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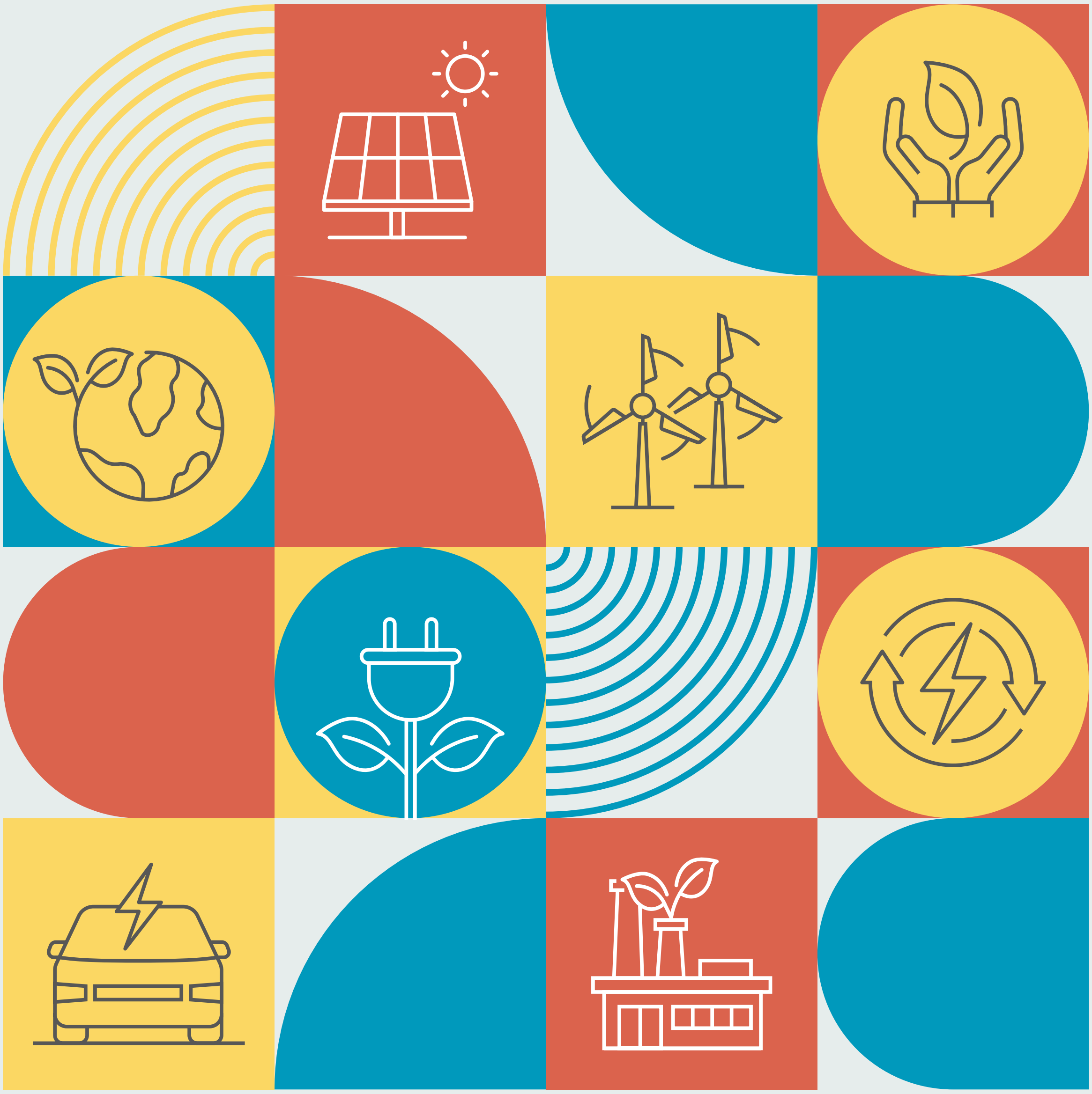
ASSAM RENEWABLE ENERGY POTENTIAL RE-ASSESSMENT

Focus of Solar, Wind and Biomass



March 2024

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Focus of Solar, Wind and Biomass

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March 2024

Citation: International Forum for Environment, Sustainability and Technology (iFOREST). (2024). Assam Renewable Energy Potential Reassessment: Focus of Solar, Wind and Biomass. New Delhi. India.

Printed at: Print Edge Inc.

Contents

Summary

According to the Ministry of New and Renewable Energy (MNRE), Assam's renewable energy (RE) potential is estimated at 14.4 GW. This includes 13.76 GW of solar, 246 MW of wind, 212 MW of biomass, 201 MW of small hydro and 8 MW of waste-to-energy. However, a reassessment of the state's RE potential is needed as MNRE's estimates are only suggestive, based on simplistic assumptions, which need to be revised to guide policymakers or investors in undertaking necessary decisions. This is particularly important as Assam must add RE capacities significantly faster. The updated renewable purchase obligation (RPO) notified by the MoP would require Assam to add nearly 2,700 MW of RE capacity by 2026-27 and almost 4,000 MW by 2029-30. Already, the state is looking to add substantial capacity under the Assam Renewable Energy Policy 2022 and the Mukhya Mantri Souro Shakti Prokolpo initiative. A more precise understanding of potential could greatly aid policy development and investment choices.

Large Solar

Against the MNRE's conservative assumptions of 3% wasteland utilisation for solar development, higher utilisation considerations across certain wasteland categories lead to significantly higher ground mounted solar generation potential of 27,748 MW, across 390.7 sq km of available wasteland. Most of the assessed potential is in East Karabi Anglong, Hojai and Goalpara districts.

In addition, 10 large wasteland clusters, aggregating an area of 144 sq km, are identified for ground-mounted solar installation. These clusters comprise less than 20 to over 150 land parcels and report an average insolation of 4.3 to 4.5 kWh/m2/day, leading to a CUF of 22% to 24%. Further, nearly 7.81 sq km of suitable wasteland area is identified to be available within a 5 km radius of existing substations in Assam, which can be readily utilised for installing 550 MW of capacity. The largest land patch area is identified in Sonitpur, which can support a 165 MW installation, at a CUF of 25% to 22%.

Floating Solar

Based on a high utilisation scenario, where 10% to 50% of the area of waterbodies (depending on waterbody category) is assumed for floating solar installation, 8.94 sq km of waterbody area is estimated to be available for floating solar installation in Assam. This can support the installation of 883 MW of solar capacity.

Rooftop Solar

Considering the roof area data sourced from high-resolution satellite imagery along with academically accepted technical assumptions, Assam's solar potential is estimated to be 1,621 MW. Of these, 1,456 MW is in urban areas and 156 MW is in rural areas. Karump metro accounts for nearly 80% of the assessed rooftop potential, including 1,185 MW from urban areas and 104 MW from rural regions.

Wind

Based on the data from Global Wind Atlas, a total of 479 sites are studied to assess wind energy potential in the state. However, due to terrain and elevation conditions, most of the scoped sites were unfeasible for wind energy installation. Ten sites are feasible for supporting wind energy installations. These sites are located across five districts: Biswanath, Dima Hasao (upper region), Kamrup Rural, Dhubri and Nagaon, with an average wind speed ranging from 3.8 m/s to 5.47 m/s at 150m hub height.

Biomass

Based on updated crop residue surplus data from the ISRO JAIVOORJA portal, Assam's cumulative biomass potential is estimated to be around 2.4 GW. Assam's biomass potential is mainly contributed by rabi rice crop residue from six districts: Nagaon, Baksa, Kamrup, Barpeta, Sonitpur, and Hojai, which contribute more than 50% of the reassessed biomass potential.

Overall, the potential reassessment of Assam suggests that it has significantly higher RE potential than previously assessed by the MNRE. The state's RE potential is sufficient to support its energy security ambitions.

1. Introduction

Assam's electricity sector discussions revolve around the state's energy security concerns. Assam is already an energy deficit state, and its power demand is projected to double in the next decade in response to economic growth[1]. The state government has a massive task ahead to meet the expanding electricity demand. At the same time, there is an added requirement due to regulatory mandates to follow a green procurement pathway aligned with national commitments to climate change mitigation. In this regard, with concerns about energy security and boosting the local green economy, Assam needs to steadily build its electricity generation through the expansion of clean energy resources.

Assam has an installed capacity of 2,037 MW, of which RE contributes 9%, while thermal and hydropower plants contribute 69% and 26%, respectively[2]. Going forward, the state has set itself a goal of expanding its installed renewable energy (RE) capacity to 1,200 MW by 2027 under the Assam Renewable Energy Policy, 2022,[3] to fulfil its commitments under Sustainable Development Goals and to ensure the state's energy security. In addition, the state government is also developing a 1,000 MW solar project under the 'Mukhya Mantri Sauro Shakti Prokolpo' initiative.

While the planned growth is commendable, Assam must add RE capacities significantly faster. The updated renewable purchase obligation (RPO) notified by the Ministry of Power entails a gradual expansion of the requirement from 29.91% in 2024-25 to 43.3% in 2029-30, with technology-specific requirements introduced for new wind, hydro, and distributed RE capacity[4]. The new RPO trajectory would require nearly 2,700 MW of RE capacity to be procured by the state by 2026-27 and almost 4,000 MW by 2029-30 (iFOREST estimates).

At present, Assam's ambitions and actions on RE expansion are being restricted by a perception of low potential. As per the Ministry of New and Renewable Energy's (MNRE) assessment, the state has an estimated RE potential of 14.4 GW, of which 13.76 GW is solar, followed by 246 MW of wind, 212 MW of biomass, 201 MW of small hydro and 8 MW of waste to energy.[5] The potential assessed by MNRE is suggestive, based on simplistic assumptions and thumb rules, which may not be sufficient to guide the policymakers or investors in undertaking necessary decisions.

A more granular assessment of the state's RE potential for each technology segment, along with identifying specific sites and regions based on updated data and assumptions, is needed. This can act as an important guide for state government, implementing agencies, and RE developers/investors in strategizing an achievable and ambitious RE capacity development in the state.

In the subsequent sections of the report, the RE generation potential for Assam has been reassessed using updated data and assumptions for three key segments: solar, wind, and biomass.

2. Solar

The solar power generation potential of any geography is a function of two critical factors – the quality of insolation and the area available for installation of the solar plants. Assam has often been considered disadvantaged for solar generation, due to relatively lower insolation intensity and low wasteland availability.

On an average, Assam experiences over 300 days of uninterrupted sunshine annually[6]. The region typically receives an average solar radiation of 4.31 kWh/m2/day, peaking at 4.7 kWh/m2/day, with solar insolation averaging at 352 W/sq m, peaking at 959 W/sq m[7]. Certain areas within the state, particularly in the Barak Valley Region, experience higher average radiation levels surpassing 4.5 kWh/m2/day.

The average insolation in Assam is lower than most states due to prolonged rainy season, the peak is higher than several states (such as Uttar Pradesh, Odisha, and Gujarat). While this may be considered low, it is worth noting that countries like Germany with a significantly lower insolation profile than Assam have managed to install more than 80 GW of solar capacity.

