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African power pools and regional electricity market design: Taking stock of regional integration in energy sectors☆

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ABSTRACT

While the traditional perspective on regional power pools is that of regional electricity markets, regional power pools in Africa are development tools with unrepresentative and under-researched dynamics in their evolution and market design. Five African power pools are under development to bring the continent into a single electricity market. This paper analyses the evolution of African power pools by examining their design factors and dynamics. It compares the three most advanced power pools (SAPP, WAPP and EAPP) to identify barriers, forces, and development approaches. The paper devises a multilayer analytical framework to organise the various elements in the institutional context of African power pools and structure the analysis of the physical, economic, institutional and political factors. The analysis shows that the unequal distribution of natural energy endowments across the regions stimulated the historical development of interconnections and trade between countries. The characteristics of regional integration were vital in shaping the power pool's institutions and development approaches. We have identified three motors of change that have driven the development; regional economic communities, members' strategies, and international institutions. It is crucial for progress that the pool staff can mitigate non-cooperative strategies, address members' concerns, and incentivise a shift in national agendas to build confidence in regional trade.

1. Introduction

Between the 1980s and 1990s, the power sector underwent several market-based public sector reforms across the globe. Rapid advances in information and communication technology have reduced barriers to entry into electricity generation and retailing, questioning the natural monopoly status of the power sector. The traditional model of a vertically integrated, state-owned power utility has been deemed inefficient [1]. The power sectors in Chile, England and Wales, and Norway underwent successful deregulation and restructuring. These reforms led to a new alternative organisation of the power sector, which became known as the 'standard textbook model' for power sector reform [2].

In Africa, the standard textbook model of power sector reforms has been considered ineffective [3,4]. African developing countries face numerous economic and sociopolitical challenges. Additionally, there is a lack of experience in constituting appropriate institutions[1] and regulations that suit local conditions [5–7]. Consequently, the power sector in African countries is severely underdeveloped and heavily draining public budgets. Africa is home to about 17% of the world's population, 60% of whom live in rural areas with an electricity access rate of 5%. The overall electrification ratio in some countries is below 20% (e.g., Burkina Faso), and the average in sub-Saharan Africa is 45% [8]. Quasi-fiscal deficits to subsidise the state-owned electricity companies in sub-Saharan Africa amounted to 1.37% of the Gross Domestic Product (GDP) in 2014–15 [9], while the annual cost of outages in some countries is estimated to be 2% of GDP, and the annual finance gap to build the necessary infrastructure is estimated at 5–20 billion U.S. dollars [10,11].

In response to this, five regional power pools have been founded to create regional electricity markets between African countries. A power pool is defined as"a group of two or more utilities that coordinate their

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[1] The term institutions here means formal rules. Another use of the term in this article is to refer to organisations, e.g., financial institutions.

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operations and planning" [12]. The definition encompasses several national (e.g., Norway and Sweden), state (e.g., Pennsylvania–New Jersey–Maryland (PJM)) or local (e.g., the National Electricity Market (NEM) in Australia) power systems that are characterised by having a highly harmonised and coordinated organisation under a traditional or market-oriented regulatory framework. Thus, it is a higher hierarchical level of organisation of multiple systems that strengthens their original interactions and renders them subject to well-defined mutually-agreed rules [13]. Regional power pools typically cover a wider geographical area that involves more than two countries. In this article, power pools refer exclusively to regional power pools.

Power pools have widely recognised theoretical benefits. They allow for the expansion of power systems across borders, which entails taking advantage of economies of scale on both the supply and demand sides and enabling investment in large-scale projects that are not viable for a single country [13]. For instance, in [14], the author estimated around $32 billion of expected savings in supply costs from regional power trade in West Africa. Expanding power systems also increases competition and private sector participation. By diversifying supply and demand and allowing for the sharing of reserves, the power pool increases the security of supply and enables a higher renewable energy penetration through a larger balancing area.

This article provides is, to the best of our knowledge, the first comparative study of African power pools. It presents a comprehensive analysis of the three most advanced power pools and aims to contribute to their further development. The following section reviews different studies on regional electricity markets and African power pools. These studies, together with our empirical findings from interviews, feed into Section 3, which describes an analytical framework that structures the institutional context of African power pools into different layers and factors. Based on the elements of the framework, Section 4 presents a comparative case study of the selected power pools in the Southern, Western and Eastern Africa (SAPP, WAPP, EAPP). Drawing on the application of the framework to the three cases, Section 5 provides insights into their barriers and further development. Finally, Section 6 concludes the key findings and implications from the cases and presents potential future research.

2. Literature review

Regional electricity markets received less attention in the literature than national electricity markets. Most of the early studies were commissioned by international organisations, especially the World Bank, to assess the benefits of regional trade [15] and to show the different institutional arrangements for regional electricity markets [16,17]. Different governance models (institutional arrangements for decision-making) of power pools were discussed in [16]. The authors compare the practices of four pioneering power pools and argue that self-governance could substitute external regulation. In [17], a list of lessons learned is presented from examining different regional markets. The authors examine the institutional settings that facilitate trade, how trade developed, and the evidence of benefits from power trade.

Establishing regional electricity markets poses many challenges; three critical problems were identified in the literature related to market operations, regional infrastructure, and institutions and governance [13]. First, market rules are to be harmonised and aligned with national concerns about the security of supply and national sovereignty. Second, the market must have effective regional institutions and regulations to oversee trade and resolve disputes between market participants. Third, the regional regulator needs to incentivise investment in regional infrastructure projects, particularly cross-border transmission, and ensure efficient capacity allocation in the long and short term.

The literature on African power pools can be grouped into three categories. The first group consists of technical studies that aim to optimise generation and transmission expansion in the long term [18–22] or in the short term by solving optimal unit commitment and dispatch problems across the region [23] or by investigating the technical efficiency of national utilities [24]. In Addition, some studies seek to quantify the optimal renewable energy mix to achieve transition scenarios [25,26].

The second group is social science studies that evaluate regional institutions, policies, regulations, and organisational capacity by using social science methods, such as interviews, surveys, institutional analysis, and cross-case comparisons [27,17,28,29]. Another set of studies in this group focuses on the development of African power pools in the context of political economy and regional integration [30–33]. These studies provide insights into the regional dynamics and how national governments play a role in either accelerating or hindering the regional integration process. Although such insights are essential for understanding the evolution of the power pools, these studies do not establish correlations.

Finally, the third group is a hybrid combination of rigorous technical representations of the electrical system with an analysis of the institutional context. [34] is an example of such a study, combining technical quantitative and institutional qualitative analyses of different methods of cost allocation of transmission lines to promote regional investments.

The literature on African power pools, so far, has not addressed questions such as how they evolve, what drives their design, and why they differ. These questions were explored for national markets in [35] using an institutional economics approach that examines the various factors of influence and market design variables. This paper builds on and extends the work in [36,37] by addressing these questions following the same approach in [35] and building on that analytical framework by integrating the different theories with evidence from the literature and from interviews, as discussed in the following section.

3. Analytical framework

To fully understand the development of African power pools in an institutional context, it is necessary to consider their formal establishment and organisational capacity. African power pools are established by regional economic communities (RECs) as a means of regional cooperation in the energy sector [30–32]. The RECs are groupings of African states that facilitate economic integration among members of the individual regions and through the wider African Economic Community [11]. They define the role and objectives of African power pools. As such, they are the policymakers that establish the legal framework of the power pools. As an instrument of cooperation, the organisational capacity of the power pools determines their success in achieving their designated objectives (i.e. their performance) [28]. This paper argues that African power pools can be viewed as regional international organisations (RIOs) because they fulfil the "four necessary and jointly sufficient attributes" [38]:

1. **State members**: RIOs are established by states and have them as their members.
2. **Organisational capacity**: RIOs are organisations with a physical headquarters and staff, regular procedures such as meetings of their member states, and the capacity to make decisions and act on them.
3. **Multilateralism**: RIOs consist of more than two member states.
4. **Geographical proximity**: RIOs' membership is geographically proximate and limited (in contrast to universal organisations).

This view requires the introduction of factors that affect the pool's performance. The following steps were taken to adapt the original framework in [35]:

1. Introducing power pool organisational factors that affect their performance.
2. Identifying design factors that constrain the power pool design.

Table 1
Organisational factors that impact the performance and outcome of the power pool. Identified from [41,28].

Factor	Impact
Governance structure	The organisation of the power pool dictates the efficiency of decision-making and project execution. A fair and inclusive representation of the members increases the interest of other parties and the power pool expansion.
Financing arrangements	The daily operation of the power pool is affected by the financing arrangements from member countries and other organisations. Effective fee collection and arrears payments are crucial for improving performance.
Staff capacity	Having qualified staff and leadership accelerates the development of the power pool. A fully staffed market committee is crucial to establish the regional electricity market.
Technical readiness	The technical capabilities to establish a coordination centre (market operator) for operating the market is a sine qua non for short-term trades.
Dispute resolution mechanism	A transparent and fair dispute resolution mechanism enhances members' trust and is essential for continuous trade operations.
Stakeholder relationships	A good reputation and relationships with various stakeholders support the pool's progress.

3. Identifying design variables that determine the space for the power pool operation.
4. Identify the dynamics of power pool design that explain how they develop.

Each of these steps is described separately in the following subsection.

3.1. Organisational factors

The development of a power pool could be hindered for reasons that are market-related but related to the pool's inability to operate adequately day-to-day. The theory of organisational capacity building addresses the factors that affect the improvement of an organisation [39,40]. The authors of [41] identify internal factors targeted by capacity-building programs to enhance organisations' performance. These include funding capacity, staff qualities, organisational structure, resource acquisition, and external relationship building. Furthermore, in [28], the author uses a framework on the theory of change to show that these factors do indeed affect the performance of two African power pools (SAPP and EAPP). Therefore, these factors are considered at the operational level of the power pool. The impact of these factors is explained in Table 1.

