Estimation of the potential for ground-based, roof-top and canal-based solar power plants in the State of Goa

Project undertaken by Center for Technology Alternatives for Rural Areas (CTARA), IIT Bombay

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Executive Summary

Goa, a State in southern India, is known for its natural beauty, high rates of literacy, high rates of electrification and one of the highest per capita annual consumption of electricity. However, Goa presently receives almost all its electricity from other States of India as per various Power Purchase Agreements. Hence, ensuring energy security is one of the major challenges faced by this State.

Solar PV proves to be an attractive and important source of Energy for the State since abundant sunlight is available for almost 7-8 months of the year. A national target of 100 GW of solar PV has been set out under the Jawaharlal Nehru National Solar Mission (JNNSM) by the Government of India. In tune with this, the Ministry of New and Renewable Energy (MNRE) has set forth a target of 150 MW of grid connected roof-top solar PV by 2022 for the State of Goa. For achieving this target, Goa has notified the Solar Policy for the State, which aims at promoting solar PV systems.

The present Project systematically estimated the solar PV potential in the State on Government Buildings, Canal tops and Abandoned Mine Lands. The Project used GIS techniques and softwares in the open domain to come up with an estimate of the solar PV potential, which was verified by site visits to around 10% locations.

It was found that the roof top potential on the Government Buildings geo-tagged on Google Earth was around 26 MWp, the canal-top solar PV potential was around 39.9 MWp while the abandoned mine lands would offer a solar PV potential of around 57 MWp. This makes the total solar PV potential to be around 123 MWp. These are conservative estimates owing to the methodology used, and it is predicted that the actual potential is more than that predicted in this Study.

This estimation study has conclusively proved that the State of Goa has the potential to meet the Solar PV RPO set out by the MNRE and in fact, even more solar PV potential to meet the rising power demands of the State in the years to come.

1 Introduction

1.1 Background

The State of Goa, located in southern India, is blessed with a bounty of natural resources and is a well-known tourist destination. Goa is spread over an area of 3702 km^2. The State has achieved 100% village electrification and above 90% household electrification (data of Ministry of Power, Government of India). Apart from this high level of electrification, the State also has one of the highest per capita consumption of electricity. It is expected that the peak power demand in the State shall increase from 540 MW in 2013-14 to 934 MW in FY 2018-19.

Today, the use of Renewable energy is being stressed upon to ensure sustainable development and a frugal utilization of the limited fossil fuels. In this context, the use of solar power is, both, attractive and important in the Goan context owing to the following factors:

- Availability of bright sunlight for 7-8 months of the year
- The fact that the State of Goa does not generate its own power and presently purchases power from other States
- The Renewable Purchase Obligation (RPO) set out by the MNRE for the State requires that 150 MW of grid connected roof-top solar power to be added by the year 2022.

1.2 Rationale for taking up the project

Since energy forms the basis of all activities and as energy consumption is usually increases with development, it is crucial for the State to take steps towards exploring the use of Solar Photo-Voltaic (PV) for meeting its energy demands.

However, the nature of terrain in Goa is largely undulating and as such availability of land is limited owing to the small size of the State. Also, around 33% of the total area of the State is under forest cover. Owing to these facts, it is essential to explore the potential of setting up solar power plants in the suitable locations in the State.

Mining activity has been a major contributor to the State's economy. Abandoned mine lands, or lands where mineral processing discards are dumped, cannot be brought under cultivation for around 20-

25 years. It is proposed that these can be used to set up solar power plants which shall aid in meeting the State's RPO obligation.

In addition, there are several Government buildings in the State. These present a large potential for roof-top systems. Solar PV systems installed on these buildings will play a significant role in promoting solar power in the State.

Canal-top solar power plants have been demonstrated in Gujarat. This potential in the State can also be explored since it offers a non-intrusive way of harnessing solar power.

Present power tariffs are very low in Goa, compared to other States in the country. A comparison of the Energy Charges for the LT Domestic Category consumers across the States of Maharashtra, Chhattisgarh, Goa and Karnataka are given in the Table below. However, since Goa has a huge reliability on external sources for supply of power, it is essential to have a back-up plan for power generation at reasonable costs of generation. This shall very strongly push the economy of Goa towards self-sufficiency in power generation.

Energy Charges for LT Domestic Category Consumers for FY 2016-17					
State	**Slab 1**	**Slab 2**	**Slab 3**	**Slab 4**	**Slab 5**
Maharashtra	0-100 units	101-300 units	301-500 units	501-1000 units	Above 1000 units
Rate (Rs/kWh)	2.98	6.73	9.69	11.17	12.45
Goa	0-100 units	101-200 units	201-300 units	301-400 units	Above 400 units
Rate (Rs/kWh)	1.3	1.9	2.4	3.1	3.6
Chhattisgarh	0-40 units	41-200 units	201-600 units	Above 600 units	NA
Rate (Rs/kWh)	1.25	1.3	2	2.5	
Karnataka (Bangalore)	0-30 units	31-100 units	101-200 units	Above 200 units	NA
Rate (Rs/kWh)	3	4.4	5.9	6.9	

Table 1-1 Comparison of Energy Charges across States

Till date, there has been no estimation of the potential of solar power generation in the State from the above mentioned potential sources. The present project aims at estimating the Solar PV generation potential in the State using GIS-based techniques as described in Chapter 3.

1.3 Possible implications of the Study

The present study shall provide help in understanding the potential of Solar PV power generation in the State, which in turn shall be useful in the following ways to the State Administration:

- Prioritizing the setting up of solar power plants to meet RPO
- Identifying locations for setting up solar power plants
- Planning for future power purchases based on the possible in-house generation
- Planning for possible incentives/ subsidies for setting up of Solar projects
- Formulation of innovative policies such as all Government buildings being solar powered, etc.
- Provide a baseline for taking up innovative, unique projects
  For e.g.: Setting up large solar power plants at strategic locations such as Stadia, Airport, etc.

2 Literature Review

2.1 Power scenario in Goa

The State of Goa has a high rate of electrification, and along with this, the State also has one of the highest per capita consumption of electricity in the country. After Dadra & Nagar Haveli and Daman & Diu, Goa has the highest per capita annual electricity consumption of around 2025 Units as against the National Average of 884 Units. The State-wise annual per capita consumption of electricity can be referred to in the Graph at Annexure C.

According to 18th Electric Power Survey (EPS), the peak demand of Goa is expected to grow to 1191 MW by 2022. The category-wise power consumption in the State of Goa for the year 2014-15 is given in the pie-chart below.

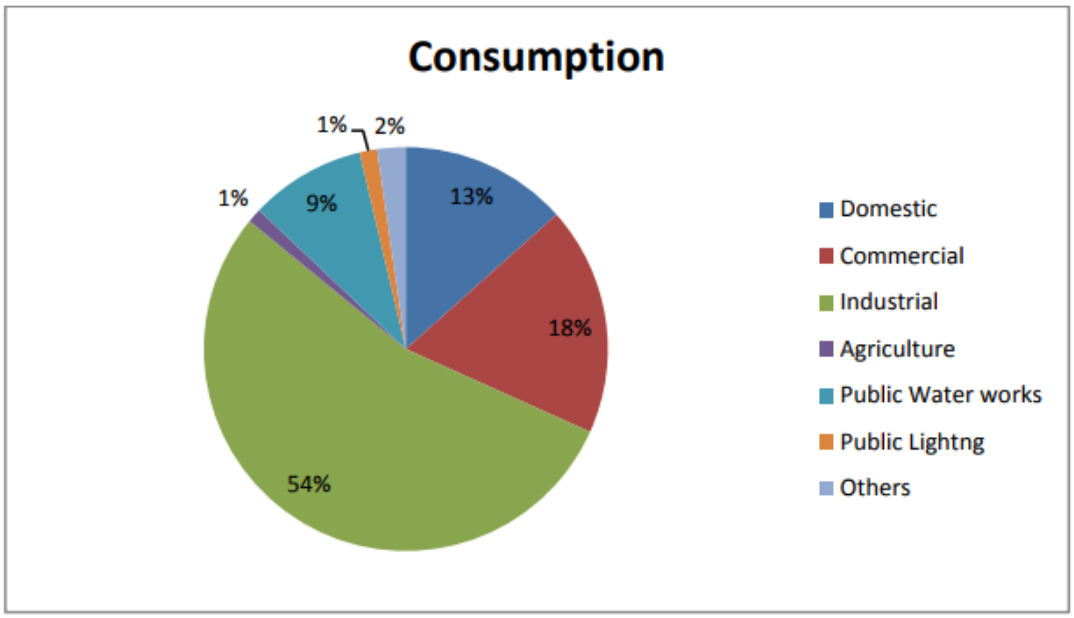


Figure 2-1 Category-wise power consumption for 2014-15 for the State of Goa

The State has been purchasing Electricity from different sources. The Power purchase cost during the last five years is depicted in the Graph given next.

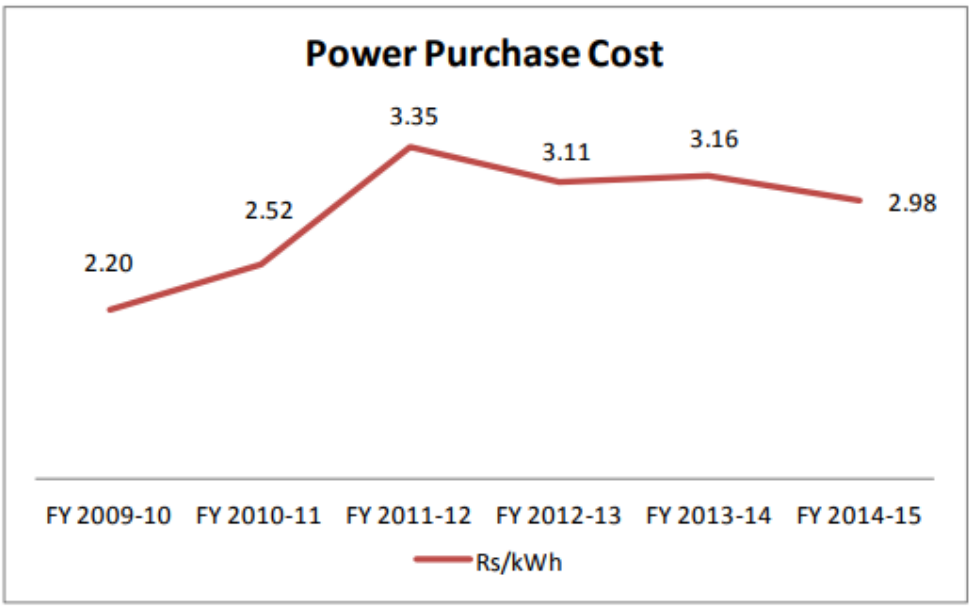


Figure 2-2 Power Purchase Rate per kWh for Goa

(Source: https://www.goaelectricity.gov.in/Regulations/BPlanFY17-FY19.pdf)

The Electricity Department of Goa was formed in the year 1963. The Electricity Department is the only licensee in the state of Goa for transmission and distribution of Electrical Energy. The Department does not have its own generation and purchases power from the Central Sector Power Stations of the National Thermal Power Corporation as per the allocation made by the Central Government. The Total allocation of power from the NTPC is 332 MW. Besides this, the Department also purchases power of 16 MW from Reliance Industries Ltd., Sancoale.

There are no direct link lines between the generating station of NTPC and Goa and hence the NTPC power is availed through the Grids of the neighbouring State of Maharashtra and Karnataka. The Electricity Department pays wheeling charges to Maharashtra State Electricity Board and KPTCC for using their line network for transmission of power from NTPC generating stations to Goa.

The power from the Western region is wheeled from the MSEBS 400 KV Sub-Station at Kolhapur to the 400 KV Sub-Station at Colvale in Goa. From here the power is transmitted at 220 kV level to Ponda and Tivim substations of the Department. From the Southern region power is transmitted from Nagjhari to Ponda. The Department has adopted Voltages of 220KV, 110KV and 33KV for sub transmission and 11KV and 440 volts for distribution purpose.

The Department has adopted overhead line system for transmission and distribution except for Panaji town where part of the area is covered by underground system. The remaining parts of Panaji and Margao town are now being provided with underground network. All the towns and villages of Goa are electrified and any intending consumer can avail power supply by submitting requisition in the prescribed form to the appropriate office of the Department subject to fulfilling the required conditions and payment of charges as per conditions of supply of Electrical Energy and miscellaneous charges.

The power supply to the new consumers is released on single phase, 230 Volts for connected load up to 3KW and on three phase, 400 volts for connected loads above 3KW but less than 70 KVA/HP connected for a single consumer. The power supply for connected loads / contract demands above 70 KVA but less than 100KVA is released at a voltage of 11KV and above 1000KVA the same is released at 33KV voltage. The Chief Electrical Engineer has however discretionary powers to release power supply at other voltages irrespective of connected load.

A power map of the State of Goa obtained from the Electricity Department of the Government of Goa appears in the following image.

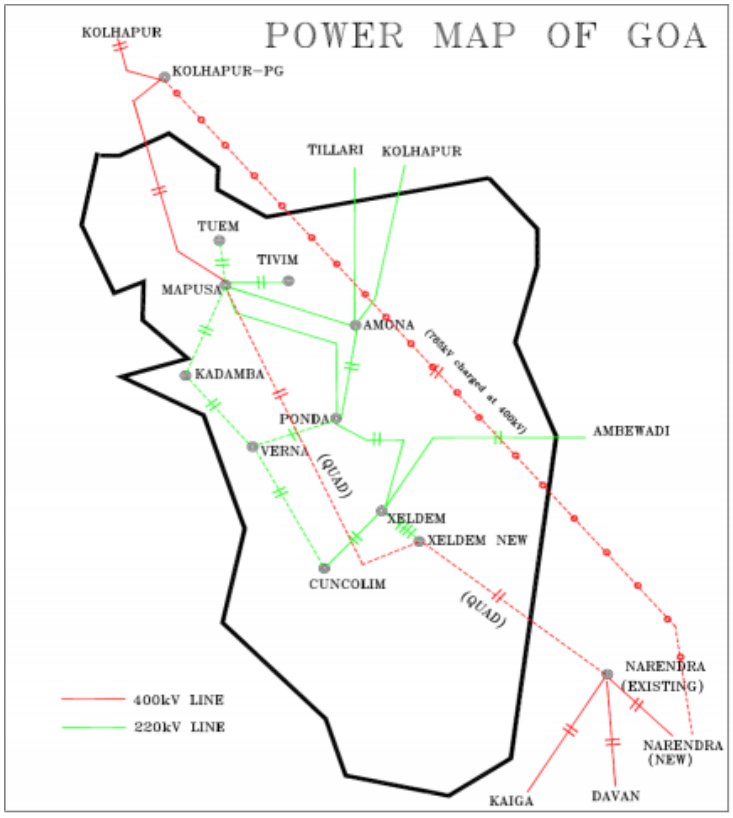


Figure 2-3 Power Map of the State of Goa

The State of Goa mostly relies on other States for the supply of electricity. A Table giving details of various Power Purchase Agreements is presented at Annexure C.

