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MASTER'S THESIS

Specialty: Economics/Policy/Infrastructure and Green Hydrogen Technology
Topic:

THE ENERGY POLICY TRIANGLE (AFFORDABILITY, SUPPLY SECURITY, AND SUSTAINABILITY): COMPARED GERMANY VS. WEST AFRICA

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DEDICATION

This thesis is lovingly dedicated to my family, whose support, sacrifices, and encouragement have been the foundation of my journey.

To my father, Mr. Bai Bureh Sesay, your strength, wisdom, and steadfast belief in my potential have guided me through every challenge. To my mother, Mrs. Hawanatu Sesay, your unwavering love, and gentle spirit have been a constant source of comfort and motivation.

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Full Meaning
AfDB	African Development Bank
AHP	Analytical Hierarchy Process
BMWK	Federal Ministry for Economic Affairs and Climate Action (Germany) (Bundesministerium für Wirtschaft und Klimaschutz)
CH_4	Methane
CO_2	Carbon Dioxide
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, Germany)
EPT	Energy Policy Triangle
EPTI	Energy Policy Triangle Index
EU	European Union
FiTs	Feed-in Tariffs
gCO_2	Grams of Carbon Dioxide
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GWP	Global Warming Potential
HDI	Human Development Index
HFO	Heavy Fuel Oil
IEA	International Energy Agency
IMF	International Monetary Fund
IPPs	Independent Power Producers
IRENA	International Renewable Energy Agency
Kgoe	Kilogram of Oil Equivalent
kWh	Kilowatt-hour
LCOE	Levelized Cost of Energy
LNG	Liquefied Natural Gas
LULUCF	Land Use, Land-Use Change, and Forestry
MCDM	Multi-Criteria Decision-Making
Mt CO_2e	Million Metric Tonnes of Carbon Dioxide Equivalent
MYTO	Multi-Year Tariff Order
NDCs	Nationally Determined Contributions
NERC	Nigerian Electricity Regulatory Commission
PM2.5	Particulate Matter with diameter $\leq$ 2.5 micrometres

PSE	Plan Sénégal Émergent
REA	Rural Electrification Agency
RE	Renewable Energy
RWTH	RWTH Aachen University (Rheinisch-Westfälische Technische Hochschule Aachen)
SDG	Sustainable Development Goal
SREP	Scaling-Up Renewable Energy Program
T&D	Transmission and Distribution
TWh	Terawatt-hour
UBA	Umweltbundesamt (German Environment Agency)
UCAD	Université Cheikh Anta Diop (Senegal)
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistics Division
USD	United States Dollar
WAPP	West African Power Pool
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WBG	World Bank Group
WHO	World Health Organization

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ABSTRACT

The research compares the performance of the energy policy of Germany with that of four West African countries, Côte d'Ivoire, Ghana, Nigeria, and Senegal. This was done by using the Energy Policy Triangle (EPT) framework, which evaluates affordability, security of supply, and sustainability. Multi-Criteria Decision-Making (MCDM) method was used to compute sixteen policy-relevant indicators that were normalized and aggregated into a composite Energy Policy Triangle Index (EPTI) between the year 2008 and 2020. Germany is evidently seen to have registered improvement on the overall EPTI based on cumulative policies, regulatory consistency, and universal renewable energy usage. Côte d'Ivoire and Senegal made gains in access and affordability, but Ghana and Nigeria experienced decrease on the basis of affordability challenges, fossil fuel reliance, and inefficient infrastructure. Trade-offs remain prominent across West Africa, with affordability and access given priority over sustainability. The study indicates the relevance of stable policy, institutions, regional integration of energy markets, and improved data systems that favour just energy transitions. Recommendations are focused on enhancing temporal data resolution, context-sensitive benchmarking, and facilitating knowledge sharing between the developed and developing world to achieve sustainable development and climate goals.

key words: energy policy triangle; affordability; supply security; sustainability; multi-criteria decision-making (MCDM).

RÉSUMÉ

L'étude consiste à comparer la performance de la politique énergétique de l'Allemagne à celle de quatre pays d'Afrique de l'Ouest : la Côte d'Ivoire, le Ghana, le Nigéria et le Sénégal. Cela a été réalisé en utilisant le cadre du Triangle de Politique Energétique (EPT), qui évalue l'accessibilité financière, la sécurité d'approvisionnement et la durabilité. La méthode de prise de décision multicritère (MCDM) a été utilisée pour calculer seize indicateurs pertinents pour les politiques qui ont été normalisés et agrégés dans un Indice composite du Triangle de Politique Energétique (EPTI) entre 2008 et 2020. Les résultats montrent que l'Allemagne semble avoir enregistré une amélioration constante dans tous les aspects grâce à des politiques cumulatives, une cohérence réglementaire et une utilisation universelle des énergies renouvelables. La Côte d'Ivoire et le Sénégal ont réalisé des progrès en matière d'accès et d'accessibilité financière, mais le Ghana et le Nigéria ont connu une baisse en raison des problèmes d'accessibilité financière, de la dépendance aux combustibles fossiles et de l'inefficacité des infrastructures. Les compromis restent importants en Afrique de l'Ouest, l'accessibilité financière et l'accès étant prioritaires sur la durabilité. L'étude souligne l'importance d'une politique stable, des institutions, de l'intégration régionale des marchés de l'énergie et de systèmes de données améliorés qui favorisent des transitions énergétiques justes. Les recommandations visent à améliorer la résolution temporelle des données, l'analyse comparative contextuelle et à faciliter le partage des connaissances entre les pays développés et les pays en développement afin d'atteindre les objectifs de développement durable et de lutte contre le changement climatique.

Mots clés : triangle de la politique énergétique ; accessibilité ; sécurité d'approvisionnement ; durabilité ; prise de décision multicritère (MCD

INTRODUCTION

The energy policy triangle (affordability, supply security, and sustainability) is a broad template for assessing the trade-offs and synergies in national energy policy (Cherp & Jewell, 2014a). This research employs an analytical framework to compare Germany, a global leader in the energy transition, with four West African countries Côte d'Ivoire, Ghana, Nigeria, and Senegal each with their respective energy systems and policy structure.

The three dimensions together allow not only for the determination of where policy goals complement each other but also where they differ, offering a systematic way of assessing the trade-offs, costs, and opportunities of energy system transformation. This view generates insights into technical feasibility, socio-economic and political implications of energy alternatives. The concept of energy policy triangle has been applied in a wide range of national and regional contexts as a comparative tool to evaluate the direction and balance of energy transitions, and it illustrates the flexibility of the concept as an analytical framework (Kamali Saraji & Streimikiene, 2024, Strojny et al., 2023).

Germany was chosen as the reference case not because of its developmental similarity to West African nations, but because it serves as an international exemplar for executing a comprehensive and sustainable energy transition policy. The reference effectively discloses both structural inconsistencies and transferable lessons. Although Germany's financial and institutional capacity differ significantly than those of West African countries, analyzing its experience allows for contextual benchmarking, helping West African policymakers to discern best practices and potential pitfalls for their energy transitions.

The four West African countries Côte d'Ivoire, Ghana, Nigeria, and Senegal were selected because they have diverse energy systems, levels of electricity access, and shares of renewable penetration, and institutional capacity within West Africa that is, the strength and effectiveness of their energy sector institutions in planning, regulating, financing, and coordinating policies. These factors provide a good comparative analysis basis.

The German energy policy is shaped by profound policy commitments for decarbonization, efficiency, and supply security, supported by robust regulatory institutions and innovation in technology (Gagnebin & Graf, 2023). On the other hand, West African countries continue to experience endemic challenges such as limited access to electricity, volatile supply chains, and financing constraints that complicate mass-scale deployment of clean technologies (International Energy Agency, 2022).

Regardless of the differences in energy policy between West Africa and Germany, West Africa is now embracing renewable energy solutions, regional power pools, and electrification programs aimed at addressing both energy poverty and climate goals (Brief, 2008).

This research is intended to provide answers to three key questions such as:

1. In what ways are the energy systems of Germany different from that of West Africa (represented by Côte d'Ivoire, Ghana, Nigeria, and Senegal)?

2. How does each region deal with trade-offs in terms of affordability, security of supply, and sustainability?

3. What indicators can most appropriately be used to quantify the three aspects of the energy policy triangle and their balances in these dimensions?

A comparative analysis was carried out using Multi Criteria Decision Method (MCDM) to analyze the trade-offs in the energy policy triangle between the two regions. In carrying out this analysis, both quantitative and qualitative data were considered among the selected countries.

By exploring the intersection of energy policy objectives and national development agendas, this study makes contributions towards the broader discussion on just energy transition. Access to clean and affordable energy in West Africa will facilitate the delivery of services such as transportation, cooling, mechanical, and communication services.

This research offers some insights into how West Africa and Germany consider making compromise on the energy triangle trade-offs, including policymaking, regional integration, and sustainable development path implications.

At the end, the results will influence policy recommendations to enhance the three dimensions (affordability, supply security, and sustainability) using an integrated approach in West Africa.

The remainder of this work is structured as follows. Chapter 1 presents the theoretical framework and reviews the relevant literature on the energy policy triangle, energy transitions, and the West African and German contexts. Chapter 2 outlines the research design and methodology, including the Multi-Criteria Decision-Making (MCDM) approach, the selection of indicators, and the weighting process. Chapter 3 reports the empirical results and discussion, beginning with a general comparison between Germany and West Africa, followed by a detailed analysis across the three dimensions of affordability, supply security, and sustainability. The thesis closes with concluding reflections and policy recommendations embedded within the discussion.

Chapter 1: THEORETICAL FRAMEWORK AND LITERATURE ON THE ENERGY POLICY TRIANGLE

The energy policy triangle (EPT) is an established concept for representing important target dimensions in energy systems. The triangle is such that all three dimensions are very much connected. The EPT captures the main policy objectives of modern energy systems such as making energy services cheap and inclusive, ensuring reliable supply and fostering environmental sustainability and decarbonization. The triangle approaches energy policy as a matter of trade-offs between partially conflicting objectives instead of single-objective optimization (Pliousis et al., 2019). The EPT is the foundation for selecting indicators, and interpreting trade-offs, because it sets the goals, the measuring map, and the framework to recognize and explain trade-offs.

The theoretical framework and empirical foundation of this research focuses on the importance of the energy policy triangle. It then continues to look at the most applicable literature regarding affordability, supply security, and sustainability. This framework shows how energy policy issues have been approached in various settings (developed and developing countries) and serves as a guide for selecting appropriate indicators and tools such as MCDM to be used for the purpose of comparison.

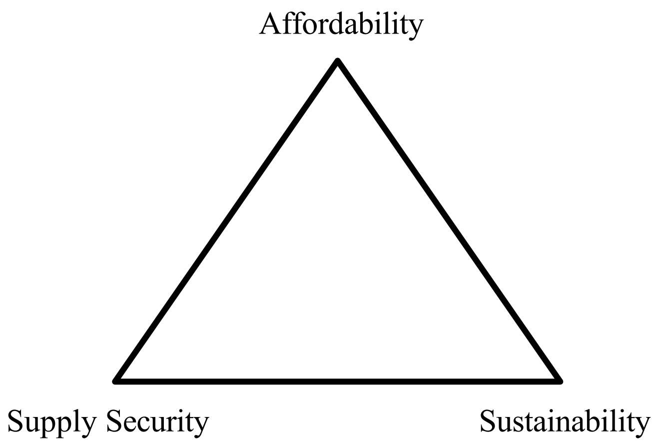


Figure 1: The Energy Policy Triangle
Source: Author's representation

1.1 Why is the Energy Policy Triangle an important tool?

The energy policy triangle is important because it helps countries, cities and large organizations to set policy or socio-corporate strategy by identifying where they want to be on each axis and what is the desirable resilient position (Okoduwa). They can benchmark their current positioning. This enables a reality check and proper understanding of the existing influences and drivers to achieve an informed position and be able to compare performance relatively to the performance of other similar entities. The power and value of the triangle tool is its ability to test whether new policies or projects are helping or hindering moving towards the desired position and what adjustments or change in emphasis of such new initiatives are needed (World Energy Council, 2020).

This research looked at some definitions of the three dimensions (affordability, supply security, and sustainability) from different authors. In the end, the author proposed a unique definition for each dimension in this research, starting with supply security.

Supply Security

There is no universal accepted definition of supply security. According to (Aboua & Toure, 2018), supply security is the ability of an energy system to avoid or manage physical and economic disruptions due to external dependencies, emphasizing vulnerability to import and geopolitical shock. According to this author, security of supply is closely aligned with acceptability (supplier/geopolitical risk management) and availability (cushions like stocks and flexibility). According to this author's external-dependence views in certain areas and energy uses that he regards are power (grid); where the risks come from imported fuels for thermal generation (gas, oil, coal), cross-border power imports, LNG/pipeline corridors, and imported spare parts. To prevent this, he proposed a solution by diversifying the mix (incl. domestically available renewables), expand storage and demand response, add route redundancy and black-start capability. Another sector of application is in industry (processing heat & feedstock), which brings about exposure through imported natural gas/LPG/HFO/coal, chemicals (e.g., ammonia), and critical spares/catalysts. His proposed solution to tackle this problem was to make LPG supply chains and storage stronger, use electricity where grids are strong, and improve efficiency to decrease peak exposure.

Also, supply security can be termed as the reliability and continuous provision of energy to meet population and industrial needs. This centres on service continuity outcomes across the value chain and maps mainly to availability (adequacy, flexibility) and accessibility (network deliverability) (Solangi & Magazzino, 2025). In accordance with the author’s service-continuity standpoint, he considers similar sectors of the energy application as discussed above. For Power (grid), his focus was to avoid blackouts/curtailment; keep frequency/voltage within limits. To achieve this, he proposed solutions such as flexible capacity (storage/DR), maintenance &

management, congestion relief, grid codes and protection upgrades should be carefully managed. The two authors look at security of supply from different perspectives. Aboua & Toure, 2018 look at where outside shocks reach the system and how to lessen their effects (focusing on acceptability and availability). Solangi and Magazzino look at how to keep the lights on and how to measure the continuity that consumers really perceive (focusing on availability and accessibility).

Supply security is the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand "World Energy Council, 2020". This research defines supply security as the ability of an energy system to ensure stable, sufficient, and timely delivery of energy to consumers, even in the face of external shocks, demand fluctuations, or geopolitical risks.

Within the context of this thesis, the following aspects are considered for supply security (availability, accessibility, and acceptability). The affordability aspect is considered as another dimension in the energy policy triangle. Affordability is considered as another dimension on its own since the economic burden on households is a separate policy goal that neither supply security nor sustainability can fully address.

The focal point when selecting indicators the supply security dimension is on the electricity sector. Other energy carriers are considered but of less importance. To do this, the supply security focuses mainly on physical and logistical aspects of electricity delivery, which include:

i. Avoiding disruptions (e.g. pipeline failures, embargoes)
ii. Ensuring adequate reserves and infrastructure including generating capacity
iii. Managing import dependence and source diversity

Affordability

In the energy trilemma literature, affordability is considered under "energy equity," (World Energy Council, 2022) i.e., whether individuals and firms can attain modern energy at prices and initial costs that they can affordably control, while systems remain economically viable. From the perspective of domestic welfare, (Bouzarovski & Petrova, 2015) defined affordability in the context of domestic energy deprivation (also referred to as energy/fuel poverty) as the failure to attain enough energy services as a result of low income, high cost, and inefficient dwellings or appliances. Remedies involve targeted income support, tariff design that protects essentials, and structural efficiency gains to reduce energy needed for comfort (Bouzarovski & Petrova, 2015).

