A PROJECT REPORT ON

THE DESIGN & INSTALLATION OF A 19.5kW GRID-TIED SOLAR PHOTO VOLTAIC PLANT

AT DEEPASHRAM

THE MOTHER TERESA HOME FOR SPECIAL-NEEDS ORPHANS IN GURGAON

Mihir Vardhan
Project Coordinator

Acknowledgements

I am very grateful for all the support and encouragement I received for this ambitious project and I am grateful that I was able to use my passion for engineering solutions to resolve a real life issue, to contribute to a very worthy cause and to reduce carbon footprint, all at the same time.

I am grateful most of all to **Father Timothy**, the head of Deepashram, who encouraged me to take on what seemed to be an impossible task at that time. It was his faith and encouragement that got me started.

I am very thankful to **Mr. Manuel Devasia** and **Mr. James Abraham** who have been my mentors in many of my prior engineering projects and who provided me very valuable support, input and guidance at all times through this project.

I want to thank **Ms. Maninder Kaur** at Motorola who helped me in the application for Corporate CSR funding for this project, and **Motorola** for sanctioning the funding and helping make the project possible.

I want to especially thank my principal, **Ms. Sudha Sahay**, my Vice Principal **Ms. Chavi Behl**, my teachers **Ms. Samta Jain** and **Ms. Monika Sen Chaudhury** and all my teachers at The Shri Ram School Aravali, for encouraging my interest in Robotics and Engineering and, even before my interest in Engineering, for instilling in me such a strong commitment to society and to the environment. This project has pulled all these teachings together and that really means a lot to me. I am grateful to my school for this.

Lastly, and very importantly, I am very thankful to **my parents** for all their support on this project and their support for and tolerance of my constant tinkering and research at home.

Thank you. I am very grateful for this opportunity and for the successful completion of this project.

Mihir Vardhan

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Introduction & Overview

"Deepashram", which means "House of Light", is the Mother Teresa home for special-needs orphan boys in Gurgaon. Started in July 1994, it is home to 43 mentally and physically challenged, orphaned and homeless boys, who are really the poorest of the poor. 3 priests from the Missionaries of Charity Contemplative and 11 resident staff also reside at Deepashram. There are several non-resident staff members who work at the home.

Deepashram is funded by volunteers and donors who contribute in terms of paying for meals or donating food, rations, clothes, medicines, other necessities and also time.

In March 2018, Father Timothy, Head of Deepashram, requested funding for Deepashram's rising electricity bills. With summer approaching and erratic power supply, Father Timothy was also concerned about the feasibility, cost and pollution of running their generators for extended periods of time.

At that time I proposed to Deepashram to consider installing a solar generation station on their roof top since they had a flat, unused terrace space. This would reduce their bills to almost zero, make power supply more reliable and also reduce their carbon foot print.

However there were many concerns with the proposal. There were so many unknowns – What would it cost? How would it be funded? Was their sufficient solar radiation available in the area? Was the terrace space adequate for the number & size of panels required? How would the priests and staff at Deepashram manage this project?

Since I have always been keenly interested in engineering solutions, I volunteered to do a feasibility study during my summer vacations. And that was the start of such an interesting, challenging, educational and fulfilling journey.

I knew nothing about solar panel installations when I started. I sought the help of two family friends from our Church, Manuel Devasia and James Abraham, who are also my mentors in some of my Robotics projects, to conduct a feasibility study and costing.

I read up extensively about solar power generation in India and the solar power industry in India. I studied the electricity consumption patterns at Deepashram for a 12-month period and, with Manuel's help, I concluded that Deepashram would require a 19.5 KW Solar Photo Voltaic Plant and it was possible to have one installed given the radiation patterns in Gurgaon and the size of terrace space and light available at Deepashram.

James runs his own solar company, Solarise, and he and Manuel shared several vendor recommendations. I used their help to seek quotes and cost the project. I then sought the help of my parents to request Corporate CSR funding through their contacts and friends. We were successful in raising the funding and today I am really happy and grateful that the Deepashram is tied to the grid and generating its' own electricity.

Theoretical Considerations

i. Why Solar?

Solar energy is a very attractive alternate source of energy because of it being relatively easily accessible globally, its pollution free generation and almost inexhaustible supply.

