Solar PV Microgrids Implementation model: A case study of Local Self Governments in the Indian State of Kerala

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Solar PV Microgrids Implementation model: A case study of Local Self Governments in the Indian State of Kerala

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Abstract. The State of Kerala in Southern part of India has significant potential for generation of power from renewable energy sources, especially solar energy. Most of the PV projects in the State are being implemented on roof-tops due to the unavailability of land area in the densely populated State for large utility scale PV power plants. The concept of implementing Solar PV projects by empowering Local Self Governments has been explained in this paper by illustrating the case study of the Indian State of Kerala. The respective Local Self Governments like Municipal Corporations are playing a key role in Kerala in this decision-making process to accomplish model carbon free solar communities by installing Solar Photovoltaic Projects. The requirement of local beneficiary will be analysed by local trained experts and feasibility study will be conducted for the beneficiary communities involving residential buildings, local industries and commercial institutions and educational institutions and the PV projects will be implemented utilising the local E.P.C players. Local Self Governments like Municipal Corporations were empowered to plan, formulate and implement their own Solar Photovoltaic Projects. This approach is being implemented in Kerala resulting in solar electrification of local communities/institutions through the decentralised approach. This created a new business model at the local level involving trained manpower and supply chain for meeting the Local Self Government targets for new PV projects in order to achieve the targets of carbon free communities.

1.Introduction

Kerala is a southern State in India mostly known as “God’s Own Country” due to its scenic beauty. The State is also known for its specific model of development with incredible performance in health and education sectors even comparable with developed nations. After the 73rd and 74th amendments to the Constitution of India, the Local Self Government Institutions were strengthened in the State to implement projects in a decentralized fashion. These institutions include Municipal Corporations, District Panchayats, Block Panchayats and Grama Panchayats. All Local Self Governments are formulating their projects in all sectors based on the needs and requirement raised by the people’s representatives. Recently renewable energy projects, especially PV projects take a major share in energy projects of Local Self Governments in Kerala because of the following main reasons:

1. All Local Self Governments are working for a self-sustainable model of generating power of their own.
2. Net metering policy is in place in the State which enables the utility to accept the generated power.
3. It makes sense for generating solar power since it has reached grid parity.

All Local Self Governments in Kerala are empowered to generate, transmit and distribute energy according to the above Constitution amendment. This paper describes the new strategy of implementing solar photovoltaic projects with local participation through Local Self Governments based on the experiences in Indian State of Kerala. Most of the projects are being implemented on shade-free roof-tops due to the unavailability of land area in the densely populated State for large utility scale PV power Plants.

2. Power Sector in Kerala

The State has been buying and importing power from outside the State to meet the increasing demand. More than 70% of power is being imported from the Central Grid. Electricity generation in Kerala is mostly from hydroelectric power stations (73.41%) as demonstrate [1]. The board has also set up several hydel power stations within the state. Because of deforestation and environmental concerns, further large hydroelectric projects could not be implemented. The State of Kerala has a total installed capacity of 2980.086MW, out of which 2089.31MW is from hydroelectric power plants, 710.67MW from thermal power plants, 110.831MW from solar PV power plants (both utility and roof-top), 59.275MW from wind and 10MW from co-generation. Pazheri et al. described the status of electricity generation in Kerala [2]. Electricity generation in Kerala from various resources is illustrated (Figure 1)

