



## **Establishment of Grid Connected Solar Photovoltaic Power Plant on Rooftop of CSIR- Staff Quarter Building - Scientific and Industrial Research Scientist Apartment (SIRSA)**

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### **Abstract**

This paper highlights the recent trends followed by CSIR- Central Glass and Ceramic Research Institute (CGCRI) in establishing Solar Photo -Voltaic Power Plants. This work is aimed at meeting up the conventional energy scarcity at CSIR-CGCRI, SIRSA Campus and developing clean/green energy in order to compensate the global challenges of energy scarcity, climate change and renewable energy development. Abiding by the scheme of Jawaharlal Nehru National Solar Mission (JNNSM) under the aegis of Ministry of New & Renewable Energy (MNRE), CSIR-CGCRI has implemented Solar Roof-top Grid connected Power Plant at SIRSA Residential staff quarter since February 2014 with the capacity of 37.5 KWp (as per agreement). From September 2017, CSIR-CGCRI has further enhanced the capacity to 100.5 KWp (as per agreement). Results revealed that there is a stable growth of solar power energy generation. Keeping this in mind, the work pertains to the basic objectives of achieving reduction in carbon food print in line with clean energy generation which leads to reduction in air-pollution and global warming and at the same time conservation of conventional resources, which is getting reduced day-by-day. Nevertheless, the solar energy generated would eventually lessen the amount of energy purchased from the local Distribution Company (DISCOM) which would benefit our organisation economically.



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### **Introduction**

From Literature review it was found, the strength of solar PV system with Net-metering arrangements has increased from 7.6 GW in 2007 to 13.5 GW in

2008 and was 21 GW at the end of 2009. Similarly, annual solar PV generation also had increased from 3.7 GW in 2007 to 10.7 GW in 2009.<sup>1</sup>

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The geographical location of India being in the equatorial sun belt of the earth, is advantageous because it receives enormous radiant energy from the sun. Clear sunny weather is available 250 to 300 days per annum in the most part of India, resulting in 1600 to 2200 kWh/sq.m radiation, which is comparable with radiation received in the tropical and subtropical regions. The equivalent energy potential is about 60,000 Lakhs GWh of energy per year.<sup>2</sup>

It is observed that during 2014 - 2017 India was able to achieve a non-conventional energy milestone, which includes solar power, wind energy or possibly small hydro plant which pushed the country's renewable generation more than one lakh gigawatt hours (GWh) in a single year for the first time.<sup>3</sup>

The Central Electricity Authority reported 93,207 GWh of renewable electricity up to the end of February, and the more updated daily data from POSOCO's National Load Despatch Centre showed that a further 6,832 GWh had been generated by the end of March 29, to push the total over the 100,000 GWh line in FY 2017 - 18 with two days to spare.<sup>3</sup>

India's renewable energy production now stands well ahead of the total electricity generation of relatively populous developing nations like the Philippines, or small but advanced economies like Belgium. It also exceeds all the electricity produced by Israel and Hong Kong combined – where virtually all power comes from burning coal, gas or oil.

More importantly, “actual generation” is a conservative and more revealing index of a country's transition to clean energy than the widely used term “generation capacity”.<sup>3</sup>

Thermal coal plants in India are currently running at a little below 60 % of their capacity, but these numbers are still substantially higher than those for renewables, dependent as they are on adequate sunshine for SPV plants. The energy actually generated for the grid puts the various sources on a more comparable footing.

Coal still dominates power production, but renewable generation now accounts for 7.7 % of grid power averaged over the last 12 months – more than twice

as much as nuclear energy. In December 2017, it exceeded large-scale hydro for the first time.<sup>3</sup>

Renewables are on track to contributing 10 % of India's year - round power by the end of 2019 – 21 years ahead of the forecast made by World Coal Association CEO Benjamin Sporton, who claimed in London's Financial Times that “renewables like wind and solar in India (are) unlikely to reach 10 per cent of the (grid) mix before 2040”. On a monthly basis, Sporton's claim was wrong even before he made it, as last July's renewable generation produced 11.7 % of India's power.

The major development this year has been the arrival of solar as a substantial contributor to the overall renewable generation – shown in red in the chart above. Several large solar parks are now up and running. Just this month, the first 600 MW of the 2000 MW Pavagada plant in Karnataka were commissioned, putting it on course to being the world's largest solar plant.

However, it's not all smooth sailing for renewable energy in India. As recently reported, solar investment has been threatened by the prospect of safeguard tariffs on imported solar equipment, the result of contradictory policy goals and the government's clear commitment to renewables is matched by equivocal statements regarding the future of coal.

But renewable generation will keep growing, and next financial year, the 100 billionth unit of renewable energy will probably be produced in January or February, not the end of March.

In the light of above studies, CSIR-Central Glass & Ceramic Research Institute (CGCRI), one of the foremost laboratories in the family of the Council of Scientific and Industrial Research under the aegis of Central Government had already installed 100.5 KWp (as per agreement) grid connected solar power plant at SIRSA in order to supplement their energy consumption of the residential complex and it is running successfully. Initially a capacity of 37.5 KWp (as per agreement) roof-top grid connected solar photo-voltaic plant was commissioned on February 2014 and another 63 KWp (as per agreement) SPV plant was commissioned on the roof - top of same

premises buildings on September 2017. Up to 31st March'2018 total generation from the plant is 251918 KWh, out of which we sold to CESC 46302 KWh after captive consumption in day time. The energy generation upto March 2018 saved Rs. 18.9 Lakhs approximately for CSIR-CGCRI.

#### Parameters Involved in Performance Evaluation

Collection of the following data pertaining to Irradiation, Performance ratio, Degradation, life expectancy should be done for a total performance evaluation [4]; (see Appendix-I)

#### Terminology [5-9]; (See Appendix-II)

One needs to have a thorough understanding of the following terminologies for execution of a Solar Power Plant:

Beam Radiation, Diffuse Radiation, Total Solar Radiation, Irradiance ( $\text{W/m}^2$ ), Irradiation ( $\text{J/m}^2$ ), Solar Constant, Direct Normal Insolation (DNI)

#### Methodology

Considering the ever depleting fossil fuel sources, the conventional energy charges are expected to increase, whereas allocation for maintenance expenditure remains almost constant, thus leaving the scope for widening gap. Considering usage of Renewable Energy Source, we had explored possible economic solutions, and approached the West Bengal Renewable Energy Development Agency (WBREDA), State Nodal Agency for implementation

of Jawaharlal Nehru National Solar Mission (JNNSM) under Ministry of New & Renewable Energy (MnRE), Govt. of India. As per JNNSM criteria, MnRE shall bear approximately 30 % of the total project cost related to Renewable Energy utilization, and balance 70 % shall be borne by the Client Agency. Moreover, as per West Bengal Energy Regulatory Commission (WBERC) Notification, Net-Metering has been introduced in the state of West Bengal. Net Metering is an arrangement, by which customer can generate own electricity through Renewable Energy route, which can offset conventional energy and related expenditure. Any excess energy generated, can be given back to the grid, thus monthly billing cycle shall consider only Net unit of energy. No Battery Bank is required for the purpose, thus recurring cost is avoided.

#### Benefit of the Plant:

- Supplementation of Conventional Energy.
- Peak Saving of demand.
- Green Energy--- Environment friendly.
- Reduction in recurring monthly electricity bill of our Institute against that complex.

#### Uniqueness of the Work:

- Conceiving this work on multistoried building roof top (Ground + 10).
- To counter the technical uncertainties for maintaining good health of the system.
- Weather pattern uncertainty and vulnerability of the total system on such height which

