# PONDICHERRY UNIVERSITY

## Master Plan & Detailed Project Reports for Development of Pondicherry University Silver Jubilee Campus as Solar Campus

Draft Master Plan & DPRs

22 March 2013

*Prepared by*

*Alternatives*

&

GSES | India

global sustainable energy solutions

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# Pondicherry University

Client Ref: PU/Dir(Res)/Tender No:/12/Poyya/Arun/Ecol/GET/SC
Consultant's Ref: ALT/RE1201

Final Draft Report
22 March 2013

## Contractor:

Alternatives &
GSES India Sustainable Energy Pvt. Ltd.
B-387 (2nd Floor)
Chittaranjan Park
New Delhi – 110019, INDIA
Telephone: +91–11-40587622
Mobile:+919560550075
E-mail: dwipen.boruah@gses.in
URL: www.gses.in

| Document control | |
|---|---|
| File path & name | GSES/project/Pondicherry University/Report |
| Author | Dwipen Boruah, Kalirajan, Punit Dubey, Sujoy Barua |
| Project Manager | Dwipen Boruah |
| Date | 22 March 2013 |
| Distribution level | Draft – not for distribution / Public Domain |

Template: GSES India Report Form 001
Issue: 01; Date: 30/06/2012

# ACKNOWLEDGEMENT

This Master Plan and Detailed Project Report for Silver Jubilee Campus of Pondicherry University is an outcome of the Ministry of New and Renewable Energy's (MNRE's) Solar City Programme as part of the 11th five year plan. Their initiatives have led to the collaboration of the Pondicherry University, with M/s Alternatives and Global Sustainable Energy Solutions for the preparation of the Master Plan for Pondicherry University Silver Jubilee Solar Campus as a part of this Programme. We gratefully acknowledge the support of the Vice Chancellor of the Pondicherry University, Registrar, Director Research, Administration and Accounts Departments, Department of Ecology & Environmental Sciences, Madanjeet School of Green Energy Technologies, Electrical and Engineering Department, Planning & Development Department and Department of Media and Publicity for providing all assistance in executing this assignment.

We specially thank to Professor H. Surya Prakash Rao, Dean, Madanjeet School of Green Energy Technologies (MSGET); Dr. G. Poyyamoli, Associate Professor, Department of Ecology & Environmental Sciences; Dr. R. Arun Prasath, Assistant Professor, Center for Green Energy Technology; Dr. M. Rajendran, Deputy Registrar; Mr. S. Murugaiyan, Assistant Registrar for their generous support and encouragement to deliver on the entire assignment.

The report would have not been possible without the generous support of the Ministry of New & Renewable Energy, Government of India and Renewable Energy Agency Puducherry (REAP). We extend our gratitude to Dr. Arun Kumar Tripathi, Director, MNRE and Mr. Hiren Borah, Scientist B, MNRE and Mr. Pankaj Kumar Jha, Project Director, REAP for their valuable advice and guidance during the preparation of this report.

## CONSULTING AND DATA COLLECTION SUPPORT

1. Dr. G. Poyyamoli,
   Associate Professor,
   Department of Ecology & Environmental Sciences

2. Dr. R. Arun Prasath,
   Assistant Professor,
   Laboratory for Energy Materials and Sustainability
   Center for Green Energy Technology

3. Mr. Nandhivarman Muthu
   Research Scholar,
   Department of Ecology & Environmental Sciences

4. Mr. V. Mourougaveloe, Assistant Engineer, Electrical Wing

5. Mr. Singaravelu, Engineer, Electrical Wing

6. Mr. R. Gopalakrishnan, Superintending Engineer, Engineering Department

7. Mr. R. Dwaraganathan, Executive Engineer, Engineering Department

8. Mr. Sankaramourthy, Assistant Engineer, Planning and Development

# PROJECT TEAM

MNRE & REAP Team:

- Dr. A. K. Tripathi
- Mr. Pankaj Kumar Jha
- Mr. Hiren Borah

University Team:

- Dr. G. Poyyamoli
- Dr. R. Arun Prasath

GSES India Team:

- Mr. Dwipen Boruah
- Mr. Kalirajan U
- Mr. Sujoy Barua
- Mr. Punit Kumar Dubey

# ABBREVIATIONS

| | |
|---|---|
| °C | Degree Celsius |
| AC | Alternate Current |
| BOS | Balance of System |
| CERC | Central Electricity Regulatory Commission |
| c-Si | Crystalline Silicon |
| CST | Concentratic Solar Thermal |
| DC | Direct Current |
| DPR | Detailed Project Report |
| IEC | International Electrotechnical Commission |
| IEC 61215 | IEC Standard code for crystalline silicon PV Modules |
| IEC 61730 | IEC standard code for product safety |
| IREDA | Indian Renewable Energy Development Agency |
| km | Kilometre |
| kV | Kilovolt |
| kVA | Kilovolt Ampere |
| kWh | Kilowatt Hour |
| $kW_p$ | Kilo Watt peak |
| LCC | Life cycle costs |
| m | Meter |
| $m^2$ | Square meter |
| MNRE | Ministry of New and Renewable Energy |
| MVA | Mega Volt Ampere |
| MW | Megawatt |
| MWh | Megawatt Hour |
| NASA | National Aeronautics and Space Administration |
| NASA -SSE | NASA Surface meteorology and Solar Energy |
| O&M | Operation and Maintenance |
| PV | Solar Photovoltaic |
| PVSYST | Software package for the study, sizing, simulation and data analysis for PV system |
| RPO | Renewable Purchase Obligation |
| SMA | SMA Solar Technology AG |
| STC | Standard Test Conditions of 1000 W/m2 irradiance, Air mass 1.5, cell temperature 25 °C |
| V | Voltage |
| $V_{dc}$ | Direct Current Voltage |
| $W_p$ | Watt peak |

## EXECUTIVE SUMMARY

The Silver Jubilee campus of Pondicherry University is a new campus of 100 acres pocket in its existing 800 acres campus. The silver jubilee campus will house 12 buildings and 2500 students once it is completed by 12th five year plan. Prime Minister of India Dr. Manmohan Singh has formally inaugurated the Silver Jubilee Campus of Pondicherry University on 30th June 2012.

The university has received financial assistance from the Ministry of New and Renewable Energy (MNRE), Govt. of India for preparing a master plan and detailed project reports to develop the silver jubilee campus as "Solar Campus". The objective of developing Pondicherry University Silver Jubilee Campus into a "Solar Campus" is to understand and assess carbon footprint of the campus and prepare an action plan to take energy conservation measures and implement renewable energy projects to achieve a targeted goal to reduce conventional energy consumption and thereby reduce GHG emission in the campus. The master plan and Detailed Project Reports for Selected Renewable Energy Projects has been prepared followed by assessment of energy demand and carbon footprint and energy conservation planning. The master plan includes year wise energy savings and GHG emission reduction goals, action plan and physical target for setting up of renewable energy projects in the campus supported by breakup of project cost and sharing of budget for the same.

**Assessment of Energy Demand:**

Electricity is the major energy component consumed by the facilities in the Pondicherry University Silver Jubilee Campus. All major facilities like buildings, water supply, sanitation, outdoor lights, and electric vehicles consumes electricity. Electricity is supplied from grid which is received at 22KV and stepped down to 430V for distribution to buildings. There are 5 substations with 500KVA, 22KV/430V transformers for different buildings and bocks. Diesel Generators are used as standby power supply source during load shedding. Five diesel generators of capacity 125KVA each are installed attached to the substations. In case of grid failure, diesel generators starts automatically to supply power to the concerned buildings/ blocks to power limited essential loads. Electricity consumed by the silver jubilee campus is a part of entire electricity consumption by the university campus. There is no separate energy meter to measure or monitor the electricity consumed by the silver jubilee campus or buildings/ establishments in the campus. Total 60 nos. of solar streetlights with capacity of solar module of 2x75Wp each have been installed in the campus.

The canteen in the campus serves tea coffee and snacks and fast food. Most of the food served in the canteen prepared in the major canteen in the main campus. As reported by the canteen manager, average LPG consumption in the canteen is 4-5 cylinders of 19 kg per month.

The Silver Jubilee campus is about 2km from the main gate No.1 and about 2.6 km from the gate No. 2 of the university. The transport department of the university ply large buses with sitting capacity 30-36 passengers to and from the silver jubilee campus. These buses make 15 trips during the working days to/from the campus. Estimated additional diesel consumption for the silver jubilee campus from the main campus for 200 working days per year is about 3000 litres.

Battery Operated Vehicles with sitting capacity of 14 passengers ply from gate No.1 to Silver Jubilee campus in scheduled time with an interval of 30 min to 75 min. These vehicles make 11 trips in all working days. These vehicles rated with maximum power of 5kW and estimated electricity consumption for 11 trips per day for 200 working days per year is about 5500kWh.

There are 'pick and ride' bicycle freely available in the stands nearby the main gates. Though there are 500 bicycles, most of them are not maintained properly and seen lying idle and scattered in the campus.

**Water Use:**

The water supply system in the silver jubilee campus is under construction. There will be a central ground water lifting and storage system for the campus. A temporary arrangement has been made for supply of water for the building sanitation, canteen and sprinkling irrigation for the gardens and plants. The estimated energy consumption by water supply system is about 23872 kWh of electricity per year.

**Waste Generated:**

The silver jubilee campus produces very little waste at present. However, the campus is going to generate considerable amount of waste both degradable and non-degradable once it is fully expanded as planned. The silver jubilee campus will accommodate 2500 students in different hostels and 60 residential apartments, one contention centre of 2500 capacity and one multipurpose auditorium in future. It is estimated that about 2000kg of bio-waste will be generated when the campus will be fully occupied as planned.

**Energy Consumption by Type of Energy Source:**

The estimates energy consumption by the silver jubilee campus is 1325MWh per year. The major share (87.54%) of energy contributed by electricity supplied from grid followed by electricity supplied by diesel generators (8.65%). Consumption of diesel for transportation is 2.49% and LPG 1.32%

**Energy Consumption by Appliances:**

Air conditioners are the largest consumer of electricity sharing 41% of total consumption followed by building lighting load (22%), street lighting load (11%), celling fans (9%) and other appliances (17%)

**Future Loads:**

The Silver Jubilee Campus is under development and not all buildings are constructed or completed. Apart from the planned expansion of 7100sqm of floor area in the existing buildings the university has the future plan to construct a multipurpose auditorium of 2500sqm area. Total projected energy demand for additional buildings in the silver jubilee campus will be about 12.5 lakh unit of electricity equivalent, which is almost double of the present energy consumption.

**Suggested Energy Conservation Measures:**

Most of the electrical appliances in the silver jubilee campus are new and energy efficient. Based on our survey and assessment in all the buildings we are suggesting the following energy conservation and energy efficiency measures for the silver jubilee complex.

- Improvising energy management & accountability system
- Use of sensors for automatic ON/OFF of indoor lights and exhaust fans
- Use of natural light during day time
- Use of star rated appliances
- Use of LED lights
- Dusk to Dawn sensors for automatic ON/OFF of outdoor/ streetlights
- Use of Power savers
- Energy Efficiency Measures in Water Pumping
- Incorporation of solar passive features in the buildings

**Renewable Energy Planning:**

The mean annual average of global horizontal solar insolation in Pondicherry is 5.36kWh/m2/day. For calculating thermal energy generation through concentrating dish, direct normal radiation is considered. The Monthly Averaged Daily Direct normal radiation at the given site is 4.72 kWh/m2/day. The figure below shows monthly average global horizontal irradiance (GHI) and direct normal radiation (DNI).

The Centre for Wind Energy Technology (C-WET) has installed four wind monitoring stations in the union territory of Pondicherry out of which two stations were located in Puducherry. The best site has mean average wind speed of 4.44 m/s and mean average wind power density at 25m height is 88Watt/sqm.

**Potential Renewable Energy Projects:**

Based on energy demand assessment, resource assessment and site survey, the following projects have been identified for the silver jubilee campus of the Pondicherry University.

| Locations | Capacity | Nos. | Total capacity |
|---|---|---|---|
| **Solar Photovoltaic Systems** | | | |
| Car parking sheds | 10kWp | 4 | 40kWp |
| Car parking sheds | 13kWp | 2 | 26kWp |
| Building roofs | 30kWp | 3 | 90kWp |
| Building roofs | 38kWp | 8 | 304kWp |
| Outer ring of inner circle landscape | 40kWp | 4 | 160kWp |
| **Solar Water Heating System** | | | |
| Academic Staff College | 1000LPD | 1 | 1000LPD |
| Canteen | 500LPD | 1 | 500LPD |
| **Wind Turbine Systems** | | | |
| Small Wind Turbines | 10.8kW | 20 | 216kWp |

**Annual Energy Savings Target:**

| Year | Energy Consumption and savings in MWh per year | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| Total Energy Demand | 1656 | 1988 | 2319 | 2650 | 2650 |
| Energy from RE | 286 | 623 | 1409 | 1409 | 1409 |
| % of RE fraction | 17% | 31% | 61% | 53% | 53% |
| Energy Savings from EE | 398 | 497 | 596 | 1988 | 3975 |
| % of EE fraction | 15% | 15% | 15% | 15% | 15% |
| % of RE & EE combined | 32% | 46% | 76% | 68% | 68% |

**Annual GHG reduction Target:**

| Year | GHG Emission and reduction per year in $MtCO_2$ equivalent (Considering Emission factor for southern India as 0.84 | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| Total GHG Emission | 1391 | 1670 | 1948 | 2226 | 2226 |
| Emission reduction from RE | 240 | 523 | 1184 | 1184 | 1184 |
| Emission reduction from EE | 334 | 497 | 596 | 1988 | 3975 |

**Project Cost and Sharing of Budget:**

| | Solar PV System (INR Lakh) | Wind Energy System (INR Lakh) | Solar Water Heaters (INR Lakh) | Total (INR lakh) |
|---|---|---|---|---|
| PV Systems | 866.14 | 462.00 | 4.52 | 1332.66 |
| MNRE Share | 259.84 | 259.00 | 1.36 | 520.20 |
| PU Share | 606.30 | 203.00 | 3.16 | 812.46 |

**Cost Benefit Analysis:**

The 620kWp PV power plants will generate average 940MWh of electricity per year, which will be directly used as captive power. The university will save Rs.36.66 lakh per year from the electricity savings from the grid @Rs.3.90 per unit. It is expected that using solar PV systems will totally offset the use of diesel generators in the silver jubilee campus which will save estimated 11200 litres of diesel every year. We have considered escalation of price for electricity @5% and that for diesel @10% per year. Similarly, degradation of solar and wind power generation are considered as 0.8% per year.

It is estimated that use of 1000LPD capacity solar water heating system for 120 days in a year will save about 50MWh of electricity. This will save an amount of Rs.1.95 lakh per year @Rs.3.90 per unit of electricity. On the other hand, use of 500LPD capacity solar water heating system for 200 working days in the canteen will save 4.72 Giga Calorie of energy per year which will save about 465kg of LPG per year saving about Rs.36000.00 per year.

Considering 20% plant load factor, 216kW wind farm will generate 37.84MWh of electricity per year, which will save grid electricity worth of Rs.14.75 Lakh per year @Rs.3.90 per kWh.

**Renewable Energy Certificates:**

As per Central Electricity Regulatory Commission (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificates for Renewable Energy Generation) Regulations, 2010, Pondicherry University will be eligible to get benefit as a renewable energy generator and could avail benefit by selling renewable energy certificates (REC) generated by the proposed PV power plants. The floor and forbearing price of REC is Rs.9880.00 and Rs.13690.00 per REC for the period (2013-2017). We have considered a depreciation of REC price @5% which is proportionate to the escalation of electricity tariff. Considering an average REC selling price of Rs.10.00 per unit of electricity generated by the PV power plant, university can sell REC worth of Rs.94.00 lakh per year in addition to saving electricity and diesel. To register the project as under REC mechanism, university will not receive any subsidy or other benefit for the power plants. Different scenarios of cost benefit analysis have been presented considering existing MNRE subsidy and REC benefit.

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# 1 INTRODUCTION

Pondicherry University located at R.V. Nagar, Kalapetat, Pondicherry is a Central University established in 1985 by the Government of India. The university has emerged as India's fastest growing and it is a collegiate university with a jurisdiction spread over the Union Territories of Pondicherry, Lakshadweep and Andaman and Nicobar Islands. It has successfully completed its 25th year of existence. The University is extended over an area of 780 acres spread on either side of the East Coast Road, Tamil Nadu with the large chunk on the landward side of the road. The institute imparts humanities, sciences, engineering and technology courses at the undergraduate, postgraduate and doctorate level. The university has seventeen hostels in the campus, 11 for men, 5 for women students/research scholars and 1 for foreign students with intake of 2650 odd students.

Silver Jubilee campus of Pondicherry University called for a new approach and a modern development in a 100 acres pocket in its existing campus. This area will house 12 buildings and 2500 students by the end of 12$^{th}$ five year plan.


*Figure 1: Silver Jubilee Campus of Pondicherry University*

The conceptual planning of the campus was to efficiently locate all the buildings with an address to central Silver jubilee sculpture. Concentric circular planning provided an evenly distributed built area ratio through out 100 acres of square piece of land and the geometry allowed a proper management of services and movement. Inner circle provided the main entry of the buildings and interconnection through central landscape. Outer cycle provided student parking lots, services feeds and annex block for future expansion. Entire planning was designed as a ring from services point of view where buildings attach themselves to the grid wherever necessary providing an easy, flexible, sustainable and green infrastructure.

Prime Minister of India Dr. Manmohan Singh has formally inaugurated the Silver Jubilee Campus of Pondicherry University on 30th June 2012.

The Ministry of New and Renewable Energy (MNRE), Govt. of India has launched a Scheme on "Development of Solar Cities" under which a total of 60 cities/towns and 50 townships/campuses are proposed to be supported for development as "Solar Campus". The program aims at minimum 10% reduction in projected demand of conventional energy at the end of five years, which can be achieved through a combination of energy efficiency measures and enhancing supply from renewable energy sources. The Ministry of New and Renewable Energy has accorded approval for developing newly developed Pondicherry University Silver Jubilee Campus as a "Solar Campus".

This report is prepared based on site visit, site survey, collection of primary data, drawings and other information from concerned departments of the university, secondary data from web and other available sources, consultation with concerned stakeholders from the university and GSES in-house knowledge and data.

We have submitted an interim report to the concerned stakeholders for review and once we receive comments and suggestion the same will be incorporated in the report as applicable.

# 2 RENEWABLE ENERGY INITIATIVES IN PONDICHERRY UNIVERSITY[1]

The Pondicherry University is one of the pioneering universities taking initiatives for promotion and use of renewable and green energy technologies both in academic practice and implementation. In 2010, Pondicherry University took a lead in creating a Centre for Green Energy Technology (CGET) to conduct teaching and research in the fields of environmentally benign "Green Energy Technologies". This step was taken in order to develop the much needed manpower as well as provide research and development in renewable energies for sustainable development. Currently, the center conducts M.Tech course for 26 students per year and research-level programs in green energy technologies.

The Department of Ecology-Environmental Sciences and Centre for Green Energy Technology of Pondicherry University are collaborating on various issues related to green campus projects (energy, grey water management, and solid waste management). Pondicherry University has already achieved many campus sustainability milestones and has implemented many of the common best green practices, such as

(1) Installation of solar water heating systems in ladies and gents hostels,
(2) Installation of solar water heating system for hostel mess for cooking
(3) Installation of 7.5kWp Solar PV system in MISARC building
(4) Installation of 160 solar street lights,
(5) Four Battery Operated vehicle for campus
(6) 500 Pick and ride bicycles for campus
(7) Fitting of all streetlights with energy efficient lighting systems etc.

Moreover, the university has initiated detailed energy /environmental auditing, planning for a green energy park and solar campus and institutional biogas plants using kitchen wastes from the hostel canteen, etc. Recently the university has been working on preparing a major proposal for using its shadow-free rooftops for solar energy harvesting through rooftop grid-interactive inverters. It is estimated that about 78,469 square meters of shadow-free rooftops are available on the campus to use for solar power harvesting. The project aims to achieve a target of approx. 30% green energy in the next five years (2013-17) through rooftop grid-interactive inverters on selected rooftops on the campus.

[1] *Contribution from Dr. R. Arun Prasath, Assistant Professor, Centre for Green Energy Technology, PU*

*Figure 2: 7.5kWp Solar PV rooftop system installed at MISARC building*


*Figure 3: Solar water heating system system for hostel mess*

The university has seventeen hostels on the campus: eleven for men, five for women students/research scholars, and one for foreign students with an intake of some 2,650 students. It has been estimated that roughly 2,200 kg of kitchen organic waste is generated per day from the gents and ladies canteens.

The university has an ambitious plan and allocated budget for 12th year plan period exclusively for renewable energy application in the campus. Some of the major projects planned are:

(1) 110kWp solar PV plant in the examination wing of administrative building
(2) 15kWp solar PV power plant for MSGET
(3) CST Based steam cooking systems for hostel mess
(4) Biogas from kitchen waste for hostel mess
(5) Solar water heating systems for guest houses
(6) New upcoming buildings with GRIHA ratings
(7) Development of silver jubilee campus as "Solar Campus"

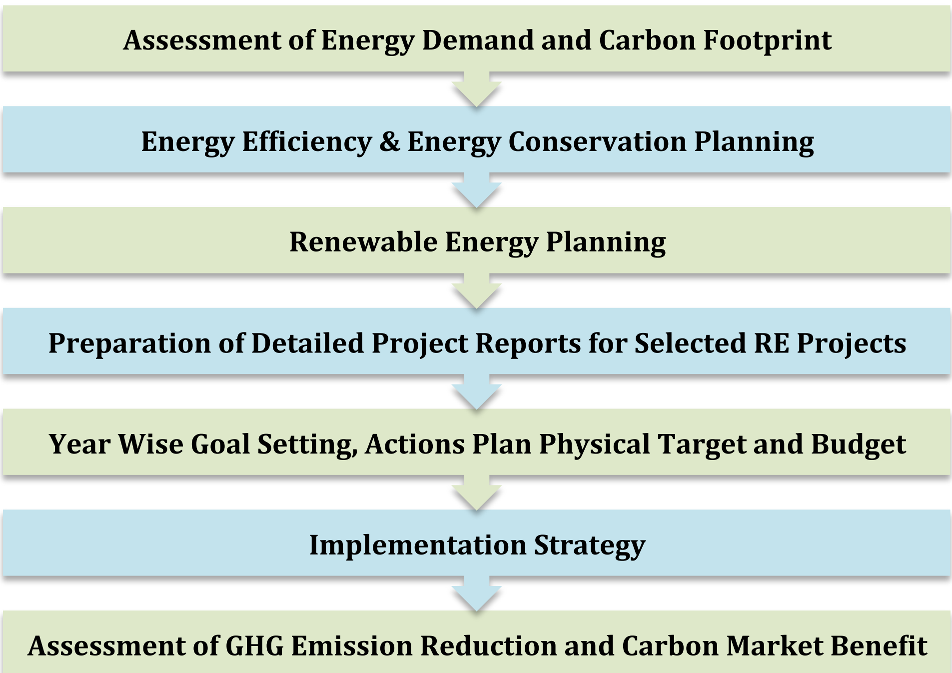
*Figure 4: Solar streetlights in the silver jubilee campus*

# 3 DEVELOPING SOLAR CAMPUS

The objective of developing Pondicherry University Silver Jubilee Campus into a "Solar Campus" is to understand and assess carbon footprint of the campus as a whole and prepare an action plan to take energy conservation measures and implement renewable energy projects to achieve a targeted goal to reduce conventional energy consumption and thereby reduce GHG emission in the campus.

The Master Plan for Pondicherry University Solar Campus include assessment of carbon footprint for all establishments in the silver jubilee campus including departmental buildings, guest houses accommodation, canteens and food services, utilities and services, community facilities, transport Facilities, vehicles etc. Further, it provide a base line on energy use pattern, water use and waste generated and GHG emissions in the Campus. Year-wise targets for energy conservation, renewable energy addition and GHG abatement have been included in the Master Plan. The Master Plan sets a goal of 40% reduction in projected total demand of conventional energy at the end of five years to be achieved through energy saving from energy efficiency measures (15%) and generation from renewable energy installations (25%). Detailed Project Reports have been prepared for solar PV, solar thermal and wind energy projects, which are proven to be most feasible.

The master plan and Detailed Project Reports for Selected Renewable Energy Projects have been prepared as per the following steps:



# 4 DATA COLLECTION & ENERGY DEMAND ANALYSIS

As the first step to establish a baseline data for GHG footprint, energy use, water use, and waste generated in the silver jubilee campus, we have collected electricity and other energy consumption data to quantify and compare environmental impacts by different consumers directly related to the campus. The Silver Jubilee Campus at present has the following energy consumers:

**A. Buildings:**

(i) School of Social Science and Humanities (10 separate Blocks)
- Department of Hindi
- Department of Sanskrit
- School of Education
- Escande Chair in Asian Christian Studies
- Department of Applied Psychology
- Department of French
- Centre for Foreign Language
- Department of English
- Department of Philosophy

(ii) Subramania Bharathi School of Tamil Language & Literature
(iii) Academic Staff College
(iv) UMISARC - Centre for South Asian Studies
(v) School of Media & Communication – under construction

**B. Other Services**

(i) Canteens and food services
(ii) Utilities and services – water, electricity & sanitation
(iii) Community facilities – outdoor lights in the street, boundaries
(iv) Transport facilities, vehicles

Electricity is the major energy component consumed by the facilities in the Pondicherry University Silver Jubilee Campus followed by LPG used in the canteen. All major facilities like buildings, water supply, sanitation, outdoor lights, and electric vehicles consumes electricity. Electricity is supplied from grid which is received at 22KV and stepped down to 430V for distribution to buildings. There are 15 sub stations with transformer capacity of 500KVA each for different buildings or group of buildings. Total 160 nos. of solar streetlights have been installed in the campus out of which 70 solar streetlights have been installed in the silver jubilee campus. The solar streetlights with capacity of solar module of 2x75Wp each operate from dusk to dawn.

*Table 1: Electrical Profile of Entire Pondicherry University Campus*

| **Electrical Profile of Entire Pondicherry University Campus including Silver Jubilee Campus** | |
|---|---|
| Total sanctioned load of the university* | 1500KVA |
| HT overhead line/ underground Cable | 10.2 km |
| Sub stations (15 Transformer of @500KVA, 22KV/430V) | 7500 KVA |
| Diesel Generator Sets (27 Nos.) | 5115 KVA |
| Total number of buildings with electricity supply | 97 Nos. |
| Street Light | 300 Nos. |
| Solar Street Light | 160 Nos. |
| Split Air Conditioners | 580 Nos. |
| Centralized Air conditioner Plant (10 Buildings) | 799.40 tons |
| Water Cooler | 120 Nos. |
| Passenger Lift | 11 Nos. |

* *Total sanctioned load of the university is 400KVA. The university has applied for 1500KVA-sanctioned load which is under process of approval from utility*

**Electricity Consumption Profile:**

The university has one single point connection to the grid where energy meter is fixed and monitored centrally. There is no separate energy meter for building and establishment. The Annual energy consumption profile for the year 2009 has been placed in table and graph below. A total amount Rs.124.47 lakh was paid during that year against 49.34 lakh units of electricity consumed.

*Since early part 2010, the energy meter has been not functioning and the university is paying a lump sum amount based on the past energy consumption data.*

*Table 2: Historical Monthly Electricity Consumption data of the entire campus*

| Month/ Year | Electricity Consumption (Lakh Unit per month) | Electricity Bill per month (Lakh INR) |
|---|---|---|
| January 2009 | 2.04 | 7.66 |
| February 2009 | 2.29 | 7.47 |
| March 2009 | 2.13 | 7.45 |
| April 2009 | 3.94 | 9.27 |
| May 2009 | 4.73 | 10.95 |
| June 2009 | 4.71 | 11.17 |
| July 2009 | 4.05 | 9.82 |
| August 2009 | 4.35 | 10.24 |
| September 2009 | 5.67 | 13.14 |
| October 2009 | 4.79 | 11.74 |
| November 2009 | 5.43 | 12.93 |
| December 2009 | 5.22 | 12.62 |
| Annual | 49.34 | 124.47 |

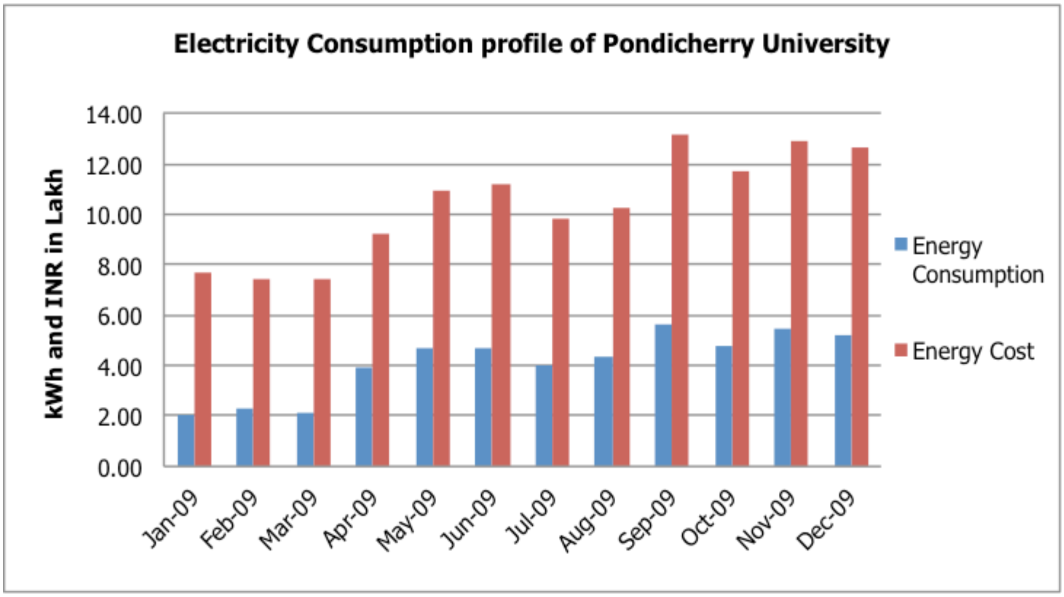



*Figure 5: Annual Electricity Consumption Profile of Pondicherry University*

| **Highlight of Electrical Profile of Silver Jubilee Campus** | Quantity | Capacity/ Load |
|---|---|---|
| Sub stations (Transformer of 22KV/430V) | 5 Nos. | 2500KVA |
| Diesel Generator Sets (4 x 125KVA + 1 x 320 KVA) | 5 Nos. | 82KVA |
| Total number of lighting fixture | 3259 Nos. | 130kW |
| Total number of fans | 983 Nos. | 59kW |
| High mast flood lights | 2 Nos. | 14kW |
| Focus lights | 2 Nos. | 01.6kW |
| Street Lights (250W sodium vapour) | 75 Nos. | 19kW |
| Solar Street Light (2 x75Wp) | 70 Nos. | |
| VRF Air conditioning systems (total capacity 541 tons) | 4 Nos. | 492kW |
| Split Air Conditioners (165.5 ton aggregate capacity) | 106 Nos. | 212kW |
| Windows Air conditioners (1.5 ton capacity each) | 35 Nos. | 70kW |
| Water Pumps for Building Water Supply | 6 Nos. | 37kW |
| Water Pumps for Horticulture | 5 Nos. | 43kW |
| Water Cooler/Purifier | 2 Nos. | 3kW |
| Passenger Lift | 4 Nos. | 23kW |

*Table 3: Electrical Profile of Silver Jubilee Campus*

Pondicherry University has a 10.2km 22KV HT line network connecting all building and establishment in the campus. This network is centrally connected to local utility grid where energy is measured through a digital metering for the entire university. Electricity is supplied to the Silver Jubilee Campus from the common grid network of 22KV HT line. There are 5 substations with 500KVA, 22KV/430V transformers for different buildings and blocks. The School of social science and Humanities has 10 building blocks and group of five blocks are connected to one substation. Similarly, the building for School of Tamil Language & Literature, Academic Staff College and Centre for South Asian Studies separately connected to one substation. Diesel Generators are used as standby power supply source during load shedding. Four diesel generators of capacity 125KVA each and one diesel generator of capacity 320KVA are installed attached to the substations. In case of grid failure, diesel generators starts automatically to supply power to the concerned buildings/ blocks to power limited essential loads. Electricity consumed by the silver jubilee campus is a part of entire electricity consumption by the university campus. There is no separate energy meter to measure or monitor the electricity consumed by the silver jubilee campus or buildings/ establishments in the campus. A schematic of electricity supply system in the silver jubilee campus has been shown below.

