SPIBEAT Pro ~
Spatially Integrated Building Energy Assessment Tool

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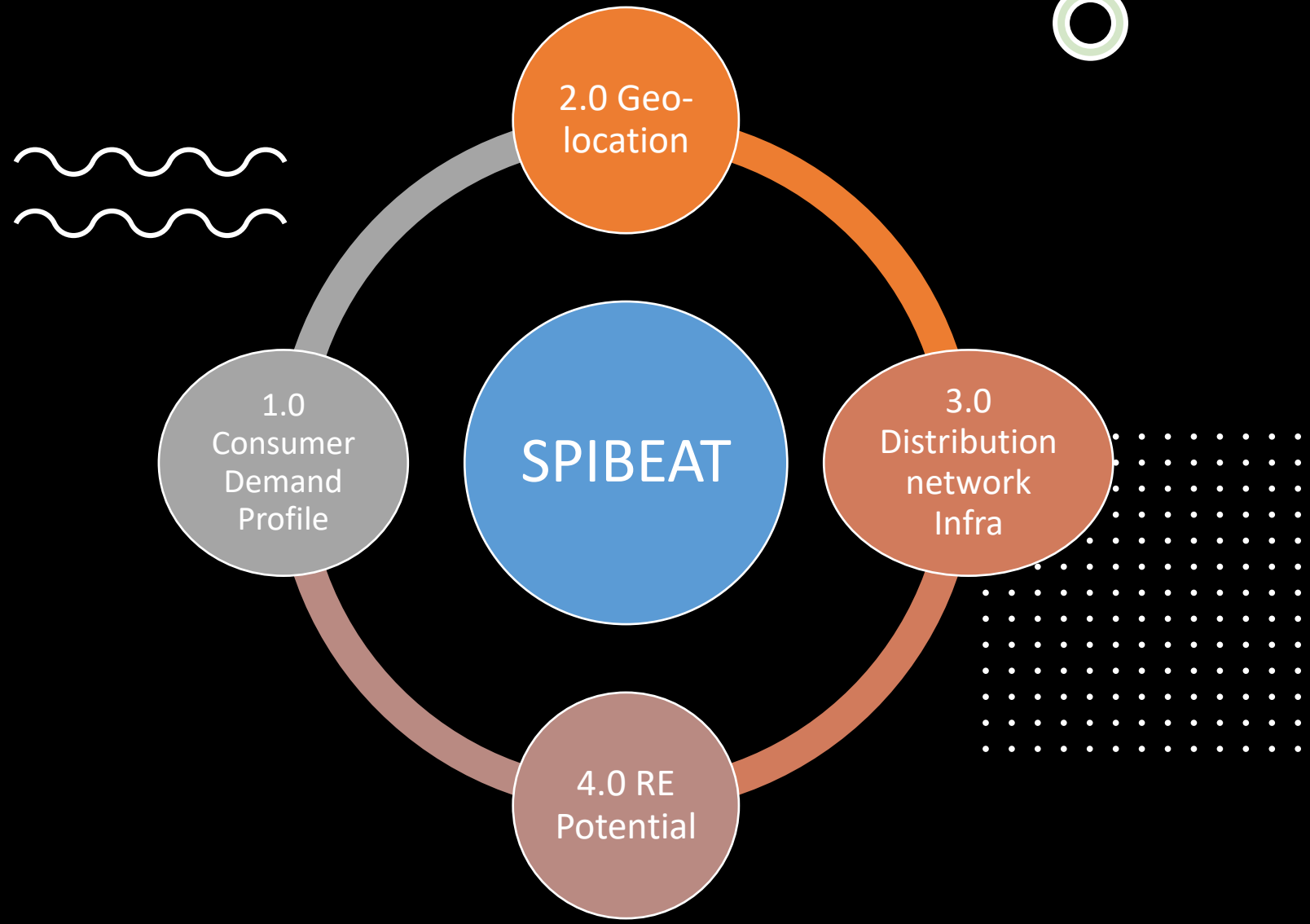
Why we need this ?

- ✓India needs massive RE capacity addition to meet the Net Zero Target by 2070 and therefore needs structured planning of generation, transmission and distribution.
- ✓As of now, distribution network level analysis is less, and very little planning is done with appropriate planning tool.
- ✓Demand data is not easily available and accessible for analysis at consumer level which hinders the network planning work.
- ✓Distribution systems are the last mile connectors and need to fully integrated to the whole RE planning process including their LT networks.
- ✓Demand flexibility is critical for integrating renewable energy and managing peak loads efficiently and managing the cost of power supply.

SPIBEAT~Pro integrates four major pillars of decision-making process of distribution network planning and capacity expansion.



Distribution Network Planning and Capacity Expansion: Inputs from SPIBEAT

- location-specific information for RE potential
- Building wise standard hourly load profile
- Demand centric distribution network infrastructure availability and its operational condition.
- Location specific non-electrical but essential planning information including population, other physical infrastructures, land use & cover, climatic condition etc.

SPIBEAT is a powerful future planning tool with full functionality of network expansion option with the users

How SPIBEAT Pro can help?

ELECTRICAL ENERGY DEMAND PROFILING BY CATEGORY AND APPLIANCES (AT EVERY BUILDING LEVEL) FOR DISCOMS, CONSIDERING EXISTING BUILDING STOCKS, POPULATION, CLIMATIC CONDITION AND OTHER BUILDING INFORMATION.

IDENTIFY AND EVALUATE SUITABLE ROOFTOP AREAS FOR SOLAR PV INSTALLATIONS, CONSIDERING BUILDING SURFACE AREA, ORIENTATION, SHADING ETC. : REALISTIC RT POTENTIAL WITH LOCATION

IDENTIFICATION OF LOCATION OF EV CHARGING INFRASTRUCTURE WITH REFERENCE TO ROAD NETWORK AND OTHER DEMOGRAPHICS, ELECTRICAL NETWORK INFRASTRUCTURE AVAILABILITY ETC.

CONDUCT COMPREHENSIVE POWER SYSTEM ANALYSIS OF THE NETWORK

DEVELOP STRATEGIES FOR INTEGRATING RENEWABLE ENERGY SOURCES INTO THE EXISTING DISTRIBUTION NETWORK, ADDRESSING CHALLENGES LIKE INTERMITTENCY GRID STABILITY, NEED FOR ENERGY STORAGE WITH CAPACITY TO MAXIMIZE RE UPTAKE.

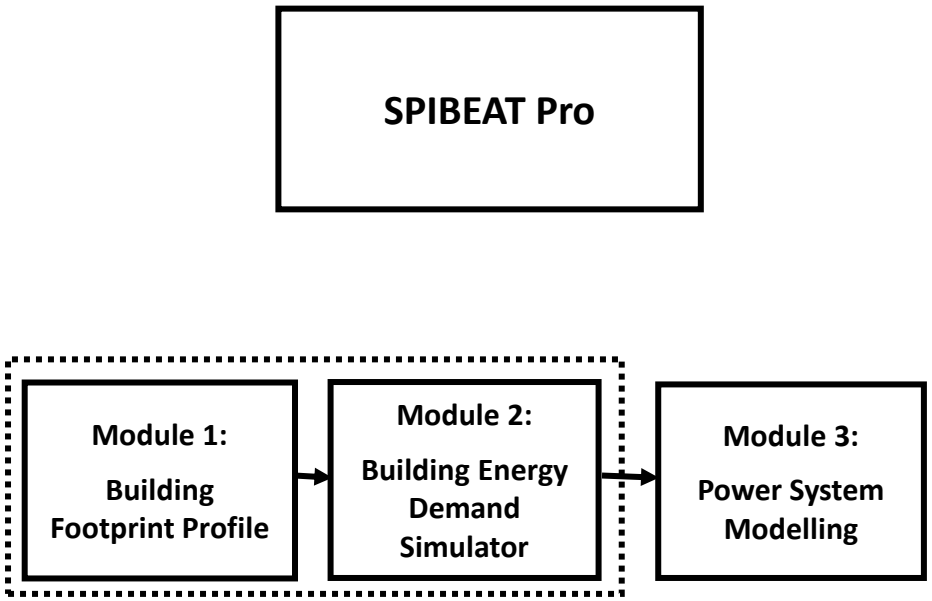
CONDUCT SITE SUITABILITY ASSESSMENT (MCA) TO IDENTIFY LOCATION SPECIFIC RE & EV CHARGING STATION INSTALLATION PLAN.

HELP TO ASSESS THE IMPACTS OF DEMAND RESPONSE & FLEXIBILITY TO REDUCE PEAK DEMAND AND OPTIMIZE COST OF POWER.

Uniqueness of the tool

- Simultaneous focus on both Energy and Environment (co-optimization) in a least cost manner.
- Obtaining suitable location for RE and EV Charging stations with electrical network analysis : network stability, reliability and quality
- Obtaining location & building wise standard hourly demand profile by appliance type without physical survey and data collection.
- The database is made under the consideration of the Indian Scenario
- An 8760-hour scheduling framework incorporating human behavioral pattern along with seasonal variations and usage typologies.
- Open source platform and User-based editing options available

Functional Steps of SPIBEAT Pro (SPIBEAT + PSA)



SPIBEAT

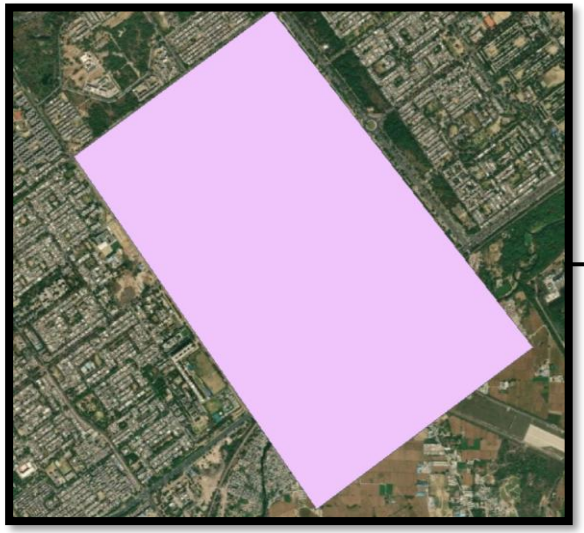
- **Step- 1:** Building Footprint Extraction
- **Step-2:** Assessing detailed electrical load demand
- **Step-3:** Estimating the Renewable Energy Potential.

Power System Analysis

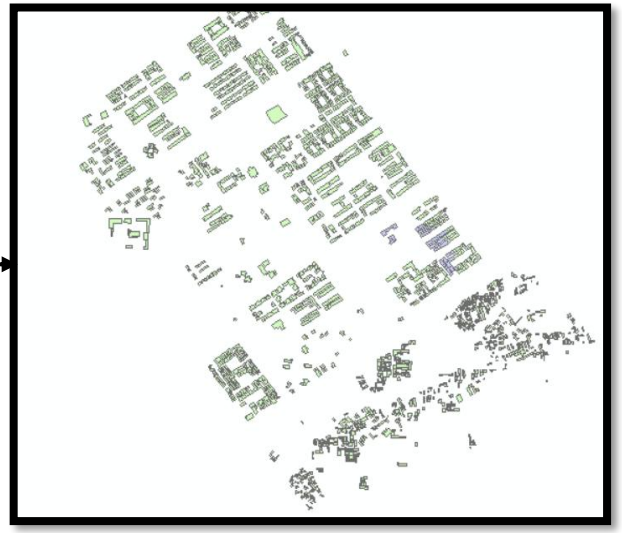
- **Step-4:** Model the Power System Network for load flow analysis.
- **Step-5:** SRT/RE Injection Site Suitability Assessment using multi-criteria analysis
- **Step-6**: Demand response & flexibility analysis.

1.0 Building Footprint Extraction

•A spatial representation of the urban built-up area for the selected city is developed.
•Building footprints are processed using a Python-based automated workflow to clean, validate, and standardize datasets as per simulator requirements.
•Building geometry attributes such as height, number of floors, GFA, rooftop area along with unique building identifiers are derived from building footprints.
•Built-up volume (occupied floor space) is captured to generate a simulation-ready database for energy modelling.



Selected Study Area



Building footprint of the selected area

2.0 Building Energy Simulator

Automated building energy simulation framework that combines EPW weather data, building geometry, archetypes, and construction properties to estimate cooling demand, electricity consumption, end-use load profiles, and rooftop solar potential.