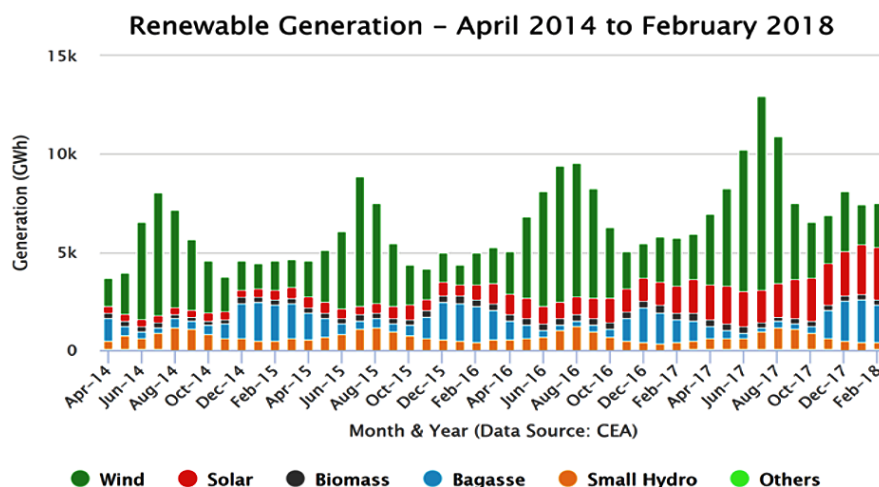
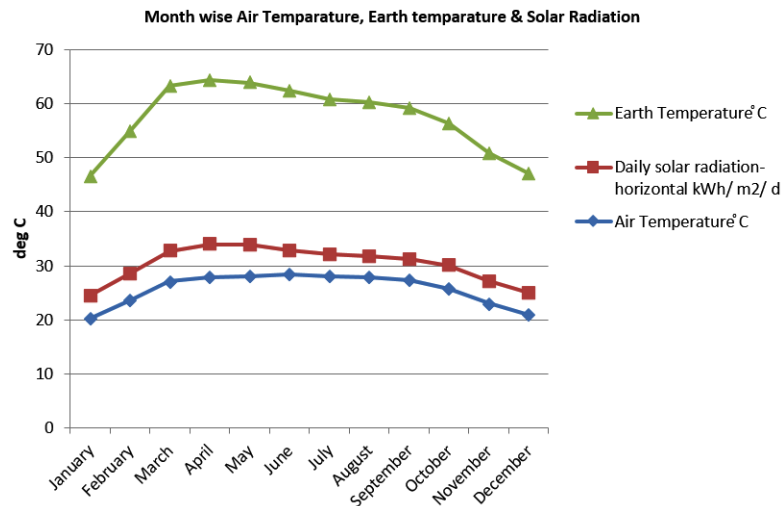


Fig. 1: Renewable generation-April 2014 to Feb 2018 <sup>3</sup>

counters lightning and wind pressure. To implement preventive measure against

lightning CSIR-CGCRI was installed Early Streamer Emission (ESE) Arrestors and



**Fig. 2: Month wise air temperature, earth temperature and solar radiation**

**Table 1: Meteorological Data**

| Unit               | Climate Data of location |       |  |
|--------------------|--------------------------|-------|--|
| Latitude           | °N                       | 22.57 |  |
| Longitude          | °E                       | 88.37 |  |
| Elevation          | M                        | 22    |  |
| Frost days at site | day                      | 0     |  |

| Month          | Air Temperature (degC) | Daily solar radiation-horizontal (kWh/ m2/ d) | Earth Temperature (degC) |
|----------------|------------------------|-----------------------------------------------|--------------------------|
| January        | 20.2                   | 4.27                                          | 22                       |
| February       | 23.6                   | 4.93                                          | 26.4                     |
| March          | 27.1                   | 5.66                                          | 30.5                     |
| April          | 27.9                   | 6.11                                          | 30.3                     |
| May            | 28.1                   | 5.82                                          | 29.9                     |
| June           | 28.4                   | 4.51                                          | 29.4                     |
| July           | 28                     | 4.11                                          | 28.6                     |
| August         | 27.8                   | 3.99                                          | 28.4                     |
| September      | 27.3                   | 3.94                                          | 27.9                     |
| October        | 25.7                   | 4.36                                          | 26.2                     |
| November       | 23                     | 4.24                                          | 23.5                     |
| December       | 20.9                   | 4.14                                          | 22                       |
| Annual Average | 25.7                   | 4.67                                          | 27.1                     |

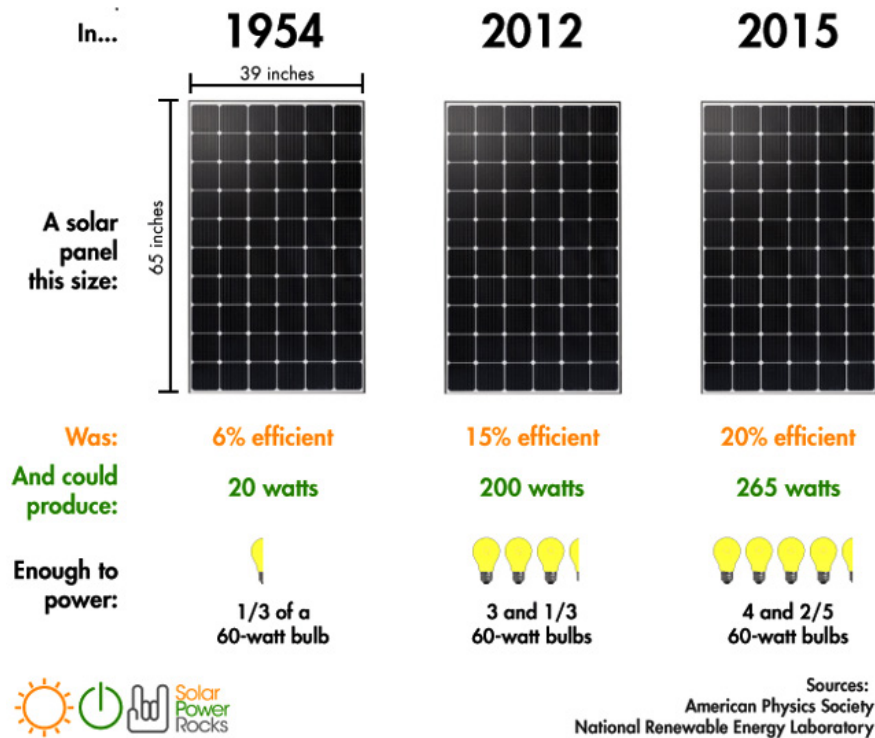
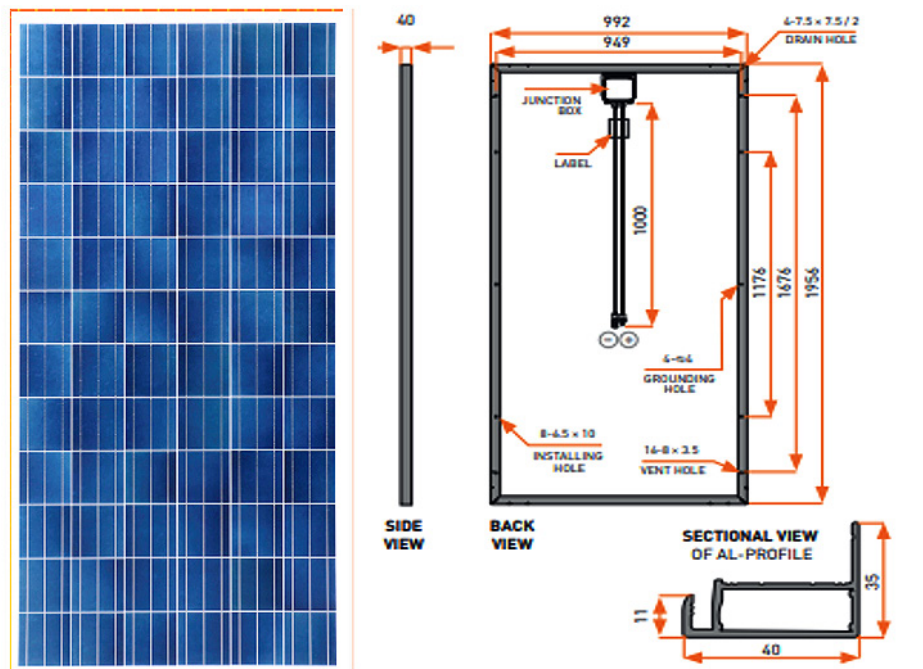
Fig. 3: Schematic view revealing size of solar panels year wise <sup>11</sup>

Fig. 4: Solar module used at SIRSA of CSIR-CGCRI Kolkata

**Table 2: Month wise daily average Terrestrial Solar radiation on inclined plane of PV Array**

| Month          | Daily Solar radiation at 20° tilt angle (kWh/ m2/ day) |
|----------------|--------------------------------------------------------|
| January        | 5.42                                                   |
| February       | 5.72                                                   |
| March          | 5.98                                                   |
| April          | 5.91                                                   |
| May            | 5.30                                                   |
| June           | 4.08                                                   |
| July           | 3.78                                                   |
| August         | 3.79                                                   |
| September      | 3.95                                                   |
| October        | 4.81                                                   |
| November       | 5.17                                                   |
| December       | 5.41                                                   |
| Annual Average | 4.94                                                   |

to counter the wind pressure at that height STAAD-PRO software was used to determine the load calculation and structural design for withstanding the load.

- This renewable energy generation root is the most suitable and clean form of energy, taking care of global warming and climate change phenomenon.
- Quality of all components including the structural system was adequately taken into consideration and has been suitably addressed.
- After witnessing a set back of an inverter getting burnt due to thunder and lightning in the first phase of work, reasons were searched and additional remedial actions were taken and hence replaced by the developers free of cost as per terms of the agreement.