From a systems and policy perspective, the IEA establishes affordability with exposure to fuel and wholesale price volatility and the design of policies to cushion vulnerable consumers without distorting incentives. The governments of nations across the world collectively invested ~USD 900 billion in affordability policies (such as transfers, temporary tax relief, and utility compensation) between the price spikes of 2021–2023, while longer-term solutions are targeted support, demand-side efficiency, and better market design (International Energy Agency, 2024). For measurement, (Hills, 2012) proposed the UK "Low-Income High-Costs (LIHC)" indicator as households are fuel-poor when they possess relatively low incomes and energy expenditures that are above a modelled threshold. This is an approach that measures both the prevalence and the severity of affordability problems (Hills, 2012).

All the definitions above focus on different perspectives on affordability. For example, Bouzarovski & Petrova, 2015 talks about affordability in relation to household or domestic use, while (IEA, WEC) talks about how markets, networks, and policy keep prices reasonable and stable across households and industry, without compromising investment or efficiency. Energy access and energy affordability have profound implications on human happiness, welfare, and quality of life. Energy affordability is the accessibility and affordability of energy supply across a given population (World Energy Council, 2020). The focal point when selecting indicators for the affordability dimension is on the economic accessibility of electricity. This includes factors such as average electricity tariffs, the share of household income spent on energy, and the cost structure of electricity generation and distribution. Affordability indicators capture how well the energy system balances cost recovery for utilities with the ability of households and businesses to pay for reliable electricity services (Sovacool, 2012). This study looks at affordability as the ability of households to have adequate energy services in the form of prices and connection charges that do not put their budgets under too much pressure and in a form that makes utilities sustainable.

Sustainability

Just like the other two dimensions, there is no single universally agreed definition of energy sustainability. However, most frameworks see it as the long-term ability of energy systems to meet present needs without compromising environmental, social, and economic well-being.

Beyond lowering greenhouse gas (GHG) emissions, improving efficiency, and shifting to cleaner fuels, sustainability also includes ensuring that energy systems support social equity such as access to affordable and modern energy for all and economic resilience (like stable energy prices, sustainable jobs, and efficient resource use). According to (Kumar et al., 2017), sustainable energy must balance environmental protection with social inclusiveness and economic development, thereby making it both a technical and societal goal. From a global policy perspective, sustainability corresponds with the environmental component of the energy triangle, which prioritizes climate change mitigation, air quality improvement, and the decarbonization of the energy system. Sovacool (2012) says that sustainability in energy systems means reducing environmental externalities like CO_2, methane emissions, and local air pollution (such PM2.5), as well as making sure that resources are used responsibly and that the ecosystem stays in balance throughout time.

The International Energy Agency (IEA) links energy sustainability to environmental outcomes at both the global and local levels. At the global level, it focuses on slowing climate change by lowering greenhouse gas emissions, especially carbon dioxide and methane. The IEA focuses on air quality, clean cooking technology, and energy efficiency at the local level. This is especially important in developing areas where using energy in ways that are wasteful or harmful to the environment is connected to ill health and environmental deterioration.

In this research, sustainability is assessed through the perspective of emissions impact, pollution and health impact, and energy productivity and efficiency (GDP per unit of energy use). When choosing sustainability indicators, the focus is to look at how the energy system helps long-term climatic and environmental goals without harming people and the environment. This research emphasizes that a genuinely sustainable energy system must not only enhance accessibility and maintain supply security but also guarantee that these objectives are achieved without compromising environmental degradation or inducing long-term climate instability.

The research now considers a case- by-case study of how developed nations like Germany make use of the energy policy triangle and draw similar comparisons to West Africa.

1.2 The Energy Policy Triangle in Developed Countries: The Case of Germany

The energy policy triangle have been applied broadly in developed countries as a means of developing and evaluating national energy policy. To start with, Germany is the most prominent example of the practical application of this triangle. It is the bedrock of their long-term energy transition policy (Energiewende) (Okoduwa; Energieverbrauch, 2023).

Examining how Germany has embraced each of these pillars in the triangle gives a clear insight about real-world energy transitions' trade-offs and synergies. The discussion in the following section addresses how Germany has approached each of the triangle's pillars, beginning with supply security.

Supply Security

Germany has always made energy supply security a priority by being part of the European energy market and getting energy from different sources. Germany wanted to diversify its energy sources and enhance power and gas exchanges with other nations (International Energy Agency, 2022) so that it wouldn't have to rely on just one energy supply. But even with these measures, the country still relied largely on Russian natural gas, which made up more than half of its gas imports before 2022. This made it vulnerable to supply shortages when delivery was cut off (Morris & Jungjohann, 2016).

As a result of this, Germany quickly started making changes to strengthen its supply security. One important step was to speed up the introduction of renewable energy, like wind and solar power, to depend less on imported fossil fuels (Xie et al., 2023). Also, Germany quickly worked to get gas from other places, including building new liquefied natural gas (LNG) terminals and importing more LNG from suppliers around the world (Kuleshova, 2023). These steps match the European Union's (EU) wider energy plans, which focus on being resilient and independent (Cherp & Jewell, 2014b).

Germany is also still putting money into smart grid technologies, storage options, and interconnectors across borders to make the system more flexible and lower the chances of supply issues (Hartz et al., 2023). The joint effort to consider both national interests and EU energy cooperation has made Germany stronger in making sure energy delivery is secure, stable, and sustainable.

Affordability

Germany's Energiewende, its plan to switch to green energy, has had mixed results when it comes to how much people pay for energy. Moving to green energy has created jobs, helped local economies grow, and encouraged new ideas in industries like wind, solar, and green tech, but it's also made electricity more expensive for homes (IEA, 2023). At first, people paid for expanding green energy through feed-in tariffs (FiTs) and improvements to the power grid, which led to some of the highest electricity prices in Europe (Häseler & Wulf, 2024; Hartz et al., 2023).

Feed-in tariffs, specifically, promised set payments to green energy producers. This encouraged them to produce more, but it also locked in long-term costs that people had to pay through a charge related to the Renewable Energy Act (EEG). These costs hit low-income homes harder and raised questions about whether the energy switch was fair to everyone (Brauers et al., 2021). Also, the growing need to update and expand the power grid to handle energy production from many different places has pushed prices up even more (Schmidt & Huenteler, 2016).

To deal with these price problems, the German government has put in place policies to help, such as energy subsidies, changes to the EEG charge, and tax breaks for both homes and energy-intensive businesses (Suedekum, 2023; Häseler & Wulf, 2024). For example, the abolition of the EEG charge in 2022 was a significant step toward lowering household electricity bills, with the costs of supporting the energy transition instead covered through federal budget allocations, revenues from carbon pricing, and dedicated climate and energy investment funds (Korten & Korten, 2024).

Also, Germany's welfare programs, like housing aid that considers energy costs and more government money for energy-efficient home upgrades, show an overall plan to protect those who are struggling while moving forward with the Energiewende (Institute, 2022). These actions show the difficult balance Germany is trying to strike between its climate goals and making sure its citizens can afford energy.

Sustainability

The energy plan of Germany focuses on being eco-friendly, a key part of the country's energy transition. Germany wants to cut down on greenhouse gas emissions, promising to have no climate impact by 2045. One step is to produce 80% of electricity from renewables by 2030 (Hartz et al., 2023). This is in line with the European Union's Green Deal and the Paris Agreement.

A key part of Germany’s green plan is getting rid of nuclear and coal energy. The remaining nuclear plants closed in 2023 after the decision to remove nuclear energy after Fukushima. Coal, once a big source of power, should be gone by 2038, but there are discussions about doing this soon as in 2033. This means moving to cleaner energy sources such as wind, solar, and biomass, which are now the top source of electricity is a priority.

Even though Germany had issues during the 2022–2023 energy crisis like commissioning coal plants briefly to meet its energy demand, it was temporal. Germany has restated its dedication to cutting carbon emissions by investing in hydrogen, offshore wind, and better grids. Also, Germany wants to lower greenhouse gases, improve air quality, and support global climate projects.

Overall, Germany is at the fore front with regards to energy sustainability through new ideas, green policies and sticking to its green goals, even with temporary problems (Morris & Jungjohann, 2016; Andrian-werburg et al., 2023).

1.3 The Energy Policy Triangle in Developing Regions: The Case of West Africa

In West Africa, the energy policy triangle (affordability, supply, affordability, and sustainability) is now being considered as a policy tool for regional energy planning and strategy development. Although its application remains uneven, some countries such as Côte d'Ivoire, Ghana, Nigeria, and Senegal have sought to reconcile these interlinked objectives against constraints in infrastructure, governance, and finance (International Energy Agency, 2022; Brief, 2008). The following sections cover how each aspect is being tackled across the region, beginning with supply security.

Supply Security

Energy supply security is still a big problem in West Africa. This is because the region is faced with limited power generation, old transmission lines, and too heavy a dependence on fossil fuels and hydropower. As a result of these issues, the region is at risk of problems, like changes in global fossil fuel prices and climate change affecting water supply (Ofosu-peasah & Sustainability, 2024). Many West African countries often face power outages, low electricity access in rural areas, and large losses during transmission, which makes the power supply system weak.

Some countries are making progress on their own. For instance, Ghana and Côte d'Ivoire are working to use different energy sources, mostly by creating natural gas infrastructure, investing a bit in renewable energy, and using independent power producers (IPPs) to stabilize the local power supply (International Energy Agency, 2022). Ghana has put money into gas-to-power plants and deals to sell power to neighbouring countries. Nigeria, on the other hand, even though it has the region's biggest gas reserves, struggles with an unreliable power grid, inadequate finance on transmission, and ongoing gas flaring, which stops it from turning its resources into a secure power supply (Sambo & Sule, 2023).

The West African Power Pool (WAPP) was created to improve energy security by trading electricity across borders and sharing power resources. WAPP hopes to lower costs and make the system more reliable through regional integration. However, this integration is limited because of technical and political issues, different regulations, and infrastructure problems

(Fiber, 2023; Ogbonna, 2024). Also, lot of more money is needed for the investment in interconnection projects, dispatch coordination, and aligning market rules.

Overall, even though some countries have started reforms and regional cooperation is increasing, West Africa's energy supply security is still unstable. Massive investments are needed in different power sources, transmission improvements, and regional management.

Affordability

The cost of electricity in West Africa is still a major concern, even though more people, particularly in cities, have gained access to it recently (Baskaran & Coste, 2024). Many people can't afford electricity because of its high cost. The main reasons for these high prices are the reliance on imported fuels, poor cost-recovery methods, and old or inefficient infrastructure. These factors increase the costs of generating and distributing electricity, making it harder for people to afford (International Energy Agency, 2022).

Nations such as Nigeria and Senegal have tried to lower consumer costs by using government money to subsidize fossil fuels. Again, such actions have caused large financial burdens and market problems. Often, richer residents are the ones who gain the most, while there is less funding for clean energy infrastructure (Soile & Mu, 2015). While subsidies are popular among citizens, they decrease the desire to save energy, and they often take the place of better-focused social support actions.

Ghana and Côte d'Ivoire have expanded access to electricity, but they still haven't changed their tariff systems completely. The changes in tariffs have been delayed because of political happenings, public opposition, and worries about what residents can afford. If utility companies want to do better and more private companies want to join in, it's important to set up tariff models that reflect the true cost. Often, electricity prices do not equal the actual cost of providing the service. This causes constant underinvestment and unreliable service.

Also, many people depend on fossil fuels, like diesel generators, to make up for unreliable grid electricity. This dependence makes it hard for people to get out of energy poverty. Lower-income groups spend a larger part of their money on energy needs (International Energy Agency, 2022). Many homes are still cut off from modern energy because they cannot connect and because they cannot afford it, even if they have access to the grid.

To deal with electricity affordability in West Africa, reforms are needed. These reforms should ensure fair cost recovery while promoting clean, local energy to reduce dependence on costly alternatives.

Sustainability

West African nations are starting to include environmental considerations in their energy plans, but they need to move faster because climate and health dangers are increasing. Some countries, like Ghana and Senegal, have created renewable energy plans to push solar, wind, and hydropower as part of their energy transition plans (Nnaji et al., 2025). In Côte d'Ivoire, solar power projects backed by groups such as the African Development Bank (AfDB) and GIZ are increasing energy access in rural areas and diversifying the types of power available (Renewable & Agency, 1981). These initiatives reflect growing political commitment, but large-scale implementation still faces institutional, financial, and technical barriers. Even with these policy attempts, biomass is still the main energy source in rural areas, making up over 80% of energy use, mostly for cooking and heating (Ngwa, 2024). This heavy use of wood and charcoal adds to deforestation, loss of biodiversity, and indoor air pollution, which are bad for health, especially for women and children (Williams et al., 2012). Also, few people have access to clean cooking tech, with numbers below 15% in countries like Nigeria, making the transition to sustainable household energy a pressing priority (Yetano Roche et al., 2024; Maitama, 2024). Even though many West African countries have made climate action plans and sent in their Nationally Determined Contributions (NDCs) under the Paris Agreement, putting them into action and checking on them is often weak or doesn't have enough resources. For instance, there are policies to increase energy savings and lower emissions but putting them into action is stopped by a lack of tech knowledge and organizational teamwork (United Nations Environment Programme (UNEP), 2016). Also, climate funds for this area are still not enough, with promised help from other countries often late or not given, which limits governments' ability to increase sustainable energy structures (Adeoye, 2024).

In general, while environmental sustainability is getting more attention in policy discussions, achieving it in practice requires stronger governance, more robust financing, and deeper integration of clean energy technologies into national development strategies.

At this point a clear comparison can be made to see how the supply systems differ between the two regions.

The energy policy triangle: compared Germany vs West Africa

Table 1: Comparison of Energy Supply Systems: Germany vs. West Africa

DIMENSION	GERMANY	WEST AFRICA
Infrastructure development and grid reliability	Highly developed, automated, and reliable grid with >99% access; smart grid integration	Fragmented, underdeveloped infrastructure; low reliability and frequent outages
Diversity and security of energy supply	Diverse energy mix (renewables, gas, imports); strong strategic reserves and international cooperation	Narrow energy mix (hydro, diesel, gas); vulnerable to climate and price shocks
Integration of renewable energy	Over 40% renewable electricity; advanced integration through supportive policy (e.g., feed-in tariffs)	Abundant renewable potential but limited integration due to financial and regulatory barriers
Regional cooperation and market integration	Part of the EU integrated market; strong regulatory coordination and energy trading	Emerging coordination through WAPP; operational and regulatory challenges persist
Strategic policy alignment and long-term planning	Long-term, integrated policy planning (Energiewende); clear phase-out timelines and carbon pricing	Policies often address individual objectives (e.g., access, affordability) without integrated trade-off frameworks
Capacity for innovation and data-driven decision-making	Strong institutional and research capacity; robust data systems and technological innovation	Limited data availability, technical capacity, and institutional coordination for evidence-based policymaking

1.4 Trade-offs in the Energy Policy Triangle

The energy policy triangle model represents the inherent trade-offs between three fundamental goals (affordability, supply security, and sustainability). Though energy policy would prefer to reconcile all three, advancements in one area tend to involve hindrance in another. The following describes the main trade-offs and typical examples.