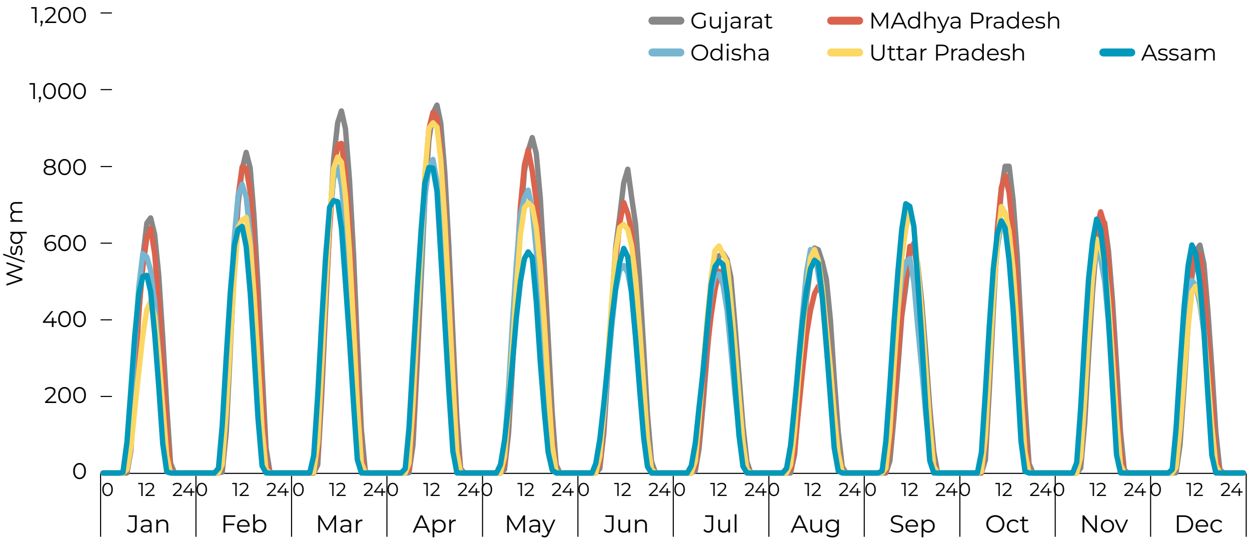
Furthermore, there are wide variations in the insolation levels across districts in Assam depending on their location. Districts in the western and southern parts of the state have higher insolation levels, and account for majority of the high potential sites for the state.

Table 2.1: Peak and average annual insolation across key states (W/sq m)

State/country	Average	Peak
Assam	352	959
Uttar Pradesh	465	889
Odisha	389	913
Madhya Pradesh	514	989
Karnataka	410	1,033
Gujarat	590	825
Germany	229	892

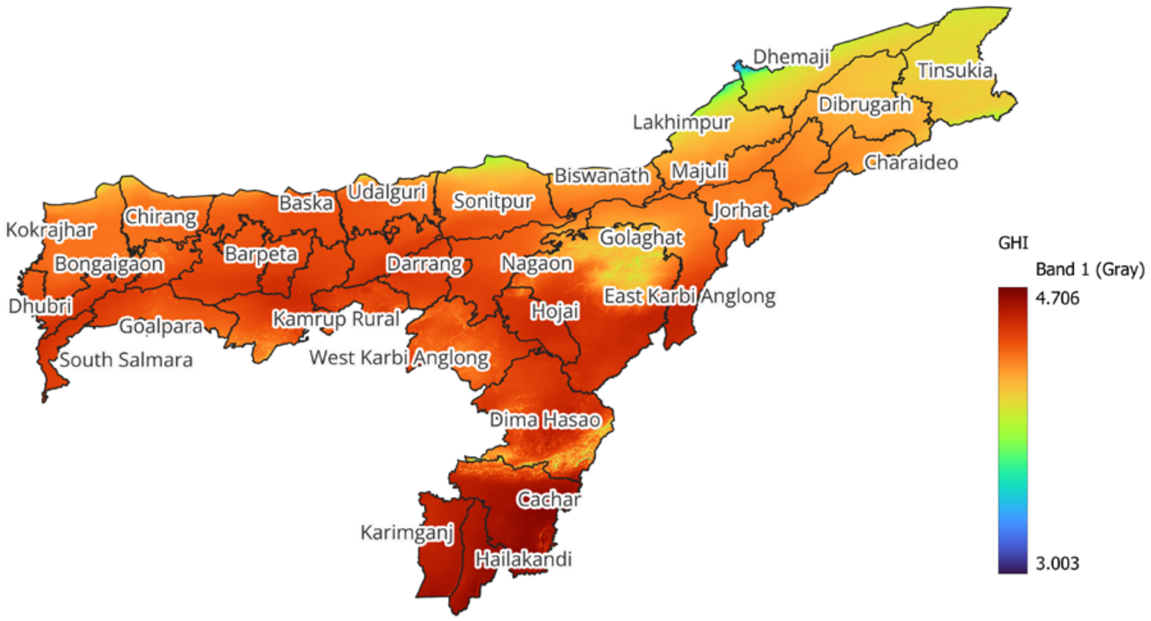
Source: NASA LaRC, iFOREST Assessment

Graph 2.1: Monthly and hourly insolation across states



Source: NASA LaRC, iFOREST Assessment

Map 2.1: Insolation map of Assam



Source: Global Solar Atlas

As for availability of area for installation of solar panels, Assam has significantly lower availability of wasteland (in absolute terms and in terms of share of total land) due to its geographical features, terrain conditions and ecological sensitivity. The National Institute of Solar Energy (NISE) has assessed the solar power generation potential of Assam to be 13.7 GW based on a generic assumption of 3% of the wasteland being covered by photovoltaic (PV) modules. However, a closer look suggests that there are several wasteland land categories which can be utilised to a greater extend for solar installation, without causing significant ecological damage. Further, land neutral solar technologies including floating solar and rooftop solar also need closer assessment to minimize the potential ecological damage, and to explore options beyond ground mounted installations.

2.1. Ground Mounted Solar

Ground mounted solar projects are highly land intensive. Industry experience suggests that installation of a 50 MW of ground mounted solar plant requires about 1 sq km of land[8]. Given the impact of large-scale PV panel installation on local ecology, wastelands are often considered ideal for their deployment. Thus, wasteland availability is a defining factor in assessing the potential for ground mounted solar projects.

The methodology adopted by NISE for solar potential assessment considers the total wasteland availability in Assam to be 8,453.86 sq km as per the Wasteland Survey of 2008-2009. However, updated data on wasteland information is now available. iFOREST has mapped wasteland for Assam, utilising satellite images from 2019 from ISRO's National Remote Sensing Centre (NRSC)[9], which suggests the aggregate wasteland availability of at least 11,061.75 sq km in the state. This amounts to about 14% of the total land area of the state.

Further, NISE's assumption of utilising only 3% of aggregate wasteland for deployment of ground mounted solar panels is based an arbitrary assumption. Based in detailed evaluation of land factors, the considerations can be relaxed for states like Assam, due to the overall low availability of wastelands, and other geographical and weather constrains which further limit their usability. Further, while other constraints of terrain, landslides, slopes/hills and floods persist, from ecological standpoint certain wasteland categories allow for a higher share of land allocation for solar energy generation.

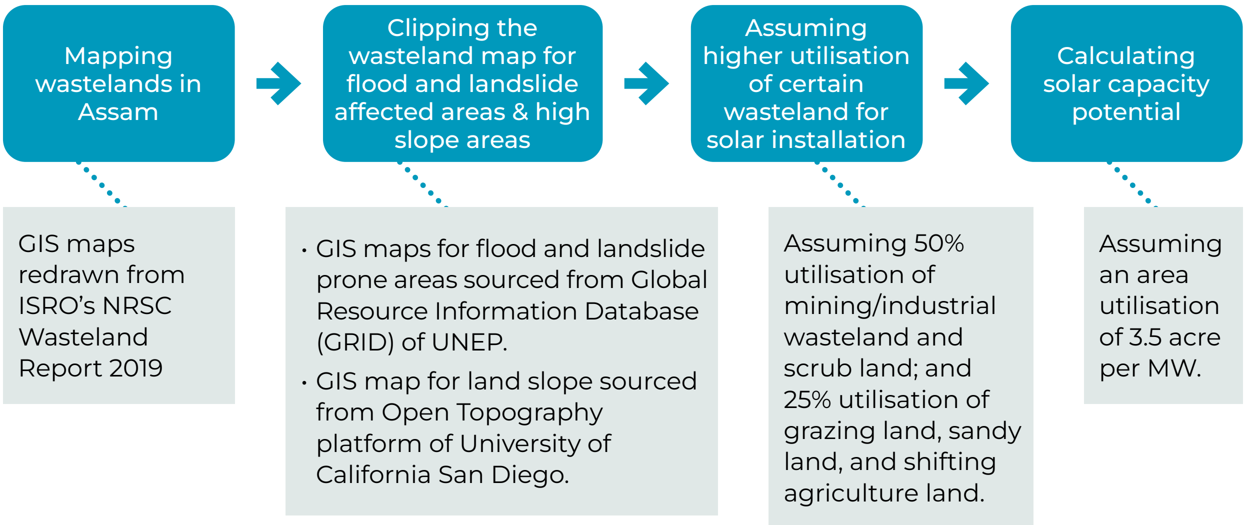
2.1.1 Re-Assessment Methodology

To reassess the ground mounted solar potential of Assam, updated wasteland data is utilized, which is then flittered for non-desired features such as high propensity to floods and landslide, and high elevation. Updated land utilisation factors are then utilized for various wasteland categories depending on the expected ecological sensitivity. The capacity potential is then estimated based on industry standards. The four-step process is described below:

- Updated wasteland in Assam, across seven key categories, is mapped using 2019 satellite images procured from ISRO's NRSC.
- The mapped wasteland is then chipped for areas with high exposure to floods and landslides. The database for flood and landslides prone areas is sourced from UNEP's Global Resource Information Database (GRID)[10]. Further, high elevation areas are clipped based on data sourced from and University of California San Diego's Topography platform[11].
- For re-assessing solar potential on clipped wasteland, new utilization factors are assumed at 50% of mining/industrial wasteland and scrub land, and 25% of grazing land, sandy land and shifting agriculture land.
- For the wasteland area identified based on the higher utilisation assumptions, the solar potential is calculated based on a utilisation assumption of 3.5 acre per 1 MW .

In addition to reassessed aggregate potential, the study also identifies major wasteland clusters, which can support utility-scale solar plants in the state, following a similar criteria of clipping wasteland data. Further, to identify most-feasible land parcels in vicinity of existing substations which can easily support power evacuation, data regarding existing transmission infrastructure is layered on the clipped wasteland data.

