
RENEWABLE ENERGY RESOURCE OUTLOOK FOR KEBBI SOUTH, NIGERIA: A REVIEW

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ABSTRACT

Reliable electricity remains scarce in rural northwestern Nigeria, yet Kebbi South—the seven local government areas of Zuru, Fakai, Sakaba, Danko/Wasagu, Yauri, Ngaski and Shanga—has received little consolidated resource assessment. This review synthesises 2019–2026 literature, institutional reports and project records on solar, wind, hydro and biomass resources relevant to the zone, and applies standard resource and techno-economic equations to cross-check reported figures. Kebbi's mean annual global horizontal irradiation is about 2,102 kWh/m²/yr ($\approx$ 5.8 kWh/m²/day), 1.4% below the northwest mean, so solar photovoltaics is the most mature option. Reported wind power density is only 64.88 W/m² (Weibull shape factor 1.40–1.84), suitable for light loads, pumping and hybrid support rather than utility-scale. Small hydropower is plausible along the Niger-river margin, with Ngaski flagged in GIS screening, but no state-level small-hydro inventory exists. Crop residues (sorghum, millet, rice, groundnut) and livestock waste are abundant but face competing uses. A HOMER-based hybrid study in Kebbi reports a levelised cost of ₦149.98/kWh for a PV–wind–hydro system; the reported figures are internally consistent with a capital recovery factor of 0.0675. Principal gaps are LGA-level measurements, hydrology and biomass inventories; a staged roadmap is proposed.

INDEX TERMS: Biomass, Hybrid Renewable Energy Systems, Kebbi State, Nigeria, Small Hydropower, Solar Photovoltaic, Wind Energy.

I. INTRODUCTION

Access to affordable, reliable electricity underpins health, education, agriculture and enterprise, yet an estimated 60% of Nigerians lack consistent access, and the burden falls hardest on rural northern communities [1]. Nigeria's renewable resource base is large—solar irradiation of 3.5–7.0 kWh/m²/day, about 14.12 GW of large-hydro potential of which roughly 2.1 GW is harnessed, and 3.5 GW of technically exploitable small hydropower of which only about 0.06 GW is tapped [1], [2]—but utilisation remains low because of weak policy implementation, financing constraints and limited data [3].

Kebbi State is promoted by its investment agency as having some of the highest renewable-energy potential in the country, citing very high solar irradiation, river systems suitable for dams and strong agricultural output [4]. Most published assessments, however, address either Nigeria as a whole, the northwest region [5], the state in aggregate [6], [7] or a single northern village [8]. To the author's knowledge, based on the sources surveyed, no consolidated resource review has focused on Kebbi South, whose hilly southern terrain, Niger-river frontage and Sudan-savanna farming systems differ from the flat, irrigated north. The contributions of this paper are: (i) a consolidated, source-graded summary of solar, wind, hydro and biomass evidence relevant to Kebbi South; (ii) the governing equations with worked indicative calculations; (iii) cross-source consistency checks that recompute reported figures; and (iv) a gap analysis and staged roadmap. Section II describes the study area and method; Section III the energy-access context; Sections IV–VII the four resources; Section VIII hybrid techno-economics; Section IX policy and programmes; and Sections X–XI the synthesis and conclusions.

