

ENERGY DEMAND AS A MODERATOR OF THE ENERGY TRANSITION IN AFRICA: A TWO-WAY FIXED EFFECTS PANEL ANALYSIS FOR 27 COUNTRIES, 2000–2022

Michał Thlon  <https://orcid.org/0000-0001-9627-7773>

Department of Applied Economics
Krakow University of Economics, Poland
e-mail: thlonm@uek.krakow.pl

Abstract: Analysing a balanced panel of 27 African economies over 2000–2022, I document a “renewable share paradox”: in 63% of countries, absolute renewable capacity grew while its share in total installed capacity declined from 54.9% to 46.3%. Using a two-way fixed effects estimator, I find a robust negative within-country relationship between log GDP per capita and the renewable capacity share (β ranging from -10.9 to -21.7 pp), supporting the demand-squeeze hypothesis. Targeted public investment in renewables can partially offset this effect.

Keywords: two-way fixed effects, energy transition, renewable energy share, demand squeeze, Sub-Saharan Africa, panel data

JEL classification: C23, Q42, Q43, O13, O55

INTRODUCTION

Standard approaches to monitoring the energy transition rely predominantly on absolute metrics: total installed renewable capacity in megawatts, annual investment volumes, and electricity generation quantities. These indicators are routinely reported in international frameworks including the SDG7 tracking system and national Renewable Energy Action Plans. However, absolute metrics can generate a misleading signal: a country may simultaneously record growth in absolute renewable capacity and a decline in the renewable share of its electricity system, if non-renewable capacity grows faster. Figure 1 documents this pattern for 27 African economies over 2000–2022, showing that 17 of 27 countries (63%) experienced a decline in the renewable capacity share despite widespread absolute capacity growth.

<https://doi.org/10.22630/MIBE.2026.27.3.9>



Sub-Saharan Africa provides a particularly important laboratory for this dynamic. The region combines the world's lowest electricity access rates - approximately 600 million people without reliable supply - with among the fastest rates of demographic and economic growth globally. Population growth of 2.5–3% annually, combined with rapid urbanisation and expanding industrial activity, implies a structural acceleration of electricity demand that will persist for decades. At the same time, many African countries enter this growth trajectory with electricity systems still dominated by hydropower, leaving them exposed to a specific form of share erosion when new fossil capacity is added to meet incremental demand.

The existing literature on Africa's energy transition has concentrated primarily on barriers to renewable investment - financing constraints, regulatory risk, grid infrastructure deficits - and on the effectiveness of specific policy instruments such as feed-in tariffs and competitive auctions [Peters et al. 2024; Schwerhoff and Sy 2019]. Far less attention has been paid to the structural role of demand growth itself as a moderator of relative transition progress. This paper addresses that gap.

This paper makes three contributions. First, it introduces the demand-squeeze hypothesis as a structural explanation for the renewable share paradox: in 63% of the 27 countries studied, absolute renewable capacity grew while the share declined, a pattern invisible to monitoring frameworks based on absolute metrics [Akrofi 2021; Mossisa and Han 2025]. Second, it applies a two-way fixed effects (TWFE) estimator - absorbing all time-invariant country heterogeneity and common year-level shocks - to isolate the within-country association between GDP per capita growth and the renewable energy share, yielding a robust negative coefficient across five specifications and two dependent variables. Third, it identifies the asymmetric role of hydropower legacy: countries where hydro exceeded the sample median share of total capacity in 2000 face a structural amplification of the demand-squeeze, as any fossil addition immediately erodes a high renewable baseline. The paper is organised as follows. Section 2 describes the data and empirical methodology. Section 3 presents and interprets the results. Section 4 concludes.

LITERATURE REVIEW

The present paper addresses a gap at the intersection of these two strands. Whereas the barriers literature asks what prevents more renewable capacity from being added, this paper asks what determines whether the capacity that is added is sufficient to maintain - let alone improve - the renewable share as total electricity demand expands. The demand-squeeze hypothesis we test is structurally distinct from the access-oriented framing of Dagnachew et al. [2020]: the concern here is not with countries that lack electricity, but with countries where economic growth generates new demand at a pace that outstrips even successful renewable deployment. Identifying this channel within countries over time, net of all country-level and year-level confounders, is what the two-way fixed effects estimator delivers.

