Master Plan and Detailed Project Reports for Development of Tezpur University Green Campus under the "Development of Solar Cities" Programme of MNRE

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ABBREVIATIONS

°C	Degree Celsius
AC	Alternate Current
BOS	Balance of System
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
IEC 62548	IEC standards code for Photovoltaic Array Design Requirements
km	Kilometre
kV	Kilovolt
kVA	Kilovolt Ampere
kWh	Kilowatt Hour
kW_p	Kilo Watt peak
LCC	Life cycle costs
LCoE	Levelized Cost of Energy
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 for PV system
RPO	Renewable Purchase Obligation
SMA	SMA Solar Technology AG
STC	Standard Test Conditions of 1000 W/m^2 irradiance, Air mass 1.5, cell temperature 25 °C
V	Voltage
V_{dc}	Direct Current Voltage
W_p	Watt peak

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1 BACKGROUND

The Tezpur university campus is at Napaam, about 15 km east of Tezpur, headquarter of the Sonitpur district of Assam. Napaam is a rural area surrounded by people of diverse caste, religion and language. The Napaam campus is in a plot of an area of 262 acres (1.06 km^2) of land. The campus has twelve hostels and special centres/cells along with the academic buildings.

The Ministry of New and Renewable Energy, Government of India is implementing a programme on Development of Solar Cities wherein about 100 small townships/campuses (new and the existing one), duly notified/permitted by the concerned Authorities being developed by the promoters/builders, SEZs/ industrial towns, Institutional campus etc. are proposed to be developed as green campus during the 12th five year plan.

The Tezpur University plans to develop its campus as a green campus, under the aforesaid MNRE programme and aims to reduce 25% fossil fuel based energy within next 5 years through renewable energy and energy efficiency measures. GSES India Sustainable Energy Pvt. Limited was assigned to prepare a master plan and detailed project reports to develop Tezpur University Campus as a "Green Campus". A group of research student from the Department of Energy, Tezpur University assisted GSES India to collect energy consumption information for baseline energy study to assess carbon footprint of the university campus.

Based on the data collected and analysed, this preliminary report has been prepared identifying energy efficiency potential and potential renewable energy projects to achieve a targeted goal to reduce conventional energy consumption and thereby reduce GHG emission in the campus. The next step will be to finalize the potential renewable energy projects in consultation with the Energy Department and university authority and prepare the detailed project reports, budget and implementation plan.

2 ASSESSMENT CARBON FOOTPRINT

2.1 Energy Use

Various Energy use types were analysed at Tezpur University:

- Electricity for all buildings
- Diesel Consumption by DG sets
- LPG consumption at Hostels and Guesthouse

2.1.1 Electricity usage:

One year data of electricity from July 2013 to June 2014 is taken for analysis as shown below:

Sl. No.	MONTH	YEAR	Electricity usage (in kWh)
1	July	2013	394860
2	August	2013	392640
3	September	2013	507810
4	October	2013	517620
5	November	2013	378840
6	December	2013	354360
7	January	2014	341910
8	February	2014	315330
9	March	2014	335100
10	April	2014	380670
11	May	2014	379650
12	June	2014	412380
		Total (kWh)	**4,711,170**

2.1.2 Diesel Consumption:

Diesel at Tezpur University is used to feed the DG sets, used as a backup power source. Data for diesel consumptions in litres from July 2013 to June 2014 is considered for analysis, as shown below:

Sl. No.	Month	Diesel Procured (litres)
1	Jul-2013	4000
2	Aug-2013	4000
3	Sept-2013	3600
4	Oct-13	4200
5	Nov-13	Nil
6	Dec-13	2000

Sl. No.	Month	Diesel Procured (litres)
7	Jan-14	2000
8	Feb-14	2000
9	Mar-14	4600
10	Apr-14	6000
11	May-14	7000
12	Jun-14	9000
	Total (Litres)	**48400**

2.1.3 LPG consumption:

Hostels/Guesthouse	MJ/month
Dhanshiri	24000
Pragjyotika	22000
Bordoichila	22000
Subansri	25000
Kopili	29000
Pobitora	26000
New women	25000
Saraighat	35000
Patkai	44000
Charaideo	28000
Nilachal	38000
Kanchanjungha	38000
Guest House	35036

Total energy consumed in the hostels and guest house for cooking is 4,692,432 MJ per year. Taking conversion factors of (1kg LPG =46.1MJ) and (1kg LPG = 0.047 MMBtu), the total energy consumed is 4784.04 MMBtu/year.

2.1.4 Waste Generated

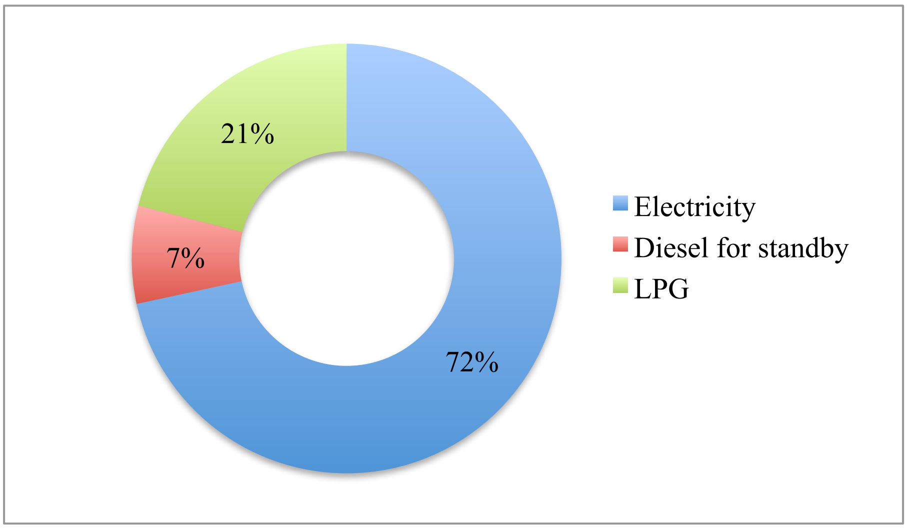
The table below shows the degradable waste for various buildings.

Sl. No.	Building	No. of Dwellers	Degradable Waste (kg/week)
1	Quarters	632	1931
2	Guest House	23	44
3	Security Barrack	60	196
4	Canteen	-	490
5	All Hostels	3195	6332
Total waste generated in Kg per week			8992
Total waste generated in Kg per year			467,576

2.1.5 Energy usage by different sources

Estimated energy used at Tezpur University is 6.54 MU per year. The major share comes from the electricity usage (77%) followed by LPG consumption (21%).

Source of energy	Consumption/year (kWh)	% of Total Mix
Electricity	47,11,170	72%
Diesel for standby	4,84,000	7%
LPG	13,84,318	21%
Total	65,79,488	100%



2.2 GHG Footprint

2.2.1 Electricity usage

For calculating CO_2 emissions from the electricity taken from grid (NE grid), we considered an emission factor of 0.82 (kg CO_2e/kWh). As already mentioned, total electricity consumption for June 2013 – June 2014 is 4,711,170kWh. Hence emissions from electricity usage as calculated are 4155795.26 kg of CO_2 per year.

2.2.2 Diesel Consumption

Emission factor used for calculating CO_2 emissions from diesel is taken as 2.653 (kg CO_2e/litre). Total consumption of diesel for standby power backup DG sets is 48,400 litres per year. Hence emissions calculated from diesel usage are 128,260 kg of CO_2 per year.

2.2.3 LPG usage

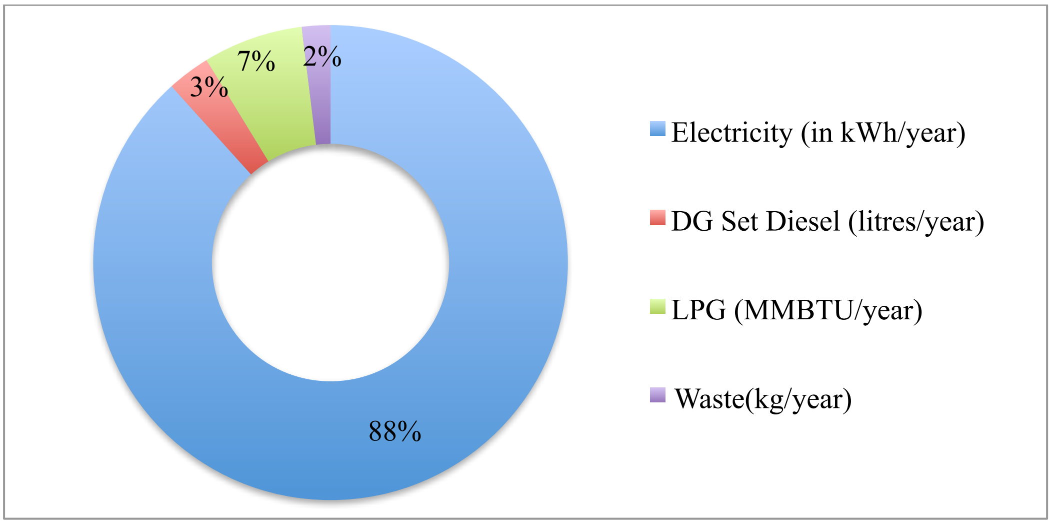
For calculating CO2 emissions from LPG usage, emission factor of 62.28 (kg CO_2e/MMBtu) is considered. Total energy used from LPG is 4784 MMBtu per year. Total CO_2 emitted from LPG usage is calculated to be 297948 kg of CO_2 per year.

2.2.4 Bio degradable waste

Emission factor for Bio degradable waste considered is 0.182 (kg CO_2e/kg of degradable waste). Total degradable waste generated in various buildings of university is 467,576 kg per year. Emissions calculated from degradable waste are 85,099 kg of CO_2 per year.

Source	Input	Emission Factor	GHG (kg of CO_2/year)
Electricity (in kWh/year)	4,711,170	0.82	3,863,159
DG Set Diesel (litres/year)	48,400	2.65	128,260
LPG (MMBTU/year)	4,784	62.28	297948
Waste (kg/year)	467,576	0.182	85,099
Total			4,374,466

As from the table above it can be seen that total CO_2 emissions from all sources at Tezpur University is 4,374,466 kg of CO_2 per year or 4374 tonnes of CO_2 per year. The percentage contribution from different sources is shown in the chart below. It also depicts that highest emitter is Electricity (89%) followed by LPG used for cooking (6%).


7%
2%
3%
88%
Electricity (in kWh/year)
DG Set Diesel (litres/year)
LPG (MMBTU/year)
Waste(kg/year)

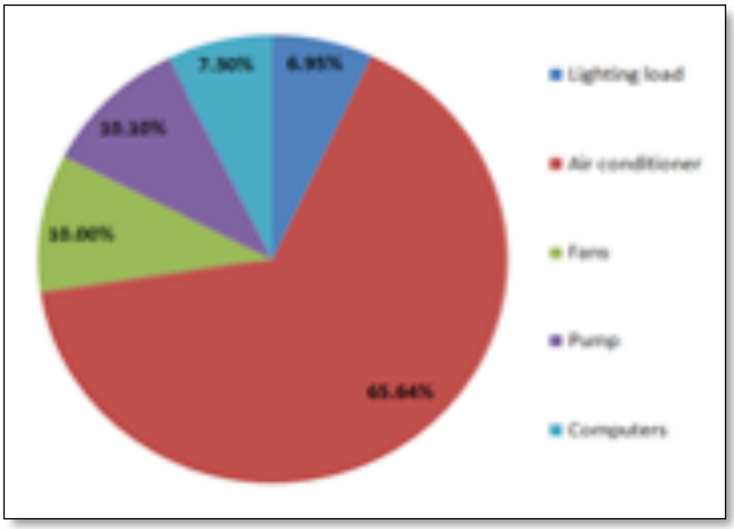
3 ROADMAP FOR ENERGY EFFICIENCY INTERVENTION

Potential for energy conservation and energy efficiency assessment has been conducted in all sectors as mentioned below:

- Administrative Building
- Guest House
- KBR auditorium and Women Facility Center
- Hostels Buildings:
  - Bordoichila
  - Charaideo
  - Dhanshiri
  - Kanchanjungha
  - Kopili
  - New Women
  - Nilachal
  - Patkai
  - Pobitora
  - Saraighat
  - Pragjyotika
  - Subanshiri
- Departmental and Laboratory buildings:
  - Chemical department
  - Civil department
  - Energy department
  - SAIC laboratory

3.1 Administrative Building

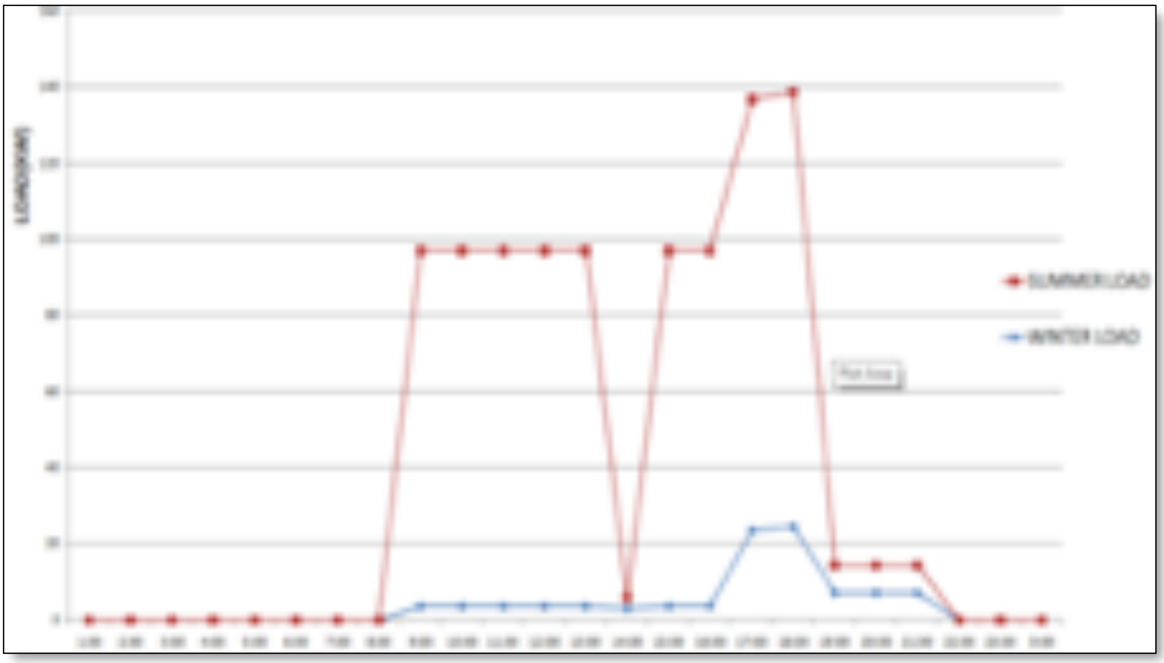
Annual energy consumption in the administrative block is 123.27 MWh/year, with the maximum share of space cooling using air conditioners. Application wise percentage Annual Load Consumption is shown below in the chart:



Detailed energy end-use by activity has been clearly depicted in the table below:

Appliances	Type & Make	Watt	Quantity	Total Load (kW)	Days of year	Days of operation	Total Energy (kWh/day)	Total Energy (kWh/year)
Lighting Load								
Indoor Lighting Type 1	CFL	18	287	5.166	365	300	10.332	3099.6
Indoor Lighting Type 2	Tube Light	40	228	9.12	365	300	18.24	5472
Appliances for comfort								
Air conditioner		2250	37	83.25	365	180	649.350	80919
Fan Type 1	Ceiling Fan	60	112	6.72	365	180	60.48	10886.4
Bathroom & Cleaning Appliances								
Water Pump (for fountain)		5625	1	5.625	365	365	28.125	10265.6
Water Pump (for fountain)		1500	1	1.5	365	365	6	2190
Exhaust fan	Exhaust fan	60	10	0.6	365	300	4.8	1440
Entertainment, Education & Other appliances								
Computers	Desktop, HP	100	30	3	365	300	30	9000
Administrative				116.981			907.227	123272.63

Air conditioner operates only few months during summers, significantly consuming 65.64% of the annual load. Tezpur falls in the subtropical climatic zone and as such, has a monsoon type of climate and enjoys pleasant weather conditions all through the year. So, for calculating the air conditioner load, it is assumed that the daily average compressor run time of air conditioner to be 60%. Zero requirement of space cooling and thus no operation of air conditioner, during winters, significantly scales down the load characteristic curve. This has been clearly depicted with the daily load profile during summers and winters as shown below:



3.1.1 Energy Efficiency Intervention for Administrative Building

(a) Air conditioning Load

Based on the energy audit in the administrative block, it was found that air conditioner accounted for the maximum annual energy consumption, that is, 65.64% of the total annual load. Presently 37 air conditioners, 2250W each, are installed in the building, operating 180 days in a year. If the existing ones are replaced by BEE 5 star rated air conditioners, 1677W each, the net energy saving in the air conditioning load will be 20607.37 kWh/year that is 20607.37 units per year.Net energy saving in the building by replacing existing ones by energy efficient air conditioners will be 17%.Approximate market cost of a BEE 5 star rated air conditioners is Rs.35000. Despite of the significant energy savings, it is not advisable to change the existing air conditioners due to huge investments involved in their purchase and installation and very high payback period. If there is a damage or chance of replacement in future, then it is suggested to buy a BEE 5 star rated air conditioner.

(b) Lighting Load

Lighting load in the administrative building is 8.57MW/year, which is only 6.95% of the total annual energy consumption in the building.287 compact fluorescent light, CLF (18W each) and 228 tube lights (40W each) are installed in the building, lit 300 days in a year, and operating only 2 hours in a day. If the existing CFL and tube lights are replaced by energy efficient LED lamps (10W each) and LED tube lights (22W each), the net energy saving in the lighting load will be 3840 kWh/year that is 3840 units per year. Net energy saving in the building by replacing existing lights by energy efficient LED lamps and tube lights will be 3%. It is not economically beneficial to replace the existing lighting system. No lighting load can be improved because of fewer operating hours. In case of damage or any replacement required, energy efficient lights, instant fit LED lamps and tube lights shall replace the existing lights.

(c) Fans

Ceiling fans and exhaust fans account for the 12.326MW/year, nearly 10% of the total annual energy consumption in the building. If the existing ceiling fans (60W each) are replaced by the BEE 5 star rated fans (approx. 52W each), 1451.52 units per year will be saved providing 1% energy saving in the building. Cost involved in replacing the existing fans by energy efficient fans will be very high delivering very high payback time. It is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

(d) Computers

30 HP Desktops (100W each) are installed in the building operating 10 hours a day and consuming 9MW/year, nearly 7.3% the total annual energy consumption. No desktop load can be improved. Existing desktops are of good quality and so no immediate replacement is suggested.

