**Keywords:** Solar, photovoltaic, solar hybrid, commercial viability

## Introduction

Sun, being the very cause of existence of our living planet, is the locus of all types of renewable energy systems on the earth. Collection of sunlight and conversion in to electrical energy is the most acceptable method used by renewable resource techniques. Solar Photo Voltaic (PV) is the method of converting solar energy in to direct current electricity and is the most common method adopted in the present world.

In Photovoltaic method, semiconducting materials those exhibit the photovoltaic effect are employed for energy conversion. A Photo Voltaic system employs solar panels composed of a number of solar cells to supply usable solar power. Power generation from solar PV is a clean sustainable energy technology and employs no moving parts in the system and no fuel is being consumed. Hence, it has low operational costs and no need for continuous maintenance. Consequently, variable costs associated with solar PV power generation are close to zero.

Being the cleanest and zero maintenance method of electrical energy generation, solar PV captures more attention in the present world. The design, procurement and installation of solar PV system are purely a technical matter and hence, non-technical public, those who interested in solar PV systems are being misguided or cheated in the present Indian scenario.

Therefore, an attempt may be made to create awareness about the technology of solar PV systems and its commercial viability among the public.

## Scope

A new era in power generation has just begun by using the renewable resources techniques. The world today is more anxious about the global warming and related environmental issues resulting from the uncontrolled usage of fossil fuels. Energy demand of present lifestyle shoots up day-by-day, and the resources are being used up faster. Such situation forces human society to promote renewable energy sources, especially solar power systems.

Solar systems demerits in its high capital costs, but now researches are being developed to reduce these costs, leading to improve its commercial viability compared to other traditional energy sources. Solar photovoltaic technology is inherently elegant in that, the direct conversion of sunlight to electricity occurs without any moving parts or pollution during the operations.

Here, an attempt is being made to examine the commercial viability of Solar PV system, by comparing the total installation expenditures, energy costs and pay-back period of various capacity systems, proposed by three different consumers of KSEB, in Calicut area. This study has been aimed to improve the public awareness of solar PV system and its technology.

**Solar PV System**

PV system uses the photovoltaic effect of semiconducting materials to convert the solar radiation into direct current (DC) electricity. This DC can be stored in battery or can be converted to AC using DC to AC power converters (Inverters) for real time use in power grids. A PV system contains an array of PV modules, a set of battery or a power inverter, electrical wirings and control/automation mechanism. Solar systems can be a small PV system capable of providing enough AC electricity to power a single home or even an isolated device in the form of AC or DC electric (roof-top systems) , or it can be large grid-connected photovoltaic power system capable of providing energy supply for multiple consumers.

In order to improve the collection of solar radiation, terrestrial PV systems aim to maximize the time they face the sun. Solar trackers achieve this by moving PV panels to follow the sun. This increase can be as much as 20% in winter and 50% in summer. Static mounted systems can be optimized by analysis of the sun path. Stationery panels are often set to latitude tilt, an angle equal to the latitude, two modules in a row placed at a distance equal to the length of a panel to prevent panels to shade each other and by adjusting the angle for summer or winter.

**PV Modules**

It is a group of solar cells connected in series and parallel to construct one panel. Each module (panel) is rated by its DC output, and typically range from 100 to 320 watts. PV module is considered to be the main component of PV system, as it converts the sunlight to DC electricity.

There are three main types of photovoltaic solar panels for both commercial and residential uses. They are;

1. Mono crystalline PV solar panel: Made from large crystal of Silicon. These panels are most efficient and most expensive panels currently available.

2. Poly crystalline PV solar panel: Characterized by its shattered glass look because of the manufacturing process of using multiple silicon crystals, poly crystalline solar panels are the most seen solar panels. A little less- efficient than mono crystalline panels, but also, less expensive.

3. Amorphous silicon thin film PV solar panels: These panels are thin and flexible. These panels are common for building integrated PV applications, because of their many application option and aesthetics. They are cheaper. Drawbacks are lower efficiency and loss of wattage/sq. feet installed and heat retention.

