Assessment of Renewable Energy Potential and Projection for Intervention of Hybrid Mini-Grid Technology in few Un-Electrified villages of Kurung Kumey district, India

Er. Bamang Apo

Abstract— Integrated technology intervention for sustainable environment which is most fitted for the very remote rural community is Mini-Grid (fed by Hybrid Power Systems i.e. Hydro, Wind and Solar energy). The power generated from the Mini-Grid will help in empowerment in the planning process, development of ST community's requirement and last mile delivery of intervention. The same will lead to socio-economic development by utilizing local resources of target communities. It is essential to develop the skill of the rural people in the areas of project. The awareness and training phase will help the rural people to know the need and necessity of technology interventions for renewable energy. The data survey and mapping involve the utilization of various tools for information assimilation. Major data can be collected through Primary sources with the help of structured questionnaire by sending survey team for door to door household survey. Additional information can also be collected from Secondary sources through discussions, literature review and database of past and running projects. Off-Grid electrification may be intervened in few Un-Electrified villages i.e. Patin, Kapu and Milli villages of Kurung Kumey district of Arunachal Pradesh, India for income generation and livelihood of the area.

Index Terms— Renewable Energy, Hybrid Mini-Grid, Wind, Solar, Hydro Power Systems, Un-electrified.

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1. INTRODUCTION:

A mini-grid is a set of small-scale electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a small, localised group of customers and operates independently from the national transmission grid. They range in a size from a few kilowatts up to 10 megawatts. Mini-grids can serve a wide range of customers. These include private households, commercial businesses such as shops, ice makers and mobile phone chargers, agricultural loads such as irrigation pumping and cold storage, productive loads such as grind mills and wood or metal working shops, and semi-industrials such as telecom towers, processing plants or flower farms.

Mini-grids can be developed or operated by state utilities, private companies, communities, non-governmental organisations, or a mix of different players such as public-private partnerships. The generation and distribution assets may be developed and managed by different players, both public and private. The hybrid mini-grids can run on diesel, renewables (solar PV, hydro, wind, biomass etc) or as renewable-diesel hybrids. Green mini-grids are those that generate a significant portion of their power from renewable energy.

Due to lack of scientific awareness and non availability of science & technology interventions the local populace have not been able reap the benefits of the available resources in a sustained manner. Introduction of advanced, integrated hybrid mini-grid is required in the state for socio-economic development and sustainable utilization of resources available in the block. Hence, it is envisaged that the proposed Hybrid Mini-Grid on being set up in the very remote villages of the state will play a major role towards science and technological interventions with technologies appropriate/suitable for the area. The Hybrid Mini-Grid project as a whole will have a major role towards creating awareness, dissemination of scientific and technological know-how to the local people for sustainable utilization of Renewable Energy resources available and also for the development of the traditional rural technologies being practiced by the local people in the true scientific perspective.

2. OBJECTIVES:

i. To mount/integrate S&T interventions specifically to address prevalent environmental (energy, water & air) challenges for improvement in environment.

ii. To apply technology to improve the living conditions of the area through S & T intervention.

iii. To bring solutions through Integration Technology for sustainable environment of the area.

iv. To use the natural resources (air, water, forest produce) available in the area for sustainable livelihood, clean environment, power for domestic use and hygienic drinking water using latest technologies.

v. Avoid greenhouse gas emissions by promoting renewable energy technologies for mini-grid rural electrification.

vi. Clean energy services in remote rural areas using renewable energy plan.

vii. Climate change mitigation through alternate renewable energy source.

viii. Bring change in socio-economic development in education, health and livelihood.

ix. Promote selected renewable energy technologies for mini-grid connected rural electrification in Patin, Kapu & Milli villages of Kurung Kumey district, Arunachal Pradesh.

3. PROJECT AREA:

1. Project Area: Rural
2. Geographical Focus Area:

a) Village(s)/urban locality: Patin village, Block/Taluka: Sangram , Circle: Nyobia
b) Village(s)/urban locality: Kapu & Milli village, Block/Taluka: Sarli, Circle: Polosang District: Kurung Kumey; State: Arunachal Pradesh

3. Project Area Profile:

i. Geographical Area:

Arunachal Pradesh is situated in the north eastern part of India is 83,743 sq km in area and has long international border with Bhutan to the west(160 km), China to the north and north-east(1,080 km) and Myanmar to the east (440km). It stretches from snow-capped mountains in the north to the plains of Brahmaputra valley in the south. Arunachal is the largest state area wise in the north-eastern region.

It is a land of lush green forests, deep river valleys and beautiful plateaus. The land is mostly mountainous with Himalayan ranges along the northern borders criss-crossed with mountain ranges running north-south. These divide the State into five river valleys: the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these rivers are fed by snows from the Himalayas and countless rivers and rivulets except Tirap which is fed by Patkai Range.

The mightiest of these rivers is Siang, called Tsangpo in Tibet, which becomes Brahmaputra after it is joined by the Dibang and the Lohit in the plains of Assam.

High mountains and dense forests have prevented intercommunication between tribes living in different river valleys. Isolation imposed by geography has led different tribes with several dialects to live and flourish with their distinct identities. Nature has endowed the people with a deep sense of beauty which finds delightful expression in their songs, dances and crafts.

The climate varies from hot and humid in the Shivalik range with heavy rainfall. It becomes progressively cold as one moves northwards to higher altitudes.

Trees of great size, plentiful climbers and abundance of cane and bamboo make Arunachal evergreen. Tropical rain forests are to be found in the foothills and the hills in the east on the border with Myanmar. Northern most border is covered with Alpine forests. Amidst the highly rugged terrain, there are green forests and plateaus.

Main form of farming and cultivation includes shifting cultivation, wet rice cultivation and terrace form of farming. Farming is the main source of livelihood in rural areas and it is not much encouraging. The main crops produced are Paddy, Maize, Barely, Millet, Soya bean, Pineapple, Banana etc, and spices viz. cardamom, Ginger and black pepper are also grown by the local people. Non-timber forest produces like canes and bamboos plays an intricate role in the day to day life of the local tribal populace viz. ranging from constructions to food.

ii. Socio-economic status:

Agriculture is the main occupation of the people of Arunachal Pradesh. Most of the state Land is covered with dense and rich forest. So, the forest product and industries based on forest products are the life line in the state and provides income and employment to large scale of people. Most of the industries in the state are based on forest products such as Timber, Veneer and Plywood. Apart from forests-based industries there are industries in tea, cement, petrochemical areas.

