

ACCESS TO ELECTRICITY AND THE TRANSITION TO RENEWABLES IN RURAL AFRICA: COMPARATIVE EVIDENCE FROM STATISTICAL DATA AND PUBLIC SURVEYS

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Abstract

The paper analyses the dynamics of rural access to electricity in ten African countries (Nigeria, Kenya, Ghana, Uganda, South Africa, Morocco, Ethiopia, Tanzania, Senegal, Zambia) over the period 2010–2022, using official statistical data and perceptions from public surveys. Correlations between the rural electrification rate, the share of renewable sources in the electricity mix and population size are examined. Descriptive results highlight significant differences between countries: from almost complete universalization in Morocco and high levels in South Africa, to accelerated but incomplete progress in Kenya, Uganda and Ethiopia, and persistent gaps in Nigeria and Zambia. Regression estimates show a negative association between population size and access expansion, but also an inverse correlation between the high share of renewables and the degree of rural electrification – a result explainable by infrastructural constraints and historical peculiarities of the energy mix. The conclusions emphasize that the transition to renewables is not sufficient to increase access if it is not accompanied by investments in networks, distribution and off-grid solutions adapted to the local context. The paper makes a contribution by comparative mapping of progress and by quantifying the structural limitations affecting rural electrification, providing useful benchmarks for prioritizing public policies and international cooperation projects.

Keywords: *access to electricity; rural electrification; Africa; renewable energies; energy transition; public policies; SDG7*

JEL: *Q42; Q48; O13; O55.*

1. Introduction

Ensuring universal access to modern energy (SDG7) remains one of the most pressing development challenges. Globally, the number of people without access to electricity was estimated at approximately 750 million in 2023, with about 80% of them living in sub-Saharan Africa. Global progress in 2023 was mainly driven by grid expansions and the adoption of solar home systems (SHS) in Africa, but the gap remains large in rural areas (IEA, 2022)

Although the rate of access to electricity in Africa increased by 15 percentage points between 2010 and 2022 (from 44% to 59%), high demographic dynamics have meant that the number of people without electricity has remained virtually unchanged (591 million in 2022). This “unreduced growth of the excluded” highlights the importance of better targeted interventions, especially in rural areas (SEforALL, 2022). At the same time, perception data show that progress is slow and uneven,

with many households continuing to report low reliability of supply and frequent outages, with considerable variation across countries and socio-economic groups (Afrobarometer. 2022).

In this context, off-grid and mini-grid renewable solutions are gaining a central role for dispersed rural communities, where grid expansion is costly or slow. REPTES, a project in the LEAP-RE portfolio, explores such solutions for rural African communities, combining technical developments with socio-economic assessments – a relevant framework for identifying areas with high needs and potential for impact of renewable-based interventions (LEAP-RE/REPTES, 2023).

This paper proposes a secondary data-based analysis for a set of ten African countries (Nigeria, Kenya, Ghana, Uganda, South Africa, Morocco, Ethiopia, Tanzania, Senegal, Zambia) over the period 2010–2022. We use: (i) rural access to electricity from the WDI (EG.ELC.ACCS.RU.ZS), (ii) indicators on the share/region of renewables (from IRENA statistics) and (iii) population (WDI), complemented, where relevant, by Afrobarometer perceptions of reliability. Thus, we examine the developments by country descriptively and estimate, through a regression model, the association between rural access to electricity, the share of renewable sources and population size – with the aim of highlighting the configurations in which the off-grid solutions promoted by REPTES may have the greatest relevance (Afrobarometer. 2022).

Our contribution is twofold: (a) we provide a comparative map of rural progress 2010–2022, integrating official statistics and population perceptions; (b) we quantify, with the inherent limitations of aggregated data, the link between renewable penetration and rural access expansion, taking into account demographic pressure. The results are relevant for prioritizing off-grid/mini-grid interventions and for contextualizing REPTES efforts in the broader landscape of SDG7 (IEA, 2023).

2. Literature review

The literature on energy access in Africa highlights the persistence of electrification gaps, especially in rural areas, despite progress over the past decade. The annual SDG7 Tracking Reports show that the pace of access expansion remains insufficient to meet the universal target by 2030, and developments are uneven across countries and regions. In this picture, two trends coexist: on the one hand, increasing investment and capacity in renewable sources; on the other hand, high demographic pressure and infrastructure constraints keep a large number of households without adequate electricity services. The official definitions and series for “electricity access – rural” in the World Development Indicators (indicator EG.ELC.ACCS.RU.ZS, powered by the SDG7.1.1 dataset) provide the necessary standardization for cross-country and long-term comparisons, but do not directly capture qualitative aspects such as reliability (Gebara, 2023; SEforALL, 2022).