**Inverters for Solar PV Systems**

The DC electricity from solar panels shall be converted to AC electricity enabling to use in domestic or industrial applications. Inverters are employed for this purpose in solar PV systems. Solar inverters may be classified in to three broad types;

1. Stand-alone inverters: Used in isolated systems where the inverter draws its DC energy from battery and feeds AC to the appliances. Battery is charged from solar PV arrays during daytime. Normally, these do not interface with utility grid.

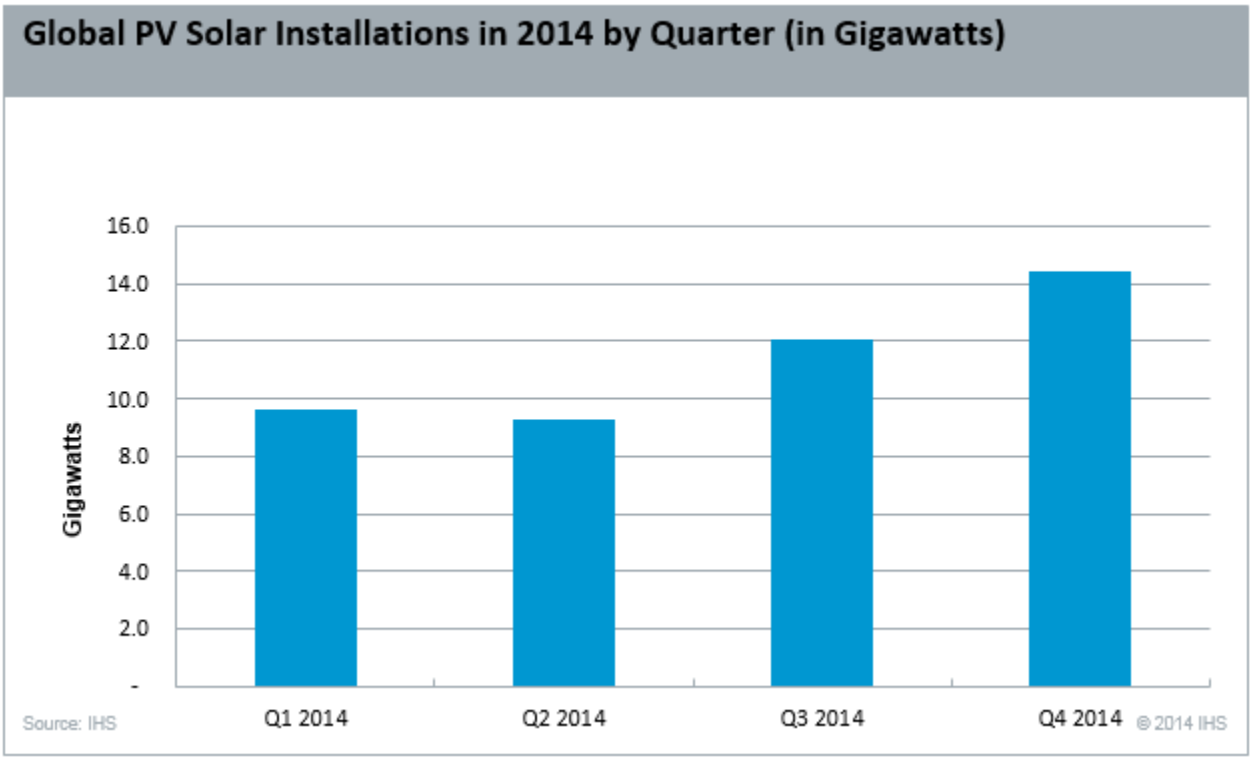
2. Grid-tie invertors: Used to match and stay connected with utility-supply power grid. DC from PV arrays converted to AC and coupled to supply mains. Power import/ export energy meter is used to measure energy fed to mains and used by own purpose. They shut down automatically when grid fails, and do not provide backup power during utility outages.

3. Battery Back-up invertors: Special invertors designed to draw energy from battery, manage battery charge via an on-board charger and export excess energy to the utility grid. They supply AC energy to selected loads during utility outages.

**Present Scenario**

Solar PV is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. More than 100 countries use solar PV. Installations may be ground mounted or built in to the roof or walls of the building.