Inputs:

- Weather file from Climate.OneBuilding.org
- Building Simulator-ready building shapefile (geometry + attributes)
- Building archetypes (use type, schedules, internal loads)
- Building assemblies and components (envelope and HVAC properties)

Outputs from Building Energy Simulator

- End-use Load Profile (Lighting, Appliances, Auxiliary, Hot Water, Cooling)
- Space Cooling Demand
- Rooftop Solar Potential

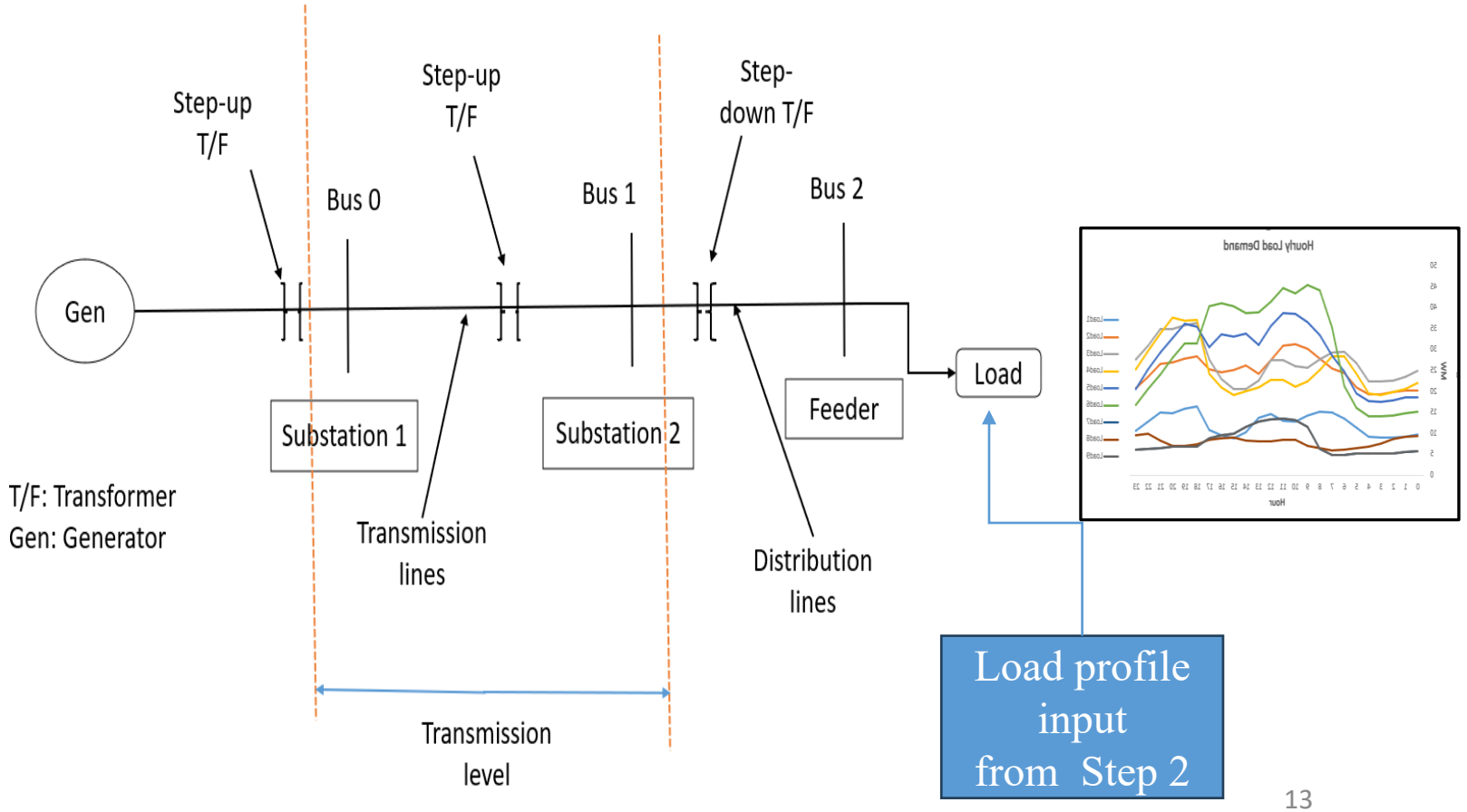
3.0 Power System Analysis: What it does ?

- ✓ Optimize the power flows and network operations to ensure a reliable and cost-effective electricity supply .
- ✓ Assess and optimize the integration of renewables and storage.
- ✓ Understanding the technical, locational and economic implications of RE and EV integration to the current electrical network.
- ✓ Assess the requirements of energy storage systems to support the RE integration.

Inputs for Power System Model

Shape Files:

- Information of Substations DTs with respective feeders, along with their capacity and RE installed capacity with geographical location
- Network information such as connectivity, length, rated capacity, and other technical parameters at distribution level
- Establishing a virtual network between DT and building level consumers to enable load mapping at DT level
- Aggregated building load data at DT level/feeder Level from building simulator (step 2)



Outputs from Power System Modelling

- **Output for different Scenarios**

✓ Identification of loaded feeders (up to DT level) beyond 75% for different RE(solar, wind, others), EV charging cases, and BESS

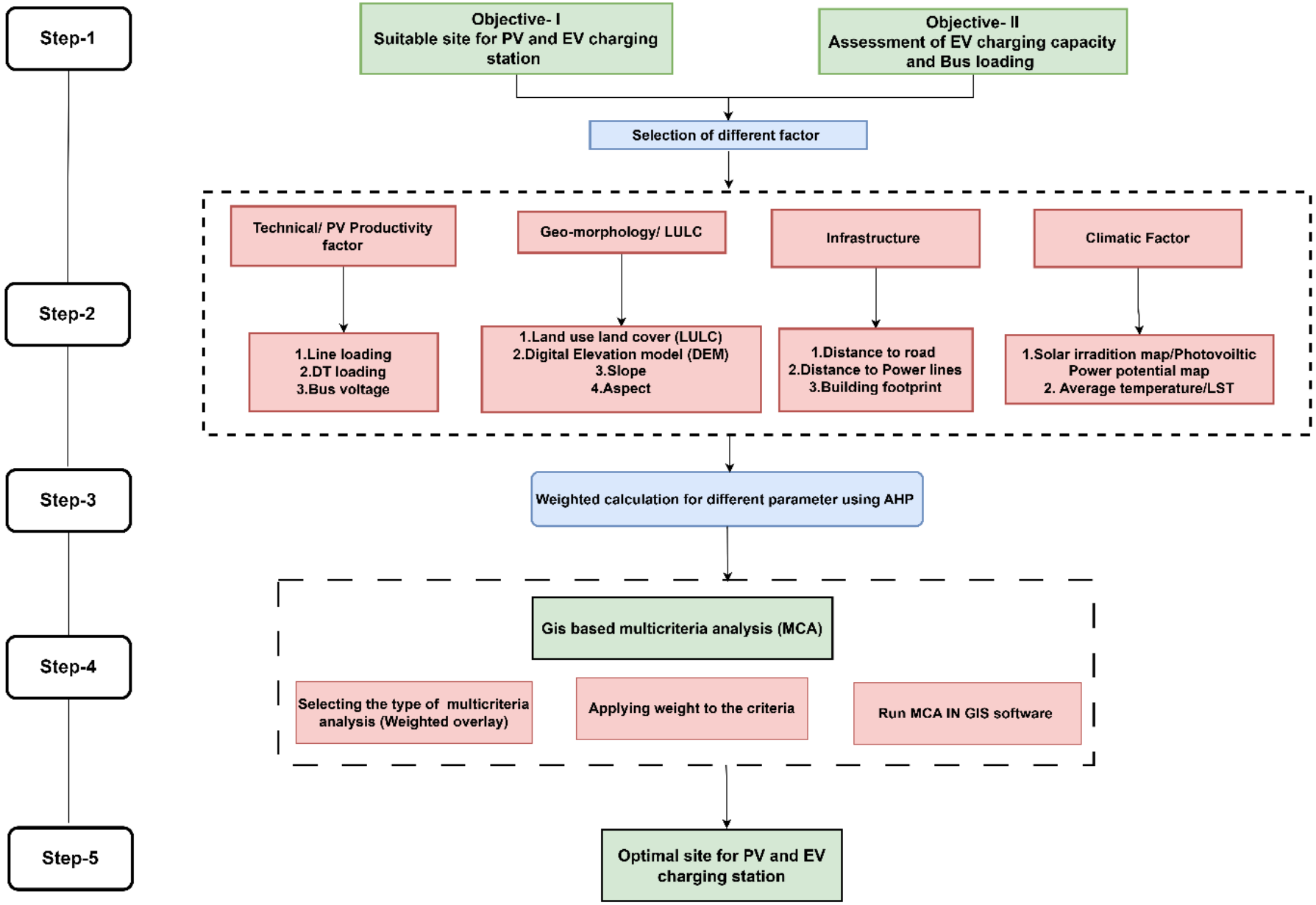
✓ Identification of the loaded DTs beyond 90% for different RE(solar, wind, others), EV charging cases, and BESS

✓ Identification of Voltage beyond 10% of the allowable range, for different capacities of RE(solar, wind, others), EV charging cases, and BESS

✓ Identifying the hosting capacity (i.e, the bottleneck) of RE EV charging cases, and BESS at the particular DT based on the technical impact on the grid due to injection

4.0 Multi-criteria Analysis for SRT/RE Injection Site Suitability Assessment

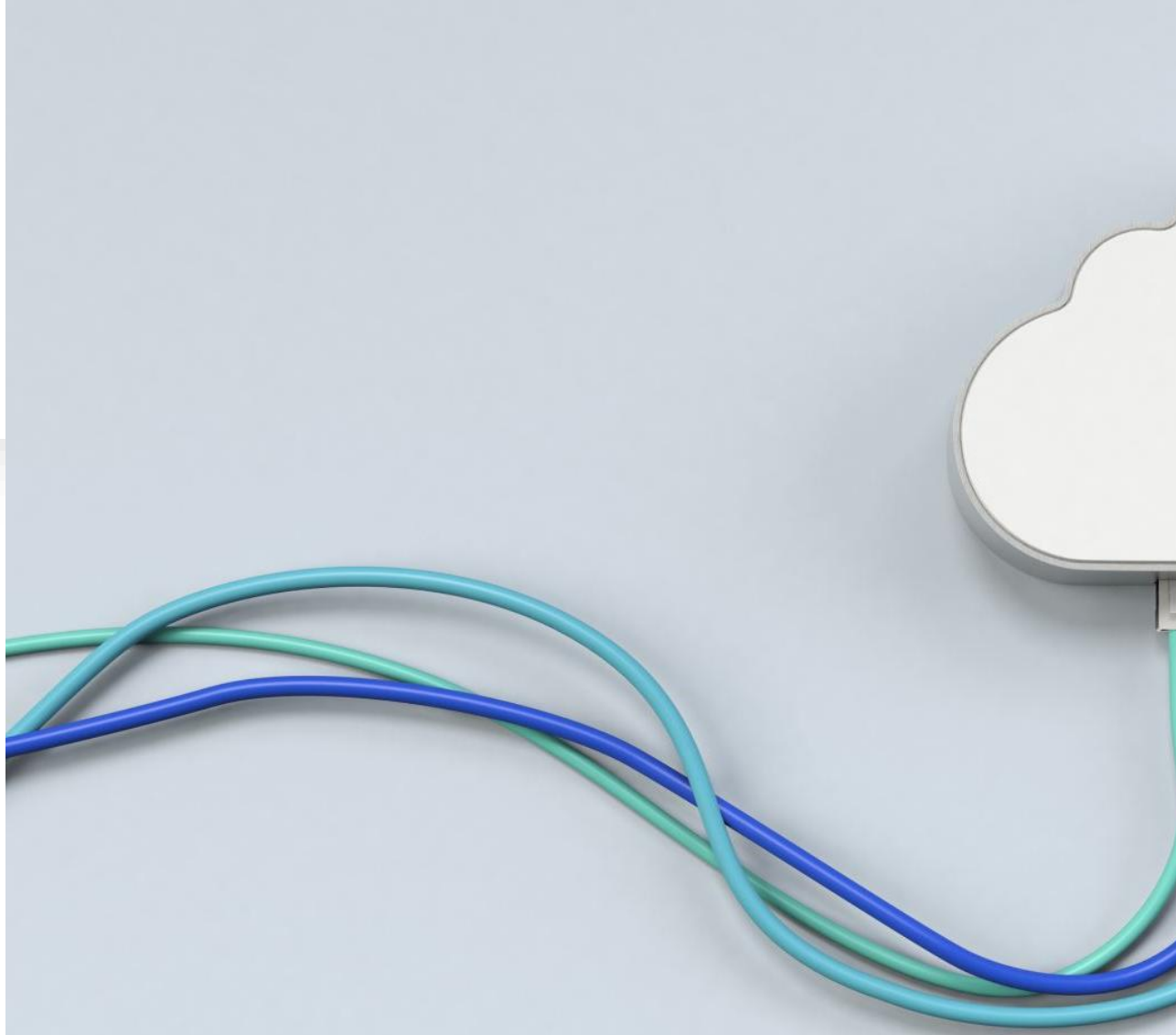
Site Suitability Assessment: MCD Framework



5.0 Demand Flexibility/Response: Using SPIBEAT~Pro

Demand Flexibility for DISCOMs

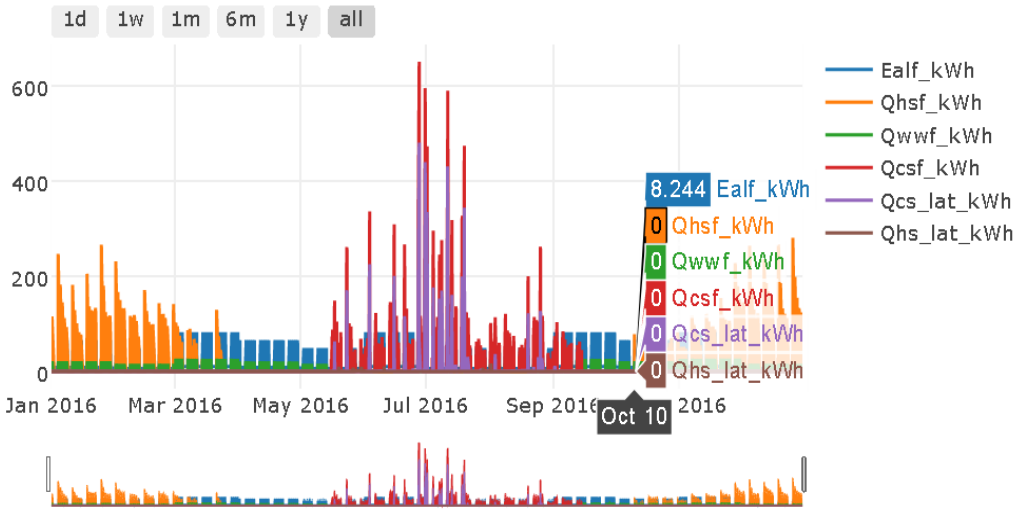
- ✓ Demand flexibility allows electricity consumption to be adjusted based on grid conditions, reducing peak loads and enhancing stability.
- ✓ Methods include:
  - ✓ Load shifting during peak hours to reduce stress on the grid.
  - ✓ Capacity reductions to optimize resource use and minimize costs.
  - ✓ Demand-side response using price signals and storage integration.
- ✓ Helps DISCOMs by lowering infrastructure costs, improving grid reliability, and increasing renewable energy utilization.