Goa has no power generating stations of its own in the state. The majority of power comes from coal-based central power generating stations, which contribute to 81% of the total power procured. Power is also procured from cogeneration plants, viz., Goa Energy Private Ltd and Goa Sponge Private Ltd of capacity 30 MW and 12 MW respectively and power from Sesa Sterlite Ltd of around 3 MW which is expected from FY 2015-16. Further, more than 70% demand of Goa is met from two major sources viz. Korba Super Thermal Power Station (STPS) and Ramagundam STPS. If there is any forced outage/ event in any of these power stations, it severely affects the power position in Goa.

(Source: Document titled "24 X 7 POWER FOR ALL GOA, A Joint Initiative of Government of India and Government of Goa")

2.2 Renewable Purchase Obligation of the MNRE

The Renewable Purchase Obligation set out for the State of Goa by the Joint Electricity Regulatory Commission (JERC) is presented in the Table given next.

Financial Year	Minimum Quantum of RPO (% in KWh consumed)		
	Total RPO (%)	Solar RPO (%)	Non-Solar RPO (%)
2010-11	1	0.25	0.75
2011-12	2	0.3	1.7
2012-13	3	0.4	2.6
2013-14	3	0.4	2.6
2014-15	3.3	0.6	2.7
2015-16	3.55	0.85	2.7
2016-17	3.95	1.15	2.8
2017-18	4.3	1.5	2.8
2018-19	4.65	1.85	2.8
2019-20	5.1	2.2	2.9
2020-21	5.5	2.6	2.9
2021-22	6	3	3

Table 2-1 RPO for the State of Goa

(Sources: Reports of the Government of Goa and MNRE)

As per the Electricity Act 2003, the Regulatory Commissions are mandated to promote co-generation and renewable energy. The Renewable Purchase Obligation is a part of this mandate, wherein the targets can be met either by generation from renewable sources or from purchase of energy generated from renewable sources by distribution license.

Owing to a stated scarcity of land for setting up ground-based power generation units, the Electricity department of Goa is purchasing renewable power from different organizations outside the State in order to fulfil the RPO.

As regard to fulfilment of Solar RPO is concerned, PPA has been executed for 6 MW i.e. 10 MU's per year by the Electricity Department with M/s NVVNL, New Delhi on 22-8-2014 for supply of solar power for a period of 5 years @ Rs 7.99 per unit exclusive of transmission charges. The supply has started w. e. f. 28-08-2014. This is for the clearance of backlog from FY 2010-11 to 2014-15.

Further M/s Solar Energy Corporation of India had allocated 10 MW of Solar power to the State and also submitted Power Sale Agreement (PSA). However, said allocation was enhanced by 15MW and hence SECI will be now supplying solar power of 25 MW @ Rs 5.50 (The rate as recommended by the Hon'ble Commission) per unit exclusive of transmission charges for a period of 25 years. The commencement of supply is yet to be started; the delay in the commencement is because of Open Access issues. It is anticipated that Power supply will commence from November 1st, 2015. As per this PSA ED Goa is expected to receive around 41.06MU's annually.

In the period when the solar obligation was not fulfilled, Electricity Department of Goa has been purchasing RECs to meet the RPO targets.

The Government of India has set a target set for installing 40 GW grid connected solar rooftop systems in the country by 2022. Order No. 03/13/2015-16/GCRT of the MNRE dated 01.07.2015 in this regard may be referred to at Annexure E.

As can be seen from the Table, a total of 150 MW of grid connected roof top solar PV is the target set for the State of Goa.

2.3 Advantages of Solar power Systems

There are several advantages of Solar PV systems:

- Saves on conventional power which usually uses polluting sources
- Saves on investment in transmission and distribution infrastructure in stand-alone systems
- Reduces electricity loss over the wires
- Saves on cost of managing power delivery
- Saves on cost of meeting carbon and renewable requirements
- The source i.e. solar energy is abundantly and freely available
- The installation of solar PV projects is relatively simple
- The maintenance requirements of solar PV systems are meagre, mostly limited to cleaning of the panels

2.4 Solar policy of Goa

The Solar Policy for the State of Goa was notified by the Goa Energy Development Agency in 2017. The Policy states that in order to achieve self-reliance in power generation and to promote clean source of power, the Solar Policy is being adopted.

Some of the features of the Policy are as follows:

- There are two categories for generating solar power: Prosumer & Producer.
- The Prosumer is a Consumer having an already connected load with the Goa Electricity Department (GED) and is also a Producer of Solar Power. Prosumer is categorised into two types namely Small and Large based on the load.
- The Producer is an entity intending to set up a Solar Power plant with a capacity of more than 100kW exclusively for sale of power to the Distribution Licensee under gross metering as per the tariff discovered by Reverse Bidding. The solar power plant can be installed on rooftop or ground based.
- Under the Renewable Energy Service Company (RESCO) model instead of prosumers the RESCO will invest on behalf of one or more roof top owner in the housing colony, towns, etc., on their roof tops and will sell the power so generated to GED
- Producer should identify suitable Rooftop or Private land for atleast 25 years for their projects within the state of Goa. No Town & Country Planning (T&CP) permission will be required for setting up of solar farm including construction for operational space as mentioned at (b) above. The Subsidy received from the Government of India will be credited to the prosumer/developer as per the guidelines of Ministry of New & Renewable Energy (MNRE).
- For Small Prosumers i.e. for solar plants of upto 100kW size, the State Government shall grant 50 % of the Capital Cost or the benchmark cost provided by MNRE whichever is lower, as interest free loan, which will be recovered in instalments after six months onwards, from the time power flows into grid. The recovery will be made from the payment to be made to the generator for every kWh supplied to the grid. The recovery will be at Rs. 4 per kWh or JERC feed in tariff rate whichever is less. The Small Prosumers will be allowed to opt for Gross Metering or Net Metering.

- Large Prosumer is a person having an HT connection i.e. connected load above 100 kW with Goa Electricity Department. All these large Prosumers shall have the option of Net Metering only.
- The State Government shall provide a subsidy of 30% of capital cost or the benchmark cost provided by MNRE, whichever is lower, for plants of size upto 100kW for the standalone systems including the cost of battery (Off-grid Systems) which will be released by way of Rupee 1 for every unit of power generated and will be paid once in six months. A sealed tested Energy meter form GED is required to be installed at the generation side to measure the solar power generation. No payment shall be made to such producer under Net/Gross metering to avoid possibility of Double benefit.

2.5 Solar Potential Estimation Studies

A similar project for estimating the Rooftop Solar potential of Greater Mumbai was undertaken jointly by the National Centre for Photovoltaic Research and Education (NCPRE), IIT Bombay in association with IEEE Bombay Section, Bridge to India, Observer Research Foundation, Mumbai and Centre for Urban Science & Engineering IIT Bombay.

This study estimates the total rooftop solar PV potential of Greater Mumbai to be 1.72 GW with residential buildings making up nearly 1.3 GWp or nearly 75% of the total rooftop solar PV potential in Greater Mumbai. The second largest potential is contributed by industries - 223 MWp, followed by educational institutions - 72 MWp and commercial buildings - 56 MWp. Mumbai's transportation sector holds some potential with the railways (stations and offices) contributing 26 MWp and bus depots contributing 4 MWp.

Their methodologies, reports, inputs are being taken in current study.

2.6 Case Studies

This section refers to various case studies which are useful in understanding the application of Solar PV system on different types of buildings and structures.

2.6.1 Solar PV systems on Canal-tops

The State of Gujarat has been proactive in harnessing solar energy by setting up canal-based solar PV projects. Details of the first pilot Project undertaken at the Narmada Branch Canal are presented below:

- Capacity: 1 MWp canal-top solar power project
- Location: Narmada Branch Canal, owned by Sardar Sarovar Nigam Narmada branch canal (SSNNL), near village Chandrasan, Taluka Kadi, District Mehsana, Gujarat.
- Time-frame: The demonstration project was completed within a period of 6 months
- Date of Commissioning: March 2012
- Implementing Agency: Gujarat State Electricity Company Limited (GSECL)
- Execution Partner: Sun Edison

Figure 2-4 Canal top Solar PV system in Gujarat

- Advantages of the Project:
    - No land acquisition required for setting up the project
    - Saving of CO_2 emissions
    - Saving canal water from evaporation
    - Reduction in transmission & distribution losses- as generation is close to consumption point, which can be at remote location.
    - Generate power with even higher efficiency compared to terrestrial solar power plants due to cooling effect on solar panels by evaporating canal water
    - No Rehabilitation & Resettlement required
    - Development of green cover in the surrounding areas

- Challenges and Constraints:
    - Canal site being in a remote location with limited connectivity, transport of materials was difficult (as understood from a personal interaction).
    - Since it was a pilot project, no readymade designs/ models were available
    - No funding from private players due to lack of knowledge about viability of the Project.
    - Erection of the structures was challenge since they were heavy. Also, erection had to be done from one side as there was no access from the other side and no support from the centre.
- Total cost of the Project: Rs 17.73 crores
- Replicability: The Project is replicable and several State Governments have shown interest in setting up similar projects in their areas, and these include the following:
    - Karnataka: 1 MW (Commissioned)
    - Punjab: 100 MW
    - West Bengal: 15 MW
    - Gujarat (Vadodara): 10 MW (Commissioned)

2.6.2 Solar PV systems on abandoned mining lands

The case of solar PV plant being set up in a mine land has been demonstrated by Tata Steel at their iron ore mine at Noamundi in Jharkhand.

Figure 2-5 Google Earth Image of the Solar PV plant set up at the iron ore mine at Noamundi, Jharkhand

- Capacity: 3 MW
- Location: Iron Ore mine at Noamundi, Jharkhand
- Year of Commissioning: 2015
- Implementing Agency: Joint venture of Tata Steel, Tata Power Solar and Tata Power Trading Company. Tata Steel is the sole buyer of all electricity at a contracted tariff.
- Area: Plant covers 19 acres (76890.3 sq.m.) of land at an elevated reclaimed mining hill with ample undulations and a very rocky terrain.
- Advantages of the Project:
    - Reducing CO2 emission by about 3,000 tonnes per annum
    - Cost saving since net metering is provided
    - In case of complete outage of grid, the solar plant has the capability to synchronise with existing DG bus at processing plant Noamundi and continue operation.
- Total cost of the Project: Rs 35 crores

  Owing to the power outages in the area, the alternative was to use DG set which used to cost Rs 14 per unit, whereas the solar power cost for the first year is Rs.7 per unit**.**

- Remarks: The power consumption of Noamundi Iron Mine is around 500 lakh units per annum and 3 MW solar will generate about 45 lakh units per annum.

  Solar lights have been used for boundary and area lighting around the solar plant. The selected site has a potential of 4.5 MW solar power generation. A rain water harvesting system has been set-up to collect all surface run-off from rains and module cleaning activities to serve as make-up water and minimize module cleaning water requirement. Horticulture has been planned under the solar panels that will add to the aesthetic value and will reduce cleaning water requirements by binding the loose top soil.

2.6.3 Solar PV systems on public amenities

2.6.3.1 Chinnaswamy Stadium, Bangalore

Figure 2-6 Google Earth image of the Solar PV plant set up at M. Chinnaswamy Stadium, Bangalore

M. Chinnaswamy Stadium in Bangalore has installed Solar PV system on the eastern stand which provides clean energy to the Stadium. The system is net-metered and excess power is exported to the BESCOM grid at the rate of Rs 9.56/unit. The entire system is automated using SCADA system, and at the end of the day, it is possible to assess the performance and power generated by the solar panels.

Details of the system appear below:

- Capacity: 400kWp (1422 Nos. of 300 Wp solar panels)
- Location: Eastern Stand of Chinnaswamy Stadium, Bangalore
- Date of Commissioning: 7 April 2015
- Timeframe: 45 days from installation to final test run
- Area: 4500 sq.ft. (418.0637 sq.m.)
- Annual power generation: 6,00,000 units
- Payback period: Mentioned to be around four years
- Implementing Agency: Karnataka State Cricket Association (KSCA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) under the Project ComSolar (Commercialization of Solar Energy in Urban and Industrial Areas)
- Executing Agency: RenXSol Ecotech Pvt. Ltd.
- Advantages of the Project: Provision of clean energy
- Challenges and Constraints:

2.6.3.2 Cochin Airport

Figure 2-7 Google Earth image of the Solar PV plant set up at Cochin International Airport

Cochin International Airport is the first airport in the world that completely operates on solar power. It generates 50,000 to 60,000 units of electricity per day to be consumed for all its operational functions, which technically renders the airport "absolutely power neutral". The system is net-metered.

The entire project was completed in a phased manner, with 100 kWp solar PV plant installed on the roof top of the arrival block in March 2013. Thereafter, a 1 MWp system was installed partly on the roof top and partly on ground in the Aircraft Maintenance Hanger Facility within the airport premises. Considering the success of these two systems, Cochin International Airport Limited (CIAL) further decided to set up the 12 MWp system as part of its green initiatives.

Details of the three phases are provided next.

Phase 1: Project on the Arrival Block

- Capacity: 100 kW
- Date of Commissioning: March 2013
- Details of panels: 400 panels of 250 Wp capacity each, 1.6 sq.m. area
- Executing Agency: Vikram Solar Power, Kolkata
- Generation: Around 400 units/day

Phase 2: Project on the Aircraft Maintenance Hanger Facility

- Capacity: 1 MWp
- Date of Commissioning: November 2013 (within record time of 7 months)
- Details of panels: 4000 monocrystalline panels of 250 Wp capacity each
- Executing Agency: M/s Emvee Photovoltaic Power Pvt Ltd

Phase 3: Project near Cargo Complex

- Capacity: 12 MWp (46,150 solar panels)
- Location: Near Cargo Complex of the Cochin International Airport
- Area: 45 acres (1,82,109 sq.m.)
- Time-frame: Around six months
- Date of Commissioning:
- Implementing Agency: Cochin International Airport Limited (CIAL)
- Execution Partner: M/s Bosch Ltd.

- Advantages of the Project: Complete independence w.r.t. energy, saving of 3,00,000 metric tonnes of CO_2 emissions.
- Payback period: Estimated to be less than six years
- Challenges and Constraints:
- Total cost of the Project: Around USD 10 million i.e. Rs 6.4 crores

3 Methodology

3.1 Work Plan

The study included estimation of the solar PV potential for the following types of set-ups:

- Roof top systems for Government buildings
- Canal-top systems
- Systems on Abandoned Mine Lands

The estimation was done using GIS mapping, with around 10% site sampling to verify the results.