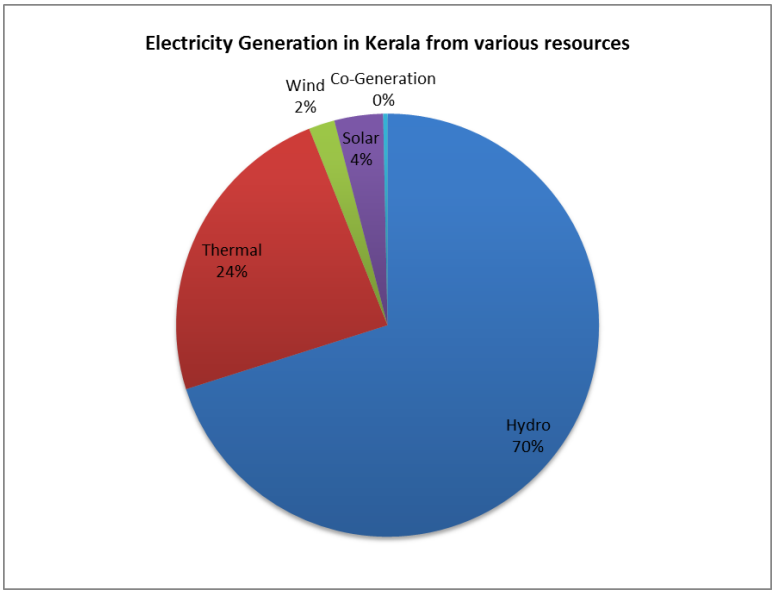

Figure 1: Electricity Generation in Kerala from various sources (Source – www.kseb.in)

Since only 30% of the power is being met from the internal generation, it is natural for the State to tap the abundant renewable energy sources to the maximum to meet it energy demands. There is a huge scope for avoiding various pollutants by utilising the significant potential of natural resources in Kerala, as described by Pazheri & Baby [2].

3. Solar Resources in Kerala

Kerala has significant potential for generation of power from renewable energy sources, especially solar energy. Except for June and July, the remaining months have significant number of clear sunny days. Interestingly, radiation analysis utilizing software (Meteonorm) also supports the view of local experts. Kerala is blessed with Solar Energy with 5 to 6 kWh/m^2 Solar Radiation per Day. Solar Radiation analysis utilizing software (Meteonorm) gives good results in the State of Kerala, which is a positive indication for achieving the energy security in the State using solar resources. The values of Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) for each district of Kerala are reproduced below (Table 1)

Table. 1: Solar Radiation (DNI & GHI) in different Districts in the State (Source: The Energy Report Kerala, WWF India & WISE 2013)

Sl. No.	District	DNI (kWh/m^2/Day)	GHI (kWh/m^2/Day)
1	Alappuzha	4.29	5.52
2	Kannur	4.47	5.43
3	Ernakulum	4.36	5.44
4	Idukki	4.52	5.44
5	Kasargod	4.77	5.54
6	Kollam	4.27	5.50
7	Kottayam	4.22	5.45
8	Kozhikode	4.50	5.47
9	Malappuram	4.70	5.49
10	Palakkad	4.55	5.51
11	Pathanamthitta	4.52	5.62
12	Thrissur	4.60	5.53
13	Thiruvananthapuram	4.34	5.52
14	Wayanad	4.68	5.33
	Average	4.49	5.49

The Global Horizontal Irradiation (GHI) daily average value in the state is 5.49 kWh/m_2/day, or an annual value of 2,003 kWh/m2/year based on Meteonorm Data. As a general principle, any site with GHI more than 1,500 kWh/m2/year is suitable for solar PV technology. The State of Kerala is getting an average of 300 sunny days a year. Thus, a simple resource-based assessment indicates that Kerala is highly suitable for developing solar PV systems. The above fact is also evident from the Solar Resource Map of India prepared by NREL (Figure 2). Kerala gets an annual average solar insolation of 5.59 KWh/m^2 /day which indicates very good solar potential in the State. The districts wise average annual insolation is discussed by Ramachandra [3].