3.2. The context of power pool design

The process of establishing and designing a power pool is subject to a number of constraints. For example, a power pool cannot be established without sufficient interconnections and generation capacity for trading. These system-related constraints are "hard" constraints that must be fulfilled. At the outset, the structure of power systems in member countries constrains the number of market participants and, hence, the competition in the market. We label this set of constraints as physical constraints because they determine the characteristics of the physical infrastructure.

A second set of constraints relates to the macroeconomic characteristics of member countries. Factors such as the level of economic development, demand growth, and financing options limit the investment opportunities in the regional infrastructure and compromise the solvency of participating members. Countries classified as Heavily Indebted Poor Countries (HIPCs) have stagnant economies and borrowing restrictions, making them vulnerable to the cost of regional trade and unable to pay for imports.

A fundamental set of constraints is derived from national and regional institutions, such as institutional stability, law enforcement, and the degree of institutional centralisation and harmonisation. A legal framework and formal rules are required to regulate regional trade. Additionally, some market designs require a high level of coordination and harmonisation between countries. Therefore, countries need to be able to adequately adapt their national institutions to regional regulations and market rules. On the other hand, having a regional body or centralised institutions facilitates the enforcement of these regulations and market rules.

The final category of constraints relates to the political situation. The ideology of national politicians influences the acceptability of normalising power trade and relying on it instead of planning adamantly for self-sufficiency. On the other hand, political instability and corruption are inimical to attracting investment and trust between countries to honour supply and payment agreements. Table 2 overviews these physical, economic, institutional, and political constraints. Within each category, the factors are identified from our empirical observations, in line with the work in [35]. We call them design factors as together they largely determine the context of power pool design.

3.3. Power pool design variables

As defined in [35], design variables are internal market settings with a path-dependence characteristic that actors can influence. The power pool design is the process by which these variables change to achieve the desired goals. We distinguish between two groups of variables: those related to the regional market of the power pool and those related to the power pool as a RIO. The former variables are the same as in the original framework. However, we adjust some variables to fit the regional market context. Namely, we change "integrated versus decentralised market" to "loose versus tight pool" [16] and network tariff to transmission tariff methodology [13]. Moreover, we introduce three variables from the observations of the current market development and planning in African power pools: voluntary versus mandatory pool, trading platform, and ancillary services. These variables differ between the power pools, can change over time and serve different purposes.

The second group of variables determines the power pool organisation and is related to the organisational factors described in Section 3.1. These are power pool autonomy of decision-making, membership, investment functionality, and the regulator's position. The introduction of these variables is based on the organisational structure of African power pools and the assessment conducted in [28]. The power pool autonomy is a function of its governance structure and affects the pace of adopting market rules. The power pool membership either permits or forbids Independent Power Producer (IPP) participation[2], hence, determining the degree of market opening and competition. Based on its defined objectives, a power pool may have an investment functionality to facilitate regional infrastructure projects. This functionality requires different expertise and the establishment of a dedicated organ within the pool organisation. Lastly, as pointed out in [35], the regulator's

[2] As well as other non-asset owners.

Table 2
Design factors that determine the context of the design process.

	Factor	Impact
Physical	Transmission infrastructure	The development of the internal transmission lines and interconnections affect the strategies of member countries and the regional trade. Low electricity access or low network coverage limits trade volume
	Generation resources	The distribution of generation resources in the region drives the pattern of trade. Seasonal resources like hydropower are particularly influential to the dynamic of power exchange.
	Structure of national power systems	The organisation of national systems affects the power pool's membership and governance structure as well as the degree of competition.
Economic	Level of economic development and growth	Influences demand growth, investment potential, and institutional stability.
	Demand growth in relation to generation capacity	Rapid demand growth or limited generation capacity increases imports and the likelihood of network congestion.
	Financing options	Limits the investment options, especially in developing or transition economies.
Institutional	Regional institutional stability and the rule of law	Facilitate investment and external funding; helps adopt policies, regulations, and decisions of the regional institution.
	Regional institutional centralisation degree and harmonisation	The degree of harmonisation and the mode of inter-jurisdictional governance arrangements determine the authority of the power pool and the regional regulator.
	Influence of stakeholders	Powerful stakeholders could influence the choice of some market mechanisms.
Political	Ideology	National supremacy undermines regional integration and the delegated authority to the power pool.
	Political stability	Member countries with a stable political system maintain a stable relationship and involvement with the power pool. The political situation affects the bilateral agreements between neighbouring countries. Political instability, like military coups, political revolutions, and civil war, is inimical to attracting investment.
	Corruption	Hampers investment rate, relationships with stakeholders, liberalising trade, and participation in the power pool.

position has consequences for the relationship between the regulator and the pool members. Since these four variables determine the organisational structure of the power pool, we label them as structural design variables. Table 3 shows the complete list of design variables for formulating possible design options.

3.4. The dynamics of power pool design

To unveil how the design of the power pool changes, it is necessary to review the starting conditions and how countries approach regional integration agendas. On the first note, the starting conditions of the region restrict the design space for the power pool at its inception. A power pool whose members have vertically integrated power sectors would have a different design than one whose members have liberalised power sectors. The initial economic development of the region and national policies and regulations influence members' strategies and interest in regional trade. National policies, such as renewable energy support, directly affect the regional market [42]. By contrast, the presence of a regional body that could issue regional policies, such as the European Commission, helps to adapt national policies and regulations [43]. Depending on the authority of the regional regulator, national regulations could be adopted to allow for specific design options.

On the second note, regional integration agendas in the energy sector drive the creation of the power pool. Regional integration theory describes two ways in which RIOs can be established and developed: through intergovernmental agreements in which member states are the key actors in the integration (intergovernmentalism theory) or through a transnational body with supranational power (neofunctionalism theory) [38]. In the former, countries retain their sovereignty and engage in regional agendas that interest them. Progress is made when countries have sufficient incentives to push these agendas. This type of integration is also known as 'low politics' integration [44]. It takes the form of a regional executive secretariat. In the latter, member states transfer their power to the transnational body and the power of this body to enforce regional agendas determines the integration progress. This type of integration is called 'high politics' integration [44] and it takes the form of a regional commission. Both theoretical views are present in the reality of African power pools.

To represent these regional dynamic forces, we use the concept of "motors of change" from the transition management literature, which describes the forces that drive the development trajectory in a system with various actors and interests. The authors of [45] introduce this concept to describe the driving forces and the pathways for change within innovation systems. The same concept was also used in [46] to describe the role of organisations in policy-formation processes. Our interviews with the power pools show three motors of change. First, as policymakers, the RECs have the primary means to change the objectives, organisation and market design of the power pool. However, this depends on its legal and institutional characteristics as well as its formal relationship with the power pool. Second, the power pool member states could directly change the power pool's design or propagate it

Table 3
Power pool design variables that determine the operation of the power pool.

Variable	Consequences
Autonomy	Whether the decision-making authority is left to the members or in the hand of a political or regional body plays an important role in the decision dynamic and its enforcement.
Membership	Membership allowing for several classes ensures fair representation of stakeholders' interests and potentially increases trade volume.
Investment unit/functionality	The investment unit facilitates the execution of infrastructure projects (or the master plan) and involves technical and financing partners in the operation of the power pool.
Position of the regional regulator	Internal to the pool or independent. Tying the regional regulator to the pool could result in a conflict of role and interest as well as inefficient resolutions. Ex-ante regulation has a different impact on agent decisions than ex-post regulation.
Loose versus tight pool	A tight pool reduces transaction costs and allows dispatch optimisation but combines economic and physical control over the electrical system in the hands of a single party. A loose pool is politically favourable.
Voluntary versus mandatory pool	Mandatory trade through the pool facilitates planning and reduces conflict, political interference, and trust issues.
Trading platform	The nature of the trading platform impacts the volume of trade and members' participation. A shorter trading platform like intra-day provides flexibility, while physical and financial platforms increase the participation of various entities.
Transmission tariff methodology	The choice of methodology affects the trade flow through the network, the cost incurred by members, and the investment in the transmission network.
Congestion management method	The method of network congestion and compensation affects trade opportunities between regions and network investment.
Balancing mechanism	Balancing mechanisms and financial settlement affect the cost and revenues of some generations, especially intermittent generations, and influence market entry.
Ancillary services	Ancillary services provide opportunities for expanding the market and helping system operations.
Capacity mechanism	Different types of capacity mechanisms exist in order to stimulate investment in capacity.

through a regional body. Whether member states are open to trade or pursue protectionist policies, their strategies impact the development of the power pool. Nevertheless, a well-functioning power pool increases members' trust in a feedback process and could eventually impact their initial strategies to increase the degree of integration [17,38]. Third, the involvement of international financial and advisory institutions plays a role in the development path. Financial institutions support the development of the regional infrastructure and provide financial and technical assistance to improve the capacity of African power pools. With such support, the power pool design is susceptible to modification, especially regarding the technical aspects of the market and tariff design. On the other hand, advisory institutions working with national governments influence the political situation and institutional arrangements for power trading.

The three motors of change operate on different layers of the institutional context of the power pools. The regional body, the REC, influences not only the higher-level objectives and foundation of the power pool but also the lower level of its operation through the structural design variables. Moreover, it also has the means to impact the design factor to facilitate particular design options (for instance, providing countries with financing options through its regional bank). Then, members' strategies and their national policies clearly operate on the market-design level and are affected by the regional regulations of the market. Lastly, as external actors, international institutions work on both the operational level with the pool organisation and the design level with member countries. The distinction between these three levels (layers) helps to conceptualise the different facets of the power pool development. Thus, we devise a multilayer analytical framework that depicts the three layers with their respective actors, factors and defining theories. Fig. 1 illustrates this conceptual framework.