Supply Security and Sustainability

Supply security can undermine environmental objectives; for instance, countries can transition to domestic fossil fuels or delay phasing out coal in a bid to reduce reliance on imports, especially during crisis. This is visible in the case of Germany energy response to the 2022 Russia–Ukraine conflict. There was a recall for the use of coal facilities temporarily, thereby increasing CO_2 emissions (Cherp & Jewell, 2014; Mišík, 2016). On the other hand, critics argue that a rapid shift to weather-dependent renewables (like wind and solar) can pose risks to electricity supply security due to their intermittent nature. But it's crucial to remember that both problems can be lessened: Investing in grid interconnectivity, flexible backup systems (such hydrogen and batteries), and demand-side management will help keep the power supply stable during times of change. This means that we won't have to rely on fossil fuels as much. To make renewable energy more reliable and resilient, we need to diversify our sources, balance them across regions, and come up with innovative technologies like smart grids and storage.

Affordability and Sustainability

Transition to renewables generally have an initial costly up-front investment. This has the implication of raising production costs in the short run. An example of this is Germany's Energiewende. Although it is environmentally progressive, it allows for higher residential electricity costs because of feed-in tariffs and infrastructure expenses (Morris & Jungjohann, 2016; Apergis & Payne, 2013; Wicker & Becken, 2013).

Affordability and Supply Security

Government policies that maintain low consumer energy prices, such as fuel subsidies, reduce the economic incentive to invest in energy infrastructure and cause energy supply volatility (Ofosu-Peasah et al., 2024; Bazilian, Nussbaumer, et al., 2012). An example is Nigeria's fuel subsidy crisis.

In general, the triangle is the broader issue of attempting to achieve all three goals simultaneously. Many authors like (Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. 2009) have applied multicriteria approach in evaluating countries' performance on the triangle. This gives an optimality on one side while compromising another.

Managing Trade-offs

In relation to the second research question (RQ2), the analysis shows that both Germany and West Africa face clear trade-offs. Germany managed them through welfare programs and policy stability, whereas West Africa has relied heavily on subsidies, which undermines long-term sustainability and financial viability.

The energy policy triangle: compared Germany vs West Africa

Table 2: Comparison of Energy Policy Trade-offs: Germany vs. West Africa

DIMENSION	GERMANY	WEST AFRICA
Supply Security vs. Sustainability	Balanced through diversified energy mix and strategic reserves; phase-out of coal/nuclear managed with renewable scale-up.	Tensions exist e.g., overreliance on hydropower can compromise supply security in dry seasons. Fossil fuels still dominate.
Affordability vs. Sustainability	Higher upfront costs for clean energy are mitigated by policy support (such as subsidies, feed-in tariffs); energy poverty low.	Clean energy seen as costly; affordability prioritized, often at the expense of long-term sustainability.
Supply Security vs. Affordability	Stable supply systems allow market regulation to keep costs competitive, reliance on imports strategically managed.	Weak infrastructure raises costs of maintaining secure supply, frequent outages and fuel import volatility increase prices.

In conclusion, Germany's implementation of the energy policy triangle illustrates the challenges of balancing affordability, supply security, and sustainability. Its experience provides important lessons for developing countries, particularly in the domains of institutional coordination, policy stability, and public participation in energy transitions.

Trade-offs are evident strongly in the West African scenario. Policies to increase supply through fossil fuel production threaten sustainability targets, and subsidy removal threatens unaffordability and social equity. For example, Nigeria's earlier attempts at containing fuel subsidies have already attracted protests from the public (Njoku, 2025). These stresses are further influenced by institutional coordination and long-term planning weaknesses. Regional cooperation, donor assistance, and decentralized renewable energy technologies are, however, positive paths to a cleaner energy future.

Moving forward, this research considers having some institutional factors that can help shape policy outcome in developing regions such as West Africa.

1.5 Institutional Factors to Help Shape Energy Policy Outcomes in West Africa

Regulatory Quality

Regulatory quality is central in determining the effective implementation and efficiency of energy policy, and particularly so for long-term infrastructure investment and roll-out of renewable energy. High-quality institutions are transparent, predictable, and capable of enforcing laws, thereby creating a stable policy environment that encourages private sector participation and attracts long-term capital investment into the energy sector (Helm, 2004).

This is especially crucial for renewable energy programs, which generally require capital spending with lengthy payback periods. Investors need to believe that policy actions like feed-in tariffs, tax relief, and grid connection policy will be stable and consistent in the long run (Directory, 2025). High regulatory quality also facilitates the ease of competition to occur, spur innovation, and builds public confidence in energy transitions.

Weak regulatory frameworks, conversely, have the potential to trigger underinvestment, inefficiency, and corruption. Where legislation is unclear, uncertain, or inadequately enforced, energy developers are in a high-risk profile that raises the cost of capital or discourages investment, at least. For example, misplaced subsidies wrongly push energy markets to fossil fuels at the expense of cleaner energy technologies, and poorly crafted tariffs end up being punished to efficiency or deceptive in reporting actual system costs (Ofosu-Peasah et al., 2024; Njoku, 2025). In all developing and poor countries, absence of an independent regulatory commission or politicization of regulation compromises policy effectiveness and accountability (Kuzemko et al., 2016). Furthermore, regulatory capture, procurement concealment, and undue delays in licensing may hamper the development of renewable energy and result in energy access gaps (Seetharaman et al., 2019). It is therefore important that regulatory institutions are made stronger and independent to be able to lead sustainable energy transitions, particularly within the Economic Community of West African States (ECOWAS), where poor regulation is still a significant barrier to scaling up clean energy (Nnaji et al., 2025; International Energy Agency, 2022).

Policy Continuity

Policy stability is one of the strongest pillars of successful energy transitions, especially given that the processes of setting up the energy system take decades and involve huge, long-term capital (Quitzow et al., 2024). Stable and predictable policy environments are those that encourage investors and developers to invest in renewable energies, grid smartening, and the roll-out of low-carbon infrastructure (Quitzow et al., 2024). These are high capital expenditure, long payback period investments and therefore highly sensitive to policy and regulation risk. Where the governments commit themselves for the long term e.g., renewable capacity targets, emission reductions, carbon pricing and pass enabling legislations within a timeframe, it is a sign of predictability and credibility to market actors (Sovacool et al., 2017; International

Energy Agency, 2022). This would be particularly crucial for emerging markets, whose political and policy-level risk perception already is very high.

Successive policy reversals, unprecedented implementation pathways, or politically motivated policy switches in the energy sector can, however, drain investor's confidence and dampen momentum. Sudden changes, i.e., phase-out of feed-in tariffs, or sudden subsidy reductions can result in stranded assets, freezing investments, or lawsuits (International Energy Agency, 2022, 2023). Political cycles that are shorter than the long-term climate or energy targets also undermine credibility and introduce inefficiencies in project planning and financing. For instance, tenders for renewable energy or power purchase agreements were put on hold or cancelled in some developing economies following a change in government, which affected foreign and domestic investor confidence (Steffen & Schmidt, 2021). Therefore, institutions that can guarantee the implementation of policies in the long term e.g., independent regulatory bodies or national energy transition councils can prevent such risks. The energy planning in the long term, national development planning, climate action, and politically backed energy plans must be included to avoid derailment and to have a just and smooth transition (Porten-Cheé, 2020; Kuzemko et al., 2016).

Governance and Institutional Capacity

Successful national energy policies must be accompanied by good governance and institutional capacity as the foundation upon which they are implemented. In addition to having clear, stable policy objectives, governments must also have these highly coordinated among ministries, departments, and regulatory institutions, and have them backed by appropriate implementation mechanisms (Libecap & Lueck, 2011). This requires institutionally strong organizations with mandate, resources, and technical capacity to convert energy plans into quality programs, apply rules, and monitor progress in the long term. Country governance structures in nations that have successfully coerced energy transitions, like Germany, are characterized by institutional coordination, cross-agency coordination, and long-term planning capacity (Quitzow et al., 2024; Sovacool & Hess, 2017). These traits enhance accountability, reduce fragmentation of bureaucracy, and realize efficient mobilization of private and public capital.

Poor governance, on the other hand, erases the effectiveness of institutions of power and results in inefficiency, wastage of resources, and chronic imbalances in access to power. Poorly designed energy frameworks are unevenly supported by duplicative mandates, coordination gaps, corruption, and politicization of energy price or infrastructure choices (Newell, 2019).

Double ministry restrictions, senior staff turnover, and low enforcement levels in most Sub-Saharan African nations discourage goal achievement in the renewable energy or electrification market (International Energy Agency, 2022; ECREEE, 2020). Policy reversals that further diminish investors and public confidence are also attributable to poor governance, along with procurement inefficiencies and dormant infrastructure. Institutional responses like civil servant training, decentralization of plans, and increased public participation can be extremely effective in improving energy service delivery and fostering more sustainable and equitable transitions (International Energy Agency, 2022; Kuzemko et al., 2016). Institutional building capacity is not a technical requirement but a political and development one.

Institutions can have good energy policy if they have good regulation and good governance. Even with the best conceived energy projects, they will fail if they do not have these. This can occur when the law is not being enforced effectively, the law is shifting, or the groups are not harmonious. Such institutional emphasis is particularly pertinent in West Africa, where energy transitions are held back by weak governance, a lack of regulatory autonomy, and political instability.

The next section discusses research on West African energy security and policy. It speaks about the technical and financial issues, and the institution and governance issues, that continue to harm the region's energy sector.

The second section speaks about regional initiatives such as the ECOWAS Renewable Energy Policy (EREP) and the West African Power Pool (WAPP), and what has occurred within each country. It enables one to see how different parts of the institution impact the entire region.

1.6 Review of Literature on Energy Security and Policy Research in West Africa

West African energy security and policy studies emphasize the long-standing issues in the availability of energy access, reliability, and affordability (Nnaji et al., 2025). Again, these studies discuss the institutional and governance arrangements that interact to address these deficits. Subregional initiatives such as the ECOWAS Renewable Energy Policy (EREP) and the West African Power Pool (WAPP) were established to drive integration, improve supply security, and expand access through coordinated infrastructure development and regulatory harmonization (Nnaji et al., 2025; International Renewable Energy Agency, 2018). EREP, approved in 2013, mandated that the share of renewable energy in the regional energy mix be increased from 10% by 2020 and to 19% by 2030 (Hyacinth et al., 2012). WAPP established in 1999, to work towards developing a power market at the regional level by means of national interconnection of grids and enabling cross-border electricity trade for balancing energy deficiencies and optimal use of resources (WAPP, 2019).

Despite such initiatives, the region remains plagued by systemic imperfections in the form of ancient, inadequate infrastructure, unstable regulatory regimes, and chronic underinvestment (Ganguly et al., 2012). Most national grid systems are not interconnected or weakly linked, limiting the scope of WAPP's regional power pool (Sovacool et al., 2016). Also, attempts to implement EREP have been constrained by weak national capacity to implement and execute regional targets, coordination problems within institutions, and investor unwillingness based on governance risk and perceived policy risk (Bazilian, Rice, et al., 2012).

Financing gaps are one of the key constraints as the region has only been able to entice a marginal proportion of foreign investment into the energy infrastructure, far too frequently due to high risks for projects, low creditworthiness of utilities, and macroeconomic volatility (Eberhard, A., & Gratwick, K. 2015). Regulatory bottlenecking moralized in opaque tariffs, non-cost-reflective tariffs, and competing institutional mandates also deter private sector investment and delays placing projects (Aboua & Toure, 2018; Arias & Naranjo, 2014). These challenges require not only technical and economic response but additional institutional change and political will to achieve energy, security and sustainable development in West Africa. West Africa is faced with two major challenges which are discussed below.

Energy Security Challenges

West Africa is characterized by low levels of electrification, frequent blackouts, and dependence on fossil fuels and biomass. Energy insecurity hinders industrialization, health, and education, perpetuating cycles of poverty.

Policy and Institutional Framework

Some regional institutions have been established to coordinate energy policy, including the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), which is actively promoting sustainable energy solutions. National energy policies also differ greatly in both scope and implementation success, reflecting the range of political will, technical capacity, and quality of governance.

The challenges discussed above revealed that West Africa's energy sector needs a more coordinated, well-governed, and well-financed regional approach to ensure sustainable and reliable energy access across the region.

This study points out key differences and similarities in the progress of energy security and policy across Côte d'Ivoire, Ghana, Nigeria, and Senegal. The energy situation in each country is different, depending on available resources, governance, markets structure, and what each country considers important for its people and economy.

Côte d'Ivoire

Côte d'Ivoire is often seen as a good example in West Africa when it comes to energy stability and working with other countries. It has one of the most stable and varied energy systems in the area, mainly using hydropower and natural gas from within the country (Obahoundje & Diedhiou, 2022). As of 2021, over 65% of its power-generating capacity came from gas-fueled plants, and most of the rest was from hydroelectric sources (Mewenemesse & Yan, 2022). The government has been actively growing its power lines and selling electricity to neighbouring countries through the West African Power Pool (WAPP), sending power to countries like Ghana, Burkina Faso, and Mali (Energie, 2020).

Even with its progress, getting electricity to rural areas is still a key goal. The country is working on extending power grids as part of its National Development Plan. Also, Côte d'Ivoire is paying attention to getting private companies involved, such as independent power producers (IPPs) and foreign investment in renewable energy, as it aims for universal access by 2030 (Dabla & Goldthau, 2023).

Ghana

Ghana has come a long way in giving more people access to electricity and using a wider mix of energy sources, but it still has some basic problems. Over 85% of the population can now get electricity, but the system struggles with subsidies that cost too much, losses from government-owned power companies, and high losses during transmission and distribution (Ofosu-Peasah et al., 2024; Plan, n.d.). Ghana is moving towards a more dependable energy system by using natural gas, hydropower, and new solar technologies.

To help with this change, Ghana started the Renewable Energy Master Plan (2019) and has put the Scaling-Up Renewable Energy Program (SREP) into action. The goal is to have renewable energy account for 10% of electricity generation by 2030 (Obiora et al., 2024; Akom et al., 2020). However, bottlenecks in project financing, regulatory clarity, and grid integration remain challenges to full implementation.

Nigeria

Nigeria is suffering from long-term energy insecurity amidst abundance of fossil fuel reserves. It has Africa's largest natural gas reserves and lots of oil, but its power sector suffers from an unreliable grid, frequent power outages, and low access rates, especially in rural (NERC, 2024;

Eweka et al., 2022). The transmission system is a major weak spot, with usually less than 5,000 MW of electricity delivered, even though the installed capacity is over 13,000 MW (Samuel et al., 2024).

The power sector has witnessed reforms such as the Multi-Year Tariff Order (MYTO) and by breaking up the power sector to some extent, but progress has been slow because of a lack of investment, poor enforcement, and political meddling. As a result of this, there is growing support for local energy solutions like solar mini-grids and individual systems, helped by the Rural Electrification Agency (REA) and projects supported by donors (World Bank, 2018; Toyin et al.; 2023).