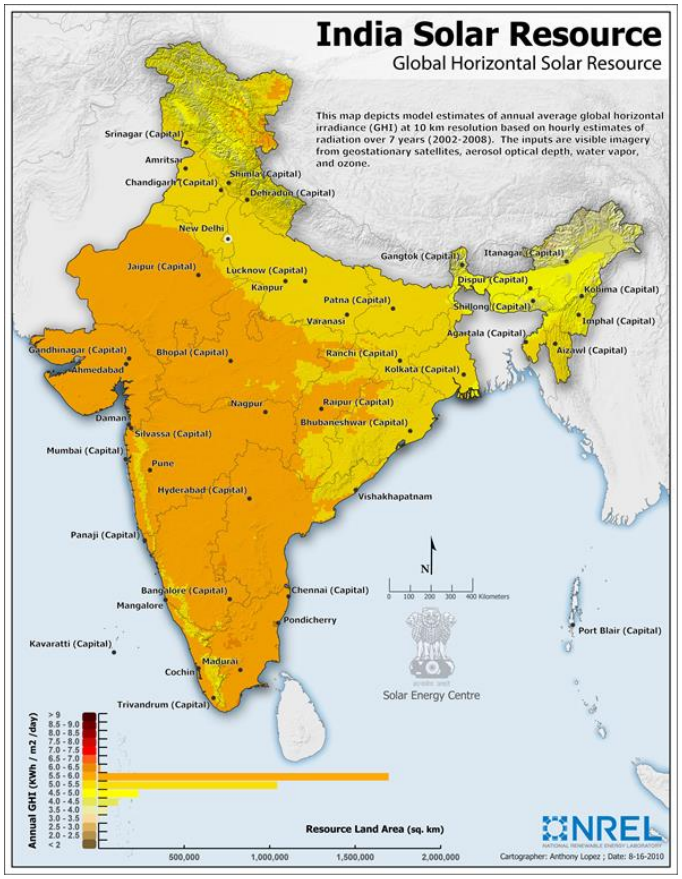

Figure 2: Solar Resource Map (Source – NREL)

4. Traditional Practices of PV Project Implementation

PV Projects were traditionally implemented based on the requirement from the community/ beneficiaries and the implementation was managed by ANERT, the State Nodal Agency of Renewable Energy under the Department of Power, through tender practices. There are various risks related with solar projects comes under the categories of political, financial, social and technical risks [3].

4.1 Role of ANERT

Agency for Non-Conventional Energy and Rural Technology (ANERT), is the autonomous body constituted under the Department of Power, Govt. of Kerala for the development and promotion of utilization of the renewable energy sources in the State. ANERT is also the State level Nodal Agency (SNA) of Central Ministry of New and Renewable Energy (MNRE). ANERT had been established in 1986 by the Government of Kerala, as an autonomous institution under the Science, Technology and Environment Committee (STEC) with the objectives of gathering and disseminating useful knowledge in various fields of Non–Conventional Energy, Energy Conservation and Rural Technology. ANERT, is currently under the Administrative Control of the Power Department of the Govt. of Kerala, implementing Renewable Energy Projects in the State (Figure 3).

Figure 3: A typical Remote Village Electrification Project

ANERT has implemented many successful solar projects in the last decades. The projects include Remote Village Electrification Programme (RVEP), 10000 solar roof-top programmes, etc. ANERT has successfully implemented programmes of the Central Ministry (MNRE – Ministry of New and Renewable Energy) like the dissemination of Solar Lanterns, Solar Home Systems and Solar Street Lighting Systems, etc. ANERT has recently come up with a Grid Connected Solar Programme for residential buildings in the State called "Solar Connect" with both Central and State financial assistance. The off-grid solar programme for the residential buildings in the State is called, "Solar Smart". ANERT has become the first solar Independent Power Producer (IPP) in the State by installing a 2MW Utility scale PV plant at Kuzhalmannam, Palakkad District in Kerala (Figure 4)

Figure 4: ANERT 2MW Kuzhalmannam PV power plant

ANERT is also positioned as a Technical Consultant in the State for helping the beneficiaries including various Govt and private institutions to install Solar PV Power Plants in their premises through its Deposit Work Scheme and Technical Consultancy Scheme. ANERT has already installed Grid Connected and Off-Grid PV Power Plants with a total capacity of more than 1MW under these schemes. 100kW Grid Connected PV Power Plant installed at the Kariavattom Campus of the Kerala University (Figure 5) and 45kW Off-Grid PV Power Plant installed at Cherthala Taluk Hospital are some examples

[4].

