GREEN POWER FOR AFRICA: OVERCOMING THE MAIN CONSTRAINTS

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Cover photo Ethiopia, Benishangul-Gumuz Region. Electricity pylons, yet to be connected to the electricity source that is being built at the Grand Ethiopian Renaissance Dam (a gravity dam on the Blue Nile River), stand next to a small village.

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Advertising enquiries Gary Edwards, Marketing and Production Officer, IDS Communications and Engagement Unit, idsbulletin@ids.ac.uk

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Green Power for Africa: Overcoming the Main Constraints

Editors **Ana Pueyo and Simon Bawakyillenuo**

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Notes on Contributors

Lucy Baker is a Senior Research Fellow in the Science Policy Research Unit at the University of Sussex and a Visiting Fellow at the Energy Research Centre, University of Cape Town. Lucy's areas of research include: the political economy of energy; socio-technical transitions; and low-carbon development in low- and middle-income countries. Before working in academia, she worked for ten years in the fields of environment, development, and human rights.

Simon Bawakyillenuo is a Human Geographer and currently a Senior Research Fellow at the Institute of Statistical, Social and Economic Research (ISSER), University of Ghana, Legon, Ghana. He attained his PhD in Human Geography and an MSc in Environmental Policy and Management from the University of Hull, UK in 2007 and 2003, respectively. His research interests include different forms of energy and their interrelationships with health and the environment; energy policy; renewable energy dissemination and utilisation discourses; climate change; environmental policy; and green economy. He has been the lead in several research projects on energy, climate change, and environment at ISSER since 2012.

Pablo del Río is head of the Environmental Economics Group and senior researcher at the Institute of Public Goods and Policies at the National Research Council of Spain (CSIC). He has done extensive research on the analysis of support schemes for renewable electricity, the interactions of climate and renewable energy policies, and the drivers to eco-innovation in industry, the energy sector, and transport. He holds a PhD in Environmental Economics and an MSc in Economics and Business. He has a hundred international publications and has participated in seven EU-funded projects on the economic analysis of renewable energy support schemes.

Chris J. Dent is Reader in Industrial Mathematics, School of Mathematics, University of Edinburgh. His principal research interests include methodology for security of supply risk analysis, and large-scale techno-economic modelling of energy systems. He has been assisting the National Grid with the design of the UK Electricity Capacity Assessment Study since 2011. In 2012, he won the IET Mike Sargeant Young Engineer Career Achievement Award, and he has also won a Durham University Award for Excellence in Research Impact. He is a Fellow of the Operational Research (OR) Society, a Chartered Engineer, and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE).

Gruffudd Edwards holds an MSci degree in theoretical physics from Durham University (2001), a PG Dip. in renewable energy systems technology from Loughborough University (2008), and a PhD in renewable resource modelling from the University of Bath (2013). He has held postdoctoral positions on statistical and mathematical aspects of sustainable energy at Heriot-Watt, Durham, and Edinburgh Universities. Prior to these, he worked in corporate communications for the public sector, and as a sustainability adviser to small businesses.

James Gachanja is a Policy Analyst at the Kenya Institute for Public Policy Research and Analysis (KIPPRA), an autonomous thinktank that provides quality public policy advice to the Government of Kenya and other stakeholders. James has seven years' post-masters working experience as a policy analyst conducting policy research related to infrastructure and economic services; urban and regional planning; and transport economics. James holds an MSc in Geo-Information Science and Earth Observation for Urban Planning and Management. He has unique skills in geographic information systems (GIS) modelling; remote sensing; and spatial decision support systems (SPDSS).

Henry Louie received his MS degree from the University of Illinois in 2004 and his PhD in Electrical Engineering from the University of Washington in 2008. He is an Associate Professor in the Department of Electrical and Computer Engineering at Seattle University. Henry is the President and co-founder of KiloWatts for Humanity, a non-profit organisation providing electricity access and business opportunities in sub-Saharan Africa. He received a Fulbright Scholar award to Copperbelt University in Kitwe, Zambia, and is recognised as an Institute of Electrical and Electronics Engineers (IEEE) Distinguished Lecturer for his expertise on energy poverty.

Hugo Lucas is Head of the Energy Department at Factor. He has 18 years' experience in the private sector, government, and multilateral institutions, working in the design and implementation of support mechanisms for the promotion of renewable energy and energy efficiency technologies. He has been deeply involved in the establishment of the International Renewable Energy Agency (IRENA) and the discussions for the European Renewable Energy Directive 2020. Recently, he has provided advice in tendering designs for renewable energy electricity to the Philippines, Madagascar, Mali, and Peru. He is an Adjunct Professor at the Faculty for Environmental Studies, York University, Canada.

Neil McCulloch is a development economist with a focus on the political economy of energy in developing countries. He has done work on the political economy of fuel subsidies, both in Indonesia and Nigeria, and the political economy of aid for power sector reform in sub-Saharan Africa and South Asia. Previously, Neil was the Director of the Economic Policy Programme at Oxford Policy Management and, before that, the Lead Economist of the Australian Aid programme in Indonesia. He also led the Globalisation Research Team at IDS, UK and was a Senior Economist for the World Bank in Indonesia.

Helen Hoka Osiolo works as a Policy Analyst at the Kenya Institute for Public Policy Research and Analysis (KIPPRA) and has over ten years' experience in the energy sector. Currently, she is the acting Head of the Infrastructure and Economic Service Division in the institute. She is an economist with a focus on energy and the environment. Her research interests are on low-carbon energy development. She is the author of several peer-reviewed scientific journal articles and she has extensive experience working with government, the private sector, and international partners.

Ana Pueyo is a Research Fellow at IDS, where she leads large multidisciplinary international research projects on energy for development. She is trained as an economist and completed her PhD in Industrial Engineering focusing on renewable energy technology transfer to developing countries. Before joining IDS, she worked in energy and climate change consultancies in the UK and Spain, advising regional, national, and supranational governments on energy and climate policy. She has also worked extensively as a consultant for the private sector, including the World Business Council for Sustainable Development (WBCSD), energy sector companies, sectoral associations, project developers in the low-carbon business, and airlines.

Barry Rawn received MASc and PhD degrees in Electrical Engineering in 2005 and 2010 respectively from the University of Toronto. He is a lecturer in the Department of Electronic and Computer Engineering at Brunel University London. Barry is an expert in the grid integration of wind and solar energy, and drives activities related to sustainable energy in developing countries through his contributions to working groups and technical programme committees of the Institute of Electronics and Electrical Engineers (IEEE). From 2015–16, he provided advice and training on power systems operations and planning through the UKAid-funded Nigeria Infrastructure Advisory Facility.

Esméralda Sindou is an engineer and an economist with a particular interest in energy policy and renewable energy, working within Intec's Sustainable Energy Team. Prior to this, Esméralda worked at the French Development Agency in India, where she participated in the monitoring of two lines of credit for renewable energy and energy efficiency. Since then, she has worked as a consultant and has been involved in a number of projects in sub-Saharan Africa relating to power sector reform, the promotion of the links between energy and the broader economy, and the improvement of framework conditions for renewable energy investments.

Neal Wade is a lecturer in Power Systems at Newcastle University, where he leads projects in the electricity distribution and off-grid power sectors. These projects are addressing the need to cost-efficiently decarbonise the power sector over the next 30 years by investigating the innovative network integration of new generation and demand technologies. Computer simulation, laboratory investigation, and demonstration projects are used together to produce the new knowledge that delivers this need. He works with a team of research associates and supervises PhD and MSc researchers. He has a PhD from Glasgow University and previous experience in the electronics industry.

John Ward is Managing Director of the economic consultancy, Vivid Economics. John has over 15 years' experience in economic strategy and analysis, the last eight of which have focused largely on the links between climate and development, particularly in Africa and Asia. Leading the rapid growth of Vivid Economics' growth and development practice area, John has worked extensively with a wide range of clients including the World Bank, the European Bank for Reconstruction and Development (EBRD), the African Development Bank, and the UK Department for International Development (DFID). He has a Masters in Economics (with distinction) from University College, University of London.

Dirk Willenbockel is a Research Fellow in the Green Transformations cluster at IDS, and has a PhD from the University of London, London Business School. He is an economist with particular expertise in forward-looking quantitative policy analysis and current research interests in climate change impact and adaptation analysis, low-carbon growth and development, long-run food system scenario analysis, trade policy, and regional economic integration analysis. His research and consultancy experience includes *inter alia* work for the World Bank, the United Nations Development Programme (UNDP), the World Food Programme (WFP), the International Labour Organization (ILO), and the Department for International Development (DFID).

Mohamed Youba Sokona is a renewable energy adviser at the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), where he is seconded by the German Corporation for International Cooperation (GIZ). He is in charge of providing technical assistance to ECOWAS member states to create the enabling environment for grid-connected renewable energy, through the design of legal and regulatory frameworks as well as operationalisation of existing ones. He previously worked for the International Renewable Energy Agency (IRENA). He holds an MSc in Environment and Energy Management from the University of Twente and an engineering degree from the University of Illinois Urbana-Champaign.

Introduction: Overcoming the Constraints to Green Electricity in Africa

Ana Pueyo and Simon Bawakyillenuo

Abstract The phenomenon of inadequate power supply in sub-Saharan Africa (SSA) has been a subject of great interest over the years because of its intractable nature and its importance for development; SSA accommodates about 55 per cent of the more than one billion people without access to electricity globally. Moreover, in many SSA countries, electricity access rates are decreasing because electrification efforts are slower than population growth. In recent years, however, certain SSA countries have demonstrated that with political will and access to appropriate finance, electricity access can be accelerated. The overwhelming calls for clean (green) energy sources into the energy mix cannot be overemphasised. Drawing from different disciplines, this *IDS Bulletin* provides new perspectives that go beyond the identification of obstacles to renewable energy development in SSA. The contents of these contributions underscore the complexity surrounding the clean electrification challenge in SSA; and demonstrate the benefits of a multidisciplinary approach in the design of interventions.

Keywords: sub-Saharan Africa, clean electricity, technical challenges, economic challenges, political challenges, multidisciplinary approach.

1 Introduction

Nearly ten years ago, sub-Saharan Africa (SSA) was defined as 'underpowered' in a World Bank report diagnosing the state of its physical infrastructure (Eberhard *et al.* 2008). SSA was in the middle of a power crisis, with a deficit of generation capacity, poor quality of electricity supply, very low access rates, and higher prices than other developing countries, but still below cost recovery.

One decade later, sub-Saharan Africa is still underpowered. Eighty per cent of enterprises experience regular power outages (World Bank 2017) and the region hosts 55 per cent of the more than one billion people without access to electricity globally (IEA and World Bank 2017). Reinforcing this gap, only 37 per cent of sub-Saharan Africans have electricity while the second region with the lowest access, South and

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Southwest Asia, provides electricity to 82 per cent of the population. Besides, in many SSA countries, electricity access rates are actually decreasing because electrification efforts are slower than population growth.

The last decade has also brought positive developments. First, populous low-access countries like Kenya, Malawi, Sudan, Uganda and Zambia have shown that rapid progress can be achieved with political will and access to appropriate finance. Second, there is increased awareness in the international development community about the importance of energy for human development, and the need for energy to be 'green'. This reflects in the definition of Sustainable Development Goal 7 to 'ensure access to affordable, reliable, sustainable and modern energy for all' by 2030. What is more, the renewed interest in universal and clean energy in the donor community has made more funding, technical, and policy support available for renewable energy (RE) investment in SSA.

When developing the policy framework to support investment in renewable energy, donors and national governments should learn from the mistakes of the past. In particular, since the 1980s, the World Bank and other donors had promoted a 'one-size-fits-all' approach to power sector reform, consisting in unbundling state monopolies, liberalisation, and privatisation. It was expected that the 'standard model', as it was called, would improve the performance of African state-owned utilities and attract much-needed investment. However, reform did not work as expected. The standard model copied the experiences of countries like Norway, Chile and the UK, but proved inappropriate for the very small power systems and struggling utilities of sub-Saharan Africa. The broken monopolies that emerged had increased their transaction costs and reduced economies of scale, while political meddling persisted despite attempts to liberalise (Besant-Jones 2006). In fact, reform was never consummated in any SSA country. Many of the former state monopolies morphed into 'hybrid models', combining and often confusing the roles of public and private actors (Gratwick and Eberhard 2008).

This *IDS Bulletin* departs from the premise that power sector reform should be context-specific. It follows on from the IDS Research Report *Green Investment Diagnostics for Africa*,[1] that departed from the premise that there are many reasons why there is not enough renewable energy investment in sub-Saharan Africa, but some reasons are more important than others. Policymakers should therefore focus on the most binding constraints. The research proposed a systematic approach to identify these binding constraints and applied it to two countries: Kenya and Ghana. Results showed that both countries needed very different policies to attract investment (Pueyo *et al.* 2017).

With this *IDS Bulletin*, we want to go further than the identification of binding constraints, to reflect on the reality of a wider set of countries (seven SSA countries are included in this issue) from a wider set of disciplines. The authors of the articles in this *IDS Bulletin* provide insights from power systems engineering, macroeconomics, microeconomics, and political economy to overcome constraints to green electricity in Africa. One of the biggest contributions of this issue is therefore allowing a dialogue between academics and practitioners that would not normally publish in the same journals. The remainder of this introductory article summarises their contributions, grouping them under three sections about technical, economic, and political challenges.

2 Overcoming technical challenges

The articles by Rawn and Louie, and Edwards, Dent and Wade focus on two technical issues particularly relevant for Africa. First, Rawn and Louie explore two potential pathways for electrification in sub-Saharan Africa: grid extension/enhancement and off-grid solutions, taking the perspective of a traditional power system planner. Second, Edwards *et al.* explore the challenges and opportunities of increasing the penetration of variable renewables like wind and solar in the small African power systems, using capacity adequacy assessments.

Rawn and Louie start by highlighting the particularities of SSA as compared to other countries that have successfully achieved universal electrification. As opposed to these previous successful experiences, SSA lacks governments with big surpluses that can pay for the heavy investments required, or a critical mass of mostly urban consumers able to cross-subsidise the poorer rural population. Another important difference is that in the past, grid extension had always been considered as the endpoint of all electrification efforts, but now technological progress has made off-grid solutions increasingly competitive with the grid in rural areas.

The article by Rawn and Louie links to other contributions in this *IDS Bulletin* when it talks about the political economy of each pathway. The grid model requires heavier state intervention and is more open to rent-seeking and patronage; it also generally allows for bigger economies of scale and a cheaper service. As raised by McCulloch, Sindou and Ward in another article in this issue, an off-grid, private sector-based model is more difficult to control by the state. If it deprives the government of useful rents, it could be sabotaged through restrictive regulation or by extending the grid with a subsidised tariff to villages where off-grid systems operate. Coordination with political actors is therefore essential, and a significant role of the state and subsidisation are unlikely to go away.

Edwards *et al*. focus on a particular challenge for grid systems: the variability of some renewable energies, mainly wind and solar. SSA power systems are remarkably unreliable, with frequent blackouts that cause significant economic losses to consumers. Wind and solar energy cannot contribute to avoiding generation caused by blackouts when the wind is not blowing and the sun is not shining. Therefore, many policymakers wonder if they are appropriate solutions for their reliability problems. Edwards *et al.* explore this issue by carrying out a simplified version (due to data availability) of a capacity adequacy assessment of wind in Kenya. Adequacy assessments are concerned with the risk of there being insufficient resources to supply demand in a given power system. Their analysis compares temporal patterns of wind availability with patterns in system demand and the availability of hydrological resource, to assess the extent to which the resources complement each other. Their results show that the large wind projects that Kenya is building are likely to contribute to the generation adequacy of the system, thanks to the complementarity between wind resource and demand, and between wind and hydro resources. This is possible thanks to the quality and consistency of wind in a number of sites in Kenya. A similar assessment should be done in SSA countries with good or excellent wind resources to understand whether they will contribute to the reliability of power supply.

The analysis by Edwards *et al.* relates in particular to the article by Osiolo, Pueyo and Gachanja, which points at system costs as one of the most important constraints to renewables in Kenya. In particular, Kenya suffers a deficit in transmission infrastructure, and some of the sites with outstanding wind resource are located in remote areas without transmission lines. There is therefore a trade-off between the resource quality and access to transmission infrastructure, an issue that also comes up in the articles by Baker, and Lucas, del Río and Sokona.

3 Overcoming economic challenges

Two articles in this *IDS Bulletin*, by Willenbockel, Osiolo and Bawakyillenuo, and by Lucas *et al*., look at economic approaches to overcome the challenges to renewables in Africa.

The first article, by Willenbockel *et al.* applies a macroeconomic perspective, using computable general equilibrium modelling, to debunk the common narrative that green energy is not compatible with economic growth. The article shows the distributional implications of a shift to renewables in Kenya and Ghana. It concludes that in both countries, it is feasible to reduce the carbon content of electricity generation without adverse consequences for economic growth, and without noteworthy distributional effects. Kenya shows much larger economic benefits than Ghana, though, thanks to abundant low-cost geothermal resources that would reduce electricity prices, and trigger a moderate real exchange rate appreciation (less fossil fuel imports), thus reducing the price of imports and leading to an economy-wide real income gain. Ghana has a much smaller potential for economically viable renewables and has an active domestic fossil fuel extraction sector. Hydro is the only RE option with a clear cost advantage over gas, yet the potential for hydro expansion is limited. There is therefore a moderate scope for an RE transition in Ghana, with marginal impacts on macroeconomic growth. Willenbockel *et al.*'s article shows that Ghana's attraction to a fossil fuel-based model, as described in Bawakyillenuo's article in this *IDS Bulletin*, is justified economically due to the possibility of higher tariffs at the beginning of the transition, the lower cost of gas, and a pre-existing gas infrastructure, as well as the contribution of natural resource extraction to real gross domestic product (GDP) growth.

The article by Lucas *et al*. uses a microeconomic lens to analyse renewable energy auctions, a policy instrument widely applied in SSA nowadays after the initially successful experience of South Africa. Donors have been heavily involved in the design and implementation of RE auctioning schemes in SSA, providing funding and technical assistance and a package of de-risking and credit enhancement. These measures have mostly attracted large international companies. The authors argue that renewable energy auctions make a lot of sense technically and economically for SSA. As opposed to feed-in tariffs (the previous policy trend in the continent), renewable energy auctions allow the market to set the most competitive price and avoid overloading the administration with unsolicited proposals. They also provide opportunities to reduce risks through the pre-selection of sites and to create local jobs through local content requirements. The authors review the design elements of the auctioning schemes in Ghana, Uganda and Zambia, showing some key elements that seem to be working: the pre-selection of sites, as opposed to geographic neutrality typical in Organisation for Economic Co-operation and Development (OECD) countries; and technology specificity with a focus on solar photovoltaic (PV) due to its decreasing cost, simplicity, and fast turnaround. They also point at some remaining obstacles to successful auctions, mainly poor planning. These reflections mirror those by Rawn and Louie, who in their article emphasise the importance of long-term planning and low technical complexity.

In addition to the challenges raised in the article by Lucas *et al*., the article by Baker in this *IDS Bulletin* shows that even for a policy like renewable energy auctions, that makes perfect economic sense, political challenges can be unsurmountable. Having looked at the articles on the technical and economic dimensions in this *IDS Bulletin*, we now discuss the next set of articles focusing on political economy.

4 Overcoming political challenges

The articles by Baker, Osiolo *et al.*, Bawakyillenuo, and McCulloch *et al*. seek to understand why policies that make perfect technical and economic sense are not implemented, or do not work as expected when they are.

First, Baker describes the history and future prospects of South Africa's Renewable Energy Independent Power Producer Procurement (REIPPP) programme, an auctioning scheme to procure renewable energy-based electricity from private generators. The REIPPP was an economically and technically sound policy, and was a success that many other SSA countries have tried to replicate. It marked the first time that South Africa had both independent power producers (IPPs) and renewable energy, and succeeded in turning South Africa into an attractive destination for commercial-scale renewables. As a result, RE added a small but significant contribution to the generation mix and many jobs were created as selection criteria included local content and job creation requirements. However, new clouds are endangering the future success of the programme. First, the monopolistic national power utility, Eskom, is acting as a gatekeeper, being reluctant to lose its grip on the sector. Second, grid availability is becoming an obstacle for many potential projects. The connection of a growing number of RE projects located in resource-rich sites is leading to grid constraints in those locations. This second problem could be addressed with geographical incentives to IPPs or the pre-selection of sites with sufficient grid availability. The first problem, however, is eminently political and harder to solve unless there is a coalition of interests in favour or renewables strong enough to counter the power of Eskom.

The article by Baker is a good continuation to the article by Lucas *et al.*, showing that a purely economic perspective is not enough for the successful implementation of auctions in SSA. It also connects to many other articles in this *IDS Bulletin*; for example, to the article by McCulloch *et al.*, showing the importance of donors in the initial success of REIPPP, as well as the need to know the interests of all stakeholders when designing such a policy. Like Osiolo *et al.*, and Rawn and Louie, Baker shows that transmission and distribution infrastructure can become the Achilles heel of RE in Africa, when the state monopoly managing it has no incentives for long-term investment.

The second article using a political economy approach, by Osiolo *et al.*, looks in depth at the policies that might address three prevailing constraints to RE investment in Kenya: the poor state of the transmission and distribution infrastructure, a very low rural demand, and high levels of local opposition to RE infrastructure. The article looks at how these constraints came to be, which policies could address them, and which actors could block or support these policies.

Even if Kenya is championing market-led approaches for the provision of off-grid electricity, rural poverty and the high costs of reaching remote, poor populations remain a key issue, as in many other SSA countries. Despite the decreasing costs of off-grid solutions (as highlighted in Rawn and Louie's article), these are still beyond the means of a majority of the rural poor. On the other hand, smaller off-grid solutions, such as solar lamps, can increase welfare through better quality light and mobile phone charging, but do not enable new productive uses to escape poverty. Sometimes the gap between the small urban elite and the large rural poor manifests violently in Kenya, through protests against new energy infrastructure that delay or block projects, and scare investors. The authors argue that an important role for donors and the state is unavoidable in Kenya, despite the dominant 'market-led' narrative. Donor support will be needed for the affordability of rural electrification, and to increase the ability of the population to pay through the promotion of productive uses. A strong state will also be necessary to allocate cross-subsidies that bridge the affordability gap, to coordinate on- and off-grid efforts, and to invest in transmission and distribution infrastructure.

The article by Osiolo *et al.* dialogues with other articles in this issue; for example, with Lucas *et al.* who also point at the importance of pre-selecting and de-risking sites to reduce investment uncertainty. Lucas *et al*. also recommend the introduction of social criteria for bid assessment, to reduce historical inequalities, which is particularly relevant for Kenya as it designs its own auctioning scheme.

The article by Bawakyillenuo departs from a similar premise as the preceding article by Osiolo *et al*., arguing that the best policies to solve Ghana's constraints to investment in RE might not be politically feasible. The article explores three constraints in depth: the poor creditworthiness of the off-taker, the inadequate power sector regulation, and lack of access to appropriate finance. The author argues that a dominant natural gas-based paradigm in the political class and the national psyche, and the lack of an organised civil society that demands renewable energy make it hard to implement RE policies in the country. Some donors are intervening to solve the financial problems of the off-taker, the Electricity Company of Ghana, pushing for the privatisation of the retailing branch of the utility. However, a large share of the population opposes privatisation, mainly for fear of price increases. As McCulloch *et al.* recommend, donors should understand the motivations of all the actors involved and try to build local coalitions before pushing for an unpopular privatisation. Otherwise the privatisation could be reversed just as rapidly as it was implemented.