A substantial body of work and institutional analysis shows the complementarity between grid expansion and off-grid/mini-grid solutions. The IEA estimates that, by 2030, grid expansion remains the option with the lowest total cost for a significant share of new connections; however, in dispersed rural areas, mini-grids and stand-alone systems (especially photovoltaics) are often the most economically and operationally viable solutions (Zebra et al., 2021). This “hybrid” planning logic places renewable energies at the heart of expanding access in rural areas, especially where low demand density makes traditional transmission and distribution infrastructure prohibitive (López-Castrillón et al., 2021; IEA, 2023).

At the same time, the viability and scaling of mini-grids depend on a set of technical, market and regulatory conditions. The ESMAP/World Bank report – Mini Grids for Half a Billion People summarises the “building blocks” of functioning markets: tariff frameworks that balance affordability with cost recovery, transparent subsidy mechanisms, technical standards, long-term financing and anchoring in productive energy uses to stabilise revenues (Kaleta, 2019). Recent literature also documents the challenges: demand uncertainty, the risk of “stranded assets” when approaching the grid, storage costs and difficulties in institutional integration (Obuseh et al., 2025; ESMAP, 2019).

The issue of reliability remains cross-cutting. IEA analyses show that chronic underinvestment in networks translates into high losses and frequent outages, reducing the social

impact of new connections. Perception-based measures, such as Afrobarometer, confirm that many households report unreliable power supply or frequent outages, even in countries that have statistically experienced increases in access rates. This disjunction between “nominal access” and “quality of service” justifies the simultaneous use of objective (WDI/IRENA) and perception indicators in comparative assessments (Münster et al., 2018; IEA, 2022).

Technological developments in energy storage and falling battery costs are rapidly changing the economics of off-grid and mini-grid projects. IEA projections indicate substantial reductions in storage costs this decade, which can significantly improve the competitiveness of battery solar solutions and, consequently, the quality of service in rural communities. From a public policy perspective, these trends support the argument for support schemes targeted at areas with low demand density, where storage becomes a critical component for reliability (Parra et al., 2017).

On the supply side, IRENA statistics show accelerated increases in renewable capacity globally, but with uneven regional distributions and gaps between installed capacity and actual energy generated. For Africa, IRENA series allow the calculation of both absolute levels and renewable shares in capacity or generation, thus providing relevant variables for analyses of associations with rural access. However, the literature warns that the share in capacity does not necessarily equate to the share in production or hourly availability, a critical aspect for service quality (Parmaksız et al., 2024; IRENA, 2023).

From a demand perspective, empirical work on the impact of rural electrification on welfare, productivity and employment indicates significant but heterogeneous benefits, depending on service quality, prices, access to finance and complementarities with other inputs (infrastructure, education, markets) (Sousa et al., 2023). Recent studies draw attention to the risk of endogeneity in quantitative assessments: the expansion of access and penetration of renewables often occur in contexts where public interventions and economic dynamics are simultaneous, requiring appropriate models to isolate the effects. In this regard, the use of an analytical framework with fixed year effects and demographic control variables is a frequent approach to capture robust correlations in aggregate data (Touitou & Waleed, 2024; IEA, 2022).

At the institutional level, EU–AU cooperation programmes such as LEAP-RE have promoted both applied research and knowledge transfer on off-grid solutions adapted to rural communities. Recent updates from the REPTES project highlight the interest in technologies appropriate to the agricultural context and for socio-economic assessments at the local level, underlining the importance of aligning technical interventions with the real needs of households and farms. This “implementation-oriented” literature complements macro energy planning frameworks and provides useful case studies for interpreting empirical results from comparative country analyses (LEAP-RE/REPTES, 2023).

The limitations of measurement should be noted. The WDI indicator for rural access is internationally harmonized, but remains an approximation of the actual availability of services at the household level; the share of renewables can be expressed in either capacity or production, with different analytical implications; and perception measurements capture qualitative dimensions that are difficult to observe in official statistics. Given these methodological precautions, the literature converges on the central role of renewable solutions – intelligently integrated between the grid, mini-grid and autonomous systems – for accelerating quality access in rural African areas (IRENA, 2023).