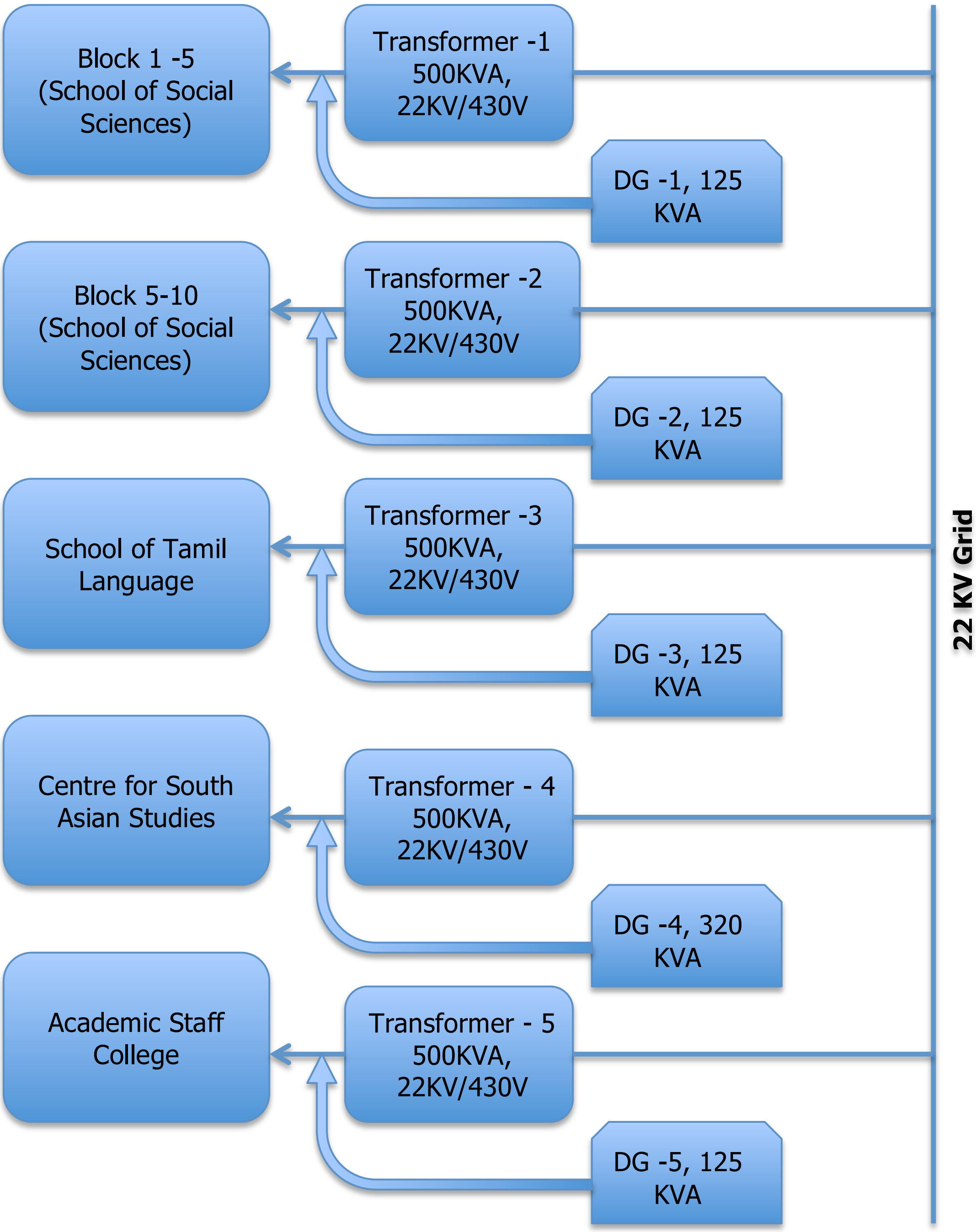



*Figure 6: Electricity Supply System in Silver Jubilee Campus of Pondicherry University*

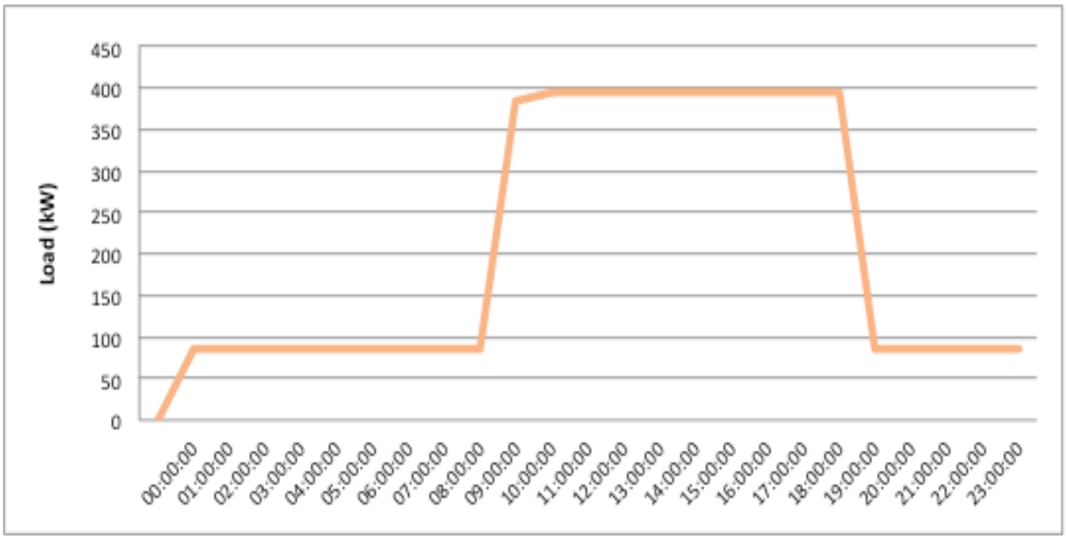



*Figure 7: Daily Load Profile of School of Social Science & Humanities*

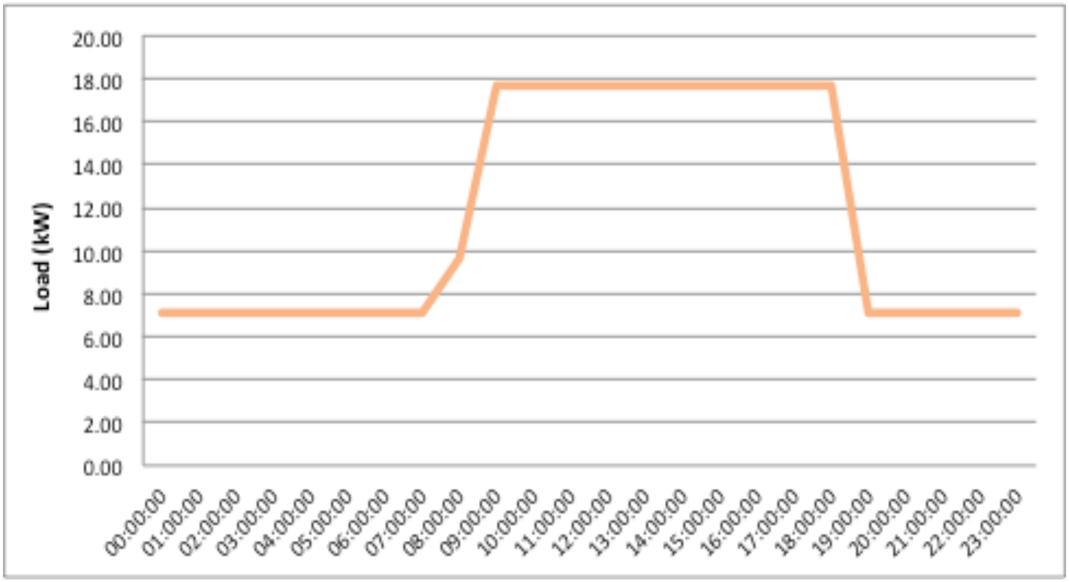



*Figure 8: Daily Load Profile of School of Academic Staff College*

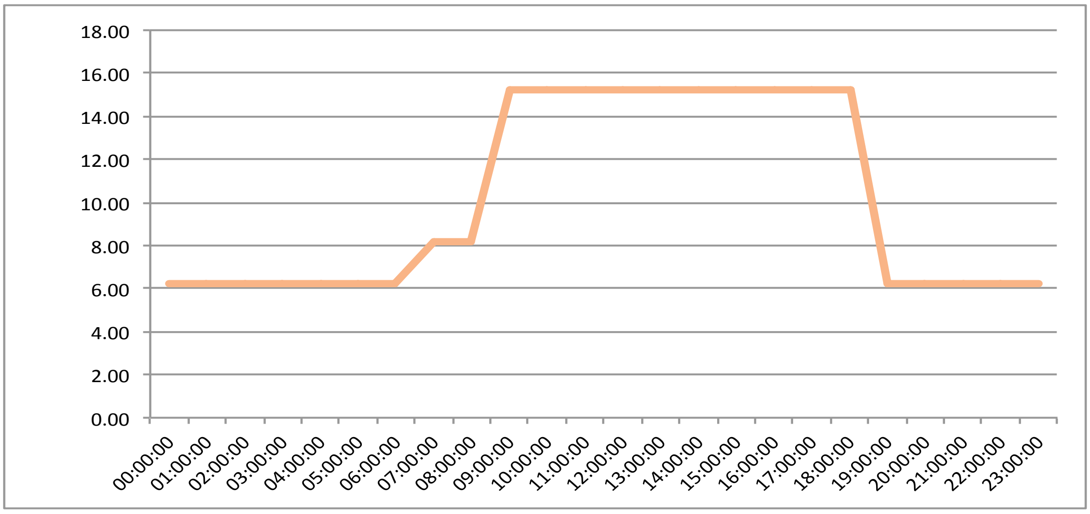



*Figure 9: Daily Load Profile of School of MISAARC*

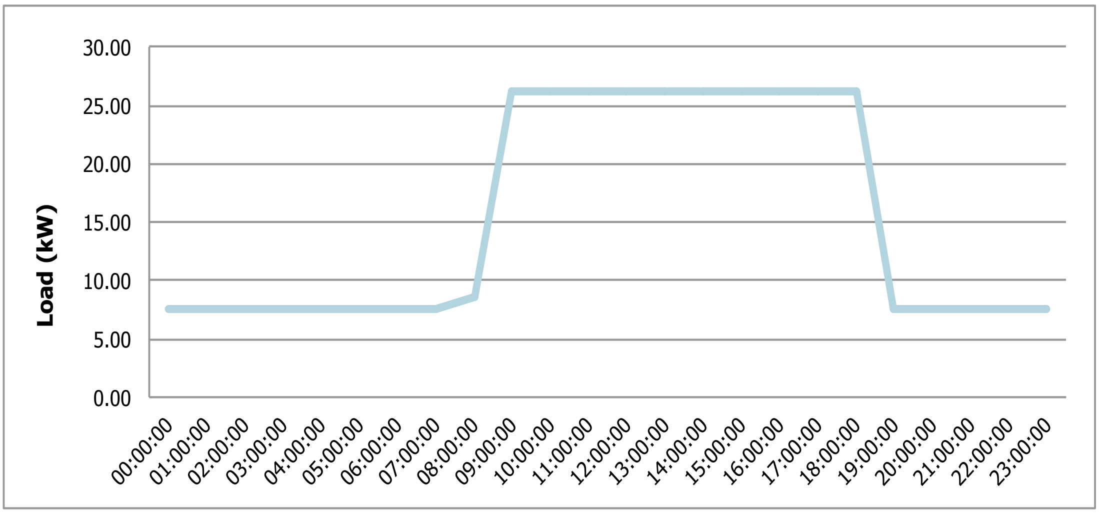



*Figure 10: Daily Load Profile of School of Tamil Language*

**Diesel Generator for Power Backup:**

Pondicherry University has 27 number diesel generators for its campus with aggregate capacity of 5115KVA. Capacity of individual diesel generator varies from 30KVA to 500KVA depending on the connected load of concerned buildings. The silver jubilee campus has five diesel generators with four generators of 125KVA capacity and one generator of 320KVA capacity contributing about 16% total captive power supply for the university.

Diesel generators are operated to maintain uninterrupted power supply to all essential services including residential facilities when there is a grid failure due to load shedding or technical snag. Electric power supply scenarios in Pondicherry state is much stable except occasional power cut due to short supply, technical snag and regular maintenance of transmission and distribution system. The main reason for power failure in the university is technical failure and maintenance in the transmission and distribution system. The technical failures of transmission and distribution system are frequent during rainy season of November-December.

Annual diesel consumption for the entire campus to maintain uninterrupted power supply is about 70,000 litres as shown in the table below. The high consumption of diesel during few months in the year is due to damage of distribution system during cyclone. There is no separate inventory for diesel consumption for the Silver Jubilee Campus. Since the total capacity of the DG is about 16% we can consider about 11200 litres of diesel consumption per year for the silver jubilee campus.

*Table 4: Diesel consumption for power backup*

| **Months** | **Diesel Consumption (Litres/ Month)** | |
|---|---|---|
| | **Total for the University Campus** | **Silver Jubilee Campus (16% of total)** |
| Nov-11 | 10000 | 1600 |
| Dec-11 | 4800 | 768 |
| Jan-12 | 4800 | 768 |
| Feb-12 | 2400 | 384 |
| Mar-12 | 2400 | 384 |
| Apr-12 | 6000 | 960 |
| May-12 | 9600 | 1536 |
| Jun-12 | 2400 | 384 |
| Jul-12 | 4800 | 768 |
| Aug-12 | 2400 | 384 |
| Sep-12 | 3600 | 576 |
| Oct-12 | 12000 | 1920 |
| Nov-12 | 4800 | 768 |
| | 70000 | 11200 |

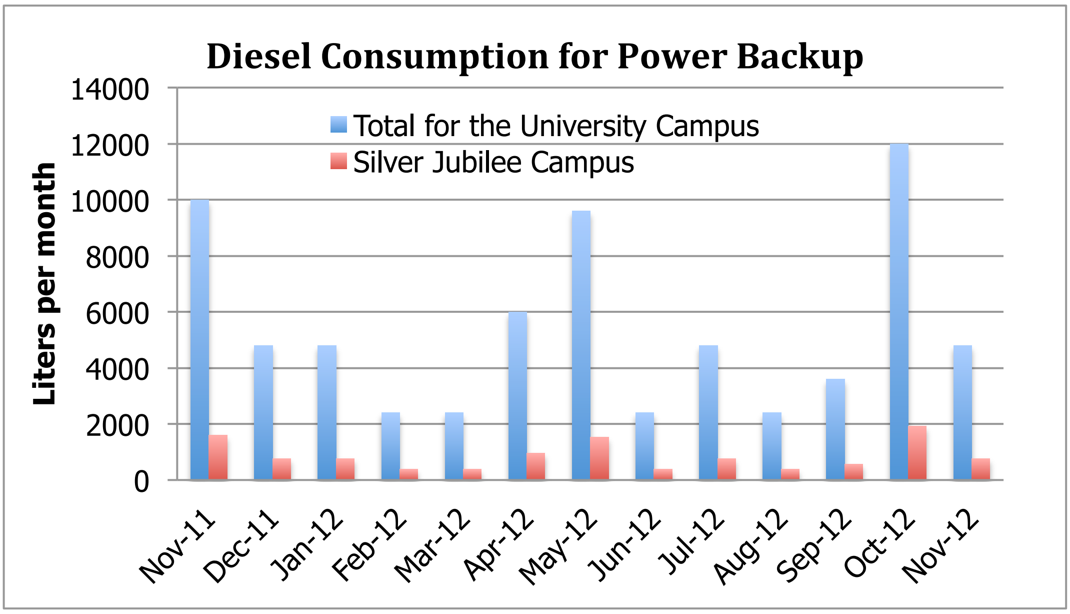



*Figure 11: Annual diesel consumption profile for power backup*

**Use of LPG:**

Use of LPG in the campus is limited. The campus has one canteen located in the building of school of social science and humanities. The canteen serves tea coffee and snacks and fast food. Most of the food served in the canteen prepared in the major canteen in the main campus. As reported by the canteen manager, average LPG consumption in the canteen is 4-5 cylinders of 19 kg per month.

**Transportation:**

The Silver Jubilee campus is about 2km from the main gate No.1 and about 2.6 km from the gate No. 2 of the university. The transport department of the university ply large buses with sitting capacity 30-36 passengers to and from the silver jubilee campus. These buses make 15 trips during the working days to/from the campus. Estimated additional diesel consumption for the silver jubilee campus from the main campus for 200 working days per year is about 3000 litres.

Battery Operated Vehicles with sitting capacity of 14 passengers ply from gate No.1 to Silver Jubilee campus in scheduled time with an interval of 30 min to 75 min. These vehicles make 11 trips in all working days. These vehicles rated with maximum power of 5kW and estimated electricity consumption for 11 trips per day for 200 working days per year is about 5500kWh.

There are 'pick and ride' bicycle freely available in the stands nearby the main gates. Though there are 500 bicycles, most of them are not maintained properly and seen lying idle and scattered in the campus.


*Figure 12: Battery Operated Vehicle in Pondicherry University*


*Figure 13: Pick and Ride Bi-Cycle & Bus services in Pondicherry University*

**Water Use:**

The water supply system in the silver jubilee campus is under construction. There will be a central ground water lifting and storage system for the campus. While three bore wells are already installed, the central water reservoir is under construction. A temporary arrangement has been made for supply of water for the building sanitation, canteen and sprinkling irrigation for the gardens and plants. The following water pumps have been used for this purpose at present. Considering average 200 days of use, it is estimated that the water supply system consumes about 23872 kWh of electricity per year.

*Table 5: Water pumping system details*

| Water Pumps | No. | Total Load (kW) |
|---|---|---|
| Water pump for Building Water supply | 6 | 37 |
| Water pump for Horticulture | 5 | 43 |

**Waste Generated:**

The silver jubilee campus produces very little waste at present. The canteen generates 3-4 kg of organic waste every day. Other waste like papers, stationary etc. are negligible.

**Energy Consumption by Type of Energy Source:**

The estimates energy consumption by the silver jubilee campus is 1.32MU per year, which is about 21% of total annual energy consumption in the entire university campus. The major share (87.54%) of energy contributed by electricity supplied from grid followed by electricity supplied by diesel generators (8.65%).

*Table 6: Energy consumption by source in Silver Jubilee Campus*

| Source of Energy | Consumption/ year (kWh) | % of total energy mix |
|---|---|---|
| Electricity | 1159755 | 87.54% |
| Diesel for standby power | 114605 | 8.65% |
| Diesel for Transportation | 33000 | 2.49% |
| LPG | 17481 | 1.32% |
| Total | 1324841 | 100.00% |

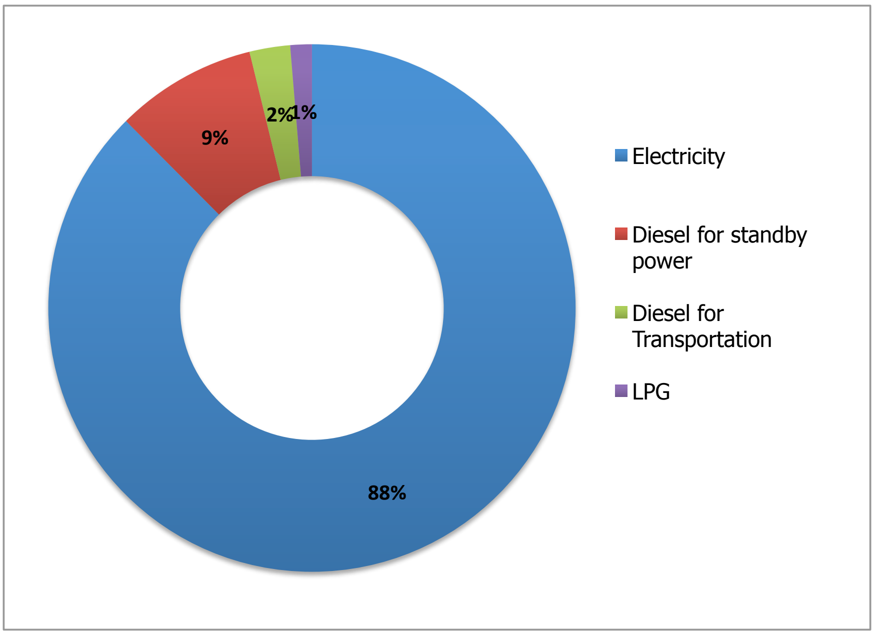



*Figure 14: Energy Supply by Sources in Silver Jubilee Campus*

**Energy Consumption by Appliances:**

Air conditioners are the largest consumer of electricity sharing 41% of total consumption followed by building lighting load (22%) and street lighting load (11%).

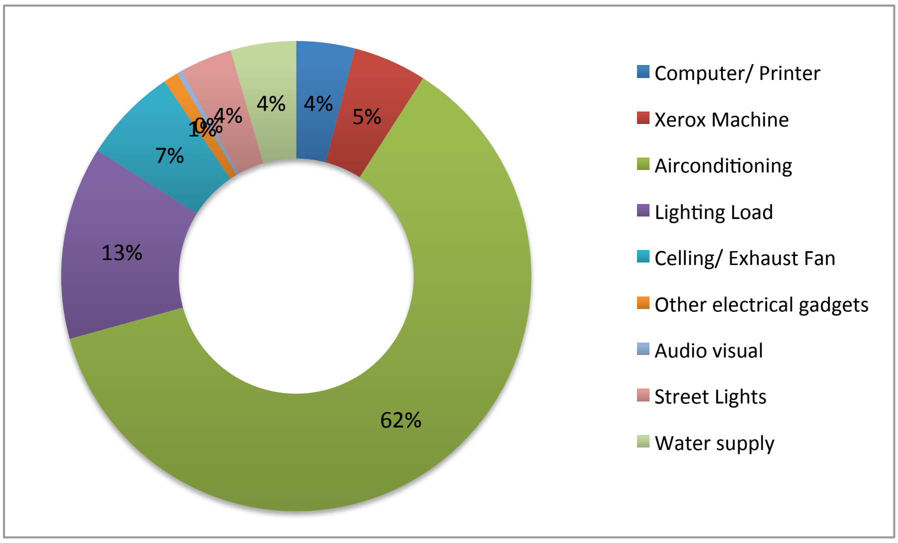



*Figure 15: Electricity consumption by appliances in Silver Jubilee Campus*

*Table 7: Electricity consumption by appliances in Silver Jubilee Campus*

| Appliances/ Uses | Energy Consumption (kWh) | % of total consumption |
|---|---|---|
| Computer/ Printer | 64000 | 5.4% |
| Xerox Machine | 20000 | 1.7% |
| Air conditioning | 488800 | 41.1% |
| Lighting Load | 262950 | 22.1% |
| Celling/ Exhaust Fan | 104160 | 8.8% |
| Other electrical gadgets | 64450 | 4.0% |
| Audio visual | 1400 | 0.1% |
| Street Lights | 130123 | 10.9% |
| Water Supply | 23872 | 2.0% |
| Total | 1159755 | 100.0% |

**Seasonal Variation of Loads:**

Most loads will not be operated the same amount of time every day and every month. The seasonal variation to the load demand in the silver jubilee campus will be mainly dependent on working days of academic calendar. Regular academic sessions are closed during January, May and June and this time energy consumption will be much lower than the other months.

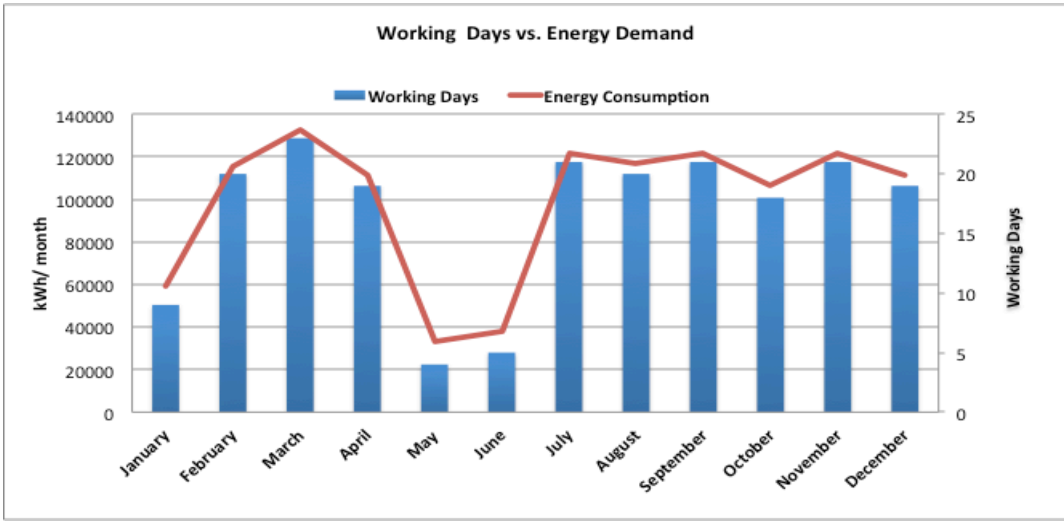



*Figure 16: Silver Jubilee Campus Working Days vs. Energy Consumption Profile*

**Future Loads:**

The silver jubilee campus is under development and not all buildings are constructed or completed. The school of social science and humanities building covers maximum areas that has 10 different blocks for different departments. This building and the school of Tamil studies will be expanded vertically with an additional floor area of 6600sqm. Similarly, the school of media and communication is under construction, which will be expanded vertically with additional area of 500sqm.

*Table 8: Projected load for planned expansion of existing buildings*

| Sl. No. | Buildings | Present/ Estimated Loads | Estimated Additional loads | Total load after expansion |
|---|---|---|---|---|
| 1 | School of Social Science and Humanities (with 10 separate Blocks) | 1329kW | 1300kW | 2629kW |
| 2 | Subramania Bharathi School of Tamil Language & Literature | 173kW | 100kW | 273kW |
| 3 | Academic Staff College | 166kW | - | 166kW |
| 4 | UMISARC - Centre for South Asian Studies | 110kW | - | 110kW |
| 5 | School of Media & Communication – under construction | 200kW | 100kW | 300kW |

Based on the present energy demand of 13.25 lakh units per year for about 1978kW load, the estimated additional energy demand for the expanded buildings will with additional 1500kW load will be 10 lakh unit per year.

Apart from the planned expansion the university has the future plan to construct a multipurpose auditorium of 2500sqm area within the silver jubilee campus for which estimated energy consumption will be approximately 250MWh per year.

*Therefore, total projected energy demand for expanded and additional buildings in the silver jubilee campus will be about 25.75 lakh unit of electricity equivalent which is almost double than the present energy consumption.*

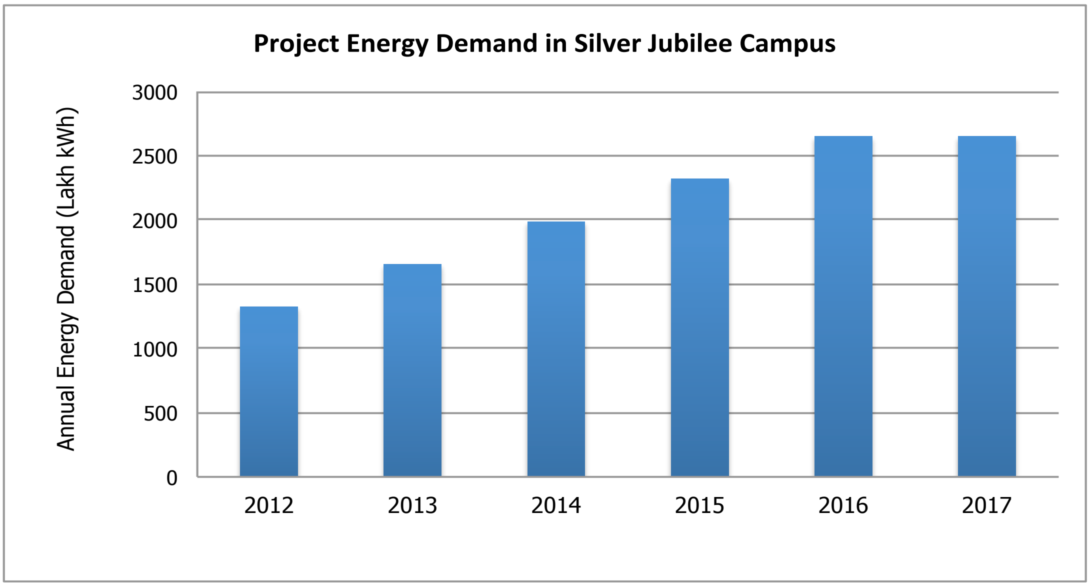



*Figure 17: Silver Jubilee Campus Projected Energy Demand Profile*

# 5 SUGGESTED ENERGY CONSERVATION MEASURES

Most of the electrical appliances in the silver jubilee campus are new and energy efficient. Based on our survey and assessment in all the buildings we are suggesting the following energy conservation and energy efficiency measures for the silver jubilee complex.

*Improvising energy management & accountability system*

It is suggested that the university have an exclusive "energy management cell" through which energy consumption and wastes can be monitored scientifically and appropriate energy conservation measures can be taken up. The university must have proper energy metering and monitoring system centrally and separately for different buildings and utilities.

*Use of star rated appliances*

Electrical appliances installed in the silver jubilee campus are energy efficient. The university has already adopted a policy to replace old inefficient appliances with star rated appliances.

*Use of sensors for automatic ON/OFF of indoor lights and exhaust fans*

Occupancy sensors provide automatic ON/OFF switching of lighting loads for enhanced convenience, security and energy savings. Motion sensor uses passive infrared, ultrasonic or a combined multi-sensing technology. Sensors are also available for automatic controlling exhaust fan in the toilets.

*Use of natural light and light level sensors*

Wherever possible, use of daylight should be maximized and light level sensors should be used switched off the lights when there are enough natural lights during the daytime. Use of windows and skylights to increase the natural light should be considered.

### *Use of LED lights*

Lighting load consumes 22% of total energy in the silver jubilee campus. The outdoors lights in the corridors, security lights and streetlights operate for longer time and shares about majority of the lighting energy demand. It is suggested that the outdoor lights and streetlights be replaced with LED lights in systematic manner when the life of the newly installed CFL and metal halide lamps are over.

### *Dusk to Dawn sensors for automatic ON/OFF of outdoor/ streetlights*

Automatic ON/OFF of outdoor/ streetlights ensure that lights turned on during daytime and do not waste energy. Solar sensors may be applied for automatic dusk to dawn operation of outdoor and streetlights.

### *Replacement of HPSV streetlights by LED lights*

| | | |
|---|---|---|
| Number of 250W HPSV light replaced by 112W LED lights | 75 | Nos. |
| Indicative cost of installation | 38 | Lakh |
| Energy saved by replacing 250 W HPSV with 112W LED | 89024 | kWh/year |
| Cost of electricity savings @Rs.3.90 per kWh | 3 | Lakh |
| Payback period | 10.80 | Years |

### *Use of Power savers*

Power saving device is also called as synchronous condensers, which improves the power factor of inductive loads. It also improves safety by reducing the overheating of electrical wiring, improve efficiency and extend life of the appliances. Use of power savers can save about 15-20% electricity in the buildings and street lighting systems.

### *Energy Efficiency Measures in Water Pumping*

The water supply system in the silver jubilee campus is under construction. Temporary arrangement has been made lifting water from bore wells. Proper water pumping and supply system design can bring down energy consumption in the running and maintenance cost of water pump systems. Careful designing is required to assess the volume of water to be pumped and the height it needs to be raised to. Fluid piping soft wares can be utilized for designing water pumps.

*Incorporation of Solar Passive Features in the buildings*

The overall principle for passive solar design in India is keeping the sun from heating the house in summer (and ensuring efficient cooling) and conversely, keeping heat in during winter (i.e. efficient heating). The design factors that influence this principle are illustrated in Figure 18.

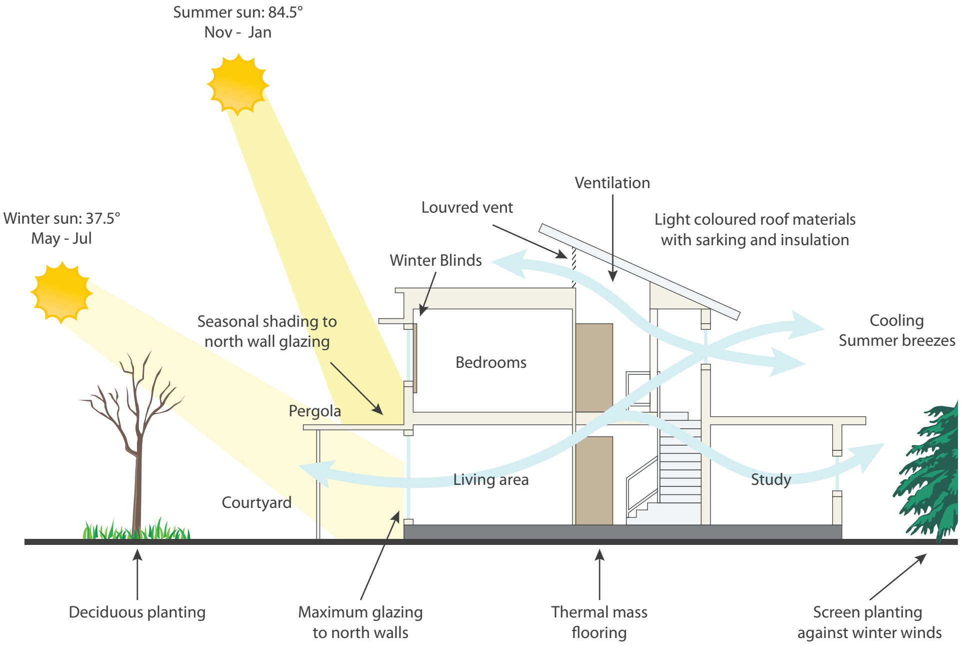



*Figure 18: Passive Solar Design Principles*

Passive design for homes combines a range of features to minimize the need for energy to be used for heating and cooling. Some of the features that can be included in the silver jubilee campus are:

- Insulating the roof or ceiling - use of Rooftop solar PV and solar water heating systems helps avoid reaching the sun directly on the roof
- The use of shading structures (pergolas), curtains and blinds to control the summer sun
- The use of good cross flow ventilation
- Ventilation in the highest part of the dwelling to ensure that any contained hot air is able to escape.
- Draught proofing to ensure that windows, chimneys and doors are properly sealed when cooling.
- Use of reflective coating or material in the building exterior

# 6 RENEWABLE ENERGY PLANNING

The objective of this exercise is to identify available renewable energy resources in Pondicherry University Campus and carry out techno-economic feasibility of different renewable energy options and prepare detailed project reports for the same.

Preliminary renewable energy resources assessment has been carried out to identify the potential renewable energy sources for the Pondicherry University Campus. This includes assessment of solar radiation, wind power density and availability, biomass resources and bio wastes generated in the campus. The detailed project reports have been prepared for the most techno economically viable renewable energy options. An implementation target for development of the solar campus project in 3 years period has been set with an objective to offset at least 20% of present and project energy consumption in the next 5 years.

## 6.1 Renewable Energy Resource Assessment

Detailed Renewable energy assessment has been done for solar and wind energy. No other resources are substantial to assess for energy generation.

### *6.1.1 Solar Resource*

Pondicherry (79.81° E and 12.01° N) receives good amount of solar radiation with an annual average of 5.36kWh/m$^2$/day. Solar Radiation data for the site has been derived from NASA website http://eosweb.larc.nasa.gov/cgi-bin/sse.

The NASA Surface meteorology and Solar Energy (SSE) data set is a continuous and consistent 22-year global climatology of insolation and meteorology data on a 1° by 1° grid system. Although the SSE data within a particular grid cell are not necessarily representative of a particular microclimate, or point, within the cell, the data are considered to be the average over the entire area of the cell. We have also collected 1-year average data collected by C-WET through an Automatic Solar Radiation Monitoring Stations (ASRMS) installed at Pondicherry and compared with the NASA data. Since 1-year average data may not be consistent for subsequent years, we considered 22-years average NASA data for all calculation and analysis in this report. Following is the typical solar insolation data for the site for an entire year.

The mean annual average of global horizontal solar insolation for the project site is 5.36kWh/m$^2$/day. For calculating thermal energy generation through concentrating dish, direct normal radiation is considered. The Monthly Averaged Daily Direct normal radiation at the given site is 4.72 kWh/m$^2$/day. The figure table and figure below shows monthly average global horizontal irradiance (GHI) and direct normal radiation (DNI).