The final article, by McCulloch *et al.*, brings to the forefront an underlying thread to all other articles in this *IDS Bulletin*: the essential role of donors to achieve sustainable energy for all in Africa. Their article looks in particular at the use of political economy analyses by donors to improve the effectiveness of their interventions for power sector reform. The authors argue that donors, with the high rotation of their staff and the consultants they hire to implement their programmes, are responsible to some extent for the uniform approach to reform that has failed in the past. The incentive structure is also wrong for targeted, politically aware interventions. Donors are often incentivised to spend their money, without the possibility to change or stop programmes once they have started and no *ex-post* reflection about successes and failures. The case of Tanzania is used to illustrate the failure of reform when it does not take into account political realities. Finally, McCulloch *et al.* recommend that donors carry out an analysis of the underlying motivations of key actors before they push for reform, to uncover politically feasible reform pathways. If this analysis concludes that reform is impossible, donors should then 'work with the grain', supporting legitimate credible domestic actors to challenge the status quo.

In summary, the contributions to this *IDS Bulletin* underline the enormity of the clean electrification challenge in Africa; and demonstrate the benefits of a multidisciplinary approach where technical, economic, and political perspectives are involved in the design of interventions. We hope that this *IDS Bulletin* will inspire future initiatives, where many other disciplines not covered here can jointly contribute to overcome the constraints to RE investment in SSA.

Notes

1 That report and this *IDS Bulletin* is part of the Green Growth Diagnostics Project led by IDS in partnership with KIPPRA, ISSER, the universities of Durham and Newcastle, and the Policy Practice, www.ids.ac.uk/project/green-growth-diagnostics-for-africa.

2 The rationale and methodology for Green Growth Diagnostics was inspired by the Growth Diagnostics approach developed by Hausmann, Rodrik and Velasco (2004).

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Planning for Electrification: On- and Off-Grid Considerations in Sub-Saharan Africa

Barry Rawn and Henry Louie

Abstract Energy poverty, in particular, the lack of access to electricity, is a chronic impediment to sustainable development in sub-Saharan Africa, affecting over one billion people. Recently, electrification efforts have bifurcated into two pathways: grid extension/enhancement and off-grid. Expanding and enhancing the existing national grid is the *de facto* approach, but is struggling to keep up with growing populations and demand in many countries. Off-grid solutions such as solar home systems and mini-grids are seen as a way to 'leap frog' the national grid, but face distribution, affordability, and regulatory challenges. This article explores each electrification pathway through the lens of a traditional power system planner. This perspective shows that implicit planning assumptions about cost recovery, procurement, reliability requirements, economic benefit, what entities are involved, and the role of renewable energy require re-visiting and re-invention in the sub-Saharan African context.

Keywords: renewable energy, off-grid, power system planning, energy poverty, grid extension, products as a service, electrification, mini-grids, micro-grids, probabilistic connection.

1 Introduction

The electrification rate of households in sub-Saharan Africa (SSA) is presently at 37 per cent (IEA and World Bank 2017). Those with electricity access are often challenged by an unreliable, unavailable, and inadequate supply (Billinton and Jonnavithula 1996). Electricity underpins many broader development goals, and its positive association with education, health, and economic prosperity has been noted in existing literature (IEA and World Bank 2017; Franco *et al.* 2017; Socvacool and Ryan 2016; White *et al.* 2008). With this impetus, governments in countries throughout SAA have moved to increase electricity access (Bhattacharyya 2013). To this end, electricity supply planning plays a crucial role. However, traditional assumptions and notions of planning as might be followed in countries with mature power systems with universal access are challenged in the context of

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SSA (Trotter, McManus and Maconachie 2017; Eberhard and Gratwick 2011; Malgas and Eberhard 2011).

A salient difference in power system planning in SSA is the notion that electricity supply can be provided not only by extension of the national grid, but also by off-grid systems. Economically viable, sustainable, and scalable off-grid electricity access – primarily by small-scale solar systems, solar lanterns, and mini-grids – has only recently become possible. It is disruptive to traditional planning processes, and may hold lessons in jurisdictions where these habits hold sway.

The literature on the subject has explored comparisons between on- and off-grid electrification from technical (Trotter *et al.* 2017; Szabó *et al.* 2011), economic, and development perspectives (Wamukonya and Davis 2001). This article focuses on electrification through the lens of a power system planner to probe how the underlying assumptions to traditional electricity supply planning tend not to be satisfied in SSA, and hence the process must be modified. It is suggested that more robust and flexible planning processes will be emerging from this context due to tight economic constraints, the need to address widely different levels of demand as well as different requirements of service quality, and the growing experience with disruptive technologies like cheaper energy storage.

The remainder of this article is arranged as follows. Section 2 provides a brief overview of historical experiences in electrification providing valuable lessons for SSA. Section 3 discusses the state of electricity access in SSA, considering on- and off-grid populations. Basic concepts of electricity supply planning are reviewed in Section 4. Sections 5 and 6 discuss how notions of traditional electricity supply planning are challenged in the context of on- and off-grid electrification in SSA. Conclusions and an outlook are provided in Section 7.

2 Historical experience in electrification

Universal access has not been a spontaneous event in the many countries that have achieved it. On the contrary, a number of conditions needed to be satisfied, among which are long-term dedicated private and public investment, access to cheap and patient capital, the ability to pay for electricity by wide segments of society, and an unclouded political vision and follow-up. This section compares the electrification-by-grid-extension experience in different countries, highlighting those factors and showing possible implications for the African context.

The United States (US) was among the early leaders in the development and implementation of electricity (Wamukonya and Davis 2001). However, access to electricity in rural areas notably lagged behind many other countries. Electrification began in urban centres serving a clientele willing and able to pay high premiums for an electricity service. Electricity providers made a concerted effort to install large generators, enlist more customers, and lower the cost of electricity production by reaching higher-capacity factors.[1] By being able to run their large generating stations fully for as much of the time as possible, they improved the returns to their investment.

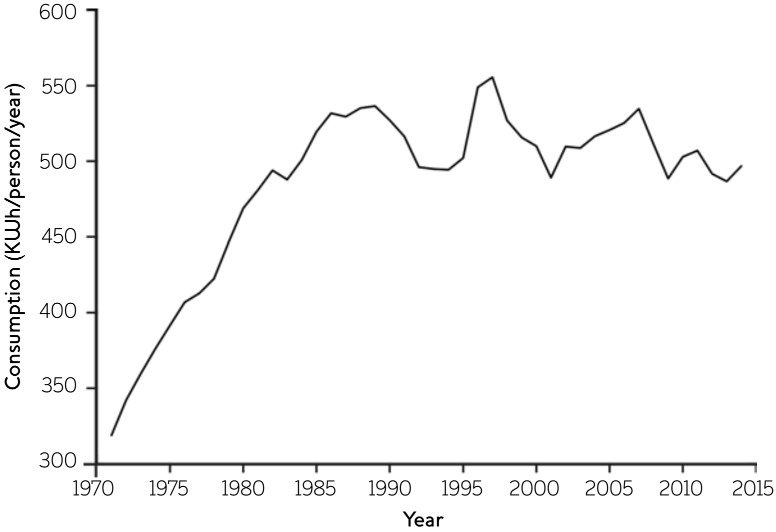
Electrification expanded quickly in urban areas, but rural areas lagged behind. In 1935, just 10 per cent of farms in the US had grid access. The reasons for the low rate are similar to those identified today in countries that struggle with electrification. As summarised in a 1934 report by the Mississippi Valley Committee, the reasons for low rural electrification include '… the lack of interest by operating companies in rural electrification… high cost of construction… restrictions covering rural line extension… and high costs' (Beal 1940). In short, the privately owned electric utilities could generate more profit by serving urban rather than rural customers.

It took government intervention to make electricity accessible to the rural population. The creation of the Rural Electrification Administration and the passing of the Rural Electrification Act in 1936 provided the catalyst for rapid rural electrification (Hughes 1983). Access to finance at low rates and high maturities and good communication with rural populations caused rural electrification rates to rise to 25 per cent by 1940, and to virtually 100 per cent by the 1950s. In less than a generation, the rural electrification of the US was complete.

China – a country of over one billion people and an expansive geography – has nearly universal access to electricity. This includes rural areas, where half of the population live, thanks to the use of community and municipal management. This is in stark contrast to India, the other Asian giant, whose rural electrification rate had reached only 70 per cent by 2014. As in the US experience, rural electrification in China lagged behind urban (Bhattacharyya 2013). The rural electrification rate was 61 per cent in 1978. By the end of the 1980s, the electrification rate reached 80 per cent, and by the turn of the millennium, it was virtually 100 per cent, for a population three to five times the size of the US.

China realised rapid electrification through various government-backed programmes, including the Township Electrification Programme, which is the largest renewable energy supply programme in the world (Bhattacharyya 2013). Over the last 50 years, the organisation of the rural electrification effort has evolved. More recent success is attributed to the empowerment of local county- or village-level government by the central government to manage rural electrification. This bottom-up approach, while still governmental and not free-market-led, is unique and could be adopted by other countries. The programme leveraged locally available energy sources, including small-scale hydro, to build out localised grids, which were eventually connected to the national grid. While this allowed access to rapidly increase, the localised grids were often poorly designed, not standardised, and used low-quality components. This underinvestment in the grid led to high system

Figure 1 **Per capita electricity consumption in sub-Saharan Africa**



Source World Bank Open Data (n.d.).

losses, low reliability, and need for replacement once connected to the national grid. However, even a lower quality electricity supply provided the conditions for the economic improvement and electricity demand growth necessary to justify and sustainably finance a grid connection, qualifying it as the successful pursuit of a socioeconomic electrification goal (Bhattacharyya 2013).

The experiences of electrification of the US and China hence show that a heavy involvement of the state was required, jointly with access to patient capital, the existence of an urban critical mass that could pay the actual cost of the service and, in the Chinese case, a bottom-up approach adapting energy supply to the local energy sources and to the characteristics of local demand.

3 Present state of electricity supply in sub-Saharan Africa

In many African nations, the demand for electricity has outpaced centralised infrastructure growth, in terms of generation sources built, transmission lines strengthened, and distribution systems extended (Practical Action 2016). The exponential tripling of population from 1970 to 2010 gives a rate to be matched in some sense by electricity infrastructure. However, population does not equate to an economically viable demand for electricity.

3.1 National grids

The total generation supply in SSA, excluding South Africa, is approximately 100,000MW in a region with almost one billion people. This supply is on a par with Spain, a country whose population is less than 50 million. Per capita electricity consumption in SSA shows a similar gap and it has not improved since the mid-1980s, as seen in Figure 1.

Power systems in developing nations tend to have a small number of generators covering a large area. In SSA, excluding South Africa, nation states have total generation capacities ranging from 0.4GW to 8GW of capacity (Macro Economy Meter 2013). For their populations, the capacity is on the order of 10–100 watts per capita, versus 500–5,000 watts per capita in industrialised countries (Sanjay 2015). Connections between neighbouring countries are not strong, making many countries electrical islands. This isolation, as well as the small number of power plants, long distances, and heavy reliance on hydropower (Macro Economy Meter 2013; Sanjay 2015) or imported fuels[2] make SSA power systems particularly vulnerable.

3.2 Off-grid

Off-grid solutions can address some of the vulnerabilities highlighted above. Furthermore, they can directly target the rural population constituting the majority of some 600 million people who have no access to the electrical grid in SSA (IEA and World Bank 2017). In rural areas, the lack of legacy electrical infrastructure has allowed electricity services to be re-imagined in the form of off-grid renewable energy electricity solutions provided by for-profit companies and energy entrepreneurs, in some cases with the support of donor agencies (Birol 2015; Byrne *et al.* 2014). Technological improvements have enabled these new business models. In particular, the steady and comparably drastic drop in solar panel, inverter, and LED technology costs due to industry experience has lowered barriers to decentralised provision of electricity (IEA and World Bank 2017; IEA 2005; Birol 2015; Energy Sector Management Assistance Program 2015; Louie *et al.* 2015; Bloomberg New Energy Finance and Lighting Global 2016; Mandelli *et al.* 2016).

New off-grid systems often provide limited amounts of power. For example, solar lanterns can only provide light. Solar home systems typically consist of a solar panel with a capacity from 5W to 300W – a lead-acid or lithium ion battery in a ruggedised case with an integrated LED light and/or ports for charging mobile phones. Larger-capacity solar home systems are capable of powering small appliances such as televisions and fans (Bloomberg New Energy Finance and Lighting Global 2016). The small size of these systems has not precluded widespread adoption, with over 40 million solar lanterns and solar home systems deployed (Bloomberg New Energy Finance and Lighting Global 2016) and a market exceeding US$500 million in 2015 (Global Leap 2016).

Larger scale off-grid systems, referred to as 'mini-grids' or 'micro-grids', provide higher-capacity access to rural customers, and are approaching or even exceeding the quality of service of grid-connected electricity (Louie *et al.* 2015). Hybrid power systems based on diesel generators, photovoltaic panels, and batteries are being developed by for-profit companies which can attract sufficient capital to offer power contracts to commercial customers with a lower cost of energy, higher reliability, and greater convenience. These systems require specialised planning to be economically viable and sustainable, and are still following a technology and system integration experience curve towards lower costs and better performance.

4 Concepts for traditional electricity supply planning

This section introduces some key concepts related to the activity of electricity supply planning, which will be necessary to assess the two potential electrification pathways for SSA. Electricity supply planning differs from day-to-day electricity supply operations by the timescales considered, its goals, and the tools used. Electricity supply operation is a real- or near-real-time activity focused on maintaining reliability at the lowest cost possible. On the other hand, planning horizons are many years in the future and decisions are based on uncertain projections of conditions, but the goals remain focused on achieving a given reliability at least cost (Conejo *et al*. 2016).

Successful planning outcomes are reached through a set of activities: (1) estimating demand and demand growth, (2) selecting generation technologies, (3) planning operations, (4) designing transmission and distribution networks, and (5) ensuring an enabling environment for plan implementation (Trotter *et al*. 2017). Sound planning decisions balance initial costs with long-term expectations, and the needs of one user against another.

We now introduce several aspects relevant for the two potential electrification pathways for SSA from the perspective of a planner, namely: the actors engaged in planning activities; the fulfilment of economic and social goals; the quality of service; and the implications of increased penetration of renewable energy sources.

4.1 Actors

Electricity supply planning has traditionally been the purview of utilities – both government and independently owned –, regulatory entities and at a high level, government ministries or agencies.

Independent power producers also plan and announce their projects, but usually in the context of a national pace set by government ministries and the regulator (Eberhard and Gratwick 2011; Malgas and Eberhard 2011; Global Leap 2016). It is the responsibility of the wider power sector, which includes technicians, standards reinforcement branches of the regulator, and regulated utility companies to cooperate with the plans set. This is part of the aforementioned activity of ensuring and enabling an appropriate environment.

4.2 Economic and social goals

The difference between economic, socioeconomic, and social goals can be usefully articulated to support planning activity, including the selection of appropriate technology and policy, as hypothesised in Conejo *et al.* (2016).

A purely economic goal is met via a traditional assessment of rates of return. In this case, the means of cost recovery is directly from users, whose ability to pay can justify the investment. Economic returns can be maximised when the capacity factor of generation assets is high.

A socioeconomic goal has overall positive social welfare (in the economic sense), but requires the careful design of cross-subsidies. In this case, it is not the particular customer, but the collection of all customers who must offer viable cost recovery.

Finally, a social electrification goal acknowledges the environmental security and health benefits that may result from access to electricity, as a means of poverty alleviation, and does not specify a direct payback. In this case, a trade-off analysis of these benefits against other options contending for support from donors, a community, or a nation state budget is warranted. Once an expected means of cost recovery is identified, a planner can consider technologies that are appropriate for the expected financing, and for the quality of electricity access needed.

4.3 Quality of service

The service experienced by a consumer of electricity can be measured by a number of metrics locally (Billinton and Jonnavithula 1996). These refer to both quantity (power[3] and energy[4]) and quality. In aggregate, industrial, commercial, and residential users, types in a region may consume roughly equal quantities of electricity, but with stark differences in the quality of supply tolerated. The quality of service continuum, more commonly referred to as 'access tiers', has different formulations, but generally considers dimensions such as technical quality, legality, and affordability (Energy Sector Management Assistance Program 2015).

Technical quality can be partly described by availability and reliability. Power system operators need to ensure that at every moment, the power consumed (inclusive of losses on the power lines) matches the power generated from some source. If there is insufficient fuel for power plants, or these are not operating due to technical faults, then energy cannot be provided to customers, and either electricity rationing or a blackout must occur (Macro Economy Meter 2013; Conejo *et al.* 2016). Similar concepts apply to off-grid systems, although at a smaller scale. A solar-powered system is limited by the power it can supply at any moment, and the energy it can supply from its storage over periods when the sun is not available.

Due to these mismatches between demand and supply, the availability of a live electrical connection expressed as a fraction of a chosen time period is often less than one. Beyond the customer level, we use several measures of system reliability, which tend not to acknowledge a specific location, but characterise the frequency and duration of interruptions across a region over a chosen time period, as well as the likelihood of demand not meeting supply at a system level, which would provoke a wider disruption. At the regulatory level, planning processes are required to result in levels of generation and transmission sufficient to make this likelihood acceptably low in the face of credible events. This provides the condition called 'adequacy', which is a term applied to indicate that the generation available has a suitable surplus to counteract unplanned events (Billinton 1970).

4.4 Renewables

Renewable energy has been increasingly incorporated into long-term plans due to significant cost reductions, and to subsidies and targets as part of climate change mitigation commitments. Renewables make sense from an energy planning perspective when they are low cost and improve energy security, being locally available (AfDB 2012). However, the most widespread renewable sources of wind and solar introduce new challenges for power planners. Their variability and uncontrollability mean that their contribution to meet electricity demand is uncertain. Additionally, the best renewable energy resource is not always located close to centres of demand, which requires heavy investments in transmission lines to both access and then channel the available power to locations with higher demand and price (Smith *et al.* 2010). As the proportion of wind and solar become greater, power system operations can be affected, as it becomes more difficult to balance supply and demand. Because of this, planners often request technical grid integration studies before they agree to new renewable generation plants. A limit on allowed generation development may be imposed to remain within these operational limits and the capabilities of planned extension of transmission links. Because wind and solar can be deployed in distributed form in small modular pieces, some amount of generation development may go unplanned and unmonitored.

5 The grid enhancement and extension path

The rest of this article will explore two parallel paths to electrification, indicating where planning activities in developing countries may differ, and considering the way forward. The first path is grid extension.

In theory, grid extension is the most cost-effective use of capital, especially when it pursues the connection of customers near the national grid rather than those who are more distant. On the contrary, the cost of installing a power line to a rural area might cost over US$20,000 per kilometre. What is more, because rurality and poverty are often associated, the customers tend to purchase modest amounts of energy and the investment in the power line is recuperated slowly over many years.

Some technological improvements have tackled the high cost of grid extension to rural areas, most notably the adoption in South Africa of different standards such as Single Wire Earth Return (SWER) and blanket extension. These initiatives have been found to reduce grid extension costs to near urban levels, but this required almost a decade and necessarily provides a lower tier of access (Gaunt 2003). Even in urban areas, grid overextension, and subsequent lack of cost recovery, is already a problem.

5.1 Actors

The monopolistic and long-term character of a national grid often means that political actors manipulate planning for political gain, and this is not restricted to developing countries. However, in developing countries, the political, regulatory, and technician actors have negatively interacted to neglect the fifth planning element of ensuring an enabling environment for implementation.

The case of Nigeria holds several examples of these challenges (Uwaifo 2005). To gain popular support, politicians demanded rapid grid extension and the creation of many small and uneconomical power plants. Regional governments also created networks that were not appropriately planned or constructed. This determined pursuit of social electrification was not backed by a considered balancing of municipal, state, or federal budget. What is more, a succession of military dictatorships resulted in over a dozen years of non-payment and non-investment in the electricity sector, stretching the vertically integrated electricity utility beyond financial viability.

Under these circumstances, unlawful practices emerged within the utility to recover additional revenue from customers. Such practices regarding collection for energy received, and for new connections, began with moonlighting employees but led to a completely separate ecosystem of installing and charging for electricity connections, often without construction and safety standards. Not only did this generate a poor customer experience and lead to a lack of trust, it also created technical challenges for those operating the existing system, now loaded with unplanned connections.

It is common for governments in developing countries to establish dedicated agencies to promote, coordinate, manage funds, train, build capacity or implement rural electrification (Bhattacharyya 2013; Smith *et al.* 2010; Government of the Republic of Zambia 2009). These agencies are generically called Rural Electrification Authorities (REAs). REAs in SSA became popular beginning in the late 1990s to mid-2000s – for example, Kenya (1997), Senegal (1998), Zambia (2003), Nigeria (2005), and Tanzania (2005) were created during this period. The purview of many REAs consists of electrification through grid extension, but increasingly (Kenya, South Africa, Nigeria) off-grid systems.

Many REAs are charged with developing Rural Electrification Master Plans (REMPs). REMPs cover a multi-year period, for example ten years, and outline strategies for achieving specific electrification targets that align with broader development goals; for example, 51 per cent electrification by the year 2030 (IEA and World Bank 2015; Tenenbaum *et al.* 2014). REMPs estimate the cost of achieving the targets, and identify technological, regulatory, and financial and economic barriers, risks, and opportunities. Priorities in terms of geography and customer types, for example schools and health facilities, are identified. Although created by the government, the budget of REAs is often supplemented by external donors, which might include foundations or other governments. REAs often oversee a Rural Electrification Fund (REF). In some countries the REA allocates REF monies on a competitive basis to for-profit organisations that do the electrification.

5.2 Quality of service

Power interruptions can occur even in grid systems with adequate generation capacity and fuel, but in SSA they are a regular experience due to actual energy shortage. In Nigeria, for example, 44 per cent of customers of the national grid received less than 2–4 hours per day and at random, giving them a probabilistic connection referred to as 'bad-grid' in literature (AllOn 2016). In Malawi, planned load-shedding is turning into emergency load-shedding as river levels drop to unprecedented lows (Sanjay 2015).

In addition to fuel shortages, SSA systems suffer high rates of transmission and distribution losses, up to 20 per cent or more, with a large share of these attributable to theft (Smith 2004). As a result of poor reliability, self-generation by businesses in SSA is around 10 per cent, with some countries reaching 25 per cent and in the Nigerian case 60 per cent (Foster and Steinbuks 2009; GIZ 2015). These conditions lead to even worse service and accessibility due to degrading utility and customer equipment (Coney 1996).

In this setting, the first planning activity of electricity demand estimation and its growth is made more difficult. Some demand is physically present but not metered or distinguishable from losses due to energy theft. Where load-shedding occurs, the so-called suppressed demand is uncertain, as it is based on experiments (Godfrey, Quarshie and Robiou 1996) or proxies such as diesel-generating set purchase (AllOn 2016). Planning infrastructure to target even the estimated quantity of suppressed demand and its growth is difficult, as commercial customers that have left the grid may not wish to come back, due to low quality of supply. Where distribution grids are in especially poor repair, demand for grid electricity may even go down.