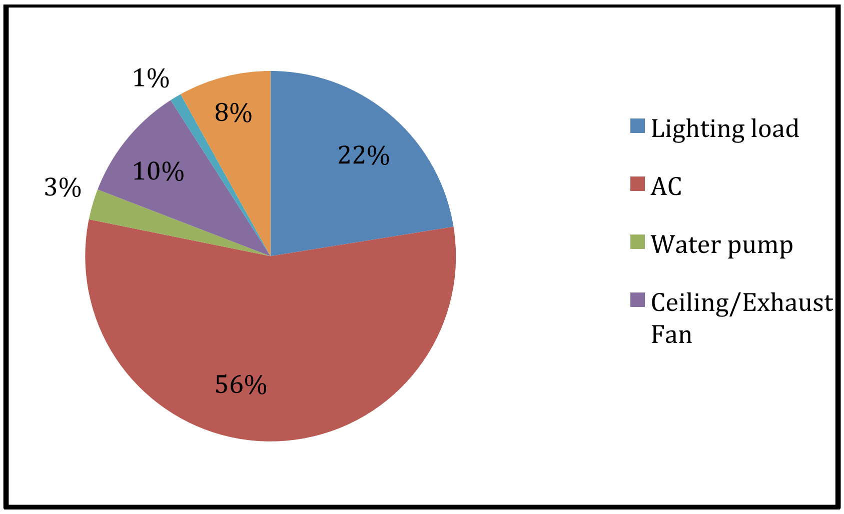
TYPE	Annual Energy Consumption (kWh/year) by Existing load	Annual Energy Consumption (kWh/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving @Rs.5.35/kWh	Simple Payback Period (in Years)	COMMENTS
Lighting Load	8571.6	4731.6	3840	20544	28	No immediate replacement required
Fans	10886.4	9434.88	1451.52	7765	28	No immediate replacement required
Air Conditioner	80919	1295000	20607.3	110294	11.7	No immediate replacement required
Desktop	9000	-	-	-	-	Replacement not required

3.2 Guest House

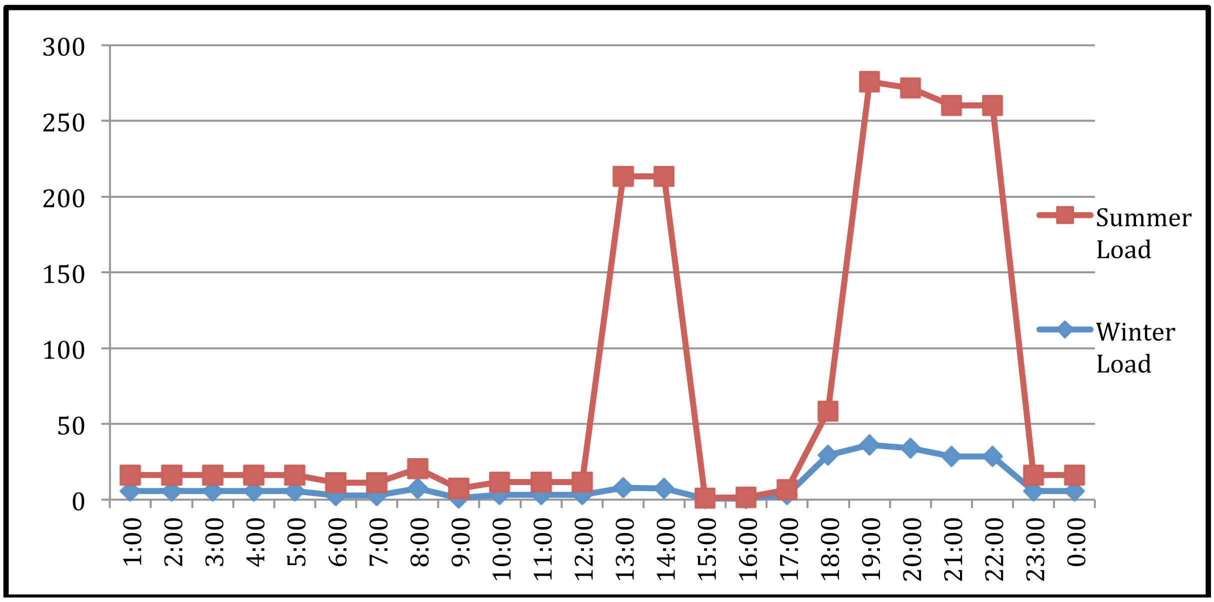
Annual energy consumption in the administrative block is 230.23 MWh/year, with the maximum share of space cooling using air conditioners followed by the lighting load. Detailed energy end-use by activity has been clearly depicted in the table below:

Appliances	Type & Make	Watt	Quantity	Total Load (kW)	Days of year	Days of operation	Total Energy (kWh/day)	Total Energy (kWh/year)
Lighting Load								
Indoor Lighting Type 1	CFL, Havells	36	74	2.664	365	365	31.97	11668.32
Indoor Lighting Type 2	Tube Light	40	294	11.76	365	365	78.80	28762.00
Outdoor lighting Type 1	HPMV	125	19	2.375	365	365	30.88	11269.38
Appliances for comfort								
Air conditioner		2250	88	198	365	180	712.80	128304.00
Fan Type 1	Ceiling Fan	60	91	1.48	365	180	98.28	17690.40
Bathroom & Cleaning Appliances								
Water Pump		5625	1	5.625	365	365	16.88	6159.38
Exhaust Fan		40	36	1.34	365	365	15.12	5518.80
Kitchen Appliances								
Dough making machine		300	1	0.3	365	365	0.60	219.00
Refrigerator (Consider 8hrs day +1/3 rd of year flat)		400	1	0.4	365	118	8.60	1051.20
Fly Trapper		60	3	0.18	365	365	1.26	459.90
Deep Freezer	Blue Star	42.5	1	0.0425	365	365	1.50	547.50
Entertainment, Education & Other appliances								
Computers	HP	100	2	0.2	365	365	1.40	511.00
Television	Sony 32"	109	1	0.109	365	365	2.54	925.28
Television	Sony 42"	116	23	1.668	365	365	18.68	6818.74
Television	Sony 32"	101	40	4.04	365	365	28.28	10317.20
Guesthouse				240.0655			1025.77	230223.08

Application wise Percentage Annual Energy Consumption is shown in chart below:



Space cooling required during summers accounts for the maximum load in the guesthouse. Load characteristic curve significantly scales down during winters. This is shown below:



3.2.1 Energy Efficiency Intervention for Guest House

(a) Air Conditioner

Space cooling using air conditioners accounts for the maximum annual energy consumption of 128.3MWh/year which is 56% of the total annual load. 2250W each, 88 air conditioners are installed in the building, operating 180 days in a year. If these are replaced by BEE 5 star rated air conditioners, 1677W each, the net energy saving in the air conditioning load will be 35623.15kWh/year that is 35623.15 units per year. Net energy saving in the building by replacing existing ones by energy efficient air conditioners will be 15%. Approximate market cost of a BEE 5 star rated air conditioners is Rs.35000. Despite of the significant energy savings, it is not advisable to change the existing air conditioners due to huge investments involved in their purchase and installation and very high payback period. If there is a damage or chance of replacement in future, then it is suggested to buy a BEE 5 star rated air conditioner.

(b) Lighting

Total lighting load in the guest house is 51.70MWh/year, with 40.43MWh/year and 11.27MWh/year indoor lighting load and outdoor lighting load respectively. Lighting load accounts for 22% of the total annual energy consumption in the building. For indoor lighting74 compact fluorescent light, CLF (36 W each) operating 12hrs a day and 394 tube lights (40 W each) are installed in the building operating 5hrs a day are used lit all year. For outdoor lighting, 19 HPMV lamps (125W each) are used. If the existing indoor lights are replaced by energy efficient LED lamps (20W each) and LED tube lights (22W each) and outdoor HPMV lamps by LED flood lights (60W each), the net energy saving in the lighting load will be 23988.90 kWh/year that is 23988.90 units per year.Net energy saving in the building by replacing existing lights by energy efficient LED lamps ,tube lights and flood lights will be 10%.Approximate market unit price of LED lamps (20W), LED tube lights (22W) and LED lamps (60W) is Rs.1500, Rs.1800 and Rs.11500 respectively. There is a wide scope of improving the lighting load in the guest house. It is advised to replace all the existing lights by energy efficient LED lights.

(c) Fans

Ceiling fans and exhaust fans account for the 23.209MW/year, nearly 10% of the total annual energy consumption in the building. If the existing ceiling fans (60W each) are replaced by the BEE 5 star rated fans (approx. 52W each), 1451.52 units per year will be saved providing 1% energy saving in the building. Cost involved in replacing the existing fans by energy efficient fans will be very high delivering very high payback time. It is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

(d) Computer and Television

2 HP Desktops (100W each) operating 7 hours a day and 64 televisions (Sony 32",42", 52") operating 13 hours a day, are installed in the building and consuming 18.58MW/year, nearly 8% of the total annual energy consumption. No desktop and television load can be improved. Existing desktops and televisions are of good quality and so no immediate replacement is suggested.

(e) Kitchen appliances

1% of the total annual energy consumption comes from the kitchen appliances like refrigerator, deep freezer, fly trapper and dough making machine. 2.27MWh/year is the total annual energy load due to kitchen appliances. Share of kitchen appliance in total annual energy consumption is very little. Also the existing kitchen appliances are of good quality and so no kitchen load can be improved. Therefore no immediate replacement is suggested for kitchen appliances.

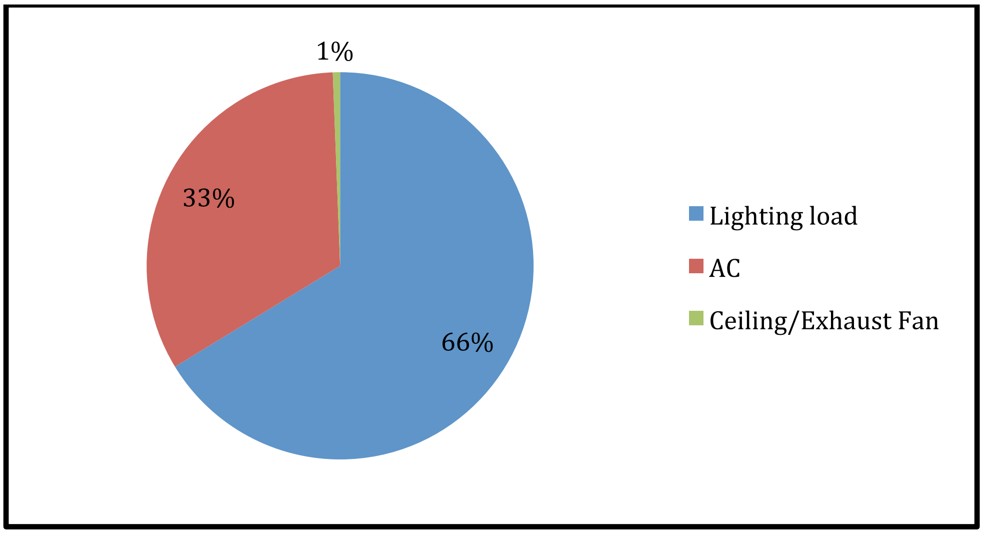
TYPE	Annual Energy Consumption (kW/year) by Existing load	Annual Energy Consumption (kWh/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving (@Rs.5.35/kWh)	Simple Payback Period (in Years)	COMMENTS
Lighting Load	51699.7	27710.8	23988.9	128341.59	8	Replacement by energy efficient lights is suggested
Fans	17690.4	15331.68	2358.72	12619.15	14.6	No immediate replacement required
Air Conditioner	120304	95629.25	19623.15	104983.06	18	No immediate replacement required
Television/Computer	10575.22	-	-	-	-	No replacement required
Kitchen appliances	2277.6	-	-	-	-	No replacement required

3.3 KBR Auditorium

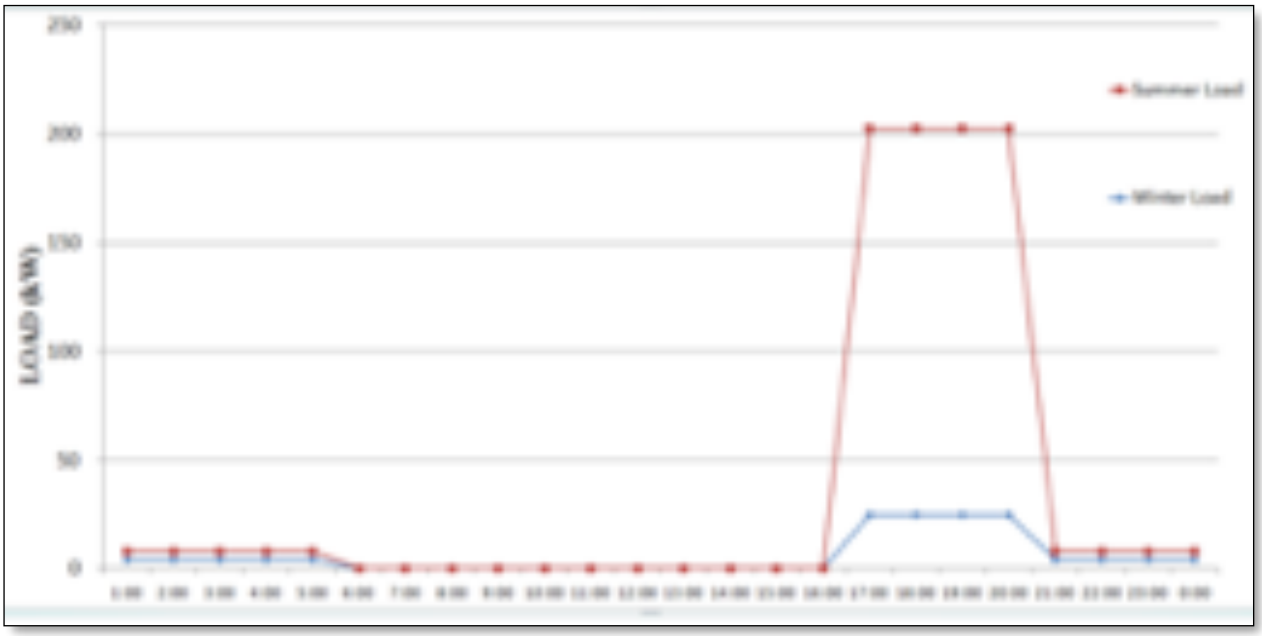
Annual energy consumption in the administrative block is 29.75 MWh/year, with the maximum share of lighting load. Detailed energy end-use by activity has been clearly depicted in the table below:

	Appliances	Type & Make	Watt	Quantity	Total Load (kW)	Days of use per year	Days of operation	Total Energy (kWh/day)	Total Energy (kWh/year)
4									
5									
6	**Lighting Load**								
7	Indoor Lighting Type 1	CFL	15	200	3	365	25	12.00	300.00
8	Indoor Lighting Type 2	Tube Light	40	110	4.4	365	25	17.60	440.00
9	Outdoor lighting Type 1	Halogen Lamp	1000	4	4	365	365	52.00	18980.00
10	**Appliances for comfort**								
11	Air conditioner	AC	2250	73	164.25	365	25	394.20	9855.00
12	Fan Type 1	Ceiling fan	60	20	1.2	365	25	4.80	120.00
13	**Bathroom & Cleaning Appliances**								
14	Exhaust fan	Exhaust fan	60	10	0.6	365	25	2.40	60.00
15	**KBR auditorium**				177.45			745.80	29755.00

Application wise Percentage Annual Energy Consumption is shown in the chart below:



Space cooling required during summers accounts for the maximum load in the auditorium. Load characteristic curve significantly scales down during winters. This is shown below:



3.3.1 Energy Efficiency Intervention for KBR Auditorium

(a) Air conditioning Load

Air conditioning load in the KBR auditorium is 9.5MWh/year, which accounts for around 33% of the total annual energy consumption in the building. Presently 73 air conditioners, 2250W each, are installed in the building, operating 25 days in a year. If the existing ones are replaced by BEE 5 star rated air conditioners, 1677W each, the net energy saving in the air conditioning load will be

2509.74kWh/year. Net energy saving in the building by replacing existing ones by energy efficient air conditioners will be 8%.Approximate market cost of a BEE 5 star rated air conditioners is Rs.35000. Since the operating days for air conditioning load are very less, it is not advisable to change the existing air conditioners due to huge investments involved in their purchase and installation and very high payback period. If there is a damage or chance of replacement in future, then it is suggested to buy a BEE 5 star rated air conditioner.

(b) **Lighting Load**

Lighting load in the administrative building is 19.72MWh/year, which is 66% of the total annual energy consumption in the building. 200 compact fluorescent light, CLF (15W each), 110 tube lights (40W each) and 4 halogen lamps (1000W each) are installed in the building .If the existing CFL, tube lights and halogen lights are replaced by energy efficient LED lamps (7W each), LED tube lights (22W each) and LED flood light (160W each), the net energy saving in the lighting load will be 16301.20kWh/year.Net energy saving in the building by replacing existing lights by energy efficient LED lamps ,tube lights and LED flood lights will be 55%.Approximate market unit price for LED lamp (7W,Rs.470), LED tube light (22W,Rs.1800) and LED (160W, Rs.32000).Since there is a significant energy saving and payback period is also very less around 4.8 years, it is economically beneficial to replace the existing lighting system with the suggested energy efficient lights.

(c) Fans

Ceiling fans and exhaust fans account for the 0.18MWh/year, nearly 1% of the total annual energy consumption in the building. Operating days of Fans in the auditorium are also very less, 25 days in a year. Hence it is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

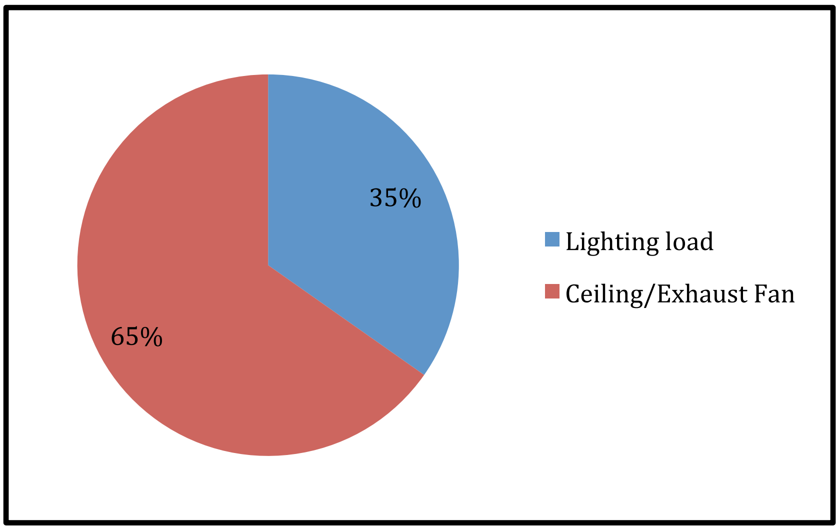
TYPE	Annual Energy Consumption (kW/year) by Existing load	Annual Energy Consumption (kWh/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving @Rs.5.35/kWh	Simple Payback Period (in Years)	COMMENTS
Lighting Load	51699.7	27710.8	23988.9	128340.59	8	Replacement by energy efficient lights is suggested
Fans	17690.4	15331.68	2358.72	12619.15	14.4	No immediate replacement required
Air Conditioner	128304	95629.25	35623.15	190583.86	16	No immediate replacement required
Television/Computer	18575.22	-	-	-	-	No replacement required
Kitchen appliances	2277.6	-	-	-	-	No replacement required

3.4 Women facility centre

Annual energy consumption in the Women Facility Centre is 5.34 MWh/year, with the maximum consumption by fan. Detailed energy end-use by activity has been clearly depicted in the table below:

	Appliances	Type & Make	Watt	Quantity	Total Load (kW)	Days in year	Days of operation	Total Energy (kWh/day)	Total Energy (kWh/year)
5									
6	**Lighting Load**								
7	Indoor Lighting Type 1	CFL	36	85	3.06	365	300	3.06	918.00
8	Indoor Lighting Type 2	Tube Light	40	78	3.12	365	300	3.12	936.00
9	**Appliances for comfort**								
10	Fan Type 1	Ceiling Fan	60	20	1.2	365	180	9.60	1728.00
11	**Bathroom & Cleaning Appliances**								
12	Exhaust fan	Exhaust fan	60	10	0.6	365	365	4.80	1752.00
13	Women Facilty Centre				7.98			20.58	5334.00

Application wise Percentage Annual Energy Consumption is shown below



3.4.1 Energy Efficiency Intervention for Women Facility centre

(a) Lighting Load

Lighting load in the Women Facility Centre is 1.84MWh/year, which is 35% of the total annual energy consumption in the building.85 compact fluorescent light, CLF (36W each), 78 tube lights (40W each). If the existing CFL and tube lights are replaced by energy efficient LED lamps (20W each) and LED tube lights (22W each), the net energy saving in the lighting load will be 829.2 kWh/year. Net energy saving in the building by replacing existing lights by energy efficient LED lamps and tube lights will be 16%.Approximate market unit price for LED lamp (20W, Rs.1500) and LED tube light (22W, Rs.1800). Payback period for replacing the existing lighting system with energy efficient lighting system will be very high due to high investment cost and less operational time for lighting load. Hence, it is not economically beneficial to immediately replace the existing lighting system with the suggested energy efficient lights. In case of damage or any replacement required, energy efficient lights, instant fit LED lamps and tube lights shall replace the existing lights.