3.5. Data collection and analysis

To employ the analytical framework, data collection involved desk research and semi-structured interviews. Initially, information on African power pools was gathered through desk research, which encompassed peer-reviewed articles, books, policy documents, white papers, technical reports, and reliable websites. However, in some cases, the available information was either outdated or publically unavailable at the time. Therefore, to validate and supplement the initially collected data, interviews were conducted to gather primary information and triangulate the secondary data. Interviews were also useful to capture different perspectives from different actors and improve the understanding of the situation. We interviewed 15 experts on African power pools and regional integration. Among the interviewees, seven individuals were affiliated with the three power pools, three from WAPP, two from EAPP, and two from SAPP. The remaining participants included four external experts on WAPP and two on SAPP and EAPP, one staff from a regional regulatory institution in the EAPP region, and one former general director of EAPP member utility. The interviews followed a semi-structured format, guided by the approach outlined in [47]. All the interviewees were invited to a 45-minute interview after receiving a brief text explaining the research objectives and the purpose of the interview. The text also included potential questions, which can be found in Appendix C. All interviews were conducted online using video call applications, such as Zoom, Microsoft Teams, and Google Meet, except for the interview with EAPP staff, which took place in person as part of the author's visit to the power pool. The information collected from the interviews was analysed to identify key findings that would inform the elements of the analytical framework,

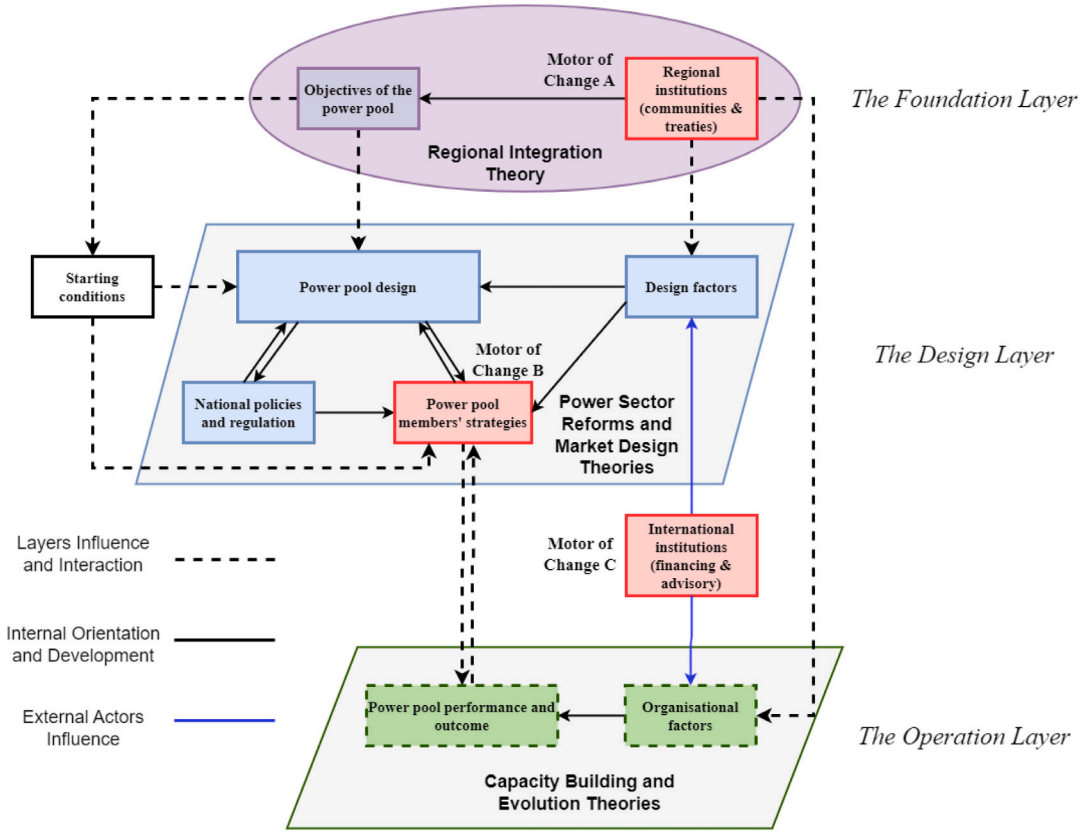

Fig. 1. The institutional context of African power pools, a multilayer analytical framework that shows the factors and motors of change, labelled A, B & C, that affect their development.

especially those that required insights into the current situation, such as members' strategies and conflicting interests. All the key findings from the interviews were consistent with the findings from the desk research.

4. Comparative study: SAPP, WAPP & EAPP

This section showcases the application of the framework to the three African power pools: Southern African Power Pool (SAPP), Western African Power Pool (WAPP) and Eastern African Power Pool (EAPP). Each power pool includes a different number of countries and belongs to a different REC, as shown in Table 4 along with their respective foundation year. Currently, only SAPP has functioning competitive markets, while the other two are developing the necessary soft (market rules and regulations) and hard (interconnections and generation) infrastructure. The following subsections provide contextual descriptions of the three cases based on the elements of the framework, highlighting the differences and similarities for each element.

4.1. Organisational factors

The governance structure of each power pool has different decision-making authority. The highest decision-making level of SAPP, the executive board, is a simple single-class board with national utilities as its board members. SAPP allows IPPs to obtain membership but excludes them from the executive board and the management committee. Additionally, IPPs have limited voting rights on certain issues. SAPP can make changes to its own operational rules, but any changes to its policy or involving other outside entities must go through SADC ministers. EAPP has a more politically driven governance structure. Its highest decision-making authority is the council of ministers, which includes countries' energy ministers. EAPP rejects IPPs in its membership and only allows national utilities. On the other hand, the governance model of WAPP does not involve political stakeholders and formally mandates its executive officers to be independent of market participants. WAPP approves IPPs and consumer representatives as official members. The general assembly is the highest decision-making authority and includes all members with equal voting rights. Hence, the governance model of WAPP is more democratic and inclusive than SAPP and EAPP. However, half of the votes belong to only two countries, Ghana and Nigeria, making it possible for these two countries to block decisions if they join forces.

The organisational committees of the power pools are similar in terms of functionalities but vary in designation. WAPP and EAPP have a dedicated secretariat for coordinating the pool activities, while SAPP has a coordination centre. Owing to its functioning market, SAPP has a dedicated market committee and market surveillance.

The financing arrangements of the three power pools consist of members' fees or contributions to cover the operation of the pool and grants from donors for the implementation of projects. While SAPP and EAPP have a fixed annual fee, WAPP members' contributions vary proportionally to their traded energy. According to our interviews, WAPP and EAPP experienced several cases of inadequate collection of membership fees; hence, they rely on donors' grants to perform their project activities. Such grants and additional funds are facilitated by ECOWAS and COMESA, respectively. SAPP, however, has market fees as an additional source of revenue and remains financially independent of SADC.

In terms of *staff capacity* and *technical readiness*, SAPP is the only case that has demonstrated staff quality through its successful management of trade and disputes between members. SAPP has also reached a level of maturity whereby its staff can perform its regular activities and only employs external consultants for newly introduced activities or market expansion. On the other hand, EAPP and WAPP depend on

Table 4
The foundation and membership of the three power pools. [48–50].
Source: [48–50].

Power Pool	Foundation year	REC	Member countries	N. of market participants
SAPP	1995	Established by the Southern African Development Community (SADC)	Angola, Botswana, Democratic Republic of Congo (DRC), Lesotho, Malawi, Mozambique, Namibia, South Africa, Eswatini, Tanzania, Zambia, Zimbabwe	19 electricity enterprises (12 national utilities and 5 private enterprises)
WAPP	1999	Established by the Economic Community of West African States (ECOWAS)	Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, The Gambia, Togo	39 electricity enterprises
EAPP	2005	Adopted by the Common Market for Eastern and Southern Africa (COMESA) in 2006	Burundi, DRC, Djibouti, Egypt, Ethiopia, Kenya, Libya, Rwanda, Sudan, Tanzania, Uganda	14 national utilities

external contracts to carry out most of their activities. WAPP is building its information and coordination centre and installing the SCADA and communication systems to launch the regional market (progress is estimated at 89.5% as of December 2021 [49]). As the youngest power pool, EAPP is still not fully staffed and has no market committee. The secretariat abolished early efforts to establish a coordination centre, and the current activities are limited to conducting regional studies and consulting for interconnections.

WAPP and SAPP maintain good *relationships with stakeholders*, with both member countries and international institutions. WAPP has strong ties with financial institutions and has a special coordination committee for mobilising financial resources for regional projects. By contrast, SAPP maintains a strong relationship with technical organisations and market experts, especially the Nordpool (the first regional market in Europe). EAPP seeks to strengthen its relationships with other institutions for technical and financial assistance, but it has no particular organ for this purpose, and previous miscommunication led to support cancellation from donors [51].

4.2. Design factors

The physical conditions are the hard constraints that determine the possibilities of trade. For SAPP and WAPP, member countries are interdependent in natural resource endowments. In SAPP, the utilities in the North depend on hydropower generation and complement the thermal generation of South Africa and Botswana (see Figs. 2 and 4). In WAPP, small countries, such as Benin and Togo, and landlocked countries, such as Mali and Burkina Faso, depend on resource-rich countries Nigeria, Ghana, and Côte d'Ivoire, which also have significant hydropower. This interdependence is absent in EAPP, where countries share hydropower generation along the Nile River. The transmission networks of the three power pools do not electrically connect all members. SAPP has three unconnected members (Angola, Malawi, and Tanzania), WAPP has five unconnected members (The Gambia, Guinea, Guinea-Bissau, Sierra Leone, and Liberia), and EAPP members are connected in three isolated blocks (Libya, Egypt, Sudan, Ethiopia, and Djibouti; Kenya, Uganda and Tanzania; Rwanda, Burundi, and DRC). Fig. 3 shows the generation and interconnection capacity normalised by the population of each power pool.