5.3 Economic and social goals

In some countries, a history of aggressive electrification targets coupled with successive sociopolitical shocks have eroded or eliminated fundamental business and technical foundations of the power sector. A functioning power sector depends on several key relationships and assumptions: payment is reliably collected from customers who find the distribution company a trustworthy and cheap alternative to home generation, distribution companies invest to maintain and upgrade their equipment while paying for energy taken from the system, the owners of generators receive payments to pay for their capital and operating costs, and the transmission owners and system operator also invest to provide all parties with a reliable connection.

In struggling power sectors (Africa, South America, Eastern Europe) it is common to find economically disadvantaged customers who receive a low quality of service, and are also extorted by current or former distribution company employees (Gratwick and Eberhard 2008). The unavailability of electricity due to rationing and blackouts leads to customer dissatisfaction and non-payment of bills (Winther 2012), as well as significant diversion of revenue from bills that are actually paid away from maintenance.

While the installation of automatic or remote meters has the technical potential to disrupt this negative cycle, the current dysfunction and bankruptcy of distribution companies starves the sector of revenue while representing a daunting renewal challenge in terms of customer trust, workforce, required civil works, and workplace culture. This shifts the fourth activity of designing distribution grids towards replacement and reinforcement. Furthermore, it makes paramount the fifth planning activity of re-establishing the environment where plans can actually be implemented.

When a power sector has arrived at a state of grid tension and poor service, it becomes common for all customers of all tiers to operate their own generation units purchased on the market. For a factory or large hotel, the prospect of offering electricity to neighbours is too great an investment of capital and effort in addition to their regular business activity, so the capacity factor of these investments remains low and no grid extension from these sources occurs. As a result, the economies of scale that are typical of the power sector are not realised and the systems become increasingly expensive and inefficient.

5.4 Renewables

The first consideration when planning the integration of renewable resources into an existing national power system is how their cost compares with other alternatives. As we have highlighted, the cost of renewable energy has experienced dramatic reductions, and SSA enjoys some of the most plentiful solar resource (Kemeny *et al*. 2014). However, the cost of renewables in SSA is higher than in developed countries as it needs to incorporate foreign exchange, payment, policy, and grid availability risk components.

Renewable energy can offer some particular advantages to electricity supply planners. For example, the implementation of many small and distributed projects connected to the distribution grid could serve as a back-up to centralised generation or reduce final demand. But as we have anticipated in a previous section, variable renewables can also bring challenges to the stability of the grid. One way of mitigating this is by building renewable power plants incrementally so that the new behaviour of the system can be observed and accommodated by operators. This is particularly relevant for the small systems of most SSA countries, where the share of renewables in the generation mix could increase substantially by adding relatively small plants.

A final consideration refers to the technical capability of renewable power plants to help maintain the voltage and frequency of the transmission system. Grid operators, planners and renewable energy developers need a fluent dialogue to adjust the technical parameters of renewables as well as to update the rules and regulations of a given transmission system to take these into account. The training and analysis tools of transmission company staff to engage in such activities is seldom adequate, and this requires extra attention in developing countries to the fifth planning activity of ensuring and enabling the right environment.

6 The off-grid path

The off-grid path to electrification has typically not been considered in traditional electricity supply planning. However, the five planning activities previously discussed also apply in the context of off-grid electricity service (Trotter *et al*. 2017). Unlike traditional grid extension, off-grid electrification in Africa has been primarily a bottom-up, market-driven, decentralised phenomenon. The planning for off-grid electrification is informal and *ad hoc* with different actors, techno-economic realities, and service expectations. Renewable energy plays a crucial role in most off-grid electrification approaches.

6.1 Actors

In SSA, much more so than in developed countries, individual households and businesses are engaged in their own electricity supply planning. They do this by acquiring small-scale generator sets, dry cell batteries, solar lanterns, solar home systems, or by subscribing to an electricity service provided by a mini-grid.

Off-grid system manufacturers and distributors also act as planners. There are over 100 companies involved in the off-grid electricity access space (Bloomberg New Energy Finance and Lighting Global 2016). By offering products – solar lanterns and solar home systems – with specific capabilities, manufacturers are implicitly engaged in the demand estimation and generation technology selection activities of electricity service planning. The customer participates in these activities by acquiring certain products based upon their needs, preferences, and ability to pay. Whereas planning for on-grid electricity service involves determining which regions to serve through new electrical connections, an off-grid system distributer performs an analogous activity by choosing which geographic markets to enter.

Governments are not entirely divorced from planning aspects of off-grid electricity supply, however. Some REAs are engaged in the planning of off-grid systems – particularly larger scale mini-grids and in some instances solar home systems and lanterns (Bhattacharyya 2013; IEA and World Bank 2015; Tenenbaum *et al.* 2014). Governments can also contribute to an enabling environment for off-grid access by: setting quality standards for off-grid products, licensing and regulating companies across the value chain – including importers, suppliers, and installers – and setting tariff caps and subsidies (Smith *et al*. 2010).

6.2 Quality of service

The quality of service requirements for electricity in rural off-grid settings has been shown to be different from urban settings connected to the grid. This can be better understood by considering the main drivers for household electricity demand in rural areas.

The first driver is the proliferation and ubiquity of mobile phones. The mobile phone subscription rate in SSA is surprisingly high – estimated to be 76 subscriptions per 100 people (Louie *et al.* 2015). Mobile phones are extremely beneficial to villagers, allowing farmers to check market prices before selling, simplifying logistics, or enabling mobile payment (Louie and Dauenhauer 2016). Even in areas without reliable mobile service, mobile phones are popular as they can often be used as radios or to play music (Kemeny *et al*. 2014). Recharging the phones can require travel to the nearest electrified town, which could be many kilometres away (Adkins, Oppelstrup and Modi 2012).

The second main driver is lighting. In many areas, kerosene has been the fuel of choice for evening lighting. However, kerosene lamps have low efficacy and are linked with negative health and safety outcomes (Energy Sector Management Assistance Program 2015; Louie and Dauenhauer 2016). Kerosene lamps are often used indoors, where they might spill, or come in contact with flammable materials. Studies have shown an increased risk of cancer, respiratory infection, asthma, tuberculosis, and cataracts associated with kerosene use (Lam *et al*. 2012).

Mobile phone charging and electric lighting require only modest amounts of power and energy – typically less than 50W and less than 10KWh per year. Consequently, the electricity supply can be modestly sized, with limited availability – a few hours per day following sunset – and be deemed acceptable.

The reliability and adequacy requirements can also be low due to fuel stacking. Fuel stacking is the use of multiple energy sources to meet the same energy need (Energy Sector Management Assistance Program 2015). For example, households with electricity service might use an electric stove as well as charcoal for cooking. Fuel stacking builds in redundancy to the energy mix so that an electricity supply with low reliability and adequacy can be more easily tolerated.

Estimating demand for off-grid users is a particularly challenging and error-prone planning activity (Blodgett *et al.* 2017). The state-of-practice demand prediction for larger size systems like mini-grids is to utilise door-to-door surveys to gather information on actual and aspirational appliance ownership and usage, from which the demand is predicted. The predictions can be largely inaccurate (Louie and Dauenhauer 2016), which can lead to over- or under-designed systems. Over-designed grids are an inefficient use of capital, as money is wasted on excessively sized equipment, and the surplus energy cannot be sold elsewhere as can be done in an interconnected grid. Under-designed mini-grids are unreliable due to either power or energy limitations, but solar PV-based mini-grids benefit from modularity and can grow as demand grows.

6.3 Economic and social goals

The economic viability of off-grid systems is based on the premise that off-grid customers are willing and capable of paying a premium for electricity. A business recharging mobile phones, for example, is often able to collect a fee ranging from 10 US cents to 50 US cents per charge. Given the small capacity of mobile phone batteries, this is approximately equivalent to US$50/KWh – roughly 500 times the rate that is charged in the US. In addition, this sum is not insignificant to the rural villager who might average US$3 per day in income. Non-electric lighting is also expensive, with 80 per cent of household fuel expenditures related to kerosene or candles reported in some areas (Adkins *et al*. 2012).

As a simple example, a US$400 solar home system with a 100W panel optimistically can supply 500Wh per day, or 182.5KWh per year. That same consumption would cost a grid-connected customer US$12.78 per year at a moderately subsidised rate of 7 US cents/KWh. Under these same rates, the solar home system would need to last 31 years for the investment to pay off, far longer than can be realistically expected. The spread of solar home systems is a testament to the high cost of energy experienced in rural areas. Electricity rates paid by the smallest customers of a for-profit mini-grid typically are in the range of US$1 to US$5/KWh. Selecting a rate that balances ability to pay with financial sustainability is important in mini-grid planning. Since many customers lack a credit profile, investing in a connection to house or business is financially risky. Collection of payment for energy consumption can be managed under pre-pay schemes in which a customer purchases units of energy, and their access is disabled once these units are consumed (Smith *et al.* 2010; Roach and Cohen n.d.).

Despite consideration of all of these factors, the financial sustainability of a mini-grid can be tenuous. Scaling up can improve financial performance for developers, but requires de-risking to attract external funding. Wider availability of business and performance data, along with best practices, can contribute to de-risk these investments.

6.4 Renewables

Renewable energy is central to off-grid electrification strategies. They are considered as the most economic off-grid electricity solution (IRENA 2015) because delivering petrol or diesel to rural and remote sites can triple their cost. However, systems with high-reliability requirements or those dependent on weather-driven renewable resources require some form of battery energy storage (typically lead-acid or lithium ion batteries), which can significantly add to their cost (Mandelli *et al.* 2016). The disposal of these batteries at the end of their life introduces additional logistical challenges, and can lead to serious environmental problems if it is not managed properly (Bensch, Peters and Sievert 2017).

7 Differentiated strengths: synthesis and conclusions

Historically, electricity access was conceptualised as a binary indicator – a home or business had access to the electrical grid, or they did not. This is the situation presumed in traditional planning methods. More recently, electricity access has come to be viewed along a quality-of-service continuum, regardless of source, that acknowledges the different use-cases and realities of users. On one end of the continuum is a user with few resources and a limited ability to pay for electricity. Their electricity need is modest – basic night lighting and perhaps recharging a mobile phone. There are also customers that are grid-connected, which allows them to use appliances such as televisions and air conditioning but the supply is unreliable and of low quality; other users such as businesses require high-quality, high-reliability electricity, and have the means to pay for a grid connection and back-up generators and batteries. On the far end of the continuum is an industrial user who may require as much energy as many of the other types of customers, and require either a high-voltage grid connection or their own power plant. Energy system planning practice in SSA must find solutions to support the development of all these tiers of users, without the benefit of strong government surpluses.

In this article, we have discussed two potential pathways for electrification in SSA: grid extension and off-grid systems. The choice of one or the other, or both in different geographies depends on the desired tier of access, their economic viability, and the new opportunities brought by technological progress. Although grid coverage has traditionally been seen as the endpoint for all electrification paths, experience has shown that insisting on grid extension can lead to overextended systems providing poor service. Off-grid systems could be a temporary salve that allows economic growth to the level where payment to a centralised system is viable. Such an approach was followed in the Chinese rural electrification model. However, the African model might provide a different role for off-grid systems, where they are sufficient for economic growth and increasing access to higher energy tiers. Under this scenario, non-industrial value-creation activities would lower the energy intensity of the economy while cheaper energy storage would improve the performance of mini-grids. In this case, the off-grid renewables model could eventually support grid extension from energy hubs, which themselves derive only limited trading and reliability advantages from the national transmission grid.

State-led and market-led approaches can coexist in SSA for the provision of electricity through the previous pathways (Byrne *et al.* 2014). In any case, the review of previous electrification experiences has shown little precedent for rural electrification by market forces alone. Rather, strong government support – financially, politically, and regulatory – were essential to achieve universal access in countries like China or the US. Low ability to pay for electricity in rural areas of SSA also implies that subsidisation will be an essential component for universality. However, the state must ensure the viability of these subsidies for the power sector as a whole to avoid the financial collapse of electric utilities, a common feature in the African power sector. As developed countries look towards uncertain future scenarios and changing business models for utilities, they will stand to learn much from the discoveries of SSA practitioners of energy planning.

Notes

1 Capacity factor is the ratio of actual energy produced by an energy-generating unit or system in a given period, to the hypothetical maximum possible (i.e. energy produced from continuous operation at full rated power). Open Energy Information https://openei.org.

2 All countries compared for 'Energy > Electricity > Installed generating capacity per thousand people', *CIA World Factbooks* 2010, 2011, 2012, 2013. Population figures from World Bank: (1) United Nations Population Division, World Population Prospects, (2) United Nations Statistical Division, Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Programme, and (6) US Census Bureau: International Database. Aggregates compiled by NationMaster. Retrieved from www.nationmaster.com/country-info/stats/Energy/Electricity/Installed-generating-capacity-per-thousand-people.

3 Power, measured in watts (W), is the flow of energy over a unit of time. Some appliances have high power requirements, for example an iron, whereas others have low power requirements, for example an LED bulb.

4 Energy, measured in watt hours (Wh) is the product of power and time. Power and energy are analogous to speed and distance; speed refers to the rate of travel, whereas power refers to the rate of energy consumption.

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Assessing the Potential Impact of Grid-Scale Variable Renewable Energy on the Reliability of Electricity Supply in Kenya*

Gruffudd Edwards,[1] Chris J. Dent[2] and Neal Wade[3]

Abstract Securing a sufficient supply of reliable and affordable electricity is a major challenge for countries in sub-Saharan Africa (SSA), due to low current access levels, and rapid population and economic growth. This article will review application and technical modelling issues associated with generation adequacy assessment (i.e. assessing the risk of available generation being less than demand) in the context of SSA countries with significant capacities of renewable energy, with Kenya as the main case study. One major challenge in performing such studies in SSA is often availability of the necessary data on renewable resource and demand – the article will further demonstrate how useful information may be gained on the extent to which wind and hydro energy resources complement each other in Kenya, in the context of limited data availability.

Keywords: electricity, renewable, energy, reliability, Africa, Kenya, grid, adequacy, risk, demand, resource.

1 Introduction

Securing a sufficient supply of reliable and affordable electricity is a huge challenge for countries in sub-Saharan Africa (SSA). Many countries in the region are experiencing rapid increases in the size of their populations, and even more rapid growth in their economies (World Bank Group 2017a). As a result, the region experienced a 45 per cent increase in annual energy consumption during 2000–12 (World Energy Outlook 2014), with the growth in some countries much higher.

In 2009, the World Bank stated (Eberhard *et al.* 2008) that SSA was amid a power crisis characterised by unreliable supplies, largely due to insufficient generating capacity, high prices, and often higher costs. Indeed, in 2008, the World Bank's Africa Infrastructure Country Diagnostic (AICD) project (Eberhard *et al.* 2011) calculated that while there was a need for 7,000MW of additional power generation capacity

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to be installed in SSA countries each year, the total installed in prior years was only one seventh of that. This is a costly problem for SSA countries (Deloitte 2015), with the AICD project calculating in 2009 (Rosnes and Vennemo 2009) that the region would have to spend roughly 4 per cent of gross domestic product (GDP) annually on power sector investments to meet the demands of economic development, keep pace with population growth, and increase energy access. Despite major efforts towards increasing the reach of electricity networks in recent years, the SSA average rate of access in 2014 was only 35 per cent. Access rates are much lower in some countries – for example, Chad's is only 4 per cent, while Ethiopia's is 25 per cent, with 73 million people without access.

Thus, building very significant generation capacity is both essential and inevitable in the near future. For many reasons – including location, maturity of technology, and speed of building – traditional fossil fuel power plants are well suited to fill the gap. However, many stakeholders in the SSA power sector are keen to see these power systems largely avoid such a highly polluting stage. Hydro power is already a major component of SSA's generation fleet, and plentiful resource means that more reservoirs will likely be built. However, in some cases the potential for economically and politically viable development is insufficient to meet the growing demand alone. There is therefore a strong desire to see high penetrations of variable renewable generation (VG) within many systems (AREI 2015).

The power systems of SSA countries generally face four fundamental and interrelated problems (although the extent of each varies considerably between countries):[4] (i) unreliable supply due to insufficient (functioning) generation capacity to meet all of the demand on the system; (ii) unreliable supply due to failing or insufficient power distribution infrastructure; (iii) very large percentages of the population without access to the grid; (iv) prices that are too high for the majority of current and potential new customers but still below cost recovery. It stands to reason that when assessing the value of proposed large-capacity VG projects in a SSA power system, the relevant policymakers and stakeholders should possess as much insight as is reasonably possible on the extent to which they might alleviate these problems. Or, if VG projects are proposed specifically to deal with one or two of these problems, rigorous assessment should be available on their impact on the others. It is immediately evident that to truly assess impacts on these problems, especially given the complex interrelationships between them, a thorough interdisciplinary approach is needed.

This article will explore in detail impacts of VG on problem number (i) – an area of analysis known as capacity adequacy assessment. Indeed, the International Energy Agency's 'Energy Outlook' summary for 2016 (World Bank Group 2017a) states that the deployment of renewable generation already plays an important role in the mitigation of traditional energy security concerns, by moderating oil and gas imports.

However, they warn, rising shares of VG puts the reliability of electricity supply under pressure in a different way, due to their unpredictable and intermittent nature. Despite the hugely ambitious scale of current and near-future planned VG investments, there has been almost no system-level analysis of the reliability impacts of grid-scale VG in SSA countries, either from the academic community or from government and industry.

The ability of the generators within a power system to consistently meet the demands made of them by customers is known as the system's generation adequacy. It may be captured through a variety of metrics, with the most meaningful being risk-based and probabilistic in nature. A popular example is the expected value for the number of periods (e.g. 30-minute intervals) within a year where the available generation is insufficient to fully meet demand – known as the loss of load expectation (LOLE). Unfortunately, there has been very little research on the potential contribution of VG to the generation adequacy of SSA power systems. Indeed, detailed risk-based assessment of generation adequacy in developing countries in general has rarely been addressed in the academic and industrial literature, an exception being the work of Billinton and Pandey *et al.* in several publications, for example Billinton *et al.* (1995).

This is not to say that it is unknown whether the addition of a large VG project might in fact decrease the reliability of an SSA power system. Adding capacity to a system cannot decrease its generation adequacy, although operational constraints might limit the adequacy contribution of VG capacity. While operational problems caused by VG might be mitigated through curtailment (i.e. the system not taking the full available output of VG at times when this is challenging), this clearly reduces the contribution VG can make and increases unit cost. Understanding precisely the extent to which this and other technical issues limit the potential contribution of VG to capacity adequacy in the new context of SSA power systems is challenging, as is discussed in Section 3 of this article, and is currently beyond the scope of analysis performed by SSA power system operators and regulators.[5]

Despite the technical barriers to conducting full and rigorous capacity adequacy assessments to assess the contribution of large-capacity VG projects to SSA capacity adequacy, it is possible for policymakers and other stakeholders to conduct much simpler analysis to gain insight on this vital issue. This article presents an illustrative example of how to conduct such analysis when the data and technical expertise for a complete probabilistic study are not available. This example investigates the wind resource in Kenya, comparing temporal patterns in its (random) availability with patterns in system demand and the (random) availability of the hydrological resource to assess the extent to which the resources complement each other.

Before the presentation of methods, models, and data sources in Section 4 and the presentation of results in Section 5, the article presents the context of the Kenyan power system in Section 2, and provides motivation for the type of analysis conducted in Section 3.

2 Overview of the Kenyan power system

Kenya is situated on the eastern coast of Africa, bisected by the equator. It has a coastal length of 470km (Theuri 2008), varied terrain, and rises to 5,199 metres above sea level. The population is rapidly expanding, having increased from 31 million people in 2000 to 46 million in 2015 (World Bank Group 2017a). The economy has been growing even more rapidly, with GDP increasing from US$12.7 billion in 2000 to US$63.4 billion in 2015 (*ibid*.). In 2010, only 20 per cent of the total population of Kenya, and only about 5 per cent of the rural population had access to electricity, although this situation is rapidly improving (Ogola, Davidsdottir and Fridleifsson 2011).

The peak demand on the system rose from 1,107MW in the 2006–07 financial year to 1,512MW in 2014–15.[6] The energy regulator's central forecast in Republic of Kenya Energy Regulatory Commission (ERC 2013) sees the peak rising from 1,606MW in 2013 to 11,318MW by 2033. The forecast, however, has much associated uncertainty, with the feasible 'low growth' forecast being roughly 50 per cent lower than the central forecast by 2033, while the 'high growth' forecast is roughly 50 per cent higher. A lack of capacity in the past means that there is still a widespread belief that the system is highly unreliable, despite the high level of reliability currently experienced in the cities (except during floods).[7] Many areas of Kenya continue to experience an unreliable supply, however: to a small extent due to insufficient transmission capacity, but mainly due to problems with insufficient distribution capacity and maintenance challenges.

In March 2015, the capacities of the Kenyan power system, grouped by generation type, were as follows: hydropower – 820.6MW; fossil fuels (including emergency power) – 717MW; geothermal – 588MW; wind generation – 25.6MW. While most of the electricity historically generated in Kenya has been from hydropower, it has not supplied most of the country's total *energy* needs – petroleum has, over the years, accounted for about 80 per cent of the country's commercial energy requirements (Oludhe 2008). It is also stated in Oludhe (2008) that the hydropower potential in Kenya in the form of large reservoirs is estimated at about 2,263MW, while the small schemes have a total potential of 3,000MW. Further, there is excellent geothermal resource within the Rift Valley, with the generation potential estimated at over 2,000MW, and geothermal capacity is rapidly being built.

Although equatorial areas are assumed to have poor-to-medium wind resource, Kenya experiences seasonal monsoon winds, and its topographic features have endowed the country with excellent wind resource areas (*ibid*.). Consequently, it is likely that multiple very large wind generation projects, of the order of hundreds of megawatts, will be constructed in the coming years (ERC 2011, 2013). Kenya's equatorial position also means that it has excellent solar resource in many areas, although there are currently no plans for any large-scale solar power projects (ERC 2011).

3 Generation adequacy in Kenya and other SSA countries

Adequacy assessment is concerned with the risk of there being insufficient resources to supply demand in a power system, considering scheduled and unscheduled outages, and availability of renewable resources. Generation adequacy assessment (GAA) studies therefore calculate quantitative measures of the risk of shortfalls, such as the probabilities of shortfalls at different times. Adequacy should not be confused with the flexibility of the system, which is its ability to deploy its resources to respond to changes in net load, both predicted and unpredicted (net load is defined as the remaining system load not served by VG). Neither should adequacy be confused with the security of a power system: its ability to withstand sudden, unexpected disturbances without any serious consequences for the supply to customers.

The generation adequacy of traditional power systems historically has often been measured by reserve margin: the amount by which generation capacity exceeds the projected peak demand, expressed as a percentage of that peak value. This is a simple and static approach that benefits from being very easy to calculate and understand, and is adopted occasionally by system operators in SSA countries, for example Ghana in 2010 (Power Systems Energy Consulting 2010). A much more meaningful approach to GAA is to explicitly consider the risks of generation capacity being insufficient to fully meet demand, using probabilistic methods to model the balance of supply and demand at each point in time.