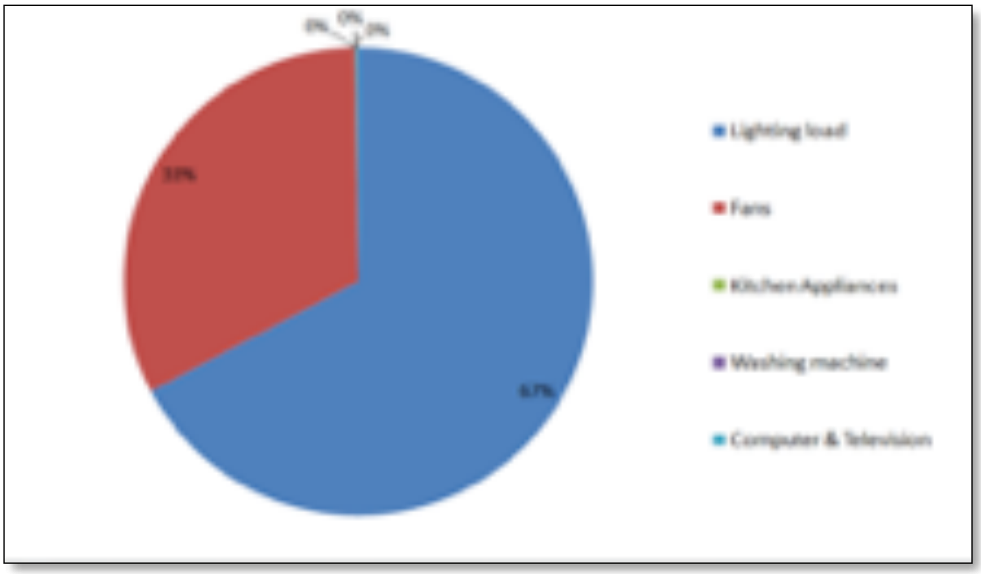
(b) Fans

Ceiling fans and exhaust fans account for the 1.7MWh/year, accounting for 65% of the total annual energy consumption in the building. If the existing ceiling fans (60W each) are replaced by the BEE 5 star rated fans (approx. 52W each), 230.40 units per year will be saved providing 4% energy saving in the building. Cost involved in replacing the existing fans by energy efficient fans will be very high delivering very high payback time. Hence it is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

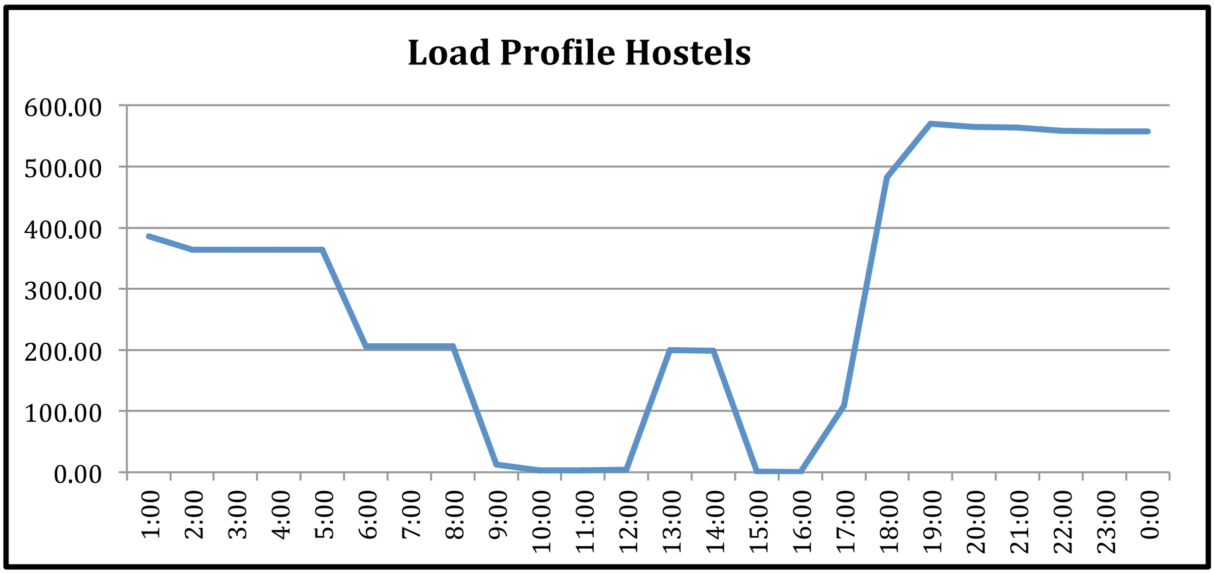
TYPE	Annual Energy Consumption (kW/year) by Existing load	Annual Energy Consumption (kW/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving @Rs.5.35/kWh	Simple Payback Period (in Years)	COMMENTS
Lighting Load	1854	1024.8	829.2	4436.22	60	Immediate replacement not required
Fans	1728	1497.6	230.4	1232.64	32	Immediate replacement not required

3.5 Hostels

Tezpur University campus comprises of total 12 hostels, 7 women's hostel and 5 men's hostel. Annual energy consumption in all the hostels is 1895.32 MWh/year, with the maximum share of lighting load followed by the cooling load through fans as shown in the chart below:



Load profile for all Hostels is shown below in the chart:



The load curve shows that there is a peak load demand after 6 PM in the evening to 12 midnight.

3.5.1 Energy efficiency Intervention for Hostels:

(a) Lighting

Total lighting load in the guest house is 1274.35MWh/year, with 1266.6MWh/year and 7.752MWh/year indoor lighting load and outdoor lighting load respectively. Lighting load accounts for 67% of the total annual energy consumption in the building. Following table shows the total quantity and wattage of lights used in all the hostels:

TYPE	WATT	QUANTITY	LIGHTING
CFL	18	340	Indoor
CFL	36	4503	
Tube Light	49	4824	
HPMV	150	8	Outdoor
HPSV	150	1	
HPSV	70	6	

If the existing indoor lights are replaced by energy efficient LED lamps (existing 18W by 10W each; 36W by 20W each) and LED tube lights (existing 40W by 22W each) and outdoor HPMV lamps by

LED flood lights (existing 150W by 80W each), outdoor HPSV lamps by LED flood lights (existing 150W by 130W and 70W by 60W) the net energy saving in the lighting load will be 568,461kWh/year that is 568461.22units per year. Net energy saving in the building by replacing existing lights by energy efficient LED lamps, LED tube lights and flood lights will be 30%. Based on the available market prices, the total investment cost in replacing the existing lights by energy efficient lights is of Rs.15,874,400 and payback period of around 5 years. There is a wide scope of improving the lighting load in all the hostels. It is advised to replace all the existing lights by energy efficient LED lights of suggested wattages.

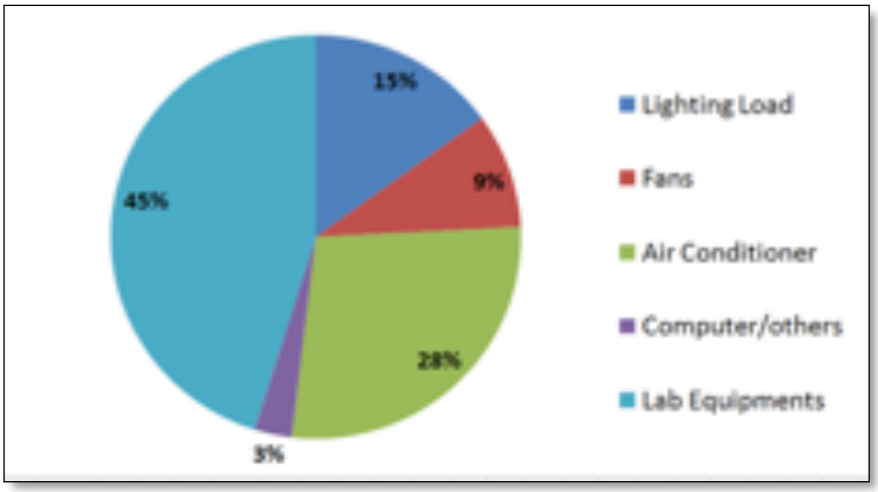
(b) Fans

Ceiling fans and exhaust fans account for the 583.5MWh/year, nearly 33% of the total annual energy consumption in the building. If the existing ceiling fans (60W each) are replaced by the BEE 5 star rated fans (approx. 52W each), 77807.52 units per year will be saved providing 4% energy saving in the building. Investment cost of replacing the existing fans by energy efficient fans will be very high delivering very high payback time. It is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

TYPE	Annual Energy Consumption (kW/year) by Existing load	Annual Energy Consumption (kW/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving @Rs.5.35/kWh	Simple Payback Period (in Years)	COMMENTS
Lighting Load	1274356.62	705895.4	568461.22	3041267.53	5	Replacement is suggested
Fans	583556.4	505748.88	77807.52	416270.23	15	No immediate replacement required
Kitchen Appliances	367.92	-	-	-	-	No immediate replacement required
Washing Machine	105	-	-	-	-	No immediate replacement required
Computer & Television	3757	-	-	-	-	No immediate replacement required

3.6 Energy Efficiency Interventions in Departmental Buildings & Labs

Annual energy consumption in all the hostels is 915.71MWh/year, with the maximum share of laboratory equipment load followed by the space cooling load through air conditioners as shown in the chart below:



(a) Lighting

Total indoor lighting load in lab and departments is 130.5MWh/year, nearly 15% of the total annual energy consumption. Following table shows the total quantity and wattage of lights used in all the hostels:

TYPE	WATT	QUANTITY
CFL	11	128
CFL	18	455
CFL	36	195
TUBE LIGHT	40	1547

If the existing indoor CFL and tube lights are replaced by energy efficient LED lamps (existing 11W by 5W each; 18W by 10W each and 36W by 20W respectively) and LED tube lights (existing 40W by 22W each), the net energy saving in the lighting load will be 42382.30kWh/year that is 42,382 units per year. Net energy saving in the building by replacing existing lights by energy efficient LED lamps and LED tube lights will be 5%.Based on the available market prices, the total investment cost in replacing the existing lights by energy efficient lights is of Rs.3,390,251 and payback period of around 15 years. In spite of the energy savings, it is not advised to replace the existing lights due to heavy expenses involved in their purchase and installation with very high payback time. In case of damage or any replacement required, energy efficient lights, instant fit LED lamps and tube lights shall replace the existing lights.

(b) Fans

Ceiling fans and exhaust fans account for the 77.16MWh/year, nearly 9% of the total annual energy consumption in the building. If the existing ceiling fans (60W each) are replaced by the BEE 5 star rated fans (approx. 52W each), 10287.36 units per year will be saved providing only 1% energy saving in the building. Investment cost of replacing the existing fans by energy efficient fans will be very high delivering very high payback time. It is not advisable to do immediate replacements. In case a fan exhausts or get damaged in future, it should be replaced by an energy efficient BEE 5 star rated fan.

(c) Air Conditioner

Space cooling using air conditioners accounts for annual energy consumption of 253.5MWh/year which is 28% of the total annual load. Total 66 air conditioners, 2250W each are installed in the all the department and laboratory buildings, operating 180 days in a year. If these are replaced by BEE 5 star rated air conditioners, 1677W each, the net energy saving in the air conditioning load will be 63843.6kWh/year. Net energy saving in the building by replacing existing ones by energy efficient air conditioners will be 7%.Approximate market cost of a BEE 5 star rated air conditioners is Rs.35000. The payback period comes out to be around 7 years. Hence, it is advised to replace the existing air conditioners by BEE 5 star rated air conditioners.

TYPE	Annual Energy Consumption (kW/year) by Existing load	Annual Energy Consumption (kW/year) by Energy efficient load	Annual Energy Saving (kWh)	Cost of electricity saving @Rs.5.35/kWh	Simple Payback Period (in Years)	COMMENTS
Lighting Load	130551.85	88169.55	42382.3	226745.3	15	Immediate replacement not required
Fans	77155.2	66867.84	10287.36	55037.38	26	Immediate replacement not required
Air conditioner	253491.12	189647.46	63843.6	341563.5	7	Replacement is suggested
Lab Equipments	413757.62	-	-	-	-	Immediate replacement not required
Computer	26787	-	-	-	-	-

4 RENEWABLE ENERGY PLANNING

The objective of this exercise is to identify available renewable energy resources in Tezpur University Campus. Preliminary renewable energy resources assessment has been carried out to identify the potential renewable energy sources for the Tezpur University Campus. This includes assessment of solar radiation, wind power density and availability and bio wastes in the campus which can potentially be converted into energy.

On finalisation of the proposed projects in consultation with the department of energy and university authority, we will study the techno commercial feasibility of those projects and prepare detailed project report.

4.1 Renewable Energy Resource Assessment

4.1.1 Solar Resource

Tezpur (92.83° E and 26.7° N) receives good amount of solar radiation with an annual average of 4.57 kWh/m2/day. Solar Radiation data for the site has been derived from NASA website http://eosweb.larc.nasa.gov/cgi-bin/sse. This data is compared with MNRE data available in the website and further compared with the ground data collected at the through Solar Radiation Resource Assessment (SRRA) monitoring station installed in the university.

The mean annual average of global horizontal solar insolation for the project site is 4.57 kWh/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 4.87 kWh/m^2/day. The figure table and figure below shows monthly average global horizontal irradiance (GHI) and direct normal radiation (DNI).

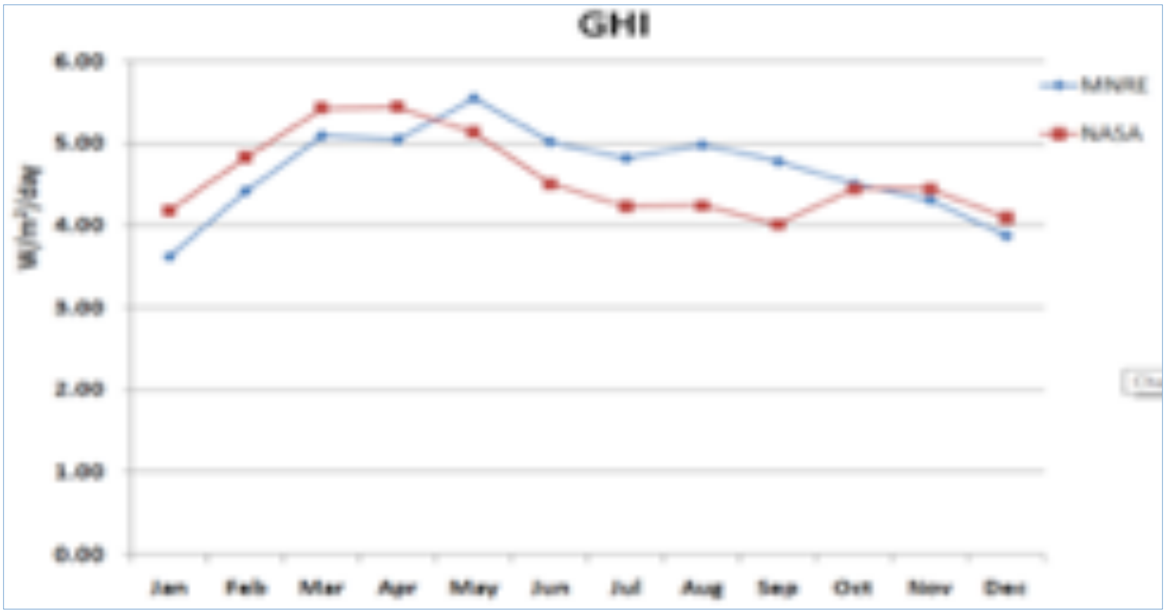
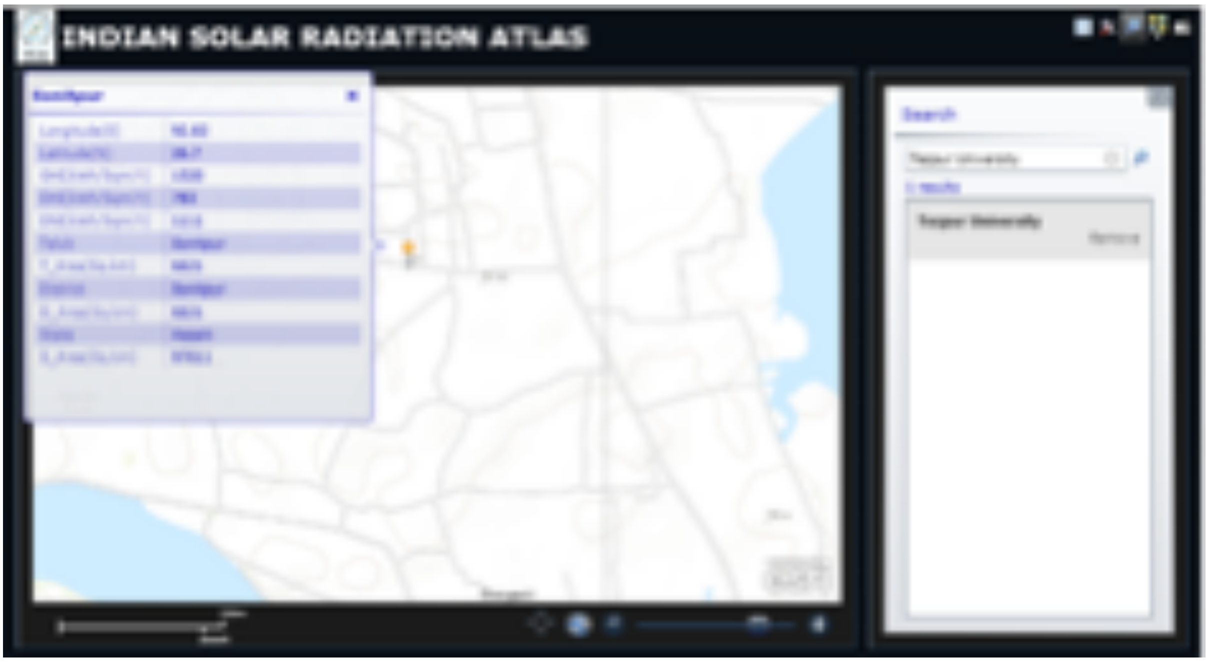