The Work Plan is depicted in the figure given next:

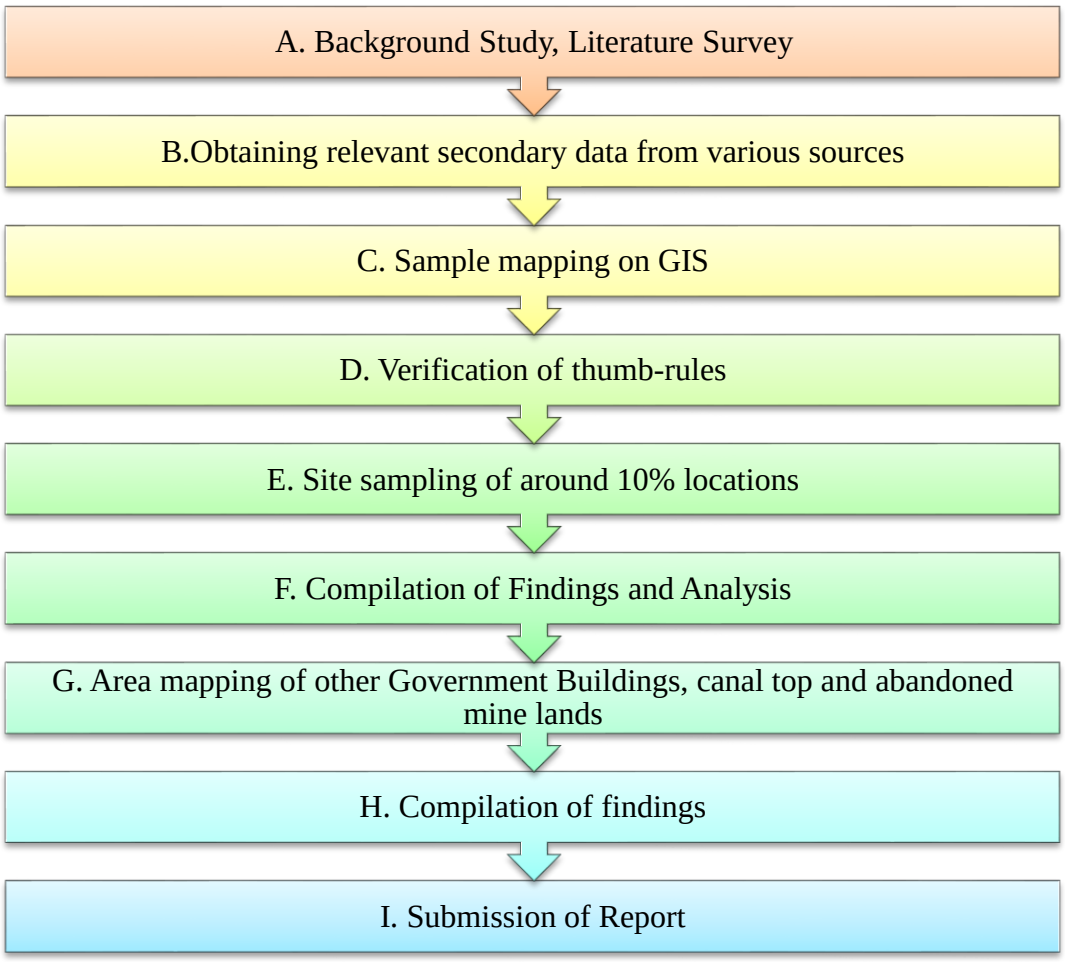


Figure 3-1 Work Plan for the Project

3.2 Methodology for Estimation of roof-top Solar PV potential

While developing the Methodology, the Study titled "Estimating the Rooftop Solar Potential of Greater Mumbai" (described at Section 2.5) was referred to as a baseline. However, the present Methodology was derived by making necessary modifications required for the case of Goa, as per findings of the GIS mapping and the site sampling. The methodology adopted for the present study for roof-top systems is as follows:

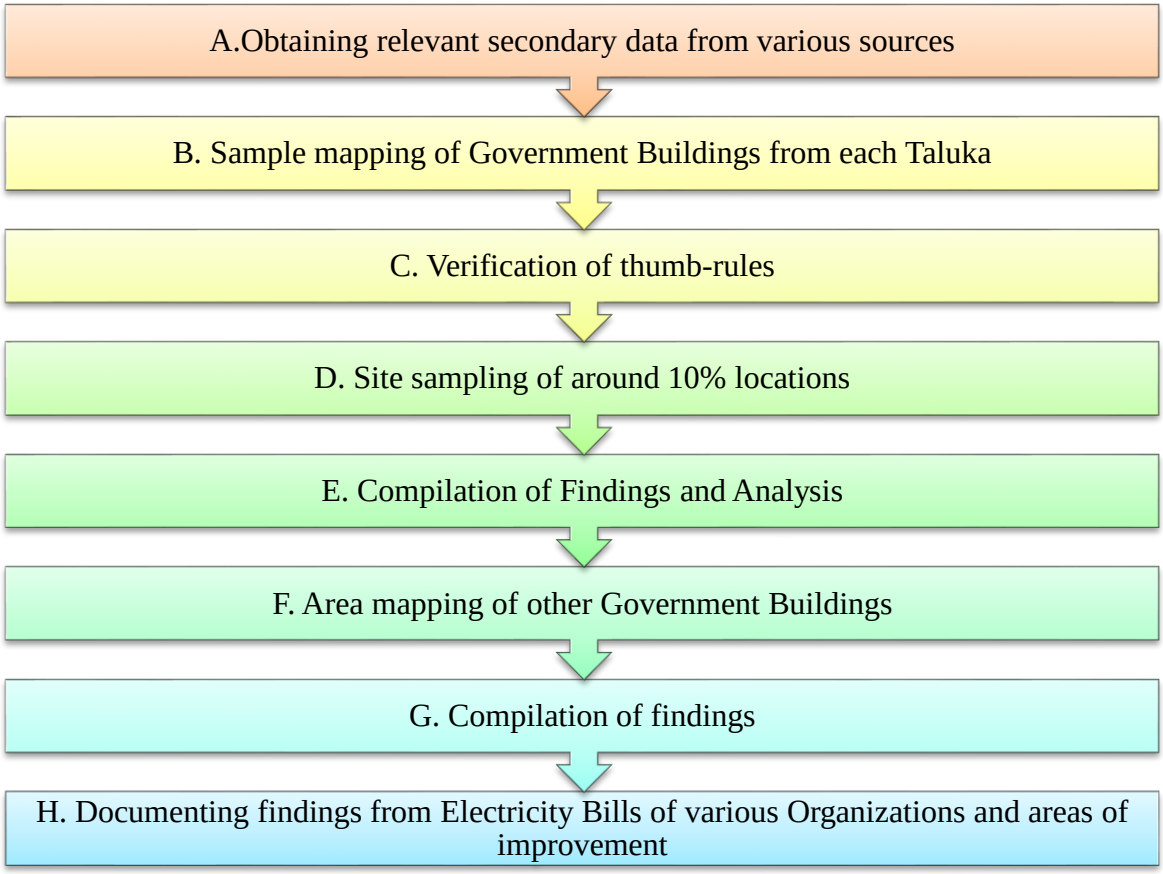


Figure 3-2 Methodology for solar PV potential estimation on Govt. buildings

3.3 Methodology for Estimation of canal-top Solar PV potential

For the estimation of canal-top potential, the following methodology was used:

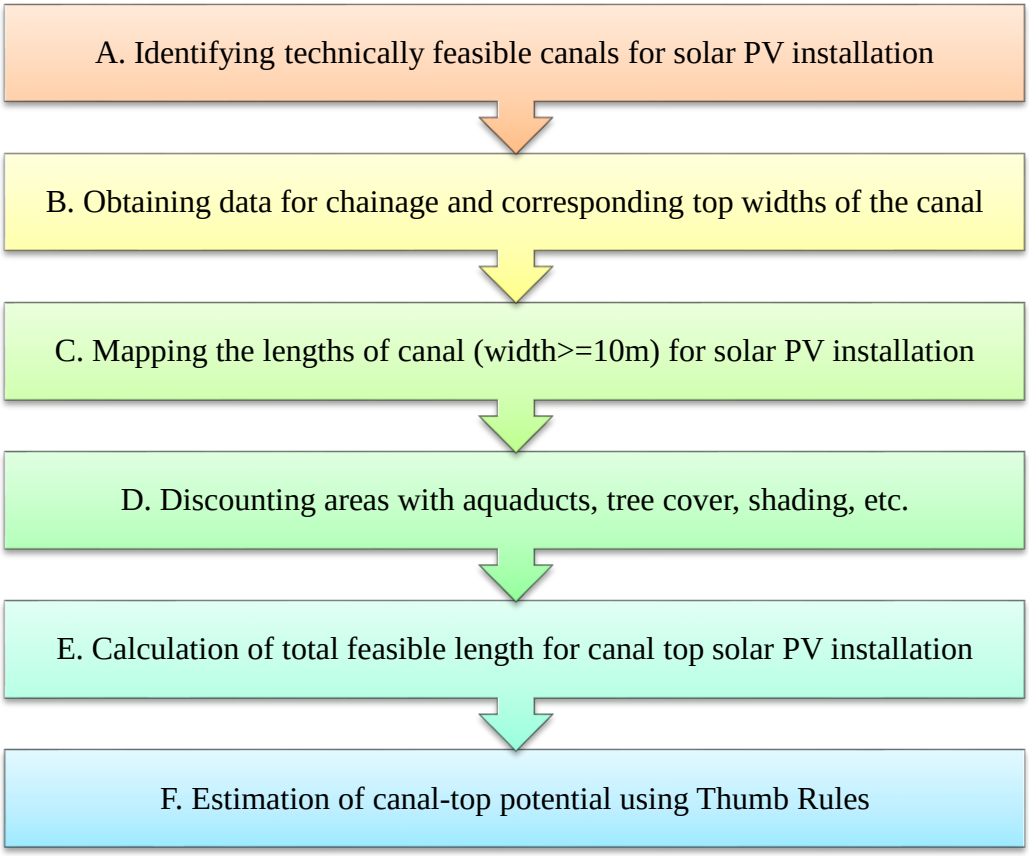


Figure 3-3 Methodology for canal-top solar PV potential estimation

3.4 Methodology for estimating solar PV potential on abandoned mine lands

For solar PV potential estimation on abandoned mine lands, the following methodology was adopted.

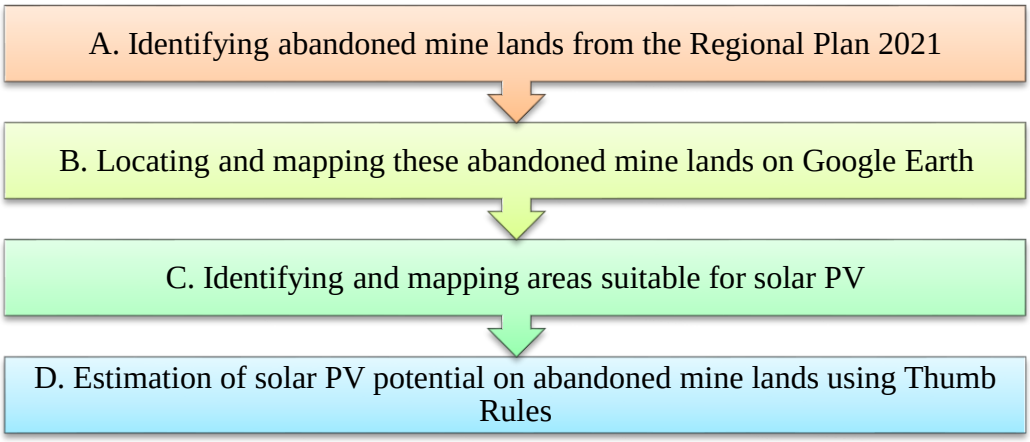


Figure 3-4 Methodology for canal-top solar PV potential estimation

3.5 Background Study, Literature Survey

Literature Survey was an important part of the Project, to understand solar PV installations in different set-ups and similar studies for potential estimation. The Literature Review including case studies has been covered in Chapter 2 of this Report.

3.6 Obtaining relevant secondary data from various sources

Secondary data including the list of Government Buildings in each of the 12 Talukas was obtained. Since a consolidated list of the Government Buildings was not available with any of the Government Departments, considerable effort went into the compilation of this list. The same was developed using the Goa Government official Telephone Directory, interactions with relevant officials, data from Internet, visits, telephonic interactions, etc.

The details of canals having a width of 10 m or more (such canals were found to be suitable for solar PV installation, as suggested by Experts in the field) were obtained from the Water Resources Department, Government of Goa.

As an additional interesting exercise, the list of top electricity consumers from each Electrical Division was obtained from the Electricity Department, Government of Goa. This list would be useful to identify these top consumers and the corresponding solar PV potential that they possess.

Since existing Land Use and Land Cover maps are not available with the Government of Goa, Regional Plans 2021 for all the Talukas (which depict the future/ planned land use) were obtained from the Town and Country Planning Department and geo-referenced as a back-up for identification for various Government Buildings.

3.7 Sample mapping of Government Buildings from each Taluka

As a first step in the mapping, five prominent Government Buildings which are already geo-tagged on Google Earth were identified. The complete mapping process including the following steps was completed for each of these buildings:

a. Obtaining the clear Google Earth image of the Building which will show the roof top area as clearly as possible. The Historical imagery tool in Google Earth was used to choose the clearest image.

Figure 3-5 Google Earth image of selected Govt. building

b. Marking of shadow-free area suitable for installation of Solar PV using polygon tool in Google Earth. Using the Colour codes as fixed up for each type of Institution. Preserving this image with the polygons marked

Figure 3-6 Marking shadow-free areas using polygon tool

c. For the purpose of mapping, the buildings were differentiated into various categories. The colour codes developed for the same are as follows:

Sr. No.	Type of Institution	Category	Colour	R	G	B	Colour
1	University (Educational institution)	University	Yellow	255	255	0	
2	College/ Graduate Level (Educational institution)	College	Purple	85	0	127	
3	School (Educational institution)	School	Pink	255	85	255	
4	Government office	Govt office	Green	0	255	0	
5	Research Centres, etc.	Research Centre	Red	255	0	0	
6	Public Amenities (Auditoriums/ Stadiums/ Sports Complex/ Hotels/ Bus Stand, etc.)	Public Amenity	Blue	0	0	255	
7	Healthcare facilities (Hospitals/ PHC/ CHC, etc.)	Healthcare	White	255	255	255	
8	Housing Boards/ Government Residential Buildings	Govt Residential	Sky blue	0	255	255	
9	Other Miscellaneous Government Buildings	Other	Orange	255	170	0	

Table 3-1 Colour coding for different categories of Institutions

d. Importing this image in Sketch up Make 2017. Scaling of the image. Placement of standard solar panels (320 Wp, 2 m x 1m panel) on the image to calculate the solar PV potential. While placing the panels, the clearance from the edges of the roof (for safety during installation, access and maintenance) and between the panels (for access and maintenance) has been maintained at around 0.3-0.5 m, as suggested in relevant literature obtained on the internet.