Since GAA is usually conducted for the mature power systems of developed countries, they are concerned with the frequency and severity of those very rare events when not all demand can be met, referred to as generation shortfall events. Although there are many possible metrics to capture a system's capacity adequacy from this perspective, the most popular are: the loss of load expectation (LOLE), the average duration during a year for which the generation capacity available will be less than the demand); and the expected energy not served (EENS), the average total energy demanded by customers that cannot be delivered by the generators during a year. The assessment of such risk-based metrics is based on a model of the possible random conditions the system might face – including weather outcomes and customer behaviour.

Some LOLE-based analysis informs the long-term planning process for Kenya, as part of the *Least Cost Power Development Plan* methodology (ERC 2011). However, the statistical methodology for converting a set of generators into a risk profile is not as detailed as the international best practice, and makes a strong implicit assumption that risks should be identical on every day of the year (which might not be the case if demand or quality of VG resource varies through the year).

When significant VG capacity is present, accurate results require that the probabilistic method accurately represents spatial relationships in the resource availabilities, for example how often it is windy or calm across the entire region where the VG is located. Where there is significant presence of energy-constrained generation such as hydropower, it is also vital to capture temporal relationships in the resource availabilities. This is the case in Kenya, due to a combination of the historical dominance of hydropower and the very significant inter-annual variability of the hydrological resource – i.e. the Kenyan system has experienced serious capacity problems in the past following a series of dry years.

This problem is being effectively mitigated by the Kenyan government by ensuring that hydropower makes up a smaller percentage of the generation mix as the system grows. However, the percentage certainly remains high enough that rigorous capacity adequacy assessment must consider the operational decisions of hydro generation. Energy constraints also typically apply, to some extent, to thermal generators in SSA countries. For instance, this is the case in Ghana, where the supply of natural gas from neighbouring Nigeria has been very unreliable (Power Systems Energy Consulting 2010), among other problems. Kenya is, however, rather unusual in that its extensive geothermal capacity renders it less vulnerable to fuel supply issues.

It was stated in the introduction that the main contribution of this article is to provide an illustrative example of a desktop study that provides insight into the potential contribution of VG to the reliability of an SSA power system. The full probabilistic generation adequacy assessments described in this section go beyond such desktop studies; however, presenting some background knowledge about full studies motivates desirable features of simpler analysis. A useful desktop study should reveal the salient aspects of spatial relationships for the VG resource availability, as well as relationships between temporal patterns in the resource availability, system demand, and the hydrological resource availability. In simpler terms, it is vital to examine the extent to which wind generation can provide power when demand is high and the power available from hydropower is compromised by drought.

4 Illustrative example: the Kenya model

This section proceeds with the main objective of the article: to present an illustrative example of a desktop study of the VG resource in an SSA country, designed to gain insight about the ability of associated VG capacity to increase the power system's capacity adequacy. The chosen example explores the potential contribution of large wind energy projects to generation adequacy in the Kenyan power system. It does so by examining temporal relationships between wind resource availability and demand, also between the wind and hydropower resources, on a coarse resolution. This section presents the data sources available and sets up the models and Kenyan system scenarios used in the analysis.

4.1 The Kenyan power system scenario

We adopt two simple scenarios for the Kenyan power system in the relatively near future, taken from the 2013–33 Least Cost Power Development Plan (LCPDP) (Ummel and Fant 2014). One scenario has the peak power demand of the system as 4,000MW (4GW), which is close to the forecasted demand of 3,939MW in the year 2022. The second scenario has the peak demand as 6,000MW (6GW) – close to the forecasted demand of 6,147MW in 2026. In the 4GW scenario, there is 925.5MW of installed wind capacity. The wind projects included in this scenario deviate somewhat from the LCPDP, and rather includes those projects that seemed most likely to be built at the time of writing (August 2016), based on their legal and financial status. They are: Lake Turkana – 310MW; Meru – 400MW; Kajiado – 100MW; Ngong Hills – 25.5MW; and Lamu – 90MW. This is referred to as the *Original* wind capacity scenario.

For the 6GW demand scenario, we assume that wind capacity has grown proportionally, i.e. increased by 50 per cent to 1,388.25MW. We consider two scenarios for the spatial distribution of wind capacity in this case: (i) the *Additional Locations* variant, where four additional projects have been built – in areas of strong wind resource where, according to online news reports, some interest has been expressed in developing projects; (ii) the *Increased Capacity* variant, where only the same five projects exist, but where the capacity of each has been increased. In the *Additional Locations* variant, the additional capacity is distributed equally among the new locations. The motivation for the two scenarios for capacity distribution is that there is uncertainty over the extent of geographical spread of wind projects in Kenya when looking forward to 2026 – and by including scenarios that represent the plausible extremes for this aspect of the modelling, sensitivity to this uncertainty can be quantified.

4.2 The wind power generation model and data available

The general approach adopted involves direct use of historic series to represent possible future output for the chosen scenarios, similarly to several examples in the literature, for example Ummel and Fant (2014). The necessary steps of obtaining time series datasets for the wind power outputs are as follows:

- (W.1) Obtain concurrent time series of wind speeds at locations close to the wind energy projects;
- (W.2) Adjust patterns in average wind speed across hours of the day to reflect values at the turbine hubs, i.e. at the centre of the rotating blades;
- (W.3) Calibrate the series through some mathematical transformation to match any known statistics for the wind resource at the project sites;
- (W.4) Convert the calibrated wind speed series to power output series and add them to establish the total wind power available.

With only limited data available, it is necessary to make many strong modelling assumptions to proceed. Therefore, for each major step listed above, two model variants were developed based on contrasting assumptions, to assess the sensitivity of results to those assumptions.

For step W.1, concurrent and hourly resolution wind speed series were found spanning a period of 22 years, from 1980 to 2001, as provided by the SWERA project (Solar and Wind Energy Resource Assessment) (Theuri 2008; NREL 2017). SWERA is a global project to supply high-quality renewable energy resource information, using a combination of analytical, numerical, and empirical methods to obtain high-resolution VG resource maps for many developing countries. Their modelling activity is also responsible for the complete and quality-assured time series of meteorological recorded data used here. The wind speeds were recorded at nine meteorological stations, each one close to a wind project. The stations for the *Original* and *Increased Capacity* wind project scenarios are Dagoretti, Lamu, Makindu, Marsabit, and Meru. For the *Additional Locations* scenario, the four extra recording stations were Lodwar, Malindi, Narok, and Nyeri. Due to the limited number of suitably located meteorological stations in Kenya, it was not possible to develop contrasting model variants for this step of the wind resource modelling.

A pattern in mean wind speed across hours of the day is known in statistics as diurnal seasonality, and dealing with any such seasonality is step W.2 of the modelling process. It is well established in the literature, for example Sturt and Strbac (2011), that diurnal seasonalities diminish significantly with height in some climates, and it is unlikely that the hub-height of every turbine will match that of the recorded data. As the extent to which diurnal seasonalities diminish with height in Kenya is also unknown, this is a type of uncertainty that must be addressed by contrasting model variants. Thus, in one variant, referred to as the *Base* model, all diurnal seasonalities are removed. In the *Keep Diurnal* model, they remain unchanged.

The next step, W.3, involves calibrating the series to any known statistics of the wind resource at the project locations (rather than reasonably nearby). For the chosen exemplar, there are no statistics available for the wind resource at the precise project locations, but reasonable estimates can be made. The two quantities estimated were the mean wind speed, and the mean of the wind speed cubed – both of which were obtained from the SWERA wind resource map of Kenya (Theuri 2008). The former set of values were extracted directly from the resource maps, by careful visual inspection coupled with coordinates for the modelled wind projects. The mean values of the cubed wind speeds were inferred indirectly from SWERA energy density maps – i.e. the mean kinetic energy contained in $1m^3$ of air, which required estimates of air density at the project sites. These density estimates were obtained using meteorological rules of thumb regarding the reduction of air density with altitude and temperature, both of which are high for the Kenyan locations.

With the two wind speed statistics estimated for each project, the next part of modelling step W.3 was to apply simple mathematical transformations to the wind speed time series, so that they precisely match the mean values, as well as matching the mean cubed values as closely as possible. Two model variants were developed here: the *Base* model that applied both linear and power transformations to the series, and the *Linear Scaling* model that applied only linear transformations. That is, for the *Base* model, if the original wind speed at time t is y_t, the new wind speed is $a \cdot (y_t)^b$, with coefficients a and b established to fit the estimated wind speed statistics as closely as possible. For the *Linear Scaling* variant, the transformation is restricted to only $a \cdot (y_t)$. The coefficients were established by simple trial and error, while restricting b to the physically sensible range of 0.7 to 1.3.

Proceeding to modelling step W.4, the transformed wind speed series were converted to normalised powers, i.e. proportions of the wind project's maximum power, using a function known as a power curve. Being a complex area of considerable modelling uncertainty, two simple contrasting model variants were again developed: the *Single Turbine* variant, where a generic power curve for a typical single wind turbine was used (as may be easily found online). Adopting such a power curve is the equivalent of assuming that all turbines in each project experience the same hourly-averaged wind speeds, i.e. that the geographical spread of the wind project is insufficient to necessitate deviation from the power curve of a single turbine. The *Base* model variant assumes that the geographical spread of each project is significant, and that the single turbine power curve should be considerably smoothed – i.e. reducing the steepest changes in turbine output over a small wind speed range, and extending the range of wind speeds for which some power is produced. This process was conducted in accordance with several examples in the literature. Finally, the normalised power series from both variants were scaled by the capacities of the planned projects, and summed.

Although the three branching points in the wind power modelling mean that there are eight variants for the overall process, we did not investigate all of these, since we are interested in the sensitivity surrounding each modelling assumption individually. Thus, the overall *Base* model is that in which the *Base* variant was chosen at each stage, while for example the overall *Single Turbine* model is one where the *Base* variant was chosen in steps W.2 and W.3, but the *Single Turbine* alternative was chosen in step W.4.

4.3 The demand model

A year-long, hourly resolution time series of generation dispatch (i.e. total power generated) was obtained from Kenya Light and Power, the country's electricity retailer and distributer. The series is taken as a proxy for temporal patterns of demand in both system scenarios, after being linearly scaled up to a peak level of 4GW and 6GW, respectively. The validity of such a simple transformation is supported somewhat by the fact that in the LCPDP forecasts, the demand load factor – the energy consumed in a year divided by the energy consumed if the demand were constantly at its peak level – remains almost unchanged. It is interesting to note that there is no discernible pattern in the demand across weeks of the year (i.e. annual seasonality), although there are obviously diurnal and weekly seasonalities.

Since there is little demand on the system for space heating and cooling, there is no obvious mechanism for demand to vary from year to year given constant underlying patterns, unlike the UK, for example, so there is little need to explicitly model this uncertainty.

4.4 The hydrological resource model

The analysis of relationships between the wind and hydrological resources presented in this article is limited to monthly resolution data, for two reasons: (i) finer resolution data on the hydropower resource is difficult to obtain, and (ii) we cannot be certain what the operating strategy for hydropower might be in the scenarios, particularly the extent to which close coordination between wind projects and hydropower reservoirs might be achievable.

Kenya has many hydropower reservoir and run-of-river schemes, including a cascade scheme of large reservoirs in a single river basin. As the analysis presented in this article aims to be illustrative and transparent, a single variable is required that can represent, in a reasonable way, the hydrological resource available. Water flow into the Masinga reservoir was chosen since, as explained in Bunyasi (2012), the Masinga dam's roles are to regulate water flow into subsequent dams, particularly during the dry seasons, as well as to prevent flooding. While downstream reservoirs have much greater power capacities, Masinga dominates in terms of energy capacity. The downstream reservoirs have other sources of river inflows apart from Masinga discharge, but during the dry season – when capacity adequacy is critical – these are insufficient for operation. The quantity modelled here is the net inflow, i.e. the gross inflow minus evaporation and spillage, and *annually averaged* values are provided in Bunyasi (2012) for the period 1982–2011.

To obtain monthly (rather than annual) resolution time series, data limitations mean that precipitation must be used as a proxy variable, following calibration. Use was made of two such data sources, and each is associated with a contrasting model variant, again for sensitivity analysis. The first model variant, labelled *Perfect Correlation*, uses a monthly-resolution precipitation time series for an unspecified location in Kenya, obtained from the World Bank's climate data repository (World Bank Group 2017b) spanning the coincident period 1982–2011. The modelling assumption made is that the relative contribution from each month to the annual Masinga dam inflow is identical to the relative contribution of each month to the total annual precipitation in the World Bank data. In other words, there is 100 per cent correlation across the county regarding the division of total precipitation between months of the year.

For the contrasting model, labelled *No Correlation*, it is assumed that there is no relationship between the division of total precipitation among the months at the unknown Kenyan location and the inflow to the Masinga dam, so that the World Bank time series is not representative of the inflow to this hydro scheme. Instead, this model variant uses the fixed climatological profile of precipitation for a nearby location, and scales it to match each year's annual net inflows. The climatological profile was obtained from *Climate-Data* (2017) for Makuyu, located in the hills feeding the Masinga reservoir.

For a year where the wet season rains were plentiful, the hydrological resource during the following dry season is likely to be better than if the rains were poor. However, this is not a direct relationship, since the resource available during the dry season depends on the water within the reservoir when that period begins, which might reflect the out-turn of precipitation over several recent years. For example, a wet season with poor rains might have a greater impact on the hydro power resource if it was preceded by a cluster of dry years. For this reason, insight can be gained by working with deviations from the mean pattern of precipitation – referred to here as inflow anomalies. Taking this a step further, we work with cumulative inflow anomalies: for any month t, this is the sum of inflow anomalies from the beginning of the time series period to that month.

A large positive cumulative anomaly implies that the dams are likely to be relatively full, while a large negative value implies that levels are likely to be relatively low, and it is thus adopted as a rough proxy for the resource available. This approach has limitations, particularly lack of knowledge of how full the reservoir was at the beginning of the period; no representation of spilling water due to the level being too high; and not considering the need to maintain minimum flow for ecological or recreational reasons.

5 Results

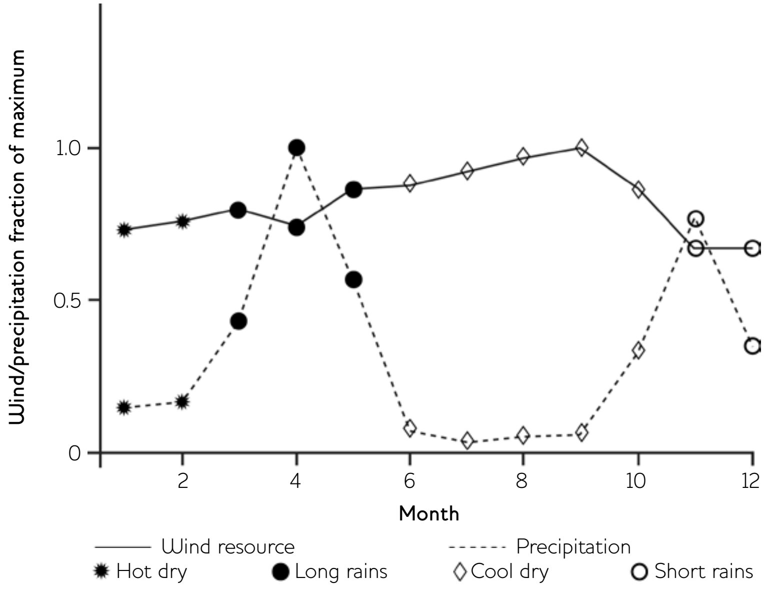
This section presents the results of analysis conducted on the wind energy resource in Kenya, with respect to the potential of wind generation to support capacity adequacy in the Kenyan power system, using the models and scenarios presented in the previous section.

5.1 Seasonal patterns in the mean wind power

The first question investigated was the extent to which the wind varies, on average, between seasons, and whether any such seasonality is complementary to the extremely seasonal nature of the hydrological resource. Since demand does not display annual seasonality, it need not be considered on this temporal resolution. Such questions have received little attention in the literature, with the notable exception of the PhD thesis of Dr Christopher Oludhe (Oludhe 1998).

Figure 1 presents the annual seasonality for the *Original* wind capacity scenario, and the *Base* model for the conversion of wind speeds to power, averaged over the 22 years in the historical sample. It also presents the

Figure 1 **Normalised monthly mean profiles of the modelled wind resource (*Base* model, *Original* scenario) and the hydrological resource (*No Correlation* model)**



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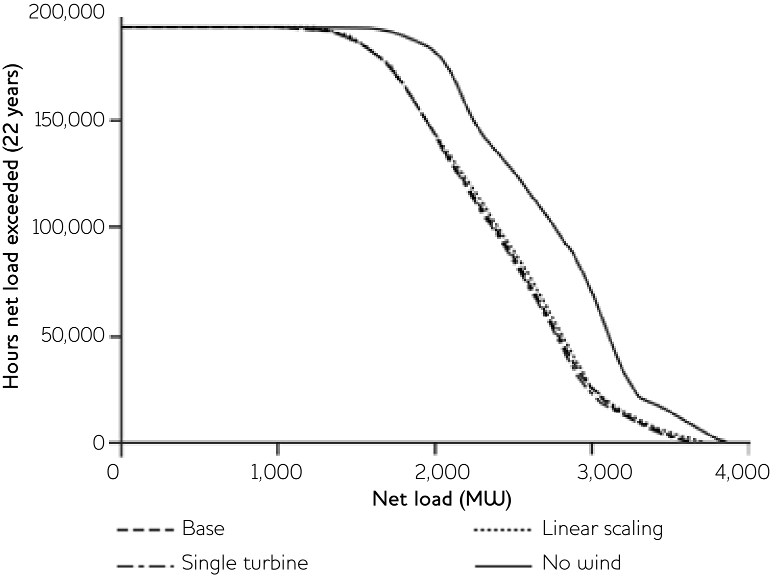
annual seasonality for the hydrological resource, using the *No Correlation* model variant. Values are normalised to facilitate comparison, and the months that roughly correspond to the four seasons experienced by Kenya are indicated. The figure demonstrates that the wind resource is fairly consistent throughout the year, with quite modest seasonality. The relative availability of the resource during the 'hot dry' month is rather disappointing; however, it is good during the longer 'cool dry' season. The plot also demonstrates how distinct the wet and dry seasons are. Very similar relationships are revealed by alternative model and scenario choices.

5.2 Load duration curves for demand net wind

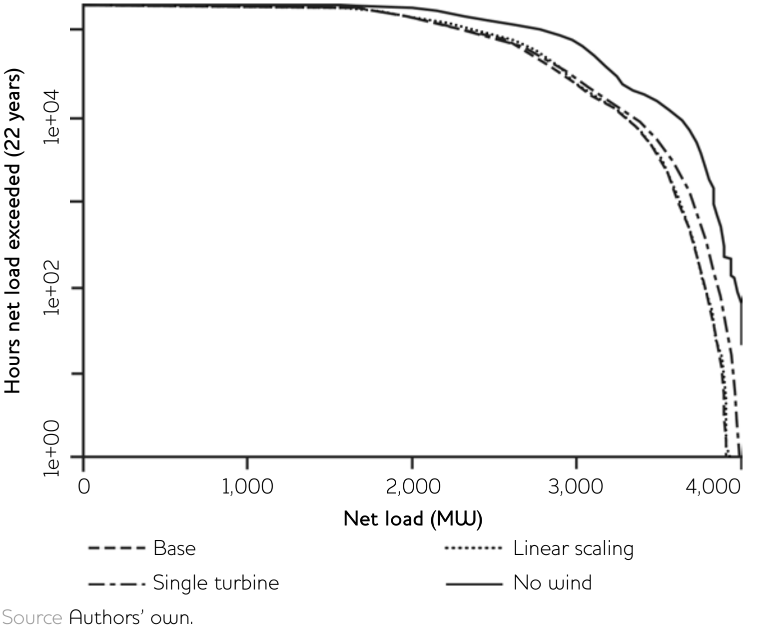
The analysis presented in this section explores the temporal relationship between the wind resource and demand on an hourly resolution. More specifically, it explores the probability distribution of the system demand net of wind generation, and compares this with the distribution of gross demand. The analysis therefore adopts a statistical approach to shed light on the extent to which the wind resource tends to be available to reduce the highest demand values experienced by the system, thus improving its reliability. It also provides some insight on the extent to which wind generation would be able to reduce the depletion of the hydrological resource and/or the consumption of expensive fuel during hours of moderate demand. The probability distributions are presented in the form of load duration curves, which are plots with demand levels plotted on the horizontal axis (either gross or net of wind), and the number of hours where the demand level was exceeded in the modelled series are plotted on the vertical axis. In more technical terms, they are plots of the complementary cumulative distribution function of demand.

Figure 2 Modelled duration curve for demand net wind generation, *Original* wind capacity scenario, linear scale for hours)



Source Authors' own.

Figure 3 Modelled duration curve for demand net wind generation, *Original* wind capacity scenario, log scale for hours)



Source Authors' own.

Several 22-year time series of net demand were obtained, one for each scenario and model variant. For each scenario, demand-net-wind series were obtained by repeating the scaled-up demand trace 22 times, and subtracting the 22-year-long wind power traces (for each variant). Figure 2 presents results for the *Original* scenario of wind capacity distribution, using a linear scale for the number of hours, while Figure 3 uses a logarithmic scale for this. The number of hours where the demand levels were exceeded in the 22-year series are presented in raw form, rather than as average hours per year, to preserve the true discrete nature of the data.

The plots include curves for the *Base*, *Linear Scaling*, and *Single Turbine* model variants, as well as where no wind capacity is present (i.e. gross demand). The curve for the *Keep Diurnal* variant was omitted from the figures, since they are visually indistinguishable from the base case. In general, the results are strikingly non-sensitive to the model variants. One partial exception is that results are moderately sensitive to the choice of power curve for peak net demand levels.

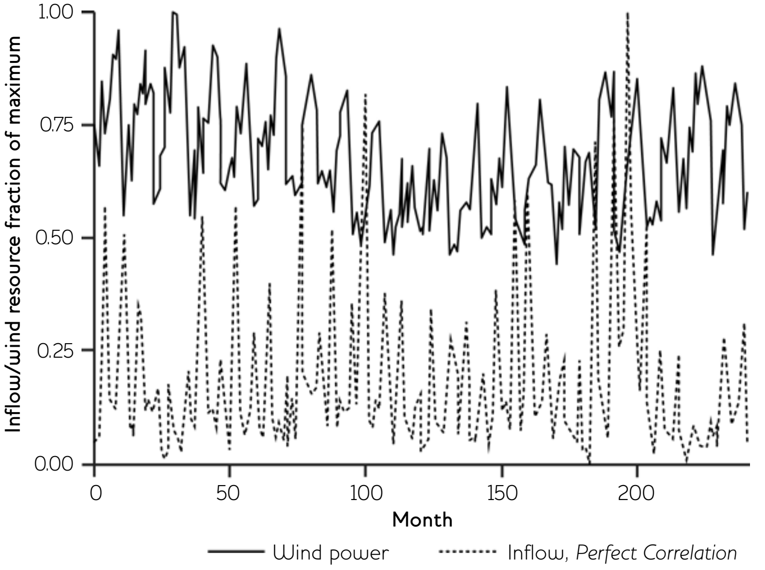
The plots strongly suggest that wind generation can indeed have a significant impact in reducing the frequency of the highest net demand levels, and thus can contribute directly to capacity adequacy assessment. Figure 2 indicates that the impact is particularly evident for demand in the range of about 2,700–3,700MW, while Figure 3 indicates that the impact remains significant right up to the highest possible demands. Figure 2 also seems to support the idea that wind capacity would reduce demand levels throughout a typical day, ensuring that more of the hydrological resource can be reserved for when it is most needed – although there are many constraints, both technical and non-technical that might limit the extent to which this is possible.

