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Research Article

Exploring the Integration of a Regional Power Market in West Africa: Challenges and Opportunities for Sustainable Energy Transition

Adebayo, Adeyinka Victor[1], Ologunwa O. P.[2], & Osinubi, Olusoga Oyindamola[3]

[1]University of Johannesburg, South Africa
[2]Project Management Department, Federal University of Technology, Akure, Nigeria
[3]University of Plymouth, Drake Circus, Plymouth PL4 8AA

Abstract

This study explores the integration of a regional power market in West Africa, focusing on the technological, economic, environmental, and regulatory dimensions. West Africa is at a pivotal moment, with 75% of its power generation capacity under construction. The region faces two converging approaches to electrification: fossil fuel-based centralised grids and renewable energy-based decentralised micro-grids. The research examines the West African Power Pool (WAPP) and the Indian Ocean Islands Power Trade Sector (IOIPTS) to model three potential market scenarios, assessing their implications for sustainable energy transitions. Findings underscore the need for tailored regional integration models, robust regulatory frameworks, and investment in renewable energy to enhance energy security and foster sustainable socio-economic development in West Africa.

Keywords	*Regional Power Market; Renewable Energy; Sustainable Development; Energy Transition; West African Power Pool; Regulatory Frameworks; Energy Security*
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Introduction

The continent of Africa is endowed with natural resources that could meet the energy needs of its people. However, the dilemma remains that many Africans have no access to electricity. Instead, they rely on candle lights, kerosene lamps, batteries and diesel generators to secure this propeller of socioeconomic development (Batinge et al., 2017). Meeting the basic electricity-driving needs of most sub-Saharan Africans is a significant challenge for the current year and beyond. Unmet electricity demand in sub-Saharan Africa remains unutilised generation capacity, with no alternative means to access energy and thereby no opportunities for socioeconomic development. However, aiding this populous region in overcoming the energy challenges before high-carbon development is an opportunity. Given that Africa has more than 80% of its land area located in the tropics, efforts could be made to utilise the abundant renewable energy resources and the concomitant current climatic conditions in Africa to enter a new climate-safe epoch by leapfrogging through a radically different form of the energy economy (Boëthius, 2012). Despite the potential, several challenges in the region hinder the integration of renewable energy into the overall energy mix. These perceived and actual challenges often shape our understanding of the opportunities and our willingness to invest in renewable energy. Bridging the knowledge gaps and enhancing our understanding and awareness of renewable energy is crucial to overcoming these challenges. This will enable us to engage more effectively with national decision-makers and foster a collective commitment to paving the way for a sustainable energy future.

Background and Rationale

West Africa is at a critical juncture for energy development, with 75% of its power generation capacity still under construction. This presents a unique and inspiring opportunity to transition towards renewable energy and sustainable socioeconomic development. The region faces two converging approaches to electrification: one reliant on fossil fuels and centralised grids and another based on renewable energy and decentralised micro-grids. As regional power markets are forming, focusing on building a system that promotes the latter approach for long-term energy security and sustainability is essential. The West African Power Pool (WAPP) and the Indian Ocean Islands Power Trade Sector (IOIPTS) offer frameworks for understanding these developments. Three market scenarios were modelled: a reference case reflecting current conditions, a scenario with enforced market organisation, and one where these conditions precede market establishment. Each scenario highlights different trajectories for power systems and technologies in the region.

Research Aim and Objectives

This research explores the integration of a regional power market in West Africa, examining its technological, economic, environmental, and regulatory dimensions. It assesses how such integration can drive a sustainable energy transition. The study addresses the lack of tailored models for regional integration, emphasising the need for context-specific solutions given the diverse resources and policies in West Africa.

Regional Power Market Integration: Conceptual Framework

The objective of the conceptual framework is to elucidate the fundamental concepts and principles underpinning regional power market integration. This section aims to provide a clear and comprehensive understanding of the theoretical foundations and the overarching framework governing power market integration in the West African region. Prior to delving into the issues and opportunities associated with regional power market integration in West Africa, it is imperative first to present a general overview of the conceptual landscape. The central focus of this framework is the notion of "regional power market integration." As a starting point, the individual components of this conceptual compound will be scrutinised and explained, including the key concepts and explanatory parameters behind each component. Furthermore, alternative forms and levels of integration will also be evaluated.

As a first step, it is essential to define the concepts of 'power market,' ‘regional power market,' and 'regional power market integration', as well as the underlying notions and mechanisms of functioning. Taking into consideration the aspect of the power market as a starting point, national power markets may be established as a wider ensemble of consumption and generation facilities interconnected through a transmission network (with operators of generation facilities, plants, and capacity and energy traders) and a legal framework institutionalised by the regulatory framework governing the rules and conditions under which different kinds of energy transactions may occur.

National power markets also tackled various systemic issues regarding this wider ensemble, including the optimal utilisation, protection, and expansion of the domestic transmission network and ensuring an adequate balance between generation and consumption (Di Foggia & Beccarello, 2024). Well-functioning power markets require the supply and demand of electrical energy to be continuously balanced by coordinating numerous generation and consumption facilities, power plants, and energy dealers to enhance competition. These conditions thus necessitate the definition and a well-structured set of rules governing the reciprocity of wholesale power transactions, including market participation and exclusion. Well-functioning national power markets may operate in alternative forms: traditional command and administrative participative forms or more recent power exchange-based competitive forms (Boëthius, 2012).

Definition and Scope

Despite the enhancing number of drivers calling for a transition to a more sustainable energy system, there is scepticism regarding the expansion of renewable energy in the energy mix on a global scale. In most developing countries, the dominant power system styles are typically fully centralised, where the role of grid-connected consumers shockingly consists only of energy supply, usually called passive consumers (Di Foggia & Beccarello, 2024). Instead, prosumers are energy units that balance energy duties in production and consumption. An energy community refers to a group of prosumers cooperating locally or nationally. In Europe, energy communities are encouraged, and their role in shaping the electricity market is becoming ever more prominent, but they have mainly emerged naturally without having been explicitly designed.

Despite extensive awareness and triggering interest in energy communities over the last years, there is a current literature gap regarding their effective and efficient integration into competitive electricity markets. Therefore, a new market design incorporating the active role of energy communities, responsive to the unique features of electricity supply, is crucial to exploit their full potential in sustaining the energy transition (Boëthius, 2012). With the recent concern about electricity price hikes, increases in demand, and unexpected supply shocks, there is a pressing need for a deeper understanding of the market design that enables energy communities and prosumers to commercialise their energy and flexibility assets effectively.