*Table 9: Monthly average solar radiation data for Pondicherry*

| Months | 1- year average ground data for Global Horizontal Irradiance (kWh/m$^2$) | 22-years average Satellite data for Global Horizontal Irradiance (kWh/m$^2$) | 22-years average Satellite data for Direct Normal Irradiance (kWh/m$^2$) |
|---|---|---|---|
| January | 4.26 | 5.00 | 5.39 |
| February | 5.86 | 5.92 | 6.31 |
| March | 5.94 | 6.76 | 6.77 |
| April | 5.83 | 6.71 | 5.95 |
| May | 5.61 | 6.15 | 5.38 |
| June | 5.40 | 5.47 | 4.27 |
| July | 5.00 | 5.09 | 3.53 |
| August | 4.52 | 5.14 | 3.62 |
| September | 4.87 | 5.34 | 4.18 |
| October | 3.84 | 4.47 | 3.54 |
| November | 3.43 | 4.05 | 3.56 |
| December | 3.26 | 4.34 | 4.31 |
| Annual | 4.82 | 5.36 | 4.72 |

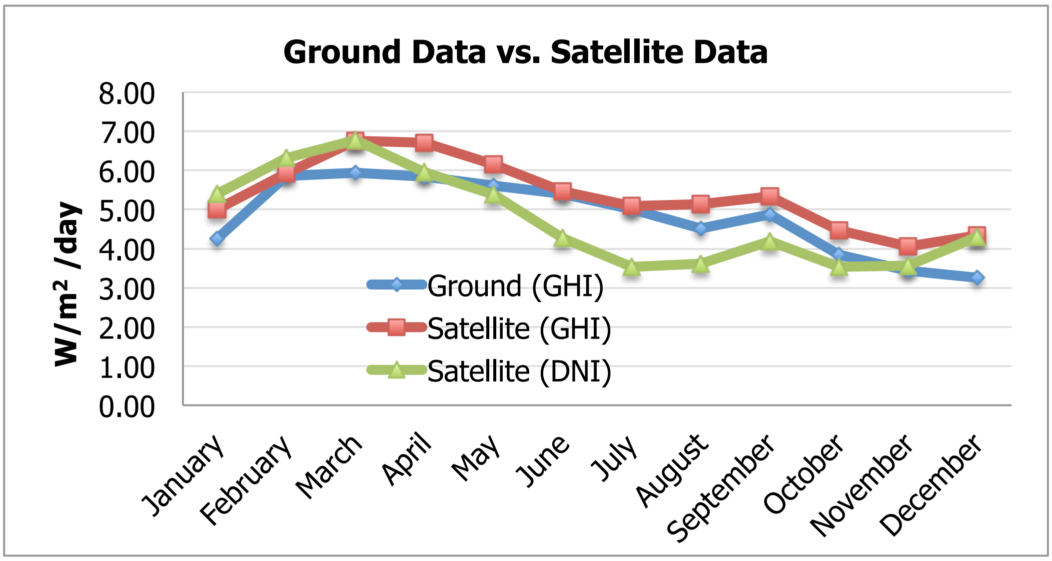



*Figure 19: Comparison of ground vs. satellite solar radiation profile of Pondicherry*

A typical daily solar radiation profile during the month of April and December has been shown below.

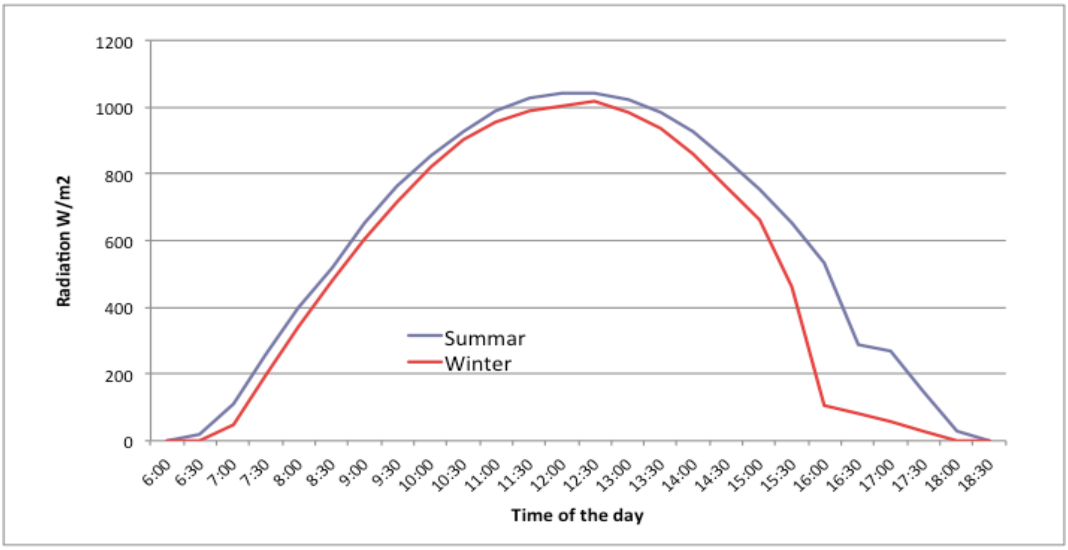



*Figure 20: Typical Daily Solar Radiation Profile of Pondicherry*

### *6.1.2 Temperature*

Monthly average, minimum and maximum ambient temperature profile for the site at 10m-height is shown in the figure below.

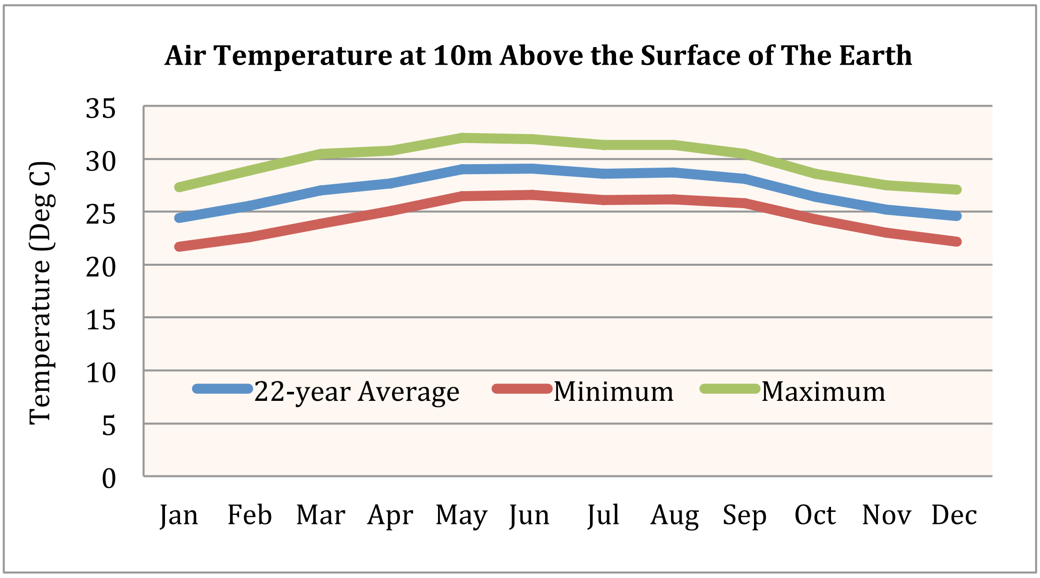



*Figure 21: Monthly average air temperature at 10m height*

### 6.1.3 Wind Resource

Centre for Wind Energy Technology (C-WET) has installed four wind monitoring stations in the union territory of Pondicherry out of which two stations were located in Puducherry. The table below shows mean annual wind power density measured in the two wind monitoring stations located at Puducherry.

*Table 10: Wind energy data for Pondicherry*

| C-WET Wind Monitoring Stations | Mast height (m) | Mean average wind speed (m/s) | Mean average wind power density (W/sqm) | Wind Power Density Extrapolated at 50m (W/sqm) |
|---|---|---|---|---|
| Dubarayapet | 25 | 4.44 | 88 | 119 |
| Pannithittu | 25 | 3.72 | 53 | 71 |

*Source: [http://www.cwet.tn.nic.in/html/departments_wms.html](http://www.cwet.tn.nic.in/html/departments_wms.html)*

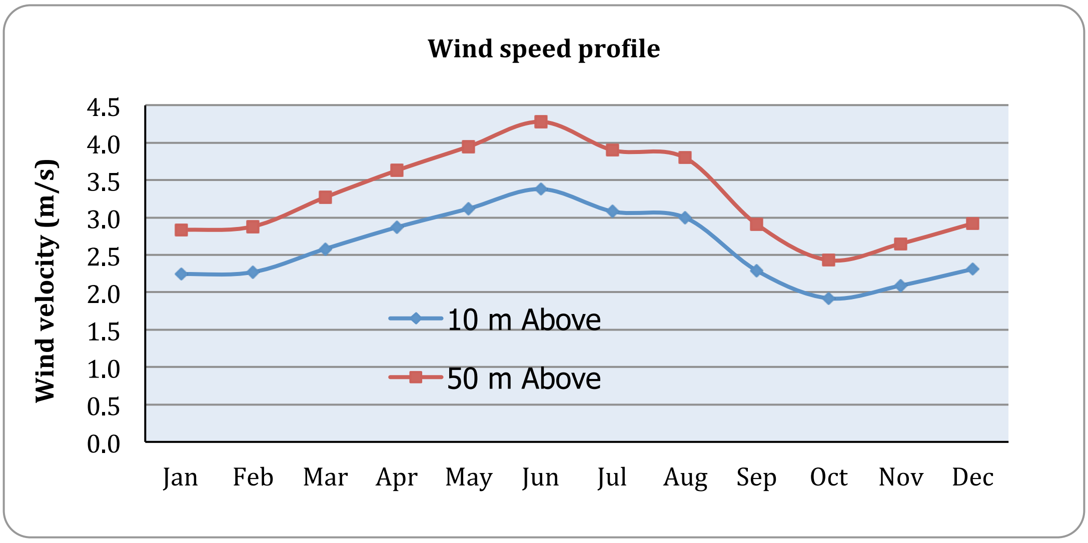



*Figure 22: Monthly Wind Speed Profile for Pondicherry*

The monthly average wind speed data obtained from NASA satellite source also comparable to these measured mean average wind speed. The same wind speed data is presented in the table and graphically in the picture below.

*Table 11: Monthly average wind energy data for Pondicherry*

| Months | Average @0130 | Average @0430 | Average @0730 | Average @1030 | Average @1330 | Average @1630 | Average @1930 | Average @2230 |
|---|---|---|---|---|---|---|---|---|
| January | 3.53 | 3.15 | 3.78 | 3.83 | 4.17 | 4.42 | 4.15 | 3.78 |
| February | 3.25 | 2.78 | 3.26 | 3.4 | 4.05 | 4.56 | 4.25 | 3.77 |
| March | 3.48 | 2.98 | 3.15 | 3.32 | 4.37 | 5.2 | 4.86 | 4.29 |
| April | 3.98 | 3.54 | 3.25 | 3.2 | 4.44 | 5.78 | 5.45 | 5.00 |
| May | 4.5 | 4.51 | 3.76 | 3.64 | 4.47 | 5.61 | 5.55 | 5.43 |
| June | 5.16 | 5.92 | 4.8 | 4.47 | 4.74 | 5.29 | 5.4 | 5.53 |
| July | 4.59 | 5.17 | 4.22 | 3.85 | 4.29 | 4.84 | 4.98 | 5.09 |
| August | 4.7 | 5.26 | 4.25 | 3.8 | 4.21 | 4.73 | 4.88 | 5.04 |
| September | 3.7 | 3.44 | 3.01 | 2.7 | 3.3 | 3.82 | 4.01 | 4.11 |
| October | 3.18 | 2.57 | 2.78 | 2.56 | 2.86 | 3.21 | 3.33 | 3.35 |
| November | 3.5 | 3.13 | 3.67 | 3.45 | 3.57 | 3.79 | 3.76 | 3.64 |
| December | 3.79 | 3.57 | 4.15 | 4.03 | 4.11 | 4.26 | 4.12 | 3.97 |
| Annual | 3.95 | 3.84 | 3.67 | 3.52 | 4.04 | 4.62 | 4.56 | 4.42 |

*Source: http://eosweb.larc.nasa.gov/cgi-bin/sse*

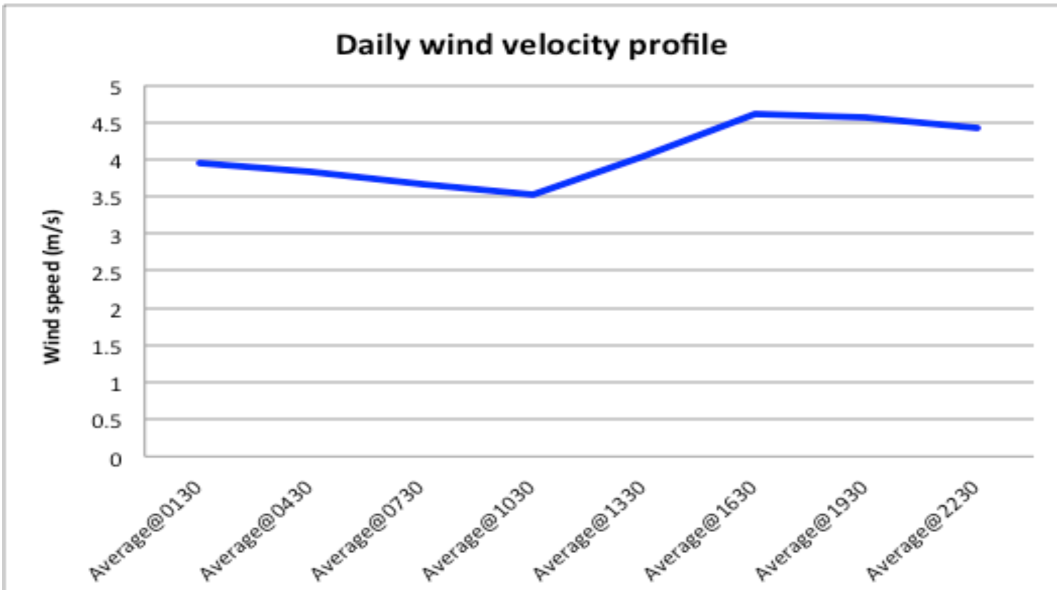



*Figure 23: Average Daily Wind velocity Profile of Pondicherry*

## 6.1 Potential Renewable Energy Projects

Based on energy demand assessment, resource assessment and site survey, the following projects have been identified for the silver jubilee campus of the Pondicherry University.

(i) Solar PV systems in the rooftop of buildings
(ii) Solar PV systems in the car parking sheds
(iii) Solar PV system in the periphery of inner circle landscape
(iv) Solar Water Heater for academic staff college and canteen
(v) Small Wind turbines in the periphery of outer circle

Since electrical energy contributes 87.54% of total energy consumption in the university, we have focused on generation of electricity by using renewable energy so that the same can be integrated to the existing system to offset the conventional energy. Thermal energy demand is limited in the campus with limited use of LPG (1.32%) and electrical geysers for hot water in academic staff college. While energy consumption for cooling load in the campus is highest with 41% contribution followed by indoor lighting load (22%) and street lighting load (11%) contribution. Majority of cooling load (541tons) provided by highly efficient VRF system followed by split air conditioners (165.5 tons) and windows air conditioners (52.5 tons). Both cooling load and majority of indoor lighting loads are operated during daytime where there is enough sunshine, therefore use of solar PV systems to match the peak load demand is justified. Use of solar thermal system for cooling is not suggested due to the fact that (i) available space on the roof any building is not sufficient to meet the cooling load demand of the subsequent building (ii) the vapour absorption system can not be integrated with the existing system (iii) it will require a major infrastructural changes.

It is suggested that the university should consider appropriate solar passive design including earth tunnel cooling system for the upcoming multipurpose auditorium.

# 7 DETAILED PROJECT REPORTS

Detailed report has been prepared for the following projects

(i) 620kWp Solar PV systems
(ii) 1500LPD solar water heating systems
(iii) 216kW small wind generating systems

## 7.1 Detailed Project Report for Solar PV System

### *7.1.1 Site Details*

Solar PV systems have been proposed in the following buildings and locations within the silver jubilee campus of Pondicherry University.

*Table 12: Capacity of solar PV systems proposed in different locations*

| Sl. No. | Location/ Buildings | Type of System | Capacity (kWp) |
|---|---|---|---|
| 1 | Block 1 of School of Social Science and Humanities building | Rooftop | 30 |
| 2 | Block 2 of School of Social Science and Humanities building | Rooftop | 38 |
| 3 | Block 3 of School of Social Science and Humanities building | Rooftop | 38 |
| 4 | Block 4 of School of Social Science and Humanities building | Rooftop | 38 |
| 5 | Block 5 of School of Social Science and Humanities building | Rooftop | 38 |
| 6 | Block 6 of School of Social Science and Humanities building | Rooftop | 38 |
| 7 | Block 7 of School of Social Science and Humanities building | Rooftop | 38 |
| 8 | Block 8 of School of Social Science and Humanities building | Rooftop | 38 |
| 9 | Block 9 of School of Social Science and Humanities building | Rooftop | 38 |
| 10 | Block 10 of School of Social Science and Humanities building | Rooftop | 30 |
| 11 | School of Media & Communication | Rooftop | 30 |
| 12 | Car shed near School of Social Science | Rooftop | 13 |

| | | | |
|---|---|---|---|
| | and Humanities building | | |
| 13 | Car parking shed near School of Social Science and Humanities building | Rooftop | 13 |
| 14 | Car parking shed near UMISARC | Rooftop | 10 |
| 15 | Car parking shed near Subramania Bharathi School of Tamil Language | Rooftop | 10 |
| 16 | Car parking shed near Academic staff college | Rooftop | 10 |
| 17 | Car parking shed near School of Media & Communication | Rooftop | 10 |
| 18 | Solar ring surrounding the round lawn | Ground mounted | 160 |
| | | Total capacity | 620 |

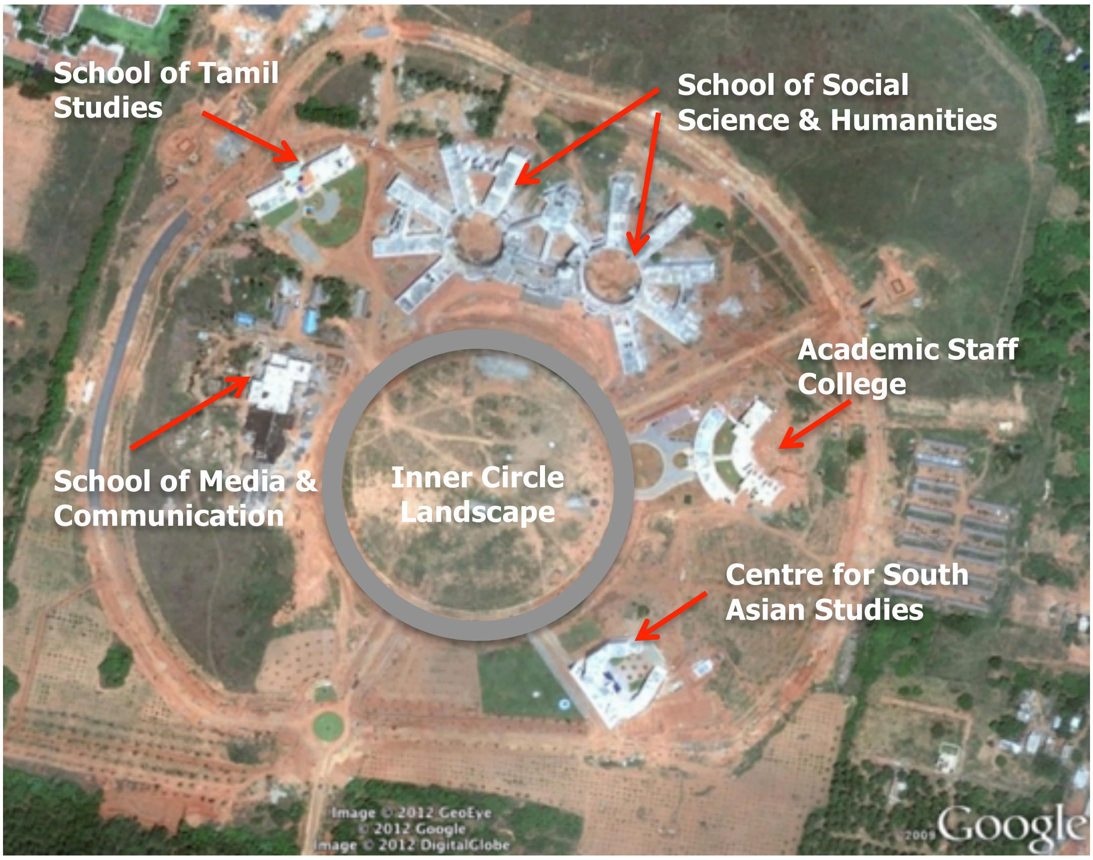



*Figure 24: Location of buildings in the silver jubilee campus*

*Figure 25: Terrace on the school of social science and humanities building*

### 7.1.1 Shadow Analysis

None of the selected site has obstruction at present to create shadow. While designing the solar PV systems, we are carefully planning the solar array layout to avoid possible shadow from the water tanks, sidewalls, columns and nearby buildings. Layouts of rows are positioned in such a way that it does not create any shadow on the other row.

### 7.1.2 Estimation of Annual Energy Yield

Annual energy yield for the proposed PV power plants is defined as the amount of energy fed into the building grid after due consideration of all kinds of generation and distribution losses. A state of the art simulation tool (PVSYST v5.64) was used to estimate energy yield from different PV power plants proposed in the silver jubilee campus. PVSYST simulation reports are placed in Annexure 1.

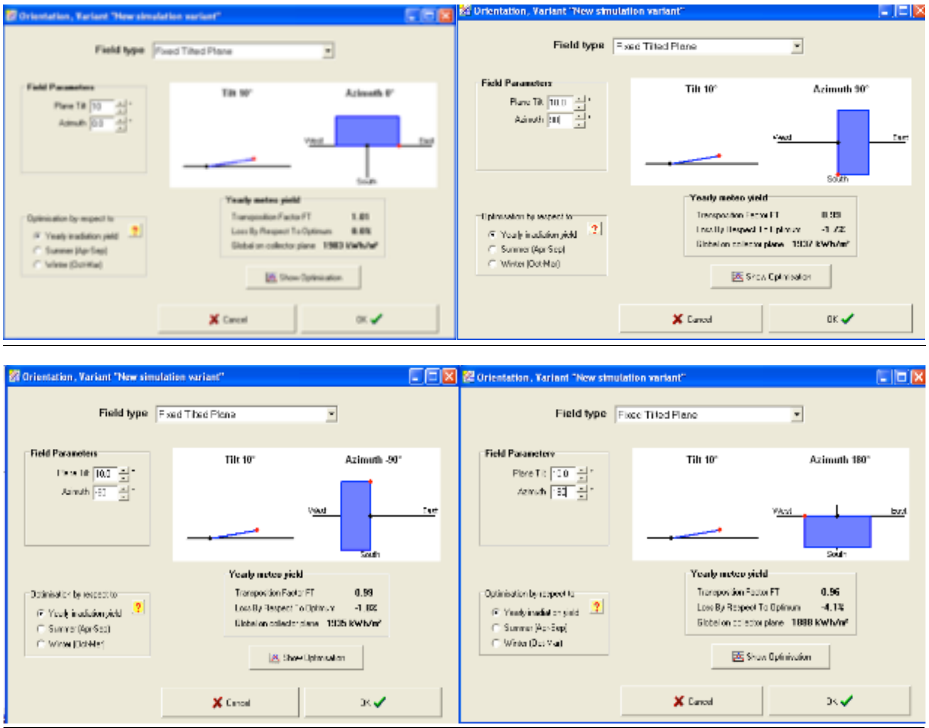
The following assumptions were made while calculating annual energy yield from the proposed PV Power plant.

*Orientation and tilt angle*

The maximum energy yield from a PV power plant could be achieved using a tracking system which keeps the incidence angle close to 90°. Such tracking system is highly expensive, technically complicated and not economically viable. A simple single axis tracking provision could be incorporated in the array structure for seasonal tracking of the PV system. The optimum tilt angles for different months of the year are shown below. However, for a large size array, it is not advisable to change the tilt angle each month, to avoid risks of module breakage and conductor and earthing system failure through pinching, stretching, loosening due to excessive handling. Since Pondicherry is located at $12^{o}$ latitude, the sun actually positioned in the north during summer. The monthly energy yield is calculated based on a tilted array surface at $10^{o}$ considering $0^{o}$ azimuth angle.

| *Ideal optimum tilt angles* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 37 | 28 | 15 | 0 | -10 | -13 | -11 | 4 | 8 | 20 | 31 | 38 |

In the case of ground mounted solar ring around the inner circle landscape, we have considered 25% of the arrays are facing south, north, east and west. Loss due to change in direction is 1.7% for east facing arrays, 1.8% for west facing arrays and 4.1% for north facing arrays. These losses are acceptable to avoid complicated tracking system and maintaining aesthetic of the "solar ring".



| Facing towards | Tilt | Azimuth | Transposition Factor FT | Loss by respect to optimum |
|---|---|---|---|---|
| South | $10^{o}$ | $0^{o}$ | 1.01 | 0.0% |
| East | $10^{o}$ | $90^{o}$ | 0.99 | -1.7% |
| West | $10^{o}$ | $-90^{o}$ | 0.99 | -1.8% |
| North | $10^{o}$ | $180^{o}$ | 0.96 | -4.1% |

*Figure 26: Effect of array tilt angle and azimuth*

*Loss in the PV system*

The loss in the PV system depends on the PV module and inverter technology; efficiency and quality of PV modules, inverter, junction box and wires; workmanship of installation and scheduled maintenance and cleaning. In the simulation process we have considered best quality modules and inverters of international standard. Typical losses in different array inverter configuration are shown in the table below. PVSyst simulation reports with loss diagrams are attached in the annexures.

*Table 13: Loss in PV systems*

| Losses | 10kWp | 13kWp | 30kWp | 38kWp | 40kWp |
|---|---|---|---|---|---|
| Loss due to irradiance level | 3.60% | 3.60% | 3.90% | 1.40% | 3.60% |
| PV loss due to temperature | 14.30% | 14.30% | 14.50% | 12.30% | 14.30% |
| Ohmic wiring loss | 1.10% | 1.10% | 1.10% | 1.10% | 1.10% |
| Inverter loss | 4.30% | 2.30% | 2.00% | 2.10% | 1.50% |

Considering all losses during generation and transmission, monthly and annual average energy yields from the power plant for different PV technologies are shown in the table and the figure below.

*Table 14: Monthly average energy generation from PV systems*

| PV Systems | Monthly energy generation from solar PV systems (MWh) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January | February | March | April | May | June | July | August | September | October | November | December | Annual |
| 8 x 38kWp rooftop | 42 | 43 | 51 | 47 | 43 | 37 | 37 | 38 | 39 | 35 | 32 | 36 | 479 |
| 3 x 30kWp rooftop | 11 | 12 | 14 | 13 | 12 | 10 | 10 | 10 | 11 | 10 | 9 | 10 | 131 |
| 2 x 13kWp car shed | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 39 |
| 4 x 10kWp car shed | 5 | 5 | 6 | 6 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 58 |
| 4 x 40kWp at ground | 19 | 20 | 25 | 24 | 22 | 19 | 19 | 19 | 19 | 17 | 15 | 16 | 233 |
| Total Energy Generation | 80 | 83 | 101 | 93 | 86 | 74 | 73 | 75 | 76 | 68 | 61 | 69 | 940 |

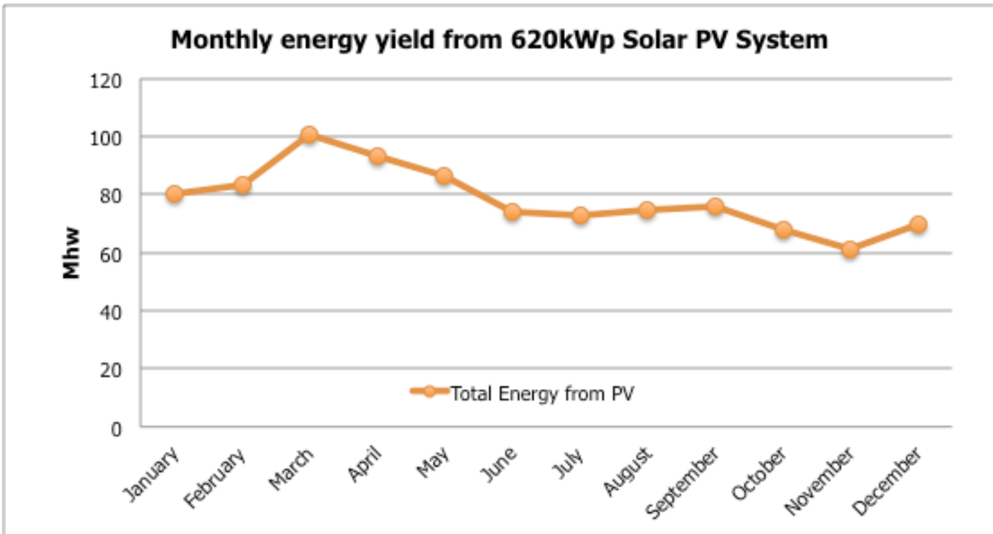



*Figure 27: Monthly energy generations from 620kWp PV power plants*

*Loss in the Electrical Systems*

The transformer and distribution losses beyond the inverter output will depend on the quality of power equipments and conditions specific to the location and connected grid infrastructure. Loss in the electrical systems will occur due to self-consumption, control, protection, and no load losses of step up transformers. The total losses from the Inverter output till the Bus bar output is considered as 2%, considering best quality equipment and best installation practice.

*Annual Degradation*

The estimated life of PV modules is considered as 25 years. Performance of PV modules degrades over its specified lifetime. Normally, PV module manufacturers provide a performance guarantee and indicate the rate of degradation over the module lifetime. Based on the world's leading manufacturers' declarations on their modules, we have considered that there will be a reduction of power generation of 0.8% per annum at the output of the inverters. Considering all losses, self-consumption and annual degradation of PV modules, exportable annual electrical energy yield from the aggregated 620kWp solar PV power plants for a projected period of 25 years is given in table below.

*Table 15: Life Cycle PLF of PV systems*

| Year | MWh/year | PLF |
|---|---|---|
| 1 | 921 | 16.96% |
| 2 | 914 | 16.83% |
| 3 | 907 | 16.69% |
| 4 | 899 | 16.56% |
| 5 | 892 | 16.42% |
| 6 | 885 | 16.29% |
| 7 | 878 | 16.16% |
| 8 | 871 | 16.03% |
| 9 | 864 | 15.91% |
| 10 | 857 | 15.78% |
| 11 | 850 | 15.65% |
| 12 | 843 | 15.53% |
| 13 | 837 | 15.40% |
| 14 | 830 | 15.28% |
| 15 | 823 | 15.16% |
| 16 | 817 | 15.04% |
| 17 | 810 | 14.92% |
| 18 | 804 | 14.80% |
| 19 | 797 | 14.68% |
| 20 | 791 | 14.56% |
| 21 | 784 | 14.44% |
| 22 | 778 | 14.33% |
| 23 | 772 | 14.21% |
| 24 | 766 | 14.10% |
| 25 | 760 | 13.99% |
| Life Cycle average | 838 | 15.43% |

### *7.1.3 Plant Load Factor (PLF)*

The Plant Load Factor or Capacity Utilization Factor (CUF) is defined as the ratio of net electrical generation for the time considered to the energy that could have been generated if the system were generating at continuous full power during the same period. Since PV converts sunlight into electricity only during the day when sunshine is available, the plant capacity factor is rather low in comparison to conventional power plants. The average monthly plant load factor for the proposed PV power plants is shown in the table and figure below. The average annual PLF for the first year is 16.98%. The same will be 13.99% on the 25$^{th}$

year i.e. the last year of the power plant's effective life. The life cycle average PLF will be 15.43%.

*Table 16: Monthly average PLF of PV systems*

| Month | Days | Energy Yield (MWh/ month) | Average PLF |
|---|---|---|---|
| January | 31 | 80.13 | 17.37% |
| February | 28 | 83.16 | 18.03% |
| March | 31 | 100.61 | 21.81% |
| April | 30 | 93.45 | 20.26% |
| May | 31 | 86.40 | 18.73% |
| June | 30 | 73.81 | 16.00% |
| July | 31 | 72.70 | 15.76% |
| August | 31 | 74.95 | 16.25% |
| September | 30 | 76.18 | 16.52% |
| October | 31 | 67.93 | 14.73% |
| November | 30 | 61.26 | 13.28% |
| December | 31 | 69.43 | 15.05% |
| Annual | 365 | 939.99 | 16.98% |

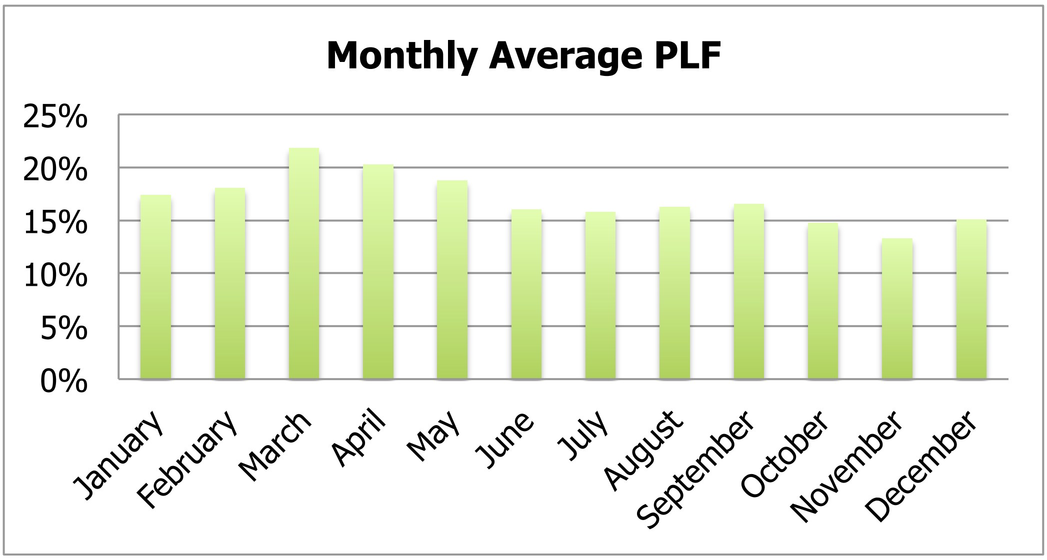



*Figure 28: Monthly average PLF (first year) of PV power plants*

### *7.1.4 Daily Generation Profile*

The solar PV power plant will operate during the daytime when sunshine is available. The output of the power plant will vary from morning to evening corresponding to the respective solar intensity. Figure below shows a typical daily load profile/ inverter output of the proposed 620kp PV power plants at Pondicherry University silver jubilee campus for a typical day in May. It may be noted that the power plant will start generating power from 7 am in the morning with 10% of its nominal capacity, which will gradually reach up to 40% at 9 am. The plant will produce 73%, the highest of its nominal power at 12 noon for that particular day and gradually reduce the generation to 48% at 3 pm, 36% at 4 pm and 15% at 5 pm. This profile will vary corresponding to the solar radiation, weather conditions and seasonal variation of daylight hours.