Figure 2.1: Methodology for reassessment of ground-mounted solar potential



Source: iFOREST Assessment

2.1.2 Potential Assessment

The mapping and identification of wasteland profile for Assam is developed using satellite image data from ISRO's NRSC. In case of Assam, majority of the updated wasteland area or 56% is scrub land. This land is highly prone to deterioration due to erosion, has shallow or skeletal soils, at times chemically degraded, moderate to extremes of slopes, with scrubs dominating the landscape. The second largest category of wasteland (37% of total) is degraded forest land, which includes lands with various types of forest cover with less than 20% vegetative cover. These lands are generally confined to the fringe areas of notified forest. The remaining 7% wasteland comprises grazing land, sandy area, mining & industrial wasteland, waterlogged area, and area being utilized for shifting cultivation. *(See Annexure A1 for district-wise, category-wise wasteland in Assam).*

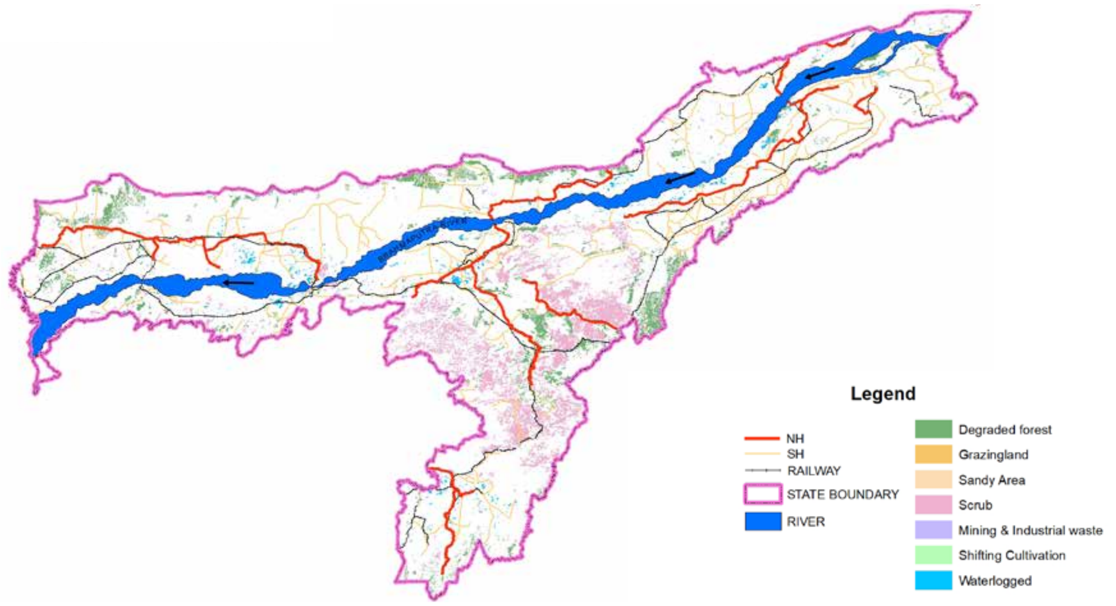
Of these land areas, scrub land, mining/industrial wasteland, grazing land, shifting agriculture land and sandy land are more suitable for solar plant installations.

Table 2.2: Wasteland categorisation in Assam

Type	Area (sq km)	Share
Grazing land	16.79	0%
Sandy area	29.95	0%
Scrub land	6,146.50	56%
Mining & industrial wasteland	74.62	1%
Waterlogged	648.54	6%
Degraded forest	4,063.86	37%
Shifting cultivation	81.49	1%
Total wasteland	11,061.75	

Source: Based on ISRO's NRSC

Map 2.2: Wasteland map of Assam



Source: Based on ISRO's NRSC

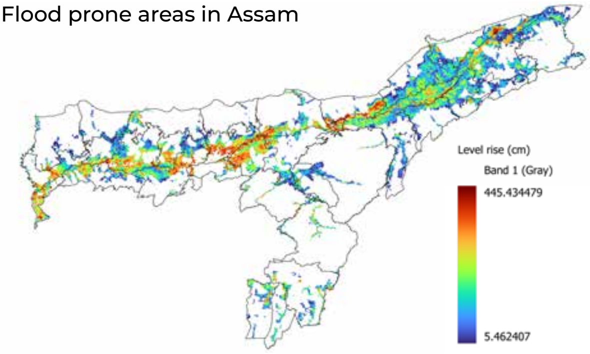
The five identified wasteland categories for solar installation – mining & industrial wasteland, scrub land, sandy area, grazing land, and shifting cultivation land – are analysed for their exposure to flooding and landslides. Flood prone regions clipped from the database are based on 25 years of modelled data for flood with water level greater than 180 cm. Further, landslide prone areas reflect annual frequency of landslide triggered by precipitation. This is filtered for medium, high and very high frequencies. A total of 526 sq km of total wasteland is clipped due to exposure to flooding, and 3,421 sq km is clipped for exposure to high landslide impact.

Note that for floods with water-level greater than 150 cm, a higher area of 674 sq km is clipped from consideration, while 366 sq km of area is clipped at water-level of 220 cm, 268 sq km at 250 cm, and 158 sq km at 300 cm.

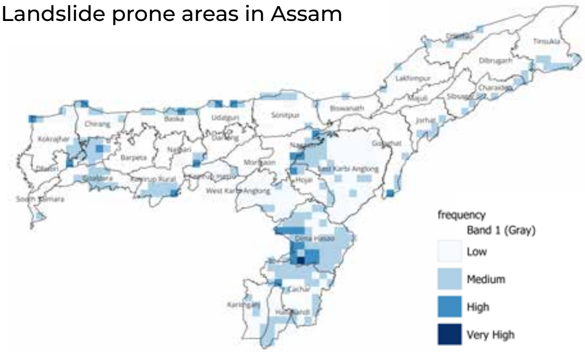
The land parcels are also filtered for terrain conditions as slopes over 8 degrees are deemed unsuitable for ground mounted solar installation. Filtering of the dataset is done on R by identifying the slope on each pixel of filtered wasteland and any pixel with greater than 8 degree is removed. A total of 1,607 sq km of wasteland area (after clipping for floods and landslide) is found to be unsuitable for ground mounted installation due to terrain conditions.

Map 2.3: Wasteland map of Assam clipped for low suitability for solar installations

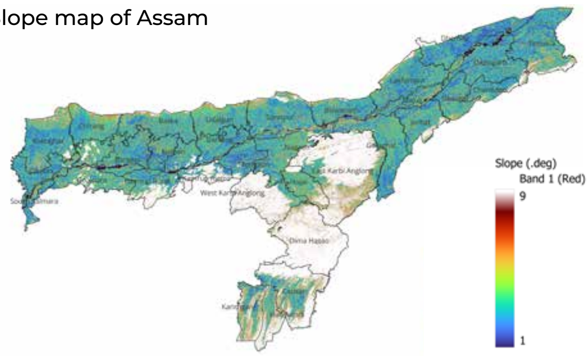
Flood prone areas in Assam



Landslide prone areas in Assam



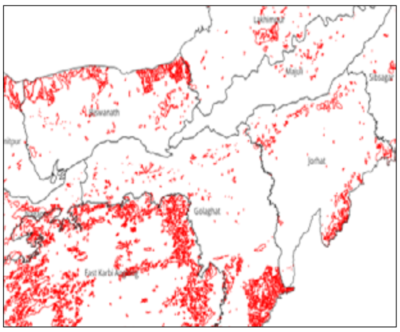
Slope map of Assam



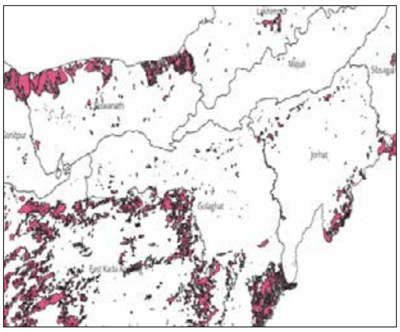
Source: iFOREST Assessment

Map 2.4: Reference image for flood and landslide clipped area

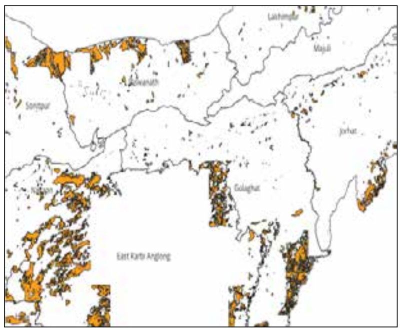
Total wasteland area →



Wasteland area clipped for flood prone area →



Clipped wasteland area clipped for landslide prone area



Source: iFOREST Assessment

Of the 6,348.67 sq km of wasteland area across the five identified categories, nearly 87% land area is clipped due to considerations of floods, landslides and high elevation.

Of the remaining 793.92 sq km area, 390.4 sq km is assessed to be utilized for solar panel installation, based on the category-wise utilization assumption of 50% to 25%. This land area can support about 27,748 MW of solar installations. This re-assessed solar potential is more than twice the assessment suggested by MNRE's thumb rules.

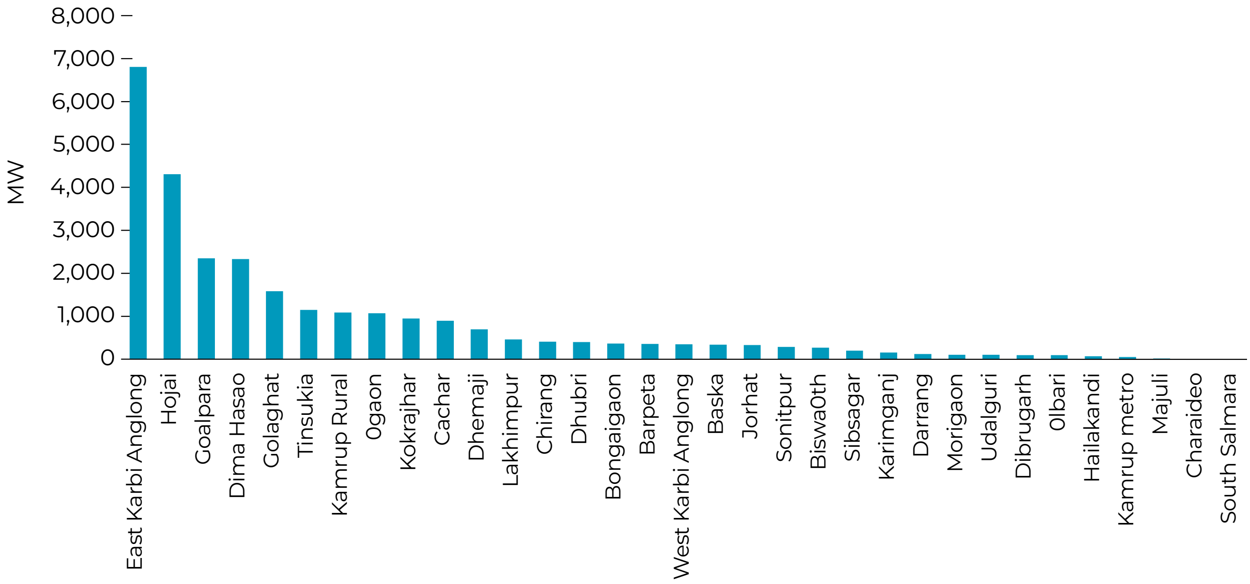
In terms of districts, East Karabi Anglong has the highest potential of 6,808 MW, followed by the district of Hojai at 4,306 MW, Goalpara at 2,346 MW nad Dima Hasao at 2,332 MW. *(See Annexure A.2 for district-wise wasteland-category wise solar ground mounted potential).*

Table 2.3: Wasteland category-wise solar ground mounted potential

Usable wasteland category	Total area (sq km)	Area after clipping for floods, landslide & slope (sq km)	Assumed land available for solar (sq km)	Estimated potential (MW)
Grazing land	16.80	14.95	3.74	264.04
Mining & industrial wasteland	74.63	53.09	26.54	1873.76
Scrub land	6,146.50	715.69	357.84	25271.18
Sandy area	29.25	0.79	0.20	14.12
Shifting cultivation land	81.49	9.40	2.35	165.91
Total	6,348.67	793.92	390.4	27,748