Inexhaustible?
On a cloudless day, with no obstructions to the sunlight reaching the earth, 1 square meter of the earth's surface receives 1.1 kW of solar energy. Assuming only 9 hours of sunlight per day, this equates to 3.5 trillion Watt hours per sq km per year. Over the total earth's surface of 500 million sq km (including the oceans), the earth receives approximately 200 million giga Watt years – more than 15,000 times what the entire human race consumes.

ii. Solar Energy as a practical alternate source of energy

Clearly there is sufficient solar energy to meet the needs of the world. The challenge is how to efficiently convert it into usable forms of energy.
Solar energy may be tapped in one of two ways:

- **The Thermal Route**: Focused light heats up a transport fluid which is used to generate steam to drive a turbine. Solar thermal uses the infrared energy of sunlight.
- **The Photo Voltaic Route:** Focused light is converted to electricity using the electronic properties of semi-conducting materials.

iii. Categorization of solar power generating facilities:

Solar Power may be categorized into 2 types based on its connectivity to the grid in the area:

1. **Solar for grid-connected electricity:**
   This form of solar power is used in areas with grid-access to supplement grid-supplied power with environment-friendly, less expensive power. This generation takes pressure off the grid during the peak load time (day time, when solar power is available abundantly).
2. **Solar for off-grid solutions:**

Where there is no grid-access or grid-access is unreliable, off-grid solutions are used. Off-grid solutions typically combine various generation options, also called hybrid power generation. Off-grid solutions offer storage and back-up power. The advantages of off-grid solutions include independence from an unreliable grid and no transmission losses as there are no overhead wires.

iv. Technology

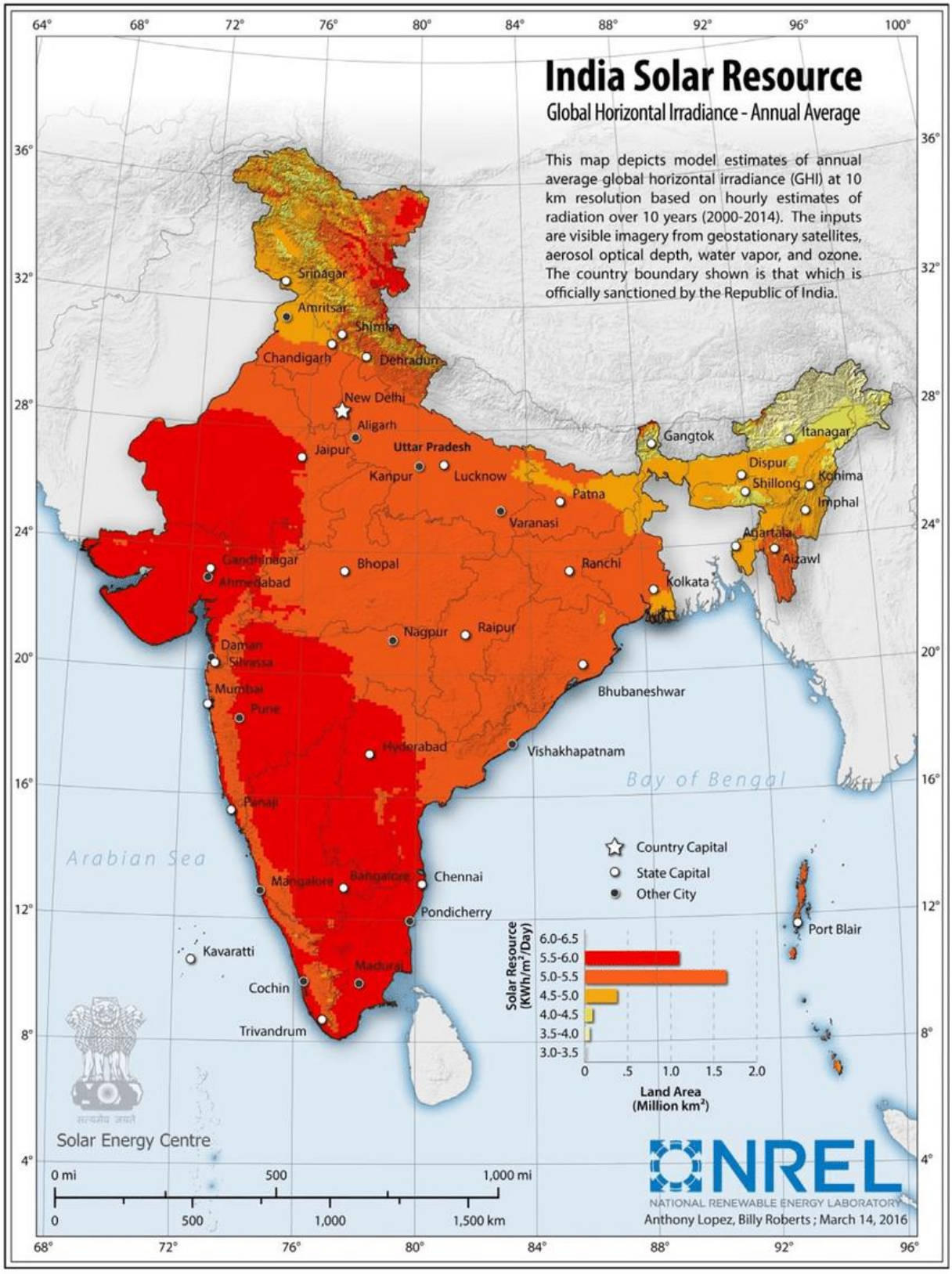
There are 2 technologies based on how solar energy is tapped.