Figure 3-7 Placement of panels using Sketchup

e. Tabulation of Results and various other parameters:

Sr.No.	Name of Building	Shape of Roof	Structure of roof	Type of Institution	Available area(SQM)	No of panels	Wattage of panel(W)	Panel Area (SQM)	Total area occupied by panels	% Area	Generation(KW)
1	Mamlatdar of Canacona	Sloping	Tiles	Govt office	519	208	320	2	416	80.15414	66.56
2	CHC Canacona	Sloping	Roofing Sheets	Healthcare	336.8	124	320	2	248	73.6342	39.68
3	KTC Bus stand Canacona	Curved	Roofing Sheets	Public Amenity	1360	502	320	2	1004	73.82353	160.64
4	Canacona Municipal Council	Sloping	Tiles	Govt office	183.9	76	320	2	152	82.65362	24.32
5	Sub Post office Canacona	Sloping	Roofing Sheets	Govt office	46.9	19	320	2	38	81.02345	6.08

Table 3-2 Tabulation of mapping exercise

3.8 Use of thumb-rules

Completing the entire procedure as described for the sample buildings was very tedious and time-consuming. After plotting of the potential shade-free area was completed on Google Earth with the decided colour-coding, the actual placement of solar panels in Sketch up was done and this was found to be the most time-consuming step.

On referring to various documents of the MNRE Govt. of India, it was found that the thumb rule regarding the space required for setting up a solar roof-top PV system is 10 sq.m. for 1 kWp system.

Hence, for the further mapping of other Government Buildings, the Solar PV estimation was achieved by mapping and measuring the potential shade-free area (in sq.m.) and then using thumb-rules to estimate the actual potential (in kW).

3.9 Site sampling

To verify the results of the GIS mapping exercise, sampling of around 10% locations was completed. A Form was developed for the site survey and the same appears at Annexure A.

During the sampling, the actual shade free areas were observed, measured and compared against the Google imagery. Various other parameters such as the condition of the roof, accessibility to the roof, etc. were observed which are important from the point of view of installation of solar PV system.

An attempt was also made to collect Electricity bills of the buildings sampled so as to understand the sanctioned load, the average monthly consumption, etc.

3.10 Compilation of Findings and Analysis

The findings of the Site Survey were compiled for further analysis. During the sampling, it was observed that the slopes of roofs in Goa vary from 15° to around 25°. In order to estimate the potential for installing solar panels, the projections of the sloping roof areas on the ground were considered, which can be estimated from Google maps. This was mainly done since the actual measurement of roof-top area becomes practically difficult due to limited access in case of sloping roofs.

Since the projections on the ground are being considered, the actual sloping roof top area shall be greater that the projected area measured by a factor of the cos α, where α is the angle of slope of the roof. In order to validate this estimation, the table given next may please be referred.

α	**Cos α**	**App. Variation from actual length**	**Remarks**
15°	0.965	3%	Slope of maximum roofs in Goa

25°	0.906	9.4%	Maximum slope observed during site sampling

Table 3-3 Variation in measurement due to slope of roof

This variation is on the under-estimation side and in fact, will project a higher potential in reality. Therefore for all area estimation of the roofs, we have considered the Google Map area (i.e. the projected area) as the potential area for setting up solar roof-top systems.

3.11 Area mapping of other Government Buildings

For the other Government buildings, the polygons were plotted as per the colour coding to identify the shadow free roof-top area. Thereafter, the solar PV potential was estimated using the thumb rule of 10 sq.m./kW. While completing the mapping, area for clearances, access, etc. have already been discounted.

3.12 Report Submission

Report preparation involved compilation of all the data, documenting all findings, analysis, recommendations, etc. and submission of the same to the concerned Government Department, i.e. Department of Science and Technology, Government of Goa.

4 Calculations and Findings of solar PV potential estimation exercise for Government Buildings

4.1 Sample mapping of Buildings from each Taluka

As the first step in mapping and sampling, 5 buildings from each Taluka were identified and the complete mapping procedure using GIS was completed for these buildings. A compilation of the mapping is given at Annexure F. The panels considered are of 320 Wp with area 2 sq.m.

4.2 Mapping of other Government Buildings

After sample mapping of 5 buildings from each taluka, other Government buildings which were geo-tagged on Google Maps/Earth were identified. The shade-free South/ South West/ South East facing roof areas were plotted using polygon tool in Google Earth. The details were noted and compiled in an Excel Sheet. Colour Coding as described for the different categories of Institutions was followed during this mapping.

However, unlike the first five sample Buildings mapped, the actual placement of Solar panels using Sketchup was not done for these buildings. The potential was estimated using the shade free area and the thumb rule of 10 sq.m./kW. The number of Institutions of different categories (which were plotted) is tabulated in the Table given next:

Category of Institution	No. of samples mapped	Total shade-free area available (sq.m.)
College	40	37234.23
Government Office	201	61235.7841
Govt Residential	3	7339.5
Healthcare	31	25042.2
Other	7	15068.8
Public Amenity	51	88675.8
Research center	3	2764.4
School	61	16181.7
University	11	6928.9
Grand Total	**408**	**260471.3**

Table 4-1 No. of samples mapped for solar PV potential estimation

4.3 Observations of site sampling

As a part of the Project, site sampling was undertaken at the following locations. The procedure was as follows:

- Site visit; Actual observations and measurements (wherever possible) of the shade-free roof top area available for solar PV in the selected institution
- Filling up the Site Survey Form with all details
- Obtaining the Electricity Bill of the Institution
- Taking photographs and other supporting data such as roof plans, etc. wherever possible

4.4 Accuracy of mapping

Since the entire exercise of estimation of the solar roof-top potential is based on Google Earth/ GIS, it is important to understand the accuracy of mapping in terms of the areas measured. For this, it is essential to compare the shade-free area measured at site versus that estimated using Google Earth. In order to do this, the shade-free area was measured using a tape wherever access for direct measurement was available. In case a roof plan of the Institution was available, shade free area was measured using the same. In case of sloping roofs, the projected area was measured, in which case the error in measurement would be less than 10% as explained in Section 3.10. The Table below captures this data for comparing the shade-free area measured on ground and measured using GIS:

Sr. No.	Taluka	Name of Building	Available area (Sqm) as per GIS	Shadow-free roof top area measured (Sqm)
1	Bardez	District Hospital Mapusa	3297	3610
2	Bardez	P.t Deendayal Upadhyaya Bhavan Porvorim	405.6	325.09
3	Bardez	Peddem Sports Complex	5844	6244
4	Bardez	Sinchan Bhavan	1097	1087.9662
5	Canacona	KTC Bus stand Canacona	1360	1661.6
6	Canacona	Canacona Police Station	338.6	333
7	Mormugao	Vasco Govt. ITI	725.1	979.2
8	Ponda	Ponda Fire Station	286	289
9	Tiswadi	Income Tax Dept.	179	252
10	Tiswadi	Commissioner Central Excise and Customs	262.8	288

Table 4-2 Area measured and estimated using GIS

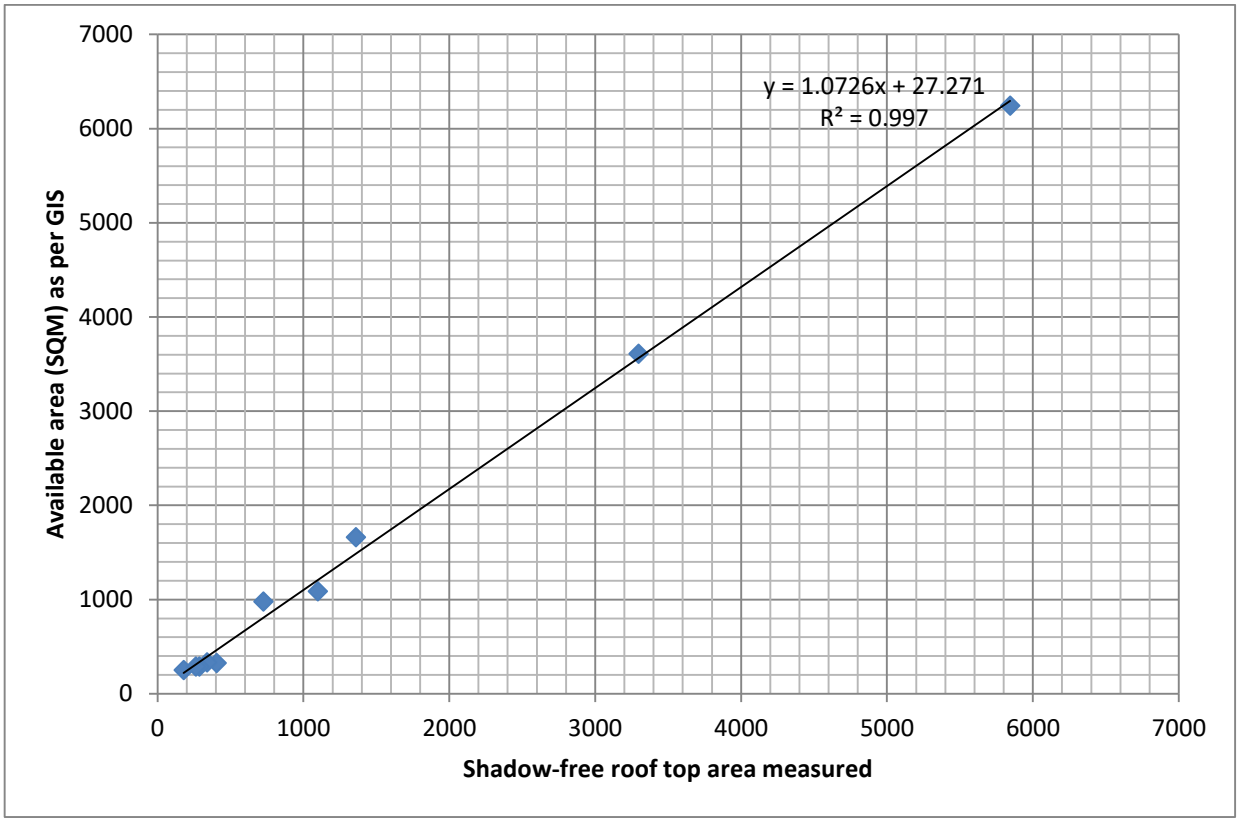


Figure 4-1 Graph of area available as per GIS v/s measured area

From the above graph, it is evident that linear fitting shows the R value to be (which indicates the variation from the equation) 0.997 which indicates a good linear fit.

As can be seen from the graph, in 7 out of 10 cases, the actual area measured during sampling is more than the area measured on GIS. This indicates that inaccuracy in GIS measurement in almost 70% cases is on the under-estimation side. This is a positive fact in the case of this study since it implies that the actual solar PV potential is more than that which is estimated. Thus, the data and figures mentioned in this Report indicate a conservative estimate of the solar PV potential.

4.5 Data Analysis of Electricity Bills of various Institutions

During the course of the Project, electricity bills and electrical data of various Institutions visited were collected to understand the electrical consumption, sanctioned load, power factor, etc. This section briefly outlines findings of this exercise.

Secondary data: Top Government consumers from each electrical division: Since the sanctioned load forms an important electrical parameter, data of the top electricity consuming Government consumers from each Taluka was sought from the Electricity Department, Government of Goa. Subsequently, the list of Government consumers having connected load more than 50 kW was provided by the Department. An effort was made to include these in the locations chosen for site sampling.

Compilation of Electricity Bills obtained during site sampling: During site sampling, electricity bills of 22 Organizations (belonging to the following categories as given in the pie-chart below) could be obtained.

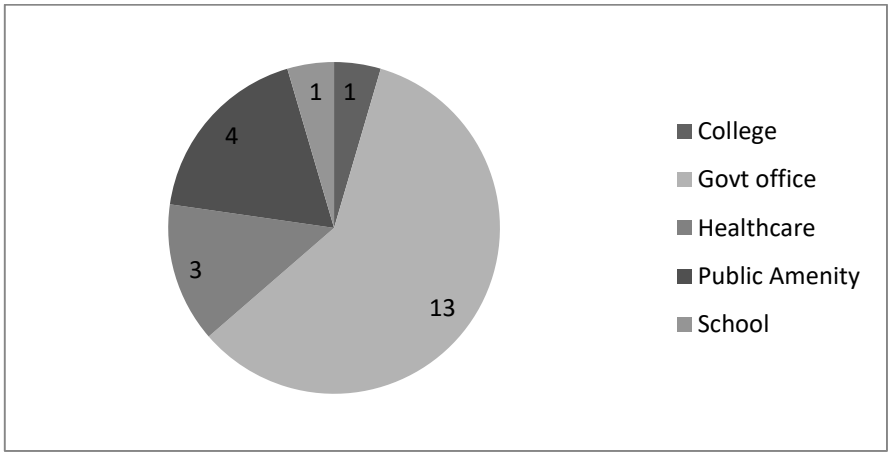


Figure 4-2 Categories of Institutions whose Electricity Bills were obtained

Total Penalty imposed due to Power Factor (PF): From analysis of these 22 Bills, it was observed that the PF was low in 5 of the cases, making them liable for payment of Power Factor Penalty. The total amount paid as penalty by these 5 Institutions was Rs 66,976.23/- during December 17 or January 18.

Meters not operational: The 22 Institutions together have a total of 36 electrical meters. After obtaining bills of these, it was found that 8 out of these meters are not working.

4.6 Case Study of existing Solar PV installation at Pt. Deendayal Upadhyay Bhavan, Porvorim, Goa

In order to understand the finer details of a solar PV installation, the 14 kW system installed on the terrace of the Deendayal Upadhyaya Bhavan (which hosts the Department of Science and Technology Government of Goa, the Department of Planning, Statistics and Evaluation and few other Government Departments) was studied during the site visit on 13-03-2018.

Photographs of the installation appear next for reference. Various measurements were taken at site using a 30 m tape and the following was observed:

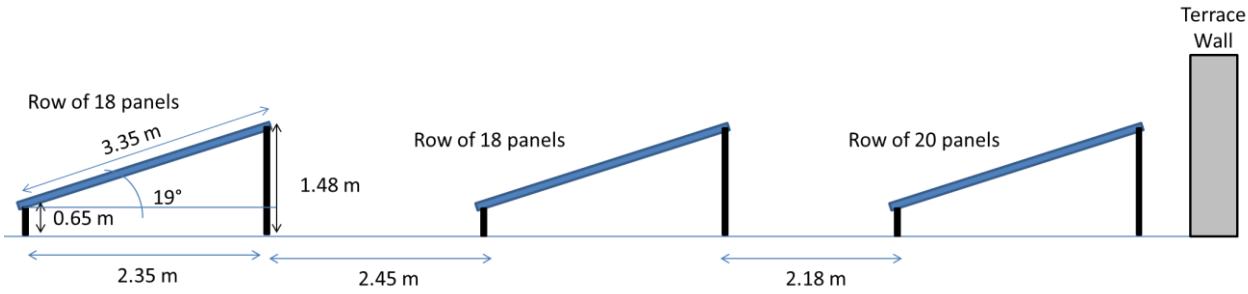


Figure 4-3 Schematic Diagram of 14 kWp system at Pt. Upadhyay Bhavan, Prorvorim, Goa

- No. of panels: There are three rows of 18, 18 and 20 panels each. Hence, total number of panels is 56.
- Panel capacity: 250 Wp
- System capacity = 250 Wp x 56 panels = 14 kW
- Panel length and width: 1.6 m x 1 m
- Distance between rows of panels: 2.45 m and 2.18 m as shown in diagram
- Angle of the panels: Around 19°

During the peak sunlight hours, there was no inter-shading effect among the rows of panels. It was observed that the total area for the installation was app. 130 m^2 which amounts to around 10 m^2/kW.