Solar PV is seen growing rapidly to a total global capacity of 139 giga watts (GW) at the end of 2013. At the end of 2009, it was more than 29GW and at the end of 2011, it was 70.5 GW. The European Photovoltaic Industry Association (EPIA) report - 2014 estimated global PV installations to grow 35 – 52GW in 2014, whereas, 45GW was originally added to the grid, globally during the period. Actual additions in each quarter have been shown in the diagram.




By 2018, worldwide PV capacity is projected to have reached up to 320 – 430 GW. China, followed by Japan and U.S is now the fastest growing market, while Germany remains the world's largest producer, contributing almost 6 per cent to its national electricity demands.

With about 300 clear sunny days in a year and an average solar insulation of 4 - 7 kWh/sq.m, India can generate 8000 GW installed solar capacity if only 10% land were used for harnessing solar energy. India is far behind in solar harvesting, but initiatives have been started from Ministry of Renewable Energy, Govt. of India, to encourage entrepreneurs in this field by introducing subsidies in solar investments. Jawaharlal Nehru National Solar Mission (JNNSM) has been launched by the central government, and India has unveiled a Rs. 11.50 crores plan to produce 20GW of solar power by 2022.

NTPC Vidyuth Vyapar Nigam (NVVN) is the nodal agency for implementing Phase I & II of JNNSM. Various bidders have submitted their project proposals at an average power cost of Rs. 12.15 / kWh for Phase I & II. Electricity generated from such projects is proposed to be purchased by various state power utilities at the rate fixed and approved by government from time to time.

**Solar Hybrid**

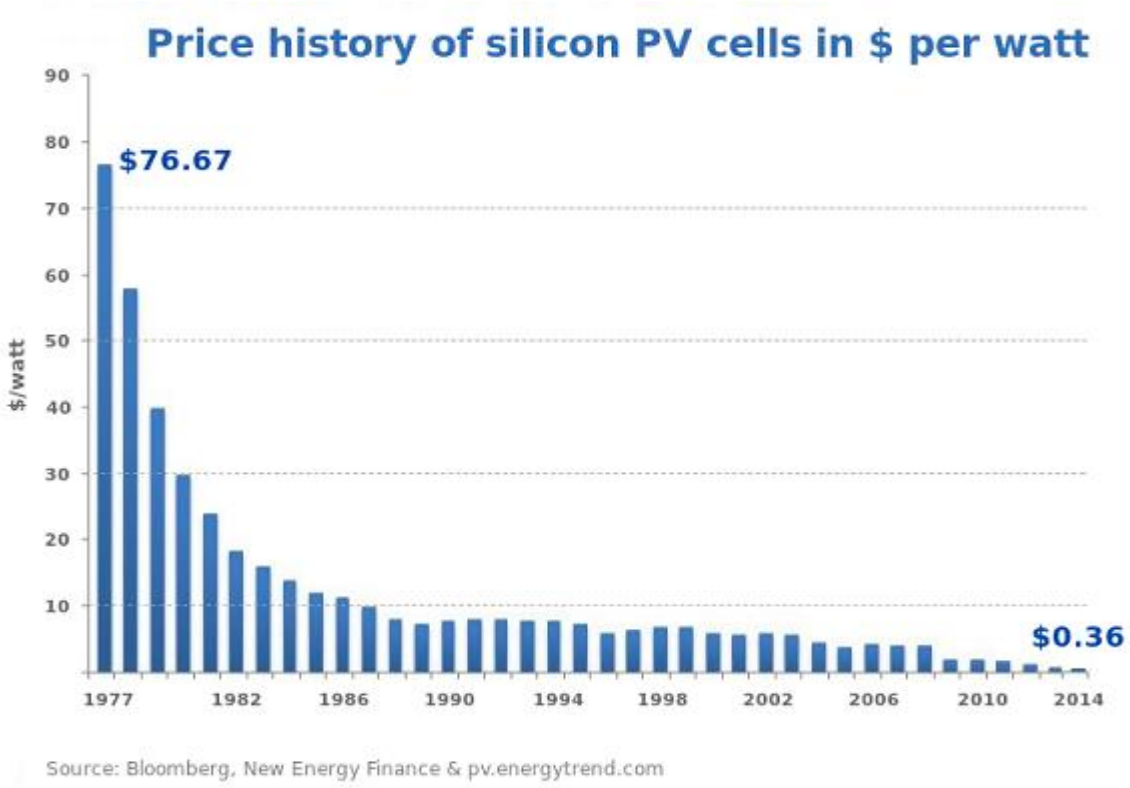
In a hybrid energy system, usually two or more energy sources are used together to provide increased system efficiency as well as greater balance of energy supply. Solar PV can be efficiently used in hybrid with wind power generation and diesel power generation. Hybrid system can improve the commercial viability of the solar PV system when used with diesel/wind power.