1. **Solar Photovoltaic (SPV)**
   An SPV cell is a semi-conducting device made of silicon and/or other materials which generate electricity when exposed to sunlight. These cells are connected in series and in parallel. There are two main types of SPV cells:
   i. Crystalline Silicon solar cells (C-Si): Monocrystalline and Polycrystalline
   ii. Thin-film solar cells: Amorphous silicon solar cells (A-Si), CIGS, CdTe

2. **Solar Thermal**
   Solar Thermal Power Systems are also called Concentrated Solar Power (CSP) systems. As the name suggests, these systems use concentrated solar radiation as a high temperature energy source to produce electricity using the thermal route.

v. Solar Power in India

i. **Geographical location advantage:** Being a tropical country, India receives sufficient solar radiation, with over 3000 hours of sunshine in a year, equivalent to over 5000 trillion kWh. Almost all regions in India receive 5-7 kWh of radiation per sq m, with an average of 2,500 – 3,000 hours of sunshine per year. India's location offers the opportunity for extensive generation at a low cost.



Annual Average Global Solar Radiation in India

ii. **Power Shortage**

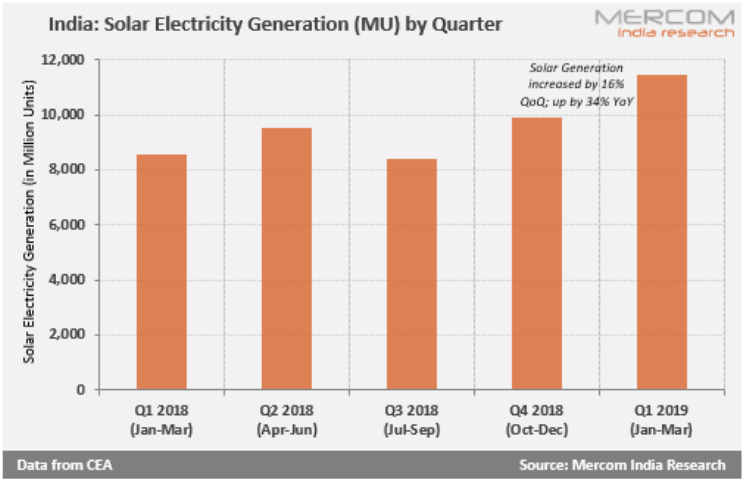
India faces serious challenges of power shortage on account of transmission and distribution losses and theft. Power shortages have impacted the country's economic progress and additional sources of power are the need of the hour.