**Table 3: Design Input Data**

| Description                              | Unit   | Data                                            |
|------------------------------------------|--------|-------------------------------------------------|
| <b>PV Array Data</b>                     |        |                                                 |
| Nominal PV array capacity                | kWp    | 101.31                                          |
| Slope angle of PV Array                  | Degree | 20                                              |
| Number of Module                         | Nos.   | 359                                             |
| Spacing factor between two row           |        | Almost 1.65                                     |
| <b>PV Array Yard Data</b>                |        |                                                 |
| Albedo                                   |        | 0.20                                            |
| Azimuth angle of PV Array wrt true south | Degree | 0.00                                            |
| <b>Inter Array Strip space data</b>      |        |                                                 |
| Shadow free time start (24 hr basis)     | hr     | 8.00                                            |
| Shadow free time end (24 hr basis)       | hr     | 15.00                                           |
| <b>PV Module data at 25 °C</b>           |        |                                                 |
| PV Module Rating                         | Wp     | 240 (157 nos.) & 315 (202 nos.)                 |
| Rated efficiency of PV Module            | %      | 14% (240Wp) & 16.15% (315Wp)                    |
| Fill factor                              | %      | 70-75                                           |
| Temperature Coefficient                  | %/C    | 0.5                                             |
| Overall system efficiency                | %      | 90                                              |
| <b>Inverter</b>                          |        |                                                 |
| Total Capacity                           | kVA    | 95                                              |
| Nos. of Inverter                         | Nos.   | 7 (20 KVA- 3 nos., 10KVA- 3nos. & 5 KVA- 1 no.) |

Here is what a label looks like on the back of the solar panel

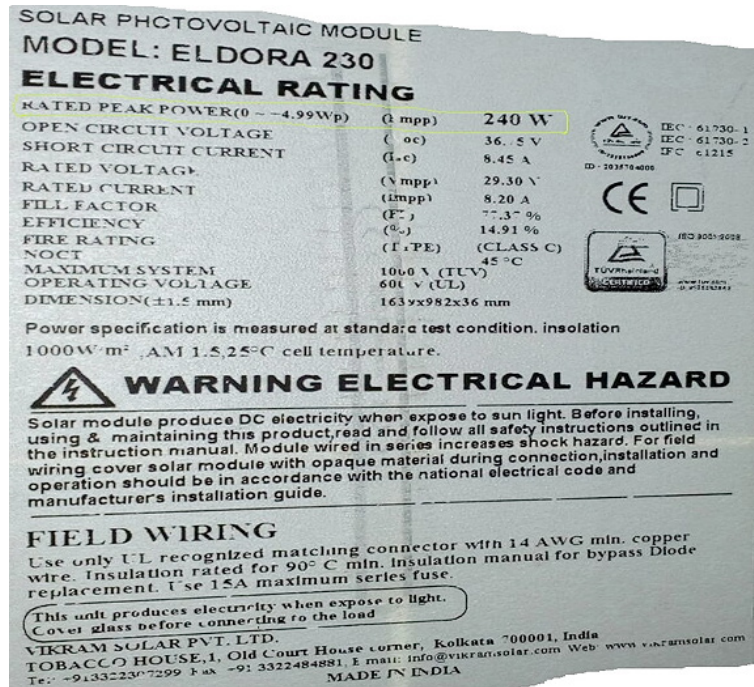


Fig. 5: Detailed specification of 240 Wp solar photovoltaic module at SIRSA of CSIR-CGCRI Kolkata

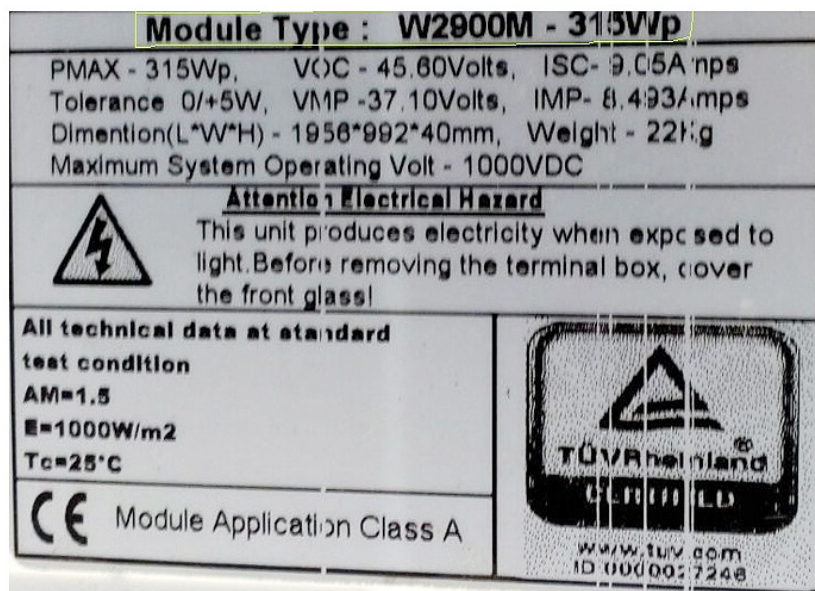


Fig. 6: Detailed specification of 315 Wp solar photovoltaic module at SIRSA of CSIR-CGCRI Kolkata

**Detail of the Project (Site)**

The proposed project site is located in the campus of CSIR Residential Complex (SIRSA), 59 Lake Road, Kolkata- 700029. In the roof of all the buildings (excluding CSIR Guest-House).

Output voltage of the Power Plant was 440V AC and has to be synchronized with grid at the AC bus bar of the Main service panel at 440V, 3ø 4 Wire system. There was no need of storage battery because the system is grid interfaced.

**Summary of the Project**

CSIR - Central Glass & Ceramic Research Institute has setup Solar PV System at their residential complex in order to supplement their energy consumption for common service of the residential complex install 100.5 kWp (as per agreement) Grid-connected Solar Plant.

Virtually there was no need of installation of distribution network, since there will be a dedicated line feeding the PV generated power in to the AC Bus Bar of main Service panel i.e. the LT receiving and load distribution point.

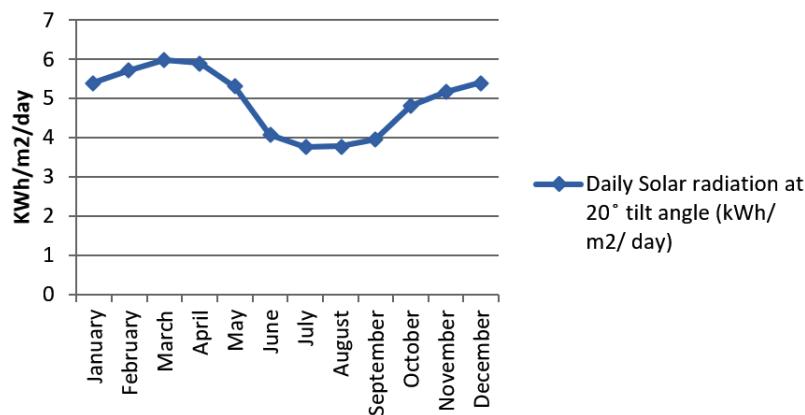
**Daily Solar radiation at 20° tilt angle**

Fig. 7: Daily Solar radiation at 20° tilt angle

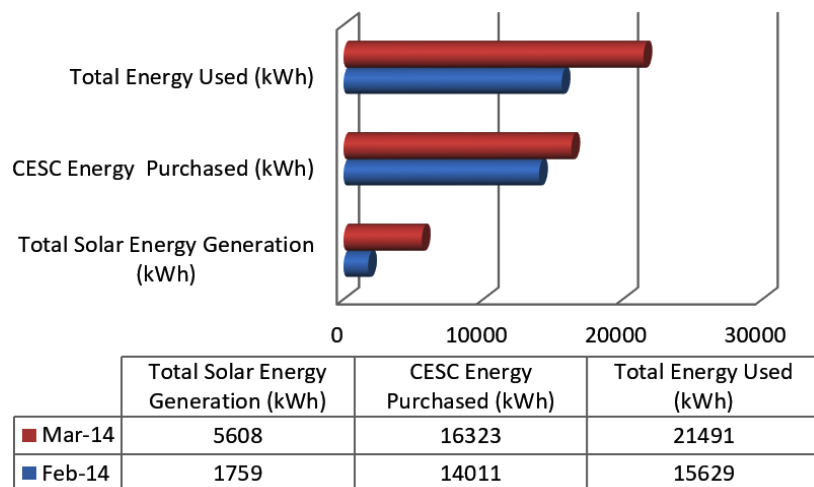


Fig. 8: Utilization of Energy for February 2014 & March 2014

Major system components are-Solar PV Module, Array Junction Box, Inverter, AC Distribution Board, Data-logger and Import-Export energy meter.

An agreement with CESC was executed for Net Metering facility.

The entire plant was insured from fire and other perils through National Insurance Co. Ltd.

