GRID

Detailed Project Report
Mini Grid Installations

16 August 2016

Draft

Table of Contents

Abbreviations **3**
Glossary **4**
Project Summary **5**
1. Introduction **6**
1.1. Power Scenario 6
1.2. Need for Renewable Energy 7
1.3. Why Rural Electrification? 8
1.3.1. Socio-Economic Background 8
1.4. Smart Nanogrid-Solution to Energy Challenges 9
1.4.1. Social Interventions for Sustainability and Scalability 9
2. Site Details **10**
2.1. Gahakia Cluster, Odisha 10
2.1.1. Site Identification 10
2.1.2. Site Pictures 12
3. Mini-Grid Design **13**
3.1. Village-level Details 13
3.2. Solar PV Power Plant Components 14
3.2.1. Basic System Description 14
3.3. MEZ load details 15
3.4. Cluster design layout 18
4. Mini-Grid Costing **19**
5. Implementation Schedule **20**

List of Tables

Table 1: Off-Grid Installation 7
Table 2: Survey Results of Villages 13
Table 3: Component Description 14
Table 4: MEZ load details 15
Table 5: Mini Grid Costing 19
Table 6: Central Financial Assistance (Rs./Wp) for SPV Lighting System .... **Error! Bookmark not defined.**
Table 7: Subsidy Arrangement .... **Error! Bookmark not defined.**
Table 8: Implementation Schedule 20

List of Figures

Figure 1: Energy and Peak Deficits- India 2016 6
Figure 2: Comparison of Power mix- India 7
Figure 3: Identified Cluster 11
Figure 4: Village Locations 11
Figure 5: Layout of Villages/Clusters 12
Figure 6: Site Pictures 12
Figure 7: Load distribution 17
Figure 8: Cluster layout 18

Abbreviations

AC	Alternate Current
CEA	Central Electricity Authority
DC	Direct Current
GW	GigaWatt
IEA	International Energy Agency
INR	Indian Rupees
IT	Information Technology
IoT	Internet of Things
Km	Kilometer
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
LV	Low Voltage
MCB	Main Combiner Box
MEZ	Micro Enterprise Zone
MU	Million Units
MW	Mega Watt
O&M	Operations & Maintenance
PCU	Power Control Unit
PV	Photovoltaic
RE	Renewable Energy
REC	Rural Electrification Corporation
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana

Glossary

Photovoltaic	The physical effect of direct conversion of light (sunlight) to electrical energy
PV cell	The smallest photovoltaic (PV) element that generates electricity from light
PV Module	A collection of interconnected PV cells, encapsulated between protective materials such as glass and back sheet or glass and glass, and mounted in an aluminum frame
String	Multiple PV modules connected in series electrically
Array	Several strings of modules with the same orientation and tilt angle, located together
Inverter	An electronic device that converts direct current electricity into alternating current electrically suitable for feeding directly to the electrical grid or to normal AC loads
Insolation	It is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter (W/m^2) or kilowatt-hours per square meter per day (kWh/m^2)
Solar Irradiation	The total electromagnetic radiation emitted by the Sun
Mounting Structure	Device used to hold modules in place, at desired angle and direction
Cable	A conductor with one or more strands bound together, used for transmitting electrical energy
Efficiency	The ratio of the output to the input of any system
Junction Boxes	Inputs of several strings are connected to this box and taken as single output
Current	A flow of electricity through a conductor measured in Amps
Voltage	The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in Volts
Lightning Arrestor	Device used to protect all the components from lightning strikes
Earthing	Described as a system of electrical connections to the general mass of earth

Project Summary

1	**Name of the Company**	**SunMoksha**
2	Proposed Project Locations	Gahakia, Daringbadi
3	District Name	Kandhamal
4	State	Odisha
5	Proposed Mini Grid capacity	Gahakia- 25 kW
	Number of hamlets/villages in the cluster	5
6	Technology	Solar PV
7	Location of place on Earth	19° 47’ 20.94” N Latitude 84° 02’ 20.36” E Longitude
8	Average annual solar isolation	5.50 kWh/m^2
9	Nearest Airport	Bhubaneshwar
10	Nearest Railway Station	Berhampur
11	Type of Module proposed	Poly Crystalline 250Wp Modules
12	Type of Inverter proposed	Central Inverter
13	Type of Battery Proposed	Lead Acid Battery- 2V, 500 Ah

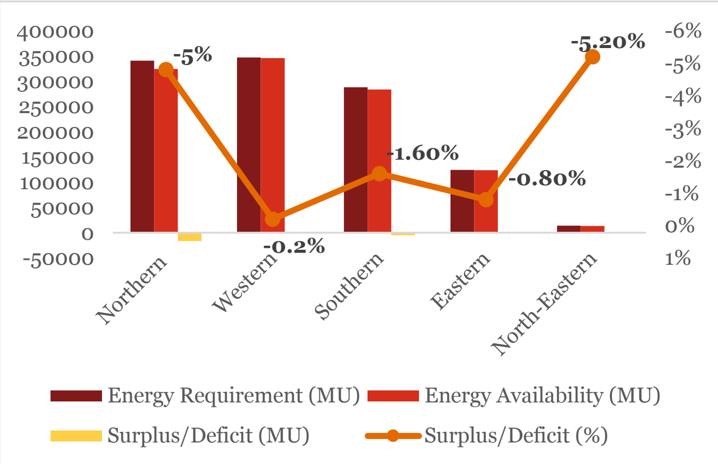
1. Introduction

Most national energy policies have been built around the assumption that large-scale generation and centralized grid systems are the principal means for developing access to electricity. The result has been a tendency towards an "all or nothing" approach. People within the reach of the grid, get electricity, subject to system reliability. Those out of reach are relatively neglected with the exception of the piecemeal development of the local mini-grids. The result is that around 300 million people in India remain without electricity but "all or nothing" approaches are increasingly out of step to what is now possible in power technology.