Input for Demand Flexibility/ Demand Response in SPIBEAT

Identifying the Flexible Load through SPIBEAT

- Projected Hourly Load Profile (MW/kW) by consumer type
- Tariff(Rs/pu) of the load (Flat Rate or TOD based on consumer type)

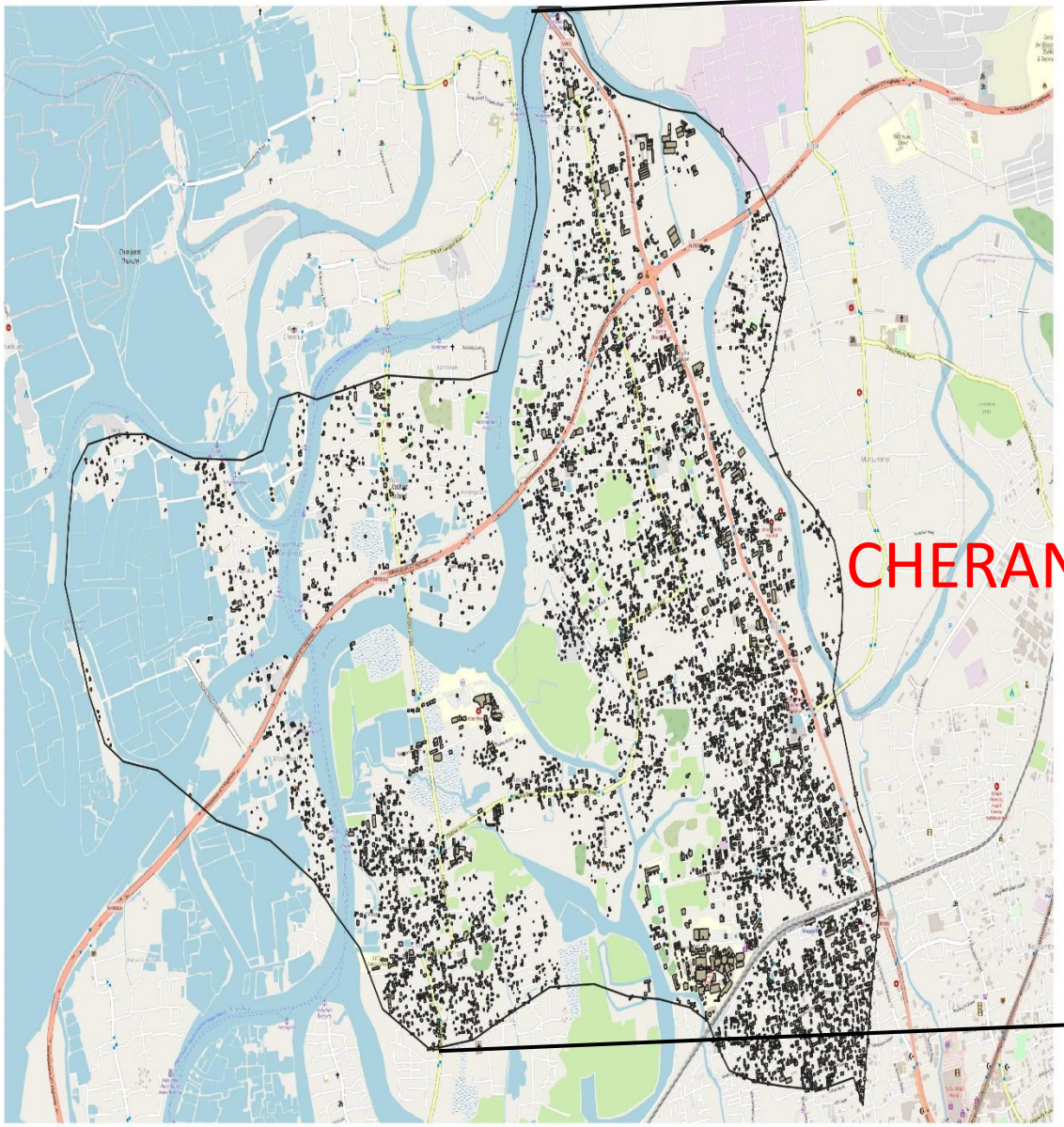


- hourly profiles of electricity consumption of various energy services inside the occupied buildings.
- Space cooling (sensible and latent)Artificial lighting
- Appliances and devices,
- Refrigeration.