A Photo voltaic diesel hybrid system ordinarily consists of a PV system, diesel generators and intelligent management system to ensure that, the amount of solar energy fed in to system exactly matches the demand at that time. In this method, PV system compliments the diesel generators and supply additional energy when loads are high or relieve the generators to minimize its fuel consumption.

Photovoltaic system can be operated in hybrid with grid supply of distribution network of utilities. The load connected to the system will be shared from the PV system as well as from grid supply. In case, excess energy is generated from the PV system and the load is lesser, the power will be drawn by the supplier utility. This energy will be metered using a separate export energy meter. The net utility energy bill to the consumer will be the difference between the import and export energy meter readings.

**Economics**

The PV industry has seen dramatic drops in module prices since 2008. Crystalline silicon solar cell prices have fallen globally, from $76.67/w in 1977 to an estimated $0.36/w in 2013. Now the modules are available at a bulk-purchase rate of Rs. 36.00/w dc (inclusive of taxes in India) for a 300Wp module. (Eg. TITAN M 6 – 72 Poly crystalline).




For a bulk purchaser, inverters are available at Rs. 14.00/W ac and the mounting hardware for panel modules available at Rs. 14.50/W ac. Connecting cables and conduits are available from Rs. 10.00/W ac for bulk consumers. Land reclamation charges for solar plant erection may be Rs. 54.00/sq.m area and labor charges for solar plant installation may be arrived to Rs. 9.00/W ac. All these rates are calculated average charges and may vary from place to place.

For solar plants capacity less than 200 kW, charges for materials and installation will practically become 2 to 3 times of the above rates and for storage type solar plants consisting of battery banks, total expenditure will be further doubled due to exorbitant high prices of storage batteries.

**Commercial Viability**

Usage of renewable energy sources shall be encouraged in the present global scenario of global warming and depletion of fossil fuel sources. Renewable energy promotion is a must for national energy security also. Solar PV system is the easiest solution for renewable energy usage.

Commercial viability of a system is assessed technically based on the calculation of its payback period, discounted payback period, net present value, internal rate of return, profitability index, cash flow etc. But for simplicity, in this paper, commercial viability is assessed based on the payback period calculation only.

For examination of commercial viability, three cases have been considered.

In case 1, a middle class businessman residing at Calicut, Kerala state, India, interested in solar PV power systems, decides to install a unit for his household. Being a domestic installation, daytime power demand will be limited, and arrives around 2kW. Therefore, a grid-tie type solar PV system has been designed for him. The customer thinks that, the running cost for this system is nearly zero, and then the system will be commercially viable for him. Design and analysis described hereunder.

In case 2, a textile shop at Calicut town, interested in solar PV systems and in an intension to reduce the electricity bills, proposes to install a system in their own commercial complex. Daytime average load calculated was around 5 kW. They also believe that the solar system is always commercially viable, since the solar power is free of cost. Design and analysis has been described.

In case 3, a textile industry in the out skirts of Calicut, interested in solar power systems, proposes a system to meet their emergency load requirement, which is now fed from diesel generator almost in all days, because of the interruptions in utility power supply grid. The industry possesses free land with required level of solar insulation to install a large-scale plant. The design and analysis has been described. The cost of energy of diesel generator set has been assessed from the log sheets and expenditure bills of the company.

