Assessment of the potential for rooftop solar electricity generation in Nigeria

Prepared by

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Acronyms

ANNs	Artificial Neural Networks
DSM	Digital Surface Model
FCT	Federal Capital Territory
GIS	Geographic Information Systems
GSV	Google Street View
KWh/sqm	Kilowatt hour per square meter
LiDAR	Light Detection and Ranging
MWh	Megawatts Per hour
NC	North Central
NE	North East
NERC	National Electricity Regulation Commission
NIMET	Nigerian Meteorological Agency
NW	North West
OBIA	Object Based Image Analysis
PV	Photovoltaic
QGIS	Quantum Geographic Information System
SDGs	Sustainable Development Goals
SE	South East
SS	South South
SVMs	Support Vector Machines
SW	South West
UMEP	Urban Multi-scale Environmental Predictor
UNFCCC	United Nations Convention on Climate Change

INTRODUCTION

This report provides a first-of-its-kind assessment of rooftop solar PV potential across the 36 states in Nigeria and the Federal Capital Territory. The rooftops selected for the study are inclined at 45 degrees or less, receive at least 800 kWh/m2 of solar radiation, and face north. Additional details on the steps taken to estimate the energy potential of rooftops in Nigeria are shown in the graphic below.

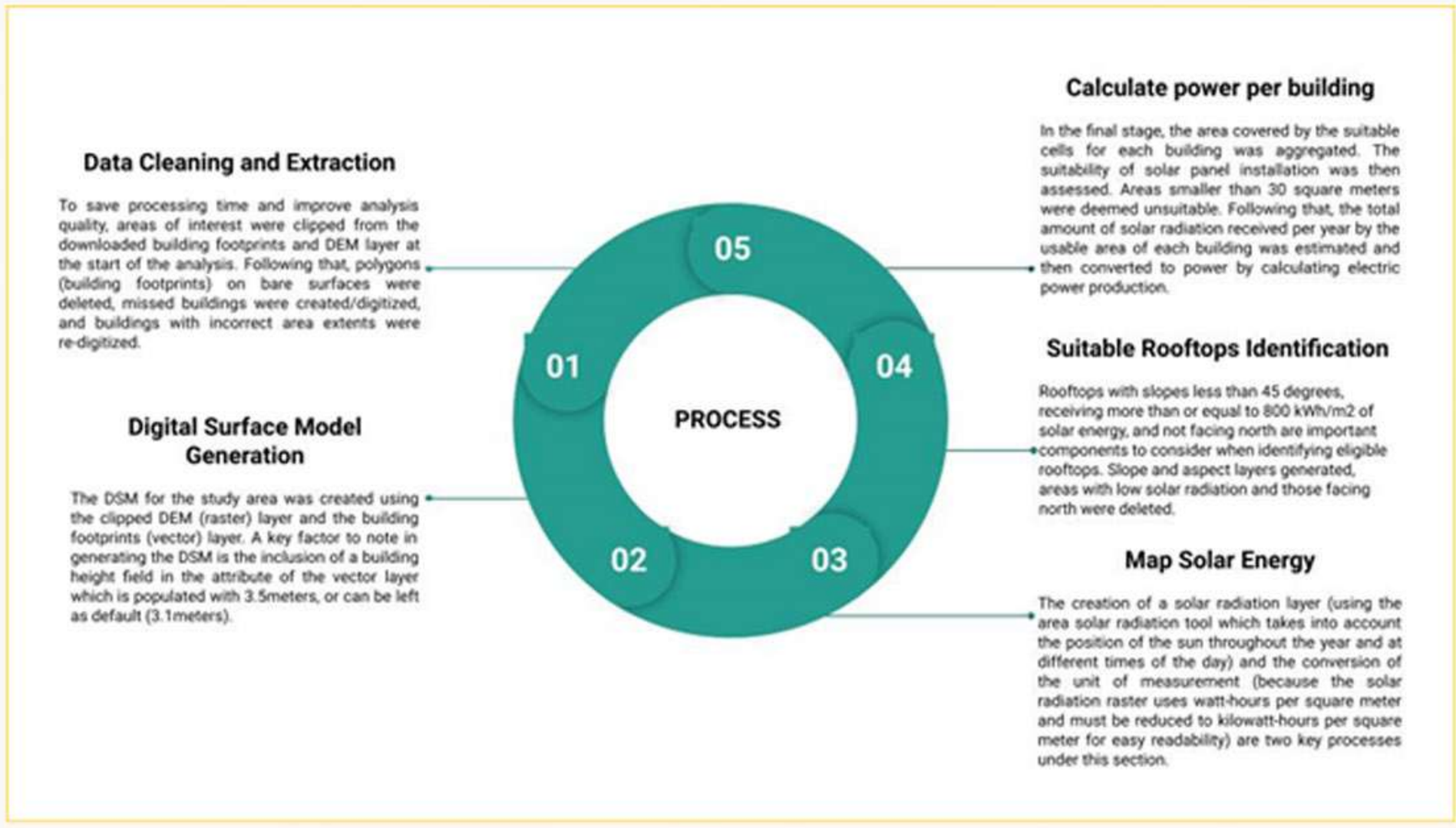


Figure 1: Solar power potential determination process

We considered the fact that solar irradiance varies throughout the day and is highly dependent on local weather conditions – thus, we collected data on solar radiation from the Nigerian Meteorological Agency (NiMET). The NiMeT data reading was converted into watts per square meter to ascertain the power density of geographical areas, and then narrowed down using rooftop area estimates to calculate the power generation potential at specified times of the day. The types of data utilized for this study included the Vector and Raster. The data sources were:

1. Building Footprint – We sourced this using digitized building polygons from satellite imagery.
2. Digital Elevation Model (DEM) – We combined the use of Lidar and DEM data we could extract from the Shuttle Radar Topographic Mission (SRTM).
3. Digital Source Model (DSM) – We used a mix of Lidar and building footprint data using a DSM generator tool.

Additional data considerations

1. The DEM and Building Footprints were converted from a geographical coordinate system to a projected coordinate system for each region in the country based on the established standards.
2. Then the converted DEM and Building Footprints were inserted in the DSM Generator tool.
3. The efficiency of the PV panels for each region/state was determined by using the current average range of efficiency for modern panels (15%-22%) averaging at about 18.5%. This was used as the basis/benchmark for our study. For every degree rise above 25°C, a reduction in efficiency of about 0.5% was considered. The roofing materials commonly used in each region/state also contribute to parasitic heating.
4. The average altitude/elevation of the region/state was also considered in our analysis. Regions/states with higher topographical elevation showed lesser nominal air mass, from the NiMet Data, and thus will have better efficiency rates. Further analysis was made to consider the impact of dust settlement, other particles, atmospheric pressure, gases, and air pollution from burning activities.

Determining solar power potential

We recognize the inefficiencies associated with PV electricity generation. Following the energy conversion, the overall energy preserved in the installed system will undergo losses in other energy forms, such as heat, electrical noise, capacitance, as well as connection points. Other environmental elements include roof top material, weather, population, and general spacing between buildings. These factors have been considered to determine the input parameters that were required to run our models.

The NiMet Data provided data on solar radiation, measured on the perpendicular surface of average elevation/altitude, groups by state. Daily, yearly figures were captured, while incorporating the effects of wind, temperature, atmosphere, rainfall, cloudiness, air mass, and other diffuse elements.

We excluded rooftops that were less than 30 sqm due to occupancy nature, total energy that can be generated, as well as panel sizing. Our analysis also showed that rooftop areas receiving at least 2 peak sun hours of solar radiation per day are considered viable for on-site solar.

This study used 250W PV panel output to make estimations because they have a decent W/m2 value. In addition, they are largely available in Nigeria, and they come in 24 Volts.

RESULTS AND INSIGHTS

This section presents a regional and state-by-state analysis of the energy that can be generated from rooftops in Nigeria.

NORTH CENTRAL ROOFTOP SOLAR ESTIMATIONS

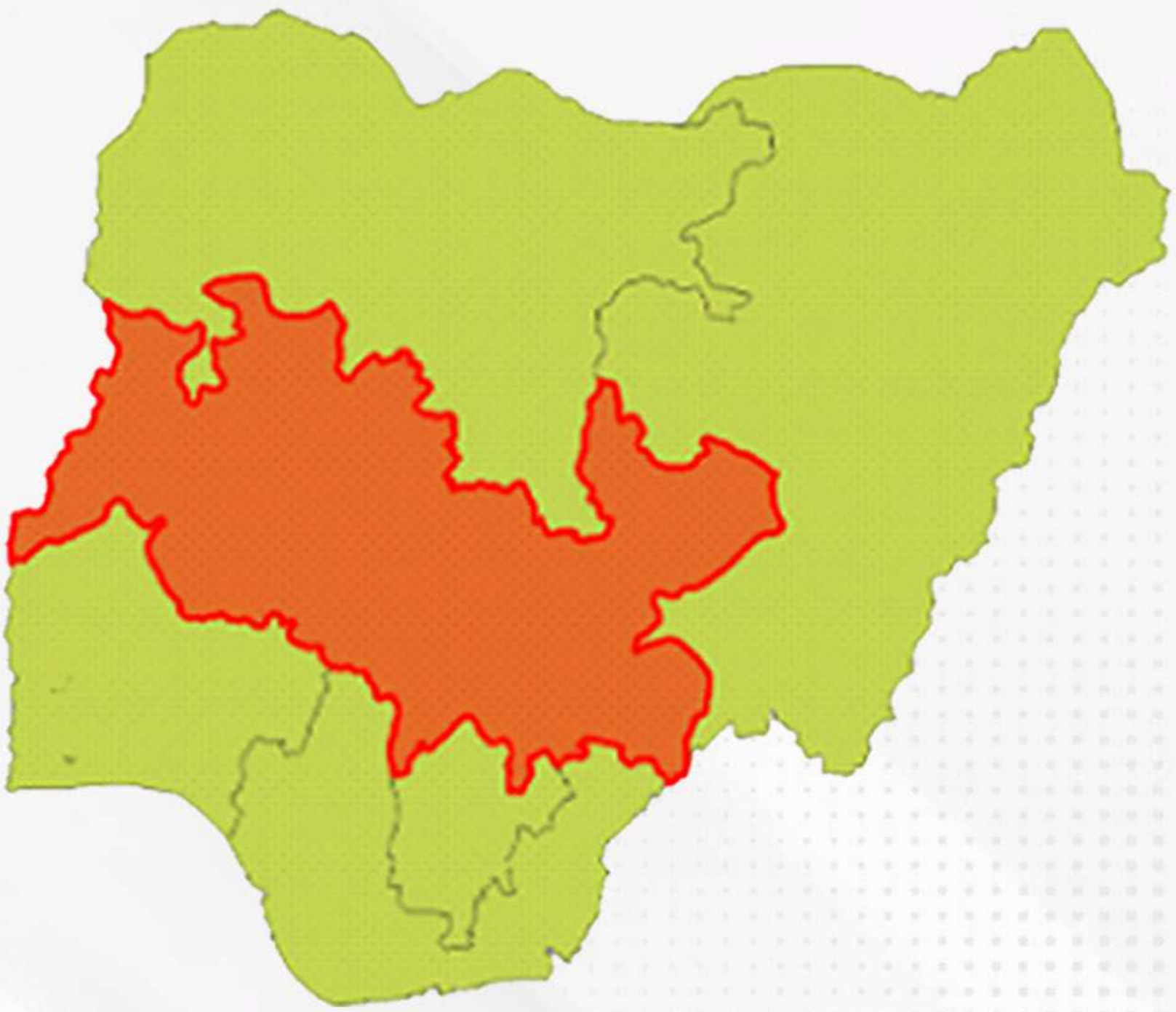
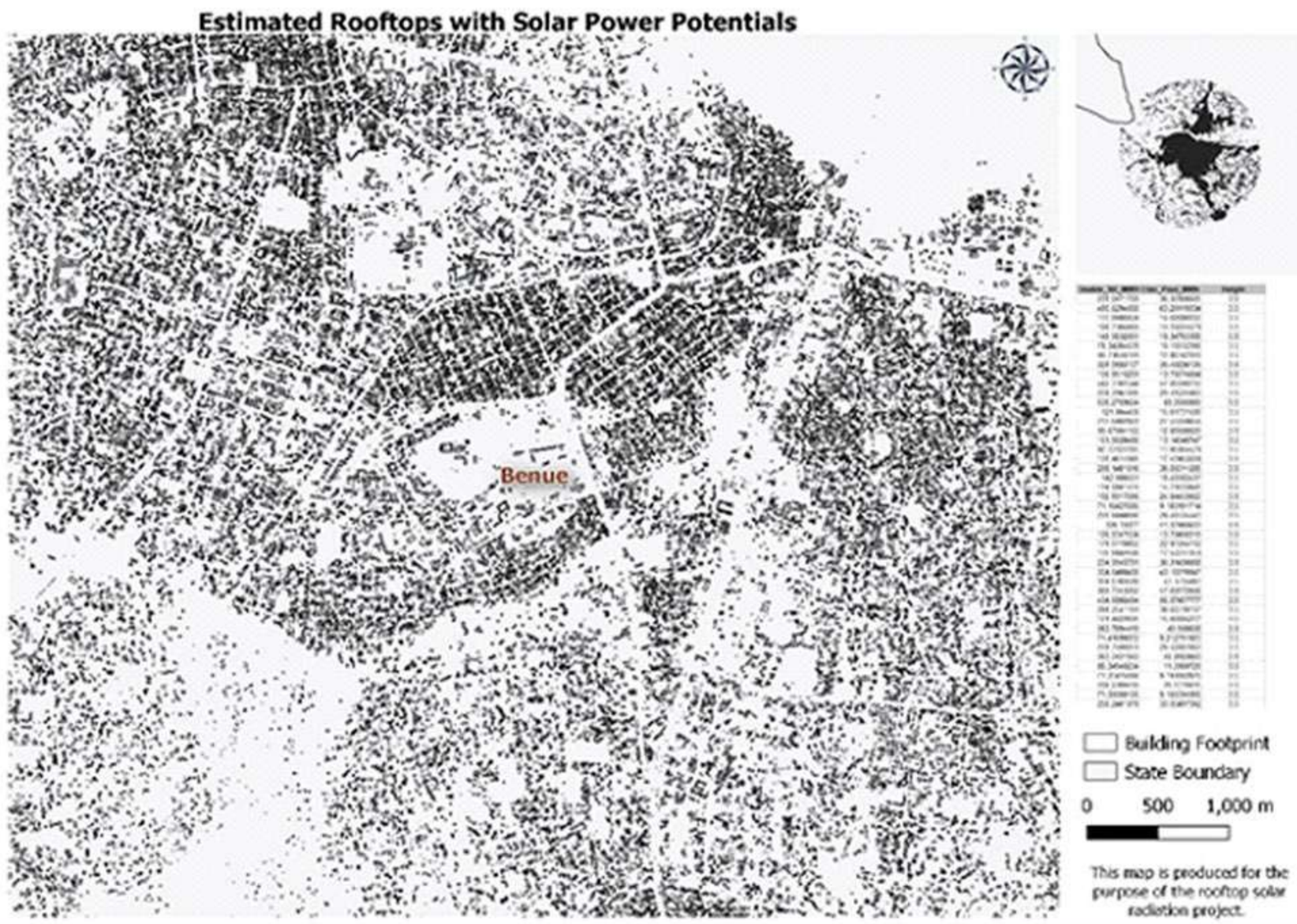


Fig 2: North Central Region of Nigeria



State Details

State: Benue
Region: North Central
City: Makurdi
Study Area: 2,772 sq. km
Total Buildings: 150,474
Suitable Buildings: 21,161
Suitability Ratio: 14 %

Solar Power Potential

Ave. Irradiation: 1779 kWh/m2
Max Usable IRR: 3462 MWh
Min Usable IRR: 52 MWh
Ave. Annual Electric power: 24 MWh
Max Annual Electric power: 447 MWh
Min Annual Electric power: 7 MWh

Fig 3: Benue State power potential details

Table 2: Comprehensive energy profile, Benue

s/n	Benue Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	514,351
2	Avg. rooftop square area (sqm)	106
3	Avg. number of sun hours per day	4.3
4	Avg. annual sun hours	1,570.58
5	Max. power potential in MW	327.49
6	Max. power potential in Watts	327,492,160.51
7	Viable rooftop space in sqm	388,080,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	215,600,000.00
9	# of 250W panels required to store energy from rooftop solar	308,227.92
10	# of 250W panels required to reach the maximum energy potential	1,541,139.58
11	# of 400W panels required to reach the maximum energy potential	963,212.24
12	Average kWh of storage required per year to ensure viability	5,497.01
13	Average battery charging potential per year (including batteries and Evs)	121,023,764.71
14	No. of batteries required ensure viability of rooftop area	22,016.28
15	Areas viable for power generation in Watts per sqm	0.8438779646

State Details

State: Federal Capital Territory
Region: North Central
City: Abuja
Study Area: 2,772 sq. km
Total Buildings: 160,526
Suitable Buildings: 17,638
Ave. Rooftop Area: 152 sq. m
Suitability Ratio: 11 %

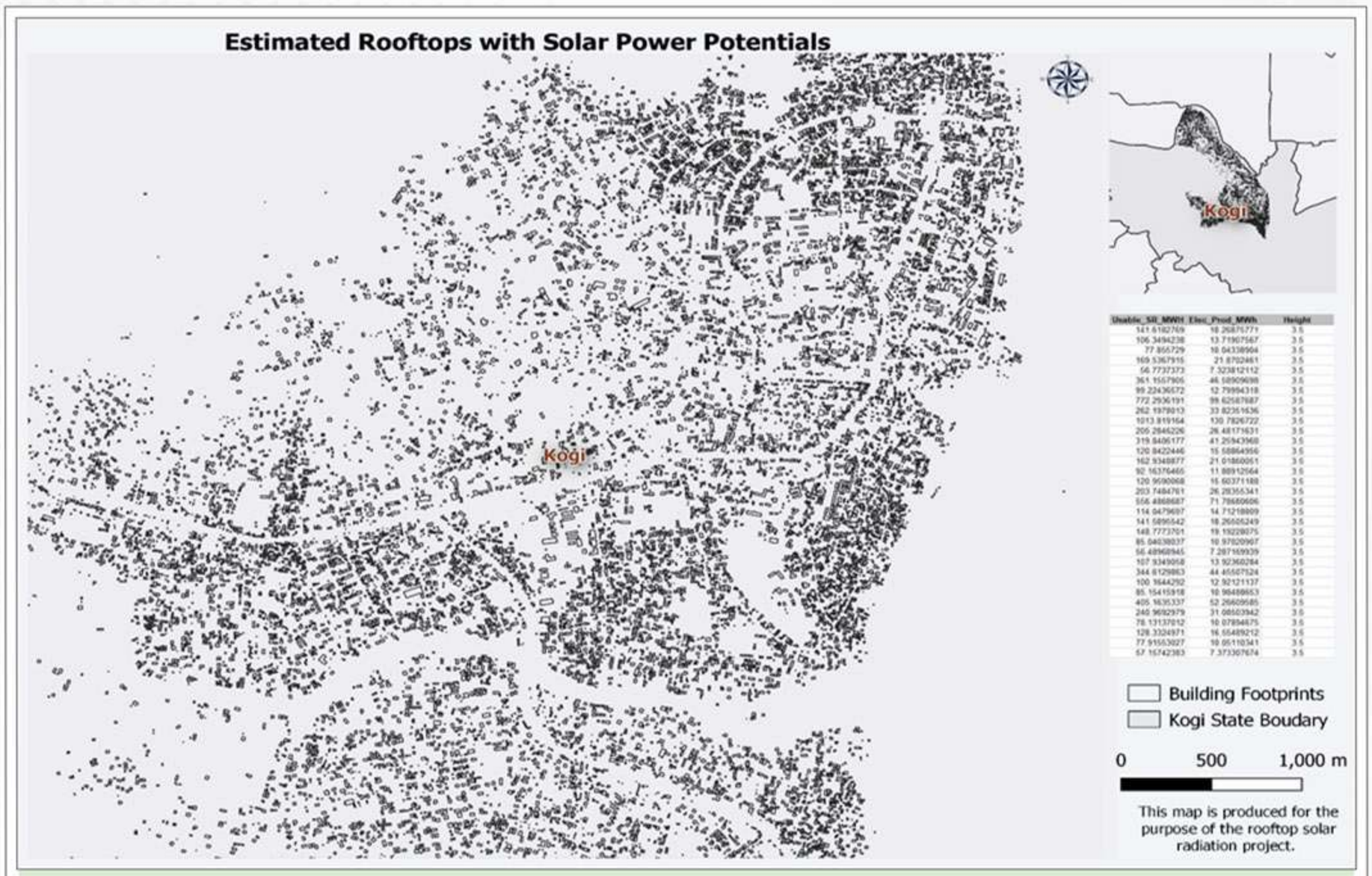
Solar Power Potential

Ave. .Irradiation: 1846 kWh/m2
Max Usable IRR: 8983 MWh
Min Usable IRR: 49 MWh
Av annual electric power: 36 MWh
Max annual electric power: 447 MWh
Min annual electric power: 7 MWh

Fig 4: Federal Capital Territory power potential details

Table 2: Comprehensive energy profile, Abuja

s/n	Abuja Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	639,899
2	Avg. rooftop square area (sqm)	152
3	Avg. number of sun hours per day	4.2
4	Avg. annual sun hours	1,534.05
5	Max. power potential in MW	417.13
6	Max. power potential in Watts	417,130,471.63
7	Viable rooftop space in sqm	304,920,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	169,400,000.00
9	# of 250W panels required to store energy from rooftop solar	392,593.39
10	# of 250W panels required to reach the maximum energy potential	1,962,966.93
11	# of 400W panels required to reach the maximum energy potential	1,226,854.33
12	Average kWh of storage required per year to ensure viability	5,369.18
13	Average battery charging potential per year (including batteries and Evs)	150,564,470.59
14	No. of batteries required ensure viability of rooftop area	28,042.38
15	Areas viable for power generation in Watts per sqm	1.36799971



State Details

State: Kogi
Region: North Central
City: Lokoja
Study Area: 3406 sq. km
Total Buildings: 97,134
Suitable Buildings: 10,290
AVE. Rooftop Area: 108 sq. m
Suitability Ratio: 10 %

Solar Power Potential

Ave. Irradiation: 1762 kWh/m2
Max Usable Irradiation: 4409 MWh
Min Usable IRR: 39 MWh
Av annual electric power: 25 MWh
Max annual electric power: 569 MWh
Min annual electric power: 5 MWh
Max combined electric power: 413000 MWh

Fig 5: Kogi State power potential details

Table 3: Comprehensive energy profile of Kogi

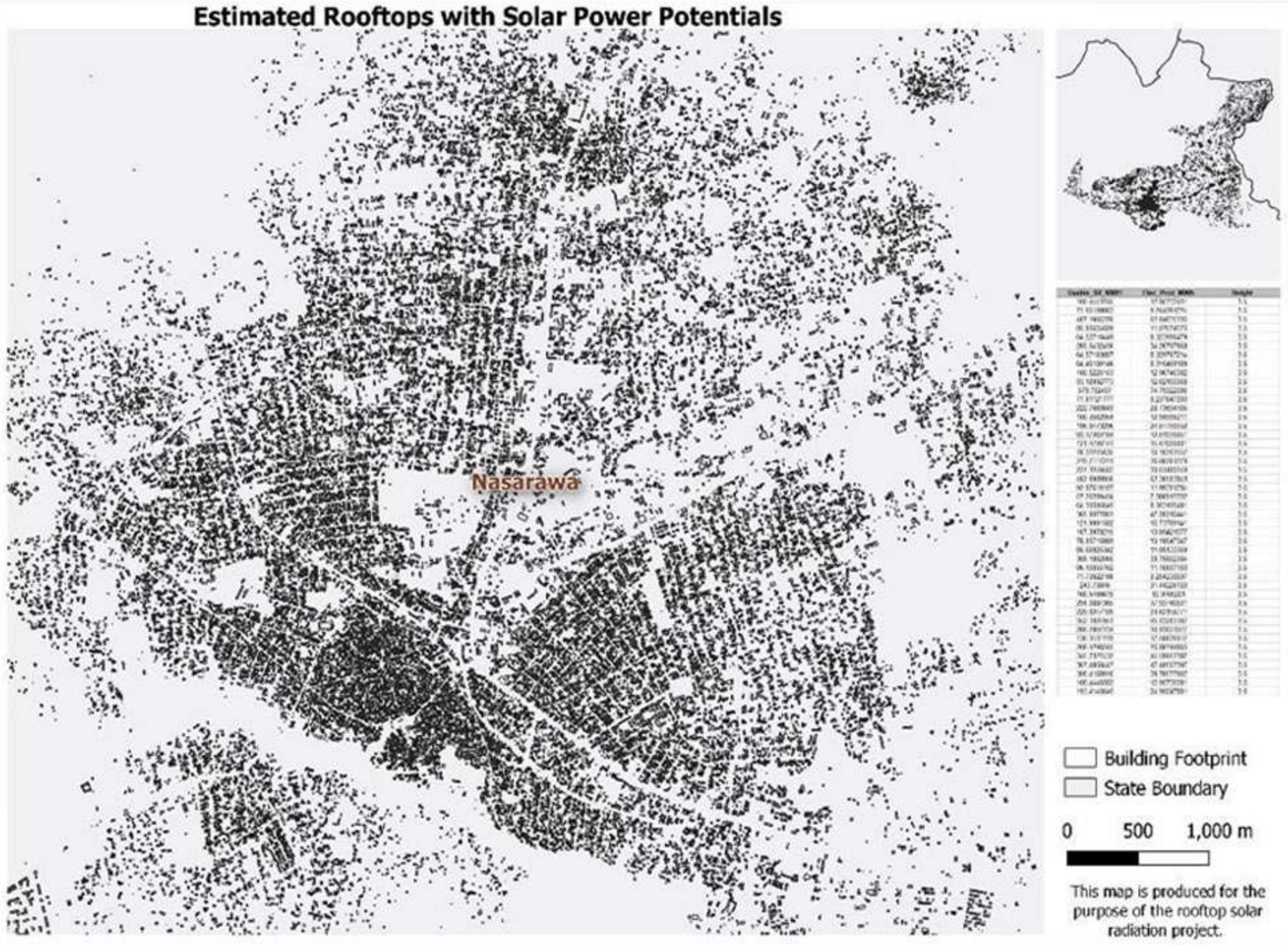
s/n	Kogi Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	413,000
2	Avg. rooftop square area (sqm)	108
3	Avg. number of sun hours per day	4.2
4	Avg. annual sun hours	1,534.05
5	Max. power potential in MW	269.22
6	Max. power potential in Watts	269,221,994.07
7	Viable rooftop space in sqm	340,600,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	189,222,222.22
9	# of 250W panels required to store energy from rooftop solar	253,385.41
10	# of 250W panels required to reach the maximum energy potential	1,266,927.03
11	# of 400W panels required to reach the maximum energy potential	791,829.39
12	Average kWh of storage required per year to ensure viability	5,369.18
13	Average battery charging potential per year (including batteries and Evs)	97,176,470.59
14	No. of batteries required ensure viability of rooftop area	18,098.96
15	Areas viable for power generation in Watts per sqm	0.7904345099

State Details	Solar Power Potential
State: Kwara	Ave. Irradiation: 1821 kWh/m2
Region: North Central	Max Usable Irradiation: 2010 MWh
City: Ilorin	Min Usable Irradiation: 48 MWh
Study Area: 1379 sq. km	Ave. Annual Electric Power: 35 MWh
Total Buildings: 105,879	Max Annual Electric Power: 260 MWh
Suitable Buildings: 11,997	Min Annual Electric Power: 6 MWh
Ave. Rooftop Area: 147 sq. m	Combined Max Electric Power: 413000 MWh
Suitability Ratio: 11 %	

Fig 6: Kwara State power potential details

Table 4: Comprehensive energy profile of Kwara state

s/n	Kwara Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	413,000
2	Avg. rooftop square area (tsqm)	147
3	Avg. number of sun hours per day	4.2
4	Avg. annual sun hours	1,534.05
5	Max. power potential in MW	269.22
6	Max. power potential in Watts	269,221,994.07
7	Viable rooftop space in sqm	151,690,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	84,272,222.22
9	# of 250W panels required to store energy from rooftop solar	253,385.41
10	# of 250W panels required to reach the maximum energy potential	1,266,927.03
11	# of 400W panels required to reach the maximum energy potential	791,829.39
12	Average kWh of storage required per year to ensure viability	5,369.18
13	Average battery charging potential per year (including batteries and Evs)	97,176,470.59
14	No. of batteries required ensure viability of rooftop area	18,098.96
15	Areas viable for power generation in Watts per sqm	1.774817022