Fig. 5 shows the energy exported and imported for all interconnected countries in the three power pools. It can be seen that exporting countries either have rich resources or significant hydro generation. A clear example of this is South Africa and Mozambique. The two countries have the largest interconnection capacity in the region, more than 3000 MW [48], and one of the oldest bilateral agreements [15]. Mozambique exports excess hydropower from the Cahora Bassa dam and imports from South Africa's coal generation during periods of shortage.

Table 5
Average GDP and GDP per capita of the three power pools in 2021. Data source: [55].

	EAPP	SAPP	WAPP
GDP (Billion US Dollar)	80.4	60.5	51.6
GDP per capita (US Dollar)	1869	2622	1226

In most countries, the structure of the national power system follows the single buyer model, in which the electricity is sold and bought exclusively by a single entity [1], with different attempted reform steps. Nigeria and Ghana are the only countries that have fully implemented all the reform steps (see Appendix B for more information).

The economic indicators in the three regions are analogous in that all countries have a dual economy, urban and rural, and that the power sector is burgeoning, with demand outpacing generation capacity, except for Egypt and Libya, which have universal electricity access [54]. In each of the three power pools, there is a single country with more than 50% of the generation capacity and the highest total GDP (Egypt, Nigeria and South Africa). SAPP members have the highest GDP per capita, followed by EAPP and WAPP (see Table 5). Most WAPP member states, as HIPCs, are subject to borrowing restrictions that apply to their state-owned utilities [31].

The characteristics of regional institutions differ significantly between the three cases. WAPP features strong regional institutions by having ECOWAS Commission playing an active role in regional integration and harmonisation. The commission has the authority to make legal demands from member countries to implement directives and regulations and has the special institute ECOWAS Regional Electricity Regulatory Authority (ERERA) for regulating regional trade. ERERA has the legal authority to enforce regulatory decisions and intervene in member countries [56]. Moreover, the ECOWAS Energy Protocol facilitates foreign investment in energy infrastructure and dispute resolution [57]. SAPP has a lower quality of regional institutions than WAPP. SADC is an executive secretariat that aims to increase regional cooperation but without legal authority to make demands from member countries. Hence, SADC agreements are not binding to member countries [32]. The region does not have a regional regulator but rather an association that supports national regulators (the Regional Electricity

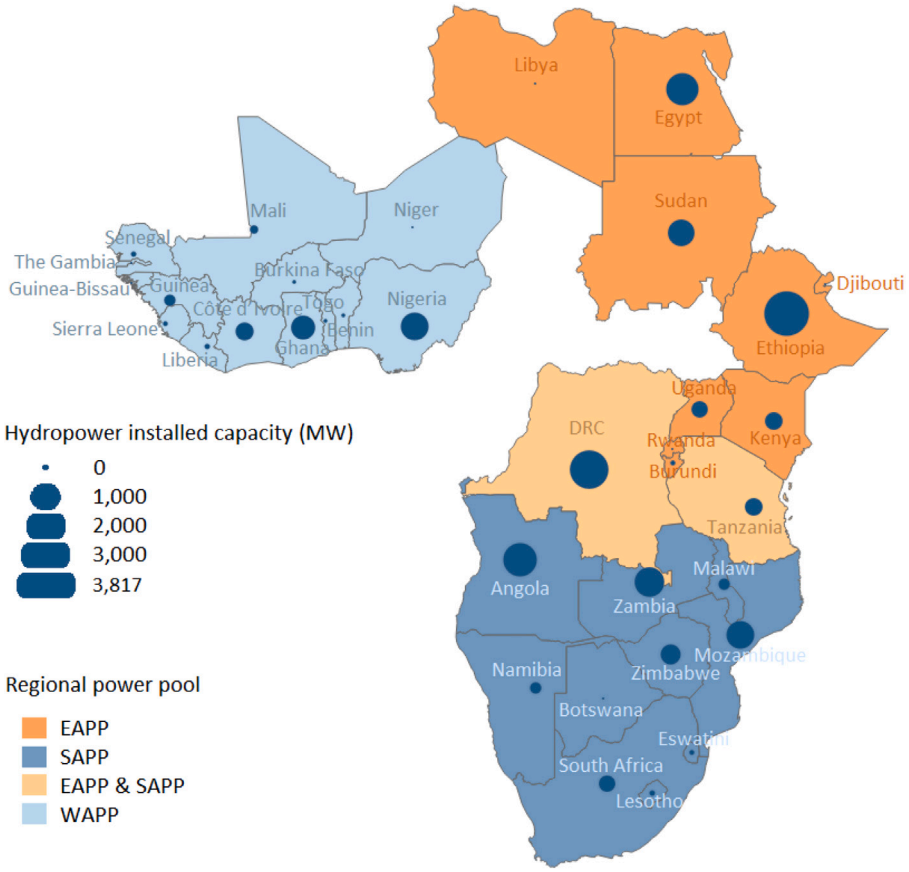

Fig. 2. Distribution of hydropower installed generation capacity in the three power pools in 2021, excluding pumped hydropower. Authors' representation based on [52].

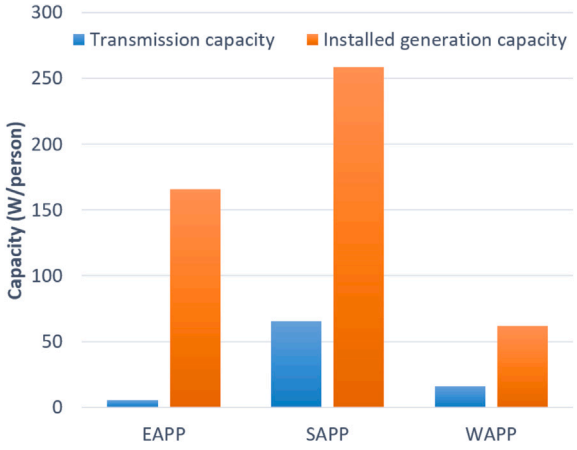

Fig. 3. The transmission interconnection and generation capacity of the three power pools in 2021. Data source: [52,53].

Regulators Association of Southern Africa (RERA)). Both SAPP and WAPP are institutions of SADC and ECOWAS, respectively. EAPP differs in that although COMESA adopted it as a special institution, it is not institutionally anchored within it. EAPP member countries lack regional institutional unity and belong to three economic communities the Inter-Governmental Authority on Development, the East African Community, and COMESA. EAPP has recently established the Independent Regulatory Board (IRB) to be the regional regulator (reporting to the ministers). This body is yet to be fully staffed and operational. Additionally, there are other regional regulatory bodies in East Africa, such as the Energy Regulators Association of East Africa and the Regional Association of Energy Regulators for Eastern and Southern Africa, with which the IRB will need to coordinate and leverage their experience. In all three cases, some countries are more influential than others, either due to their prominent position as exporters, e.g., South Africa in SAPP and Ethiopia in EAPP, or their voting share, e.g., Ghana and Nigeria in WAPP (each has ten votes [49]).

Considering the political situation, SAPP has witnessed a stable geopolitical situation since the end of the historical tension between South Africa and the other countries [32]. In EAPP, there has been geopolitical tension between Ethiopia, Sudan, and Egypt over the Grand Ethiopian Renaissance Dam (GERD) since 2012 [58]. Central to this geopolitical tension are the conflicting interests of the countries. On the one hand, Ethiopia wants to increase its hydropower generation to become a major power exporter. On the other hand, Egypt fears losing its hegemony over controlling the Nile flow and the consequences for its agricultural areas [59]. Our interviews revealed that in the past, whenever the GERD was included in the master plans of the EAPP, the Egyptian and Sudanese ministers objected to its adoption, leading to a delay in the decision. It is also worth noting that the first EAPP master plan in 2011 did not include the GERD despite being under construction at that time [60,58]. This shows that the political conflict affected the decision-making process in EAPP. WAPP region saw major instabilities with frequent civil wars, conflicts, and military coups d'état. These events have disrupted regional integration pushing ECOWAS to step

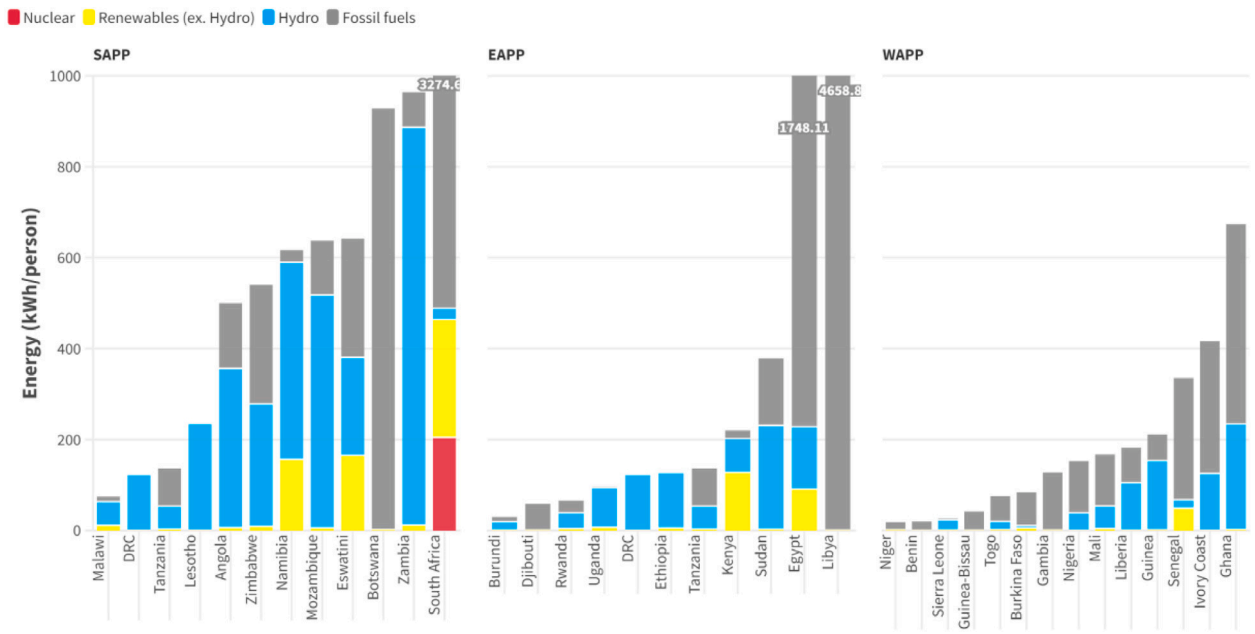

Fig. 4. Profile of power generation, normalised by country's population, by source of all members of the three power pools in 2021. Data source: [52,53].