Benefits and Challenges

The upcoming West African Power Pool is expected to foster regional power market integration through the interconnections established. The anticipated benefits of integrating regional power markets include opportunities for optimal power generation and expansion, investments in exploiting local resources, improved asset utilisation, economic diversity, and loss minimisation (Boëthius, 2012). Regional market integration is also expected to entail reduced electricity supply costs due to competition, improved service delivery due to better technology, improved access to electricity to low-income people, and reduced environmental impacts. Regional power market integration is also expected to improve power security. However, despite the expected advantages of regional power market integration, some challenges can delay the implementation of efficient market mechanisms in the Massachusetts power systems and generation (Ochieng & Jonyo, 2015). Matching significant technical and economic developments in different control areas is a major challenge to regional integrated market operations. Uncertainty created by both market and non-market obligations on a day-ahead basis and the obligation of generation entities to offer capacity to both the ancillary system should be synchronised with accurate resource forecast.

West Africa's Energy Landscape

This section provides an overview of the current energy landscape in West Africa, encompassing the existing energy mix and the key players and institutions involved in the energy sector. Understanding the energy landscape is crucial for contextualising the subsequent regional power market integration discussions. However, the power sector in ECOWAS remains national, with only two cross-border interconnectors in operation, owned and managed by the vertically integrated national utility of the two countries involved.

Ghana's alternative energy landscape is discussed using Sigerud and Hai's Emerging alternative energy market: South Africa. Initial energy mix supply analysis of Ghana reveals that the country continues to rely heavily on hydropower and gas-fueled thermal generation. Historically, Ghana was noted for being the first country in sub-Saharan Africa

to provide electricity. However, the country has experienced significant challenges meeting electricity demand over the past decades. These challenges led to the establishment of the GoG's Energy Sector Strategy and Development Plan in 1996, which represented a paradigm shift that sought to address issues in the sector through private investment and liberalisation. Expansion in electricity generation capacity through public-private partnerships followed the plan. However, climate variability from El Niño led to significant reductions in hydropower generation between 2012 and 2015.

Consequently, the government of Ghana (GoG) signed a significant power purchasing agreement with several private gas-fueled thermal generation IPPs (Independent Power Producers). In 2018, the total installed capacity was primarily from gas and hydropower. The country experienced a surplus in electricity supply. Ghana aims to derive 10% of electricity from direct and indirect solar energy by 2030.

Current Energy Mix

The Energy Generation and Consumption in West Africa

Energy generation in West Africa relies heavily on fossil fuels, with the energy mix comprising 68% crude oil, 13% natural gas, 7% coal, 3% biomass, and 9% hydro and other technologies (IEA, 2016). Nigeria dominates, supplying over 80% of energy in ECOWAS countries (Abdellah et al., 2021). Resource scarcity makes other countries dependent on Nigeria's fossil fuels, risking energy security due to climate impacts and price fluctuations. To reduce environmental impact, Nigeria must increase renewable energy use. Seven resource-rich countries (e.g., Ghana, Nigeria) have the potential for sustainable energy transitions, while resource-poor countries (e.g., Benin, Mali) need investment in renewable resources like wave energy (Mukhtar et al., 2023; Batinge et al., 2017). Table 1 captures the key aspects of energy generation and consumption in West Africa, highlighting the regional energy mix, disparities in energy resources, risks to energy security, and the need for renewable energy investments.

Table 1: The Energy Generation and Consumption in West Africa based on the provided information

Aspect	*Details*	*References*
Regional Energy Mix	**68% Crude Oil** **13% Natural Gas** **7% Coal** **3% Biomass** **9% Hydro and Other Technologies**	**International Energy Agency (2016)**
Key Energy Producer	**Nigeria:** Supplies more than 80% of energy generation in ECOWAS countries. Dominates the regional energy landscape with a heavy reliance on fossil fuels. Faces pressure to transition to renewable energy due to environmental commitments.	**Abdellah et al. (2021)**
Energy Resource-Rich Countries	**Ghana:** Hydropower and emerging renewable sector. **Guinea:** Significant hydropower potential. **Liberia:** Limited fossil fuel reserves but untapped hydropower. **Nigeria:** Fossil fuel giant with growing renewable commitments. **Senegal:** Diversifying energy mix with a focus on renewables. **Sierra Leone:** Relies on hydropower and biomass. **Togo:** Small but increasing renewable energy initiatives.	**Mukhtar et al. (2023)**
Energy Resource-Poor Countries	**Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, The Gambia, Guinea-Bissau, Mali, Niger:** Depend on imports and limited domestic resources, primarily fossil fuels. Vulnerable to energy insecurity due to reliance on external energy sources and fossil fuel price fluctuations.	**Mukhtar et al. (2023)**
Risks to Energy Security	**Natural Disasters and Climate Change:** Hydropower systems at risk from changing weather patterns. **Fuel Price Fluctuations:** Heavy reliance on fossil fuels exposes economies to volatile global energy markets. **Supply Chain Vulnerability:** Disruptions in fossil fuel supply chains can severely impact energy availability.	**Mukhtar et al. (2023)**
Renewable Energy Potential	**Coastal West African Countries:** Significant potential for harnessing wave energy and other renewables. **Diversification Need:** Increased investment required to develop renewable energy infrastructure to reduce dependence on fossil fuels.	**Batinge et al. (2017)**
Environmental Commitments	**Nigeria:** As a signatory to various international agreements, Nigeria is called to reduce greenhouse gas emissions and increase the share of renewable energy in its energy mix, aligning with the global environmental goals.A	**Abdellah et al. (2021)**

Investment Necessity	**Renewable Energy Development:** Essential for reducing environmental impact and ensuring long-term energy security. **Focus Areas:** Coastal regions of wave energy, expansion of hydropower, and solar energy development.	**Mukhtar et al. (2023); Batinge et al. (2017)**

Figure 1 illustrates the funding distribution and energy flow among West African countries, highlighting significant energy generation and consumption disparities. Nigeria, Ghana, and Senegal receive the highest funding levels, correlating with their dominant roles in regional energy production. As the primary energy producer, Nigeria stands out with the highest funding, underscoring its critical role in supplying over 80% of energy to ECOWAS countries. Meanwhile, smaller nations like Liberia, Sierra Leone, and Togo receive minimal funding, reflecting their lower energy generation capacity and dependence on external energy sources. The graph underscores the need for balanced investment to enhance energy security and promote sustainable regional development.