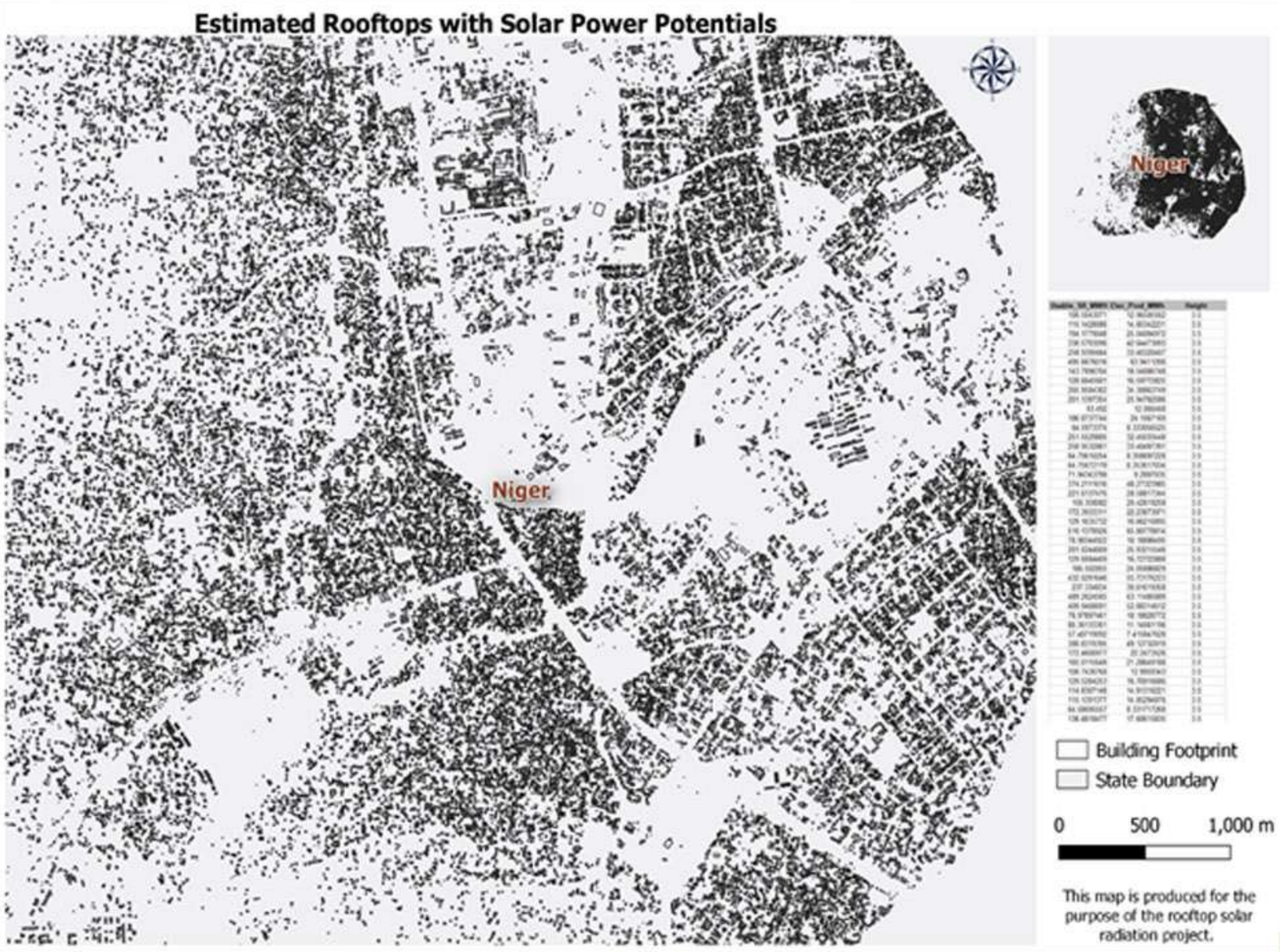


State Details	Solar Power Potential
State: Nasarawa	Ave. Irradiation: 1793 kWh/m2
Region: North Central	Max Usable Irradiation: 4012 MWh
City: Lafia	Min Usable Irradiation: 48 MWh
Study Area: 2,772 sq. km	Ave. Annual Electric Power: 23 MWh
Total Buildings: 142,092	Max Annual Electric Power: 518 MWh
Suitable Buildings: 24,721	Min Annual Electric Power: 6 MWh
Ave. Rooftop Area: 99 sq. m	Combined Max Electric Power: 568,387 MWh
Suitable Ratio: 17 %	

Fig 7: Nasarawa State power potential details

Table 5: Comprehensive energy profile of Nasarawa state

s/n	Kaduna Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	25,191
2	Avg. rooftop square area (tsqm)	254
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	13.79
6	Max. power potential in Watts	13,793,839.84
7	Viable rooftop space in sqm	2,321,700,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,289,833,333.33
9	# of 250W panels required to store energy from rooftop solar	12,982.44
10	# of 250W panels required to reach the maximum energy potential	64,912.19
11	# of 400W panels required to reach the maximum energy potential	40,570.12
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	5,927,294.12
14	No. of batteries required ensure viability of rooftop area	927.32
15	Areas viable for power generation in Watts per sqm	0.005941267104



State Details

State: Niger
Region: North Central
City: Mina
Study Area: 71,934 sq. km
Total Buildings: 63,835
Suitable Buildings: 16,246
Ave. Rooftop Area: 107 sq. m
Suitability Ratio: 25 %

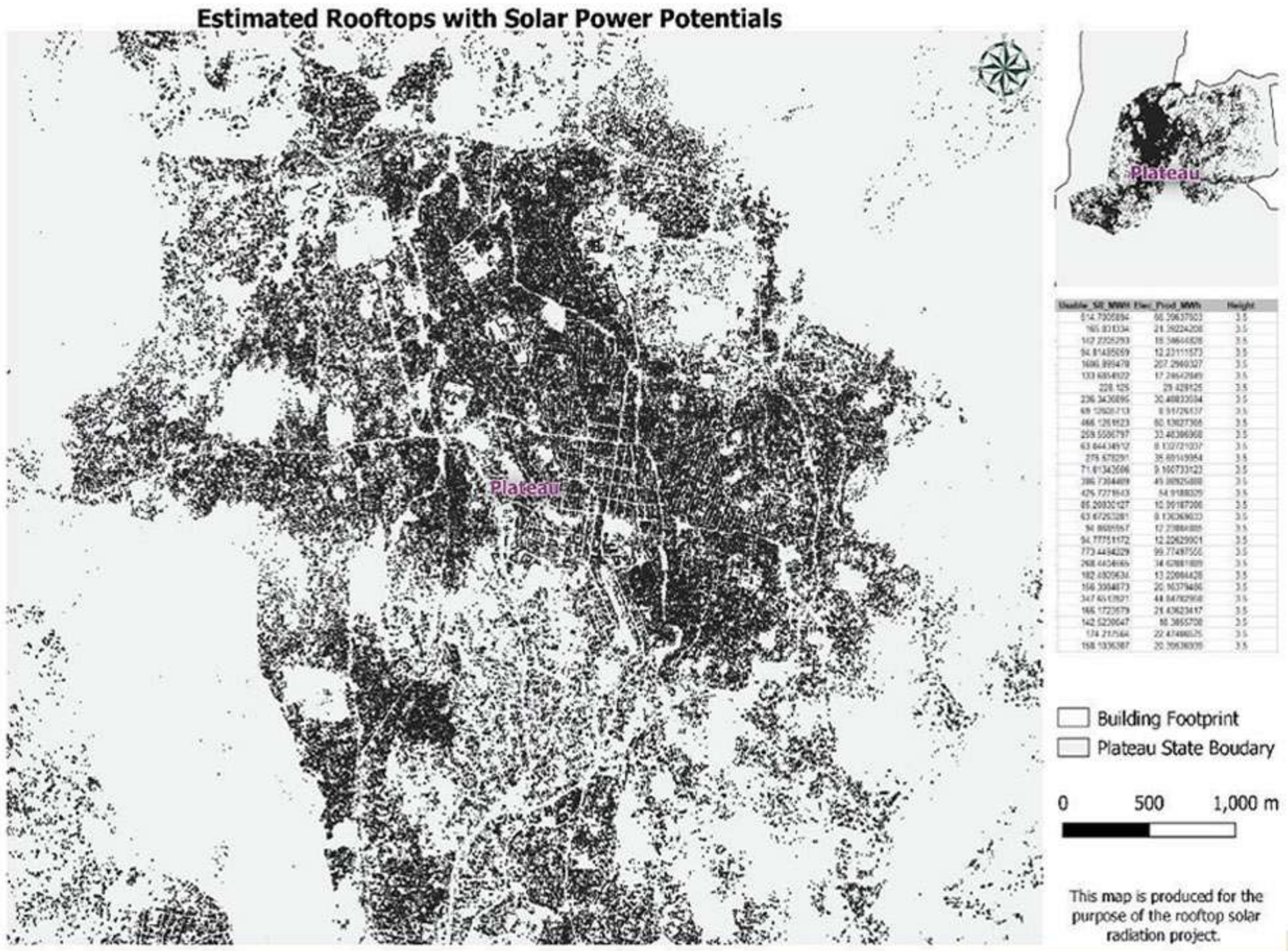
Solar Power Potential

Ave Irradiation: 1796 kWh/m2
Max Usable Irradiation: 5365 MWh
Min Usable Irradiation: 51 MWh
Ave. Annual Electric Power: 23 MWh
Max Annual Electric Power: 692 MWh
Min Annual Electric Power: 7 MWh
Max combined electric power: 366,089 MWh

Fig 8: Niger State power potential details

Table 6: Comprehensive energy profile of Niger state

s/n	Niger Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	366,089
2	Avg. rooftop square area (tsqm)	107
3	Avg. number of sun hours per day	4.5
4	Avg. annual sun hours	1,643.63
5	Max. power potential in MW	222.73
6	Max. power potential in Watts	222,732,679.29
7	Viable rooftop space in sqm	17,983,500,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	9,990,833,333.33
9	# of 250W panels required to store energy from rooftop solar	209,630.76
10	# of 250W panels required to reach the maximum energy potential	1,048,153.78
11	# of 400W panels required to reach the maximum energy potential	655,096.12
12	Average kWh of storage required per year to ensure viability	5,752.69
13	Average battery charging potential per year (including batteries and Evs)	86,138,588.24
14	No. of batteries required ensure viability of rooftop area	14,973.63
15	Areas viable for power generation in Watts per sqm	0.01238539101



State Details

State: Plateau
Region: North Central
City: Jos
Study Area: 1653 sq. km
Total Buildings: 288,004
Suitable Buildings: 22,965
Ave. Rooftop Area: 107 sq. m
Suitability Ratio: 8 %

Solar Power Potential

Ave. Irradiation: 1968 kWh/m2
Max Usable Irradiation: 8110 MWh
Min Usable Irradiation: 48 MWh
Ave. Annual Electric Power: 27 MWh
Max Annual Electric Power: 1046 MWh
Min Annual Electric Power: 6 MWh
Max combined electric power: 626,466 MWh

Fig 9: Plateau State power potential details

Table 7: Comprehensive energy profile of Plateau state

s/n	Plateau Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	626,466
2	Avg. rooftop square area (tsqm)	107
3	Avg. number of sun hours per day	4.5
4	Avg. annual sun hours	1,643.63
5	Max. power potential in MW	381.15
6	Max. power potential in Watts	381,148,984.71
7	Viable rooftop space in sqm	132,240,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	73,466,666.67
9	# of 250W panels required to store energy from rooftop solar	358,728.46
10	# of 250W panels required to reach the maximum energy potential	1,793,642.28
11	# of 400W panels required to reach the maximum energy potential	1,121,026.43
12	Average kWh of storage required per year to ensure viability	5,752.69
13	Average battery charging potential per year (including batteries and Evs)	147,403,764.71
14	No. of batteries required ensure viability of rooftop area	25,623.46
15	Areas viable for power generation in Watts per sqm	2.882251851

Table 8: North-central Power Potential Result

s/n	Power parameters	Plateau	Niger	Benue	FCT Abuja	Kogi	Kwara	Nassarawa	Total
1	Max. Combined Electric Power	626,466	366,089	514,351	639,899	413,000	413,000	568,387	3,541,192.00
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	107	107	106	152	108	147	99	826.00
3	Ave. SUN Hours from NiMET data	4.5	4.5	4.3	4.2	4.2	4.2	4.4	30.30
4	Ave. Annual Hours	1,643.63	1,643.63	1,570.58	1,534.05	1,534.05	1,534.05	1,607.10	11,067.08
5	Max. MW	381.15	222.73	327.49	417.13	269.22	269.22	353.67	2,240.62
6	Max. MW IN WATTS	381,148,984.71	222,732,679.29	327,492,160.51	417,130,471.63	269,221,994.07	269,221,994.07	353,672,453.49	2,240,620,737.77
7	Viable Sqm from building data	132,240,000.00	17,983,500,000.00	388,080,000.00	304,920,000.00	340,600,000.00	151,690,000.00	526,680,000.00	19,827,710,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	73,466,666.67	9,990,8	215,600,000.00	169,400,000.00	189,222,222.22	84,272,222.22	292,600,000.00	11,015,394,444.44
9	# of 250W Panels for Charging Batteries for viable rooftops	358,728.46	33,333.33	308,227.92	392,593.39	253,385.41	253,385.41	332,868.19	2,108,819.52
10	# of panels required to generate Max MW from Irradiation	1,793,642.28	209,630.76	1,541,139.58	1,962,966.93	1,266,927.03	1,266,927.03	1,664,340.96	10,544,097.59
11	No. of 400W PV Panels required to generate Max MW from Irradiation	1,121,026.43	1,048,153.78	963,212.24	1,226,854.33	791,829.39	791,829.39	1,040,213.10	6,590,060.99
12	Average KWH of Storage required per year	5,752.69	655,096.12	5,497.01	5,369.18	5,369.18	5,369.18	5,624.85	38,734.76
13	Average Charging Power Per Year	147,403,764.71	5,752.69	121,023,764.71	150,564,470.59	97,176,470.59	97,176,470.59	133,738,117.65	833,221,647.06
14	No. of Batteries to make rooftop study area viable	25,623.46	86,138,588.24	22,016.28	28,042.38	18,098.96	18,098.96	23,776.30	150,629.97
15	Areas viable for power generation (W per Sq Meter)	2.882251851	14,973.63	0.8438779646	1.36799971	0.7904345099	1.774817022	0.6715129746	8.34

SOUTH WEST ROOFTOP SOLAR ESTIMATIONS

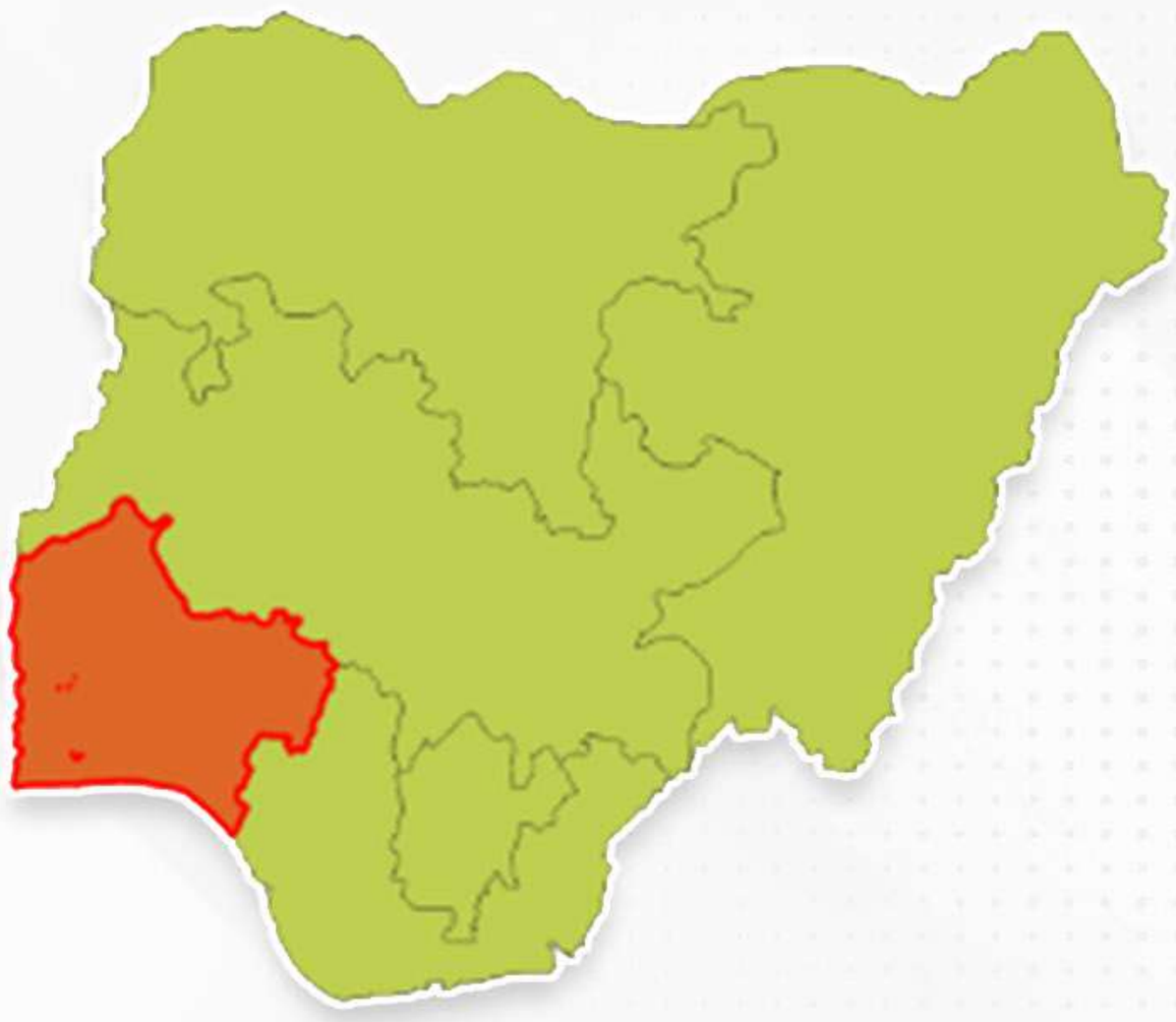
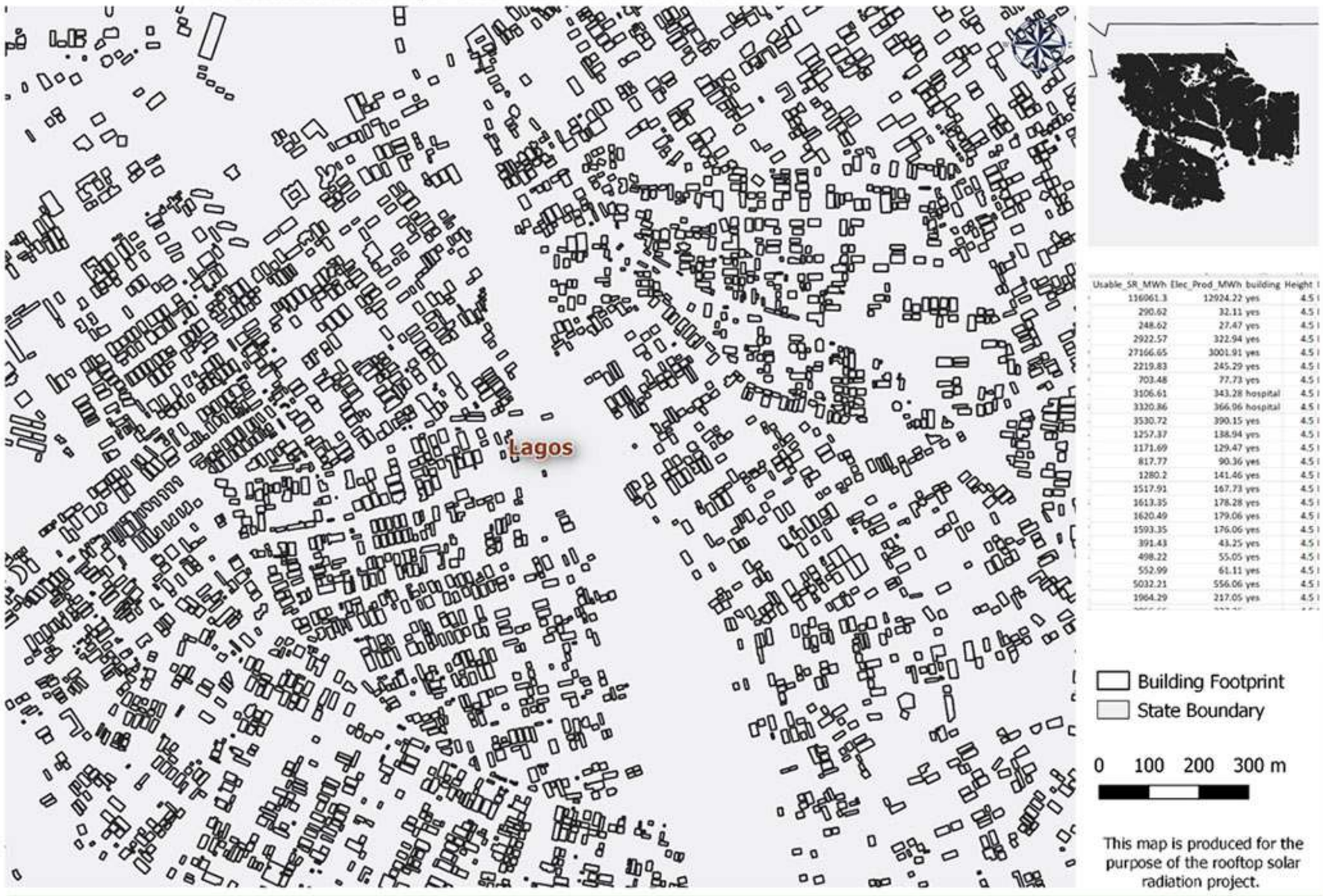


Figure 10: Nigeria map showing the Southwest region of Nigeria



State Details

State: Lagos
Region: SouthWest
City: Lagos Mainland
Study Area: 3671 sq.km
Total Buildings: 249 986
Suitable Buildings: 103 518
Ave. Rooftop Area: 134 sq.m
Suitability Ratio: 41%

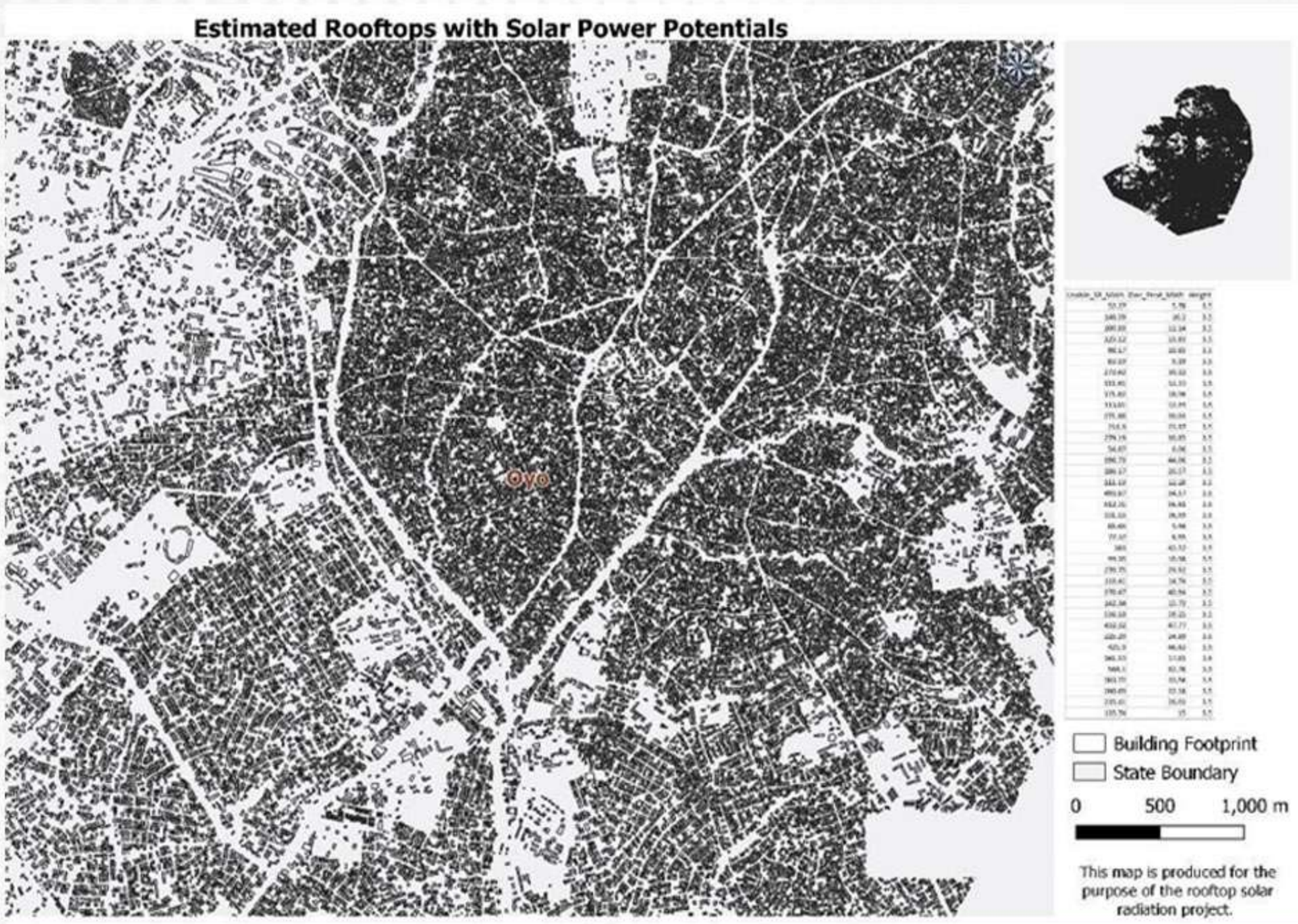
Solar Power Potential

Average Irradiation: 1772 kWh/m^2
Max Usable IRR: 116 961 MWh
Min Usable IRR: 49
Ave. Annual Electric Power :26 MWh
Max Annual Electric Power: 12924 MWh
Min Annual Electric Power: 5 MWh
Max combined electric power 2,726,003 MWh

Fig 11: Lagos State power potential details

Table 9: Comprehensive energy profile of Lagos state

s/n	Lagos Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	366,089
2	Avg. rooftop square area (tsqm)	107
3	Avg. number of sun hours per day	4.5
4	Avg. annual sun hours	1,643.63
5	Max. power potential in MW	222.73
6	Max. power potential in Watts	222,732,679.29
7	Viable rooftop space in sqm	17,983,500,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	9,990,833,333.33
9	# of 250W panels required to store energy from rooftop solar	209,630.76
10	# of 250W panels required to reach the maximum energy potential	1,048,153.78
11	# of 400W panels required to reach the maximum energy potential	655,096.12
12	Average kWh of storage required per year to ensure viability	5,752.69
13	Average battery charging potential per year (including batteries and Evs)	86,138,588.24
14	No. of batteries required ensure viability of rooftop area	14,973.63
15	Areas viable for power generation in Watts per sqm	0.01238539101



State Details

State: Oyo
Region: Southwest
City: Ibadan
Study Area: 15, 473 sq.km
Total Buildings: 289, 349
Suitable Buildings: 122 095
Ave. Rooftop Area: 153 sq.m
Suitability Ratio: 51%

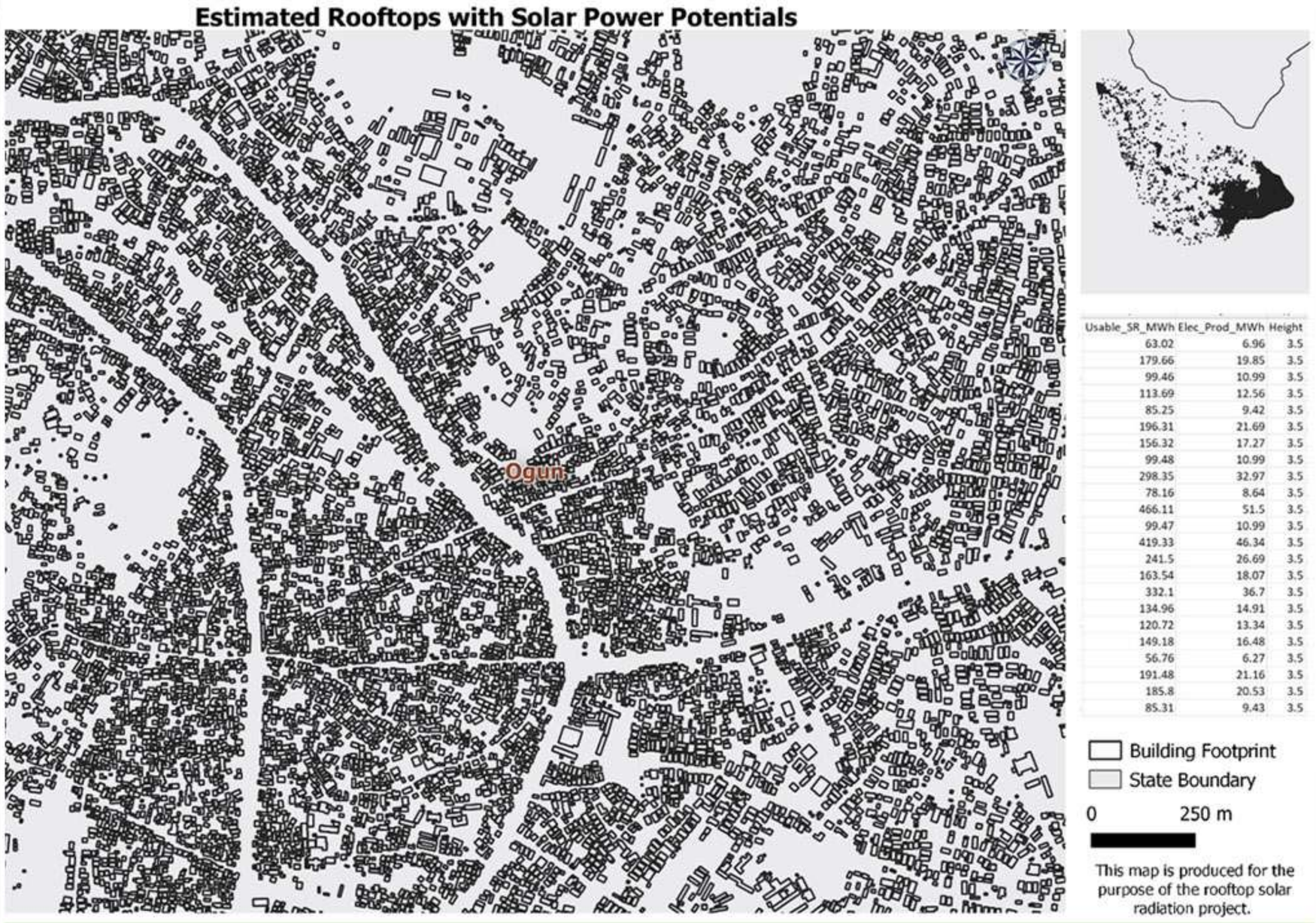
Solar Power Potential

Average Irradiation: 1762 kWh/m^2
Max Usable IRR: 46 399 MWh
Min Usable IRR: 37 MWh
Ave. Annual Electric Power: 30 MWh
Max Annual Electric Power: 5127 MWh
Min Annual Electric Power: 4
Max combined electric power 3, 647, 973 MWh