Senegal

Senegal is trying to be a leader in the region by giving more people access to electricity, especially through its Plan Sénégal Émergent (PSE), which focuses on upgrading infrastructure and getting private companies involved. The country has gained attention for its work in setting up solar and wind power projects, like the Taiba N'Diaye wind farm, which is the largest in West Africa (International Energy Agency, 2023).

Partnerships between the government and private companies have allowed for quick growth in power generation, but making sure tariffs are affordable and that rural areas have a reliable supply are still critical problems. Over 30% of rural households still don't have consistent electricity access and many rely on expensive off-grid options. Senegal's policies are shifting towards using electricity efficiently, setting energy efficiency standards, and planning the grid in a joined-up way (Hirsch, 2021; Gopalakrishnan & Miller, 2023; van den Bold, 2022).

1.7 Research Gaps on Energy Policy Triangle in West Africa

While many countries in the region have renewable energy action plans, these often focus heavily on expanding access and affordability without systematically integrating energy security and environmental sustainability. There is limited analysis on how scaling up renewables impacts overall energy system reliability and long-term sustainability goals.

The common identified gaps are stated below.

I. ***Integrated Assessments in West Africa***

Most West African energy research (Dzamesi et al., 2024; Hafner & Raimondi, 2022) addresses issues like access or affordability in isolation, rather than in an integrated way. There is lack of sufficient integrated analysis that considers supply security, affordability, and sustainability in conjunction with one another in alignment with the energy policy triangle. For instance, policies that expand access without considering affordability can leave electricity unaffordable for households, while affordability-focused subsidies often undermine both supply security and sustainability by discouraging cost-reflective tariffs and reinforcing fossil fuel dependence. This hinders the region from considering trade-offs and development of balanced energy policy. Comparative, system-level, country-to-country analysis is specifically lacking.

II. Lack of Trade-off and Comparative Benchmarking Studies

Most research lack comparative benchmark, example (Nunoo et al., 2025, comparing Ghana and Nigeria) with advanced economies such as Germany. This reduces the potential for policy learning and strategic alignment. The comparison is below the region's capacity to develop evidence-based, balanced energy transitions that are contextually relevant yet internationally informed.

To address the analytical gaps that limit the region’s capacity to develop well-balanced, resilient, and forward-looking energy policies using the triangle, here are some possible suggestions that can be considered.

1.8 Possible Suggestions to Bridge the Energy Policy Triangle Research Gap in West Africa

I. **Integrated Assessments in West Africa**

To close this gap, West African energy planning should make the Energy Policy Triangle a permanent decision-making tool. This way, every national plan, least-cost expansion study, and regional strategy can be looked at for (affordability, supply security, and sustainability) all at once instead of separately. Energy planners can apply the EPTI/MCDA procedure from this research and recommend each country to update their EPTI once a year. This necessitates a unified ECOWAS dataset that includes not just access and tariffs but also effective household costs in areas with prevalent self-generation, reliable capacity, sufficient interconnection, technical and commercial losses, and carbon intensity. The integrated evaluation should include scenarios to evaluate plans against droughts in hydrology, gas supply shocks, and spikes demand. The results should then be used directly in tariff reforms, grid investment programs, and clean-firm capacity procurement. Capacity building is important. Regulators, utilities, and planning units need to learn how to copy the index and understand trade-offs. Universities and think tanks can help with methods, and an open data portal to make sure that data is available for everyone to use.

II. **Trade-off and Comparative Benchmarking Studies**

To address trade-offs at regional level, ECOWAS should have a dashboard that can provide country scorecards, let users create policy-relevant weighting scenarios (for example, focusing on affordability, security, or sustainability) and add dates to scores to show events like new interconnectors, fuel-supply contracts, and droughts results. Structured partnerships across European institutions, such as pairing regulators with system operators, can put benchmarking into action on issues including loss-reduction initiatives, auction design, interconnector operation, and ancillary-service markets. At project appraisal, development partners should request an EPTI style trade-off analysis and employ dimension targets in results frameworks. This way, savings on costs do not come at the cost of reliability or emissions. Finally, to make sure that people use the benchmarking, it should be followed by short policy notes and country workshops that turn the comparative findings into action plans, such as what to build, in what order, and who pays. This way, West African transitions can stay relevant to their own situations while still being informed by international best practices.

The next aspect of this research looks at the socio-economic landscape of West Africa and Germany. It is essential to have an insight of the socio-economic landscape of West Africa and Germany, since they both differ in development levels, institutional capacity, and economic structures. This strongly influences how energy security, affordability, and sustainability are prioritized. An overview of two metrics (GDP, Industrialization) as key drivers of economic development in West Africa is also mentioned of.

1.9 Socio-Economic Landscape and Development Metrics in West Africa and Germany

a. Socio-Economic Situation of West Africa

West Africa is among the regions across the globe that faces extreme development constraints. The region has more than 430 million people and is marked by widespread poverty, under-industrialization, and persistent energy insecurity (UNSD, WHO, IEA, IRENA, 2025). GDP growth is still unevenly distributed. Countries such as Côte d'Ivoire, Senegal, and Niger experience higher economic growth rate of over 5%, whereas leading regional economies like Nigeria and Ghana suffer economic deceleration because of inflation, government debt overhang, and volatile commodity prices (Singh et al., 2020).

Figure 2: Map Africa and West Africa shaded in Blue

At least 36% of the population are multidimensionally poor ("African Development Bank," 2022), and there is high youth unemployment. Most individuals are in informal work, which limits social mobility and reduces returns to taxation. Infrastructure shortages, especially in transport and power, are discouragements to development. For example, rates of access to electricity are disproportionately distributed, more than 80% in Ghana, but less than 25% in Burkina Faso (Nassar, 2024). Energy insecurity is built on underinvestment, inefficiency, neglect, and poor energy governance (Ofosu-Peasah et al., 2024).

Socially, the region is experiencing the challenge of population growth, Sahel insecurity, and exposure to climate. Regional coordination through ECOWAS and clean energy and education reforms investment is addressing hope in resilience and inclusive growth (Asiamah & Agyei, 2023).

b. Socio-Economic Situation in Germany

Germany, the EU's largest and fourth-largest global economy in nominal GDP, is being reshaped socio-economically owing to crises over the past few years (Ahn, 2024). The energy crisis of the war in Ukraine led to the greatest fall in living standards in Germany since World War II with families hit by inflation and wage freeze. Low unemployment levels (about 5.8%)

inspite of it, labour shortage in major sectors and ageing population pose threats to long-term productivity (Ahn, 2024).

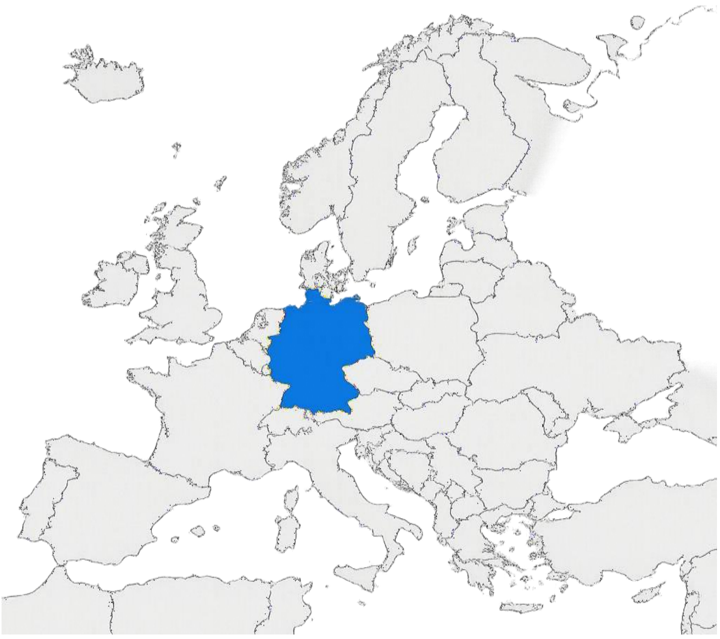


Figure 3: The EU region with Germany shaded in blue

Regional differences persist, with the country's eastern regions remaining behind industrialized Western Europe (Raimi et al., 2024). The foundation of Germany's power is robust institutions, industrial core, system of innovation, and conservative fiscal policy (Folkerts-landau, 2016). Energiewende policy has spurred the shift to a low-carbon economy whereby more than 50% of electricity comes from renewable sources (Fraunhofer Ise, 2024). Germany's sustainable development paradigm of innovation and institutional stability provides lessons that are critical to West Africa.

c. *Overview of West African Indicators of Economic Development*

To be informed about West Africa's economy, it's important to check economic development indicators such as GDP growth, industry production, and jobs. Even though the area has plenty of resources and people, it still has problems because of unstable governments, lack of investment in basic infrastructure, and too much dependence on basic industries. This part will look at GDP and industrial progress to get a good sense of how strong the region’s economy is and if it can grow steadily in the future.

Gross Domestic Product (GDP)

West African GDP growth remains uncertain due to external shocks and domestic strife. The average 2023 annual growth was 3.6%, down from 4.2% in 2022 (Callaghan et al., 2024; IMF, 2024). High growth continues in Côte d'Ivoire, Senegal, and Niger, but Nigeria and Ghana are facing inflation and depreciation of the exchange rate (Oyadeyi et al., 2025; Baba Abba et al., 2024). Regional per capita GDP remains below USD 2,500 (UNSD, WHO, IEA, IRENA, 2025).

Industrialization

West African industrialization is still in its infancy with regional GDP still below 20% (Yusuf, 2024). The economy is still agricultural and informal services dominated. Efforts like the West Africa Industrial Policy are in their infancy due to a lack of infrastructure, absent funds, and poor practice. Industrial manufacturing is highly concentrated in Nigeria, Ghana, and Côte d'Ivoire with a prejudice towards lower-value-added industries. Employment in manufacturing is still trailing at a paltry 7% (Yusuf, 2024).

Socio-Economic Contrast Between West and Germany

High per capita GDP, institutional stability, and wide energy provision make large and secure energy transition planning possible in Germany. West Africa has structural bottlenecks, energy poverty, and fast population growth, and thus the need for energy policy is access and affordability (Ahn, 2024; Ofosu-Peasah et al., 2024). It reflects the need for development and energy policy to be based on indigenous socio-economic conditions and for learning from best practice internationally.

Chapter 2: MATERIALS AND METHOD

This section presents the overall approach used to assess and compare the energy policy performance of Germany and selected West African countries. Given the complexity of energy systems and the need to evaluate multiple policy objectives simultaneously, a structured analytical framework was developed to organize and interpret relevant data. The methodology integrates quantitative indicators across the three key dimensions of the Energy Policy Triangle (Affordability, Supply Security, and Sustainability) to facilitate a balanced and evidence-based comparison between countries.

2.10 Methodological Approach Overview

The study used a Multi-Criteria Decision-Making (MCDM) framework to assess Germany and the chosen West African nations in relation to the three pillars of the Energy Policy Triangle (EPT). The MCDM is a group of analytical procedures that are used to solve complicated policy problems that involve looking at several criteria at once, some of which may be in conflict with each other. Multi-Criteria Decision-Making does not use just one metric. Instead, it has a structured, open workflow that allows you set policy goals, choose performance indicators for each goal, normalize different types of data to a common scale, give weights to show how important they are, combine scores, and rank options (in this case, countries) (Wang et al., 2009). Some common methods that use MCDM are the analytical hierarchy process (AHP, that uses pairwise comparisons to find weights), and Delphi models. The MCDM is used a lot when governments or businesses must make decisions on trade-offs while following rules (Huang et al., 2011). For example, it is utilized in energy planning (choosing technology and portfolios, designing renewable auctions, and deciding where to put plants and lines).

The Multi-Criteria Decision-Making (MCDM) framework offers several advantages that make it particularly well-suited for evaluating the energy policy triangle. To start with, it provides a holistic assessment of complex policy challenges by integrating economic, social, and environmental dimensions within a single evaluative structure, rather than focusing on one dimension in isolation. This is essential because energy policy outcomes cannot be captured by a single metric such as cost or emissions alone. Also, the method is transparent and replicable, with a structured workflow that involves indicator selection, normalization, weighting, and aggregation. This allows stakeholders to follow and critically assess how final scores and rankings are derived (Huang et al., 2011). The MCDM is flexible in handling both quantitative indicators, such as electricity prices or carbon emissions, and qualitative assessments, such as regulatory quality or institutional strength, bridging data gaps that are common in cross-country studies (Pohekar & Ramachandran, 2004). Another advantage of MCDM is that it explicitly supports decision-making in situations of trade-off, such as when a country seeks to improve affordability through subsidies but risks undermining fiscal sustainability (Kumar et al., 2017). Finally, the method has been widely applied in energy research, including in technology choice, renewable integration, and national energy benchmarking, which strengthens its methodological credibility (Huang et al., 2011).

However, the framework is not without its limitations. A major challenge lies in the subjectivity of assigning weights to different dimensions. Whether equal weighting is used, as in this study, or expert-determined weights are applied, results may be influenced by these assumptions, which may not fully reflect country-specific policy priorities (Cinelli et al., 2014). Data availability and comparability also present difficulties. While Germany benefits from rich and transparent datasets, data in West Africa are sometimes outdated, potentially affecting reliability (Bazilian, Nussbaumer, et al., 2012).

Normalization further introduces challenges because indicators measured in different units such as cents per kilowatt-hour, or renewable energy percentages can produce different results depending on the scaling method employed (Figueira et al., 2005). Another limitation is that MCDM generally provides a static assessment of performance based on the selected period. This may not capture the dynamic nature of energy transitions or ongoing reforms (Madlener et al., 2009). Finally, while the aggregation of scores offers clarity, it also risks oversimplifying complex realities by masking important contextual differences. For instance, affordability challenges in Germany stem largely from policy surcharges, whereas in West Africa they are linked to energy poverty and subsidies (Sovacool & Hess, 2017).

In light of these considerations, MCDM remains appropriate for this study because it allows for a structured and transparent comparison of Germany and West African countries across the three pillars of the Energy Policy Triangle. Its strengths in integrating diverse indicators and highlighting trade-offs outweigh its limitations, provided that results are interpreted as comparative insights rather than as absolute rankings.

2.11 Application of MCDM in this research

The application of MCDM in this research ensures that each dimension of the energy policy triangle is encompassed by relevant and measurable indicators which are normalized and aggregated in an open fashion under equal weights. The multi-year focus of this research also renders the methodology more appropriate by reflecting the dynamic nature of energy transformations, thus allowing a fair comparison between West Africa and Germany.

2.11.1 Selection of Indicators and Weighting

A total of sixteen (16) policy-relevant indicators were found and categorized along the three dimensions of the energy policy triangle. The selected indicators and the framework provided do not quantify the economic efficiency of countries (i.e., balancing costs against the benefit from resource usage). However, the focus is on measuring the countries' performance on the dimensions of the energy triangle.

The selection of indicators was guided by three main considerations. To start with, each indicator had to be directly relevant to one of the three dimensions of the energy policy triangle so that it meaningfully represented either affordability, supply security, or sustainability. The next point is that each indicator is to be measurable, with reliable and consistent data available from recognized statistical sources such as the IEA, World Bank, or national regulators for both Germany and the selected West African countries. Finally, comparability was essential, meaning that the chosen indicators had to allow cross-country application without losing their interpretive value, so that performance differences between developed and developing contexts could be assessed in a consistent way.