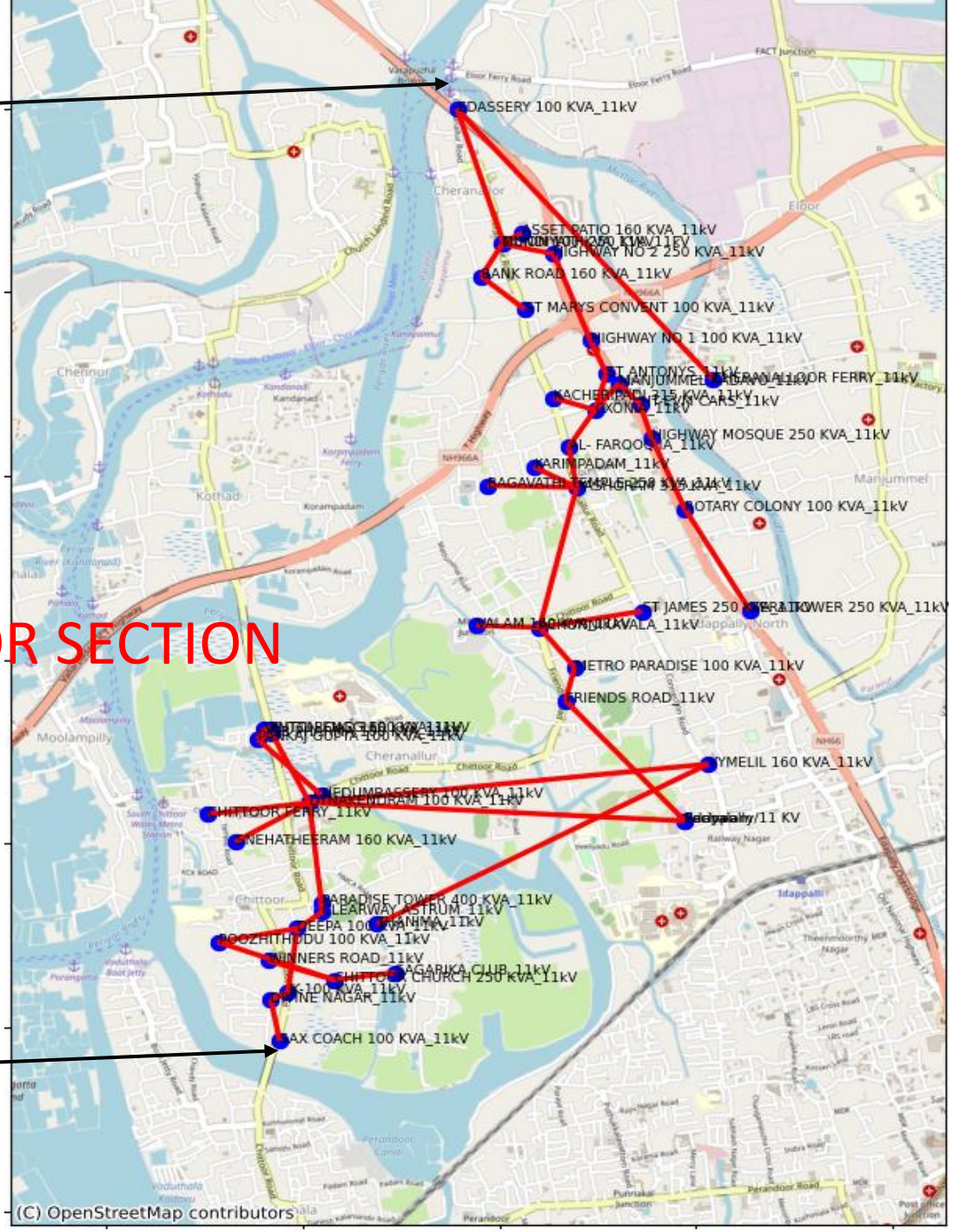
Application of SPIBEAT~Pro

1.0 Building wise load profile (For Cheranallor Section of KSEB, Kerala)

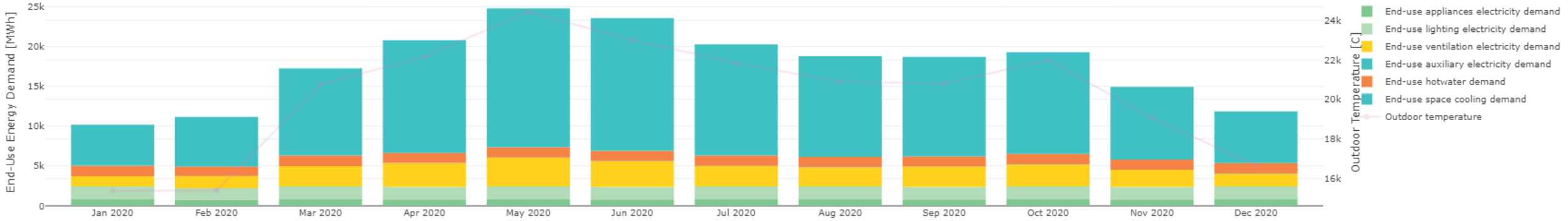
The CelestialEarth



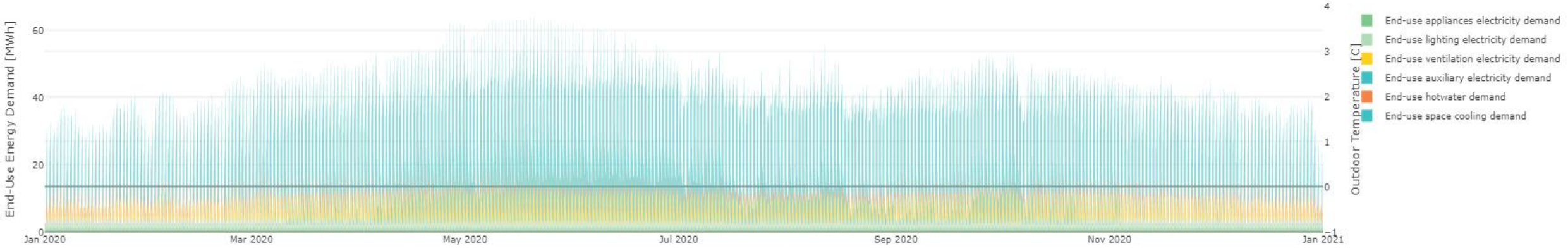
CHERANALLOR SECTION



Load profile of 2000 buildings in Cheranallor Section of KSEB



Monthly load Profile

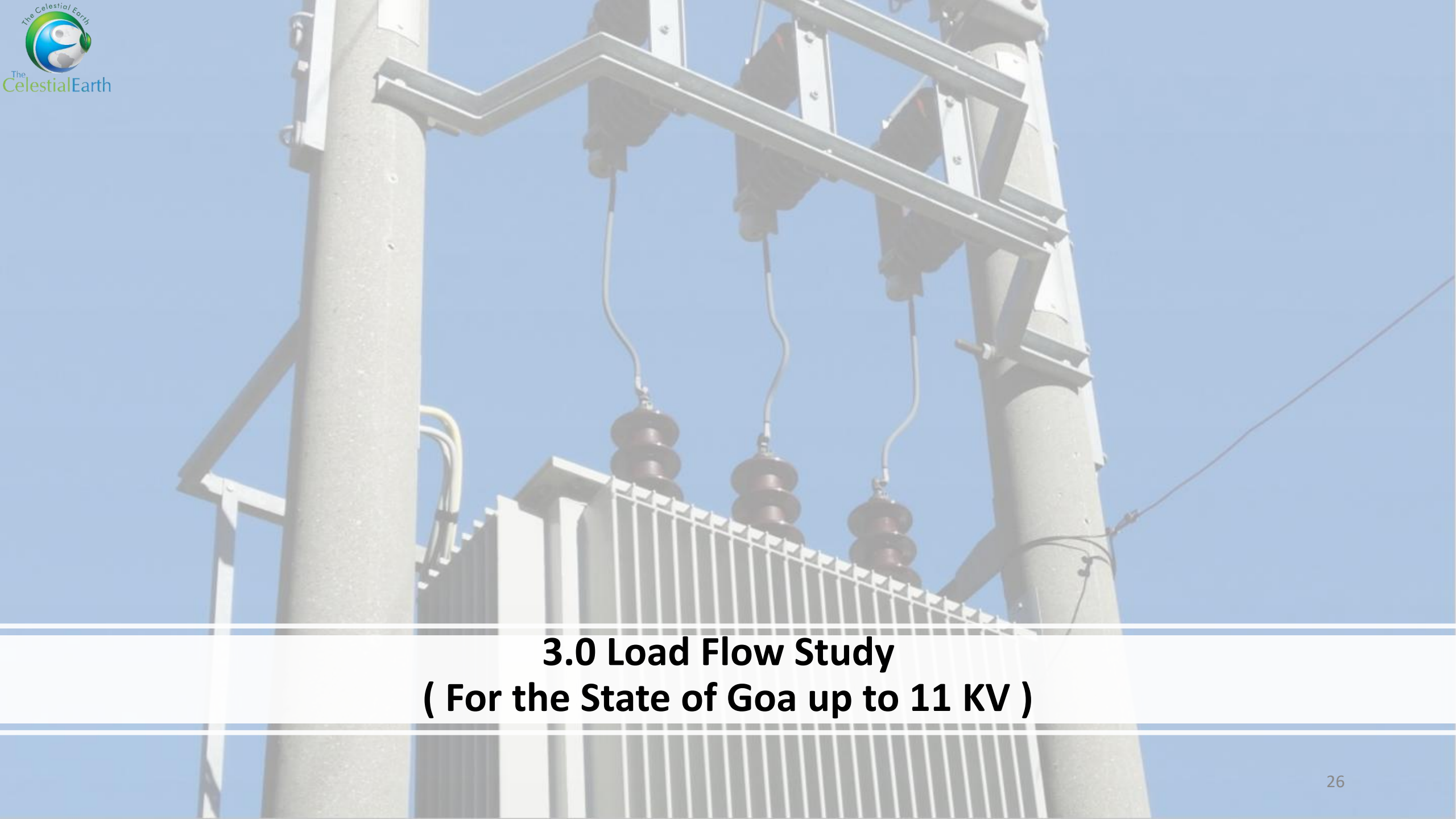


Annual load Profile

2.0 Building wise solar roof top potential (For Rohini Section of TATA Power, Delhi)

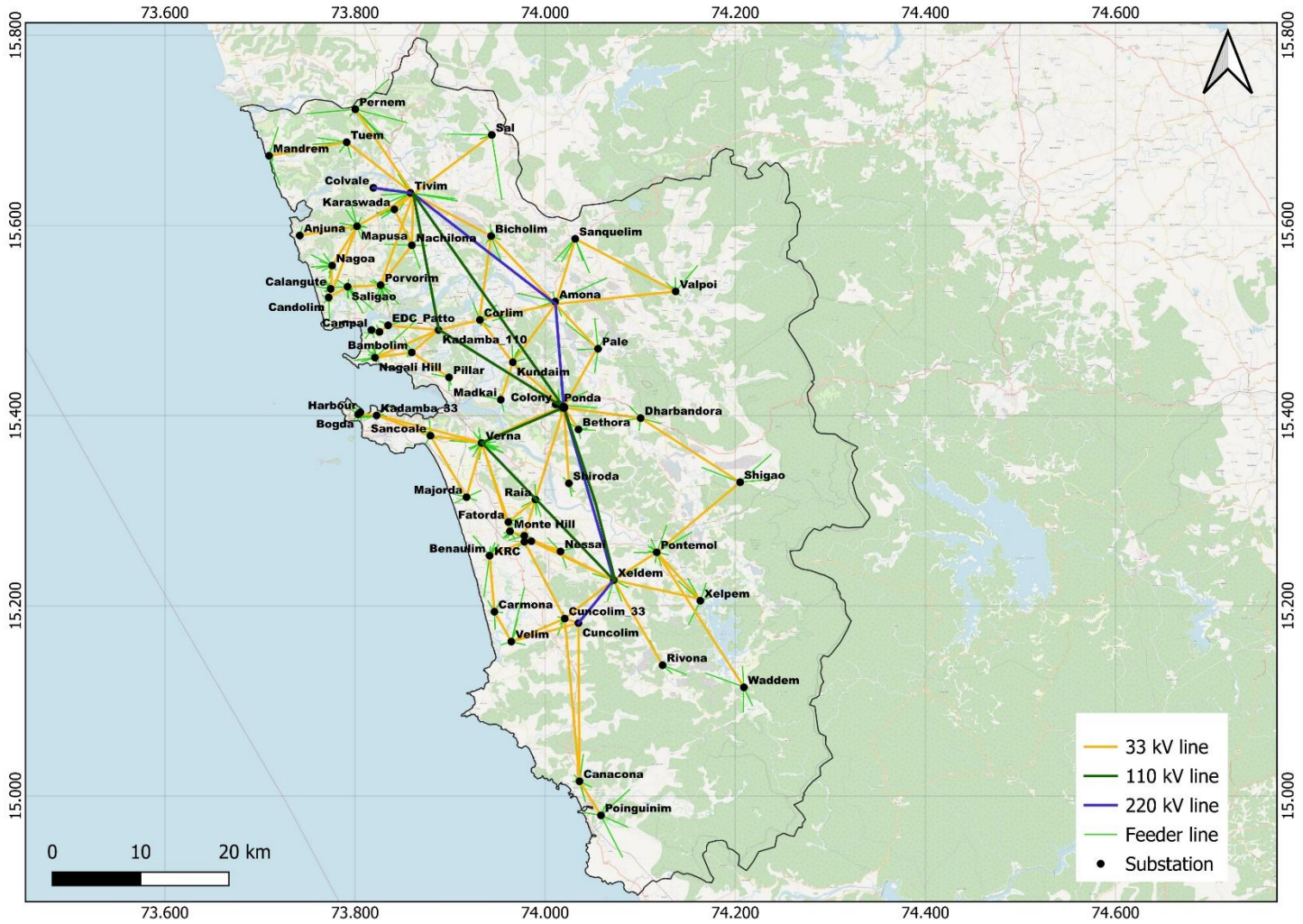
Building wise SRT potential with location (Samples from Rohini area under TATA Power)

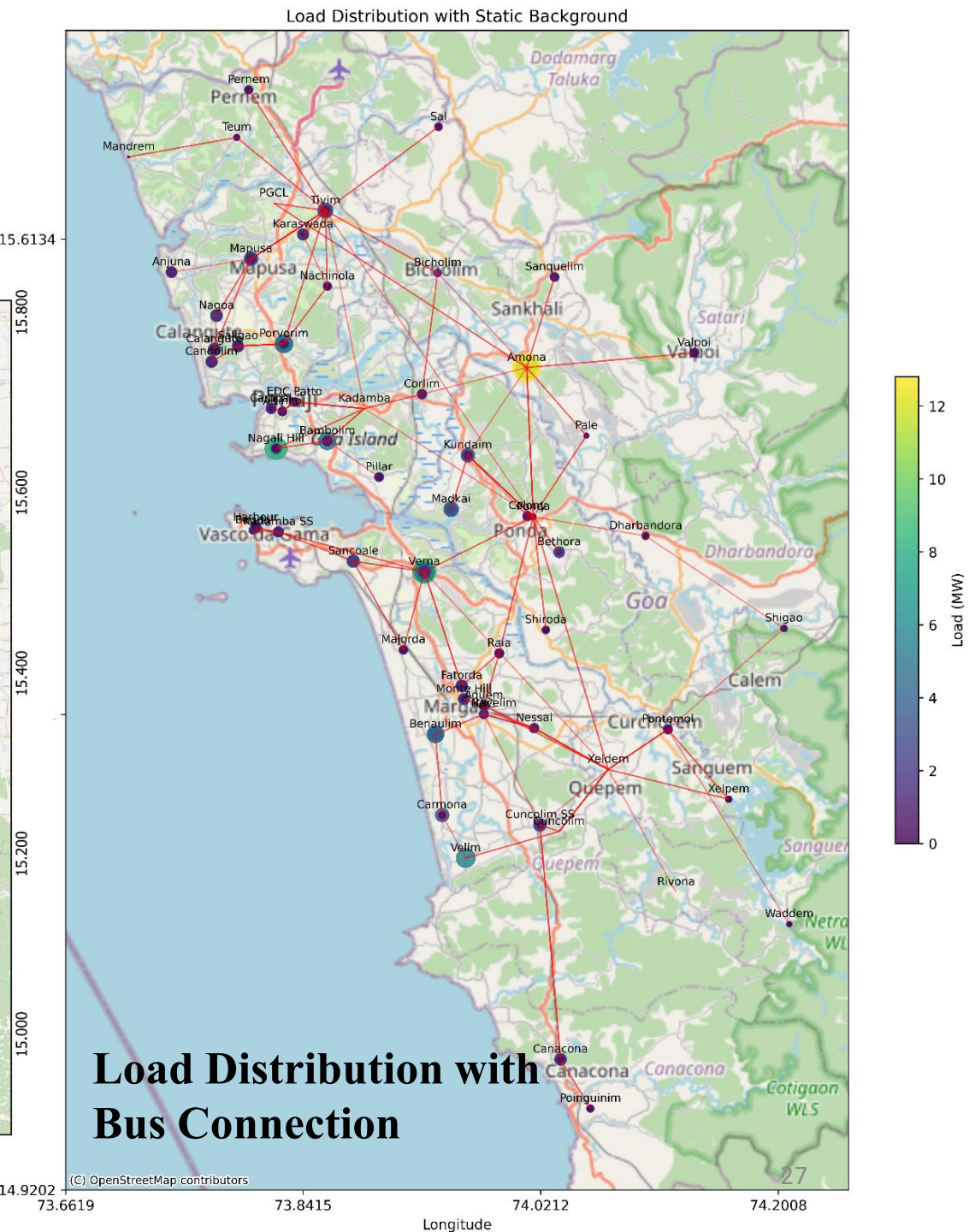
BUILDING ID	ELECTRICITY PRODUCTION FROM PHOTOVOLTAIC PANELS ON ROOF TOPS (KWH)	ROOF TOP SOLAR ENERGY POTENTIAL (KW)	COLLECTOR SURFACE AREA ON ROOF TOPS (M2)	LONGITUDE	LATITUDE	HEIGHT_M
B09880000000000000154	5699.34	3.2	29	77.0703	28.7124	8.08
B09880000000000000218	8756.84	4.9	45	77.0704	28.7123	6.84
B09880000000000000470	15915.15	9.0	81	77.0708	28.7120	7.40
B09880000000000000722	3082.56	1.7	16	77.0708	28.7119	7.30
B098800000000000008ea	2025.71	1.1	10	77.0704	28.7123	6.35
B09880000000000000944	6989.62	3.9	36	77.0705	28.7122	7.47
B098800000000000000b18	4541.97	2.6	23	77.0706	28.7121	7.10
B098800000000000000113c	4607.38	2.6	24	77.0706	28.7069	10.89
B098800000000000014b0	9559.01	5.4	49	77.0693	28.7131	4.59
B09880000000000001537	6822.12	3.8	35	77.0736	28.7152	6.64
B09880000000000001575	2058.36	1.2	11	77.0670	28.7129	4.32
B09880000000000001588	5222.73	2.9	27	77.0695	28.7129	6.36
B09880000000000001922	14958.17	8.4	76	77.0670	28.7100	7.43
B09880000000000001beb	3620.9	2.0	18	77.0684	28.7164	7.55
B09880000000000001bf4	8200.98	4.6	42	77.0722	28.7130	8.06
B09880000000000001bfd	2914.57	1.6	15	77.0678	28.7131	4.41



3.0 Load Flow Study
(For the State of Goa up to 11 KV)

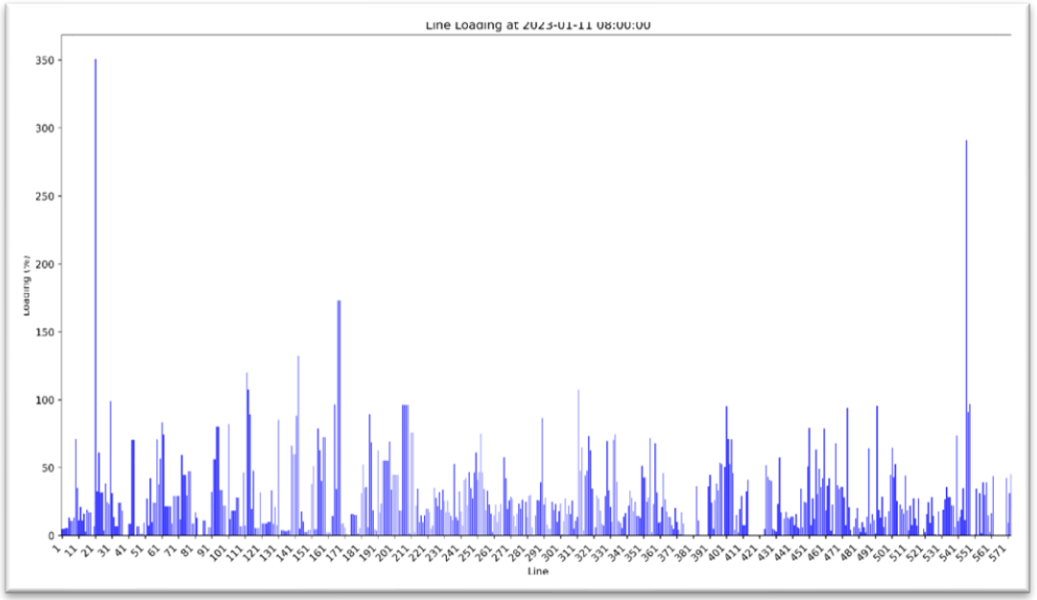
Network Map



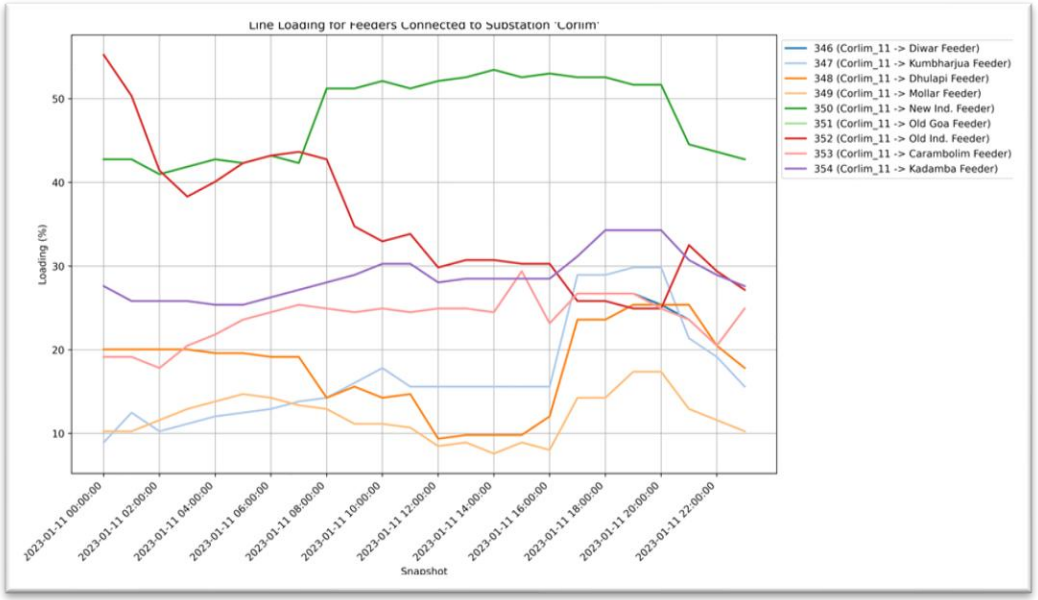


Load Distribution with Bus Connection

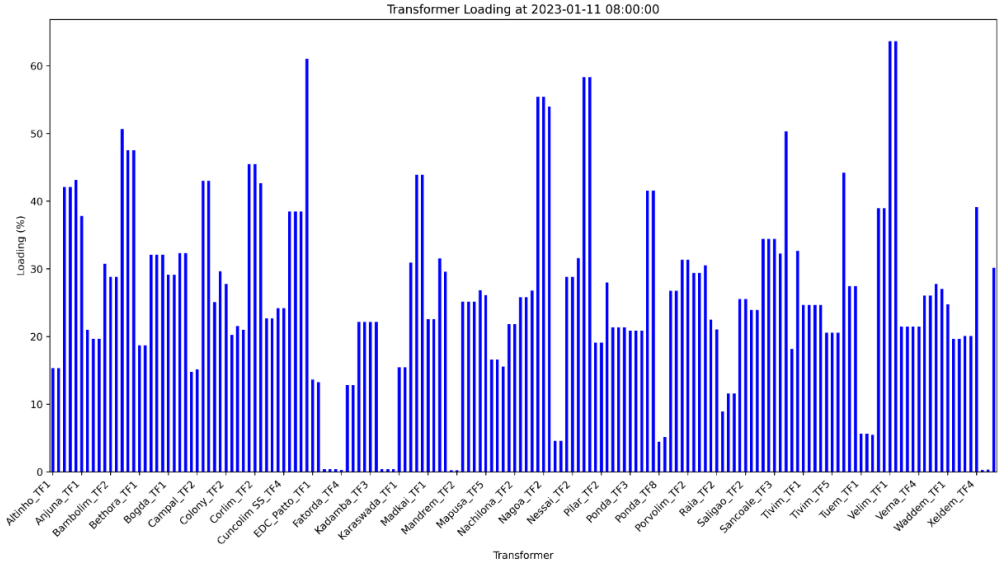
Illustrative example of Line Loading and Transformer Loading