Fig 12: Oyo State power potential details

Table 10: Comprehensive energy profile of Oyo state

s/n	Oyo Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	3,647,973
2	Avg. rooftop square area (tsqm)	153
3	Avg. number of sun hours per day	3.6
4	Avg. annual sun hours	1,314.90
5	Max. power potential in MW	2,774.33
6	Max. power potential in Watts	2,774,334,930.41
7	Viable rooftop space in sqm	7,891,230,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	4,384,016,666.67
9	# of 250W panels required to store energy from rooftop solar	2,611,138.76
10	# of 250W panels required to reach the maximum energy potential	13,055,693.79
11	# of 400W panels required to reach the maximum energy potential	8,159,808.62
12	Average kWh of storage required per year to ensure viability	4,602.15
13	Average battery charging potential per year (including batteries and Evs)	858,346,588.24
14	No. of batteries required ensure viability of rooftop area	186,509.91
15	Areas viable for power generation in Watts per sqm	0.3515719261



Usable_SR_MWh	Elec_Prod_MWh	Height
63.02	6.96	3.5
179.66	19.85	3.5
99.46	10.99	3.5
113.69	12.56	3.5
85.25	9.42	3.5
196.31	21.69	3.5
156.32	17.27	3.5
99.48	10.99	3.5
298.35	32.97	3.5
78.16	8.64	3.5
466.11	51.5	3.5
99.47	10.99	3.5
419.33	46.34	3.5
241.5	26.69	3.5
163.54	18.07	3.5
332.1	36.7	3.5
134.96	14.91	3.5
120.72	13.34	3.5
149.18	16.48	3.5
56.76	6.27	3.5
191.48	21.16	3.5
185.8	20.53	3.5
85.31	9.43	3.5

State Details

State: Ogun
Region: SouthWest
City: Abeokuta
Study Area: 16667 sq..km
Total Buildings: 139, 327
Suitable Buildings: 68 223
Ave. Rooftop Area: 139.12 sq..m
Suitability Ratio: 49%

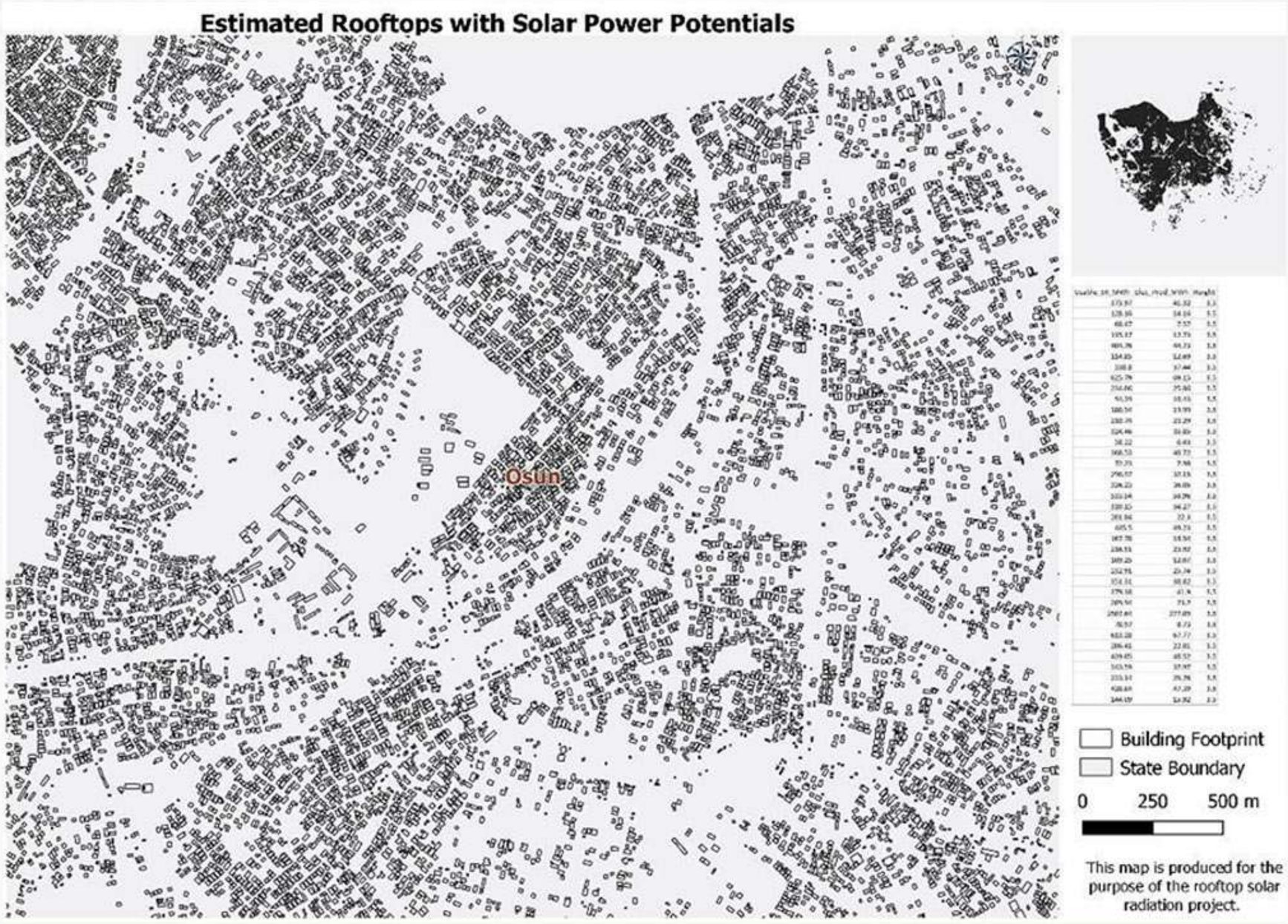
Solar Power Potential

Average Irradiation: 1724 kWh/m²
Max Usable IRR: 7753 MWh
Min Usable IRR: 38 MWh
Ave. Annual Electric Power : 27 MWh
Max Annual Electric Power: 857 MWh
Min Annual Electric Power: 4
Max combined electric power 1,818,692 MWh

Fig 13: Ogun State power potential details

Table 11: Comprehensive energy profile of Ogun state

s/n	Oyo Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	3,647,973
2	Avg. rooftop square area (tsqm)	153
3	Avg. number of sun hours per day	3.6
4	Avg. annual sun hours	1,314.90
5	Max. power potential in MW	2,774.33
6	Max. power potential in Watts	2,774,334,930.41
7	Viable rooftop space in sqm	7,891,230,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	4,384,016,666.67
9	# of 250W panels required to store energy from rooftop solar	2,611,138.76
10	# of 250W panels required to reach the maximum energy potential	13,055,693.79
11	# of 400W panels required to reach the maximum energy potential	8,159,808.62
12	Average kWh of storage required per year to ensure viability	4,602.15
13	Average battery charging potential per year (including batteries and Evs)	858,346,588.24
14	No. of batteries required ensure viability of rooftop area	186,509.91
15	Areas viable for power generation in Watts per sqm	0.3515719261

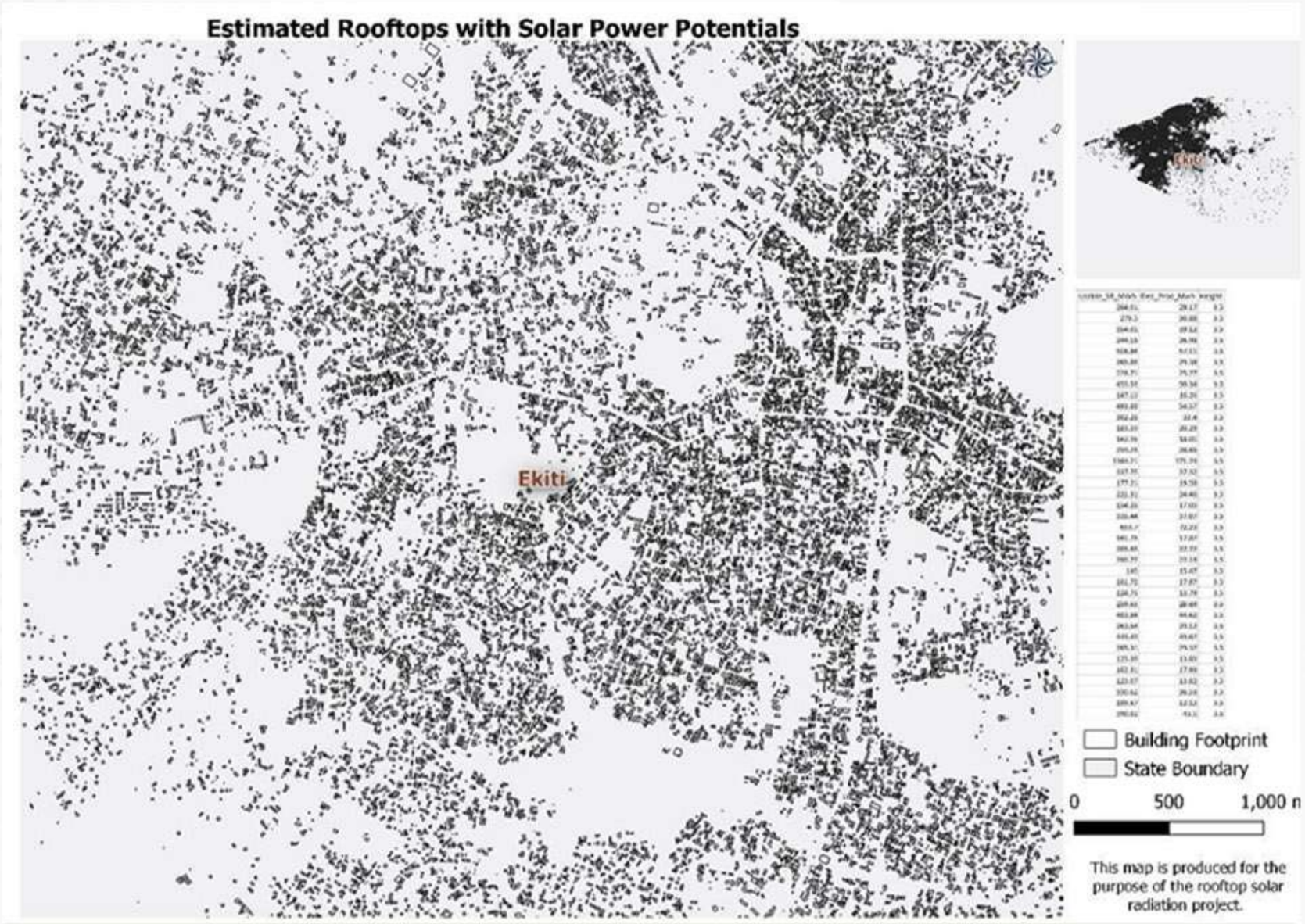


State Details	Solar Power Potential
State: Osun	Average Irradiation: 1778 kWh/m²
Region: Southwest	Max Usable IRR: 9558 MWh
City: Osogbo	Min Usable IRR: 46 MWh
Study Area: 11854 sq.km	Ave.Annual Electric Power: 29 MWh
Total Buildings: 164,349	Max Annual Electric Power: 1056 MWh
Suitable Buildings: 23,678	Min Annual Electric Power: 5
Ave. Rooftop Area: 149.4 sq.m	Combined Max Electric Power: 698,395 MWh
Suitability Ratio: 31%	

Fig 14: Osun State power potential details

Table 12: Comprehensive energy profile of Osun state

s/n	Osun Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	698,395
2	Avg. rooftop square area (tsqm)	149.4
3	Avg. number of sun hours per day	3.5
4	Avg. annual sun hours	1,278.38
5	Max. power potential in MW	546.31
6	Max. power potential in Watts	546,314,657.28
7	Viable rooftop space in sqm	3,674,740,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	2,041,522,222.22
9	# of 250W panels required to store energy from rooftop solar	514,178.50
10	# of 250W panels required to reach the maximum energy potential	2,570,892.50
11	# of 400W panels required to reach the maximum energy potential	1,606,807.82
12	Average kWh of storage required per year to ensure viability	4,474.31
13	Average battery charging potential per year (including batteries and Evs)	164,328,235.29
14	No. of batteries required ensure viability of rooftop area	36,727.04
15	Areas viable for power generation in Watts per sqm	0.1486675676



State Details

State: Ekiti
Region: Southwest
City: Ado-Ekiti
Study Area: 5,754 sq.km
Total Buildings: 66, 868
Suitable Buildings: 38, 014
Ave. Rooftop Area: 124.5 sq.m
Suitability Ratio: 57%

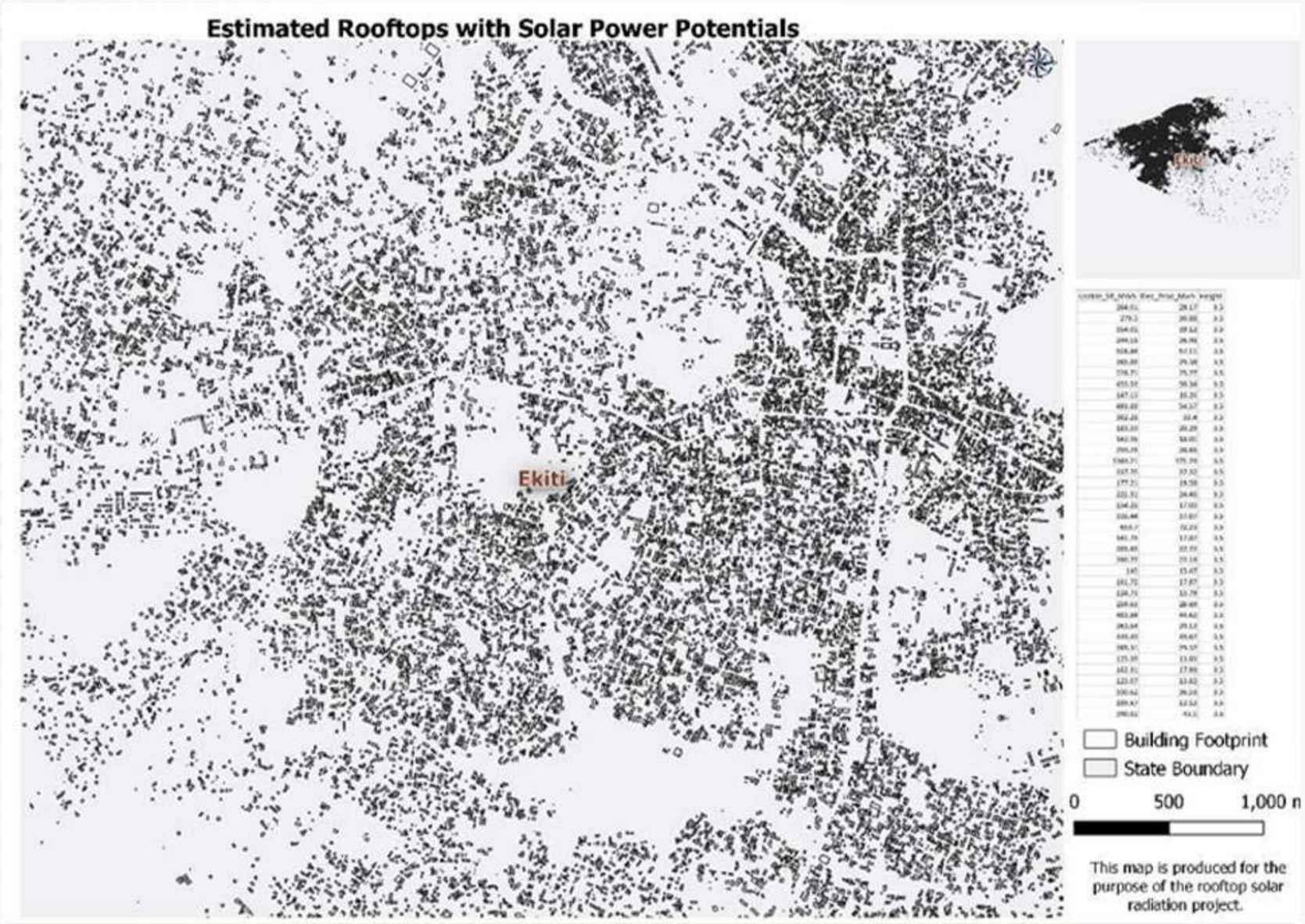
Solar Power Potential

Average Irradiation: 1835 kWh/m^2
Max Usable IRR: 19014 MWh
Min Usable IRR: 41 MWh
Ave. Annual Electric Power: 25 MWh
Max Annual Electric Power: 2101 MWh
Min Annual Electric Power: 4
Max combined electric power: 960,376 MWh

Fig 15: Ekiti State power potential details

Table 13: Comprehensive energy profile of Ekiti state

s/n	Osun Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	960,376
2	Avg. rooftop square area (tsqm)	124.5
3	Avg. number of sun hours per day	3.6
4	Avg. annual sun hours	1,314.90
5	Max. power potential in MW	730.38
6	Max. power potential in Watts	730,379,496.54
7	Viable rooftop space in sqm	3,279,780,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,822,100,000.00
9	# of 250W panels required to store energy from rooftop solar	687,416.00
10	# of 250W panels required to reach the maximum energy potential	3,437,079.98
11	# of 400W panels required to reach the maximum energy potential	2,148,174.99
12	Average kWh of storage required per year to ensure viability	4,602.15
13	Average battery charging potential per year (including batteries and Evs)	225,970,823.53
14	No. of batteries required ensure viability of rooftop area	49,101.14
15	Areas viable for power generation in Watts per sqm	0.2226916124



State Details

State: Ekiti
Region: Southwest
City: Ado-Ekiti
Study Area: 5,754 sq.km
Total Buildings: 66, 868
Suitable Buildings: 38, 014
Ave. Rooftop Area: 124.5 sq.m
Suitability Ratio: 57%

Solar Power Potential

Average Irradiation: 1835 kWh/m^2
Max Usable IRR: 19014 MWh
Min Usable IRR: 41 MWh
Ave. Annual Electric Power: 25 MWh
Max Annual Electric Power: 2101 MWh
Min Annual Electric Power: 4
Max combined electric power: 960,376 MWh

Fig 15: Ekiti State power potential details

Table 13: Comprehensive energy profile of Ekiti state

s/n	Osun Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	960,376
2	Avg. rooftop square area (tsqm)	124.5
3	Avg. number of sun hours per day	3.6
4	Avg. annual sun hours	1,314.90
5	Max. power potential in MW	730.38
6	Max. power potential in Watts	730,379,496.54
7	Viable rooftop space in sqm	3,279,780,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,822,100,000.00
9	# of 250W panels required to store energy from rooftop solar	687,416.00
10	# of 250W panels required to reach the maximum energy potential	3,437,079.98
11	# of 400W panels required to reach the maximum energy potential	2,148,174.99
12	Average kWh of storage required per year to ensure viability	4,602.15
13	Average battery charging potential per year (including batteries and Evs)	225,970,823.53
14	No. of batteries required ensure viability of rooftop area	49,101.14
15	Areas viable for power generation in Watts per sqm	0.2226916124

Table 23: North-West Power Potential Result

s/n	Power parameters	Oyo	Osun	Ekiti	Lagos	Ogun	Ondo	Total
1	Max. Combined Electric Power	3,647,973	698,395	960,376	2,726,003	1,818,692	1,149,263	11,000,702.00
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	153	149.4	124.5	134.4	139.1	141	841.40
3	Ave. SUN Hours from NiMET data	3.6	3.5	3.6	3.5	3.7	3.7	21.60
4	Ave. Annual Hours	1,314.90	1,278.38	1,314.90	1,278.38	1,351.43	1,351.43	7,889.40
5	Max. MW	2,774.33	546.31	730.38	2,132.40	1,345.76	850.41	8,379.59
6	Max. MW IN WATTS	2,774,334,930.41	546,314,657.28	730,379,496.54	2,132,396,988.36	1,345,758,736.15	850,408,272.75	8,379,593,081.49
7	Viable Sqm from building data	7,891,230,000.00	3,674,740,000.00	3,279,780,000.00	1,542,010,000.00	8,166,830,000.00	3,316,720,000.00	27,871,310,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	4,384,016,666.67	2,041,522,222.22	1,822,100,000.00	856,672,222.22	4,537,127,777.78	1,842,622,222.22	15,484,061,111.11
9	# of 250W Panels for Charging Batteries for viable rooftops	2,611,138.76	514,178.50	687,416.00	2,006,961.87	1,266,596.46	800,384.26	7,886,675.84
10	# of panels required to generate Max MW from Irradiation	13,055,693.79	2,570,892.50	3,437,079.98	10,034,809.36	6,332,982.29	4,001,921.28	39,433,379.21
11	No. of 400W PV Panels required to generate Max MW from Irradiation	8,159,808.62	1,606,807.82	2,148,174.99	6,271,755.85	3,958,113.93	2,501,200.80	24,645,862.00
12	Average KWH of Storage required per year	4,602.15	4,474.31	4,602.15	4,474.31	4,729.99	4,729.99	27,612.90
13	Average Charging Power Per Year	858,346,588.24	164,328,235.29	225,970,823.53	641,412,470.59	427,927,529.41	270,414,823.53	2,588,400,470.59
14	No. of Batteries to make rooftop study area viable	186,509.91	36,727.04	49,101.14	143,354.42	90,471.18	57,170.30	563,333.99
15	Areas viable for power generation (W per Sq Meter)	0.3515719261	0.1486675676	0.2226916124	1.382868456	0.1647834883	0.2564003813	2.53

NORTH WEST ROOFTOP SOLAR ESTIMATIONS

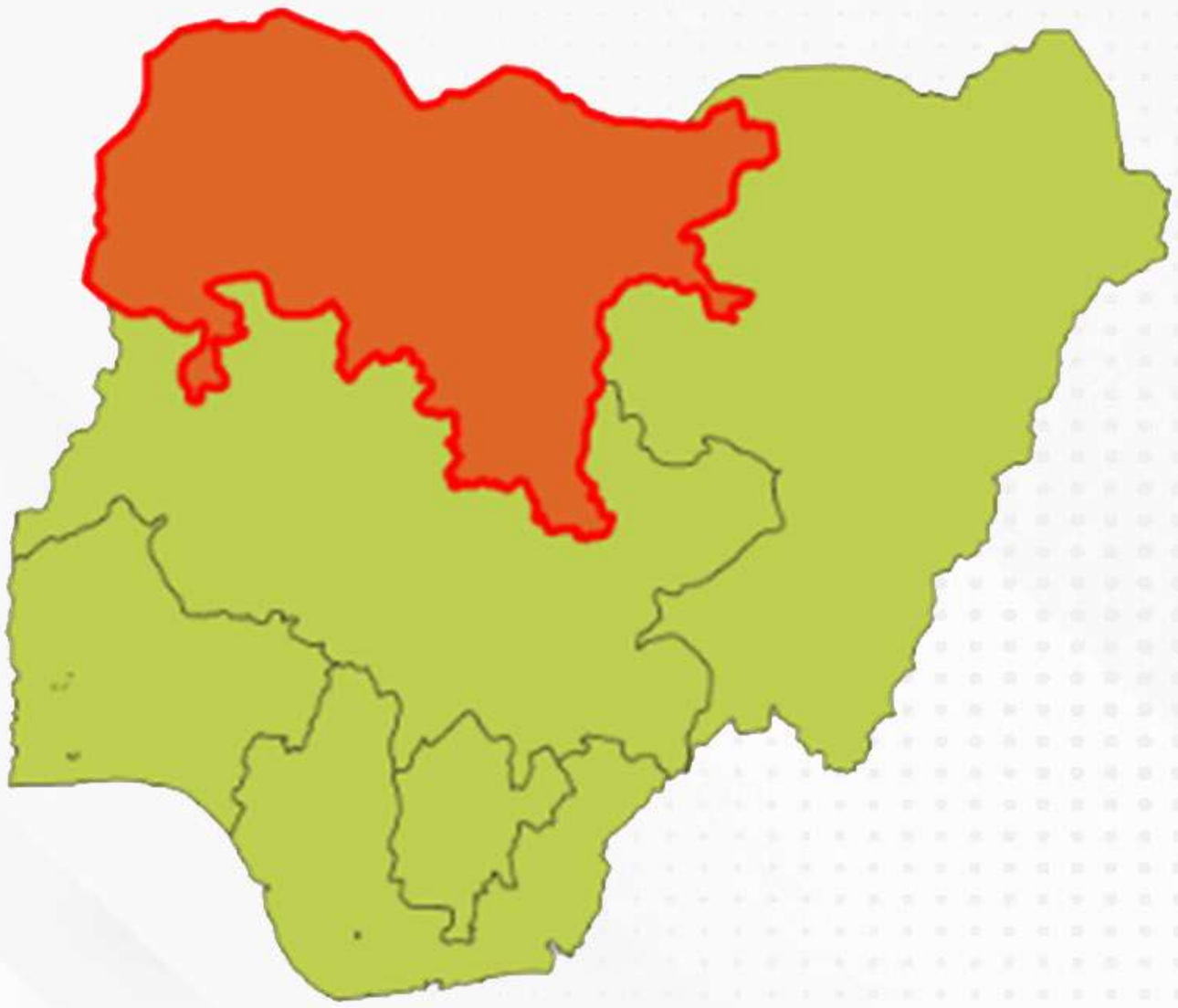
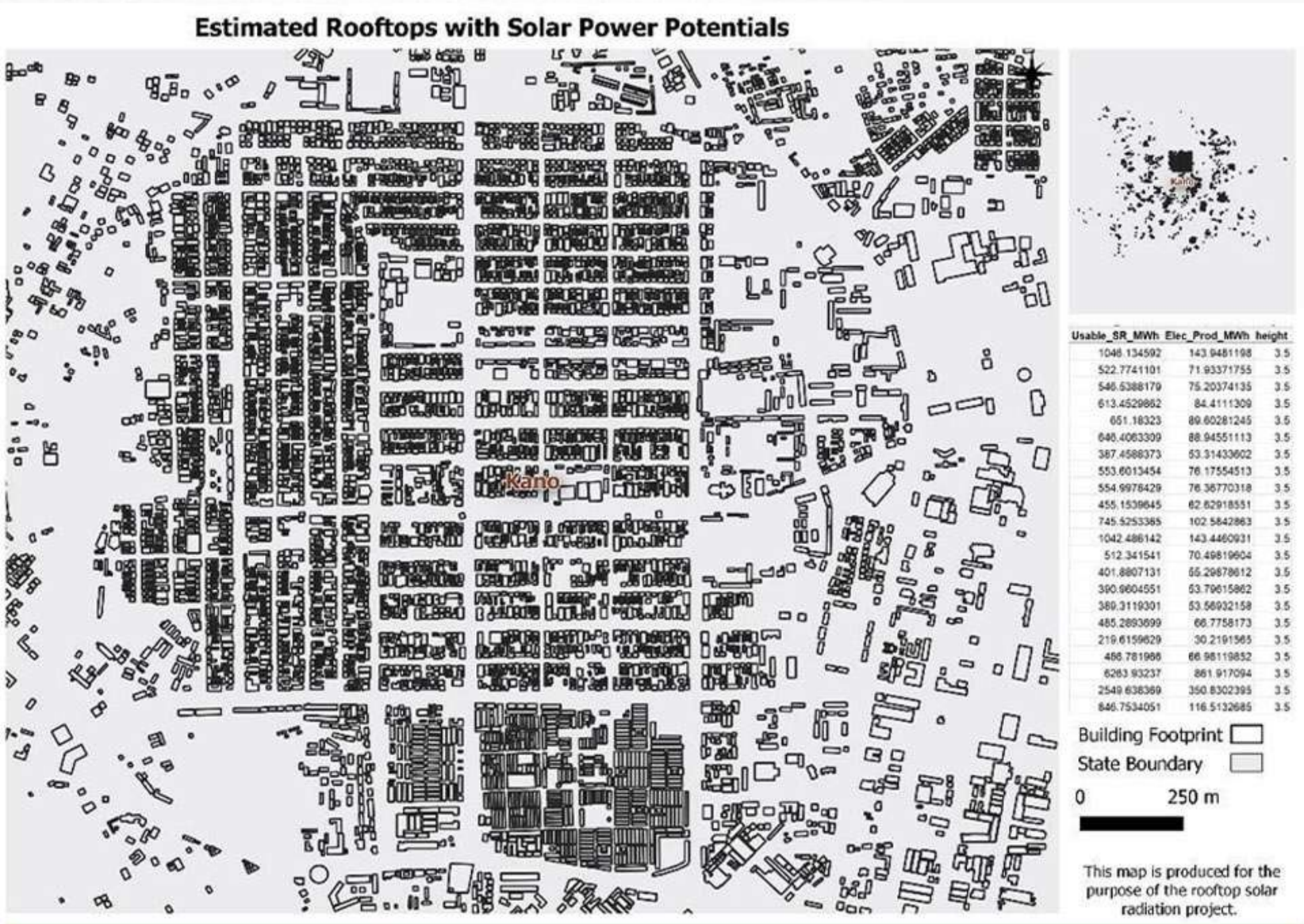