Development is a multi-dimensional phenomenon. Some of its major dimensions include - the level of economic growth, level of education, level of health services, degree of modernization, status of women, level of nutrition, quality of housing, distribution of goods and services, and access to transportation and communication. In Arunachal Pradesh, the progress of socio-economic development among tribal population is not uniform. Development has both positive and negative implications on society and people.

The state's economy is largely agrarian, based on the terraced farming of rice and the cultivation of crops such as maize, millet, wheat, pulses, sugarcane, ginger, oilseeds, cereals, potato, and pineapple. In 2018-19 total horticulture production reached 213.87 thousand metric tonnes.

Some of the other key industries of the state include art and crafts, weaving, cane and bamboo, horticulture, power and mineral based industry. Due to its topography, the state has varied agro-climatic conditions suitable for horticulture of flowers and aromatic and medicinal plants. Arunachal Pradesh is home to 601 species of orchids, or 52 per cent of the species of orchids known in India, indicating a huge potential for attracting tourists, especially foreign ones.

The state and central governments have both offered huge fiscal and policy incentives for the development of thrust sectors in the state. Some of these policies include Public Private Partnership Policy 2011, the State Industrial Policy 2008 and the Hydro Power Policy 2008. In October 2014, the According to the Department of Industrial Policy & Promotion (DIPP), FDI inflows to the Northeast states totalled to US$ 116 million from April 2000 to March 2019.

iii. **Target Beneficiaries:**

Type of Target Beneficiaries:	No. of Beneficiaries
☐ SC population	0
☐ ST population	1425
☐ Economically weaker section	1425
☐ Farmers	490
☐ Labourers	20
☐ Artisans	
☐ Women	729
☐ Youth	
☐ Children	266
☐ Disabled/senior citizens	
☐ Industrial workers	3
☐ Any other: ____________________	
Total Size of Target Group(s) indicating % of women/SC/ST of total population in project area:	51%
Present average income level at the household level:	Rs.1000/- p.m.

**All details provided the in the Appendix-1*

iv**. Baseline data sheet**: which may be assessed annually with respect to results and deliverables during implementation of the project activities is given below:

Sl.No.	Basic Data			
1.	Name of Village	Patin	Kapu	Milli
2.	District	Kurung Kumey	Kurung Kumey	Kurung Kumey
3.	Block	Sangram	Sarli	Sarli
4.	Gram Panchayat	Patin	Kapu	Milli
5.	Distance from District HQ.	65	30	45
6.	Total Land Area	4.2672Sqkm	5.4864 Sqkm	3.048Sqkm
7.	Population Census2011(Total)	112	91	121
8.	Male	58	45	56
9.	Female	54	37	65
10.	No. of Households	123(plus Cluster villages)	65(plus Cluster villages)	42(plus Cluster villages)
11.	Cluster of Villages with Main village	Rowa,Lengrik,Lengro	Waru,Chulu, Vatalin	Machane,Gane
12.	ST/ST/Other Dominated	100% ST		
13.	Average Annual Rainfall	800 mm to 1200 mm		
14.	Soil Type	loamy or sandy loam mixed with coarser		
15.	Economic Status of Households	All BPL, Depends on: Agriculture, Dairy, Fisheries, Poultry and other Meat Production, Forestry, Rural Artisan		
16.	Land-holding Pattern	Irrigated=5% Un-Irrigated=95%		
17.	Health & Nutritional Status of Women & Children	Good		
18.	Educational Dynamics	90% Illiterate		
19.	Physical Infrastructure	Govt. Buildings for CO and its staffs, Few MIBT Buildings, All are temporary structure house.		
20.	Social Infrastructure	No, like Health Sub-Centre		
21.	Economic Infrastructure	No, Electricity Sub-station(33/11 KV)		
22.	Social Dynamics	Bonded Labour, Alcoholism		

23.	Social Strengths: Availability of Civic Bodies/Civil Society	Village level committee, Panchayati Raj system, Gun Bura system
24.	Banking & Credit	No
25.	Coverage under Various Development Schemes	MGNREGA, IAY, Old Age Pension
26.	Transport	No, Only Foot March
27.	Drinking water supply	Yes, but not connected at every household
28.	Quality of drinking water	Good
29.	Electrification/Energy	No
30.	Demand for Electricity	Yes
31.	Status of use of renewable energy sources	Only using portable small solar light set in few household which are privately procured
32.	Communication connectivity	No
33.	Road Connectivity	No
34.	Main Agriculture Product	Rice, Maize, Millet, Paddy
35.	Land availability for project	Yes
36.	Source for cooking and boiling	Firewood
37.	Availability of school	Pr. School
38.	Availability of Medical	No
39.	Animal Rearing	Mithun, Pig, Goat, Cow
40.	Water Source	Polosang River, Kapu Nallah1,Kapu Nallah2
41.	Distance from China border	90Km by foot march(It takes 3(three) days to reach border by walking 4-5 hours per day

4.STATEMENT OF THE PROBLEM:

a. Having no source of light other than candle and kerosene for lightening, the using of the same sometime leads to burning of home/house and heavy expenses.

b. Lack access to clean cooking and the use of traditional biomass cookstoves is responsible for many premature deaths every year, affecting women and children, due to the emissions of carbon monoxide and particulate matter.

c. Burning of carbons through burning firewood for cooking and heating leads to depletion of ozone layer due to carbon-monoxide emissions.

d. The majority of the poor in rural areas are children and young people having no light to study during night time, so leads to low level of education.

e. No any source to run home appliances and electronic devices like TV, refrigerator etc.

5.WHO HAS THIS PROBLEM:

a. Schedule Tribe community of Arunachal Pradesh, India.

b. Out of many villages of the state, few villages of Kurung Kumey district has been choosen as a pilot project i.e. Pating village under Nyobia circle, CD Block Sangram, Kapu and Milli village under Polosang circle, CD Block Sarli of Kurung Kumey district.

6.WHY IS IT IMPORTANT TO SOLVE IT?

a. Providing Energy is crucial for eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change in these areas.
b. People of these villages lack access to electricity since independence of the country, so such gap may be filled on immediate basis.
c. Citizen stand in the last miles being deprived for many years may be given such facilities and same must be the fundamental duty of the nation.
d. It is very important to solve the problems of the poor people of these areas who are still living in dark age though the other part of the nation has reached to Digital and Space Technologies. Through intervention of Science & Technologies in different fields, such problems can be solved in batch-wise in days to come. So, this Mini-Grid project is the main source through which many difficulties can be solved by providing this sustainable source of energy to filled the needs and necessities of the villagers of the region.