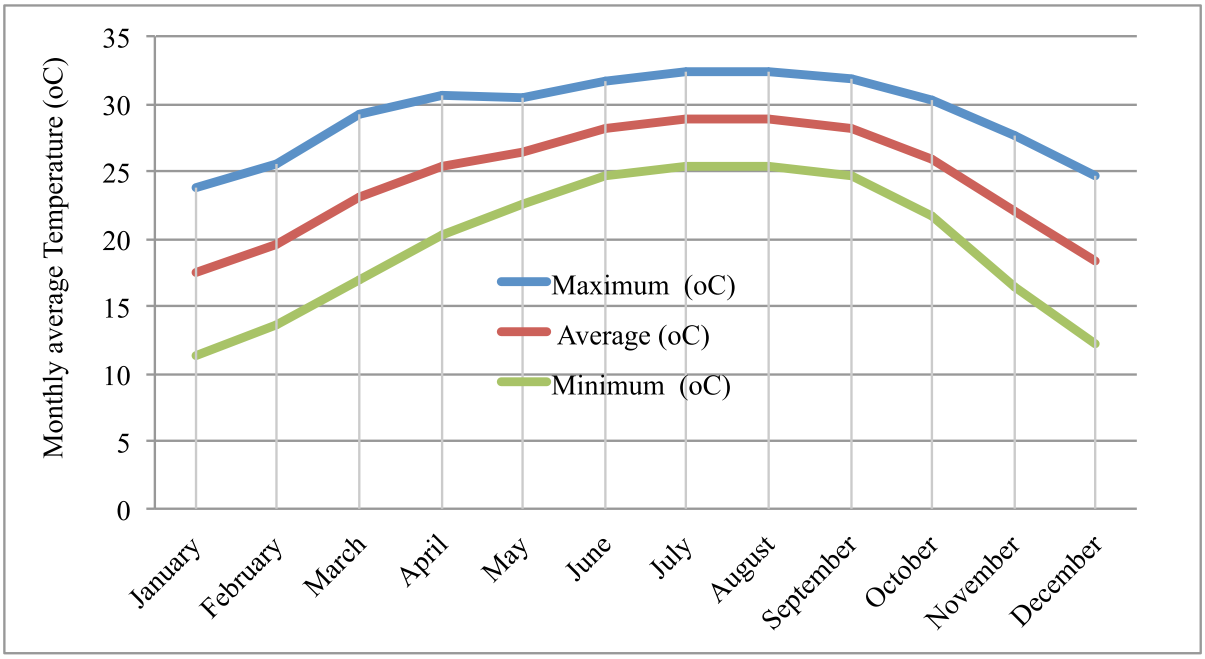
Table: Monthly average solar radiation data for Tezpur

MONTH	MNRE (GHI) ($kWh/m^2/day$)	NASA (22-years average Satellite data for GHI) ($kWh/m^2/day$)	NASA (22-years average Satellite data for DNI) ($kWh/m^2/day$)
January	3.63	4.18	6.69
February	4.42	4.83	6.55
March	5.10	5.43	6.09
April	5.05	5.44	4.9
May	5.55	5.13	3.9
June	5.02	4.5	2.87
July	4.82	4.23	2.57
August	4.99	4.24	2.84
September	4.78	4.01	3.07
October	4.51	4.44	5.04
November	4.31	4.44	6.91
December	3.88	4.09	7.09
Annual	**4.67**	**4.57**	**4.87**



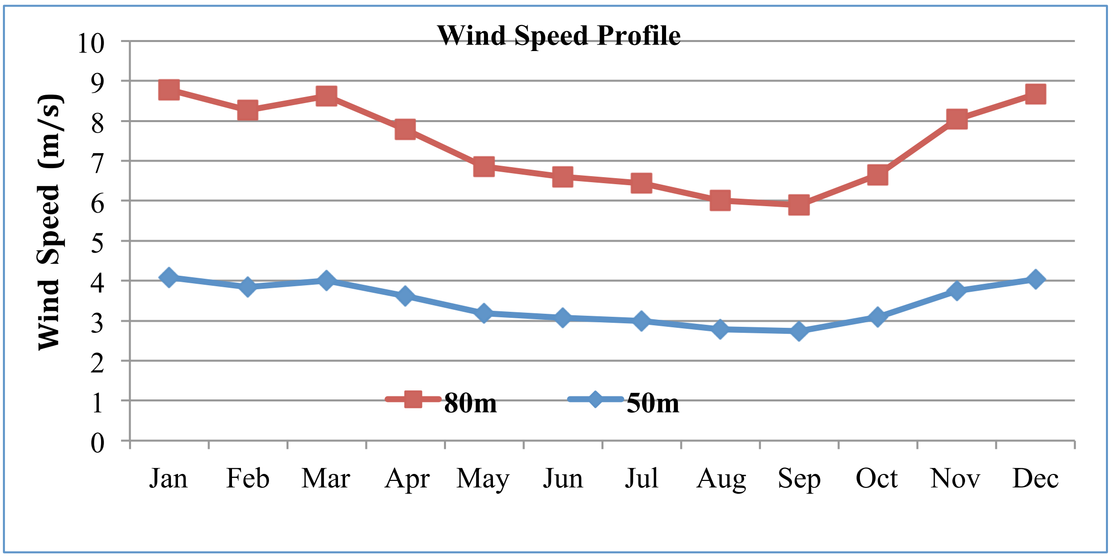
Temperature

Ambient temperature is one of the major factor that influence in energy generation through solar photovoltaic technologies. Monthly average, minimum and maximum ambient temperature profile for the site is shown in the figure below:



4.1.2 Wind Resource

The monthly average wind speed data at 50m height for Tezpur University was obtained from NASA satellite source (http://eosweb.larc.nasa.gov/cgi-bin/sse.) The same data was extrapolated for monthly average wind speed at 80m height.



Monthly Wind Speed Profile for Tezpur

Average wind density at 80m height was calculated to be 37.88 W/m^2. The table below shows the monthly extrapolated wind density.

Month	Wind Density at 80 m height (W/m^2)
Jan	63.76
Feb	53.16
Mar	60.54
Apr	44.54
May	30.48
Jun	27.16
Jul	25.10
Aug	20.39
Sep	19.31
Oct	27.70
Nov	49.11
Dec	61.45
Average	**37.88**

Calculated wind density at Tezpur University is not sufficient to implement a viable wind energy generation project.

4.1.3 Energy from Waste

Total kitchen waste generated from various buildings at Tezpur University is shown in the table below:

Hostels	Total Kitchen Waste (Kg/day)
Bordoichila Women Hostel (BWH)	36
Dhanshiri Women Hostel (DWH)	44
Kopili Women Hostel (KWH)	54
New Women Hostel (NWH)	32
Pobitora Madam Curie WH (PMWH)	71
Pragjyotika Women's Hostel (PWH)	39.5
Subansri Women Hostel (SWH)	60
Charaideo Men Hostel (CMH)	123.5
Kanchanjungha Men Hostel (KMH)	151.5
Nilachal Men Hostel(NMH)	87.5
Patkai Men's Hostel (PMH)	104.5
Saraighat CV Raman Men's Hostel(SCVRMH)	101
Residential quarters	92.9
Old Guest House	6.25
Security Barracks	28
CANTEEN	70
TOTAL	**1101.65**

From the table above it is seen that total 1101.65 kg of Kitchen waste is generated per day at the campus building. This amount of kitchen waste can generate approx. 367 m^3 of biogas per day which is equal to 165 kg of LPG per day.

4.2 Potential sites for Solar Photovoltaic Projects

Based on preliminary site assessment, the following sites may be considered for further investigation for installing solar photovoltaic systems.

- Department of Management studies
- Guest House Parking site
- Community Hall
- Outdoor Stadium-1
- Outdoor Stadium-2
- ISI building
- Patkai Men's Hostel (PMH)

Approximate area was measured for the potential sites and the corresponding approximate PV capacity (in kW) was calculated as shown in the table below:

Sl. No.	Potential Sites for Photovoltaic Projects	Approx. surface Area (Sqm)	Indicative PV array capacity for installation in flat surface (kW)
1	Dept. of Management Studies Rooftop Block 1	240	12
2	Dept. of Management Studies Rooftop Block 2	126	6
3	Dept. of Management Studies Rooftop Block 3	240	12
4	Dept. of Management Studies Rooftop Block 4	203	10
5	Dept. of Management Studies Rooftop Block 5	98	5
6	Guest House Parking Site	481	24
7	Community hall Site	415	21
8	Outdoor Stadium1 Site-1	4146	207
9	Outdoor Stadium1 Site-2	5330	267
10	ISI Building Rooftop	1348	67
11	Outdoor Stadium2 Site	977	49
12	Patkai Men's Hostel (PMH) Rooftop Site	860	43
	Total	**14464**	**723**


Outdoor Stadium 1 site-2
Outdoor Stadium 1 site-1
Community hall site
Outdoor Stadium 2 site
Google earth


Dept. of Management studies Rooftop Block-5
Dept. of Management studies Rooftop Block-1
Dept. of Management studies Rooftop Block-4
Dept. of Management studies Rooftop Block-2
Dept. of Management studies Rooftop Block-3
Guest House Parking Site
Google earth

5 DETAILED REPORTS FOR SHORTLISTED PROJECTS

In consultation with the Energy Department and university authority five renewable energy projects have been selected for preparation of detailed project reports. The following independent detailed projects reports includes site details, system description and technical specification, project cost and life cycle cost benefit analysis.

Sl. No.	Identified Projects for Detailed Report	Capacity
1	Grid connected solar PV power plant Site 1: North side of outdoor stadium (football field)	207kWp
2	Grid connected solar PV power plant Site 2: Northwest side of outdoor stadium (football field)	230kWp
3	Grid connected solar PV power plant Site 3: ISI Building roof	72kWp
4	Grid connected solar PV power plant Site 4: Guesthouse car parking area	24kWp
5	Concentrated Solar Thermal (CST), Biogas and LPG hybrid system for steam cooking	256sqm CST 50m^3 biogas

These Detailed Project Reports are prepared separately and attached to this report

Detailed Project Reports on:

Grid connected solar PV power plants

Site 1: North side of outdoor stadium (football field)
Site 2: Northwest side of outdoor stadium (football field)
Site 3: ISI building roof
Site 4: Guest house car parking area

TABLE OF CONTENTS

1 SITE LOCATIONS

Grid connected solar PV power plants have been proposed in the following locations in the Tezpur University Campus.

Site 1: North side of outdoor stadium (football field)
Site 2: Northwest side of outdoor stadium (football field)
Site 3: ISI Building roof
Site 4: Guesthouse car parking area

Figure 1.1: View of four selected site for installation of grid connected solar PV systems

1.1 Estimation of PV Array Capacity

The aggregate capacity of solar array that could be installed in the selected sites is estimated to be 535.4kWp. The estimation is based on silicon crystalline solar modules with efficiency of 15.5% or more. In case of thin film, which has lower efficiency the estimated array capacity will be less. Available areas suitable for installation of solar PV arrays are given in the table below.

Table 1.1: Estimated PV array capacity in four identified sites

Sl. No.	Identified Projects for Detailed Report	Array Capacity
1	Site 1: North side of outdoor stadium (football field)	207kWp
2	Site 2: Northwest side of outdoor stadium (football field)	230kWp
3	Site 3: ISI Building roof	72kWp
4	Site 4: Guesthouse car parking area	26.4kWp
	Total	**535.4kWp**

2 ESTIMATION OF ENERGY GENERATION POTENTIAL

Solar Resource:

Tezpur (92.83° E and 26.7° N) receives good amount of solar radiation with an annual average of 4.57 $kWh/m^2/day$ in a horizontal surface as per solar radiation data from NASA website http://eosweb.larc.nasa.gov/cgi-bin/sse. The university has a solar radiation resource assessment station installed by the National Institute of Wind Energy (NIWE) under a MNRE programme. NIWE has recently published solar radiation atlas for India which reports annual average global horizontal irradiation in Tezpur as 1520$kWh/m^2/year$ or 4.16$kWh/m^2/day$. Considering about 10% increase in radiation for a tilted surface at 26^o, solar radiation received by the proposed power plants will be 4.58$kWh/m^2/day$.

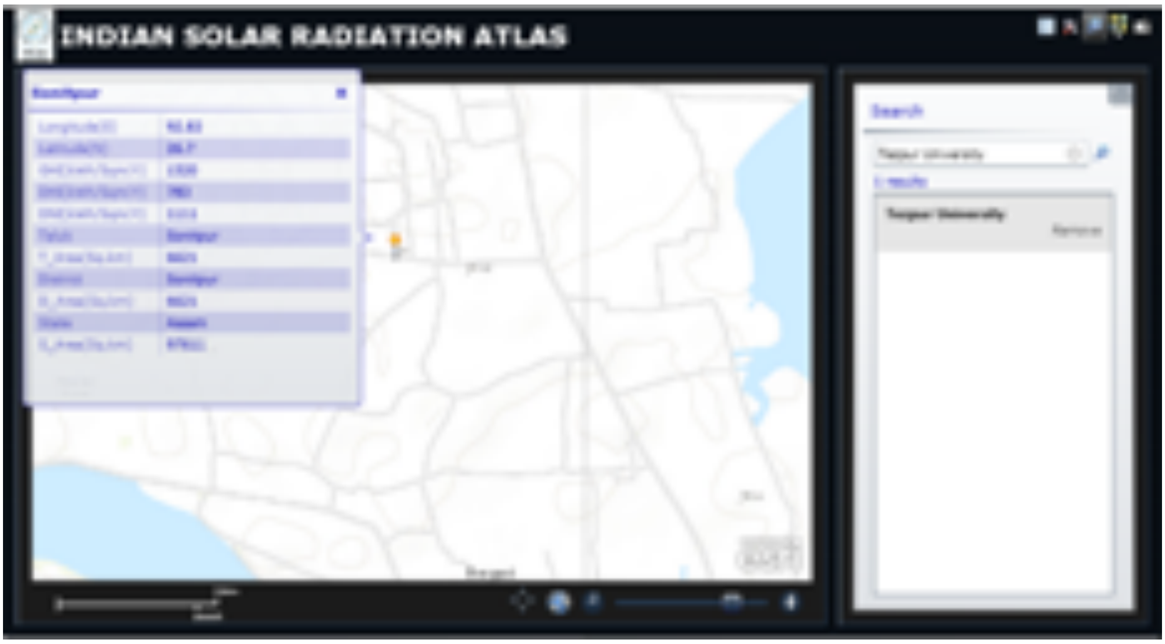


Figure 2.1: Solar radiation data from Indian solar radiation atlas of NIWE

Generation Loss due to Temperature:

Ambient temperature is one of the major factors that influence in energy generation through solar photovoltaic technologies. Energy generation is estimated based on maximum monthly average temperature, which is likely to occur during a sunny day when PV power plants will generate energy.

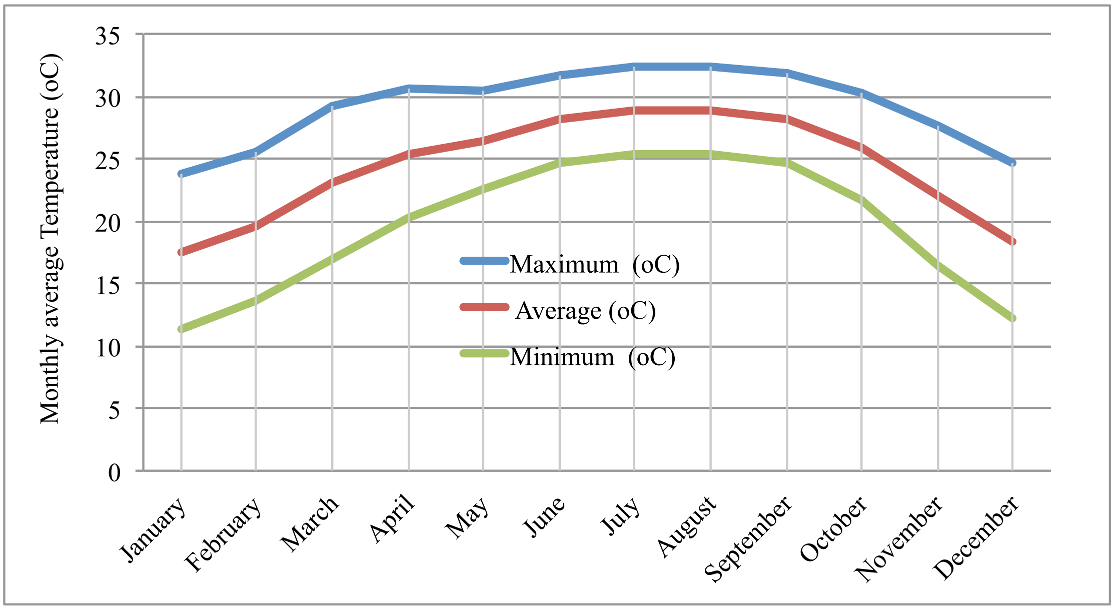


Figure 2.2: Monthly average, maximum and minimum ambient temperature at Tezpur
Source http://en.climate-data.org

Table below shows cell operating temperature pertaining to variable average monthly ambient temperature during the year. Considering crystalline module power temperature co-efficient as 0.42% /°C at rated NOCT of 47°C, average generation loss due to higher cell operating temperature is estimated to be 13% with lower loss (11%) during winter months and higher loss (15%) during summer months.

Table 2.1: Temperature Data and estimation of generation loss due to higher cell temperature

Month	Ambient temperature (°C)[1]	Cell Operating Temperature (°C)[2]	Temperature Derating Factor [3]	PV generation loss (%)[4]
January	23.7	50.70	0.89	11%
February	25.5	52.50	0.88	12%
March	29.2	56.20	0.87	13%
April	30.6	57.60	0.86	14%
May	30.5	57.50	0.86	14%
June	31.7	58.70	0.86	14%
July	32.3	59.30	0.85	15%
August	32.3	59.30	0.85	15%
September	31.8	58.80	0.86	14%

Month	Ambient temperature (^oC)[1]	Cell Operating Temperature (^oC)[2]	Temperature Derating Factor [3]	PV generation loss (%)[4]
October	30.2	57.20	0.86	14%
November	27.6	54.60	0.87	13%
December	24.6	51.60	0.89	11%
Annual Average	29.17	56.17	0.87	13%

Note:

1. Solar PV Modules are expected to work at this ambient temperature in a sunny day

2. Cell operating temperature for PV modules rated with 47^o C NOCT (^oC). Modules with higher NOCT will have higher cell operating temperature

3. Temperature derating factor is used to derate P_{max} of PV modules with respect to P_{max} at STC

4. PV generation loss due to higher cell temperature with respect to STC temperature

Loss due to Shadow:

All the selected sites are free from near and far shadow. However, we have considered minimum line shadow from the PV arrays placed in different rows for optimum placement. This will resulted into about 2% loss during December and January and 1% loss during November and February.

Other Losses:

Apart from the temperature and shadow losses, which are variable during the year, there are other generation and transmission losses in a PV system, which can be considered similar during the year subject to type of PV technology, engineering design, and operation and maintenance practice. Description of such losses, estimated loss and derate factors are shown in the table 2.2 below:

Table 2.2: Other losses affects PV power plant generation

Description of Lossess	Estimated Loss (%)	Derating Factor[1]	Remarks
PV loss due to irradiance level	3.00%	0.97	For crystalline modules
Soiling loss	3.00%	0.97	Assumed considering regular cleaning of modules
Manufactruer Tolerance	0.00%	1.00	Considering Positive Tolerance Modules
Inverter loss during operation	3.00%	0.97	Considering 97% inverter efficiency at minimum 20% load
Loss in DC cables	1.00%	0.99	Maximum loss allowed in DC cables is 3% (IEC62548)
Loss in the Transformer	0.00%	1.00	No transformer used

Description of Lossess	Estimated Loss (%)	Derating Factor[1]	Remarks
Loss in AC Transmission	1.00%	0.99	Maximum loss allowed in AC circuit is 2% (IEC 62548)
Total Other losses	11%	0.89	

Note:
1. Derating factors are used to derate P_{max} of PV modules with respect to P_{max} at STC

2.1 Estimation of Energy Generation Potential

Considering all generation and transmission losses, the estimated energy generation potential from 535.4kWp solar array is 6,91,239kWh of electricity annually and replace average 16.12% of total electricity consumption in the campus. The maximum solar fraction of 32.87% will be achieved during the month of March and lowest solar fraction of 8.71% will be achieved during the month of September. This is due to variation in solar radiation during the year and monthly variation in energy consumption in the campus. The table below provides month wise solar fraction from a 535.4kWp solar array. The monthly energy yield is calculated based on a tilted array surface at 26° considering 0° azimuth angle.