1.1. Power Scenario

India is one of the fastest growing economies of the world with its energy consumption increasing at a relatively fast rate due to the population growth and economic development. However, India still has one of the lowest per capita electricity consumption as compared to most other countries or regions in the World. Even those who have access to power, suffer from power shortages and poor quality of power supply. The extent of power shortage varies from state to state. The power supply position during April 2015 – March 2016 for each region is plotted below in two charts- left one represents energy deficit and right one represents peak load deficit.

Source: CEA- Power Supply position March 2016



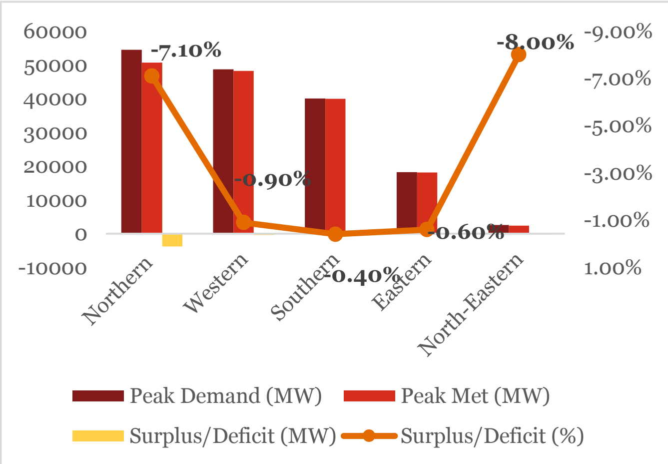


Figure 1: Energy and Peak Deficits- India 2016

Since the last two decades, governments at State and Central level have tried to focus on off-grid solutions to meet the power demands, though still the country is not in a position to applaud any major achievement in this sector. The total off-grid installation is still at a miniscule level when compared to around 298[1] GW of installed power capacity in India. Out of this total capacity, renewable energy contributes about 42.7[2] GW (~14%). The current status of off-grid capacity in India is represented in the table below:

[1] As of March 2016-http://cea.nic.in/reports/monthly/executivesummary/2016/exe_summary-03.pdf

[2] As of March 2016-http://mnre.gov.in/mission-and-vision-2/achievements/

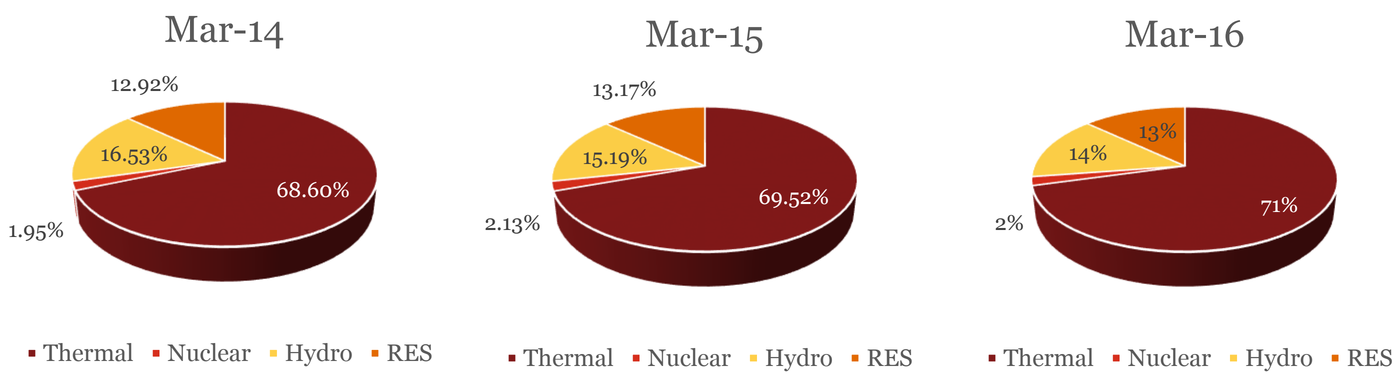
Table 1: Off-Grid Installation

Technology	Cumulative Achievement (as of 31st March 2016) (in MW)
Waste to Energy	160.16
Biomass (non-bagasse) Cogeneration	651.91
Biomass Gasifiers	
Rural	18.15
Industrial	164.24
Aero-Generators/ Hybrid Systems	2.69
SPV systems	313.88
Water mills/ micro hydel	18.71
Total	**1329.74**

Source: Ministry of New and Renewable Energy

1.2. Need for Renewable Energy

India's energy requirement is constrained by country's energy resources and import possibilities. Unfortunately, India is not well endowed with natural energy resources. While coal is abundant, it is regionally concentrated and is of low calorific value and high ash content, though it has an advantage of low sulfur content. The extractable reserves, based on current extraction technology, remain limited. Hydro potential is quite significant but small compared to India's needs. Further to mitigate environmental and social impacts of storage schemes often delays hydro development thereby resulting in huge overruns. Reserves of oil, gas and thorium are meager. This shifts the need to clean, cheap and reliable sources of energy available through renewable energy sources where there is no fuel cost involved. Current mix of various sources of power for last 3 years is represented in the figure below:



Source: CEA- All India Installed Capacity Monthly Reports

Figure 2: Comparison of Power mix- India

India meets close to 65% of its electricity needs from fossil fuels and is expected to continue doing so in the foreseeable future. This poses questions on cost of electricity supply in future, environmental impacts and energy security. At this juncture, Renewable Energy (RE) is being seen as one of the important means to meet the growing power needs of the economy while enhancing energy security through diversification of fuel sources and providing opportunities for mitigating greenhouse gas emissions.

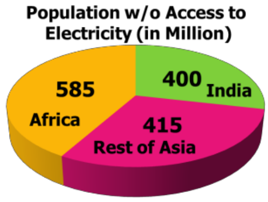
1.3. Why Rural Electrification?