3. Methodology

The analysis is based on a quantitative, comparative design with panel data for ten African countries (Nigeria, Kenya, Ghana, Uganda, South Africa, Morocco, Ethiopia, Tanzania, Senegal, Zambia) over the period 2010–2022. The unit of analysis is the country–year pair, resulting in a nearly balanced panel with a maximum of 13 observations per country. The choice of time interval is guided by the availability of official indicators and the coherence of the series after 2010.

The dependent variable is access to electricity in rural areas expressed as a percentage of the rural population with access, according to the harmonized series of World Development Indicators

(indicator EG.ELC.ACCS.RU.ZS). The values are kept in percentage points for direct interpretability of the coefficients.

The main predictors are two explanatory variables motivated theoretically and by data availability. The first is the share of renewable sources in the electricity sector at country level (denoted RE_share_{it}), measured as a percentage of total electricity production or capacity, depending on the available dataset (in the analysis we explicitly retain the definition used). The second is the population size (denoted Popit), for which we use the natural logarithm of the annual level (lnPopit) to capture scale effects and limit the influence of very large values. When available, we prefer the rural population; in the absence, we use the total population and mark this choice as a limitation. The variables were harmonized on the same countries and years; observations with simultaneous missingness on the dependent and predictors were eliminated listwise, keeping a sample as stable as possible over time.

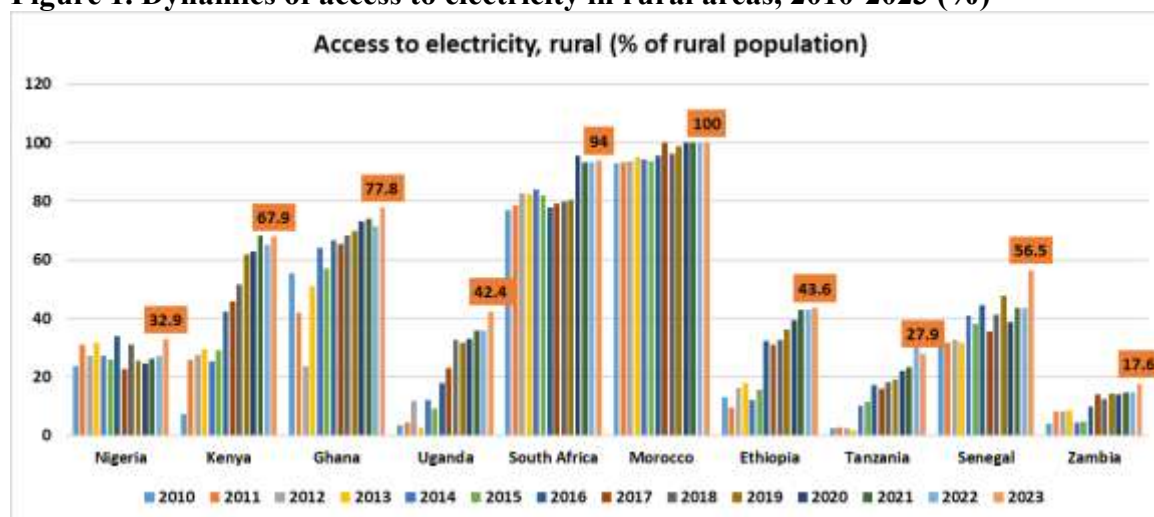
$$\text{rural_access}_{it} = \beta_0 + \beta_1 \cdot \text{RE_share}_{it} + \beta_2 \cdot \ln(\text{population}_{it}) + \varepsilon_{it}$$

Methodological limitations concern the observational nature of the data and the potential endogeneity between renewable penetration and access expansion. Fixed-effects models partially reduce bias from unmeasured time-invariant factors, and the lag on RE_share reduces the risk of short-term simultaneity; however, the results are interpreted as robust associations, not strict causal effects. The sensitivity of the choice of definition for “RE share” (in capacity vs. in production) is tested when data allow, and differences are explicitly discussed in the results section.

4. Results and Discussion

Before determining the model and regression equation, a quantitative analysis of secondary data was performed, extracted from international databases regarding the variables taken into account, conducting an analysis on the 10 countries and in dynamics during the period 2010-2023, data that ultimately forms the data set with which to work.

