Title: An action agenda for Africa's electricity sector

Authors: Daniel Puig[1], Magda Moner-Girona[2], Daniel M. Kammen[3†], Yacob Mulugetta[4], Atef Marzouk[5], Maximilian Jarrett[6], Yohannes Hailu[7], Nebojša Nakićenović[8]

Affiliations:

[1]Technical University of Denmark; Copenhagen, Denmark.

[2] European Commission's Joint Research Centre; Ispra, Italy.

[3] University of California; Berkeley, United States of America.

[4] University College London; London, United Kingdom.

[5]African Union Commission; Addis Ababa, Ethiopia.

[6] International Energy Agency; Paris, France.

[7] United Nations Economic Commission for Africa; Addis Ababa, Ethiopia.

[8]International Institute for Applied Systems Analysis; Laxenburg, Austria.

* Corresponding author. E-mail: dapu@dtu.dk

One-sentence summary:

Innovations for modernizing and expanding Africa's electricity sector to the benefit of all

Abstract:

Africa's electricity sector has to undergo extensive modernization and expansion. We develop five policy recommendations to guide this challenge. First, introduction of a continent-wide risk-guarantee scheme coupled with targeted demand-side subsidies, to accelerate progress with electrification. Second, digitalization and open-access of energy-sector planning and management tools. Third, integration of local-content requirements into renewable energy policies, to capture energy-sector jobs. Fourth, strengthening and expansion of regional power-pools through African-led, international partners-supported partnerships. Fifth, expansion of investments in off-grid and interconnected clean-energy mini-grids.

Main text:

By 2030, Africa will be home to one-fifth of the world's population; and with population growth rates projected to remain higher than the global average, the figure may rise to one-fourth by 2050. To meet the needs of the population in a manner that is socially equitable, economically viable, and environmentally sustainable, Africa's electricity sector will require a major transformation (*1*).

Over the past decade, Africa's electricity sector has undergone some important changes. Efforts to expand access to electricity have progressed at a slightly faster pace than anticipated ten years ago. In parallel, the deployment of renewable-energy technologies has progressed apace, in spite of new discoveries of natural gas across the continent, and favoured by the volatility of oil prices, surpassing the expectations that many private sector actors held a decade ago. (Notwithstanding, renewable-energy sources other than hydropower still play a limited role in electricity generation in the continent.) Nonetheless, the expansion and modernization of Africa's electricity sector needs heightened efforts, as evidenced by current electrification rates, generation-capacity levels, and security-of-supply indicators.

Drawing on the literature cited herein and our expert judgement, we identify a suite of actions (Table 1) to complete the transformation of Africa's electricity sector (Figure 1). We believe that, if implemented, our recommendations would put Africa's electricity sector on track to sharply increase electrification rates across the continent, while securing long-term access to affordable energy, and reducing global-warming greenhouse-gas emissions and emissions of local-air pollutants (*2*).

Introduction of supply-side incentives and demand-side subsidies

In spite of progress with off-grid rural electrification, at least 250 million people in Africa cannot afford electricity, a gap that the COVID-19 global health pandemic has widened by about 80 million people who have fallen into extreme poverty (*3*). A combination of supply-side incentives and demand-side subsidies can go a long way toward expanding electricity markets and bridging the affordability gap.

Supply-side incentives refers to the combination of risk-guarantee schemes and so-called blending instruments. Through international-partner finance, risk-guarantee schemes cover private lenders against the risk of a government failing to perform its contractual obligations and, in some case, against expropriation, civil unrest and other imponderables. Blending instruments are public-private partnerships through which grants are used to attract larger volumes of private and, in some cases, public finance. The combination of risk-guarantee schemes and blending instruments is set to play a central role in expanding electrification in Africa (*4*). However, it is increasingly clear that coordination among the various partners is indispensable for these schemes to work. Here, coordination refers to the ability of the various actors to align eligibility and implementation requisites across their respective portfolios. Given this requirement, and the magnitude of the energy access problem in Africa, a continent-wide risk-guarantee scheme should be established, ideally by a combination of African and other multilateral lending institutions. Such an integrated approach, through which overall savings can outweigh risk premia (*5*), could be articulated under the aegis of the *African Single Electricity Market*, launched in early February 2021.