Source: iFOREST Assessment

Graph 2.2: District-wise solar ground mounted potential



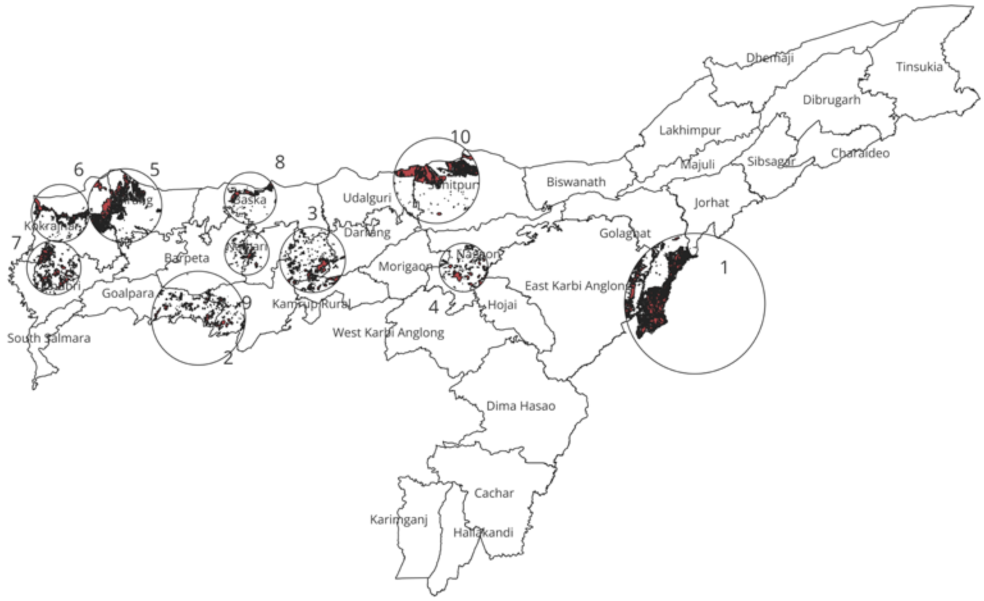
Source: iFOREST Assessment

2.1.3 Suitable Wastelands Clusters

Building on the clipped wasteland map of Assam across the five categories considered suitable for solar installation, 10 large wasteland clusters are identified. These clusters aggregate to a land area of about 144 sq km.

These comprise three larger clusters of 37 sq km to 44 sq km in Goalpara, Golaghat and Kamrup rural districts, four medium clusters of 8 sq km to 2.5 sq km in Nagaon, Chirang, and Kokrajhar districts; and three smaller clusters in Baska, Barepta and Sonitpur. These clusters comprise less than 20 to over 150 land parcels and report an average insolation of 4.3 to 4.5 kWh/m2/day, leading to a CUF of 22% to 24%. *(See Annexure A.3 for details on major clusters for solar ground mounted project development).*

Map 2.5: Suitable large wasteland clusters for solar installations



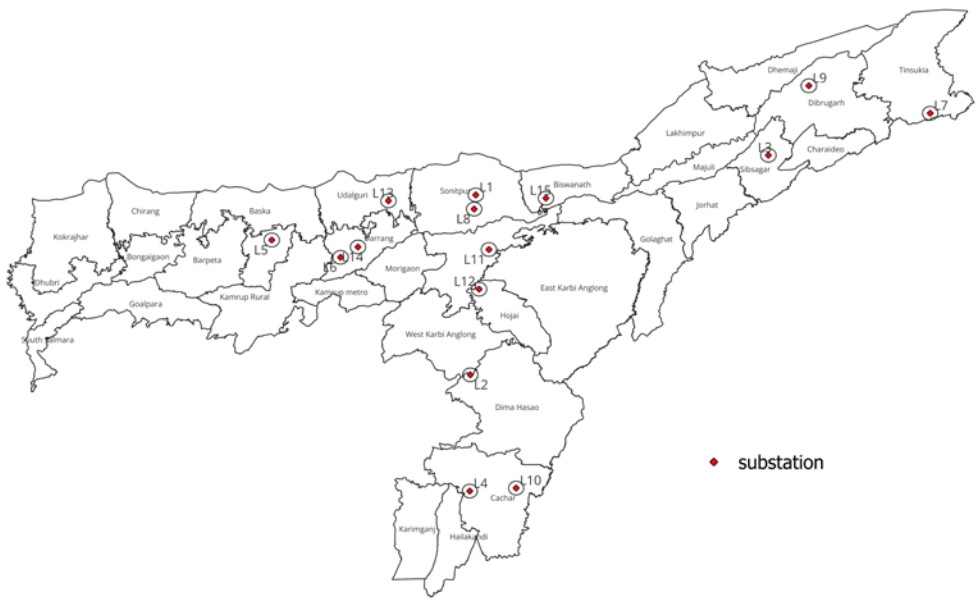
Source: iFOREST Assessment

2.1.4 Wasteland Around Substations

Suitable wasteland available within 5 km radius of existing substations are also identified and mapped, as these land patches can be readily utilized for installing solar PV panels. A total of 15 15 transmission substations of 132 kV and above are considered for this assessment. Suitable patches are identified as clipped, consolidated wasteland after filtering for category, flood and landslide sensitivity, and elevation.

Nearly 7.81 sq km of area is identified as suitable for solar installation around the vicinity of these substations, which can support 550 MW of solar capacity. The largest land patch area is identified in Sonitpur that can support a 165 MW installation., This is followed by Hojai, Dibrugarh, Cachar and Nalbari where solar plants of 50 MW and above can be installed. These locations are estimated to support a CUF of 22% to 25%.

Map 2.6: Wasteland patches around existing substations



Source: iFOREST Assessment

Table 2.4: Wasteland patches available across major sub-stations

Sl no	District	Latitude	Longitude	Voltage (kV)	Area (sq km)	Potential (MW)	CUF (%)
L1	Sonitpur	92.7606	26.7619	132	2.33	164.22	22.78
L2	Hojai	92.7247	25.5869	220	1.22	86.23	24.40
L3	Dibrugarh	94.6725	27.0212	132	0.90	63.63	23.73
L4	Cachar	92.7215	24.8274	400	0.85	59.83	25.06
L5	Nalbari	91.4279	26.4676	132	0.69	49.01	23.93
L6	Darrang	91.8775	26.3543	132	0.41	28.74	23.87
L7	Tinsukia	95.7297	27.2954	132	0.32	22.59	23.01
L8	Sonitpur	92.7500	26.6695	132	0.25	17.30	23.05
L9	Dibrugarh	94.9367	27.4750	132	0.24	16.65	23.12
L10	Dima Hasao	93.0243	24.8469	132	0.20	14.27	25.51
L11	Nagaon	92.8467	26.4054	220	0.20	14.09	23.95
L12	Dhemaji	92.7825	26.1463	400	0.08	5.97	24.41
L13	Udalguri	92.1901	26.7234	132	0.05	3.78	22.50
L14	Darrang	91.9911	26.4219	132	0.04	2.98	23.61
L15	Biswanath	93.2189	26.7409	132	0.03	1.89	23.40
	Total				7.81	551.21	

Note: For solar potential estimation around existing substations 100% wasteland utilisation is assumed.
Source: iFOREST Assessment

2.2 Floating Solar

Availability and usability of wasteland is limited in Assam due to geographic conditions. Hence, there is important for Assam to explore alternatives to land area for solar installations. Assam is blessed with numerous water bodies which can support floating solar installations of varying capacities. Assam is currently developing several floating solar projects aggregating a capacity of 120 MW and further plans to expand floating solar installations in the state. However, there is no official guidance on the estimated floating solar potential of the state.

2.2.1 Assessment Methodology

The floating solar potential of Assam is assessed based on the number of waterbodies available in the state, and its key features, namely purpose, depth and area of waterbody.

- Identification of waterbodies: Detailed list of all waterbodies in Assam is identified and compiled from two major data sources including Central Water Commission (CWC) dataset and the European Space Agency (ESA) World Cover product[13]. The compiled waterbodies' dataset[12] is checked for duplicates and verified using ISRO's Bhuvan Water Bodies Information System[14] and Google Earth.
- Categorising waterbodies: The identified waterbodies are categorised as per their utilisation and depths. Four key categories of waterbodies exist in Assam – hydropower dam, thermal power plant (TPP) pond, temple tanks and natural lakes/wetlands. These are further segregated based on average depth of waterbody. Those waterbodies with depth 3 meters or above were deemed feasible for floating solar installation.[15]
- Spread area and available area: Waterbodies with depth 3 m or above are shortlisted for assessment of spread area and area available for floating solar. The area available for floating solar is defined as

the share of waterbody area which can be utilised for floating solar installation. This is calculated for three area utilisation scenarios:

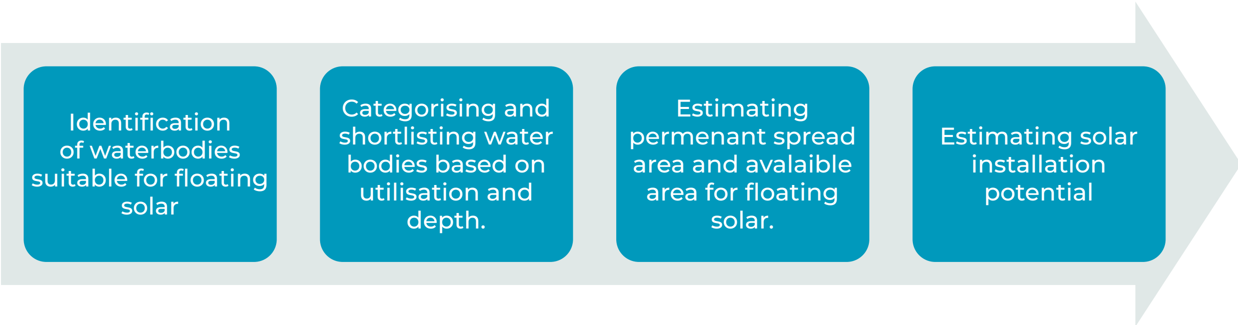
» Low utilisation: In this scenario, 3% of hydropower dam, 10% of TPP pond, and 5% of temple tanks and natural lakes are assumed for solar floating area;

» Medium utilisation: In the medium utilisation scenario, 5% of hydropower dam, 10% of TPP pond, and 10% of temple tanks and natural lakes are assumed for solar floating area; and,

» High utilisation scenario: In the high utilisation scenario, 10% of hydropower dam, 50% of TPP pond, and 20% of temple tanks and natural lakes are assumed for solar floating area.

- Solar Potential estimation: The potential of each of the waterbody is assessed based on assumption of area requirement of 10,117 sq m per 1 MW to be installed.[16]

Figure 2.2: Methodology for floating solar potential assessment



Source: iFOREST Assessment

2.2.2 Potential Estimation

The recent Waterbody Census of Assam suggests that the state has 1,72,492 water bodies, however 97% of enumerated waterbodies are in flood plain areas, distant tribal areas and other climatic or social sensitive zones.[17] For the perspective of floating solar projects development, a total of 20 potential water bodies are identified including two TPP ponds, four hydropower dams, four temple tanks and 10 natural lakes, through multiple open-source databases.

The identified suitable water bodies are further shortlisted based on depth of 3 m and above. Followed by potential estimation for each of water bodies under three area-utilisation scenarios.