Current Projects (includes both- installed and under installation projects)

S.No	State	Photovoltaic Capacity (MW)	Solar Thermal Capacity (MW)
1.	Rajasthan	43	400
2.	Gujarat	722	45
3.	Maharashtra	133	-
4.	Karnataka	10	-
5.	Andhra Pradesh	20.5	-
6.	Uttarakhand	4	-
7.	Punjab	5	-
8.	Haryana	7.8	-
9.	Uttar Pradesh	11	-
10.	Jharkhand	16	-
11.	Chhattisgarh	4	-
12.	Madhya Pradesh	7.25	-
13.	Odisha	11	-
14.	Tamil Nadu	12	-
TOTAL		**1006.55**	**445**

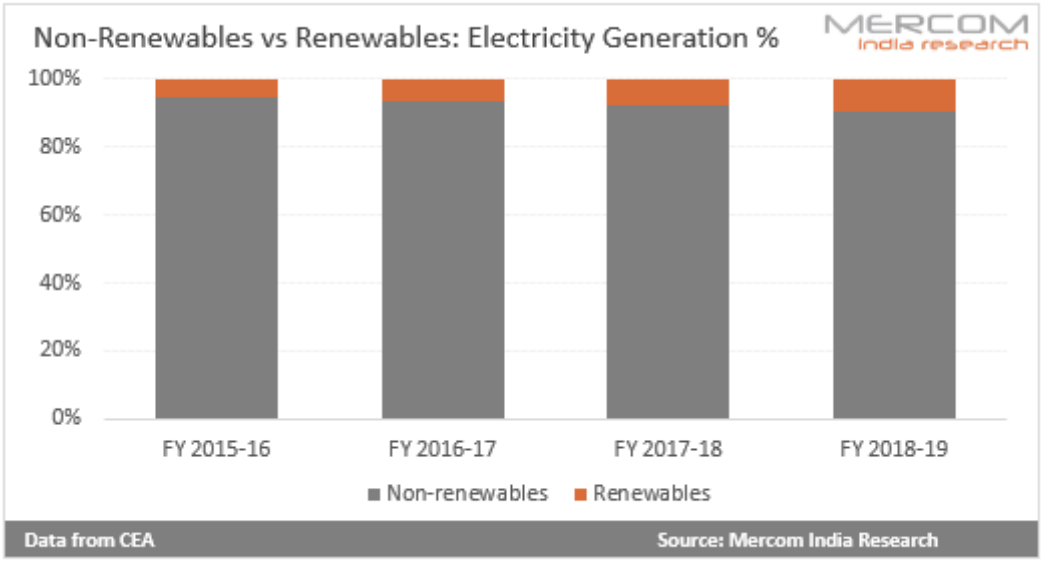
Current distribution of Solar Power Capacity in India

Source: EAI. Catalyzing CleanTech & Sustainability



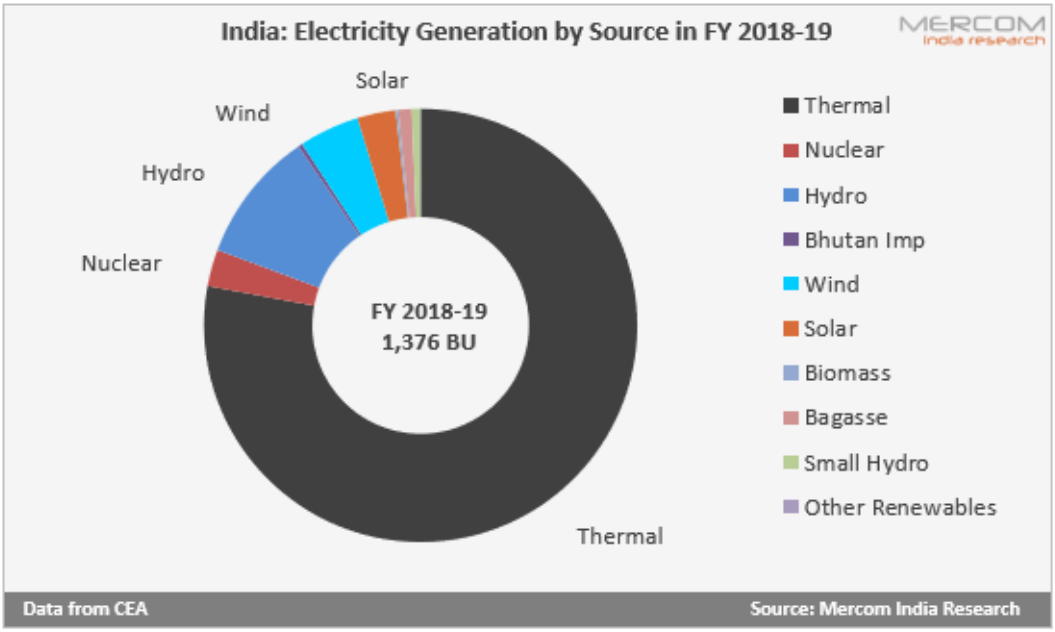
Source: Mercom India

CEA (Central Electricity Authority) data shows that solar power generated 11.4 billion units of electricity in India in Q1, 2019, up 34% versus year go and up 19% versus last quarter.