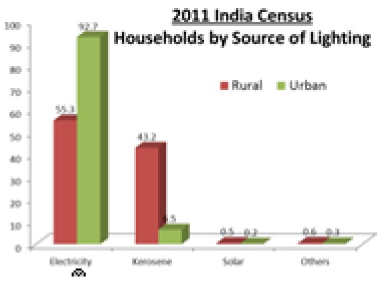
Despite several policy initiatives by the Central Government and focus on extending the national grid, 55% of rural households still do not have access to electricity. And those areas where grid is extended, most people do not opt to connect due to poor reliability and inadequate supply. The supply of electricity to rural areas has been through conventional grid supply by the State Utility with a significant disincentive from the part of the State Utilities to extend better service to the rural consumer or provide extended hours of supply. This has resulted in high distribution losses and low collection efficiency despite low tariffs in rural areas. The delivered cost per unit for which dues are collected by the utility rises sharply with deterioration in supply and collection parameters.

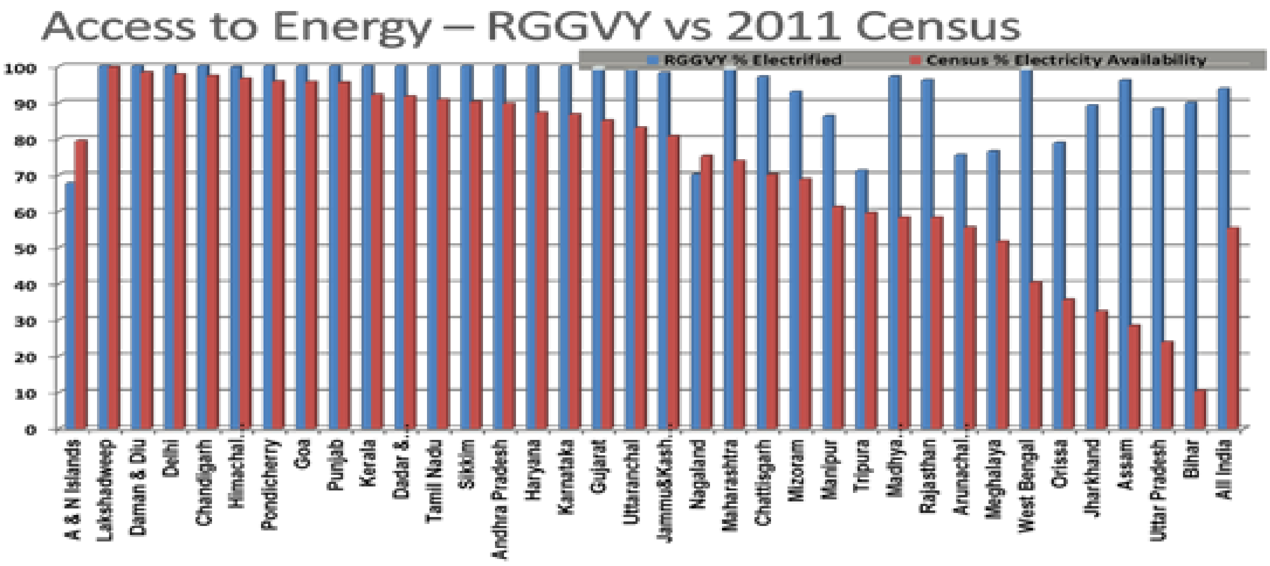
1.3.1. Socio-Economic Background

India's rural economy revolves around agriculture; however most of the activities have been focused on growing crops, which most often does not fetch them enough earnings. Serious efforts need to be made in moving the farmers up the value chain by implementing post-harvesting processing in rural areas and appropriate storage to increase the life and value of agricultural produce. This would not only increase farmer income, but also reduce food wastage. Hence there a need to establish local 'micro-enterprise zones (MEZs)' for livelihood activities (agro- and/or non-agro) to improve the economic status of the rural populace, and lead to 'Gram Swaraj'. It also prevents migration of youth from rural to urban areas, and reduces the strain on city infrastructures. Creation of non-agro-based livelihood and enterprise activities will, in turn, reduce the pressure on agriculture and land, and lead to triple bottom-line impact.

The agricultural economy, in turn, revolves around the nexus of food, water, and energy. Access to energy plays a key role in moving the farmers up the value chain. A 2010 study by World Energy Council, confirms that "energy poverty is the main reason for rural poverty which in turn gives rise to health issues" and "restricts the income level and industrial and commercial activity leading to economic stagnation or slow growth." However, according to IEA's report on World Energy Outlook 2011, 1.4 billion people in the world do not have access to electricity, with 400 million residing in India. India's latest census data also show that only 43% of the rural population do not have access to grid electricity; the rest who have access, electricity is of very poor quality and highly unreliable. The 2011 census data also show that even for villages electrified under RGGVY, the actual census data shows a wide disparity and gap. More than 40% of the electrified villages have less than 60% availability of electricity. Thus, this concludes that energy deficit is the root cause of this gap.







1.4. Smart Nanogrid-Solution to Energy Challenges

Smart Nanogrid is a holistic solution with a 'systems' approach to address these challenges of energy access. While several solutions have been and are being implemented to make the micro-grid model succeed in the rural hinterland, these solutions have been unable to achieve scale, due to several challenges-uninterrupted access to energy and digital connectivity is paramount. *Smart Nanogrid,* a technical intervention, addresses these gaps and requirements. The word "*Nano*" signifies small, modular, and affordable for the masses. A typical *Smart Nanogrid™ Village* consists of a power generation unit from renewable sources, a distribution grid to make power available to homes, streets lights, and most importantly to farms and micro-enterprises, and a complete automation system for managing the microgrid operations. For villages with energy-deficiency, decentralized hybrid renewable power generation with smart micro-grid is a set-up. The renewable sources depend on local availability, such as solar, wind, biomass, biogas, pico-hydro, etc. These solutions are applicable in both electrified and un-electrified villages. An IT-based remote monitoring, control, management and maintenance of the microgrid, scheduling and automated management of demand and supply of energy and other resources, metering, billing & payment, and IT-enabled interfaces with the citizens of the village, are the key technical interventions. *Smart Nanogrid™* enables ***sustainable*** and ***scalable*** development path.