Figure 4-4 Study of existing solar PV installation at Pt. Deendayal Upadhyay Bhavan, Porvorim

4.7 Excluded buildings

In the case of the Study stated at Section 2.5, a digital geo-referenced map providing the existing land use of the entire city of Greater Mumbai was available with the Project Team due to which the mapping exercise was easier.

However in the present case, the existing land use maps are not available with the Government of Goa; only Regional Plan 2021 maps are available in scanned soft copy format. These are neither digitized nor geo-referenced. Also, a compiled list of all the Government Buildings in the State is not available. In addition, it was also observed that all the Government Buildings in the State as per the list compiled from the Government directory are not geo-marked on Google Maps/ Earth.

Wherever possible, identification of buildings has been done using local resource persons or during site visits. However, many buildings have not been found or marked. Such buildings where the exact location is not marked on Google Earth have been excluded from the scope of the present study.

This is because geo-mapping of all the Government Buildings is not in the scope of the present study. This task can be taken up as a separate project.

4.8 Total solar PV potential

As explained in Section 4.1 and Section 4.2 , the total solar roof-top PV potential for Government Buildings in the State is estimated to be around 27 MWp.

5 Estimation of Canal-top Solar PV potential

5.1 Technical Feasibility of canal-top Solar PV systems

As a part of the present Project, interactions were held with officials of the Water Resources Department (WRD), Government of Goa to understand on which canals solar PV installation is feasible. It was understood that a feasibility study was undertaken by WRD jointly with Goa Energy Development Agency (GEDA) and it was concluded that canals with width of 10 m or more prove to be economically feasible for canal-top solar PV comparing the power generated vis-à-vis the structural and installation costs. However, the Reports of this study were not made available to the Project Team. Yet, the canals with width >= 10 m have been considered in this Study.

5.2 Standard Solar PV Module for canal-top systems

In the course of the same feasibility study of WRD and GEDA mentioned above, a Standard Module of 15 m x 15 m size had been designed for canal-top systems with width more than 10 m. Details of the design of this Truss were not made available during this Project.

However, as suggested by officials of WRD and Subject Expert Dr. Pathak, the Standard Truss of 15 m x 15 m was used for potential estimation during the present study.

The Module was so designed as to fit around 84 panels of 250 Wp each, thus making the total capacity of the Module as 20 kW. These Modules also considered the clearance for access, the area to be maintained for the structural support, etc.

These Modules can be fitted end-to-end i.e. there is no requirement of maintaining any clearance between two such 15 m x 15 m Modules.

5.3 Canal Lengths technically feasible for Solar PV

The details of the Chainage and corresponding canal width along with any aquaducts, etc. were obtained from WRD and the same appear at Annexure C. The Chainage feasible for solar PV for these canals is extracted and compiled in the Table given next.

Details of Canal Chainage for Canal Width more than 10 m					
Sr. No.	**Canal Name**	**Chainage (km)**		**Length (km)**	**Width of Canal (m)**
		From	**To**		
1	Tillari RBMC	0.000	1.180	1.180	11.46
2		1.180	4.144	2.964	10.81
3		4.190	4.740	0.550	10.81
4		5.120	6.020	0.900	10.81
			TOTAL	**5.594**	
5	Tillari LBMC	0.000	1.700	1.700	12.8
6		1.700	13.100	11.400	11.2
7		13.100	18.100	5.000	10.8
			TOTAL	**18.100**	
8	Salaulim Canal	0.095	13.260	13.165	13.050
9		13.260	13.870	0.610	12.100
10		13.870	17.050	3.180	10.900
			TOTAL	**16.955**	
			Grand Total	**40.649**	

Thus, a total canal length of around 40.6 km could be explored for setting up solar PV projects.

5.4 Site Sampling for canals

Even though it was calculated that around 40 km canal length had a width of 10 m or more, it was essential to verify the same on ground. Hence, a visit was made on 15.03.2018 to Tillari Dam canals along with WRD officials and Dr. Pramod Pathak.

Parts of the probable canal length were visited and it was found that in some places, the canal was not suitable for solar PV because of the following reasons:

- Unavailability of straight length (presence of bends in the canal)
- Presence of extremely steep slopes along the bank of the canal making access very difficult
- Presence of tree cover creating shadows

During the site sampling, canal widths were actually measured at few geo-tagged locations along with other observations. A tabulation of these is presented next:

No.	Name of Point	Latitude	Longitude	Width as measured on site (m)	Width as per GIS (m)	Width as per WRD data (m)	Remarks
(A) Tillari RBMC							
1	RBMC startpoint	15°44'18.45"N	73°56'31.67"E	NA	11.15	11.46	Starting point of RBMC
2	RBMC 2	15°40.385' N	73°49.522' E	5.8	5.76	5.77	End point of RBMC
3	RBMC 3	15°41.705' N	73°50.422' E	6.1	4.47	7.43	
4	RBMC 4	15°42.616' N	73°51.242' E	NA	5.43	7.61	
5	RBMC 5	15°44.898' N	73°51.242' E	15	9.72	10.81	
6	RBMC 6	15°44.901' N	73°53.412' E	9	6.73	10.81	
7	RBMC 7	15°44.838' N	73°53.752' E	NA	8.52	NA	
(B) Tillari LBMC							
8	LBMC Start point	15°40'10.57"N	73°57'44.04"E	12.4	10.27	12.8	Starting point of LBMC
9	LBMC 2	15°40.175' N	73°57.627' E	14	11.79	12.8	Near starting of LBMC
10	LBMC 3	15°39.749' N	73°57.154' E	NA	12.32	11.2	
11	LBMC 5	15°38.664' N	73°55.299' E	11.7	8.88	11.2	8 Km LBMC
12	LBMC 6	15°37.555' N	73°54.261' E	NA	12.05	11.2	13.1 Km LBMC
13	LBMC 10 m End	15°38'41.75"N	73°52'3.00"E	NA	6.09	10.8	End of 10 m width on LBMC

Table 5-1 Measurement of canal widths

As can be seen from the Table above, there is an error in measurement of the canal width using GIS, since the points for measuring the canal width cannot not be identified accurately. Hence, the chainage data from WRD has been used for identification of canal lengths with width >= 10 m.

5.5 Mapping of potential lengths for setting up solar PV

Even though the total canal length with width more than 10 m was obtained from WRD, it is essential to verify the same for solar PV feasibility using Google Earth. To achieve this, the suitable chainages were marked on Google Earth. The Maps next depicts this mapping of the feasible canal lengths for

Tillari LBMC. These lengths were observed on Google Earth for the solar PV feasibility, to check if any forest cover, bends, etc. are present in the lengths.

The co-ordinates of the 0 points i.e. the start of the jurisdiction of the Tillari RBMC and LBMC within the Goa State boundary were obtained by interacting with the WRD officials.

Thereafter, from the Chainage and corresponding canal width data provided by WRD, the entire length having a width of 10 m or more was plotted on Google Earth using the "Add Path" tool. The same is visible as the Red coloured path in the map given below. The locations captured during the site visit were also marked as LBMC 1 to LBMC 6.

Thereafter, the entire length available for solar PV was checked for presence of aquaducts, tree cover, bends, etc. The feasible lengths are marked in blue colour in the map given below. The procedure was completed for each of the three canals: Tillari RBMC, Tillari LBMC and Salaulim Dam canal.

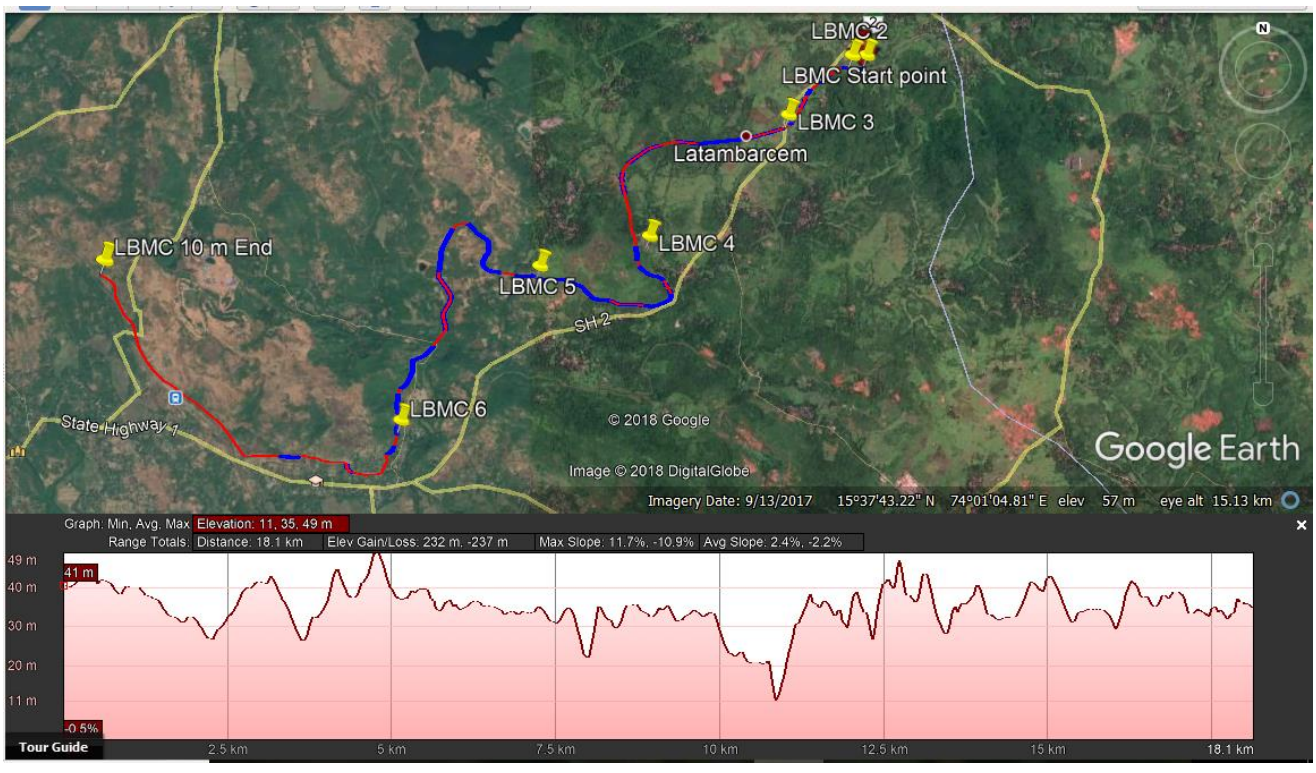


Figure 5-1 Mapping of technically feasible area for canal-top solar PV

5.6 Calculation of canal-top solar PV potential

The feasible length for canal-top solar PV installation obtained as per the procedure given above is compiled in the Table given next.

Sr. No.	Canal Name	Chainage (km) with width more than 10 m		Length available more than 10 m wide (km)	Length of canal actually feasible for solar PV (km)
		From	To		
1	Tillari RBMC	0.000	6.020	**5.594**	**5.32**
2	Tillari LBMC	0.000	18.100	**18.100**	**10.2487**
3	Salaulim Canal	0.095	17.050	**16.955**	**14.3487**
			TOTAL	**40.649**	**29.9174**

Table 5-2 Feasible lengths for canal-top solar PV

Thus, the total canal length feasible for solar PV installation is 29.9174 km. Considering each module of 15 m x 15 m, a total of around 1995 modules can be accommodated in this length, with each module having a capacity of 20 kW.

This amounts to a potential of around 39.9 MWp on the canal length in Goa State.

5.7 Further Exploration

The canal width of 10 m or more has been considered for using the Standard Module of 15 m x 15 m designed by WRD and GEDA. However, there are minor canal extensions with widths of upto 8 m, which can also be explored for installation of solar PV.

As per data obtained from the WRD, a length of at least 10 km on Tillari LBMC and around 8 km on Tillari RBMC is available, which has a width of around 8 m.

This length can be further explored for canal-top solar PV potential estimation as a separate study.

6 Solar PV potential for abandoned mine lands

6.1 Concept of Abandoned Mine Land

In open cast mines, land is excavated to extract minerals. The typical lie cycle of a mine is as below:

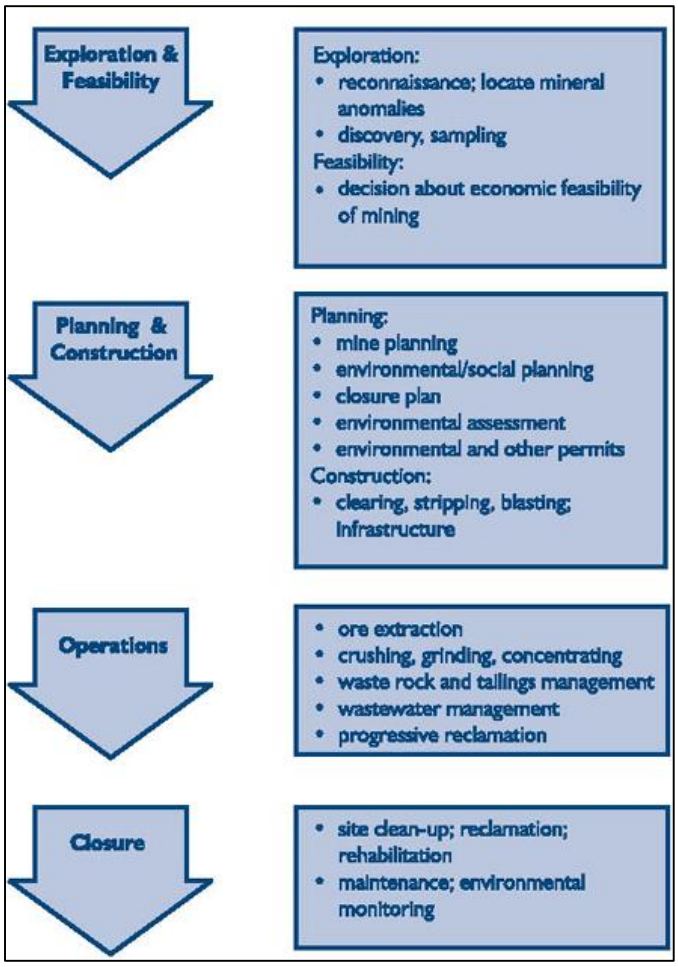


Figure 6-1 Life cycle of a mine

(Source: https://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=CBE3CD59-1&offset=4)

Land is the most important element in all mining operations, and hence, planned and scientific reclamation and rehabilitation of mined out areas and mine waste dumps is the key issue of sustainable development in the mining industry *(http://mines.gov.in/writereaddata/UploadFile/remediationofmined4.pdf).*

As per the Statutory Provisions of the Mineral Conservation and Development Rules (MCDR) 1988, every holder of prospecting license or mining lease shall undertake the phased restoration,

reclamation and rehabilitation of lands affected by prospecting or mining operations and shall complete this work before the conclusion of such operations and the abandonment of prospector mine.