II. STUDY AREA AND REVIEW METHOD

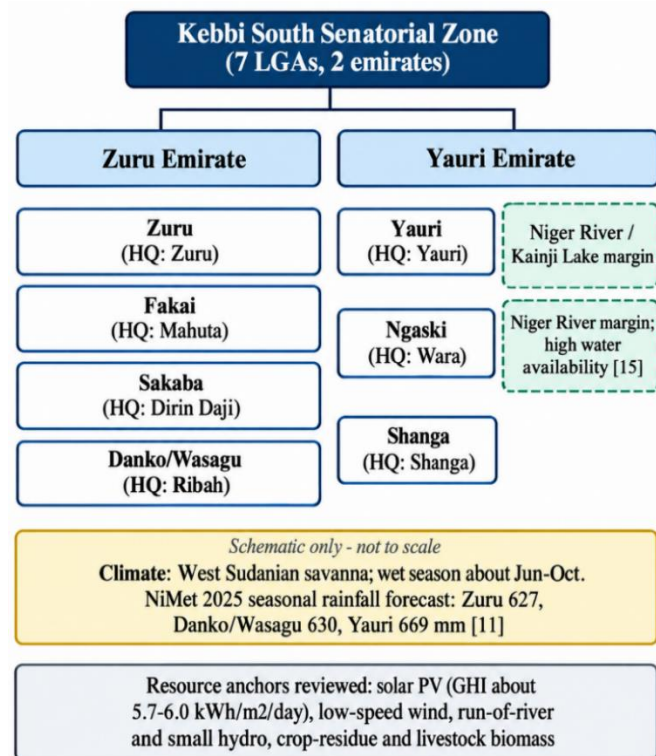
A. Study area

Kebbi South is one of the state's three senatorial districts and comprises seven LGAs [9] (Table I and Fig. 1). The state lies in the West Sudanian savanna, with two agro-climatic zones (Northern Guinea and Sudan savanna) and rainfall of roughly 400–1,100 mm [10]. NiMet's 2025 seasonal forecast gave 627 mm (114 rain days) for Zuru, 630 mm (115 days) for Danko/Wasagu and 669 mm (127 days) for Yauri, with a wet season of about June to October [11]. Agriculture is the largest employer, and the state agency reports Kebbi as second in national livestock production [4].

TABLE I: LOCAL GOVERNMENT AREAS OF KEBBI SOUTH.

LGA	Headquarters	Emirate	Wet-season forecast 2025 (mm)
Zuru	Zuru	Zuru	627
Fakai	Mahuta	Zuru	—
Sakaba	Dirin Daji	Zuru	—
Danko/Wasagu	Ribah	Zuru	630
Yauri	Yauri	Yauri	669
Ngaski	Wara	Yauri	—
Shanga	Shanga	Yauri	—

Sources: LGAs and headquarters [9]; rainfall [11].

**Fig. 1. Administrative structure and resource anchors of Kebbi South.**

B. Review method

A structured narrative review was conducted. Web and repository searches (publisher sites, institutional repositories and government portals) targeted Kebbi, Kebbi South and northwest Nigeria together with solar, wind, hydro, biomass, hybrid systems and policy. Inclusion required publication between 2019 and 2026 and a Nigerian focus; peer-reviewed articles were preferred, institutional reports used for access statistics, and news items only for project announcements. The 19 sources retained comprise 11 journal articles, one World Bank

report, two state-government documents and five web or news items. Quantities were harmonised to common units (e.g., $\text{kWh/m}^2/\text{yr} \div 365 = \text{kWh/m}^2/\text{day}$).

III. ENERGY-ACCESS CONTEXT

Kebbi is served by Kaduna Electric and sits in the World Bank's Multi-Tier Framework survey of northwest Nigeria (3,668 households; with Kebbi contributing 336) [12]. Although collected in 2017–2018, it remains the most detailed zone-level benchmark (Table II, Fig. 2). Only 40.0% of households were grid-connected, and 2.1% used off-grid sources, leaving 57.9% without electricity; rural grid access was 26.7% against 78.7% in urban areas. Among grid users, about 94% faced frequent unplanned outages, and 81.7% of households cooked mainly with wood. Willingness to pay for a low-capacity solar home system priced at ₦9,000 was about 82%, but only about 45% for a ₦100,000 high-capacity system [12]. LGA-level figures for Kebbi South are not available.

TABLE II: ENERGY-ACCESS INDICATORS, NORTH-WEST NIGERIA. (2017–2018 SURVEY)

Indicator	Value
Households with any electricity access	42.1%
National-grid access / off-grid access	40.0% / 2.1%
No electricity access	57.9%
Grid access, urban/rural	78.7% / 26.7%
Grid users with frequent outages	≈94%
Grid users with >14 outages per week	24.3%
Households using three-stone stoves	82.8%
Wood as primary cooking fuel	81.7%
Households with clean-fuel stoves	3.7%

Source: [12].

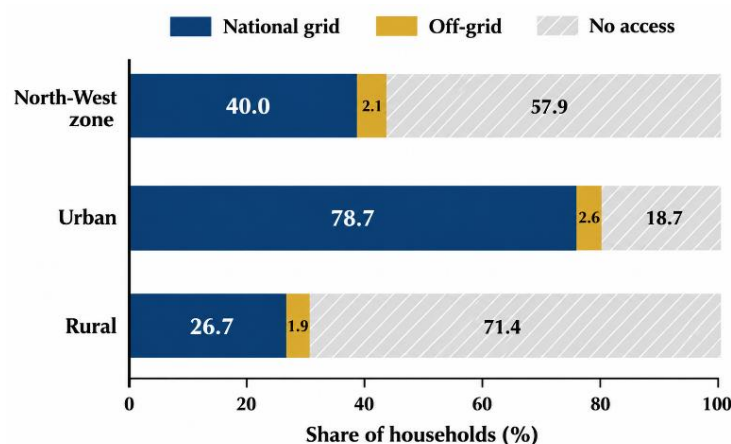


Fig. 2. Electricity access by source for the northwest zone and for urban and rural households [12].