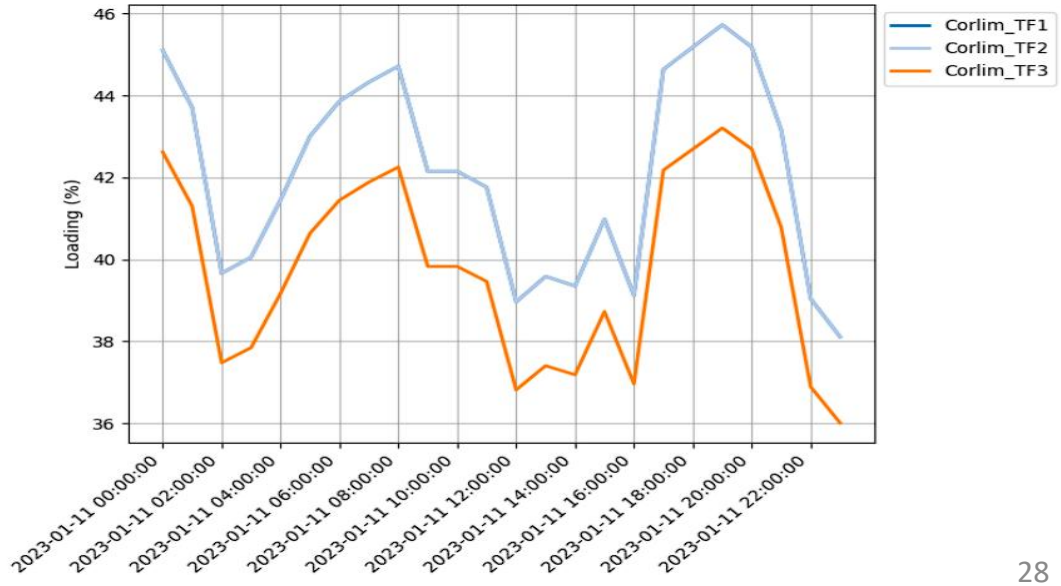
Line congestion/Loading for All Lines



Line Loading for Corlim SS

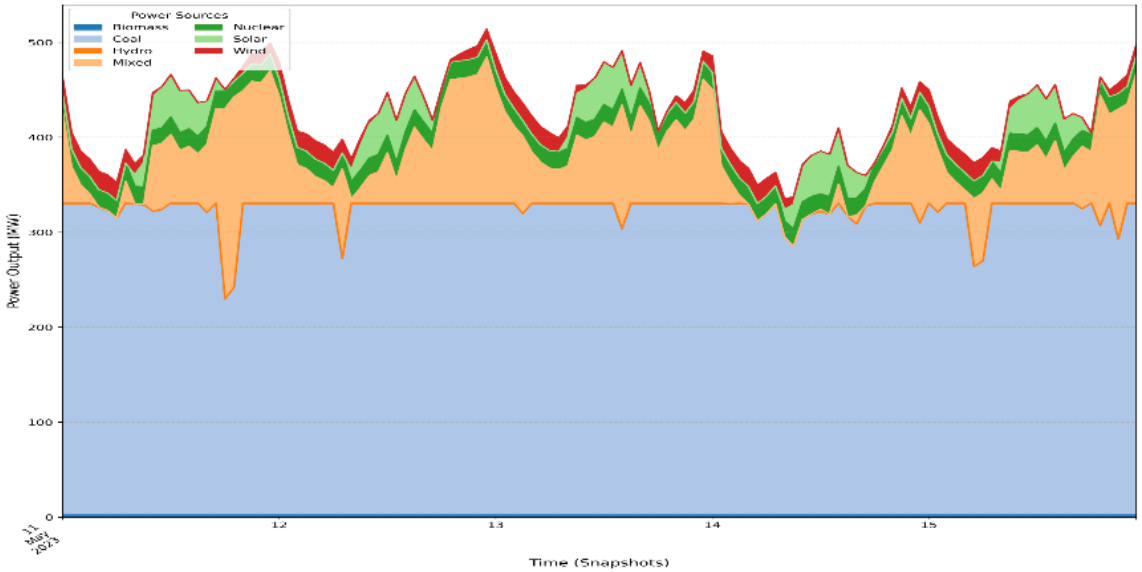


Transformer loading

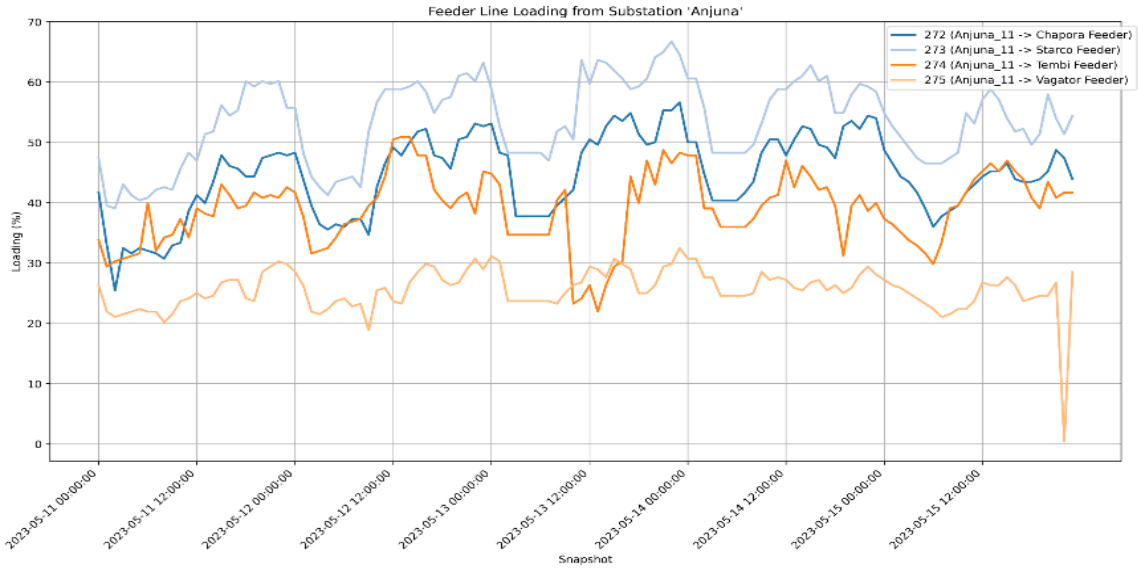


Transformer Loading for Corlim SS

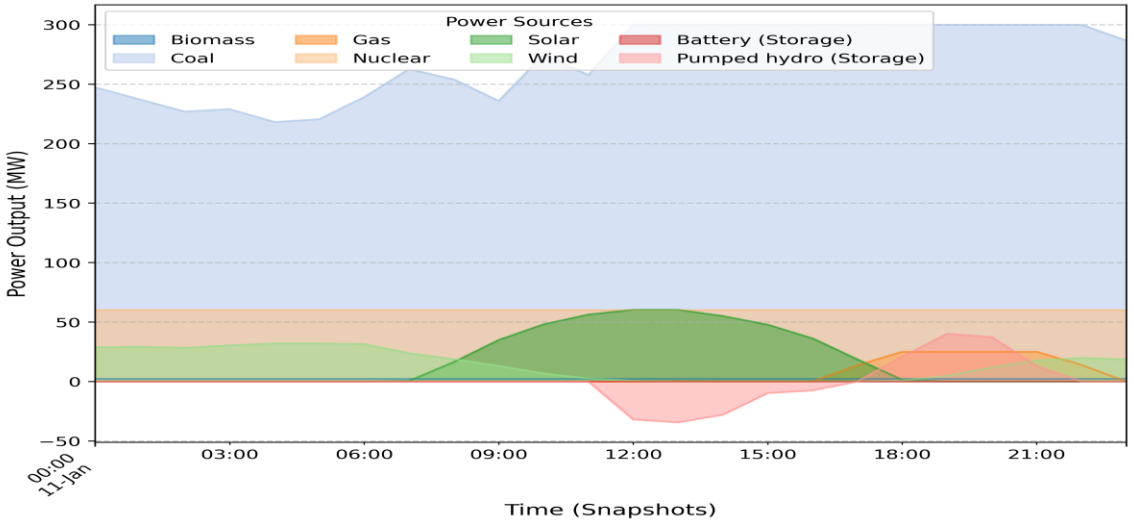
SPIBEAT Pro: Outputs



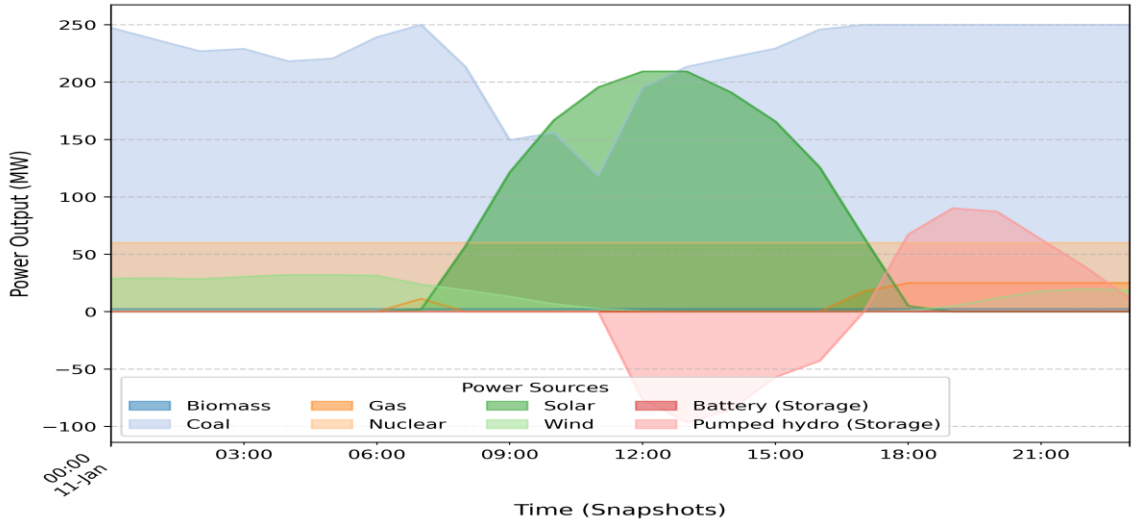
Optimal Generation Mix of 11 May 2023 Load



Line Loading (%) with 11 May 2023 Load



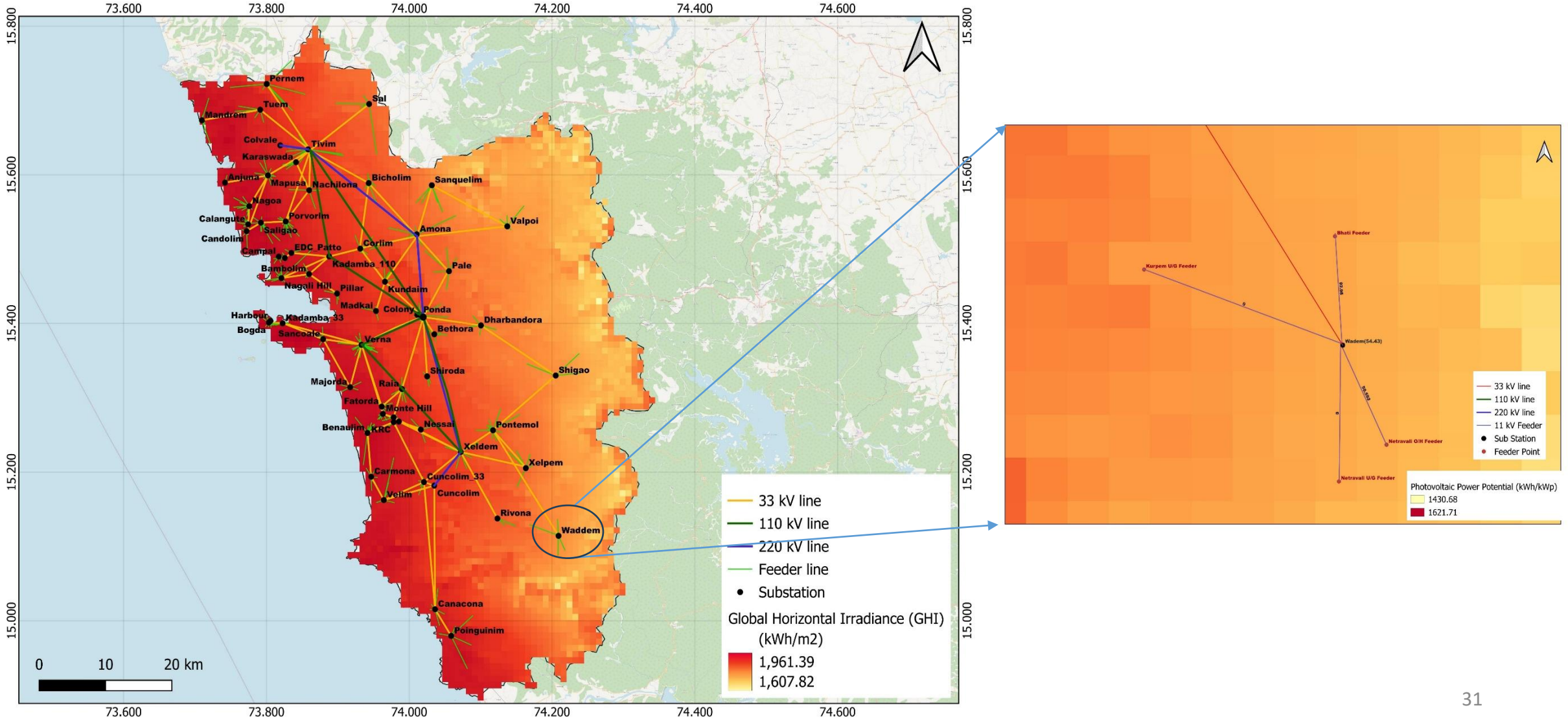
Optimal Generation Mix with Storage with current network status