Figure 5: 100kWp Solar PV power plant at Kerala University Campus

4.2. Role of KSEB Ltd. and CIAL

Kerala State Electricity Board Limited (KSEBL), the major Power Utility in the State, has also taken up PV Power Plant projects in the State. KSEB has installed a 1MW Grid Connected PV Power Plant Project at Kanjikkode, Palakkad District. The biggest Solar farm installed in Kerala so far is the 30MW Plant at Cochin Airport premises by Cochin International Airport Limited (CIAL). This is the first Airport in the world to be completely powered on solar power (Figure 6) [5], [6]

Figure 6: 30MWp Solar PV power plant at Cochin Airport

5. Proposed New Strategy of Implementation

Solar Projects in communities can be implemented in a decentralized fashion by empowering Local Self Governments in planning and formulating the projects after feasibility studies. The Local Self Governments will include Solar PV projects in their Plan Document and implements projects with the help of suitable Consultants and E.P.C Companies. The warrantee and Annual Maintenance Contracts can be also arrived with the EPC companies for making the project sustainable. The local utility will accept the generated power based on the guidelines issued by the State regulatory commission. The

State Nodal Agency of the Central Ministry, will technically assess the PV Plant in communities during installation and commissioning.

5.1. Local Self Governments as the project developers

After the 73rd and 74th amendments to the Constitution of India, the Local Self Government Institutions were strengthened in the State to implement projects in a decentralized fashion as indicated (1). These institutions include Municipal Corporations, District Panchayats, Block panchayats and Grama Panchayats. In every year, all Local Self Governments in Kerala shall formulate their Plan Document after several brain storming sessions at the local level participating local people, experts, people's representatives, Government officials, NGOs etc. Based on their deliberations, a number of energy projects including renewable energy projects shall be formulated. Local trained experts will help the Local Self Governments to plan and formulate the PV projects based on the requirements based on the basic feasibility studies at the respective sites. These project reports will be evaluated at the district level after assessing the ground realities. One of the example for the above, is that the local Panchayat (local governance bodies) and citizen political dissent blocked the development of full-scale 200 MW Kasaragod solar park, which significantly reduced the overall land available for the initiative [7].

5.2. New approach

The decision will be made at the local level in this new approach. The respective Local Self Governments will play a key role in this decision-making process to accomplish model carbon free solar communities by installing solar photovoltaic projects. The requirement of local communities and beneficiaries will be analysed by local trained experts and feasibility study will be conducted for the beneficiary communities involving residential buildings, local industries, commercial institutions and educational institutions. Majorly, two major strategies are adopted for these feasibility studies:

- Identifying the remote communities where the conventional electricity could not be extended
- Detailed mapping of residential buildings, commercial establishments, educational institutions, religious places and industries within the boundary of Local Self Governments for finding the feasibility of installing either off-grid or grid connected PV power plants.

5.3. Solar Village Electrification of Remote Colonies

Based on the feasibility studies conducted on remote colonies, survey and detailed study has been conducted in remote villages of Kerala with the help of Local Self Governments in different districts. Mahapatra et al. discussed smart village models which has to be settled and this includes the availability of grid infrastructure, the location economic distance limit, the operating hours of the renewable energy systems, the life cycle cost of the energy generation equipment, customer engagement issues as well as the micropower system business strategy [8]

The remote villages have been identified and the following strategies were adopted for the solar electrification of remote colonies:

- Solar Home Systems are proposed for the households in remote colonies which are scattered in nature.
- Centralized Stand-alone PV plants or micro grids are proposed for the colonies which are clustered in nature

Beneficiary Societies have been constituted in all the colonies selected for solar electrification. All beneficiaries in each colony is a member of this society. The concerned Local Self Government President will be the Chairman of the beneficiary society. Selected members of the society will be

trained both by the EPC contractor and ANERT for topping up the batteries, cleaning the solar modules and timely reporting of faults. These members contribute a fixed amount per month to the society which is kept in a separate Bank account by the beneficiary society. This amount will be used for maintain the PV plant. Also, the concerned Local Self Governments are also financially helping these societies for maintenance and repair of the PV plants. Two representatives from the colony were trained for the operation maintenance of the SPV system by the EPC contractor [9].