The reclamation of waste dump may be done by afforestation or other suitable methods while back filling, Pisciculture, Rainwater harvesting, recreational water sports etc. may be explored as options for exhausted mine pits. One more option which can be explored for the abandoned mine lands is the setting up of solar PV plants, since a very large area is available in the mine.

In Goa, mining operations have been undertaken on a large scale, mainly in the Talukas of Bicholim, Salcete, Sanguem, Quepem and Dharbandora. In the present study, an estimation of the solar PV potential on the abandoned mine lands in Goa has been done.

The advantage that these abandoned mine lands offer is the abundant supply of water accumulated in the deeper parts of the mine. It can be utilized for panel cleaning purposes.

During the Project, the Project Team was informed that it is not desirable to undertake any land survey on site under the current turbulent scenario of mining within the Goa State. Hence site survey has not been done at any of the mine lands, which would give a clear and complete potential assessment. However, with the help of Mining Department officials, the Project team was able to identify the major abandoned mine lands and for these, the estimation of ground-based solar PV potential using the GIS imagery has been accomplished.

It is necessary that when these land mines will be accessible in future, it is suggested that conducting site survey will help to estimate the actual potential with more reliability and accuracy.

6.2 Data of abandoned mine lands

The data of abandoned mine lands was obtained through the Regional Plan 2021 (RPG) maps from the Town and Country Department, Government of Goa. Data was also obtained from the Mines and Geology Department, Government of Goa. Using the RPG 2021 maps, abandoned mine lands from each of the Talukas were identified on Google Earth for further potential estimation.

6.3 Mapping of the feasible area for solar PV

After identification of the abandoned mine land, the same was marked on Google Earth using the RPG 2021 as a reference. Thereafter, the mine land was explored for potential areas where ground-based solar PV systems could be installed. Such technically feasible areas were marked on Google Earth. The total area feasible was calculated and tabulated along with other details of the mine.

The Diagram given below shows the mapping done for the abandoned mine at Codli in Dharbandora Taluka of Goa. The overall abandoned mine area and the feasible sub-areas for solar PV have been both marked in the map.

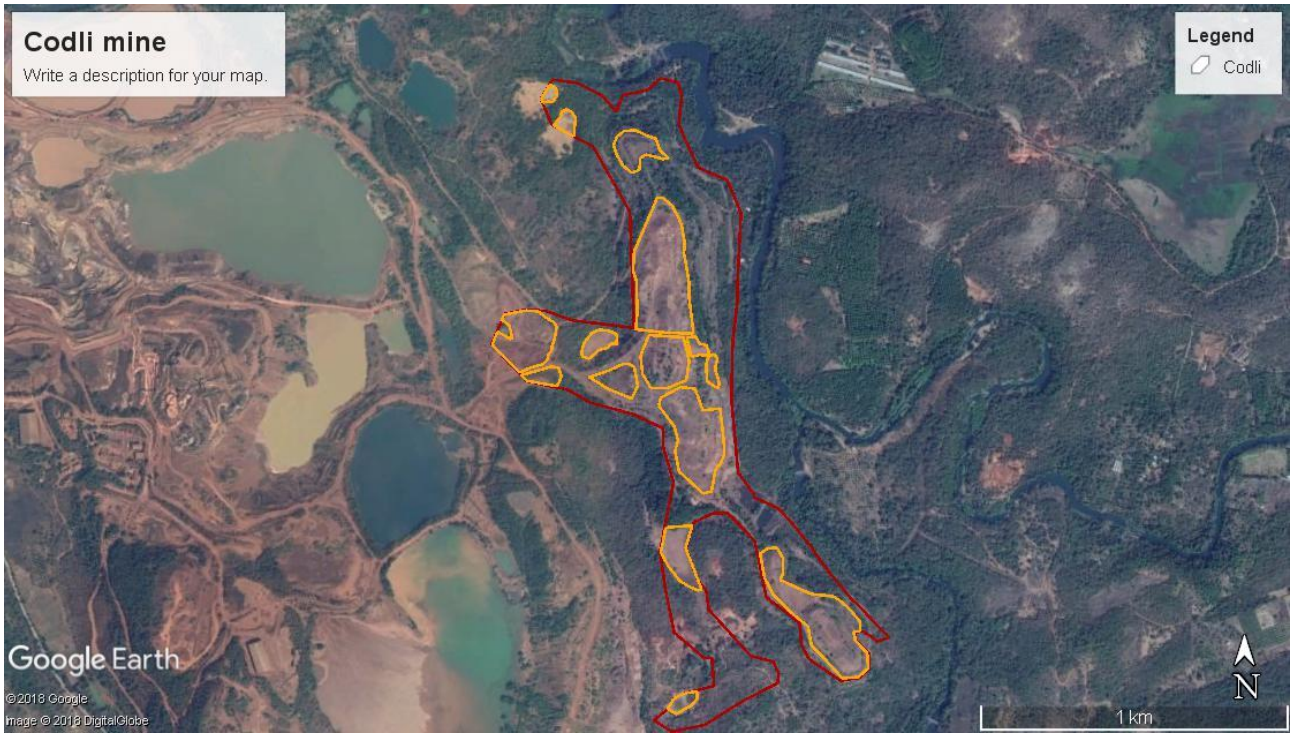


Figure 6-2 Mapping of feasible areas for solar PV in abandoned mine lands

6.4 Estimated solar PV potential in abandoned mine lands

The above procedure was completed for all major abandoned mine lands in the State of Goa. The results of this mapping exercise are tabulated next for reference

No.	Mine ID*	Village	Taluka	Latitude	Longitude	Total Mine Area(m2)	Total feasible area for solar PV (m2)	Generation (kW)
1	Colamb	Colamb	Sanguem	15° 8'29.44"N	74° 7'26.43"E	129920	9509	469.95
2	Uguem 1	Uguem	Sanguem	15°14'16.83"N	74°11'24.66"E	22957	2164	106.95
3	Uguem 2	Uguem	Sanguem	15°14'17.64"N	74°11'38.31"E	22392	2833	140.01
4	Uguem 3	Uguem	Sanguem	15°14'7.00"N	74°11'29.95"E	28380	2048	101.21
5	Uguem 4	Uguem	Sanguem	15°14'4.89"N	74°11'14.57"E	63260	2986	147.57
6	Dharbandora 1	Dharbandora	Dharbandora	15°23'31.09"N	74° 6'27.72"E	300099	40302	1991.77
7	Codli 1	Codli	Dharbandora	15°20'31.45"N	74° 8'51.07"E	786572	281746	13924.19
8	Pissurlem	Pissurlem	Sattari	15°32'15.94"N	74° 4'43.80"E	1803596	338782	16742.97
9	Sirsaim1	Sirsaim	Bardez	15°38'21.22"N	73°53'10.12"E	379269	109368	5405.08
10	Sirsaim2	Sirsaim	Bardez	15°38'43.46"N	73°52'52.72"E	207895	73435	3629.24
11	Sanquelim	Sanquelim	Bicholim	15°33'25.77"N	74° 0'32.15"E	Data not available	38726	1913.88
12	Sangod 1	Sangod	Dharbandora	15°21'38.95"N	74°12'20.06"E	224046	25587	1264.54
13	Sangod 2	Sangod	Dharbandora	15°21'23.76"N	74°12'42.16"E	166331	162761	8043.82
14	Bhati 1	Bhati	Sanguem	15°11'43.23"N	74°14'41.29"E	131930	57916	2862.27
15	Bhati 2	Bhati	Sanguem	15°12'6.56"N	74°13'50.83"E	77385	15478	764.94
	*ID has been given for the purpose of this project only					**TOTAL**	**1163641**	**57508.391**

Thus, the estimated solar PV potential on the abandoned mine lands in Goa is around 57.5 MWp.

7 Conclusions and the Way Forward

7.1 Total roof-top potential estimated for Government Buildings

As per the present study, the roof top solar PV potential on select Government Buildings in the State of Goa is estimated to be 26.05 MWp.

7.2 Canal top potential

The total canal top solar PV potential in the State of Goa is estimated to be 39.9 MWp.

7.3 Potential on abandoned mine lands

The solar PV potential on abandoned mine lands in Goa is estimated through GIS analysis.to be around 57.5 MWp.

7.4 Conclusion

This estimation study has conclusively proved that the State of Goa has the potential to meet the 150 MW solar PV RPO set out by the MNRE and in fact, even more solar PV potential to meet the rising power demands of the State in the years to come.

7.5 The Way Forward

The present Project has given many important insights about the status of power and renewable energy in the State of Goa. Based on these findings, it is possible to take up several related studies/ projects which will prove to be valuable in planning the Energy Scenario in Goa. These are explained below:

- *Solar PV Potential Estimation for Educational Institutions:* In the scope of this Project, the Government Schools which are already mapped on Google Earth were considered for solar PV potential estimation.

  It is proposed that a dedicated study project be taken up to find out the solar PV potential on all Educational Institutions in Goa, right from primary to post-graduation level. If solar PV systems are installed on educational institutions, they will act as a direct demonstration of the concepts of renewable energy given in text books. These systems can be grid-connected and net-metered for

annual billing purpose so as to take care of the months of holidays when the Institutions are not operational.

- *Mapping of all government buildings:* One of the major challenges faced during this Project was the fact that there is no ready-reference which gives the list of all Government Buildings in the State and their geographical locations.

  It is proposed that a Project be taken up for marking/ geo-tagging all the Government Buildings in the State by using GPS. This data can be useful to the Government in several ways such as planning the solar PV installations or O&M of these buildings, etc.
- *Solar PV potential for parking spaces:* Parking lots/ spaces are usually present in all Institutions, are usually covered, and are long. Also their rooftops are usually easily accessible. These can be explored for the solar PV potential.
- *Avoidable losses and correctable faults:* It was observed during the course of this study, that there are a large number of consumers who are paying penalties due to a low power factor. In a large number of cases, Meters were found to be not working. These facts need to be acknowledged and corrected.

8 Annexures

Annexure A: Site Survey Format – for Roof-top

Site Sampling for Solar PV potential estimation	
	Date of sampling: _____
GENERAL INFORMATION	
Name of Taluka:	
Name of Department/ Office/Organization:	
Name of Division/ Sub-Division/Branch (If applicable):	
Total Plot Area (sq.m.):	
Type of Institution:	☐ University ☐College ☐School ☐Govt. office ☐Research Centre ☐Public Amenity ☐Healthcare ☐Govt. Residential ☐ Other: _____
SOLAR RESOURCE AND WEATHER	
Latitude:	Longitude:
Basic Wind Speed (kmph): _____	Insolation (_____) : Avg _____ Max _____ Min _____
Temperatures : Avg _____ Max _____ Min _____	Potential for Extreme Weather: _____
ROOFING	
Shape: ☐ Flat ☐ Curved ☐ Sloping	If sloping, direction of slope: ☐ South ☐ South West ☐ South East ☐ Other
Roof age: _____ years	Structure: ☐ RCC Slab ☐ Ferrocrete ☐ Tiles ☐ Roofing Sheets

Roof condition: ☐ Excellent ☐ Fair ☐ Replace 3-5 years ☐ Replace immediately	Roof pitch: ☐ Flat ☐ Very shallow ☐ Average ☐ Very steep Approx. pitch angle from the horizontal: _____
Details of access to Rooftop: ☐ Staircase ☐ Ladder ☐ No Access ☐ Other: _____	Ease of accessibility of Rooftop: ☐ Easily accessible ☐ Accessible with some trouble ☐ Very difficult to access ☐ Not accessible
Total Roof top area (sq.m.):	Shadow-free Roof top area (sq.m.):
Shading Analysis: _____	

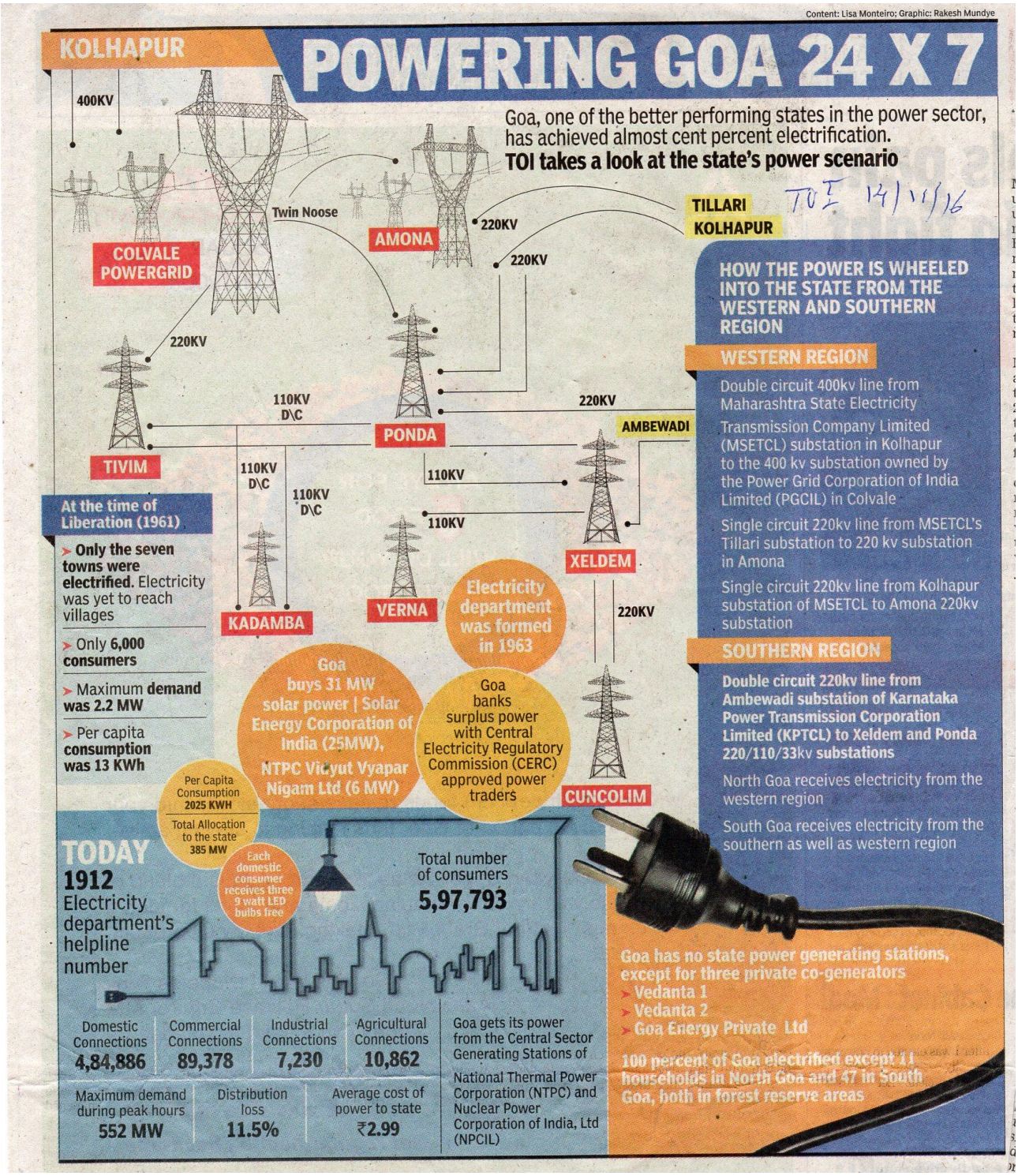
ELECTRICAL SYSTEM

Total Sanctioned Electrical Load (kW):	Average monthly units consumed (kWh/month):
	Incoming Supply: ☐ Single Phase ☐ Three Phase