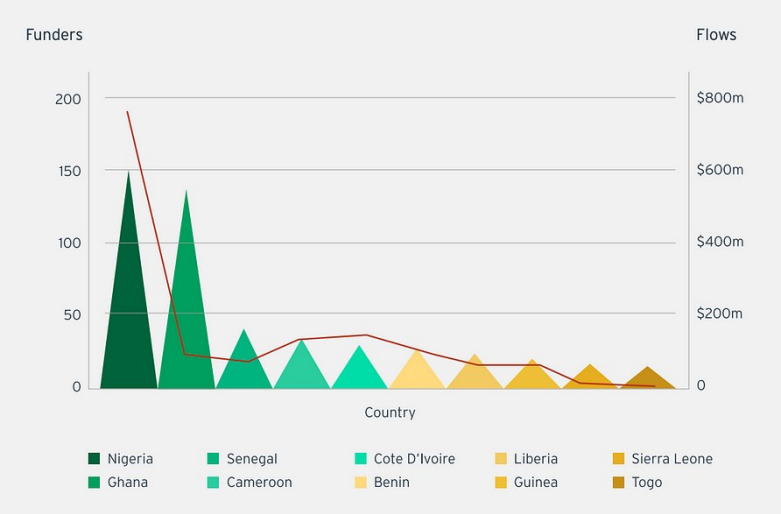

Figure 1: The funding distribution and energy flow among West African countries. (Celine Zins 2019)

Key Players and Institutions

Prominent entities and institutions within the energy sector of West Africa have varying roles and missions but with significant commonalities in their objectives and target clientele. These stakeholders include policymakers, regional institutions, governments, and energy utility companies. Institutions often form networks to build capacity or provide donor-sourced funds to states. The Energy Sector Management Assistance Program (ESMAP) has been established using pooled funds from the United Nations Development Fund (UNDP), the United Nations Environment Program (UNEP), and the World Bank to assist numerous developing countries in building stakeholder capacity. et al. A. N-Yaaba, 2009). Other regional energy institutions targeted towards investment opportunities in West Africa's energy and utility sector include the West Africa Power Pool (WAPP), the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE), and an array of stakeholder councils and institutional frameworks to ensure harmony among stakeholders. Local energy institutions with a regional focus include Ghana's Energy Commission, Mali's Energie du Mali S.A. and various Ministry departments, Nigeria's Energy Commission of Nigeria and Power Holding Company of Nigeria, and Togo's Compagnie d'Energie Electrique du Togo and Direction de l'Energie, among others.

Regional Power Market Initiatives in West Africa

The integration of power markets in West Africa has gained momentum, with regional organisations and initiatives undertaking several initiatives and programs. The ECOWAS Regional Electricity Market (EREM) is a key focused effort. Initiated in 2006 with the support of the West African Power Pool (WAPP) organisation and with funding from the African Development Bank (AFDB), the EREM aims to form a competitive regional power market under the jurisdiction of ECOWAS. A comprehensive set of market rules was developed in line with this effort, covering

procedures for market operations, supplier purchasing, demand bidding, and market settlements. In 2012, a pilot project was implemented in Burkina Faso to validate the market rules and accompanying software.

Alongside this focused effort, ECOWAS launched several other regional power market utilities, including the establishment of the Regional Regulatory Authority (RRA) in 2008 and the West African Power Pool Market Monitoring Unit (MMU) in 2010 (K. et al., 2009). Additionally, a detailed assessment of the state of the transmission systems was undertaken by the EAMU to quantify the operational efficiencies and reliability on a regional basis, and actions necessary to comply with the specifications in the WAPP rules were defined (Sakellaris, 2011). In order to monitor compliance with the operations specifications in the EAPP and ECOM rules, the EAPP MMU was created. Various efforts and solutions were established to monitor the operation's compliance with numerous planning specifications, including benchmark index monitoring to monitor the network's reliability. Furthermore, several collaborative efforts within the region's transmission system operators and consultants have been initiated to assist in developing the EAPP's legal framework.

ECOWAS Regional Electricity Market (EREM)

The ECOWAS Regional Electricity Market (EREM) has been initiated to establish a viable market infrastructure and a stable, reliable, and competitive environment to provide electricity for its members. To this end, a sustainable ERE Market roadmap has been developed, with a Plan of Action providing a reliable action program for its implementation up to 2020 (Sakellaris, 2011). The main objective of this road map is to provide, as of 2017, the conditions to build a competitive regional electricity market. The EREM is just one of the major initiatives to promote the adequate establishment and functioning of an integrated West African Power Market (WAPM). It is intrinsically linked to the activities and findings of the WAPP. In broad strokes, the ERE Market Road Map consists of three phases: (i) Implementation Phases up to 2020, (ii) Follow-up Phases up to 2030, and (iii) Consolidation Phases beyond 2030. The implementation steps to phase in the market are outlined in terms of time, cost, and methodology. There are different levels and phases of market integration. The WAPM adopts the five-staged approach to market integration developed by the International Energy Agency (IEA). Each phase must be regarded as a provisional group of market entities governed by bilateral contracts (K. et al., 2009). In addition, the market entities may opt for a wider pool of partners involved in electricity exchange transactions. The participants in one pool must face the costs of the established physical connection with the market entities of the other pools. The formalisation of complementary markets has a high economic and political dimension.

Other Regional Initiatives

In addition to the ECOWAS initiative, other notable regional initiatives for power market integration in West Africa could provide insights into the competitive market design in Senegal, Mali and Guinea. These initiatives are briefly explored and analysed below.

Power market integration in West Africa has significantly evolved over the last decade. The West African Power Pool (WAPP) was formally created in 2006 to develop a regional power market for economic utilisation of the generation resources in the West Africa region. The WAPP market design has been developed, and several regional projects are currently being implemented to invest in interconnection lines and generation projects and create institutional frameworks. A competitive power market in West Africa is expected to provide many benefits, including overall cost savings for utilities and consumers and access to better and more reliable electricity supply (K. et al., 2009).