IV. SOLAR ENERGY RESOURCE

A. Assessment fundamentals

Where ground irradiation records are sparse, global horizontal irradiation H is estimated from relative sunshine duration with the Ångström–Prescott relation, and the clearness index K_T expresses atmospheric transmittance [5], [8]:

$$\frac{H}{H_0} = a + b \frac{S}{S_0} \quad (1)$$

$$K_T = \frac{H}{H_0} \quad (2)$$

where H_0 is extraterrestrial irradiation, S and S_0 are actual and maximum possible sunshine hours, and a , b are site constants. Satellite and reanalysis products (e.g., NASA POWER) are now commonly used instead [5], [8].

B. Resource evidence for Kebbi

Satellite and meteorological analysis of northern Nigeria gives Kebbi a mean annual irradiation of 2,087.1 kWh/m²/yr (satellite) and 2,101.8 kWh/m²/yr (meteorological), i.e., 5.72–5.76 kWh/m²/day, with a satellite range of 1,961.0–2,156.9 kWh/m²/yr across the state (about ±9%) [5]. The northwest mean is 2,132.2 kWh/m²/yr, so Kebbi lies 1.4% below it (Fig. 3). NASA POWER data at Argungu give 5.98 kWh/m²/day, peaking at 6.76 in April and falling to 5.29 in August [8]. The same study of Kebbi reports 14,928 km² of suitable land out of 37,728 km² (39.6%) for PV siting [5] (Table III); its tabulated PV energy potentials mix GW and GWh units and are therefore not reproduced here.

TABLE III: ANNUAL SOLAR IRRADIATION INDICATORS RELEVANT TO KEBBI.

Indicator	kWh/m ² /yr	kWh/m ² /day*
Kebbi, satellite mean [5]	2,087.1	5.72
Kebbi, meteorological mean [5]	2,101.8	5.76
Kebbi, satellite range [5]	1,961.0–2,156.9	5.37–5.91
Northwest zone mean [5]	2,137.5	5.86
Argungu, NASA POWER [8]	2,183†	5.98
Nigeria, typical range [1]	1,278–2,555†	3.5–7.0

Computed as kWh/m²/yr ÷ 365. †Back-calculated from the daily value

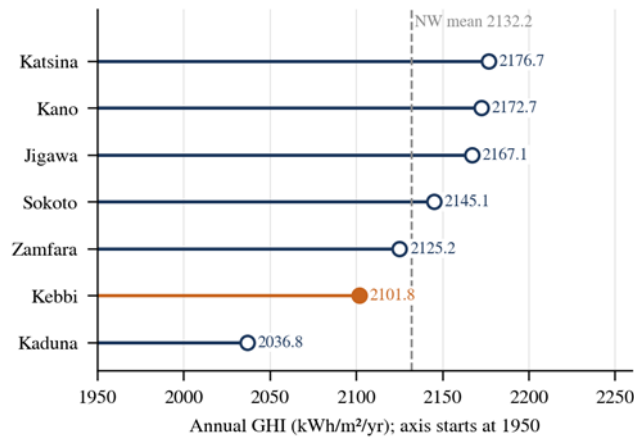


Fig. 3. Mean annual global horizontal irradiation of northwest states (meteorological means) [5]; Kebbi highlighted.

C. PV performance model and indicative yield

DC power from a module depends on irradiance G and cell temperature T_c , which in hot climates reduces output through the power temperature coefficient γ :

$$P_{dc} = P_{STC} \left(\frac{G}{G_{STC}} \right) [1 + \gamma(T_c - 25)] \quad (3)$$

$$T_c = T_a + \frac{NOCT - 20}{800} G \quad (4)$$

$$E_{PV} = P_{STC} \cdot H_t \cdot PR \quad (5)$$

Here T_a is the ambient temperature, NOCT is the nominal operating cell temperature, H_t is the daily plane-of-array irradiation (kWh/m²/day), PR is the performance ratio, and E_{PV} is the daily energy per kW_p of installed capacity. With $H_t = 5.72$ – 5.98 kWh/m²/day and an assumed PR of 0.75–0.80, (5) gives 4.3–4.8 kWh/kW_p/day, or roughly 1,570–1,750 kWh/kW_p/yr. This is indicative only: tilt gains, soiling and dust (harmattan) were not modelled, and PR is an assumption, not a measured value.