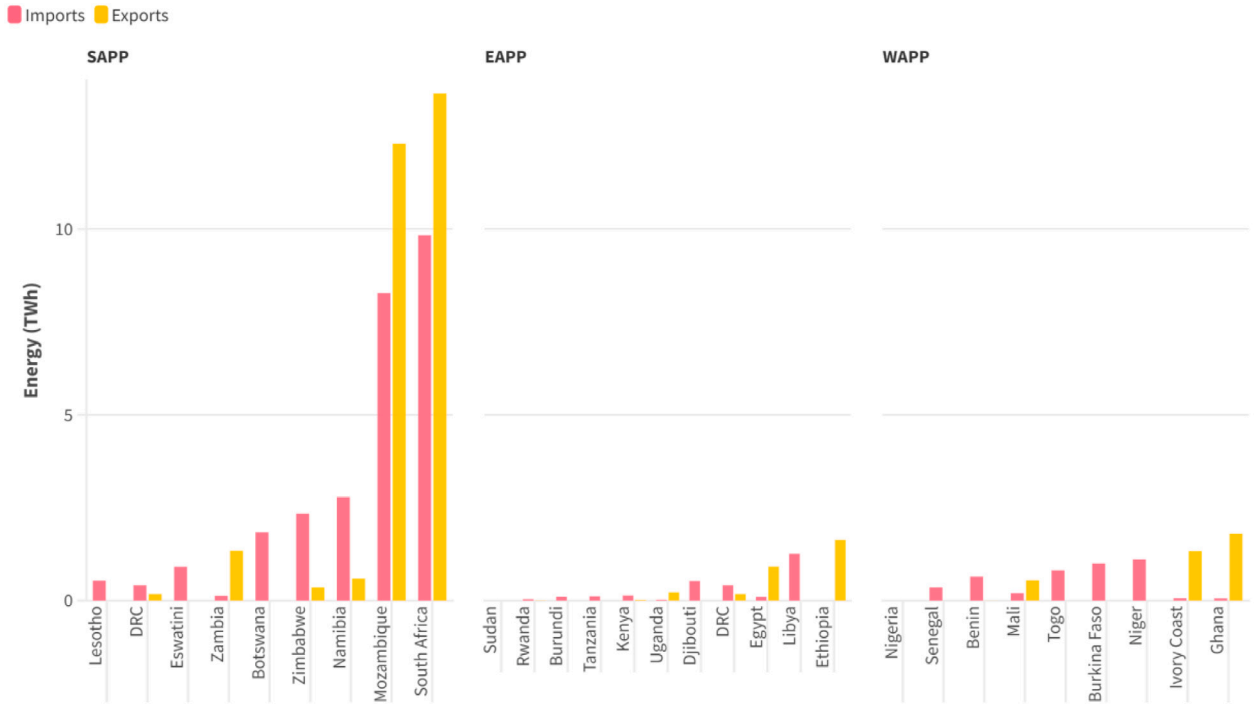

Fig. 5. Energy trade between interconnected members of the three power pools in 2021. Data source: [52].

into the peace and security agenda.[3] These conflicts contributed to the damage and vandalism of infrastructure and are seen as a significant barrier to private sector investment. Additionally, our interviews reveal an atmosphere of mistrust between WAPP member countries due to frequently unpaid debts and political conflicts in bilateral agreements. In all three cases, countries view the power sector as national sovereignty and have a political agenda of self-sufficiency.

4.3. Design variables

Table 6 shows the design variables of the three power pools. Similarities include the trading mechanisms and the classification of the

[3] ECOWAS intervened militarily in several countries such as Liberia in 1990, Sierra Leone in 1997, Guinea-Bissau in 1999, Côte d'Ivoire in 2007, Burkina Faso in 2015, the Gambia in 2017, and Mali in 2020.

pools as loose or 'new style' pools, as defined by the World Bank [16]. However, WAPP and EAPP differ from SAPP because they intend to unify bilateral agreements and mandate their approval by the pool and the regulator.

The regulatory bodies of both SAPP and EAPP are effectively dysfunctional. The two pools are so far self-regulated by internal agreements. In both cases, planning and investment in infrastructure are left to the countries, and no regional entity has the mandate to carry out regional projects. Both pools only provide a list of priority projects. However, SAPP has a Project Advisory Unit (PAU) to facilitate projects. By contrast, WAPP has ERERA that enjoys both statutory and quasi-judiciary for issuing regulations and decisions that are binding and directly applicable in the ECOWAS territory [56]. Furthermore, ECOWAS mandates WAPP to implement regional projects adopted from the master plan [61]. For this purpose, WAPP deploys a special purpose vehicle to implement projects, e.g., WAPP Solar Parks, funded by the World Bank.

Differences include the degree of autonomy and membership. WAPP is fully autonomous in its decision-making process, and its membership includes all entities involved in the power sector activities, each with equal voting rights. SAPP is semi-autonomous; internal affairs are effective upon consensus, while external affairs require SADC approval. EAPP has no autonomy as all its decisions are subject to approval by the council of ministers, and its membership is limited to national utilities only.

4.4. Motors of change

The *regional bodies, the RECs*, vary notably between the three cases. SADC is an intergovernmental institution and a secretariat for regional cooperation in specific sectors. It operates through regional protocols and agreements between member states. ECOWAS is a supranational entity with a commission empowered to issue legal demands through directives and regulations. COMESA has a technical foundation, and its treaty is based on the Preferential Trade Area that explicitly promotes regional integration through the removal of trade barriers. The regional dynamics within these RECs are also differ. Generally, in both ECOWAS and SADC, Nigeria and South Africa enjoy hegemonic power [30]. Due to their economic or military superiority, these countries have some degree of leverage to drive or block elements of their region's integration agenda. In COMESA, however, no single member state can exercise this kind of influence across the various issue areas [30].

Because of these institutional differences, the involvement with the power pool varies. ECOWAS strongly influences WAPP and manages it through its special regional institutions such as ERERA. ECOWAS also adopts the master plans of WAPP and supports market creation by adopting policies and regulations at the national level. In contrast, COMESA is primarily a trading platform for collaborations between Eastern and Southern countries and does not include all EAPP members. EAPP is, therefore, loosely tied to COMESA. SAPP occupies a middle position in that it is an institute of SADC, but the latter does not interfere with its operation and gives it a degree of autonomy in deciding internal affairs. In all three cases, the regional body has no power or mechanism to enforce decisions on member states. Although ECOWAS has the legal power to make binding decisions, it lacks adequate supranational power to enforce them.

When it comes to *members' strategies*, it is common for countries to naturally seek energy self-sufficiency as a security measure, and, thus, their initial strategies are not pro-regional trade. Nonetheless, small countries that cannot afford large-scale generation projects rely on imported electricity to meet their demand (Burundi imports from the SINELAC joint utility, Togo and Benin import from Ghana and Nigeria, and Lesotho imports from South Africa). Some members of WAPP and EAPP have sub-regional cooperation for using shared hydro resources. This cooperation has manifested itself in the form of joint utilities between countries (SOGEM between Senegal, Guinea, Mali, Mauritania and Senegal and SINELAC between Burundi, DRC and Rwanda).

In the case of SAPP, member countries initially cooperated to reduce their dependence on imports from South Africa [32]. As the major exporter in the region, South Africa played an important role in pushing for the establishment of SAPP in SADC. After a decade of running the competitive markets, our interviews show that members' strategies have shifted to rely on trade in scheduling maintenance and meeting peak demand. In WAPP and EAPP, our interviews reveal a general disinterest on the part of some national utilities in cooperating with the power pool. Utilities in Nigeria, Ghana, and Côte d'Ivoire have an ambiguous approach toward WAPP, fearing that it will constrain and control their operations. In EAPP, Ethiopia's reign of EAPP organs has distanced other countries, such as Kenya and Rwanda, which previously wanted to host the pool coordination centre, and Egypt, which wanted to host the regional regulator [62].

International institutions have played a catalytic role in the development of the three power pools. The same international institutions financially support the three power pools: the World Bank, the African Development Bank, USAID, SIDA, NORAD, and the EU. These institutions also facilitate technical support with other parties (for example, the International Renewable Energy Agency). In the case of WAPP and SAPP, they also receive financial support from the regional development banks of ECOWAS and South Africa, respectively. SAPP receives more technical support from the Swedish and Norwegian governments, the U.S. Energy Association, and the Nordpool, while WAPP receives more financial support from the World Bank directly or through trust funds with other donors. Besides donors and financial institutions, other international advisory institutions, such as the Tony Blair Institute, work actively with the national governments of both WAPP and EAPP to facilitate political decisions on regional trade.

5. Discussion: Developing power pools

Based on the three cases, this section discusses the infrastructure, the market, and the design of the power pools. showing the different approaches and their outcomes from a regional integration perspective. It concludes with a discussion of the development barriers.

5.1. Regional infrastructure

Regional infrastructure can be developed through a centralised or a decentralised approach. The choice between the two approaches is correlated to the type of regional integration. In 'low politics' integration, infrastructure development tends to be decentralised as member states maintain their independence. In this situation, the power pool would play a minor role, reflecting the preference of powerful member states. SAPP is an example of this case, where the power pool initially had no role in infrastructure development beyond identifying priority projects. Later, when member states needed expertise in facilitating projects, SAPP PAU was created. This functionality expansion is a demand-generating process known as 'spillover' in regional integration theories [63].