To ensure the success and sustainability of the regional market, an independent and strong market operator must be established and entrusted to manage the fair and efficient running of the market. Broadly, the power market blockchain for WAPP Full Members is being erected in two phases. The first phase will be a pool with a bilateral framework and a single daily auction. In contrast, the second phase will be a real-time central dispatch with security-constrained economic dispatch (Batinge et al., 2017). The lessons learned in the regional initiative and developments can help Senegal, Mali, and Guinea develop a market design to ensure national market integration into the WAPP regional market.

Challenges to Regional Power Market Integration

Political and Regulatory Barriers

Regional integration of electricity markets is a complex and ambitious process which necessitates intricate structural and operating adjustments in the electricity supply industry. Establishing a regional electricity market is crucial to allow market participants to trade competition benefits to surplus electricity due to complementarities in production cost curves. Power market integration is at various stages, depending on supply-demand configuration, national policy frameworks, existing interconnections, and socio-political acceptance (Boëthius, 2012). However, it has encountered several barriers. Among them, political and regulatory barriers are the most complex and difficult to approach. (1) Lack of Agreement Among Participants and Between Market Stakeholders. Governments and market authorities have a low interest in establishing a regional power market. State Authorities, regulators, and TSOs agree with the intentions, principles, and motivations to undertake market integration but hesitate to adopt a specific strategy. There is a window of opportunity to increase market integration, though politicians and regulators require active collective action. Individual market participants would benefit from market integration but, simultaneously, would have to give up certain national gains. Consequently, it is in the common interest of all market stakeholders to promote market integration to avoid free-riding attitudes. (2) Regional Market Organisation. National authorities, regulators, and TSOs are concerned that the current observance of national interests would impact the competitiveness of national economies. Small countries are more concerned that participation in a regional market dominated by large countries would impact their competitiveness and vulnerability.

Infrastructure Barriers

Reform, development, and investments in infrastructure are preconditions for the efficient functioning of a competitive regional electricity market. A competitive electricity market was implemented in all Nordic countries at the beginning of 2001, creating the largest regional market in Europe. However, it was only made possible through significant investments in interconnection capacity. Establishing a regional electricity market in southeastern Europe and Middle and Eastern Europe (MOE) and supplementary investments in infrastructure and interconnections are necessary for market integration and functioning. The current transmission capacities on international interconnections are critically low, and investments in this sector are urgently required. Establishing a trans-European electricity market is an enormous construction task requiring significant distribution of investments across countries and market participants. (1) Lack of Interconnections. There is a fear that power market integration would result in a closure of exchanges on national interconnections. (2) Level of Development of Physical Market. There are plans and intentions to participate in developing a competitive regional electricity market, but they are not formally stated. Market participants are in an early participation stage with connection agreements in various directions. At the same time, discussions about including the growth of the regional competitive market into power exchange operations are ongoing.

Financing Barriers

Integrating electricity markets requires investments in the electricity infrastructure to develop additional interconnectors and the necessary communication and information technology. Investment is needed to ensure a seamless and efficient operation of the markets, involving the improvement of both commercial and physical infrastructures. (1) Poor Cost-Benefit Ratio of Investment. Currently, there is no sense of common interest among the relevant political actors in the market involving either financial contribution or political commitment. Governments and market authorities are concerned that national market investments would redistribute national income and wealth to other markets involving a wealth transfer. (2) Insufficient, Highly Qualified Staff. There are fears of using multiple and incompatible trading platforms, leading to a lack of flexibility in trading. The simultaneous market operation would be complex and inefficient at the lowest level of books and available capacity on interconnections and the bunged congestion management.

Political and Regulatory Barriers

In West Africa, massive investments in electricity generation have taken place. Despite these investments, immense energy poverty persists. A regional solution is proposed to this predicament by integrating a regional power market. However, while the technology, demand, and resources exist for a regional power market, political will and driver(s) for its creation are missing. More specifically, political and regulatory barriers to integration are evaluated, while gains and costs of integration and utilities' concerns regarding integration are not evaluated. Recommendations include steps that West African governments can take to promote integration and the creation of a regional power market, drawing lessons from the E.U. experience with liberalisation.

The political and regulatory dimension of integrating a regional power market in West Africa is neglected. Privatisation, restructuring, and other introduced competitive electricity market policies seem to have led to fragmentation rather than integration of the electricity market in West Africa. In addition to the vehement opposition and politicisation of restructuring, institutional and governance problems within the electricity sector hamper collaboration. The East African Power Pool is excessively dependent on the development of regard for technical issues and neglects the regulatory framework. Comparing the success and failure of the integration of electricity markets elsewhere, it appears that institutional and governance problems, as well as transparencies in the political arena, play a vital role in the regulatory dimension and need to be addressed (Batinge et al., 2017; Boëthius, 2012).

Infrastructure and Financing Constraints

Infrastructure development and financial mechanisms constitute the core issues that challenge the region's prospects of power market integration. Integrating countries' domestic electricity markets into a regional wholesale electricity market would be tricky without the necessary infrastructure. Infrastructure development refers to constructing and maintaining physical structures and facilities, such as roads, bridges, water supply systems, buildings and power generation facilities, transmission lines and distribution networks. Power infrastructure is essential for connecting power-generating sources with electricity consumers and other market participants (B. Afful et al., 2017).

In West Africa, the creation of domestic electricity markets has not been followed by substantial investment in transmission infrastructure and other physical facilities necessary to develop a regional market. Creation of a market for electricity trading among the WAPP member countries requires intervention in three areas: i) Substantial investment in new or upgraded physical transmission facilities that create the capability for large-scale trade in electricity, ii) A set of transparent, widely accepted rules and standards governing the technical operation of the interconnected system and the terms and conditions of electricity trade among suppliers, distributors and other market participants, iii) Rules and procedures for the establishment of information systems that support the efficient functioning of the market and are necessary for its ongoing monitoring and evaluation (Batinge et al., 2017). Establishing a power market trading system based on these elements is one significant first step in creating a regional power market.