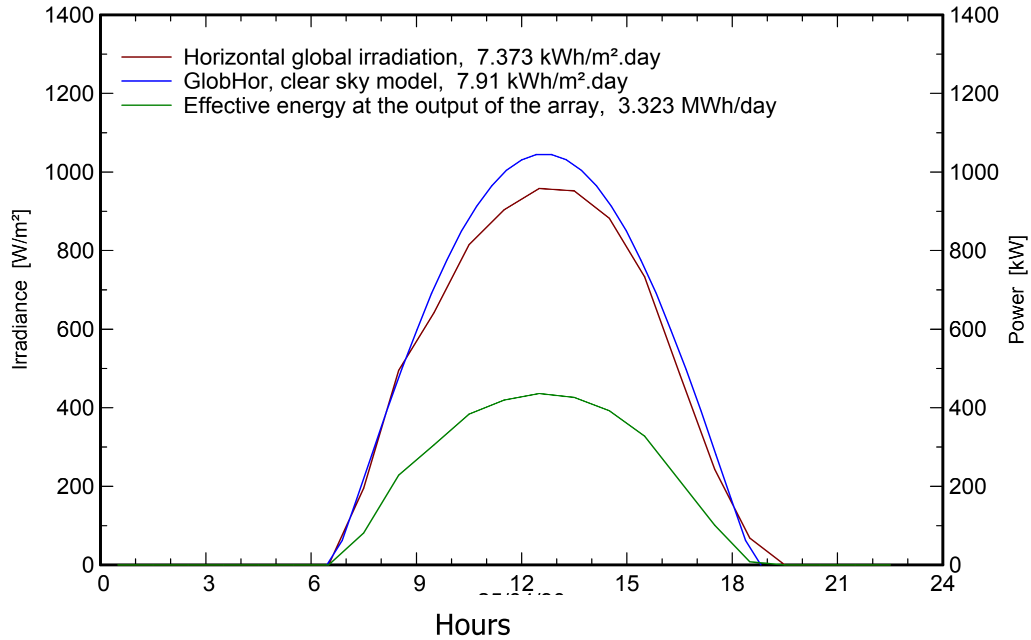



*Figure 29: A typical daily load profile of 620kWp PV power plant at Pondicherry*

### *7.1.5 The Array layout*

All the solar arrays on the building rooftops will be installed at a suitable tilted angle with a provision for seasonal tilt angle variation. Rows of the arrays will be laid in such a way that there is no shadow from one row to another. A minimum of 1m passages has been left between two rows for easy movement for cleaning and maintenance. Arrays will be placed at least one meter away from the sidewalls for allowing free movement of people for inspection and maintenance.

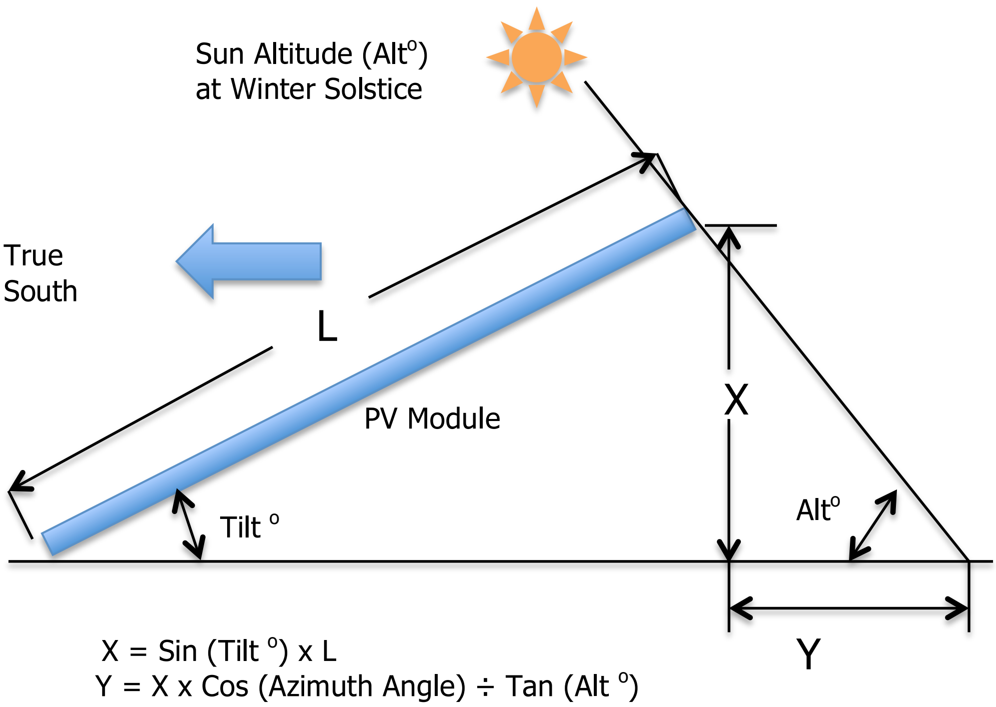



*Figure 30: Minimum distance between two rows of PV array*

The 620kWp system will be constituted of the following independent systems installed in different buildings, car parking sheds and outer ring of inner circle landscape.

*Table 16: Capacity of PV systems by type of installation*

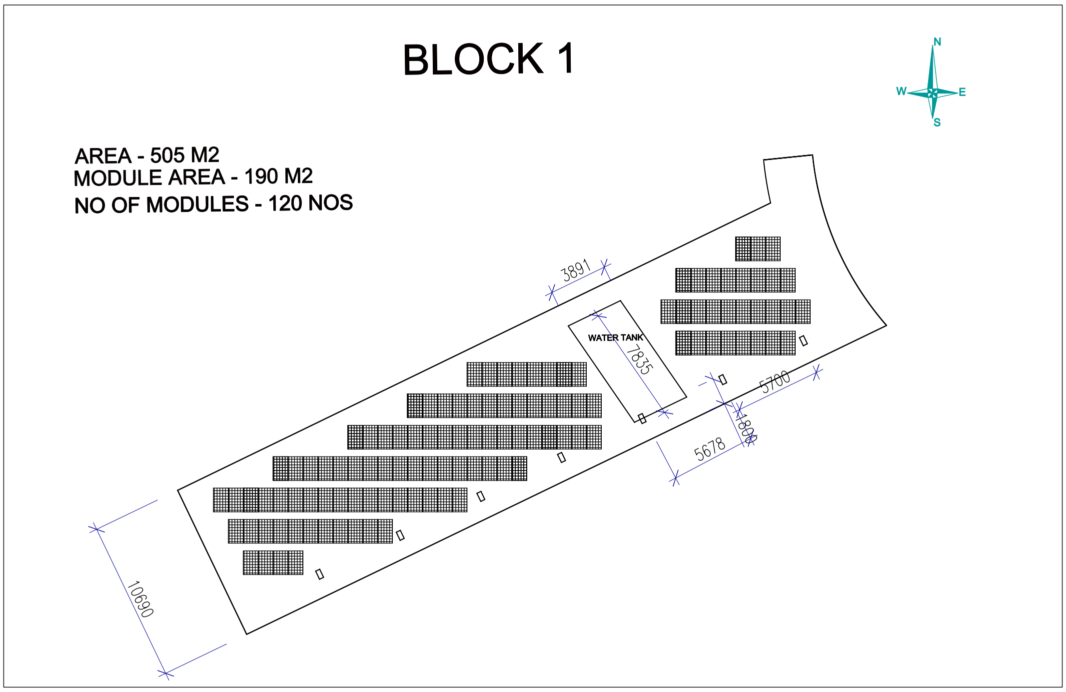
| Locations | Capacity (kWp) | No. of systems | Total capacity (kWp) |
|---|---|---|---|
| Car parking | 10 | 4 | 40 |
| Car parking | 13 | 2 | 26 |
| Building roof | 30 | 3 | 90 |
| Building roof | 38 | 8 | 304 |
| Outer ring of inner circle landscape | 40 | 4 | 160 |
| | | | 620 |

*Table 17: Array capacity, inverter and no. of strings*

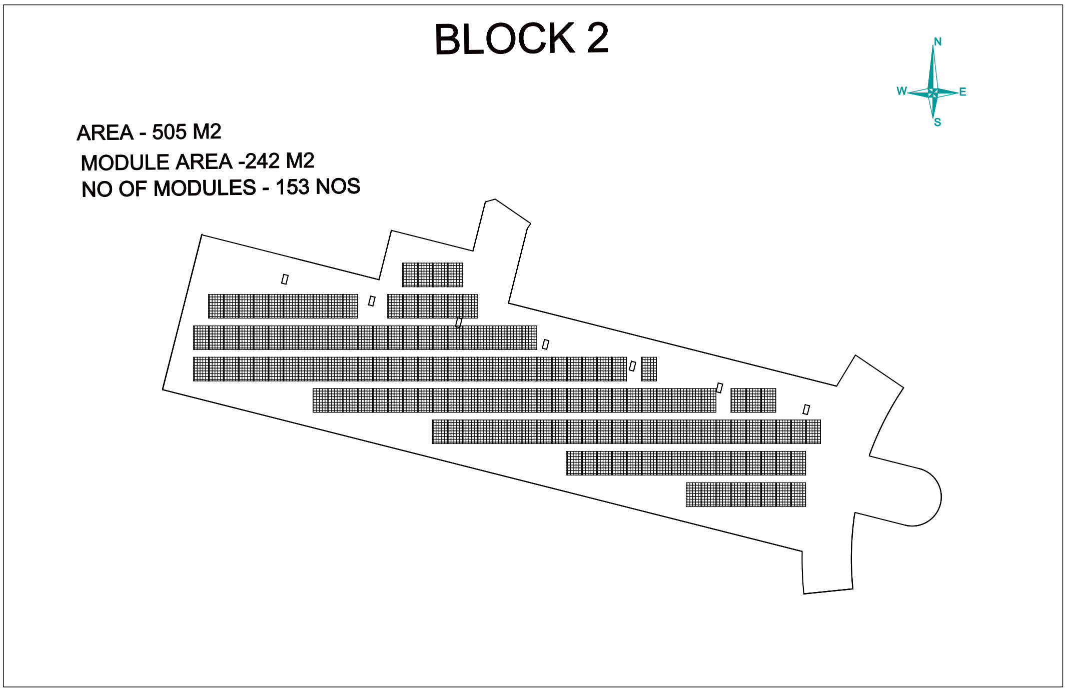
| Sl. No. | Array capacity (kWp) | Inverter capacity per string (kVA) | No. of modules (250Wp) per string | No. of string per system |
|---|---|---|---|---|
| 1 | 30 | 15 | 60 | 2 |
| 2 | 38 | 19 | 76 | 2 |
| 3 | 13 | 13 | 52 | 1 |
| 4 | 10 | 10 | 40 | 1 |
| 5 | 40 | 20 | 80 | 2 |

The following figures show the array and electrical layout drawings for each of these systems.

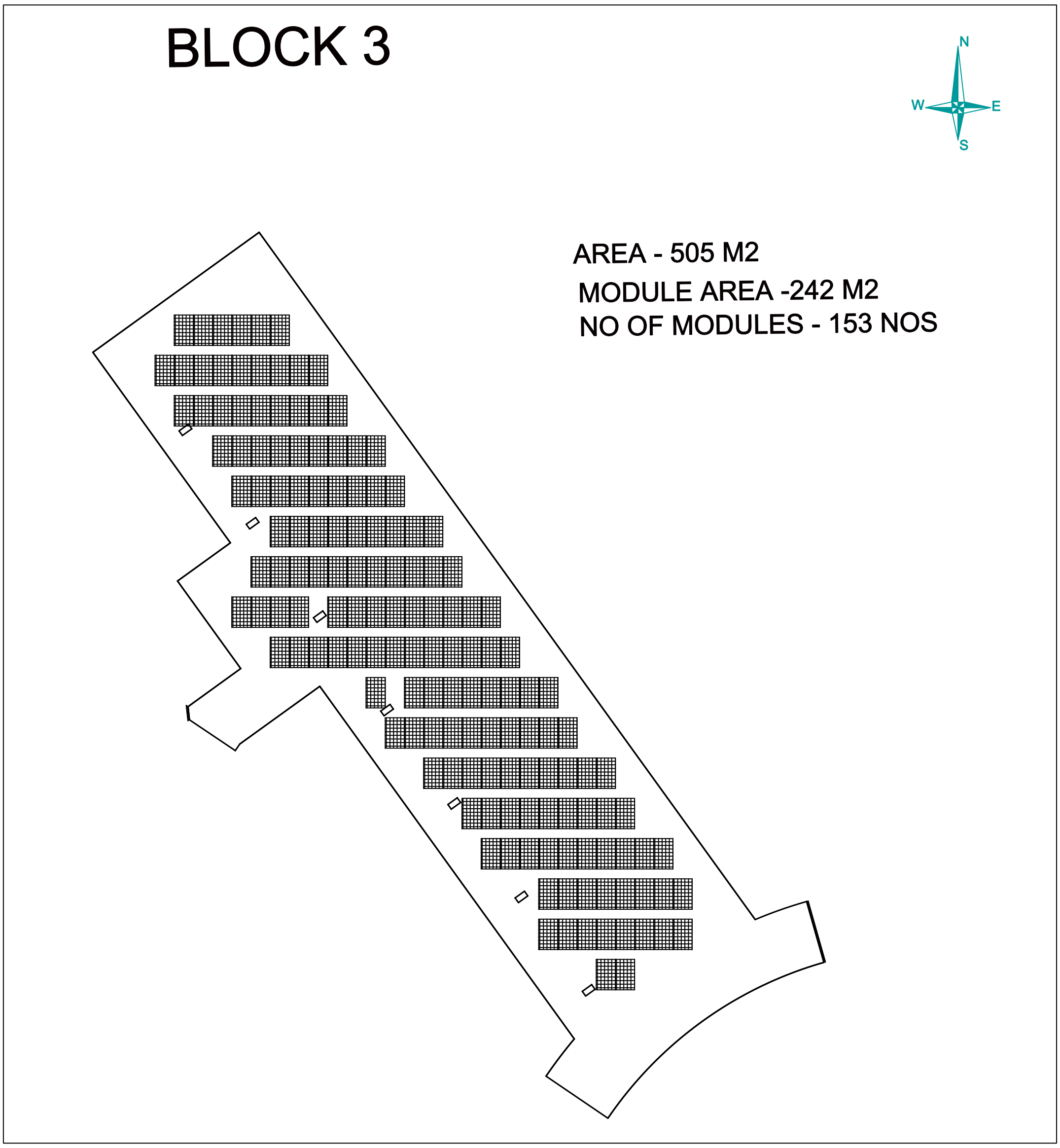
*1) Array layout drawing for 30kWp system at Block 1 of School of social science*



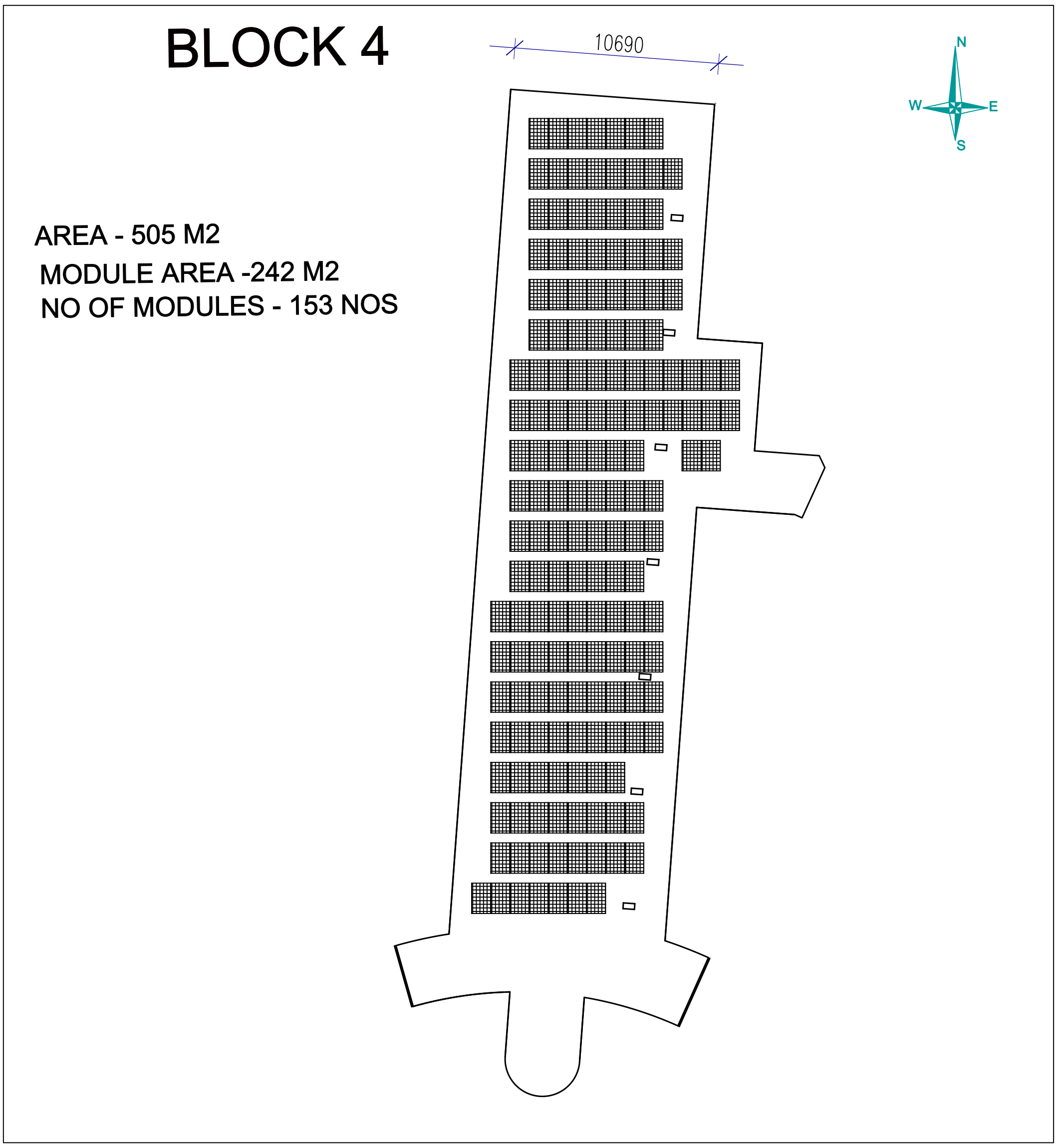
*2) Array layout drawing for 38kWp system at Block 2 of School of social science*



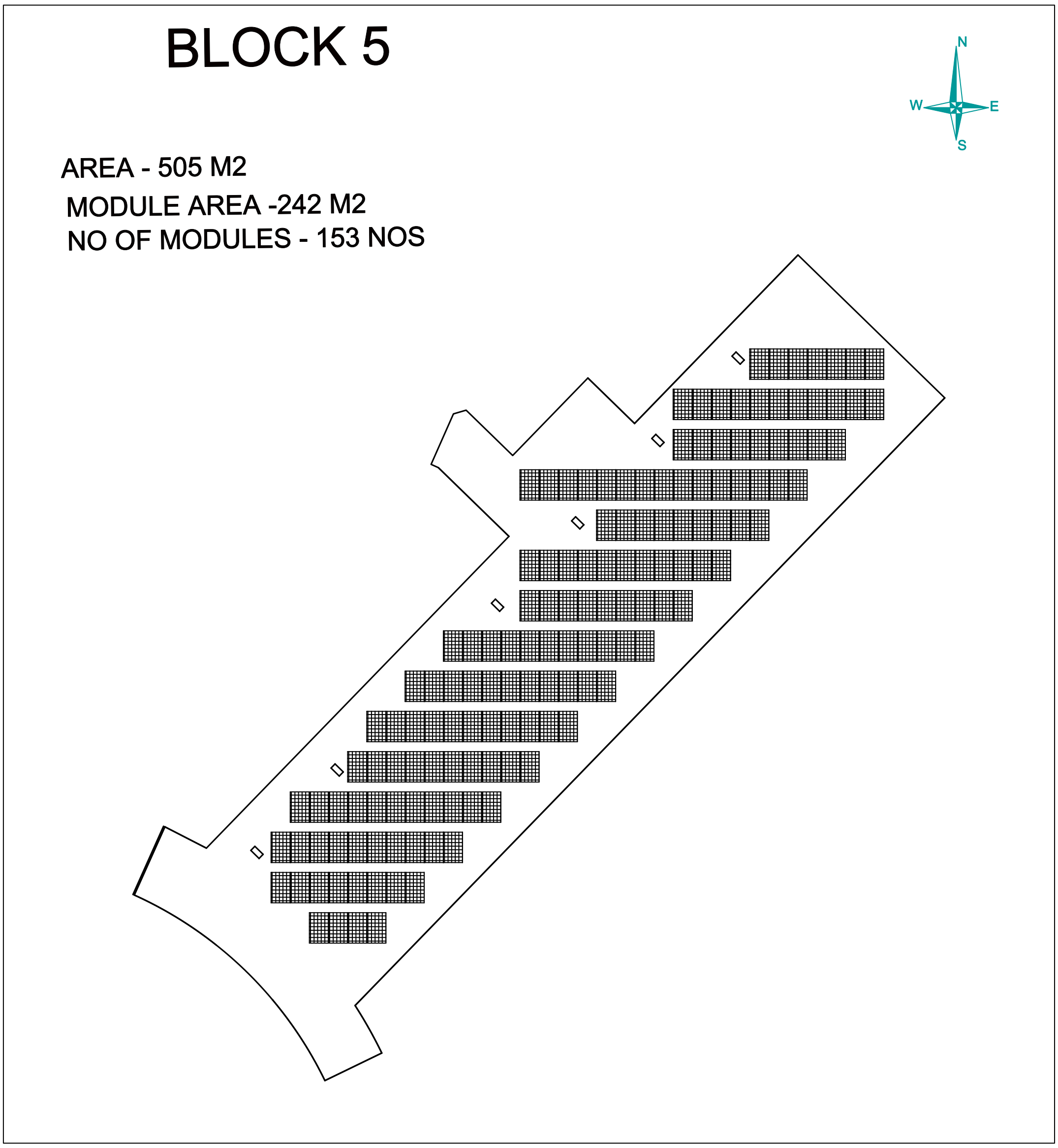
*3) Array layout drawing for 38kWp system at Block 3 of School of social science*



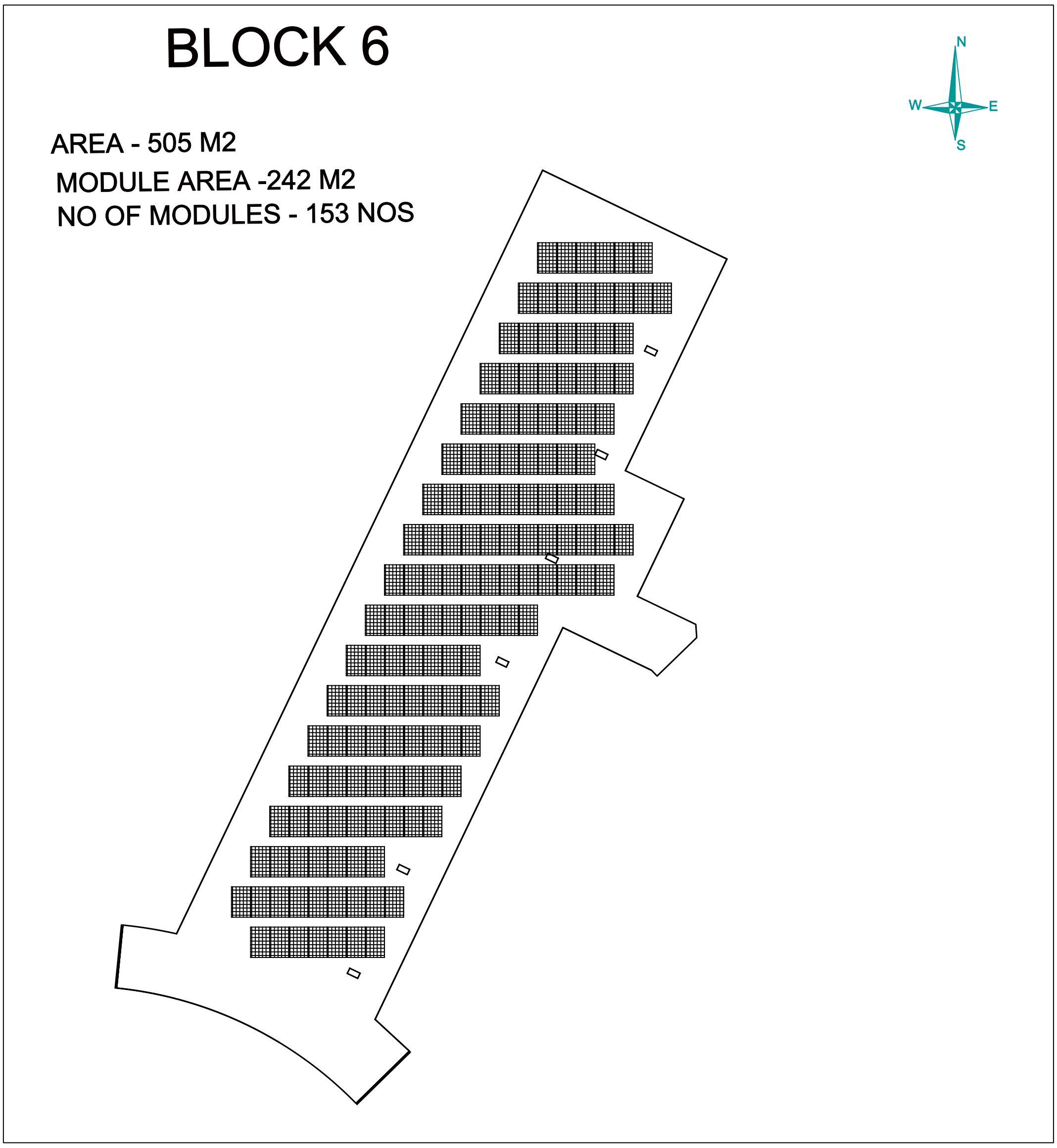
*4) Array layout drawing for 38kWp system at Block 4 of School of social science*



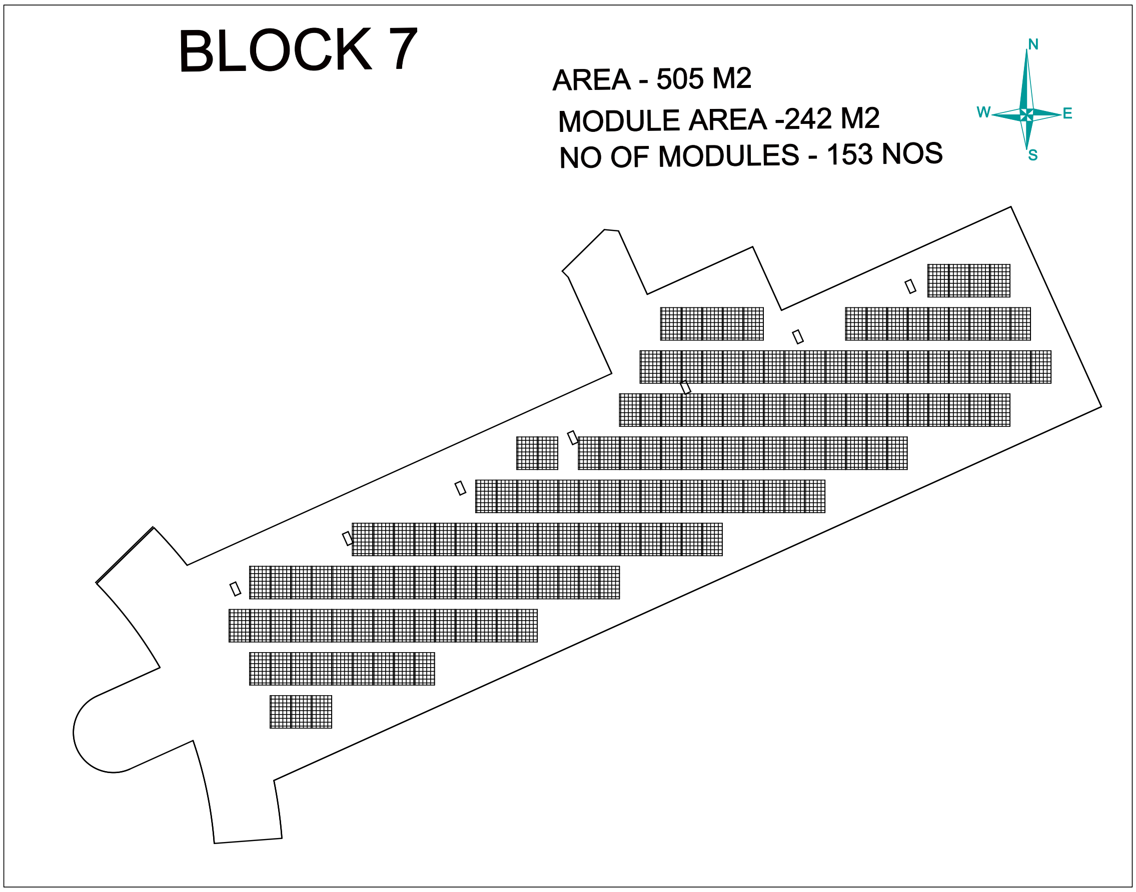
*5) Array layout drawing for 38kWp system at Block 5 of School of social science*



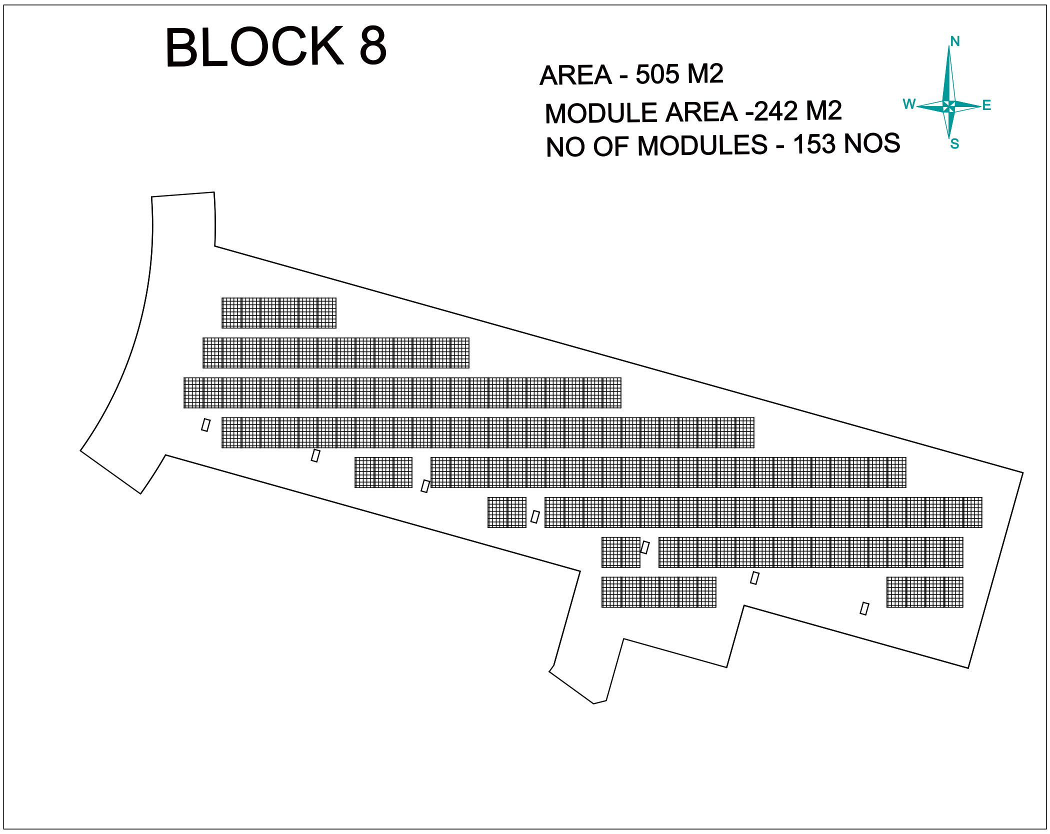
*6) Array layout drawing for 38kWp system at Block 6 of School of social science*



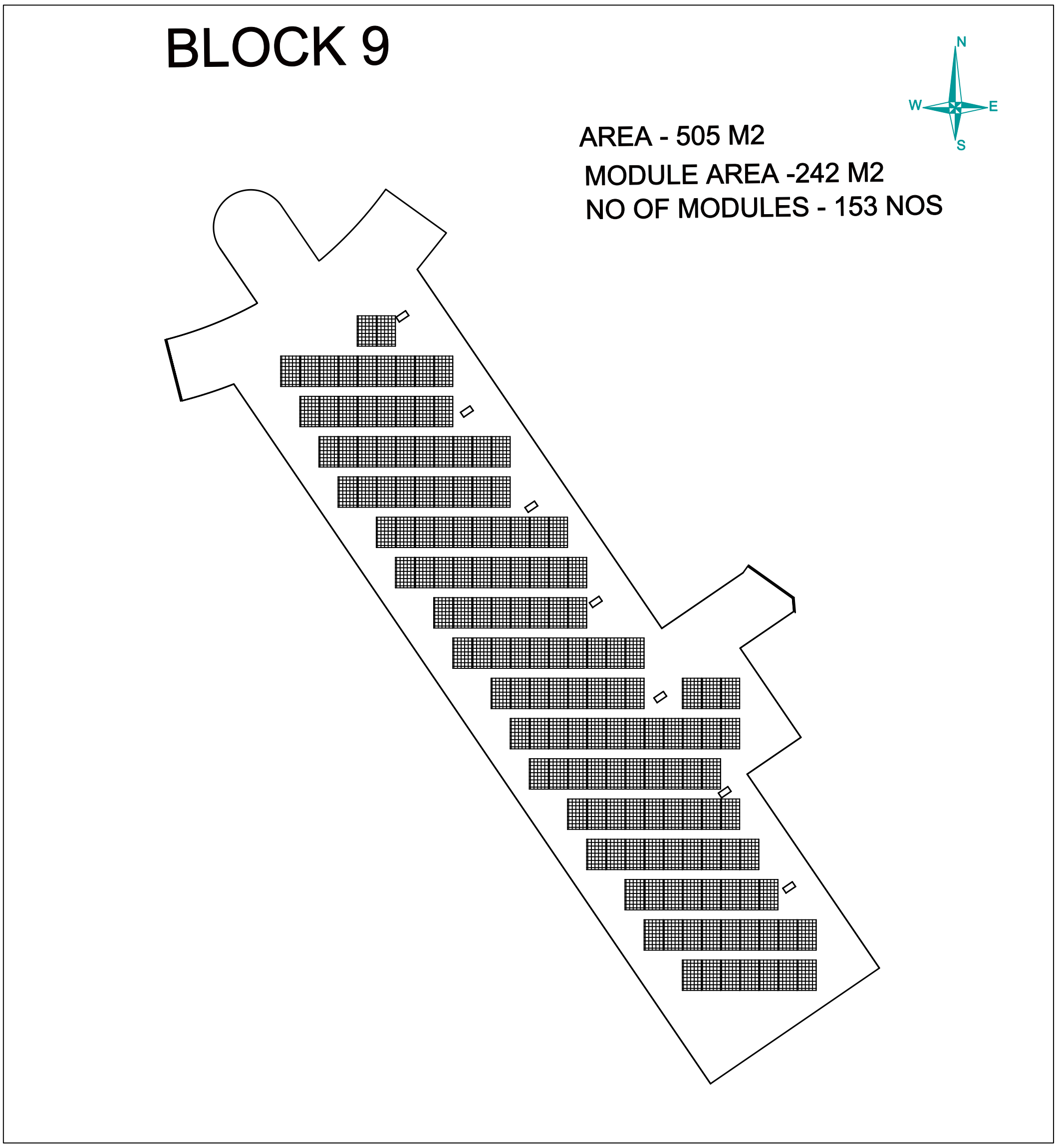
*7) Array layout drawing for 38kWp system at Block 7 of School of social science*