Figure 1. Dynamics of access to electricity in rural areas, 2010-2023 (%)



Source: own processing of World Bank Data

Figure 1 highlights the marked heterogeneity of rural electricity access among the ten countries analyzed and its dynamics over the period 2010–2023. Two distinct profiles are clearly emerging. On the one hand, Morocco and South Africa start from high levels and reach or maintain values close to universalization: Morocco crosses the 100% threshold starting in 2017 and maintains it until 2023, and South Africa rises from 76.9% in 2010 to around 94% in 2023, with a slight

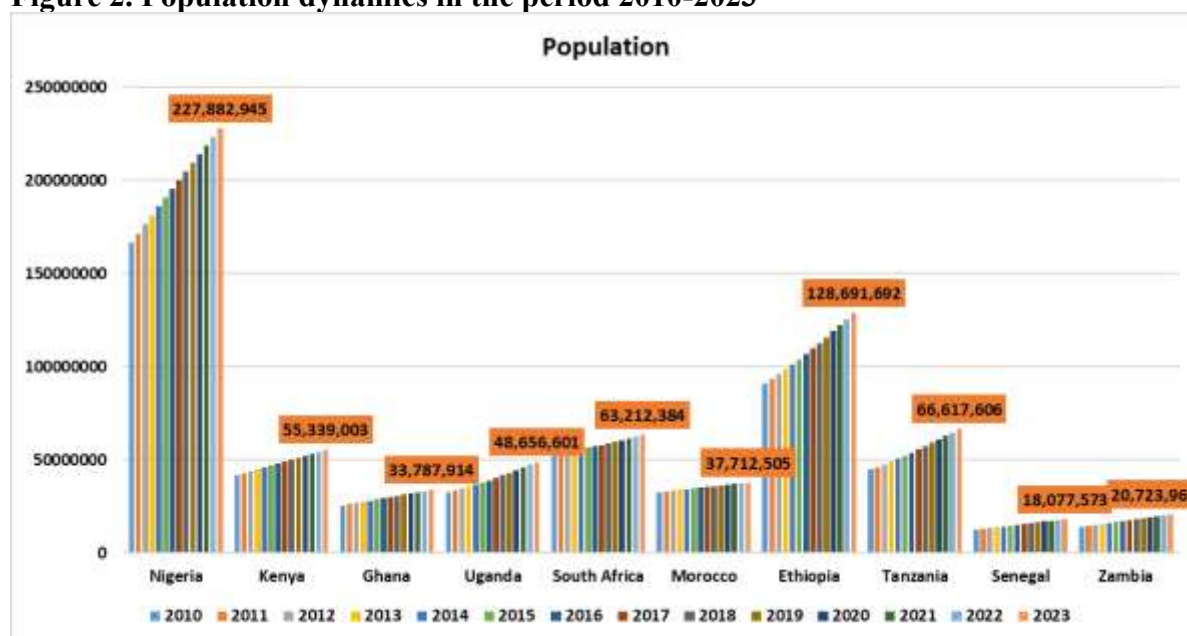
correction after the peak in 2020. On the other hand, a large group of sub-Saharan economies start from very low levels and gradually recover, but without completely eliminating the gaps by the end of the period.

The case of Kenya is emblematic of the dynamics of accelerated catch-up in rural areas: starting from 7.2% in 2010, the indicator increases to 67.9% in 2023, an improvement of over 60 percentage points in thirteen years. Uganda, Ethiopia and Tanzania follow similar trajectories, although at more moderate rates and with episodes of volatility: Uganda advances from 3.5% to 42.4% (+38.9 pp), Ethiopia from 12.9% to 43.6% (+30.7 pp), and Tanzania from 2.5% to 27.9% (+25.4 pp). In West Africa, Ghana records an irregular course, with temporary drops at the beginning of the decade, followed by a robust recovery to 77.8% in 2023 (+22.4 pp), while Senegal progresses steadily towards 56.5% (+21.6 pp).

Nigeria and Zambia stand out with modest progress compared to the initial level. In Nigeria, the indicator remains volatile throughout the interval and reaches 32.9% in 2023, only about 9.4 percentage points above the 2010 level. Zambia starts from 4.0% and rises to 17.6% (+13.6 pp), but remains at the lower end of the distribution. These developments indicate the persistence of structural constraints – low population density, high network expansion costs, institutional and financial limitations – that can slow the speed of rural connectivity, even in the context of investments in energy production.

Overall, the graph suggests partial convergence: several economies start from very low bases and visibly recover, but the variation between countries remains considerable at the end of the period. The rapid universalization in Morocco and the high level in South Africa contrast with the still low levels in Nigeria, Tanzania and Zambia, highlighting that expanding rural access depends not only on generation capacity, but also on investments in distribution networks, financing mechanisms for household connections and solutions adapted to dispersed geographies. From this perspective, the results in the figure provide the empirical justification for differentiated interventions: strengthening the network and reliability where access is high, and accelerating off-grid and mini-grid solutions where recovery remains slow and the terrain is difficult to cover through classic network expansion.