Equal weighting was chosen for this study because it is clear, simple, and does not rely on expert opinions like AHP does, which can lead to bias. Equal weighting ensures that no single dimension affordability, supply security, or sustainability is privileged over another, which is important given the clear different energy priorities between the Germany and West Africa. For example, West African countries tend to prioritize affordability and access, while Germany places greater emphasis on sustainability and decarbonization. Applying different weights based on current policy priorities would risk biasing the comparison in favour of one context, thereby undermining cross-country comparability. Equal weighting instead provides a neutral and transparent baseline, allowing performance differences to emerge from the data itself rather than from subjective judgments. This approach is consistent with prior comparative EPT and MCDM studies, where equal weighting has been used to ensure fairness and simplicity in multi-country assessments (Wang et al., 2009; Sovacool & Hess, 2017; Cinelli et al., 2014).

The energy policy triangle: compared Germany vs West Africa

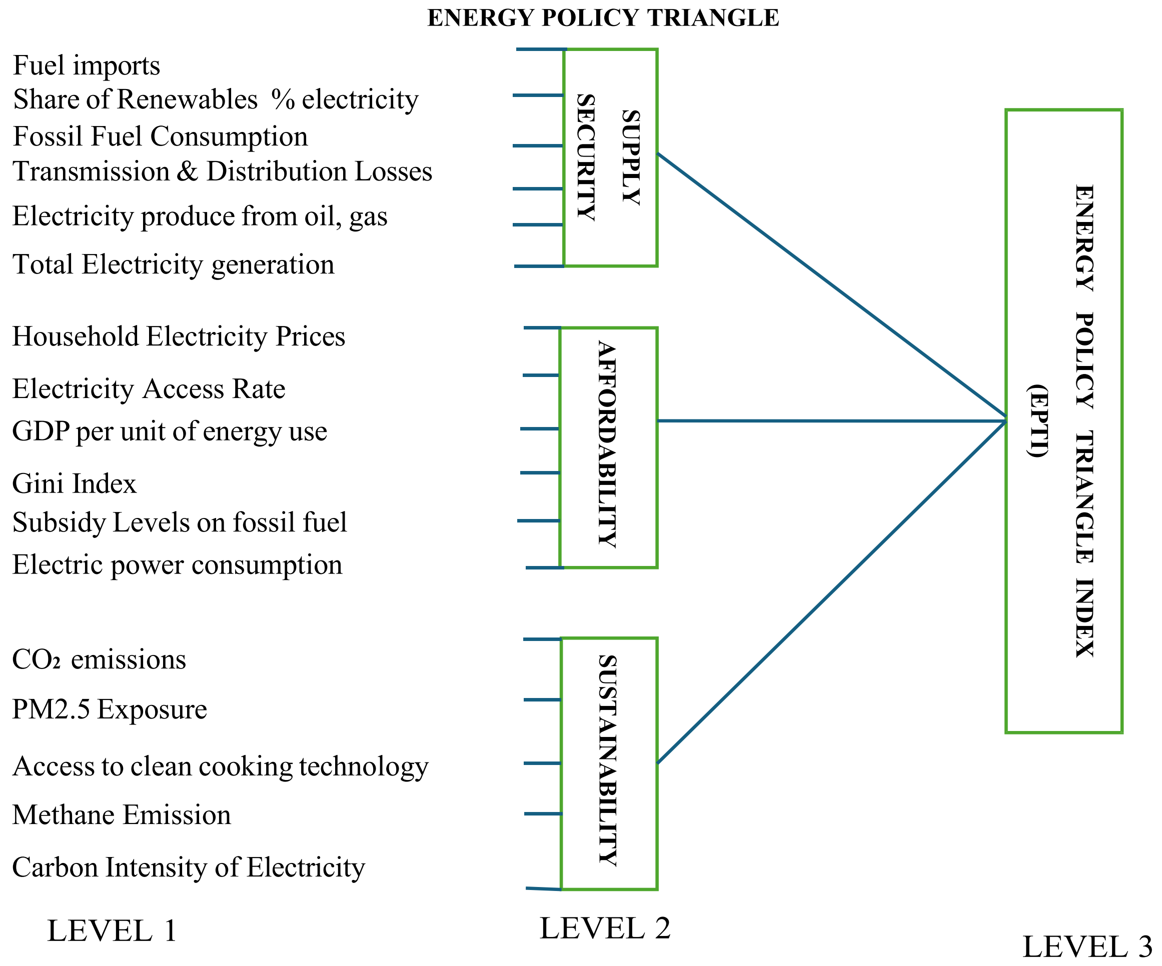


Figure 4: The Energy Policy Index

In the previous chapter (1), the definition of each dimension (Affordability, Supply Security, and Sustainability) has been discussed extensively.

Here, the focus is to justify, give relevance and direction (high or low) of the selected indicators. This clearly explains how each indicator fits into each dimension, starting with affordability.

Affordability Indicators

To select energy affordability indicators, considerations of some relative purchasing power indicators were carried out.

A country is evaluated more favourably when its households can acquire energy at a smaller fraction of their income and income is more equally distributed with less pressure from increasing prices.

Electricity Price for Households (USD/kWh): Electricity price directly impacts the cost burden on residential consumers and is a core determinant of affordability. Higher prices can strain household budgets, particularly for low- and middle-income households, and may limit electricity use for essential needs. Comparing this indicator across countries helps reveal how equitably the benefits of energy systems are distributed and whether policies are keeping energy affordable during transitions. (World Bank DataBank/Our World in Data).

Electricity Access Rate (%): Although often associated with availability, electricity access also reflects affordability, especially in low-income settings where even minimal connection fees or usage costs can be prohibitive. High access rates typically indicate successful policies in making electricity both available and economically reachable for a broad population base (World Bank DataBank)**.**

Access to clean fuels and technologies for cooking (% of population): This indicator reflects not only health and environmental sustainability but also energy affordability, as households without financial means often resort to cheaper but polluting fuels like wood or charcoal. Increasing access to clean cooking options signals progress in making modern energy services financially accessible and overcoming energy poverty (IEA, IRENA, UNSD, World Bank).

Gini index: Income inequality has a strong influence on energy affordability. In highly unequal societies, a large portion of the population may find even moderately priced energy unaffordable. The Gini Index helps contextualize energy pricing within a country's income distribution and allows assessment of whether energy systems are inclusive or disproportionately benefiting wealthier segments (Our World in Data).

Subsidy Levels on fossil fuel: While subsidies can make energy more affordable in the short term, they often distort true costs and discourage investment in sustainable energy. This indicator helps evaluate whether affordability is being achieved through economically and environmentally sound means or through dependency on government support, which may not be fiscally or environmentally sustainable (International Energy Agency (IEA).

Electric power consumption (kWh per capita): This indicator serves as a proxy for both access and affordability. Higher per capita consumption generally reflects that electricity is not only available but also used widely and affordably for productive and household activities. Low consumption may signal that electricity is either too expensive or unreliable, limiting its use even when technically accessible (International Energy Agency (IEA).

Supply Security Indicators

For the supply security dimension, we focus on evaluating a country's sensitivity to a supply disruption by considering how much fuel is imported, how resiliently it uses energy, while also considering the changes in energy use over time.

Fuel imports (% of merchandise imports): This indicator reflects a country's dependency on foreign energy sources, particularly fossil fuels. A high share of fuel in merchandise imports signals vulnerability to global price fluctuations, supply chain disruptions, and geopolitical shocks factors that can threaten national energy security. Lower dependency, in contrast, enhances supply autonomy and resilience, especially in crisis situations (World Bank DataBank).

Renewables - % electricity: A higher share of renewables contributes to long-term supply security by reducing reliance on imported fuels and finite fossil resources. Unlike fossil fuels, renewables (e.g., solar, wind, hydro) are domestically sourced and less exposed to international market volatility. This diversification strengthens energy sovereignty and system stability, especially in regions with rich renewable potential (World Bank DataBank/IEA).

Transmission and distribution losses (% of output): This indicator acts as a proxy for infrastructure quality and system reliability. High transmission & distribution losses indicate inefficiencies, technical weaknesses, or theft, which can undermine the secure delivery of electricity even when generation is sufficient. Reducing losses is essential for maintaining stable electricity supply and ensuring that generated power reaches end-users reliably (International Energy Agency IEA).

Electricity production from oil, gas and coal sources (% of total energy consumed): A high reliance on fossil fuels for electricity production indicates exposure to fuel price volatility and supply disruption risks, especially if these fuels are imported. While fossil fuels may offer short- term dispatchable power, overdependence can create long-term vulnerabilities. A lower share suggests a more balanced and potentially secure energy mix, particularly when coupled with local or renewable alternatives (Our World in Data/IEA).

Total Electricity generation (TWh): This indicator measures the total amount of electricity produced within a country. It reflects the scale and robustness of the national energy system and its capacity to meet demand. High generation levels indicate strong infrastructure and availability of resources, which are essential for energy security (Our World in Data).

Sustainability Indicators

For the sustainability dimension the impact on the environment is brought into consideration by energy sources. Also, health wise, consideration was made for people using clean cooking technologies.

CO_2 emissions (total) excluding LULUCF (Mt CO_2e): This indicator reflects the total volume of carbon dioxide emissions from key sectors of energy, industry, agriculture, and waste excluding emissions and removals from land use and forestry. It provides a comprehensive picture of the climate impact of a country's energy and industrial systems (World Bank DataBank)**.**

PM2.5 Exposure (µg/m³): This indicator measures population exposure to fine particulate matter, a major pollutant resulting from fossil fuel combustion (especially coal, diesel, and biomass). PM2.5 levels are closely linked to health outcomes and are a proxy for the environmental and social externalities of energy use (International Energy Agency IEA).

GDP per unit of energy use ($ per kg of oil equivalent): This indicator measures how efficiently a country uses energy to generate economic output. While it is primarily an economic indicator, it is strongly relevant to sustainability because it reflects the energy intensity of economic activity, which is a key driver of environmental impact. A greater value of the economic output needs less energy, which means less pollution and less resource depletion (World Bank DataBank).

Methane Emission (Mt CO_2e): it quantifies the impact of methane (CH_4) on global warming by converting it into a standardized unit comparable to carbon dioxide (CO_2). This conversion accounts for methane's greater potency as a greenhouse gas compared to CO_2, specifically multiplying the mass of methane emitted by its Global Warming Potential (GWP) (International Energy Agency IEA).

Carbon Intensity of Power (gCO_2/kWh): is a metric that quantifies the amount of greenhouse gas (GHG) emissions produced for every unit of electricity generated or consumed. This measure indicates the "dirtiness" of electricity, with lower values signifying cleaner energy sources and higher values indicating greater carbon emissions, typically from fossil fuels (Our World in Data).

Table 3: Indicators and data sources

DIMENSIONS	INDICATORS	DATA SOURCE 2008	DATA SOURCE 2020
SUPPLY SECURITY	Fuel imports (% of merchandise imports)	World Bank DataBank	World Bank DataBank
	Share of Renewables - % electricity	World Bank DataBank/IEA).	World Bank DataBank/IEA).
	Transmission & Distribution Losses	International Energy Agency (IEA)	International Energy Agency (IEA)
	Electricity production from oil, gas and coal sources (% of energy consume)	Our World in Data/IEA	Our World in Data/IEA
	Total Electricity generation - TWh	World Bank DataBank	World Bank DataBank
AFFORDABILITY	Electricity Price for Households (USD/kWh)	https://ec.europa.eu/eurostat/data/database. (Abe, 2021) (Energy Commission of Ghana, 2010) (Prizzon et al., 2024)	International Energy Agency (IEA) (*Ivory COast Solar Report*, n.d.) (U4E, 2022) (PURC, 2022) (U4E, 2022)
	Electricity Access Rate (%)	World Bank DataBank	World Bank DataBank
	GDP per unit of energy use ($ per kg of oil equivalent)	World Bank DataBank	World Bank DataBank
	Gini Index	World Bank (Index et al., 2008c) (Index et al., 2008b) (Index et al., 2008a) (Index et al., 2008d)	World Bank (Donner & Schwarz, 2020) (BTI, 2020) (Large, 2020a) (Large, 2020b)
	Subsidy Levels on fossil fuel as a % of GDP	(Collins et al., 2021) (International Monetary Fund, 2008) (New Climate Economy, 2014) (Coady et al., 2010) (Whitley & van der Burg, 2015)	Our World in Data
	Electric power consumption (kWh per capita)	International Energy Agency (IEA)	International Energy Agency (IEA)
SUSTAINABILITY	CO_2 emissions (total) excluding LULUCF (M	World Bank DataBank	World Bank DataBank
	PM2.5 Exposure(μg/m³)	International Energy Agency (IEA)	International Energy Agency (IEA)
	Access to clean fuels and technologies for cooking (% of population)	International Energy Agency (IEA) World Bank DataBank	International Energy Agency (IEA) World Bank DataBank
	Methane Emission (Mt CO_2e)	International Energy Agency (IEA)	International Energy Agency (IEA)
	Carbon Intensity of Electricity (gCO_2/kWh)	Our World in Data	Our World in Data

2.11.2 Data Collection and Normalization

Values were obtained from credible databases like the World Bank, International Energy Agency (IEA), Our World in Data (OWD), and national statistic agencies. Since indicators are in different units and scales, they were normalized using min-max scaling to enable comparison between countries.

This normalization method transforms data into scales from 0 to 1 across each indicator but rescaled the data by multiplying each by 100. The Mini-Max normalization was used to carry out this normalization process as shown below.

Min-Max Normalization Formula: $x' = \frac{x_i - x_{min}}{x_{max} - x_{min}}$ x100

For cases where lower is better (e.g. CO_2 emissions), rescaling was done i.e.:

$$x' = \frac{x_{min} - x_i}{x_{max} - x_{min}} \text{ x100}$$

Where for a particular country, say x:

x_i = original value

x_{min} = minimum value in the dataset

x_{max} = maximum value in the dataset

x' = normalized value (between 0 and 100)

2.11.3 Scoring and Aggregation

Normalized scores for every indicator were combined within their own dimensions to obtain composite scores for Supply Security, Affordability, and Sustainability for each country. These scores are used as the reference point for inter-country comparisons and trade-off analysis. To assign weight to the normalized indicators, equal weighting was across each dimension and indicator.

2.11.4 Computation of the Composite Index

The Energy Policy Triangle Index (EPTI) is calculated by normalizing all indicators, aggregating them into weighted scores for Affordability, Supply Security, and Sustainability, and then combining these dimension scores into a composite index using assigned dimension weights.