Source: Mercom India

Even in 2018-19, renewal sources of energy in India (solar, wind) account for only 9% of energy production, with the majority production continuing to be thermal (coal, gas, lignite, diesel, 78%).



Solar installed capacity in India at the end of Q1 2019 had reached 30 GW, a 32% increase versus year ago. Even then, solar power accounts for just 3% of the total power generated in the country.

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STUDY OF REQUIREMENTS | DEEPASHRAM

1. Analysis of 1 years electricity consumption

Deepashram Energy Consumption Summary

Period	Unit	Consumption	Remarks
Apr-17	kWh	1,896	Anomaly?
May-17	kWh	3,896	
Jun-17	kWh	3,352	
Jul-17	kWh	3,928	
Aug-17	kWh	4,488	
Sep-17	kWh	3,616	
Oct-17	kWh	2,808	
Nov-17	kWh	2,416	
Dec-17	kWh	2,120	
Jan-18	kWh	2,656	
Feb-18	kWh	8,464	Anomaly?
Mar-18	kWh	4,768	
Total		**44,408**	

Summary

Average monthly energy consumption (kWh): 3,405

(assuming that Apr'17 and Feb'18 are 'anomalies' and therefore excluded)

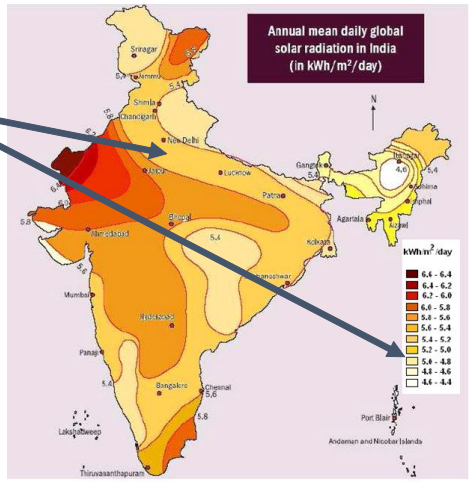
Studied 12 months electricity bills at Deepashram.

Excluding April 2017 & February 2018, which appear to be anomalies, the average monthly consumption is 3,405 kWh.

2. Computing Solar Sizing

SOLAR SIZING FOR DEEPASHRAM

Description	Unit	Value
Average energy consumed per month	kWh	3,405
Average solar insolation in Gurgaon	kWh/day/m2	5
Energy consumed per day	kWh	113
Account for degradation over 25 years (20%)	20%	136
System size	kWp	27
System size in Watts	Wp	27,238
No of 300Wp solar modules	unit	91
Inverter Capacity required	W	32,686
Total area for solar modules (2 sq m per module)	Sq m	182



3. **Practical Solar Sizing & Costing**

SIZING PROPOSAL

Proposal based on controling initial CAPEX (INR 10 lacs) and smart usage/planning of energy consumed

1) It must be noted that trying to install a full capacity solar may not be the most efficent in terms of RoI

2) Energy consumed at Deepshram may be planned so as to have consumption via Dishwashers, washing machines, pumps during sun-hours