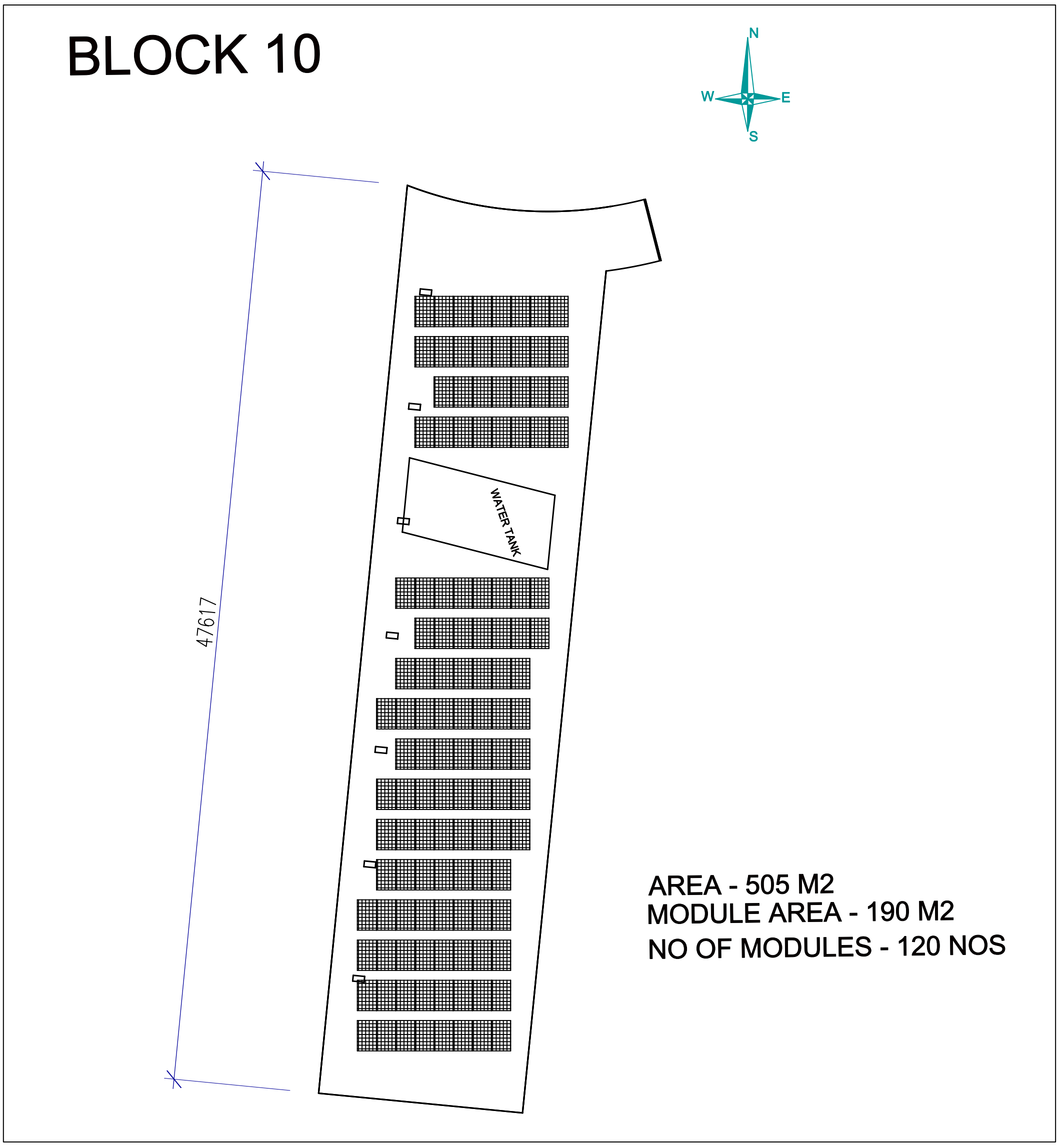
*8) Array layout drawing for 38kWp system at Block 8 of School of social science*



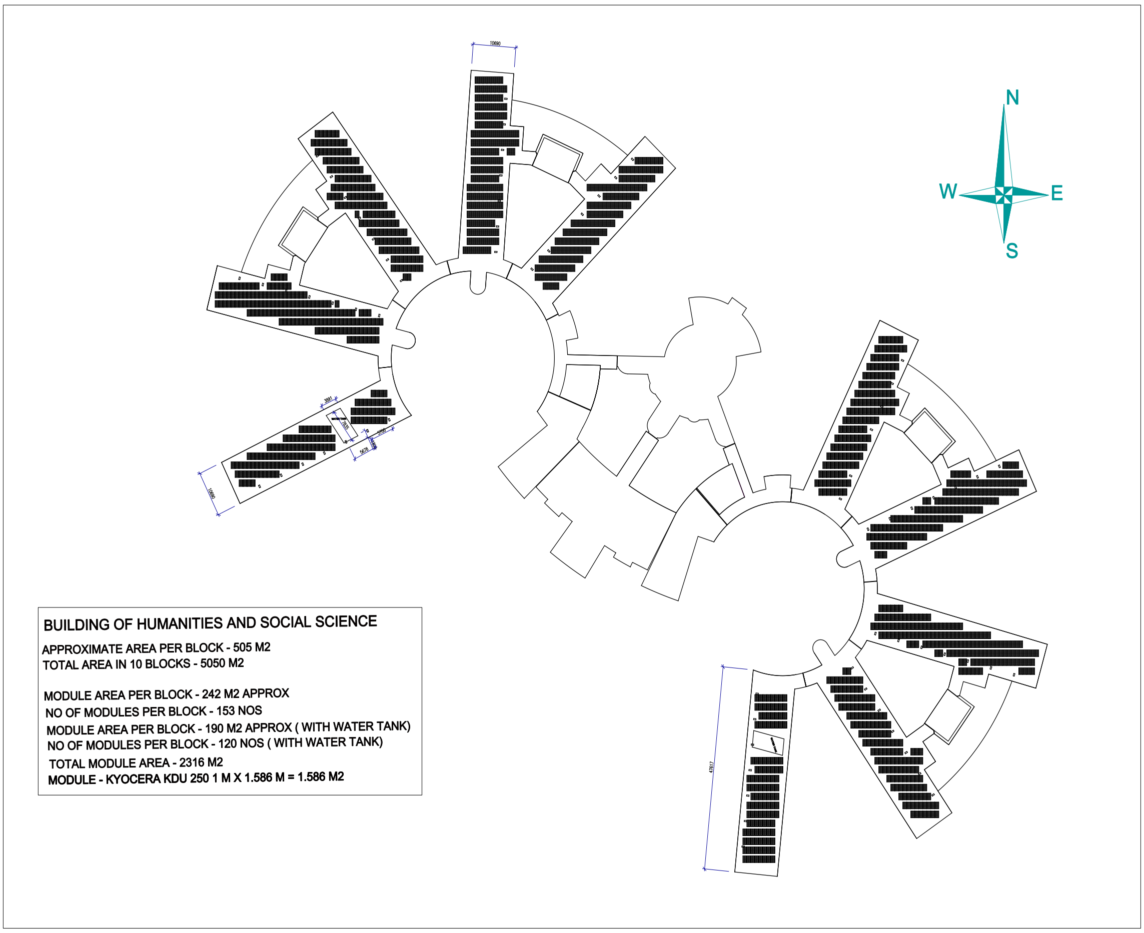
*9) Array layout drawing for 38kWp system at Block 9 of School of social science*



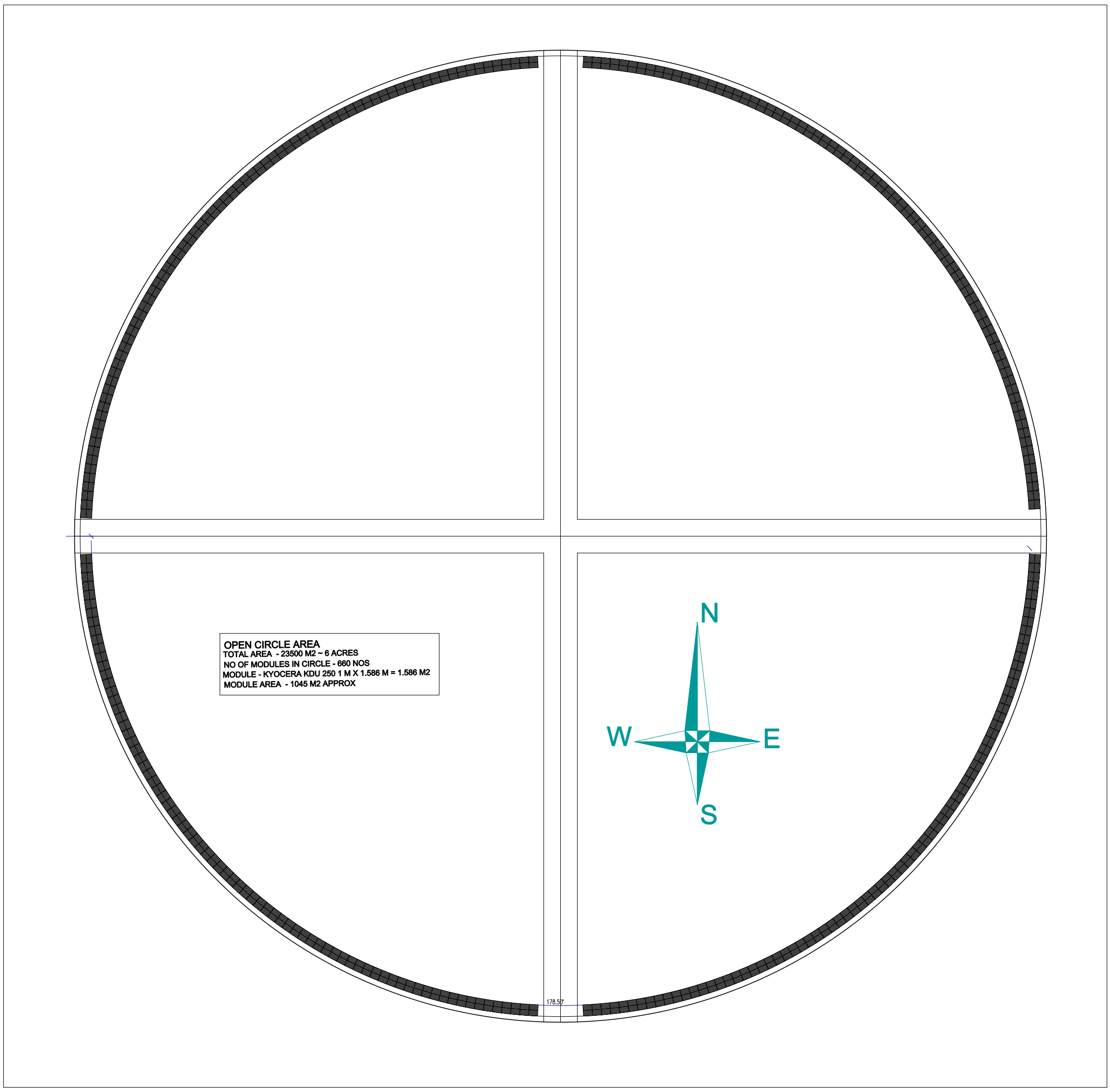
*10) Array layout drawing for 30kWp system at Block 10 of School of social science*



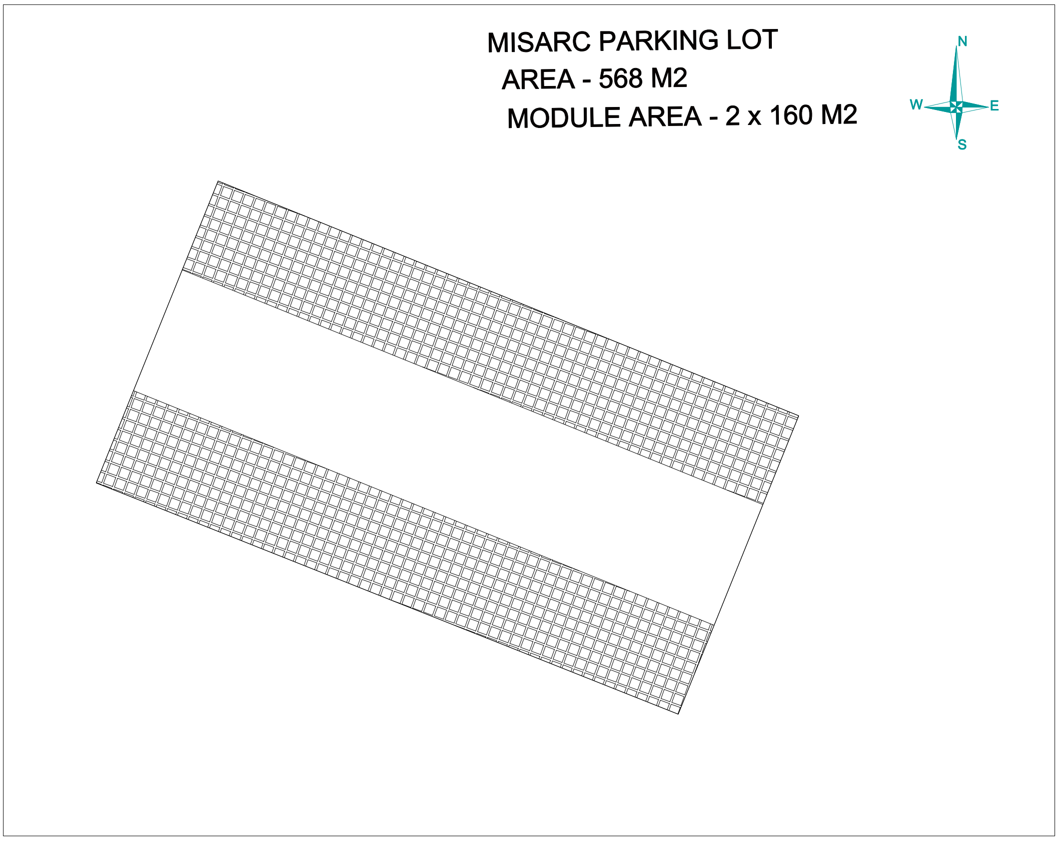
*11) Array layout drawing for combined 2 x 182kWp system at School of social science*



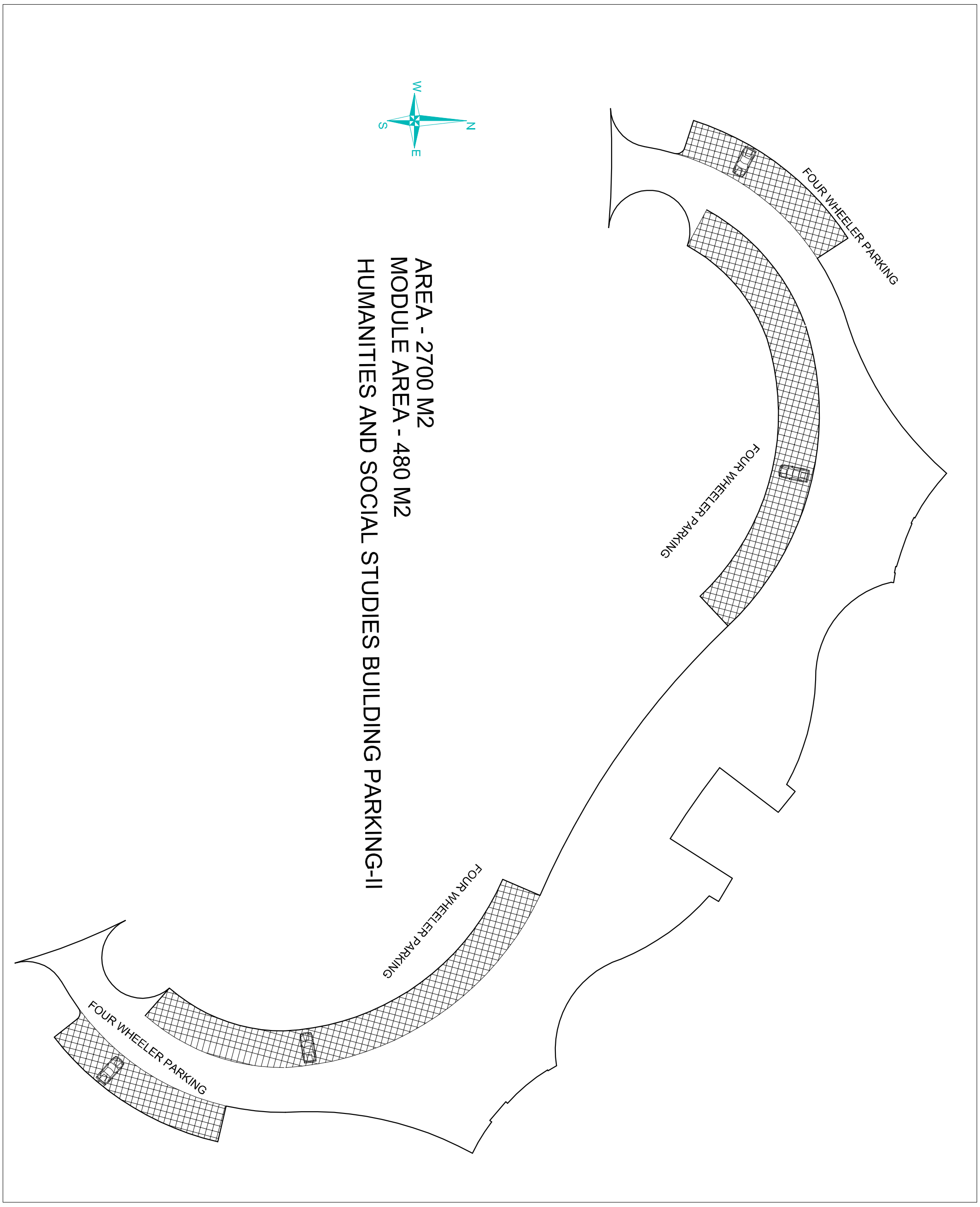
*12) Array layout drawing for 160kWp system at outer ring of inner circle landscape*



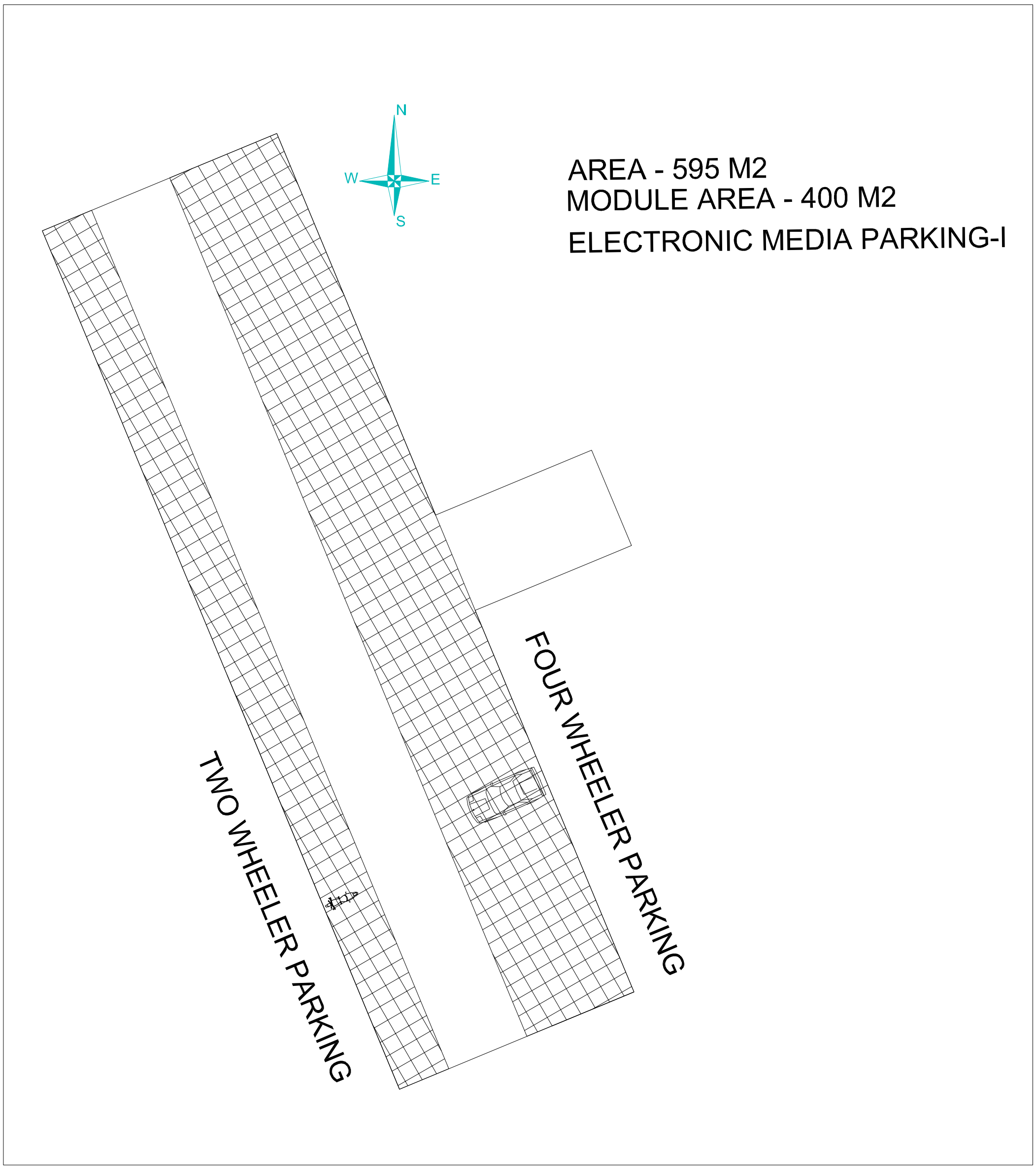
*13) Array layout drawing for 10kWp system MISARC car parking shed*



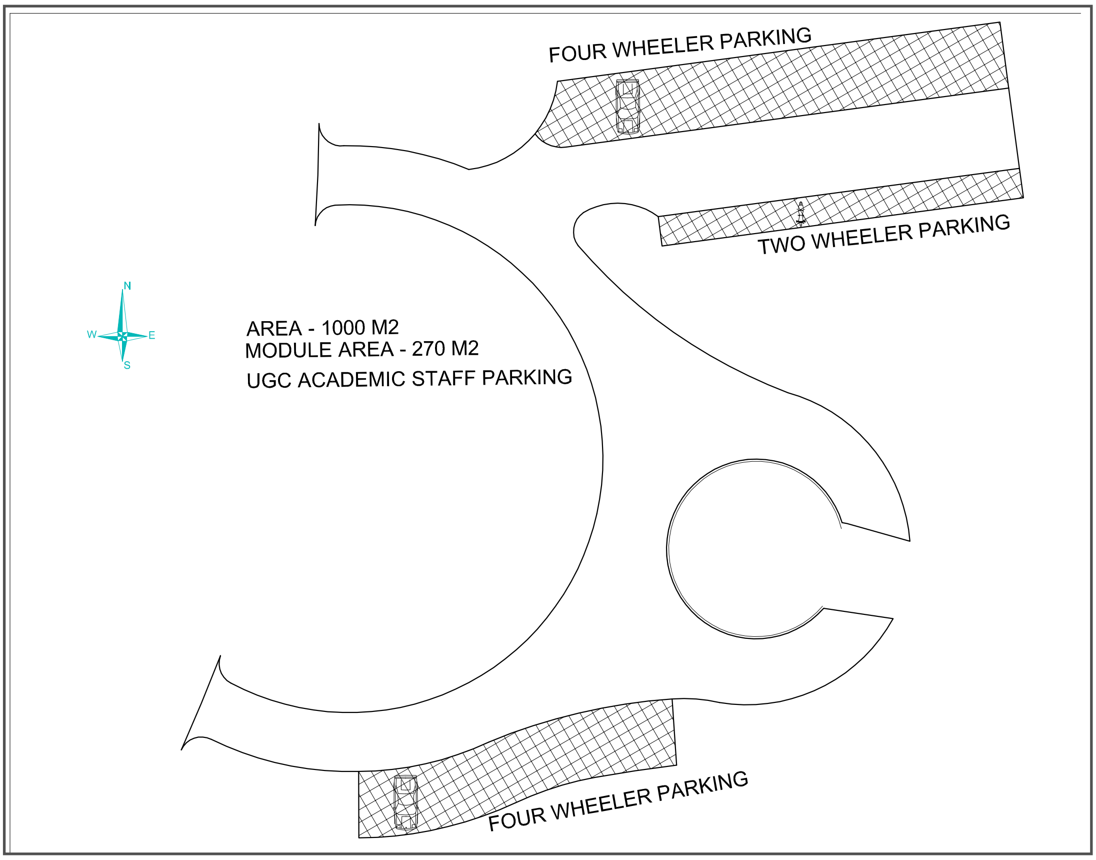
*14) Array layout drawing for 2 x 13kWp systems at School of SS & H car parking*



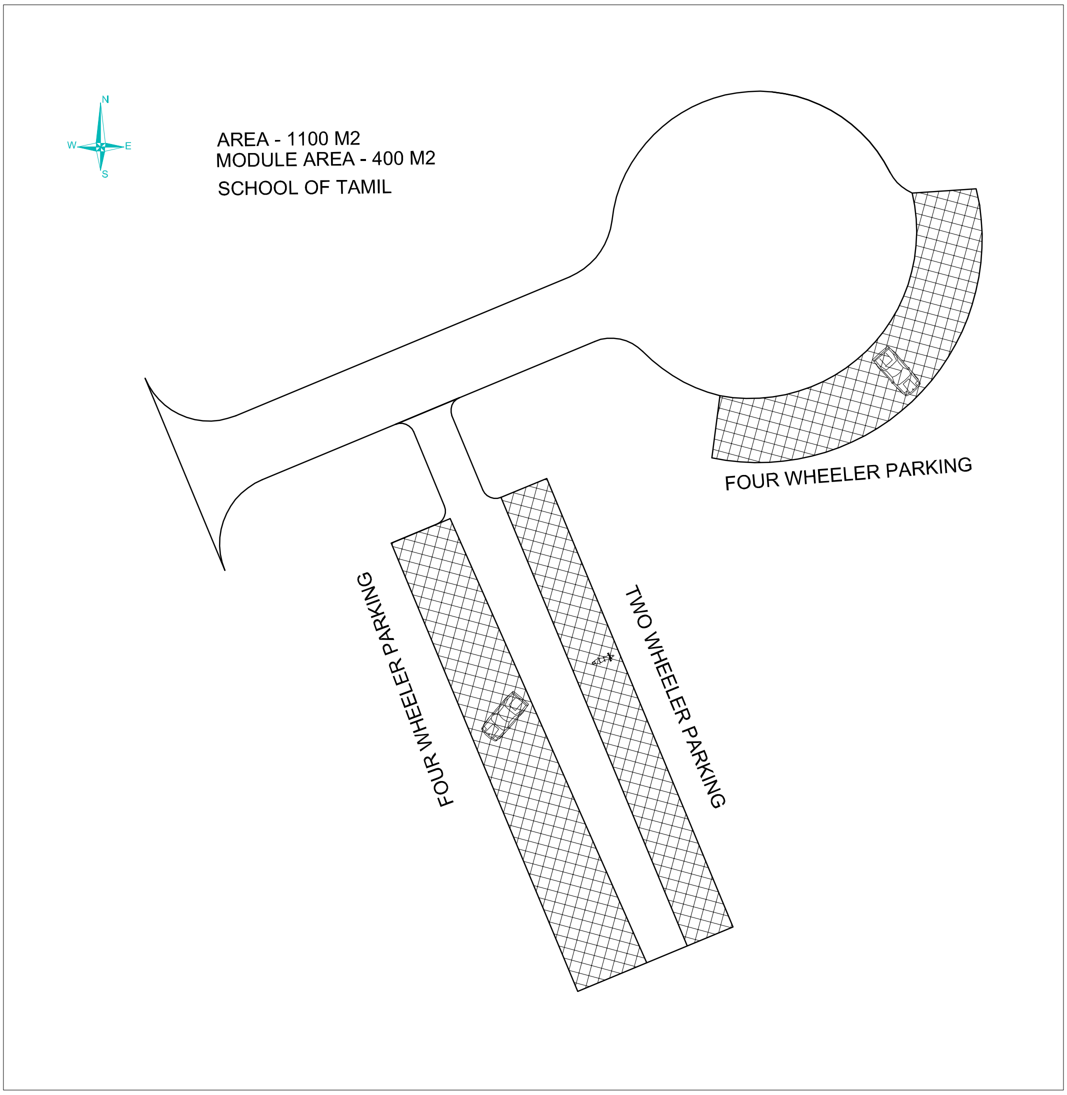
*15) Array layout drawing for 10kWp systems at school of Electronic media parking*



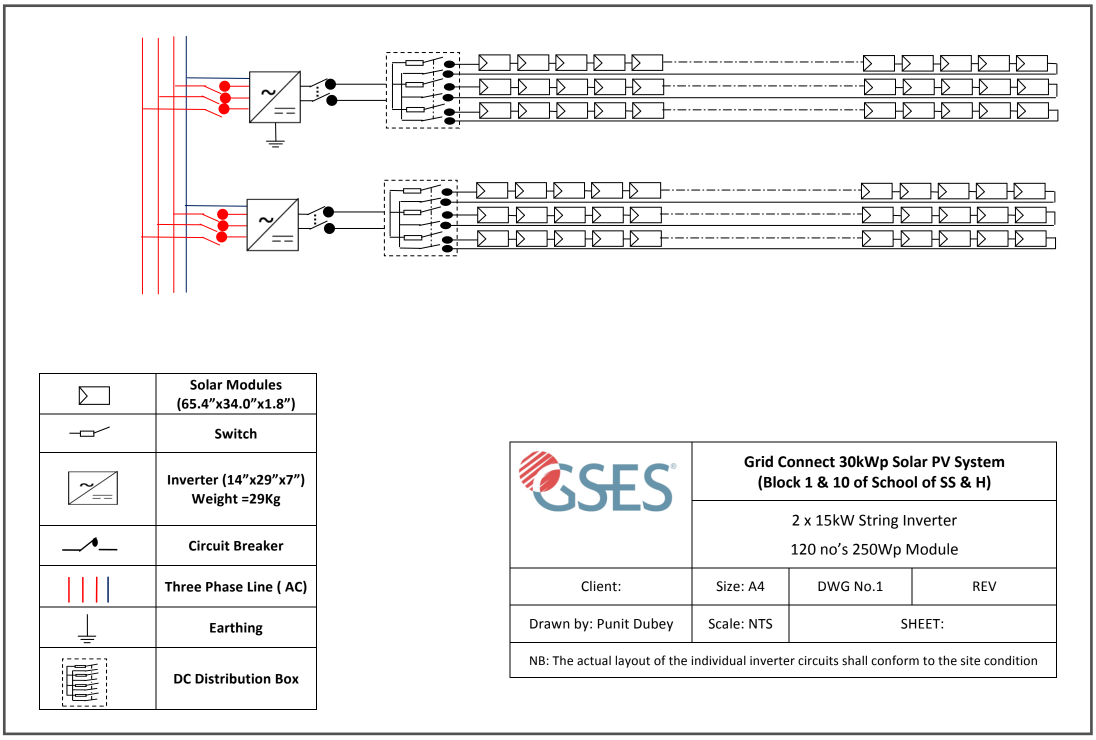
*16) Array layout drawing for 10kWp systems at Academic staff college*



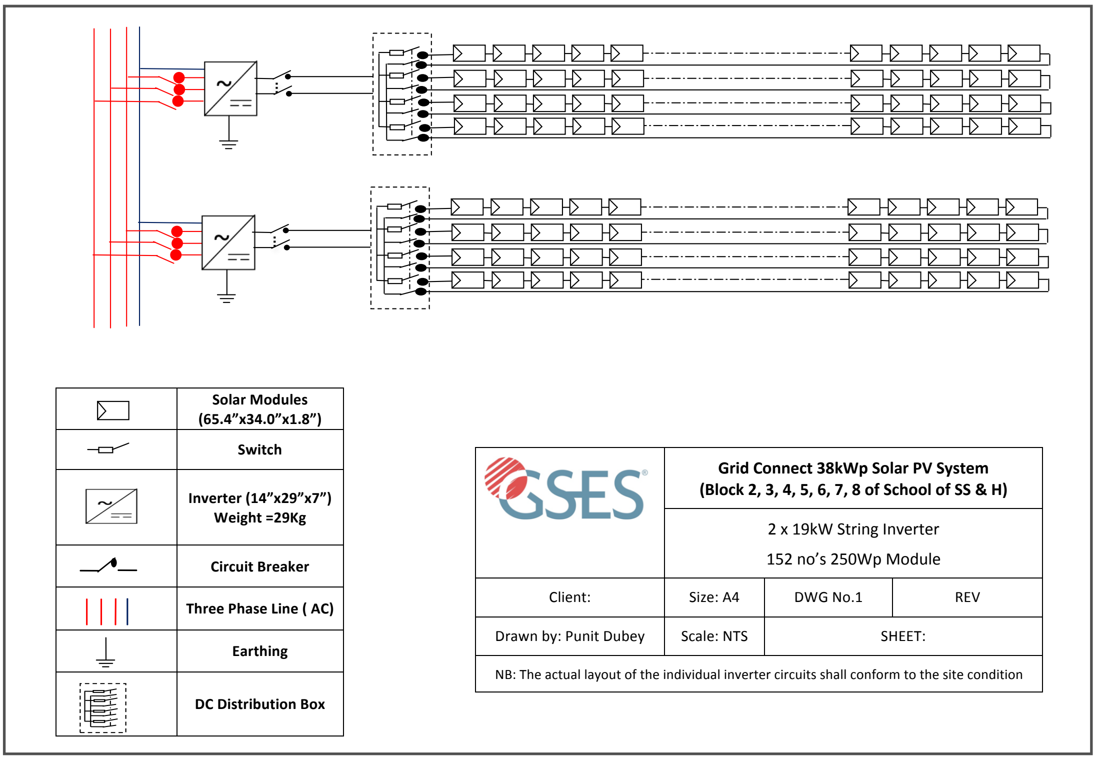
*17) Array layout drawing for 10kWp systems at School Tamil car park*