D. Deployments

The Rural Electrification Agency broke ground in July 2026 on a 3.5 MW solar project at Ambursa, Kebbi State, under a \$750 million federal facility [13]. It includes a three-kilometre distribution network, refurbishment of 31 transformers, more than 5,000 solar home systems with batteries and inverters, and street lighting, serving about 1,500 households [14]. Ambursa lies outside Kebbi South, but the delivery model is directly transferable.

V. WIND ENERGY RESOURCE

A. Statistical framework

Wind speeds are conventionally described by the two-parameter Weibull density with shape k and scale c (m/s), from which the mean speed and power density follow [6], [7]:

$$f(v) = \frac{k}{c} \left(\frac{v}{c}\right)^{k-1} \exp \left[-\left(\frac{v}{c}\right)^k \right] \quad (6)$$

$$\bar{v} = c \Gamma \left(1 + \frac{1}{k} \right) \quad (7)$$

$$\frac{P}{A} = \frac{1}{2} \rho c^3 \Gamma \left(1 + \frac{3}{k} \right) \quad (8)$$

$$v(z) = v_r \left(\frac{z}{z_r} \right)^\alpha \quad (9)$$

$$P_t = \frac{1}{2} \rho A C_p v^3 \quad (10)$$

Here Γ is the gamma function, ρ is air density ($\approx 1.225 \text{ kg/m}^3$), α is the terrain-dependent power-law exponent used to extrapolate from the measurement height z_r , A is the swept area, and C_p is the power coefficient ($\leq 16/27 \approx 0.593$, the Betz limit).

B. Evidence for Kebbi

Five years of NiMet data (2017–2021) for Kebbi give monthly mean speeds mostly between 3 and 4 m/s, a February maximum of 6.372 m/s, Weibull shape factors of 1.404–1.844 (skewed toward low speeds) and a mean power density of 64.88 W/m² (Table IV), classified “poor” by the European Wind Energy Association scale [6]. Results are very sensitive to α : yearly means were 2.863–4.933 m/s at $\alpha = 0.143$ but 4.486–7.731 m/s at $\alpha = 0.4$ [6]. An ARIMA(1,1,2) analysis likewise found usable surface wind across the state, with highest values in 2009–2011 [7]. NASA POWER data at Argungu give 4.99 m/s at 17 m, from 6.61 m/s in January to 3.49 m/s in September [8]. For northern Nigeria generally, 10 m speeds of 3.5–7.0 m/s are reported as insufficient for utility-scale generation [1].

TABLE IV: WIND INDICATORS REPORTED FOR KEBBI.

Source/site	Quantity	Value
NiMet 2017–2021 [6]	Monthly mean speed	3–4 m/s
	Weibull shape k	1.404–1.844
	Mean power density	64.88 W/m ²
	Yearly mean, $\alpha = 0.143$	2.863–4.933 m/s
	Yearly mean, $\alpha = 0.4$	4.486–7.731 m/s
NASA POWER, Argungu [8]	Mean at 17 m	4.99 m/s
	Jan / Sep	6.61 / 3.49 m/s

As a consistency check, Eq. (8) with $k = 1.404$ and 1.844 gives 79.1 and 54.7 W/m^2 at a mean speed of 3.5 m/s (and 118.1 and 81.6 W/m^2 at 4 m/s). The reported 64.88 W/m^2 therefore corresponds to a mean speed near 3.5 m/s (Fig. 4). Because power density scales with $\bar{v}^3$, the $3\text{--}4$ m/s NiMet range and the 4.99 m/s NASA value differ by roughly a factor of two to three in power; differences in height, dataset and terrain explain part of this, and only on-site masts can resolve it.