Duration curves were also plotted for the two other wind capacity distributions, *Increased Capacity* and *Additional Locations*, for the *Base* model variant, to examine sensitivity to the number of locations. It was found, rather surprisingly, that there is very little difference in the duration curves for these variants, with a small difference occurring at the high net demand extreme only. There are two implications of this: firstly, we have some evidence that any conclusions drawn about the relationships between wind, hydro resource, and demand are robust to changes in the location and geographical spread of wind power projects compared to current plans. This also constitutes evidence that wind projects should be built where they are most likely to be profitable, in Kenya at least, with no motivation to compromise on this for a greater overall contribution to capacity adequacy. The curves are not included as figures for brevity, since the two model's results were so similar.

5.3 Temporal relationships between the wind and hydrological resources

This section presents analysis of the temporal relationship between the wind and hydrological resources, in statistical terms, to establish the extent to which the two are complementary. The more they are complementary, the greater the potential of wind capacity to contribute to capacity adequacy. Figure 4 presents 20-year series for modelled wind generation and Masinga reservoir inflow, using the *Original* scenario for wind capacity, the *Base* model variant for converting wind speed series into wind power, and the *Perfect Correlation* model for the reservoir inflow.

Figure 4 Normalised 20-year series, monthly resolution, for the modelled wind resource (*Base* model, *Original* scenario), and the Masinga reservoir inflow (*Perfect Correlation* model)



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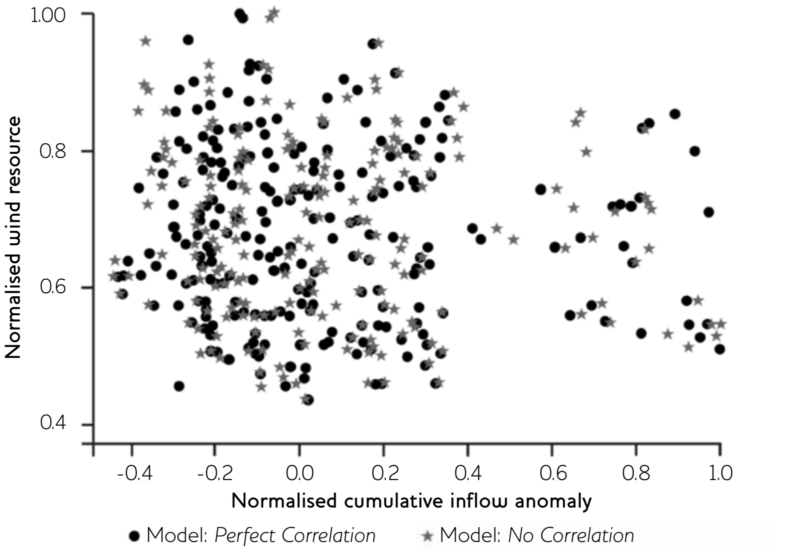
The plot shows that the height of the wet season inflow peaks exhibit clear but complex clustering behaviour. The wind power series also displays long-term trends, over many years, but such behaviour is much smoother and less pronounced than for inflow. Indeed, the availability of the wind resource is consistently high, with even the worst month being >40 per cent of the best month. For the *No Correlation* model variant, the inflow series displays the same characteristics, but the exact location and amplitude of spikes within the clusters are occasionally quite different. The resources therefore appear to be somewhat complementary, although the relationship requires further elucidation – in particular, due to limited access to metered wind power output for calibration, results based on relative wind resource between months are expected to be more robust than the assessment of absolute level of wind resource.

Figure 5 provides an alternative view of the same datasets, making use of the cumulative inflow anomaly described in Section 4.4 which acts as a proxy for the Masinga reservoir level. In this case, the data are shown as a scatter plot, rather than as coincident time series. The cumulative anomalies naturally have a mean of zero, and were normalised to have a maximum of one for clarity of presentation. The wind power values are for the *Original* wind capacity scenario, and the *Base* wind model. Results are shown for both variants of the Masinga inflow model.

The figure shows that there is not a strong relationship between the two variables. During the most extreme anomaly values (roughly in the range -0.44 to -0.36), when wind generation might be most needed to help avoid generation shortfalls, the resource is disappointing (though

Figure 5 Relationship between wind resource (*Base* model, *Original* scenario) and cumulative Masinga inflow anomalies, for both inflow models



Source Authors' own.

there are few data points so confident conclusions cannot be made on this basis). However, most of the strongest months for the wind resource occur when the anomaly is either moderately or strongly negative, i.e. in the range -3.6 to -1, providing evidence that wind can make a useful contribution to adequacy. The two inflow models display good agreement for central values, but considerable disagreement at the extremes. The extent to which the wind resource is present when most needed appears somewhat more favourable when the Masinga inflow is modelled using the *No Correlation* variant. As the dataset is too small to draw firm conclusions, a more meteorological analysis, based on the long-term climatology of the region could greatly improve understanding of the relationship.

6 Conclusions

This article took as its premise the following idea: when evaluating the merits of potential investments in large-capacity VG projects, policymakers and stakeholders in the power systems of SSA countries (and elsewhere in the global South) would benefit from some insight into the impact the project might have on one of the biggest problems experienced by those systems. That problem is unreliable supply, and in some cases a constant suppression of demand, due to insufficient capacity adequacy. However, assessing the contribution of large VG projects to capacity adequacy in SSA countries is technically challenging, and has typically proved to be beyond the resources available to the system operators and regulators in studies to date. Both the need and the technical challenge are greatest in those countries where demand is growing rapidly, and that are likely to see a large penetration of variable renewable generation.

Despite the high technical barriers associated with thorough capacity adequacy assessment – perhaps chief among them being access to relevant data – this article has demonstrated that valuable insight can be gained from a relatively straightforward desktop analysis where limited data are available. In such a situation, the key uncertainties associated with the lack of data can be dealt with by developing several simple model variants, each using a different data source where possible.

The illustrative example of this approach presented in this article examined the wind resource in Kenya, with the objective of gaining insight into the potential for wind generation projects, with very large capacities in relation to the Kenyan power system, to contribute to capacity adequacy roughly within the next decade. Several variants were developed for the wind capacity scenarios and for the process of transforming wind speed time series into generated power. Assessing the wind resource with respect to capacity adequacy requires temporally matched time series for the system demand and the hydrological resource available – so several model variants were also developed for these series.

Results of the analysis indicate that there is a moderately complementary relationship between the wind resource and demand, and between the wind and hydro resources. The wind resource is also strikingly consistent, and seems able to significantly reduce many (but not all) of the highest demands likely to be experienced by the future system. This supports a view that the large wind projects that are either currently being built in Kenya, or will be in the near future, are likely to contribute significantly to generation adequacy of the system.

Notes

* The authors would like to thank our partners in the Green Growth Diagnostics for Africa Project, along with interviewees in Kenya and Ghana who kindly gave their time.

1 University of Edinburgh.
2 University of Edinburgh.
3 Newcastle University.

4 Private conversation with Chair of Lowest Cost Power Development Plan Committee, Energy Regulatory Committee, Republic of Kenya, Nairobi, 10 June 2015; and private conversation with Chief Engineer for Generation Planning, Kenya Power, Nairobi, 9 June 2015.
5 Private conversation with Chair of Lowest Cost Power Development Plan Committee, Energy Regulatory Committee, Republic of Kenya, Nairobi, 10 June 2015; and private conversation with Chief Engineer for Generation Planning, Kenya Power, Nairobi, 9 June 2015.
6 Private conversation with Chair of Lowest Cost Power Development Plan Committee, Energy Regulatory Committee, Republic of Kenya, Nairobi, 10 June 2015.
7 Private conversation with Chair of Lowest Cost Power Development Plan Committee, Energy Regulatory Committee, Republic of Kenya, Nairobi, 10 June 2015.

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Exploring the Macroeconomic Impacts of Low-Carbon Energy Transitions: A Simulation Analysis for Kenya and Ghana

Dirk Willenbockel, Helen Hoka Osiolo and Simon Bawakyillenuo

Abstract The study applies purpose-built dynamic computable general equilibrium models for Kenya and Ghana with a disaggregated country-specific representation of the power sector, to simulate the prospective medium-run growth and distributional implications associated with a shift towards a higher share of renewables in the power mix, up to 2025. In both countries, the share of fossil fuel-based thermal electricity generation in the power mix will increase sharply over the next decade and beyond according to current national energy sector development plans. The overarching general message suggested by the simulation results is that in both countries it appears feasible to reduce the carbon content of electricity generation significantly without adverse consequences for economic growth and without noteworthy distributional effects.

Keywords: low-carbon growth, scenario analysis, CGE, green growth, renewable energy, climate change mitigation, sustainable energy.

1 Introduction

This study provides a forward-looking simulation analysis of economy-wide and distributional implications associated with alternative pathways for the development of the electricity sector in Kenya and Ghana. From an economic perspective, significant shifts in the power mix of an economy, as well as policy measures to induce or support such shifts, are bound to affect the structure of domestic prices across the whole economy with repercussions for the growth prospects of different production sectors and for the real income growth paths of different socioeconomic groups. Understanding these economy-wide repercussions is crucial for a study concerned with the obstacles to – and political feasibility of – adopting a low-carbon growth strategy. The analysis requires the adoption of a multisectoral general equilibrium approach that allows the capture of the input–output linkages between

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the electricity sector and the rest of the economy, as well as the linkages between production activity, household income and expenditure, and government policy.

Thus, we employ purpose-built dynamic computable general equilibrium (CGE) models for Kenya and Ghana with a detailed country-specific representation of the power sector to simulate the prospective medium-run growth and distributional implications associated with a shift towards a higher share of renewables in the power mix, up to 2025.

The following section explains the methodological approach and describes the key features of the CGE models in a non-technical manner. Each model is calibrated to a social accounting matrix (SAM) which reflects the observed input–output structure of production, the commodity composition of demand, and the pattern of income distribution for the country at a disaggregated level at the start of the simulation horizon. Section 3 spells out the data sources for the construction of the social accounting matrices and outlines the model calibration process. Sections 4 and 5 present the results of the dynamic simulation analysis for Kenya and Ghana respectively. In each case, we first develop a stylised baseline scenario that simulates the evolution of the economy under current power sector expansion plans up to 2025 and then contrast this baseline with an alternative lower-carbon energy scenario. Furthermore, the sensitivity of results to alternative projections for world market fossil fuel prices is explored. Section 6 draws conclusions.

2 The analytic framework

2.1 Rationale for the adoption of a CGE approach

CGE models are widely used tools in energy and climate mitigation policy analysis.[1] The prime appeal of adopting a general equilibrium approach to energy policy and energy-related environmental policy analysis arises from the fact that energy is an input to virtually every economic activity. Hence, changes in the energy sector 'will ripple through multiple markets, with far larger consequences than energy's small share of national income might suggest' (Sue Wing 2009: 2). The unique advantage of the CGE approach over partial equilibrium approaches is its ability to incorporate these 'ripple effects' in a systematic manner.

In contrast to partial equilibrium approaches, CGE models consider all sectors in an economy simultaneously and take consistent account of economy-wide resource constraints, intersectoral intermediate input–output linkages, and interactions between markets for goods and services on the one hand, and primary factor markets including labour markets on the other. CGE models simulate the full circular flow of income in an economy from (i) income generation through productive activity, to (ii) the primary distribution of that income to workers, owners of productive capital, and recipients of the proceeds from land and other natural resource endowments, to (iii) the redistribution of that income through taxes and transfers, and to (iv) the use of that income for consumption and investment (Pueyo *et al.* 2015).

2.2 Specification of the dynamic CGE models for Kenya and Ghana

In terms of theoretical pedigree, the CGE models for Kenya and Ghana employed in this study can be characterised as modified dynamic extensions of standard comparative-static single-country CGE models for developing countries in the tradition of Dervis, de Melo and Robinson (1982), Robinson *et al.* (1999), and Lofgren *et al.* (2002). Models belonging to this class have been widely used in applied development policy research. Apart from the incorporation of capital accumulation, population growth, labour force growth, and technical progress,[2] the main difference to the standard model is a more sophisticated specification of the electricity sector as detailed in Sections 2.2.2 and 3.2.

2.2.1 Domestic production and input demand

Domestic producers in the model are price-takers in output and input markets and maximise intra-temporal profits subject to technology constraints. The technologies for the transformation of inputs into real outputs are described by sectoral constant-returns-to-scale production functions. In line with common practice in energy-focused, top-down CGE models,[3] technology specifications belonging to the generic class of KLEM (Capital (**K**), **L**abour, **E**nergy, **M**aterials) production functions are employed to capture substitution possibilities among energy and non-energy inputs and among different energy sources.

2.2.2 Electricity supply

In standard energy-focused top-down CGE models, electricity generation and distribution is typically treated as a single production activity. In these models, a transition towards a higher share of hydro, solar, or wind in the power mix is represented in a highly stylised abstract form as a substitution of fossil fuel inputs by physical capital under the assumption of a continuous space of available technologies. The lack of explicit detail with regard to the characterisation of current and future technology options entails the danger that simulation results may violate fundamental physical restrictions such as the conservation of matter and energy (Böhringer and Rutherford 2008) or exceed other technical feasibility limits (McFarland, Reilly and Herzog 2004; Hourcade *et al.* 2006). Moreover, the lack of technological explicitness limits the ability of top-down models to incorporate detailed information on cost differentials among alternative energy technologies from engineering cost studies (Hourcade *et al.* 2006). In response to these limitations of conventional top-down CGE models, various approaches to the incorporation of detailed ‘bottom-up’ information on energy technology options into a CGE modelling framework have emerged.[4]

The present study adopts a similar hybrid top-down bottom-up approach by decomposing electricity generation according to power source and by treating transmission and distribution (T&D) as a separate activity. This approach enables us to incorporate extant information on levelised cost of electricity (LCOE) differentials by power source into the simulation analysis and to consider exogenous policy-driven changes in the power mix that are not necessarily driven by changes in relative market prices. A consideration of off-grid renewable generation scenarios is beyond the remit of the present study and beyond the scope of the models applied here.[5]

2.2.3 Primary factor supply

The model distinguishes skilled and unskilled labour. The dynamic labour supply paths are exogenous and both types of labour are intersectorally mobile. The supply of agricultural land and natural resource endowments is imperfectly elastic, i.e. the supply of these primary factors varies endogenously in response to changes in the corresponding factor price. The accumulation of productive capital by sector is co-determined by capital return differentials – i.e. sectoral investment is a positive function of a sector's rate of return to capital relative to the economy-wide average return to capital.

2.2.4 Final domestic demand

Consumer behaviour is derived from intra-temporal utility-maximising behaviour subject to within-period budget constraints. The commodity composition of investment and government demand is kept constant according to the observed shares in the benchmark SAM, while the total volumes of government and investment demand grow in line with aggregate income and are determined by the macro closure rules detailed in Section 2.2.6.

2.2.5 International trade

In all traded commodity groups, imports and goods of domestic origin are treated as imperfect substitutes in both final and intermediate demand. The equilibrium ratio of imports to domestic goods in any traded commodity group varies endogenously with the corresponding relative price of imports to domestically produced output in that commodity group. On the supply side, the model takes account of product differentiation between exports to the rest of the world and production for the domestic market in all exporting sectors. The equilibrium ratio of exports to domestic goods in any exporting sector is determined by the price relation between export and home market sales. Both Kenya and Ghana are treated as small open economies – i.e. changes in their export supply and import demand quantity have no influence on the structure of world market prices.

2.2.6 Equilibrium conditions and macro closure

The prices for goods, services, and primary factors are flexible and adjust in order to satisfy the market clearing conditions for output and factor markets. Foreign savings and hence the current account balance follow an exogenous time path. This time path is kept fixed across the simulation scenarios considered in subsequent sections in order to enable meaningful welfare comparisons across the scenarios. This external sector closure entails that the real exchange rate adjusts endogenously to maintain external balance-of-payments equilibrium. A standard balanced macroeconomic closure rule (Lofgren *et al.* 2002) is adopted, according to which the shares of government demand,

Table 1 **Levelised cost of electricity by technology and country (US cents/KWh)**

	Ghana	Kenya
Hydro	6.8–11.2	7.4–10.9
Wind	12.6–19.5	7.7–10.3
Geothermal	Not applicable	4.7–7.5
Solar PV	16.0–26.9	9.9–14.8
Thermal – oil	19.0	26.0–42.0
Thermal – gas	13.0	13.3

Source Pueyo *et al.* (2016).

investment demand, and hence private household consumption demand in total absorption remain invariant. Under this macro closure, household and government saving rates adjust residually to establish the macroeconomic saving–investment balance.

3 Data sources and model calibration

3.1 The social accounting matrices for Kenya and Ghana: overview

Each model is calibrated to a SAM which reflects the input–output structure of production, the commodity composition of demand, and the pattern of income distribution for the country at a disaggregated level at the start of the simulation horizon. Starting point for the construction of the model-conformable SAMs are the input–output matrices for Kenya and Ghana contained in the GTAP 9 database (Aguiar, Narayanan and McDougall 2016). This data set provides a detailed and internally consistent representation of the global economy-wide structure of production, demand, and international trade at a regionally and sectorally disaggregated level for the benchmark year 2011.[6]

The GTAP database treats electricity generation, transmission, and distribution as a single aggregate activity and the data on household income and household consumer expenditure are for a single aggregate household. For the purposes of the present study, both the electricity activity and the household sector are disaggregated as detailed in Sections 3.2 and 3.3.

3.2 Disaggregation of the electricity sector

For Kenya, the electricity activity is disaggregated into T&D, hydro, geothermal, thermal, and wind. The electricity sector decomposition for Ghana splits the sector into T&D, hydro, and thermal. From a SAM perspective, the decomposition of the power activity for each country involves splitting the single electricity activity of the original GTAP input–output matrix into the various electricity subsectors distinguished in the CGE models in such a way that (i) the cost composition by input type in the subsectors is adequately represented; (ii) the contribution of each subsector to value-added and gross output value of the electricity sector is captured; and (iii) the accounting consistency of the SAM is preserved. To perform this non-trivial task, we combine data on the cost composition for different power generation technologies as well as for transmission and distribution from Peters (2016), Sue Wing (2008), and Lehr *et al*. (2011) with the LCOE estimates for Kenya and Ghana (Table 1) by Pueyo, Bawakyillenuo and Osiolo (2016) and data on the power mix in the benchmark year reported in Republic of Kenya (2014) and EnCG (2016). A matrix-balancing algorithm is employed to establish full SAM consistency.[7]

3.3 Disaggregation of the household accounts

The household disaggregation for Ghana distinguishes five household groups – labelled H1 (bottom quintile) to H5 (top quintile) – by household income quintile in the benchmark year, and is based on income and expenditure data from the Ghana Living Standards Survey (GLSS 6; GSS 2014). The available data do not support a consistent rural–urban split at the level of detail required for SAM construction purposes. The household sector decomposition for Kenya draws upon the household disaggregation generated by Kiringai *et al.* (2007). The Kenya model distinguishes four household groups – labelled Rural Low, Rural High, Urban Low and Urban High – which represent respectively the bottom and top 50 per cent of rural and urban households by expenditure level.

3.4 SAM dimensions

The benchmark SAM for Kenya distinguishes 19 production activities, seven primary production factors including three sector-specific natural resource factors (forest, fish, and mineral stocks) beside skilled and unskilled labour, capital, and agricultural land, and four household categories. The Ghana SAM for the benchmark year contains 18 production activities, eight primary factors including oil/gas resource stocks in addition to the same factors as in the Kenya SAM, and five household groups. Both SAMs contain 18 commodity groups (Agriculture, Forestry, Fishing, Crude Oil, Natural Gas, Other Mining, Beverages and Tobacco, Processed Food, Textiles and Clothing including Footwear and Leather Goods, Refined Petrol, Chemicals including Plastic and Rubber Goods, Other Light Manufacturing, Other Heavy Manufacturing, Electricity, Construction Services, Trade Services, Transport Services and Other Services).

3.5 Model calibration

The numerical calibration process involves the determination of the initial model parameters in such a way that the equilibrium solution for the benchmark year exactly replicates the benchmark SAM. The selection of values for the sectoral factor elasticities of substitution, the elasticities of substitution between imports and domestically produced output by commodity group, and the target income elasticities of household demand is informed by available econometric evidence from secondary sources and uses estimates provided by the GTAP behavioural parameter database (Hertel and van der Mensbrugghe 2016).

Table 2 **Outline of scenarios for Kenya**

	Business-as-usual power mix	Lower-carbon power mix
Low fossil fuel prices	*Baseline scenario*	*Lower-carbon scenario*
	Power mix follows current Ten-Year Plan: Rising share of Thermal Falling share of Hydro Constant share of Geothermal Rising but small share of Wind	Falling share of Thermal Falling share of Hydro Rising Share of Geothermal Rising but small share of Wind
	Oil import price 50% below 2011 level; Gas import price 55% below 2011 level	Oil import price 50% below 2011 level; Gas import price 55% below 2011 level
High fossil fuel prices (HFFP)	*HFFP scenario*	*Lower-carbon HFFP scenario*
	Power mix follows current Ten-Year Plan: Rising share of Thermal Falling share of Hydro Constant share of Geothermal Rising but small share of Wind	Falling share of Thermal Falling share of Hydro Rising Share of Geothermal Rising but small share of Wind
	Oil import price 19% below 2011 level; Gas import price 17% below 2011 level	Oil import price 19% below 2011 level; Gas import price 17% below 2011 level

Source Authors' own.

4 Dynamic scenario analysis: Kenya

4.1 Overview

The simulation analysis for Kenya considers four dynamic scenarios up to 2025 that differ with respect to (i) the evolution of the power mix in on-grid electricity generation, and (ii) the evolution of world market fossil fuel prices. Table 2 provides a concise outline of the alternative scenario assumptions along these two dimensions.

The specification of the lower-carbon scenarios is motivated by the results of the comparative LCOE analysis by Pueyo *et al.* (2016, 2017) which indicates a clear cost advantage of geothermal over all other electricity generation technologies, and by the presence of a considerable potential for the further expansion of geothermal capacity in the country. The consideration of alternative conceivable time paths for the evolution of international fossil fuel prices is motivated by the strong sensitivity of the cost differences between thermal and renewables to fossil fuel price projections.

4.2 Baseline scenario

The dynamic baseline scenario provides a projection of the evolution of Kenya's economy up to 2025 under the assumptions that international oil and gas prices remain at low 2015/16 levels and that the evolution of the electricity generation capacity from hydro, geothermal, and wind follows Kenya's Ten-Year Power Sector Expansion Plan 2014–2024 (Republic of Kenya 2014) under the Plan's moderate load growth scenario.

The construction of the baseline scenario starts from the 2011 benchmark SAM outlined in Section 3. For the period up to 2015, the forward projection takes account of the most recent available data observations, while the projections from 2016 to 2025 draw upon expert forecasts for the determination of the main model-exogenous drivers of economic growth.

