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ANALYSIS OF SOLAR AND WIND ENERGY UTILISATION IN EUROPE AND AFRICA*

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Abstract. The increasing reliance on renewable energy sources is essential for achieving global sustainability, with solar and wind energy playing pivotal roles in mitigating climate change and reducing dependency on fossil fuels. This study presents an in-depth comparative analysis of solar and wind energy utilisation in Europe and Africa, examining the key differences in resource availability, adoption rates, technological advancements, economic factors, and policy frameworks. Europe has made significant progress integrating renewable energy into its energy mix through comprehensive policies, substantial financial investments, and cutting-edge technological developments. In contrast, despite possessing immense renewable energy potential, particularly in solar energy, Africa faces considerable challenges, including inadequate infrastructure, limited funding, and inconsistent policy implementation. The findings highlight the barriers and opportunities for both regions and propose strategies to optimise renewable energy deployment, fostering sustainable development across diverse socio-economic contexts.

Keywords: renewable energy; solar energy; wind energy; Europe; Africa; energy policy; sustainability; technological advancements; energy transition; grid infrastructure

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Additional disciplines: ecology and environment; electricity electronic environmental engineering; energetics and thermo-energetics

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1. Introduction

The global energy sector is undergoing a fundamental transformation driven by the urgent need to decarbonise economies and expand access to affordable, sustainable energy. Renewable energy—particularly solar and wind—has emerged as a central pillar in this transition. Over the past two decades, Europe has positioned itself as a global leader in renewable energy integration through ambitious climate legislation, technological innovation, and strong market incentives (European Commission, 2020; IEA, 2023). Notably, the EU achieved a 45.3% share of renewables in gross electricity consumption in 2023, the most significant annual increase on record, with wind and solar contributing 38.5% and 20.5%, respectively. As of early 2025, renewables accounted for 47.4% of net electricity generation, reinforcing the EU's role as a frontrunner in clean energy deployment (Statista, 2025).

In contrast, while endowed with exceptional solar and wind resources, many African regions face persistent structural challenges that hinder widespread renewable energy adoption (Chukwu et al., 2022; Anekwe et al., 2024). These include underdeveloped grid infrastructure, high capital investment requirements, inconsistent policy frameworks, and limited access to concessional finance (UNEP, 2021). Sub-Saharan Africa, in particular, remains one of the most energy-poor regions, with more than 550 million people lacking access to electricity as of 2022 (IEA, 2022; Villar-Roldán et al., 2025).

Despite these contrasts, both continents exemplify distinct paths toward renewable energy transition. Europe operates within a highly interconnected, mature energy market, while many African countries are attempting to leapfrog centralised fossil-based systems through decentralised, renewable-based electrification. Crucially, Africa is not a monolithic energy landscape. This study focuses on North, East, and Southern Africa—regions where renewable energy deployment has been most active—to reflect intra-continental diversity in opportunity and constraint.

The primary aim of this study is to conduct a comparative analysis of solar and wind energy utilisation in Europe and Africa, with particular attention to how contextual, institutional, and infrastructural factors influence renewable energy adoption in each region. The study identifies region-specific barriers and enablers by mapping these dimensions, offering insights adaptable to differing socio-economic, geographic, and governance contexts. Doing so contributes to a deeper understanding of how renewable energy transitions can be regionally responsive and globally relevant.

1.1 Analytical Framework

This study employs a tripartite analytical framework grounded in energy transition and governance literature to guide the comparative analysis of renewable energy adoption in Europe and Africa. The framework categorises the determinants of solar and wind energy deployment into three broad but interrelated domains: contextual, institutional, and infrastructural factors. These categories are informed by prior studies in energy systems research, sustainable development, and comparative policy analysis (Sovacool, 2009; Alex-Oke et al., 2025).

Contextual Factors
Contextual factors refer to the environmental, geographic, and socio-economic conditions that shape the technical feasibility and social relevance of renewable energy deployment. These include:

- Solar irradiation and wind speed profiles
- Population distribution and density
- Economic development levels
- Energy access rates and demand patterns
- Regional climate variability and vulnerability

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In Europe and Africa, these factors influence the physical viability of renewable technologies and the urgency and design of deployment strategies (Skosana et al., 2023).