Opportunities for Sustainable Energy Transition

Renewable energy sources have the potential to be effectively harnessed to leverage sustainable energy transition in West Africa. For abundant renewable energy sources such as hydro, solar, and wind energy, there would be opportunities for joint assessments of the impacts of regional integration of carbon emissions and asset relocations. For this purpose, good benchmark models would be available for testing model upgrades (Taliotis et al., 2017). There are opportunities for consideration of extended modelling of infrastructure considerations beyond the energy sector to link with other sectors. Similarly, there is a need to integrate renewable energy technology diffusion; empirical investments in renewable energy may be more effective in achieving comparable mitigation and adaptation targets, inducing changes in global market supply and demand, rather than merely allowing unfettered expansion (Batinge et al., 2017). This modelling could represent investment opportunities in energy infrastructure shifting towards closed carbon markets because of new unilateral policies or climate agreements with carbon-market access factors.

A few investment opportunities could be rapidly assessed concerning beneficial or detrimental ecological, economic, or social impacts. An example of a negative long-term effect is indirect land-use change associated with the growth of biofuels. Models could be employed to assess the tradeoffs between biofuel deployment and land availability across the globe. There are also opportunities for modelling humanitarian responses to increased climatic extremes. Climate change-induced shocks and migration must be better understood to avoid political instability. The assessment would need to include investments in improving the resilience of countries exposed to climate shocks, which would need to be better represented in modelling frameworks. If investment opportunities increase with global capital stock and population growth, emerging markets such as West Africa or China will benefit from more objectively based policy recommendations.

Renewable Energy Potential

In West Africa, vast oil and gas reserves are believed to be undersupplied, resulting in a reliance on energy imports. Nevertheless, even with these abundant reserves and ongoing investments in gas infrastructure, many nations in the region are still struggling to fulfil their energy requirements. In light of this situation, numerous stakeholders, including regional bodies like the Economic Community of West African States (ECOWAS) and various national governments, are advocating for the gradual evolution of an Integrated Power Market. This would allow the establishment of a Regional Electricity Market that can facilitate energy purchases from low-cost producers and their sale to customers in alternative nations. The standard option chosen to determine suitable investment locations in a systems assessment of power generation technologies in six selected West African countries is the maximisation of the average present value of profit across twenty years (Mukhtar et al., 2023).

Wind and solar energy potential in ECOWAS countries is substantial, but harnessing this potential is not straightforward. Although it is possible to establish grid-connected photovoltaic systems shortly, such projects would highly depend on African and international energy policies that aim to promote large-scale investments. Prior to handling future uncertainty, the most pressing challenges to developing grid-connected photovoltaic systems are identifying investment schemes that would provide investors with sufficient economic incentives, examining each ECOWAS country's legal framework for relevance, coherence, and application, and assessing the capabilities of each ECOWAS country's institutions to comply with relevant energy policies (Batinge et al., 2017).

Investment Opportunities

While energy transition in the context of renewable energy development is widely regarded as absolutely vital, it is not enough to ensure a safe future. Apart from energy transition, a third development paradigm, sustainable development (S.D.), is also a prerequisite for a safe future. Therefore, integrating or mainstreaming S.D. with energy transition and climate response is as important as the energy transition and climate response. However, mainstreaming S.D. with international climate response is a challenge due to differing levels of commitment between developed and developing countries, regarding S.D. as an exclusive concern of developing countries (Batinge et al., 2017). This concern is aggravated by climate response being primarily perceived as a development opportunity by developing countries and as a burden in developed countries, owing to the former being low-carbon concern countries and the latter being high-carbon concern countries.

There is a pressing need for a new initiative that encourages developed countries to respond to climate change by integrating or mainstreaming efforts to develop energy transition and sustainable development in developing countries with their climate concerns. This need emanates from the fact that climate change is a global concern. Hence, efforts to address it must be globally representative and uniformly applied to grapple with its universally adverse impacts (Ajao & Sadeeq, 2023). The proposed initiative outlines a global proposal for energy transition and S.D. to help developing countries cope with the devastating impacts of climate change on their socioeconomic and environmental systems. Regarding energy transition and S.D., concrete projects are identified to promote clean energy development and efficiency improvement. However, assistance is also sought to address socioeconomic hindrances to implementing climate projects, such as poverty alleviation and sustainable livelihood development efforts.

Case Studies of Successful Regional Power Market Integration

In addition to analysing the WAPP market, two successful case studies of regional power market integration in other geographical regions are presented. The first case is the Southern African Power Pool (SAPP), and the second is the Nordic Power Market. The investigation of these case studies aims to draw lessons that can be replicated in the West African context.

The Southern African Power Pool (SAPP) is proposed as a case study due to its relatively recent and comprehensive regional power market integration efforts. The SAPP was established in 1995, and power trading commenced in 1996. Prior to that, a Power System Master Plan was developed and mutually agreed upon by the member utilities. The Ydesen (2004) report was prepared in 2003 and provides valuable insights into the challenges faced during the SAPP market establishment and strategies for addressing these challenges.

The SAPP has an installed capacity of approximately 50,000 MW, with an MVAA of 433.1 GWh at the end of 2007. Although the regional energy trade has doubled since 1997, it accounts for only about 2% of the total regional energy generated. There is still significant room for growth. Trading occurs at the day-ahead and short-term weekly horizontal markets with the market clearing mechanism using a zonal price optimisation methodology employing linear programming (Boëthius, 2012). It was emphasised that the SAPP expansion and market establishment depend on transmission expansion from the utility side, requiring new interconnections. It was acknowledged that market integration impacts the power system, which could lead to a crisis if it is carefully managed (Ydesen, 2004).

In the case of the Nordic Power Market, the experience of the Nordic countries (Norway et al.) is presented and viewed as a success story regarding regional market integration. The Nordic electricity market, implemented on 1 May 1996, is characterised by a standard physical transmission grid and a common market for day-ahead and intraday trading. Trading occurs in a single auction for each hour of the next day. The competitive market environment is supported by legislation, the unbundling of power utilities, and establishment of an independent regulator. In addition to the incremental expansion of the shared solution, there are equally important initiatives that have helped broaden the user base of the shared solution and ensure that it remains internationally competitive (Sakellaris, 2011). The experience of the Nordic power market integration could provide valuable insights for establishing the WAPP power market.

Southern African Power Pool (SAPP)

The integration of the Southern African Power Pool (SAPP), consisting of 12 countries in the Southern African region, into a regional power market has proved successful since 2002. A priori, developing countries are generally disadvantaged compared to developed countries in terms of regional energy cooperation, especially when the connection countries have different political systems, economic circumstances, and energy demands. However, experiences from the SAPP region demonstrated this is not necessarily the case. The successful integration of the regional electricity market in the Southern African region could offer valuable insights and lessons relevant to West Africa.