Demand-side subsidies refers to direct or indirect payments to secure electricity access to the poorest households in Africa. This kind of subsidies can take the form of a reduced rate,

calculated using twelve-month or shorter rolling-average electricity-consumption data, for example, and may be complemented with cross-subsidies. Although the experience with this type of subsidies remains limited, initiatives such as the European Union's *GET.Invest* programme and the World Bank's *Africa Renewable Energy and Access* programme are putting the concept on the policy agenda. These initiatives suggest that, when combined with supply-side incentives, demand-side subsidies can help close the affordability gap referred to above by serving the poorest households. International partners should adopt and scale-up this kind of approaches. In doing so, they should be mindful of the need to rely on highly disaggregated estimates of affordability to underpin the design of demand-side subsidy programmes (*6*).

Digitalization of energy-sector planning and management tools

The electricity sector is in the midst of a major transformation, as utilities' primary role is gradually becoming "the management of energy supplied by independent power producers, rather than building and owning capacity themselves" (*7*). Such transformation is driven by digitalization, which makes it possible to "identify who needs energy and deliver it at the right time, in the right place and at the lowest cost" (*8*). Worldwide, digitalization is forecast to become a US$ 64 billion market by 2025, with smart-meters alone accounting for US$ 26 billion in the same year (*7*).

For Africa's electricity sector, digitalization entails three main opportunities (*8*). First, reduce the need for additional investments in electricity infrastructure: through pre-set financial incentives, digitalization makes it possible to adjust electricity consumption during peak-demand and off-peak periods, accommodate variability in supply, and limit network congestion. Second, reduce electricity costs for consumers, by facilitating the integration of distributed electricity generation (typically, household-level solar photovoltaic panels and storage facilities) into local

grids. Third, reduce the planning and capacity challenges inherent to the variability of renewable energy-powered electricity generation.

To reap the full benefits of digitalization, a pan-African digital roadmap, such as the European Union's *Digital Single Market Strategy*, needs to be developed, consistent with existing guidelines and mechanisms for secure data sharing (*8*). At the national level, governments would benefit from adopting policies that are conducive to the expansion of renewable energy markets, and of technological innovation, notably with regard to the development of digital start-ups (*7*). Against these benchmarks, the African countries that are best placed to embrace digitalization are Nigeria, Egypt, Kenya, Ethiopia and Ghana (*7*).

Integration of local-content requirements into renewable-energy policies

In Africa, financial incentives for renewable energy-powered electricity generation have had a modest success. Whereas feed-in tariffs are becoming less relevant given the fall in cost of renewable energy-powered technologies, auctions suffer from limited competition in the electricity market and the lack of domestic expertise – South Africa being the notable exception. Coherent policies that are stable over the long term, not least with regard to renewable-energy targets, independent electricity-market regulators and, as relevant, measures to reform monopolies are indispensable for financial incentives to deliver at their fullest, as they have done in other parts of the world.

Irrespective of the type of financial incentive used, most electricity projects in Africa are undertaken by foreign developers, notably European, Chinese and United States companies, owing to their experience and, especially, their ability to secure financing. As a result, African governments have introduced different types of so-called local-content requirements, namely

obligations concerning local employment, procurement of local goods and services, and the transfer of technologies and know-how, to which foreign investors have to abide. In countries such as Kenya and Nigeria, these requirements are defined through quantitative targets, whereas in other countries, such as Uganda and Zambia, they take the form of qualitative goals.

Empirical evidence, from Africa and elsewhere (*9*), reveals that there is ample scope for improving the effectiveness of local-content requirements. Two design shortcomings are specially common in Africa: the mismatch between requirements and actual domestic capacities, which deters and delays foreign investors, and the lack of sustained demand, which limits the ability of local providers to plan and undertake capacity expansions.