Table 2.5: List of potential waterbodies in Assam for floating solar development

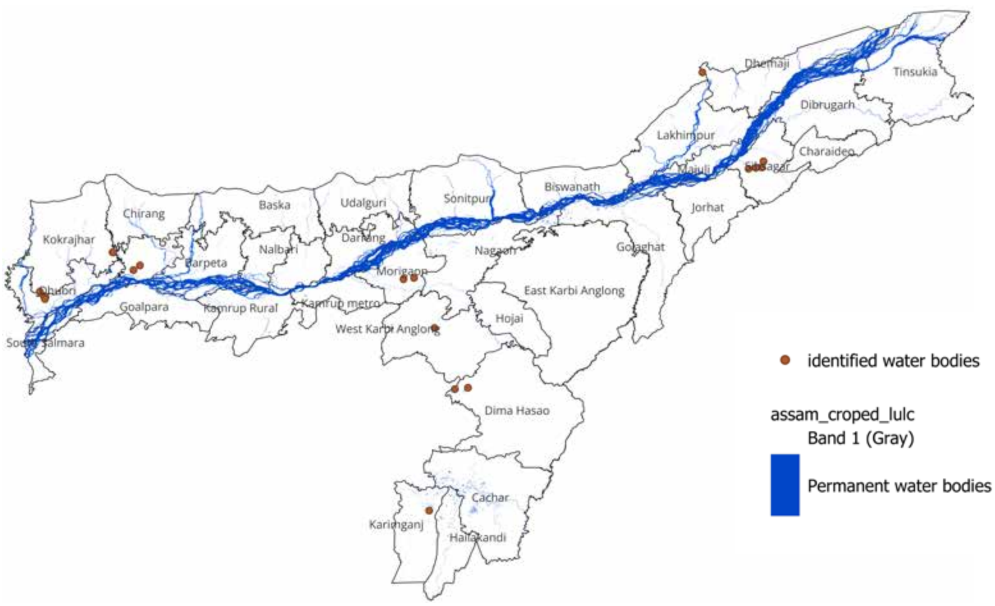
Name of water body	District	Type	Depth (m)	Area (sq km)	Utilisation assumptions		
					Low	Medium	High
Umrong dam	Dima Hasao	Hydropower dam	>15	18.81	3%	5%	10%
Kopili reservoir	Dima Hasao	Hydropower dam	>15	12.23	3%	5%	10%
Subansiri dam	Lakhimpur	Hydropower dam	>15	0.29	3%	5%	10%
Karbi hydro project	west karbi anglong	Hydropower dam	>15	0.17	3%	5%	10%
Bongaigaon TPP Reservoir 1	Kokrajhar	TPP pond	5	0.2	10%	25%	50%
Bongaigaon TPP Reservoir 2	Kokrajhar	TPP pond	5	0.2	10%	25%	50%

Table 2.5 continued

Name of water body	District	Type	Depth (m)	Area (sq km)	Utilisation assumptions		
					Low	Medium	High
Sivasagar tank	Sibsagar	Temple tanks	18.5	0.5	5%	10%	20%
Joysagar tank	Sibsagar	Temple tanks	18.5	0.46	5%	10%	20%
Gaurisagar	Sibsagar	Temple tanks	18.5	0.48	5%	10%	20%
Napukhuri	Sibsagar	Temple tanks	18.5	0.16	5%	10%	20%
Son beel	Karimganj	natutal lake, wetland	8	26.35	5%	10%	20%
Sareswar beel	Kokrajhar	natutal lake, wetland	<3	1.13	0%	0%	0%
Dhir beel	Dhubri	natutal lake, wetland	<3	4.4	0%	0%	0%
Tamranga beel	Bongaigaon	natutal lake, wetland	<3	2.7	0%	0%	0%
Dolani beel	Bongaigaon	natutal lake, wetland	<3	2.39	0%	0%	0%
Charan beel	Morigaon	natutal lake, wetland	<3	0.44	0%	0%	0%
Laukhowa sanctuary lake 1	Dhubri	sanctuary lake	<3	0.16	0%	0%	0%
Laukhowa sanctuary lake 2	Dhubri	sanctuary lake	<3	0.13	0%	0%	0%
Laukhowa sanctuary lake 3	Dhubri	sanctuary lake	<3	0.09	0%	0%	0%
Barigaon	Morigaon	Wetland	<3	0.22			
Total				71.5	2.38	4.47	8.94

Source: iFOREST Assessment

Map 2.7: Mapping of identified water bodies in Assam



Source: iFOREST Assessment

Based on the employed methodology, a total of 71.50 sq km of water body area is evaluated for floating solar assessment under three scenarios:

- **Low utilisation assumption:** In this scenario, 3% to 10% of waterbodies' area (depending on waterbody category) is assumed for floating solar installation, which allows a total of 2.38 sq km of waterbody area for floating solar installation. This can support installation of 235 MW of solar capacity.
- **Medium utilisation assumption:** In this scenario, 5% to 25% of waterbodies' area (depending on waterbody category) is assumed for floating solar installation, which allows a total of 4.47 sq km of waterbody area for floating solar installation. The medium area utilisation can support installation of 442 MW of solar capacity.
- **High utilisation assumption:** In this scenario, 10% to 50% of waterbodies' area (depending on waterbody category) is assumed for floating solar installation, which allows a total area of 8.94 sq km of waterbody area for floating solar installation. The high area utilisation can support installation of 883 MW of solar capacity.

Son Beel alone has more than 50% of estimated solar potential in the state with 130 MW to 520 MW in low and high utilisation scenarios, respectively following Son beel, Umrong dam and Kopli reservoir have significant floating solar potential which put together contribute to 35% of total estimated potential. *(See Annexure A.4 for monthly spread areas for waterbodies in Assam).*

Table 2.6: Water body wise floating solar potential in Assam

Name of water body	District	Type	Total area (sq km)	Effective area (sq km)			Potential (MW)		
				Low	Medium	High	Low	Medium	High
Son Beel	Karimganj	Natural Lake, Wetland	26.35	1.32	2.63	5.27	130.22	260.43	520.86
Umrong Dam	Dima Hasao	Hydropower dam	18.81	0.56	0.94	1.88	55.77	92.96	185.91
Kopili Reservoir	Dima Hasao	Hydropower dam	12.23	0.37	0.61	1.22	36.28	60.47	120.93
Bongaigaon Tpp Reservoir	Kokrajhar	TPP pond	0.39	0.04	0.1	0.2	3.87	9.69	19.37
Sivasagar Tank	Sibsagar	Temple tanks	0.5	0.02	0.05	0.1	2.46	4.92	9.84
Joysagar Tank	Sibsagar	Temple tanks	0.46	0.02	0.05	0.09	2.29	4.58	9.15
Gaurisagar	Sibsagar	Temple tanks	0.48	0.02	0.05	0.1	2.37	4.74	9.49
Subansiri Dam	Lakhimpur	Hydropower dam	0.29	0.01	0.01	0.03	0.85	1.42	2.83
Karbi Hydro Project	west karbi anglong	Hydropower dam	0.17	0.01	0.01	0.02	0.51	0.85	1.7
Napukhuri	Sibsagar	Temple tanks	0.16	0.01	0.02	0.03	0.78	1.55	3.1
Total			0	2.38	4.47	8.94	235.4	441.6	883.2

Source: iFOREST Assessment

2.3 Rooftop Solar

Given the limited availability of wasteland parcels for ground mounted solar and waterbodies for floating solar, rooftop solar offers a viable alternative to expand solar generation capacity in Assam. The state government has initiated several measures to promote solar rooftop segment, including a mandate for installation of rooftop solar on all new buildings, solarising government buildings and subsidies for consumers over and above central subsidies.

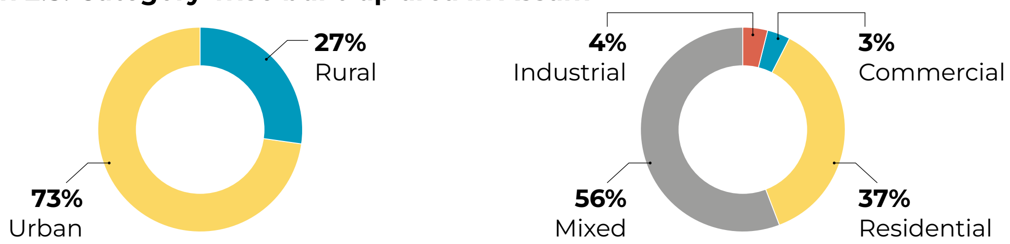
At present, clear estimates on Assam's rooftop potential are not available. Overall, solar rooftop potential for a region is a factor of built-up area, subject to technical features such as tilt area and shadow free area. The potential estimation approach for Assam demands adapted approach considering its building practices wherein, less than 10% of built up area is covered by flat roofs and more than 90% is covered by slant roofs.

For identifying build up area of Assam, GIS maps are generated using satellite image of 5.8 m spatial resolution sourced from land use map of Assam published by Department of Space, Government of India in the Bhuvan Portal[18] which is then referenced with Google Earth. The mapped data suggests that Assam has a gross built-up area of 3,991 sq km, of which the rooftop built up area is 1,995 sq km. This includes 1,447 sq km (72.5%) in urban areas and 548.88 sq km (27.5%) in rural areas.

The built-up area is further categorised across types – residential, industrial, commercial, and mixed. The mixed built-up area is built-up patches that could not be delineated from satellite imagery and include a mix of residential, commercial, industrial, public/government buildings and other miscellaneous buildings. Of the total, 730.42 sq km is residential built-up area, 82.48 sq km is industrial, 69.41 sq km is commercial and remaining 1113.63 sq km is mixed.

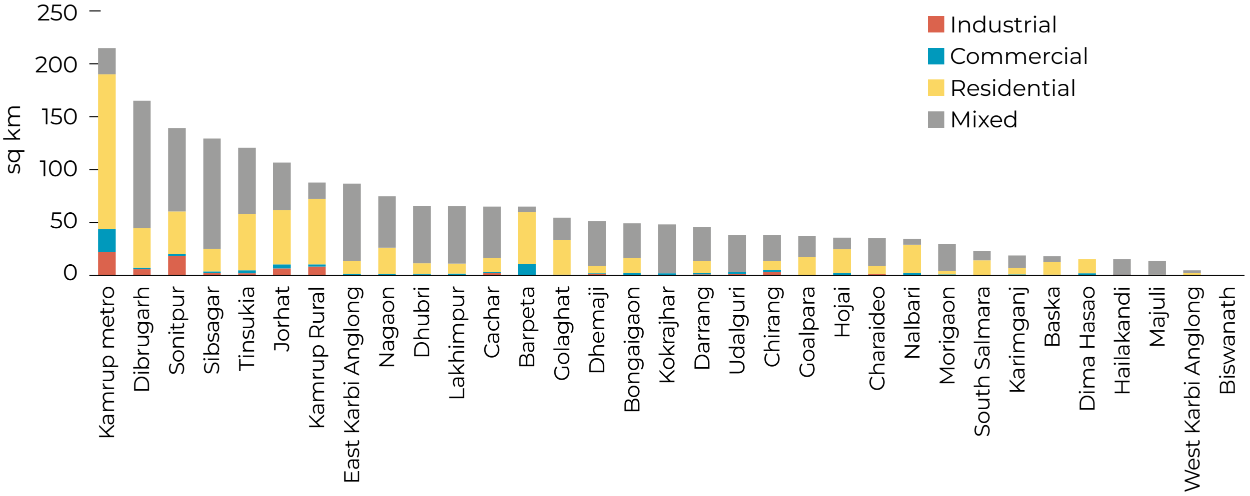
District-wise, Kamrup metro accounts for the highest built-up are in the residential segment (146.27 sq km), followed by Kamrup rural (62.14 sq km), Tinsukia (53.45 sq km), Jorhat (51.44 sq km) and Barpeta (49.29 sq km). In terms of industrial built-up area also Kamrup metro leads among the districts (22.11 sq km). This is followed by Sonitpur (18.31 sq km), Kamrup rural (8.41 sq km), Jorhat (6.78 sq km) and Dibrugarh (5.88 sq km).