Figure 2. Population dynamics in the period 2010-2023

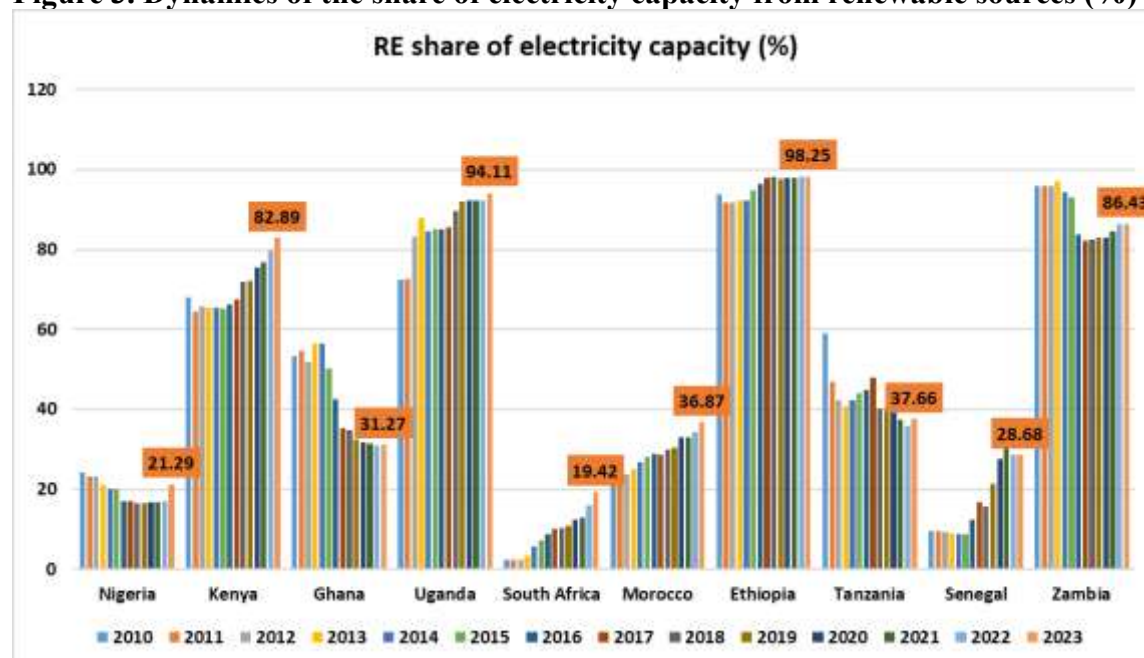


Source: own processing of World Bank Data

The population graph shows robust growth across all countries, with Nigeria leading the way, surpassing 220 million in 2023, putting pressure on grid investment and new connections. Ethiopia is experiencing similarly strong population growth, rising to ~130 million, with Tanzania, Kenya and Uganda each adding tens of millions of people over the period. In contrast, Morocco and South Africa

are growing moderately, while Ghana, Senegal and Zambia are growing more slowly in absolute terms. This dispersion of growth rates suggests very different planning contexts: from massive infrastructure expansions in booming economies to more focused programs in moderate economies. From a rural access perspective, population expansion is continuously increasing the “denominator” and can slow down the percentage growth in connectivity even as the number of households connected increases annually.

Figure 3. Dynamics of the share of electricity capacity from renewable sources (%)



Source: own processing of IRENASTAT data

The distribution of the share of electricity capacity from renewable sources is extremely heterogeneous, outlining three patterns. A first group has deeply “green” mixes, dominated by hydro, with persistent values above 80–90%: Ethiopia rises to ~98% at the end of the period, Uganda exceeds 90%, and Zambia remains in the 80–90% range with a slight intermediate correction. A second group presents medium to high shares and upward trajectories: Kenya increases steadily from about two-thirds to over 80% amid the expansion of geothermal and hydro; Morocco gradually advances from the 20–30% range to almost 37%; Senegal starts from below 10% and reaches almost 30%. Finally, a third group maintains low or volatile shares: South Africa starts from almost zero and rises to ~19%; Nigeria remains around 15–22% with fluctuations; Ghana drops from the 50% range to ~31%; Tanzania peaks in 2020, then recedes to ~38% in 2023.