Institutional Factors

Institutional factors encompass the policy, legal, and governance structures that support or constrain renewable energy growth. These involve:

- National and regional energy policies
- Political stability and regulatory quality
- Investment incentives, subsidies, and tariffs
- Stakeholder engagement and policy continuity
- Institutional capacity for implementation and monitoring

Institutional strength and alignment are crucial for attracting investment, securing public trust, and ensuring long-term project success (Dube & Horvey, 2023; Muoneke et al., 2023).

Infrastructural Factors

Infrastructural factors relate to the physical and technical systems required for renewable energy generation, integration, and distribution. These include:

- Grid connectivity and reliability
- Energy storage systems
- Transmission and distribution infrastructure
- Access to digital technologies (e.g., smart grids, metering)
- Domestic supply chains and technical expertise

While Europe benefits from well-established energy networks and high grid interconnectivity, many African countries rely on fragmented or non-existent infrastructure, influencing the scale and type of viable renewable projects (Nwaigwe, 2021; Dalla Longa & Zwaan, 2024; Chiki et al., 2025).

2.Renewable energy potential

Solar and wind energy potential differs markedly across Europe and Africa, reflecting variations in geography, climate, and infrastructure (Oxford Institute for Energy Studies, 2021; Chetty et al., 2023; Tachega et al., 2025).

As illustrated in Figure 1, which uses synthesised data to represent general trends based on average global datasets (Global Solar Atlas, 2023), Northern Africa—particularly the Sahara and Sahel zones—has some of the highest levels of solar irradiation globally, often exceeding 2,000 kWh/m² per year.

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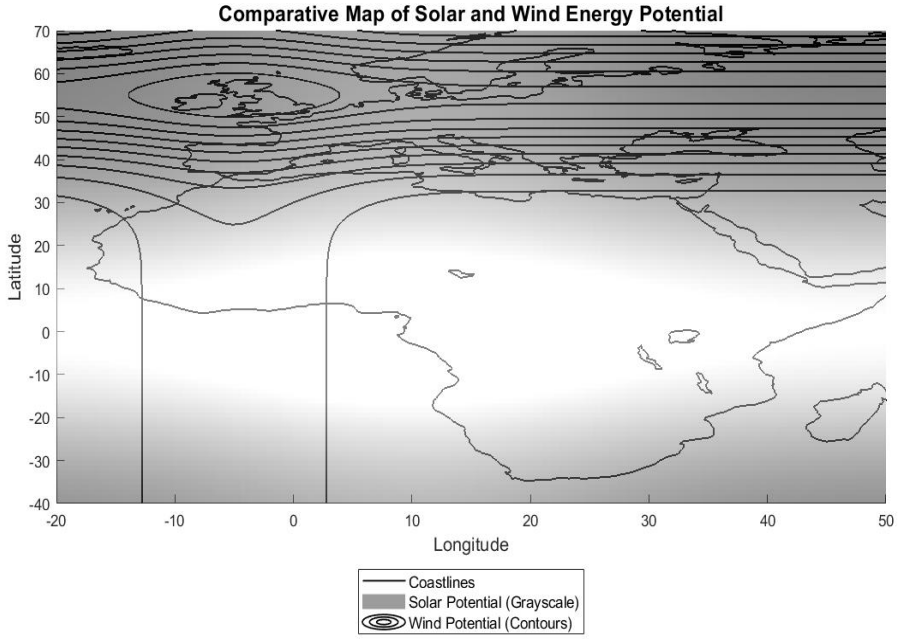


Figure 1. Solar and wind energy potential in Europe and Africa
Source: Generated using synthetic data for visualisation purposes

These values significantly surpass those of Southern Europe, where the most irradiated regions include Spain, Italy, and Greece, averaging between 1,400–1,800 kWh/m²/year (Global Solar Atlas, 2023).

This geographical advantage positions African regions, particularly North and East Africa, as ideal for utility-scale photovoltaic (PV) and concentrated solar power (CSP) installations. Despite this, actual deployment remains limited due to infrastructural, financial, and policy constraints (REN21, 2021; AfDB, 2023).