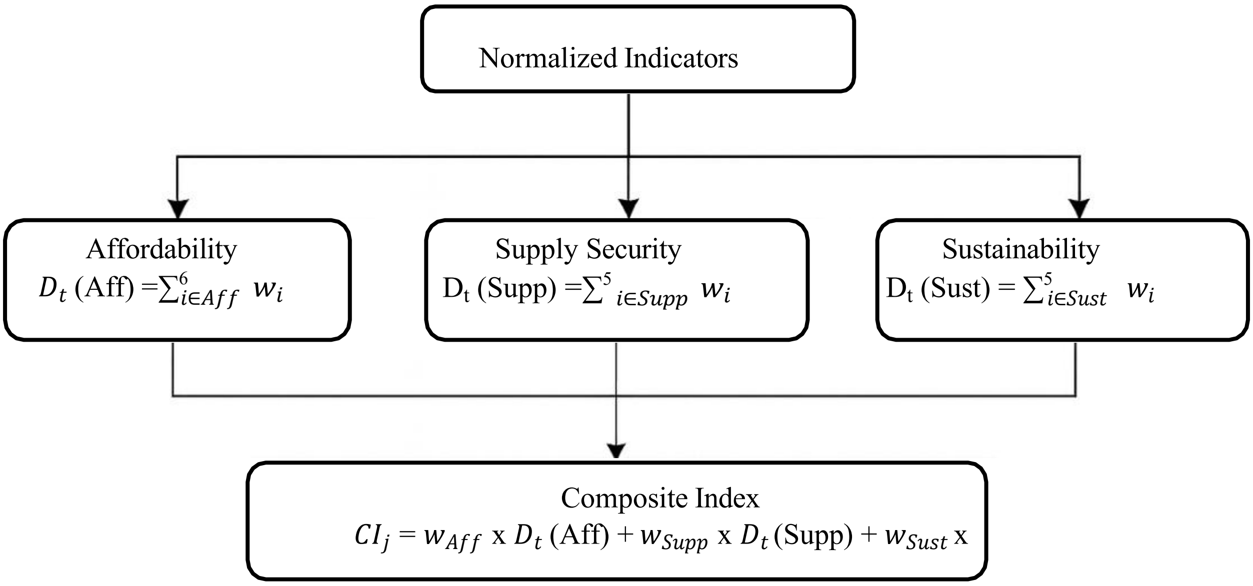


Figure 5: The Composite Index Indicator

Where:

D_t (Aff), D_t (Supp), D_t (Sust) represents respectively the dimension scores (or sub-indexes) for: Affordability, Supply Security, and Sustainability

w_i is the weight assigned to the ***i***-th indicator within a given dimension.

$x_{i,j}$ is the normalized value of indicator ***i*** for country *j*.

w_{Aff}, w_{Supp}, w_{Sust} are the weights assigned to each dimension (affordability, supply security, and sustainability).

CI_j is the final composite index score (Energy Policy Triangle Index) for country *j*.

Visualization and Interpretation

The study employs a systematic comparative MCDM methodology, aided by visual analytics in Jupyter Notebook, to analyze German and West African country performance on the most important energy policy dimensions. By employing quantitative indicators, standardized scoring, and visualization ability, the approach enables in-depth examination of trade-offs and supports context-sensitive, evidence-based decision-making in energy policy.

2.11.5 Data Description

Careful observations were made, and results are recorded as follows using equal weighting.

i. Data Analysis

Before running the analysis, the following preprocessing was carried out: Data filtering with retention of years 2008 and 2020 only, ensure that there are no missing data and normalizing all indicators.

The selected indicators fall under three dimensions, as illustrated in the figure below, characterized by its repartition.

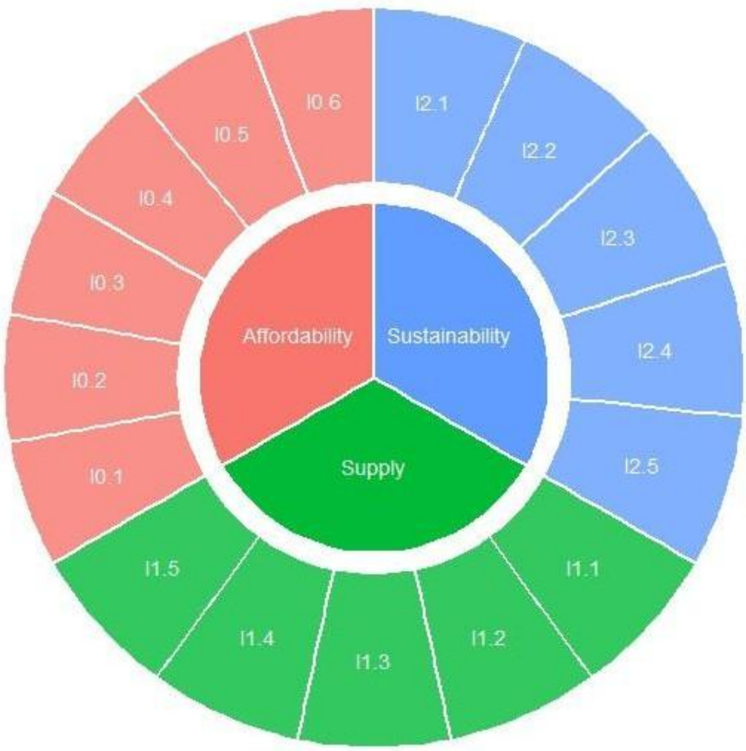
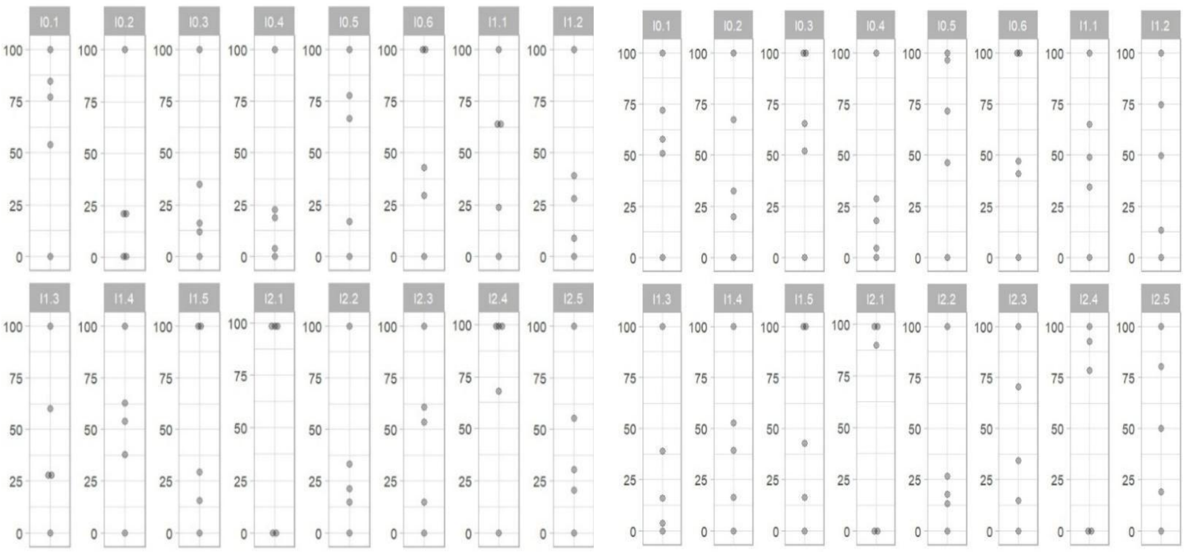


Figure 6: Energy Policy Triangle Index Framework

The energy policy triangle: compared Germany vs West Africa



2008 2020

Figure 7: Histogram of normalized data between 0 and 100 (for 2008 and 2020)

Each vertical bar plot shows the distribution of an indicator's normalized values (scaled between 0 and 100). The dots are the actual data points for different countries (or cases). Each dot's position on the vertical scale tells you that country's normalized score for that year

The table below is used to match the names and the codes of all the indicators.

Table 4: Indicators names and codes

iCode	Indicator Name
I0.1	Electricity Price for Households (USD/kWh)
I0.2	Electricity Access Rate (%)
I0.3	Access to clean fuels and technologies for cooking (% of population)
I0.4	Gini Index
I0.5	Subsidy Levels on fossil fuel as a % of GDP
I0.6	Electric power consumption (kWh per capita)
I1.1	Fuel imports (% of merchandise imports)
I1.2	Renewables - % electricity
I1.3	Transmission & Distribution Losses (% of output)
I1.4	Electricity production from oil, gas and coal sources (% of energy consume)
I1.5	Toal Electricity generation - TWh
I2.1	CO2 emissions (total) excluding LULUCF (Mt CO_2e)
I2.2	PM2.5 Exposure (µg/m^3)
I2.3	GDP per unit of energy use ($ per kg of oil equivalent)
I2.4	Methane Emission (Mt CO_2e)
I2.5	Carbon Intensity of Electricity (gCO_2/kWh)

These selected indicators respond to the third and final research question (RQ3). This demonstrates that indicators such as electricity tariffs (affordability), share of renewables (security), and CO_2 intensity (sustainability) are most effective at capturing cross-country performance. Their comparability across contexts validates the chosen MCDM framework.

Having established the methodological foundation and the rationale for indicator selection, the next chapter moves from framework design to empirical application. It presents the result analysis and discussion, where the comparative performance of Germany and the selected West African countries is systematically examined across the Energy Policy Triangle dimensions.

Chapter 3: RESULT ANALYSIS AND DISCUSSION

A grouped bar plot as shown illustrates the evolution of Energy Policy Triangle Index (EPTI) for proper analysis and interpretation.

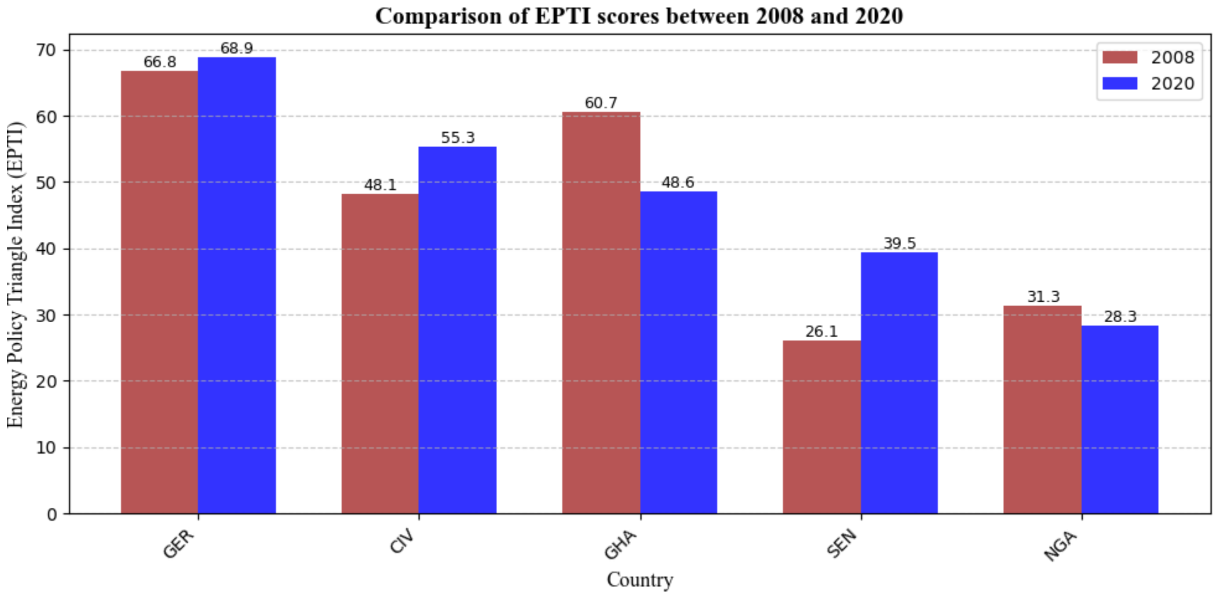


Figure 7: Final EPTI Ranking and Result

To facilitate interpretability of results, graphical analysis and inspection of performance of countries were performed with the help of Jupyter Notebook. Python data visualizations libraries such as Matplotlib, NumPy, and Plotly were used for creating barplots, and radar charts. This visualization shows each country's strengths and weaknesses using the energy triangle and allows easy comparison.

EPTI Results Overview

Table 5: Summary of EPTI results

Country	EPTI 2008	EPTI 2020	Change
Germany (GER)	66.75	68.89	+2.14
Côte d'Ivoire (CIV)	48.12	55.28	+7.16
Ghana (GHA)	60.66	48.63	-12.03
Senegal (SEN)	26.05	39.46	+13.41
Nigeria (NGA)	31.30	28.30	-3.0

These findings directly address the first research question (RQ1), by highlighting Germany's stronger performance on supply security, contrasted with West Africa's relative emphasis on affordability. The results confirm that while Germany's challenges are sustainability-driven, West Africa's energy transition is hindered by reliability and governance issues.

3.10 Result Interpretation

This section interprets the results from the Energy Policy Triangle Index (EPTI) evaluation, analyzing the progress made by Germany, Côte d'Ivoire, Ghana, Senegal, and Nigeria in balancing affordability, supply security, and sustainability. The analysis draws on both the level of indicator's developments and previous literature to contextualize the observed trends and provide a comparative perspective. It reflects on the specific differences between the selected West African countries and Germany, drawing on developments from the past decade as identified in some literatures.

The values in this result are the normalized values ranked across each country. For example, Germany changed from 83.33 to 66.67 means in 2008 its normalized value in that dimension when ranked with the other countries was 83.33. Now, in 2020 it is 66.67. Also, be reminded that the highest a country can score by ranking is 100, which means it ranked best among other countries, but the least by ranking is a value greater than zero.

Germany:

Germany's electricity affordability within this result (from 83.33 to 66.67) worsened as a result of policy and grid cost surcharges driving up retail prices. The EEG levy rose from 1.12 ct/kWh (2008) to 6.756 ct/kWh (2020), approximately 6 times increase transferred to customers (Fraunhofer Ise; Net-work Charges; EEG Surcharges). Besides the prices of energy purchases, network charges make up a large part of the domestic price, and state-requiring elements the tax on electricity (2.05 ct/kWh) as well as VAT work to increase the end bill (Jochen Homann, 2020; BMWK; State-Imposed Electricity Price Components Introduction).

Germany's supply security improved from 2008 to 2020 in the results (from 67.11 to 100.00) and is consistent with reliable data. Notably, outage minutes dropped from 12.20 min during 2019 to 10.73 min during 2020, the all-time record low based on BNetzA, the Federal Network Agency. Strong cross-border integration and new capacity like the 1,000 MW ALEGrO HVDC (ALEGrO) interconnector to Belgium started operation in Nov 2020, which TSOs emphasize enhances security of supply and market integration. Enough firm conventional capacity (such as Datteln 4 coming into operation; hard-coal fleet c.24 GW end-2020) to sustain variable renewables, backed by well-established balancing markets. The IEA similarly concluded in

2020 that Germany had guaranteed high electricity supply security during the transition (IEA, 2020).

Germany's sustainability score dropped (from 49.81 to 40.00) because the phase-out of nuclear wiped out a large portion of zero-carbon supply (policy introduced in 2011) (BMU, 2021). There was a nuclear generation reduction from 148 TWh in 2008 down to 60.9 TWh in 2020. Meanwhile, coal still supplied large amounts in 2020 (lignite 82 TWh; hard coal 35.6 TWh). So, while renewables overtook 50% of net supply in 2020, the mix remained very carbon intensive (Agora Energiewende and Ember, 2021).