### Results and Discussion

For the first time in India's power generation history, the financial year 2017-18 saw renewable energy production reach the 1 lakh Gigawatt-hour mark. This achievement came almost at the end of the financial year on 29 March, tracked by the National Load

Dispatch Centre of the Power Systems Operations Company (POSOCO). Within a span of two years, Pavagada Solar Park in Karnataka would be the largest single-site solar plant in the world after attaining its full 2 GW installed capacity.<sup>10</sup>

The city of Diu, which is actually a centrally administered territory was recognized as the first city in India to meet - up its day - time power requirement through the solar plant. This small city has historically been dependent on Gujarat to supply almost all its power. This changed with the Smart Cities mission. Diu set up a 9 Megawatt (MW) solar plant and installed another 1.3 MW capacity using government building rooftops. Diu also started incentivizing rooftop solar installations, paying Rs

**Table 4: Energy generation for the FY- 2013-14 ( Feb 2014-March 2014)\***

|             | Solar Energy Used (kWh) | Solar Energy Sold (kWh) | Total Solar Energy Generation (kWh) | CESC Energy Purchased (kWh) | Total Energy Used (kWh) |
|-------------|-------------------------|-------------------------|-------------------------------------|-----------------------------|-------------------------|
| February'14 | 1618                    | 141                     | 1759                                | 14011                       | 15770                   |
| March'14    | 5168                    | 440                     | 5608                                | 16323                       | 21931                   |
| Total       | 6786                    | 581                     | 7367                                | 30334                       | 37701                   |

\*For the year 2013-14 ( As the SPV Plant was installed in Feb'2014, the general energy generation is taken for two months)

**Table 5: Energy generation for the FY -2014-2015**

| Month        | Solar Energy Used kWh | Solar Energy Sold kWh | Total Solar Energy Generation (kWh) | CESC Energy Purchased (kWh) | Total Energy Used (kWh) |
|--------------|-----------------------|-----------------------|-------------------------------------|-----------------------------|-------------------------|
| April'14     | 5242                  | 115                   | 5357                                | 22537                       | 27779                   |
| May'14       | 4821                  | 68                    | 4889                                | 24169                       | 28990                   |
| June'14      | 3458                  | 23                    | 3481                                | 24233                       | 27691                   |
| July'14      | 3355                  | 58                    | 3413                                | 21556                       | 24911                   |
| August'14    | 3735                  | 141                   | 3876                                | 20747                       | 24482                   |
| September'14 | 3836                  | 222                   | 4058                                | 20815                       | 24651                   |
| October'14   | 3878                  | 262                   | 4140                                | 18208                       | 22086                   |
| November'14  | 4234                  | 185                   | 4419                                | 14867                       | 19101                   |
| December'14  | 3938                  | 190                   | 4128                                | 13806                       | 17744                   |
| January'15   | 4153                  | 232                   | 4385                                | 13716                       | 17869                   |
| February'15  | 4286                  | 229                   | 4515                                | 12074                       | 16360                   |
| March'15     | 5238                  | 398                   | 5636                                | 15519                       | 20757                   |
| Total        | 50174                 | 2123                  | 52297                               | 222247                      | 272421                  |
| Average p.m. | 4181.17               | 176.92                | 4358.08                             | 18520.58                    | 22701.75                |

10,000 subsidy for every kilowatt (KW) of installed capacity. Running entirely on solar power during day-time, even negotiating the summer peaks is no mean achievement for any Indian city. Gandhinagar in Gujarat also aspires to use solar as its predominant power supply source. The city is working towards creating a 5 MW captive installed base, using

government and private residential buildings to put up generation units.<sup>10</sup>

#### Off - Grid and On - Grid Solar PV Systems

The “Usage of Solar power” benefits to the society by the means of green revolution along with economy. It is noteworthy that in the long run there is a reduction

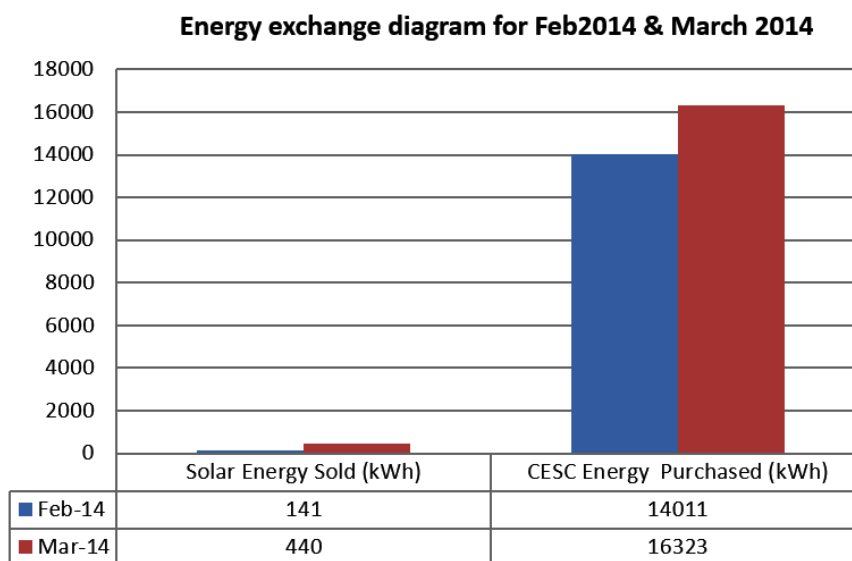


Fig. 9: Energy exchange diagram for Feb2014 & March 2014

#### Utilization of Energy for FY:2014-15

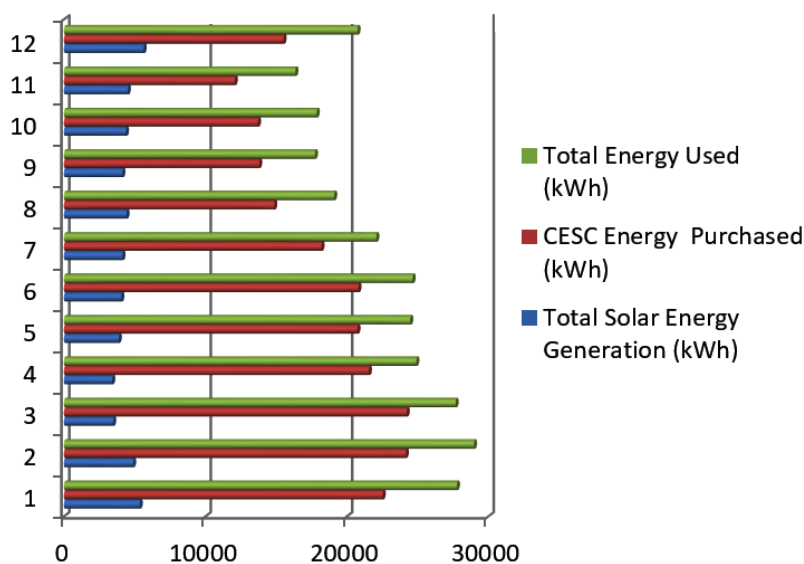


Fig. 10: Utilization of Energy for FY- 2014-2015

in electricity energy charges. However, there are two types of system we choose -1) grid - tied solar power systems and 2) off-grid systems, in order to select the solar power option that is suitable to us.

#### Off - Grid Solar PV Systems

This type of solar electric system is not connected to the electrical utility grid. It relies on batteries to store the electricity produced by the solar panels for use when the system is unable to produce sufficient energy (for example: at night) to meet household

functions or any other electrical loads. This system is expensive than Grid - tied system due to Battery cost and it will require a recurring maintenance cost of battery at the same time disposal of waste battery is an another big issue.

#### Grid - Tied Solar PV Systems

The system comprising grid interfacing between Utility supply and Solar Power. It includes the possibility to earn, sell, and generate revenue from local DISCOM's. In this case, the utility company