**CASE 1:** A middle class, domestic consumer in Calicut, Kerala state, India. He has an average continuous demand of 2kW and has a 3-phase power connection in his house from Kerala State Electricity Board Ltd. His monthly bill carries an average energy charge of Rs. 6.70/ unit (kWh). If he is interested in equipping a solar PV unit for his day time usage of 2kW load, and expecting to avoid usage of grid power during day time and to reduce energy bills; cost calculations are as follows;

**Power Plant Design:**

1. Total capacity of solar plant : 2 kWp
2. Average sun hours per day : 7 hrs
3. Total power per day : 14 kWh/day
4. Solar insulation in Kerala : 4.5 kWh/m²

5. Divide kWh/day by insulation : 14/4.5 = 3.11kWh/ m²/day
6. Multiply with 1.25 (Efficiency Factor) : 3.88 kWh/ m²/day
7. Number of solar panels(300wp) : (3.88x1000)/300 = 12.93 =13 panels

At present, a 13 panel (300Wp), solar PV system along with inverter, connecting cables and hardware etc. will cost **Rs. 2,86,400.00**

**Energy cost calculations:**

Useful life span of system : 15 years (practically with rated output)

Energy produced for 200 days per year and 7 hrs/day: 200 days x 15 x 2 x7= 42,000kWh

Energy cost/unit : (2, 86,400/-)/42,000 : **Rs. 6.82/unit**

The cost of energy generation is more than the utility energy charges. Payback period will be calculated only if any savings exists.

**Result:** The consumer has to bear a loss of Rs. 0.12 per unit (Rs. 6.82 – Rs. 6.70) in solar PV production, without storage. If he needs storage battery for extending the use to night period, his energy cost will be Rs.9.52 and his loss/unit increases to Rs.2.82/unit. ***Hence this project is commercially not viable.***

Space required for installing 13 panels is 18m x 6m in measurements. This shall be at ground level or at roof-top.

**CASE 2:** A commercial consumer, (Textile retail shop) in Calicut, Kerala state, India. The shop has an average continuous demand of 5kW during day time and has a 3 phase power connection from Kerala State Electricity Board Ltd. Their monthly bill carries an average energy charge of Rs. 7.40/ unit (kWh) and a fixed charge of Rs. 120.00/kW. The shop is interested in equipping a solar PV unit for their daytime usage of 5kW load; cost calculations are as follows;

**Power Plant Design:**

1. Total capacity of solar plant : 5 kWp
2. Average sun hours per day : 7 hrs
3. Total power per day : 35 kWh/day
4. Solar insulation in Kerala : 4.5 kWh/m²
5. Divide kWh/day by insulation : 14/4.5 = 7.77kWh/ m²/day
6. Multiply with 1.25 (Efficiency Factor) : 9.72 kWh/ m²/day
7. Number of solar panels(300wp) : (9.72x1000)/300 = 32.4 =33 panels

At present, a 33 panel (300Wp), solar PV system along with inverter, connecting cables and hardware etc. will cost **Rs. 6,08,800.00**

**Energy cost calculations:**

Useful life span of system : 15 years (practically with rated output)

Energy produced for 200 days per year and 7 hrs/day : 200 days x 15 x 5 x7= 105,000kWh

Energy cost/unit : (6, 08,800/-)/105,000 : **Rs. 5.80/unit**

**Payback Period Calculations:**

Savings in energy charges: Rs. 7.40 – Rs 5.80 = Rs. 1.60/unit (Savings in fixed charges will not be entertained since small consumers are not installed with TOD Energy meter)

Annual energy production: 200 days x 7 hrs/day x 5 kW = 7000 unit

Savings per year: Rs 1.60 x 7000 unit = Rs. 11200.00

Payback period: Rs. 608800.00 / Rs. 11200.00 = **54 years**

**Result:** The consumer will get a profit of Rs. 1.60 per unit in solar PV production, without storage. But, the pay-back period calculated arrives to be 54 years, more than the useful life of the power plant. ***Hence, this project is commercially not viable.***

Space required for installing their 33 panels is 27m x 12m in measurements. This shall be at ground level or at rooftop.

**CASE 3:** An Industrial consumer (Textile Production plant) operates industry in Calicut, Kerala, India. Due to frequent power interruptions in grid, the critical loads of the company fed from a continuous running Diesel generator set 400KW (500 KVA) capacity. The monthly electricity bill carries a fixed charge portion of Rs.300/-/KVA and energy charge of Rs. 05.20/unit. The consumer proposes a solar PV plant of 400kW capacity in the company premises and will use this energy as hybrid with diesel power, feeding to his emergency load mains.