PROPOSED SOLAR SIZING FOR DEEPASHRAM

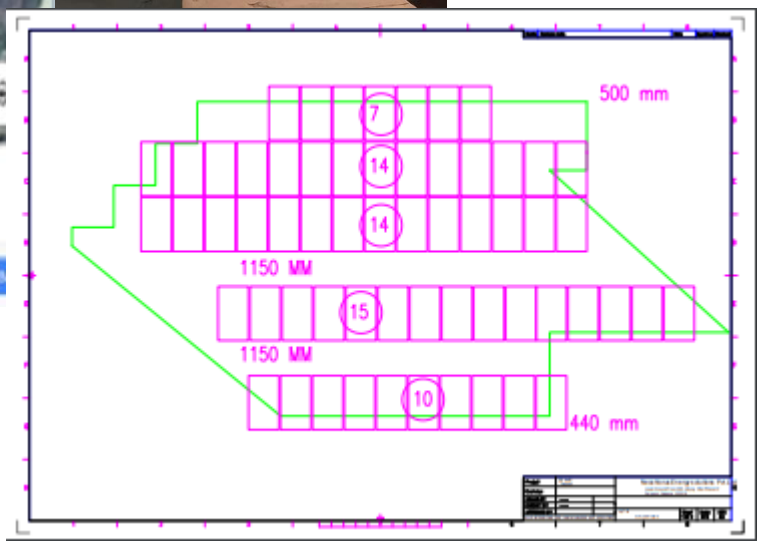
Description	Unit	Value
Energy consumed per month	kWh	2,250
Average Insolation	kWh/day/m2	5
Energy consumed per day	kWh	75
Account for degradation over 25 years (20%)	20%	90
System size	kWp	18
System size in Watts	Wp	18,000
No of 300 Wp solar modules	unit	60
Inverter Capacity required	W	21,600
Total area for solar modules (2 sq m per module)	Sq m	120

Approximate costing	**Unit**	**Value**	**Notes:**
Cost of solar modules	INR 28 per Watt peak	504,000	Assuming sourced directly from maufacturer/distributor
Cost of Support structure and installation	INR 5 per Watt	90,000	Provided by Local Agency
Cost of Inverter (3-phase) + breakers ++	INR 15 per Watt	324,000	Assuming sourced directly from maufacturer/distributor
Total (approximate)		918,000	

Feasibility Study

Study of size & orientation of rooftop, direction with respect to the sun, length of shadows from surrounding objects and space available for laying panels contiguously.

Measuring the available roof top area at Deepashram, noting the direction of the sun and planning for the layout of the panels required for 19.5 kW.



Funding

Since the funding required was significant, Manuel recommended that we should seek Corporate CSR (Corporate Social Responsibility) Funding.

I prepared a write up sharing all details of Deepashram and of the plan to set up a grid tied solar photo voltaic plant. I shared this write-up and request for funding with several Corporates, either directly or through my parents, Manuel & James.

Motorola approved Rs. 10.77 lakhs for the project.

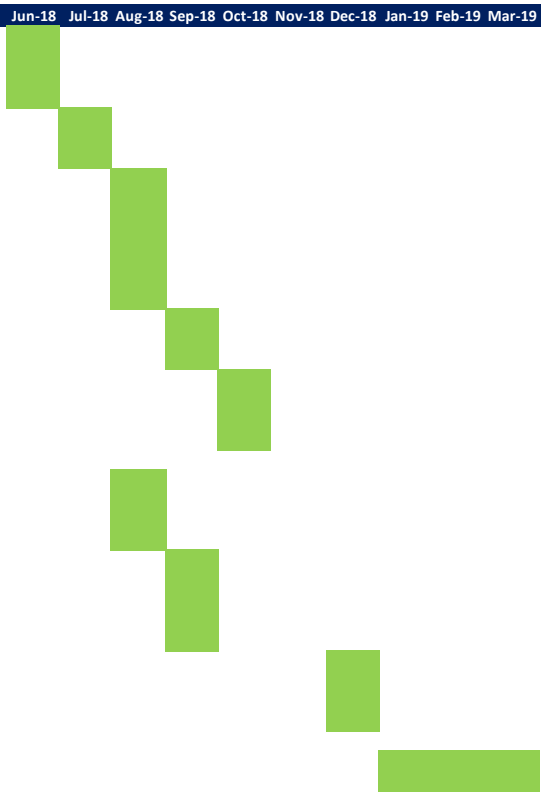
Project Planning

Defining the RASCI matrix for the project.