### Energy exchange diagram for FY: 2014-15

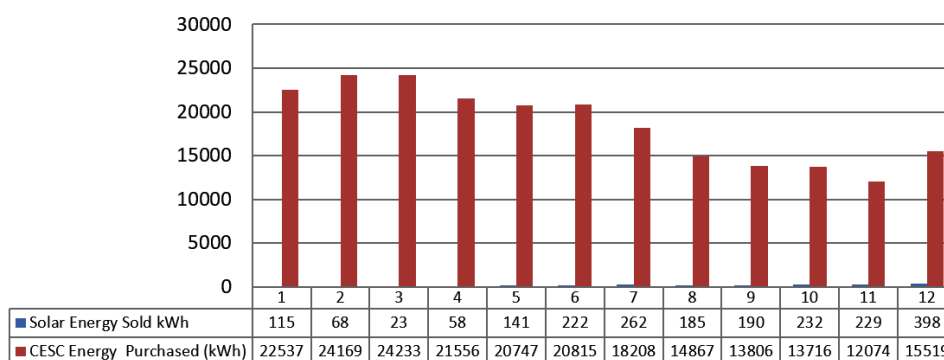


Fig. 11: Energy exchange diagram for FY-2014-2015

Table 6: Energy generation for the FY- 2015-2016

| Month        | Solar Energy Used, kWh | Solar Energy injected to the grid of utility provider, kWh | Total Solar Energy Generation, kWh | CESC Energy Purchased, kWh | Total Energy consumed, kWh |
|--------------|------------------------|------------------------------------------------------------|------------------------------------|----------------------------|----------------------------|
| April'15     | 4028                   | 111                                                        | 4139                               | 18133                      | 22161                      |
| May'15       | 5021                   | 43                                                         | 5064                               | 22945                      | 27966                      |
| June'15      | 3493                   | 59                                                         | 3552                               | 22674                      | 26167                      |
| July'15      | 2871                   | 43                                                         | 2914                               | 19981                      | 22852                      |
| August'15    | 3586                   | 85                                                         | 3671                               | 23508                      | 27094                      |
| September'15 | 3685                   | 88                                                         | 3773                               | 21589                      | 25274                      |
| October'15   | 4006                   | 136                                                        | 4142                               | 20962                      | 24968                      |
| November'15  | 3917                   | 187                                                        | 4104                               | 15950                      | 19867                      |
| December'15  | 3057                   | 54                                                         | 3111                               | 15567                      | 18624                      |
| January'16   | 3603                   | 67                                                         | 3670                               | 14933                      | 18536                      |
| February'16  | 3466                   | 114                                                        | 3580                               | 14506                      | 17972                      |
| March'16     | 4685                   | 320                                                        | 5005                               | 16996                      | 21681                      |
| Total        | 45418                  | 1307                                                       | 46725                              | 227744                     | 273162                     |
| Average p.m. | 3784.83                | 108.92                                                     | 3893.75                            | 18978.67                   | 22763.50                   |

will pay us for the exported solar energy, which we could inject in the utility grid after captive use. Further, where the Solar Power Plant is not capable to generate enough electricity to power the home/ Electrical loads, the utility supply grid will supply electricity whenever needed. This system also is more cost effective than Off - grid system.

When choosing a solar power system, it is important to decide when we are going to utilize the system. For example, if we want to utilize the solar power at night, then battery based off - grid system is the only option, otherwise a grid-tied system may be the best choice.

Grid - tied solar power systems is connected, or "tied" to the existing utility electrical grid. Electricity that is produced by the solar power plant flows freely back to the grid, and to the utility company through net-metering arrangements. The direct benefit for the electricity generated by the solar panels of the consumers is obtaining credit. As long as the solar array generates more electricity than the captive use, the electricity will be free to inject in the utility grid. If the consumer consumes more electricity than is generated, then they will be billed for only the excess consumption.

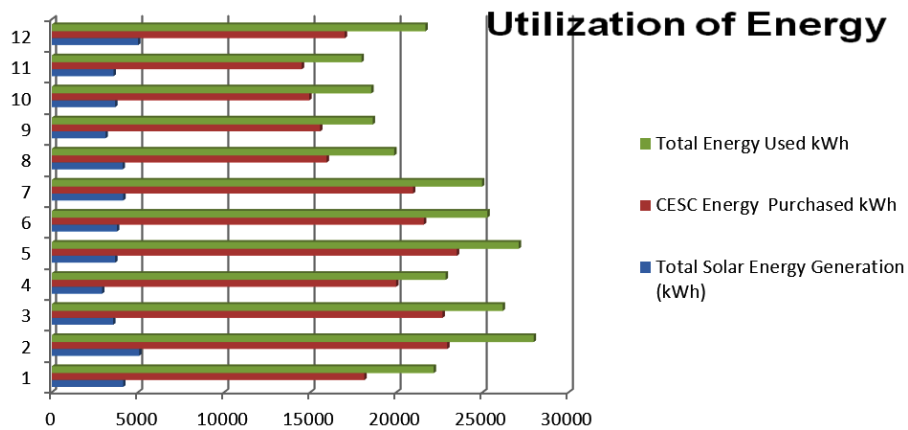


Fig. 12: Utilization of Energy for the FY- 2015-2016 February 2014 & March 2014

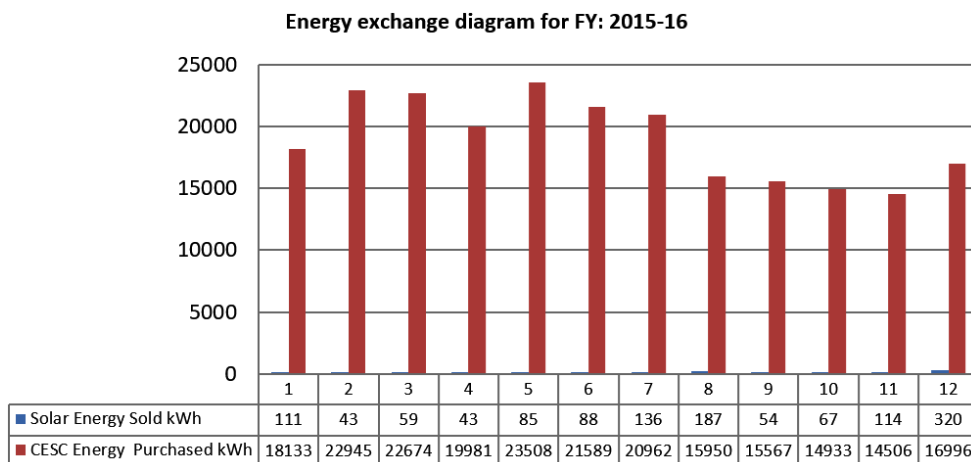


Fig. 13: Energy exchange diagram for the FY- 2015-2016 Feb2014 & March 2014

For the SIRSA SPV Plant, energy generated through solar modules is initially consumed by the connected load at day time (captive use). If solar power generation exceeds the load demand, then the excess power will feed to the DISCOM's grid.

#### Why does Solar Panel Size Matter?

Output Power is directly proportional to the no. of solar cell in a panel. The more solar cells working

in tandem, the more power they'll create. Therefore, the size of a panel matters.

The efficiency of solar cell is increasing day by day, resulting in comparatively more electricity generation from similar size solar panel than earlier.

If one looks closely at the solar panel in the image above, one would notice 60 little squares. These

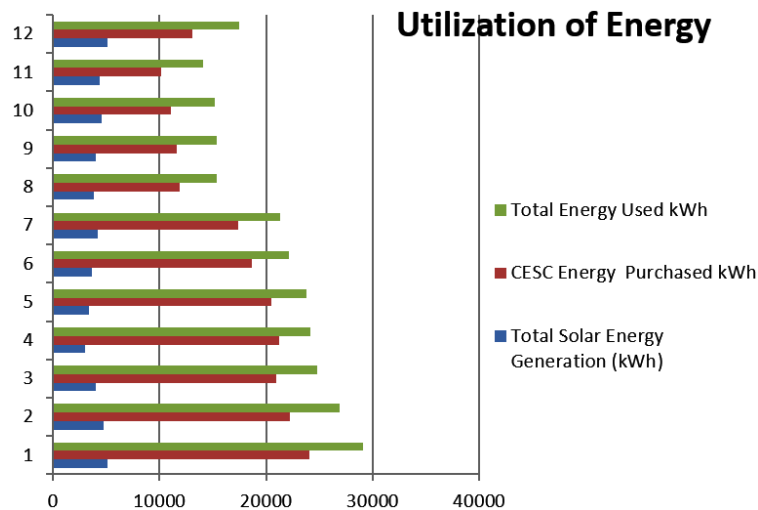


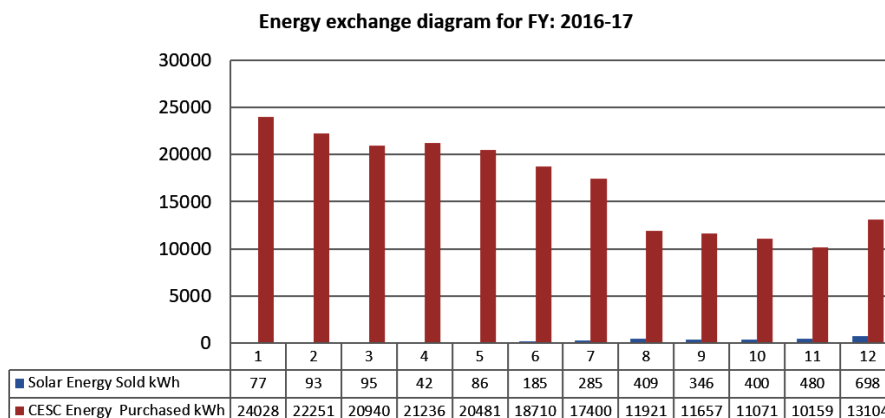
Fig. 14: Utilization of Energy for the FY- 2016-2017 February 2014 & March 2014