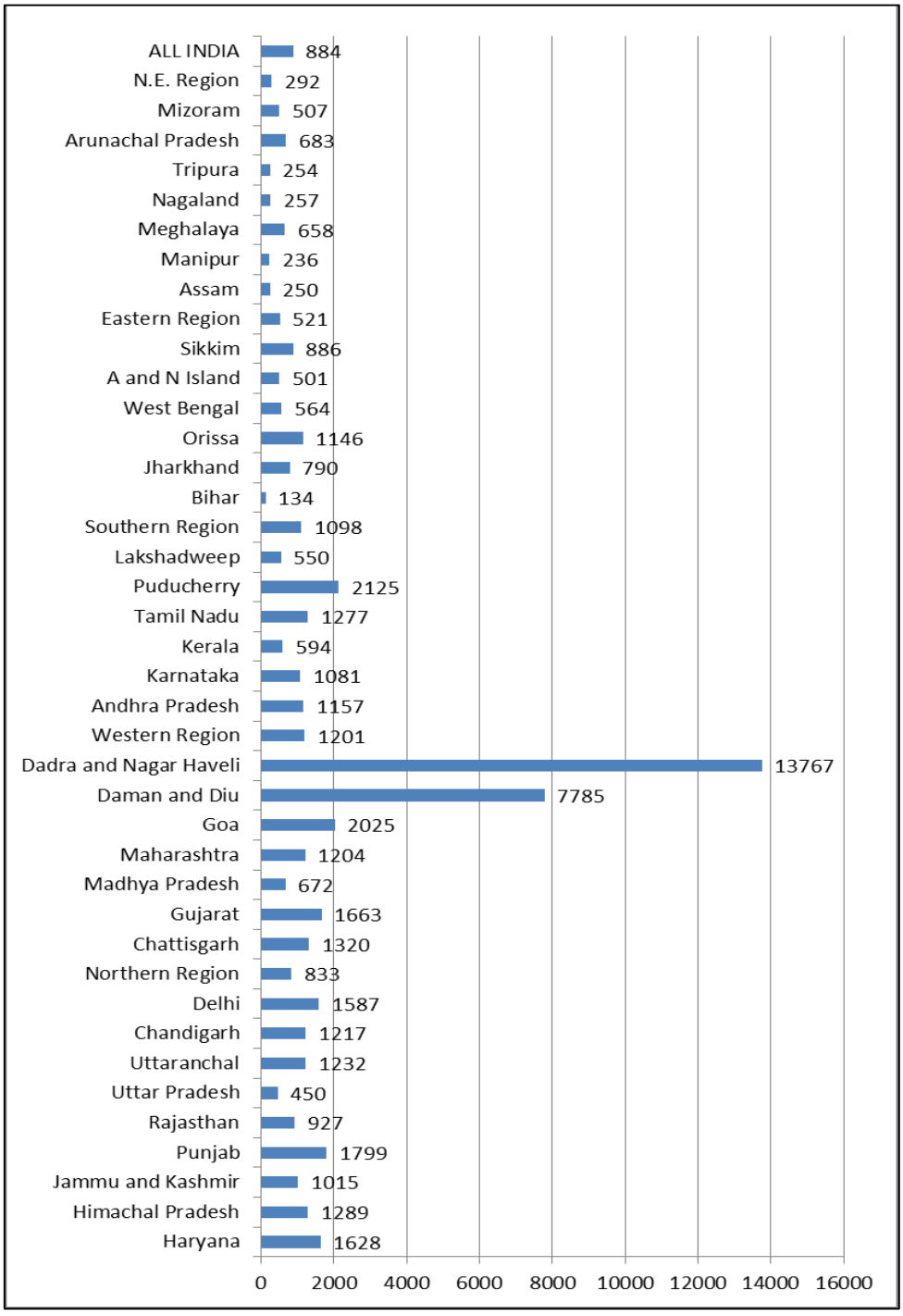
Remarks (if any):
Photos/ Sketch of the site:

Signature: Name: _____	Signature: Name: _____

Annexure B: Power situation in Goa



Annexure C: Graph showing State-wise per capita per year electricity consumption



(Source: https://community.data.gov.in/per-capita-electricity-consumption-during-2006-07-and-2011-12/)

Annexure D: Power Purchase Agreements for the State of Goa

Sr. No.	Sources	State	Capacity	Expected Allocation	Start Date
1	Nuclear Power Corporation of India Ltd. for purchase of power from KAPP – 1 & 2 and TAPP 3 & 4	Gujarat and Maharashtra	2 × 700 = 1400 MW	16 MW	FY 2016-17
2	NTPC Ltd. for purchase of power from Barh Stage – II	Bihar	2x660 =1320 MW	-	-
3	NTPC Ltd. for purchase of power from Solapur STPS	Maharashtra	2X660 MW	13.7 MW	May/Nov-16
4	NTPC Ltd. for purchase of power from Mauda STPS – II	Maharashtra	2 × 660 = 1320 MW	15 MW	March/Nov -16
5	NTPC Ltd. for purchase of power from Vindhyachal STPS – V	Madhya Pradesh	500 MW	6 MW	August 2015
6	NTPC Ltd. for purchase of power from LARA STPS – I & II	Chhattisgarh	2X800 MW	8.7 MW	June/Oct - 16
7	RGPPL for purchase of power from RGPPL Stage – II	Maharashtra	2100 MW	-	-
8	NTPC Ltd. for purchase of power from Khargone STPP	Madhya Pradesh	2X660 MW	8.2 MW	June/Dec-19
9	NTPC Ltd. for purchase of power from Gadarwara STPP – I & II	Madhya Pradesh	2649 MW	9.9 MW	May/Sept - 17

(Source: Document titled "24 X 7 POWER FOR ALL GOA, A Joint Initiative of Government of India and Government of Goa")

Annexure E: Targets for solar roof-top grid connected systems

States wise and Year wise targets proposed for 40,000 MWp Grid Connected Solar Rooftop Projects.

States wise and Year wise targets proposed for 40,000 MWp Grid Connected Solar Rooftop Projects

Sl. No.	States	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
1	Andhra Pradesh	10	240	250	300	350	400	450	2000
2	Bihar	5	120	125	150	175	200	225	1000
3	Chhattisgarh	4	84	88	104	120	140	160	700
4	Delhi	5	132	138	165	190	220	250	1100
5	Gujarat	15	385	400	480	560	640	720	3200
6	Haryana	5	200	200	235	280	320	360	1600
7	Himachal Pradesh	2	38	40	48	56	64	72	320
8	Jammu & Kashmir	2	54	55	74	80	90	95	450
9	Jharkhand	4	96	100	120	140	160	180	800
10	Karnataka	10	275	290	344	403	460	518	2300
11	Kerala	4	96	100	120	140	160	180	800
12	Madhya Pradesh	10	265	275	330	385	440	495	2200
13	Maharashtra	20	565	588	704	823	940	1060	4700
14	Orissa	5	120	125	150	175	200	225	1000
15	Punjab	10	240	250	300	350	400	450	2000
16	Rajasthan	10	275	288	344	403	460	520	2300
17	Tamil Nadu	15	420	438	524	613	700	790	3500
18	Telangana	10	240	250	300	350	400	450	2000
19	Uttarakhand	2	42	44	52	60	70	80	350
20	Uttar Pradesh	20	510	538	660	762	860	970	4300
21	West Bengal	10	252	263	315	370	420	470	2100
22	Arunachal Pradesh	2	5	5	6	10	10	10	50
23	Assam	4	30	30	38	42	50	56	250
24	Manipur	4	3	6	8	9	10	10	50
25	Meghalaya	1	6	6	8	9	10	10	50
26	Mizoram	1	6	6	8	9	10	10	50
27	Nagaland	1	6	6	8	9	10	10	50
28	Sikkim	1	6	6	8	9	10	10	50
29	Tripura	1	6	6	8	9	10	10	50
30	Chandigarh	1	12	12	14	18	20	23	100
31	Goa	1	20	20	22	23	30	34	150
32	Dadra & Nagar Haveli	1	24	25	30	35	40	45	200
33	Daman & Diu	1	12	12	14	18	20	23	100
34	Puducherry	1	12	12	14	18	20	23	100
35	Andaman & Nicobar Islands	1	2	2	2	5	4	4	20
36	Lakshadweep	1	1	1	1	2	2	2	10
	Total	200	4800	5000	6000	7000	8000	9000	40000

Source: https://mnre.gov.in/file-manager/UserFiles/Allocation-of-target-for-750MWp.pdf

Annexure F: Data of sample mapping of Buildings from each Taluka

No.	Taluka	Name of Building	Shape of Roof	Structure of roof	Type of Institution	Available area (SQM)	No of panels	Generation(KW)
1	Sanguem	Mamlatdar Sanguem	Sloping	Tiles	Govt office	94.8	36	11.52
2	Sanguem	Government Higher Secondary School Sanguem	Sloping	Roofing Sheets	School	542.6	202	64.64
3	Sanguem	KTC Bus Stand Sanguem	Sloping	Tiles	Public Amenity	182	120	38.4
4	Sanguem	Government Primary School Sanguem	Sloping	Roofing Sheets	School	50.3	22	7.04
5	Sattari	Govt High School	Sloping	Roofing Sheets	School	407	136	43.52
6	Sattari	Police Training School	Sloping	Roofing Sheets	Government Office	834	250	80
7	Sattari	Valpoi Old Municipality	Sloping	Roofing Sheets	Government Office	123	51	16.32
8	Sattari	PWD,DIVXVI,Valpoi	Sloping	Roofing Sheets	Government Office	500	214	68.48
9	Sattari	Govt Hospital,Valpoi	Sloping	Roofing Sheets	Health Care	1236	340	108.8
10	Sattari	KTC Bus stand,Valpoi	Sloping	RCC Slab	Public Amenity	3332	906	289.92
11	Quepem	Ravindra Bhavan Curchorem	Sloping	RCC Slab	Public Amenity	293	238	76.16
12	Quepem	Quepem Government Office Complex	Sloping	Tiles	Govt office	333	154	49.28
13	Quepem	GOVT. COLLEGE OF ARTS, SCIENCE AND COMMERCE, QUEPEM-GOA	Curved	Roofing Sheets	College	3160.5	1247	399.04
14	Quepem	Fire Station Curchorem	Sloping	Tiles	Govt office	187.5	121	38.72
15	Quepem	Cacora Govt. ITI	Sloping	Roofing Sheets	College	617.6	367	117.44
16	Salcete	RAVINDRA BHAVAN-MARGAO	Curved	RCC Slab	Public Amenity	1262	413	132.16
17	Salcete	SGPDA Market Margao	Sloping	Tiles	Public Amenity	5506	1799	575.68