Figure 17: Nigeria map showing the North-West region



State Details

State: Kano
Region: Northwest
City: Kano
Study Area: 20, 325 sq.km
Total Buildings: 72,832
Suitable Buildings: 14,275
Ave. Rooftop Area: 160 sq.m
Suitability Ratio: 100%

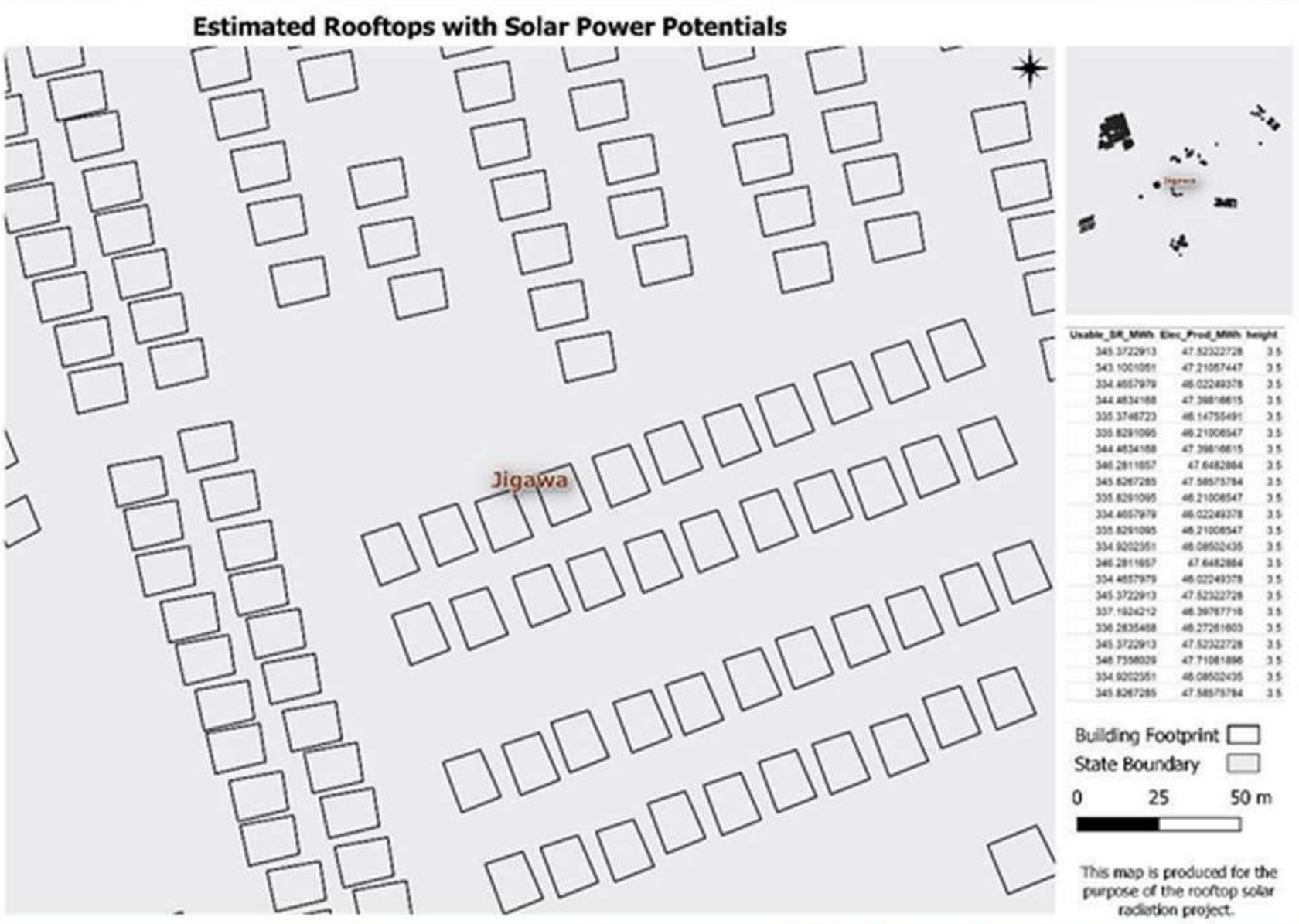
Solar Power Potential

Able IRR: 11,516 MWh
Min Usable Irradiation: 1,817 kWh/m^2
Max Usable IRR: 37 MWh
Ave. Annual Electric Power: 40 MWh
Max Annual Electric Power: 1,585 MWh
Min Annual Electric Power: 5
Max combined electric power: 574,519 MWh

Fig 18: Kano State power potential details

Table 16: Comprehensive energy profile of Kano state

s/n	Kano Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	574,519
2	Avg. rooftop square area (tsqm)	160
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	314.59
6	Max. power potential in Watts	314,589,459.27
7	Viable rooftop space in sqm	20,325,000,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	11,291,666,666.67
9	# of 250W panels required to store energy from rooftop solar	296,084.20
10	# of 250W panels required to reach the maximum energy potential	1,480,420.98
11	# of 400W panels required to reach the maximum energy potential	925,263.12
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	135,180,941.18
14	No. of batteries required ensure viability of rooftop area	21,148.87
15	Areas viable for power generation in Watts per sqm	0.01547795618



State Details

State: Jigawa
Region: Northwest
City: Dutse
Study Area: 23, 217 sq.km
Total Buildings: 35,004
Suitable Buildings: 2,368
Ave. Rooftop Area: 254 sq.m
Suitability Ratio: 10%

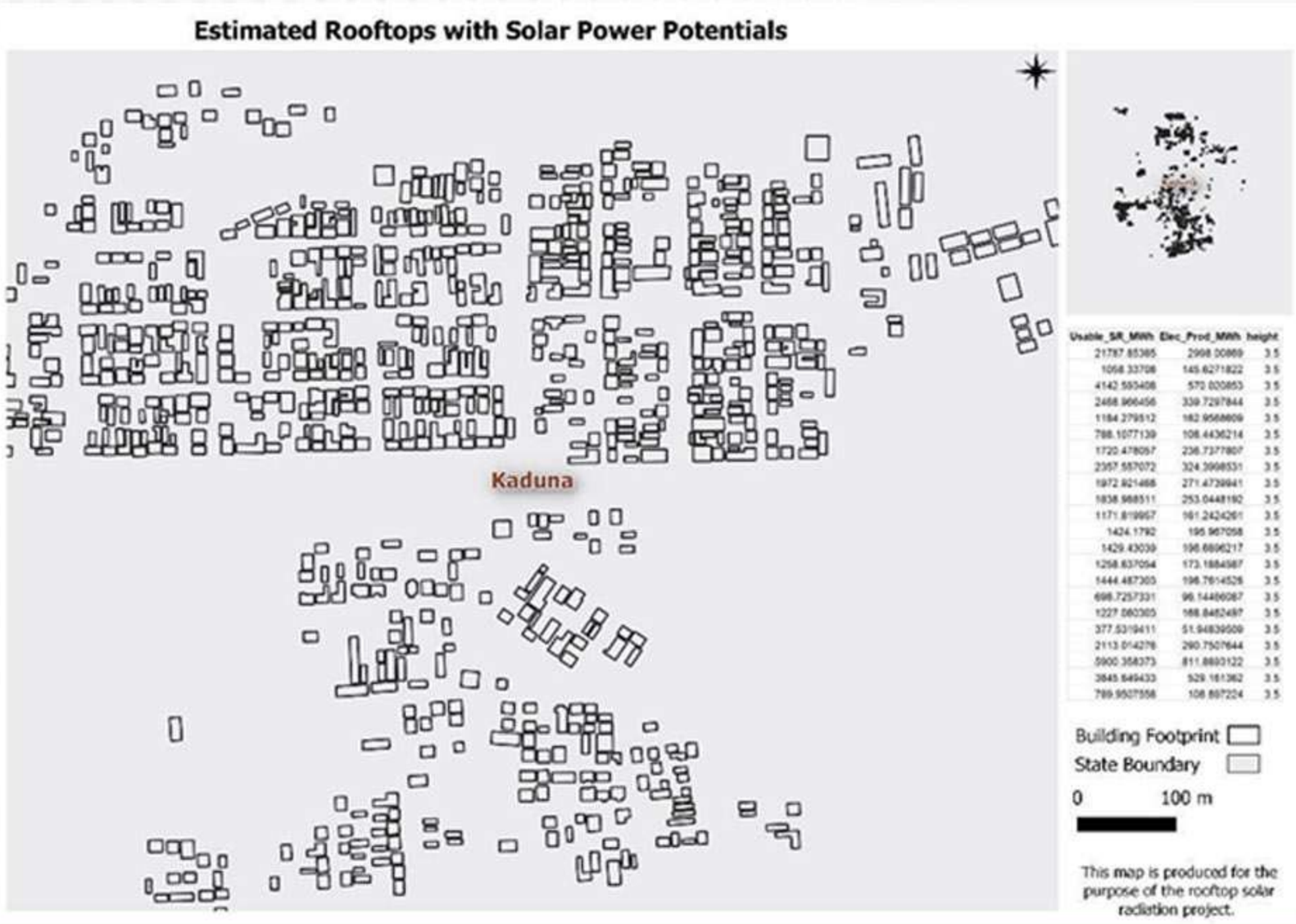
Solar Power Potential

Average Irradiation: 1,803 kWh/m^2
Max Usable IRR: 9,966 MWh
Min Usable IRR: 170 MWh
Ave. Annual Electric Power: 63 MWh
Max Annual Electric Power: 1,371 MWh
Min Annual Electric Power: 27
Max combined electric power: 25, 191 MWh

Fig 19: Jigawa State power potential details

Table 17: Comprehensive energy profile of Jigawa state

s/n	Jigawa Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	25,191
2	Avg. rooftop square area (tsqm)	254
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	13.79
6	Max. power potential in Watts	13,793,839.84
7	Viable rooftop space in sqm	2,321,700,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,289,833,333.33
9	# of 250W panels required to store energy from rooftop solar	12,982.44
10	# of 250W panels required to reach the maximum energy potential	64,912.19
11	# of 400W panels required to reach the maximum energy potential	40,570.12
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	5,927,294.12
14	No. of batteries required ensure viability of rooftop area	927.32
15	Areas viable for power generation in Watts per sqm	0.005941267104



State Details

State: Kaduna
Region: Northwest
City: Kaduna
Study Area: 44,155 sq.km
Total Buildings: 66,578
Suitable Buildings: 3,784
Ave. Rooftop Area: 288 sq.m
Suitability Ratio: 40%

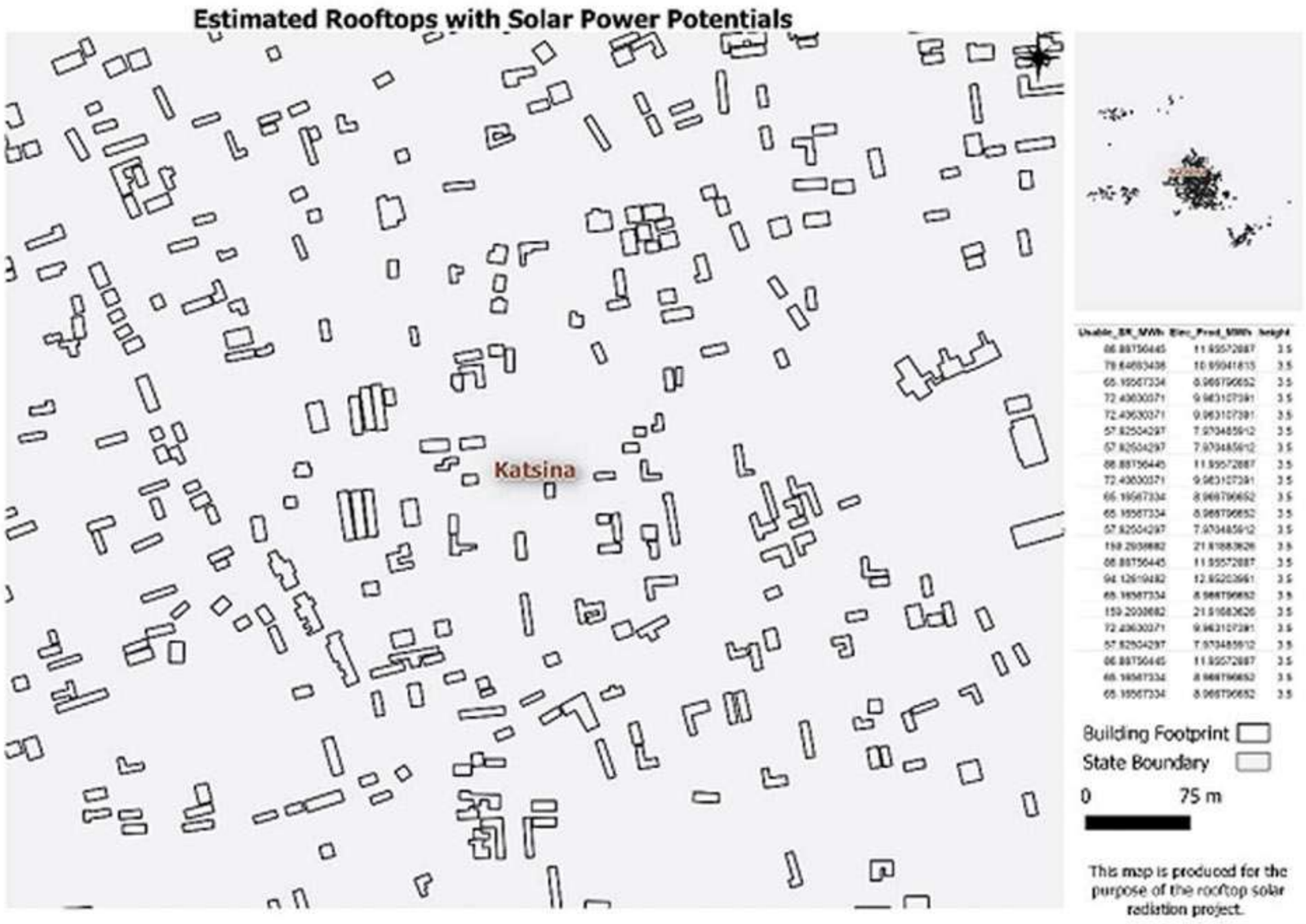
Solar Power Potential

Average Irradiation: 1,854 kWh/m^2
Max Usable IRR: 21,787.8 MWh
Min Usable IRR: 56 MWh
Ave. Annual Electric Power: 74 MWh
Max Annual Electric Power: 2,998 MWh
Min Annual Electric Power: 8
Max combined electric power: 278,468 MWh

Fig 18: Kaduna State power potential details

Table 17: Comprehensive energy profile of Kaduna state

s/n	Kaduna Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	25,191
2	Avg. rooftop square area (tsqm)	254
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	13.79
6	Max. power potential in Watts	13,793,839.84
7	Viable rooftop space in sqm	2,321,700,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,289,833,333.33
9	# of 250W panels required to store energy from rooftop solar	12,982.44
10	# of 250W panels required to reach the maximum energy potential	64,912.19
11	# of 400W panels required to reach the maximum energy potential	40,570.12
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	5,927,294.12
14	No. of batteries required ensure viability of rooftop area	927.32
15	Areas viable for power generation in Watts per sqm	0.005941267104



State Details

State: Katsina
Region: Northwest
City: Katsina
Study Area: 23,963 sq.km
Total Buildings: 5,481
Suitable Buildings: 859
Ave. Rooftop Area: 64 sq.m
Suitability Ratio: 25%

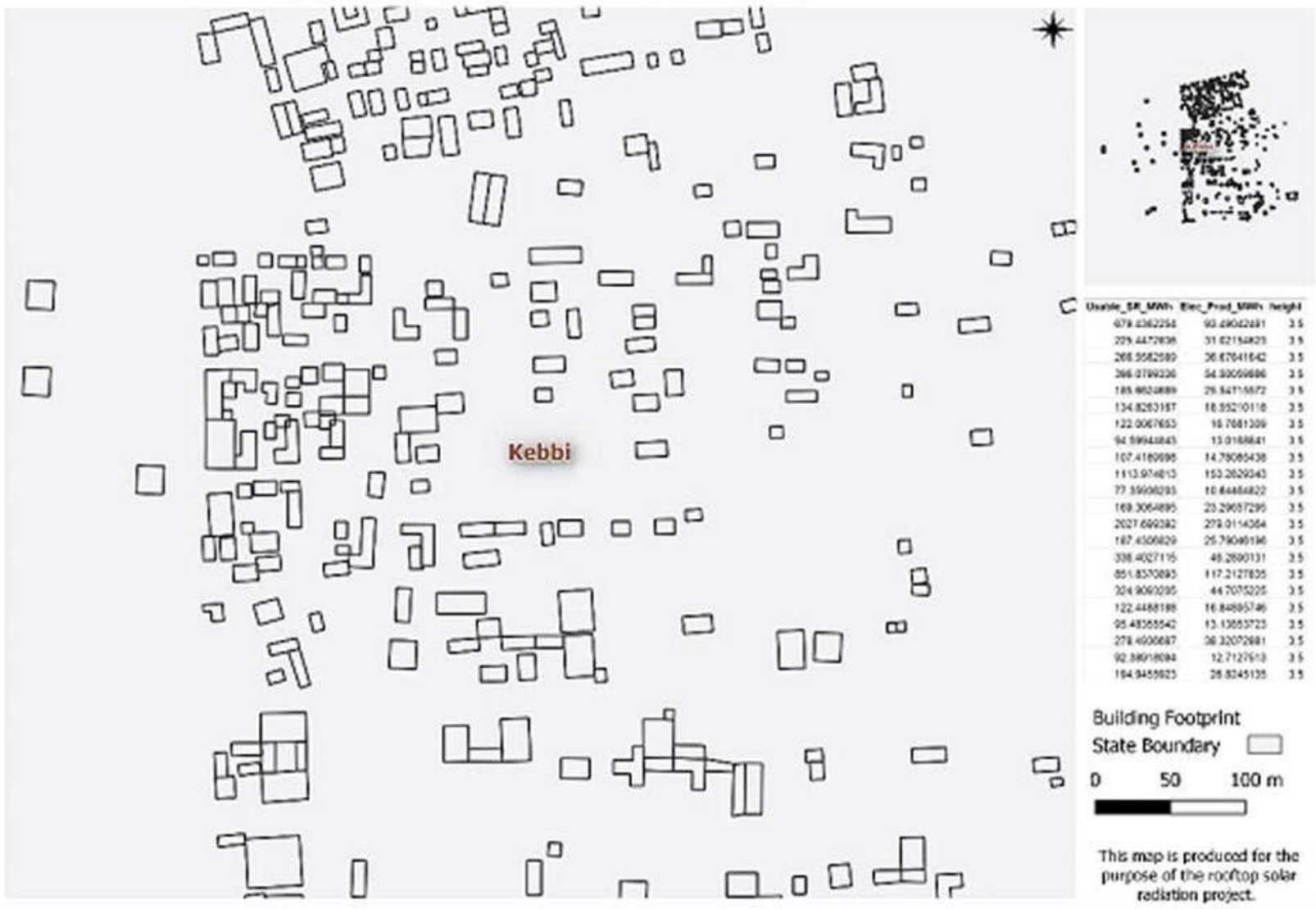
Solar Power Potential

Average Irradiation: 1,810 kWh/m^2
Max Usable IRR: 941 MWh
Min Usable IRR: 58 MWh
Ave. Annual Electric Power: 16 MWh
Max Annual Electric Power: 130 MWh
Min Annual Electric Power: 8
Max combined electric power: 13,641 MWh

Fig 21: Katsina State power potential details

Table 19: Comprehensive energy profile of Katsina state

s/n	Katsina Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	13,641
2	Avg. rooftop square area (tsqm)	64
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	7.47
6	Max. power potential in Watts	7,469,404.52
7	Viable rooftop space in sqm	5,990,750,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	3,328,194,444.44
9	# of 250W panels required to store energy from rooftop solar	7,030.03
10	# of 250W panels required to reach the maximum energy potential	35,150.14
11	# of 400W panels required to reach the maximum energy potential	21,968.84
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	3,209,647.06
14	No. of batteries required ensure viability of rooftop area	502.14
15	Areas viable for power generation in Watts per sqm	0.001246822938



State Details

State: Kebbi
Region: Northwest
City: Kebbi
Study Area: 36,597 sq.km
Total Buildings: 34,873
Suitable Buildings: 15,679
Ave. Rooftop Area: 140 sq.m
Suitability Ratio: 18%

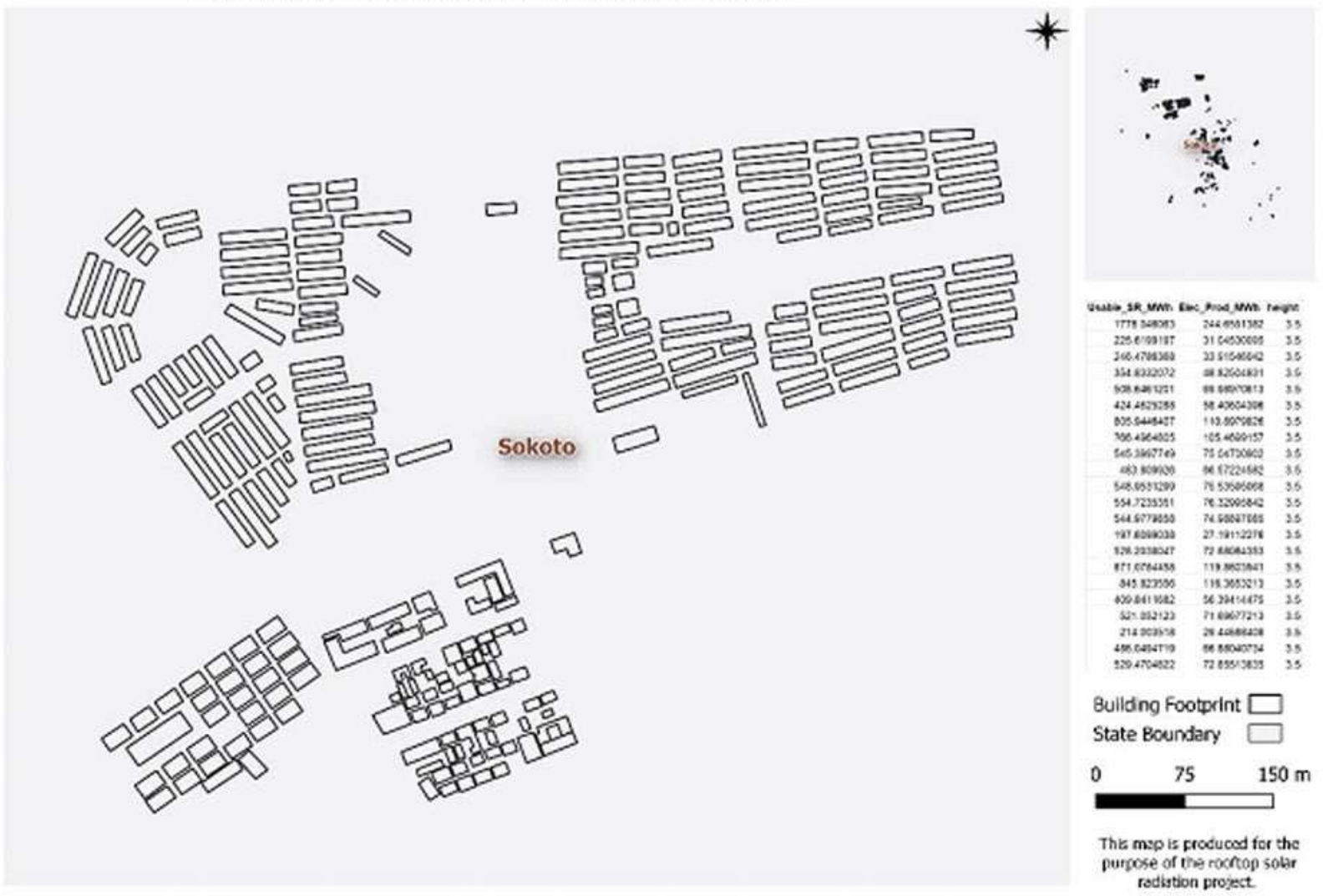
Solar Power Potential

Average Irradiation: 1,767 kWh/m^2
Max Usable IRR: 3,537 MWh
Min Usable IRR: 53 MWh
Ave. Annual Electric Power: 34 MWh
Max Annual Electric Power: 487 MWh
Min Annual Electric Power: 7
Max combined electric power: 15, 680 MWh

Fig 22: Kebbi State power potential details

Table 20: Comprehensive energy profile of Kebbi state

s/n	Kebbi Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	15,680
2	Avg. rooftop square area (tsqm)	140
3	Avg. number of sun hours per day	4.7
4	Avg. annual sun hours	1,716.68
5	Max. power potential in MW	9.13
6	Max. power potential in Watts	9,133,936.24
7	Viable rooftop space in sqm	6,587,460,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	3,659,700,000.00 8,596.65
9	# of 250W panels required to store energy from rooftop solar	42,983.23
10	# of 250W panels required to reach the maximum energy potential	26,864.52
11	# of 400W panels required to reach the maximum energy potential	6,008.36
12	Average kWh of storage required per year to ensure viability	3,689,411.76
13	Average battery charging potential per year (including batteries and Evs)	614.05 0.001386564206
14	No. of batteries required ensure viability of rooftop area	
15	Areas viable for power generation in Watts per sqm	

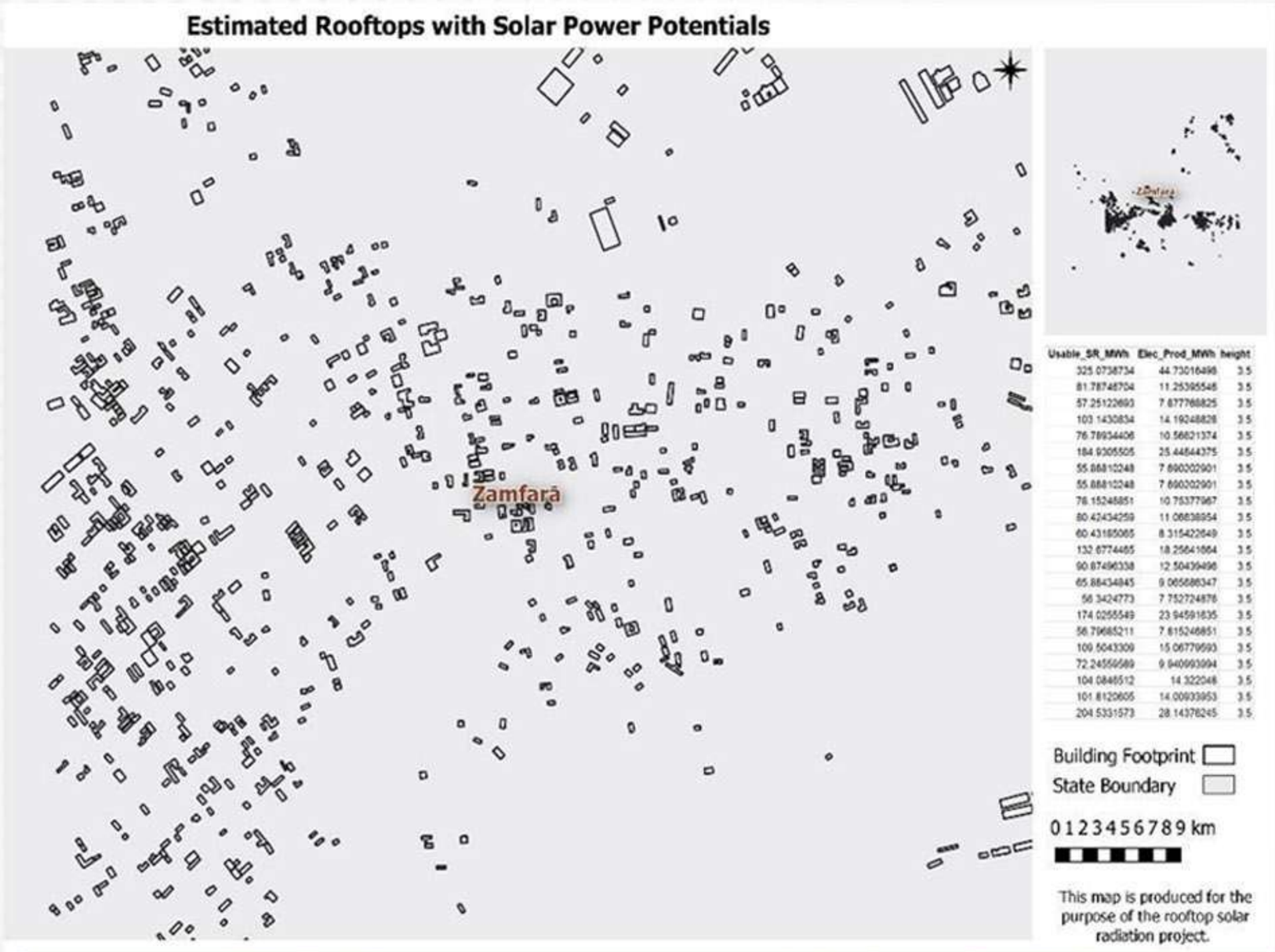


State Details	Solar Power Potential
State: Sokoto	Average Irradiation: 1,770 kWh/m^2
Region: Northwest	Max Usable IRR: 2,979 MWh
City: Sokoto	Min Usable IRR: 53 MWh
Study Area: 32,153 sq.km	Ave. Annual Electric Power: 56 MWh
Total Buildings: 4, 873	Max Annual Electric Power: 410 MWh
Suitable Buildings: 738	Min Annual Electric Power: 7
Ave. Rooftop Area: 229 sq.m	Max combined electric power: 41,097 MWh
Suitability Ratio: 29%	