The *Smart Nanogrid™* is managed by *NanoSoft Remote™* that provides metering, billing and payment (prepaid/post-paid), and alerts/cut-off if unpaid. Moreover, it provides differential tariff for business, irrigation, and households. *NanoSoft Remote™* schedules demands of microenterprises, irrigation pumps, street lights, etc. The microenterprise load is scheduled to match the power generation constraints. The system switches off power supply, if a consumer exceeds maximum energy or power allocated. The irrigation time and amount is designed to be controlled by measuring the moisture of the soil. These measures help manage demand to meet supply constraints. Local consumers can also get their usage information, payment status, as well as register complaints through a simple Mobile App and Energy Card with QR Code. *NanoSoft Remote™* manages all customer information, technical support, continuous training, and local value add services to consumers.

Thus, *NanoSoft Remote™,* ensures operational efficiency of the *Smart Nanogrid™,* as well as its scalability – by remotely monitoring and technically supporting the village projects in a cost-efficient and timely manner. It brings the expertise to the village and the village to the experts. *Nanogrid™* is a convergence of Clean Energy, IoT (Internet of Things) and IT (Information Technologies) for automated remote monitoring, management and maintenance of the system over cloud server and mobile devices such as tablets and smartphones. *NanoSoft* utilizes state-of-the-art telecommunication, information and mobile technologies, and integrates international standards and protocols for universal compatibility and security. It makes data available to experts in real time for a timely intervention, in case of failures or malfunctions; thus bringing long-term sustainability and scalability. The data is available to all remote stakeholders such as sponsors, government agencies, implementers, O&M providers, and domain experts to *remotely monitor* the performance of the project and intervene, if needed.

1.4.1. Social Interventions for Sustainability and Scalability

Social interventions of this system address the operational sustainability & scalability of the solutions. Innovative business models, access to finance and close partnerships with grass root organizations for scalable and sustainable operations and socio-economic development are key interventions. The business model creates micro-enterprises in the villages in an MEZ to not only make them self-sufficient, but also to create local economic growth and move the villagers up the economic value chain. The business model includes the *Smart Nanogrid™* operations, citizen services such as health, education, governance, and other viable microenterprises in the village.

Training and skill development to run these microenterprises and agricultural value-add livelihood activities along with the *Nanogrid™*, form the last important aspect of this intervention. Sun Moksha has addressed this through integrated partnership with technical, vocational, and business institutions to develop skillset and Entrepreneurial capacity. With ties-ups to academic and vocational institutes, the skill training of the local operators and workers are continuously upgraded with technology. The operators get real hands-on training at the *Living Laboratory* of the training institute, as well as remotely via *NanoSoft* Remote.

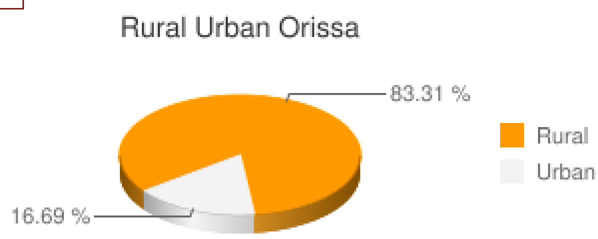
2. Site Details

2.1. Gahakia Cluster, Odisha

Odisha is the 9th largest state by area and the 11th largest by population. Odisha stands for its ancient glory and modern endeavor. It is endowed with nature's bounty, a 482 km stretch of coastline, serpentine rivers, and mighty waterfalls, forest-clad and blue hills of Eastern Ghats with rich wild life. A brief profile of the state is represented below:

Odisha State Profile	
Area (Sq km.)	155707
Approximate Population	4.2 crores (2011)
Population Growth	14.05%
Total Number of Villages	51,583
Total Number of Households	96,61,085 (2011)
GDP per Capita	INR 60,800
GDP growth	8.78% (2014-15)
Literacy Rate	72.87%

The state has a quite high percentage of rural population compared to urban population and the electrification status of these rural population is quite low. The daily household consumption for the rural population is estimated to be around 2.3 kWh/Day/household.



2.1.1. Site Identification

Daringbadi is one of the hill station in Odisha state of Eastern India. It is widely known as "*Kashmir of Odisha*", situated at a height of 915 m in Kandhamal district, the place is gifted with natural bounties including pine jungles, coffee gardens and beautiful valleys. Daringbadi is set in a beautiful spot surrounded by thick rain forests with wild animals. Daringbadi can be reached from Bhubaneshwar (~251 km), and other important places of the state by regular bus services. The nearest railway station is at Berhampur (~120 km).

The site selection for a mini-grid Solar PV power plant is pre-dominantly determined by the level of electrification in a particular cluster and the demand and need for clean energy. Other factors that are equally important are:

- Availability of adequate solar irradiance
- Accessibility to the village
- Financial strength of the households to pay for the power
- Adequate land/ roof for PV installation

Hence considering these factors, Gahakia cluster, a beautiful valley in Daringbadi, consisting of around nine habitations in six villages has been identified for installing Solar PV mini-grids to provide power to the commercial enterprises.