These trajectories reflect both historical structures and investment cycles. Countries with high shares tend to be systems where hydropower has been the backbone of installed capacity, with recent increases often being incremental. Countries with relative declines or stagnation typically have new conventional capacity entries (which increase the “denominator”), or accelerated diversification of the mix, which reduces the share of RE even as the absolute volume of renewables increases. Volatility episodes can also reflect the timing of large projects (new hydro coming online one year, followed by thermal projects the next), such that the annual share moves significantly without implying deep, lasting structural changes.

In interpreting the relationship with rural electrification, it is essential to remember that the indicator represents the share in capacity, not necessarily in actual production or hourly availability. Therefore, very high levels of renewables share (e.g. Ethiopia and Uganda) can coexist with still modest rates of rural access, if investments in distribution networks, reliability and household connections do not keep pace. Conversely, Morocco and South Africa illustrate that universalizing or maintaining high rural access is also possible with medium or low shares of RE, when the transmission and distribution infrastructure is mature.

The results of the multiple linear regression model were obtained in Figure 4.

Figure 4. Result of the linear multiple regression model

Dependent Variable: ACC_ELECTR_RURAL

Method: Panel Least Squares

Date: 09/12/25 Time: 09:38

Sample: 2010 2023

Periods included: 14

Cross-sections included: 10

Total panel (balanced) observations: 140

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_POP	-2.308210	2.925681	-0.788948	0.4315
RE_SH_ELECTR_CAP	-0.489257	0.068879	-7.103157	0.0000
C	107.9797	51.90332	2.080400	0.0394
R-squared	0.269825	Mean dependent var		42.79429
Adjusted R-squared	0.259165	S.D. dependent var		29.83684
S.E. of regression	25.68110	Akaike info criterion		9.350583
Sum squared resid	90354.08	Schwarz criterion		9.413618
Log likelihood	-651.5408	Hannan-Quinn criter.		9.376199
F-statistic	25.31307	Durbin-Watson stat		0.064983
Prob(F-statistic)	0.000000			

Estimation Command: LS ACC_ELECTR_RURAL LN_POP RE_SH_ELECTR_CAP C

Estimation Equation: $ACC_ELECTR_RURAL = C(1)*LN_POP + C(2)*RE_SH_ELECTR_CAP + C(3)$

Substituted Coefficients: $ACC_ELECTR_RURAL = -2.30820955029*LN_POP - 0.48925744404*RE_SH_ELECTR_CAP + 107.979658507$

Source: own calculations using EViews Student version

The regression analysis was estimated in EViews using a linear model in which the dependent variable is the proportion of the rural population with access to electricity, and the predictors are the logarithm of the population and the share of renewable sources in the electricity sector. The estimated equation with the substituted coefficients $\beta_0 \approx 107.98$, $\beta_1 \approx -2.308$ and $\beta^2 \approx -0.489$. In concrete terms, the resulting specification in EViews is: $ACC_ELECTR_RURAL = 107.98 - 2.308 \cdot LN_POP - 0.489 \cdot RE_SH_ELECTR_CAP$, estimated by LS on the 2010–2022 panel of the ten countries analyzed.

The negative sign of the coefficient associated with the logarithm of population suggests a semi-elastic relationship: a 1% increase in population is associated, ceteris paribus, with a decrease of about 0.023 percentage points in rural access; a doubling of population ($\approx +0.693$ in $\ln Pop$) would correlate, on average, with about -1.6 percentage points in the access indicator. The economic interpretation is in line with the literature on high marginal costs of connection in large and sparsely populated territories: highly populated countries with high rural dispersion face more severe budgetary and logistical constraints in expanding the network, so that, at the annual aggregate level, population variations can be associated with relatively slower rates of access growth. The negative coefficient of the share of renewables indicates, on average, an inverse correlation between the “greener” electricity mix and the proportion of the rural population with access, after controlling for population size. Numerically, the equation suggests that a 10 percentage point increase in the share of renewables in the electricity sector is associated with approximately 4.9 percentage points less rural access. Although counterintuitive at first glance, this result is plausible in the presence of known structural mechanisms. First, high shares of renewables often reflect a historical composition of the system (e.g., hydro dominance), not necessarily recent investments aimed at connecting rural households. Countries with very “green” electricity mixes may remain with modest rural connection rates if grid expansion is slow or if investments are concentrated in production/generation without the necessary correlative in distribution networks and household connections. Second, the indicator

used is a share and not a measure of volume per capita; thus, a high share can also occur in small systems (in absolute terms), without this translating into sufficient effective capacity to absorb new consumers in isolated areas. Third, policy sequencing can produce an inverse correlation in the short term: countries with low rural access may accelerate renewables development for energy security or cost reasons, while household connection lags behind; in aggregate annual data, this lag manifests as a negative slope.