7.DETAILS OF TECHNOLOGY GAPS ARE AS FOLLOWS: -

a. Include inadequate technology and lack of infrastructure necessary to support the technologies.
b. Lack of Systemic Interventions and Problem of Last Mile Delivery
c. Actual requirements are not mapped
d. Lack of connect between the implementing organisations/investigators and problems at grassroots level
e. Activities along value chain are not mapped

9.SUGGESTED SOLUTIONS ARE AS FOLLOWS: -

a. Immediate assessment like survey and mapping of the rural villages for S & T intervention through renewable energy for sustainable environment and improve livelihood.
b. Immediate equipment procurement, installation and commissioning of the households for improving the socio-economic of the society.
c. Provide hybrid energy with latest technologies and bring sustainable development in education, health, agriculture sectors and climate change.

10.METHODOLOGY:

Some of the key tools are highlighted below:

A. Primary Sources

- ✓ **Individual Interviews:** Small and Marginal framers, members of the local SHGs shall be individually interviewed to seek personal opinions. This can be done on a random sample basis. Individual interviews can also be conducted with the traders and other intermediaries who are associated with the livelihood systems of the poor tribals since long.
- ✓ **Focus Group Discussions (FGDs):** FGDs are useful in terms of extracting qualitative information and cross-checking the same to have concrete understanding of the situation. Although it consumed so much time, the outcome are always very good. Moderating and leading discussion as per the objective shall be important. It is necessary to keep the discussions focused and cautiously make the participants give the information sought. In each village at least one FGD must be conducted.
- ✓ **Observations:** The information collectors have to be careful and they shall verifying facts through their own observations as well. It can be a successful methodology, which will enable us to compare the responses of the people with physical observations in the area.
- ✓ **Key Informant Interviews:** Opinion leaders at the village level, block and district level Govt. officials and the Chief Functionaries of the NGOs can be interviewed as key informants. And awareness and training programme may be conducted for them from time to time.

B. Secondary Sources

- ✓ Collection of Relevant documents from Block Office, Horticulture Office, Administration office etc: Relevant documents, papers can be collected from the key information sources like the Horticulture Department, Block Offices, Agriculture Department, Panchayati Raj Institutions (PRIs), NGOs, etc who have been closely associated with the work and life of the poor tribals. The same were reviewed to enhance understanding of the livelihood system.
- ✓ Creation of Database of the past and current S&T intervention projects which can be collected from government departments, national and international institute for easy data mapping/spatial data for accurate and authentic application of technology intervention in the rural community for capacity building, livelihood projects and to fill the gap.

11.WORK PLAN:

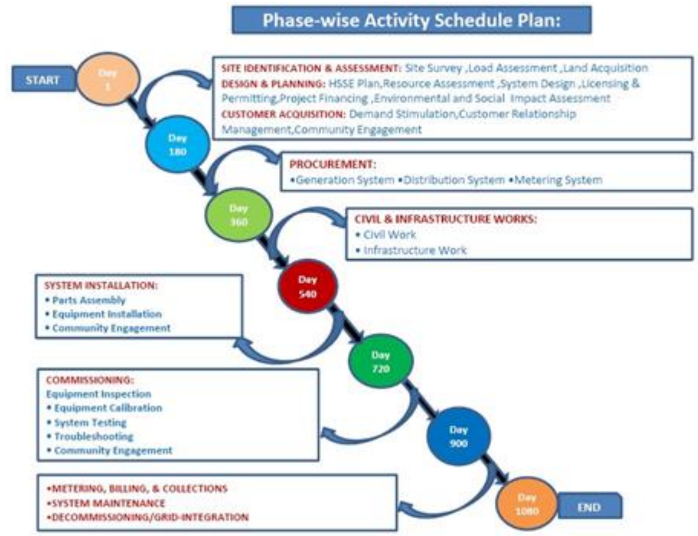
The Mini-Grid is proposed to be set up within a period of 36 months. At the initial stage, project site will be located and construction activities will be taken up. Once the construction activities are completed, procurement of equipment, staffing will start and installation of equipments will be done. Then survey & mapping and creation of database will be taken place. Finally, Installation, Demonstration, Training activities and Production activities will be taken place.

The following are the envisaged and proposed milestones:

S/N	Particulars	Time schedule of activities and milestones (In Months)					
		1-6	7-12	13-18	19-24	25-30	31-36
1.	➢ Site Survey and mapping of the project sites. ➢ Land Acquisition. ➢ Resource Assessment. ➢ Environmental and						

	Social impact assessment. ➢ Demand Simulation. ➢ Customer relationship management. ➢ Linkages with institutions and organizations within and outside the state. ➢ Staffing for the project.						
2	➢ Procurement of required instruments and equipments i.e. Generation System, Distribution System, Metering System and communication equipments for remote monitoring of the project site etc.						
3	➢ Organize and impart training to villagers, technician, Village Level Committee, SHGs and demonstrate modern technologies of Renewable Energy for skill development of the rural people						
4	➢ Construction of 35x10sqm shed. ➢ Construction of bay, channel, etcs for small hydro power.						
5	➢ Laying of pole and cable. ➢ Equipment assembly and installation.						
6	➢ Equipment inspection and calibration. ➢ System testing and troubleshooting.						
7	➢ Usage monitoring. ➢ Load management. ➢ Customer invoicing. ➢ Payment collection. ➢ Plant monitoring and system maintenance						
8	➢ Work on sustainability, promotional aspects of the Hybrid Mini-Grid. Pro-active steps for sustain-ability of the HMD with involvement of NGO's, village community and panchayat etc.						

Days-wise activity schedule is given below:



12.TECHNOLOGY COMPONENTS:

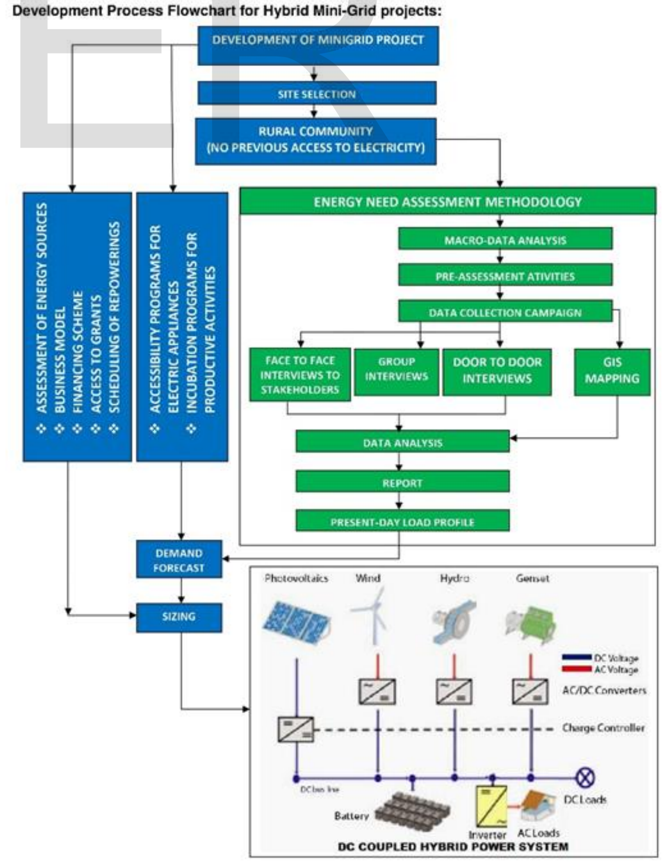
Key steps in mini-grid technical design

There are five key steps in the mini-grid technical design process:

1. Define the geographic scope of the project
2. Assess the available energy resources
3. Size the system
4. Select system configuration
5. Design distribution system

Developmental process Flowchart is shown below:

Development Process Flowchart for Hybrid Mini-Grid projects:



Successful design is an iterative process, not a linear one. In

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each technical design step, project developers must consider tradeoffs in cost, operations and maintenance (O&M) requirements, ability to provide power on demand, grid connection potential, load efficiency and load flexibility. Decisions in later steps influence choices made in earlier steps. In particular, project developers will need to revisit availability and cost of energy resources after sizing the system.

1. Define the geographic scope of the project

The first step in mini-grid design is to define the project's geographic area, including the total number of customers to be served. A mini-grid may supply power to multiple communities, a single village or a cluster of buildings. The number and type of customers (i.e., residential vs. commercial/industrial) are key factors in selecting the resource and power generation technology. Geographic features such as terrain, and ease of accessing resources, will also influence system design.

Finally, developers need to consider policies and grid extension plans that may affect the mini-grid in the future. Rural electrification plans and other potential grid expansion or power projects impact the viability of a mini-grid in a particular area.

2. Assess available energy resources

After defining the geographic scope of the project, developers need to assess local energy resources, including quantity, availability, cost, sustainability and potential conflicting uses. Mini-grids require reliable, affordable supplies of energy resources that can meet local power needs—and different resources have distinct benefits and drawbacks. For example, a mini-grid in an area with seasonally available biomass resources could provide on-demand power for an anchor commercial customer such as a mill, but not year-round electricity for a community. Similarly, in drought-prone areas, hydropower may not be a reliable year-round resource.

During the assessment process, developers need to work closely with local communities. The women and men who use local natural resources can provide valuable information about availability and potential conflicting uses.

After identifying the most promising resources, developers select the energy generation technology (or technologies). Developers can choose from among different technologies for each energy resource. The following section introduces the most common technologies for biomass, diesel, hydropower, photovoltaic (PV), wind and hybrid energy generation, including where each technology works best.

Most Prevalent Mini-Grid Generation Technologies

1. **Biomass:** Biomass power generators can use solid biomass (including wood chips from timber milling and solid crop waste from agricultural processing), liquid biofuels (such as biodiesel) or gaseous fuel (such as methane from organic liquid waste) to produce electricity. Biomass-based electricity can work well in areas with reliable sources of inexpensive biomass, where electricity is expensive, and where industry must pay to dispose of biomass.
2. **Diesel:** Diesel generators have historically powered mini-grids, particularly in remote areas. Diesel can provide power on demand, but fuel is expensive, and burning diesel produces greenhouse gas emissions. Diesel gen-sets require periodic maintenance and overhaul, but because the technology is so prevalent, many rural areas have skilled technicians who can maintain them. Integrating renewable energy into existing diesel mini-grids can improve system performance, decrease costs and reduce environmental impacts.
3. **Hydropower:** Hydropower converts the power of flowing water into electricity. Hydropower is a site-dependent energy source: The power produced is directly proportional to the amount of water and the height from which the water falls. In rural communities with adequate water resources, mini-hydro may be the least-cost option. Developers can choose from among a wide variety of turbine types and designs that maximizes performance under different conditions.
4. **PV:** PV power systems convert energy from sunlight into electricity. PV is becoming more financially viable for mini-grids. Once very expensive, the cost of PV panels has decreased by more than 80 percent from year to year, and costs are continuing to fall. PV systems, which provide intermittent power supply, often integrate well into hybrid mini-grids that can co-generate with diesel systems.
5. **Wind:** Wind power turbines generate electricity from wind energy. Wind is available on a variable basis, but the resource is dependable and easy to monitor and forecast over time. Wind conditions vary significantly by geography, so wind-based mini-grids are only good options in areas with proven wind resources. Good locations for wind-powered systems include mountain ranges and coastal areas with persistent trade winds. Wind is commonly used in hybrid mini-grids.
6. **Hybrid:** Hybrid-power generation systems use more than one source of energy. Combining technologies with different energy sources provides operational and reliability advantages compared to using a single technology. Integrating diesel power with PV, for example, combines PV's low- maintenance requirements with power on demand from diesel.

3. Size the system

A mini-grid's size dictates its maximum power output. The power generation system should have sufficient installed capacity to meet loads. To size the system, planners must calculate variations in loads in half-hour intervals and estimate future load growth. Estimating and planning for current and future loads are critical steps, especially for financial viability.

Mini-grid developers can estimate current loads by surveying and assessing current and potential customers. Anticipating future loads is more difficult. Demand for electricity grows in conjunction with demographic changes and economic expansion, which are difficult to predict. Developers and planners can use a tool like Hybrid Optimization of Multiple Energy Resources (HOMER) software to model and define a system's expected loads, network design, consumption and cost. Well-developed models give planners insight into how to best use different fuel sources and those decisions' impact on resource usage, consumption and cost.

Ideally, mini-grids should be scalable, allowing operators to add generation capacity as demand for electricity grows. A mini-grid that can meet increased demand over time is more financially sustainable. The best size for a mini-grid also depends on whether it is likely to connect to the national grid in the future.

4. Select system configuration

Mini-grids can have three basic configurations: alternating current (AC) coupled, direct current (DC) coupled or hybrid (both AC and DC). Energy generation technologies, system sizing and battery use are the primary factors in deciding which configuration to use.

Different energy generation technologies favor different configurations. Hydropower, geothermal energy, diesel power and biomass-based power generate AC, so they generally use AC configurations. Solar PV systems produce DC, and wind turbines can be configured to produce either AC or DC. System designers therefore have to decide which configuration to use. Cost, expected usage, and plans to eventually integrate into a larger (typically AC) network are factors that influence decision making.