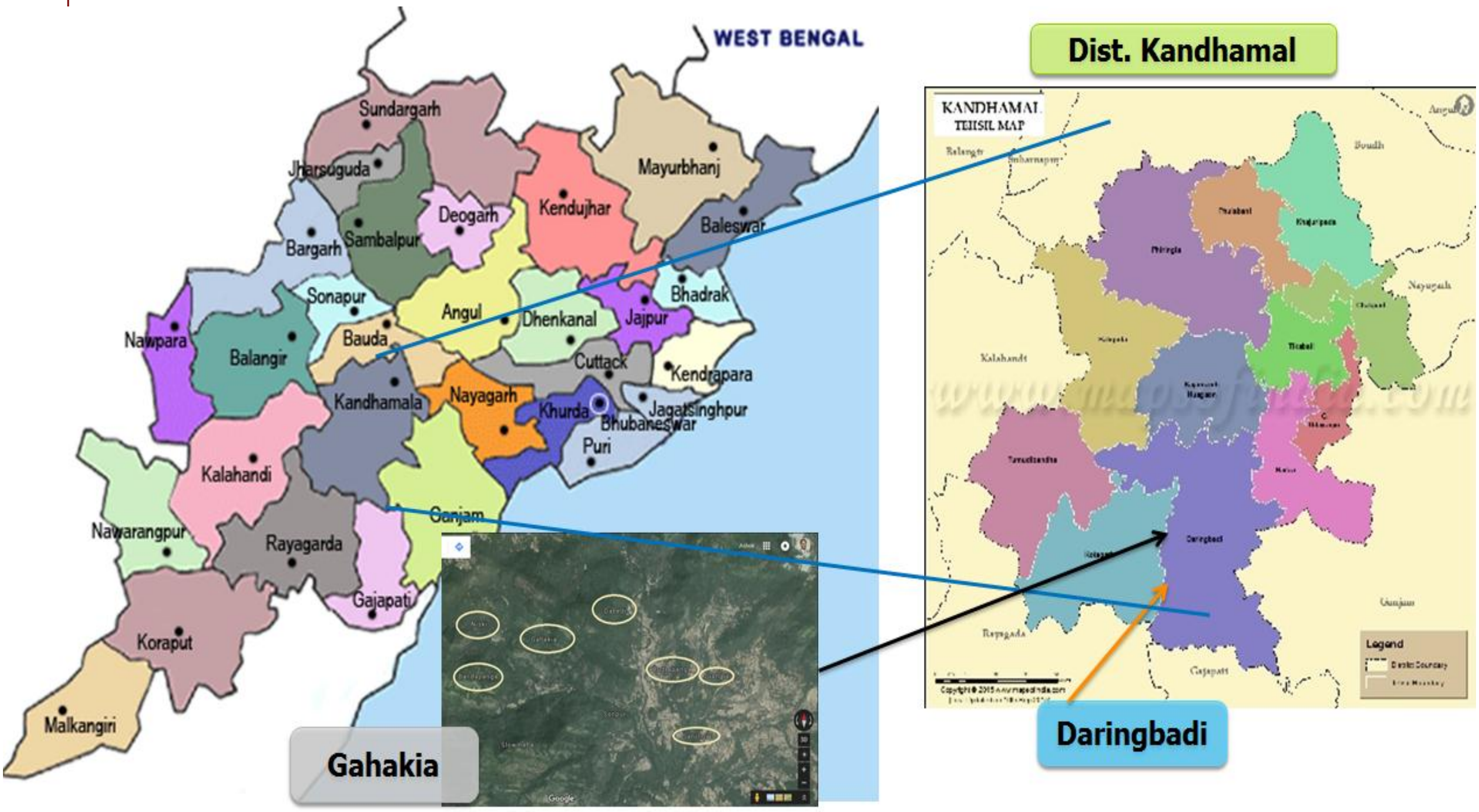


Figure 3: Identified Cluster

The villages/clusters identified are:

- Dabedi
- Budrapanga
- Satungia
- Juangia
- Gaspanka
- **Gahakia Cluster comprising of 4 small villages – Niski, Badasahi, Rangasahi, Singipanga**

The Gahakia cluster comprises of more than 590 households with agriculture as their main occupation.