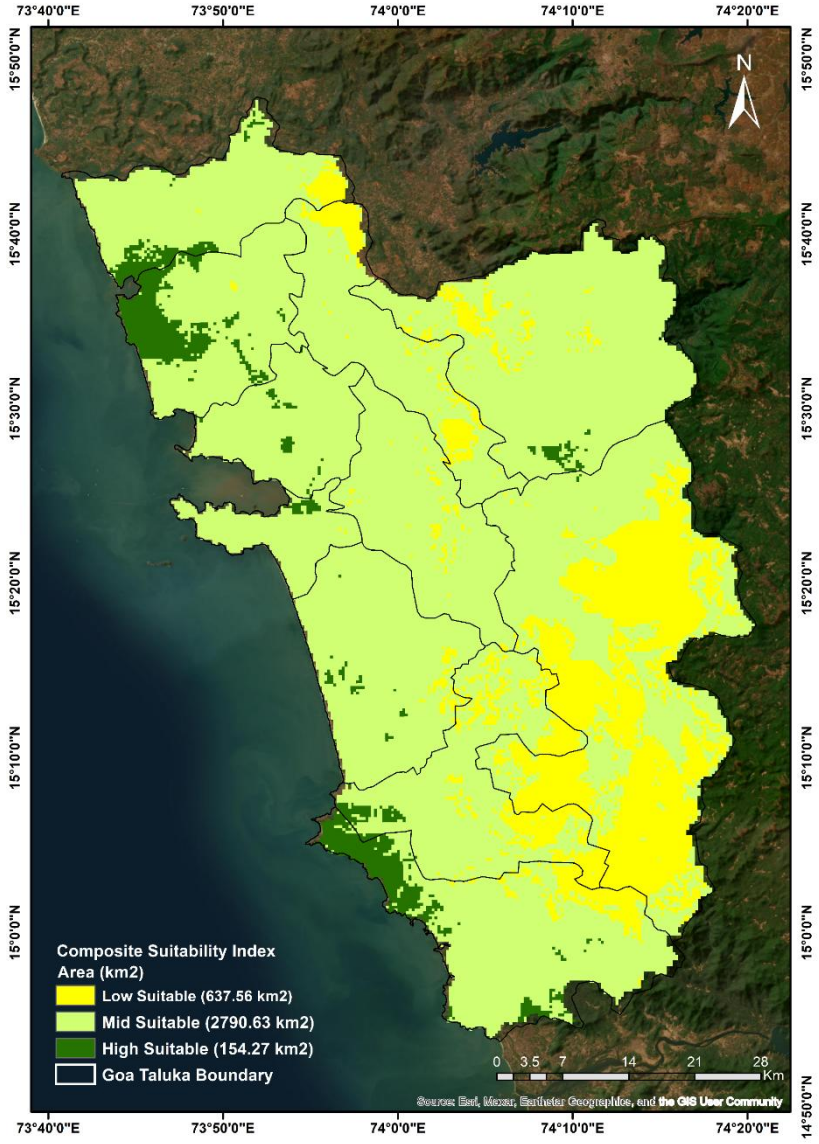
Optimal Generation Mix with 200 MW Solar Injection and Storage with 11 May 2023 Load

4.0 Solar Injection Points Site Suitability Analysis (Goa)

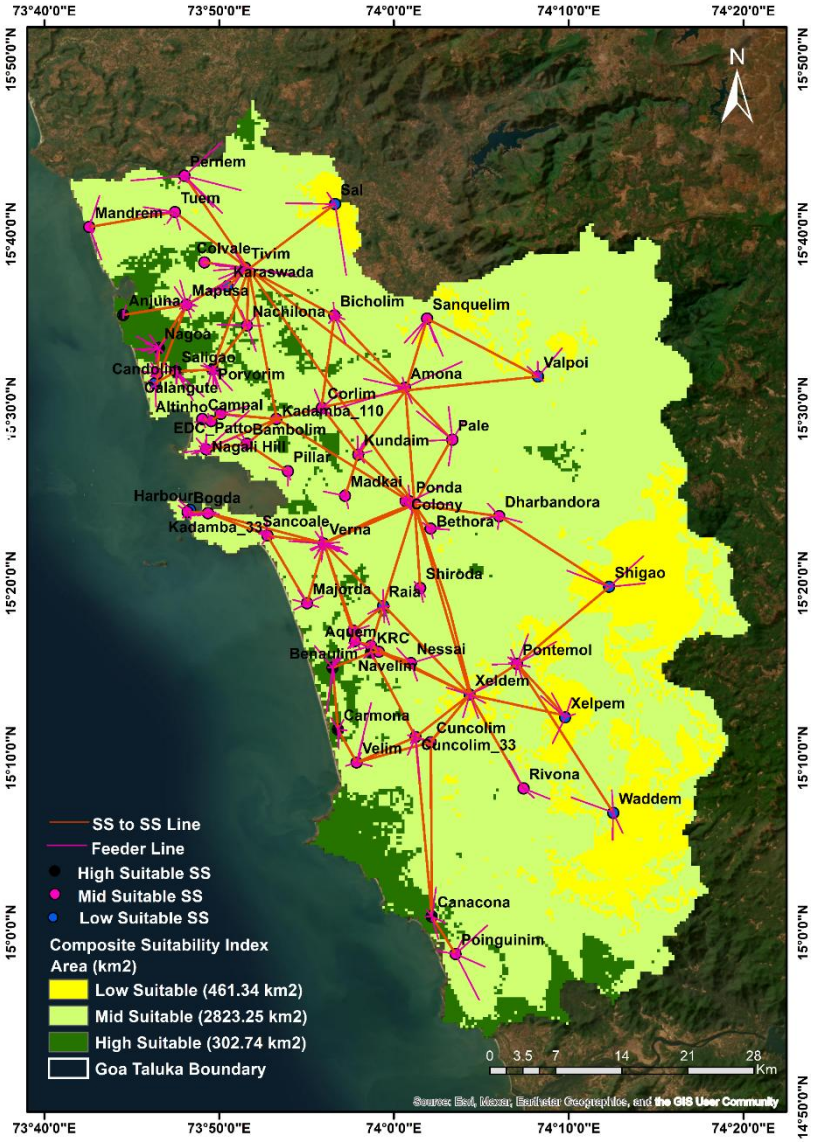
SPIBEAT Site Suitability Module Output: Solar Potential Map with Electrical Network of Goa