Wind energy potential shows a different distribution. Europe has substantial wind resources along its northwestern coasts and offshore regions, especially the North Sea, which has become a hub for high-capacity offshore wind farms (IEA, 2023; GWEC, 2023). These regions benefit from consistent wind speeds, shallow water depths, and proximity to industrial demand centres. In Africa, wind resources are promising but more regionally dispersed. High wind zones are concentrated along the Atlantic and Indian Ocean coasts—particularly in Morocco, South Africa, and Kenya—with average wind speeds often exceeding 6 m/s at 100 m height (UNEP, 2021). However, the exploitation of these resources has been slow due to weak transmission infrastructure, limited investment, and policy uncertainty.

These geographic patterns underline the importance of tailoring renewable energy strategies to regional characteristics. While Europe has developed a coordinated, large-scale integration model, many parts of Africa may benefit more from distributed, decentralised renewable energy systems adapted to local contexts.

2.1. Solar Energy Potential

Solar energy potential across Africa is among the highest globally, particularly in the Sahara and Sahel regions, where average annual global horizontal irradiance (GHI) often exceeds 2,000–2,300 kWh/m²/year (Global Solar Atlas, 2023; IRENA, 2022). This makes North and parts of East Africa exceptionally well-suited for both photovoltaic (PV) and concentrated solar power (CSP) installations. Countries such as Morocco, Egypt, and

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Namibia have already begun leveraging these conditions, with landmark projects like the Noor CSP complex and Benban Solar Park leading regional development (REN21, 2021; AfDB, 2023).

By contrast, solar potential in Europe is geographically concentrated in the Mediterranean belt, including Spain, Italy, and Greece, with annual irradiance ranging from 1,400 to 1,800 kWh/m²/year (Fraunhofer ISE, 2022). Though lower than in Africa, Europe has achieved high deployment rates through favourable policies, grid reliability, and financing mechanisms. The continent's technological innovation—such as bifacial panels and tracking systems—has helped increase the efficiency of solar capture in less optimal environments (IEA, 2023).

However, while Africa's natural advantage in solar potential is undisputed, technical, economic, and political challenges continue to limit large-scale deployment. These include inadequate transmission systems, limited domestic manufacturing, and uncertainties in policy execution across different countries. As a result, despite its superior solar resource base, Africa contributes only a small fraction of global solar capacity. Moving forward, regional cooperation, cross-border energy markets, and decentralised systems—such as mini-grids and solar home systems—offer promising, context-appropriate solutions (Adom et al., 2025; Adaji et al., 2025).

2.2. Wind Energy Potential

With significant regional disparities, wind energy potential is unevenly distributed across Europe and Africa. Europe's North Sea basin, including coastal areas of Germany, Denmark, and the United Kingdom, has become a global leader in offshore wind deployment thanks to high wind consistency, shallow waters, and strong policy support (GWEC, 2023; European Commission, 2020). Onshore wind is widespread in Spain, France, and Sweden, where long-term planning and public acceptance have facilitated grid integration.

In Africa, wind resources are strongest along coastal regions such as Morocco's Atlantic shore, South Africa's Western Cape, and the Rift Valley regions of Kenya. Wind speeds in these areas often exceed 6.5 m/s at 100m hub height, meeting international thresholds for commercial-scale development (IRENA, 2019; UNEP, 2021). Projects like Lake Turkana Wind Farm (Kenya) and Tarfaya Wind Farm (Morocco) demonstrate the viability of large-scale wind initiatives when supported by political stability and grid access.

Nevertheless, Africa's broader wind development is hindered by high capital costs, grid limitations, and a lack of long-term power purchase agreements (PPAs). In many landlocked or politically unstable countries, bankable projects remain rare. A key difference is that Europe's wind sector benefits from continental coordination and integrated electricity markets, while Africa's is still fragmented. For wind energy to scale in Africa, national efforts must be coupled with regional grid development, standardised regulations, and stronger investor safeguards.

3. Current Adoption and Installed Capacity

As of 2023, Europe and Africa exhibit significant disparities in the adoption of solar and wind energy technologies, both in terms of installed capacity and the degree to which these systems meet regional energy needs (IRENA, 2023; IEA, 2023) (see Figure 2).