Table 7: Energy generation for the FY 2016-2017

| Month        | Solar Energy Used, kWh | Solar Energy injected to the grid of utility provider, kWh | Solar Energy Generation, kWh | CESC Energy Purchased, kWh | Total Energy consumed, kWh |
|--------------|------------------------|------------------------------------------------------------|------------------------------|----------------------------|----------------------------|
| April'16     | 5060                   | 77                                                         | 5137                         | 24028                      | 29088                      |
| May'16       | 4644                   | 93                                                         | 4737                         | 22251                      | 26895                      |
| June'16      | 3889                   | 95                                                         | 3984                         | 20940                      | 24829                      |
| July'16      | 2939                   | 42SS                                                       | 2981                         | 21236                      | 24175                      |
| August'16    | 3332                   | 86                                                         | 3418                         | 20481                      | 23813                      |
| September'16 | 3458                   | 185                                                        | 3643                         | 18710                      | 22168                      |
| October'16   | 3953                   | 285                                                        | 4238                         | 17400                      | 21353                      |
| November'16  | 3447                   | 409                                                        | 3856                         | 11921                      | 15368                      |
| Dece,ber'16  | 3675                   | 346                                                        | 4021                         | 11657                      | 15332                      |
| January'17   | 4133                   | 400                                                        | 4533                         | 11071                      | 15204                      |
| February'17  | 3912                   | 480                                                        | 4392                         | 10159                      | 14071                      |
| March'17     | 4384                   | 698                                                        | 5082                         | 13104                      | 17488                      |
| Total        | 46826                  | 3196                                                       | 50022                        | 202958                     | 249784                     |
| Average p.m. | 3902.17                | 266.33                                                     | 4168.50                      | 16913.17                   | 20815.33                   |

squares are actually individual solar “cells,” which are linked together by wires. The cells are where

electricity is made, and the wires carry the electricity to a junction box where the panel is hooked into a larger array.



**Fig. 15: Energy exchange diagram for the FY- 2016-2017**

**Table 8: Energy generation for the FY- 2017-2018**

| Month     | Solar Energy Used kWh | Solar Energy Sold kWh | Total Solar Energy Generation (kWh) | CESC Energy Purchased kWh | Total Energy Used kWh |
|-----------|-----------------------|-----------------------|-------------------------------------|---------------------------|-----------------------|
| April'17  | 4453                  | 304                   | 4757                                | 17772                     | 22225                 |
| May'17    | 4977                  | 108                   | 5085                                | 21607                     | 26584                 |
| June'17   | 3908                  | 75                    | 3983                                | 22475                     | 26383                 |
| July'17   | 2768                  | 117                   | 2885                                | 18227                     | 20995                 |
| August'17 | 3062                  | 206                   | 3268                                | 17224                     | 20286                 |
| Total     | 19168                 | 810                   | 19978                               | 97305                     | 116473                |

\* FY 2017-18 (The 2nd phase Solar Plant having capacity of 63 KWp (as per agreement) was installed at the same premises to enhance the entire plant capacity by 100.5 KWp (as per agreement) in the month of September-2017

Continuation of Table 8-----

| Month        | Solar Energy Used kWh | Solar Energy Sold kWh | Total Solar Energy Generation (kWh) | CESC Energy Purchased kWh | Total Energy Used kWh |
|--------------|-----------------------|-----------------------|-------------------------------------|---------------------------|-----------------------|
| September'17 | 4650                  | 1771                  | 6421                                | 18884                     | 23534                 |
| October'17   | 5524                  | 4785                  | 10309                               | 12726                     | 18250                 |
| November'17  | 5298                  | 6410                  | 11708                               | 9733                      | 15031                 |
| December'17  | 5154                  | 4976                  | 10130                               | 9532                      | 14686                 |
| January'18   | 5628                  | 6288                  | 11916                               | 9248                      | 14876                 |
| February'18  | 4904                  | 6895                  | 11799                               | 7916                      | 12820                 |
| March'18     | 6086                  | 7163                  | 13249                               | 11825                     | 17911                 |
| Total        | 37244                 | 38288                 | 75532                               | 79864                     | 117108                |

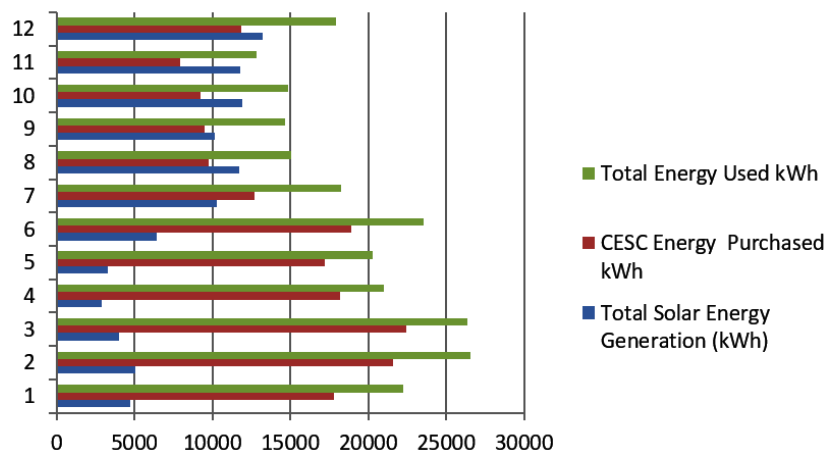
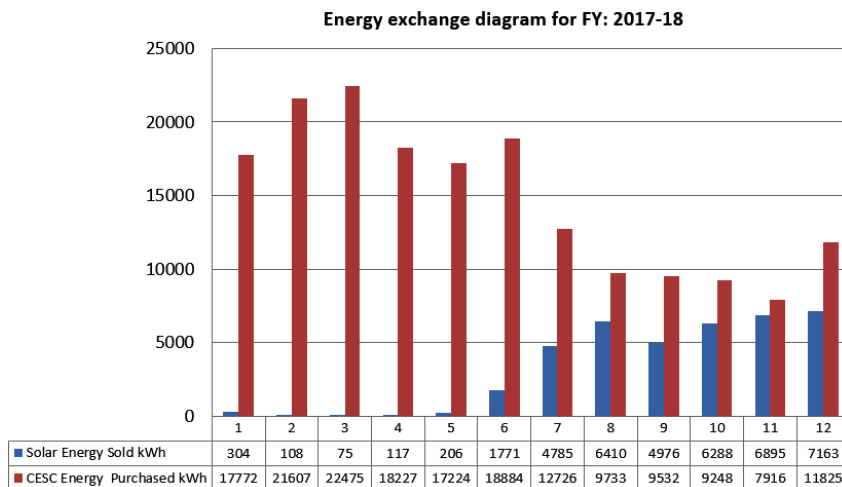
**Table 9: Year wise Solar generation  
(February 2014 - March 2018)**

| Financial year | Generation (KWh) |
|----------------|------------------|
| FY 2013-14     | 7367             |
| FY 2014-15     | 52297            |
| FY 2015-16     | 46725            |
| FY 2016-17     | 50022            |
| FY 2017-18     | 95510            |

**Table 10**

| Financial Year | PR(%) |
|----------------|-------|
| 2013-14        | 73.28 |
| 2014-15        | 72.79 |
| 2015-16        | 80.51 |
| 2016-17        | 77.74 |
| 2017-18        | 78.89 |

### Utilization of Energy

**Fig. 16: Utilization of Energy for the FY- 2017-2018****Fig. 17: Energy exchange diagram for the FY- 2017-2018**

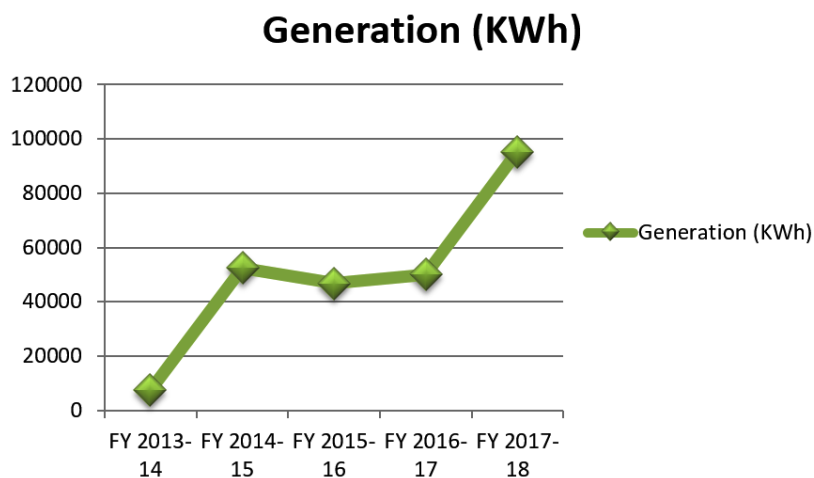


Fig. 18: Solar generation pattern (February 2014 - March 2018)