**Power Plant Design:**

1. Total capacity of solar plant : 400 kWp
2. Average sun hours per day : 7 hrs
3. Total power per day : 2800 kWh/day
4. Solar insulation in Kerala : 4.5 kWh/$m^2$
5. Divide kWh/day by insulation : 14/4.5 = 622.22kWh/ $m^2$/day
6. Multiply with 1.25 (Efficiency Factor): 777.77 kWh/ $m^2$/day
7. Number of solar panels(300wp) : (777.77x1000)/300 = 2592.5 = 2593 panels

At present, a 2593 panel (300Wp), solar PV system along with inverter, connecting cables and hardware etc. will cost **Rs. 4,27,77,000.00**

**Energy cost calculations:**

Useful life span of system : 15 years (practically with rated output)

Energy produced for 200 days per year and 7 hrs/day : 200 days x 15 x 400 x7 = 8,400,000kWh

Energy cost/unit : (4,27,77,000/-)/8,400,000

: **Rs. 5.09/unit**

Using a diesel generator, the consumer gets uninterrupted power, but considering the diesel and oil charges alone.

The cost/ unit of energy from DG set arrived as follows:

During each hour of operation, DG set generates 400 kWh energy.

Running charges/hour:

1. Cost of Diesel : 105.50 Ltr x 54.50 = 5777.00
2. Cost of Lube oil : 0.200 Ltr x 240 = 48.00

Total running charges/ hr = 5800.00

Cost of energy generated: 5800.00/400 = **Rs. 14.50/unit**

**Payback Period Calculations:**

Savings in energy charges: Rs. 14.50 – Rs 5.09 = Rs. 9.41/unit

Annual energy production: 200 days x 7 hrs/day x 400kW = 560,000 unit

Savings per year: Rs 9.41 x 560,000 unit = Rs. 52,69,600.00

Savings in fixed charge: Rs. 300/-x500kVAx12x0.467 = Rs. 8,40,000.00

Total Savings: Rs. 5,26,96,00.00 + Rs. 8,40,000.00 = Rs. 61,09,600.00

Payback period: Rs. 4,27,77,000.00/ Rs. 61,09,600.00 = **7 years**

**Result:** Using solar PV power, in hybrid with diesel generator set, the consumer can save Rs. 9.41/unit along with a savings in fixed charges of Rs. 70,000.00 per month (fixed charge estimated for 7 hrs/day rate). The payback period of this solar PV plant is calculated to be 7 years. ***Hence this project is commercially viable.***

Being solar PV used in hybrid with diesel generator, the savings is much higher. If the industry proposes to add the capacity of the solar PV power plant, payback period can be considerably reduced.

Area calculations for this large-scale power plant are complex and it needs more space than a small-scale plant, invariably at ground level itself.

**CASE 3A**: The same consumer proposes the solar PV in grid-tie system and not in hybrid with diesel generator; situation is analyzed as follows;

| | |
|---|---|
| Cost of Solar PV power plant | : Rs. 4,27,77,000.00 |
| Cost of Energy generated | : Rs. 5.09/unit |
| Annual energy production | : 200 days x 7 hrs/day x 400kW = 560,000 unit |
| Utility energy charge | : Rs. 5.20/unit + Fixed charge: Rs. 300.00/kVA |
| Savings in energy charges | : Rs. 5.20 – Rs. 5.09 = Rs. 0.11/unit |
| Savings per year | : Rs 0.11 x 560,000 unit = Rs. 61,600.00 |
| Savings in fixed charge | : Rs. 300/-x500kVAx12x0.467 = Rs. 8,40,000.00 |
| Total annual savings | : Rs. 61,00.00 + Rs. 8,40,000.00 = Rs. 9,01,600.00 |
| Payback period | : Rs. 4,27,77,000.00/ Rs. 9,01,600.00 = **47 years** |

**Result:** The consumer proposes the solar PV in grid-tie system and not in hybrid with diesel generator; still he gets the profit of Rs.0.11/unit along with the saving in fixed charge of Rs. 70,000.00 per month (fixed charge estimated for 7 hrs/day rate). Then payback period of this solar PV plant is calculated to be 47 years, more than the useful life of the power plant, and ***the project is commercially not viable.***