5.4. Stand-alone or Micro Grids for remote tribal settlements

Remote tribal settlements are usually located in the midst of dense forests in Kerala and hence conventional grid lines cannot be extended due to the existing forest regulations. ANERT had identified such 11 numbers of remote tribal colonies in the State with the help of Local Self Governments. Local Self Governments had allocated funds for solar electrification of these tribal settlements in their budget based on the project reports of ANERT. Solar electrification of these tribal settlements had been conducted by installing PV micro grids. A typical PV micro grid will have a solar array in an open shade free area, a control room for placing the solar inverter/inverters and batteries. The list of PV Micro Grids installed in remote tribal colonies are given in Table 2.

Table. 2: PV Micro Grids installed in remote Tribal Colonies of Kerala as part of Kerala through Local Self Governments (Source: ANERT)

Sl. No	**Name of Colony**	**Name of Grama Panchayat**	**Name of Block Panchayat**	**Name of District**	**No.of families**	**Capacity of the Micro Grid installed (kW_p)**
1	Plamalakkudy	Adimali	Adimali	IDKI	**33**	3.36
2	Chambakkad	Marayoor	Devikulam	IDKI	**68**	5.60
3	Mavalikudi(Thayanamkudi)	Marayoor	Devikulam	IDKI	**20**	2.52
4	Kozhiyilakkudy	Munnar	Devikulam	IDKI	**48**	4.20
5	Mundakkadavu	Karulayi	Nilamboor	MPM	**30**	3.08
6	Nedumkayam	Karulayi	Nilamboor	MPM	**41**	3.92
7	Moolaganga	Sholayoor	Attappadi	PKD	**36**	3.64
8	Vellakulam	Sholayoor	Attappadi	PKD	**32**	3.36
9	Vechumaram	Athirappally	Thrissur	TCR	**33**	3.36
10	AnapandamST colony	Mattathoor	Kodakara	TCR	**50**	4.48
11	Kokkathode	Aruvappulam	Konny	PTA	**45**	2.52
			TOTAL		**436**	**40.04**

5.5. Solar Power Roof-top Power Plants for Residential Buildings and Institutions

Solar Roof-top Power Plants are becoming popular in the State since the cost of PV generation has almost reached grid parity. Though residential buildings started this trend initially, industrial &

commercial establishments, hospitals and educational institutions are adapting the technology in a faster pace presumably because of their higher tariffs of conventional energy use. Local Self Governments are allocating funds for establishing Solar Power Plants ANERT has initially implemented this programme through its Deposit Work and Consultancy schemes. All these projects are implemented with the financial assistance of Local Self Governments. Local Self Governments will allocate sufficient funding for solar electrification in their Plan Documents and the projects will be implemented with the help locally trained solar installers. The Local Self Governments has a pool of trained technicians as installers. The Operations and Maintenance (O&M) of the projects will be taken up by the EPC companies during the warrantee period. Once the warrantee period is completed, new Annual Maintenance Contract (AMC) for the upkeep of the PV power plants can be taken up with EPC companies. A list of Solar Power Plants (both Grid Connected and Off-Grid) implemented with the help of Local Self Government is given below in Table 3.