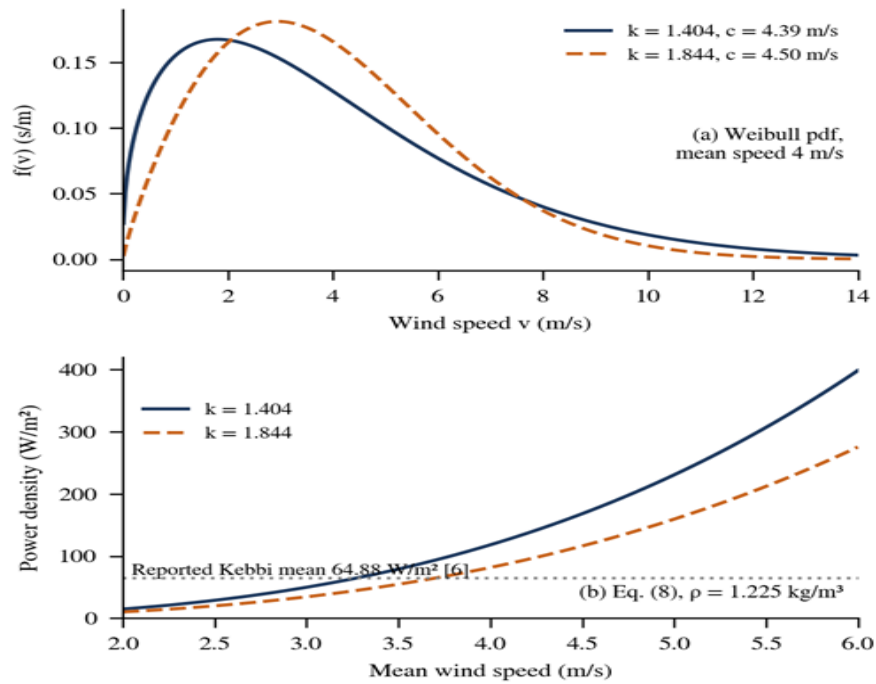


Fig. 4. Illustrative Weibull analysis for Kebbi's reported shape-factor range: (a) probability density at 4 m/s mean speed; (b) power density versus mean speed, with the reported value [6].

For Kebbi South, the practical implication is that wind suits water pumping, light loads and seasonal support to PV (strongest in January, when solar is weaker), using low-cut-in turbines; utility-scale wind is not supported by current evidence [1], [6].

VI. HYDROPOWER RESOURCE

A. Governing relations

Hydraulic power depends on net head H and flow Q ; sizing a run-of-river unit follows from rearranging the same relation:

$$P_h = \eta \rho g Q H \quad (11)$$

$$Q_{\text{req}} = \frac{P_h}{\eta \rho g H} \quad (12)$$

with η overall efficiency, $\rho = 1,000 \text{ kg/m}^3$ and $g = 9.81 \text{ m/s}^2$. For example, a 20 kW unit at 30 m head and $\eta = 0.80$ needs only $Q \approx 0.085 \text{ m}^3/\text{s}$.

B. National and regional evidence

The federal minister of power reported hydropower potential of about 14 GW with roughly 15% explored, and 3.5 GW of technically exploitable small hydro (70 micro, 126 mini and 86 small sites), of which 1.7% (0.06 GW) is tapped [2]; these figures agree with the 14.12 GW and 2.1 GW (14.9%) in [1]. GIS screening of Nigerian water bodies places hydropower-suitable areas in Kebbi, Kano and Jigawa, identifies Ngaski (Kebbi) among northwest areas of comparatively high water availability, and counts 95 potential small-dam sites in the northwest zone, second only to the northeast [15]. The inventory table in that study lists 277 sites (734.2 MW) in twelve states but not Kebbi (Table V) [15]. Since Kebbi was created from Sokoto State in 1991, historical Sokoto–Rima figures may include sites now in Kebbi; disaggregation is needed.

TABLE V: SMALL-HYDRO INVENTORY OF SELECTED SURVEYED STATES.

State	Basin	Capacity (MW)	Sites
Sokoto	Sokoto–Rima	30.6	22
Katsina	Sokoto–Rima	8.0	11
Kaduna	Niger	59.2	19
Niger	Niger	117.6	30
Kwara	Niger	38.8	12
Kano	Hadejia–Jama’are	46.2	28
Kebbi	—	not listed	—
Total (12 states)		734.2	277

Source: [15], Table 1 (subset shown).

Methodologically, GIS–AHP site suitability using ten thematic layers (land use, precipitation, geology, soil, slope, elevation, stream-power and wetness indices, drainage density and flow) identified 18 field-validated sites in the upper Benue watershed and is a ready template for Kebbi South [16]. The 2025 forecast of 114–127 rain days for Zuru, Danko/Wasagu and Yauri [11] implies strongly seasonal small-stream flow; Goronyo-station records used for Argungu range from $3.3 \text{ m}^3/\text{s}$ (November) to $113.0 \text{ m}^3/\text{s}$ (September), with a mean of $31.35 \text{ m}^3/\text{s}$ [8]. Large-scale hydro (Kainji 760 MW, Jebba 578 MW, Shiroro 600 MW, Zungeru 700 MW) already supplies about 20% of grid electricity [1], [2]; the Kainji reservoir margin borders Yauri and Ngaski, but no plant-level assessment for those LGAs was found.