Population and labour force growth is based on UNDESA (2015) medium-variant projections according to which the total population of Kenya rises from 42.5 million in 2012 to 58.6 million in 2025. The second exogenous driver of economic growth in the model is the economy-wide total factor productivity (TFP) growth rate, which reflects the speed of autonomous technical progress. In the development of the baseline scenario, the time path for the annual TFP growth rate is determined indirectly by imposing a target growth path for Kenya's real gross domestic product (GDP) and by calibrating the TFP parameter of the model dynamically to match this target growth path. The GDP baseline growth rates up to 2015 are the reported actual national accounts figures and the projections up to 2018 are taken from KIPPRA (2016). The assumed constant growth rate of 7.5 per cent per annum beyond 2018 is an optimistic compromise between the annual growth rate target of 10 per cent envisaged in Kenya's aspirational Vision 2030 development plan (Republic of Kenya 2007, 2013) for the same period and the growth rates projected by the CGE model under the assumption that TFP grows at a pace that is more in line with the country's actual observed growth performance over recent years.

The assumed evolution of the power mix in the baseline scenario draws upon Kenya's Ten-Year Power Sector Expansion Plan 2014–2024 (Republic of Kenya 2014) while taking into account that under the assumed baseline economic growth path, the electricity demand growth over the simulation horizon endogenously generated by the CGE model is significantly lower than in the Ten-Year Plan.

As shown in Table 3, the baseline scenario assumes that hydro, geothermal, and wind generation evolves in line with the moderate load growth scenario of the Ten-Year Plan while thermal (gas- and oil-fired) generation fills the gap between total demand and non-fossil-based supply. Correspondingly, the direction of the changes in the power mix over the period 2015–25 are broadly in line with the Ten-Year Plan moderate scenario, in the sense that (i) the hydro share drops markedly despite a substantial increase in absolute capacity; (ii) the geothermal share remains roughly constant following the rapid increase over the period 2011–15, which means that absolute geothermal generation grows strongly and approximately in proportion to total electricity demand; (iii) the share of thermal rises strongly; and (iv) the wind share roughly doubles but remains below 1 per cent. The main difference to the Ten-Year Plan scenario is that, due to the lower overall electricity demand growth, the baseline 2025 thermal share is slightly lower (35.2 per cent versus 39.2 per cent) and greener as it contains no coal-fired generation.

Table 3 **Domestic electricity generation by type – baseline scenario**

	Electricity generation (GWh)				
Year	**Total**	**Hydro**	**Geothermal**	**Thermal**	**Wind**
2011	7,250	3,427	1,453	2,352	18
2015	10,675	3,427	5,333	1,868	47
2020	22,735	4,466	11,343	6,829	97
2025	35,641	4,466	18,331	12,529	315
			Shares (%)		
2011	100.0	47.3	20.0	32.4	0.2
2015	100.0	32.1	50.0	17.5	0.4
2020	100.0	19.6	49.9	30.0	0.4
2025	100.0	12.5	51.4	35.2	0.9

Source All figures for 2011 and all GWh figures for Hydro, Geothermal, and Wind: Republic of Kenya (2014: Tables 6 and 33). Domestic total generation figures are model-determined and Thermal shares beyond 2015 follow residually.

4.3 Lower-carbon scenario

4.3.1 Scenario specification

Considering alternative conceivable pathways towards a less carbon-intensive power mix, the LCOE analysis for the Green Growth Diagnostics for Africa (GGDA) project by Pueyo *et al.* (2015) identifies geothermal electricity generation as the most promising technology option for Kenya. This assessment is in line with the Kenyan government's own assessment:

> In Kenya, more than 14 high temperature potential sites occur along the Rift Valley with an estimated potential of more than 10,000MW. Other locations include Homa Hills in Nyanza, Mwananyamala at the Coast and Nyambene Ridges in Meru. The expansion to existing geothermal operations offers the least-cost, environmentally clean source of energy (green) and highest potential to the country (Republic of Kenya 2014: 101).

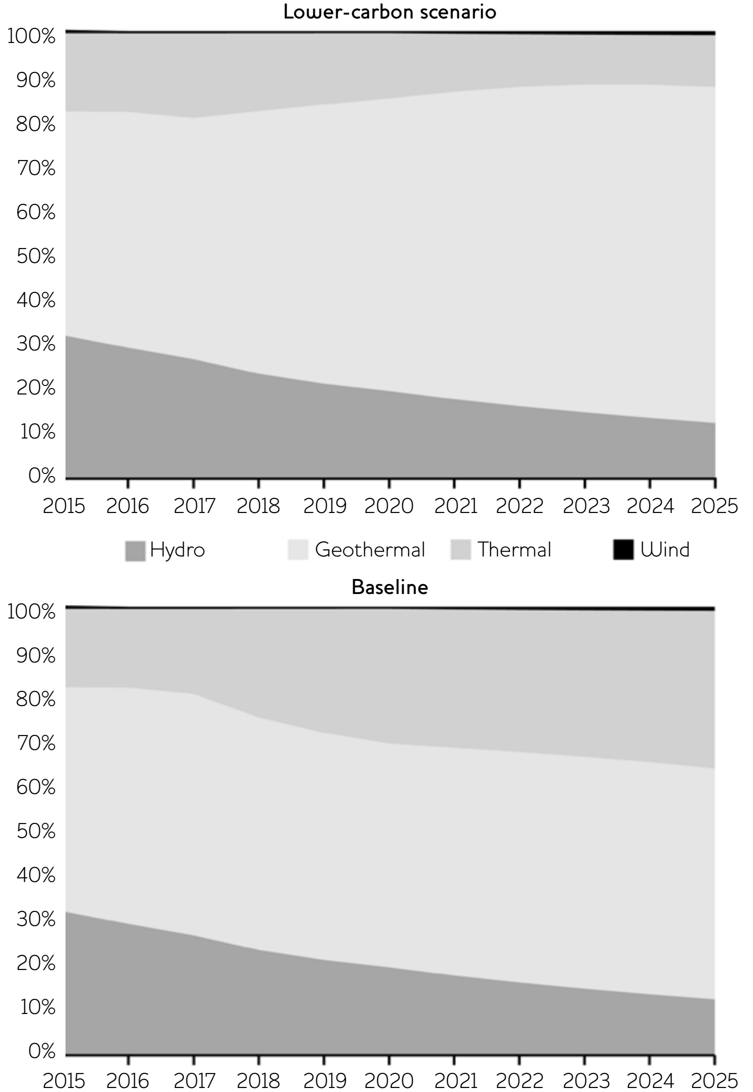
The following simulation analysis contemplates a deliberately drastic scenario in which the geothermal share in total domestic generation increases from 2018 onwards along a steep linear schedule to reach 75 per cent in 2025, so that the 2025 geothermal share is 23.6 percentage points higher than in the baseline. The thermal share drops correspondingly from 35.2 per cent in the 2025 baseline to 11.6 per cent (Table 4 and Figure 1). The hydro and wind shares remain unchanged. In absolute terms, this assumed expansion of geothermal electricity generation by 2025 is very close to the Ten-Year Plan's least-cost high growth scenario, in which geothermal is projected to generate 26,000GWh by 2024. The falling share of thermal does *not* imply an absolute contraction of thermal generation. Given the strong overall electricity demand growth, thermal generation still grows year on year, albeit at a lower rate than in the baseline.

Table 4 **Geothermal and thermal shares in total power mix – lower-carbon scenario (percentage shares)**

Year	Baseline		Lower-carbon	
	Geothermal	Thermal	Geothermal	Thermal
2015	50.0	17.5	50.0	17.5
2020	49.9	30.0	65.4	14.6
2025	51.4	35.2	75.0	11.6

Source Authors' assumptions as explained in text.

Figure 1 **Power mix in baseline and lower-carbon scenarios**



Source Authors' assumptions as explained in text.

Table 5 **Sectoral impacts for Kenya – lower-carbon scenario (percentage deviations from baseline level 2025)**

	Output	Exports	Imports	Producer price
Agriculture	0.1	-1.6	2.8	-0.4
Forestry	-0.6	-2.5		-0.3
Fishing	0.7	-1.4		-0.2
Crude oil	–	–	-9.7	–
Mining	-2.6	-2.7	1.6	-1.3
Food processing	0.2	-1.6	2.7	-0.4
Beverages and tobacco	0.6	-1.2	1.6	-0.4
Textiles and clothing	-0.4	-1.6	2.4	-0.7
Petrol refining	-9.7		-9.8	-1.2
Chemicals, rubber, plastics	0.3	0.0	1.5	-1.1
Other light manufacturing	0.1	-0.6	1.4	-0.9
Other heavy manufacturing	0.7	0.8	0.0	-1.4
Electricity	4.9			-12.5
Construction	1.0			-0.4
Trade services	0.1		2.0	-0.3
Transport services	-0.8	-1.7	3.0	-0.7
Other services	0.6	-1.3	2.8	-0.3

Source Authors' simulation results.
Note The reported trade flow changes exclude commodity groups with negligible trade volumes.

4.3.2 Results

The assumed gradual shift from high-cost thermal to lower-cost geothermal electricity generation entails a notable drop in the effective average supply price relative to the baseline scenario (Table 5). In 2025, the domestic electricity price – here expressed relative to the equilibrium wage of unskilled workers – is over 12 per cent lower than in the baseline scenario. The reduction in the cost of electricity affects the production costs and thus the supply prices across all sectors and is more pronounced in sectors with a higher share of electricity in total cost such as mining, the chemical industry, and heavy manufacturing than in sectors with a low power intensity.

The assumed low-carbon transition entails a strong reduction in fossil fuel imports. Both refined petrol and crude oil imports drop by nearly

10 per cent in volume terms relative to the baseline scenario towards 2025 (Table 5). The indirect effect on crude oil imports arises due to the fact that in the baseline scenario, Kenya's domestic petrol-refining sector – which actually ceased production in the second half of 2013 – is reactivated as envisaged in the 2015 National Energy and Petroleum Policy (Republic of Kenya 2015). In the baseline projection, this sector operates at a modest scale using imported crude oil, with a negligible 2025 baseline contribution to GDP and total employment.

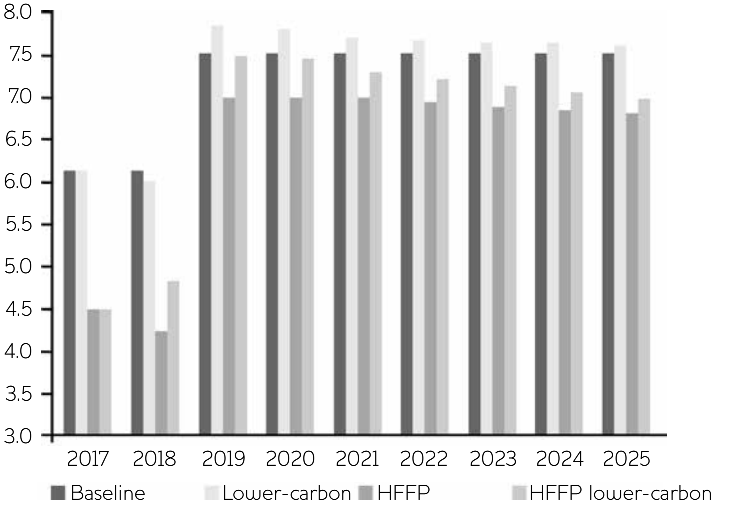
As Kenya remains a net importer of fossil fuels in the baseline scenario, the drop in the fossil fuel import bill is associated with a real exchange rate appreciation on the order of 0.7 per cent. The real appreciation lowers the prices of imports relative to domestically produced goods from the perspective of domestic residents. This induces a substitution effect towards imports for commodities in cases where the exchange rate effect dominates the simultaneous drop in the prices of domestic output due to the electricity cost reduction in the new equilibrium. A further positive effect on imports across all final goods arises due to the positive aggregate real income effects associated with the shift towards lower-cost electricity generation. Thus, Table 5 shows moderate welfare-raising increases in the import quantities relative to baseline levels for most traded non-fuel goods and services, and these are generally more pronounced for the commodity groups with smaller domestic supply price reductions.

On the export side, the real exchange rate appreciation effect *per se* reduces in tendency the price of exports relative to the price obtained in the domestic market from the viewpoint of domestic producers, and thus shifts the optimal profit-maximising output mix between export and home market production in favour of the latter. Correspondingly, Table 5 reports moderate drops in export quantities for most sectors. An exception is heavy manufacturing, which is the sector with the highest electricity cost share. In this case, the cost reduction effect dominates the exchange rate effect, so that exports expand. The trade effects can also be explained from a balance-of-payments perspective: the reduction in the fossil fuel import bill relaxes the balance-of-payments constraint as it allows domestic residents to enjoy simultaneously an increase in real imports and a higher share in domestically produced output, as less of that output needs to be shipped abroad to pay the import bill.

The equilibrium impact on real gross output by production sector for 2025 compared to the baseline scenario is also shown in Table 5. The sectoral employment effects have the same direction and broadly the same orders of magnitude, and are therefore not separately shown. Not surprisingly, in percentage terms the effect on the size of the small domestic oil refinery sector in relation to the baseline is most pronounced as the demand growth for fuel by thermal power plants slows down.

It is worth emphasising that no sector contracts in absolute terms and thus no sector sheds existing workers along the dynamic scenario time path.

Figure 2 **Annual growth rates of real GDP for Kenya by scenario (in per cent)**



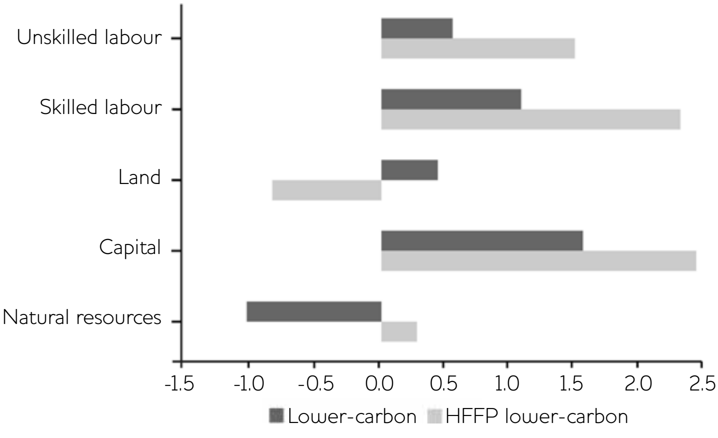
Source Authors' simulation results.

A negative-signed output effect in Table 5 merely indicates that the sector grows at a lower rate and that new workers are hired at a slower pace than in the baseline scenario, for example while the domestic refining sector at the 2025 endpoint of the simulation horizon is projected to be nearly 10 per cent smaller than in the baseline scenario for the same year, the sector is still 127 per cent larger in 2025 than in 2017.

In line with economic theory, the real exchange appreciation tends to shift productive resources from traded to non-traded activities. Among the non-power sectors that expand relative to baseline are all sectors that have simultaneously negligible or small export/output shares and negligible or little competition from imports in their domestic market, such as construction services, the fishery sector, and trade services. In contrast, the small domestic mining sector with its baseline export–output ratio of over 75 per cent and an import share of over 50 per cent in Kenya's domestic demand for mining products is squeezed noticeably as mining exports drop and mining imports rise. The sectors that expand despite relatively high trade shares are heavy manufacturing and chemicals, which are among the most electricity-intensive sectors and thus benefit disproportionally from the reduction in energy input costs. However, the main message is that the effects of the assumed low-carbon transition on the sectoral composition of output and employment are very moderate.

The real resource savings associated with the switch to a lower-cost mode of electricity generation is reflected in a moderately positive transitory effect on GDP growth, as shown in Figure 2. The cumulative effect of the small annual growth rate increments reported in Figure 2 over the period 2018–25 entails that the level of real GDP by 2025 is 1.1 per cent higher than in the baseline scenario.

Figure 3 **Impact on factor returns in Kenya by scenario (percentage deviation of factor prices relative to consumer price index (CPI) from baseline or high fossil-fuel price (HFFP) level 2025)**



Source Authors' simulation results.

Turning to the effects on the functional income distribution – i.e. the distribution of primary income by type of factor – Figure 3 displays the impacts on real factor prices (i.e. nominal factor prices deflated by the consumer price index) in 2025 relative to the baseline level in the corresponding year. By 2025, the real returns to all factors except mineral resources are slightly higher than in the baseline. Capital returns rise relative to labour wages and the wage gap between skilled and unskilled increases marginally.

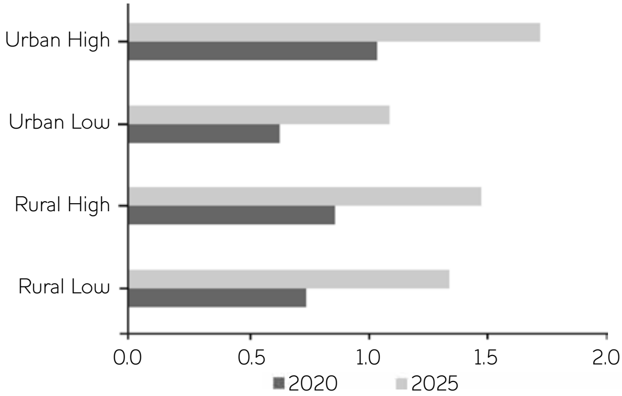
The differential factor price effect arises from factor intensity differentials between sectors that grow quicker and sectors that grow slower than in the baseline. On balance, the higher-growing sectors as a group are relatively skill- and capital-intensive and thus their additional factor input demand drives up capital returns and skilled wages more than unskilled wages.

For households with a single source of factor income, Figure 3 directly indicates the direction of the effects on total factor income. Figure 4 shows the implications for mixed-income households with factor income mixes equal to the income compositions of the four household categories the benchmark SAM. Both lower- and higher-income households gain. However, since the urban and rural high-income groups have higher shares of capital and skilled labour in their total income mix than the low-income groups, the former groups gain disproportionally. In other words, the low-carbon transition has a pro-poor effect in an absolute or 'weak' sense (i.e. the poorer households are better off than in the baseline), but is not pro-poor in a relative or 'strong' sense (i.e. the poorer households do not gain disproportionally).[8]

4.4 Sensitivity of results to future fossil fuel prices

As the cost differentials between thermal and renewable technologies are necessarily contingent on the assumptions about future fossil fuel

Figure 4 **Impact on real household income – lower-carbon scenario (percentage deviation from baseline level 2020 and 2025)**



Source Authors' simulation results.

prices over the lifetime of thermal power plants, and the results of the quantitative low-carbon scenario analysis are driven by the size of these cost differentials, we now briefly assess the sensitivity of the findings in the previous section to a variation in the assumed exogenous international fossil fuel price time paths. In contrast to the baseline scenario, crude oil and refined petrol world prices are now assumed to return to higher levels beyond 2016. More specifically, between 2016 and 2018 oil prices rise linearly to a level that is 62 per cent higher than the 2018 baseline price (but still 19 per cent lower than the 2011 benchmark price) and then stay put at that level beyond 2018.

The high fossil fuel price (HFFP) scenario under *baseline* assumptions about the power mix provides the relevant reference scenario for comparison with the HFFP lower-carbon scenario. As the purpose of this study is not to provide an exhaustive analysis of the sensitivity of Kenya's economy to oil price shocks, the exposition of this reference scenario can be concise and focuses on key differences to the baseline scenario.

In macroeconomic terms, the simulated oil price shock is an adverse terms-of-trade shock, i.e. the aggregate ratio of import prices paid by Kenya to export prices paid by the rest of the world for Kenya's exports rises. Thus, Kenya must devote more domestic productive resources to export production at the expense of production for the home market in order to pay for the higher import bill. The welfare-reducing terms-of-trade shock requires a real exchange depreciation on the order of 7.6 per cent by 2025 relative to the baseline. The depreciation effect discourages imports and stimulates exports. The effects on GDP growth are displayed in Figure 2. GDP growth rates are hit strongly initially and then recover partially as international oil prices settle at the new higher level and the economy adapts to the shock. By 2025, the annual growth rate is still about 0.7 percentage points below the baseline growth rate. The simulation results suggest that by 2025 the level of GDP would be some 9 per cent below base.

Since higher fossil fuel prices increase the cost advantage of geothermal *vis-à-vis* thermal power generation, the positive effect of the shift to a higher geothermal share on real GDP growth is noticeably stronger than in the previous lower-carbon scenario. The cumulative effect of the increases in annual GDP growth means that by 2025 GDP is 2.6 per cent higher than in the HFFP reference scenario. The corresponding GDP increase reported in Section 4.3 for the low-oil-price case amounted to 1.1 per cent.

The real exchange rate appreciation associated with the lower dependency on fossil fuel imports is on the order of 1.2 per cent by 2025 and thus likewise slightly more pronounced than the corresponding real appreciation of 0.7 per cent reported in Section 4.3. The general pattern of the sectoral effects is the same as in the earlier lower-carbon scenario, but in quantitative terms the sectoral changes in output, employment, and trade flows are again moderately stronger.

The same conclusion applies to the impacts on the functional income distribution (Figure 3), except for the impact of the low-carbon transition on the real returns to agricultural land. The export–output ratio of agriculture is higher in the HFFP reference scenario than in the baseline scenario, since Kenya needs to export more to pay for the higher fossil-fuel import bill. Thus, the stronger real appreciation under the HFFP low-carbon scenario which slows down agricultural export growth has a stronger effect on agricultural output growth than in the low-carbon scenario under low oil prices. As a result, agricultural land rents grow slightly slower than in the HFFP reference scenario up to 2025.

5 Dynamic scenario analysis: Ghana

5.1 Overview

The scenario design for the Ghana study follows the same basic logic as the Kenya study (Table 2). The specification of the lower-carbon scenarios is again motivated by the results of the LCOE analysis by Pueyo *et al.* (2016, 2017), as detailed in Section 5.3.

5.2 Baseline scenario

The construction of the baseline scenario starts from the 2011 benchmark SAM for Ghana outlined in Section 3. According to the UNDESA (2015) medium-variant projections used here, the total population of Ghana rises from 25.5 million in 2012 to 33.7 million in 2025. The GDP baseline scenario growth rates up to 2014 are the reported official national accounts figures (GSS 2015) and the projections up to 2018 are taken from World Bank (2016). For the period beyond 2019, it is assumed that annual GDP continues to grow at rates just below the World Bank forecast for 2017/18. The growth rates imply that aggregate GDP in 2025 is 2.7 times higher than in 2011 and per capita GDP doubles over this period.

The assumed evolution of the on-grid power mix in the baseline takes account of the Strategic National Energy Plan 2006–2020 (EnCG 2006), the Energy Sector Strategy and Development Plan (Ministry of Energy

Table 6 **Outline of scenarios for Ghana**

	Baseline power mix	Lower-carbon power mix
Low fossil fuel prices	*Baseline scenario*	*Lower-carbon scenario*
	Rising share of Thermal Falling share of Hydro	Less steep rise of Thermal share Less steep drop of Hydro share
	Oil import price 50% below 2011 level; Gas import price 55% below 2011 level	Oil import price 50% below 2011 level; Gas import price 55% below 2011 level
High fossil fuel prices (HFFP)	*HFFP scenario*	*Lower-carbon HFFP scenario*
	Rising share of Thermal Falling share of Hydro	Less steep rise of Thermal share Less steep drop of Hydro share
	Oil import price 19% below 2011 level; Gas import price 17% below 2011 level	Oil import price 19% below 2011 level; Gas import price 17% below 2011 level

Source Authors' own.