Table 2.3: Estimated energy yield and contribution to total energy demand in the university

Months	Total Energy Demand in the University (kVAh)	Output from a 535.4kWp array (kWh/month)	Solar energy fraction of total energy demand
January	2,04,256	54,206	26.54%
February	2,28,720	56,663	24.77%
March	2,12,904	69,977	32.87%
April	3,93,824	67,382	17.11%
May	4,72,904	65,692	13.89%
June	4,71,272	55,438	11.76%
July	4,04,920	53,689	13.26%
August	4,35,128	53,816	12.37%
September	5,66,864	49,377	8.71%
October	4,78,840	56,940	11.89%
November	5,43,120	55,247	10.17%
December	5,21,696	52,812	10.12%
Annual Total	49,34,448	6,91,239	16.12%

Table 2.4: Site wise monthly energy generation from solar PV power plant

Project Site	Site 1: (Outdoor stadium)	Site 2: (Outdoor stadium)	Site 3: (ISI Building Roof)	Site 4: (Guest House car Parking)	Total for four sites
Capacity	**207kWp**	**230kWp**	**72kWp**	**26.4kWp**	**535.4kWp**
Jan	20,957	23,286	7,290	2,673	54,206
Feb	21,907	24,341	7,620	2,794	56,663
Mar	27,055	30,061	9,410	3,451	69,977
Apr	26,052	28,946	9,061	3,323	67,382
May	25,398	28,220	8,834	3,239	65,692
Jun	21,434	23,815	7,455	2,734	55,438
Jul	20,758	23,064	7,220	2,647	53,689
Aug	20,807	23,119	7,237	2,654	53,816
Sep	19,090	21,212	6,640	2,435	49,377
Oct	22,015	24,461	7,657	2,808	56,940
Nov	21,360	23,733	7,430	2,724	55,247
Dec	20,419	22,687	7,102	2,604	52,812
Annual	**2,67,252**	**2,96,946**	**92,957**	**34,084**	**6,91,239**

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 0.7% per annum for the first 10 years and 0.87% degradation per year from 11^{th} year to 25^{th} year of project life. Considering annual degradation of PV modules, annual electrical energy yield from the aggregated 535.4kWp solar PV power plants for a projected period of 25 years is estimated as below:

Table 2.5: Degradation of Annual Energy Yield of 535.4kWp Solar PV power plant

Year of estimated life	Annual Energy Yield (kWh)	Annual Specific Yield (kWh/kW/year)	Annual Performance Ratio	Annual Plant Load Factor
Year 1	6,91,239	1,291.07	77%	15%
Year 2	6,86,401	1,282.03	77%	15%
Year 3	6,81,596	1,273.06	76%	15%
Year 4	6,76,825	1,264.15	76%	14%
Year 5	6,72,087	1,255.30	75%	14%
Year 6	6,67,382	1,246.51	75%	14%
Year 7	6,62,711	1,237.79	74%	14%
Year 8	6,58,072	1,229.12	74%	14%
Year 9	6,53,465	1,220.52	73%	14%
Year 10	6,48,891	1,211.97	73%	14%
Year 11	6,43,246	1,201.43	72%	14%
Year 12	6,37,649	1,190.98	71%	14%
Year 13	6,32,102	1,180.62	71%	13%
Year 14	6,26,603	1,170.34	70%	13%
Year 15	6,21,151	1,160.16	70%	13%
Year 16	6,15,747	1,150.07	69%	13%
Year 17	6,10,390	1,140.06	68%	13%
Year 18	6,05,080	1,130.15	68%	13%
Year 19	5,99,815	1,120.31	67%	13%
Year 20	5,94,597	1,110.57	67%	13%
Year 21	5,89,424	1,100.90	66%	13%
Year 22	5,84,296	1,091.33	65%	12%
Year 23	5,79,213	1,081.83	65%	12%
Year 24	5,74,174	1,072.42	64%	12%
Year 25	5,69,178	1,063.09	64%	12%
Life Cycle Average	6,31,253	1,179	71%	13%

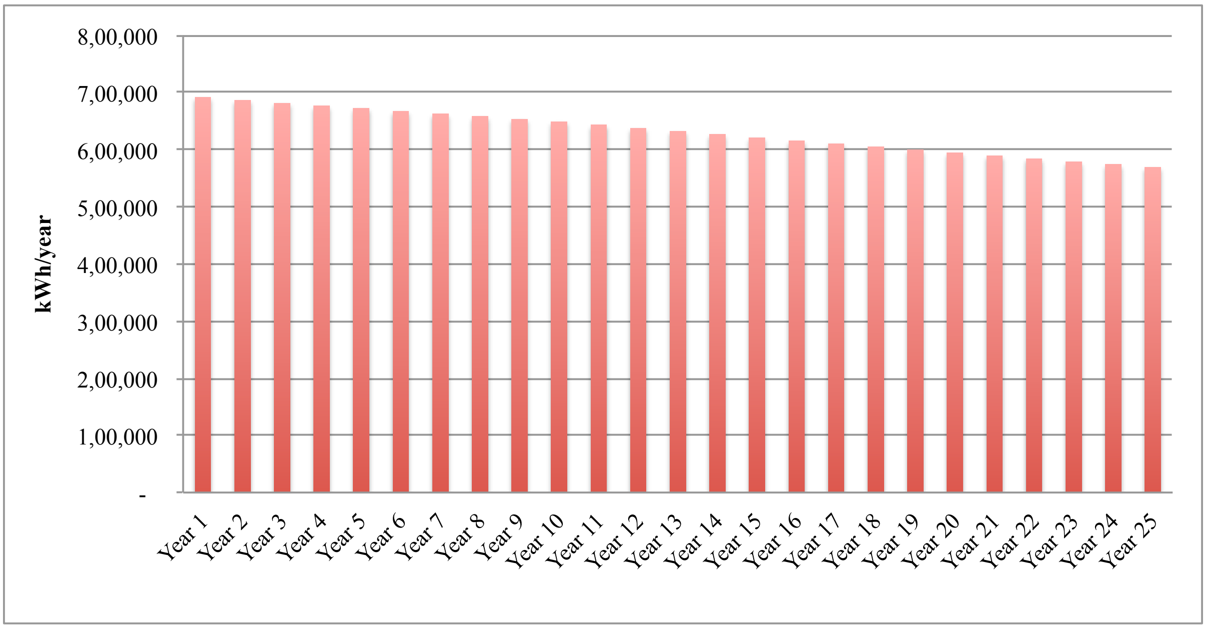


Figure 2.3: Reduction in energy generation due to degradation of PV power plant

3 SYSTEM DESIGN AND TECHNICAL SPECIFICATIONS

3.1 General Description

The aggregate capacity of proposed rooftop Grid connected solar PV systems is estimated as 535.4kWp (DC) to be installed in the shadow free rooftop areas in five buildings as shown in the figure below. The estimated capacity is based on actual survey and shadow analysis of the building roofs. We have considered crystalline modules of size 1956 mm x 990mm with minimum capacity of 250Wp at Standard Test Conditions. Total capacity of solar array may be increased by 5-10% based on efficiency of the module and inverter maximum DC input capacity. The aggregate nominal AC capacity of all systems will be 465kW (AC) using 10 numbers of 3-phase multistring and central inverters of capacity 25kW (one), 30kW (three), 50kW (four) and 60kW (three). All these inverters will be connected to a suitable distribution panel available in the campus.

The PV arrays installed in the rooftop will produce DC power and the same will be converted into 3-phase AC power using sixteen multi string inverters. The inverters will be equipped with Maximum Power Point Trackers (MPPTs) to enhance solar power and will have a control system to synchronise with the grid power and safety system for connect disconnect when required i.e. Anti-Islanding Protection. The system will have a web based remote monitoring and display system through which the day-to-day power generation and performance status of the system can be monitored remotely. The solar array will be installed on the ground and roof as the case may be in south orientation using extruded aluminium or galvanised iron mounting structure which can withstand wind speed of 150km/hr. UV protected solar DC copper cables will be used for module interconnection and array to inverter connections i.e. stringing. Surge protection device (SPD) and fuses will be used wherever required. For the Grid connection armoured copper AC cable will be used from inverters to grid injection point with ACDB and circuit breakers for protection. Appropriate safety devices will be used for personnel safety, short circuit protection, lightening protection, earthing and anti islanding protection. Applicable codes and standards will be followed for all equipments, accessories, and installation practice. The inverter will be installed near to the solar array and 3-phase output from the inverter will be conducted to the nearest distribution panel in the campus.

The proposed 535.4kWp 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.

3.2 System configurations and array layout

There will be 10 separate arrays connected to 10 multistring and central inverters. Based on the available shadow free space on the roofs, arrays will be placed in such way that there is minimum loss in cables, cost of structure is minimised, there is enough passages for movement of maintenance personnel, and aesthetics of the roof is protected. The AC output from the inverters at each site will be combined in an AC combiner box and output from the combiner box will be taken to the nearest grid distribution panel.

The table 3.1 provides distribution of arrays and inverters in different sites.

Table 3.1: Distribution of array and inverters in different site

Sl. No.	Roof of the Building	PV array capacity (DC Power at STC)	Inverter Nominal Power (AC)	Estimated oversizing of Array w.r.t nominal AC power
1	Site 1: North side of outdoor stadium (football field)	207kWp	3 x 60 = 180kW	15%
2	Site 2: Northwest side of outdoor stadium (football field)	230kWp	4 x 50 = 200kW	15%
3	Site 3: ISI Building roof	72kWp	2 x 30 = 60kW	20%
4	Site 4: Guesthouse car parking area	26.4kWp	1 x 25 = 25kW	5.6%
	Total	**535.4kWp**	**465kW**	

The array layout diagrams for each site are placed in the following pages.

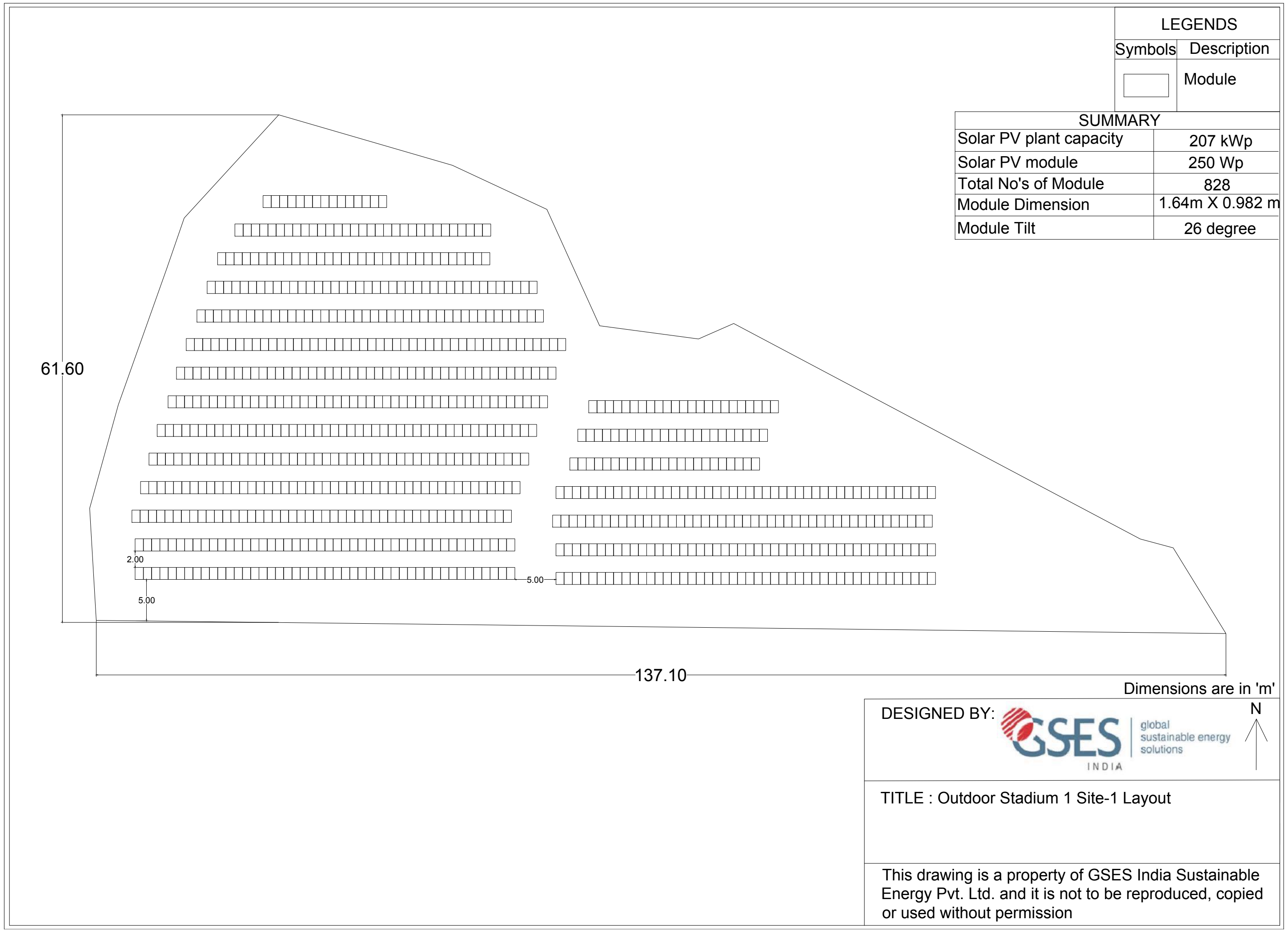


Figure 3.1: 207kWp Array layout diagram for Site 1 (Outdoor stadium)

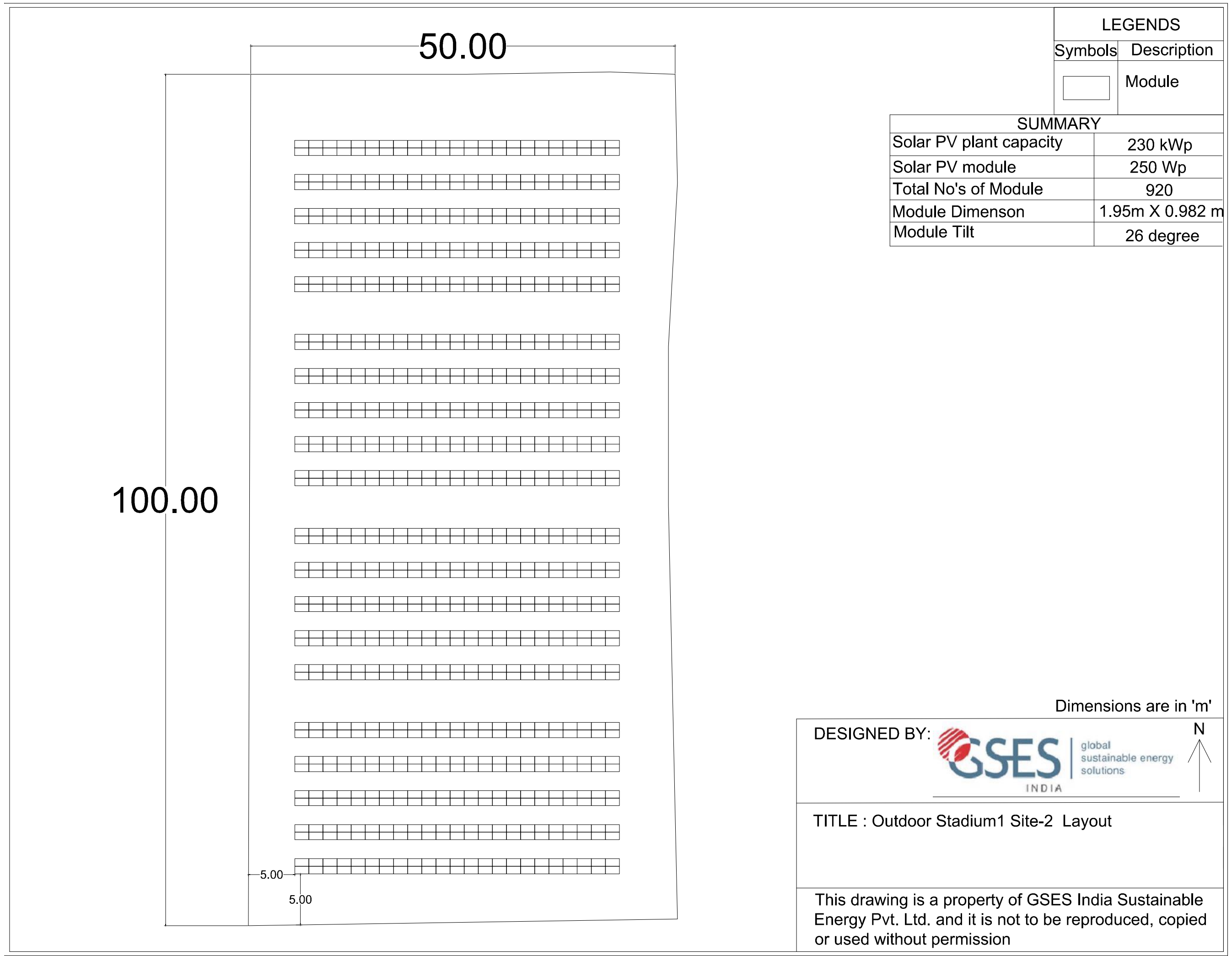


Figure 3.2: 230kWp Array layout diagram for Site 2 (Outdoor stadium)

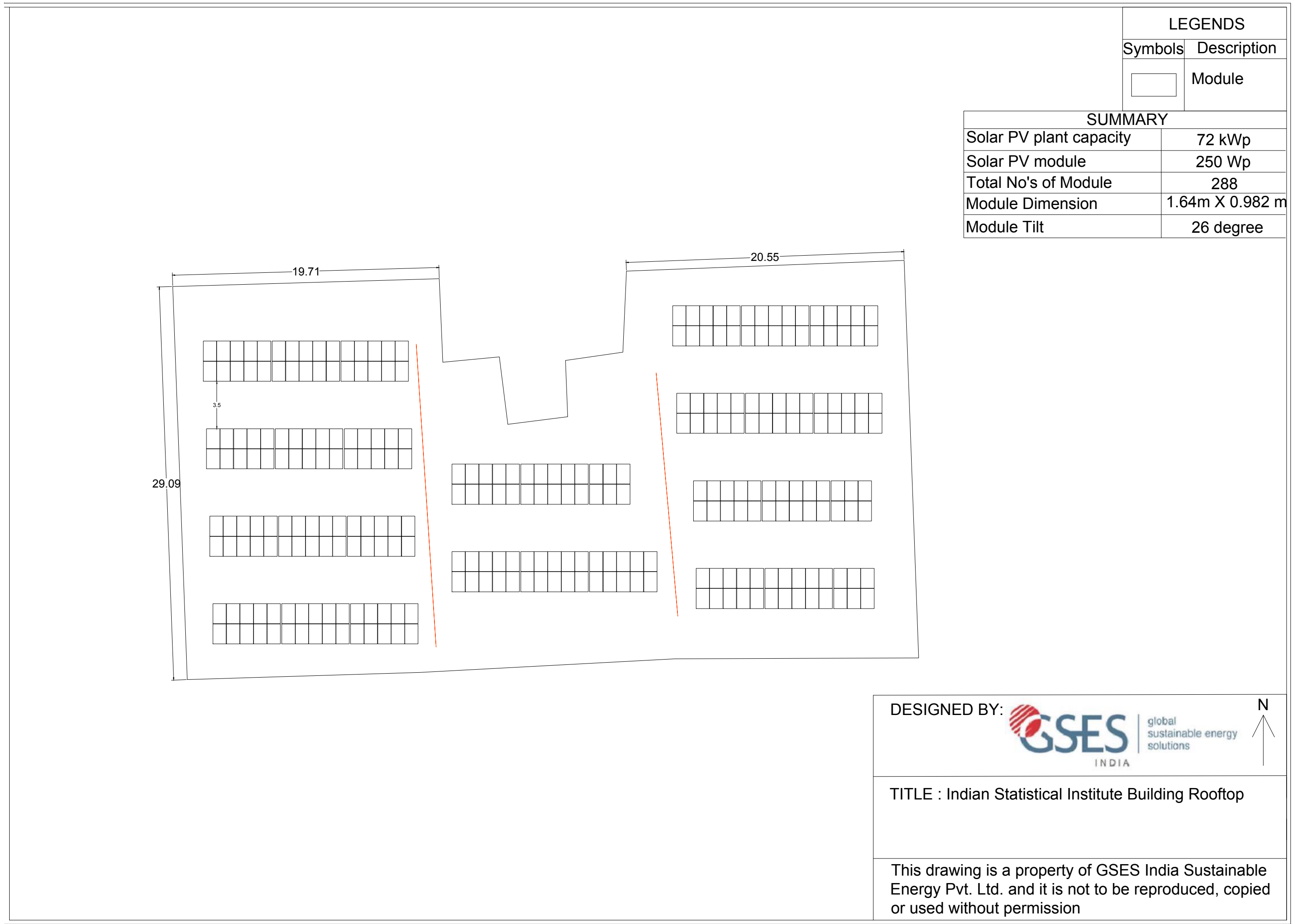


Figure 3.3: 72kWp Array layout diagram for the Site 3 (ISI Building roof)