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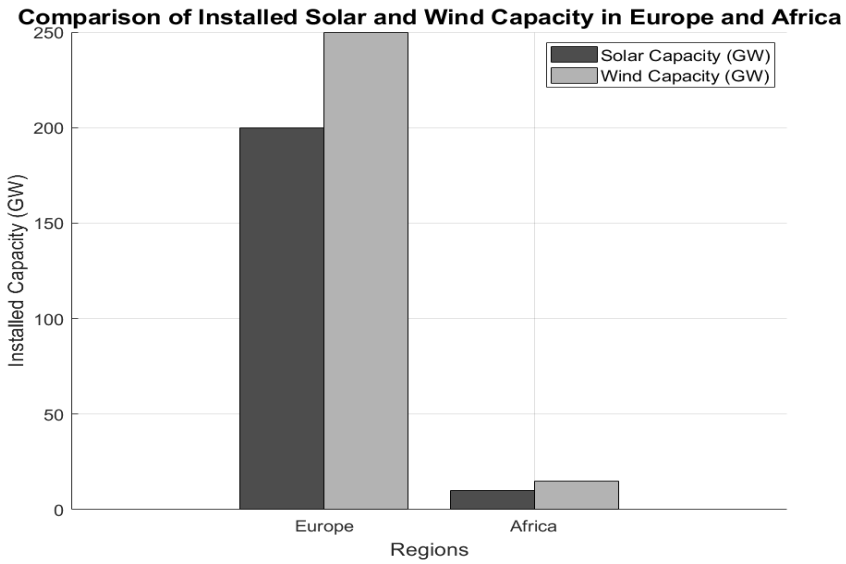


Figure 2. Installed solar and wind capacity in Europe and Africa
Source: International Renewable Energy Agency (IRENA), 2023.

According to IRENA, Europe accounts for over 640 GW of cumulative renewable energy capacity, with approximately 255 GW from wind and 209 GW from solar. In contrast, Africa has a total installed renewable capacity of around 59 GW, of which solar PV represents just under 12 GW and wind approximately 7 GW (IRENA, 2023).

While these absolute numbers highlight a clear capacity gap, the contrast is more nuanced when considered relative to demand. Europe's high penetration of renewables—particularly in countries like Germany, Denmark, and Spain—has been integrated into existing power systems to displace fossil fuels. For example, Denmark sourced over 50% of its electricity from wind power in 2022 (Danish Energy Agency, 2023). However, most European countries already have near-universal electricity access and mature infrastructure.

The situation differs in Africa: many regions remain energy-poor, and even small-scale renewable projects can have outsized social and economic impacts. Sub-Saharan Africa, where over 550 million people still lack electricity access (IEA, 2022), benefits enormously from decentralised solar mini-grids and off-grid systems. Countries like Morocco, Egypt, and South Africa have made notable progress, with Morocco's Noor Ouarzazate CSP plant and South Africa's REIPPPP wind projects emerging as continental benchmarks (AfDB, 2023; REN21, 2021; Daoudi et al., 2025).

However, other nations—particularly in Central Africa—continue to lag due to limited investment and institutional support.

Figure 2 illustrates the current disparity in installed capacity but does not fully capture the uneven energy access or the different stages of transition. In Africa, capacity expansion must be aligned with decarbonisation goals and broader development priorities such as electrification, energy justice, and rural infrastructure.

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4. Infrastructural and Economic Factors

The availability of robust energy infrastructure and access to sustained economic investment has strongly influenced Europe's advancement in renewable energy deployment. Over the past two decades, the region has developed and modernised smart grid systems, expanded high-voltage interconnectors, and built large-scale offshore wind platforms, especially in the North Sea. Countries like Germany, Denmark, and the Netherlands have adopted grid-scale battery storage and digitalised grid management systems to better balance intermittent renewable generation (IEA, 2023; Fraunhofer ISE, 2022). These infrastructural advancements have been reinforced by predictable market instruments—including feed-in tariffs, green bonds, and capacity auctions—reducing investor risk and accelerating private sector engagement (Lazard, 2022; European Commission, 2020).

In contrast, many African countries face substantial infrastructural constraints, particularly in rural or off-grid areas. Challenges such as low electrification rates, outdated or non-existent grid networks, and limited energy storage capacity hinder the integration of utility-scale renewable projects (IRENA, 2022; van der Zwaan et al., 2021).