As EAPP does not institutionally belong to any of the RECs (fragmented 'low politics' integration), its infrastructure development is de facto decentralised. Not surprisingly, infrastructure has developed to connect member states of the sub-regional communities (EAC: Kenya, Uganda, and Tanzania, and Great Lakes countries: Burundi, DRC, and Rwanda). One consequence of the decentralised approach is that it is difficult to identify all the beneficiaries of interconnection projects, which reduces their feasibility and results in inadequate cost allocation [13]. As a result, interconnections become dependent on the financing capacity of only the two interconnected countries.

In contrast, in 'high politics' integration, infrastructure development tends to be centralised. In this case, the power pool exhibits more authority and its role reflects regional needs, as in WAPP. According

Table 6
The design variables of the three power pools.

Design variable	SAPP	WAPP	EAPP
Autonomy	Semi-autonomy	Complete autonomy	No autonomy: all decisions are subject to the approval of the council of ministers
Loose or tight pool	Loose	Loose	Loose
Voluntary or mandatory pool	Voluntary pool, only monitoring bilateral agreements	Voluntary pool, unified bilateral model, and mandatory approval of bilateral agreements by WAPP and ERERA	Voluntary pool (currently working on unifying Power Purchase Agreements)
Membership	Vertically integrated utilities (full voting rights) and IPPs (limited voting rights)	Transmission Owner/Operator (Transmission and System Operators), Transmission User (Generators and distribution/retail companies), and others	Vertically integrated utilities
Trading platform	Day-Ahead Market (DAM), Intra-Day Market, Forward Physical Market Weekly/Monthly, and planned balancing market	Planned DAM and ancillary services	Planned African Day-Ahead Market (ADAM)
Transmission tariff methodology	MW-km load flow-based tariff (currently under revision)	MW-km load flow-based tariff (currently under revision)	None
Congestion management	Unknown	Unknown	None
Balancing mechanism	Is left to the different system operators. A balancing market is currently under trial	None	None
Ancillary Services	None	Planned	None
Capacity mechanism	None	None	None
Investment unit (functionality)	Project Advisory Unit: does not execute projects	WAPP donors' coordination committee and WAPP project unit: execute projects	None
Position of the regulator	No regional regulator, self-regulation	The regional regulator, ERERA, is external to the pool	The regional regulator, IRB, is internal to the pool

to interviewees, the bad economic conditions and the development principle of equality in the ECOWAS region stimulated the ECOWAS Commission to task WAPP with infrastructure development. An advantage of this approach is that it allows for more investment from non-member states due to a larger market, an effect that is known as geographical spillover [63]. Additionally, it enables optimal planning and use of resources in the region and identifies the beneficiaries of interconnections. As an independent institution with no direct political involvement, WAPP has a level of transparency that potentially accelerates investment from international institutions (e.g., the World Bank) that seek to reduce transaction costs by avoiding corruption (presumably in member countries). This is also due to the fact that the ECOWAS Energy Protocol protects foreign investment in infrastructure.

Following a centralised approach to regional infrastructure development, WAPP has successfully implemented and coordinated a significant number of regional projects. 65% of the priority projects that were stipulated in the 2016–2019 WAPP Business Plan were achieved by August 2019 [64]. This list of priority projects includes 16 transmission lines and 19 generation projects. Out of these projects, 3928 MW of generation was commissioned and 1105 Km of high voltage transmission lines were built, amounting to a total investment of US$1.9 billion. Cumulatively, over the past ten years, the World Bank alone financed approximately US$2.3 billion of investments in transmission infrastructure and institutional capacity in support of the WAPP [65]. This includes financing the construction of the Côte d'Ivoire–Sierra Leone–Liberia–Guinea (CLSG) interconnection and the OMVG interconnection connecting Guinea, Guinea-Bissau, The Gambia, and Senegal. According to our interviews, the construction of these two projects has already been completed, which will lead to connecting all WAPP member countries by the end of 2023 once they are operational. On the other hand, both EAPP and SAPP are not involved in the execution of regional infrastructure projects, although the latter provides an annual update on the progress made by countries. Comparing the interconnections reported in the 2010 and 2021 SAPP reports, only one interconnection of 120 MW was constructed between Namibia and Zambia and a reinforcement of 340 MW was added to the DRC-Zambia interconnection. Additionally, although all SAPP reports highlight the need to accelerate the interconnection of non-operating members, these projects remain at the feasibility stage [48].

5.2. Regional market

The existence of demand precedes the creation of a market. Regional integration theory gives two conditions for regional demand: interdependence between member states and their preferences [38]. From a

power sector point of view, this interdependence lies in power generation. On the one hand, the presence of hydropower plays a salient role in creating this interdependence; in the rainy seasons, there is excess generation for export, while in the dry seasons, there is a shortage to be compensated by imports. This natural dynamic stimulates the construction of interconnections. In fact, historically, interconnections were built in the three regions to export surplus hydropower generation. The first cross-border interconnection in sub-Saharan Africa was the 132 kV transmission line that was constructed in 1958 to supply power from Uganda's Owen Falls hydropower station to the capital of Kenya, Nairobi [15]. Similarly, in WAPP, a 161 kV double-circuit line was constructed to export power from Ghana's Akosombo hydroelectric dam to Togo and Benin since 1972. Early interconnections were also built in the SAPP region to export hydropower from the Cahora Bassa hydroelectric dam in Mozambique and the Inga hydropower station in DRC [15]. Moreover, the presence of shared hydro resources led to the creation of joint utilities, such as SOGEM and SINELAC, to manage hydropower generation and their transmission assets among the different countries.

Assuming that countries are interdependent, the other condition, state preference, explains whether the market is created ad hoc or systematically. Member states' preference for regional integration is a function of their interests and needs. WAPP is creating the regional market systematically by developing regulations and building infrastructure to connect all members before creating the regional market. This is a consequence of adhering to ECOWAS's guiding principle of equal opportunity, which requires WAPP to integrate all member countries. In the case of SAPP, the regional market was ad hoc due to the strong interdependence between member countries and the need for trade during drought seasons. SAPP established a competitive regional market by taking advantage of the already existing interconnections and the substantial thermal generation in South Africa, both of which were missing conditions from WAPP. Additionally, unlike ECOWAS, because SADC does not have a regional regulator but rather a regulatory association, there was no strict need to follow a systematic approach to regulations, although establishing a regional regulator is a step that is usually emphasised in the literature [13,17,66]. Therefore, SAPP shows that internal governance could replace regulation, as suggested in [16]. Indeed, while regional markets between vertically integrated power sectors would still require a level of operational and regulatory harmonisation, establishing market rules for trade could potentially be simpler than harmonising market rules between liberalised power sectors.

One factor that played a role in accelerating market creation is the presence of a dominant player (net exporter with considerable excess generation) with multiple regional interconnections. For instance, South Africa, with its multiple bilateral agreements, was keen on creating a regional market and benefiting from cheap hydropower in the northern countries. Such a catalyst (the hegemonic player) is lacking in both WAPP and EAPP. Nigeria and Egypt do not have several interconnections to play this role. Alternatively, in EAPP, Ethiopia, with its hydropower projects and strategic position in the region, could play this role in the future. This empirical observation of a hegemonic player is in line with regional integration theories that regional demand is derived by 'the commercial interests of powerful economic producers' [67].

5.3. Regional design

A power pool can be designed bottom-up or top-down. The bottom-up approach does not necessitate the development of regional regulations but rather the signing of internal agreements between utilities and establishing market rules for trading between electrically connected systems. SAPP is an example of a bottom-up power pool. By contrast, the top-down approach means that national systems adapt to the requirements of the power pool by implementing regional regulations and policies. WAPP is a case of a power pool that was established top-down through the directives and regulations of the ECOWAS Commission. The two approaches correlate with the two theoretical views debating regional integration: intergovernmentalism and neofunctionalism. The bottom-up approach correlates with intergovernmentalism, which sees regional integration as a process in which members negotiate and bargain over their interests. The top-down approach correlates with neofunctionalism, which sees regional integration as an outcome of supranational institutions that replace state-centrism with transnational interdependence.

Some power pool design variables, such as membership and regulation, can be understood through the ongoing power sector reforms in member countries and their national policies. For instance, when looking at the regulation of SAPP, member countries did not have a national regulator until 1997 (see Appendix B). Therefore, it is not surprising that SAPP has no regional regulator. The extent to which the pool membership is open to IPPs or not depends on the degree of private sector involvement in national power systems. In 1995, there was no private sector involvement in SAPP as privatisation and IPPs were not implemented. Therefore, SAPP membership at that time was limited to national utilities. As the reforms progressed in the member countries, IPPs were admitted in 2007. However, as national utilities are still reluctant to give away their dominant position, IPPs are given limited voting rights. The situation was different in WAPP. By 2006, countries such as Ghana, Côte d'Ivoire, Mali, and Senegal had already privatised their utilities, and the number of IPPs was significant in Nigeria. WAPP membership was, therefore, open to all enterprises. In EAPP, some countries attempted privatisation but without divesting national utilities (except in Uganda). IPPs were also introduced but were obliged to sell to state utilities to protect leaking domestic generation. Therefore, in the case of EAPP, the reforms were limited to a few steps in a few countries and did not beget strong private sector involvement to push for power pool membership.

5.4. Development barriers

The first barrier to establishing a regional market is developing the necessary soft and hard infrastructure. African staff are inexperienced in developing the necessary market rules, procedures, and regulations because of the fact that there is no national competitive market in Africa. Building the organisational capacity of the power pools at the operation layer is the first challenge. In the early stages, support from international institutions is indispensable to acquiring expertise. Similarly, developing infrastructure requires supporting countries with difficult economic conditions. The traditional role of a power pool is to promote infrastructure development by conducting feasibility studies. However, the pool can also play a role in infrastructure development by facilitating the mobilisation of financial resources and overseeing regional projects. This role is enabled at the foundation layer and requires regional institutions to protect foreign investment.