Graph 2.3: Category-wise built-up area in Assam



Source: Based on Bhuvan portal

Graph 2.4: District-wise rooftop built-up area for Assam



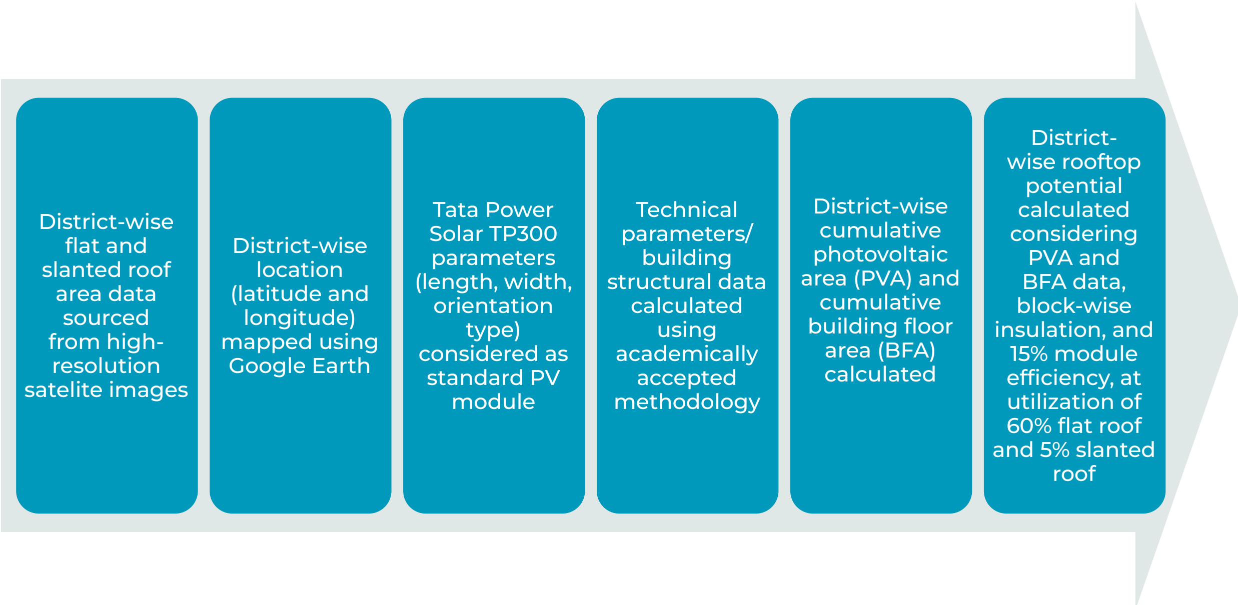
Source: Based on Bhuvan portal

2.3.1 Assessment Methodology

The assessment of solar rooftop potential in Assam utilizes secondary datasets and assumptions regarding technical aspects. Initially, data pertaining to rooftops, both flat and slanted, across all 33 districts is obtained from high resolution satellite images (5.8 m spatial resolution). The required technical parameters are then derived from the mapped rooftop data, block location coordinates (latitude, longitude), and technical assumptions related to standard module dimensions and orientation. The parameters include solar elevation angle, azimuth correction angle, tilted module height variance, module row spacing relative to solar azimuth, actual module row spacing, row width, panel base height, degree of variance, and shading factor. These factors collectively contribute to the computation of cumulative photovoltaic area (PVA) and cumulative building floor area (BFA).

The aggregate rooftop potential is then calculated using PVA and BFA data, the block-wise insulation, and the module efficiency assumption of 15%, considering 80% utilization of flat roof and 10% utilization of slanted roof in urban areas, and 60% utilization of flat roof and 5% utilization of slanted roof in rural areas.

Figure 2.3: Methodology for rooftop solar potential assessment in Assam



Source: iFOREST

Table 2.7: Data sources and technical assumptions for rooftop solar potential assessment

Data	Source/Assumptions
Flat and slanted roof data across 33 district	High resolution satellite imagery (5.8 m resolution)
Building structural data	Rhythm Singh, Approximate rooftop solar PV potential of Indian cities for high-level renewable power scenario planning, Sustainable Energy Technologies and Assessments, Volume 42, 2020, 100850, ISSN 2213-1388
Standard module considered for installation	Tata Power Solar TP300 export series
Solar technical parameters calculations (solar elevation angle cut-off, azimuth correction angle, tilt angle and sun chart)	Google earth, University of Oregon solar radiation monitoring lab and NASA LaRC

2.3.2 Potential Assessment

Considering the roof area data sourced from high resolution satellite imagery along with aforementioned technical assumptions, Assam's solar potential is estimated to be 1,621 MW. Of which, 1,456 MW is located in urban areas, and 156 MW in rural areas.

Karump metro accounts for nearly 80% of the assessed rooftop potential, including 1,185 MW from its urban areas and 104 MW from rural areas. Meanwhile, districts of Sibsagar, Jorhat, Sonitpur, Dibrugarh and Cachar account for 3% to 2% of the assessed potential. This is despite large build-up areas, due to high share of slated roofs.

Table 2.8: Top ten districts with estimated rooftop solar potential in Assam

District	Rooftop potential (MW)		
	Urban	Rural	Total
Kamrup metro	1,185.03	104.16	1,289.19
Sibsagar	36.89	10	46.89
Jorhat	30.63	4.01	34.65
Sonitpur	28.35	2.62	30.96
Dibrugarh	22.09	8.68	30.76
Cachar	26.49	0.21	26.7
Tinsukia	15.34	2.74	18.07
Dhubri	13.05	2.55	15.6
Nagaon	12.07	3.04	15.11
Bongaigaon	12.34	0.83	13.17

Source: iFOREST estimates

3. Wind

Assessing high wind quality sites is the primary prerequisite for estimating wind potential for a region. This entails assessment of wind speed, direction, turbulence, air density and shear, among many. In the context of Assam, the overall wind energy generation potential is limited due to relatively lower wind speed, except for few identified locations which provide adequate conditions for wind energy development.

The National Institute of Wind Energy (NIWE) has established the wind energy potential of Assam to be 560 MW at a hub heigh of 150 m above ground level (agl).[19] This assessment is based on an advanced meso-micro coupled numerical wind flow model, supplemented by data from 406 actual measurement sites across the country, while considering multiple land use and environmental factors. For collecting ground level data, NIWE has also installed wind monitoring stations at 80 m agl in Dhubri, Goalpara, Barpeta, Nalbari, Kamrup(rural), Karimganj, Hailakandi and Cachar districts, and at 50 m agl in Morigaon, Nagaon, Gohpur, Biswanath, Lakhimpur and Dhemaji.

This study focuses on utilizing secondary data on wind speeds and terrain for a preliminary identification of high wind speed sites.

Table 3.1: NIWE's potential assessment at various heights for Assam

Height	Potential (MW)	CUF (%)
50 m	53	-
80 m	112	-
120 m	246	25-28
150 m	459	25-32

Source: NIWE

3.1 Assessment Methodology

The initial assessment of wind resources involves identifying wind-rich areas. In Assam, this process began by utilizing publicly accessible wind resource maps to identify potential wind-rich locations. A more detailed review ensued, focusing on wind density and speed at a resolution of 250 m. The data for this initial assessment and identification of wind-rich sites in Assam are sourced from the Global Wind Atlas (GWA 3.1)[20]. Further, evaluation of the identified sites involved scrutinizing their land features using Google Earth to gain insights into land use and terrain characteristics. These sites were then cross-referenced with NASA's Shuttle Radar Topography Mission (SRTM) database[21] to filter out high elevation areas, as implementing wind projects in high elevation regions poses challenges in terms of technological and commercial feasibility.

3.2 Potential Estimation

Based on initial scoping of data from GWA 3.1, a total of 479 high wind speed sites are identified in Assam with average wind speed greater than 3 m/s, which is the minimum wind speed needed for wind turbines to generate power. This was followed by mapping of 479 locations on NASA's SRTM database to filter out high elevation areas.

Most of the initially scoped areas from mountainous districts of Dima Hasao and Cachar are found to be unsuitable for wind projects due to geographical and terrain conditions. Following the filtering of wind sites for terrain and elevation conditions, 10 sites are found to be feasible for wind project development in the state.

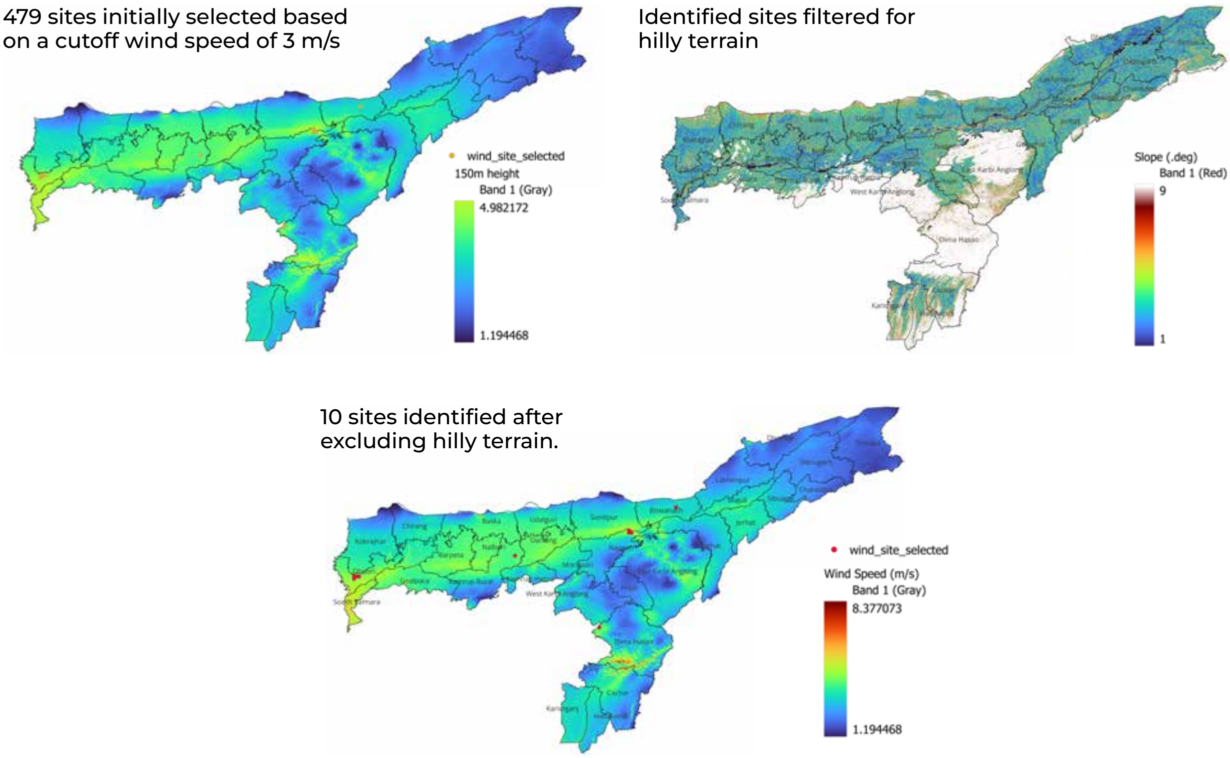
The shortlisted sites are located across five districts of Biswanath, Dima Hasao (upper region) , Kamrup Rural , Dhubri and Nagaon, for which CUF is estimated based on a standard turbine model

(GE 130) and wind speed data for 15 years sourced from NASA NERL (National Renewable Energy Laboratory) for hub heights of 100 m and 150 m agl.