The following is a synopsis of the SAPP experiences and lessons, which could serve as a reference for decision-makers in West Africa. Critical factors contributing to successful integration include (1) clear objectives, political will, and involvement of heads of state; (2) adequate institutional arrangement and governance; (3) equal treatment of members regardless of market readiness; (4) a stepwise, phased implementation focusing on low-hanging fruit and win-win projects; (5) Prioritisation of mutual benefits to attract interest, support, and participation of potential members; (6) open and transparent mutual exchange of information and data; (7) recognition of the role of electricity interconnections in the energy development strategy of the region (Boëthius, 2012; Trotter et al., 2017).

Nordic Power Market

The Nordic Power Market, formed in 1996, is one of the pioneering market initiatives for cross-border power transactions. It is widely recognised as an inspirational model for other countries in transitioning to a competitive electricity market. Transmission companies cooperate voluntarily through NORDEL, a network of Nordic transmission system operators. The owners of the transmission companies are the power companies; hence, these companies have a dual role in the market. They are both competitors and the owners of the companies supplying

the transmission network. The dual role has resulted in potential inefficiencies in the power markets. The Norwegian experience of setting up an electricity market has a long history. The existing Nordic power market, established over the last eight years, was an attempt to build a competitive power market based on these earlier experiences (Bye & Hope, 2005).

The Nordic Power Market is relatively small compared with power markets in other regions of the world. The socioeconomic conditions, such as geography, natural resources and political and regulatory frameworks, differ considerably. These differences shape the market structure in each region. The Nordic countries cooperated in the late 1960s to trade electricity, and the Mæglerne was established in 1993 to market power daily. The power exchange Nord Pool was set up in April 1996 and became the world's first power exchange handling both day-ahead spot and long-term futures contracts. Therefore, the Nordic Power Market is a natural case for studying power market integration and cooperation (Boëthius, 2012).

Lessons Learned and Best Practices

Critical lessons from regional power market integration in Europe, America, the Middle East, and Africa highlight the importance of transparent objectives, gradual implementation, robust regulatory frameworks, and active stakeholder engagement (Boëthius, 2012; Nepal et al., 2017). Due to fragile infrastructure and uncertain regulatory environments, a gradual approach is crucial for emerging markets like West Africa. Establishing a competitive market without the necessary telecom, network interconnections, and standards would delay benefits. Flexibility in targets and fostering regional trading blocks, rather than a single integrated market, alongside capacity building, is essential for successful integration. Moreover, it would continue to pay to allow existing and past agreements to stay as they are. Finally, the lessons learned and best practices underlined in this section are crucial and have lessons for the West African regional power market where the study is conducted. The case studies and the integration experiences provide valuable insights and guidance for formulating the regional power market integration strategy in West Africa.

Policy and Regulatory Frameworks

This section considers the key aspects of policy and regulatory frameworks required for a thriving regional power market. Lessons learned from case studies and best practices have been reviewed. Policy and regulatory frameworks were among the most common issues identified. Robust policies and regulations were pivotal building blocks stimulating a conducive energy collaboration and integration environment. However, the heterogeneity of policies and regulations, particularly in how effectively they have been enforced and adhered to, has influenced the motivations and commitment of the various players involved (Nepal et al., 2017). Thus, the trust that originally existed among the players has diminished. In some instances, regulatory frameworks have inhibited investment flows; in others, they have provided incentives to build interconnectors and facilitate trade (Boëthius, 2012). Current energy and economic policy contexts refer to these broader political backdrops influencing energy integration and cooperation plans.

It is apparent from the case studies that there has been a desire, for a multiplicity of reasons, to cooperate and integrate energy systems at the regional level. A complexity of historical, political and economic motivations has influenced current integration proposals and discussions. Standard configurations regarding the technology of interconnected systems, hydro potential, carbon intensity, currency stability, the variability of solar and wind resources and volcanic activity (in the case of Iceland) have encouraged some countries to think about cooperative unity. Nevertheless, the interaction of these motivations varies according to circumstance and has resulted in heterogeneous compliance with regional collaborative initiatives and dissimilar energy integration systems.

Below is a table outlining the **Policy and Regulatory Frameworks** for exploring the integration of a regional power market in West Africa, including examples of specific countries and references.

Table 2: Policy and Regulatory Frameworks for exploring the integration of a regional power market

Framework Aspect	Description	Country Example	Challenges	Opportunities	References
Regional Power Market Integration	Establishing a harmonised regional electricity market for cross-border trade and energy exchange.	**Nigeria**: A key player in the West African Power Pool (WAPP).	Disparities in national energy policies. Interconnection infrastructure gaps.	Nigeria's large generation capacity can stabilise the regional market. Enhanced regional energy security and cooperation.	**ECOWAS** (2018); **WAPP** (2020)
Regulatory Harmonisation	Aligning national regulations with regional frameworks, ensuring consistency in tariffs, licensing, and operational standards.	**Ghana**: Active participant in regulatory alignment through the Energy Commission and PURC.	National regulatory differences complicate alignment. Lack of harmonised tariff structures.	Ghana's regulatory framework could serve as a model for other ECOWAS members. Potential for streamlined cross-border electricity trade.	**Agyemang & Hussey** (2021); **ECOWAS** (2018)
Institutional Framework	Strengthening the roles of regional organisations like ECOWAS and WAPP in coordinating the power market.	**Senegal**: Host to the WAPP Information and Coordination Centre.	Limited institutional capacity at the regional level. Coordination and challenges between national and regional bodies.	Senegal's role in WAPP supports enhanced regional governance. Centralised coordination could improve grid reliability across borders.	**WAPP** (2020); **Sakho** (2019)
Legal Frameworks	Developing binding regional agreements to govern electricity trade and dispute resolution.	**Côte d'Ivoire**: Leading in cross-border energy export agreements.	Conflicts between regional and national legal frameworks. Jurisdictional challenges in enforcing regional agreements.	Côte D'Ivoire's successful bilateral agreements could pave the way for multilateral treaties. Legal certainty improves investor confidence.	**Kouassi & Assoumou** (2019); **ECOWAS** (2018)
Tariff and Pricing Mechanisms	Creating transparent and competitive tariffs that reflect the cost of generation, transmission, and distribution.	**Benin**: Participates in the Benin-Togo electricity exchange agreement.	Inconsistent tariff structures and subsidy policies across countries. Affordability concerns for consumers in less developed markets.	Harmonised tariffs encourage private-sector investment. Transparent pricing mechanisms foster cross-border energy trade.	**Gupta** (2020); **ECOWAS** (2018)
Grid Code Development	Establishing a unified grid code for technical and operational standards across the regional power network.	**Ghana** Has developed a robust national grid code that could integrate with a regional framework.	Technical challenges in synchronising grids across countries. High costs of updating and aligning national grids with regional standards.	Ghana's experience in grid code development can aid regional efforts. Improved grid reliability and efficiency through standardisation.	**Agyemang & Hussey** (2021); **ECOWAS** (2018)
Sustainable Energy Policies	Promoting policies that support renewable energy integration and energy efficiency.	**Cape Verde**: Leading in renewable energy adoption with a focus on wind and solar.	Inadequate financing for renewable projects. Variability in national commitments to renewables across the region.	Cape Verde's renewable energy success can serve as a case study. Regional cooperation on renewables could enhance energy security and reduce emissions.	**Castro et al.** (2021). **ECREEE** (2019)
Market Design and Structure	Designing a competitive market structure that balances public and private sector roles.	**Nigeria**: Transitioning to a partially privatised electricity market.	Balancing public utility roles with private sector participation. Ensuring affordability and reliability in a competitive market.	Nigeria's market reforms could inform regional market design. Increased competition and innovation improve service quality.	**Amadi** (2020); **ECOWAS** (2018)