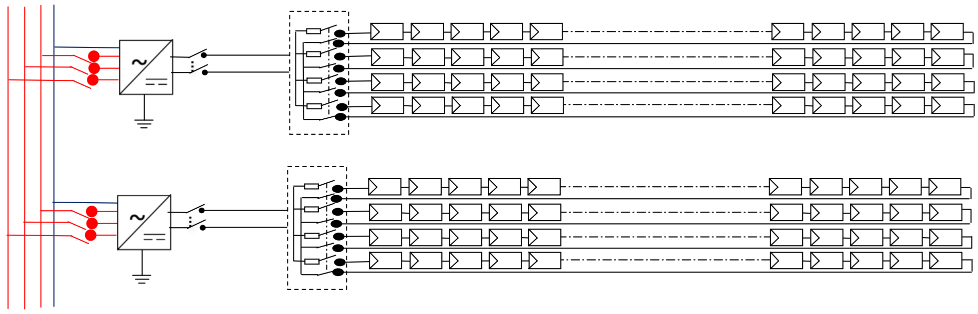
## 18) Electrical System layout for 30kW system




## 19) Electrical System layout for 38kW system



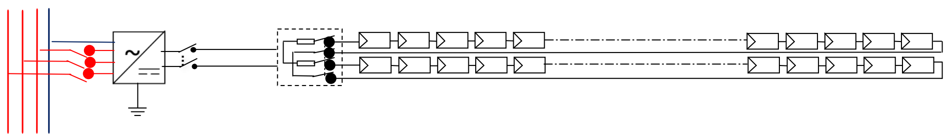
## *20) Electrical System layout for 40kW system*



| | |
|---|---|
| | **Solar Modules (65.4"x34.0"x1.8")** |
| | **Switch** |
| | **Inverter (14"x29"x7") Weight =29Kg** |
| | **Circuit Breaker** |
| | **Three Phase Line ( AC)** |
| | **Earthing** |
| | **DC Distribution Box** |

| GSES | **Grid Connect 40kWp Solar PV System (East, West, South and North side of Solar Ring)** | | |
|---|---|---|---|
| | 2 x 20kW String Inverter<br>160 no's 250Wp Module | | |
| Client: | Size: A4 | DWG No.1 | REV |
| Drawn by: Punit Dubey | Scale: NTS | SHEET: | |
| NB: The actual layout of the individual inverter circuits shall conform to the site condition | | | |

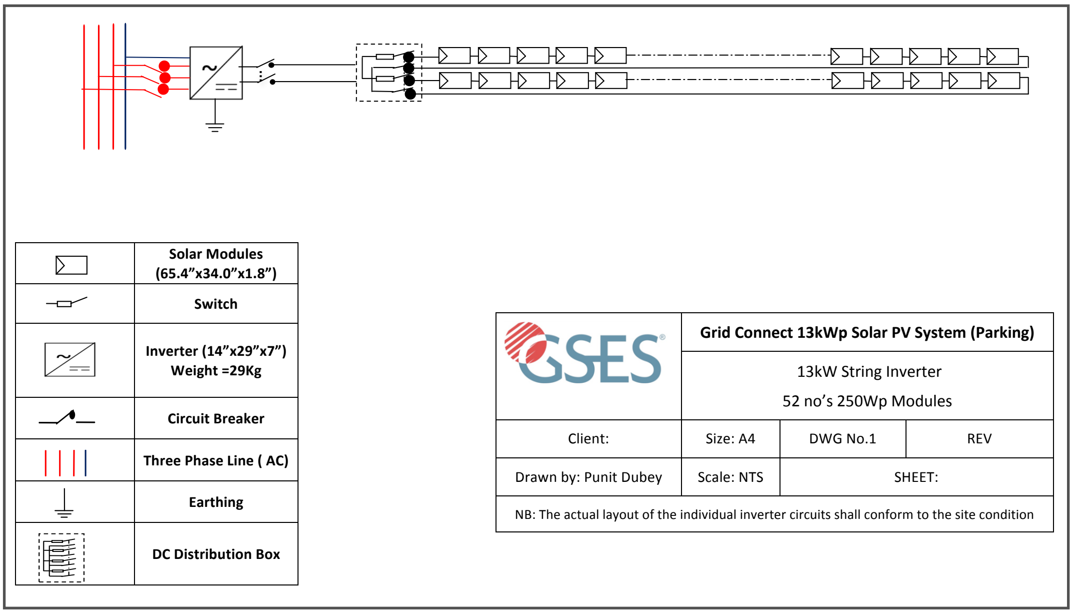
## *21) Electrical System layout for 10kW system*



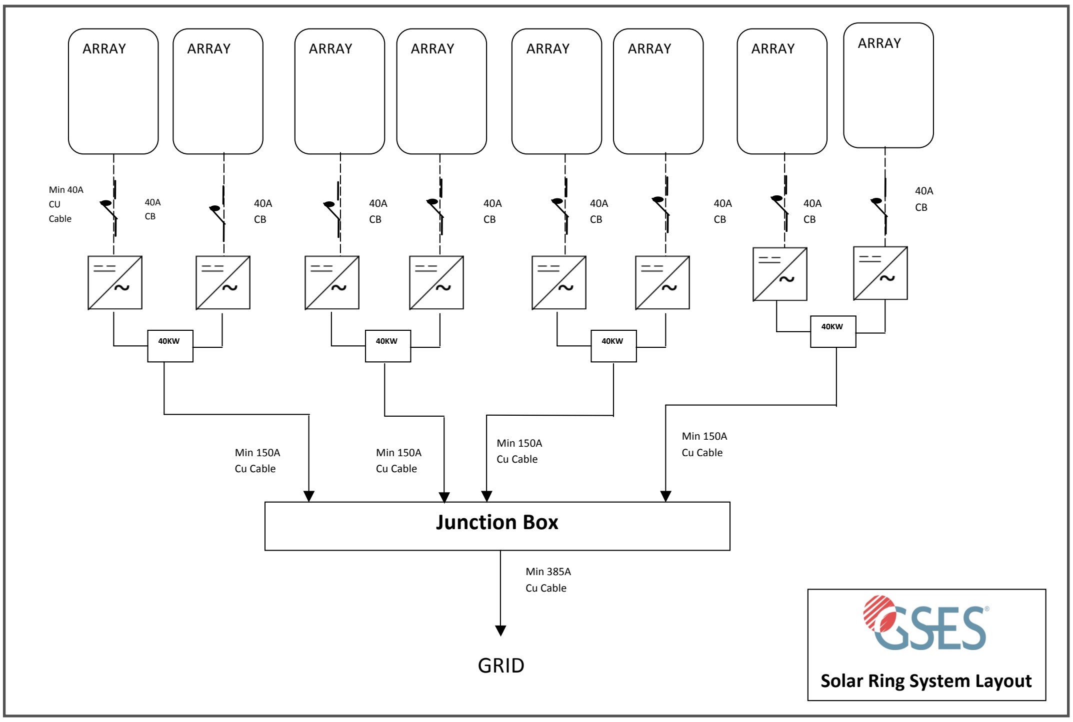
| | |
|---|---|
| | **Solar Modules (65.4"x34.0"x1.8")** |
| | **Switch** |
| | **Inverter (14"x29"x7") Weight =29Kg** |
| | **Circuit Breaker** |
| | **Three Phase Line ( AC)** |
| | **Earthing** |
| | **DC Distribution Box** |

| GSES | **Grid Connect 10kWp Solar PV System (Parking)** | | |
|---|---|---|---|
| | 10kW String Inverter<br>40 no's 250Wp Modules | | |
| Client: | Size: A4 | DWG No.1 | REV |
| Drawn by: Punit Dubey | Scale: NTS | SHEET: | |
| NB: The actual layout of the individual inverter circuits shall conform to the site condition | | | |

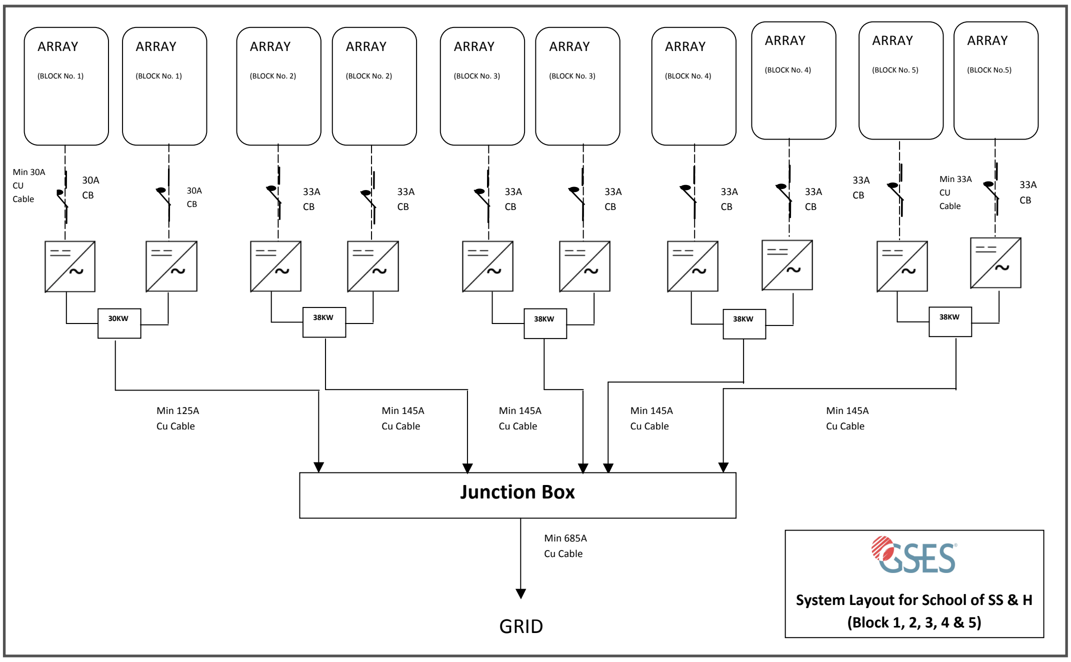
## 22) Electrical System layout for 13kW system



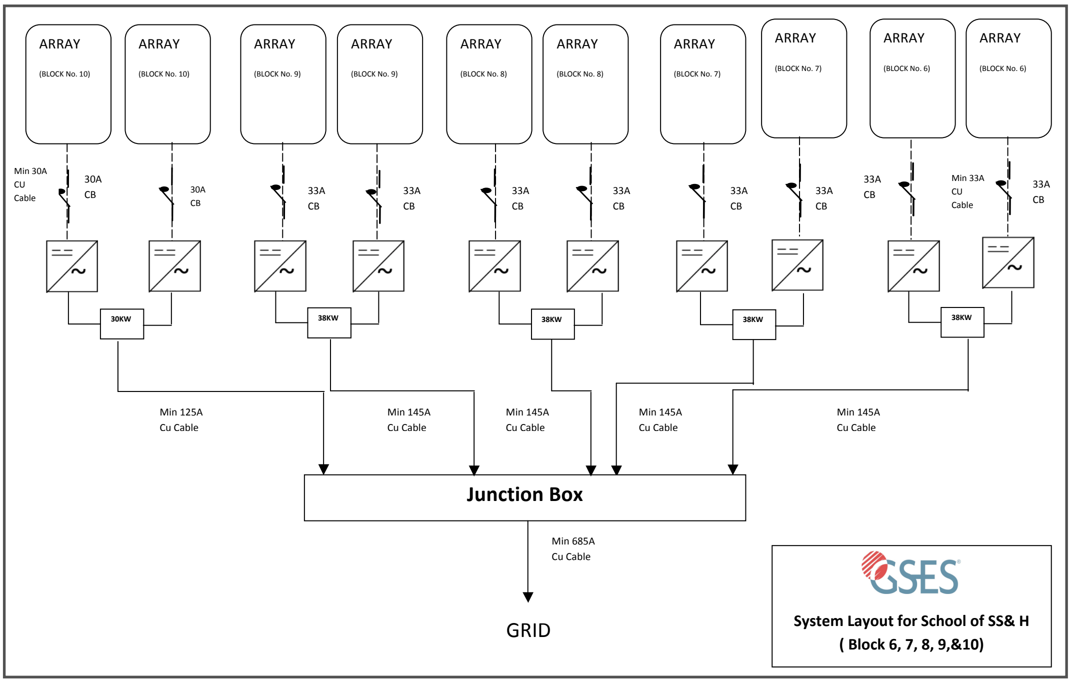

## 23) 160kWp PV System Layout for Solar Ring at inner circle landscape



*24) 182kWp PV System Layout for Block No. 1, 2, 3, 4, & 5 of School of SS & H*




*25) 182kWp PV System Layout for Block No. 6, 7, 8, 9, & 10 of School of SS & H*



### *7.1.6 Technical Specifications of PV System*

The proposed 620kWp grid interactive PV power plants will have the following equipments and accessories. Apart from the specifications/ criteria mentioned below, all technical requirements as per national and international standards, electrical codes and safety standards will be followed.

*Solar PV Array*

PV modules guaranteed with more than 80% of minimum rated power for 25 years of suitable nominal voltage and peak power rating and certified by IEC or UL standards will be used. Modules must be supplied with a manufacturer warrantee that fabrication is in compliance with at least one of the above-referred standards and guaranteed with more than 80% of minimum rated power for 25 years with not more than 1% degradation over a period of one year. In addition, PV modules must qualify to IEC 61730 for safety qualification testing. Many series-connected photovoltaic modules should easily be wired using preassembled solar cables and multi-contact plugs.

*Inverter and Control*

Grid interconnection of PV systems is accomplished through the inverter, which converts DC power generated from PV modules to AC power used for ordinary power supply for electric equipments. It is also required to generate high quality power to AC utility system with reasonable cost. To meet with these requirements, up to date technologies of power electronics are applied for PV inverters. By means of high frequency switching of semiconductor devices with PWM (Pulse Width Modulation) technologies, high efficiency conversion with high power factor and low harmonic distortion power can be generated. The microprocessor based control circuit accomplishes PV system output power control. The control circuit also has protective functions, which provide safety grid interconnection of PV systems. The inverter output always follows the grid in terms of voltage and frequency. This is achieved by sensing the grid voltage and phase and feeding this information to the feedback loop of the inverter. Thus control variable then controls the output voltage and frequency of the inverter, so that inverter is always synchronized with the grid.

Software controlled Maximum Power Point Tracking (MPPT) techniques will be utilized in the control system to optimize the solar energy fed into the grid. The control system detects if the insolation level is above a predetermined value and the grid supply is within the pre-set limits in voltage and frequency, the inverter modules synchronise and connect to the grid supply and proceed to export the available solar energy. The control unit will automatically disconnect from the grid if the grid voltage or frequency moves out of its operating range. Also the unit will switch over to a low power sleep mode at night and during periods of low insolation and automatically wake up, when the insolation level rises above a pre-set point. Once the grid is back into its operating range, the inverter unit will synchronize and connect to the grid to export all the available energy generated by the PV array. The inverter will be based on power MOSFET/IGBT transistors with very low resistance in the output stage and a toroidal transformer with ultra-low hysteresis losses and also provide galvanic insulation between the DC and AC side.

Inverters should be selected based on industry standards and MNRE equipment guidelines. Inverters communicating over Ethernet protocols and uploading performance data to websites are also available; these allow the system owners to view and track energy production.

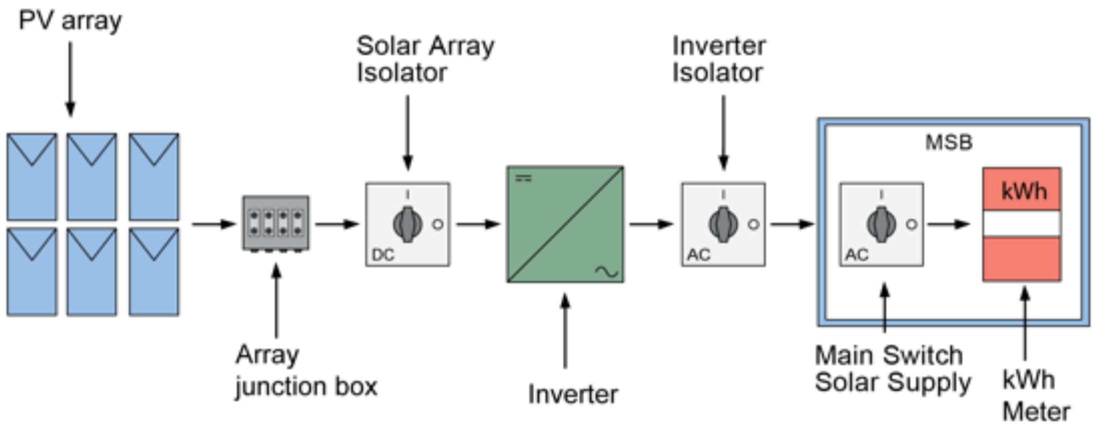



*Figure 31: Schematic of typical grid interactive PV power plant*

The inverter will have the following features:

- Typically conversion efficiency of the PCU is >95%.
- No-load loss <1% of rated power
- Wide range of Grid voltage & frequency parameters for synchronization
- Sinusoidal current modulation with excellent dynamic response,

- Optional VAR control
- Protection against - Over current, Sync loss, Over temperature, DC bus over voltage and Power regulation in the event of thermal overloading
- Set point pre-selection for VAR control
- Degree of protection-IP31
- Bus communication via -interface for integration
- Integrated protection in the DC and three phase system
- Ground fault detector - which is essential for large PV generators in view of appreciable discharge current with respect to ground.

*Monitoring and Display System*

The monitoring system shall have features for simultaneous monitoring and recording of various parameters of different sub-systems, power supply of the Power Plant at the DC side and AC side. This will enable monitoring the status of inverters to gather information on energy generation. Periodic reports of the plant's performance will be provided by the monitoring system. Remote data access will be provided through data module communication interface with web connect function for inverters.


*Figure 32: Typical display of data in SMA web-connect monitoring system*

*Array Support Structure*

Modules shall be mounted on a non-corrosive support structure suitable for site condition (extreme site conditions to be taken account) with facility to adjust tilt to maximize annual energy output. The structure will be designed for simple mechanical and electrical installation. It shall support SPV modules at a given orientation, absorb and transfer the mechanical loads to the ground properly. The frames and legs of the array structures shall be made of anodized aluminium or MS hot dip galvanized of suitable sections of angle, channel, tubes or any other sections as may deemed fit conforming to national/ international standards for steel structure to met the design criteria. Minimum thickness of galvanization should be at least 120 microns. All nuts & bolts will be made of very good quality stainless steel. The minimum clearance between the lower edge of the modules and the developed ground level shall be 800 mm. The array structure shall be so designed to withstand storm condition with wind speed up to maximum 180Kmph.

It is suggested that modules shall be mounted on extruded aluminium rails (Extruded Aluminum EN-AW-6063 T6 or equivalent) directly fixed to the roof/ terrace floor with the help of stainless steel hooks (Stainless steel X5CrNi18-10 A2-70 or equivalent). The structure will be designed for simple mechanical and electrical installation to absorb and transfer the mechanical loads to the roof structure and ground subsequently.

*Cables and Accessories*

The size of the cables module/array interconnections, array to junction boxes and junction boxes to PCU etc. shall be selected to keep the voltage drop and losses to the minimum. All cables shall be PVC insulated with appropriate grade conforming to IS 694:1990/equivalent. Underground cables shall be laid direct in ground at a depth of 500mm in the excavated trenches along the approved route and covered with sand cushion. A continuous single brick protective layer of first class brick shall be placed over the entire length of the underground cable before refilling the trench with loose soil. Underground cables wherever applicable shall be laid inside class-B GI pipes of suitable size under road crossings, drains, sewerage lines, entry of exit points of the buildings or where there are chances of mechanical damage. Only terminal cable joints shall be accepted. No cable joints to join two cable ends shall be accepted. Cables inside the control room shall be laid in suitable Cable Trays of approved type.

Only bright-annealed 99.97% pure bare copper conductor wires which offers low resistance, lower heating and of reputed make shall be used. Cable terminations shall be made with suitable cable lugs & sockets etc., crimped properly and passed through brass compression type cable glands at the entry & exit point of the cubicles. The panel's bottoms should be properly sealed to prevent entry of snakes / lizard etc., inside the panel. All cable/wires shall be marked with good quality letter and number ferrules of proper sizes so that the cables can be identified easily.

### *Junction Boxes*

Three types of Junction Boxes will be used in the power plant,

- Array Junction Box
- Sub Main Junction Box
- Main Junction Box

The junction boxes shall be dust, vermin, and waterproof and made of metal or thermoplastic. The junction boxes will have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and out going cables or alternatively the modules may be provided with connector cables. Each Array Junction Box will have Suitable Reverse Blocking Diodes of maximum DC blocking voltage of 1000 V with suitable arrangement for its connecting. The Array junction Box will also have suitable surge protection such as MOV devices.

### *DC Distribution Board*

DC distribution board is used to connect all the main junction boxes, which in turn is connected to the solar modules through sub main & array junction boxes.

### *Monitoring and Display System*

The monitoring system shall have features for simultaneous monitoring and recording of various parameters of different sub-systems, power supply of the Power Plant at the DC side and AC side. This will enable monitoring the status of inverters to gather information on energy generation. Periodic reports of the plant's performance will be provided by the monitoring system. Remote data access will be provided through a secure login on a website. The data acquisition system will measure and record continuously the following parameters:

- Ambient Air Temperature near Array Field
- Control Room Temperature
- Module Back Surface Temperature
- Wind Speed at the level of Array Plant
- Solar Radiation incidental to Array Plant
- Inverter Output
- System Frequency
- DC Bus output
- Energy delivered to the GRID in kWh.

### *7.1.7* Safety System

*Islanding*

The condition of a Distributed Generation (DG) generator continuing to power a location even though power from the Electric utility is no longer present is termed a "islanding". The situation may cause an electrical shock hazard to service personnel operating on the islanding network section while it has been supposedly shut down, by separating it from the main power station. Islanding can be dangerous to Utility workers, who may not realize that the utility is still powered even though there's no power from the Grid. For that reason, Distributed Generators must detect Islanding and immediately stop producing power.

To prevent islanding, the Power Conditioning Unit has to disconnect quickly (within a few second) in response to failures on the immediate distribution line. To provide this safety function, voltage, frequency and current have to be monitored and in case of exceeding the limit, the system has to trip. A disconnect switch which is accessible to only utility people is recommended. When the power plant is disconnected from the Grid it will supply power for captive use.

*Lightning and Over Voltage Protection*

The SPV Power plant shall be provided with Lightning and over voltage protection connected to proper earth mats. The main aim of over voltage protection is to reduce the over voltage to a tolerable level before it reaches the PV or other sub-system components. The source of over voltage can be lightning or other atmospheric disturbance. The Lightning Conductors shall be made as per applicable Indian or International Standards in order to protect the entire Array Yard Lightning stroke. Necessary concrete foundation for holding the lightning conductor in position will be made.

The lightning conductor shall be earthed through flats and connected to the Earth mats as per applicable Indian/International Standards with earth pits. Each Lightning Conductor shall be fitted with individual earth pit as per required Standards including accessories, and providing masonry enclosure with cast iron cover plate having locking arrangement, watering pipe using charcoal or coke and salt.

*Earthing System*

Each Array structure of the SPV Yard shall be grounded properly. The array structures are to be connected to earth pits as per Indian/International standards. Necessary provision shall be made for bolted isolating joints of each earthing pit for periodic checking of earth resistance. The earth conduction shall run through appropriate pipes partly buried and partly on the surface of the control room building. The complete earthing system shall be mechanically & electrically connected to provide independent return to earth.

### *7.1.8 Codes and Standards*

All equipments of the PV power plant shall conform to international standards including IEEE for design and installation of grid connected PV system. The standards cover various aspects such as PV modules, cable types and selection, temperature considerations, voltage ratings, BOS wiring, inverter wiring, blocking diodes, bypass diodes, disconnect devices, grounding requirements, surge and transient suppression, load centre, power qualities, protection features and safety regulations. The following codes and standards will be followed while constructing the power plant:

- IE Rules for design of the electrical installation
- National Electrical NFPA 70-1990(USA) or equivalent national standard
- National Electrical Safety Code ANSI C2 -1990(USA) or equivalent national standard
- IEEE 928 - 1986: Recommended criteria for terrestrial PV Power Systems
- IEEE 929 – 1988: Recommended practice for utility interface or residential and intermediate PV systems
- IEC 61215: Standard for crystalline silicon PV Modules
- IEC 61646: Standard for thin film PV Modules
- IEC 61730: PV modules must qualify for safety qualification testing
- IEC 61701: For modules to be used in highly corrosive atmosphere

### *7.1.9* **Energy Metering**

PCU and lines will be provided with microprocessor based ABT compliant trivector meters to record energy. The accuracy class of energy meters will be of suitable class. The lines will be provided with main and check meters. The meter will be capable of metering active & reactive energies both import and export. The meter will indicate maximum demand by integrating the energy for the pre-set period. The meter will register maximum demand in separate pre-set periods of the day with provision for recording of tamper/ abnormal events with date and time stampings in its non-volatile memory.

### *7.1.10 Construction Schedule*

The scheduled commissioning period of the power plant is 6 months from the date of approval from the concerned authority.

| Sl. No. | Activities | Progress Months | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Procurement Process (After approval) | | | | | | |
| 2 | Site survey & Engineering design | | | | | | |
| 3 | Erection of array mounting Structures | | | | | | |
| 4 | Module mounting and cabling | | | | | | |
| 5 | Installation of Power Conditioning Unit | | | | | | |
| 6 | Testing and commissioning | | | | | | |

### *7.1.11 Operation And Maintenance*

The operation of solar power plant is relatively simple and restricted to daylight hours in a day. With automated functions of inverter and switchyard controllers, the maintenance will be mostly oriented towards better up keep and monitoring of overall performance of the system. The solar PV system requires the least maintenance among all power generation facility due to the absence of fuel, intense heat, rotating machinery, waste disposal, etc. However, keeping the PV panels in good condition, monitoring and correcting faults in the connected equipment and cabling are still required to get maximum energy from the plant. A maintenance schedule needs to be planned as per service/ guarantee terms of supplier to maintain optimum availability of plant at all times.

The maintenance functions of a typical solar PV power plant can be categorised as given below.

*Day to day maintenance checks*

- Ensure security of the power plant
- Monitor power generation and export

- Monitor load centre wise power generation values to detect any abnormality
- Entry of unauthorised person, stray animal or migration of birds at the site
- Healthiness of fencing and loss of any material from site

*Weekly maintenance checks*

- Inspection of PV panel glass surface clean / wash solar PV panels to free from dust and other dirt like bird's dropping etc.

*Monthly maintenance checks*

- Removal of weeds and grass below PV panels and pathways if any
- Inspection of solar PV modules and arrays for any damage
- Check the power terminals for corrosion and proper torque, clean and apply anti-oxidant jelly, if necessary

*Half yearly maintenance checks*

- Check all the wiring for physical damage and for any sign of excessive heating
- Check all the junction boxes for proper covering and sealing
- Check the fasteners of Solar PV panel mounting structure and array for proper torque and tightening

*Annual maintenance checks*

- Check for discoloration of solar PV cells
- Check all the connections and ensure that they ate not loose
- Verify the array output for $V_{oc}$, $I_{sc}$, $V_{mpp}$, & $I_{mpp}$ for any sign of deterioration
- Insulation characteristic checking for the transformer oils
- Checking corrosion, cleaning and painting switch yard structures
- Checks and cleaning of drains and cable trenches in switch yard
- Checking barbed wire fencing for damages and rectifications

### 7.1.12 Project Cost Estimation

The project cost is estimated based on present Indian and global PV market situation and data available with the consulting engineers and the prevailing prices of materials. The project cost presented here covers all costs for complete execution of the project including all system hardware, insurance, civil and electrical works, installation and commissioning, contingencies and 5 years of annual maintenance. The project cost inclusive of all as mentioned above will be Rs.866.14 lakh. Breakup of project cost is given below.

*Table 18: Breakup of project cost for PV systems*

| Sl. No. | Particulars | Unit | Qty. | Total (Rs. Lakh) |
|---|---|---|---|---|
| 1 | Systems Hardware | 110/Wp | 620kWp | 682.00 |
| 2 | Transportation and insurance | 2% | 620kWp | 13.64 |
| 3 | Civil works and electrical works | 8% | 620kWp | 54.56 |
| 4 | Installation and commissioning | 8% | 620kWp | 54.56 |
| 5 | Annual Maintenance for 5 years | 8% | 620kWp | 54.56 |
| 6 | Contingencies | 1% | 620kWp | 6.82 |
| 7 | Total project cost | | 620kWp | 866.14 |

### *7.1.13* Renewable Energy Certificate (REC) Mechanism

As per Central Electricity Regulatory Commission (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificates for Renewable Energy Generation) Regulations, 2010, grid connected Renewable Energy Generator are eligible trade Renewable Energy Certificates to the entities who are to fulfil Renewable Purchase Obligation (RPO) as per law. There shall be two categories of renewable energy certificates, viz., solar certificates issued to eligible entities for generation of electricity based on solar as renewable energy source, and non-solar certificates issued to eligible entities for generation of electricity based on renewable energy sources other than solar. The solar certificate shall be sold to the obligated entities to enable them to meet their renewable purchase obligation for solar, and non-solar certificate shall be sold to the obligated entities to enable them to meet their obligation for purchase from renewable energy sources other than solar.

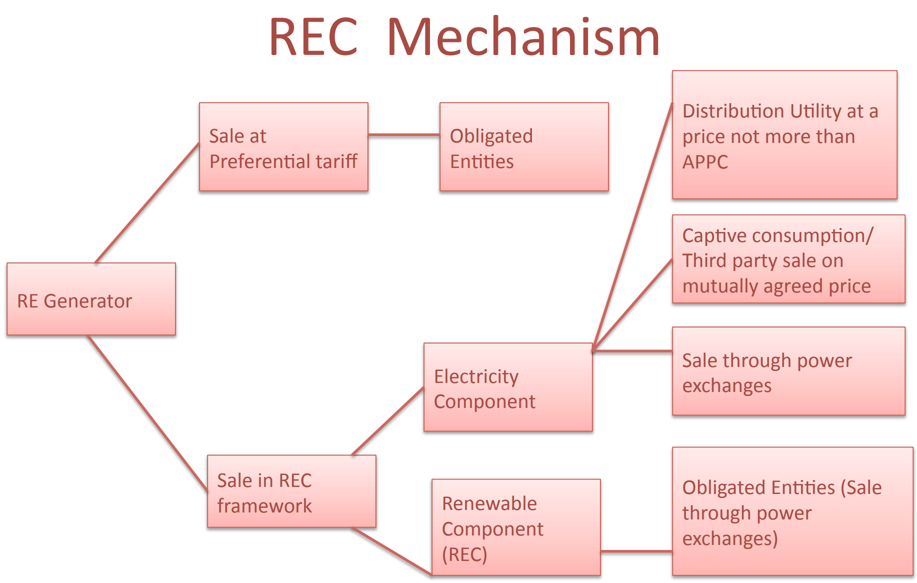



*Figure 33: Renewable Energy Certificate Mechanism*

A generating company engaged in generation of electricity from renewable energy sources shall be eligible to apply for registration for issuance of and dealing in Certificates if it fulfils the following conditions:

(i) It has obtained accreditation from the State Agency;

(ii) It does not have any power purchase agreement for the capacity related to such generation to sell electricity at a preferential tariff determined by the Appropriate Commission; and

(iii) It sells the electricity generated either (a) to the distribution licensee of the area in which the eligible entity is located, at a price not exceeding the pooled cost of power purchase of such distribution licensee, or (b) to any other licensee or to an open access consumer at a mutually agreed price, or through power exchange at market determined price.

*REC Price Range: 2012-2017*

| | Non-Solar REC (Rs/MWh) | Solar REC (Rs/MWh) |
|---|---|---|
| Forbearance Price | 3,480 | 13,690 |
| Floor Price | 1,400 | 9,880 |

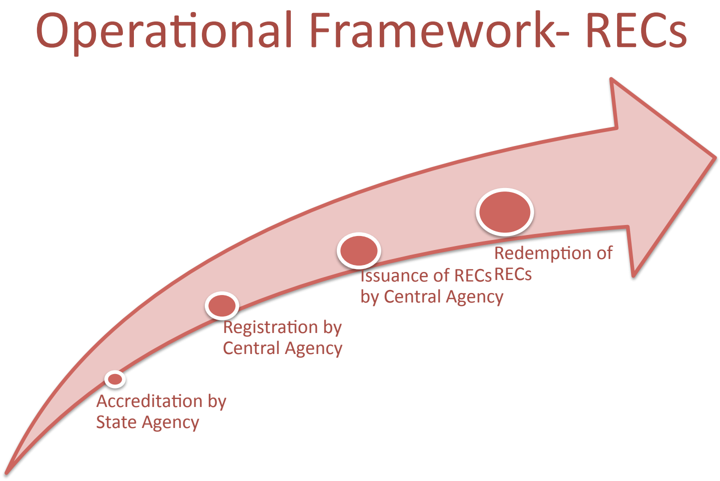



*Figure 34: Renewable Energy Certificate Operational Framework*

### *7.1.14* Cost Benefit Analysis

The 620kWp PV power plants will generate average 939.99 MWh of electricity per year, which will be directly used as captive power. The university will save Rs.36.66 lakh per year from the electricity savings from the grid @Rs.3.90 per unit. It is expected that solar PV systems will totally offset the use of diesel generators in the silver jubilee campus which will save estimated 11200 litres of diesel every year. In the financial model we have considered 5% annual escalation of electricity tariff, 10% annual escalation of diesel price, 5.72% escalation of O&M cost, 0.8% degradation of energy generation and 10% discount factor. Considering 30% subsidy from MNRE, the payback period is calculated as 12.10 years with an IRR of 9.54%.

If the university is not an obligated entity to purchase renewable energy, it can sale Renewable Energy Certificates (REC) as a renewable energy generator. In the previous section, we have discussed REC mechanism in details. Considering an average REC selling price of Rs.10.00 per unit of electricity generated by the PV power plant, university can sell REC worth of Rs.94.00 lakh per year in addition to saving electricity and diesel. It is considered that the REC price will depreciate @5% every year which is proportionate to escalation of electricity tariff. To register the project as under REC mechanism, university will not receive any subsidy or other benefit for the power plants. In this case, the payback period is 6.80 years only. Two scenarios of cost benefit analysis one with MNRE subsidy and other with REC benefit are presented in the table below.