Each configuration has tradeoffs in costs, maintenance requirements, efficiency, safety and end-use versatility. For example, it is easier to transport electricity long distances using AC systems, but AC systems are more complex and expensive. While DC systems require less equipment to condition and transform power, there are very few consumer appliances that function using DC technology. And converting from AC to the DC generates losses in energy (and therefore in money).

System Configuration Tradeoffs:

1. DC-coupled Systems

Generally, more compact with fewer pieces of equipment and controls (no inverter, for example).

- More efficient power generation due to lack of inverter losses but less efficient power distribution.
- Limited to smaller system sizes
- Fewer appliance and equipment options for end users (most available appliances are AC).
- Greatly impacted by the distance between power generation and use due to voltage losses and construction costs.

2. AC-coupled Systems

- Higher cost
- Require inverters, which need more space and system controls
- More complicated to control and operate
- More appliance and equipment options for end users

3. Hybrid AC/DC-coupled Configurations

- Increased system complexity
- Advantages of both AC and DC systems

DC configurations are typically used for shorter distances, lower voltages and systems generating less power (W rather than kW). AC configurations, which transmit power more efficiently, are more commonly used for longer distances, higher distribution voltages and systems generating more power (MW). Small grids of only a few kilowatts, however, can also use AC.

In addition to choosing a current type, developers must choose between a single-phase or three-phase system. Single-phase systems cannot serve as many load types as three-phase systems. Single-phase systems normally serve lighting and resistive loads. Three-phase systems can handle more diverse loads, including large motors. To connect to the national grid, mini-grid systems generally need three-phase systems.

In terms of cost, single-phase systems require less expensive inverters and have simpler wiring, but they require more expensive transmission cables. Three-phase systems, on the other hand, require more expensive inverters and switches.

5. Design distribution system

To design the distribution system, developers first need to design the system layout and select system attributes. The next step is to model system performance based on the preliminary layout and system attributes. Once developers have defined the model for the distribution system, they can evaluate different conductor sizes based on the load allocated across the distribution system. Once project developers have completed the base case model, they can model variations in line routing, single- versus three-phase service and loads.

When planners have finalized system layout and attributes, design crews determine the structural (as opposed to electrical) design features of the distribution system. The design crews produce a list of materials based on benchmarks for the type and number of pole-top structures required for the line length and then determine the total length of the distribution line. Crews perform a final survey of the distribution system alignments to determine pole locations, structures and other requirements.

Mini-grid distribution systems are often more complex than those of standard grids. Unlike standard grids, mini-grids may have bidirectional power flows and multiple energy sources. This operational complexity requires extra controls and software. In hybrid systems, each power source requires separate controllers, and the mini-grid must have an overall management control to integrate the different power sources.

Developers should consider the end-user system, including meters, while designing the distribution system. Tariff collection and the business aspects of the mini-grid project are the primary factors in selecting metering technologies. Developers can select the payment system during one of several parts of the design process. Depending on the required controls, some developers may design metering and payment systems prior to the technical systems. The end-user system should accommodate loads and tariffs while respecting the local cultural context and user preferences.

Distribution System Design Impacts on Efficiency and Cost:

1. **Voltage:** The higher the voltage, the greater the distance energy can be transmitted. Accordingly, power is run through transformers to increase voltage in preparation for long-distance transmission. At the destination, it must pass through another transformer to drop the voltage back down. The higher the voltage, the more dangerous it is.

2. **AC vs. DC:** AC can run at higher voltages more easily, reducing distribution losses for longer runs, but converting between DC and AC also results in losses. In general, shorter distribution lines favor DC, and longer runs favor AC on the scale of mini-grids.
3. **Single-phase vs. Three-phase Distribution:** Three-phase AC power distribution is more efficient and requires smaller conductors compared to single-phase distribution. Because three-phase AC power provides constant power transfer, longer distribution lines tend to use three-phase. Single-phase AC power is commonly used at the household level, where loads are typically lighting. Three-phase distribution is better for industrial enterprises using larger motors. Single-phase distribution uses less wire and costs less but cannot run large electric motors.

13.TECHNOLOGY SELECTION:

A. Energy Generation Technologies:

Mini-grid energy generation technologies can include diesel generators, hydropower systems, solar photovoltaic (PV) modules, wind turbines, biomass-powered generators and geothermal-powered generators. A mini-grid may use a single energy source or mix of sources (hybrid) that are either renewable or nonrenewable.

1. **Inverters**

   Mini-grid production systems use power inverters when end users need a different type of electrical current than what the energy production technology generates. Some energy generation technologies produce direct current (DC) while others produce alternating current (AC). Solar power, for example, generates DC, whereas nearly all mainstream appliances require AC. So a solar-powered mini-grid serving households would need an inverter as part of its production system. Battery charging, on the other hand, requires DC power. An inverter would convert electrical current from AC to DC if the current were coming from a grid-tied (utility) system or from a diesel generator.

   In an AC-coupled configuration with storage (a battery), the energy generation and storage systems each have their own inverter. These separate inverters connect to one another on the AC side of the system. Operators can use the battery inverter to control charging and discharging.

   In a DC-coupled PV configuration, the energy generation and energy storage systems share an inverter. DC coupling can provide better performance; battery charging is more efficient when there are fewer power conversion steps.

2. **Management System**

   Mini-grid production systems include management systems, which measure, monitor and control electrical loads. A charge controller, for example, connects between the solar panel and the battery or inverter/charger to prevent over-charging of the battery. Likewise, metering and monitoring equipment allow mini-grid managers to gather data about energy use across end users, which informs operational decisions. Management systems often couple computerized energy management tools with smart metering to optimize performance. Some management systems allow operators to control the system remotely, including shedding loads as needed.

3. **Storage**

   Some mini-grid production systems require energy storage (such as batteries). Solar and wind resources, for example, are non-dispatchable. This means they only produce power when the renewable resource is available, not according to user demand. If end users require power on demand, the mini-grid must be able to store energy and supply it when resources are not available. Energy storage adds stability to the system by storing energy for peak consumption. Large mini-grid systems that run diesel generators continuously do not require batteries, but nearly all other mini-grid systems require some type of energy storage.

   To optimize system performance, longevity and cost, project developers need to identify the most appropriate energy storage technology for their mini-grid. Lead-acid batteries are the most common, but fuel cells and advanced battery technologies—like lithium-ion, nickel metal hydride and sodium-ion batteries—are generally more efficient and last longer. Costs for these new technologies continue to decrease.