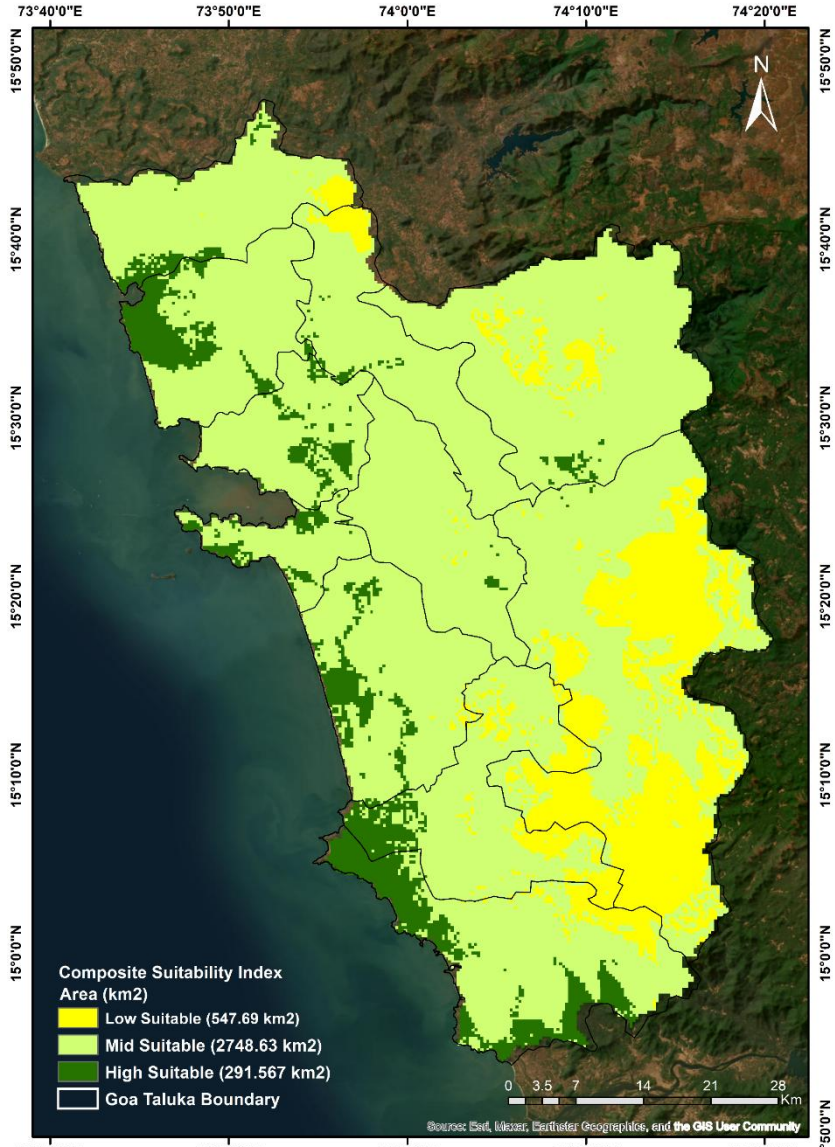
Site Suitability for Solar Uptake



January Month

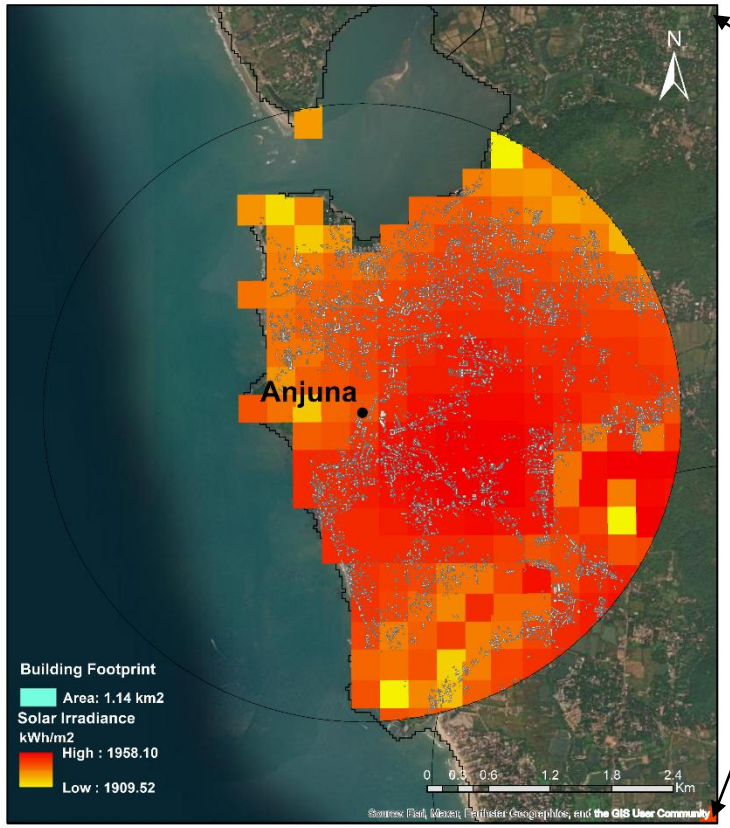


May Month

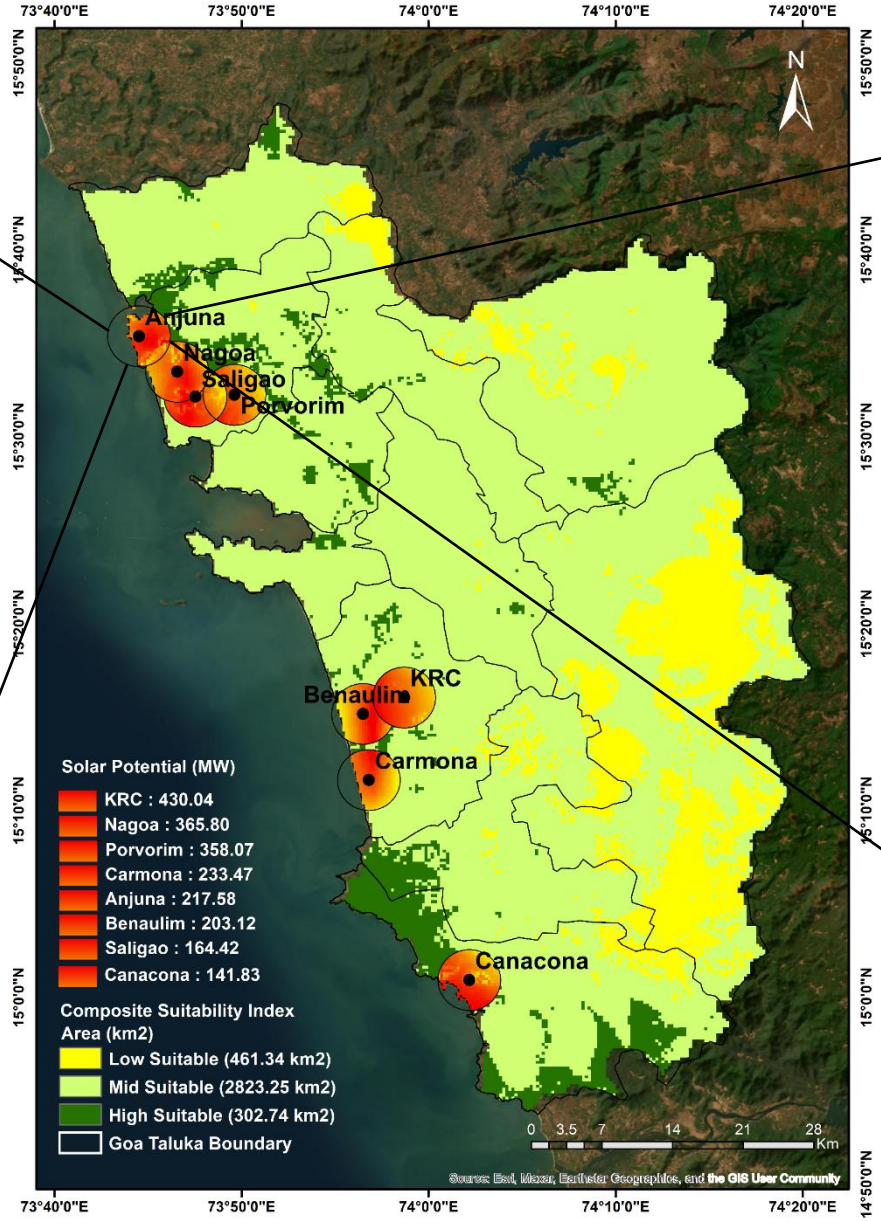


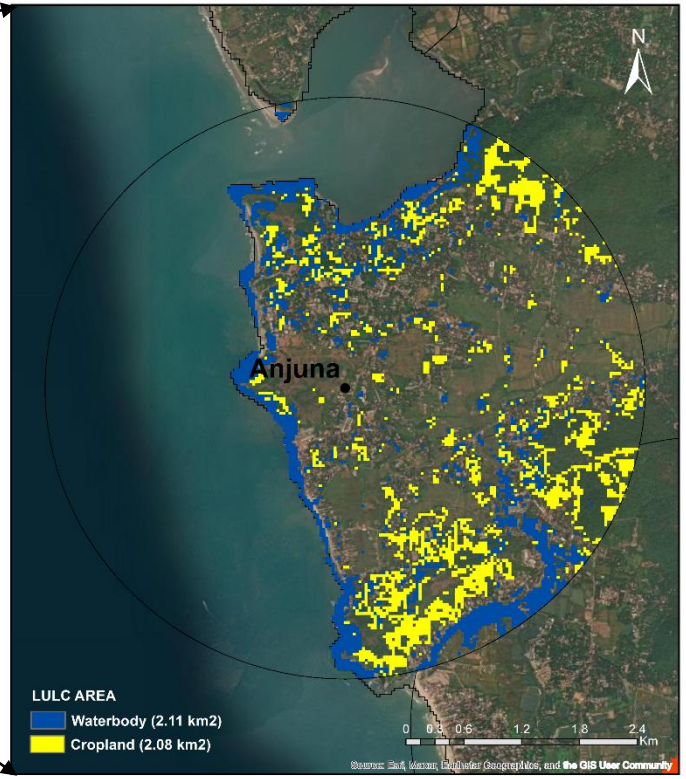
August Month

Solar Potential of Highest Suitable Area



Anjuna SS Rooftop Solar Potential



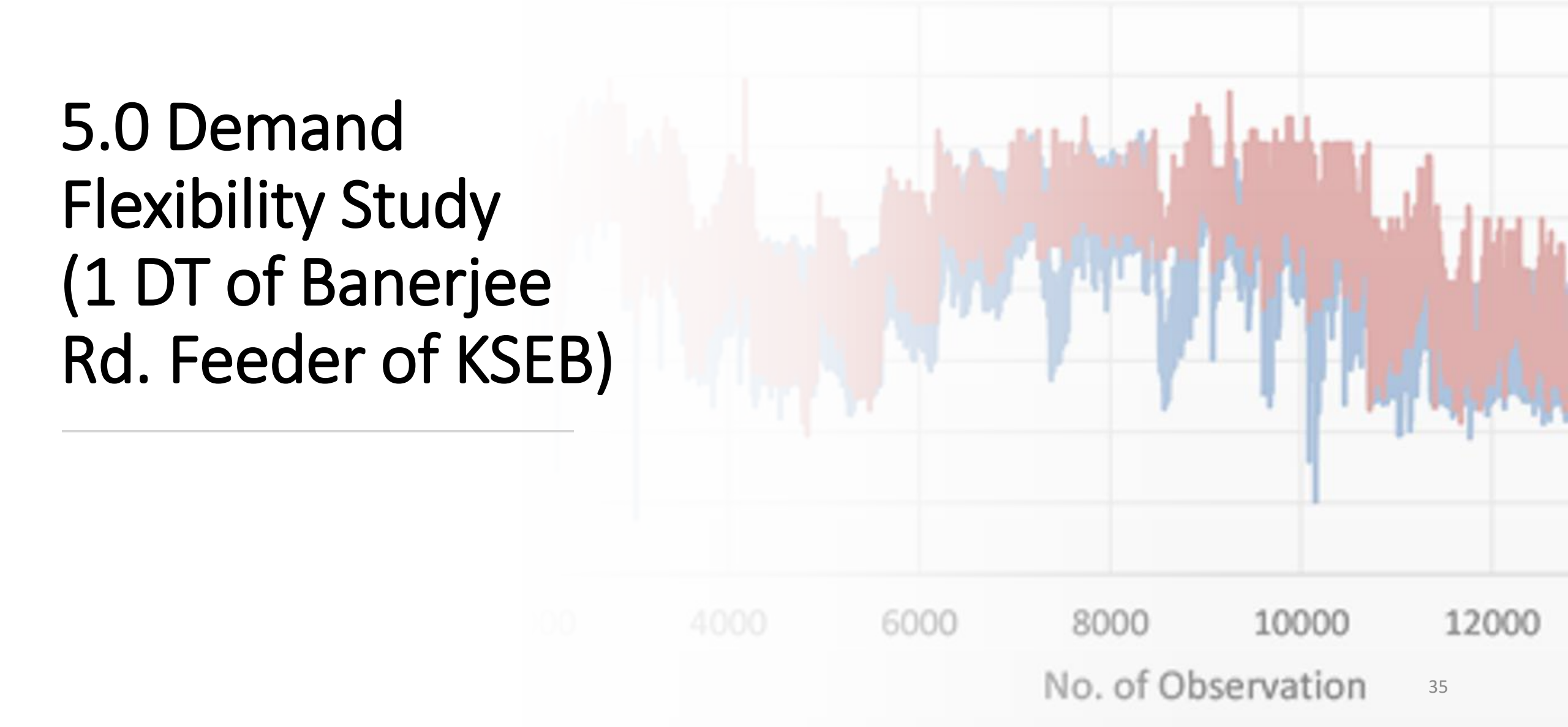


Anjuna SS Agro-PV and Floating Solar Potential

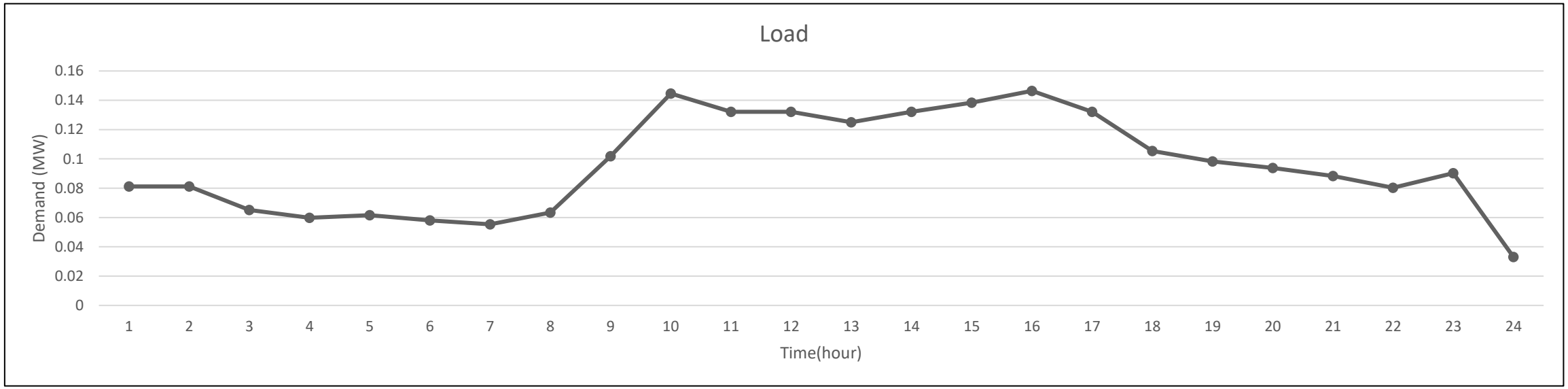
Estimated Solar PV Potential for Highest Suitable SSs

Estimated Solar PV Potential in MW					
Sl.No.	**High Suitable Sub-stations**	**Rooftop**	**Agri-PV**	**Waterbodies**	**Total**
1	Anjuna	124.18	46.54	46.85	217.58
2	Benaulim	140.43	49.11	13.58	203.12
3	Canacona	61.62	56.62	23.59	141.83
4	Carmona	72.94	42.02	118.51	233.47
5	KRC	385.03	36.24	8.77	430.04
6	Nagoa	229.76	79.53	56.51	365.80
7	Porvorim	217.07	105.31	35.69	358.07
8	Saligao	77.51	28.86	58.05	164.42

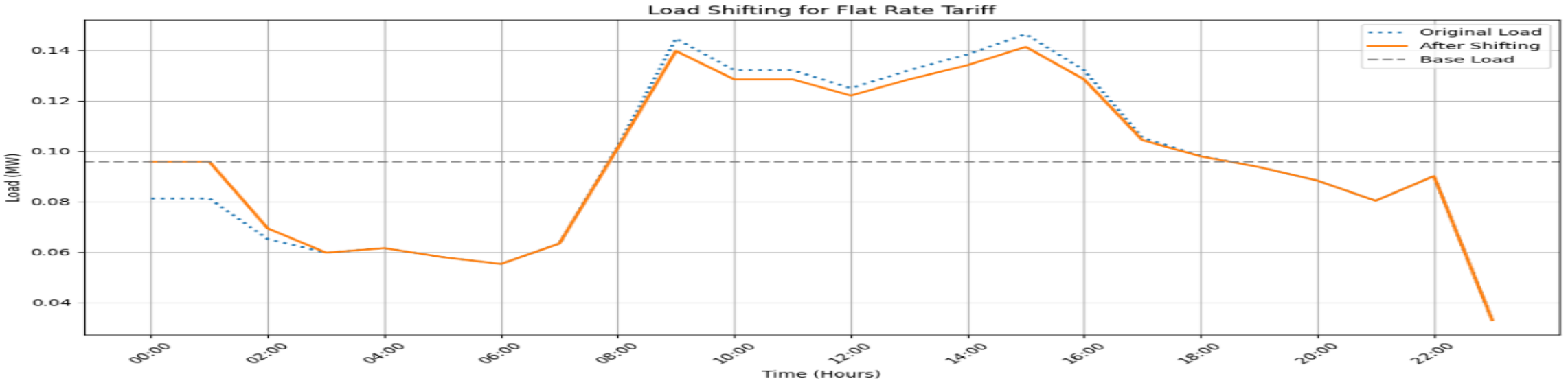
5.0 Demand Flexibility Study (1 DT of Banerjee Rd. Feeder of KSEB)