Table 3: List of Roof-top PV Power Plants installed with the help of Local Self Governments in the State of Kerala (Source: ANERT)

Solar Power Plants Commissioned - Deposit Work and Consultancy Scheme

I. Deposit Work Scheme

Sl No	District	Name of LSG/Dept/PSU	Capacity (kWp)	Offgrid/Grid connected
1	Kollam	Thrikkadavoor Grama Panchayath	3	offgrid
		Kulasekharapuram Grama Panchayath	2	offgrid
2	Pathanamthitta	Kalanjoor Grama Panchayath	2	offgrid
3	Idukki	Kumily Grama Panchayath	6	offgrid
4	Thrissur	Thrikkur Grama Panchayath	3	offgrid
		Govt. Mental Health Centre	5	offgrid
		Mathilakam Block Panchayath	5	offgrid
		Pig Production & Research Centre	4	offgrid
5	Kozhikode	Perambra Taluk Hospital	2	offgrid
		Chelannur Block Panchayath	4	offgrid
		CHC Narikuni	4	offgrid
		Govt. Homeopathic medical College	5	offgrid
6	Kannur	Kannur Block Panchayath	5	offgrid
		Aralam Wild Life Dormitory	2	offgrid
		Aralam Wild Life Division Office	2	offgrid

7	Wayanad	Govt. Polytechnic Meppady	3	offgrid
8	Kasaragod	Govt. College, Kasargod	10	offgrid
9	Eranakulam	Vengola Grama Panchayat	2	offgrid
10	Thiruvananthapuram	KSIHFW	15	offgrid
		CWRDM Neyyattinkara	4	offgrid
11	Alappuzha	Cherthala Taluk Hospital	45	offgrid
12	Thrissur	Irinjalakuda Municipality	25	offgrid
13	Kozhikode	Thamarassery Grama Panchayath	3	offgrid
14	Kannur	Kadannappally-Panappuzha Grama Panchayath	6	offgrid
15	Kasaragod	Pullur-Periya Grama Panchayath	4	offgrid
16	Thiruvananthapuram	University of Kerala	100	on grid
Total			**271**	
		2. Consultancy Scheme		
1	Kottayam	Assumption college, Changanassery	3	Offgrid
2	Thiruvananthapuram	Attingal Municipality	3	offgrid
3	Palakkad	Kozhinjanpara Grama Panchayath	4	Offgrid
4	Thrissur	Thrissur Corporation	200	ongrid
5	Thiruvananthapuram	Perumkadavila Block Panchayat-Anappara Community Health Centre	25	offgrid
6	Thiruvananthapuram	Technopark-Ganga&Yammuna Building	200	ongrid
7	Thrissur	Kerala Forest Research Institute (KFRI), Peechi	2	ongrid
Total			**437**	

6. Outcome of the Project in Kerala

This approach worked well in Kerala resulting in electrification of local communities / institutions through the decentralised approach. Local Self Governments like Municipal Corporations, District panchayats, Block panchayats and Grama Panchayats were empowered to formulate their own Solar Photovoltaic Projects according to the feasibility studies conducted utilising local trained technicians. It created a new business model at the local level involving trained manpower and supply chain for meeting the Local Self Government targets for new PV projects in order to achieve the targets of carbon free communities. A typical example is the 200kWp Grid Connected Solar Roof-top Project installed by Trissur Corporation as shown in Figure 7.

Figure 7: A 200kWp Solar Power Plant installed by Thrissur Corporation, a Local Self Government Institution in the State of Kerala

7. Conclusion

Based on a recent study of WWF and World Institute of Sustainable Energy (WISE), Pune, it is estimated that Kerala State has a domestic PV roof-top potential of 13079MW and industrial and commercial PV roof-top potential of 18066MW adding a total PV roof-top potential of 31145MW. Decentralization empowers the Local Self Governments and communities to take appropriate decisions at the right time with creativity and growth. All the Local Self Government Institutions will be trained for taking up this new challenge. The implementation of Solar PV Projects by through Local Self Governments is a unique model which can be implemented worldwide to make the projects sustainable. Local Governments like Municipal Corporations can thus play a crucial role in addressing global warming and climate change.

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Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in the submitted manuscript. The opinion /findings/ discussions in the document are solely of the authors and do not necessarily reflect the opinion of any organization

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