VII. BIOMASS AND BIOGAS RESOURCE

A. Estimation approach

Residue energy is estimated from crop production Y , residue-to-product ratio (RPR), an availability fraction f (after feed, soil and fuel uses) and lower heating value (LHV); biogas from dung mass m and specific yield y ; and electricity through a conversion efficiency η_c [17], [18]:

$$E_{\text{res}} = \sum_i Y_i \cdot \text{RPR}_i \cdot f_i \cdot \text{LHV}_i \quad (13)$$

$$V_{\text{bg}} = y \cdot m \quad (14)$$

$$E_{\text{el}} = \eta_c E_{\text{res}} \quad (15)$$

B. Evidence

Nigeria's technical biomass potential is about 2.33 EJ: 1.09 EJ from agricultural residues, 0.65 EJ from animal waste, 0.11 EJ from municipal waste and 0.05 EJ from forest residues, plus 0.38 EJ wood fuel and 0.05 EJ charcoal [17]. Residues have competing uses (feed and soil), so f is well below one [17]. National estimates for crops grown in Kebbi South are in Table VI and Fig. 5; measured calorific values of maize, millet, rice, sorghum and groundnut by-products span 11.68–17.48 MJ/kg [19]. Livestock waste of about 227,500 t/day at 0.03 m³ biogas/kg corresponds to 6.8 million m³/day nationally [1] (the per-species table in that review does not sum to this aggregate, so only the aggregate is used). Northern cattle-rich states hold the greatest biogas potential [1].

TABLE VI: NATIONAL RESIDUE CHARACTERISTICS FOR CROPS RELEVANT TO KEBBI SOUTH.

Crop	RPR	LHV (MJ/kg)	Potential (PJ/yr)
Rice (husk)	0.17–0.35	12–16	20–120
Sorghum	0.3–1.0	18.2	88–89
Millet	0.4–0.75	15.27	90
Groundnut	0.37–1.2	18–27	30.31–77

Source: [1], Table 4 (national values; not Kebbi-specific).

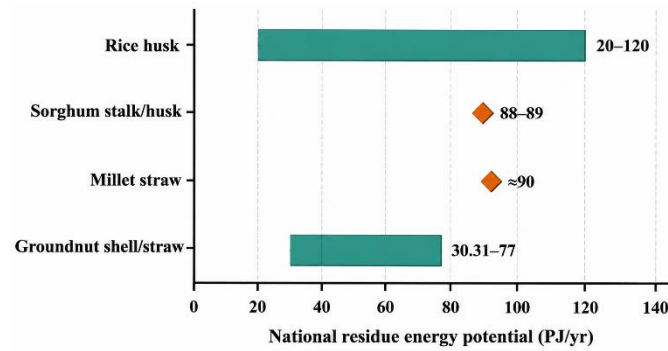


Fig. 5. National residue energy potentials for four crops grown in Kebbi South [1].

Illustration. For 1,000 t of sorghum grain, RPR 0.3–1.0 gives 300–1,000 t residue; assuming $f = 0.30$ (an assumption) leaves 90–300 t, equal to 1.6–5.5 TJ at 18.2 MJ/kg. At $\eta_c = 0.20$, this yields about 91–303 MWh of electricity. For livestock, each tonne of fresh dung yields about 30 m³ of biogas. A regional analogue, northeast Nigeria, estimates 6.89×10^4 t/yr of agro-waste available for power, giving 55.8 GWh/yr [18]—about 810 kWh/t, equivalent to 16–24% conversion for fuels of 12–18 MJ/kg.

In the northwest zone, 81.7% of households cook mainly with wood, and 70.6% spend more than seven hours weekly collecting or preparing fuel [12]. Improved stoves and household biogas therefore address clean cooking and fuelwood pressure at least as directly as they address power. Kebbi-specific residue and livestock inventories are lacking and are the main data gap for biomass.