Capacity Building and Training	Enhancing technical, management, and regulatory capacities of stakeholders.	**Ghana**: Hosts the West African Power Pool (WAPP) training programs.	Limited access to advanced training and retention of skilled personnel. High costs associated with capacity-building initiatives.	Ghana's role in capacity building strengthens regional expertise. - Development of a skilled workforce to manage and operate the regional grid.	**Agyemang & Hussey** (2021); **WAPP** (2020)
Investment and Financing	Establishing mechanisms to attract investment for infrastructure, including generation, transmission, and distribution.	**Senegal**: Attracting international investment for renewable energy projects.	High perceived risks for investors due to political and economic instability. Limited access to long-term financing.	Senegal's success in attracting green finance could serve as a model. Regional investment opportunities increase through shared infrastructure projects.	**Sakho** (2019); **World Bank** (2020)

Table 2 provides a structured view of the policy and regulatory frameworks necessary for integrating a regional power market in West Africa. It incorporates examples from specific countries and is backed by academic and institutional references.

Stakeholder Engagement

Integrating a regional power market requires an inclusive engagement of the diverse stakeholders. The key stakeholders in the integration of the power market in the WAPP region were identified as a) Electra and FENEL of Mali, b) Transmission System Operators (TSOs), c) Regulators of the TSOs, d) Power pools and Regional Coordinators, e) Ministries of Energy of the TSOs, f) National regulatory agencies of the TSOs, g) Consumers and their representatives, and h) State/Electricity Holds and their representatives. Each stakeholder in the workshop in Kampala acknowledged the importance of their involvement in the proposed integration process. The engagement of the different stakeholders at the different phases of the process and the requirements placed on them concerning data provision were discussed. In the WAPP region, it was found that surveying stakeholder perception of the proposed integration benefit, design, and market rules is essential, considering the diversity of stakeholders, regulatory arrangements, and the free access environment in which some TSOs operate (Hickey, 2022). The current knowledge of the potential stakeholders deemed important in the power market integration was based on the experience of modelling the integration of Ethiopia and Kenya's energy systems.

Lessons were drawn from the experience of European EMVAs on stakeholder engagement in the day-ahead market. Stakeholder involvement is critical to any successful integration project and should be embraced from the conceptual phase (Boëthius, 2012). A well-structured approach ensures stakeholder coordination and consistency across the various workstreams carried out in the project. Regular meetings, workshops, webinars, and a dissemination plan tailored to different audiences were suggested as tools involved in addressing stakeholder involvement activities. In the case of the day-ahead market, it was noted that the awareness of stakeholders' importance is pivotal in securing their involvement and support in the process.

Technological Innovations for Regional Integration

Technological advancements play a vital role in integrating a regional power market. The evolution of smart grids enables deploying an intelligent, manageable, and resilient power system, ultimately improving control and interaction between transmission operators and energy market participants. The dissemination of smart meters will provide policymakers with valuable information on consumption patterns. Smart grid technologies and systems are the fundamental developments for transmission expansion. They allow for a shift from reactive to proactive transmission system operation and facilitate high penetration levels of renewable generation. A robust Information and Communication Technology (ICT) backbone is essential (Boëthius, 2012).

The energy storage technologies market is expected to reach US$375 billion by 2050. Energy storage technologies can support the integration of the regional power market. The growing importance of energy storage in managing variable generation sources and providing better flexibility to load and generation is emphasised. Technologies such as pumped hydroelectric storage, batteries, supercapacitors, and compressed air and flywheel technologies are being developed. From a market perspective, interest in energy storage is growing due to the liberalised electricity energy sector, where the opening of markets has led to more significant risks for investors and increased uncertainty in managing hydropower systems.

Smart Grids and Energy Storage

In the changing energy landscape, advanced technologies could transform how electricity is generated, transmitted, used, and stored. These transformative technologies could create a seamless power market and regional market integration. Smart grid technologies could be utilised to overcome the integration challenges in harmonising regulatory and institutional frameworks as they could facilitate real-time monitoring of the transmission system's integrity and performance and establish a data-sharing platform on the fluctuations of generation and load between utilities. On the other hand, energy storage solutions could help overcome the intermittency of generation (Mukhtar et al., 2023). Globally, there is an increasing interest in battery technologies that could store both end-use electricity from the grid and large amounts of unutilised renewable electricity and shift the released electricity for later use. Traditional pumped hydro storage facilities were the only commercial-scale energy storage installed globally with an identified potential of 591 GWh. However, other ESS technologies with varying maturity levels are emerging, such as liquid-air energy storage and flywheel storage.