Fig 23: Sokoto State power potential details

Table 21: Comprehensive energy profile of Sokoto state

s/n	Sokoto Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	41,097
2	Avg. rooftop square area (tsqm)	229
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	22.50
6	Max. power potential in Watts	22,503,490.76
7	Viable rooftop space in sqm	9,324,370,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	5,180,205,555.56
9	# of 250W panels required to store energy from rooftop solar	21,179.76
10	# of 250W panels required to reach the maximum energy potential	105,898.78
11	# of 400W panels required to reach the maximum energy potential	66,186.74
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	9,669,882.35
14	No. of batteries required ensure viability of rooftop area	1,512.84
15	Areas viable for power generation in Watts per sqm	0.002413406027



State Details

State: Zamfara
Region: Northwest
City: Gusau
Study Area:33,512 sq.km
Total Buildings: 9,873
Suitable Buildings: 3,826
Ave. Rooftop Area: 116 sq.m
Suitability Ratio: 59%

Solar Power Potential

Average Irradiation: 1,812 kWh/m^2
Max Usable IRR: 3,546 MWh
Min Usable IRR: 31 MWh
Ave. Annual Electric Power: 29 MWh
Max Annual Electric Power: 488 MWh
Min Annual Electric Power: 4
Max combined electric power: 110,601 MWh

Fig 24: Zamfara State power potential details

Table 22: Comprehensive energy profile of Zamfara state

s/n	Zamfara Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	110,601
2	Avg. rooftop square area (tsqm)	116
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	60.56
6	Max. power potential in Watts	60,561,806.98
7	Viable rooftop space in sqm	19,772,080,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	10,984,488,888.89
9	# of 250W panels required to store energy from rooftop solar	56,999.35
10	# of 250W panels required to reach the maximum energy potential	284,996.74
11	# of 400W panels required to reach the maximum energy potential	178,122.96
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	26,023,764.71
14	No. of batteries required ensure viability of rooftop area	4,071.38
15	Areas viable for power generation in Watts per sqm	0.003062996254

Table 23: North-West Power Potential Result

s/n	Power parameters	Zamfara	Sokoto	Jigawa	Kaduna	Kano	Katsina	Kebbi	Total
1	Max. Combined Electric Power	110,601	41,097	25,191	278,468	574,519	13,641	15,680	948,596.00
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	116	229	254	288	160	64	140	1,135.00
3	Ave. SUN Hours from NiMET data	5	5	5	4.6	5	5	4.7	29.30
4	Ave. Annual Hours	1,826.25	1,826.25	1,826.25	1,680.15	1,826.25	1,826.25	1,716.68	10,701.83
5	Max. MW	60.56	22.50	13.79	165.74	314.59	7.47	9.13	533.23
6	Max. MW IN WATTS	60,561,806.98	22,503,490.76	13,793,839.84	165,739,963.69	314,589,459.27	7,469,404.52	9,133,936.24	533,230,094.32
7	Viable Sqm from building data	19,772,080,000.00	9,324,370,000.00	2,321,700,000.00	17,662,000,000.00	20,325,000,000.00	5,990,750,000.00	6,587,460,000.00	62,211,280,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	10,984,488,888.89	5,180,205,555.56	1,289,833,333.33	9,812,222,222.22	11,291,666,666.67	3,328,194,444.44	3,659,700,000.00	34,561,822,222.22
9	# of 250W Panels for Charging Batteries for viable rooftops	56,999.35	21,179.76	12,982.44	155,990.55	296,084.20	7,030.03	8,596.65	501,863.62
10	# of panels required to generate Max MW from Irradiation	284,996.74	105,898.78	64,912.19	779,952.77	1,480,420.98	35,150.14	42,983.23	2,509,318.09
11	No. of 400W PV Panels required to generate Max MW from Irradiation	178,122.96	66,186.74	40,570.12	487,470.48	925,263.12	21,968.84	26,864.52	1,568,323.81
12	Average KWH of Storage required per year	6,391.88	6,391.88	6,391.88	5,880.53	6,391.88	6,391.88	6,008.36	37,456.39
13	Average Charging Power Per Year	26,023,764.71	9,669,882.35	5,927,294.12	65,521,882.35	135,180,941.18	3,209,647.06	3,689,411.76	223,199,058.82
14	No. of Batteries to make rooftop study area viable	4,071.38	1,512.84	927.32	11,142.18	21,148.87	502.14	614.05	35,847.40
15	Areas viable for power generation (W per Sq Meter)	0.003062996254	0.002413406027	0.005941267104	0.009383986168	0.01547795618	0.001246822938	0.001386564206	0.04

SOUTH-SOUTH ROOFTOP ROOFTOP SOLAR ESTIMATIONS

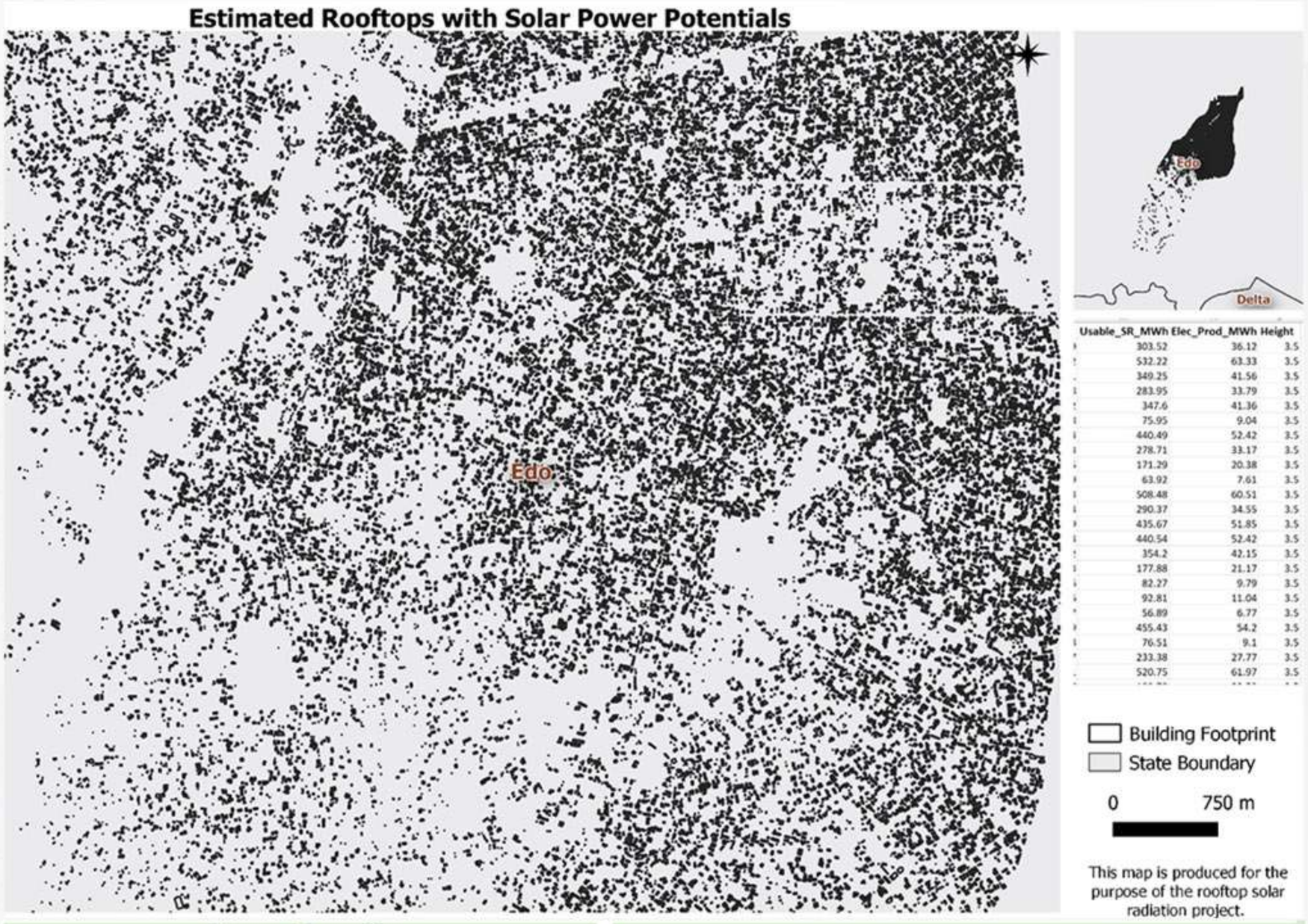
Figure 25: Nigeria map showing the South-South region

Table 23: North-West Power Potential Result

s/n	Power parameters	Plateau	Niger	Benue	FCT Abuja	Kogi	Kwara	Nassarawa	Total
1	Max. Combined Electric Power (MWh) Per Year	110,601	41,097	25,191	278,468	574,519	13,641	15,680	948,596.00
2	Ave. Rooftop Square Area (sqm)	116	229	254	288	160	64	140	1,135.00
3	Ave. SUN Hours from NiMET data	5	5	5	4.6	5	5	4.7	29.30
4	Ave. Annual Hours	1,826.25	1,826.25	1,826.25	1,680.15	1,826.25	1,826.25	1,716.68	10,701.83
5	Max. MW	60.56	22.50	13.79	165.74	314.59	7.47	9.13	533.23
6	Max. MW IN WATTS	60,561,806.98	22,503,490.76	13,793,839.84	165,739,963.69	314,589,459.27	7,469,404.52	9,133,936.24	533,230,094.32
7	Viable Sqm from building data	19,772,080,000.00	9,324,370,000.00	2,321,700,000.00	17,662,000,000.00	20,325,000,000.00	5,990,750,000.00	6,587,460,000.00	62,211,280,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	10,984,488,888.89	5,180,205,555.56	1,289,833,333.33	9,812,222,222.22	11,291,666,666.67	3,328,194,444.44	3,659,700,000.00	34,561,822,222.22
9	# of 250W Panels for Charging Batteries for viable rooftops	56,999.35	21,179.76	12,982.44	155,990.55	296,084.20	7,030.03	8,596.65	501,863.62
10	# of panels required to generate Max MW from Irradiation	284,996.74	105,898.78	64,912.19	779,952.77	1,480,420.98	35,150.14	42,983.23	2,509,318.09
11	No. of 400W PV Panels required to generate Max MW from Irradiation	178,122.96	66,186.74	40,570.12	487,470.48	925,263.12	21,968.84	26,864.52	1,568,323.81
12	Average KWH of Storage required per year	6,391.88	6,391.88	6,391.88	5,880.53	6,391.88	6,391.88	6,008.36	37,456.39
13	Average Charging Power Per Year	26,023,764.71	9,669,882.35	5,927,294.12	65,521,882.35	135,180,941.18	3,209,647.06	3,689,411.76	223,199,058.82
14	No. of Batteries to make rooftop study area viable	4,071.38	1,512.84	927.32	11,142.18	21,148.87	502.14	614.05	35,847.40
15	Areas viable for power generation (W per Sq Meter)	0.003062996254	0.002413406027	0.005941267104	0.009383986168	0.01547795618	0.001246822938	0.001386564206	0.04

SOUTH-SOUTH ROOFTOP SOLAR ESTIMATIONS

Figure 25: Nigeria map showing the South-South region



Usable_SR_MWh	Elec_Prod_MWh	Height
303.52	36.12	3.5
532.22	63.33	3.5
349.25	41.56	3.5
283.95	33.79	3.5
347.6	41.36	3.5
75.95	9.04	3.5
440.49	52.42	3.5
278.71	33.17	3.5
171.29	20.38	3.5
63.92	7.61	3.5
508.48	60.51	3.5
290.37	34.55	3.5
435.67	51.85	3.5
440.54	52.42	3.5
354.2	42.15	3.5
177.88	21.17	3.5
82.27	9.79	3.5
92.81	11.04	3.5
56.89	6.77	3.5
455.43	54.2	3.5
76.51	9.1	3.5
233.38	27.77	3.5
520.75	61.97	3.5

State Details

State: Edo
Region: Sout-South
City: Edo
Study Area: 19, 514 sq.km
Total Buildings: 78, 449
Suitable Buildings: 14,584
Ave. Rooftop Area: 160 sq.m
Suitability Ratio: 19%

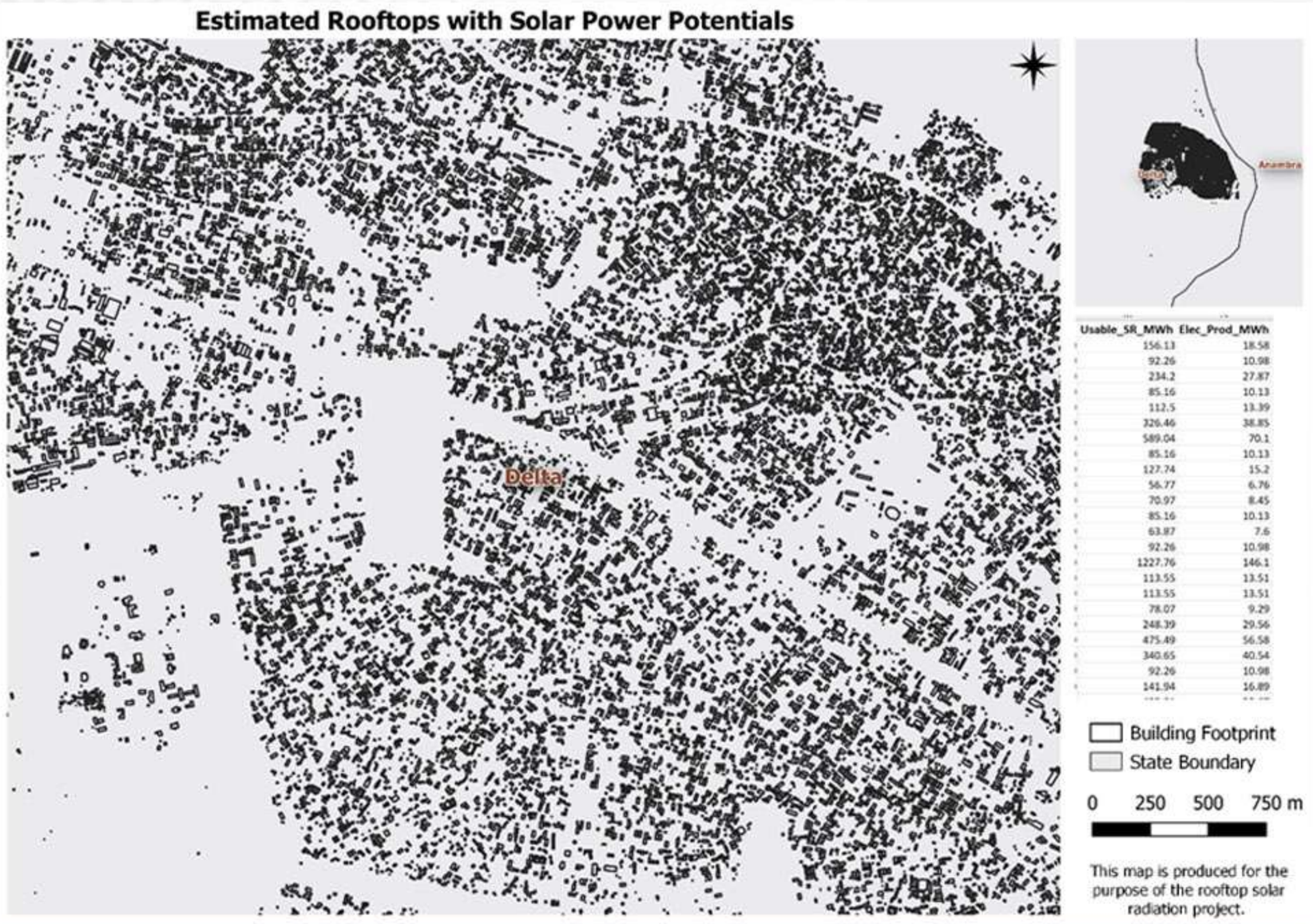
Solar Power Potential

Average Irradiation: 1,741 kWh/m^2
Max Usable IRR: 3, 080 MWh
Min Usable IRR: 43 MWh
Ave. Annual Electric Power: 33 MWh
Max Annual Electric Power: 367 MWh
Min Annual Electric Power: 5
Max combined electric power: 485,656 MWh

Fig 26: Edo State power potential details

Table 24: Comprehensive energy profile of Edo state

s/n	Edo Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	485,656
2	Avg. rooftop square area (tsqm)	160
3	Avg. number of sun hours per day	4.2
4	Avg. annual sun hours	1,534.05
5	Max. power potential in MW	316.58
6	Max. power potential in Watts	316,584,205.21
7	Viable rooftop space in sqm	3,707,660,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	2,059,811,111.11
9	# of 250W panels required to store energy from rooftop solar	297,961.60
10	# of 250W panels required to reach the maximum energy potential	1,489,808.02
11	# of 400W panels required to reach the maximum energy potential	931,130.02
12	Average kWh of storage required per year to ensure viability	5,369.18
13	Average battery charging potential per year (including batteries and Evs)	114,272,000.00
14	No. of batteries required ensure viability of rooftop area	21,282.97
15	Areas viable for power generation in Watts per sqm	0.08538652552



State Details

State: Delta
Region: South-South
City: Asaba
Study Area: 4,806 sq.km
Total Buildings: 36,213
Suitable Buildings: 19,568
Ave. Rooftop Area: 140 sq.m
Suitability Ratio: 54%

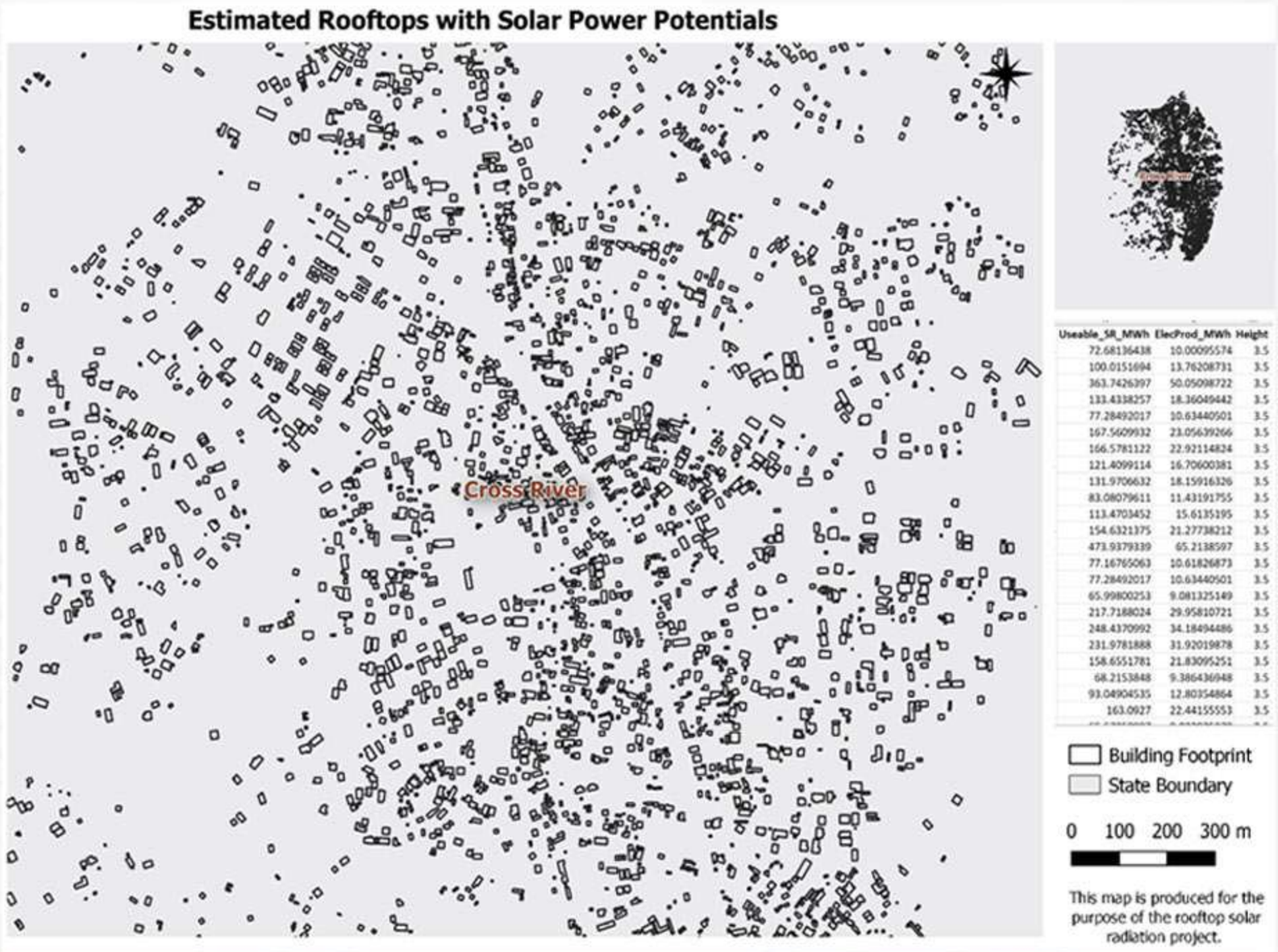
Solar Power Potential

Average Irradiation: 1,774 kWh/m^2
Max Usable IRR: 7,438 MWh
Min Usable IRR: 57 MWh
Ave. Annual Electric Power: 30 MWh
Max Annual Electric Power: 885 MWh
Min Annual Electric Power: 7 MWh
Max combined electric power: 579, 723 MWh

Fig 27: Delta State power potential details

Table 25 Comprehensive energy profile of Delta state

s/n	Delta Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	579,723
2	Avg. rooftop square area (tsqm)	140
3	Avg. number of sun hours per day	3.4
4	Avg. annual sun hours	1,241.85
5	Max. power potential in MW	466.82
6	Max. power potential in Watts	466,822,079.96
7	Viable rooftop space in sqm	2,595,240,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,441,800,000.00
9	# of 250W panels required to store energy from rooftop solar	439,361.96
10	# of 250W panels required to reach the maximum energy potential	2,196,809.79
11	# of 400W panels required to reach the maximum energy potential	1,373,006.12
12	Average kWh of storage required per year to ensure viability	4,346.48
13	Average battery charging potential per year (including batteries and Evs)	136,405,411.76
14	No. of batteries required ensure viability of rooftop area	31,383.00
15	Areas viable for power generation in Watts per sqm	0.1798762658



Useable_SR_MWh	ElecProd_MWh	Height
72.68136438	10.00995574	3.5
100.0151694	13.76208731	3.5
363.7426397	50.05098722	3.5
133.4338257	18.36049442	3.5
77.28492017	10.63440501	3.5
167.5609932	23.05639266	3.5
166.5781122	22.92114824	3.5
121.4099114	16.70600381	3.5
131.9706632	18.15916326	3.5
83.08079611	11.43191755	3.5
113.4703452	15.6135195	3.5
154.6321375	21.27738212	3.5
473.9379339	65.2138597	3.5
77.16765063	10.61826873	3.5
77.28492017	10.63440501	3.5
65.99800253	9.081325149	3.5
217.7188024	29.95810721	3.5
248.4370992	34.18494486	3.5
231.9781888	31.92019878	3.5
158.6551781	21.83095251	3.5
68.2153848	9.386436948	3.5
93.04904535	12.80354864	3.5
163.0927	22.44155553	3.5

State Details

State: Cross River
Region: South-South
City: Cross-River
Study Area: 6,739 sq.km
Total Buildings: 12,838
Suitable Buildings: 3,657
Ave. Rooftop Area: 126 sq.m
Suitability Ratio: 64%

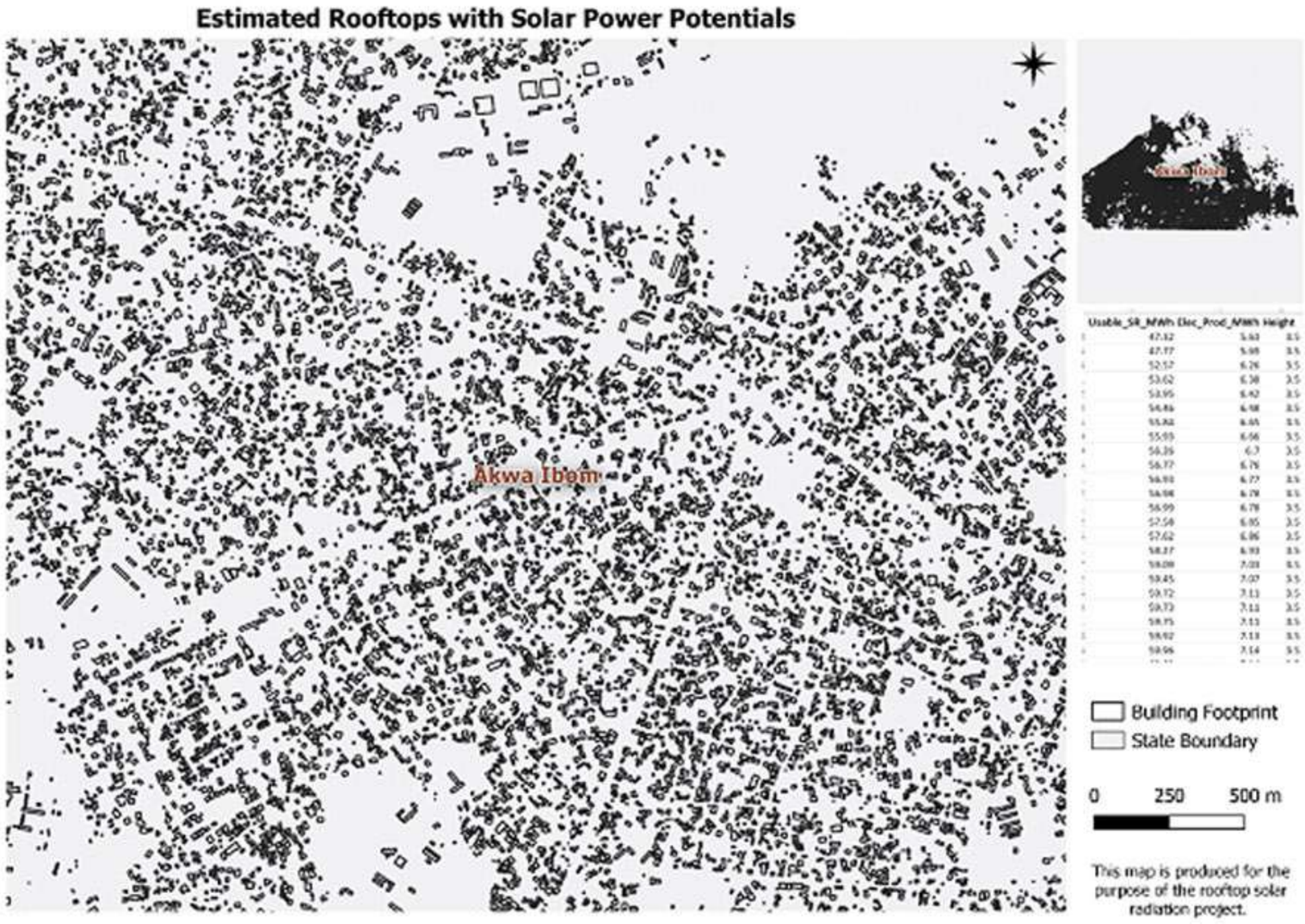
Solar Power Potential

Average Irradiation: 4,801 kWh/m^2
Max Usable IRR: 11,949 MWh
Min Usable IRR: 123 MWh
Ave. Annual Electric Power: 83 MWh
Max Annual Electric Power: 1,644 MWh
Min Annual Electric Power: 17 MWh
Max combined electric power: 304,511 MWh