VIII. HYBRID SYSTEMS AND TECHNO-ECONOMICS

Hybrid systems exploit the complementary timing of resources. Lifecycle cost is ranked by net present cost (NPC) and levelised cost of energy, using the capital recovery factor (CRF) for real discount rate i and project life N , and the capacity factor (CF):

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (16)$$

$$LCOE = \frac{CRF \cdot NPC}{E_{served}} \quad (17)$$

$$CF = \frac{E_{annual}}{P_{rated} \times 8760} \quad (18)$$

Magaji *et al.* simulated seven PV, wind and micro-hydro configurations in HOMER Pro for Bakaramba, Argungu LGA, over 25 years (load 156.33 kWh/day; 27.87 kW connected; 423 residents) [8]. The PV–wind–hydro system had the lowest total energy loss (4,935 kWh/yr) at

₦149.98/kWh; stand-alone hydro was cheapest (₦94.43/kWh) but had the highest unmet load (3,158 kWh/yr) [8]. Recomputing from the reported values, the tri-hybrid's NPC is 14.8% below stand-alone PV and 67.9% below stand-alone wind. Rearranging Eq. (17) gives an implied CRF of 0.0675 for PV, wind, hydro, and the tri-hybrid—equivalent to a real discount rate of about 4.5% over 25 years—and 0.0662 for the three two-source hybrids (Table VII), so the reported costs are mutually consistent to within about 2%.

TABLE VII: REPORTED HOMER RESULTS FOR BAKARAMBA, ARGUNGU [8] AND IMPLIED CRF.

Configuration	NPC (₦M)	LCOE (₦/kWh)	Load served (kWh/yr)	Implied CRF
Solar PV	145.25	168.41	58,214	0.0675
Wind	385.72	468.44	55,577	0.0675
Hydro	75.41	94.43	53,902	0.0675
PV–Wind	152.22	179.90	55,985	0.0662
PV–Hydro	145.27	172.09	55,880	0.0662
Wind–Hydro	341.47	405.19	55,786	0.0662
PV–Wind–Hydro	123.81	149.98	55,722	0.0675

Implied CRF = $\text{LCOE} \times \text{load served} \div \text{NPC}$, computed here from the reported values.

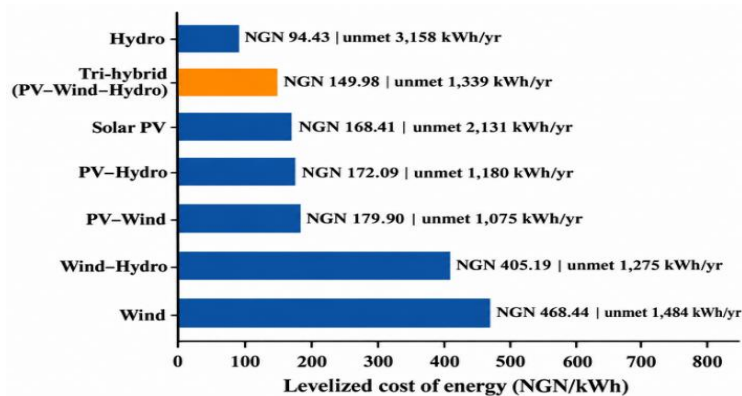


Fig. 6. Levelised cost of energy and unmet load of the seven configurations.[8]

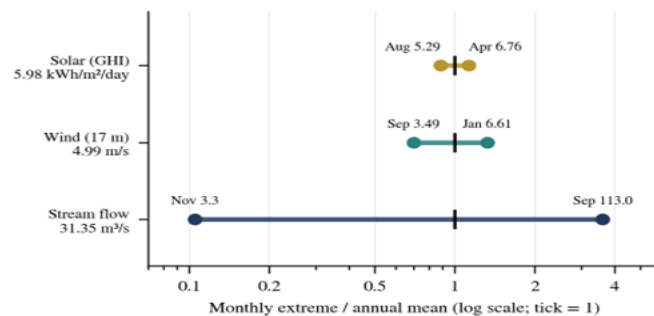


Fig. 7. Seasonal range of solar, wind and stream flow at Argungu relative to annual means, showing resource complementarity.[8]

Fig. 6 compares costs and unmet load. The complementarity is visible in Fig. 7: solar peaks in April, wind in January and river flow in September [8]. Three cautions apply. First, the site is in northern Kebbi, so transferability to Kebbi South requires re-simulation with local resource and load data. Second, the study's hydro stream-flow minimum (3.3 m³/s) greatly exceeds the 0.085 m³/s that Eq. (12) requires for a 20 kW unit at 30 m head, so the reported hydro shortfall probably reflects the site flow actually diverted rather than basin flow; this should be clarified. Third, the source text states the tri-hybrid's cost advantage over stand-alone PV as 19.5%, whereas its own table gives 14.8%.