RASCI MATRIX | DEEPASHRAM SOLAR POWER PROJECT			
Stakeholders (RASCI)			**RASCI**
Fr. Timothy	A, C, I		R = Responsible
Manuel	C,S,I		S = Supportive
Mihir	S, I		C= Consulted
Agency / Vendor	R,A		I = Informed

PROJECT DEEPASHRAM SOLAR POWER | PERT CHART

No	Action Item	Owner
1	Study Deepashram energy consumption through prior 12-month bills; ascertain proposed plant capacity.	Mihir
2	Compute sizing of plant based on solar irradiation maps of India.	Mihir & Manuel
3	Request Manuel/ James help to seek vendor estimate of total costing (including components, support, warranties) in order to seek funding.	Mihir & Manuel
4	Stakeholders at Deepashram, along with Manuel, to agree on the dimensioning and total project costs.	Fr. Timothy & Manuel
5	Work with vendor to refine costing based on revised dimensioning.	Manuel & Mihir
6	Mihir to compile a complete Bill of Material. To work with Manuel to see if any of the items can be sourced through known vendors for discounted costs.	Mihir
7	Create pitch document to seek Corporate CSR funding. Share document with Corporates.	Mihir
8	Send out RFP (Request For Proposal)	Mihir
9	Compile vendor responses for evaluation	Mihir
10	Review of vendor proposals & vendor selection	Fr. Timothy & Manuel
11	Final discussions and agreement with selected vendor	Manuel
	Once funding is approved:	
12	Admin/ Manager at Deepashram to create an account & apply online at HAREDA portal (http://www.dnreapplyonline.gov.in/displaydata/default/submenudata?pageid=1&parentid=4)	Fr. Timothy
13	After application submission online, HAREDA personnel will inspect site to review and give approval for project	HAREDA
14	Deepshram to apply for net-metering (metering that accounts for solar production and on-site consumption) online at the HAREDA portal	Fr. Timothy
15	Once the installation is complete and certified by the approved agency, the netmeter will be installed and the system deemed operational with billing accounting for solar generation	Mihir
	After installation	
16	Troubleshooting - Any issues to be taken up with the relevant stakeholder to drive closure.	



RFP & VENDOR SELECTION

The RFP was floated to 3 vendors recommended by Manuel & James.

- Delta RPI
- Zeversolar
- Neochlorus Energy Solutions

The bids were evaluated by Manuel & Father Timothy. Neochlorus Energy Solutions (NES) was selected on the counts of most competitive pricing, comprehensive solution and good feedback from current customers. They were awarded the project as a turnkey project, with NES being responsible for civil work as well.

Implementation

The implementation phase was a great learning for me and was also hard work!

1. It was critical to set clear expectations on specifications, sourcing and timelines. A delay in the panels on account of unclear specifications cost the project 2 weeks.
2. From all of his experience, Manuel's concern and focus was about essential small details such as those listed below that were critical to get right the first time around.
    - **Panel Direction & Shadows:** The angling of the face of the panels had to be extremely accurate to ensure the most efficient solar power generation and the panels had to be installed to ensure no shadows or blockage of sunlight. We monitored the set up as it was in progress to prevent rework in the future.
    - **Structure:** The correct choice of material to be used for the mounting structure was very important to ensure strength to carry the weight of 60 panels and also withstand the force of winds on the large open panel surfaces. It was decided that galvanized iron (GI) would be used. Manuel got me to work with the vendor to document details of the gauge & the weight per running foot of the selected material and also details of the maximum wind velocity that the structure would be able to withstand.
    - **Joints & Surface Treatment:** With a GI structure, it was important that the joint welds be treated appropriately to ensure structural strength and the surface be appropriately coated with the correct paint to prevent corrosion and damage to the structure.

Special paint for the GI structure to prevent

corrosion

- **Anchoring:** The bolts used to anchor the structure to the floor were special bolts, with specific material and dimensions.

Conclusion

Deepashram is now generating its own power, with a significantly reduced carbon foot print and electricity bills.

When I first made the suggestion for a solar generating station to Father Timothy, no one was sure that this could be accomplished. There were so many unknowns – What would it cost? How would it be funded? Was their sufficient solar radiation available in the area? was the terrace space adequate for number & size of panels required? Who would project manage this project over such a long period?

It took 14 months, a lot of self-study, work with various mentors and a lot of trust from Father Timothy and my parents, to help me support this projects implementation. I am so grateful that I was able to get the help required from Manuel, from the vendor, Neochlorus and from my parents to make this installation possible.

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