A second strand of scholarship examines Africa's electricity systems through the lenses of energy diversification, access, and spatial spillovers. Akrofi [2021] analyses diversification trends across the continent and finds that aggregate statistics obscure substantial heterogeneity in national trajectories. Mossisa and Han [2025] examine the structural tensions between electricity access expansion and emissions intensity in rapidly urbanising Sub-Saharan economies. Ndayishimiye et al. [2025] document the political-economic drivers of generation overcapacity in selected Sub-Saharan countries, pointing to the role of fossil-fuel incumbents in shaping capacity additions. Jeetoo [2022] employs a spatial panel estimator to examine spillovers in renewable energy consumption across the region. Dagnachew et al. [2020] integrate demand-side projections with supply-side policy scenarios to model electricity access pathways under alternative climate targets. This literature advances the understanding of Africa's energy landscape considerably, but does not model demand growth as a source of renewable share erosion or estimate the within-country relationship between income and renewable share using panel variation.

Research on Africa's energy transition has concentrated predominantly on the supply side. A substantial body of work documents the barriers that slow renewable investment: financing constraints and the high risk premiums attached to sovereign debt in Sub-Saharan economies, grid infrastructure deficits that raise the cost and complexity of connecting variable renewables, and regulatory environments that have historically favoured incumbent fossil-fuel utilities [Peters et al. 2024; Schwerhoff and Sy 2019; Deichmann et al. 2011]. The policy instrument most carefully evaluated in this literature is competitive procurement; South Africa's Renewable Energy Independent Power Producer Procurement Programme, launched in 2011, is widely regarded as the most successful implementation on the continent, having mobilised substantial private investment and added several gigawatts of wind and solar capacity by the early 2020s [Peters et al. 2024]. This body of work yields important design lessons for renewable energy policy, but it treats demand growth as a background condition rather than as an active moderator of whether the transition succeeds or fails in relative terms.

DATA AND METHODOLOGY

Data

The analysis uses three publicly available data sources. Installed electricity capacity by technology is sourced from the IRENA Renewable Energy Statistics database [IRENA 2025], providing annual MW data for 2000–2022. GDP per capita in constant 2015 USD is from the World Bank World Development Indicators [World Bank 2026]. Public renewable energy investment in millions of 2022 USD is from the IRENA Public Finance Database [IRENA 2025].

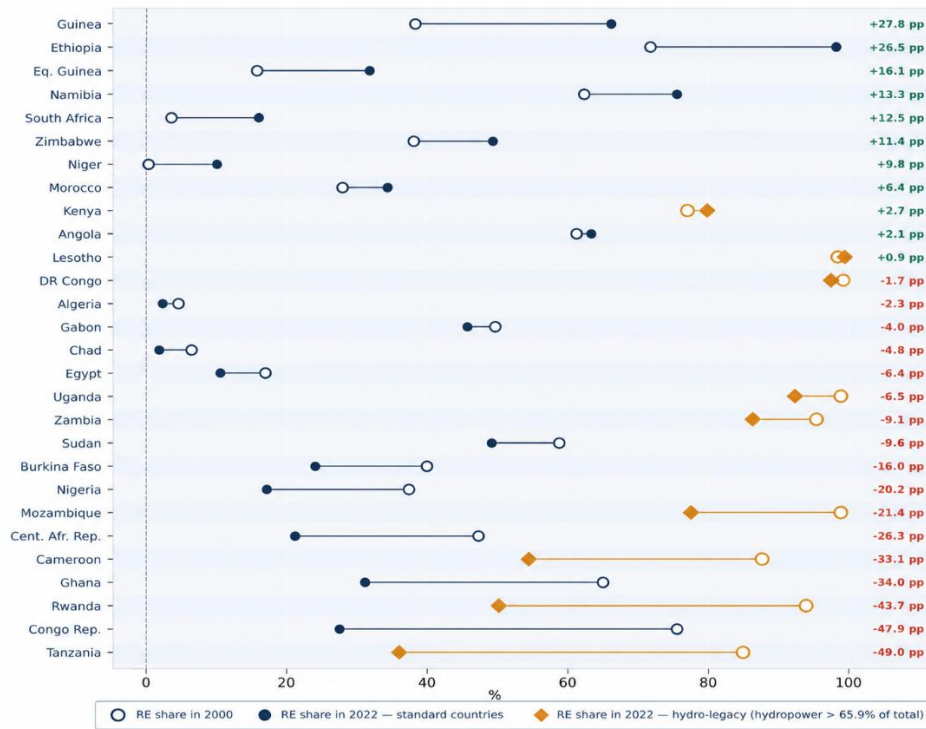
The country sample comprises 27 African economies for which complete data are available for the full 2000–2022 period, including both Sub-Saharan and North African countries (Algeria, Egypt, Morocco, Sudan among the latter). The balanced panel yields 621 country-year observations. The primary dependent variable is the renewable energy capacity share - total renewable installed capacity as a percentage of total installed capacity. Table 1 presents descriptive statistics including the newly added maximum column.