Germany's significant progress in EPTI is reflective of consistent and integrated policy frameworks under the Energiewende initiative. Major improvements were observed in the share of renewable energy (increased from approximately 30% in 2011 to over 50% in 2024) (Energieverbrauch, 2023). Primary energy intensity declined due to energy efficiency measures. Greenhouse gas (GHG) emissions and CO_2 intensity substantially reduced. According to (Kelnreiter et al., 2022), these outcomes are attributed to policy stability, citizen engagement, and advanced grid infrastructure. (Burger & Weinmann, 2022) emphasize Germany's leadership in combining technological innovation with clear regulatory support, setting a global benchmark for energy transitions.

Côte d'Ivoire:

Côte d'Ivoire boasts of affordable electricity (from 39.80 to 60.59). This was because of supply mix that was made cheaper for electricity generation. These mixes include large gas CCGT refurbs (Azito's 2015) combined-cycle upgrade; CIPREL IV in 2014–2016 (Azito Power Plant Expansion, Abidjan, Côte d'Ivoire), generating a 111 MW decrease heat rates and unit prices (Azito Power Plant Expansion, Abidjan, Côte d'Ivoire). A 275 MW Soubré hydro power station (completed 2017) added cheap power to the system. At the same time, a secure tariff regime with ANARE-CI (Interministerial Order No. 027/MPE/MPMBPE/MPMEF of June 28, 2017, Amending Electricity Tariffs, AfDB & IFC, 2019) setting tariffs by inter-ministerial decree and a social/domestic lifeline tariff saved bills to consumers. High plant loading and exports to neighbours (a feature of the Ivorian system dating from before the crisis) also supported cost recovery without high retail rises (AfDB & IFC, 2019). Finally, polices that reduced initial connection prices (World Bank-supported revolving fund since 2013) eased the aggregate affordability for new consumers, complementing per-kWh price effects (Pelizan, 2019).

The supply security of Côte d’Ivoire increased (from 27.18 to 31.68). Installed capacity rose to approximately 56% between 2011(1391 MW) to 2018 to (2,200 MW). Most of the supply comes from Soubré hydro (275 MW, 2017) and Azito's 2015 combined-cycle renovation coupled with CIPREL IV gains in availability (2014 to 2016). Added to this, transmission improvements (such as new 225 kV lines and reinforcement of substations) increased voltage stability and regional flows as WAPP interconnections and exports were strengthened by Côte d'Ivoire (Sparavier et al., 2018). Simultaneously, the fuel side remained to be a constraint (limited commercial natural gas and having to import LNG), and the network had to undergo massive investment (losses of approximately 22% pre-upgrade) (S. Fan, J. li, Y. Zhang, X. Tian, 2017), causing supply security to only improve gradually (Kmm, 2020).

The small decline in sustainability in Côte d'Ivoire (from 77.38 to 73.60) is because of shift toward gas-fired production over the course of the 2010s. In 2020 the electricity mix was approximately 69% gas and 30% renewables (almost all is from hydro; solar/biomass <1%) (Energy in Ivory Coast). This helps in improving low-carbon emission in the total electricity generation.

Concurrently, growth in demand was met by efficient gas IPPs, and therefore even the 2017 commissioning of the 275 MW Soubré dam, despite increasing low-carbon production did not manage to reverse the dominance of thermal production (Côte d’Ivoire Energy Report).

Côte d'Ivoire showed notable gains in affordability and access in the EPTI. This as a result of electrification rate growth from (65% in 2015 to over 80% in 2023) (Africa et al.). Tariff restructuring benefits low-income consumers. Regional integration through WAPP enhancing supply reliability. A report from (Yeo, 2024) highlight Côte d'Ivoire effective alignment with ECOWAS energy objectives, noting that investment in infrastructure and donor support have improved affordability.

Ghana:

Electricity was more affordable in Ghana (from 51.16 to 53.96). This is because of Ghana's lifeline tariff protection for poor consumers policy. This means that household consumers paid a lower rate and service charge for 0–50 kWh/month until 2019 (Jain et al., 2020). This approach helped to smooth out bills for people at the bottom of the distribution. A fuel-mix transition with local gas from TEN (2016) (Energy Commission, 2016) and Sankofa (from 2018/19) (Official et al., 2020) and the Atuabo (Belay, 2022) processing plant replacing more expensive light crude/diesel, which saved on the economic cost of production. Rising PPP incomes also helped to keep the affordability down.

Supply security in Ghana drops (from 64.40 to 41.74) because of gas supply disruptions on the West African Gas Pipeline. Notably the August 2012 pipeline rupture near Lomé that halted gas to Ghana and forced expensive liquid-fuel switching. This leads to widespread load-shedding, with WAPCo (West African States Unhappy with WAPCo, 2013) invoking force majeure throughout 2013, and officials later citing repeated WAGP outage (Nyarko, 2020). Also, the hydrology shortages at Akosombo which were extremely low in 2015 restricted hydro generation, a main reason for rolling blackouts until 2016. Domestic gas processing between 2014–2018 to reduce import dependence and stabilize thermal generation, were delayed, so security had not yet returned by 2020 to the fullest. Transmission fragilities (radial lines/single transformers) and the system's high hydro dependence before 2016 also further limited supply security.

Sustainability (from 66.42 to 50.18). This is because of structural shifts from hydro dominance to a hydrothermal mix. Thermal production at around approximately 69% in 2020 and modern renewables <1%. This mix shift raises carbon grid intensity compared to the hydro-rich system in the late 2000s (Osei-Tutu et al., 2021). Hydrology deficits (notably 2014 to 2015) reduced reliable hydro output and placed marginal fossil generation on the margin. Despite indigenous Sankofa gas flowing from 2018, displacing expensive oil, the overall fossil share increased until 2020, and hence sustainability worsened still (Osei-Tutu et al., 2021). To put this into perspective, Ghana missed out on its proposed 10% renewables-by-2020 target (extended to 2030 (Obeng-Darko, 2019), and hence utility-scale solar/wind was too small to resist the fossil switch.

The decline of Ghana in the EPTI stems from challenges in affordability and supply security. Electricity tariffs increased due to subsidy reforms. Persistent reliance on fossil fuel generation. Technical and financial inefficiencies in the power sector. According to (Arthur et al., 2025) report that while Ghana achieved high electrification rates, inconsistent policy enforcement and fiscal constraints hinder renewable energy expansion.

Senegal:

The rise in affordable electricity in Senegal (from 22.76 to 51.46), is because of the arrival of super-cheap independent power producers (IPPs). Most prominent among these are the two scaling solar plants with tariff of 24.93, and 26.11 cfa/kWh respectively. This pushed down marginal supply cost. Additionally, the 158.7 MW Taiba N'Diaye windfarm coming onstream in phases from Feb 2020, bringing zero-fuel energy (Sy, 2023).

On the business side, the average actual household tariff was about 17 US¢/kWh in 2018, and people were willing to pay more for good service. This is because of policy-maintained bills which stayed in pretty good shape even as reliability went up. Reforms to connection fees (a new "lifeline connection policy" for low-income customers) made it even easier for people to get connected (The World Bank, 2022). Liquid fuels had very high generation costs in the past, although subsidies helped cut the costs. However, the supply from solar and new wind power made buying prices lower between 2016 and 2020.

Senegal experiences minimal growth in terms of supply security (from 4.71 to 6.92). The 158.7 MW Taïba N'Diaye windfarm came into operation in phases during 2020, adding a big block of generation (U.S. DFC puts this at a 24% increase over 666 MW available installed capacity). This helps utilities and regulators to start formal mechanisms for tracking restoring power outage. The outages for clients in Dakar were still significant, which is about 17.4 hours/year. So, even with the extra wind and operational improvements, limited firm capacity and network constraints kept the security of supply slow instead of fast (UNSD, WHO, IEA, IRENA, 2025).

There was an advancement in sustainability (from 50.69 to 60.00) in Senegal. In 2020, Senegal generated 17% of its electricity from renewables, with solar increasing from 0 to 6% since 2016, wind contributing approximately 4% in its first year (Taïba N'Diaye's early days), and the remainder imported primarily hydro through OMVS, which is a regional hydro power organization (Gupta, 2014). At the same time, Taïba N'Diaye expansion added 11% of installed capacity in 2020 (full 158.7 MW added later) again adding to the renewable generation; Sendou coal power plant was not functional between 2019 and 2020, also helping the emissions reduction (Gupta, 2014). The grid was still 80% fossil-powered throughout 2020 (oil/coal) (Niang et al., 2024).

Senegal shows advancement in renewable energy deployment, notably in solar PV installations. There are still challenges in affordability and policy implementation. The country still faces constraints related to energy equity and system resilience. Institutional and regulatory capacity gaps, as pointed out by (Apfel & Dorothee, 2022) slow down progress in sustainability. While renewable energy deployment is increasing, execution remains limited by financing and technical challenges.

Nigeria:

The Affordability dimension for Nigeria increased (from 19.64 to 29.32) because of subsidies that kept most retail rates below cost in the 2010s. A good example is the MYTO model, which figured out how much money it would lose after it froze Residential (R2) tariffs in 2015. The 2020 Service-Based Tariff kept a lifeline class (≤50 kWh/month) for homes that didn't consume much energy (AEDC MYTO2020.Pdf). The Power Sector Recovery Program (PSRP) specifically looked at the disparity between cost-reflective and approved tariffs at the sector level. It also confirmed that budget support and under-recovery will continue throughout this time. That said, several customers still used self-generation (diesel/petrol generated of about 14 GW, half of usage self-generated), which was an expensive approach to get around the problem. This is why affordability was just a little bit better (Nigeria Electricity Sector).

The supply of Nigeria drops (from 65.16 to 42.21), because of grid instability and fuel shortages. There were roughly 206 partial or total failures on Nigeria's grid between 2010 and 2019. NERC's own reports for 2019 said there were 5 total failures in Q1 and 3 in Q2. NERC reported one catastrophic collapse in Q1, two in Q2, none in Q3, and one in Q4 of 2020 (NERC Q1 Report, 2019). This shows that operations were still not progressing well. Gas supply shortages, especially 2016 pipeline sabotage repeatedly restricted generation and shook the system (NERC particularly warned that dependence on gas leaves the grid vulnerable to sabotage, "as it was in 2016"). A harsh example is the Niger Delta Avengers' attack that year, which cut gas supplies and necessitated load-shedding (Yeeles & Akporiaye, 2016).

Nigeria experienced a modest sustainability growth (from 9.11 to 13.37). This is so because of the additional gas supply that pushes out some oil/diesel use and the first evidence of solar mini grids/SHS. The grid was still gas-dominated (73% in Q1-2020) with hydro 27% and non-hydro renewables still minimal. Hence the carbon intensity of the power system was still high; meanwhile, widespread diesel/petrol self-generation further suppressed sustainability gains (Sakhi Shah, Olatunde Okeowo).

Nigeria's steep decline in the overall EPTI is due to systemic issues. By this we mean frequent grid failures and high transmission losses. There is minimal progress in renewable energy uptake. The country experiences poor management of electricity subsidies. A work that was put forward by (Olanrewaju & Kirikkaleli, 2024) shows that Nigeria faces entrenched governance and infrastructure problems, with reform initiatives producing limited outcomes over the past decade.

3.11 Comparative Reflections: Germany vs. West Africa (from 2008 to 2020)

Germany improved supply security (from 67.11 to 100.00) but made it less affordable (from 83.33 to 66.67) and made it a little less sustainable (from 49.81 to 40.00). The result varies for the West African countries.

Côte d'Ivoire (CIV) made big strides in affordability (from 39.80 to 60.59) and a tiny security gain (27.18 to 31.68). Côte d'Ivoire (CIV) still leads in sustainability, though it dropped somewhat (77.38 to 73.60).

Senegal got better at being affordable (22.76 to 51.46) and sustainable (50.69 to 60.00), but only slightly better in terms of security (4.71 to 6.92).

Ghana became more affordable (51.16 to 53.96) but drops in security (64.40 to 41.74) and less sustainable (66.42 to 50.18).

Nigeria also got a little better at being affordable (19.64 to 29.32) and sustainable (9.11 to 13.37), but a lot worse at security (65.16 to 42.21).

What caused the differences?

Affordability indicators (retail price in PPP/kWh, subsidies) were better when cheap new capacity came in through competitive IPPs (Senegal's solar PV, Côte d'Ivoire CCGT upgrades and Soubré hydro). In Ghana and Nigeria lifeline tariffs protect local consumers. In Germany, affordability got worse because the EEG levy and network expenses and taxes went up as a percentage of the total cost.

Security indicators (fuel import, technical losses) got better when the grid became more reliable, and the capacity became more reliable. This happened in Germany through interconnectors and a stable thermal reserve, and in CIV through capacity expansion and gradual transmission augmentation. When there were fuel shortages (WAGP gas to Ghana; Nigeria's gas vandalism), hydrological shocks (2014–16 in Ghana), or weak networks/high losses (Nigeria, Senegal), security got worse or better slowly.

Sustainability indicator (Carbon Intensity of Electricity) shows where oil was replaced by new renewables (Senegal) or hydro for the case of Côte d'Ivoire. Sustainability dropped when Germany's nuclear plants closed and Ghana switched from hydro to gas/oil, which raised the thermal share. Nigeria's minor gain includes switching from diesel to gas and early solar mini grids, but the level is still low.

In conclusion, Germany traded some price and sustainability for security, while West African countries traded small price benefits for various security outcomes as their systems grew.

3.12 Discussion

In this section, the analysis uses the selected indicators to explain what specifically drove developments in each country and how these dynamics differed over time.

The affordability indicator for Germany (household energy price in PPP/kWh) got worse because policy surcharges (especially the EEG fee), rising network charges, and taxes made the bill for the end user higher. The supply security indicator set points to improvement since transmission and distribution losses went down, interconnection capacity went up (as shown by the ALEGrO link), and firm/available capacity went up, all of which made the system more reliable. With regards to sustainability, carbon intensity from electricity worsened due to the nuclear phase-out despite rising wind/solar.

The levelized cost of electricity went down in Côte d'Ivoire because of combined-cycle gas conversions at Azito and CIPREL and the installation of Soubré hydropower. This made things more affordable. Social tariffs and connection-cost financing schemes also made it easier for families to pay for electricity up front. Supply security indications reveal went up, but losses and fuel availability slowed down advances. A still-high hydro share kept performance solid, but a little spike in gas use pushed carbon intensity up from very low levels, which caused the sustainability score to drop slightly, even though it was still rather strong.

In Ghana, things got a little cheaper since the lifeline tariff protected low-income customers and the increased availability of natural gas made it cheaper to generate electricity than liquid fuels (diesel). However, supply security indicators got worse, hydrological problems and interruptions on the West African Gas Pipeline made outage-related consequences worse. The power mix became more carbon-intensive than it was in the late 2000s since the thermal share expanded and modern renewables stayed below the 10% target.

For Senegal, affordability improved with the emergence of utility-scale renewables, such as two solar farms with prices of roughly 25–26 cfa/kWh and the Taïba N'Diaye wind project. These projects lowered procurement costs and eased pressure on tariffs. Security indicators show just a minor improvement. New capacity helped, but transmission and distribution losses stayed high, and limited firm capacity and network constraints made reliability advances slow. Sustainability improved as the share of renewable energy sources like solar, wind, and hydropower imports through the OMVS basin scheme grew. The Sendou coal plant's downtime also helps in emission reduction.