However, Africa also presents opportunities for leapfrogging traditional grid systems. Innovations such as modular solar mini-grids, mobile pay-as-you-go systems, and community-based energy cooperatives—especially in Kenya, Rwanda, and Ghana—demonstrate how infrastructural decentralisation can support equitable and adaptive energy transitions (IFC, 2021; UNEP, 2021).

Despite the limited scale of Africa’s infrastructure, these models have been highly effective in reaching underserved populations and enabling bottom-up energy access. Moreover, international partnerships and multilateral frameworks, such as the African Continental Power Systems Master Plan and cross-border transmission projects under Power Africa, are beginning to address regional infrastructure gaps (AfDB, 2023; African Union Commission, 2021).

From an economic perspective, European countries rely on domestic capital markets and coordinated EU mechanisms. At the same time, African nations remain heavily dependent on foreign direct investment, development finance, and public-private partnerships. This funding asymmetry directly impacts the scope and reliability of infrastructure development and maintenance. It also reflects more profound differences in market maturity and fiscal autonomy. Infrastructural and economic conditions must be understood as mutually reinforcing. Rather than promoting replication of Europe's centralised grid model, policy and investment strategies should prioritise context-responsive infrastructure adapted to each region's energy access needs and financing realities.

5. Institutional and Financial Factors

Institutional and financial structures play a central role in shaping the trajectory of renewable energy deployment across Europe and Africa. These include formal governance mechanisms, regulatory stability, and access to capital, which influences investment flows, policy enforcement, and long-term planning.

In Europe, the energy transition has been supported by robust, regionally coordinated institutional frameworks such as the European Green Deal, the Renewable Energy Directive, and the Fit for 55 packages (European Commission, 2020; IEA, 2023). These initiatives provide clear legislative targets for decarbonisation and ensure alignment among member states. Institutional strength is also reflected in regulatory transparency, monitoring capacity, and long-term policy consistency. Financial instruments such as green bonds, feed-in tariffs, and renewable energy auctions have provided strong price signals, reduced perceived risks, and attracted public and private sector investment (Lazard, 2022; REN21, 2021).

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That said, institutional performance in Europe is not uniform. Northern and Western European countries tend to lead in implementation, while Eastern and Southeastern Europe have faced challenges related to institutional fragmentation, weaker regulatory enforcement, and differing national energy priorities (IEA, 2022). Public acceptance of specific technologies (e.g., onshore wind, biomass) also varies, affecting the pace and direction of local transitions.

In Africa, institutional diversity is even more pronounced. While no overarching continental framework is equivalent to the EU, several countries have developed effective national strategies. Examples include Morocco's Integrated Wind and Solar Plan, South Africa's REIPPPP, and Kenya's feed-in tariff and net-metering schemes, which have demonstrated policy innovation and attracted international investment (IRENA, 2022; UNEP, 2021). However, many other African nations struggle with weak institutional capacity, inconsistent policy implementation, and political instability, which often undermine investor confidence and delay project execution (Adebiyi & Moloi, 2024).

A significant divergence between the two continents lies in financial autonomy. Europe's energy transition is primarily financed through internal capital markets, fiscal tools, and EU-wide financial instruments. In contrast, African renewable energy development depends heavily on foreign direct investment (FDI), development aid, and public-private partnerships (AfDB, 2023; IFC, 2021). This dependence introduces volatility, limits local control, and constrains strategic planning, especially in politically or economically fragile states. Additionally, issues like currency risk, regulatory uncertainty, and limited access to affordable long-term credit deter private investors (Pan et al., 2023).

Table 1 summarises the key institutional mechanisms and financial models shaping the renewable energy sectors in Europe and Africa.

Table 1. Institutional and Financial Characteristics of Renewable Energy Development

Region	Institutional Mechanisms	Financial Trends
Europe	• European Green Deal • Renewable Energy Directive • Fit for 55 Package • National Energy and Climate Plans (NECPs) • Coordinated EU policy and regulatory frameworks	• Strong reliance on domestic public and private investment • Use of green bonds, feed-in tariffs, and competitive auctions • Access to EU capital markets and European Investment Bank (EIB) financing • Risk mitigation through stable policy and regulation
Africa	• Renewable Energy Independent Power Producer Programme (South Africa) • Morocco's Solar and Wind Plan • Kenya's Feed-in Tariff and Net Metering • Regional initiatives (e.g., Power Africa, AREI) • Fragmented cross-border governance	• Heavy dependence on foreign direct investment (FDI) and development aid • Frequent use of public-private partnerships (PPPs) • Volatile financing environment due to political and currency risks • Early adoption of green bonds in countries like Nigeria and South Africa

Source: International Renewable Energy Agency (IRENA), 2022, IEA (2023), REN21 (2021), AfDB (2023), UNEP (2021), and European Commission (2020).