Ethiopia and Uganda have consistently high renewable shares (often above 90% in recent years), but rural access levels remain well below 50% for much of the range, amid challenges related to grid expansion and reliability across vast territories. Conversely, Morocco and South Africa have very high rural access rates, coupled with more moderate shares of renewables in the electricity mix; in these cases, the near-universal connection reflects historical investments in grid and distribution, not necessarily a renewable-dominated mix. These antithetical configurations amplify, at the panel level, the negative correlation between "RE_share" and "rural access", without implying, by itself, an adverse causal effect of renewables on connection. The results should be read in the light of the empirical design. The LS model used does not explicitly control for time-invariant country characteristics (institutions, geography, rural density, grid history) nor for common shocks through year fixed effects; under these conditions, the captured coefficients have conditional correlations on the minimum set of controls. In addition, the share of renewables in capacity is not equivalent to the share in generation or hourly availability, which introduces measurement noise in the relationship with a "connection" indicator such as rural access. Last but not least, the connection between variables is susceptible to endogeneity: rural electrification policies and the transition to renewables may be driven by common factors and may influence each other over time, making strict causal interpretations require fixed-effects models, instrumental variables or dynamic specifications.

The estimates show that, in the analyzed set and over the horizon 2010–2022, the variation in rural access to electricity is negatively correlated with population size and the share of renewables in the electricity mix, conditioned by the factors included in the equation. The interpretation highlights the structural nature of these correlations: the "greener" mix does not guarantee, in itself, the rapid expansion of rural household connectivity if investments in the grid, distribution and targeted connection schemes are not simultaneous, and the size and dispersion of the population raise the cost barrier. These findings support the need for integrated policies that synchronize the development of renewable resources with dedicated rural electrification programs, including off-grid and mini-grid solutions adapted to the local context, in order to transform technological potential into tangible increases in access.

5. Conclusions

The analysis confirms that rural electrification in Africa has made significant progress over the past decade, but it is unevenly distributed and insufficient to achieve universal access by 2030. The results show a polarization between countries that have managed to achieve or approach full coverage (Morocco, South Africa) and those where gaps persist (Nigeria, Zambia). Intermediate examples, such as Kenya, Uganda and Ethiopia, highlight that accelerated growth is possible when consistent policies and targeted investments are in place, but at the same time show that absolute levels remain low relative to the total population. Statistical and econometric findings confirm that population size is a structural constraint: rapid demographic growth dilutes the impact of new connections and amplifies the pressure on networks and financial resources. In parallel, the negative correlation between the share of renewables and the rural electrification rate suggests that a greener energy mix does not automatically translate into expanded access, reflecting the fact that, in the absence of transmission and distribution infrastructure, even abundant renewable resources do not guarantee effective household connection.

Beyond these findings, the overall conclusion of the research is that the renewable energy transition must be synchronized with dedicated rural electrification policies to produce visible results in the well-being of the population. The public policy lessons drawn from the comparative analysis

emphasize the importance of an integrated approach: the development of renewable production capacities must be accompanied by investments in local networks, financial support mechanisms for household connection, and solutions adapted to dispersed areas. Mini-grids and off-grid systems based on solar or small hydropower are emerging as indispensable tools in regions where grid expansion costs are prohibitive, and the experience of projects carried out under EU-AU initiatives, such as REPTES, provides practical benchmarks in this direction. At the same time, quality of service must be seen as a central dimension: nominal access is not enough if supply remains intermittent and unreliable. Thus, in order to transform technological potential into real social progress, close coordination between energy transition strategies, rural development policies and international support programmes is essential.