Outputs of Demand Flexibility Study



Example with a load (one DT of Banerjee Road Feeder) over 24 hours

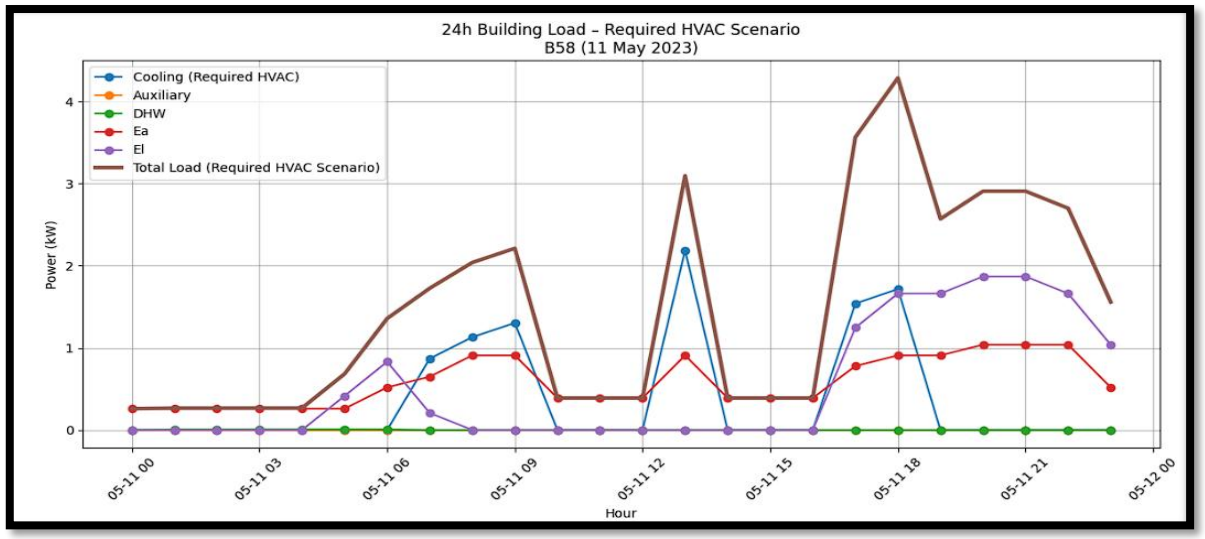


Demand Response(Shifting) for Flat Rate Tariff using SPIBEAT~Pro

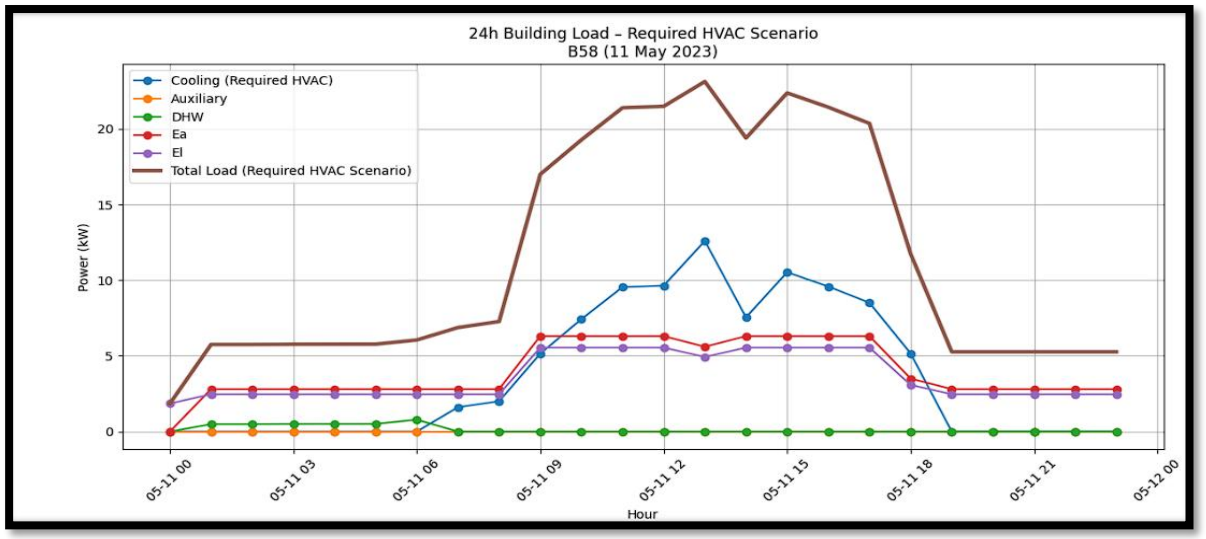
6.0 Case Study: Chandigarh

Building Level Load Profile by use-type and Solar Rooftop Potential

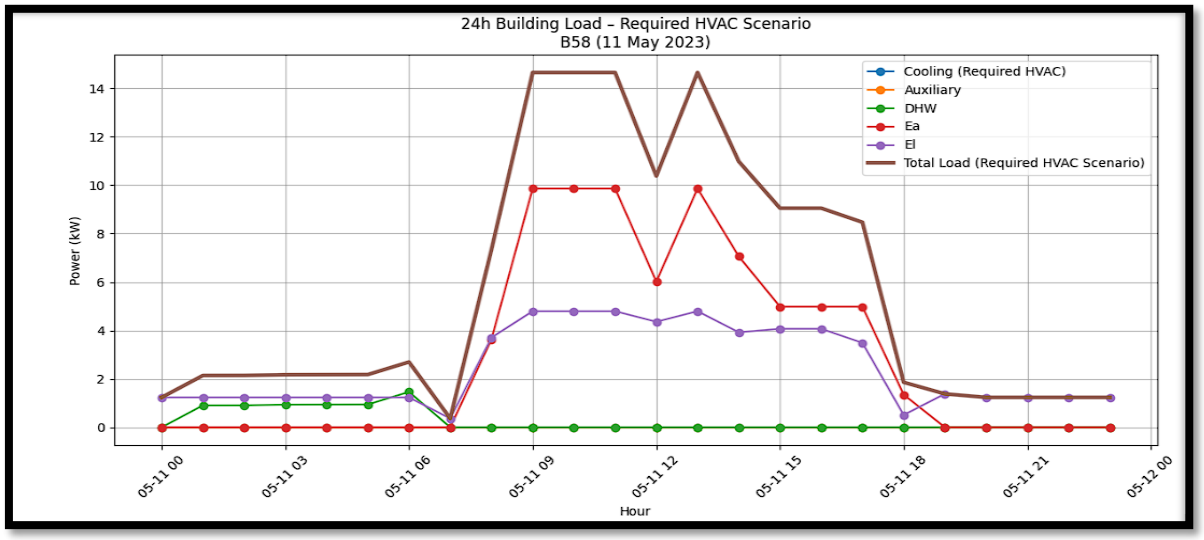
Building-wise load demand by use type: For a representative building on 11th May 2023 in Chandigarh



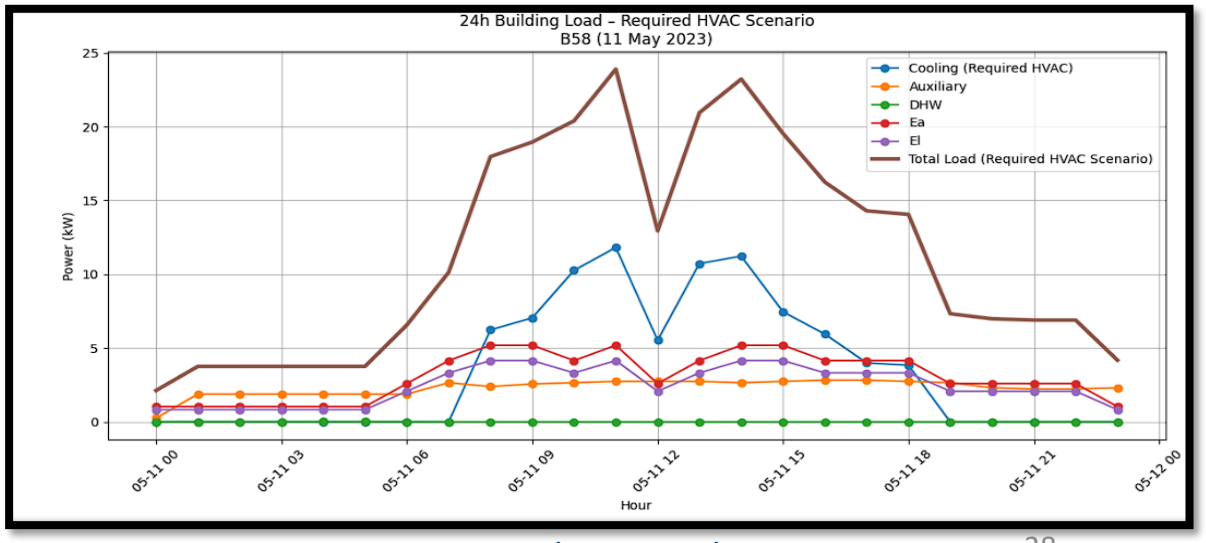
HIG Residential Load



Office Load



School Load



Industry Load

Load Demand of Consumers at Building Level

Building IDs	Total_Area	HIG_occ	KWh/building (MM_changed)	KWh/capita	Average_kWh/capita
B58	197.372156	7	11787	1791.59	
B70	207.222827	7	10088.04	1460.463	
B318	92.5833939	3	4885.5	1583.059	
B465	332.432054	11	15599.5	1407.761	
B471	182.022296	6	7952.3	1310.658	
B480	116.319899	4	5790	1493.296	
B524	378.664879	13	15722.2	1245.603	
B597	157.636434	5	6976.3	1327.669	
B886	64.3854425	2	3452.7	1608.764	
B1175	91.4468196	3	4176.4	1370.108	
B1358	87.0977249	3	4745.2	1634.44	
B1369	73.0249283	2	4479	1840.057	
B1454	87.4457733	3	3711.6	1273.338	
B1581	92.1343092	3	4288.7	1396.45	
B1674	85.751662	3	4121	1441.721	
B1892	118.537298	4	5118.8	1295.491	
B2024	15.0950621	1	993.3	1974.089	
B2197	176.895264	6	7797	1322.308	
B2218	197.377217	7	10370	1576.17	
B2290	33.2776314	1	1124	1013.293	
					1468.3

Annual Load demand calculated by the tool: representative buildings under Sector 48, of Sub Div 5 in Chandigarh

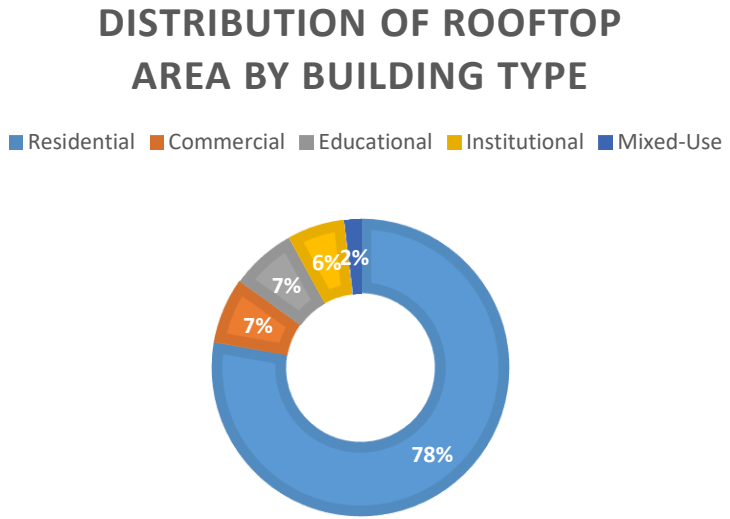
1	Cont.Account	Load		Sector	House No	Cycle wise Consumption						Annual Consumption
74771	3000147315	5.48	KW	SECTOR NO - 48	0008 48B					730	931	1661
74772	3000017892	100.5882	KVA	SECTOR NO - 48	0000 48B					11680	9840	21520
74773	3000017808	31.9294	KVA	SECTOR NO - 48	00000000 4					4456	7009	11465
74774	3000146398	56.3	KW	SECTOR NO - 48	00000000 4					2640	3560	6200
74775	3000017868	70.4471	KVA	SECTOR NO - 48	00000000 4					2080	1773	3853
74776	3000144299	13.15	KW	SECTOR NO - 48	0296 48A						423	423
74777	3000145973	7.16	KW	SECTOR NO - 48	0331 48A					985	1169	2154
74778	3000145968	7.16	KW	SECTOR NO - 48	0332 48A					369	317	686
74779	3000145978	7.16	KW	SECTOR NO - 48	0335 48A					1008	1357	2365
74780	3000145971	11.87	KW	SECTOR NO - 48	0341 48A					326	518	844
74781	3000145985	7.16	KW	SECTOR NO - 48	0343 48A					500	176	676
74782	3000145977	7.16	KW	SECTOR NO - 48	0344 48A					431	886	1317
74783	3000145982	7.16	KW	SECTOR NO - 48	0354 48A					366	502	868
74784	3000170543	5.06	KW	SECTOR NO - 48	0516 48A					976	1664	2640
74785	3000146041	6.86	KW	SECTOR NO - 48	2389 48					716	1217	1933
74786	3000170375	8.86	KW	SECTOR NO - 48	1306 48B					1565	2337	3902
74787	3000170618	8.54	KW	SECTOR NO - 48	1371 48B					1107	1047	2154
137969	3000007824	2	KW	SECTOR NO - 48	00000000 4	53	14	343	498	276	372	1556
137970	3000149277	5.48	KW	SECTOR NO - 48	0001 48B	585	419	436	454	561	643	3098
137971	3000149273	14.17	KW	SECTOR NO - 48	0002 48B	12	2	0	0	0	0	14
137972	3000149344	5.48	KW	SECTOR NO - 48	0003 48B	1142	425	678	556	1230	1156	5187
137973	3000201281	5.48	KW	SECTOR NO - 48	0004 48B	1205	692	1227	913	1914	1878	7829
137974	3000149354	7.98	KW	SECTOR NO - 48	0005 48B	1014	444	508	537	1138	1141	4782
137975	3000201282	5.48	KW	SECTOR NO - 48	0006 48B	742	540	1053	663	629	767	4394
137976	3000149189	5.48	KW	SECTOR NO - 48	0007 48B	437	289	391	342	442	511	2412

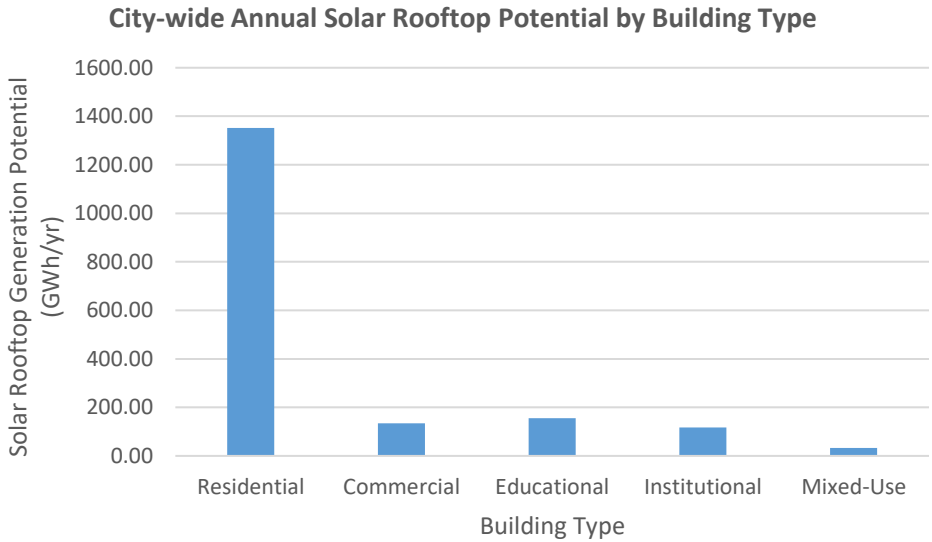
Consumer consumption annual data of as received by CPDL: data for representative buildings under Sector 48, of Sub Div 5 in Chandigarh

- ✓ **Average per capita consumption, as calculated by SPIBEAT Pro, has an accuracy of 85% when compared with the actual consumer consumption data provided by CPDL**

Solar Rooftop Potential by Building-type

Chandigarh City: Solar Rooftop Potential by Building Category				
Building Type	**Number of Buildings**	**Total Rooftop Area (m^2)**	**Annual Solar Rooftop Generation Potential (GWh/year)**	**Installable Capacity (MW)**
Residential	131743	9216066	1352	862
Commercial	10955	845185	134	85
Educational	1037	835050	156	99
Institutional	2194	741669	117	75
Mixed-Use	2733	211323	33	21





THANK YOU

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