   Large battery banks pose safety hazards. High concentrations of hydrogen gas can cause explosions, and leaks can cause electrolyte spills. Installers should locate batteries in well-ventilated locations such as utility rooms or outbuildings.

   Purchasing and operating a battery can sometimes cost more than operating a diesel generator continuously, especially when operators are unlikely to maintain and use the battery correctly.

4. **Distribution System**

   The electricity distribution system moves power from the energy production system to end users. The distribution system consists of distribution and/or transmission lines, transformers and the infrastructure to support the lines, such as poles. Lines can be overhead or underground; overhead transmission is most common because it is far cheaper to build.

   The distribution system can use a variety of voltages, either AC or DC and either single- or three-phase power. Transformers change the AC voltage levels in a mini-grid network covering a large area. Step-up transformers increase the AC output voltage to transmit electricity more efficiently over a distance. Step-down transformers decrease the voltage from high- or medium-voltage transmission lines to 120 V or 220 V for residential use.

Transformers in AC mini-grids decrease distribution network costs and system losses. Distributing electricity at medium voltage allows systems to use smaller conductors, reducing cable costs. Higher voltage poses greater safety risks for operators and users, however, so operators need special training.

Different components have different efficiencies, so the choice of voltage, current and transformers impacts energy losses. Cost usually dictates which option project developers choose. DC is generally less expensive than AC, because AC requires power conditioning equipment. Developers should also consider the availability of appliances for different currents. Today the overwhelming majority of consumer appliances require AC; DC appliances are considered "niche" or specialty. In addition, the provision of "future proofing" of the network virtually always defaults to an AC-based system due to its ability to be expanded and grown as consumer demand matures and grows. Ideally the mini-grid will eventually be connected to the national grid, with minimal system or component replacements, but this would not be possible in a DC-based network.

5. **End-user System**

End-user systems provide an interface for end users to access, use and monitor electricity from the mini-grid. End-user systems should take into account consumers' needs and energy uses. Businesses that are operating machinery for productive uses, for example, need different systems than households that use electricity for lighting and small appliances. The end-user system consists of connections to and from the mini-grid, systems to prevent electrical shocks and harm to both equipment and users and power consumption metering.

End-user systems provide information to end users, or consumers, that allow them to monitor their energy consumption, estimate the cost of their consumption and understand the current status of the system. They also provide useful data back to the system operator, reporting on consumption rate and timing, like when and how much energy is used. These data provide valuable feedback to system operators, which enables them to estimate and predict demand and consumption patterns. The data also allows regulators to establish tariffs that balance the needs of the operator and the consumer, while ensuring differing use cases are priced fairly and competitively. Finally, the end-user system provides important electrical bond and grounding mechanisms to ensure the safety of its users and protect valuable and expensive equipment.

Mini-grid enterprises rely on frequent, small payments from their customers, making metering, billing and collection time consuming. Innovative metering and payment systems automate these otherwise complex tasks. Individual meters (one per end user) provide the greatest degree of control over energy use. Meters can be pre- or post-paid; pre-paid meters typically are called pay-as-you-go (PAYG) metering.

Newer generation meters are typically considered "smart meters." Although older, traditional meters are still in use, both have advantages and disadvantages.

B.Technologies used in Electrical Energy Generation:

Major technologies used in electrical energy generation are as follows:-

1. **Synchronous Generators**

Most large electricity generating plants have a prime mover that drives a rotating generator. The prime mover may be a hydraulic turbine, a diesel engine, a steam turbine, or any other system that produces mechanical energy through a rotating shaft. This rotating shaft is made to drive a generator that converts energy from mechanical to electrical form. The generator is usually a synchronous machine, rotating at constant speed to deliver an alternative current and voltage at a given standard frequency.

2. **Induction Generators**

In recent years, the use of asynchronous or induction generators for production of energy from rotating machines has developed considerably, especially for relatively small installations such as mini hydroelectric plants or wind power generators. These systems present different characteristics from the synchronous generators as will be explained in the next section on frequency and voltage control. Such generators are considered more rugged, more reliable and cheaper than the equivalent synchronous machines.

3. **Rotating DC Generators**

In a few cases, mostly for very low power in the range of a few dozen or hundred Watts, DC generators are used. This is mostly the case for systems built by hobbyist to take energy through a small hydro or wind turbine. As these are not common we shall not be concerned with such systems.

4. **Photovoltaic generators**

The direct conversion of solar energy into electricity is done through solar panels in what is referred to as photovoltaic (PV) generators. The output of such panels is in the form of a direct current (DC). The actual voltage and current delivered by such panels depends not only on the surface of the panel, its orientation and the incident solar radiation, but also on the load connected to the system.

B. Technologies used in Energy Storage

Many of the traditional technologies for electricity generation (hydro, thermal, nuclear, etc.) are "dispatchable", which means that they can, to some extent , deliver electricity when required. On the other hand, some of the renewable energy sources, such of solar and wind power, are "nondispatchable", as that they depend on the availability of the resource at a specified time (sun, wind). To take care of this characteristic it is often required, mostly for independent mini-grid, to store the energy produced in order to ensure its availability when required. Towards this a number of technologies have been developed for storage and briefly described below:

1. Storage in batteries

Batteries are certainly the most common technology for energy storage. They come in many different forms and capacities, with various chemistry backgrounds. They are often the simplest to integrate in a min-grid. Batteries store energy in DC form. They usually need an electronic interface to control their charge and discharge cycles. They also need more sophisticated electronic controls (rectifiers / inverters) if they have to be integrated in an AC mini-grid.

2. Storage in super-capacitors

Some recent developments in capacitor technologies have led to the development of super-capacitors which can now play a role of energy storage components for mini-grids. As for the storage in batteries, super-capacitors are DC elements and they need electronic control for their charge and discharge and rectifiers / inverters if integrated in an AC mini-grid.

3. Storage as kinetic energy

Some systems store energy in the form of kinetic energy by having a large flywheel accelerating during storage and decelerating while returning energy to the mini-grid. To be efficient the flywheels arrangement must minimize friction and therefore are often designed with magnetic suspension and vacuum. The wheel may be activated through an induction machine that act as a motor during storage and as a generator when returning energy to the mini-grid.

4. Storage as potential energy

Another technology used for energy storage consists in pumping water from a low level to a storage basin at a higher elevation. That water can be used later to generate electricity through a turbine-generator group. This technology implies significant investments and is mostly envisaged for large systems. It may become important with the development of very large wind and PV "farms".

14.LOAD DEMANDS:

The demand load is the sum of the operational load (including any tactical load) and nonoperational demand loads. It is determined by applying the proper demand factor to each of the connected loads and a diversity factor to the sum total.