2010), the Ministry of Petroleum's Gas Master Plan (Republic of Ghana 2015a), the Ghana Scaling-Up Renewable Energy Programme (SREP) (Republic of Ghana 2015b), and is also informed by a range of other sources including World Bank (2013), EnCG (2016), and IRENA (2015).

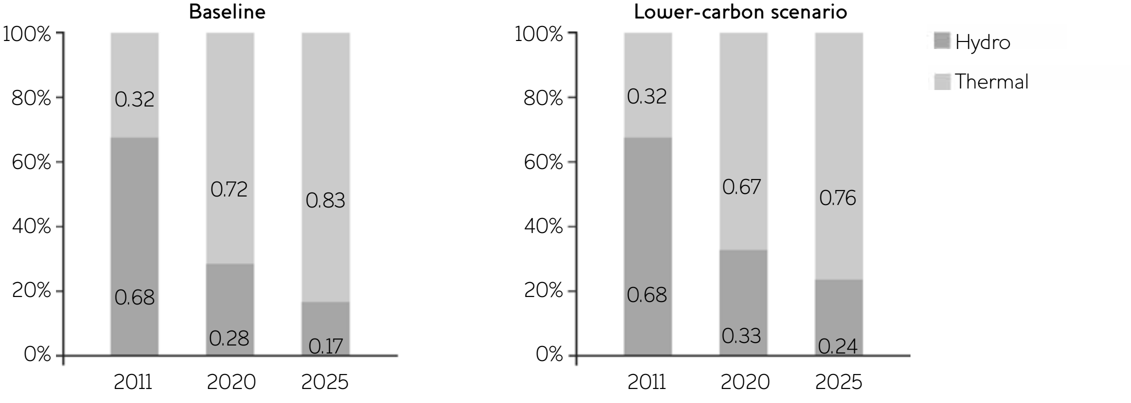
The key assumptions for the construction of the baseline scenario are that (i) hydro capacity remains constant beyond 2015 up to 2025, i.e. the hydro share drops as total generation grows (Figure 5); (ii) the on-grid share of non-hydro renewables remains negligibly small, i.e. the binding constraints to investments in renewable energy capacity in Ghana identified by Pueyo *et al.* (2017) are not relaxed, and thus Ghana's official aspirational target to reach a renewable share (excluding large-scale hydro) of 10 per cent by 2020 is not achieved; (iii) the rising gap between hydro generation and total demand for electricity is entirely bridged by additional thermal generation, and thus the share of thermal in total generation is rising; and (iv) the share of gas in total thermal generation is rapidly rising from 2018 onwards. In line with Ghana's Gas Master Plan and the recommendations in World Bank (2013), the baseline scenario assumes further that natural gas extraction from domestic sources develops at a fast pace, so that by the 2020s a significant fraction of the expanding gas demand by the power sector is covered by domestically sourced supplies.

5.3 Lower-carbon scenario

5.3.1 Scenario specification

Pueyo *et al.* (2016) suggest that in comparison to Kenya, Ghana's renewable energy potential is considerably smaller and presently hydro is the only renewable energy option with a clear cost advantage over gas-fired thermal generation, yet the potential for a further expansion of hydro capacity is limited. Based on IRENA (2015) estimates for Ghana's untapped small- and medium-scale hydro power expansion potential, we consider a moderate lower-carbon transition scenario in which the hydro share in total generation by 2025 is seven percentage

Figure 5 **Electricity generation shares in baseline and lower-carbon scenario**



Source Authors' simulation results.

points higher than in the baseline scenario, and the 2025 thermal share drops from 83 per cent to 76 per cent. IRENA estimates suggest that the LCOE 'for new small hydropower projects is between 3 US cents and 11.5 US cents/KWh in developing countries',[9] which is within the range of the LCOE estimate used for the initial calibration of the hydro sector parameters in the CGE model for Ghana (Table 1).

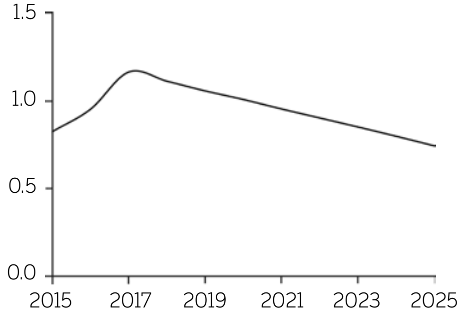
5.3.2 Results

The moderate and gradual shift from thermal to hydro electricity generation entails modest changes in the system-wide average cost of electricity production over the period 2018–25. By 2025, the electricity supply price in this scenario is a moderate 1.1 per cent lower than in the baseline.

The dynamic macroeconomic adjustment process in this scenario is complicated by the fact that the baseline hydro-thermal generation cost differential endogenously generated by the CGE model has a hump-shaped time profile as shown in Figure 6: over the period 2015–17, the thermal generation costs drop sharply relative to hydro unit costs, so that by 2017 the initial cost advantage of hydro turns into cost disadvantage. Beyond 2017, this trend reverses as the thermal unit cost begins to rise relative to the hydro unit cost, and beyond 2021 hydro restores its status as the least-cost electricity technology.

Primarily, three features of the baseline scenario drive this peculiar time path of the hydro-thermal cost differential. First, fossil fuel import prices and particularly gas prices drop strongly over the period 2015–17, and entail a sharp drop in the thermal generation cost over this period. Second, the strong increase in demand for thermal electricity associated with the rise in the thermal share over the whole simulation horizon drives up the equilibrium rate of return to capital in the thermal sector – i.e. the return on investments in thermal capacity must rise in order to attract the new capital required for the expansion of the thermal sector. This effect raises the cost of capital in the thermal sector.

Figure 6 **Ratio of average hydro to average thermal generation cost, 2015–2025**



Source Authors' simulation results.

Third, as Ghana has an initial trade deficit with the rest of the world and the foreign savings required to cover the trade deficit grow at a lower exogenous rate than Ghana's real income and import demand, the real exchange rate depreciates slightly over the entire simulation interval. Thus, while fossil fuel prices remain constant beyond 2017 in foreign currency terms, they rise gradually from 2018 to 2025 from the perspective of domestic firms and households due to the depreciation effect. The first effect dominates the time profile of the hydro-thermal cost differential up to 2017, while the second and third effect become jointly dominant after 2018.

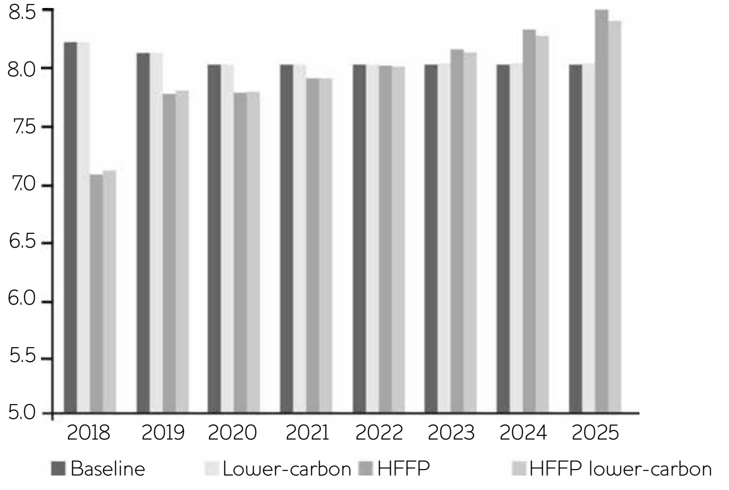
The small direct electricity cost reduction effect towards 2025 triggers only weak intersectoral spillover effects via input–output linkages and other general equilibrium repercussions. The equilibrium effects on the supply prices of other sectors are generally tiny. The only noteworthy indirect price effect is the 0.8 per cent drop in the domestic natural gas supply price. This effect occurs since the thermal sector expands at a lower rate than in the baseline, and thus its demand for gas grows at a lower rate.

For the same reason, fossil fuel imports drop relative to the baseline. As in the case of Kenya, the reduction in the fossil fuel import bill entails a mild real exchange rate appreciation effect, i.e. the additional 'space' in Ghana's external balance-of-payments account created by the reduced fossil fuel import payments enables a simultaneous increase in the volume of non-fuel imports and a reduction in the volume of exports that must be shipped to the rest of the world in order to pay for imports.

In an aggregate macroeconomic sense, the net welfare effect for Ghana associated with the low-carbon transition scenario considered here is unambiguously positive: using virtually the same total real resources as in the baseline, Ghana can simultaneously command a higher real volume of imports and retain a higher share of total domestic output as less of this output is exported than in the baseline.

This positive welfare effect is reflected in a positive but very small increase in real GDP. The cumulative effect of the tiny annual growth rate

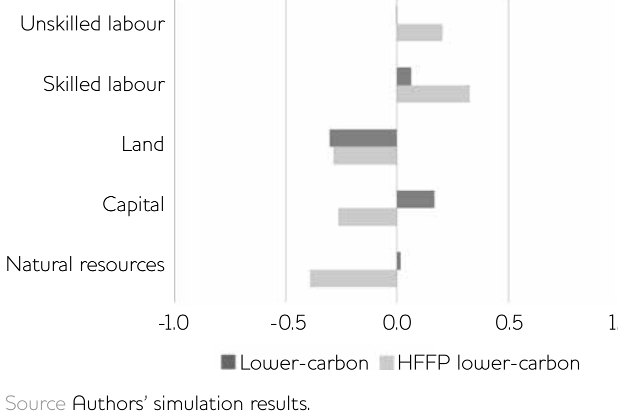
Figure 7 **Annual growth rate of real GDP for Ghana by scenario (in per cent)**



Source Authors' simulation results.

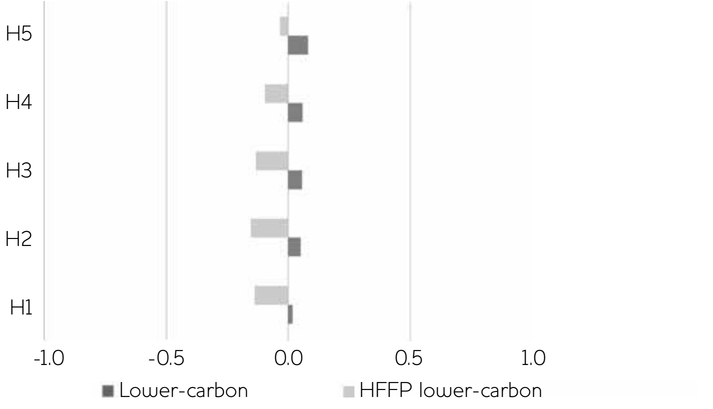
increments reported in Figure 7 over the period 2021–25 entails that the level of real GDP by 2025 is a negligible 0.025 per cent higher than in the baseline scenario. Part of the reason for the small GDP effect is that between 2018 and 2020 the low-carbon transition initially raises the average price of electricity (by about 1 per cent) due to the hump-shaped time profile of the hydro-thermal cost differential discussed previously. A further reason is that the reduction in demand for domestic natural gas by the thermal sector leads to a small reduction in the primary resource extraction activity of the domestic fossil fuel sector. In economic terms, this means a reduction in the supply of a primary production factor which entails *per se* a negative effect on real GDP. However, this effect is likewise tiny: the 2025 supply of domestic fossil fuel primary resources drops by 1.8 per cent, while the baseline contribution of this factor to GDP is about 2 per cent – so the effect on real GDP is well below 0.05 per cent.

Figure 8 **Impact on factor returns in Ghana by scenario (percentage deviation of factor prices relative to CPI from baseline level 2025)**



Source Authors' simulation results.

Figure 9 **Impact on real household income in Ghana by scenario (percentage deviation from baseline level or HFFP level 2025)**



Source Authors' simulation results.

Figures 8 and 9 report the effects on the functional distribution of income and real factor income by household type for 2025. Unsurprisingly, the impacts are again tiny. As in the case of Kenya, the distribution impact is slightly regressive in tendency as by 2025 capital and skilled labour gain slightly in relation to other factors.

5.4 Sensitivity of results to future fossil fuel prices

5.4.1 HFFP scenario

The world market crude oil price increase under the HFFP scenario incentivises a marked rise in Ghana's crude oil export supply and the domestic fossil fuel extraction sector expands *vis-à-vis* the baseline. Due to the large thermal share in total electricity generation by 2025, the cost-push effect on the price of electricity is strong (+38 per cent). The supply prices of non-energy sectors with relatively high energy cost (direct fuel plus electricity) shares in total production costs including the chemical industry, heavy and light manufacturing, other mining, and transport services are likewise pushed up significantly, and the growth of these sectors slows down accordingly.

In the baseline scenario, Ghana remains a marginal net fossil fuel importer despite its crude oil exports, and thus the rise in international fossil fuel prices is an adverse terms-of-trade shock for the country. However, due to the additional crude oil export revenue growth in the HFFP scenario, the absolute size of the annual net fossil fuel import bill relative to the baseline scenario becomes smaller over time, and thus towards 2025 Ghana needs to earn less non-fuel export revenue than in the baseline to pay for the net fossil fuel import bill. This is a noteworthy difference to the HFFP scenario for Kenya discussed in Section 4.4.

Figure 7 shows the effects on GDP growth. As in the case of Kenya, GDP growth rates are hit strongly by the initially higher energy costs and then start to recover as international oil prices settle at the new higher level and the economy adapts to the shock. In contrast to Kenya, however, from

2023 onwards GDP growth rates start to overshoot the baseline rates. The reason for this effect is that the expansion of the domestic fossil fuel sector is associated with a higher rate of domestic natural resource extraction than in the baseline. By 2023, the impact of this increase in the supply of a primary production factor on total economy-wide value-added is sufficiently strong to dominate the growth-depressing effects of higher energy prices on the annual growth rate. However, this effect is not strong enough to push the level of GDP above the baseline path: by 2025, real GDP is still 3.2 per cent below baseline level.

It is important to note that the hump-shaped time profile of the hydro-thermal cost differential (Figure 6) does *not* occur in the HFFP scenarios: since fossil fuel prices remain high over the entire 2015–25 period, the hydro-thermal unit cost ratio remains below unity throughout.

5.4.2 HFFP lower-carbon scenario

Higher fossil fuel prices increase the cost advantage of hydro *vis-à-vis* thermal power generation, and so the impact of the transition towards a higher hydro share entails a stronger reduction of the electricity than in the low-carbon scenario of Section 5.3: by 2025, the electricity price is 6.2 per cent lower than in the HFFP reference scenario, whereas in the low-carbon scenario with low fossil fuel prices, the electricity price impact is only -1.1 per cent.

Moreover, since in contrast to the previous low-carbon scenario the hydro cost advantage now prevails over the entire 2018–25 period, the gradual downward shift in electricity prices begins right at the start of the transition process in 2018, whereas in the low-carbon scenario with low fossil fuel prices the same transition entails an initial electricity price increase due to the hump-shaped time profile of the hydro-thermal cost differential.

However, the reduction in demand for domestic natural gas by the thermal sector and the real appreciation effect due to the reduced net fossil fuel import bill again leads to a small reduction in the primary resource extraction activity of the domestic fossil fuel sector. This effect entails *per se* a negative impact on real GDP. By 2022, this effect begins to slightly dominate the growth-enhancing effect of lower electricity prices. The cumulative impact of these miniscule effects on annual GDP growth rates remains small: by 2020, the level of real GDP in the HFFP low-carbon scenario is 0.1 per cent higher and by 2025, 0.11 per cent lower than in the HFFP reference scenario.

Thus, in contrast to the corresponding analysis for Kenya, the *quantitative* impact of the lower-carbon transition in the electricity sector on macroeconomic growth in Ghana is not particularly sensitive to variations in the assumptions about international fossil fuel prices: both in the low-carbon scenario and the HFFP low-carbon scenario the impacts on real GDP remain negligibly small despite the *qualitative* differences across the two scenarios. Also in contrast to the findings for Kenya, higher fossil fuel prices do not enlarge but rather reduce the beneficial impacts of a transition from thermal to lower-cost renewable electricity generation in the case of Ghana. The main reason for these differences is related to the endogenous changes in domestic fossil fuel resource extraction that occur in the case of Ghana but not in the case of Kenya. Impacts on the functional distribution of income and the distribution by household quintile remain small (Figures 8 and 9).

6 Conclusions

The present study applies purpose-built dynamic CGE models for Ghana and Kenya with a disaggregated country-specific representation of the power sector, to simulate the prospective medium-run growth and distributional implications associated with a shift towards a higher share of renewables in the power mix, up to 2025.

In both countries, the share of fossil fuel-based thermal electricity generation in the power mix will increase sharply over the next decade and beyond according to current national energy sector development plans.

Kenya has a considerable potential for a further expansion of geothermal electricity generation and existing estimates suggest a significant cost advantage of geothermal over thermal power generation. In line with this assessment, the simulation analysis for Kenya considers a stylised low-carbon transition scenario in which the geothermal share in total domestic on-grid electricity generation increases along a steep linear schedule, so that the 2025 geothermal share is 24 percentage points higher than in the baseline scenario.

The higher share of low-cost geothermal in the power mix reduces electricity prices and mildly stimulates economic growth. The associated reduction in the fossil fuel import bill triggers a moderate real exchange rate appreciation, which reduces the prices of imports faced by domestic producers and households and entails a further economy-wide real income gain. The size of these beneficial aggregate effects depends on the evolution of international fossil fuel prices over the simulation horizon: under a low-carbon transition scenario with low world market fossil fuel prices, real GDP in 2025 is about 1.1 per cent higher than in the baseline scenario. In a low-carbon scenario with high fossil fuel import price scenario, real GDP in 2025 is more than 2 per cent higher than in the corresponding HFFP baseline scenario. All household groups gain, but urban and rural higher-income households gain relatively more than urban and rural low-income households, because skilled real wages and real returns to capital rise slightly more than unskilled wages and returns to land. Impacts on the sectoral structure of production are generally small. In tendency, sectors with a higher baseline share of electricity costs in total production cost expand relative to sectors with a low electricity cost share.

In comparison to Kenya, Ghana's potential for an economically viable expansion of renewable on-grid power generation is considerably smaller. Moreover, in contrast to Kenya, Ghana has an already active domestic fossil fuel extraction sector and is planning to satisfy a significant share of the fuel demand of its expanding gas-fired thermal generation using domestic natural gas resources. The available levelised cost estimates suggest that in the case of Ghana presently, hydro is the only renewable energy option with a clear cost advantage over gas-fired thermal generation, yet the potential for a further expansion of hydro capacity is limited. In line with this assessment, the simulation analysis for Ghana considers a moderate lower-carbon transition scenario in which the hydro share in total generation by 2025 is seven percentage points higher than in the baseline scenario and the 2025 thermal share drops from 83 per cent to 76 per cent.

This moderate electricity sector transition shock generates only marginal impacts on macroeconomic growth. The presence of a domestic fossil fuel extraction sector in Ghana changes the qualitative nature of the dynamic adjustment to the transition shock in relation to the case of Kenya. As in the analysis for Kenya, the partial shift to lower-cost renewable power generation reduces the cost of electricity and this *per se* stimulates economic growth. However, the associated drop in demand for domestic natural gas by the electricity sector slightly dampens the growth of domestic natural resource extraction, and this reduction in primary factor supply growth *per se* reduces real GDP growth. Thus, in the case of Ghana, these two effects drag GDP in opposite directions and the net effect is miniscule. Similar to Kenya, the impacts on the sectoral structure of domestic production are small and thus the effects on relative factor prices that determine the functional income distribution remain unremarkable.

The overarching general message suggested by the simulation results presented here is that in both countries it appears feasible to reduce the carbon content of electricity generation significantly without adverse consequences for economic growth and without noteworthy distributional effects.

Notes

1 Sue Wing (2009) and Kemfert and Truong (2009) survey this literature. For a concise recent survey of the small number of CGE studies concerned with a low-carbon energy transition in developing countries, see Pueyo *et al.* (2015: 52–59).

2 See e.g. Robinson, Willenbockel and Strzepek (2012) for an earlier recursive-dynamic extension of the standard model.

3 See e.g. Böhringer and Löschel (2004), Böhringer, Löschel and Rutherford (2009), and Willenbockel and Hoa (2011). For further reference to the literature on energy-focused top-down CGE models, see Pueyo *et al.* (2015: Chapter 6).

4 Examples for the development and application of such hybrid top-down bottom-up models include *inter alia* McFarland, Reilly and Herzog (2004), Böhringer and Löschel (2006), Sue Wing (2008), Böhringer and Rutherford (2008, 2013), Sassi *et al.* (2010), Boeters and Koornneef (2011), Lanz and Rausch (2011), Okagawa *et al.* (2012), Proenca and St. Aubin (2013), and Fortes *et al.* (2013).

5 In the recent low-carbon development literature, the deployment of decentralised renewable energy systems is widely seen as a promising and economically viable approach to reducing energy poverty in remote rural areas (see Willenbockel 2015: 171–72 for further reference), and thus the incorporation of such scenarios in future research appears desirable. However, assessing the scope for a cost-effective expansion of stand-alone renewable energy generation as an alternative to centralised grid supply is a complex task and requires spatially explicit modelling, as exemplified by Deichmann *et al.* (2011) for Ethiopia, Ghana, and Kenya. For a study of the evolution of the solar home system market in Kenya see Byrne *et al.* (2014).

6 The raw data for the Ghana country bloc of the GTAP database include a SAM for 2005 constructed by Breisinger, Thurlow and Duncan (2007) and the raw data for Kenya in GTAP include a 2001 SAM developed at the Kenya Institute for Public Policy Research and Analysis (KIPPRA) in collaboration with the International Food Policy Research Institute (IFPRI), a predecessor of the latest available KIPPRA–IFPRI SAM for 2003 (Kiringai, Thurlow and Wanjala 2006). In the case of Kenya, the GTAP input–output data have been triangulated with information from more recent unpublished supply-and-use tables (SUTs) provided by Dr Bernadette Wanjala (KIPPRA). Following minor revisions in the course of this triangulation process, the SAM has been rebalanced using a variant of the cross-entropy approach proposed by Robinson, Cattaneo and El-Said (2001). For Ghana, no recent SUT data are available.

7 See Willenbockel, Osiolo and Bawakyillenuo (2017) for further elaboration. See Peters and Hertel (2016a, 2016b) for a detailed discussion and comparison of existing matrix-balancing algorithms commonly used in this context and further references to the related technical literature.

8 See Willenbockel (2015) for critical reflections on the recent literature concerned with pro-poor low-carbon development in this context.

9 http://costing.irena.org/technology-costs/power-generation/hydropower.aspx (accessed December 2016).

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Design and Assessment of Renewable Electricity Auctions in Sub-Saharan Africa

Hugo Lucas,[1] Pablo del Río[2] and Mohamed Youba Sokona[3]

Abstract Auctions have recently been regarded as a useful alternative to other support schemes for setting the remuneration of renewable electricity (RES-E) worldwide. They have also been increasingly adopted in the sub-Saharan Africa (SSA) region, mostly due to their promise to support the deployment of RES-E projects cost-effectively. The aim of this article is to identify the design elements of RES-E auctions in SSA and assess their pros and cons with respect to different criteria. The results show that the design elements adopted in the SSA auctions are similar to other countries, but some design elements are deemed very relevant in order to address specific constraints to RES-E investments in SSA countries, including pre-selection of sites, technology-specific (solar PV), and price-only auctions. However, the main distinctive feature of auctions in SSA is that they are part of a broader policy mix of support mechanisms aimed at de-risking and providing technical support.