The implementation and installation of energy storage systems (ESS) in renewable energy source (RES) integrated power systems could help in making the grid relatively well regulated; moreover, it would compensate for sudden momentary dips in system voltage without the need for new generating plants (SARKAR & Odyuo, 2019). A detailed literature review reveals that many issues related to RES integration have been addressed. However, challenges still arise with increased penetration of RES in the power system due to advances in renewable energy generation. Therefore, with advancements in weather forecasting using satellite monitoring, it is now possible to forecast weather conditions accurately. This would result in the curtailment of under and over-solar generation and storage and non-storage schemes. Proper regulation is the need of the hour globally to monitor the achievements and productivity of generators. The intelligent grid plays an imperative role in the complete, seamless integration of renewable power sources into the grid, and the importance of microgrids is on the rise.

The Role of International Partnerships

Partnership and cooperation with multilateral organisations, such as the African Development Bank (AFDB), the International Renewable Energy Agency (IRENA), the United Nations Development Programme (UNDP), the West African Economic and Monetary Union (UEMOA), the United Nations Economic Commission for Africa (UNECA), and the World Bank Group, can provide internal support through regional initiatives and access to international projects (Batinge et al., 2017). In addition, international economic partners such as the European Union, the United States of America, Canada, China, India, Japan, and the United Arab Emirates are involved in various development initiatives (Guler, 2018). The B2B partnerships and decentralised cooperation promote cooperation and exchange of experiences among global local authorities. International collaboration has significant benefits and opportunities, including funds, sharing knowledge and best practices, exchanging staff and experts, supporting project implementation, and regional and bilateral initiatives.

Support from Multilateral Organizations

International engagements in the energy transition of West Africa are critical in addressing regional energy challenges. Multilateral organisations provide resources and synergies to participating states. The African Union identifies the fragmentation of the regional energy market as a core challenge problem. The United Nations (U.N.) proposes sustainable energy for all as an opportunity to upgrade and integrate the fragmented subsectors of the regional energy market. Energy transition issues are huge preconditions to achieving sustainable development goals. Renewable energy sources (RES), especially solar energy, are present in abundance in West Africa; therefore, they could be thoroughly used to secure low-carbon, affordable, inclusive, and accessible energy services for all and to achieve national and regional sustainable development goals (Batinge et al., 2017). The West African Power Pool (WAPP) was created to develop an efficient electricity market by developing good rules and regulations for the entire West African region to create a regional electricity market able to reduce the cost of electricity and increase the reliability, quality, and accessibility of electricity services for all in the countries. However, the sustainability of the entire investment of regional interconnection facilities in transmission systems is being jeopardised because of the lack of political will for a regional electricity market from the governments of the member countries (Suleiman Momodu, 2018).

Conclusion and Future Directions

The potential for integrating a regional power market in West Africa offers opportunities for sustainable energy transition and broader access to Western Dawn, ensuring the appropriate connectivity and local infrastructure for development and implementation in local communities. Each solution relies on sustainable technologies and resources without environmental damage, further developing indigenous human resources, capabilities, and technical knowledge. These solutions are building blocks for the renovation and modernisation of West African energy security, stability, and affordability, ensuring long-term energy access for all, starting with cost-effective empowerment of vulnerable communities dependent on wood fuels, oil lamps, diesel generators and promoting rural economic growth and cooperation. Policy recommendations are offered with timelines for addressing the implementation challenges (Batinge et al., 2017). Future scenarios depict a gradual yet stable regional energy market development and renewable energy facilities for interconnected West African countries. Preliminary modelling results suggest regions with high renewable energy potential but poor access to electrical energy (E.g., right corridor of Sierra Leone) strategically connected to the regional power market and neighbouring countries with complementary energy portfolios for achieving significant renewable energy use. This approach minimises costs, strengthens inter-country cooperation, and enhances regional stability.

West Africa is moving toward its regional vision for an integrated and interconnected energy market, with broad access to stable electricity, ensuring economic growth, regional cooperation, and climate change mitigation. This is an excellent opportunity for the sustainable energy transition of the entire Western Dawn, although specific challenges must first be addressed for successful implementation (Mukhtar et al., 2023). Sustainable and robust energy market integration must rely on political commitment, openness towards good-willing cooperation, sound planning based on mutual technological and market understanding, and innovative concepts accounting for regional independence, avoiding costly lock-ins.

Summary of Findings

The integration of a regional power market in West Africa is explored, drawing on experiences from the emergence of similar markets across Europe, Latin America, and the Southern African Development Community. Focused on the Electricity Exchange of West Africa project, it reviews the background, market structure, and organisation. It discusses challenges related to cost allocation, tariffs, cross-border transmission congestion, balancing energy and reliability, load forecasting, and transmission service payments. Development initiatives include the West African Gas Pipeline and Power Pool. Emphasis is placed on governance structures as critical factors for market development. Key recommendations address the need for a well-defined roadmap and vision for market integration, a standard set of market rules and procedures for trading and settlement, and continued collaboration and coordination of efforts with all stakeholders, including regional organisations (Batinge et al., 2017). Access to reliable, affordable electricity significantly hinders economic growth in many Developing Countries (D.C.s), particularly in Sub-Saharan Africa. This has resulted in an increased focus on energy policy and the implementation of energy sector reforms and restructuring aimed at addressing the problems of energy inefficiency, poor service delivery, inadequate investment, and other structural and organisational weaknesses. In many D.C.s, the power industry comprises vertically integrated (state-owned) monopolies that manage the entire electricity supply chain (generation, transmission, distribution, and supply) with little or no involvement from the private sector (Mukhtar et al., 2023).

Recommendations for Policymakers

We offer specific recommendations for policymakers about regional power market integration in West Africa. Given the current efforts to establish a regional power market in West Africa, the recommendations may be helpful for countries wishing to broaden the scope of policies and governance frameworks to facilitate effective regional power market integration. Transforming national markets into a regional market requires the implementation of many legal and regulatory provisions and can, therefore, be both complex and resource-intensive. It is recommended that an appropriate starting point be identified in the concerned countries. It first evaluates the region's current level of market integration and harmonisation and, secondly, determines which policies and governance frameworks may effectively address challenges preventing more regional integration. This initial assessment may also indicate how different countries are influenced differently by specific challenges, opportunities and entry points, guiding the prioritisation of actions (Batinge et al., 2017). In order to assess the level of regional integration in the region,

indicators for successfully functioning markets need to be evaluated. A helpful approach would be to draw upon the experience gained in Europe in this regard (Mukhtar et al., 2023).

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