IX. POLICY, PROGRAMMES AND BARRIERS

The Electricity Act 2023 repealed the 2005 reform act and lets states and private entities generate, transmit and distribute power within their jurisdictions, recognising renewables for rural electrification [1]. The Renewable Energy Master Plan targets 23% renewables by 2025 and 36% by 2030, and the 2022 Energy Transition Plan targets net zero by 2060 [1]. Federal support is channelled through the REA, including the \$750 million facility behind the Ambursa project [13] (Table VIII).

TABLE VIII: POLICIES AND PROGRAMMES RELEVANT TO KEBBI SOUTH.

Instrument	Year	Relevance
Electricity Act	2023	States may regulate and license local generation and distribution [1]
Renewable Energy Master Plan	—	Targets 23% (2025) and 36% (2030) renewables [1],[20]
Energy Transition Plan	2022	Net zero by 2060; solar as backbone [1],[21]
REA \$750M facility	2026	Interconnected mini-grids; Ambursa 3.5 MW project [13]

Barriers repeatedly cited are perceived financing risk and high interest rates, import dependence for modules, batteries and inverters, weak grid and unreliable power-purchase agreements, weak enforcement, limited skills, and insecurity in parts of the northwest [1], [3]. For households, affordability dominates: most unconnected households cited distance to the grid or inability to pay the connection and wiring costs [12].

X. SYNTHESIS, GAPS AND ROADMAP

Table IX ranks the resources by the maturity of available evidence for Kebbi South; the ranking is the author's qualitative judgement from the sources reviewed, not a measured index.

TABLE IX: RESOURCE SYNTHESIS FOR KEBBI SOUTH.

Resource	Key indicator	Main constraint	Near-term use
Solar PV	$\approx 5.7\text{--}6.0$ kWh/m ² /day [5], [8], [22]	Cost, batteries, dust	Mini-grids, clinics, pumping
Wind	64.88 W/m ² (Kebbi) [6]	Low speed; data conflict	Pumping, hybrid support
Small hydro	Ngaski high water availability [15]	No inventory; seasonal flow	Screened run-of-river sites
Biomass	Residues and manure [1], [17]	Competing uses; no inventory	Biogas, improved stoves

Evidence maturity: solar highest; wind and biomass moderate; hydro lowest.

The main gaps are: (G1) no LGA-level measured solar or wind data; (G2) no hydrological or head surveys for Kebbi South streams; (G3) no residue and livestock inventories; (G4) no village load profiles or productive-use surveys; (G5) no open grid-network data for the Kaduna Electric area; and (G6) no locally validated cost data. The proposed response is staged (Fig. 8):

- Phase 1: install pyranometers, 30–50 m wind masts and stream gauges in at least one site per LGA; survey residues and livestock.
- Phase 2: deploy pilot PV–battery systems for health facilities, schools, markets and pumping; begin biogas and improved-stove pilots.
- Phase 3: build hybrid mini-grids and screened run-of-river sites using GIS–AHP [16] and HOMER-type optimisation [8].
- Phase 4: scale up grid-interactive systems under the Electricity Act 2023 with state-level regulation and local operation-and-maintenance capacity [1].

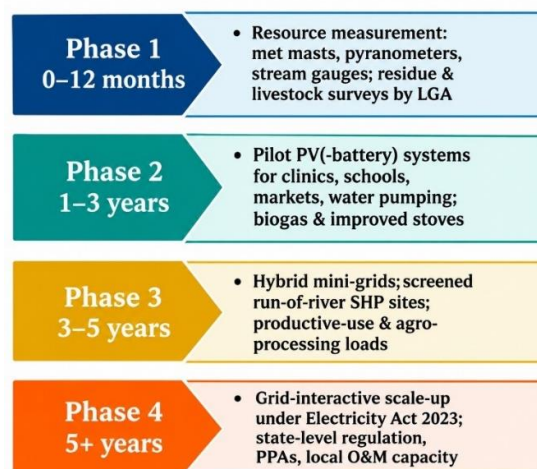


Fig. 8. Proposed staged roadmap for renewable-energy development in Kebbi South (author’s synthesis).

XI. CONCLUSION

Kebbi South has a strong solar resource ($\approx 5.7\text{--}6.0$ kWh/m²/day), a low-speed wind regime suitable for light loads, plausible small hydro along the Niger margin, and abundant but contested biomass. Solar PV, ideally in hybrid mini-grids with storage and, where flows allow, small hydro or biogas, is the most credible near-term path. Reported techno-economic results for northern Kebbi are internally consistent but not directly transferable. The binding constraint is data, not resource: LGA-level measurements, hydrological surveys and biomass inventories should precede large investment decisions.

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