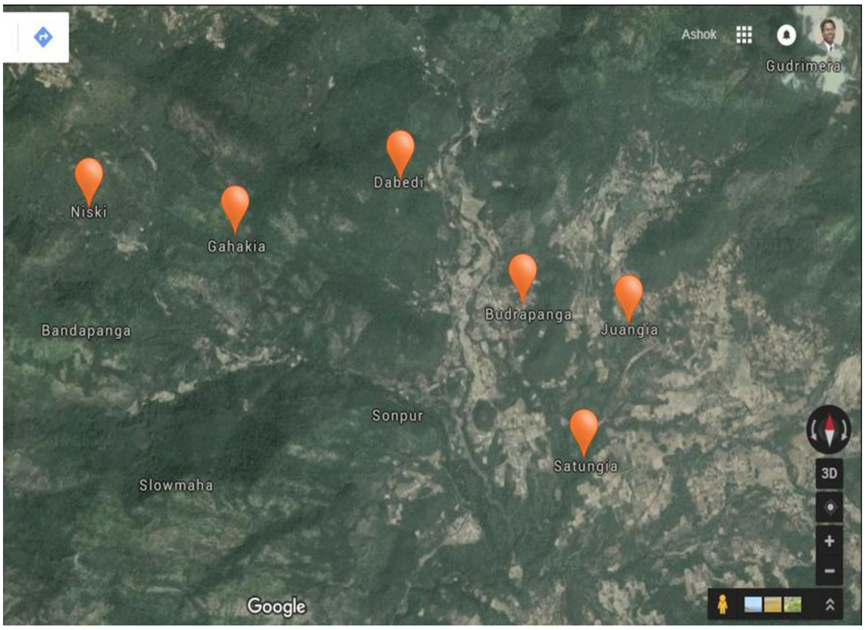


Figure 4: Village Locations

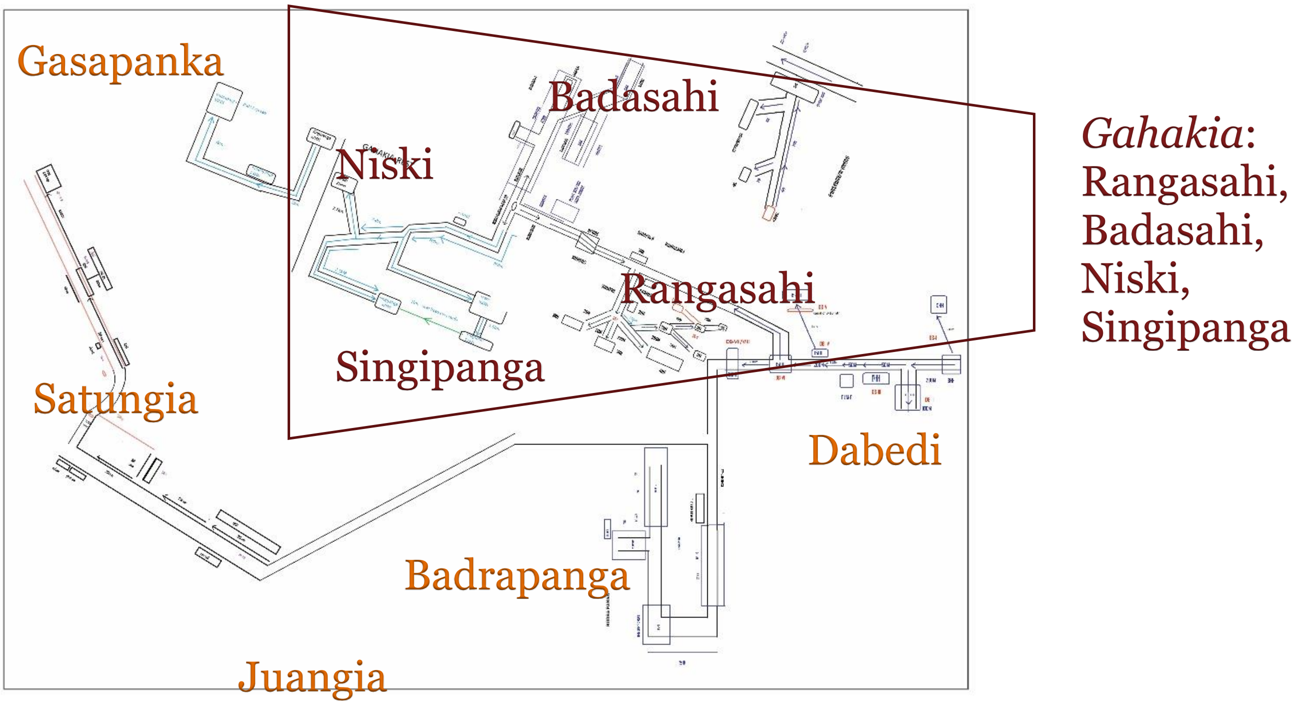
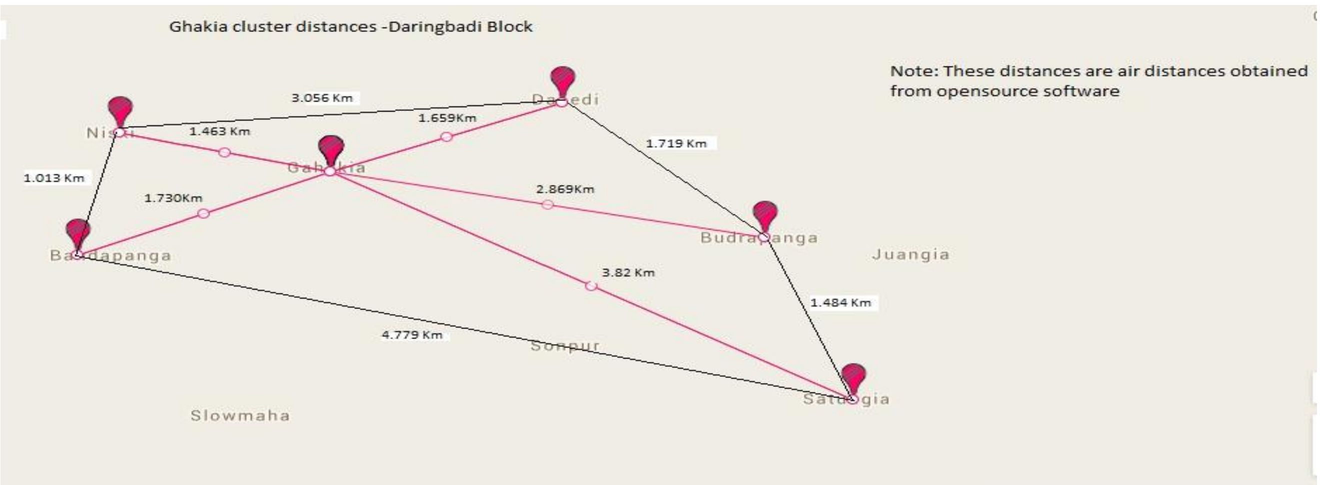


Figure 5: Layout of Villages/Clusters



2.1.2. Site Pictures

Figure 6: Site Pictures

3. Mini-Grid Design

3.1. Village-level Details

Detailed surveys were conducted in each of the above identified villages to understand the load requirement and the willingness of the households to switch to clean energy to support their livelihood activities and basic lighting needs. The results of 4 of the villages are summarized below:

Table 2: Survey Results of Villages

Village Name	Gahakia, Daringbadi
Census Code	3771200
Block/Panchayat	Daringibadi
District	Kandhamal
Number of hamlets/villages in the cluster	5
Number of households in the village	590+
Proposed Capacity (kW)	25
Length of LT Line, Km	0.75
Nearest market	Daringibadi
Distance from market	20-25 Km
Types of livelihood activities	
Main occupation	Agriculture
Other occupation	Daily Labor
Crops	Paddy once a year, other pulses once a year
Horticulture	Yes - Arhar, Turmeric, Vegetables
Any other local employment	Farming and selling raw produce
Average monthly income of the households?	Rs. 1500-2000/-
Average paying capacity?	Rs. 100-200/month
Major Issues	1. Unemployment, 2. No electricity, 3. No irrigation
Means of Irrigation	
Main source of water	Small running river
Source of irrigation water	Water streams, bore wells
Number of irrigation pumps used	None-no power
Type/specification of the pumps used	N/A
Load requirement for irrigation pumps, kW	5 with scheduling
Load requirement for households, kW	0
Average number of electrical appliance used per household	NA
Number of hours of power requirement	Most 4-8 hrs for Microenterprises, some 24hrs
Time of day when electricity requirement is preferred	9am-5pm -for pumps and microenterprises, evening for common services
Total commercial load proposed, kW	25
Number of shops/businesses	Presently 1 (one)
Other microenterprises	None