Of the 10 identified sites, four sites across Dima Hasao and Dhubri have wind speed above 4.5 m/s and CUF of 22 per cent and above at 150 m agl. The western district of Assam, Dhubri has three sites with an average wind speed of 4.5 m/s and CUF of 22 and above.

The hilly district of Dima Hasao has highest average wind speed in the state, however due to its hilly terrain only one site is found to feasible and techno-commercially viable for project development. The identified site in Dima Hasao also offers highest CUF amongst the sites, more than 32 per cent.

Map 3.1: High wind speed site identification for Assam



Source: iFOREST Assessment

Table 3.2: Identified high potential sites for wind power development

No.	Latitude	Longitude	District	Average wind speed at 150 m (m/s)	CUF at 150 m (%)	Average wind speed at 100 m (m/s)	CUF at 100 m (%)
L1	26.861975	93.49955	Biswanath	3.82	12.56	3.73	11.82
L2	25.529835	92.649124	Dima Hasao	5.47	32.83	5.12	30.34
L3	26.323996	91.71639	Kamrup Rural	4.36	18.24	4.1	14.92
L4	26.093433	89.933235	Dhubri	4.84	22.02	4.52	18.12
L5	26.067814	89.933235	Dhubri	4.81	21.6	4.49	17.62
L6	26.093433	89.96067	Dhubri	4.85	22.1	4.53	18.28
L7	26.093433	89.988106	Dhubri	4.85	22.19	4.54	18.41
L8	26.580175	92.97832	Nagaon	4.15	15.88	3.94	13.1
L9	26.605793	92.97832	Nagaon	4.21	15.37	4.01	13.55
L10	26.580175	93.00575	Nagaon	4.2	15.78	3.96	13.08

Source: iFOREST Assessment

4. Biomass

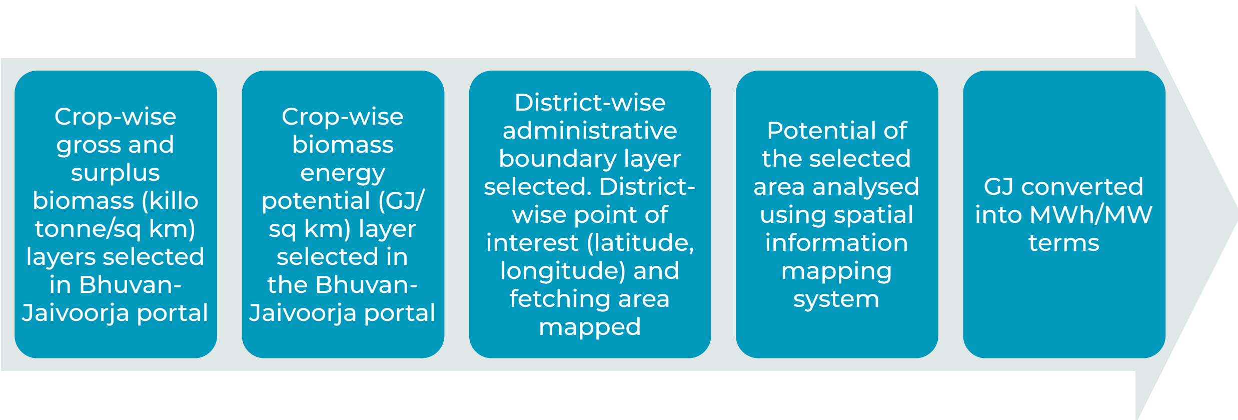
Biomass energy potential is mainly a factor of quantum of surplus crop residue and its calorific value. In context of a state, the biomass-based energy potential depends on the extent of land under cultivation, cultivated crops and cultivation seasons.

Assam has a geographical area of 78,438 sq km of land, and a gross annual cultivated area of 38,883 sq km, of which 24,179 sq km is under cereal production (rice, jowar, maize, wheat, ragi and barley)[22]. Agriculture residue from cereal production has massive potential to be used for power generation. The data from Ministry of New and Renewable Energy (MNRE) suggests that Assam produces annual biomass of 12.57 MT of which 2.54 MT is surplus biomass which can support biomass-based energy generation of 212 MW.[23]

4.1 Re-assessment Methodology

For Assam, biomass-based bioenergy potential at the district-level is reassessed using the ISRO's Bhuvan-Jaivoorja portal.[24] Based on the cropping information available on the portal, potential crop masks are built for each of the district using multi-temporal satellite data, which are then transformed into crop fractions at a resolution of 1 km grid based on the MODIS Gross Primary Production (GPP) dataset. Subsequently, the surplus biomass data is converted into biomass energy potential using the heating value/calorific value specific to each crop residue.

Figure 4.1: Methodology for assessment of biomass-based bioenergy potential



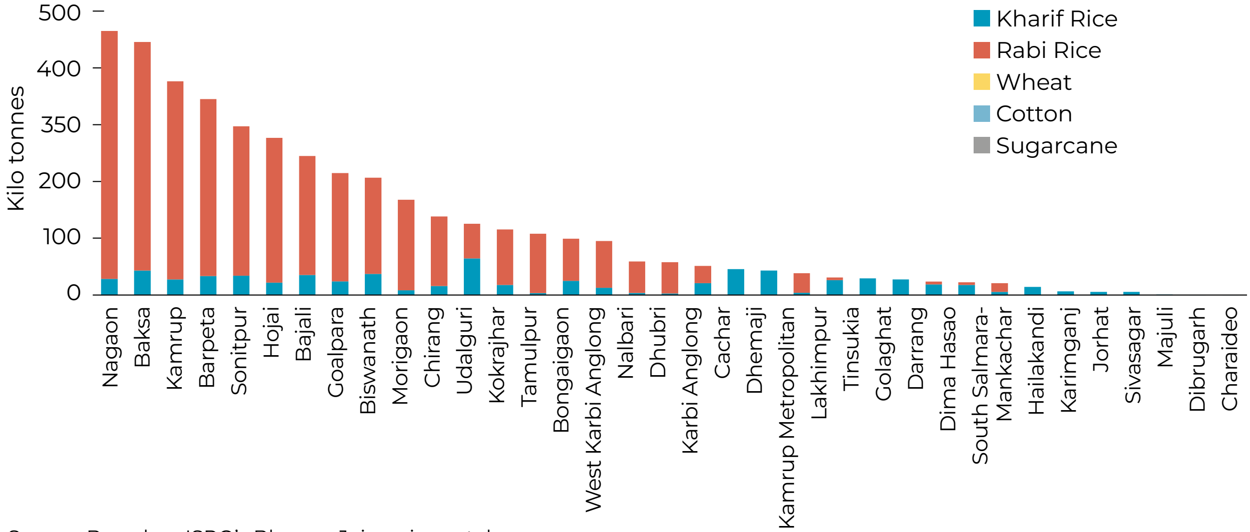
Source: iFOREST Assessment

4.2 Potential Estimation

According to the mapping and estimation done through the Bhuvan-Jaivoorja portal, Assam produces 4,214 kilo tonnes of gross biomass. This is almost exclusively generated by rice, including 83 per cent contribution from kharif rice and 17% from rabi rice. Of this, 562 kilo tonnes is assessed to be surplus biomass produced, including 30% from kharif rice and 70% from rabi rice. Based on this, the cumulative theoretical potential for biomass power in Assam is estimated to 2,419 GW.

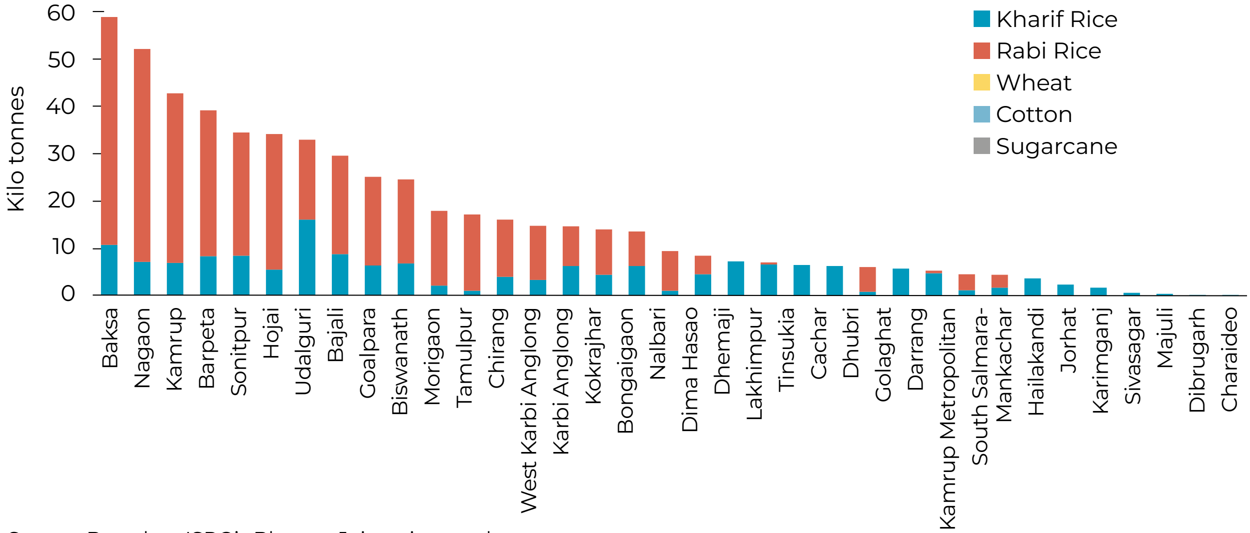
The districts of Baksa, Nagaon, Kamrup, Barpeta, Sonitpur, Hojai and Udalguri make up to more than 50% of surplus biomass and biomass-based energy potential. Majority of these biomass surplus districts are in the western parts of Assam.