The second barrier is the level of commitment of members to the power pool. The pool provides services to its members such as conducting studies, training, developing regional planning, coordinating, and resolving disputes over power exchange. The issue with member commitment is that some countries join the pool as a defensive measure against possible exclusion from the market (Baldwin's domino effect). These countries maintain protectionist policies and could block certain decisions at the design level. The other issue is that major exporters with a strong interest could exert leverage and attempt to dominate the pool. Such a strategy could lead to inefficient market design and the exclusion of other members. By contrast, members may be reluctant to commit to the pool when the market design is complex and the benefits are not obvious. The pool staff can tackle this barrier by addressing members' concerns and needs. The performance of the power pool provides corrective feedback to non-cooperative strategies.

Another barrier to developing an efficient regional market is the structure of national power systems. The majority of national power systems in Africa are organised under monopolistic utilities with protectionist regulations for IPPs. This reduces the number of market participants and increases the opportunities for exercising market power. Imperfect competition is still beneficial for utilities interacting with the market and stimulates cooperation on public projects [68]. However, it becomes necessary to adapt the regulation and market design to such a structure. Regulation should allow IPPs to trade regionally to increase market liquidity and improve the price signal. Additionally, market surveillance is needed if there is a risk of exercising market power. In trade theory, if markets were initially monopolised, opening them up to trade and competition between monopolists could lead to welfare loss [69]. If one country sells electricity below cost-reflective tariffs and another at actual costs, the result of interconnecting the two would be a deterioration in overall welfare compared to no interconnection [70]. Therefore, ensuring that trade follows cost-reflective tariffs through regulation or harmonising the price-setting mechanisms of member countries becomes crucial to developing an efficient market.

The development of the three power pools can be classified according to the primary motor of change. In the case of SAPP, the development is classified as ***members lead***. South Africa played a salient role in establishing SAPP. The country's favourable geographical position connects five neighbouring countries and provides the physical infrastructure for power exchange. In the case of WAPP, the development is classified as ***regional lead***. The ECOWAS Commission has played an important role in issuing directives for establishing the regional market and providing a framework for attracting foreign investment. In the case of EAPP, the development is classified as ***donors lead***. The involvement of COMESA did not play a tangible role in its development aside from facilitating Funds. Except for Ethiopia, the engagement of member countries was not strong, and our interviews revealed that country representatives were sometimes absent. Thus, financial institutions relatively had the most significant role in the development of EAPP. The World Bank especially has a strong interest in EAPP, and it is believed that it was behind its creation [66].

6. Conclusions

Regional power pools in Africa are a form of economic integration. They were founded to allow energy sector cooperation and resource-sharing between countries. This article provides a comprehensive analysis of African power pools and, to the best of our knowledge, the first comparative study. It argues that while regional power pools are traditionally regional electricity markets, regional power pools in Africa are development tools that have unrepresentative dynamics in their evolution and market design. It does so by conceiving and applying a multilayer analytical framework that portrays the factors influencing the pool organisation and market design, as well as the motors of change driving their development. It should be emphasised that the findings of this research rely predominantly on qualitative analysis drawing on data and information collected from desk research and interviews. The number of interviews was particularly limited by the author's network, and given the broad geographical coverage of the research, the data available for all countries was also limited. As a result, this research ultimately concludes with the need for evidence-based research on the topic.

The analysis shows that the design of the power pool is affected by several physical, institutional, economic, and political factors. As a starting condition, there must be sufficient physical interconnections between countries to allow for power pooling. The unequal distribution of natural energy endowments, with some countries having excess generation and others having generation deficit, created interdependence between countries and the need for trade. Particularly, the seasonality of hydropower emerged as a primary stimulus to export in the rainy seasons and import in the dry seasons. Additionally, the historical presence of excess hydropower resources played a pivotal role in the construction of interconnections.

The design of the power pool can be bottom-up or top-down, depending on the regional institutions. In the presence of strong centralised institutions, the pool is designed top-down through directives and regulations issued at the regional level, to which countries must adapt at the national level. This is the case when countries approach regional integration by establishing transnational bodies with supranational power to make legal demands from member countries, as in the case of WAPP. In the absence of centralised institutions, member countries retain their sovereignty, and the pool is designed bottom-up to fit national systems. In such a case, changes arising from national power sector reforms will be reflected in the design of the power pool. For instance, in SAPP, the power pool membership changed from being exclusive to national utilities to including IPPs as their presence in national power sectors grew significantly.

One of the first barriers faced in all three cases is developing sufficient physical infrastructure to establish the regional market. This is because many African countries have poor economic conditions and limited financial resources. The case of WAPP provides an example of how the power pool can play a role in accelerating infrastructure development by following a centralised planning approach to pool financial resources from international financial institutions. Such a role requires regional institutions to protect foreign investment.

Another barrier is the need to develop the soft infrastructure of market rules and regulations. Owing to the absence of national markets in African countries, power pool staff lack experience in market design. To tackle this barrier, support from international institutions is indispensable at the outset and continues to be essential for the pool to become operationally sustainable. With external support for market design, it is important to simplify this design in the first stage to facilitate its implementation by national utilities.

An important implication of this analysis is that the development of the power pools needs to be considered holistically. We identified three motors of change that drove the development of the power pools, showing that regional economic communities are the policymakers that defines the roles and objectives that drive the power pool activities in the first place, followed by member strategies that also influence the power pool design and finally international institutions that support the power pool technically and financially. What remains crucial for progress is how power pool staff can mitigate non-cooperative strategies, such as protectionism, and incentivise a shift in their agendas to encourage trust in regional trade. To achieve this, it is recommended that the pool activities should be tailored to address members' concerns and that the market should be designed to meet their needs. Because of these aspects of political economy and regional integration, African power pool design is much more than a mere market design exercise.

Finally, future research could focus on a single power pool to provide quantitative evidence on the dynamics of trade in relation to the seasonality of hydropower and the distribution of natural energy resources. Another potential research could give special attention to the structure of national power sectors. Rules and regulations should be formulated to incentivise efficient trade between monopolistic utilities and to prevent the exercise of market power and the deterioration of the overall welfare. They should also be practical to implement. In addition, further research should explore ways to tackle members' strategies that impede efficient market design from a political economy perspective, addressing protectionist policies and specific national regulations that affect regional trade.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table A.1
The percentage of trade in electricity consumption and transmission capacity in all member countries of the three power pools in 2021. Data source: [52], transmission capacity data were collected from various secondary data sources: [48,64,71,72].

	Countries	Transmission Capacity (MW)	Installed Capacity (MW)	Electricity Consumption (MW)	Export (MW)	Import (MW)	Cross border Trade (MW)	Trade % of Transmission Capacity	Trade % of Consumption
SAPP									
1	Angola	0	7344	1662.2	0	0	0	0	0
2	Botswana	840	766	382.77	0	209.78	209.78	24.97	27.39
3	DRC	600	2919	1018.3	19.86	46.8	66.67	11.11	2.28
4	Eswatini	2981	295.7	170.68	0	104.34	104.34	3.5	35.29
5	Lesotho	230	73.9	103	0	61.84	61.84	26.89	83.68
6	Malawi	0	735.9	110.1	0	0	0	0	0
7	Mozambique	5320	2765	1539.8	1402.97	944.75	2347.72	44.13	84.91
8	Namibia	970	609.98	392.05	67.69	317.92	385.62	39.75	63.22
9	South Africa	6171	63276	21854	1557.88	1122.03	2679.91	43.43	4.24
10	Tanzania	0	1588.79	821.13	0	13.01	13.01	0	0.82
11	Zambia	2120	3365.4	1634.8	152.97	14.84	167.81	7.92	4.99
12	Zimbabwe	2550	2476	952.07	40.53	266.78	307.31	12.05	12.41
Total		**21782**	**86215.67**	**30641**	**3241.89**	**3102.1**	**6343.99**	**29.12**	**20.7**
WAPP									
1	Benin	1389	474.9	59.75	0.23	73.74	73.97	5.33	123.81
2	Burkina	427	391.8	301.68	0	114.16	114.16	26.73	37.84
3	Côte d'Ivoir	981	2197	910.65	151.83	7.09	158.91	16.2	17.45
4	Ghana	683	5349.37	2086	205.59	6.7	212.3	31.08	10.18
5	Guinea	0	992	283.29	0	0	0	0	0
6	Guinea Bissau	0	27.77	8.73	0	0	0	0	0
7	Liberia	0	195.58	99.44	0	0	0	0	0
8	Mali	610.3	919.6	305.73	62.79	22.83	85.62	14.03	28
9	Niger	190	324.04	146.03	0	126.48	126.48	66.57	86.62
10	Nigeria	967	11 696.23	3036	0	0	0	0	0
11	Senegal	283.3	1504.29	604.99	0	40.64	40.64	0	6.72
12	Sierra Leone	0	180.38	14.94	0	0	0	0	0
13	The Gambia	0	136.5	27.16	0	0	0	0	0
14	Togo	868	264.3	141.56	0	93.04	93.04	10.72	65.72
Total		**6398.6**	**24653.77**	**8026**	**420.43**	**484.68**	**905.12**	**14.15**	**11.28**
EAPP									
1	Burundi	200	99.5	47.71	0	11.42	11.42	5.71	23.92
2	Djibouti	180	150.36	53.45	0	60.5	60.5	0	0
3	DRC	252	2919	1018.3	19.86	46.8	66.67	26.46	6.55
4	Egypt	321	60073	19215	104.68	11.19	115.87	36.1	0.6
5	Ethiopia	552	4902.3	1086.9	186.87	0	186.87	33.85	17.19
6	Kenya	145	3483.3	1034.4	1.88	15.61	17.49	12.06	1.69
7	Libya	180	10517	3102.7	0	143.72	143.72	79.85	4.63
8	Rwanda	252	271.69	79.02	0.71	4.11	4.82	1.91	6.11
9	Sudan	513	4471	1511.6	0	0	0	0	0
10	Tanzania	70	1588.79	821.13	0	13.01	13.01	18.59	1.58
11	Uganda	215	1459.9	350.81	25.34	2.4	27.74	12.9	7.91
Total		**2880**	**89935.84**	**28321**	**339.35**	**308.76**	**648.11**	**22.5**	**2.29**

Data availability

Data will be made available on request.