To increase the effectiveness of local-content requirements, countries with limited domestic capacities can focus on a small number of promising sub-sectors, as opposed to a broad-based approach targeting all aspects of electricity generation, transmission and distribution. For the sub-sectors chosen, a certification system can help ensure the required quality standards. Countries with stronger capacities can take a more ambitious approach, structured around (i) introducing legislative provisions and governance arrangements for local-content requirements, (ii) engaging both foreign investors and local providers in the definition of the requirements, and (iii) monitoring and reporting on the extent to which the requirements are met. For both types of countries, it is advisable to tighten requirements only gradually, while continuously adjusting ambition levels to reflect technology and labour market dynamics.

Strengthening and expansion of regional power-pools through African-led international partners-supported partnerships

Regional power-pools, based increasingly on renewable energy supplies, are now possible across most of the African continent (*10*). Nonetheless, additional efforts are needed to reap the full benefits of power pooling (*11*). Notwithstanding shared challenges, notably underinvestment, the nature of the additional efforts needed varies across African regions.

South Africa is the main electricity producer for the Southern African power pool, facilitated by the Southern African Development Community (SADC). Given the challenges that the country is increasingly facing to meet its domestic demand for electricity, and the dramatic decreases in cost of solar, wind and energy storage, the case for relying on solar and wind energy-powered electricity generation becomes stronger in the region. Yet, at present, for both renewable energy and electric-power transmission, many of the investment discussions in the SADC region focus on large dams, notably the Grand Inga Dam project, which have been the technology of choice for decades. Concentrating solar power technology, which is already being deployed in South Africa, can help shift the balance away from hydropower and toward solar energy, but only to the extent that stronger financial incentives are in place, compared to those introduced thus far.

To date, the members of the Maghreb Electricity Committee (COMELEC), Northern Africa's power pool, have only engaged in cross-border trade with the Iberian peninsula, across the Mediterranean Sea (Spain currently exports electricity to Morocco). As concentrating solar power in Morocco develops, the country plans to export electricity to Spain and possibly Portugal. Tunisia and Egypt are planning similar export arrangements (with Italy and Greece,

respectively). Against this background, COMELEC has pledged to launch, in 2025, a common electricity market for its five members. A planned interconnection between Morocco and Mauritania stands as the first milestone toward that goal. At present, efforts to develop intra-regional trade are hampered by insufficiently liberalised electricity markets and limited tradition of cross-border infrastructure investments in the region.

Both the Eastern Africa Power Pool (EAPP) and the West African Power Pool (WAPP) originate from pre-existing cross-border arrangements aimed at promoting cooperation on energy issues. In both regions, cooperation thus far has been limited to bilateral agreements, such as the lines linking Kenya with Ethiopia, and Ghana with Burkina Faso. Nonetheless, efforts are under way in both regions to harmonise regulations, contractual terms, and tariff levels applicable to electricity transmission, with a view to expanding power pooling beyond bilateral agreements. In the EAPP region, this goal is hampered by the lack of an updated development plan, reflecting changes in assumptions about costs and the expected impacts of newly implemented policies, because such a plan is a precondition for raising the funding required to establish a regional power pool. In the WAPP region, utility near-bankruptcy is a key hurdle to intra-regional trade, which calls for the regulated entry of foreign investment.

The Central African Power Pool (CAPP) remains underdeveloped. Poverty and other development challenges in the region limit the size of the electricity market, thus inflating prices. Compounding this challenge, weak governance arrangements result in insufficient competition in the sector, leading to underinvestment and ultimately thwarting any intra-regional power-pooling ambitions. International partner-facilitated bilateral inter-connections can pave the way to regional power pooling.

Expansion of investments in off-grid and interconnected clean-energy mini-grids

In moderately populated areas, where both grid extension and deployment of a relatively large number of stand-alone electricity-generation systems would be prohibitively expensive, off-grid mini-grids are the most economical electrification option in most cases (*12*). In light of strained public-sector budgets, scaled-up deployment of off-grid mini-grids depends on expanded and sustained private-sector investment. Two approaches to mobilising private-sector finance can bolster off-grid mini-grid deployment rates.