**Comparison between cases:**

| Parameters | CASE 1 | CASE 2 | CASE 3 | CASE 3a |
|---|---|---|---|---|
| Type of consumer | Domestic | Commercial | Industrial | Industrial |
| Type of PV Plant | Grid-Tie (No Battery) | Grid-Tie (No Battery) | Hybrid with DG Set | Grid-Tie only |
| Rating of Power Plant | 2 kW | 5 kW | 400 kW | 400 kW |
| Cost of Power Plant in Rs. | 2,86,400.00 | 6,08,800.00 | 4,27,77,000.00 | 4,27,77,000.00 |
| Cost of Energy Rs./unit | 6.82 | 5.80 | 5.09 | 5.09 |
| Annual Savings in Rs. | NIL | 11,200.00 | 61,09,600.00 | 9,01,600.00 |
| Pay-back period | NA | 54 years | 7 years | 47 years |
| Commercially Viable | **No** | **No** | **Yes** | **No** |

**Summary**

Solar PV systems become more popular and approachable to households as well as industries, as a secondary energy source. It is being used as an energy source for satellites, road transports, airplanes, ships, railways, various signal and traffic control systems etc. worldwide. Solar PV is used for power plants usually in hybrid with wind or diesel power.

Solar PV systems are the best choice for powering at a remote user, where the grid supply of electricity utility is not available. Solar PV can then be used along with storage battery to obtain continuous power supply during night period also.

In this study, the commercial viability of solar PV system was examined, where the grid supply of electricity utility is present. The systems considered were grid-tie types; they have no storage battery in use. It was assumed that, grid was live during the 7 hrs solar generation period.

The following are concluded from this study:

1. Power utilities worldwide are struggling to meet the increasing power demand of consumers. The resources for power generation face depletion in reserve. In this situation, search for non-traditional energy sources and their development is highly promoted.

2. Solar PV is being more promoted worldwide, among other renewable energy sources, because of its easiness in installation, zero maintenance costs and cleanliness in operation.

3. Price of solar PV modules seen reduced every year and now for a bulk purchaser, solar panel is available at Rs. 36.00/w dc.(for 300 wp module)

4. Solar PV system using grid-tie invertors have more commercial viability than back-up battery type. But, such system can be used only at places where utility power connection is available.

5. Solar PV system equipped with storage battery can ensure the back-up power during night hours shut downs also. Commercially such systems are least viable due to exorbitant high price of storage batteries.

6. Power utilities are now promoting solar PV backup systems in order to reduce evening peak power demand on grid. KSEB introduces a program "Sun shift" in which a consumer can purchase a back-up type solar PV system from authorized agency, along with a subsidy sponsored by KSEB. During evening peak hours, consumer shall use power from this system only, so that, grid demand reduces. Battery gets charged during daytime.

7. For a small domestic consumer, the solar PV system is not commercially viable. For a medium commercial consumer, he can save small amount of energy charges during usage of solar power. However, since the payback period calculated is as long as the useful lifespan of the system, the project is commercially not viable.

8. For an industrial consumer, he can use solar PV system in hybrid with diesel generator supply and hence, it is commercially viable for him. He can reduce the payback period further by increasing the system capacity.

9. For the same industrial consumer, if he use the solar PV plant as grid-tie (not hybrid with diesel generator), the project becomes commercially non-viable.

10. A solar PV system is commercially viable, if it can be used in hybrid with diesel power generation, because of the large savings/unit obtained due to costly fossil fuel usage in diesel generator. Hybrid use also helps to reduce the atmospheric pollution from burning of fuel.

11. Diesel generators are used in most of industries as stand-by power source, due to its easiness in installation and usage. Solar PV can be efficiently used by such institutions as hybrid with diesel, so that, reduction in atmospheric pollution and increased availability of diesel for road transport etc. can be assured. Government shall propose subsidy for promotion of such installation, or shall make available interest free loans from banks for such projects.

12. Coming years will witness further reduction in costs of Solar PV modules. Researchers are still in progress to achieve a cheaper solar PV system. Such power system will then be viable commercially for all types of consumers and the contribution of solar PV in the power generation will increase significantly, worldwide.

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