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6.Referernces

- [1]. Afrobarometer. (2022). Round 9 Survey Data (2021/2022). Disponibil la: <https://www.afrobarometer.org>
- [2]. ESMAP/World Bank. (2019). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. Washington, DC: World Bank. Disponibil la: <https://www.esmap.org>
- [3]. ESMAP/World Bank. (2022). Tracking SDG7: The Energy Progress Report 2022. Washington, DC: World Bank. Disponibil la: <https://trackingsdg7.esmap.org>
- [4]. Gebara, C. H. (2023). Towards Better Assessments of the Sustainable Development Goals : Advancing Methodologies for Comprehensive Evaluation and Implementation across Different Scales. Research Portal Denmark, 380. <https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=dtu&id=dtu-d9082cfc-6c1c-40b0-a55b-5cc15a7784d5&ti=Towards%20Better%20Assessments%20of%20the%20Sustainable%20Development%20Goals%20%3A%20Advancing%20Methodologies%20for%20Comprehe nsive%20Evaluation%20and%20Implementation%20across%20Different%20Scales>
- [5]. International Energy Agency (IEA). (2022). Africa Energy Outlook 2022. Paris: IEA. Disponibil la: <https://www.iea.org/reports/africa-energy-outlook-2022>
- [6]. International Energy Agency (IEA). (2023). World Energy Outlook 2023. Paris: IEA. Disponibil la: <https://www.iea.org/reports/world-energy-outlook-2023>
- [7]. International Renewable Energy Agency (IRENA). (2023). Renewable Capacity Statistics 2023. Abu Dhabi: IRENA. Disponibil la: <https://www.irena.org/Statistics>
- [8]. Kaleta, M. (2019). Aided design of market mechanisms for electricity clusters. Central European Journal of Operations Research, 28(4), 1291. <https://doi.org/10.1007/s10100-019-00640-1>
- [9]. LEAP-RE/REPTES. (2023). Renewable Energy for Productive Uses in Rural Africa – Project Brief. Disponibil la: <https://www.leap-re.eu>
- [10]. López-Castrillón, W., Sepúlveda, H. H., & Mattar, C. (2021). Off-Grid Hybrid Electrical Generation Systems in Remote Communities: Trends and Characteristics in Sustainability Solutions. Sustainability, 13(11), 5856. <https://doi.org/10.3390/su13115856>
- [11]. Münster, M., Werner, S., Svendsen, S., Furbo, S., & Elmegaard, B. (2018). District heating and cooling systems innovation challenge. Research Portal Denmark, 89. <https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=dtu&id=dtu-aea1f39e-4b3e->

46ad-8f58-

c939e1bdd2ff&ti=Disctric%20heating%20and%20cooling%20systems%20innovation%20challenge

- [12]. Obuseh, E., Eyenubo, O. J., Alele, J., Okpare, A., & Ikponmwosa, O. (2025). A Systematic Review of Barriers to Renewable Energy Integration and Adoption [Review of A Systematic Review of Barriers to Renewable Energy Integration and Adoption]. *Journal of Asian Energy Studies*, 9, 26. <https://doi.org/10.24112/jaes.090002>
- [13]. Parra, D., Świerczyński, M., Stroe, D., Norman, S. A., Abdon, A., Worlitschek, J., O’Doherty, T., Rodrigues, L., Gillott, M., Zhang, X., Bauer, C., & Patel, M. (2017). An interdisciplinary review of energy storage for communities: Challenges and perspectives. *Renewable and Sustainable Energy Reviews*, 79, 730. <https://doi.org/10.1016/j.rser.2017.05.003>
- [14]. Reuters. (2022). Falling battery costs could speed up renewable energy adoption in Africa. Disponibil la: <https://www.reuters.com>
- [15]. Sousa, R. M., Kyophilavong, P., Abdullah-Al-Baki, C., Uddin, G. S., & Park, D. (2023). The Effect of Electrification on Socioeconomic Well-Being and Environmental Outcomes: Evidence for the Lao People’s Democratic Republic. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4652273>
- [16]. Sustainable Energy for All (SEforALL). (2022). *Energy Progress Report 2022 – Tracking SDG7: The Energy Progress Report*. Washington, DC: World Bank. Disponibil la: <https://www.seforall.org>
- [17]. Touitou, M., & Waleed, A. (2024). The Relationship between Public Health Expenditure and Air Pollutants: An Empirical Analysis for MENA Countries for the Period 2000-2021. *Polish Journal of Environmental Studies*. <https://doi.org/10.15244/pjoes/188697>
- [18]. World Bank. (2023). *World Development Indicators – Access to electricity, rural (% of rural population) (EG.ELC.ACCS.RU.ZS)*. Washington, DC: World Bank. Disponibil la: <https://databank.worldbank.org>
- [19]. Zebra, E. I. C., Windt, H. van der, Nhumaio, G., & Faaij, A. (2021). A review of hybrid renewable energy systems in mini-grids for off-grid electrification in developing countries [Review of A review of hybrid renewable energy systems in mini-grids for off-grid electrification in developing countries]. *Renewable and Sustainable Energy Reviews*, 144, 111036. Elsevier BV. <https://doi.org/10.1016/j.rser.2021.111036>