Fig 28: Cross River State power potential details

Table 26: Comprehensive energy profile of Cross River state

s/n	Cross River Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	304,511
2	Avg. rooftop square area (tsqm)	126
3	Avg. number of sun hours per day	3.7
4	Avg. annual sun hours	1,351.43
5	Max. power potential in MW	225.33
6	Max. power potential in Watts	225,325,859.74
7	Viable rooftop space in sqm	4,312,960,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	2,396,088,888.89
9	# of 250W panels required to store energy from rooftop solar	212,071.40
10	# of 250W panels required to reach the maximum energy potential	1,060,356.99
11	# of 400W panels required to reach the maximum energy potential	662,723.12
12	Average kWh of storage required per year to ensure viability	4,729.99
13	Average battery charging potential per year (including batteries and Evs)	71,649,647.06
14	No. of batteries required ensure viability of rooftop area	15,147.96
15	Areas viable for power generation in Watts per sqm	0.05224390204

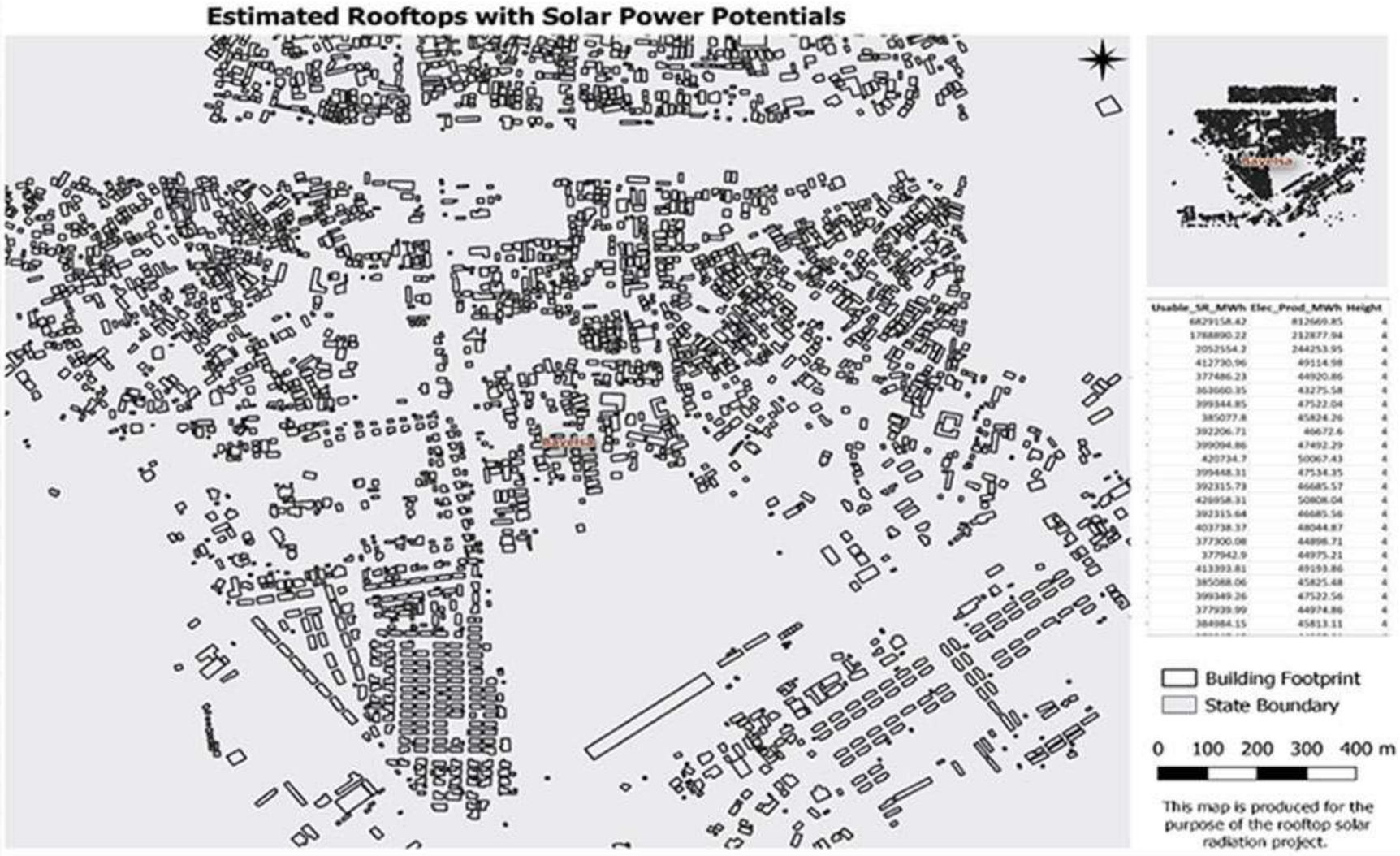


State Details	Solar Power Potential
State: Akwa Ibom	Average Irradiation: 4,018 kWh/m²
Region: South-South	Max Usable IRR: 13,649 MWh
City: Uyo	Min Usable IRR: 47 MWh
Study Area: 6,739 sq.km	Ave. Annual Electric Power : 61 MWh
Total Buildings: 35,004	Max Annual Electric Power: 1,624 MWh
Suitable Buildings: 19,363	Min Annual Electric Power: 6
Ave. Rooftop Area: 123 sq.m	Combined Max Electric Power: 1,182,500
Suitability Ratio: 55%	MWh

Fig 30: Akwa Ibom State power potential details

Table 28: Comprehensive energy profile of Akwa Ibom state

s/n	Akwa Ibom State Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	1,182,500
2	Avg. rooftop square area (tsqm)	123
3	Avg. number of sun hours per day	3.8
4	Avg. annual sun hours	1,387.95
5	Max. power potential in MW	851.98
6	Max. power potential in Watts	851,975,935.73
7	Viable rooftop space in sqm	3,706,450,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	2,059,138,888.89
9	# of 250W panels required to store energy from rooftop solar	801,859.70
10	# of 250W panels required to reach the maximum energy potential	4,009,298.52
11	# of 400W panels required to reach the maximum energy potential	2,505,811.58
12	Average kWh of storage required per year to ensure viability	4,857.83
13	Average battery charging potential per year (including batteries and Evs)	278,235,294.12
14	No. of batteries required ensure viability of rooftop area	57,275.69
15	Areas viable for power generation in Watts per sqm	0.2298630592



State Details

State: Bayelsa
Region: South-South
City: Yenagoa
Study Area: 9, 529 sq.km
Total Buildings: 3,642
Suitable Buildings: 2,819
Ave. Rooftop Area: 156 sq.m
Suitability Ratio: 77%

Solar Power Potential

Average Irradiation: 1,782 kWh/m^2
Max Usable IRR: 5539 MWh
Min Usable IRR: 48 MWh
Ave. Annual Electric Power: 25 MWh
Max Annual Electric Power: 756 MWh
Min Annual Electric Power: 6
Max combined electric power: 902,580 MWh

Fig 31: Bayelsa State power potential details

Table 29: Comprehensive energy profile of Bayelsa state

s/n	Bayelsa State Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	93,302,580
2	Avg. rooftop square area (tsqm)	156
3	Avg. number of sun hours per day	3.7
4	Avg. annual sun hours	1,351.43
5	Max. power potential in MW	69,040.15
6	Max. power potential in Watts	69,040,146,512.02
7	Viable rooftop space in sqm	7,337,330,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	4,076,294,444.44
9	# of 250W panels required to store energy from rooftop solar	64,978,961.42
10	# of 250W panels required to reach the maximum energy potential	324,894,807.12
11	# of 400W panels required to reach the maximum energy potential	203,059,254.45
12	Average kWh of storage required per year to ensure viability	4,729.99
13	Average battery charging potential per year (including batteries and Evs)	21,953,548,235.29
14	No. of batteries required ensure viability of rooftop area	4,641,354.39
15	Areas viable for power generation in Watts per sqm	9.40943729

Table 30: South-South Power Potential Result

s/n	Power parameters	Rivers	Cross River	Akwa Ibom	Bayelsa	Delta	Edo	Total
1	Max. Combined Electric Power	1,237,867	304,511	1,182,500	93,302,580	579,723	485,656	97,092,837.00
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	126	126	123	156	140	160	831.00
3	Ave. SUN Hours from NiMET data	3.5	3.7	3.8	3.7	3.4	4.2	22.30
4	Ave. Annual Hours	1,278.38	1,351.43	1,387.95	1,351.43	1,241.85	1,534.05	8,145.08
5	Max. MW	968.31	225.33	851.98	69,040.15	466.82	316.58	71,869.17
6	Max. MW IN WATTS	968,312,897.23	225,325,859.74	851,975,935.73	69,040,146,512.02	466,822,079.96	316,584,205.21	71,869,167,489.89
7	Viable Sqm from building data	7,840,910,000.00	4,312,960,000.00	3,706,450,000.00	7,337,330,000.00	2,595,240,000.00	3,707,660,000.00	29,500,550,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	4,356,061,111.11	2,396,088,888.89	2,059,138,888.89	4,076,294,444.44	1,441,800,000.00	2,059,811,111.11	16,389,194,444.44
9	# of 250W Panels for Charging Batteries for viable rooftops	911,353.32	212,071.40	801,859.70	64,978,961.42	439,361.96	297,961.60	67,641,569.40
10	# of panels required to generate Max MW from Irradiation	4,556,766.58	1,060,356.99	4,009,298.52	324,894,807.12	2,196,809.79	1,489,808.02	338,207,847.01
11	No. of 400W PV Panels required to generate Max MW from Irradiation	2,847,979.11	662,723.12	2,505,811.58	203,059,254.45	1,373,006.12	931,130.02	211,379,904.38
12	Average KWH of Storage required per year	4,474.31	4,729.99	4,857.83	4,729.99	4,346.48	5,369.18	28,507.76
13	Average Charging Power Per Year	291,262,823.53	71,649,647.06	278,235,294.12	21,953,548,235.29	136,405,411.76	114,272,000.00	22,845,373,411.76
14	No. of Batteries to make rooftop study area viable	65,096.67	15,147.96	57,275.69	4,641,354.39	31,383.00	21,282.97	4,831,540.67
15	Areas viable for power generation (W per Sq Meter)	0.1234949639	0.05224390204	0.2298630592	9.40943729	0.1798762658	0.08538652552	10.08

SOUTH-EAST REGION ROOFTOP SOLAR ESTIMATIONS

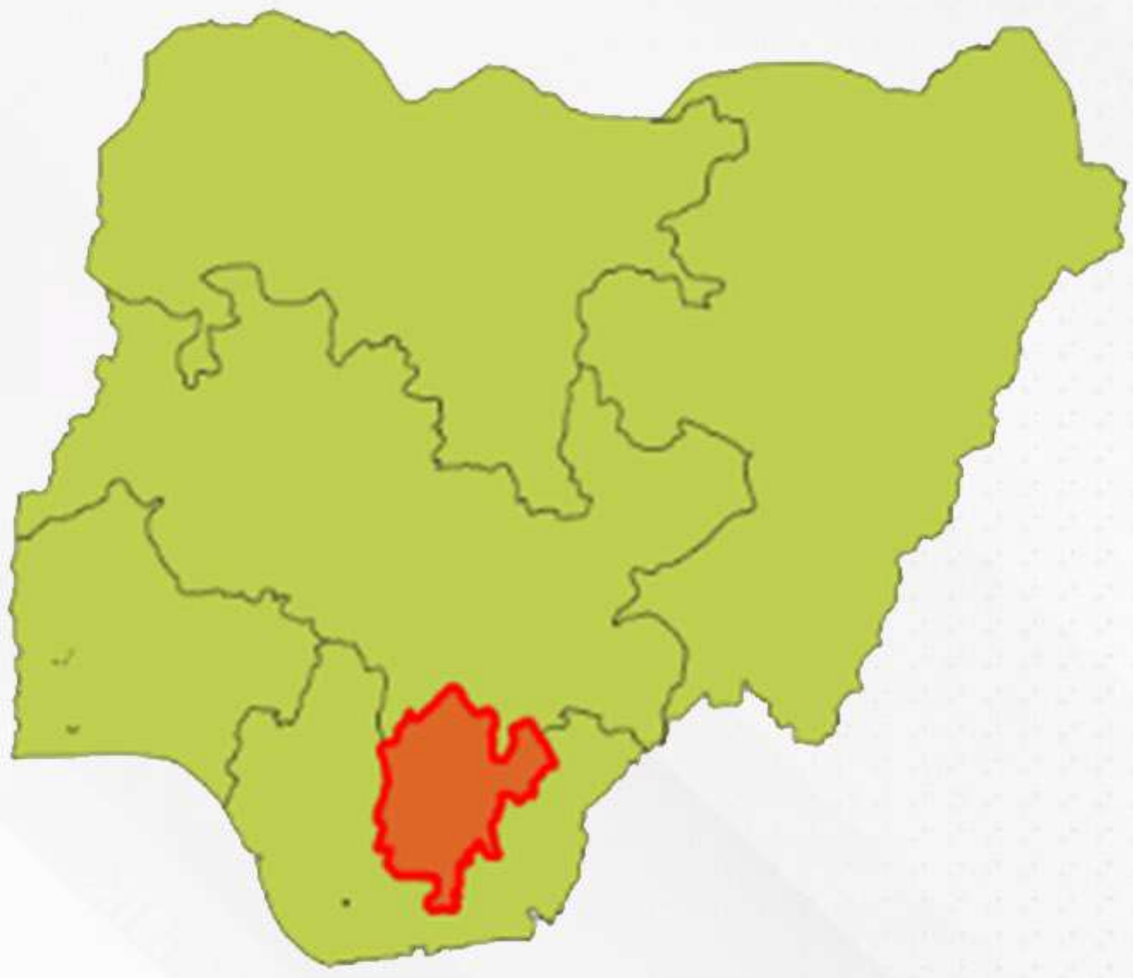
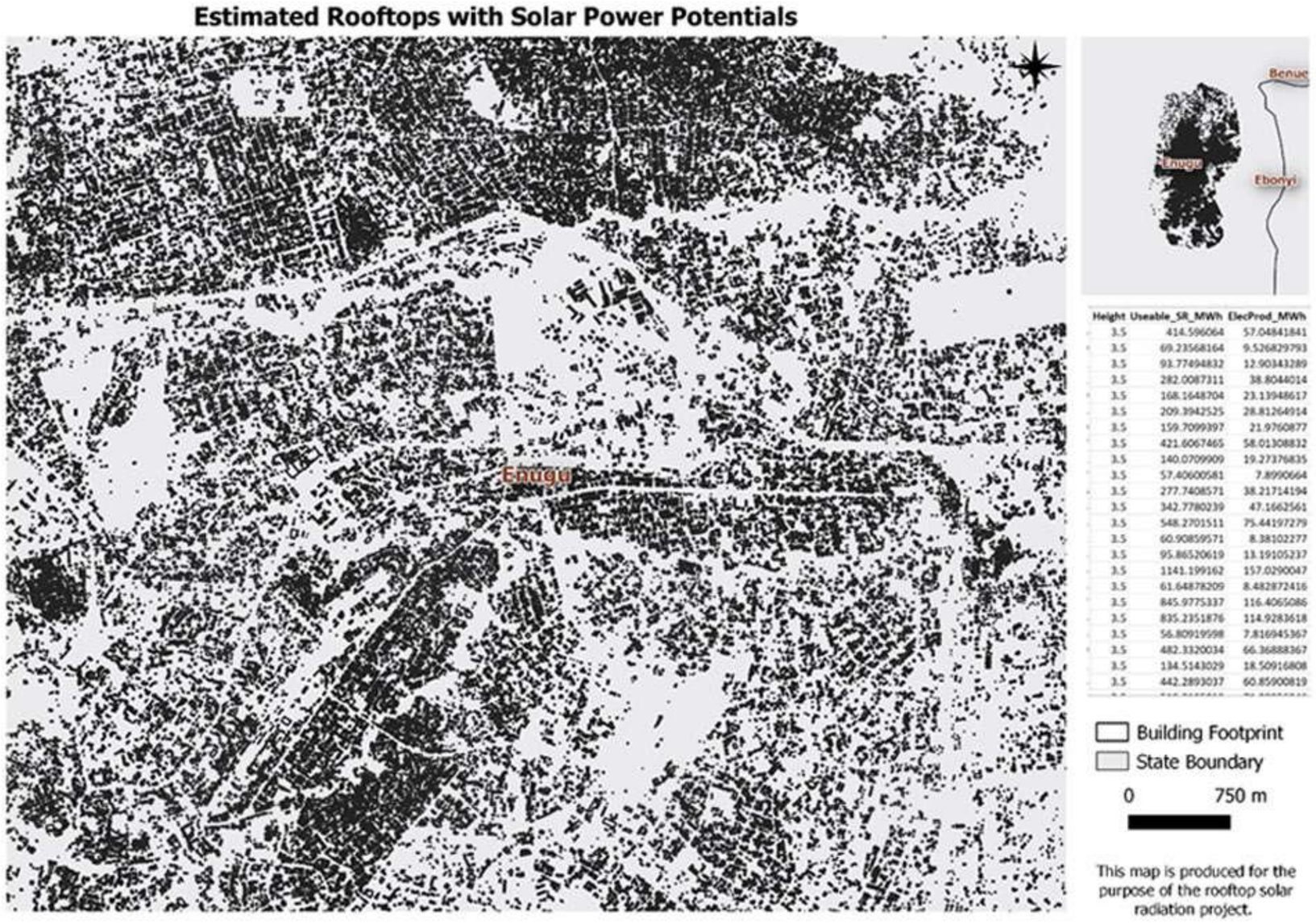


Figure 32: Nigeria map showing the South-East region



Height	Useable_SR_MWh	ElecProd_MWh
3.5	414.596064	57.04841841
3.5	69.23568164	9.526829793
3.5	93.77494832	12.90343289
3.5	282.0087311	38.8044014
3.5	168.1648704	23.13948617
3.5	209.3942525	28.81264914
3.5	159.7099397	21.9760877
3.5	421.6067465	58.01308832
3.5	140.0709909	19.27376835
3.5	57.40600581	7.8990664
3.5	277.7408571	38.21714194
3.5	342.7780239	47.1662561
3.5	548.2701511	75.44197279
3.5	60.90859571	8.38102277
3.5	95.86520619	13.19105237
3.5	1141.199162	157.0290047
3.5	61.64878209	8.482872416
3.5	845.9775337	116.4065086
3.5	835.2351876	114.9283618
3.5	56.80919598	7.816945367
3.5	482.3320034	66.36888367
3.5	134.5143029	18.50916808
3.5	442.2893037	60.85900819

State Details

State: Enugu
Region: South-East
City: Enugu
Study Area: 7,636.12 sq.km
Total Buildings: 202, 989
Suitable Buildings: 20, 252
Ave. Rooftop Area: 150.7 sq.m
Suitability Ratio: 10%

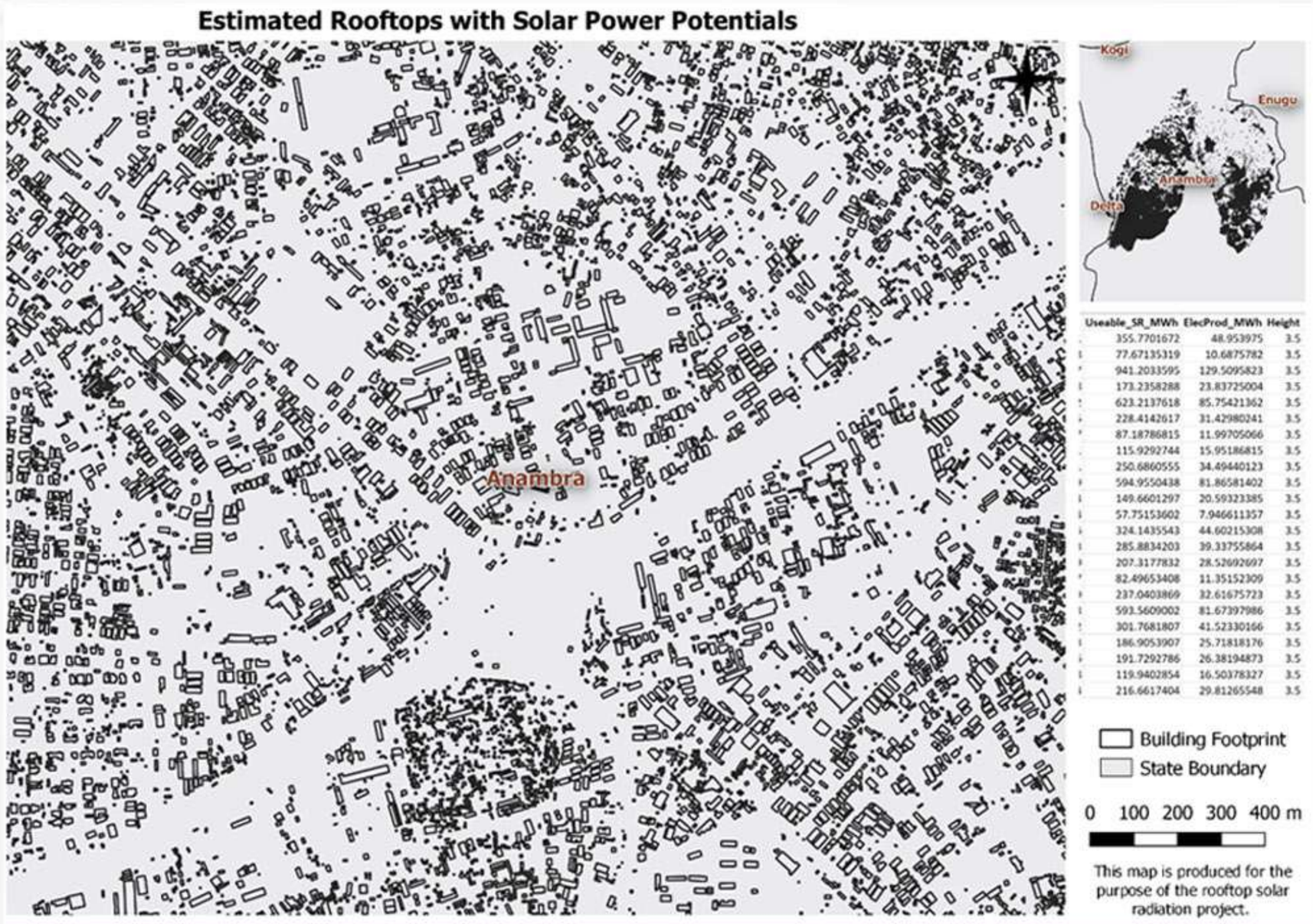
Solar Power Potential

Average Irradiation: 1802 kWh/m^2
Max Usable IRR: 45961 MWh
Min Usable IRR: 49 MWh
Ave. Annual Electric Power: 37 MWh
Max Annual Electric Power: 6324 MWh
Min Annual Electric Power: 7
Max combined electric power: 757,300 MWh

Fig 33: Enugu State power potential details

Table 28: Comprehensive energy profile of Akwa Ibom state

s/n	Akwa Ibom State Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	1,182,500
2	Avg. rooftop square area (tsqm)	123
3	Avg. number of sun hours per day	3.8
4	Avg. annual sun hours	1,387.95
5	Max. power potential in MW	851.98
6	Max. power potential in Watts	851,975,935.73
7	Viable rooftop space in sqm	3,706,450,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	2,059,138,888.89
9	# of 250W panels required to store energy from rooftop solar	801,859.70
10	# of 250W panels required to reach the maximum energy potential	4,009,298.52
11	# of 400W panels required to reach the maximum energy potential	2,505,811.58
12	Average kWh of storage required per year to ensure viability	4,857.83
13	Average battery charging potential per year (including batteries and Evs)	278,235,294.12
14	No. of batteries required ensure viability of rooftop area	57,275.69
15	Areas viable for power generation in Watts per sqm	0.2298630592



State Details

State: Anambra
Region: South-East
City: Akwa
Study Area: 4860 sq.km
Total Buildings: 246,491
Suitable Buildings: 14,306
Ave. Rooftop Area: 153 sq.m
Suitability Ratio: 6%

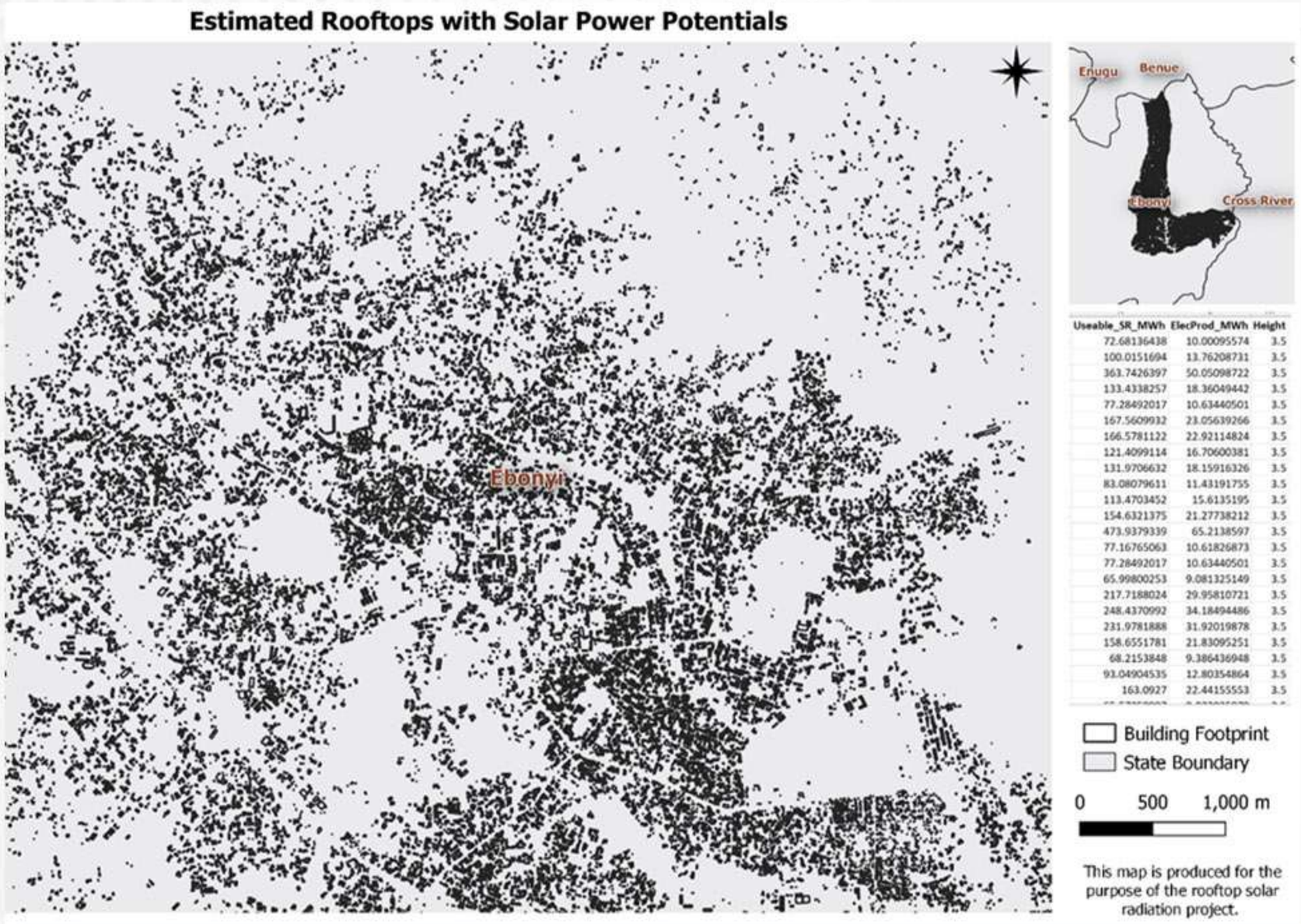
Solar Power Potential

Average Irradiation: 1787 kWh/m^2
Max Usable IRR: 11 871 MWh
Min Usable IRR: 44 MWh
Ave. Annual Electric Power: 38 MWh
Max Annual Electric Power: 1633 MWh
Min Annual Electric Power: 6
Max combined electric power: 538,026 MWh

Fig 34: Anambra State power potential details

Table 32: Comprehensive energy profile of Anambra state

s/n	Anambra Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	538,026
2	Avg. rooftop square area (tsqm)	153
3	Avg. number of sun hours per day	3.7
4	Avg. annual sun hours	1,351.43
5	Max. power potential in MW	398.12
6	Max. power potential in Watts	398,117,542.59
7	Viable rooftop space in sqm	291,000,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	161,666,666.67
9	# of 250W panels required to store energy from rooftop solar	374,698.86
10	# of 250W panels required to reach the maximum energy potential	1,873,494.32
11	# of 400W panels required to reach the maximum energy potential	1,170,933.95
12	Average kWh of storage required per year to ensure viability	4,729.99
13	Average battery charging potential per year (including batteries and Evs)	126,594,352.94
14	No. of batteries required ensure viability of rooftop area	26,764.20
15	Areas viable for power generation in Watts per sqm	1.368101521