While Europe demonstrates the advantages of policy harmonisation and long-term planning, Africa's experience highlights the importance of localised governance innovations and the need for stronger regional policy coordination. Sustainable progress in Africa will depend on building infrastructure and the institutional and financial ecosystems needed to support it over time.

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6. Challenges and Opportunities

The trajectory of renewable energy development in Europe and Africa is shaped by structural, institutional, and economic conditions, many of which present significant challenges—but also open vital opportunities for context-specific innovation (Charamba et al., 2025). In Africa, limited grid infrastructure remains one of the most pressing constraints. Many countries still rely on isolated or underdeveloped national grids, making integrating utility-scale renewable energy projects difficult. The lack of transmission capacity is compounded by weak regulatory enforcement, limited local manufacturing, and a shortage of skilled professionals in renewable energy sectors (AfDB, 2023). Financing is also a central barrier: while Africa has seen growing interest from international investors, renewable energy projects are often perceived as high-risk due to political instability, currency fluctuations, and regulatory uncertainty (IFC, 2021; UNEP, 2021).

Nevertheless, Africa's decentralised and flexible market environment has enabled a different kind of innovation. Off-grid and mini-grid solutions are increasingly used to electrify remote communities without waiting for full national grid coverage. Pay-as-you-go solar home systems, particularly in East Africa, are examples of how local innovation—combined with mobile finance and donor support—can address energy access while building renewable capacity (IRENA, 2022). These models offer potential not as alternatives to centralised infrastructure but as parallel systems tailored to rural and underserved populations (Okorie, 2025).

The key challenges in Europe are not access but integration, equity, and political consensus. As renewable penetration increases, grid stability and energy storage have become pressing issues, particularly during seasonal demand shifts and extreme weather events (IEA, 2023). Additionally, the expansion of wind and solar projects has sometimes met local resistance due to environmental or aesthetic concerns, revealing the need for more inclusive energy planning processes. These issues suggest that Europe's renewable transition, while technically advanced, also faces important social and governance questions.

Comparing the two regions reveals not a linear progression but two distinct but complementary pathways. Europe's centralised grid-based model, emphasising regulatory alignment and high-tech solutions, provides valuable insight into systems integration and long-term planning. Africa's experience highlights the importance of modular, affordable, and community-oriented solutions that are responsive to development needs and local realities. The opportunity lies not in replication but in mutual learning and co-development of resilient and adaptive energy strategies.

Conclusions

This study has examined the comparative dynamics of solar and wind energy deployment in Europe and Africa, revealing how geographic, institutional, and economic conditions shape the pathways of renewable energy transition in markedly different ways. While Europe has advanced through a centralised, policy-driven model supported by technological innovation and regulatory coherence, Africa's energy transition is more fragmented but flexible, characterised by decentralised innovations and context-responsive strategies.

The analysis confirms that a one-size-fits-all approach to renewable energy deployment is neither feasible nor desirable. Europe's experience provides insight into grid integration, financing mechanisms, and long-term planning. However, Africa's trajectory—especially in regions like East and North Africa—demonstrates that distributed, low-cost, and adaptive energy systems can offer viable alternatives, particularly in areas underserved by central infrastructure.

The comparison is not about prescribing a universal model but identifying what works, where, and why. It highlights the importance of aligning renewable energy strategies with regional development priorities,

governance capacities, and socio-economic realities. Furthermore, it suggests the value of mutual learning: Africa can draw technical and policy insights from Europe, while Europe can learn from Africa's leadership in decentralised systems and energy access innovation.

Future research should explore these dual transitions through a more granular lens—by country, technology type, or socio-political context—and assess the impact of emerging tools such as artificial intelligence, local energy markets, and regional interconnection. In doing so, scholarship can move beyond comparison toward more constructive models of co-adaptation, where diverse energy transitions are not ranked but coordinated to serve both climate goals and local needs.

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