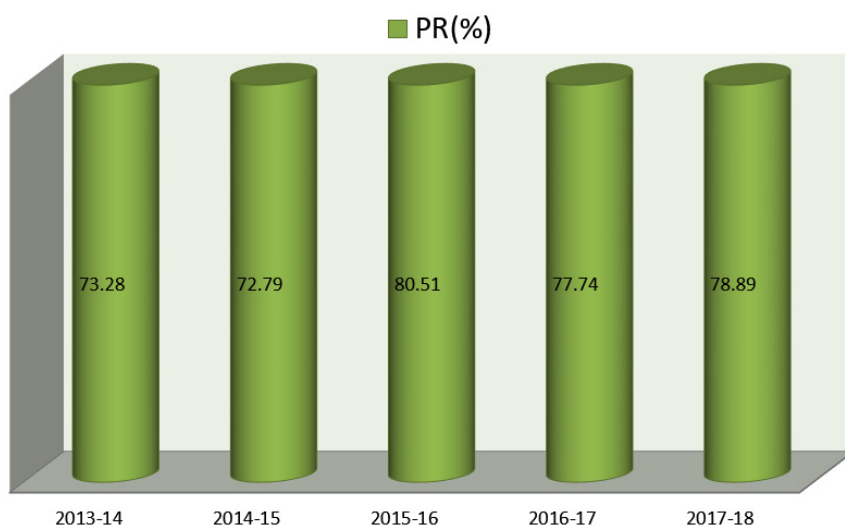


Fig. 19: PR percentage year wise (2013-14 to 2017-18)

Table 11: Energy Compensation Scenario  
for FY 2013-14

| Financial Year : 2013-14   |        |
|----------------------------|--------|
| Guest House Consumption    | 48200  |
| Common Service Consumption | 93908  |
| Allottees' Consumption     | 118652 |
| CSIR-CGCRI burden          | 134741 |
| Solar Compensated          | 7367   |

Table 12

| Financial Year: 2014-15    |        |
|----------------------------|--------|
| Guest House Consumption    | 50918  |
| Common Service Consumption | 91404  |
| Allottees' Consumption     | 129588 |
| CSIR-CGCRI burden          | 90025  |
| Solar Compensated          | 52297  |

In the SIRSA Plant, each 240 Wp (1639 mm x 982 mm x 36 mm) module consisting 60 cells and each 315 Wp (1956mm x 992mm x 40mm) module consisting 72 number of cells.

#### How is a Solar Panel's Rating Calculated?

Solar panels would have a number listed on the back that indicates how much power they would pump out

### SIRSA 2013-14

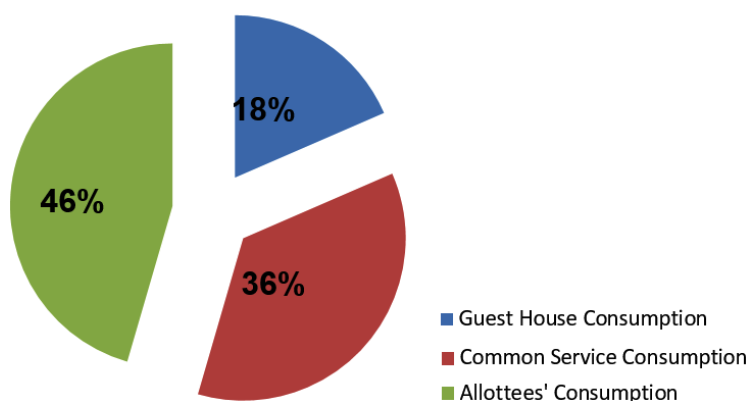


Fig. 20: Energy consumption scenario for FY 2013-14

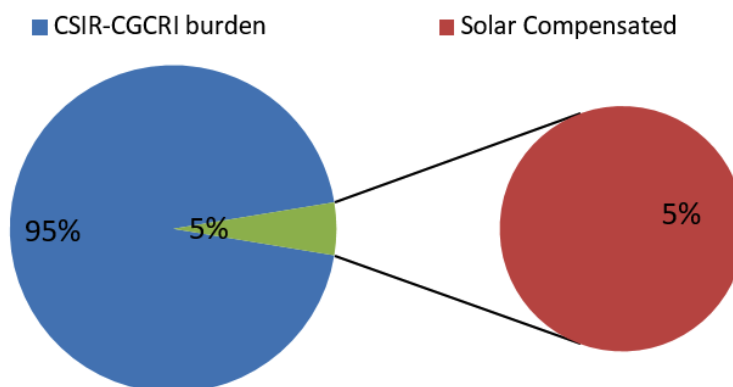


Fig. 21: Energy compensation scenario for FY 2013-14

Table 13

| Financial Year: 2015-16    |        |
|----------------------------|--------|
| Guest House Consumption    | 54409  |
| Common Service Consumption | 92701  |
| Allottees' Consumption     | 126771 |
| CSIR-CGCRI burden          | 100387 |
| Solar Compensated          | 46723  |

Table 14

| Financial Year : 2016-17   |        |
|----------------------------|--------|
| Guest House Consumption    | 55580  |
| Common Service Consumption | 77082  |
| Allottees' Consumption     | 117134 |
| CSIR-CGCRI Burden          | 82640  |
| Solar compensated          | 50022  |

### SIRSA 2014-15

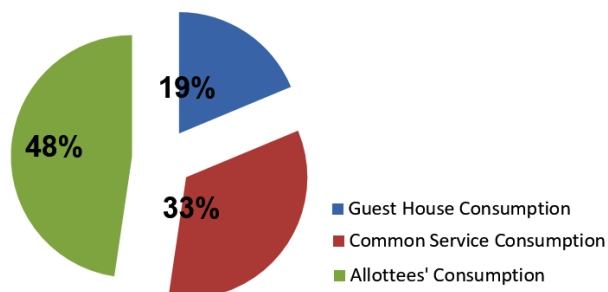


Fig. 22: Energy consumption scenario for FY 2014-15

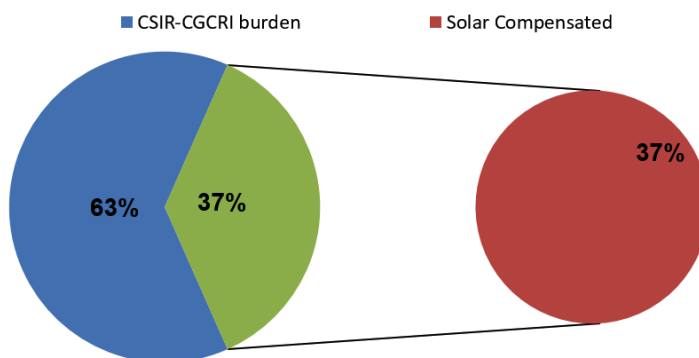


Fig. 23: Energy compensation scenario for FY 2014-15

### SIRSA 2015-16

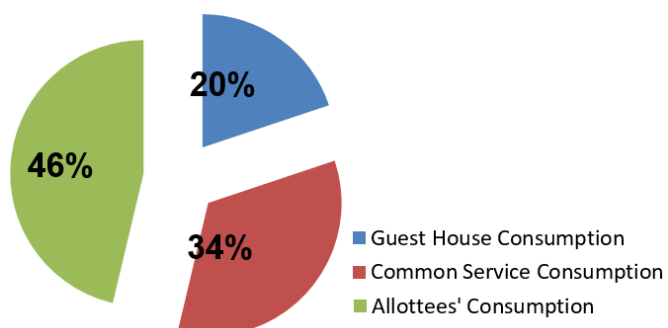


Fig. 24: Energy consumption scenario for FY 2015-16

during ideal conditions. This is called the Standard Test Condition rating (STC for short).

To determine an STC rating, solar labs test the panels under ideal conditions called “peak sun,” or 1000 watts of sunlight per square meter of surface.

That approximately equals to the power of the sun at noon, on a sunny day, at the equator.