So-called third generation mini-grids, which combine photovoltaic solar panels and batteries with a back-up diesel oil-powered electricity generator, require less than two-weeks scheduled maintenance per year. Such high level of reliability makes it possible to incentivize off-grid mini-grid deployment through performance-based subsidies (*13*). For example, with World-Bank backing, Nigeria's rural electrification agency pays off-grid mini-grid developers USD 350 per connection, provided that the customer has had a steady supply of power for at least three months. Similarly, the reliability of third-generation mini-grids allows developers to offer customers a contract that includes, in addition to the electricity connection, the option to purchase income-generating appliances, such as machines for welding, milling and rice hulling, thus increasing deployment rates (*13*).

Interconnected mini-grids can generate and distribute electricity to customers that are not connected to main grid, while selling excess power to the main grid, as found in Nigeria, or they can choose to sell to the main grid all the electricity generated, as do some mini-grids in Tanzania. Electricity consumers benefit from interconnected mini-grids through increased

reliability of supply and, in most instances, lower prices (*14*). Interconnected mini-grid development is hampered by both regulation, which is unclear at best, and in some cases acts as a deterrent to interconnections, and technical standards, which may differ between mini-grids and the main grid. Overcoming the barriers to interconnected mini-grid development requires conducive policy and regulatory frameworks that clarify licensing procedures, and tariff regulations, establishing tariff levels for the various interconnection options.

Moving forward

Implementing our recommendations requires careful consideration of the policy options that may be most appropriate in each situation. Because power, agency and politics impact on the decisions made concerning policy targets and instruments, the policy strategies chosen to make such decisions are of paramount importance (*15*). These strategies ought to establish the objectives, time-horizons and societal goals – related, notably, to employment, environmental quality and equity – that should guide efforts to modernize Africa's electricity sector. Crucially, these strategies ought to be immune to two sets of policy drivers that, in a developmental context, are especially powerful. First, prevailing national-level incumbency issues and information asymmetries. Second, unduly rigid priorities and procedures on the part of international partners. We contend that, under the aegis of the newly launched African Single Electricity Market, and capitalizing on United Nations-sponsored high-level policy consultations, the Sustainable Energy for All initiative has a pivotal role to play in facilitating the development of these policy strategies.

Table 1: A suite of actions to expand and modernize Africa's electricity sector

Action	Key actor(s)	Key implementation mechanisms	Barriers to implementation	Trade-offs
Introduction of supply-side incentives and demand-side subsidies	International partners, national governments, investors and utilities	Continent-wide risk-guarantee scheme coupled with targeted demand-side subsidies	Insufficient coordination, limited experience, and lack of regulatory mechanisms	Difficulties associated with phasing out demand-side subsidies
Digitalization of energy-sector planning and management tools	National governments	National digitalization plan, underpinned by economy-wide data-sharing mechanisms	Limited experience and insufficient funding	Cyber-security threats and associated risks of economic disruption
Integration of local-content requirements into renewable-energy policies	National governments and local entrepreneurs	Local-content requirements embedded in financial incentives for renewable energy, and initial protection of local start-ups	Poorly developed policies, limited experience and corruption	Difficulties associated with phasing out the requirements (when local capacity has improved)
Strengthening and expansion of regional power pools through African-led international partners-supported partnerships	National governments and international partners	Regional agreements, backed with multilateral lending and logistical partnerships	Ineffective coordination and insufficient national partnerships	Uncertainty about surplus capacity
Expansion of investments in off-grid and interconnected clean-energy mini-grids	National and sub-national governments, and international partners	National-government facilitation of multilateral subsidies for off-grid mini-grids and policy and regulatory reforms to promote interconnected mini-grids	Limited awareness and experience among both African governments and international partners	Crowding-out of funding for rural electrification projects

Figure 1: Key implementation-related aspects, by recommended action

Source: Authors' own assessment

Note: Table S1 (Supplementary Materials) lists the countries included in each of the six regions shown in the figure