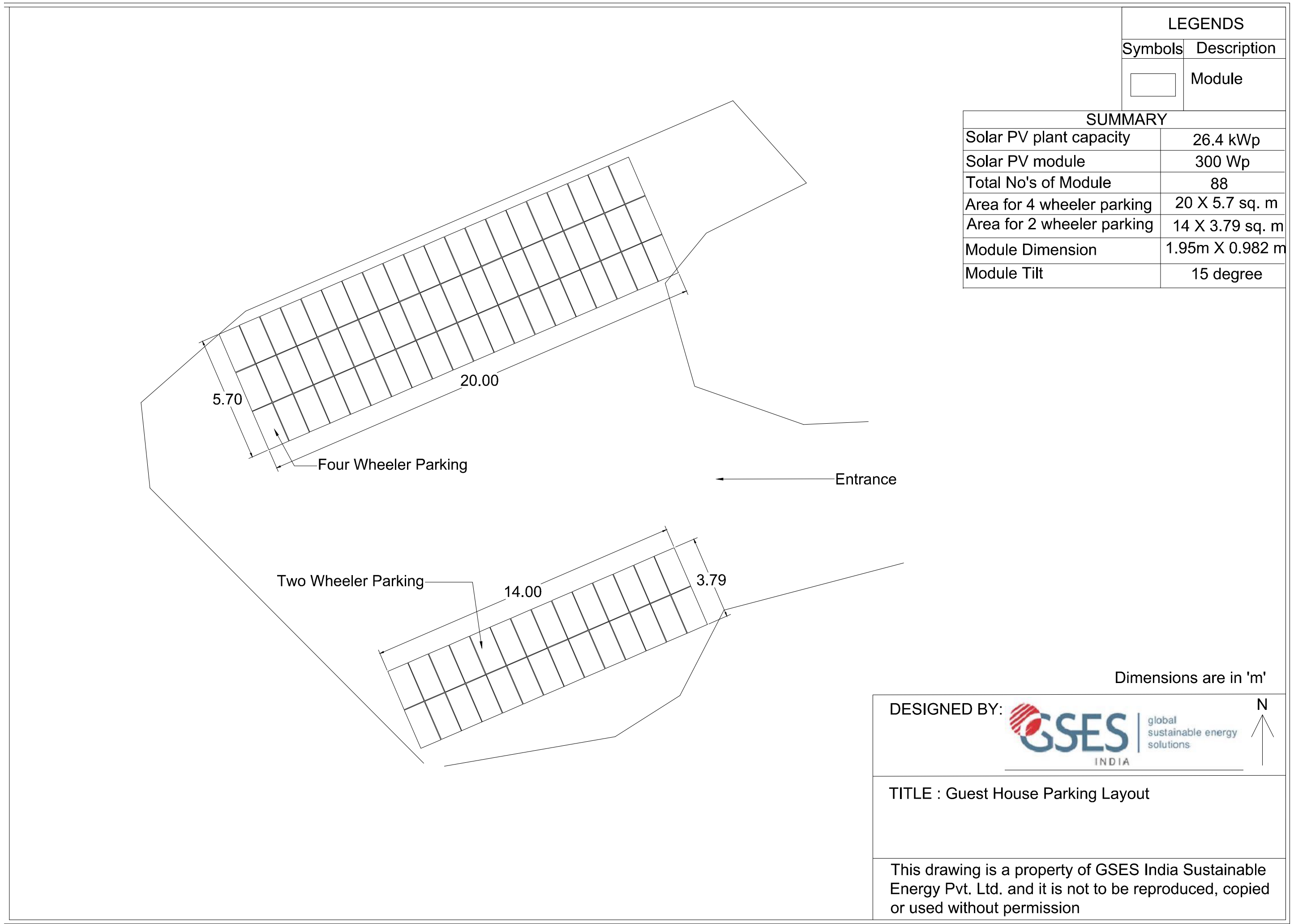


Figure 3.4: 26.4kWp Array layout diagram for the Site 4 (Guest House Car Parking)

3.3 Technical specifications and Code of Standards

3.3.1 Photovoltaic (PV) Modules

Crystalline silicon PV modules complied with IEC 61215 shall be used. Module efficiency should be more than 15.5% for effective utilization of limited roof space. Each module will have minimum of 72 cells. All modules should include bypass diodes. Only "Class A" modules according to IEC 61730-1 and IEC 61730-2 shall be used. **Class B Modules shall not be used.**

Capacity of a single module shall be 250Wp or more.

Aggregate array capacity at STC is estimated as 535.4kWp. This may be increased by 5-10% based on efficiency of the module and inverter maximum DC input capacity. All modules shall be from a single manufacturer with similar wattage and shall be with positive power tolerance only. **Negative power tolerance shall not be accepted.**

Performance of all PV modules shall be warranted with more than 90% power output for 12 years and 80% of minimum rated power for 25 years with not more than 1% degradation over a period of one year.

The manufacturer should warrant the solar module(s) to be free from the defects and/or failures specified below for a period not less than ten (10) years from the date of supply.

Modules deployed must use a RF identification tag. Only the module manufacturer in the factory must fix the RFID tag at the time of testing and before dispatch of modules. The following information must be mentioned in the RFID used on each module (This can be inside or outside the laminate, but must be able to withstand harsh environmental conditions).

- Name of the manufacturer of the PV module
- Name of the manufacturer of Solar Cells.
- Month & year of the manufacture (separate for solar cells and modules)
- Country of origin (separately for solar cells and module)
- I-V curve for the module
- Wattage, I_m, V_m and FF for the module
- Unique Serial No and Model No of the module
- Date and year of obtaining IEC PV module qualification certificate.
- Name of the test lab issuing IEC certificate.

3.3.2 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. 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. 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 nominal capacity of the inverter shall be as per table 3.2 below from reputed manufacturer with credible track record.

The inverter system should be provided with surge protection device. The inverter must be equipped with GSM based data module for uploading performance data to websites to view and track energy production online.

Table 3.2: Basic Technical Features of Inverter

TECHNICAL DATA	VALUE
Nominal Rated Power	25kW, 30kW, 50kW, 60kW
Maximum DC input power	10-20% of nominal Power
Maximum input voltage	1000V
MPPT Voltage Range	350 – 800V
Number of independent MPP inputs	2 Minimum
Nominal AC voltage	3 / N / PE; 230 V / 400 V
AC power frequency / range	50 Hz, ±5 Hz
Power factor at rated power	1
Displacement Power Factor configurable	0.8 leading – 0.8 lagging
Total Harmonic distortion (TDH)	< 3 % @ nominal apparent power
Maximum efficiency / European efficiency	98% minimum
Protection degree for outdoor installation	IP65
Surge Protection Device (SPD)	Required (Type I)
Overload behaviour	Current limitation; power limitation
DC reverse-polarity protection / AC short-circuit current capability / galvanically isolated	Required
Anti-islanding protection / Grid regulation	As per EN, VDE standard
Protection class (according to IEC 62103) / overvoltage category (according to IEC 60664-1)	I / III

3.3.3 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. Daily reports of the plant's energy generation will be provided by the monitoring system. Remote data access will be provided through GSM based communication interface.

3.3.4 Energy Metering

A separate energy meter to measure and monitor energy generation from PV system shall be installed at the main distribution panel in the substation where inverter power will be injected. The meter will be of electronic, Trivector Type, suitable for 3- phase 4-wire connections, with initial and sustained accuracy of class 0.2S. The meter shall be ISI marked and shall fully comply with all stipulations in applicable standards with latest amendments/ the relevant provisions of national grid code 2011.

3.3.5 Array Mounting Structure

(i) The structural design of module mounting structures shall be as per design criteria specified under IS-800 and/or IS-801.

(ii) The frames and leg assemblies of the array structures shall be made of hot rolled steel sections of grade E-300 (minimum) conforming to IS 2062 or Cold Rolled Section made-up of Hot rolled steel strips conforming to IS 11513 with minimum 85 micron hot dip Galvanization as per IS 4759:1996.

(iii) In case of aluminium structure, extruded aluminium EN-AW-6063 T6 or equivalent shall be used.

(iv) All fasteners shall be of Stainless steel - SS 304 or higher grade. Nut & bolts, supporting structures including module Mounting Structures shall have to be adequately protected against all climatic condition. High tensile stainless steel deco coated fasteners is acceptable.

(v) Design and dimensions of the structure must confirm to withstand minimum wind speed of 150kms/h

(vi) Provisions should be taken in the mounting arrangement of PV modules to allow for the maximum expansion/contraction of the modules under expected operating temperatures, according to the module manufacturer’s recommendations.

3.3.6 PV array and PV string combiner boxes

PV array and PV string combiner boxes exposed to the environment shall be at least IP 65 compliant in accordance with IEC 60529, and shall be UV resistant. Any enclosure IP rating shall suit the environmental conditions. This IP rating shall apply for the relevant mounting position and orientation.

3.3.7 Circuit breakers

Circuit breakers used for overcurrent protection in PV arrays shall

(i) Be certified to either IEC 60898-2 or IEC 60947-2 and
(ii) Not be polarity sensitive;
(iii) Be rated to interrupt full load and prospective fault currents from the PV array, diesel generators and the grid;

(iv) Be rated for overcurrent as per IEC 62548

3.3.8 Disconnectors and switch-disconnectors

All disconnectors, shall comply with the following requirements:

(i) Not have exposed live metal parts in connected or disconnected state;
(ii) Have a current rating equal to or greater than the associated overcurrent protection device, or in the absence of such device, have a current rating equal to or greater than the minimum required current carrying capacity of the circuit to which they are fitted.

Switch-disconnectors shall be certified to IEC 60947-1 and IEC 60947-3 and have mechanisms that have independent manual operation.

In addition, circuit breakers and any other load breaking switch-disconnectors used for protection and/or disconnecting means shall comply with the following requirements:

(i) Not be polarity sensitive
(ii) Be rated to interrupt full load and prospective fault currents from the PV array, diesel generators and the grid;
(iii) When overcurrent protection is incorporated, it shall be rated as per IEC 62548

3.3.9 Cables

The DC solar cable must be of copper with UV protection type insulation with minimum voltage rating of 1000V DC. Cable sizes for PV string cables, PV sub-array cables and PV array cable shall be determined with regard to overcurrent protection ratings where in use, the minimum current rating as specified in IEC 62548: Photovoltaic Arrays Design Requirement, the voltage drop and prospective fault current. The largest cable size obtained from these criteria shall be applied. Cable derating factors shall be taken into account according to IEC 60364 based on cable location and installation method. Maximum cumulative voltage drop in all cable length should not be more than 2% in DC side and 1% in AC side.

Cables used within the PV array shall be suitable for DC application, have a voltage rating equal to or greater than the PV array maximum voltage at lowest possible temperature, have a temperature rating according to the application. Cable insulation of wiring installed in contact or near PV modules shall be rated at 90°C, be UV-resistant, be water resistant, double insulated and shall be flame retardant.

String cables shall be flexible to allow for thermal/wind movement of arrays/modules. Cables shall be supported so they do not suffer fatigue due to wind/snow affects. They shall also be protected from sharp edges. Cables shall be supported so that their properties and installation requirements are maintained over the stated life of the PV plant. All non-metallic conduit and ducting exposed to sunlight shall be of a UV resistant type. Cable ties shall not be used as a primary means of support.

Only bright-annealed 99.97% pure bare copper conductor wires, which offer low resistance, lower heating and of reputed make shall be used. Preferred solar cable may be LAPP cable or equivalent.

AC cable must be of copper armoured XLPE insulation with minimum voltage rating of 1kV. All AC cables shall be Electrolytic tinned copper Class 2, according to IEC 60228. Insulation shall be as per IEC 60502-1 and IS 1554. Cables shall also confirm to IEC 60189 for test and measuring methods.

3.3.10 Plugs, sockets and connectors

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer i.e. a plug from one manufacturer and a socket from another manufacturer or vice versa shall not be used to make a connection.

Plugs, sockets and connectors shall comply with EN 50521; shall be rated for DC use; have voltage rating of 1000V DC; shall be protected from contact with live parts in connected and disconnected state; have a current rating equal to or greater than the current carrying capacity for the circuit to which they are fitted. Preferred MC4 cable connectors may be LAPP connectors or equivalent.

When installed outdoor, plugs, sockets and connectors shall be UV-resistant and be rated for IP 65 or above.

Plugs, sockets and connectors shall be installed in such a way as to minimise strain on the connectors (e.g. supporting the cable on either side of the connector).

Plugs and socket outlets normally used for the connection of household equipment to low voltage AC power shall not be used in PV arrays.

3.3.11 Wiring in combiner boxes

There should be segregation between positive and negative conductors within combiner boxes to minimise the risks of DC arcs occurring between these conductors. The cable conductor must be provided with heat sink and lugs for termination.

Fuses, if used in PV arrays, shall be rated for DC use; have a voltage rating of 1000V DC; shall be rated to interrupt fault currents from the PV array, generators and the grid; shall be of an overcurrent and short current protective type suitable for PV complying with IEC 60269-6.

When fuses are provided for overcurrent protection, switch-disconnectors shall be used.

Fuse holders shall have a voltage rating of 1000V DC; have a current rating equal to or greater than the corresponding fuse and provide a degree of protection suitable for the location and not less than IP 2X.

The combiner box shall have minimum IP rating of IP65.

3.3.12 Wiring system

Wiring of PV arrays shall be undertaken with care such that the possibility of line-to-line and line-to-earth faults occurring is minimised. All connections shall be verified for tightness and polarity during installation to reduce the risk of faults and possible arcs during commissioning, operation and future maintenance.

The PV array wiring shall comply with the cable and installation requirements as specified in IEC 62548 and the wiring requirements mandated by IS-732 and the national electrical code 2011. Particular attention needs to be given to the protection of wiring systems against external influences.

To reduce the magnitude of lightning-induced over voltages, the PV array wiring should be laid in such a way that the area of conductive loops is minimum. String cables between modules shall be protected from mechanical damage and all cables must be clamped to relieve tension in order to prevent the conductor from coming free from the connection.

Wiring installation in combiner boxes
Where conductors enter a combiner box without conduit, a gland connector shall be used to avoid cable disconnections inside the box. All cable entries when installed shall maintain the IP rating of the enclosure.

Provision may need to be provided to drain water build-up due to condensation inside the combiner box.

Wiring identification
Permanent indelible identification shall be provided for PV array cabling installed in or on buildings. PV array (and sub-array) cabling shall be identified by one of the following methods:

(i) PV cabling using distinctively marked PV cables shall be permanently, legibly and indelibly marked or
(ii) Where cabling is not distinctively marked, distinctive coloured labels marked with the words 'SOLAR DC' shall be attached at an interval not exceeding 5 m under normal conditions and not exceeding 10 m on straight runs where a clear view is possible between labels.
(iii) Where cable is enclosed in a conduit or ducting, labelling shall be attached to the exterior of the enclosure at intervals not exceeding 5 m.

3.3.13 Junction Boxes

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 outgoing 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 connection. The Array junction Box will also have suitable surge protection devices. The combiner box shall have minimum IP rating of IP65.

3.3.14 Safety and System Protection

(i) Protection against electric shock

The maximum voltage of PV arrays shall not be greater than 1000 V DC.

All electrical installation should meet the requirements of IEC 60364-4-41 for protection against electric shock.

Earthing System
The following options for earthing shall be considered:

(i) The earthing system must have less than 1 ohm resistance.
(ii) All the combiner boxes, structure, inverter body must be earthed.
(iii) Functional earthing of conductive non-current carrying parts to allow for better detection of leakage paths to earth.
(iv) Earthing for lightning protection and structural body earthing must be provided separately.
(v) Equipotential bonding to avoid uneven potentials across an installation.

The conductor used to earth exposed metallic frames of the PV array shall have a minimum size of $6mm^2$ copper or equivalent.

If a separate earth electrode is provided for the PV array, it shall be connected to the main earthing terminal of the electrical installation by main equipotential bonding conductors.

PV array frame bonding shall be done in accordance with IEC 62548

PV array bonding conductors shall be run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning.

The connection to earth shall be made at a single point and this point shall be connected to the main earthing terminal of the electrical installation. This connection point shall be between the PV array and the power conversion equipment and as close as possible to the power conversion equipment.

(ii) Protection against overcurrent

Overcurrent within a PV array can result from earth faults in array wiring or from fault currents due to short circuits in modules, in junction boxes, combiner boxes or in module wiring.

Overcurrent protection devices required for the protection of PV modules and/or wiring shall be selected to reliably and consistently operate within 2h when an overcurrent of 135 % of the nominal device current rating is applied.

Sub-array overcurrent protection shall be provided if more than two sub-arrays are connected to a single Inverter.

Each PV string shall be protected with an overcurrent protection device, where the nominal overcurrent protection rating of the string overcurrent protection device shall be $I_{n.}$

Where:
$I_n > 1.5 \times I_{SC\_MOD}$ and
$I_n < 2.4 \times I_{SC\_MOD}$ and
$I_n \leq I_{MOD\_MAX\_}OCPR$

For string overcurrent protection, overcurrent protection devices shall be placed where the string cables join the sub-array or array cables in the string combiner box and for sub-array overcurrent protection devices, they shall be placed where the sub-array cables join the array cables in the array combiner box. For array overcurrent protection devices, they shall be placed where the array cables join the application circuit or the inverter.

In systems that include a functional earth, overcurrent protective devices required for string and sub-array cables shall be placed in all unearthed conductors (i.e. all circuits not directly connected to the functional earth)

(iii) Protection against effects of lightning and overvoltage

The need for a lightning protection system to be assessed by the contractor in accordance with IEC 62305-2 and, if required, it should be installed in compliance with IEC 62305-3 or IS 2309. The lightning protection system must be able to provide coverage for full plant.

(iv) Protection against overvoltage

All DC cables should be installed so that positive and negative cables of the same string and the main array cable should be bundled together, avoiding the creation of loops in the system. The requirement for bundling includes any associated earth/bonding conductors.

Long cables over about 50 m should be either:

- Installed in earthed metallic conduit or trunking,
- Be buried in the ground using appropriate mechanical protection,
- Incorporated with mechanical protection which will provide a screen, or
- Be protected by a surge protective device (SPD).

Conduit or trunking shall be designed and installed in such a way that there is no accumulation of water or condensation.