Appendix A. Power pools infrastructure

Table A.1 shows the details of the infrastructure and trade for each country in the three power pools. The units were standardised to megawatts for comparison purposes. Data on average annual electricity consumption and trades were converted from gigawatt-hours to megawatts by multiplying by the constant 0.1142 (equal to 1000/(24*365)) to be in the same unit as the transmission capacity. The largest transmission capacity and trade volume exist in SAPP, while EAPP has both the lowest transmission capacity and trade volume, although EAPP has the largest installed generation capacity. The exact order persists for the utilisation of transmission capacity (percentage of trade to the capacity) and the percentage of consumption met by trade. While the percentages suggest an under-utilisation of the transmission capacity in the three cases, it should be noted that transmission capacity usually facilitates peak demand and that the consumption data used here is an annual average. It can be seen from the table that some countries rely heavily on imported electricity to meet their consumption. The largest importers are the neighbouring countries of Benin and Togo in WAPP, with Benin importing 100% of its consumption, plus 8.85% distribution losses and Togo importing 86.03%. This percentage is significantly lower for EAPP. The only country with a relatively high percentage is Burundi, which imports electricity from the joint utility, SINELAC, on its due debt to the company.

A shortcoming of the database used is that it is country-based. Therefore, it includes trade happening with other countries outside the power pool. For example, Libya trades with Tunisia, Egypt trades with Jordan, and Senegal trades with Mauritania. Also, DRC trades with its neighbours from three different power pools; Zambia from SAPP, Burundi and Rwanda from EAPP, and the Republic of the Congo from the Central African Power Pool (CAPP). DRC itself is divided internally into two isolated power systems: the eastern part connected to EAPP and the western-southern part connected to CAPP and SAPP [81]. Moreover, these statistics do not include joint utilities like SINELAC

Table B.1
Member countries' implementation of the standard textbook model. Collected by the author from various secondary sources, including [73–77,3,78–80], and the World Bank project documentations. It is worth mentioning that some discrepancies were found between these documents regarding the year of implementation of certain reform steps. The author consulted interviewees and his best judgement to decide which information was the most likely correct.

	Country	Electricity Law/Act	Corporatisation & Commercialisation	Regulation	IPPs	Unbundling	Management /Concession Contracts	Privatisation
SAPP								
1	Angola	1996	2003	2011	2003	2014	1997	2019
2	Botswana	2003	2005	Pending	2007	Pending	Pending	Pending
3	DRC	2006	2010	2014	2000	Pending	2014	Pending
4	Lesotho	1996	2001	2004	None	2001	Pending	2001
5	Malawi	1995	1998	2007	2011	Pending	2001	2000
6	Mozambique	1997	2000	2008	2003	Pending	2017	Pending
7	Namibia	1995	1995	2000	2014	Pending	1996	2001
8	South Africa	1995	1995	2004	2003	Pending	2015	Pending
9	Eswatini	2007	2007	2007	2014	Pending	Pending	Pending
10	Tanzania	2002	2002	2006	2004	Pending	2002	Pending
11	Zambia	1996	1997	1997	1997	Pending	Pending	2001
12	Zimbabwe	1996	2002	2002	1998	2002	2009	2002
WAPP								
1	Benin	2003	2006	2009	2006	Pending	2015	Pending
2	Burkina Faso	1997	2007	2010	2017	Pending	2010	Pending
3	Côte d'Ivoir	1989	1995	1998	1994	Pending	1990	1990
4	Ghana	1997	1997	1997	2000	2008	1997	2005
5	Guinea	1993	2005	2005	2013	Pending	2005	Pending
6	Guinea Bissau	2007	Pending	2010	None	Pending	1997	1995
7	Liberia	1973	1973	2015	None	Pending	2010	Pending
8	Mali	1994	1998	2000	1994	Pending	1995	2000
9	Niger	1991	Pending	2013	2011	Pending	Pending	Pending
10	Nigeria	2005	1988	2005	1999	2007	2013	2012
11	Senegal	1995	1998	1998	1997	Pending	1999	2003
12	Sierra Leone	2011	2011	2011	None	2016	Pending	Pending
13	The Gambia	2005	Pending	2001	2006	Pending	Pending	Pending
14	Togo	2000	2001	2000	2006	Pending	2000	Pending
EAPP								
1	Burundi	2005	1997	2014	2016	Pending	Pending	Pending
2	DRC	2006	2010	2014	2000	Pending	2014	Pending
3	Djibouti	Pending	Pending	2009	None	Pending	Pending	Pending
4	Egypt	1996	1997	1997	1998	Pending	2001	2001
5	Ethiopia	1997	1997	1997	1999	2013	2007	2001
6	Kenya	1997/2006	1995	1997	1997	1997	2006	2001
7	Libya	Pending	Pending	1997	2013	Pending	Pending	Pending
8	Rwanda	2008	2011	2011	2011	Pending	2012	2011
9	Sudan	2001	Pending	2011	None	2010	Pending	Pending
10	Tanzania	2002	2002	2006	2004	Pending	2002	Pending
11	Uganda	1999	1999	2000	2000	2001	2001	2001

(EAPP) and SOGEM (WAPP) since they are independent and belong to more than one country, which might give a slightly misleading representation of exports and imports. Given the difficulty of obtaining detailed data for these cases and the fact that they do not comprise a large portion of the total trade volume, these approximations do not undermine the general conclusions.

Appendix B. Power sector reforms in member countries

Table B.1 shows the reform steps taken by member countries of the three power pools according to the 'standard textbook model' for power sector reform as endorsed by the World Bank [82]. The reforms implemented and their sequence vary from country to country. The effectiveness of the applied reforms is also different in each case, as the same reform step could be implemented differently. A country with more reform steps does not necessarily perform better than a country with fewer steps. Eventually, the performance of the power sector depends on numerous factors, from the overall capital market of the country to the way utilities are managed and assessed.

Appendix C. Interview protocol

The interview protocol consists of three main sections: an introductory explanation before the interview begins, which includes the collection of informed consent for the use of interview data, a general list of interview questions, and concluding remarks to allow the interviewee to give final words and thank them for their time.

A different set of questions from a question bank is asked to each interviewee depending on their role within their organisation and expertise. All interviewees were given the option of not answering questions with which they felt uncomfortable. Consequently, the questions and their order were changed, sometimes on the spot, according to the flow of the conversation and the interviewee's experience. Table C.1 shows a list of the questions used and their division based on the targeted topics. Once the interview is transcribed, the script is sent to the interviewee to prove the author's interpretation of the answers and provide any necessary modifications. Information from the approved transcript is then used to fill in the analytical framework and correct any discrepancies within the initially collected data. All the interviewees were interviewed once, except one interview that had to be split into two days due to the interviewee's time schedule.

Table C.1
Question bank for interviews (semi-structured).

General
5. Could you please introduce yourself, your role in your organisation and your experience? 6. Could you describe the role of your organisation in regional integration and trade? 7. Could you please mention any relevant engagements with African power pools?
Validation
8. Could you comment on/confirm the development timeline of the power pool depicted in the picture below? 9. Could you confirm/comment on the interconnections and peak demand of the power pool depicted in the figure below? 10. Are the following reforms (based on the standard textbook model), shown in the table below, correct? 11. Does the following regional trade patterns, shown in the picture below, look correct?
Regional Institutions
12. Could you describe the institutional characteristics of the regional economic community? 13. Could you describe the role of the regional economic community in the development of the power pool? 14. Could you describe the formal relation between the power pool and other regional institutions? 15. Could you describe how the situation and the relation between countries affect the regional communities and/or the power pools?
Factors
16. What could be internal factors that affect the performance of the power pool? (factors that can be influenced directly) 17. What could be external/exogenous factors that affect the performance of the power pool? (factors that cannot be influenced directly) 18. Could you mention the important factors delaying the establishment of the regional market?
Governance
19. Could you describe the decision-making process in the power pool? 20. Do you observe any conflicts among member countries of the power pool? 21. In the context of the three power pools, who are the important stakeholders? 22. What could be the advantages and disadvantages of having a supreme governing body that includes national governments/politics (the council of ministers)? 23. Could you comment on the geopolitical situation in the region? who are the important actors/countries? Which countries are pro-domestic generation (national political agenda) and which are pro-regional trade?
Development
24. How is the current progress of establishing the coordination centre? 25. How is the current progress with connecting all members of the power pool with the regional transmission network? 26. What is the role of international partners in the performance of the power pool? (technical and financial assistance) 27. What do you think are current or future challenges facing the progress of the power pool? 28. Does the power pool have a mechanism for allocating the investment cost of transmission interconnection projects? How do the existing processes for regional transmission planning and cost allocation influence investment decisions? 29. How do you think the development of the power pool can be accelerated? 30. How is the current development of regional regulations?
Market
31. When do you expect to operate the short-term competitive market? 32. How can member countries benefit from short-term trade in opposition to the current bilateral agreements? Which countries are expected to be important exporters and importers? 33. How is the current situation with drafting and approving market documents? 34. How does the organisational structure of national power systems affect the regional market? which characteristics of the power sector organisation are important for short-term trade? 35. What could be a possible effect of having one country with more than 50% of the total installed generation capacity on the performance of the market?

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