Useable_SR_MWh	ElecProd_MWh	Height
72.68136438	10.00095574	3.5
100.0151694	13.76208731	3.5
363.7426397	50.05098722	3.5
133.4338257	18.36049442	3.5
77.28492017	10.63440501	3.5
167.5609932	23.05639266	3.5
166.5781122	22.92114824	3.5
121.4099114	16.70600381	3.5
131.9706632	18.15916326	3.5
83.08079611	11.43191755	3.5
113.4703452	15.6135195	3.5
154.6321375	21.27738212	3.5
473.9379339	65.2138597	3.5
77.16765063	10.61826873	3.5
77.28492017	10.63440501	3.5
65.99800253	9.081325149	3.5
217.7188024	29.95810721	3.5
248.4370992	34.18494486	3.5
231.9781888	31.92019878	3.5
158.6551781	21.83095251	3.5
68.2153848	9.386436948	3.5
93.04904535	12.80354864	3.5
163.0927	22.44155553	3.5

State Details

State: Ebonyi
Region: South-East
City: Ebonyi
Study Area: 6,339.61 sq.km
Total Buildings: 105,145
Suitable Buildings: 18,902
Ave. Rooftop Area: 157 sq.m
Suitability Ratio: 18%

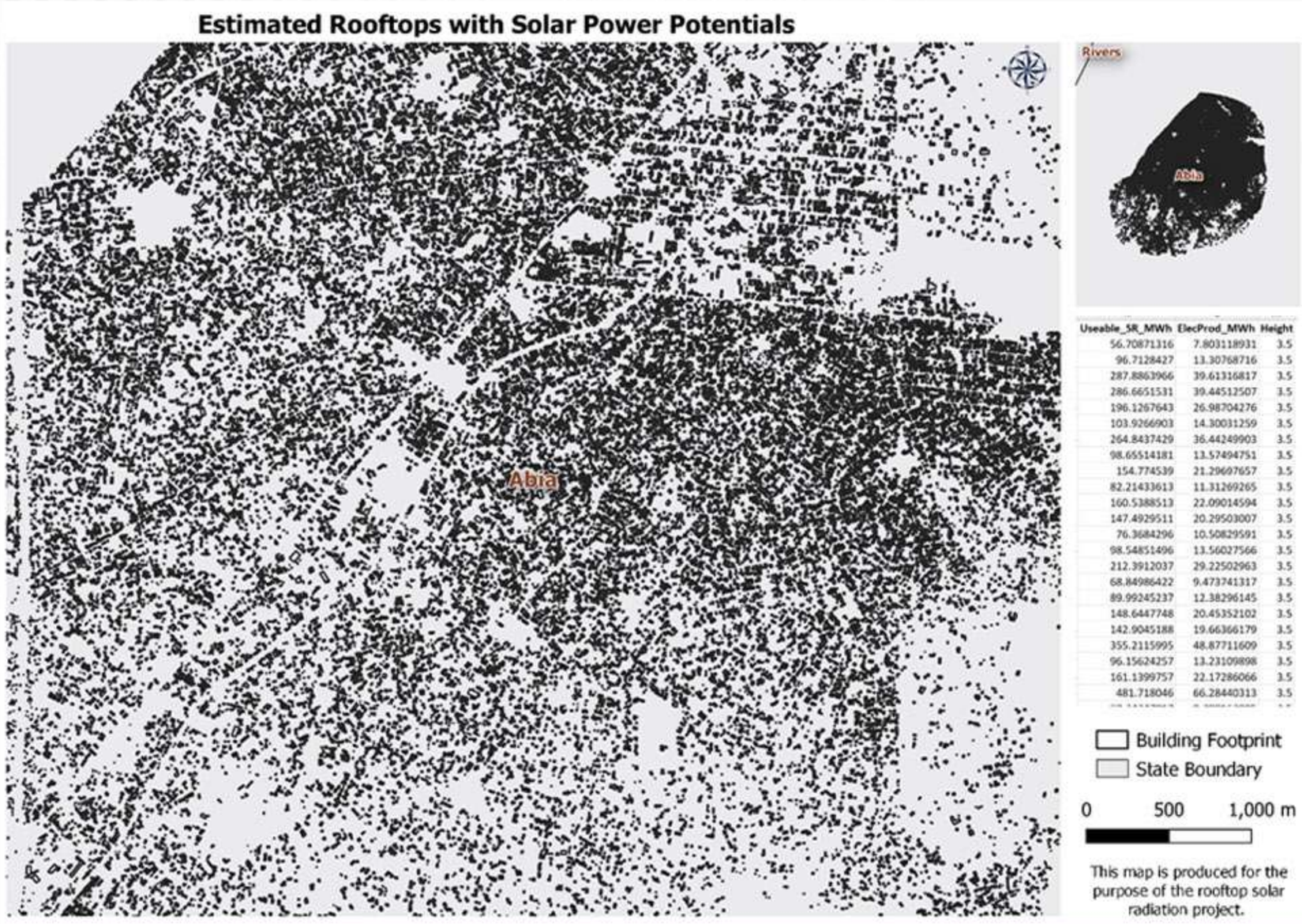
Solar Power Potential

Average Irradiation: 1781 kWh/m^2
Max Usable IRR: 37,100 MWh
Min Usable IRR: 45 MWh
Ave. Annual Electric Power: 39 MWh
Max Annual Electric Power: 5105 MWh
Min Annual Electric Power: 6
Combined Max Electric Power: 729,586 MWh

Fig 35: Ebonyi State power potential details

Table 33: Comprehensive energy profile of Ebonyi state

s/n	Ebonyi Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	729,586
2	Avg. rooftop square area (tsqm)	157
3	Avg. number of sun hours per day	3.4
4	Avg. annual sun hours	1,241.85
5	Max. power potential in MW	587.50
6	Max. power potential in Watts	587,499,295.41
7	Viable rooftop space in sqm	1,141,129,900.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	633,961,055.56
9	# of 250W panels required to store energy from rooftop solar	552,940.51
10	# of 250W panels required to reach the maximum energy potential	2,764,702.57
11	# of 400W panels required to reach the maximum energy potential	1,727,939.10
12	Average kWh of storage required per year to ensure viability	4,346.48
13	Average battery charging potential per year (including batteries and Evs)	171,667,294.12
14	No. of batteries required ensure viability of rooftop area	39,495.75
15	Areas viable for power generation in Watts per sqm	0.5148399804



State Details

State: Abia
Region: South-East
City: Umuahia
Study Area: 4860 sq.km
Total Buildings: 133,685
Suitable Buildings: 15,650
Ave. Rooftop Area: 141 sq.m
Suitability Ratio: 12%

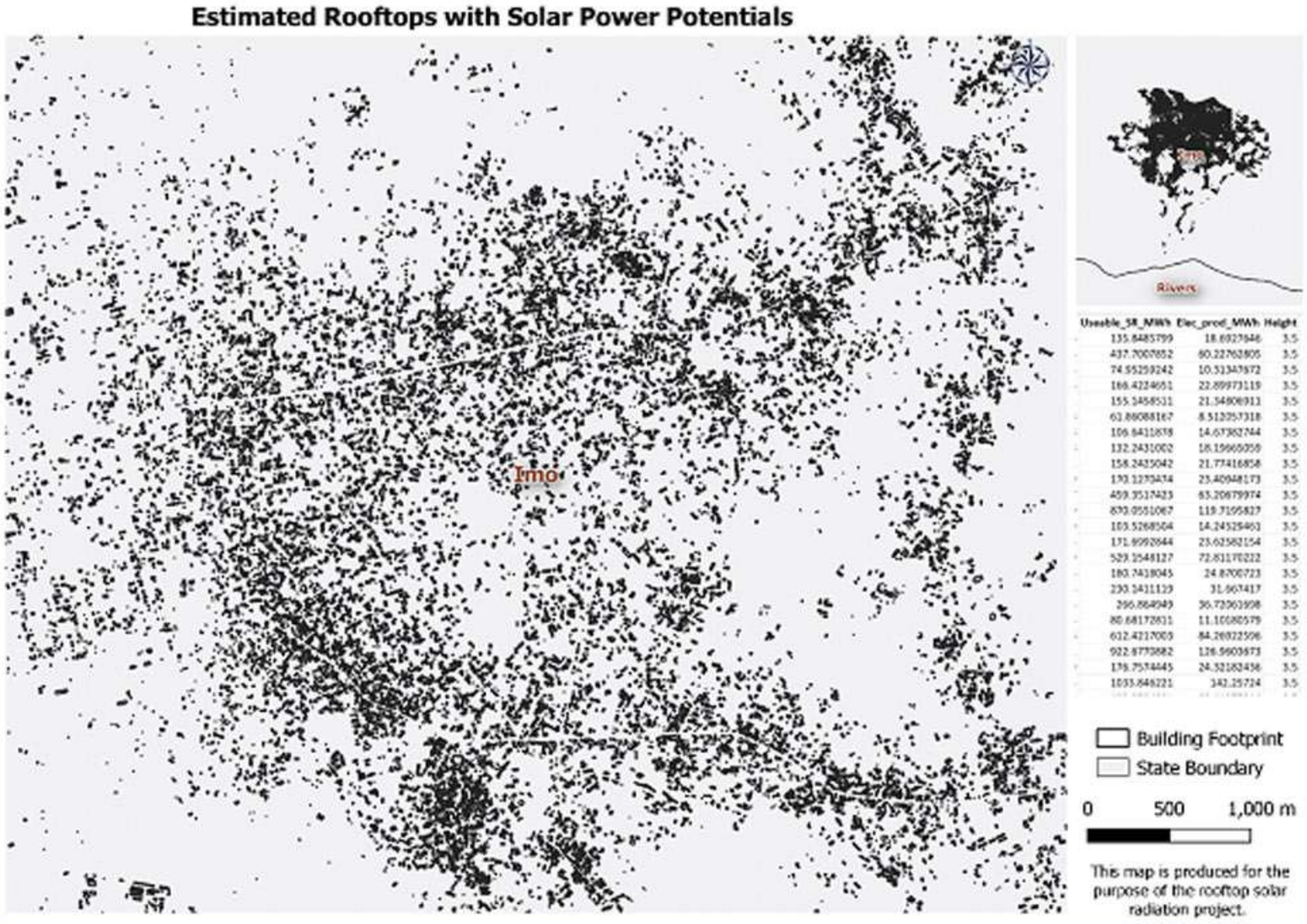
Solar Power Potential

Average Irradiation: 1798 kWh/m^2
Max Usable IRR: 31044 MWh
Min Usable IRR: 35 MWh
Ave. Annual Electric Power: 35 MWh
Max Annual Electric Power: 4272 MWh
Min Annual Electric Power: 5
Combined Max Electric Power: 546,327 MWh

Fig 36: Abia State power potential details

Table 34: Comprehensive energy profile of Abia state

s/n	Abia Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	546,327
2	Avg. rooftop square area (tsqm)	141
3	Avg. number of sun hours per day	4
4	Avg. annual sun hours	1,461.00
5	Max. power potential in MW	373.94
6	Max. power potential in Watts	373,940,451.75
7	Viable rooftop space in sqm	583,000,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	323,888,888.89
9	# of 250W panels required to store energy from rooftop solar	351,943.95
10	# of 250W panels required to reach the maximum energy potential	1,759,719.77
11	# of 400W panels required to reach the maximum energy potential	1,099,824.86
12	Average kWh of storage required per year to ensure viability	5,113.50
13	Average battery charging potential per year (including batteries and Evs)	128,547,529.41
14	No. of batteries required ensure viability of rooftop area	25,138.85
15	Areas viable for power generation in Watts per sqm	0.6414072929



Useable_SR_MWh	Elec_prod_MWh	Height
135.6485799	18.6927646	3.5
437.7007852	60.22763805	3.5
74.55259242	10.51347672	3.5
166.4224651	22.89973119	3.5
155.1458511	21.34806913	3.5
61.86088167	8.512057318	3.5
106.8411878	14.67382744	3.5
132.2431002	18.19665059	3.5
158.2425042	21.77416858	3.5
170.1270434	23.40944173	3.5
459.3517423	63.20879974	3.5
870.0551067	119.7195827	3.5
103.5268564	14.24529463	3.5
171.9092644	23.62582154	3.5
529.1548127	72.81170222	3.5
180.7418045	24.8700723	3.5
230.1411123	31.667417	3.5
266.864949	36.72901998	3.5
80.68172831	11.10080579	3.5
612.4217003	84.26922596	3.5
922.8770882	126.9603673	3.5
176.7574445	24.32182456	3.5
1033.646221	142.25724	3.5

State Details

State: Imo
Region: South-East
City: Owerri
Study Area: 5,074 sq.km
Total Buildings: 85,646
Suitable Buildings: 22,350
Ave. Rooftop Area: 141.5 sq.m
Suitability Ratio: 26%

Solar Power Potential

Average Irradiation: 1793 kWh/m^2
Max Usable IRR: 14,908 MWh
Min Usable IRR: 52 MWh
Ave. Annual Electric Power : 35 MWh
Max Annual Electric Power: 2051 MWh
Min Annual Electric Power: 7
Max combined electric power:: 780,485 MWh

Fig 36: Imo State power potential details

Table 34: Comprehensive energy profile of Imo state

s/n	Imo Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	780,485
2	Avg. rooftop square area (tsqm)	141.5
3	Avg. number of sun hours per day	3.4
4	Avg. annual sun hours	1,241.85
5	Max. power potential in MW	628.49
6	Max. power potential in Watts	628,485,726.94
7	Viable rooftop space in sqm	1,319,240,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	732,911,111.11
9	# of 250W panels required to store energy from rooftop solar	591,515.98
10	# of 250W panels required to reach the maximum energy potential	2,957,579.89
11	# of 400W panels required to reach the maximum energy potential	1,848,487.43
12	Average kWh of storage required per year to ensure viability	4,346.48
13	Average battery charging potential per year (including batteries and Evs)	183,643,529.41
14	No. of batteries required ensure viability of rooftop area	42,251.14
15	Areas viable for power generation in Watts per sqm	0.4763998415

Table 36: South-East Power Potential Result

s/n	Power parameters	Imo	Enugu	Abia	Anambra	Ebonyi	Total
1	Max. Combined Electric Power	780,485	757,300	546,327	538,026	729,586	3,351,724
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	141.5	150.7	141	153	157	743.2
3	Ave. SUN Hours from NiMET data	3.4	3.8	4	3.7	3.4	18.3
4	Ave. Annual Hours	1,241.85	1,387.95	1,461.00	1,351.43	1,241.85	6,684.08
5	Max. MW	628.49	545.62	373.94	398.12	587.50	2,533.67
6	Max. MW IN WATTS	628,485,726.94	545,624,842.39	373,940,451.75	398,117,542.59	587,499,295.41	2,533,667,859.08
7	Viable Sqm from building data	1,319,240,000.00	763,612,000.00	583,000,000.00	291,000,000.00	1,141,129,900.00	4,097,981,900.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	732,911,111.11	424,228,888.89	323,888,888.89	161,666,666.67	633,961,055.56	2,276,656,611.11
9	# of 250W Panels for Charging Batteries for viable rooftops	591,515.98	513,529.26	351,943.95	374,698.86	552,940.51	2,384,628.57
10	# of panels required to generate Max MW from Irradiation	2,957,579.89	2,567,646.32	1,759,719.77	1,873,494.32	2,764,702.57	11,923,142.87
11	No. of 400W PV Panels required to generate Max MW from Irradiation	1,848,487.43	1,604,778.95	1,099,824.86	1,170,933.95	1,727,939.10	7,451,964.29
12	Average KWH of Storage required per year	4,346.48	4,857.83	5,113.50	4,729.99	4,346.48	23,394.26
13	Average Charging Power Per Year	183,643,529.41	178,188,235.29	128,547,529.41	126,594,352.94	171,667,294.12	788,640,941.18
14	No. of Batteries to make rooftop study area viable	42,251.14	36,680.66	25,138.85	26,764.20	39,495.75	170,330.61
15	Areas viable for power generation (W per Sq Meter)	0.4763998415	0.7145315191	0.6414072929	1.368101521	0.5148399804	3.715280155

NORTH-EAST ROOFTOP SOLAR ESTIMATIONS

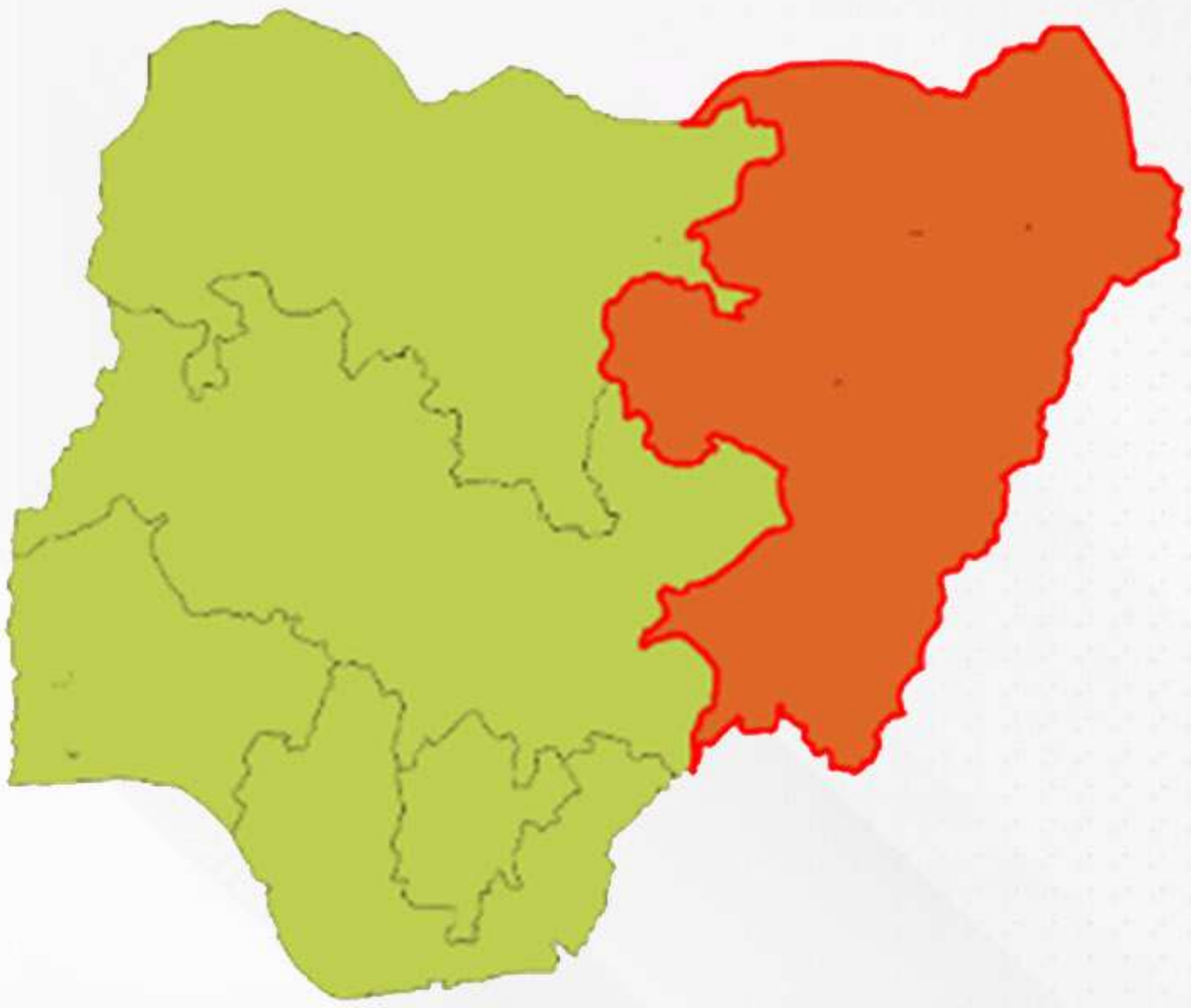
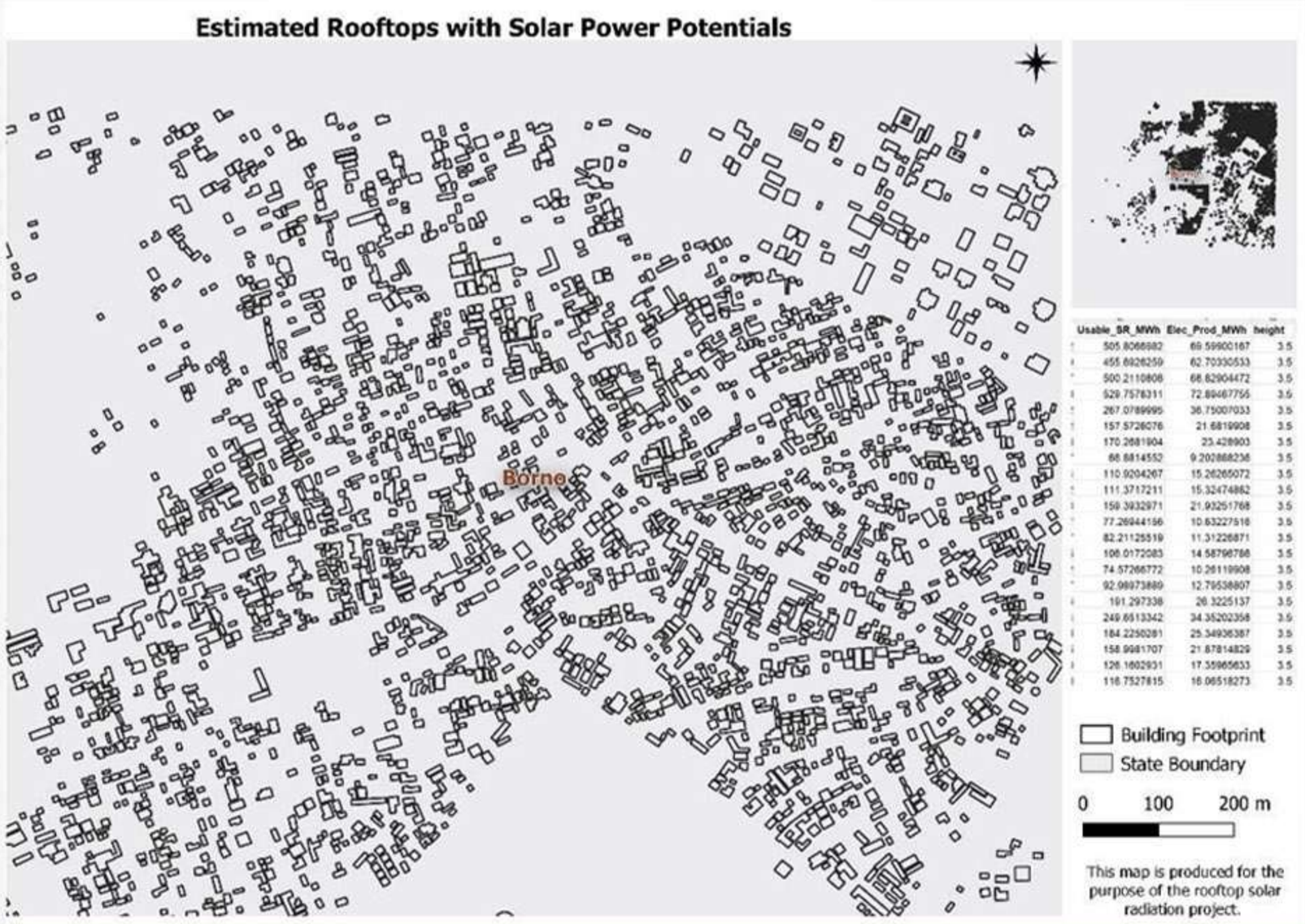


Figure 38: Nigeria map showing the North-East region

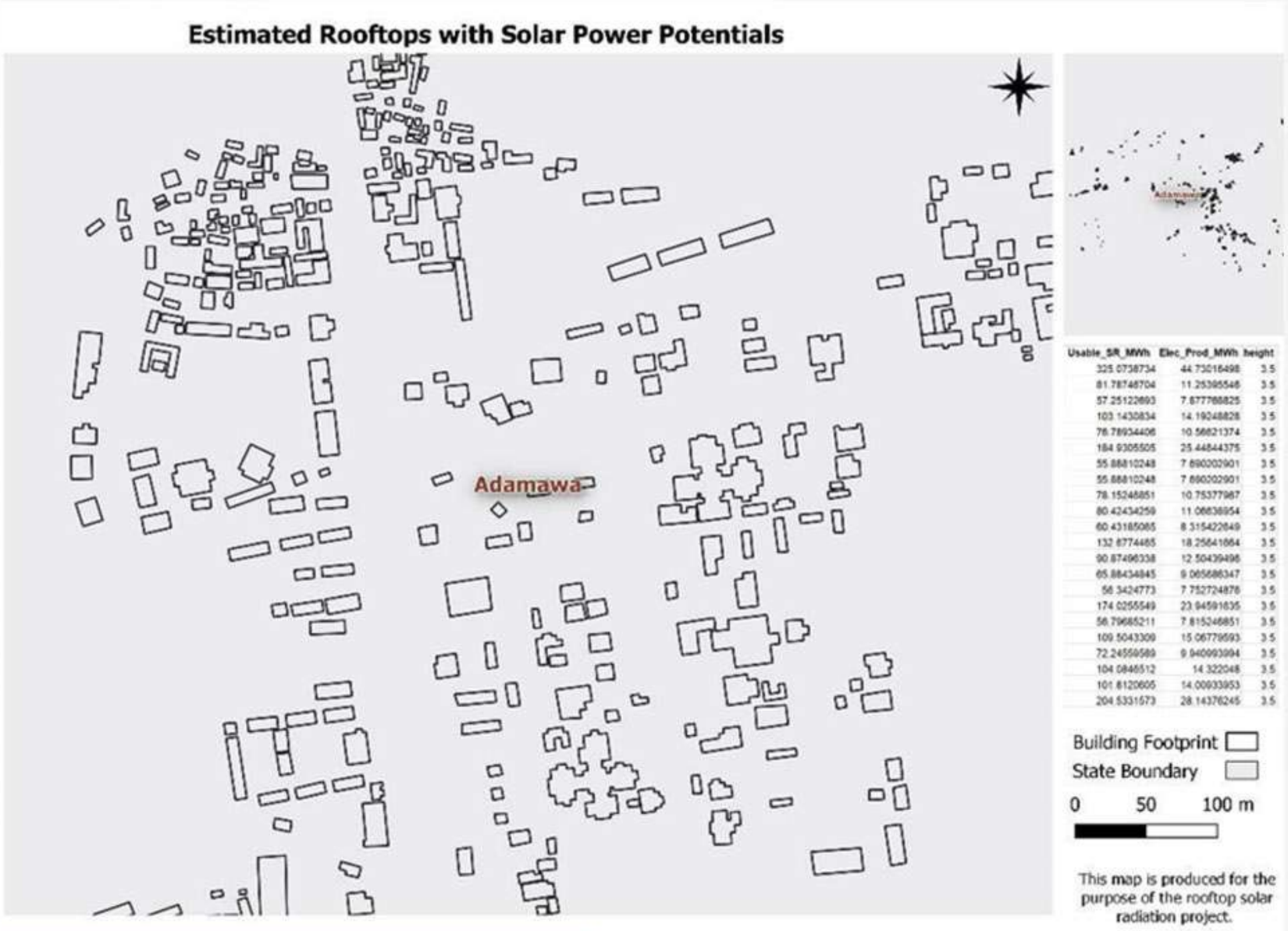


State Details	Solar Power Potential
State: Borno	Average Irradiation: 1,796 kWh/m^2
Region: North East	Max Usable IRR: 5,023 MWh
City: Maiduguri	Min Usable IRR: 54 MWh
Study Area:72,156.6 sq.km	Ave. Annual Electric Power: 25 MWh
Total Buildings: 29,873	Max Annual Electric Power: 691 MWh
Suitable Buildings: 5,831	Min Annual Electric Power: 7
Ave. Rooftop Area: 100 sq.m	Max combined electric power: 144, 169
Suitability Ratio: 95%	MWh

Fig 39: Borno State power potential details

Table 37: Comprehensive energy profile of Borno state

s/n	Borno Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	144,169
2	Avg. rooftop square area (tsqm)	100
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	78.94
6	Max. power potential in Watts	78,942,642.03
7	Viable rooftop space in sqm	68,548,770,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	38,082,650,000.00
9	# of 250W panels required to store energy from rooftop solar	74,298.96
10	# of 250W panels required to reach the maximum energy potential	371,494.79
11	# of 400W panels required to reach the maximum energy potential	232,184.24
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	33,922,117.65
14	No. of batteries required ensure viability of rooftop area	5,307.07
15	Areas viable for power generation in Watts per sqm	0.001151627404



State Details

State: Adamawa
Region: North East
City: Yola
Study Area: 12,512 sq.km
Total Buildings: 5,873
Suitable Buildings: 923
Ave. Rooftop Area: 113 sq.m
Suitability Ratio: 20%