To protect the DC system as a whole, surge protective devices shall be fitted between active conductors and earth at the Inverter end of the DC cabling and at the array.

(v) Disconnecting means

Disconnecting means shall be provided in PV arrays as specified in IEC 62548 to isolate the PV array from the power conversion equipment and vice versa and to allow for maintenance and inspection tasks to be carried out safely.

For inverters repaired by replacement, one of the following disconnecting methods shall be used:

(i) An adjacent and physically separate switch - disconnector; or
(ii) A switch-disconnector that is mechanically connected to the inverter and allows the inverter to be removed from the section containing the switch-disconnector without risk of electrical hazards; or
(iii) A switch-disconnector located within the inverter, if the inverter includes a means of isolation only operable when the switch-disconnector is in the open position; i.e. the maintainable section of the inverter can only be opened or withdrawn if the switch-disconnector is in the open position; or
(iv) A switch-disconnector located within the inverter, if the inverter includes a means of isolation, which can only be operated with a tool and is labeled with a readily visible warning sign or text indicating - "Do not disconnect under load".

For inverters repaired by replacing internal components, the switch-disconnector shall be located such that maintenance of the inverter (e.g. change of an inverter module, change of fans, cleaning of filters) is possible without risk of electrical hazards. This switch-disconnector may be in the same enclosure with the inverter.

As specified in Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 the following disconnecting means are to be installed:

(i) An Inverter AC isolator to be installed on the output of the Inverter
(ii) A Main Switch lockable in off position is required to be installed in the switchboard to allow the PV system to be disconnected from the mains power supply. This main switch may not be rated for load break nor may have feature of overcurrent protection.

3.3.15 Marking and Signage

All electrical equipment shall be marked according to the requirements for marking as per IEC or IS standards and national electrical code 2011 when applicable. Markings should be in Hindi and English or appropriate warning symbols must be used.

All signs required in this clause shall be indelible; be legible from at least 0.8 m; be constructed and affixed to remain legible for the life of the equipment it is attached or related to; be understandable by the operators.

Disconnection devices shall be marked with an identification name or number according to the PV array wiring diagram. All switches shall have the ON and OFF positions clearly indicated.

The PV array DC switch disconnector shall be identified by a sign affixed in a prominent location adjacent to the switch disconnector.

3.3.16 Documentation

Documentation shall be provided in accordance with IEC 62446 specifications for PV arrays.
Documentation (As per IEC 62446: Grid-Connected Photovoltaic Systems—Minimum Requirements for System Documentation, Commissioning Tests and Inspection):

(i) System data
(ii) Nameplate data – Rated power, manufacturers, models, and quantities of PV modules and inverters.
(iii) Cover page data - contact information for the customer, system designer and system installer, relevant project dates
(iv) Wiring Diagrams (Single line diagram with equipment information)
(v) Data sheets (Module and inverter)
(vi) O&M information includes:

- Test results and commission data
- Procedures for verifying correct system operation
- A checklist of what to do in case of a system failure
- Emergency shutdown and isolation procedures.
- Maintenance and cleaning recommendations

3.4 Electrical Single Line Diagram (SLD) Schematic

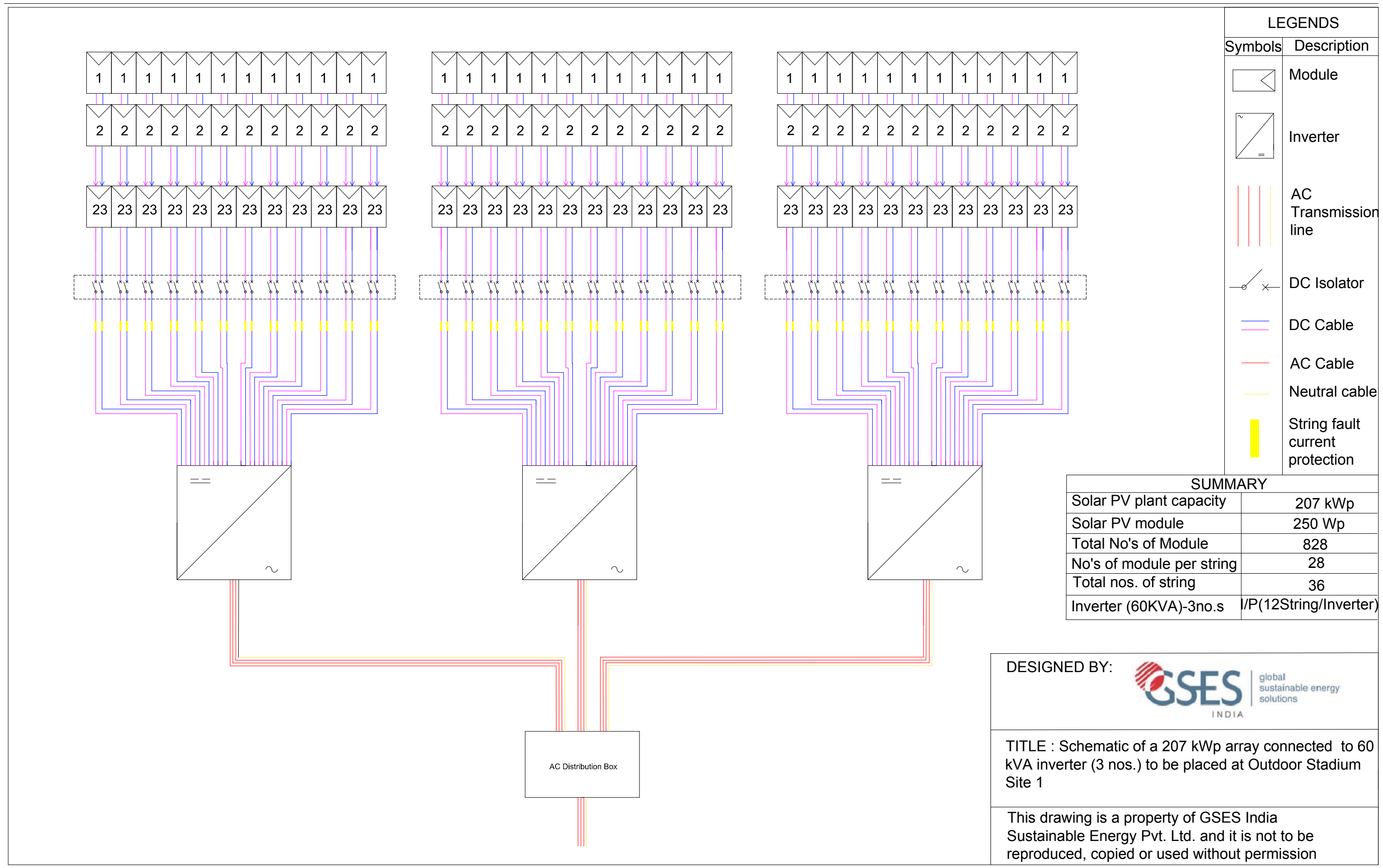


Figure 3.5: Electrical SLD for 207kWp system connected to three 60kW inverters at Site 1 (Outdoor Stadium)

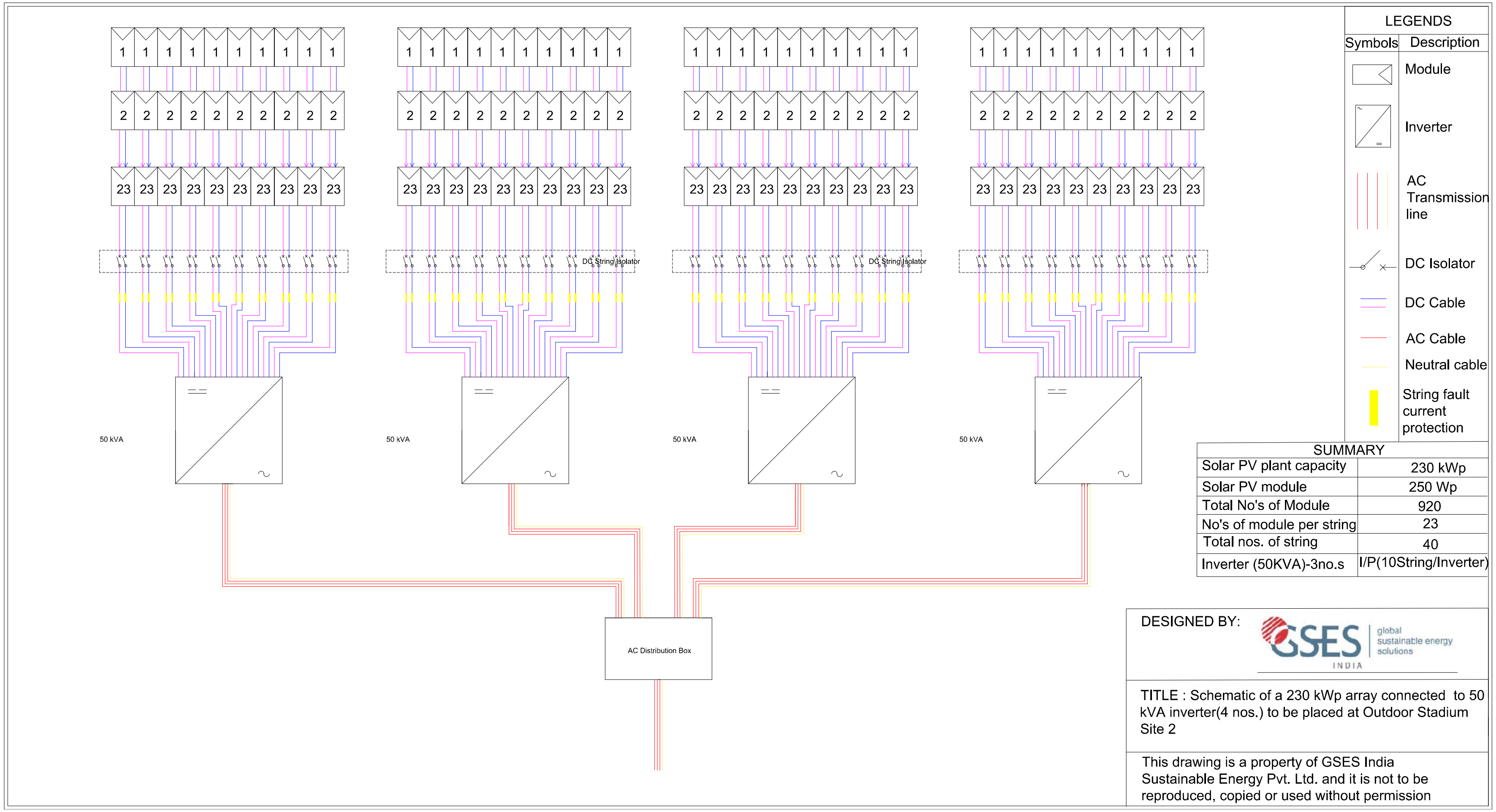


Figure 3.6: Electrical SLD for 230kWp system connected to four 50kW inverters at Site 2 (Outdoor Stadium)

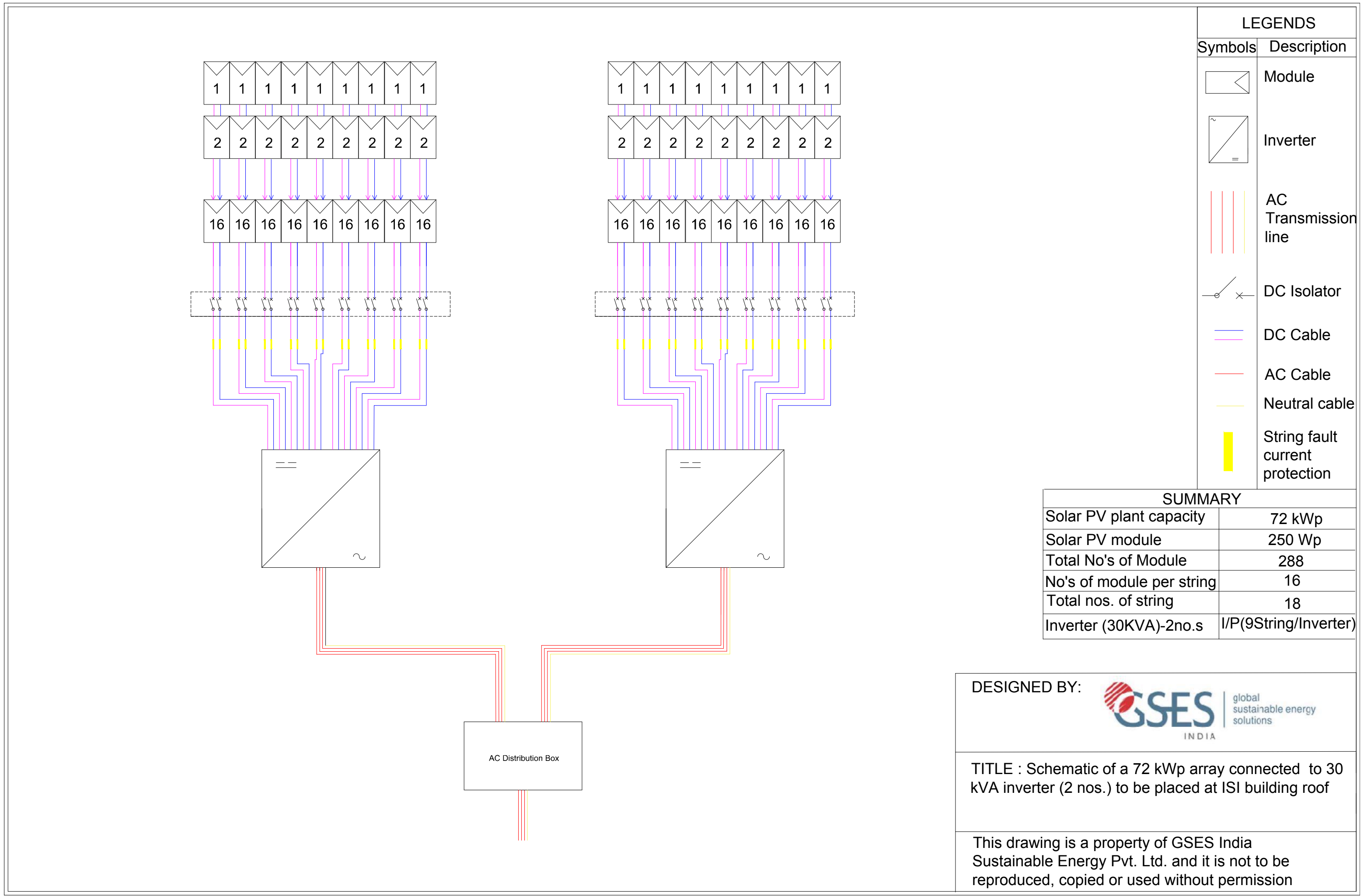


Figure 3.7: Electrical SLD for 72kWp system connected to two 30kW inverters at Site 3 (ISI Building)

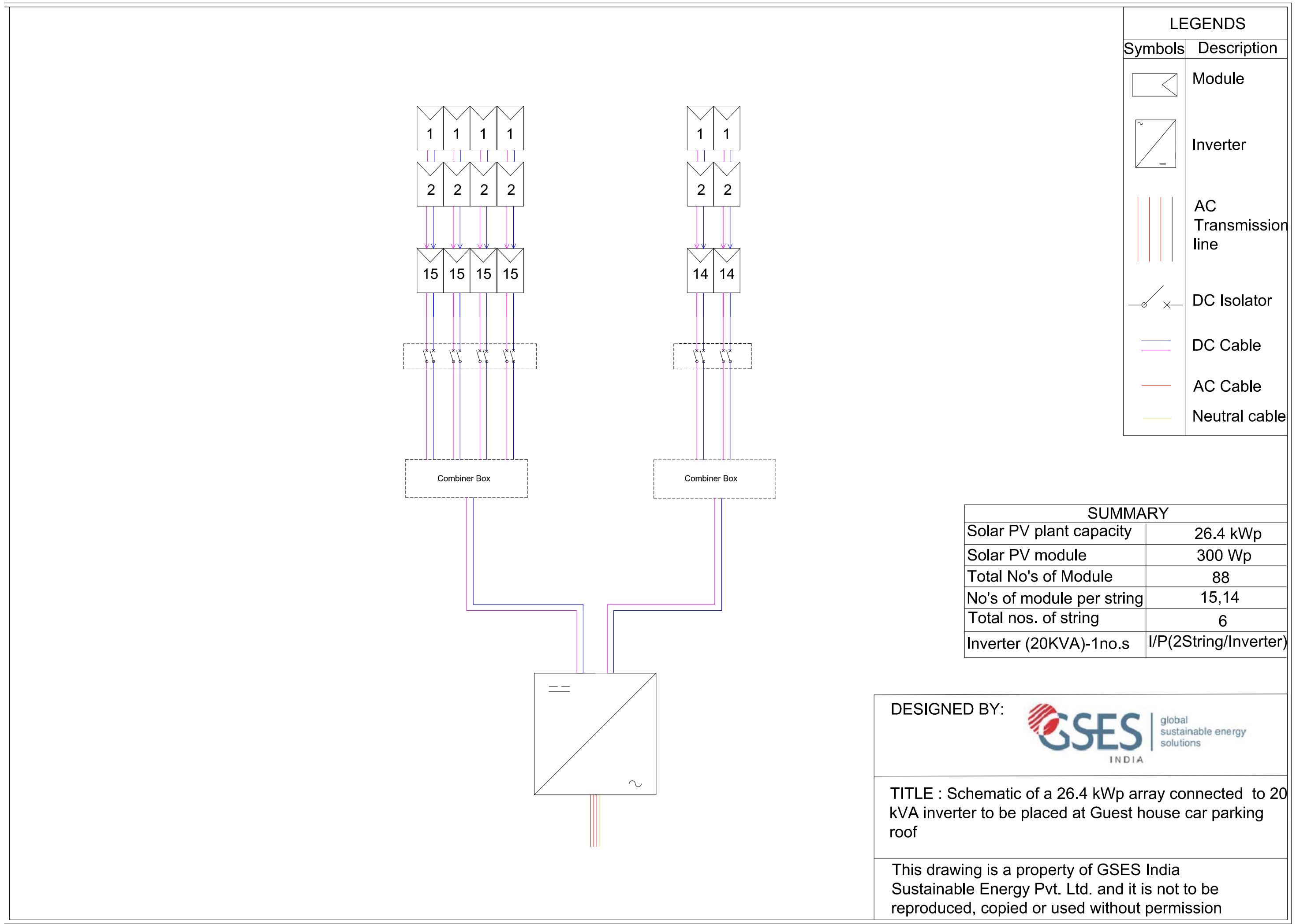


Figure 3.8: Electrical SLD for 26.4kWp system connected to a 25kW inverter at Site 4 (Guest house car parking)

3.5 Construction Schedule

Solar PV power plants has lowest gestation period. Once administrative and financial approval for such projects is confirmed, engineering, procurement and construction takes less than six months depending upon the site complexity. A tentative construction schedule for 535.4kWp solar power plants is presented below.

Table 3.3: Construction Schedule of Solar PV power plants

S. No.	Activities	Progress Months				
		1	2	3	4	5
1	Tendering and evaluation					
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					

3.6 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 Voc, Isc, Vmpp, & Impp 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

4 PROJECT COST AND BILL OF MATERIALS

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 and 25 years of annual maintenance. The project cost inclusive of all as mentioned above will be Rs.248.68 lakh. Breakup of project cost is given below.