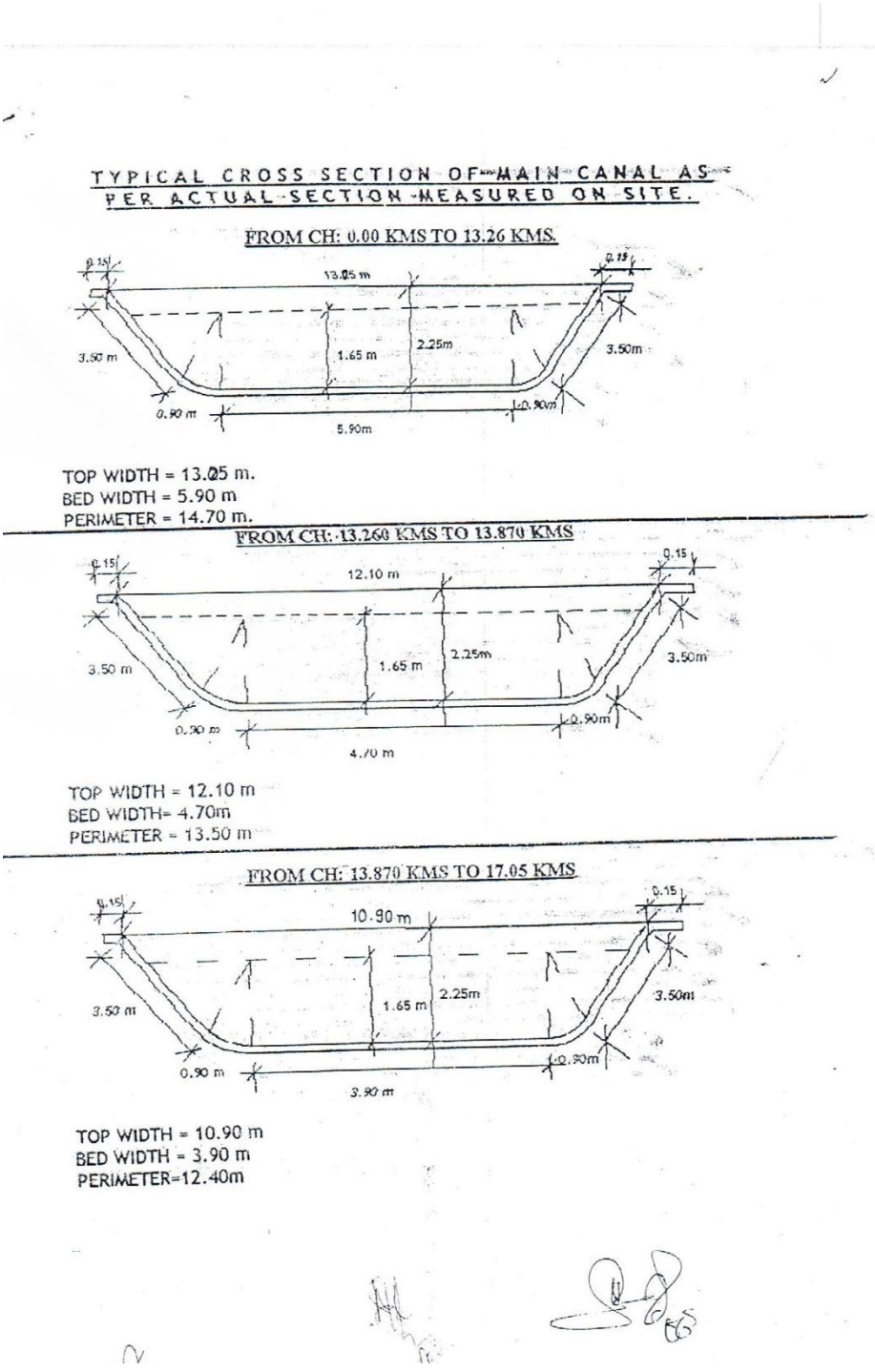
18	Salcete	South Goa District Collectorate	Sloping	Tiles	Govt office	1451	551	176.32
19	Salcete	Margao Municipal Council	Sloping	Tiles	Public Amenity	489	184	58.88
20	Salcete	PJN Stadium Fatorda Margao	Curved	Roofing Sheets	Public Amenity	10872	4055	1297.6
21	Mormugao	Mormugao Municipal Council	Sloping	Tiles	Govt office	687	121	38.72
22	Mormugao	NATIONAL CENTRE FOR ANTARCTIC & OCEAN RESEARCH	Sloping	Tiles	Research center	2211.3	587	187.84
23	Mormugao	NATIONAL CENTRE FOR ANTARCTIC & OCEAN RESEARCH-2	Sloping	Tiles	Research center	292.8	72	23.04
24	Mormugao	Vasco Govt. ITI	Sloping	Tiles	College	1176	332	106.24
25	Mormugao	KV 1	Sloping	Tiles	School	2000.8	483	154.56
26	Mormugao	KV 2	Flat	RCC Slab	School	1195.5	256	81.92
27	Mormugao	RAVINDRA BHAVAN - BAINA, VASCO	Flat	RCC Slab	Public Amenity	1005	366	117.12
28	Canacona	Mamlatdar of Canacona	Sloping	Tiles	Govt office	519	208	66.56
29	Canacona	CHC Canacona	Sloping	Roofing Sheets	Healthcare	336.8	124	39.68
30	Canacona	KTC Bus stand Canacona	Curved	Roofing Sheets	Public Amenity	1360	502	160.64
31	Canacona	Canacona Municipal Council	Sloping	Tiles	Govt office	183.9	76	24.32
32	Canacona	Sub Post office Canacona	Sloping	Roofing Sheets	Govt office	46.9	19	6.08
33	Dharbandora	Village Panchayat Dharbandora	Sloping	Tiles	Govt office	68.9	26	8.32
34	Dharbandora	Mamlatdar Dharbandora	Sloping	Tiles	Govt office	78.8	36	11.52
35	Bardez	KTC Bus Stand	Sloping	Roofing Sheets	Public Amenity	712	237	75.84
36	Bardez	Police Station,Mapusa	Sloping	Roofing Sheets	Government Office	224	74	23.68
37	Bardez	Peddem Sports Complex	Curved	RCC Slab	Public Amenity	5844	2134	682.88
38	Bardez	Mapusa District Hospital	Flat	RCC Slab	Health Care	3297	986	315.52

39	Bardez	Mapusa Municipality Market	Sloping	Roofing Sheets	Health Care	1547	498	159.36
40	Ponda	Admin GEC	Sloping	Tiles	University	1250	306	97.92
41	Ponda	GEC Boys Hostel II	Sloping	Roofing Sheets	University	301	72	23.04
42	Ponda	GEC Boys Hostel III	Sloping	RCC Slab	University	1063	220	70.4
43	Ponda	GEC Boys Hostel IV	Sloping	RCC Slab	University	371	88	28.16
44	Ponda	GEC Building Near IT Department	Sloping	Roofing Sheets	University	470	114	36.48
45	Ponda	GEC Buildings Near to extc Dept	Sloping	Roofing Sheets	University	456	144	46.08
46	Ponda	GEC Civil +Mechanical+ Science Lab(Building opp to workshop)	Sloping	Roofing Sheets	University	4592	1140	364.8
47	Ponda	GEC Electronics and telecommunications	Sloping	Roofing Sheets	University	1385	287	91.84
48	Ponda	GEC Girls Hostel I	Sloping	Roofing Sheets	University	166	36	11.52
49	Ponda	GEC Goa IITand GEC girls hostel	Sloping	Ferrocrete	University	984	152	48.64
50	Ponda	GEC Gymkhana	Sloping	Roofing Sheets	University	191	40	12.8
51	Ponda	GEC Happening Ground building	Sloping	Roofing Sheets	University	182	32	10.24
52	Ponda	GEC Information Technology	Sloping	Roofing Sheets	University	1255	286	91.52
53	Ponda	GEC Lshape Buiding+Electrical Dept	Sloping	Roofing Sheets	University	2916	424	135.68
54	Ponda	GEC Mining Dept	Sloping	Roofing Sheets	University	1404	344	110.08
55	Ponda	Post Office	Sloping	Roofing Sheets	University	119	12	3.84
56	Ponda	GEC Workshop	Sloping	Roofing Sheets	University	996	192	61.44
57	Ponda	Ponda Fire Station	Sloping	Roofing Sheets	Government Office	286	61	19.52
58	Ponda	Rajiv Gandhi Kalamandir	Flat	RCC Slab	Public Amenity	1982	572	183.04
59	Ponda	ID hospital	Flat	RCC Slab	Health Care	1182	380	121.6

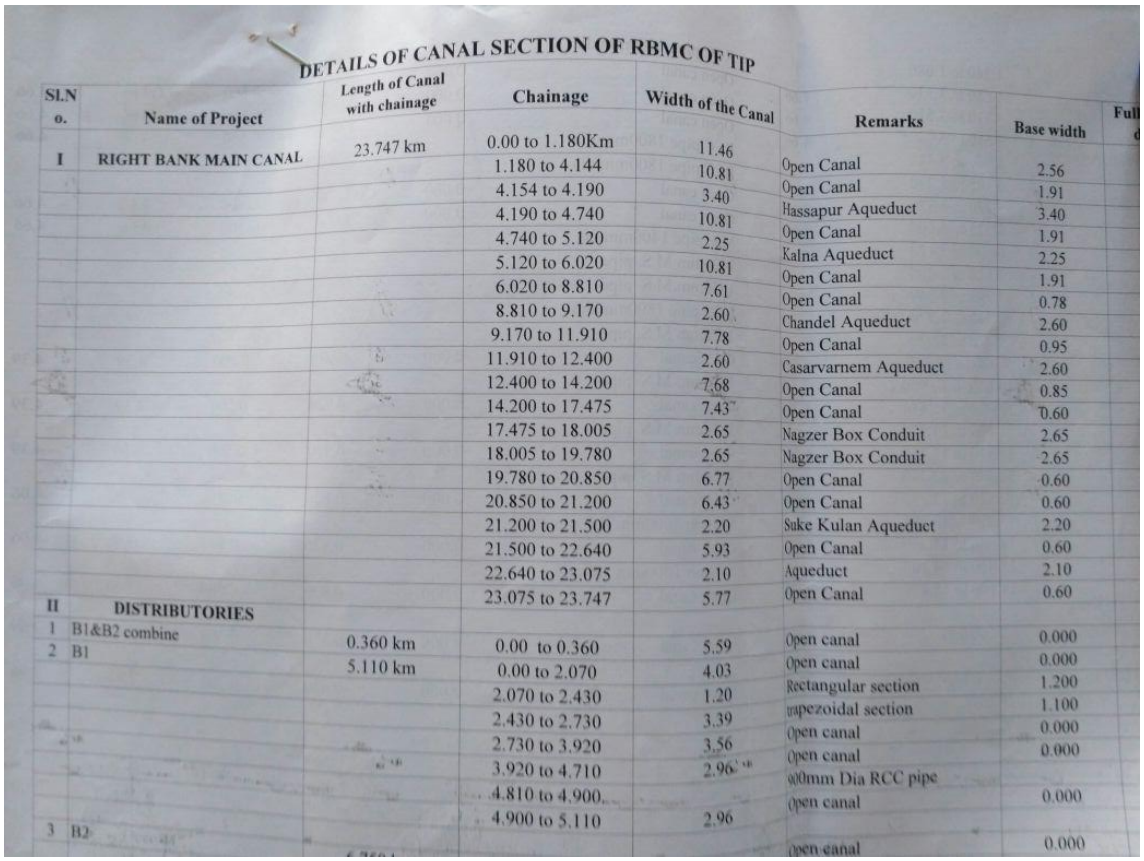
60	Ponda	Mamlatdar Office	Sloping	RCC Slab	Government Office	333	76	24.32
61	Tiswadi	Directorate of Art and Culture	Sloping	Roofing Sheets	Government Office	1717	375	120
62	Tiswadi	RAJ BHVAN	Sloping	Roofing Sheets	Government Office	874	242	77.44
63	Tiswadi	Secretariat	Sloping	RCC Slab	Government Office	1278	465	148.8
64	Tiswadi	Goa Education Department	Flat	RCC Slab	Government Office	552	92	29.44
65	Tiswadi	Aayakar Bhavan	Flat	RCC Slab	Government Office	179	54	17.28
66	Tiswadi	Vidyut Bhavan	Sloping	Tiles	Government Office	453	157	50.24
67	Pernem	Pernem Municipal Council	Sloping	Tiles	Government Office	843	220	70.4
68	Pernem	Police station-Pernem	Sloping	Roofing Sheets	Government Office	421	120	38.4
69	Pernem	Pernem Govt Gym	Sloping	Roofing Sheets	Public Amenity	217	70	22.4
70	Pernem	Pernem ITI	Sloping	Roofing Sheets	College	1017	330	105.6
71	Pernem	Health Care Center,Tuyem	Sloping	Roofing Sheets	Health Care	664	152	48.64
72	Bicholim	RTO office	Sloping	Roofing Sheets	Government Office	182	54	17.28
73	Bicholim	Govt Primary School	Sloping	Roofing Sheets	School	298	104	33.28
74	Bicholim	Police Station	Sloping	Roofing Sheets	Government Office	362	110	35.2
75	Bicholim	Health Care Center	Sloping	Roofing Sheets	Health Care	436	148	47.36
76	Bicholim	Govt Hospital,Sanquelim	Sloping	Roofing Sheets	Health Care	1076	312	99.84
77	Sattari	Govt High School	Sloping	Roofing Sheets	School	407	136	43.52
78	Sattari	Police Training School	Sloping	Roofing Sheets	Government Office	834	250	80
79	Sattari	Valpoi Municipality	Sloping	Roofing Sheets	Government Office	123	51	16.32
80	Sattari	PWD,DIVXVI,Valpoi	Sloping	Roofing Sheets	Government Office	500	214	68.48
81	Sattari	Govt Hospital,Valpoi	Sloping	Roofing Sheets	Health Care	1236	340	108.8
82	Sattari	KTC Bus stand,Valpoi	Sloping	RCC Slab	Public Amenity	3332	906	289.92

Annexure G: Data of Canals obtained from Water Resources Department, Government of Goa

1. Salaulim Dam Canal



2. Tillari Right Bank Main Canal



DETAILS OF CANAL SECTION OF RBMC OF TIP

SL.No.	Name of Project	Length of Canal with chainage	Chainage	Width of the Canal	Remarks	Base width	Full d
I	RIGHT BANK MAIN CANAL	23.747 km	0.00 to 1.180Km	11.46			
			1.180 to 4.144	10.81	Open Canal	2.56	
			4.154 to 4.190	3.40	Open Canal	1.91	
			4.190 to 4.740	10.81	Hassapur Aqueduct	3.40	
			4.740 to 5.120	2.25	Open Canal	1.91	
			5.120 to 6.020	10.81	Kalna Aqueduct	2.25	
			6.020 to 8.810	7.61	Open Canal	1.91	
			8.810 to 9.170	2.60	Open Canal	0.78	
			9.170 to 11.910	7.78	Chandel Aqueduct	2.60	
			11.910 to 12.400	2.60	Open Canal	0.95	
			12.400 to 14.200	7.68	Casarvarnem Aqueduct	2.60	
			14.200 to 17.475	7.43	Open Canal	0.85	
			17.475 to 18.005	2.65	Open Canal	0.60	
			18.005 to 19.780	2.65	Nagzer Box Conduit	2.65	
			19.780 to 20.850	6.77	Nagzer Box Conduit	2.65	
			20.850 to 21.200	6.43	Open Canal	0.60	
			21.200 to 21.500	2.20	Open Canal	0.60	
			21.500 to 22.640	5.93	Suke Kulan Aqueduct	2.20	
			22.640 to 23.075	2.10	Open Canal	0.60	
			23.075 to 23.747	5.77	Aqueduct	2.10	
					Open Canal	0.60	
II	DISTRIBUTORIES						
1	B1&B2 combine	0.360 km	0.00 to 0.360	5.59	Open canal	0.000	
2	B1	5.110 km	0.00 to 2.070	4.03	Open canal	0.000	
			2.070 to 2.430	1.20	Rectangular section	1.200	
			2.430 to 2.730	3.39	Trapezoidal section	1.100	
			2.730 to 3.920	3.56	Open canal	0.000	
			3.920 to 4.710	2.96	Open canal	0.000	
			4.810 to 4.900		900mm Dia RCC pipe		
			4.900 to 5.110	2.96	Open canal	0.000	
3	B2				Open canal	0.000	

3. Tillari Left Bank Main Canal

CANAL SECTIONS OF LBMC OF TIP					
Chainage		Bottom width	Full supply depth	Free Board	Top width at Free board
From	To				
Ch. 0.000 km	1.700 km	2.80m	2.40m	0.75m	12.80m
Ch. 1.700 km	13.100 km	2.20m	2.10m	0.75m	11.20m
Ch. 13.100 km	18.100 km	1.80m	2.10m	0.75m	10.80m
Ch. 18.100 km	21.040 km	1.10m	1.90m	0.75m	9.45m
Ch. 21.040 km	28.970 km	1.10m	1.90m	0.75m	9.45m
Ch. 28.970 km	37.425km	Pressure conduit			

Annexure H: Photographs

Site sampling of Government Buildings

Sampling at Goa Engineering College, Ponda

Sampling at Panjim

Site sampling of canals

Sampling at Tillari RBMC

9 References

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