It is the ratio of total energy (KWh) used in the billing period divided by the possible total energy used within the period, if used at the peak demand (KW) during the entire period. Demand Load Factor is usefull in qualifing the benefits of demand control and battery energy storage strategies

Load demands of three different project site i.e. Patin, Kapu and Milli village are shown below:

Design, supply, installation, testing and commissioning of 2075 KW AC (690kW DC) Hybrid Mini-Grid(Solar Power Generation Plants (SPGP),Wind Power Generation Plant and Hydro Power Generation Plant) in Patin,Kapu and Milli village under Kurung Kumey district of Arunachal Pradesh as shown in Table-1.

Tabel-1

Power Plant Type	Mini-Grid	State	District	Site/ Location	SPGP/Other Plant AC Capacity (kW)	SPGP PV/Other Capacity (DC) kWp	BESS (kWh)	DG (KW)
(A) SOLAR	No.1	Arunachal Pradesh	Kurung Kumey	Patin	100	120	1000	20
	No.2	Arunachal Pradesh	Kurung Kumey	Kapu	100	120	1000	20
	No.3	Arunachal Pradesh	Kurung Kumey	Milli	75	90	800	15
				Total	**275**	**330**		
(B) WIND	No.1	Arunachal Pradesh	Kurung Kumey	Patin	100	120	1000	
	No.2	Arunachal Pradesh	Kurung Kumey	Kapu	100	120	1000	
	No.3	Arunachal Pradesh	Kurung Kumey	Milli	100	120	800	
				Total	**300**	**360**		
(C) HYDRO	No.1	Arunachal Pradesh	Kurung Kumey	Patin	500			
	No.2	Arunachal Pradesh	Kurung Kumey	Kapu	500			
	No.3	Arunachal Pradesh	Kurung Kumey	Milli	500			
				Total	**1500**			
(A+B+C) TOTAL					**2075**	**690**		

Design, supply, installation, testing and commissioning of Power Distribution Network (PDN) of 230V, 415V, 11kV as detailed given in Table -2.

Table -2

Power Plant Type	Mini-Grid	Site/ Location	SPGP/Other Plant AC Capacity (kW))	Estimate Power Distribution Netwoek(PDN)			Estimated Consumers	
				11KV, 3φ,Line (Km)	415V, 3φ,LV (Km)	230V, 1φ,LV (Km)	415V, 3φ (Nos.)	230V, 1φ (Nos.)
(A) SOLAR	No.1	Patin	100	NIL	3.0	4.09	83	332
	No.2	Kapu	100	NIL	3.0	4.09	83	332
	No.3	Milli	75	NIL	2.0	2.305	45	180
		Total	**275**					
(B) WIND	No.1	Patin	100	NIL	3.0	4.09	83	332
	No.2	Kapu	100	NIL	3.0	4.09	83	332
	No.3	Milli	100	NIL	2.0	2.305	45	180
		Total	**300**					
(C) HYDRO	No.1	Patin	500	5.5 km	10	22.2	350	1395
	No.2	Kapu	500	5.5 km	10	22.2	350	1395
	No.3	Milli	500	5.5 km	10	22.2	350	1395
		Total	**1500**					
			2075					

Power Requirement Calculation:

Total Capacity of the Hybrid Mini-Grid= 2075kW

2075kW is Converted to: =2594KVA
=2782HP
=6505KVA GENSET SIZE

Ampere for (3 φ ,415V) =2890
for (3 φ ,230V) =5215
for (1 φ ,415V) =5000
for (1 φ ,230V) =9025

Estimated Demand & Harmonization of SPGP, WPGP, SHPGP & PDN: Mini Grid No-1 & No-2 at Patin and Kapu Village

Load Demand	

Estimated Design demand in 5 Year	440 kWh/day
Estimated Maximum peak demand	60.0 kW
6 PM evening to 7 AM load demand factor	70%
PV Solar Power Plant Generator Plant	
AC Capacity	100 kW
PV modules capacity	120Wp (120% of AC capacity)
Types of modules	Mono/Poly Crystalline
PV mounting	Ground Mounted
Solar Inverters	100 kW AC (4X25 kW string inverters or as per design of bidder), 415 V , 3 Phase
Wave type	Sinusoidal
Battery Energy Storage System	
Battery type	Lithium-ion
Autonomy	2 Days
BESS Output Voltage	3 phase 415 V(KPLC Norms) as per approved design
Battery depth of discharge	Minimum 80%
BESS Battery Capacity	1000-kWh
Battery Inverter cum Charger (Dual type)	75kW
Battery Inverter set mode	Multi-mode (DC to AC and AC to DC)
BESS Wave type	Sinusoidal
Diesel Generator (at the cost of Bidder)	
Diesel Generator capacity	20 kW (20 % of AC size of Plant), 415 Volts, 3 Phase
Power Evacuation System from SPGP	
SPGP Out Put (Solar plant +BESS+DG)	3 Phase, 415 V as per Norms
Power Distribution Network (KPLC Norms)	
Distribution System	Low Voltage, 3-phases and Single phase
LV distribution line (KPLC Norms) total length	415V, 3 phase, 3.0 km
	230V, 1 phase, 4.09 km
Number of Cement/ECO poles	As per norms
Expected Number of consumers in 5 year	415

Mini Grid No-3 at Milli Village

Load Demand	
Estimated Design demand in 5 Year	315 kWh/day
Estimated Maximum peak demand	35.0 kW
6 PM evening to 7 AM load demand factor	62%
PV Solar Power Plant Generator Plant	
AC Capacity	75 kW
PV modules capacity	90Wp (120% of AC capacity)
Types of modules	Mono/Poly Crystalline
PV mounting	Ground Mounted
Solar Inverters	75 kW AC (3X25 kW string inverters or as per design of bidder), 415 V , 3 Phase
Wave type	Sinusoidal
Battery Energy Storage System	
Battery type	Lithium-ion
Autonomy	2 Days
BESS Output Voltage	3 phase 415 V(KPLC Norms) as per approved design
Battery depth of discharge	Minimum 80%
BESS Battery Capacity	800-kWh
Battery Inverter cum Charger (Dual type)	50kW
Battery Inverter set mode	Multi-mode (DC to AC and AC to DC)
BESS Wave type	Sinusoidal
Diesel Generator (at the cost of Bidder)	
Diesel Generator capacity	15 kW (20 % of AC size of Plant), 415 Volts, 3 Phase
Power Evacuation System from SPGP	
SPGP Out Put (Solar plant +BESS+DG)	3 Phase, 415 V as per Norms
Power Distribution Network (KPLC Norms)	
Distribution System	Low Voltage, 3-phases and Single phase
LV distribution line (KPLC Norms) total length	415V, 3 phase, 3.0 km
	230V, 1 phase, 4.09 km
Number of Cement/ECO poles	As per norms
Expected Number of consumers	225

15.MECHANISMS FOR BENEFICIARIES MOBILIZATION & INVOLVEMENT:

- Formation of new SHGs/technology user group or beneficiaries' group for project implementation
- Involvement of existing SHGs
- Through demonstration of usefulness of technology or training package
- Involvement of beneficiaries through formation of enterprises
- Provision of certificates for participation/proficiency for beneficiaries
- Involvement of the beneficiaries as trainees
- Financial contribution by beneficiaries in project execution
- Material contribution (tools/raw material, labour, etc.) by beneficiaries in project execution
- Handholding through local panchayats/welfare organizations.