*Table 19: Cost benefit analysis for PV systems*

| Sl. No. | Particulars | Scenario with MNRE Subsidy | Scenario with REC Benefit |
|---|---|---|---|
| 1 | Project Capacity | 620kWp | 620kWp |
| 2 | Procurement, construction & installation | 6 months | 6 months |
| 3 | Annual net power generation | 940MWh | 940MWh |
| 4 | Plant Load Factor | 17.31% | 17.31% |
| 5 | Electricity Tariff | Rs.3.90/ kWh | Rs.3.90/ kWh |
| 6 | Annual degradation | 0.8% | 0.8% |
| 7 | Annual escalation of electricity tariff | 5.0% | 5.0% |
| 8 | Diesel Savings @11200Litres/ year | Rs.5.94 Lakh | Rs.5.94 Lakh |
| 9 | Annual escalation of diesel price | 10.0% | 10.0% |
| 10 | Operation and maintenance | Rs.5.00Lakh | Rs.5.00Lakh |
| 11 | Escalation in O & M | 5.72% | 5.72% |
| 12 | Plant life assumed for depreciation | 25years | 25years |
| 13 | Total Project cost | Rs.866.14 lakh | Rs.866.14 lakh |
| 14 | MNRE Subsidy @30% | Rs.259.84 lakh | 0 |
| 15 | REC Sale Value | 0 | Rs.10,000/MWh |
| 16 | Depreciation of REC value | 0 | -5.0% |
| 17 | University share | Rs.606.30 lakh | Rs.866.14 lakh |
| 18 | Discount Factor | 10% | 10% |
| 19 | IRR | 9.54% | 15.83% |
| 20 | Project payback period | 12.10 years | 6.80 years |
| 21 | Average cost of electricity generation | Rs.3.55/kWh | Rs.3.55/kWh |

## 7.2 Detailed Project Report for Solar Water Heating System

### *7.2.1 Site Details*

Solar Water Heater is proposed in the canteen of the silver jubilee campus and the academic staff college. The canteen in the silver jubilee campus serves only hot beverages and snacks. Therefore hot water demand in the canteen is considerably low. A 500 LPD solar water heating system is considered to be suitable to meet the present demand.

The academic staff college has 30 guest rooms, which are used to accommodate guest attending different residential training programmes/ summer schools in the university. A solar water heating system of 1000LPD capacity proposed for the academic staff college to supply hot water to the guest rooms.

*Table 20: Solar water heating systems*

| Sl. No. | Location | Capacity | Collector Area |
|---|---|---|---|
| 1 | Academic Staff College | 1000 LPD | 20 sqm |
| 2 | Silver Jubilee Campus Canteen | 500 LPD | 10 sqm |
| | Total | 1500 LPD | 39 sqm |

*Figure 35: Academic Staff College Building in the Silver Jubilee Campus*

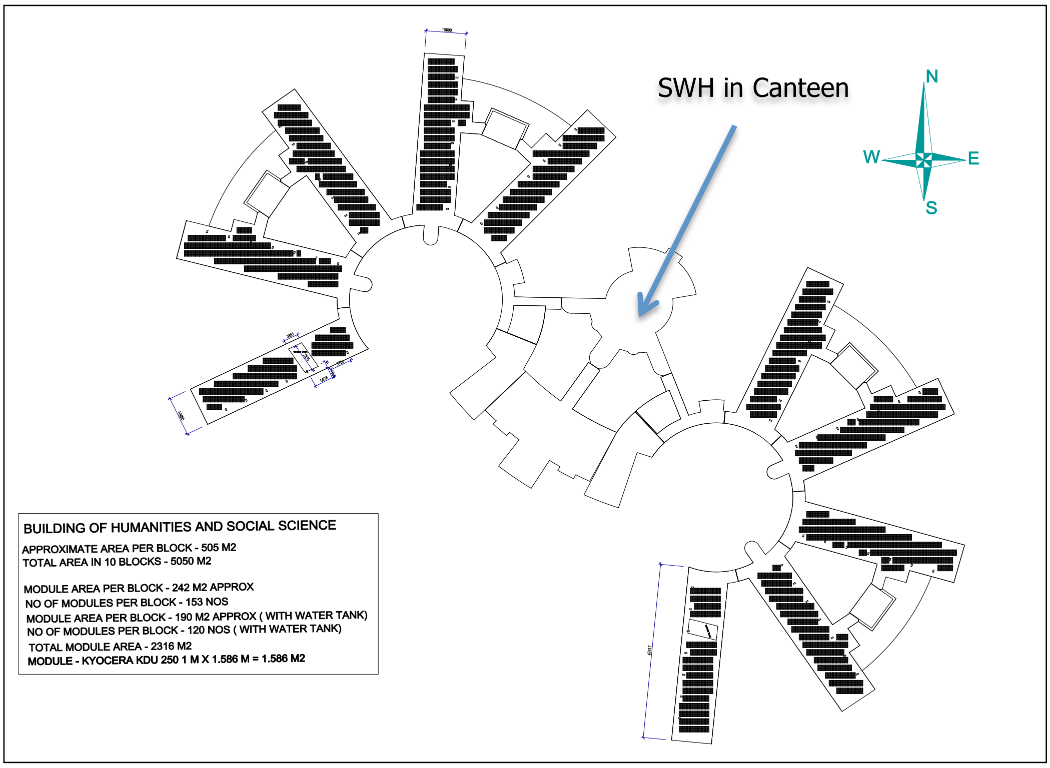



*Figure 36: Solar Water Heating System for canteen the School of SS & H Building*

### *7.2.2 Water Supply*

Both the locations have its own cold-water storage tanks and water is delivered to these storage tanks from independent water supply system at present. Storage tanks are installed on the roof where bathrooms/ kitchen are located. Water is reported to be good with less total dissolved solids (TDS).

### *7.2.3 Shading*

There are no such tall buildings, towers or tall trees around the sites. While preparing the site plan, positioning of the solar collectors, storage tanks, piping system and other control systems in such a way to avoid any shadow on the solar collector / reflector field. Effect of far shading is nil as the topography is flat.

### *7.2.4* **Existing system**

Presently hot water demand is met through electric geysers in the academic staff college and LPG in the canteen. Electric geysers are installed in all guest rooms in the academic staff college.

### 7.2.5 Performance Analysis

A performance analysis has been carried out for a typical 1000LPD system considering hot water demand for 30 guests based on available solar radiation in different months of the year. Mean hourly solar data form NASA –SSE has been used for the estimation of energy gain for the proposed solar water heating system. The results of the performance analysis are shown in the table below.

*Table 21: Performance analysis of solar water heating system*

| Months | Solar Radiation ($kWh/m^2/day$) | Average ambient temperature (deg C) | Total Energy Demand (kcal/ day) | Energy Gained from SWH (kcal/day) | Actual energy gained (kcal/day) |
|---|---|---|---|---|---|
| Jan | 5.00 | 24.4 | 46700 | 44290 | 44290 |
| Feb | 5.92 | 25.6 | 43400 | 50740 | 43400 |
| Mar | 6.76 | 27 | 37400 | 55642 | 37400 |
| Apr | 6.71 | 27.7 | 32000 | 53320 | 32000 |
| May | 6.15 | 29 | 28900 | 50568 | 28900 |
| Jun | 5.47 | 29.1 | 28300 | 46526 | 28300 |
| Jul | 5.09 | 28.6 | 30800 | 40936 | 30800 |
| Aug | 5.14 | 28.7 | 32000 | 39560 | 32000 |
| Sep | 5.34 | 28.1 | 33300 | 45322 | 33300 |
| Oct | 4.47 | 26.4 | 36300 | 49880 | 36300 |
| Nov | 4.05 | 25.2 | 40700 | 47644 | 40700 |
| Dec | 4.34 | 24.6 | 45300 | 42484 | 42484 |
| Average | 5.36 | 27 | 36258 | 47243 | 35823 |

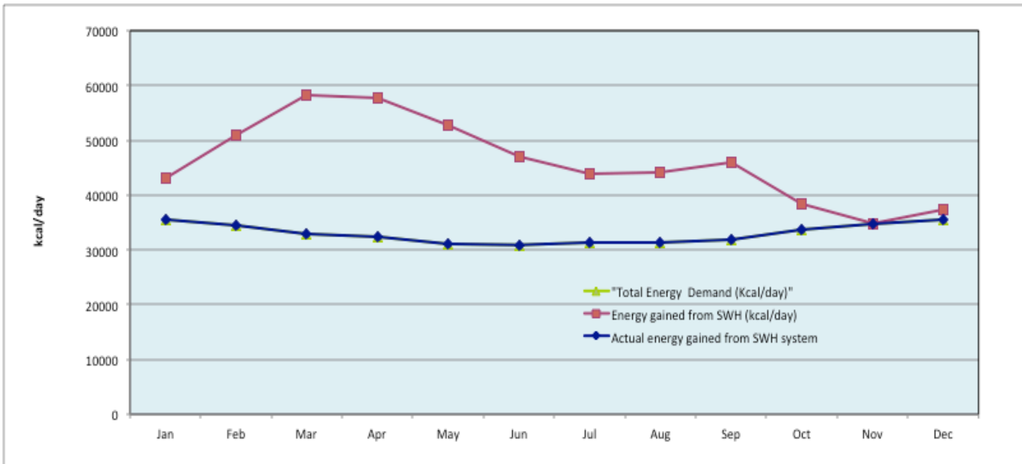



*Figure 37: Performance Model for typical 1000LPD Solar Water Heater system*

### 7.2.6 System Layout

A typical system integration layout for 1000 LPD and 500 LPD SWH system to the exiting water supply system has been shown in the Figures below.

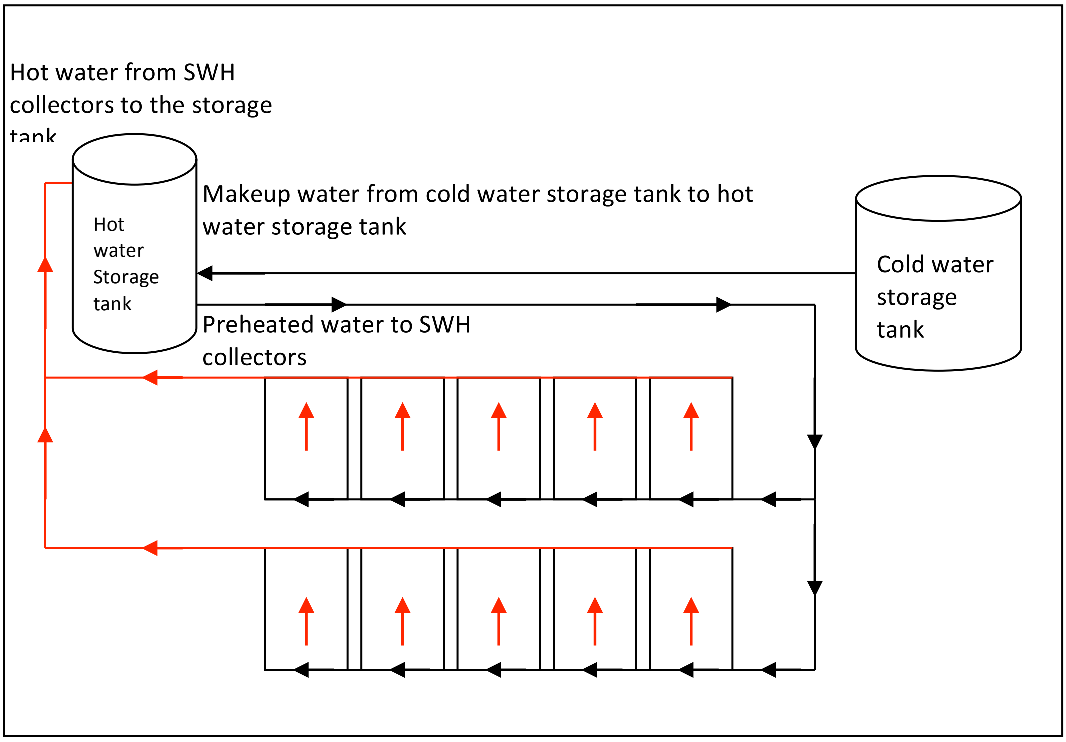



*Figure 38: An indicative layout for a typical 1000 LPD SWH system*

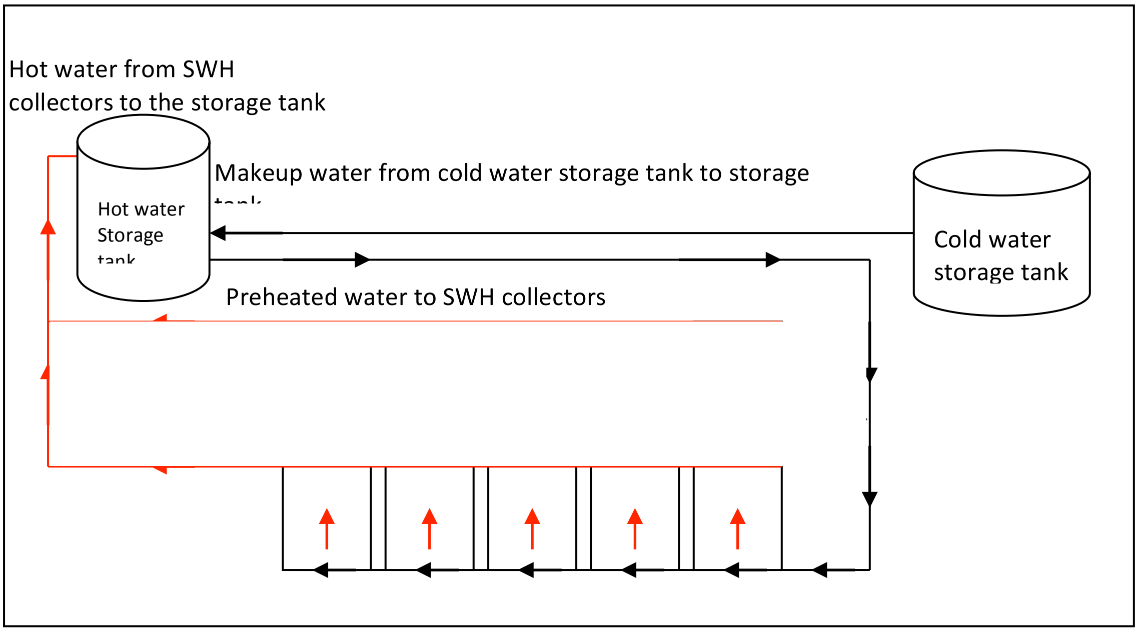



*Figure 39: An indicative layout for a typical 500 LPD SWH system*

### 7.2.7 Implementation Schedule

| Activities | Progress Weeks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Permission and Clearances | | | | | | | | |
| Engineering design & Drawings | | | | | | | | |
| Civil and structural work | | | | | | | | |
| Erection of Collectors & Storage tanks | | | | | | | | |
| Piping | | | | | | | | |
| Testing & Commissioning | | | | | | | | |
| Monitoring and Verification | | | | | | | | |

### 7.2.8 Operation and Maintenance

*Periodic Checks and Maintenance*

Regular and periodic maintenance is important for durable service life of any equipment. Solar water heater systems too need regular periodic maintenance for satisfactory service out of it. Typical maintenance requirements of solar water heating systems are mentioned below.

(i) Top glass cover is required to be cleaned periodically with soft water/DM water to allow the solar radiation to reach the absorber surface.

(ii) Look for any sign of leakages in the system, in the collector and plumbing joints and have these rectified early. Leaving leakages, unattended in insulated piping, results in corrosion of the pipes.

(iii) Check for the back-up elements/ thermostats every year before winter period and have these replaced if required.

(iv) Check for water flow in the hot water pipes after each summer. At times scale deposits chocks the hot water outlet. In such cases, the hot water outlet along with the heat exchanger needs to be cleaned.

(v) Check for physical conditions of supports. These may be required to paint periodically to avoid corrosion.

(vi) If water quality is bad and unsuitable for tank material, the tank may start leaking. Check for any leakages and report for changes/replacements.

(vii) Check for any construction in the neighbourhood or growth of trees which is causing a shadow on the collector.

(viii) Check for any damage to insulation cladding, it may require replacement /repair if damaged for any reason.

*Trouble shooting*

(i) Tank pressure is too high. This could be due to high filling pressure or vent / pressure release is not provided or not functioning properly.

(ii) Tank pressure is too low. This could be caused by leakage or loss of cold water supply.

(iii) Storage tank cools down very fast at night. This could be caused due to insulation of the tank got damaged.

(iv) Water does not heat sufficiently on clear days. This could be caused by dust on collectors, undersize system or damage to collector coating.

### *7.2.9* Technical Specification

*Table 22: Technical specifications of 1000LPD system*

| SI. NO | Description | Specification |
|---|---|---|
| **System Specification** | | |
| 1. | System capacity | 1000LPD |
| 2. | Solar collectors | Flat plate collector |
| 3. | Collector area | 20sqm |
| 4. | Operating principle | Active indirect heating system |
| 5. | Mode of circulation | Forced circulation |
| 6. | Medium | Propylene glycol + De-mineralized water |
| 7. | No of FPC collectors of 2 m2 | 10 Nos. |
| 8. | Storage tank capacity | 1000 Litres |
| 9. | Final temperature required | 60 Deg C |
| **Material of construction** | | |
| 10. | Tubes | SS 304/Copper |
| 11. | Heat exchanger (Finned) | Copper |
| 12. | Cover plate | Tempered/toughened glass |
| 13. | Fixtures | Galvanized Mild steel |
| 14. | Tank | SS304 |

| | | |
|---|---|---|
| 15. | Gasket material | Neoprene/EPDM/silicone rubber |
| 16. | Insulation | Rock wool, 150 mm thick/PUF |
| 17. | Cladding | Aluminum 22 gauge |

*Table 23: Technical specifications of 500LPD system*

| SI. NO | Description | Specification |
|---|---|---|
| **System Specification** | | |
| 1. | System capacity | 500LPD |
| 2. | Solar collectors | Flat plate collector |
| 3. | Collector area | 10sqm |
| 4. | Operating principle | Active indirect heating system |
| 5. | Mode of circulation | Forced circulation |
| 6. | Medium | Propylene glycol + De-mineralized water |
| 7. | No of FPC collectors of 2 m2 | 5 Nos. |
| 8. | Storage tank capacity | 500 Litres |
| 9. | Final temperature required | 60 Deg C |
| **Material of construction** | | |
| 10. | Tubes | SS 304/Copper |
| 11. | Heat exchanger (Finned) | Copper |
| 12. | Cover plate | Tempered/toughened glass |
| 13. | Fixtures | Galvanized Mild steel |
| 14. | Tank | SS304 |
| 15. | Gasket material | Neoprene/EPDM/silicone rubber |
| 16. | Insulation | Rock wool, 150 mm thick/PUF |
| 17. | Cladding | Aluminum 22 gauge |

### *7.2.10 Standard and Certification*

As per guidelines of the Jawaharlal Nehru National Solar Mission, the following standards and certification has to be followed to avail subsidy under the programme. All Solar Flat Plate Collectors should conform to the BIS standard as mentioned below:

a) IS 12933 (Part 1): 2003, Solar flat plate collector -Specification, Part 1- Requirements.
b) IS 12933 (Part 2): 2003, Solar flat plate collector -Specification, Part 2- Components.
c) IS 12933 (Part 3): 2003, Solar flat plate collector -Specification, Part 3- Measuring instruments.
d) IS 12933 (Part 5): 2003, Solar flat plate collector -Specification, Part 5- Test methods.

These Standards does not apply to concentrating & unglazed collectors and built-in-storage water heating systems.

(ii) For domestic size solar water heating systems based on thermo-siphon mode of operation, the Ministry has supported development of a test protocol with certain minimum performance requirements. In addition, the Ministry empanels manufacturers of solar water heating systems based on evacuated tube collectors.

(iii) There is a network of test centres in the country which is recognized by BIS for carrying out certification testing as per Indian Standards.
(iv) All solar thermal devices/ systems must be tested at one of these test centres.

### *7.2.11 Project Cost*

The estimated cost of one 1000LPD and one 500LPD solar heater will be Rs.4.52 lakhs including installation, commissioning, additional piping and civil work, augmentation and five years AMC etc. Expected subsidy from MNRE is Rs.1.36 Lakh (@30% of the SWH system cost).

*Table 24: Cost breakup of solar water heating systems*

| **Sl. No.** | **Description** | **Total Cost (INR. Lakhs)** |
|---|---|---|
| 1 | Cost of Systems Hardware | 3.45 |
| 2 | Cost of transportation and insurance | 0.10 |
| 3 | Cost of civil works and electrical works | 0.28 |
| 4 | Cost of installation and commissioning | 0.35 |
| 5 | Cost of Annual Maintenance for 5 years | 0.28 |
| 6 | Any other costs (Contingency) | 0.07 |
| **Total cost** | | **4.52** |

### *7.2.12 Cost Benefit Analysis*

It is estimated that use of 1000LPD capacity solar water heating system for 120 days in a year will save about 50MWh of electricity. This will save an amount of Rs.1.95 lakh per year @Rs.3.90 per unit of electricity. On the other hand, use of 500LPD capacity solar water heating system for 200 working days in the canteen will save 4.72 Giga Calorie of energy per year which will save about 465kg of LPG per year saving about Rs.36000.00 per year

*Table 25: Cost benefit analysis of solar water heating systems*

| | | |
|---|---|---|
| Electricity Savings by 1000 LPD SWH system | 50 | MWh/ year |
| LPG savings by 500 LPD SWH system | 465 | kg/year |
| Cost of electricity | 3.9 | INR/ kWh |
| Cost of LPG | 77.50 | INR/kg |
| Amount of electricity saved per year | 1.95 | Lakh/ year |
| Amount of LPG save per year | 0.36 | Lakh/ year |
| Total project cost for 1500LPD system | 4.52 | Lakh |
| MNRE subsidy (30%) | 1.36 | Lakh |
| Simple Payback period | 1.37 | Years |

## 7.1 Detailed Project Report for Small wind turbines

### *7.1.1 Site for Wind Turbines*

It is recommended that small wind turbines be installed in the east side of the periphery of the silver jubilee campus. Twenty turbines of 10.80 kW nominal capacity and 7.2m rotor diameter have been proposed. Total nominal capacity of mini wind farm will be 216kW. The generated energy will be fed into the campus grid.


*Figure 40: Placement of 20 nos. 10.8kW wind turbine in Silver Jubilee Campus*

### 7.1.2 Case studies

*Case Study 1*

A Wind solar hybrid system was installed at the Coimbatore bus stand to meet the basic electricity requirement of the complex. The electricity generation and monthly PLF from the wind turbine (2.7 KW) are given in the following table.

| Month | Wind (kWh) | PLF-Wind |
|---|---|---|
| June | 313 | 15% |
| July | 481 | 22% |
| August | 440 | 20% |
| Sept | 373 | 17% |
| Oct | 261 | 12% |
| Nov | 205 | 10% |
| Dec | 360 | 16% |
| January | 357 | 16% |
| **Average** | **349** | **16%** |

*Figure 41: The average PLF obtained from the Wind turbine is 16%*

*Courtesy: Coimbatore Municipal Corporation*

*Case Study 2*

The Wind Machine BC-200 was installed on the rooftop of the Park Guest House, Pondicherry which is located on the beach road at a hub height of 14.5m from sea level. The power curve was plotted based on the data as provided by the supplier, which was measured during Sept to October at 3 minutes interval. The machine cuts in at wind speed of 2.5m/s and attains a maximum production level of 20.35 W at a speed of 6.5m/s. The machine produces an average daily energy output of 0.18kWh at the location with the range varying between 0.16 and 0.21kWh.

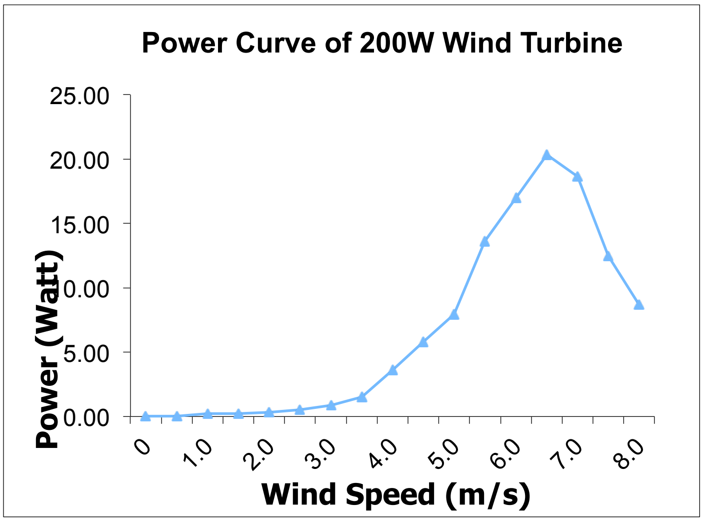



*Figure 42: Power Curve of 200W wind turbine installed at Park Guest House, Pondicherry*

*Courtesy: IT Power*

*Case Study 3*

The District Rural Development Agency in Pondicherry had set up a Wind-PV hybrid system at Chunnambar Resort, located close to Pondicherry. The daily energy requirement at the site is about 12 kWh/day and the annual energy requirement is around 4300 kWh. The annual estimated energy generation from the Wind-PV Hybrid system at Chunnambar Resort was around 5300 kWh (3347kWh from the Wind and 2007kWh from the Solar).

The project was implemented with an institutional arrangement involving the MNES, DRDA Pondicherry, IT Power India, UNITRON (the equipment supplier), and the Pondicherry Tourism and Transport Development Corporation (PT&TDC). MNES supported with financial assistance for the project.

| Wind speed | | | Model: W 3300 |
|---|---|---|---|
| Kmph | mph | m/s | |
| 8 | 5 | 2.2 | 26 |
| 9.6 | 6 | 2.7 | 60 |
| 11.2 | 7 | 3.1 | 110 |
| 12.8 | 8 | 3.6 | 174 |
| 14.5 | 9 | 4.0 | 252 |
| 16 | 10 | 4.5 | 341 |
| 17.7 | 11 | 4.9 | 437 |
| 19.3 | 12 | 5.4 | 538 |
| 21 | 13 | 5.8 | 640 |
| 22.5 | 14 | 6.3 | 740 |
| 24 | 15 | 6.7 | 836 |
| 25.7 | 16 | 7.1 | 926 |
| 27.3 | 17 | 7.6 | 1008 |
| 29 | 18 | 8.0 | 1080 |
| 30.5 | 19 | 8.5 | 1236 |
| 32 | 20 | 9.0 | 1480 |
| 33.7 | 21 | 9.4 | 1706 |
| 35.4 | 22 | 9.8 | 1972 |
| 37 | 24 | 10.2 | 2160 |
| 38.6 | 25 | 10.7 | 2246 |
| 40 | 26 | 11.2 | 2710 |
| 41.8 | 27 | 11.6 | 2865 |
| 43.4 | 28 | 12 | 3125 |

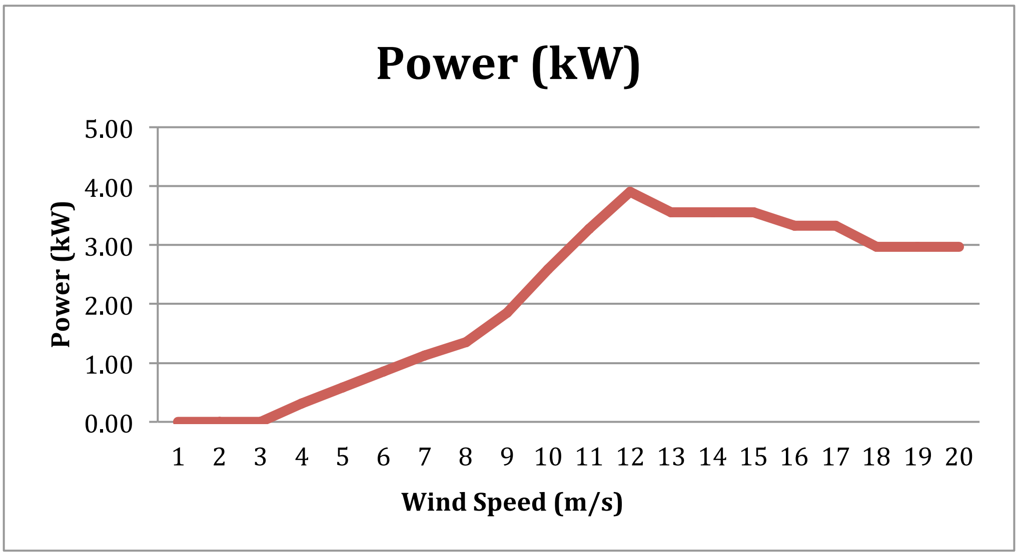



*Figure 43: 3.3kW Wind Turbine System at Chunamber Island, Pondicherry*

*Courtesy: IT Power*

### *7.1.3 Technical Specifications*

Following section describes the specifications of available small wind turbines in India. Turbines up-to 5 KW is suitable for installation on rooftops of buildings. Turbines of capacities 10KW-20KW can be placed on open land on towers of 20-30 m height. The cut-in speeds of 10-20 KW turbines are higher, but the loss in generation as compared to small wind turbines can have a trade-off owing to economies of scale. The table 26 below compares different small wind turbines available in India.

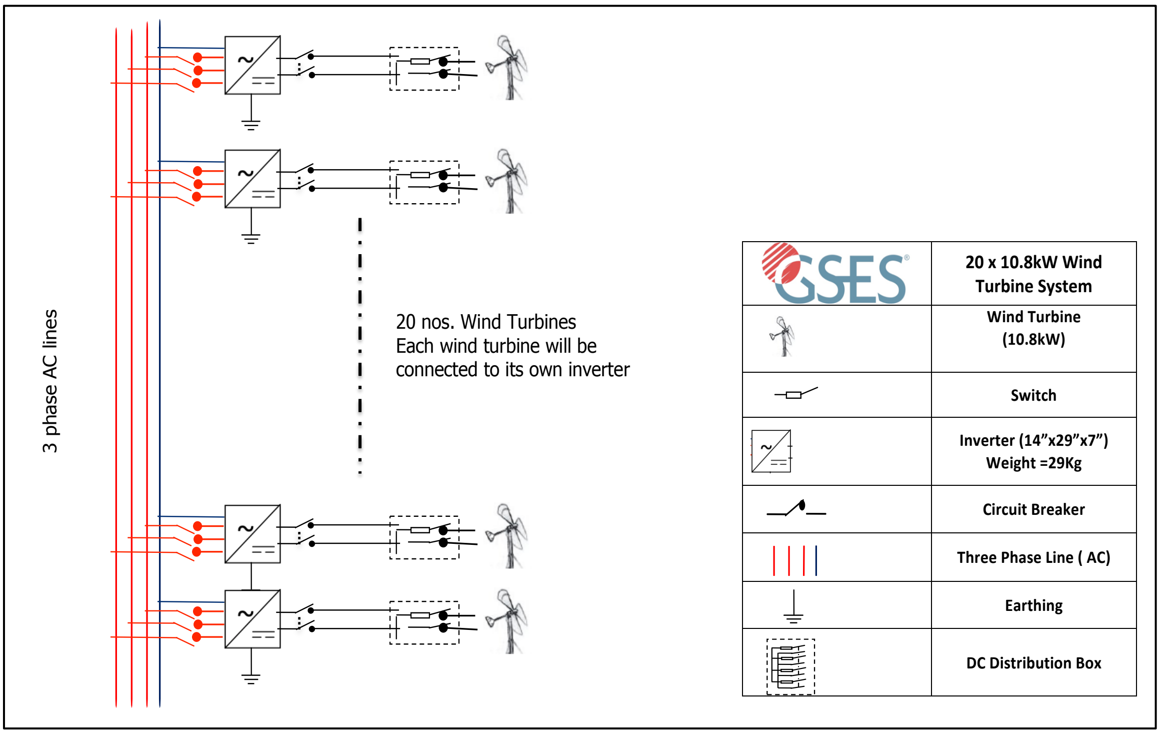



*Figure 44: 216 KW Mini Wind Farm Grid Connected System Schematic*

*Table 26: Technology Comparison of Small scale wind turbines*

| **Supplier** | **Luminous Renewable Energy** | **Luminous Renewable Energy** | **Luminous Renewable Energy** | **Luminous Renewable Energy** | **Unitron Energy systems** | **Unitron Energy systems** | **Alpha Power** | **Alpha Power** | **Machinor-craft energy systems** |
|---|---|---|---|---|---|---|---|---|---|
| Model | Skystream 3.7 | Air Breeze | Whisper 200 | Whisper 500 | UE 33 | UE 42 | AP 10.8 | AP 5.4 | |
| Rated Capacity | 2400 W | 160 W | 700 W | 3000 W | 3300 W | 4200 W | 10800 | 5400 | 20000 |
| Weight | 77 kg | 5.9 kg | 30 kg | 70 kg | 77 kg | 89 kg | 189 kg | 120 kg | |
| Rotor Diameter | 3.72 m | 1.17 m | 2.7 m | 4.5 m | 4.65 m | 4.9 m | 7.2 m | 6 m | 10 |
| Blade Material | Fibre glass reinforced composite | Injection-molded composite | Polypropylene/carbon glass reinforced | Carbon reinforced fiberglass | Carbon Fiber composite | Carbon Fiber composite | Carbon Composite Fibre | Carbon Composite Fibre | |
| Number of Blades | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Voltage | 120/240 VAC 50-60/Hz | 12, 24 and 48 VDC | 24, 36, 48 VDC (HV 120/240 available) | 24, 32, 48 VDC | 12 - 240 | 24 - 240 | 120 | 72 | 360 VDC |
| Braking System | Electronic stall regulation | Electronic torque control | Patented side-furling | Side-furling | Electro-dynamic | Electro-dynamic | | | |
| Cut-in Wind Speed | 3.5 m/s | 2.6 m/s | 3.1 m/s | 3.4 m/s | 2.7 | 2.7 | 3 | 3 | 3 |
| Rated Wind Speed | 9 m/s | 12 m/s | 12.8 | 10.5 | 10.5 | 11 | 6 | 6 | 12 |
| Survival Wind Speed | 63m/s | 49.2 m/s | 55 m/s | 55 m/s | 55 m/s | 55 m/s | 55 | 55 | |

### 7.1.4 Construction Schedule

| Sl. No. | Activities | Progress Months | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Procurement Process (After approval) | | | | | | |
| 2 | Site survey & Engineering design | | | | | | |
| 3 | Civil Engineering & Foundations | | | | | | |
| 4 | Erection of Turbines with Towers | | | | | | |
| 5 | Installation of Power Conditioning Unit | | | | | | |
| 6 | Testing and commissioning | | | | | | |

### 7.1.5 Project Cost

The estimated project cost for establishment of 216kW wind farm with small wind turbines is 462lakhs. The cost includes wind turbines, towers, inverters, switchgear, cables, civil and mechanical work, transportation, installation and commissioning.