Table 1. Descriptive statistics

Variable	N	Mean	Median	SD	Min	Max	2000	2022
Panel A: Outcome variables								
RE capacity share (%)	621	49.8	46.8	30.0	0.1	100.0	54.9	46.3
RE generation share (%)	621	56.2	52.0	31.5	0.0	100.0	65.0	52.0
Panel B: Key regressors								
GDP per capita (const. 2015 USD)	621	2,283	1,163	2,897	228	13,073	1,534	2,624
Public RE investment (USD mn)	621	92.3	19.5	194.7	0.0	1,825	2.0	150.9

Source: IRENA (2025), World Bank (2026). Panel of 27 African economies, 2000–2022
(N = 621 country-year observations)

Figure 1. Renewable Energy Capacity Share Change, 2000–2022 (27 African Economies)



Source: IRENA (2025); World Bank WDI (2026). Open circle = 2000 value; filled marker = 2022 value. Gold diamonds = hydro-legacy countries (hydropower > 65.9% of total installed capacity in 2000). Change in RE share shown in rightmost column.

Empirical specification

The baseline specification is a two-way fixed effects model:

$$REshare_{it} = \alpha_i + \gamma_t + \beta \ln(GDPpc_{it}) + \varepsilon_{it}$$

where α_i are country fixed effects and γ_t are year fixed effects. Standard errors are clustered at the country level. The coefficient β captures the within-country association between log GDP per capita and the renewable share, holding constant all time-invariant characteristics and common macroeconomic shocks.

The baseline specification is intentionally parsimonious, following the standard approach in within-country panel energy studies [Jeetoo 2022; Dagnachew et al. 2020]. Country fixed effects absorb time-invariant confounders - resource endowments, geography, institutional quality - that drive cross-country differences in renewable shares, while year fixed effects control for global technology cost trends, oil price cycles, and international climate agreements. The within-country

coefficient on log GDP per capita therefore captures the demand-squeeze channel net of these confounders.

Five specifications are estimated: (1) the baseline TWFE model described above; (2) adds log public RE investment and interacts log GDP per capita with a hydropower legacy indicator - a binary variable equal to one for countries where hydropower exceeded 65.9% (sample median) of total installed capacity in the base year 2000, capturing the greater vulnerability of hydro-dominated systems to share erosion when any fossil capacity is added; (3) excludes South Africa and Egypt to test sensitivity to the two largest economies; (4) replaces the dependent variable with renewable generation share; and (5) uses a first-difference estimator with changes in log GDP and log public investment as regressors.