Graph 4.1: District-wise and crop-wise yearly gross biomass generation



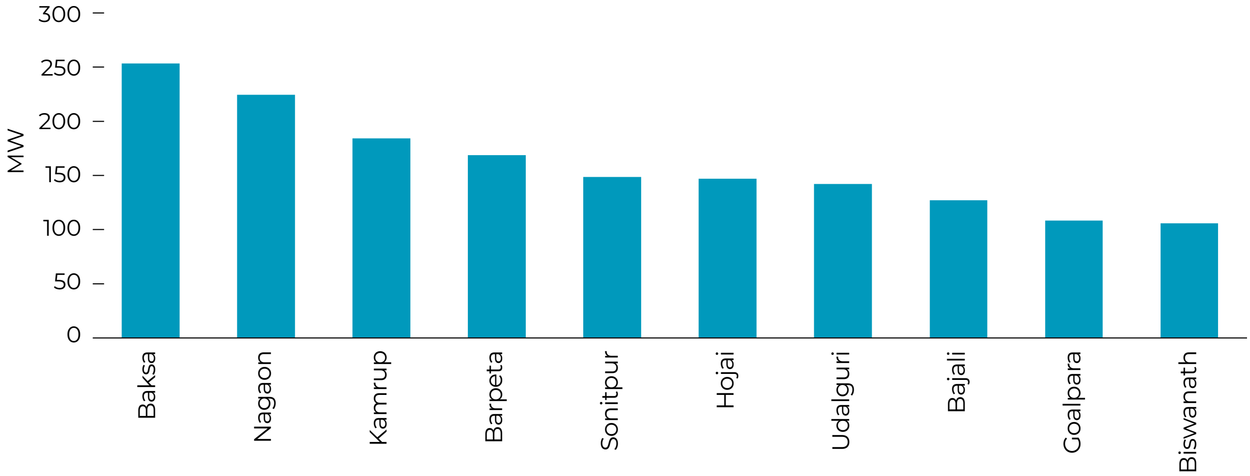
Source: Based on ISRO's Bhuvan-Jaivoorja portal

Graph 4.2: District-wise and crop-wise yearly surplus biomass generation



Source: Based on ISRO's Bhuvan-Jaivoorja portal

Graph 4.3: Leading district-wise in biomass potential



Source: iFOREST estimates

Annexure

A.1: District-wise category-wise wasteland area in Assam (sq km)

District	Grazing land	Sandy area	Scrub land	Mining & industrial waste	Waterlogged area	Degraded forest	Shifting cultivation
Barpeta	0.42	0.75	6.09	4.13	43.14	-	-
Baska	1.29	1.54	9.9	1.85	12.78	84.27	-
Cachar	-	-	148.71	6.21	43.61	52.99	15.2
Chirang	2.96	0.08	7.72	-	3.56	233.2	-
Darrang	0.1	-	46.79	3.39	4.12	9.69	-
Dibrugarh	-	0.55	5.19	0.76	23.43	90.61	-
Golaghat	0.05	-	107.59	3.5	22.45	459.87	-
Hailakandi	-	-	14.26	1.8	11.89	81.81	13.81
Jorhat	-	-	12.79	1.58	29.71	75.02	3.18
Kamrup metro	0.087	-	33.95	7.48	14.07	12.08	0.45
Kamrup Rural	0.15	-	92.85	5.48	76.15	59.5	8.87
Kokrajhar	5.69	0.14	26.92	0.51	8.02	408.83	-
Lakhimpur	-	11.1	19.09	-	18.45	54.38	0.13
0gaon	0.27	-	203.16	10.91	88.24	110.39	-
0lbari	0.34	1.07	2.73	1.64	33.06	-	-
Sibsagar	-	-	9.73	0.48	32.6	65.22	0.01
Sonitpur	1.08	0.71	6.19	2.19	12.35	444.69	-
Tinsukia	-	-	34.92	1.71	33.74	114.52	0.3
Udalguri	1.2	-	3.44	0.31	3.12	139.89	-
Bongaigaon	1.75	1.7	15.27	1.73	4.54	25.41	-
Morigaon	-	0.088	1.76	4.59	19.03	12.22	-
Dhemaji	-	7.2	23.27	-	20.19	21.96	-
Goalpara	0.54	0.06	93.4	1.05	15.39	67.71	-
Dima Hasao	-	-	1461.67	-	-	205.15	11.45
West Karbi Anglong	-	-	808.57	0.22	0.15	70.77	3.08
East Karbi Anglong	-	-	1953.2	1.07	0.81	566.43	17.89
South Salmara	-	-	-	0.16	0.67	1.12	-
Charaideo	-	-	-	0.1	0.15	45.43	-
Hojai	-	0.05	958.92	1.07	7.06	260.58	0.05
Biswa0th	0.85	4.85	5.2	3.94	23.29	226.82	-
Majuli	-	-	0.41	-	7.83	-	-
Karimganj	-	-	21.13	2.88	29.73	42.28	7.04
Dhubri	-	0.048	11.63	3.83	5.19	20.96	-
Total	**16.8**	**29.96**	**6,146.50**	**74.63**	**648.55**	**4,063.87**	**81.49**

Source: Based on ISRO's NRSC

A.2 District-wise solar ground mounted potential and associated wasteland utilization

District	Solar generation potential (MW)		Wasteland utilization for solar installation (sq km)				
	NISE	iFOREST	Grazing land	Sandy area	Scrub	Mining & industrial waste	Shifting cultivation
Barpeta			0.1	0.13	2.8	2.42	0
Baska	64.19	357.07	0.29	0.47	3.97	1.48	0
Cachar	131.36	334.88	0	0	9.3	2.87	0.5
Chirang	313.84	894.71	0.73	0.02	5.05	0	0
Darrang	291.26	408.16	0.02	0	0.4	1.23	0
Dibrugarh	75.4	116.02	0	0.02	1.02	0.4	0
Golaghat	141.84	97.17	0.02	0	20.83	1.88	0
Hailakandi	698.28	1,579.30	0	0	0.2	0.32	0.43
Jorhat	145.42	67.17	0	0	3.49	0.83	0.64
Kamrup metro	143.89	328.64	0.02	0	0.57	0.12	0.01
Kamrup Rural	80.16	49.84	0.02	0	12.48	2.65	0.29
Kokrajhar	285.93	1,089.76	1.48	0.04	11.87	0.27	0
Lakhimpur	529.61	945.23	0	2.22	6.47	0	0.02
Nagaon	121.38	457.59	0	0	9.98	5.18	0
Nalbari	485.93	1,070.26	0.09	0.36	1.58	0.67	0
Sibsagar	45.7	94.6	0	0	2.48	0.26	0
Sonitpur	127.12	193.45	0.27	0.18	2.73	1.13	0
Tinsukia	549.74	287.03	0	0	16.03	0.14	0.01
Udalguri	217.91	1,142.45	0.26	0	0.99	0.17	0
Bongaigaon	174.1	100.22	0.37	0.41	4.53	0.29	0
Morigaon	59.31	366.92	0	0	0.17	1.32	0
Dhemaji	44.36	105.1	0	1.76	9.83	0	0
Goalpara	85.46	693.83	0.11	0.02	32.78	0.33	0
Dima Hasao	209.61	2,345.79	0	0	32.13	0	0.91
West Karbi Anglong	1,974.68	2,332.25	0	0	4.92	0	0.03
East Karbi Anglong	1,038.71	349.03	0	0	94.88	0.03	1.52
South Salmara	2,987.90	6,807.86	0	0	0	0	0
Charaideo	2.31	0.27	0	0	0	0.05	0
Hojai	53.74	3.5	0	0.02	60.85	0.12	0
Biswanath	1,444.58	4,305.58	0.23	0.76	1.72	1.98	0
Majuli	311.75	263.69	0	0	0.17	0	0
Karimganj	9.71	11.85	0	0	0.46	2.81	0.36
Dhubri	121.27	150.16	0	0.01	4.18	1.46	0

Source: iFOREST Assessment

A.3: Major clusters for solar ground mounted project development

Sl no	District	Longitude	Latitude	Usable land (sq. km)	Potential (MW)	CUF (%)	Distance from substation (km)	No. of parcels across wasteland categories
1	Golaghat	93.9347	26.1294	43.79	2,164.16	24.47	10.64	· 74 parcels of scrubs land · 29 parcels of mining & industrial land · 1 parcel of grazing land
2	Goalpara	90.93420517	25.94098957	42.81	2,115.82	23.56	20.72	· 10 parcels of shifting cultivation · 132 parcels of scrubs land · 1 parcel of sandy area · 1 parcel of mining and industrial land · 2 parcels of grazing land
3	Kamrup rural	91.6758973	26.3201755	37.12	1,834.32	24.31	8.54	· 42 parcels of scrubs land · 2 parcels of sandy area · 83 parcels of mining & industrial land · 3 parcels of grazing land
4	Nagaon	92.6577776	26.2701363	7.98	394.14	24.07	18.91	· 11 parcels of scrubs land · 44 parcels of mining & industrial land
5	Chirang	90.45605282	26.67100589	4.32	213.61	23.47	18.07	· 16 parcels of scrubs land · 1 parcel of sandy area · 1 parcel of mining & industrial · 7 parcels of grazing land
6	Kokrajhar	90.03572354	26.62207867	2.62	129.31	23.50	15.49	· 10 parcels of scrubs land · 3 parcels of mining & industrial land · 31 parcels of grazing land
7	Kokrajhar	89.99402421	26.26846833	2.57	127.11	23.14	18.88	· 5 parcels of scrubs land · 5 parcels of mining & industrial land · 1 parcel of grazing land
8	Baska	91.27057979	26.71937712	1.50	74.03	23.39	31.78	· 12 parcels of scrubs land · 2 parcels of mining & industrial land · 10 parcels of grazing land
9	Barpeta	91.24889613	26.36465479	0.92	45.68	24.15	21.69	· 2 parcels of sandy area · 3 parcels of scrubs · 8 parcels of mining & industrial land · 3 parcels of grazing land
10	Sonitpur	92.48152842	26.83446728	0.501	24.98	22.73	19.04	· 1 parcel of scrubs land · 2 parcels of sandy area · 13 parcels of mining & industrial · 6 parcels of grazing land

Source: iFOREST Assessment

A.4: Monthly spread areas for waterbodies in Assam (sq km)

Dam/reservoir, District	Max spread area	Water spread area parameter	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Son Beel, Karimganj	26.34	Average	2.09	1.39	1.08	11.91	14.84	22.76	22.56	25.56	25.55	23.42	20.66	10.57
		Minimum	0.9	0.17	0.02	0.21	2.74	2.79	23.29	24.84	25.15	15.68	10.40	0.12
Umrong Dam, Dima Hasao	18.80	Average	9.66	7.42	5.33	7.82	8.11	9.39	14.21	12.3	12.64	11.52	12.96	11.04
		Minimum	0.90	0.9	0.97	0.91	1.04	3.34	7.05	1.27	0.98	0.753	0.98	0.91
Kopili Reservoir, Dima Hasao	12.23	Average	6.19	5.36	4.91	5.79	7.08	7.45	8.53	7.92	8.23	8.74	8.23	7.11
		Minimum	2.28	1.57	2.17	2.27	1.57	0.77	5.14	2.80	3.60	5.22	4.43	2.32
Bongaigaon TPP Reservoir, Kokrajhar	0.39	Average	0.23	0.18	0.18	0.16	0.22	0.2	0.19	0.24	0.23	0.19	0.15	0.2
		Minimum	0.11	0.12	0.13	0.11	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11
Sivasagar Tank, Sibsagar	0.49	Average	0.44	0.48	0.45	0.44	0.39	0.37	0.41	0.41	0.4	0.4	0.42	0.43
		Minimum	0.36	0.40	0.39	0.34	0.2	0.12	0.39	0.38	0.21	0.25	0.38	0.35
Joysagar Tank, Sibsagar	0.463	Average	0.46	0.41	0.40	0.39	0.37	0.34	0.35	0.38	0.35	0.35	0.35	0.38
		Minimum	0.36	0.36	0.36	0.38	0.28	0.11	0.11	0.35	0.19	0.27	0.32	0.33
Gauri Sagar, Sibsagar	0.48	Average	0.41	0.43	0.44	0.43	0.39	0.4	0.37	0.41	0.33	0.33	0.36	0.39
		Minimum	0.12	0.40	0.4	0.38	0.22	0.32	0.18	0.37	0.12	0.19	0.33	0.32

Source: ISRO NRSC WBIS; iFOREST Assessment

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