In Nigeria, indices of affordability got better from a low starting point because regulated prices were kept below cost by administered tariffs and the lifeline band (as shown by the PSRP's tariff-gap assessment). On the other hand, supply security indicators got worse because of system failures, gas supply problems caused by vandalism of gas infrastructure, and ongoing significant technical and economic losses. Sustainability went up a little bit since some diesel use was replaced by gas and early solar mini grid was added to the mix. However, overall development was still limited because the system was mostly fossil-based and there was a lot of self-generation.

This study also captures the major differences between the countries and over time and this is what it states. The results show Germany improving overall while West Africa prioritizes access and affordability.

However, the country-level differences within West Africa are important: Senegal’s renewables-led strategy contrasts with Nigeria’s subsidy-driven affordability, Ghana balances affordability with rising carbon intensity, while Côte d’Ivoire leverages natural gas and hydropower to improve security and exports. Exploring these divergences reveals that regional averages mask heterogeneous national trajectories.

The levels in 2020 show notable differences. Germany is well ahead in terms of supply security, followed by Côte d'Ivoire and Ghana (with Côte d'Ivoire being a little stronger), then Nigeria, and finally Senegal. Côte d'Ivoire is the most sustainable country, followed closely by Senegal. Germany is next, then Ghana, and Nigeria is far behind. When it comes to affordability, Côte d'Ivoire comes out on top, followed closely by Senegal, then Ghana, then Germany, and finally Nigeria. It's important to remember that Nigeria's regulated rate is lower than the higher effective cost that many households experience when they use generators.

From 2008 to 2020, Senegal and Côte d'Ivoire saw the biggest increases in affordability, while Germany saw a big drop in affordability. Germany has the biggest improvements in supply security, while Ghana and Nigeria have the biggest losses in security. Sustainability goes up in Senegal, stays high in Côte d'Ivoire with a small drop, goes down in Germany and Ghana, and goes up a little in Nigeria from a very low base.

Changes in each country help explain these paths. The nuclear phase-out and the EEG charge used to pay for the transition in Germany affected sustainability and affordability outcomes, even while interconnections and available capacity made supply security as high as possible. Ghana's economic problems in the middle of the 2010s were caused by power outage, as a result of the unavailable hydropower and problems with the WAGP. Côte d'Ivoire's successes are intimately linked to the

Azito/CIPREL renovations and the arrival of Soubré, even though gas shortages happened from time to time. Senegal's first wave of utility PV (2016–2020) and the start of wind in 2020 came late. The Sendou coal plant that was not in operation helped with sustainability in Senegal. Gas supply shocks in 2016, fundamentally high losses, and tariff changes under MYTO/SBT all influenced Nigeria's patterns.

Finally, some policy actions can be directly connected to these changes. Germany's better supply security is due to the expansion of interconnectors, well-developed supportive service markets, and the preservation of stable capacity. Côte d'Ivoire's IPP framework, CCGT conversions, and Soubré hydropower all help make the country gain an increase in affordability and sustainability. Senegal's better prices and long-term viability come from the Taïba N'Diaye wind project and competitive solar auctions. Ghana's lifeline tariff made things more affordable, but domestic gas didn't arrive in time to fully restore security by 2020. In Nigeria, the lifeline/SBT strategy helped make things more affordable, but the lack of gas-supply security, poor metering, and limited loss reduction made supply security worse.

CONCLUSION

In conclusion, this research has provided a comparative Energy Policy Triangle Index (EPTI) analysis of Germany's energy policy performance and the four West African countries. By aggregating sixteen indicators into the three dimensions, the research has provided a multidimensional measure in evaluating energy transition progress between Germany and West Africa. Germany's dramatic turnaround underscores the importance of long-term strategic planning, institutional continuity, and investment in renewables. Conversely, West Africa's performance is uneven rather than uniformly deteriorating. Côte d'Ivoire and Senegal see big improvements in affordability (and Senegal also sees improvements in sustainability), whereas Ghana and Nigeria see big drops in supply security. These disparities show how policies aren't always consistent, how fuel and grid limits work, and how much money is being spent especially in Ghana and Nigeria, where networks and firm capacity are not being invested in enough. The results demand a paradigm change in the energy policy trajectory of the West African countries, one that initiated an integrated planning, cross-sectoral coordination, and ambitious regional collaboration. The energy transitions must be tailored to local socio-economic circumstances but led by international best practice. This report urges stakeholders, governments, development partners, and researchers to scale up collaboration and investment in the transformative energy agenda desperately needed across West Africa.

Recommendation

Based on the EPTI results, the recommendations focused on each country's individual needs and on the system's most important limiting factor. Whether that is network losses, gas supply risk, affordability design, or integration constraints. The goal is to raise affordability, security, and sustainability at the same time, without making one side of the triangle weaker in order to make the other side stronger.

In the case of Germany, needs to keep high supply security while make it affordable and more sustainable. To do that, they need to eliminate fixed transition costs on bills, make it more flexible (storage and demand response), and replace old thermal capacity with firm low-carbon capacity. For Côte d'Ivoire, it can sustain its lead in affordability by increasing gas supply, improving the rate of loss reduction, and increasing the use of renewable sources that complement the hydro power supply. By doing this, it will increase supply security without harming sustainability.

Ghana needs to improve on its supply security by making sure gas supply is constant, improving its hydro rehabilitation and lessening losses. At the same time, it must ramp up its use of advanced renewables and make tariffs smart while providing targeted protection to ensure price competitiveness. Senegal must increase storage, flexible gas-to-electricity, and transmission upgrades so security can catch up to gains in affordability and sustainability. Nigeria needs to improve on supply security by focusing on making gas-to-power a priority, cutting down on metering and losses, and keeping the grid stable. At the same time, it needs to change subsidies to focus on targeted support and scale up distributed solar and mini grids to enhance all three areas at the same time.

Limitations

This study gives useful information on how Germany and the selected West African nations compare in energy policy triangle. Still, there are some aspects which are considered as limitations and are listed below.

1.The analysis uses secondary data from global sources, which might have some problems like data that does not match the situation in each country

2. The weighting method in the MCDM setup could change how countries are ranked, if expert opinions are to be considered.

3. The choice of four countries does not give a detailed representation of West Africa. This is because of lack of data for most other countries within the dimensions being considered.

Future research should base data collection on primary data and incorporate more countries from the region

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APPENDIX

Table 6: Indicators names, Directions, and Parent

iCode	IndName	Weight	Direction	Level	Type	Parent
I0.1	Fuel imports (% of merchandise imports)	1.00	-1	1	Indicator	Supply
I0.2	Share of Renewables - % electricity	1.00	1	1	Indicator	Supply
I0.3	Fossil Fuel Consumption as % of Total Energy	1.00	-1	1	Indicator	Supply
I0.4	Transmission & Distribution Losses (% of output)	1.00	-1	1	Indicator	Supply
I0.5	Electricity production from oil, gas and coal sources (% of electricity consume)	1.00	-1	1	Indicator	Supply
I0.6	Toal Electricity generation - TWh	1.00	1	1	Indicator	Supply
I1.1	Electricity Price for Households (euro/kWh)	1.00	1	1	Indicator	Affordability
I1.2	Electricity Access Rate (%)	1.00	1	1	Indicator	Affordability
I1.3	GDP per unit of energy use ($ per kg of oil equivalent)	1.00	1	1	Indicator	Affordability
I1.4	Gini Index	1.00	1	1	Indicator	Affordability
I1.5	Subsidy Levels on fossil fuel as a % of GDP	1.00	1	1	Indicator	Affordability
I1.6	Electric power consumption (kWh per capita)	1.00	1	1	Indicator	Affordability
I2.1	CO_2 emissions (total) excluding LULUCF (Mt CO2e)	1.00	-1	1	Indicator	Sustainability
I2.2	PM2.5 Exposure (µg/m³)	1.00	-1	1	Indicator	Sustainability
I2.3	Access to clean fuels and technologies for cooking (% of population)	1.00	1	1	Indicator	Sustainability
I2.4	Methane Emission (Mt CO2e)	1.00	-1	1	Indicator	Sustainability
I2.5	Carbon Intensity of Electricity (gCO_2/kWh)	1.00	-1	1	Indicator	Sustainability
Supply	Supply Security	1.00	1	2	Aggregate	EPTI
Affordability	Affordability	1.00	1	2	Aggregate	EPTI
Sustainability	Sustainability	1.00	1	2	Aggregate	EPTI
EPTI	Energy Policy Triangle Index	1.00	1	3	Aggregate	

Table 7: Result and ranking of each country (2008 and 2020)

COUNTRY	Rank	EPTI (2008)	COUNTRY	Rank	EPTI (2020)
GER	1	66.75	GER	1	68.89
GHN	2	60.66	CIV	2	55.28
CIV	3	48.12	GHN	3	48.63
NGA	4	31.30	SEN	4	39.46
SEN	5	26.05	NGA	5	28.30

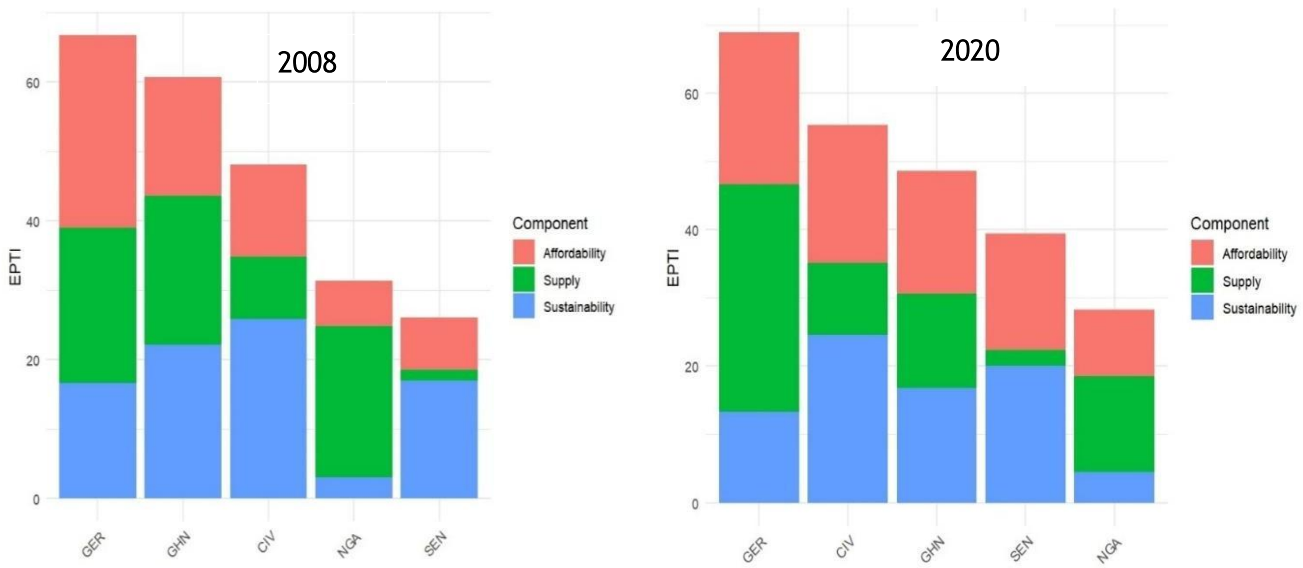

Figure 8: EPTI results 2008 and 2020

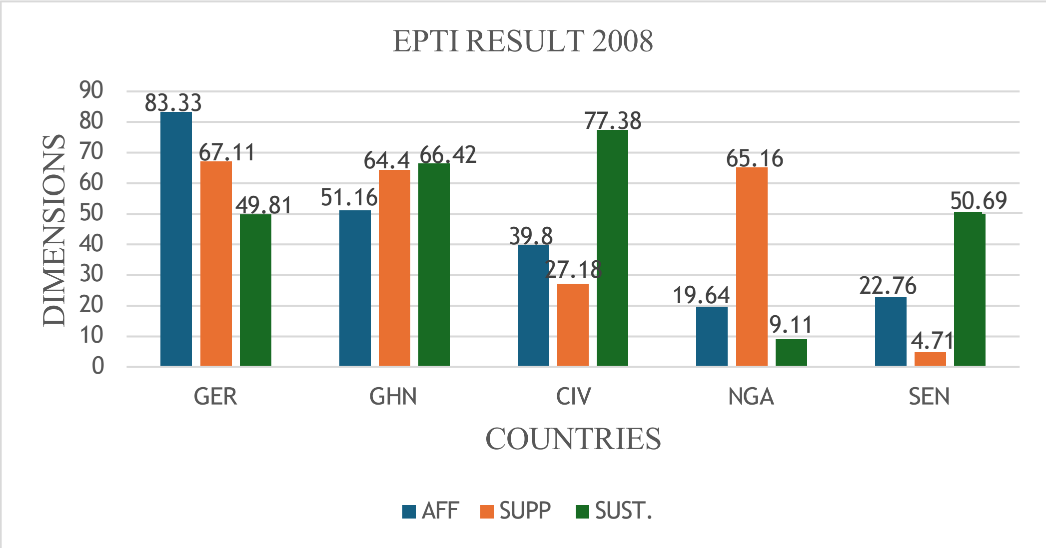

Figure 9: EPTI Result for Each Dimension and Country 2008

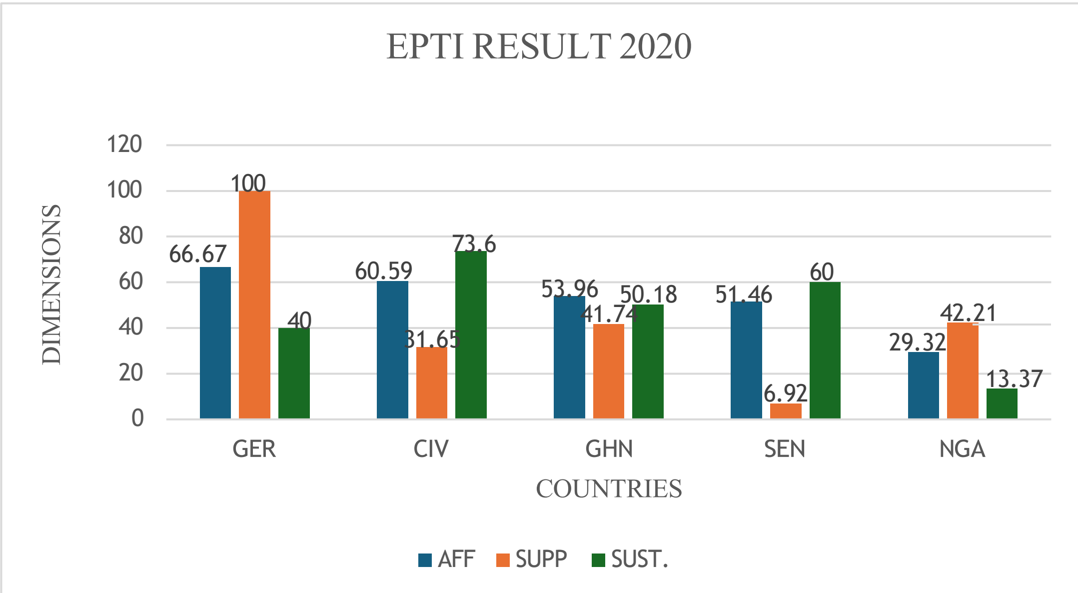

Figure 10: EPTI Result for Each Dimension and Country 2020

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