Average load requirement per business	1-2 units/day for small shops; 10-15units/day for workshop, food processing, etc.;
Hours of electricity requirement in each business/livelihood	8-12 Hrs
Time of day when power is required	9am-9pm
Any school or community hall in the village	1 School; 1 community hall; 1 Anganbadi; 4 churches
Load requirement	4kW
Hours of power requirement	8hrs
Number of electrical appliances used	4
Type of appliances (AC/ DC)	AC
Is the land used for solar project purchased or taken on lease?	Govt (OREDA to acquire)
Cost implications on the same?	N/A

3.2. Solar PV Power Plant Components

3.2.1. Basic System Description

Solar Photovoltaic power system consists of solar modules in series and parallel connections, these convert solar radiations into DC electrical power at the pre-determined range of voltages whenever sufficient solar radiation is available. The individual crystalline solar cells are connected together in a module (in series connection), which are hermetically sealed to survive in rugged weather conditions and ensure optimum performance during its long life.

In order to achieve a higher system voltage, modules are installed in a row arrangement, called a string. A higher system voltage has the advantage of lesser installation work, higher efficiency of the entire plant and usage of smaller cross-section cables. Calculated no. of strings is connected in parallel by cables in Junction Boxes. Outputs from many such junction boxes are connected in parallel in the Main Combiner Box (MCB). This Main Combiner Box is fed to the central inverters/Power Control Unit (PCU) to invert solar generated DC power in to conventional 3 phase AC power. AC power from inverters will be fed to LV panel.

The following are the major components in a mini-grid power plant:

Table 3: Component Description

S.Nb.	Item/Component	Description
1	Solar Module	Polycrystalline 250Wp Module
2	Inverter	Central Inverter
3	Battery	2V,500 Ah Battery
4	Monitoring System	Smart Nanogrid

3.3. MEZ load details

The total load distribution in the Gahakia cluster is as illustrated below:

Table 4: MEZ load details

S.Nb.	Micro-enterprise	Hrs. of Operation (daytime)	Hrs of Operations (night time)	HP/unit	Units	Total HP	kW	Utilization factor	Total Utilized Load (kW)
1	Holler Machine	3	0	5	2	10	7.457	75%	5.59275
2	Pump Set – irrigation	4	0	2	2	4	2.9828	100%	2.9828
3	Pulse/Chiranji/Sal docoater	1	0	1	1	1	0.7457	100%	0.7457
4	Puff Rice Machine	2	0	1	1	1	0.7457	100%	0.7457
5	Grinder Machine	4	0	1	1	1	0.7457	100%	0.7457
6	Stitching Machine	6	0	1	5	5	3.7285	50%	1.86425
7	Cold room	6	12				3	50%	1.5
8	Health center refrigerator	6	18				0.5	50%	0.25
9	Common Service Center – CSC	4	0				2	50%	1
10	Reading Space (night), computer training centre (night, free)	0	4	0	1	0	0.2	100%	0.2
11	Post-Hatchery (Breeder, day/night)	0	12	0	1	0.5	0.5	100%	0.5
	TOTAL				**14**	**22.5**	**21.8597**		

Based on the load requirement, monthly distribution of loads considering the hours of usage during day and night time is prepared to identify the load requirement during different months in a year. The distribution of the same is illustrated below:

	January	February	March	April	May	June	July	August	September	October	November	December
kW	14.77	18.50	21.48	17.38	14.40	13.65	12.16	11.04	19.25	15.52	14.77	11.79
Day kWh	32.77	45.45	44.70	28.67	16.74	16.74	14.50	27.18	39.85	39.85	39.11	27.18
Night kWh	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Total kWh	62.07	74.75	74.00	57.97	46.04	46.04	43.80	56.48	69.15	69.15	68.41	56.48