In (Figs. 5&6), the label shows an STC rating of 240 watt (Fig..5) & 315 watt (Fig..6) for the panel. If that panel received full sun for one hour, one would

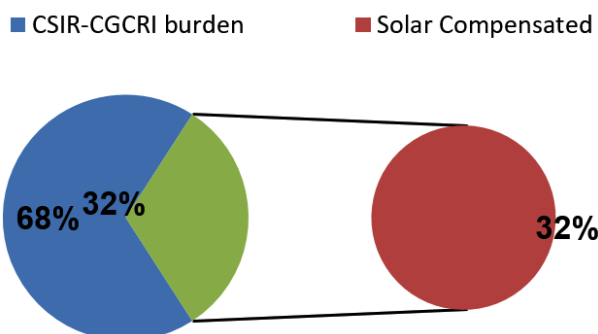


Fig. 25: Energy compensation scenario for FY 2015-16

## SIRSA 2016-17

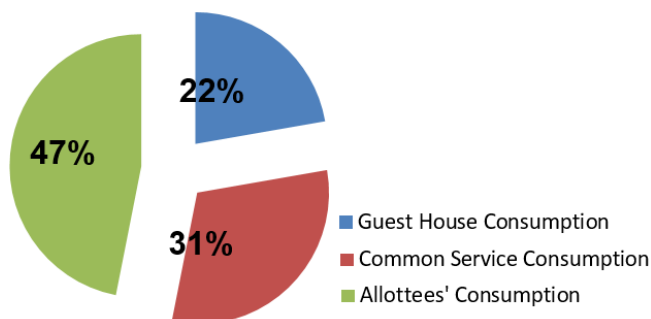


Fig. 26: Energy consumption scenario for FY 2016-17

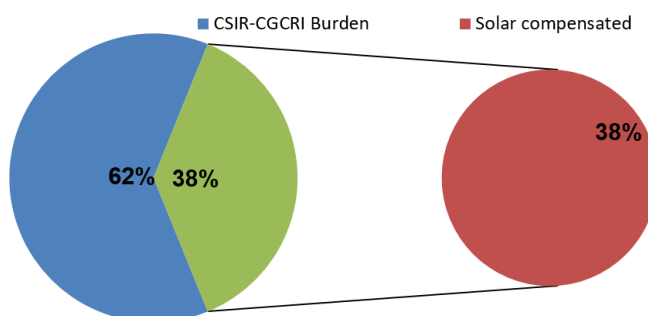


Fig. 27: Energy compensation scenario for FY 2016-17

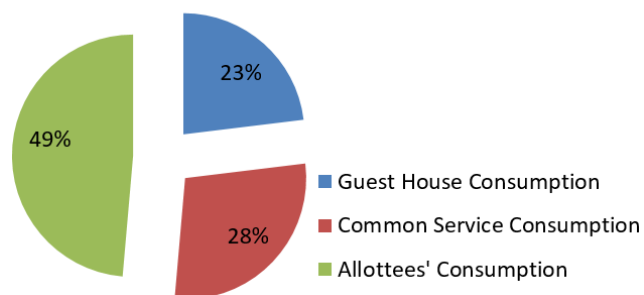
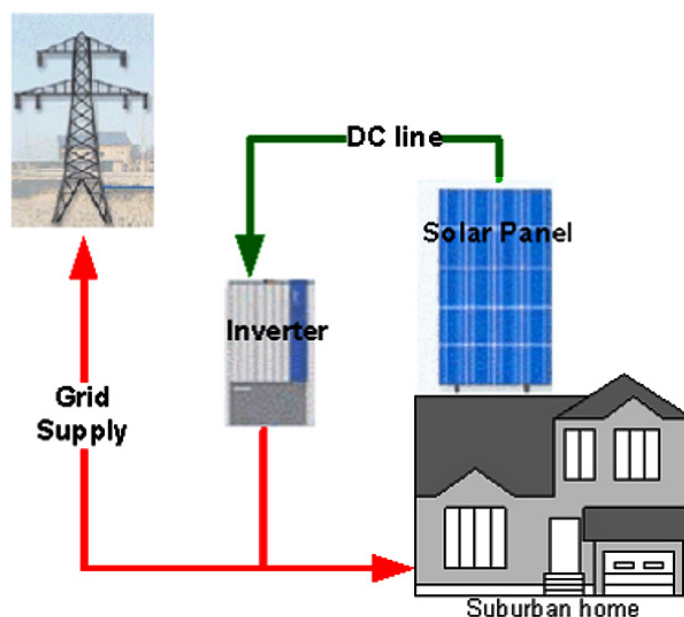
**Table 15**

| <b>FY 2017-18</b>          |        |
|----------------------------|--------|
| Guest House Consumption    | 53896  |
| Common Service Consumption | 66111  |
| Allottees' Consumption     | 113571 |
| CSIR-CGCRI burden          | 24497  |
| Solar Compensated          | 95510  |

get 240 watt-hours & 315 watt-hours respectively of electricity.

The results of solar power generation at our SIRSA complex have been explained in their proper perspective.

Month wise daily average Terrestrial Solar radiation on inclined plane of PV Array at SIRSA complex is revealed in Table. 1

**SIRSA 2017-18****Fig. 28: Energy consumption scenario for FY 2017-18****Fig. 29: Schematic of the grid connected solar photovoltaic power plant**

### Energy Generation Scenario

Financial year (FY) wise, the Energy Generation Scenario has been exemplified in Tables (3 - 7) & also in Figs. (8-17).

### Performance Ratio (PR) of the Plant

Performance Ratio (PR) of a plant for a period of time is :-

energy measured(kWh)/(Irradiance(kWh/m<sup>2</sup>) on the panel x Active area of PV module(m<sup>2</sup>) x PV module efficiency.....(1)

### Year Wise Performance Ratio

Fig.23 and Table 13 depict the trend and performance the year wise performance ratio of our Solar Power Generating system.

### Performance Monitoring Mechanism

Performance data monitoring (Daily, Monthly, Yearly energy generation) system will be provided for generation and other parameters data-logging.

Web enable data logging system is a separate unit. The data logging system includes PV string monitoring system also. The data Logger should have the provision of recording the data of solar insolation and ambient temperature and associated electrical parameters at different stages to study performance of system as well as to study status of the system at a particular instant. The data logger should have required transducer to monitor and record the required system data. The data logger should be provided with an insolation meter and a temperature meter matched with the system. The data logger shall have reliable battery backup and data storage capacity to record all sorts of data simultaneously round the clock. Web based Data Logger and remote monitoring must be compatible with data logger software. The system shall be provided with GSM Modem with required SIM card. The modem must be compatible to GSM and /or GPRS system. The other required accessories, hardware and compatible software shall have to be provided as an integrated part of the system to monitor the real time data (maximum 20 minutes delay) through web server. The Data logger shall continuously send data to the server. The system can be monitored from anywhere through internet

without installing any special software.

The Schematic of the grid connected solar photovoltaic power plant is revealed in Fig.34.

### Conclusion

The aforesaid study leads to the following conclusions: At present, the most crucial global challenge is to control the global warming which in turn largely depends upon carbon emission which eventually depends upon type of energy generated. Solar Photovoltaic Energy Generation is such a key technology to produce decarbonised electrical energy and has currently emerged as an attractive alternate electricity source to combat such temperature rise. As a contribution to the above global green energy revolution, CSIR-CGCRI has utilised the entire available roof tops of the residential quarters and installed 37.5 (as per agreement) kWp Solar Photovoltaic Power Plant in 2014 and further enhanced its capacity in 2017 to 100.5 kWp (as per agreement) thereby reducing the carbon footprint to a substantial level.

Results revealed that due to the capacity enhancement, there is an overall growth of solar power energy generation having on an average performance ratio more than 80%.

Apart from generating clean energy, CSIR-CGCRI is also benefitted by less energy purchase from local DISCOM.

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#### Appendix-I, Ref.-4

- A. Irradiation – Data from different sources has been analysed and the source identified based on the accuracy perception for the present study.
- B. Performance ratio – It is observed that performance ratio depends on the irradiation, the optimum angle of tilt, air temperature, design parameters, quality of modules, efficiency of inverter etc. The results have been compared with some data available on the recently installed grid connected power plants in India.
- C. Degradation – All manufacturers stand a guarantee of performance over a period of 25 years with 90% output for first 12 years and up to 80% after 25 years of operation. Various studies carried out by global renowned institutions on the extent of degradation of output of modules after long term operation in field. These results are analyzed to arrive at the actual field performance.
- D. Life expectancy – Trends in the accelerated tests for modules, inverters, supporting structure and cabling have been studied.

#### Appendix-II, Ref.-5-9

Beam Radiation – solar radiation received from the Sun without being scattered by the atmosphere and propagating along the line joining the receiving surface and the sun. It is also referred as direct radiation. It is measured by a pyrheliometer.

Diffuse Radiation – the solar radiation received from the Sun after its direction has been changed due to scattering by the atmosphere. It does not have a unique direction and also does not follow the fundamental principles of optics. It is measured by shading pyranometer.

Total Solar Radiation – the sum of beam and diffused radiation on a surface. The most common measurements of solar radiation is total radiation on a horizontal surface often referred to as 'global radiation' on the surface. It is measured by pyranometer.

Irradiance ( $\text{W/m}^2$ ) – the rate at which incident energy is incident on a surface of unit area. The symbol  $G$  is used to denote irradiation.

Irradiation ( $\text{J/m}^2$ ) – the incident energy per unit area on a surface, found by integration of irradiation over a specified time, usually an hour (I) or a day (H).

Solar Constant - The solar constant is the amount of incoming solar radiation per unit area, measured at the outer surface of Earth's atmosphere, in a plane perpendicular to the rays

Direct Normal Insolation (DNI) - It is the direct component of the solar radiation incident normal to the collector; that is, the angle of incidence of solar radiation with the normal of the collector is zero throughout the day.