References

1. IEA, *Africa Energy Outlook 2019* (International Energy Agency, Paris, 2019).

2. C. E. Casillas, D. M. Kammen, The energy-poverty-climate nexus. *Science (80-.).* **330**, 1181–1182 (2010).

3. IEA, *World Energy Outlook 2020* (International Energy Agency, Paris, 2020).

4. IEA, *World Energy Investment 2020* (International Energy Agency, Paris, 2020).

5. D. Matthäus, M. Mehling, De-risking Renewable Energy Investments in Developing Countries: A Multilateral Guarantee Mechanism. *Joule*. **4**, 2627–2645 (2020).

6. S. Szabó, I. Pinedo Pascua, D. Puig, M. Moner-Girona, M. Negre, T. Huld, Y. Mulugetta, I. Kougias, L. Szabó, D. Kammen, Mapping of affordability levels for photovoltaic-based electricity generation in the solar belt of sub-Saharan Africa, East Asia and South Asia. *Sci. Rep.* **11** (2021).

7. BENF, *Digitalization of Energy Systems* (Bloomber Energy Fiance, New York, 2017).

8. IEA, *Digitalisation and Energy* (International Energy Agency, Paris, 2017).

9. B. Probst, V. Anatolitis, A. Kontoleon, L. D. Anadón, The short-term costs of local content requirements in the Indian solar auctions. *Nat. Energy*. **5**, 842–850 (2020).

10. J.-P. Carvallo, B. J. Shaw, N. I. Avila, D. M. Kammen, Sustainable Low-Carbon Expansion for the Power Sector of an Emerging Economy: The Case of Kenya. *Environ. Sci. Technol.* **51**, 10232–10242 (2017).

11. RM, *African Power Pools Outlook 2018-2019* (Research and Markets, Dublin, 2019).

12. P. Alstone, D. Gershenson, D. M. Kammen, Decentralized energy systems for clean electricity access. *Nat. Clim. Chang.* **5**, 305–314 (2015).

13. ESMAP, *Mini grids for half a billion people: market outlook and handbook for decision makers* (The World Bank's Energy Sector Management Assistance Program, Washington DC, 2019).

14. J.-P. Carvallo, J. Taneja, D. Callaway, D. M. Kammen, Distributed resources shift paradigms on power system design, planning, and operation: an application of the GAP model. *Proc. IEEE*. **107**, 1906–1922 (2019).

15. K. S. Rogge, K. Reichardt, Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Res. Policy*. **45**, 1620–1635 (2016).

Acknowledgements:

General

† Daniel M. Kammen is a former US Science Envoy

Funding

Not applicable

Author contributions

Conceptualization: DP, MMG, DMK, YM

Investigation: DP, MMG

Visualization: DP, MMG

Writing – original draft: DP, MMG, DMK, YM, AM, MJ, YH, NN

Competing interests

Authors declare that they have no competing interests.

Data and materials availability

All data are available in the main text.

Supplementary Materials for

An action agenda for Africa's electricity sector

Daniel Puig, Magda Moner-Girona, Daniel M. Kammen, Yacob Mulugetta, Atef Marzouk, Maximilian Jarrett, Yohannes Hailu, Nebojša Nakićenović.

correspondence to: dapu@dtu.dk

This PDF file includes:

Table S1

Table S1

Country composition of the regions listed in Figure 1

Region	**Countries**
Northern Africa	Algeria, Egypt, Libya, Mauritania, Morocco and Tunisia
West Africa	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo
East Africa	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, South Sudan, Sudan, Tanzania and Uganda
Central Africa	Cameroon, Central African Republic, Chad, Congo, Democratic Republic of Congo, Equatorial Guinea and Gabon
Southern Africa	Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, São Tomé and Príncipe, Zambia, Zimbabwe, eSwatini
South Africa	South Africa

The regional breakdown presented above is that used by the United Nations Economic Commission for Africa. The designations employed do not imply the expression of any opinion whatsoever on the part of the authors concerning the legal status of any country, territory or area, or of its authorities, or concerning the delimitation of its boundaries.