Table 3.4: Bill of Materials and Project Cost for 535.4kWp Solar PV systems

Sl. No.	Description	Qty	Unit	Unit Price (INR)	Amount (lakh)
1	250Wp, Mono/Poly Si Crystalline Solar PV Module with minimum efficiency of 15.5% as specified	535.4	kWp	45,000	240.93
2	25kW Grid Tied 3-phase multistring Inverter with efficiency of 98% as specified	1	W	17	4.25
3	30kW Grid Tied 3-phase multistring Inverter with efficiency of 98% as specified	2	W	17	10.20
4	50kW Grid Tied 3-phase multistring Inverter with efficiency of 98% as specified	4	W	15	12.00
5	60kW Grid Tied 3-phase multistring Inverter with efficiency of 98% as specified	3	W	15	9.00
6	Module mounting structure (Hot deep galvanised steel and/ or anodised aluminium as specified)	535.4	kWp	4,500	24.09
7	1000V, 15A DC Isolator for string disconnection (Load breaking), IP 65	100	Nos.	3,000	3.00
8	440V, 32A per contact AC Isolators to disconnect individual inverters (to be installed in AC combiner box), IP 65	10	Nos.	3,000	0.30
9	440V, 300A AC Isolator to disconnect power from inverters to main distribution panel to grid	4	Nos.	13,000	0.52
10	Type I Surge Protector Device	24	Nos.	9,000	2.16
11	4 In - 1 Out AC Combiner Box complete with cable entry flanges, cable glands, terminal block, IP 65	1	Nos.	4,500	0.05

Sl. No.	Description	Qty	Unit	Unit Price (INR)	Amount (lakh)
12	3 In – 1 Out AC Combiner Box complete with cable entry flanges, cable glands, terminal block, IP 65	1	Nos.	4,000	0.04
13	2 In - 1 Out AC Combiner Box complete with cable entry flanges, cable glands, terminal block, IP 65	1	Nos.	3,500	0.04
14	Single core, 4mm^2, Module Interconnecting cable (single core DC cable, UV stabilized, multistrand XLPE PVC insulated)	4280	m	0	-
15	Single core, 4mm^2 String Cable to Inverter (Single core DC cable, UV stabiulised, multistrand XLPE PVC insulated)	4800	m	45.00	2.16
16	4 -core, 16mm^2 Cable from invrter to AC DB (4 core bright annealed copper conductor, PVC insulated, GI wire braided flexible armouring)	800	m	771.00	6.17
17	4 -core, 120mm^2 Cable from AC DB to Main panel (4 core bright annealed copper conductor, PVC insulated, GI wire braided flexible armouring) From PGP I to main distribution panel at substation	600	m	6,930.00	41.58
18	Earthing (Earthing cable/ strips, earth pit) as per IS 2309	4	set	30,000.00	1.20
19	Energy Meter as specified	4	Set	5,000.00	0.20
20	Monitoring System as specified	4	Set	75,000.00	3.00
21	PCC Concrete block foundation for installation of array mounting structure	250	CuM	3,000.00	7.50
		Total for Materials			**368.38**
22	Transport, carriage and insurance	3%	LS	368.38	11.05
23	Installation & commission	12%	LS	368.38	44.21
		Total for construction			**423.64**
24	Operation and Maintenance for first 5 years after warrantee period	5 Years	LS	3,50,000.00 per year	17.50
		Grand total			**441.14**

(Rupees Four Hundred Forty One and Fourteen Lakh only)

5 LIFE CYCLE COST BENEFIT ANALYSIS

The 535.4kWp PV power plants will generate average 691.24MWh of electricity per year, which will be directly used as captive power. The university will save Rs.36.98 lakh per year from the electricity savings from the grid @Rs.5.35 per unit. In the financial model we have considered 2% annual escalation of electricity tariff and lump sum O&M cost of Rs.3.50lakh with an escalation of 5.72% (As per CERC). Three scenarios have been developed.

Scenario 1: Without MNRE subsidy and REC benefits

Scenario 2: Only REC benefits (@ floor price to be Rs.3500.00 / MWh)

Scenario 3: Only MNRE subsidy (@ 15%, capital subsidy)

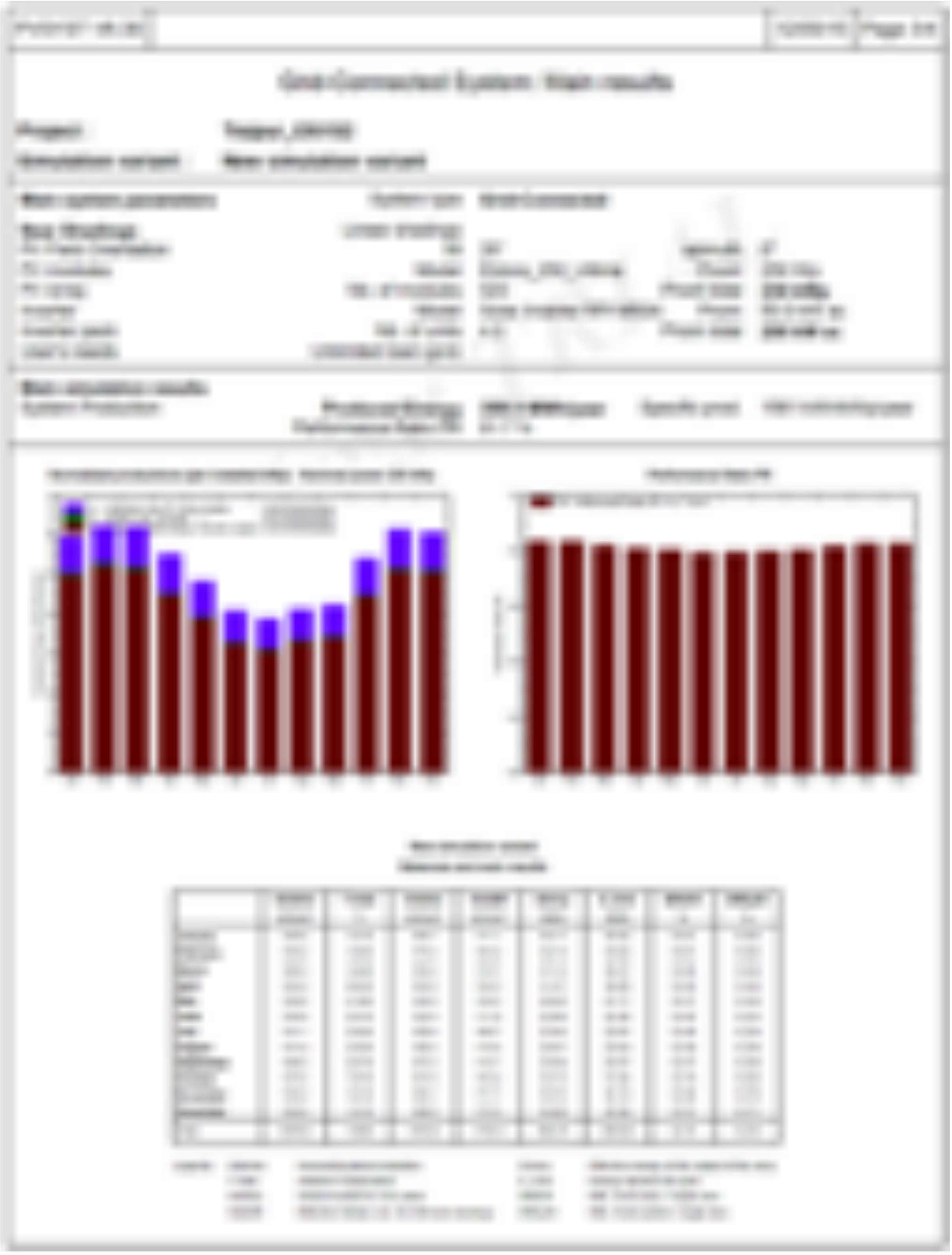
The results f the scenario analysis have been presented in the table below:

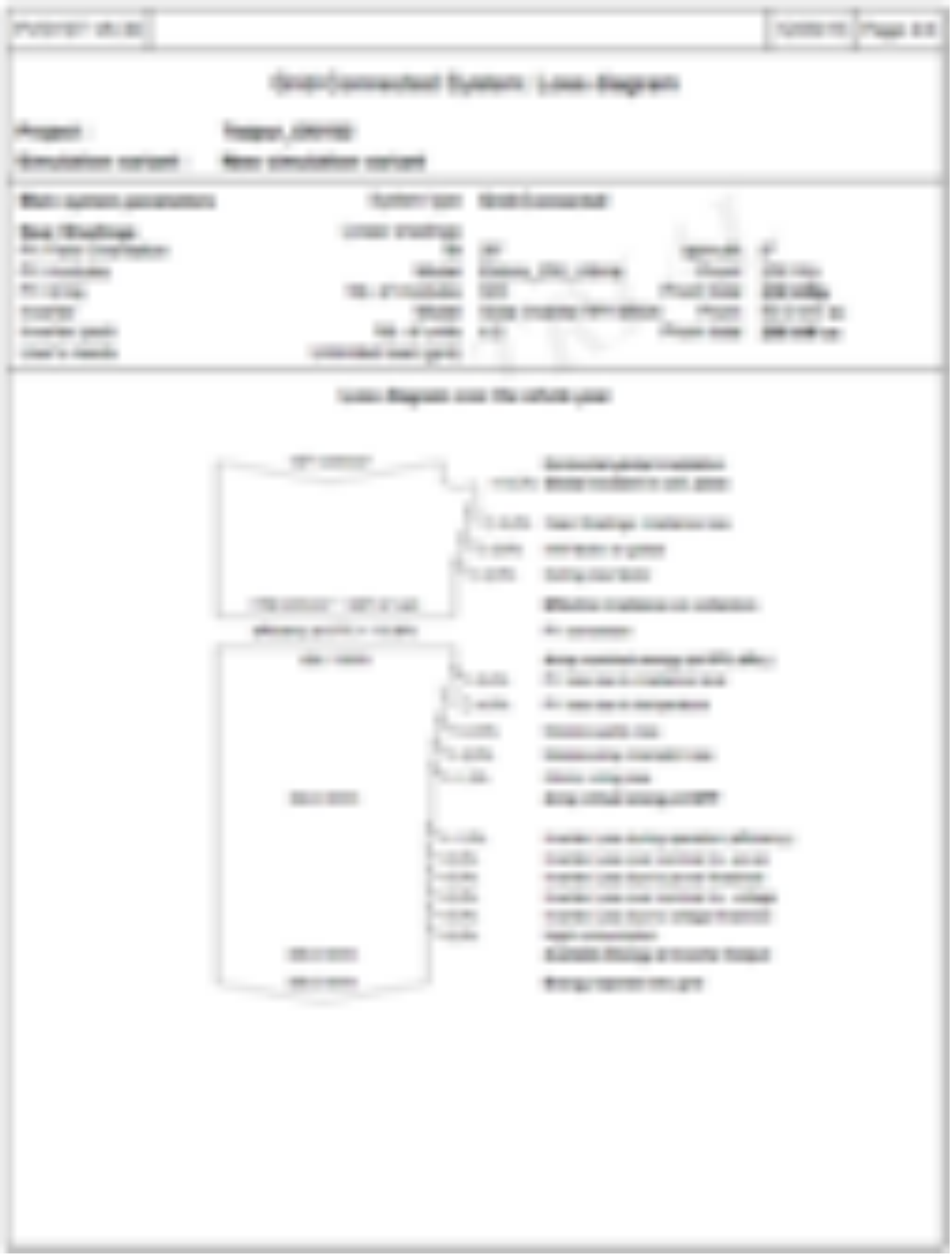
Table 3.5: Cost Benefit Analysis for three different scenarios

Sl. No.	Particulars	Scenerio Analysis		
		Without MNRE Subsidy & REC Benefits	With only REC Benefits	With only MNRE Subsidy
1	Project Capacity	535.4kWp	535.4kWp	535.4kWp
2	Annual Net Power Generation	691.24MWh	691.24MWh	691.24MWh
3	Electricity Tariff	Rs.5.35/kWh	Rs.5.35/kWh	Rs.5.35/kWh
4	Annual savings (first year)	Rs.36.98 Lakh	Rs.36.98 Lakh	Rs.36.98 Lakh
5	Annual escalation of electricity tariff	2.00%	2.00%	2.00%
6	Annual Degradation of PV	0.80%	0.80%	0.80%
7	O&M Cost	Rs.3.5 lakh per year	Rs.3.5 lakh per year	Rs.3.5 lakh per year
8	Escalation in O&M (As per CERC)	5.72%	5.72%	5.72%
9	Plant life assumed	25 years	25 years	25 years
10	Total Capital Cost	Rs.423.64 lakh	Rs.423.64 lakh	Rs.423.64 lakh
11	MNRE Subsidy (15% of capital cost)	NIL	NIL	Rs.63.54 lakh

Sl. No.	Particulars	Scenerio Analysis		
		Without MNRE Subsidy & REC Benefits	With only REC Benefits	With only MNRE Subsidy
12	REC Sale Value (assuming floor price only)	NIL	Rs.3500.00 per MWh	NIL
13	Depreciation of REC value	NA	-5%	NA
14	University Share	Rs.423.64 lakh	Rs.423.64 lakh	Rs.360.10 lakh
15	Project payback period	12.23 years	7.70 years	10.44 years
16	Levelized cost of electricity	Rs.3.17/kWh	Rs.3.17/kWh	Rs.3.17/kWh

APPENDIX A: PVSyst Report of 230kWp solar PV systems at Tezpur University





Detailed Project Reports on:

Pilot Project on Integrated Solar-Biogas System for Steam Cooking

TABLE OF CONTENTS

1 INTRODUCTION

Tezpur University was established by an Act of Parliament in 1994. The university campus at Napaam, Sonitpur district of Assam has twelve hostels, one administrative block, one guesthouse, one auditorium, five departmental buildings and two canteens.

The hostels in Tezpur University demands significant amount of thermal energy on daily basis for various applications such as hostel mess cooking, bathing, cleaning, washing etc. The primary source to meet the thermal energy demand is LPG. Total energy consumed in the hostels and guesthouse for cooking is estimated as 4692432 MJ per year. The university canteen feeds around 350 people per day consuming 32-34 LPG cylinder (19kg) per month. The estimated cooking energy demand in the university canteen is around 30000 MJ/month.

The total vegetable and food waste collected in the university from hostels and canteen is around 900 kg/day. The canteen produces about 70Kg of organic waste.

An integrated solar-biogas system is proposed as a pilot and demonstration project in the university canteen to check viability of the same to deploy in the other places. A schematic of the proposed system is presented in the figure below.

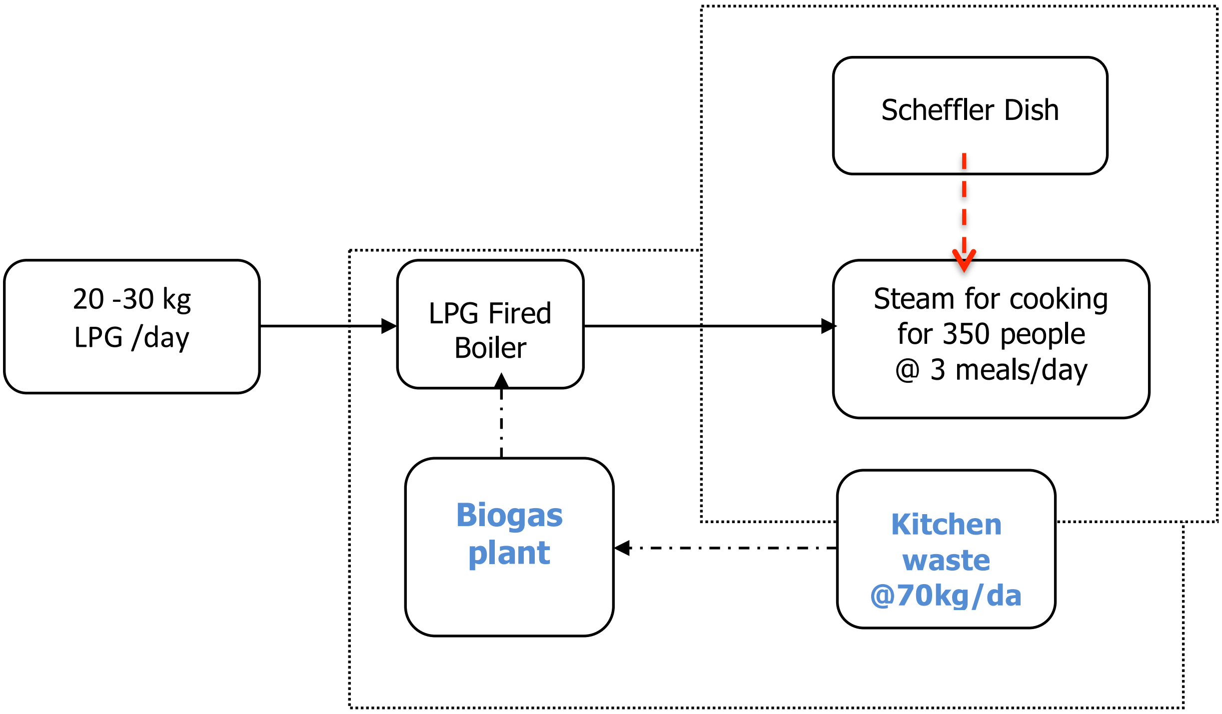


Figure1.1: Proposed integrated solar-biogas cooking system

2 TECHNICAL SPECIFICATION

Technical features and specifications of the proposed solar-biogas integrated system is presented in the table 1.1 below:

Table 1.1: Specifications of the integrated solar biogas cooking system

Sl. No.	Description	Units	Values
1	Number of Students	Nos.	350
2	Meals per day	Nos./day/person	3
3	Kitchen waste (from hostels & canteen)	Kg/day	905
4	LPG consumption	Kg/day	20 -30
5	LPG fired boiler efficiency	%	80
6	Boiler pressure	Bar G	4.5
7	Boiler feed water temperature	˚C	Ambient
8	Average energy requirement for steam cooking in canteen	MJ/day	1000
9	Amount of steam required to meet cooking energy requirement	Kg/day	367
Biogas Plant			
10	Type of digestion		Anaerobic
11	Biogas Produced	M^3/day	50
12	Energy generated	MJ/day	997
13	Combustion efficiency	%	60
14	Steam produced through biogas fired boiler	Kg/day	276
15	Additional steam required	Kg/day	91
16	LPG saving	Kg/day	16
17	% LPG saving through biogas	%	67
18	Monthly saving of LPG cylinders	Nos.	25-26
Concentrating Solar Collector			
19	Annual Direct Normal Irradiation	kWh/ m^2 /year	1111
20	Design Irradiation (Hourly)	W/m^2	~390
21	Type of CSP technology	Concentrating dish (Scheffler)	
22	Mode of Operation	Direct steam generation for cooking	
23	Thermal Power output	kW_{th}	30

23	Saturated steam pressure	Bar G	4.5
24	Saturated steam temperature	^oC	131
25	Water inlet temperature	^oC	Ambient
26	Specifications of 16 m^2 Scheffler Dish		
27	Total collector area required	m^2	256
28	Area of a single collector	m^2	16
29	Number of collector required	Nos.	16

3 PROJECT COST BENEFIT ANALYSIS

Solar steam generation system of collector area 256sqm is proposed for the pilot project for integrated solar-biogas cooking system. The total cost of the solar steam generating system is estimated at Rs.75.33 Lakhs including installation, commissioning, additional piping, civil work, and five years AMC. Expected financial assistance from MNRE is Rs.22.60 Lakhs (@ 30% of project cost). The summary of the cost breakup has been shown below.

Description	Units	Value
Total cost of the CST system	INR lakhs	28.16
Total cost of biogas system	INR lakhs	3.50
Total cost of combined system	INR lakhs	31.66
Total LPG saving per year	Kg/year	7750
Cost of LPG	INR/kg	40
Total saving through combined system	INR lakhs/year	3.10
Simple Payback Period	Years	10.21

4 SHARING OF FUNDING

The proposed project may be submitted to the Ministry of New and Renewable Energy (MNRE) for 100% grant as pilot/ demonstration / R&D project.