Establishing a fully causal interpretation of the demand-squeeze coefficient would ideally require an instrument that shifts within-country income growth without directly affecting the renewable share. Plausible candidates face a non-trivial exclusion restriction problem in this context: rainfall shocks affect hydro generation directly, and commodity price windfalls alter the political economy of fuel subsidies in ways that independently influence capacity mix decisions [Staiger and Stock 1997]. In the absence of a credible instrument for a 27-country African panel, the two-way fixed effects design represents the strongest available identification strategy. The consistency of the negative coefficient across all five specifications provides reassurance that the result is not an artefact of any single modelling choice.

RESULTS

Table 2 presents all five specifications. The coefficient on log GDP per capita is negative in all specifications and statistically significant at the 10% level in four of five. In the baseline specification (column 1), a 10% within-country increase in GDP per capita is associated with approximately a 1.3 percentage point decline in the renewable capacity share ($\beta \times \ln(1.10) = -13.72 \times 0.0953 \approx -1.3$ pp), holding constant all time-invariant country characteristics and common year trends. This magnitude is economically meaningful: across the 17 countries where the renewable share declined, average GDP per capita grew by 58% over the sample period, implying a demand-driven share reduction of approximately 8 pp - closely matching the observed mean decline of 8.6 pp.

The robustness of the negative sign across all five specifications, including different samples and dependent variables, is the central result: the demand-squeeze mechanism is not artefactual. The larger coefficient in specification (4) using generation share (-21.7 vs -13.7) reflects the compounding effect of thermal plants operating at higher utilisation rates than variable renewables, which accelerates the generation share deterioration relative to the capacity share.

Table 2. Panel regression results: determinants of renewable energy share

Variable	(1) RE cap share	(2) Hydro split	(3) Excl. ZAF/EGY	(4) RE gen share	(5) First diff.
log GDP per capita	-13.72 [†] (7.31)	-10.92* (4.43)	-12.47 [†] (7.13)	-21.66* (10.36)	-
Δlog GDP per capita	-	-	-	-	-1.89 (3.34)
Δlog Public RE investment	-	-	-	-	0.21 [†] (0.11)
Country FE / Year FE	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	No/Yes
N	621	575	575	621	594
R ²	0.044	0.075	0.047	0.073	0.012

Notes: Dependent variable is RE capacity share (%) in columns (1)–(3), generation share (%) in (4), annual change in capacity share (pp) in (5). Standard errors clustered by country in parentheses. [†]p < 0.10, *p < 0.05.

Source: IRENA (2025); World Bank WDI (2026). Authors' calculations

Ten countries recorded improvements in their renewable capacity share over the period, and their trajectories reveal three distinct escape routes from the demand squeeze. In Ethiopia and Guinea, large-scale hydropower investments - most notably the Grand Ethiopian Renaissance Dam and Guinea's Souapiti project, both delivering first power in the late 2010s - added renewable capacity at a pace that outstripped overall system growth, effectively reversing what had been a fossil-dominated expansion. In South Africa and Morocco, proactive procurement frameworks directed new capacity additions toward renewables: South Africa's REIPPPP programme and Morocco's Noor solar complex channelled private investment into wind and solar at scale, decoupling capacity expansion from fossil-fuel additions. A third group, exemplified by Niger, benefited from a base effect: starting from a near-zero renewable share in 2000, even modest additions of rural solar mini-grids and small wind capacity translated into double-digit percentage-point improvements. These contrasting trajectories reinforce the paper's central argument: the demand squeeze is not inevitable, but overcoming it requires either the scale of public investment or the institutional architecture of targeted procurement - neither of which is costless or automatic.

Column (5) provides evidence from the first-difference estimator. Annual changes in log GDP per capita are not significantly associated with annual RE share changes (-1.89, p = 0.57), consistent with the demand-squeeze operating over multi-year investment horizons. The coefficient on changes in log public RE investment is positive and marginally significant at the 10% level ($\beta = 0.21$, p = 0.06), indicating that years of above-average public renewable investment are associated with modest short-run improvements in the renewable share. This provides qualified support for

the view that targeted, concentrated public finance can partially counteract the structural demand effect.