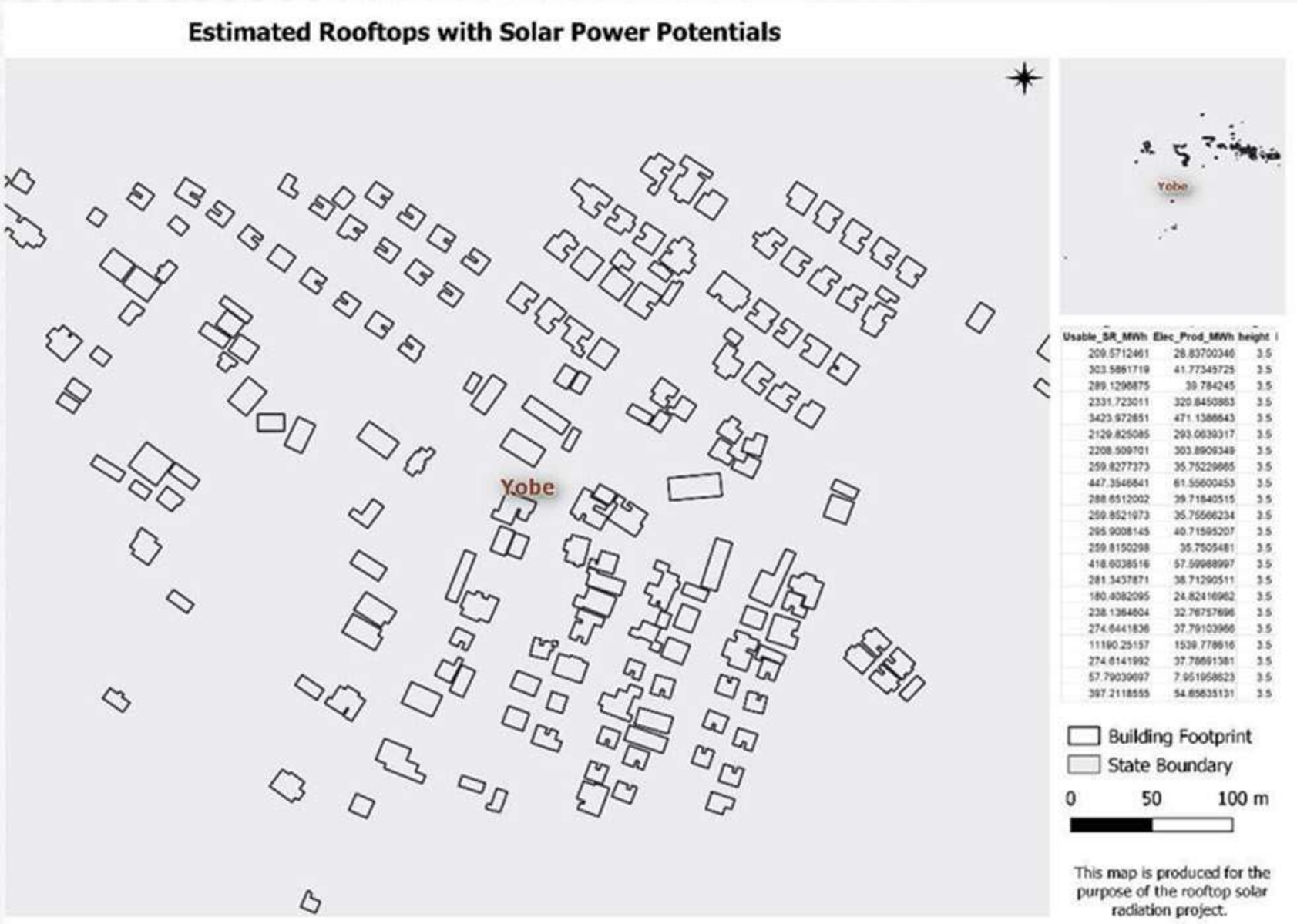
Solar Power Potential

Average Irradiation: 1,754 kWh/m^2
Max Usable IRR: 1,546 MWh
Min Usable IRR: 42 MWh
Ave. Annual Electric Power: 35 MWh
Max Annual Electric Power: 431 MWh
Min Annual Electric Power: 6
Max combined electric power: 56,753 MWh

Fig 40: Adamawa State power potential details

Table 38: Comprehensive energy profile of Adamawa state

s/n	Adamawa Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	56,753
2	Avg. rooftop square area (tsqm)	113
3	Avg. number of sun hours per day	4.6
4	Avg. annual sun hours	1,680.15
5	Max. power potential in MW	33.78
6	Max. power potential in Watts	33,778,531.68
7	Viable rooftop space in sqm	2,502,400,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	1,390,222,222.22
9	# of 250W panels required to store energy from rooftop solar	31,791.56
10	# of 250W panels required to reach the maximum energy potential	158,957.80
11	# of 400W panels required to reach the maximum energy potential	99,348.62
12	Average kWh of storage required per year to ensure viability	5,880.53
13	Average battery charging potential per year (including batteries and Evs)	13,353,647.06
14	No. of batteries required ensure viability of rooftop area	2,270.83
15	Areas viable for power generation in Watts per sqm	0.01349845416



Usable_SR_MWh	Elec_Prod_MWh	height
209.5712461	28.83700346	3.5
303.5861719	41.77345725	3.5
289.1298875	39.784245	3.5
2331.723011	320.8450863	3.5
3423.972851	471.1388643	3.5
2129.825085	293.0639317	3.5
2208.509701	303.8909349	3.5
259.8277373	35.75229665	3.5
447.3546841	61.55600453	3.5
288.6512002	39.71840515	3.5
259.8521973	35.75566234	3.5
295.9008145	40.71595207	3.5
259.8150298	35.7505481	3.5
418.6038516	57.59988997	3.5
281.3437871	38.71290511	3.5
180.4082095	24.82416962	3.5
238.1364604	32.76757696	3.5
274.6441836	37.79103956	3.5
11190.25157	1539.778616	3.5
274.6141992	37.78691381	3.5
57.79039697	7.951958623	3.5
397.2118555	54.65635131	3.5

State Details

State: Yobe
Region: North East
City: Damaturu
Study Area: 44.844 sq.km
Total Buildings: 9,174
Suitable Buildings: 1,340
Ave. Rooftop Area: 153.2 sq.m
Suitability Ratio: 18%

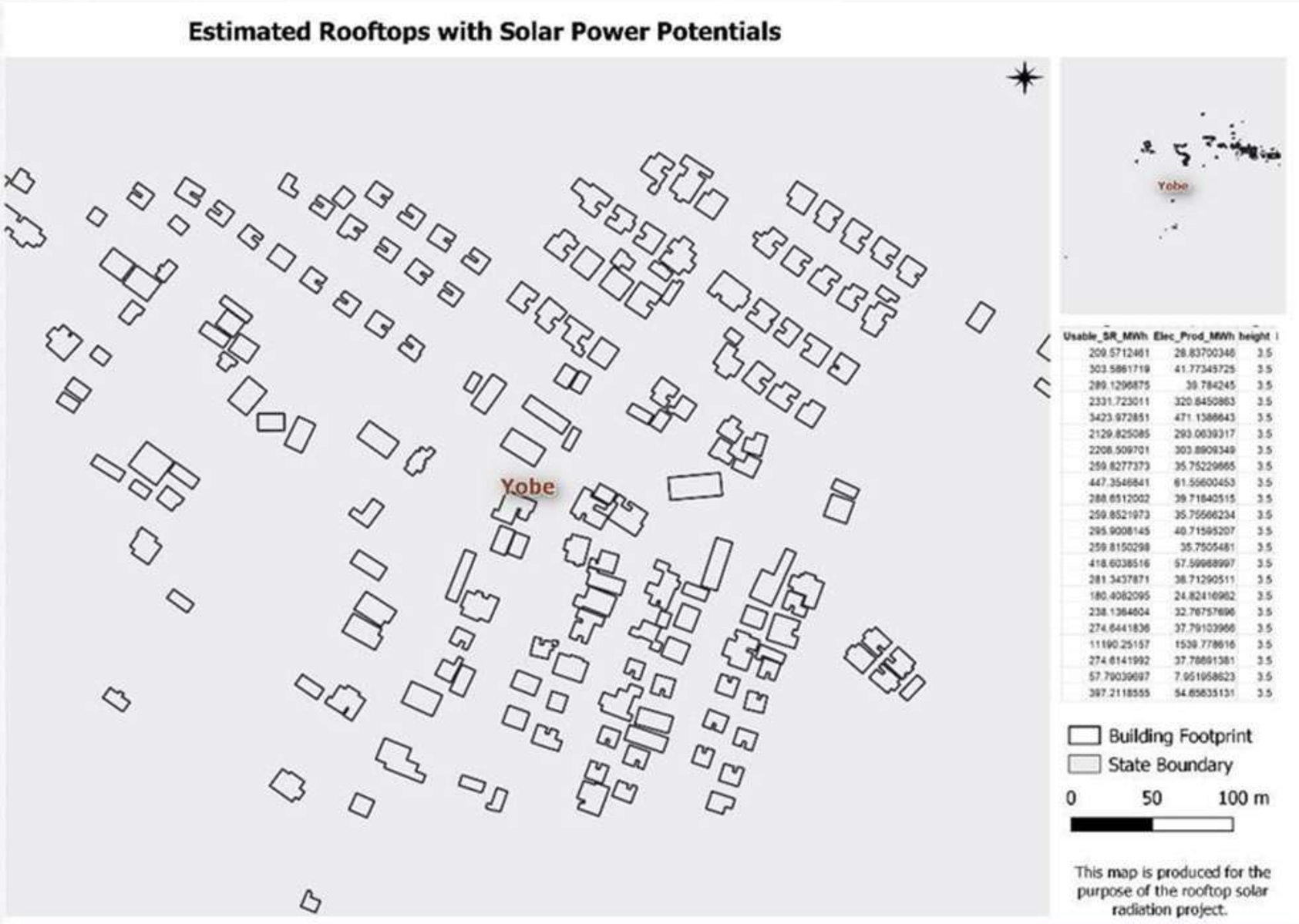
Solar Power Potential

Average Irradiation: 1,802 kWh/m^2
Max Usable IRR: 11,190 MWh
Min Usable IRR: 56.7 MWh
Ave. Annual Electric Power: 38 MWh
Max Annual Electric Power: 1539.7 MWh
Min Annual Electric Power: 7.8
Max combined electric power: 50,909 MWh

Fig 41: Yobe State power potential details

Table 39: Comprehensive energy profile of Yobe state

s/n	Yobe Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	50,909
2	Avg. rooftop square area (tsqm)	153.2
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	27.88
6	Max. power potential in Watts	27,876,249.14
7	Viable rooftop space in sqm	8,071,920,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	4,484,400,000.00
9	# of 250W panels required to store energy from rooftop solar	26,236.47
10	# of 250W panels required to reach the maximum energy potential	131,182.35
11	# of 400W panels required to reach the maximum energy potential	81,988.97
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	11,978,588.24
14	No. of batteries required ensure viability of rooftop area	1,874.03
15	Areas viable for power generation in Watts per sqm	0.003453484319



State Details

State: Yobe
Region: North East
City: Damaturu
Study Area: 44.844 sq.km
Total Buildings: 9,174
Suitable Buildings: 1,340
Ave. Rooftop Area: 153.2 sq.m
Suitability Ratio: 18%

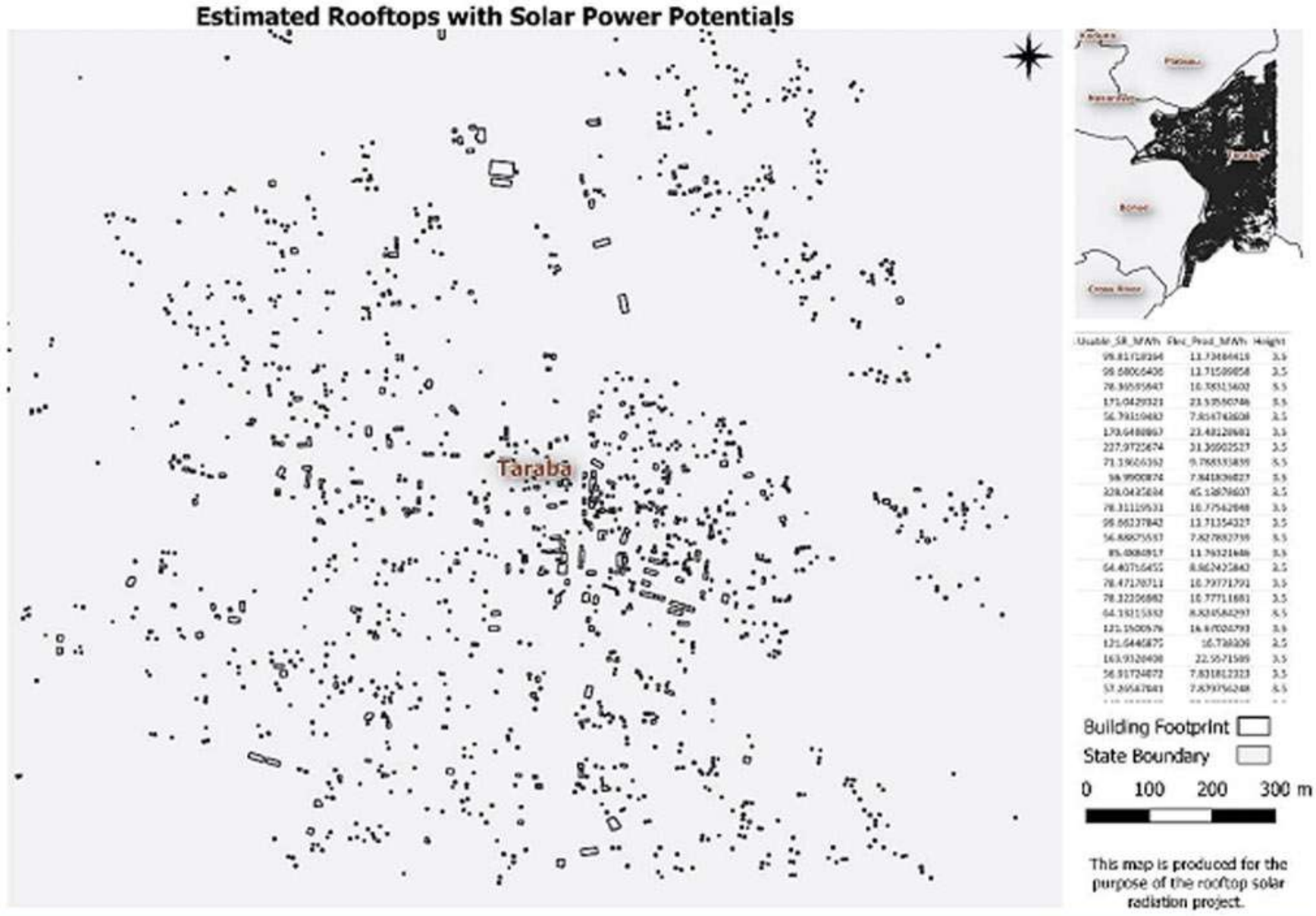
Solar Power Potential

Average Irradiation: 1,802 kWh/m^2
Max Usable IRR: 11,190 MWh
Min Usable IRR: 56.7 MWh
Ave. Annual Electric Power: 38 MWh
Max Annual Electric Power: 1539.7 MWh
Min Annual Electric Power: 7.8
Max combined electric power: 50,909 MWh

Fig 41: Yobe State power potential details

Table 39: Comprehensive energy profile of Yobe state

s/n	Yobe Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	50,909
2	Avg. rooftop square area (tsqm)	153.2
3	Avg. number of sun hours per day	5
4	Avg. annual sun hours	1,826.25
5	Max. power potential in MW	27.88
6	Max. power potential in Watts	27,876,249.14
7	Viable rooftop space in sqm	8,071,920,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	4,484,400,000.00
9	# of 250W panels required to store energy from rooftop solar	26,236.47
10	# of 250W panels required to reach the maximum energy potential	131,182.35
11	# of 400W panels required to reach the maximum energy potential	81,988.97
12	Average kWh of storage required per year to ensure viability	6,391.88
13	Average battery charging potential per year (including batteries and Evs)	11,978,588.24
14	No. of batteries required ensure viability of rooftop area	1,874.03
15	Areas viable for power generation in Watts per sqm	0.003453484319



State Details

State: Taraba
Region: North East
City: Jalingo
Study Area: 58,545.6 sq.km
Total Buildings: 31,691
Suitable Buildings: 7,936
Ave. Rooftop Area: 78.6 sq.m
Suitability Ratio: 29%

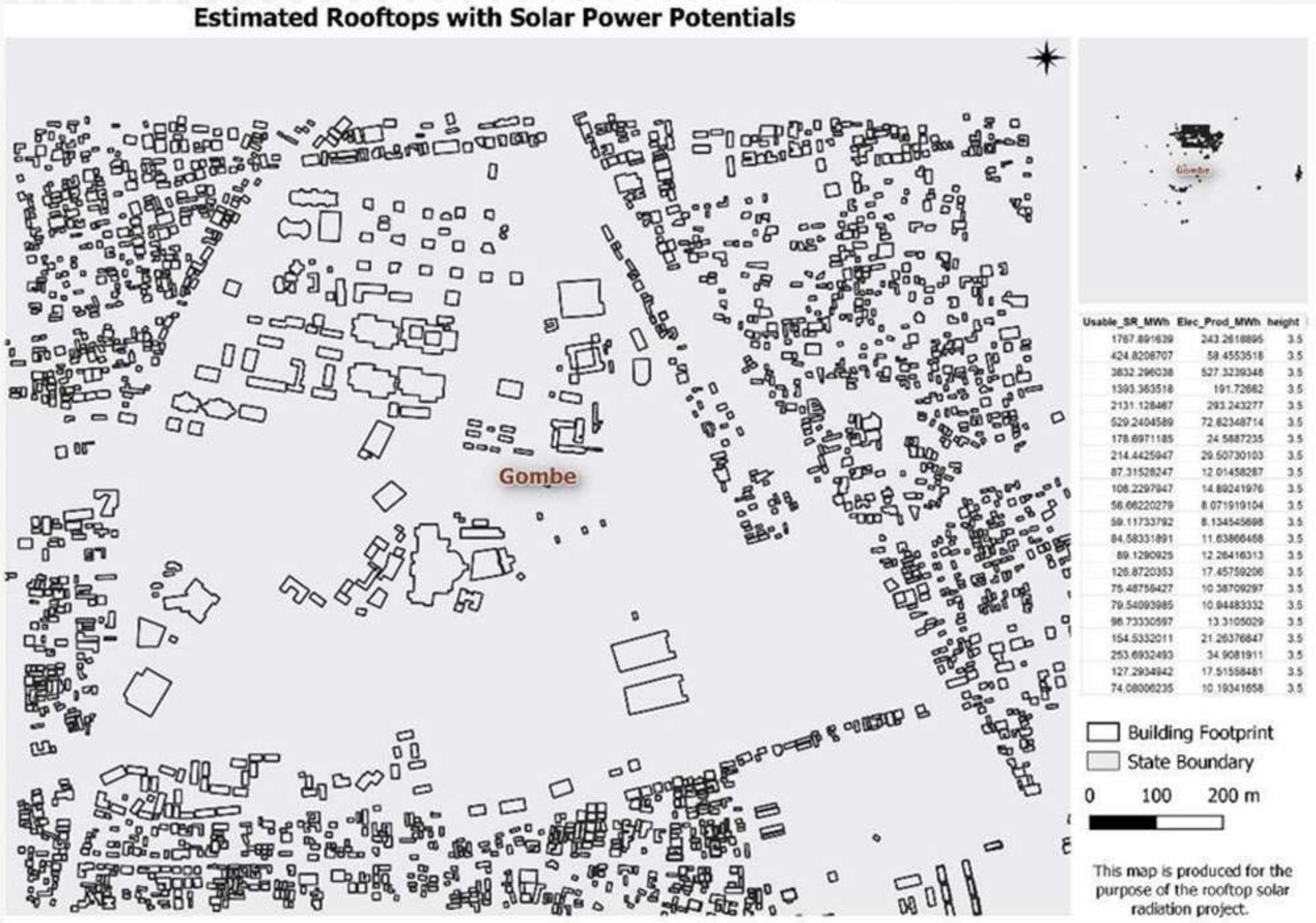
Solar Power Potential

Average Irradiation: 1,794 kWh/m^2
Max Usable IRR: 2301.4 MWh
Min Usable IRR: 55.5 MWh
Ave. Annual Electric Power: 19 MWh
Max Annual Electric Power: 316.6 MWh
Min Annual Electric Power: 7
Max combined electric power: 154,087 MWh

Fig 42: Taraba State power potential details

Taraba Rooftop energy profile

s/n	Taraba Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	154,087
2	Avg. rooftop square area (tsqm)	78.6
3	Avg. number of sun hours per day	4.4
4	Avg. annual sun hours	1,607.10
5	Max. power potential in MW	95.88
6	Max. power potential in Watts	95,878,912.33
7	Viable rooftop space in sqm	16,978,224,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	9,432,346,666.67
9	# of 250W panels required to store energy from rooftop solar	90,238.98
10	# of 250W panels required to reach the maximum energy potential	451,194.88
11	# of 400W panels required to reach the maximum energy potential	281,996.80
12	Average kWh of storage required per year to ensure viability	5,624.85
13	Average battery charging potential per year (including batteries and Evs)	36,255,764.71
14	No. of batteries required ensure viability of rooftop area	6,445.64
15	Areas viable for power generation in Watts per sqm	0.005647169711



Usable_SR_MWh	Elec_Prod_MWh	height
1767.891639	243.2618895	3.5
424.8208707	58.4553518	3.5
3832.296038	527.3239348	3.5
1393.363518	191.72682	3.5
2131.128467	293.243277	3.5
529.2404589	72.82348714	3.5
178.6971185	24.5887235	3.5
214.4425947	29.50730103	3.5
87.31528247	12.01458287	3.5
108.2297947	14.89241976	3.5
58.68220279	8.071919104	3.5
59.11733792	8.134545698	3.5
84.58331891	11.63866468	3.5
89.1290925	12.26416313	3.5
126.8720353	17.45759206	3.5
75.48756427	10.38709297	3.5
79.54093985	10.94483332	3.5
96.73330597	13.3105029	3.5
154.5332011	21.26376847	3.5
253.6932493	34.9081911	3.5
127.2934942	17.51558481	3.5
74.08006235	10.19341658	3.5

State Details	Solar Power Potential
State: Gombe	Average Irradiation: 1,829 kWh/m^2
Region: North East	Max Usable IRR: 11,802 MWh
City: Gombe	Min Usable IRR: 54 MWh
Study Area: 17,426.6 sq.km	Ave. Annual Electric Power: 32 MWh
Total Buildings: 29,793	Max Annual Electric Power: 1,623.99 MWh
Suitable Buildings: 2,805	Min Annual Electric Power: 7
Ave. Rooftop Area: 125 sq.m	Max combined electric power: 88,399 MWh
Suitability Ratio: 36%	

Fig 43: Gombe State power potential details

Table 41: Comprehensive energy profile of Gombe state

s/n	Gombe Rooftop energy profile	
1	Maximum combined energy potential (MWh) per year	88,399
2	Avg. rooftop square area (tsqm)	125
3	Avg. number of sun hours per day	4.6
4	Avg. annual sun hours	1,680.15
5	Max. power potential in MW	52.61
6	Max. power potential in Watts	52,613,754.72
7	Viable rooftop space in sqm	6,273,760,000.00
8	Actual # of 250W panels that can be used for the viable rooftop area for the viable Sq Area (Rooftops)	3,485,422,222.22
9	# of 250W panels required to store energy from rooftop solar	49,518.83
10	# of 250W panels required to reach the maximum energy potential	247,594.14
11	# of 400W panels required to reach the maximum energy potential	154,746.34
12	Average kWh of storage required per year to ensure viability	5,880.53
13	Average battery charging potential per year (including batteries and Evs)	20,799,764.71
14	No. of batteries required ensure viability of rooftop area	3,537.06
15	Areas viable for power generation in Watts per sqm	0.008386319324

Table 43: North-East Power Potential Results

s/n	Power parameters	Adamawa	Taraba	Yobe	Bauchi	Borno	Gombe	Total
1	Max. Combined Electric Power	56,753	154,087	50,909	571,484	144,169	88,399	1,065,801
2	(MWh) Per Year Ave. Rooftop Square Area (sqm)	113	78.6	153.2	81.2	100	125	651
3	Ave. SUN Hours from NiMET data	4.6	4.4	5	5	5	4.6	28.6
4	Ave. Annual Hours	1,680.15	1,607.10	1,826.25	1,826.25	1,826.25	1,680.15	10,446.15
5	Max. MW	33.78	95.88	27.88	312.93	78.94	52.61	602.02
6	Max. MW IN WATTS	33,778,531.68	95,878,912.33	27,876,249.14	312,927,583.85	78,942,642.03	52,613,754.72	602,017,673.75
7	Viable Sqm from building data	2,502,400,000.00	16,978,224,000.00	8,071,920,000.00	48,138,090,000.00	68,548,770,000.00	6,273,760,000.00	150,513,164,000.00
8	Actual # of 250W panels that can be used for the viable Sq Area (Rooftops)	1,390,222,222.22	9,432,346,666.67	4,484,400,000.00	26,743,383,333.33	38,082,650,000.00	3,485,422,222.22	83,618,424,444.44
9	# of 250W Panels for Charging Batteries for viable rooftops	31,791.56	90,238.98	26,236.47	294,520.08	74,298.96	49,518.83	566,604.87
10	# of panels required to generate Max MW from Irradiation	158,957.80	451,194.88	131,182.35	1,472,600.39	371,494.79	247,594.14	2,833,024.35
11	No. of 400W PV Panels required to generate Max MW from Irradiation	99,348.62	281,996.80	81,988.97	920,375.25	232,184.24	154,746.34	1,770,640.22
12	Average KWH of Storage required per year	5,880.53	5,624.85	6,391.88	6,391.88	6,391.88	5,880.53	36,561.53
13	Average Charging Power Per Year	13,353,647.06	36,255,764.71	11,978,588.24	134,466,823.53	33,922,117.65	20,799,764.71	250,776,705.88
14	No. of Batteries to make rooftop study area viable	2,270.83	6,445.64	1,874.03	21,037.15	5,307.07	3,537.06	40,471.78
15	Areas viable for power generation (W per Sq Meter)	0.01349845416	0.005647169711	0.003453484319	0.006500623183	0.001151627404	0.008386319324	0.0386376781

Table 44: Regional comparisons

We have provided a regional comparison below with the most favorable region for each category highlighted in green.

	South West	South South	South East	North East	North West	North Central
Maximum combined energy potential (MWh) per year	1,833,450.33	782,139.50	670,344.80	177,633.50	151,313.86	505,884.57
Avg. rooftop square area (sqm)	140.23	138.50	48.64	108.50	178.71	118.00
Avg. number of sun hours per day	3.60	3.72	3.66	4.77	4.90	4.33
Avg. annual sun hours	1,314.90	1,357.52	1,336.82	1,741.03	1,789.73	1,581.01
Max. power potential in MW	1,396.60	582.82	506.73	100.34	84.83	320.09
Max. power potential in Watts	1,396,598,846.92	582,815,629.80	506,733,571.82	100,336,278.96	84,827,414.47	320,088,676.82
Viable rooftop space in sqm	4,645,218,333.33	4,916,758,333.33	819,596,380.00	25,085,527,333.33	11,711,908,571.43	2,832,530,000.00
Actual # of 250W panels that can be used for the viable rooftop area	2,580,676,851.85	2,731,532,407.41	455,331,322.22	13,936,404,074.07	6,506,615,873.02	1,573,627,777.78
# of 250W panels required to store energy from rooftop solar	1,314,445.98	548,532.36	476,925.71	94,434.15	79,837.57	301,259.93
# of 250W panels required to reach the maximum energy potential	6,572,229.87	2,742,661.79	2,384,628.57	472,170.73	399,187.83	1,506,299.66
# of 400W panels required to reach the maximum energy potential	4,107,643.67	1,714,163.62	1,490,392.86	295,106.70	249,492.40	941,437.29
Average kWh of storage required per year to ensure viability	4,602.15	4,751.30	4,678.86	6,093.59	6,264.04	5,533.54
Average kWh of storage required per year to ensure viability	4,602.15	4,751.30	4,678.86	6,093.59	6,264.04	5,533.54
No. of batteries required ensure viability of rooftop area	93,889.00	39,180.88	34,066.12	6,745.30	5,702.68	21,518.57
Areas viable for power generation in Watts per sqm	0.42	1.68	0.74	0.01	0.01	1.19

Implications for energy planning in Nigeria

Going by the regional analysis above, the data shows that solar irradiation is highest in the North West and North East. Given that gas power supply is concentrated in southern Nigeria, our findings show that solar could meet the energy needs of northern Nigeria and perhaps supply to other areas in the South. Rooftops provide a good opportunity to utilize the solar resources without having to compete for land use. There are also opportunities to potentially interconnect on-site solar generation in areas where grid coverage is weak.

Potential areas for follow-on studies

- Site-specific GIS mapping of solar potential across clusters.
- Deeper dive into the potential for energy storage as a way to even our disparities in solar resources across Nigeria.
- Transmission network mapping to overlay solar resource data with electricity infrastructure, to enable net-metering.
- Updated cost analysis and payback period estimates for on-site solar in Nigeria after removal of fuel subsidies.