16.ENVIRONMENTAL, LEGAL AND ETHICAL ISSUES:

Clearance certificate may be taken from Deputy Commissioner, Community Block Development Officer of Sangram and Sarli circles under Kurung Kumey district, Arunachal Pradesh.

17.DELIVERABLES:

Deliverable	Brief description
Technology package for development of the project area and local community	1.Number of new electricity connections – target 230 households, institutions and businesses.

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	2.Number of people with electricity access – target 1425 people 3.Reduced GHG emissions and increased access to rural electrification.
Technology capability development, training & documentation	1.Capacity Building training to all villagers for effective use of the energy and security measures. 2.Training, Demo and workshop for the technical staffs.
Product development/adaptation	Adaptation of the Renewal Energy technologies will bring sustainable development.
Process development/adaptation	It will be benefited to the target group from installation of equipments to till metering process.
Technology package for development of the project area	1.Improvement in the socio economic conditions of people at localized level and through need based approach. 2.Systemic and effective manner for sustainable development of st communities through collective cooperation between different stakeholders which includes government functionaries, industry, academia and the society at large. 3.Promote research, development & adaptation of s & t for improving quality of life of scheduled tribal groups in the rural areas.
Other (Please specify)	1.It will reduce isolation ✓ It will improve health care and quality of life ✓ It will help farmers be more productive ✓ It will improve safety in the community ✓ It will give them light.ne Generator for Power

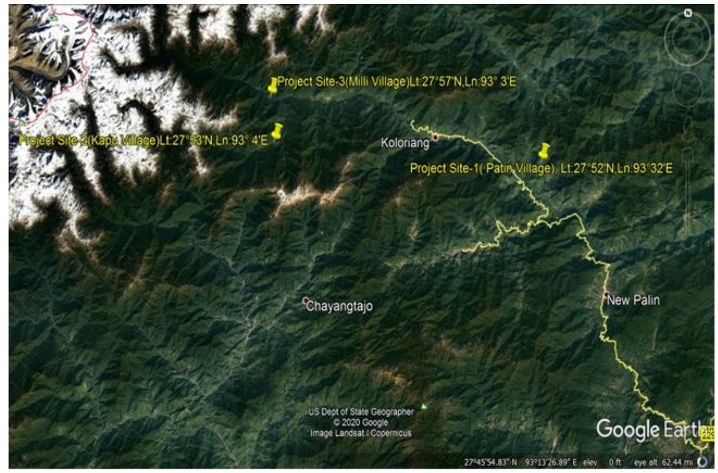
18.ESTIMATED BENEFITS:

Benefit	**Brief description**
Economic (Cost-benefit analysis)	❖ The economic analysis of a project is a very important part of the CBA because it measures whether society as a whole benefits from the project. It does so by adjusting the financial analysis of a project's activities by correcting the economic distortions that exist in the economy. The economic analysis establishes economic prices (the prices that would exist if there were no distortions) for each of the inputs used in the course of the project's activities, as well as the outputs produced by the project. Using these economic prices shows the total benefit (or resource inflows) of what the project produces and the total costs (resource outflows) of what the project used up. It shows the net benefit (or cost) of the project to society as a whole. ❖ Cost-benefit analysis involves assessing the projected costs and benefits of an intervention from several perspectives. Each perspective provides a look at the incentives for one group of stakeholders in a project—the primary recipients, the primary implementer of an investment, the government, financial institutions, and/or the whole economy. In the financial analysis, we look at the intervention from the perspective of key stakeholders in the economy, using actual market prices to reflect the value of costs and benefits as they are actually experienced by the stakeholder. In addition to measuring the incremental net cash flow for each stakeholder, the financial analysis considers the financial sustainability of the investment. ❖ A standardised cost framework is proposed to increase the consistency, clarity and completeness of cost figures presented for RE mini-grid implementation. ❖ The framework would include a standardised set of cost heads

	against which all costs should be accounted, and a set of qualifying information which address key variables identified that affect costs.
Employment generation	❖ Renewable energy-based mini and micro grids offer the benefits of boosting rural local economy and enterprise development, thereby generating employment. ❖ Mini-grid also permits the use of generation technologies that give employment to local people in installing and maintaining the technologies.
Social	❖ Social benefits of sustainable design include knowledge transfer, improved environmental quality, neighborhood restoration, and reduced health risks from pollutants associated with building energy use. ❖ Mini-grids also enable community uses of energy, providing for instance energy for schools, which can improve the quality of education, or for health clinics, which can reduce mortality rates and help maintain cool chains for vaccines.
Environmental including potential for CDM benefits	❖ CDM benefits the designed project to meet a dual objective: to help developed countries fulfill their commitments to reduce emissions and to assist developing countries in achieving sustainable development. ❖ The economic cost of carbon is much higher than existing carbon market prices, as the price of carbon should ideally equal the social cost.

19.POSSIBILITY OF REPLICATION OF PROJECT IN SIMILAR AREAS:
After successful implementation of the project, it may be used as model for further implementation in the remote areas of the state. The technology may be transferred to the state government. And local entrepreneur may be encouraged to replicate the same in other interior villages by preparing business model.

20.VIEW OF PROJECT STATE:
Latitude & Longitude View of Hybrid Mini-Grid No-1, No2 and No-3:



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CONCLUSION:
Baseline data has been collected, assessment for implementation of Hybrid Mini-Grid in three Un-electrified villages i.e. Patin,Kapu and Milli villges has been done successfully.

Er. Bamang Apo, Scientist-D,
Arunachal Pradesh State Council for Science & Technology
(Department of Science & Technology), Govt. of Arunachal Pradesh,
India-791113. Email: bamang.apo@nic.in/Ph-9436068867.