CONCLUSIONS

This paper demonstrates that the TWFE estimator, applied to a 27-country African panel over 2000–2022, identifies a robust negative within-country relationship between GDP per capita growth and the renewable energy share. Across five specifications using capacity and generation shares, alternative samples, and first-difference estimation, the demand-squeeze mechanism - whereby fossil fuel capacity additions outpace renewable investment in rapidly growing economies - is consistently supported. A 10% within-country GDP increase is associated with approximately a 1.3 pp decline in the renewable capacity share.

Two methodological implications follow. First, energy transition assessments should incorporate relative share metrics alongside absolute capacity indicators; the two can move in opposite directions, with the share carrying greater relevance for welfare outcomes related to carbon intensity and fossil fuel price exposure. Second, the marginal offset provided by public RE investment surges (column 5) supports investment frameworks calibrated explicitly to outpace total capacity growth, not merely to expand absolute renewable megawatts.

The first-difference estimates in Specification (5) allow a tentative quantification of the investment challenge. Average public renewable energy investment in the countries experiencing share declines grew from approximately USD 2 million to USD 151 million per country over the study period - a 75-fold increase. Under the Specification (5) coefficient ($\beta = 0.21$), this rate of investment growth translates into a predicted share improvement of roughly 0.04 percentage points per year, or approximately 0.9 percentage points cumulatively over 22 years. Against the observed mean share decline of 8.6 percentage points in this group, the investment expansion that occurred offset only a modest fraction of the structural demand pressure. The implication is not that public finance is ineffective but that, to overcome the demand squeeze, it must be sustained at a rate calibrated explicitly against total system expansion - a materially more demanding benchmark than the simple growth of renewable megawatts.

The demand-squeeze mechanism is structurally general. Rapidly growing economies in South Asia and parts of Latin America - combining high population growth, rapid urbanisation, and expanding electricity access requirements - may exhibit the same paradox. The TWFE framework developed here provides a replicable methodology for testing this hypothesis in other regional contexts.

REFERENCES

- Akrofi M. M. (2021) An Analysis of Energy Diversification and Transition Trends in Africa. *International Journal of Energy and Water Resources* 5(1), 1-12.
- Dagnachew A. G., Poblete-Cazenave M., Pachauri S., Hof A. F., Van Ruijven B. and Van Vuuren D. P. (2020) Integrating Energy Access, Efficiency and Renewable Energy Policies in Sub-Saharan Africa: a Model-Based Analysis. *Environmental Research Letters*, 15(12), 125010.
- Deichmann U., Meisner C., Murray S., Wheeler D. (2011) The Economics of Renewable Energy Expansion in Rural Sub-Saharan Africa. *Energy Policy*, 39(1), 215-227.
- IRENA (2025) Renewable Energy Statistics 2025. Abu Dhabi: International Renewable Energy Agency.
- Jeetoo J. (2022) Spatial Interaction Effect in Renewable Energy Consumption in Sub-Saharan Africa. *Renewable Energy*, 190, 148-155.
- Mossisa A. T., Han A. T. (2025) Transitioning to Renewable Electric Energy in Rapidly Urbanizing Sub-Saharan Africa: Challenges and Opportunities. *Energy Strategy Reviews*, 61, 101842.
- Ndayishimiye V., Bakkabulindi G., Miyingo E. W., Nibagwire D. (2025) Power Generation Overcapacity in Selected Sub-Saharan African Countries: Political-Economic Drivers and Grid Infrastructure Challenges. *Frontiers in Energy Research*, 13, 1549844.
- Peters R., Berlekamp J., Kabiri C., Kaplin B. A., Tockner K., Zarfl C. (2024) Sustainable Pathways towards Universal Renewable Electricity Access in Africa. *Nature Reviews Earth & Environment*, 5(2), 137-151.
- Schwerhoff G., Sy M. (2019) Developing Africa's Energy Mix. *Climate Policy*, 19(1), 108-124.
- Staiger D. O., Stock J. H. (1997) Instrumental Variables Regression with Weak Instruments. *Econometrica*, 65(3), 557-586.
- World Bank (2026) World Development Indicators. Washington DC: The World Bank Group. Available at <https://databank.worldbank.org/source/world-development-indicators> (accessed March 2026).