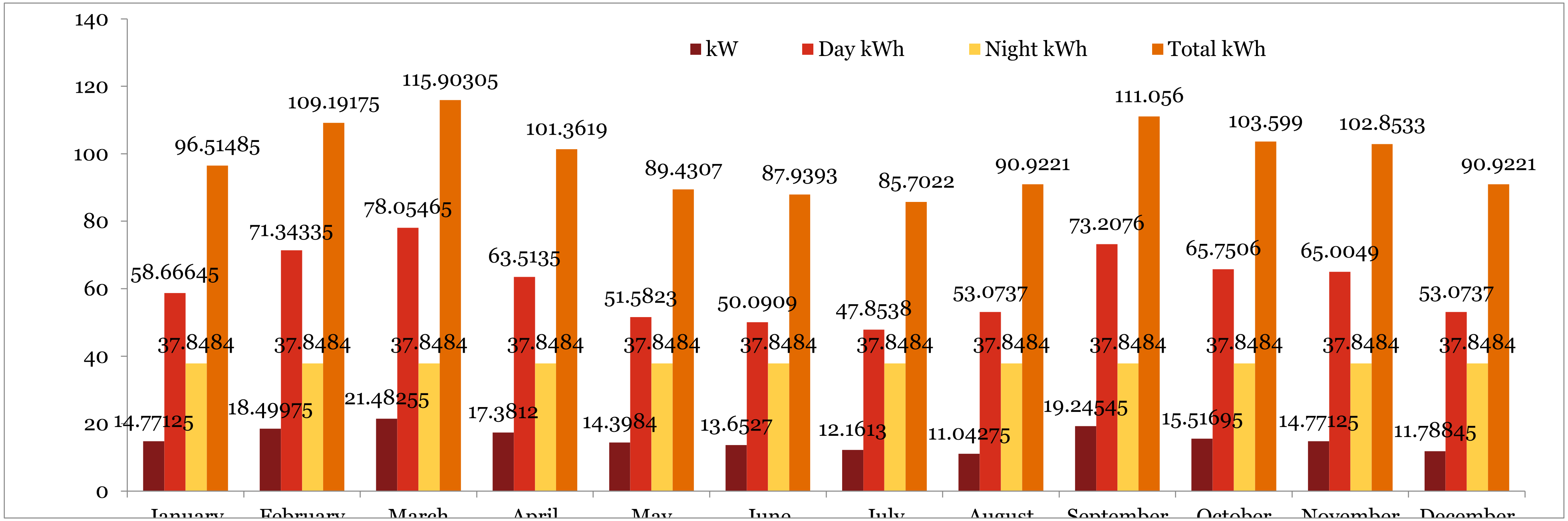


Figure 7: Load distribution

3.4. Cluster design layout

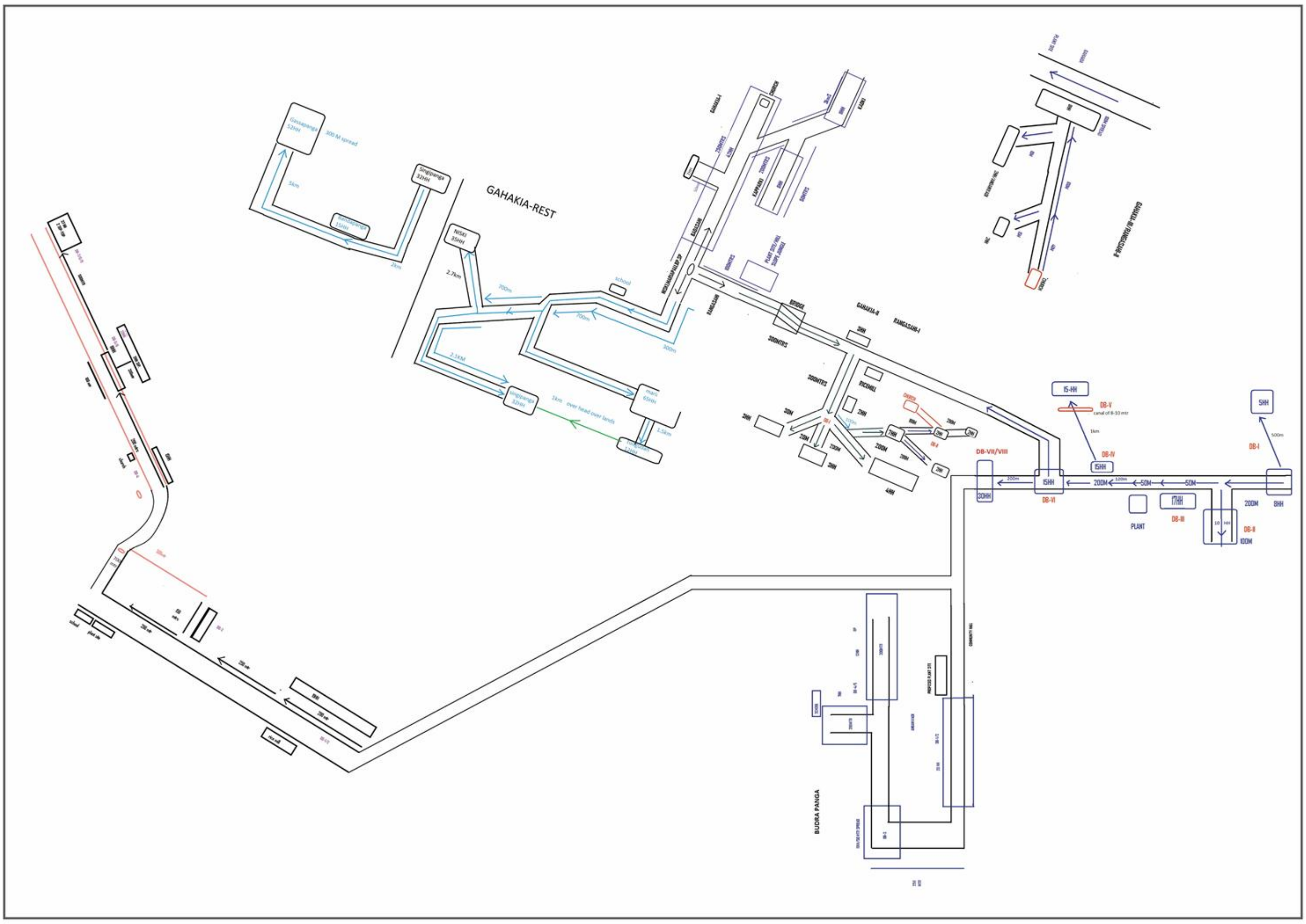


Figure 8: Cluster layout

4. Mini-Grid Costing

Based on the surveys conducted, a mini grid system size was approximated to cater to the load requirements in each of the villages. The detailed cost break-up of the system is represented below:

Table 5: Mini Grid Costing

Items	Gahakia (in INR)
Solar PV Modules	1,186,875
Hybrid Inverter	817,625
Battery system with 3 days autonomy	1,218,525
BOS inclusive of I&C	1,213,250
Transportation	115,000
Electrical Microgrid+ Household wiring+ streetlights	402,752
Smart Nanogrid	1,730,069
Spares	127,192
Civil Construction	660,050
O&M for 5 years	1,235,992
Travel and accommodation	230,000
Contingency	218,965
Project Management	563,965
Taxes (w/o any taxes etc.)	**9,720,261**

The above project is proposed to be funded by **ADB** by providing a fund **of ~USD 150,000 (INR 10,017,000)** which shall be able to cover the major components of the mini grid system proposed.

5. Implementation Schedule

The implementation schedule for the above identified projects is represented below:

Table 6: Implementation Schedule

Project Activities	W-1	W-2	W-5	W-6	W-7	W-10	W-12	W-14	W-15	W-16
Identification of site for PV installation										
Identification of vendors for EPC for turnkey										
Ordering the material- Monitoring system										
Site levelling										
Other civil works- module mounting structure, control room work										
Material on site- Monitoring system and other equipments										
Commissioning of 70% plant –Battery and Inverter installation, Nano Grid installation										
Plant boundary with wire mesh										
Module Mounting										
Electrical connection within the plant and in the village										
Installation of equipments										
Final Testing of the system										