*Table 27: Cost breakup of wind turbine project*

| Particulars | Amount (INR Lakh) | |
|---|---|---|
| 216 kW Wind Turbine | 320 | Lakhs |
| Towers | 20 | Lakhs |
| Grid tie Inverter | 30 | Lakhs |
| Fiber glass Canopy | 8 | Lakhs |
| Misc. switch gear / cabling | 20 | Lakhs |
| Civil works for tower etc. | 10 | Lakhs |
| Transportation | 4 | Lakh |
| Installation and Commissioning | 41 | Lakhs |
| Contingency | 9 | Lakhs |
| Total | 462 | Lakhs |
| MNRE subsidy @Rs.1.20 Lakhs/kW | 259 | Lakhs |
| University share | 203 | Lakhs |

### *7.1.1 Cost Benefit Analysis*

MNRE provides capital subsidy for installation of small wind turbines. Present MNRE subsidy is Rs.1.50 Lakh per kW. However, MNRE is likely to revise the subsidy @Rs.1.20Lakh/kW as reported by the MNRE channel partner. Since floor and forbearance price for wind (non-solar) REC (Rs.1.40 and Rs.3.48 respectively per unit) is much lower than the solar REC, benefit for small wind turbines is not attractive in comparison to direct subsidy. Both the scenarios have been presented below.

*Table 28: Cost benefit analysis scenarios for wind turbine project*

| Sl. No. | Particulars | Scenario with MNRE Subsidy | Scenario with REC Benefit |
|---|---|---|---|
| 1 | Project Capacity | 216 kW | 216 kW |
| 2 | Procurement, construction and installation | 6 Months | 6 Months |
| 3 | Annual net power generation from the project | 378MWh | 378MWh |
| 4 | Plant Load Factor | 20% | 20% |
| 5 | Electricity Tariff | Rs.3.90/kWh | Rs.3.90/kWh |
| 6 | Annual degradation | 0.8% | 0.8% |
| 7 | Annual escalation of electricity tariff | 5.0% | 5.0% |
| 8 | Diesel Savings per year | Rs.1.78 lakh | Rs.1.78 lakh |
| 9 | Annual escalation of diesel price | 10.0% | 10.0% |
| 10 | Operation and maintenance per year | 5.0 lakh | 5.0 lakh |
| 11 | Escalation in O & M | 5.72% | 5.72% |
| 12 | Plant life assumed for working of depreciation | 15years | 15years |
| 13 | Total Project cost | Rs.462 lakh | Rs.462 lakh |
| 14 | MNRE Subsidy @ Rs.1.20Lakhs/kW | Rs.259 lakh | 0 |
| 15 | REC Sale Value | 0 | Rs.2440/MWh |
| 16 | Depreciation of REC value | 0 | -5.0% |
| 15 | University Share | Rs.203 lakh | Rs.462 lakh |
| 16 | IRR | 8.13% | 6.08% |
| 17 | Project payback period | 13.25years | 15.04years |
| 18 | Average cost of electricity generation | Rs.9.33/kWh | Rs.9.33/kWh |

## 7.2 Water Harvesting

Annual normal rainfall (30 years average) in Puducherry is 1338mm[2]. However, IMD data for the period 2007-11 shows average 1623mm rainfall during that period. The total roof area of the silver jubilee campus buildings (already constructed) is 6500sqm. It is estimated that using rooftops all these buildings more than 8 million cubic meter of water can be harvested per year. The rainwater falling on the roofs can be conveyed to the storage reservoir via a series of gutters and pipes.

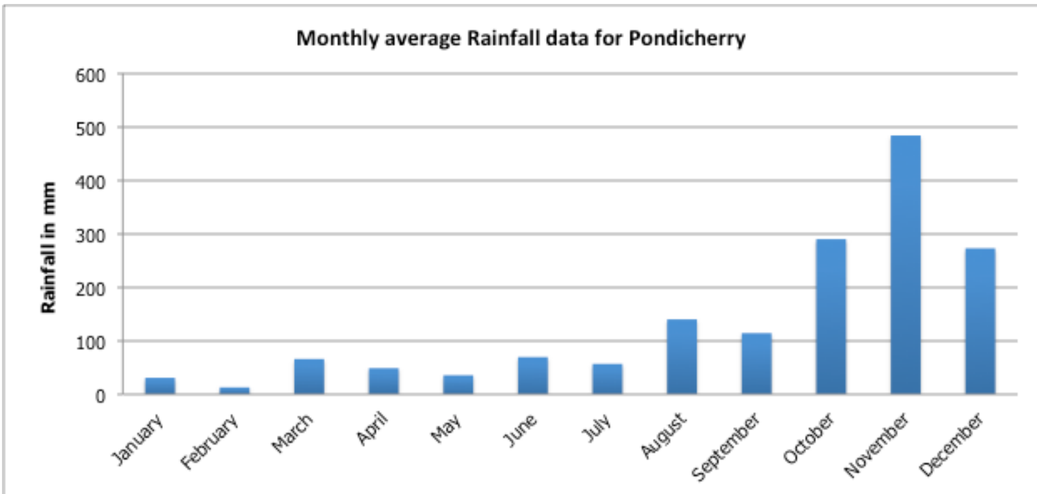



*Figure 45: Monthly average rainfall in Pondicherry*

The terraces of the buildings are flat and well guarded which is ideal for water rainwater harvesting. Assuming 80% collection efficiency, maximum water harvesting potential is 25.35 lakh litres during the month of November when the monsoon is at its prime.

| |
|---|
| Rainwater Captured ($m^3$) =Rainfall (mm/1000)× Collection Surface Area ($m^2$) × Collection Efficiency (assumed 80%) |

Monthly rainwater harvesting potential is shown in the table below. The reservoir has to be designed to balance the quantity of water harvested during the rainy

[2] *Source: PWD, Pondicherry*

season and the costs associated with the construction of this tank. Reservoir should be designed so that the elevation of its maximum water level is slightly below the elevation of the buildings. Typically, a drop in elevation of 1 vertical foot for every 100-300 horizontal feet is used. The harvested water will primarily be used for non-potable functions such as garden watering, general cleaning and toilet flushing. Such collected and treated water accounts for considerable reduction in water pumping, resulting in energy savings.

*Table 29: Rainwater harvesting potential*

| Months | Average[3] (mm) | Potential Rainwater harvesting (CuM) |
|---|---|---|
| January | 31 | 162 |
| February | 13 | 69 |
| March | 66 | 347 |
| April | 49 | 257 |
| May | 36 | 187 |
| June | 70 | 365 |
| July | 57 | 299 |
| August | 140 | 735 |
| September | 115 | 600 |
| October | 290 | 1520 |
| November | 484 | 2535 |
| December | 273 | 1431 |
| Annual | 1623 | 8507 |

[3] *IMD data for the period 2007-11*

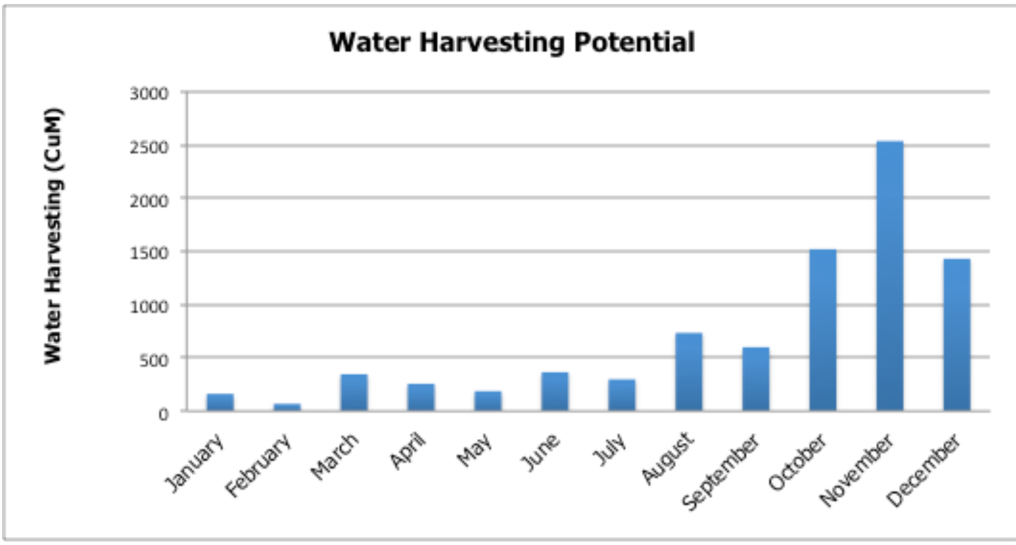



*Figure 46: Water harvesting potential for each month*

Table below shows the potential of rainwater collection in each building. The gutters and pipes have to be sized based on the rainwater collection rate.

*Table 30: Building wise rainwater harvesting potential*

| Buildings | Roof Area (sqm) | Rainwater harvesting potential (CuM/year) |
|---|---|---|
| School of Social science & Humanities | 5050 | 6559 |
| School of Tamil Studies | 500 | 649 |
| UMISARC | 500 | 649 |
| ASC | 500 | 649 |
| Total for the campus | 6550 | 8507 |

## 7.3 Future Renewable Energy Projects

The expansion plan of silver jubilee campus includes one multipurpose auditorium in the future. Solar PV system in the rooftop of the multipurpose auditorium and inclusion of green building features is recommended.

# 8 ENERGY SAVINGS & GHG REDUCTION

## 8.1 Annual Energy Savings Target

| Year | Energy Consumption and savings in MWh per year | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| Total Energy Demand | 1656 | 1988 | 2319 | 2650 | 2650 |
| Energy from RE | 286 | 623 | 1409 | 1409 | 1409 |
| % of RE fraction | 17% | 31% | 61% | 53% | 53% |
| Energy Savings from EE | 398 | 497 | 596 | 1988 | 3975 |
| % of EE fraction | 15% | 15% | 15% | 15% | 15% |
| % of RE & EE combined | 32% | 46% | 76% | 68% | 68% |

## 8.2 Green House Gas Emission Reduction

| Year | GHG Emission and reduction per year in $MtCO_2$ equivalent (Considering Emission factor for southern India as 0.84 | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| Total GHG Emission | 1391 | 1670 | 1948 | 2226 | 2226 |
| Emission reduction from RE | 240 | 523 | 1184 | 1184 | 1184 |
| Emission reduction from EE | 334 | 497 | 596 | 1988 | 3975 |

# 9 IMPLEMENTATION STRATEGY

## 9.1 Year wise Physical Goal

| RE Projects | Total Target | Year Wise Target for Physical Achievement | | |
|---|---|---|---|---|
| | | 2013 | 2014 | 2015 |
| PV Systems | 620kWp | 66kWp | 160kWp | 310kWp |
| Solar Water Heater | 1500LPD | 1500LPD | | |
| Wind Turbines | 216kW | 54kW | 54kW | 108kW |

## 9.2 Year wise Energy Savings Goal

| Sources | Targeted Savings (MWh) | | | | | |
|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
| PV Systems | 152 | 394 | 940 | 940 | 940 | 940 |
| Solar Thermal Systems | 91 | 91 | 91 | 91 | 91 | 91 |
| Wind Turbines | 95 | 189 | 378 | 378 | 378 | 378 |
| | 337 | 674 | 1409 | 1409 | 1409 | 1409 |

## 9.3 Year wise Financial Goal

| Projects | Financial Target in INR Lakh per year | | | |
|---|---|---|---|---|
| | 2013 | 2014 | 2015 | Total |
| PV Systems | 92.20 | 223.52 | 550.42 | 866.14 |
| Solar Thermal Systems | 4.52 | | | 4.52 |
| Wind Turbines | 115.50 | 115.50 | 231.00 | 462.00 |
| Total for all projects | 212.22 | 339.02 | 781.42 | 1332.66 |

## 9.4 Project Implementation

(i) Reputed manufacturers and system integrator will design, manufacture and install the renewable energy systems with best quality materials of international standard and will operate and maintain the systems for 5 years. The system will be handed over to university at the end of 5 years.

(ii) Pondicherry University will engage an exclusive technical team under the banner of "Solar/ Green Campus Cell" for regular operation and maintenance of the renewable energy systems. The team will be constituted by electrical engineers, electricians, mechanic and plumbers and will be led by a responsible manager. This cell may be created as a part/ within the "energy management cell" as we suggested in section 5 and overall management should be taken over by electrical department of the university.

(iii) If the university is not able to provide such manpower, it can also identify local entrepreneurs/ Energy Service Company to provide such services on contract basis.

(iv) The identified team will be trained by the technology providers' system integrator/supplier in all respect of operation, maintenance, monitoring and repair of solar water heating systems before the system is handed over to university.

## 9.5 Performance Monitoring

(i) All the renewable energy systems installed will be monitored and evaluated for their performance on regular basis by a competent team of personnel.

(ii) A data logging system capable of recording the following system operating statistics should be supplied.

(iii) Periodic logging of power, voltage, power factor and frequency on both the wind turbine and inverter outputs.

(iv) Periodic logging of battery bank statistics (if there is any) including battery voltage, current and temperature also with PV current contribution.

(v) kWh metering and run time meters on the wind electric generators.

(vi) kWh metering on the inverter output with separate power input, kWh, kWh summations with PV kWh.

(vii) Instantaneous feedback of power, voltage, power factor and frequency of both wind generation and the inverter output and the PV contribution as well as instantaneous power and loads.

(viii) Energy Meteorological parameters such as Global Horizontal Solar Radiation, Ambient Temperature, Wind speed at hub height; The manufacturer may supply on a calibrated PV cell with temperature compensation (through open circuit Voltage) in lieu of a Pyranometer/ Solarimeter/ Radiometer.

(ix) Digital flow meter and temperature gauge will be installed for performance monitoring of the systems in case of large solar water heating system.

(x) Data loggers for recording water flow and temperature would be installed. This system will keep a log of the amount of water delivered by the system along with and inlet and outlet temperature of the delivered water.

(xi) Energy delivered in kcal by the SWH system will be calculated based on the quantity of the water consumed and temperature rise of the water ($\Delta t$).

(xii) After installation the monitoring and verification team will check all technical specifications, size, materials, accessories, installation practice, civil work, control, electrical work, system integration, insulation, cladding, health, safety and security to the system and human and will ensure that supply and installation has been done as per required design and specification and best practices are followed to ensure system performance, reliability and long life. If found shortcomings in any of the aspects as stated above, the suppliers/ manufacturers will be asked to rectify/ complete the work at per.

(xiii) It is also suggested that students and scholars from Department of Ecology & Environmental Science, Green Energy Technology and other relevant schools can take part in the data collection, monitoring and evaluation of the project for their upkeep and day-to-day performance.

# 10 SHARING OF BUDGET

| Project Head | Total Budget | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| | | All figures are in INR Lakh | | |
| PV Systems | 866.14 | 92.20 | 223.52 | 550.42 |
| MNRE Share (30%) | 259.84 | 27.66 | 67.06 | 165.13 |
| PU Share | 606.30 | 64.54 | 156.46 | 385.29 |
| | | | | |
| Solar Water Heater | 4.52 | 4.52 | | |
| MNRE Share (30%) | 1.36 | 1.36 | | |
| PU Share | 3.16 | 3.16 | | |
| | | | | |
| Wind Turbines | 462.00 | 115.50 | 115.50 | 231.00 |
| MNRE Share | 259.00 | 64.75 | 64.75 | 129.50 |
| PU Share | 203.00 | 50.75 | 50.75 | 101.50 |
| | | | | |
| Total Budget | 1332.66 | 212.22 | 339.02 | 781.42 |
| Total MNRE Share | 520.20 | 93.77 | 131.81 | 294.63 |
| Total PU Share | 812.46 | 118.46 | 207.21 | 486.79 |

# *Annexure 1: PVSYST Simulation Reports*

## *PVSYST Simulation Report for 10kWp system*

| PVSYST V5.64 | | 27/02/13 | Page 1/3 |
|---|---|---|---|

### Grid-Connected System: Simulation parameters

| | | | | |
|---|---|---|---|---|
| **Project :** | **Pondicherry University** | | | |
| **Geographical Site** | **Pondicherry** | | **Country** | **India** |
| **Situation** | Latitude | 12.0°N | Longitude | 79.9°E |
| Time defined as | Legal Time | Time zone UT+6 | Altitude | 20 m |
| | Albedo | 0.20 | | |
| **Meteo data :** | Pondicherry, Synthetic Hourly data | | | |
| **Simulation variant :** | **New simulation variant** | | | |
| | Simulation date | 27/02/13 19h03 | | |
| **Simulation parameters** | | | | |
| **Collector Plane Orientation** | Tilt | 10° | Azimuth | 0° |
| **Horizon** | Free Horizon | | | |
| **Near Shadings** | No Shadings | | | |
| **PV Array Characteristics** | | | | |
| **PV module** Si-mono | Model | **Emmvee Black Pearl 250** | | |
| | Manufacturer | Emmvee Solar | | |
| Number of PV modules | In series | 20 modules | In parallel | 2 strings |
| Total number of PV modules | Nb. modules | 40 | Unit Nom. Power | 250 Wp |
| Array global power | Nominal (STC) | **10.00 kWp** | At operating cond. | 8.97 kWp (50°C) |
| Array operating characteristics (50°C) | U mpp | 553 V | I mpp | 16 A |
| Total area | Module area | **65.7 m²** | | |
| **Inverter** | Model | **StecaGrid 10 000 3ph** | | |
| | Manufacturer | Steca | | |
| Characteristics | Operating Voltage | 350-700 V | Unit Nom. Power | 9.50 kW AC |
| **PV Array loss factors** | | | | |
| Thermal Loss factor | Uc (const) | 20.0 W/m²K | Uv (wind) | 0.0 W/m²K / m/s |
| => Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind=1 m/s.) | | | NOCT | 56 °C |
| Wiring Ohmic Loss | Global array res. | 567 mOhm | Loss Fraction | 1.5 % at STC |
| Module Quality Loss | | | Loss Fraction | 1.5 % |
| Module Mismatch Losses | | | Loss Fraction | 2.0 % at MPP |
| Incidence effect, ASHRAE parametrization | IAM = | 1 - bo (1/cos i - 1) | bo Parameter | 0.05 |
| **User's needs :** | Unlimited load (grid) | | | |

| PVSYST V5.64 | | 27/02/13 | Page 2/3 |
|---|---|---|---|

## Grid-Connected System: Main results

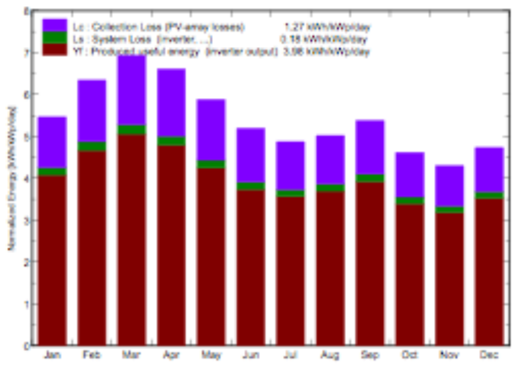
**Project :** **Pondicherry University**

**Simulation variant :** **New simulation variant**

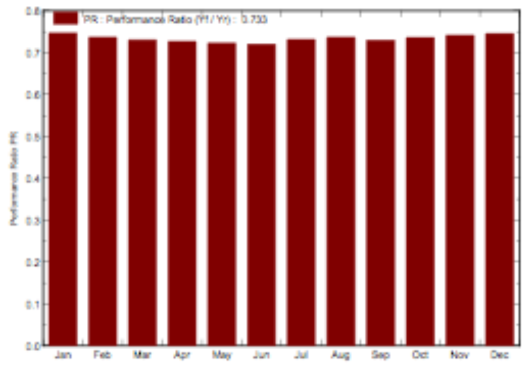
| | | | | |
|---|---|---|---|---|
| **Main system parameters** | System type | **Grid-Connected** | | |
| PV Field Orientation | tilt | 10° | azimuth | 0° |
| PV modules | Model | Emmvee Black Pearl 250 | Pnom | 250 Wp |
| PV Array | Nb. of modules | 40 | Pnom total | **10.00 kWp** |
| Inverter | Model | StecaGrid 10 000 3ph | Pnom | 9.50 kW ac |
| User's needs | Unlimited load (grid) | | | |

| | | | | |
|---|---|---|---|---|
| **Main simulation results** | | | | |
| System Production | **Produced Energy** | **14.54 MWh/year** | Specific prod. | 1454 kWh/kWp/year |
| | Performance Ratio PR | 73.3 % | | |

**Normalized productions (per installed kWp): Nominal power 10.00 kWp**




**Performance Ratio PR**




**New simulation variant**

**Balances and main results**

| | GlobHor kWh/m² | T Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray MWh | E_Grid MWh | EffArrR % | EffSysR % |
|---|---|---|---|---|---|---|---|---|
| **January** | 155.0 | 26.00 | 169.4 | 164.1 | 1.320 | 1.265 | 11.85 | 11.36 |
| **February** | 165.8 | 27.00 | 177.5 | 172.3 | 1.365 | 1.307 | 11.70 | 11.20 |
| **March** | 209.6 | 27.90 | 214.8 | 208.8 | 1.637 | 1.569 | 11.59 | 11.11 |
| **April** | 201.3 | 29.50 | 198.0 | 192.3 | 1.501 | 1.438 | 11.53 | 11.05 |
| **May** | 190.6 | 31.40 | 182.2 | 176.2 | 1.375 | 1.316 | 11.48 | 10.99 |
| **June** | 164.1 | 30.40 | 155.5 | 150.0 | 1.172 | 1.120 | 11.47 | 10.95 |
| **July** | 157.8 | 29.00 | 151.0 | 145.6 | 1.156 | 1.105 | 11.64 | 11.13 |
| **August** | 159.3 | 29.10 | 155.5 | 150.2 | 1.198 | 1.146 | 11.71 | 11.21 |
| **September** | 160.2 | 29.80 | 161.3 | 156.3 | 1.229 | 1.176 | 11.59 | 11.10 |
| **October** | 138.6 | 29.40 | 143.0 | 138.5 | 1.101 | 1.053 | 11.71 | 11.20 |
| **November** | 121.5 | 27.50 | 129.0 | 124.6 | 1.000 | 0.956 | 11.80 | 11.27 |
| **December** | 134.5 | 26.80 | 146.6 | 141.6 | 1.142 | 1.092 | 11.85 | 11.34 |
| Year | 1958.3 | 28.66 | 1983.8 | 1920.3 | 15.194 | 14.543 | 11.65 | 11.15 |

| Legends: | | | | |
|---|---|---|---|---|
| | GlobHor | Horizontal global irradiation | EArray | Effective energy at the output of the array |
| | T Amb | Ambient Temperature | E_Grid | Energy injected into grid |
| | GlobInc | Global incident in coll. plane | EffArrR | Effic. Eout array / rough area |
| | GlobEff | Effective Global, corr. for IAM and shadings | EffSysR | Effic. Eout system / rough area |

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|---|---|---|---|

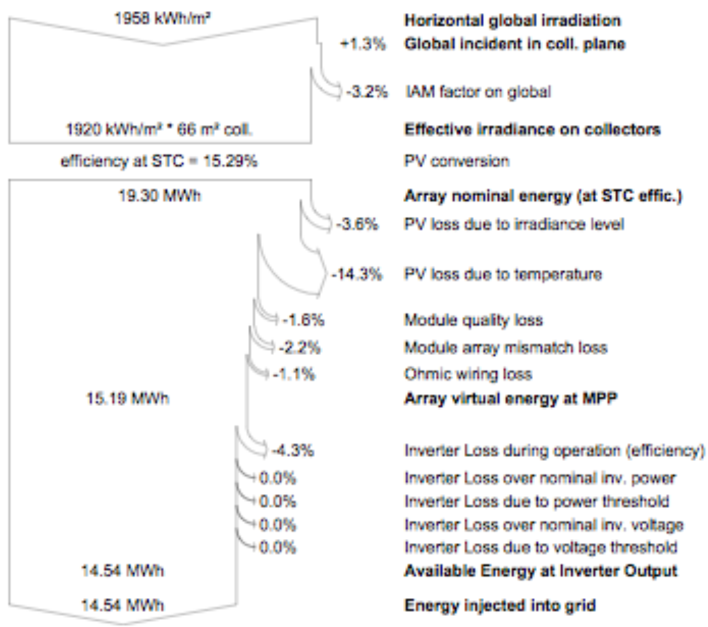
## Grid-Connected System: Loss diagram

**Project :** **Pondicherry University**

**Simulation variant :** **New simulation variant**

| | | | | |
|---|---|---|---|---|
| **Main system parameters** | System type | **Grid-Connected** | | |
| PV Field Orientation | tilt | 10° | azimuth | 0° |
| PV modules | Model | Emmvee Black Pearl 250 | Pnom | 250 Wp |
| PV Array | Nb. of modules | 40 | Pnom total | **10.00 kWp** |
| Inverter | Model | StecaGrid 10 000 3ph | Pnom | 9.50 kW ac |
| User's needs | Unlimited load (grid) | | | |

**Loss diagram over the whole year**



## *PVSYST Simulation Report for 30kWp system*

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|---|---|---|---|

### Grid-Connected System: Simulation parameters



| | | | | |
|---|---|---|---|---|
| **Project :** | **Pondicherry University** | | | |
| **Geographical Site** | **Pondicherry** | | **Country** | **India** |
| **Situation** | Latitude | 12.0°N | Longitude | 79.8°E |
| Time defined as | Legal Time | Time zone UT+6 | Altitude | 20 m |
| | Albedo | 0.20 | | |
| **Meteo data :** | Pondicherry, Synthetic Hourly data | | | |

| | | | | |
|---|---|---|---|---|
| **Simulation variant :** | **New simulation variant** | | | |
| | Simulation date | 26/02/13 17h19 | | |

**Simulation parameters**

| | | | | |
|---|---|---|---|---|
| **Collector Plane Orientation** | Tilt | 10° | Azimuth | 0° |
| **Horizon** | Free Horizon | | | |
| **Near Shadings** | No Shadings | | | |

**PV Array Characteristics**

| | | | | |
|---|---|---|---|---|
| **PV module** Si-poly | Model | **ND-R250A5** | | |
| | Manufacturer | Sharp | | |
| Number of PV modules | In series | 20 modules | In parallel | 6 strings |
| Total number of PV modules | Nb. modules | 120 | Unit Nom. Power | 250 Wp |
| Array global power | Nominal (STC) | **30.0 kWp** | At operating cond. | 26.76 kWp (50°C) |
| Array operating characteristics (50°C) | U mpp | 562 V | I mpp | 48 A |
| Total area | Module area | **197 m²** | Cell area | 175 m² |

| | | | | |
|---|---|---|---|---|
| **Inverter** | Model | **Sunny Tripower15000 TL** | | |
| | Manufacturer | SMA | | |
| Characteristics | Operating Voltage | 150-800 V | Unit Nom. Power | 15.0 kW AC |
| Inverter pack | Number of Inverter | 2 units | Total Power | 30.0 kW AC |

**PV Array loss factors**

| | | | | |
|---|---|---|---|---|
| Thermal Loss factor | Uc (const) | 20.0 W/m²K | Uv (wind) | 0.0 W/m²K / m/s |
| => Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind=1 m/s.) | | | NOCT | 56 °C |
| Wiring Ohmic Loss | Global array res. | 194 mOhm | Loss Fraction | 1.5 % at STC |
| Module Quality Loss | | | Loss Fraction | 2.5 % |
| Module Mismatch Losses | | | Loss Fraction | 2.0 % at MPP |
| Incidence effect, ASHRAE parametrization | IAM = | 1 - bo (1/cos i - 1) | bo Parameter | 0.05 |

**User's needs :** Unlimited load (grid)

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|---|---|---|---|

## Grid-Connected System: Main results

**Project :** **Pondicherry University**

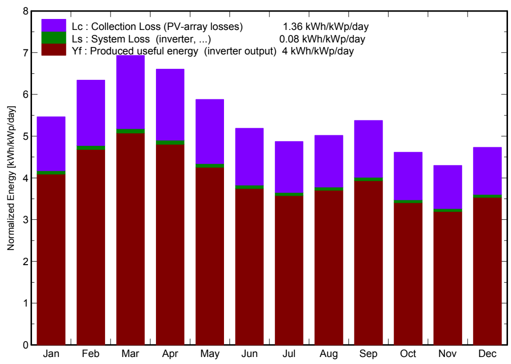
**Simulation variant :** **New simulation variant**



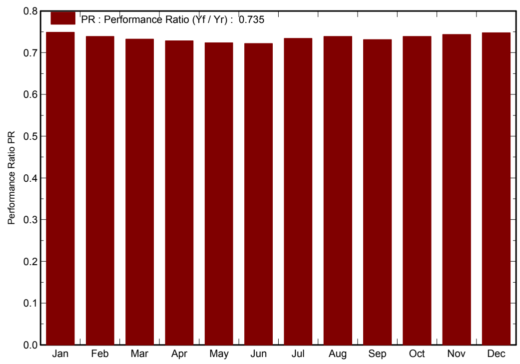
| **Main system parameters** | System type | **Grid-Connected** | | |
|---|---|---|---|---|
| PV Field Orientation | tilt | 10° | azimuth | 0° |
| PV modules | Model | ND-R250A5 | Pnom | 250 Wp |
| PV Array | Nb. of modules | 120 | Pnom total | **30.0 kWp** |
| Inverter | Model | Sunny Tripower15000 TL | Pnom | 15.00 kW ac |
| Inverter pack | Nb. of units | 2.0 | Pnom total | **30.0 kW ac** |
| User's needs | Unlimited load (grid) | | | |

| **Main simulation results** | | | | |
|---|---|---|---|---|
| System Production | **Produced Energy** | **43.76 MWh/year** | Specific prod. | 1459 kWh/kWp/year |
| | Performance Ratio PR | 73.5 % | | |

**Normalized productions (per installed kWp): Nominal power 30.0 kWp**




**Performance Ratio PR**




**New simulation variant**
**Balances and main results**

| | GlobHor | T Amb | GlobInc | GlobEff | EArray | E_Grid | EffArrR | EffSysR |
|---|---|---|---|---|---|---|---|---|
| | kWh/m² | °C | kWh/m² | kWh/m² | MWh | MWh | % | % |
| **January** | 155.0 | 26.00 | 169.4 | 164.1 | 3.881 | 3.805 | 11.63 | 11.40 |
| **February** | 165.8 | 27.00 | 177.5 | 172.3 | 4.015 | 3.933 | 11.48 | 11.25 |
| **March** | 209.6 | 27.90 | 214.8 | 208.8 | 4.818 | 4.720 | 11.38 | 11.15 |
| **April** | 201.3 | 29.50 | 198.0 | 192.3 | 4.415 | 4.326 | 11.31 | 11.09 |
| **May** | 190.6 | 31.40 | 182.2 | 176.2 | 4.041 | 3.956 | 11.26 | 11.02 |
| **June** | 164.1 | 30.40 | 155.5 | 150.0 | 3.444 | 3.369 | 11.24 | 10.99 |
| **July** | 157.8 | 29.00 | 151.0 | 145.6 | 3.395 | 3.326 | 11.41 | 11.18 |
| **August** | 159.3 | 29.10 | 155.5 | 150.2 | 3.519 | 3.448 | 11.48 | 11.25 |
| **September** | 160.2 | 29.80 | 161.3 | 156.3 | 3.612 | 3.539 | 11.37 | 11.14 |
| **October** | 138.6 | 29.40 | 143.0 | 138.5 | 3.234 | 3.170 | 11.47 | 11.25 |
| **November** | 121.5 | 27.50 | 129.0 | 124.6 | 2.938 | 2.878 | 11.56 | 11.32 |
| **December** | 134.5 | 26.80 | 146.6 | 141.6 | 3.355 | 3.288 | 11.62 | 11.38 |
| Year | 1958.3 | 28.66 | 1983.8 | 1920.3 | 44.667 | 43.758 | 11.43 | 11.19 |

| Legends: | | | | |
|---|---|---|---|---|
| GlobHor | Horizontal global irradiation | | EArray | Effective energy at the output of the array |
| T Amb | Ambient Temperature | | E_Grid | Energy injected into grid |
| GlobInc | Global incident in coll. plane | | EffArrR | Effic. Eout array / rough area |
| GlobEff | Effective Global, corr. for IAM and shadings | | EffSysR | Effic. Eout system / rough area |

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|---|---|---|---|

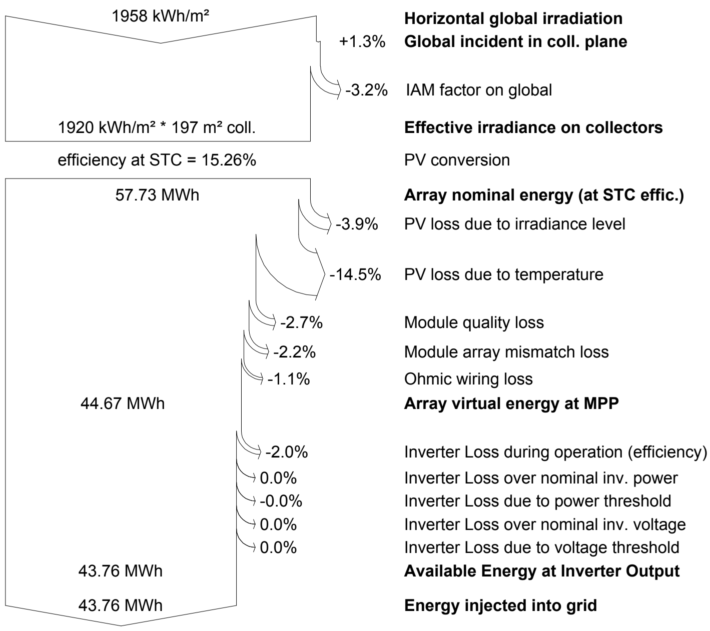
## Grid-Connected System: Loss diagram

**Project :** **Pondicherry University**

**Simulation variant :** **New simulation variant**

| | | | | |
|---|---|---|---|---|
| **Main system parameters** | System type | **Grid-Connected** | | |
| PV Field Orientation | tilt | 10° | azimuth | 0° |
| PV modules | Model | ND-R250A5 | Pnom | 250 Wp |
| PV Array | Nb. of modules | 120 | Pnom total | **30.0 kWp** |
| Inverter | Model | Sunny Tripower15000 TL | Pnom | 15.00 kW ac |
| Inverter pack | Nb. of units | 2.0 | Pnom total | **30.0 kW ac** |
| User's needs | Unlimited load (grid) | | | |

**Loss diagram over the whole year**



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## *Contact*

Dwipen Boruah
GSES India Sustainable Energy Pvt. Ltd.,
B-387 (2nd Floor), CR Park,
New Delhi - 110019, India
Ph: +91-11-40587622
Mobile: +91 9560550075
e-mail: dwipen.boruah@gses.in
www.gses.in