Keywords: sub-Saharan Africa, renewable energy, auctions, PV, design elements, policy mix.

1 Introduction

Many countries in sub-Saharan Africa (SSA) have experienced or are currently experiencing an energy crisis. Six-hundred million people in SSA lack access to electricity (Castellanos *et al.* 2015). With an electrification rate of only 26 per cent (World Bank 2017), the region has 13 per cent of the world's population, but 48 per cent of the share of the global population without access to electricity. SSA is the only region in the world where the absolute number of people living without electricity is increasing (IEA 2014: 30).

Some authors provide in-depth analyses of the SSA electricity sector (see Castellanos *et al*. 2015; KPMG 2016; Quitzow *et al.* 2016; Eberhard *et al.* 2016; Climatescope 2016; IEA 2014). Several factors are behind the energy crisis, including high-demand growth, low installed capacity, non-cost recovering tariffs, low utilisation rate of existing capacity,

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ageing, insufficient, and poorly maintained power infrastructures leading to transmission and distribution losses, dominance of one energy source (hydro), and negligible power trading across countries. Large investments are thus required to address this energy crisis.[4]

Electricity from renewable energy sources (RES-E) has the potential to mitigate the energy crisis since it is domestically available, it can be cost-competitive, and deployed much faster than fossil fuel-based power plants. It can trigger additional economic benefits and it is a core component for any low-carbon strategy, offering important environmental co-benefits, including improved local air quality (Quitzow *et al*. 2016).

However, non-hydro RES-E represents a tiny fraction of SSA's electricity mix. Renewables accounted for around 30 per cent of SSA-installed capacity in power generation (about 31GW) in 2016. However, most of this capacity is hydro-based (25 per cent, 25GW), with other RES accounting for only 5 per cent (6GW). Fossil fuels account for the largest share (68 per cent, 67GW), followed by nuclear (2 per cent, 1.9GW) (estimations based on IRENA 2017a and UNSD 2017).

Strong barriers to RES-E in SSA persist. A useful theoretical framework on the barriers to investments in RES-E in less developed regions, such as SSA, is provided by Pueyo *et al*. (2015). According to these authors, RES-E investments face three types of constraints: economic/financial, regulatory/political and technical, which are more severe in developing countries (*ibid*.: 32). In particular, the economics of renewable energy projects in developing countries are more challenging due to: (i) the capital-intensive nature of RES-E projects, which amplifies funding cost differentials; (ii) the higher level of perceived risk, which raises costs through the higher cost of finance and the larger share of equity in a project's finance structure; (iii) the lack of domestic debt-finance of suitable maturity, and scarcity of equity finance, particularly private equity; and (iv) low prices of electricity that prevent cost-recovery (*ibid*.: 30). Several studies have identified the specific barriers to RES-E in SSA (*The Economist* 2016; Quitzow *et al*. 2016; Castellanos *et al*. 2015; Climatescope 2016). The required capital spending in the power sector is an unbearable financial burden for government budgets (Castellanos *et al*. 2015). But other (interrelated) barriers include higher capital costs than elsewhere due to higher risks (*The Economist* 2016), different types of risks (construction and operation, foreign exchange and country risks), poor financial health of utilities (Quitzow *et al*. 2016), off-taker risk (Eberhard *et al.* 2016), the structure of the electricity sector (dominated by single, and often state-owned utilities responsible for a large share of generation, transmission, and distribution) (Climatescope 2016), technical limitations of weak grids (*The Economist* 2016; Quitzow *et al*. 2016; Eberhard *et al.* 2016), artificially low tariffs, and the large amounts of investments being required.

Different barriers could justify the adoption of different policies (policy mix). Pueyo *et al* (2015) identify several policies to address the different constraints to RES-E investments (economic/financial, regulatory/political, and technical). Focusing on the economic and financial barriers, administratively-set feed-in tariffs (FITs) and feed-in premiums (FIPs) are main alternatives to address those barriers. Under FITs, a total payment per MWh of RES-E generated, paid in the form of guaranteed prices and combined with a purchase obligation by the utilities is provided. Under FIPs, a payment per KWh on top of the electricity wholesale-market price is granted. FITs were adopted in a number of SSA countries in the past, including Ghana, Kenya, South Africa, and Uganda. However, they only delivered very small investments in SSA (Kruger and Eberhard 2016; Eberhard *et al.* 2016). Some of these countries (Ghana, South Africa, and Uganda), but also others in the SSA region have recently implemented auctions as a more appealing instrument than FITs, following the successful experience in South Africa and elsewhere. Auctions have also been implemented in Burkina Faso, Zambia, Namibia, Ethiopia, and Mauritius.

An auction is a process in which a good or several goods are offered up for bidding. In so-called procurement auctions, an auctioneer will buy the good (RES-E), from the bidder(s) offering the best bid, for example lowest support level (AURES 2017). The main differences with respect to FITs are: (i) auctions are more transparent in the setting of support levels; (ii) support is restricted to those being awarded in the auction; and (iii) FITs are an open window for a long period of time. Project developers can apply for the FIT anytime whereas, in tenders, project developers can only apply when a call is open. Auctions are now implemented in 67 countries worldwide (up from six countries in 2005) (IRENA 2017b). The attractiveness of auctions lies in several advantages compared to administratively-set support. They mitigate the information asymmetry problem when setting remuneration levels; they are particularly suitable to control costs, expansion, and the technology mix; and they are more likely to lead to allocative efficiency (Haufe and Ehrhart 2015).

Auctions have increasingly been adopted due to their alleged advantages in terms of efficiency in RES-E promotion. This is something particularly convenient in developing countries, where economic resources are more limited, given budget constraints (Spratt *et al.* 2016). A critical problem in these countries is the unavailability of finance. Financial markets tend to be immature and perceived risks are higher (Spratt *et al.* 2016: 7), which raises the cost of finance.

Whether auctions will fulfil the expectations depends on the choice of design elements but also on their combination with other instruments (i.e. a policy mix). Therefore, the aim of this article is to analyse recent experiences with RES-E auctions in SSA. The pros and cons of their design elements are assessed, and an analysis of the functioning of those schemes with respect to different criteria is provided. Whereas previous contributions have analysed specific schemes, mostly the South African one (see e.g. Eberhard, Kolker and Leigland 2014; del Río 2016), but

Table 1 **Main design elements in RES-E auctions**

Design element	Description
Volume	There are three main ways to set the volume auctioned: capacity (MW), generation (MWh) or budget (million €).
Timing	The existence of regular rounds with a schedule is a critical design element. The alternative is stand-alone auctions, i.e. set at irregular intervals.
Diversity	Diversity with respect to technologies, locations, actors, and sizes of the installations could be promoted in an auction by organising different auctions per alternative (e.g. technology-neutral vs technology-specific), by including minimum quota per alternative, by providing different remuneration levels for different alternatives, or by lowering pre-qualification requirements or penalties for specific categories (i.e. small actors).
Participating conditions: facilitation and requirements	Several elements may facilitate the participation in an auction, while others are rather requirements for this participation: • Streamlining of administrative procedures • Supporting dialogue with stakeholders and information provision (e.g. measurement of resource potentials) • Pre-qualification requirements are required in order to participate in the bidding procedure and are adopted to prove the seriousness of bids. They can refer to specifications of the offered project (such as technical requirements, documentation requirements, and preliminary licences) or to the bidding party (providing evidence of the technical or financial capability of the bidding party). They also include economic guarantees (bid bonds). • Local content rules refer to the requirement to use renewable energy equipment which is manufactured by local firms.
Support conditions: types and forms of remuneration	Remuneration in an auction can be provided for generation (MWh) or capacity (MW). Generation-based remuneration can be provided as full payment (FIT) or through a premium top-up on the market price (FIP).
Selection criteria	Price-only auctions are organised using only one criterion (the bid price). In multi-criteria auctions, the price is the main criterion among other criteria (e.g. local content rules, deliverability, impact on local R&D, industry and jobs, and environmental impacts).
Auction format	In a single-item auction there is a single product which is allocated to a single owner and the product cannot be split (e.g. 50MW of PV are allocated to a single bidder, to be deployed at a specific site). In a multi-item auction the auctioned product is split among different owners and bids are submitted for only part or the total auctioned amount (e.g. 50MW of PV are allocated to several bidders, to be deployed at a specific site or in different places).
Auction type	Under sealed-bid auctions, project developers simultaneously submit their bids with an undisclosed offer of the price at which the electricity would be sold. An auctioneer ranks and awards projects until the sum of the quantities offered covers the volume of energy being auctioned. Under the multi-round descending-clock auction, the auctioneer offers a price in an initial round, and developers bid with offers of the quantity they would be willing to provide at that price. The auctioneer then progressively lowers the offered price in successive rounds until the quantity in a bid matches the quantity to be procured. Hybrid models may use the descending-clock auction in a first phase and the sealed-bid auction in a second phase.
Pricing rules	Under uniform pricing, all winners receive the strike price set by the last bid needed to meet the quota (highest accepted bid) or the first bid that does not meet the quota (lowest rejected bid). Under the pay-as-bid (PAB) alternative, the strike price sets the amount of generation eligible for support and each winner receives his/her bid.
Price ceilings	In order to limit the costs of support, the auctioneer can set a maximum bid price.
Realisation period	Deadlines are set for building the projects which have been awarded contracts.
Penalties	Penalties can take different forms: they can forbid participation in successive auctions, reduce the level of support, reduce the length of the support period by the time of the delay, lead to the confiscation of bid bonds or result in penalty payments.

Source Authors' own elaboration based on del Río *et al.* (2015a).

also Uganda (e.g. Castalia LLC 2016) and Zambia (Lucas 2016), there is not a joint comparison of different schemes in SSA, which are very recent. The pros and cons of their design elements have not been studied. Those design elements have not been compared with auctions for RES-E worldwide. Finally, their functioning has not been assessed in a systematic manner, using different criteria.

Accordingly, this article is structured as follows. The next section provides the analytical framework for the analysis of the choice of design elements in RES-E auctions. Section 3 explains the methodology followed in the analysis of those design elements in SSA countries. The analysis is carried out in Section 4. Section 5 discusses the results and concludes.

2 Analytical framework: components for the assessment of design elements in auctions for RES-E[5]

Before an auction is implemented to promote RES-E investments, governments must consider whether this is an appropriate mechanism, taking into account their energy policy priorities. An analysis of the market should be carried out, including potential bidders, potential barriers to RES-E deployment, the situation of the supply chain, grid infrastructures, and so forth. Then specific design elements can be chosen. These are highly context-specific and what works in one market is not necessarily applicable to another.

2.1 Design elements in auctions for RES

The most relevant design elements in RES-E auctions are described in Table 1 (see del Río *et al*. 2015a and del Río 2017a for further details).

Table 2 Description of the criteria and indicators

Criteria	Description
Effectiveness	'*A priori* effectiveness': degree to which the volume offered is contracted. 'Realisation rate effectiveness': degree to which the volume contracted is actually built.
Static efficiency (direct and indirect costs)	Reaching the target at the lowest possible system generation costs (€, €/MWh). An auction outcome is efficient if the bidders with the lowest generation costs are awarded. The relevant costs here include generation costs and transaction costs. Indirect costs (balancing, profile, and grid costs (€, €/MWh)) should be included.
Impact on the local supply chain	This refers to impacts on the local supply chain.
Actor diversity	The participation of small actors is actively encouraged.

Source Adapted from del Río *et al*. (2015a).

2.2 Assessment criteria

Defining 'success' in the choice of design elements is certainly not a trivial issue. Assessment criteria are used for this purpose. Although effectiveness and (static) efficiency are the most common criteria used in the assessments, several contributions expand the set of relevant criteria to include other aspects, such as dynamic efficiency, impact on the local supply chain, and actor diversity (see del Río *et al*. 2015a). However, an unambiguously preferred ranking of criteria does not exist in the literature. Table 2 describes the criteria considered in this article.[6]

Static efficiency refers to the minimisation of the (system) costs of RES-E generation, which can be disaggregated into direct and indirect costs. The former include installation, operation, and maintenance of renewable energy technologies. Direct generation costs refer in this article to allocative efficiency, to which the equi-marginality principle applies.[7] Indirect costs refer to balancing, profile, and grid costs.[8]

2.3 Market, bidders and system effects

The links between specific design elements and criteria to assess those design elements are mediated by the effects on bidders and the market. Design elements affect the participation of bidders in the auction by influencing the costs, risks, and expected benefits of participation (bid levels with respect to generation costs). In general, the higher the costs, the higher the risks or the lower the expected benefits, the lower the number of participants (del Río 2015). The lower the level of competition, the higher the bid prices and the lower the efficiency of the auction (Haufe and Ehrhart 2015). Effectiveness is affected by those design options with an impact on investors' risks (negative influence), competition (negative influence, since a higher level of competition induces more aggressive bidding and, eventually, underbidding and underbuilding), and bid levels (the higher these levels, the higher the realisation rate). The impact at bidders' level translates into market effects, which include the number of bidders in the auction, the diversity of those bidders, and their market concentration. In turn, these aspects have consequences on the functioning of the auction (assessed with the aforementioned criteria).

3 Method

The analysis of the design elements in SSA auctions is based on country case studies. We have selected those countries which have implemented auctions for RES-E and where winning projects have been awarded contracts as of 1 February 2017. These include Zambia, Uganda, and Ghana. Zambia should be lauded for being one of the first SSA countries to run a solar tender efficiently and effectively. The Uganda tender for solar is one of the main pillars of a comprehensive support framework for small-scale renewable energy deployment, the GET FiT programme, that converts the awarded FIP into a grant fully reimbursed after the first five years of operation of the project. Ghana was one of the first countries in SSA to introduce a Renewable Energy Act along with a FIT scheme that attracted the interest of many developers looking

Table 3 **Main socioeconomic and power sector data for the selected countries (2015)**

	Ghana	Uganda	Zambia
Nominal GDP (US$ billion)	36.2	21.9	16.2
GDP per capita (US$)	1,343	619	1,044
Real GDP annual growth (%)	3.4	5.4	3.1
Population (million)	27.4	39	16.2
Unemployment (% of labour force)	4.3	4.1	13.3
Ease of doing business within SSA (1: most friendly, 47: least friendly)	11	12	6
Electricity generation mix (%)	Hydro: 73 Oil: 20 Gas: 7	Hydro: 80 Oil: 14 Other renewables (biomass): 6	Hydro: 97 Oil: 3
Net installed capacity (GW)	3.1	0.9	1.9
Total electricity generation (TWh)	14.1	3.8	11.3
Transmission and distribution losses (%)	27.6	7	16.3
Electrification rate (%)	76	15	26
Per capita electricity consumption (KWh)	362.1	83.8	583.2

Source Based on data from KPMG (2016), IEA (2017).

to develop up to 1.5GW of RES-E-based power plants. However, given the low credit worthiness of the off-taker and the inability of the government to provide a credit enhancement mechanism, only a 20MWp solar PV plant was built under the FIT. In order to unlock the pipeline of projects and select good projects at low prices, the government launched a first auction in 2015.[9] The RES-E auctions analysed in SSA are based on PV. They aim to diversify the electricity generation mix, reducing the dependence on hydro and conventional electricity sources, in a context of fast-growing populations, economies and, thus, electricity demand and considerable solar potentials in those countries. PV projects are deemed particularly suitable for auctions, given their maturity, standardised nature, and the likely high degree of international competition in PV compared to other RES-E technologies (e.g. biomass). The three countries have implemented their first and only auction for RES-E during 2014 and 2016. This is in contrast to South Africa, the country in the SSA region with the largest (seven-year) experience in the organisation of RES-E auctions.

Table 4 **Design elements in auctions for RES-E in selected SSA countries**

Design element (category and subcategory)		Uganda	Zambia	Ghana	Rest of the world*
Period and technological scope		11 months (January–December 2014) Small PV (< 5MW)	2016 PV	12 months (November 2015–November 2016) PV	
1 **Volume**	Generation (GEN), budget (BUD) or capacity-based (CAP)	CAP (20MW)	CAP (2x50MW)	CAP (20MW)	CAP: 21 BUD: 4 GEN: 4
2 **Periodicity**	Schedule (Y/N)	N	N	N	Y: 10 N: 16
3 **Diversity**	Technology-neutral (TN), multi-technology (MT) and technology-specific (TS)	TS (solar PV)	TS (solar PV)	TS (Solar PV)	TS: 20 MT: 2 TN: 5
	Geographically neutral (Y/N)	N; preferred zones for the location identified	N (site-specific)	Y; the developer chooses the site in coordination with the off-taker (ECG)	Y: 17 N: 9
	Actor neutral (Y/N)	Y	Y	Y	Y: 25 N: 1
	Size neutral (Y/N)	N Maximum project capacity 5MW	N	N Maximum project capacity 20MW	Y: 10 N: 16
4 **Participation conditions**	Pre-qualification requirements	Previous experience, financial capability Bids and performance bonds	Experience, expertise, and financial resources Bid bonds Technical requirements	Technical criterion: successful track record of developing PV projects Financial criterion: submission of financial statement for at least 3 years; show positive value of equity and profits for each of the last 3 years	Variable
	Local content rules (Y/N)	N	N	Y (minimum of 20%)	Y: 11 N: 15
	Information provision (Y/N)	Y	N	Y	Y: 6 N: 20

Table 4 **Design elements in auctions for RES-E in selected SSA countries (cont.)**

Design element (category and subcategory)		Uganda	Zambia	Ghana	Rest of the world*
5 **Support cost condition**	Type of remuneration (capacity vs generation)	Generation	Generation	Generation	GEN: 24 CAP: 3
	Form of remuneration (FIT, sliding FIP, fixed FIP)	Sliding FIP (difference between winning bid prices and a FIT 11 US cents/KWh)	FIT	FIT	FIT: 17 sFIP: 8 fFIP: 1
6 **Selection criteria**	Price-only vs multi-criteria	Multi-criteria 70% price 30% (technical, financial, environmental, and social parameters)	Price	Price	Price: 18 Multi-criteria: 8
7 **Auction format**	Multi vs single-item	Multi	Single (project-specific)	Single-item	Single: 6 Multi: 20
8 **Auction type**	Static, dynamic, and hybrid	Static	Static	Static	Static: 25 Dynamic: 0 Hybrid: 1
9 **Pricing rules**	PAB vs uniform	PAB	PAB	PAB	PAB: 21 Uniform: 3 First-price: 3
10 **Ceiling prices**	Ceiling prices (Y/N)	Y	N	Y (ceiling price is the FIT)	Y: 19 N: 7
11 **Realisation period**	Deadlines for construction (years)	2	1	2	Variable
12 **Penalties**		Contract termination, confiscation of bids, and performance bonds	Contract termination, bid bond withheld	Contract termination, confiscation of bids, and performance bonds	Variable

Source Authors' own elaboration.
*Number of countries applying each design element.

The research consisted of country fieldwork and desktop research. Secondary literature, official data, and documents were consulted. This was complemented with interviews with relevant stakeholders in the three countries. Table 3 compares the chosen countries on the basis of selected socioeconomic and energy indicators. The three countries are similar in some respects (medium-size, low gross domestic product (GDP) per capita levels, moderate GDP growth rates, and power mixes strongly based on hydro). However, they show some differences regarding some indicators. Unemployment is comparatively higher in Zambia. Transmission and distribution losses are relatively high in Zambia, and especially in Ghana, and much more modest in Uganda. Ghana has a high electrification rate, which is very low in both Zambia and Uganda. Finally, per capita electricity consumption is orders of magnitude lower in Uganda than in the other two countries.

4 Results

4.1 Design elements

Table 4 summarises and compares the design elements in the three countries. It also shows which design elements are more common in the rest of the world (last column).[10]

A main feature of the schemes in SSA is the strong involvement of international institutions and donors, which have provided funding and technical assistance. In Zambia, a main role has been played by the World Bank through the Scaling Solar programme. Scaling Solar provides advice to assess the right size and location for solar PV power plants in the country's grid; simple and rapid tendering to ensure strong participation and competition from committed industry players; fully developed templates of bankable project documents that can reduce negotiation time; concessional financing and insurance attached to the tender; delivering competitive bidding and ensuring rapid financial close; risk management; and credit enhancement products to lower financing costs and deliver power at lower tariffs.

In Uganda, external support was also provided to implement a tendering process, in this case through the GET FiT programme. GET FiT is supported by the governments of Norway, the UK and Germany, the EU (through the EU Africa Infrastructure Fund) and the World Bank (GET FiT Uganda 2015). The main support instruments implemented within the GET FiT programme include: the GET FiT Premium Payment Mechanism (GFPPM),[11] a standardised set of legal documents (including bankable power purchasing agreements (PPAs), implementation agreements, and developer financing agreements for small independent power producers (IPPs)), World Bank International Development Association (IDA) Partial Risk Guarantee (PRG) Facility, the Technical Assistance (TA) Facility,[12] an interconnection component and additional funds to build new interconnection infrastructure and refurbish existing infrastructure (Castalia LLC 2016). A unique feature of the GFPPM in Uganda is that donor-funded premium payments are received up-front. The developer will receive the first 50 per cent, of the total 20 years' premium payment amount, upon commercial operation. The remaining 50 per cent is paid in annual 10 per cent tranches over the first five years of operation. For biomass and hydro projects, the GFPPM is administratively set. However, due to the rapid fall in the price of PV, it was decided that, for PV projects, the premium should be the result of an auction process.

In Ghana, the government received technical assistance from GIZ (German Society for International Cooperation), which implemented the programme 'Capacity for a Successful Implementation of the Renewable Energy Act in Ghana' (C-SIREA) to design an auction scheme that would allocate at least cost the scarce resources that the country could spend on credit enhancement mechanisms. C-SIREA supported the government in defining the auction process and features, preparing standardised documents (including minimum technical requirements) and supporting the established tender committee along the different phases of the process through the provision of technical and transaction advisers.

Regarding specific design elements adopted in SSA countries, most of them are standard in other countries (Table 4), such as volume defined in capacity terms (instead of generation or budget), and remuneration based on generation (rather than on capacity). The absence of a schedule for auctions is common to other countries, which is somehow surprising, given the detrimental consequences of auctions at irregular intervals or infrequent ones in terms of underbidding, higher investor risks, and constraints to the development of a robust supply chain (see del Río 2017a).

We would like to stress the relevance of some design elements applied in order to address the constraints to investments faced by many SSA countries.

A main difference from other countries is the lack of geographical neutrality, with the exception of South Africa, where auctions are geographically neutral. Auctions in SSA are either site-specific (Uganda and Zambia) or the off-taker has an important role in the choice of the site (the developer chooses the site in coordination with the off-taker in Ghana). Site-specific auctions optimise the integration of variable RES-E into the grid and reduce the administrative burden for project developers. In Uganda, preferred zones for project location were identified.[13] In Zambia, the two projects (50MW each) will be located in the Lusaka South Multi-Facility Economic Zone. The pre-selection of sites is related to the lack of assessments of the stability of the grid and the weak grids in these countries, which encourages the location of projects close to the grid. Simplicity and transparency of design is key to attract investors in a high-risk perceived environment, as in SSA countries. This is why several design element choices have been made: technology-specific (only PV, rather than technology-neutral), sealed-bid with PAB (rather than dynamic auctions or static auctions with uniform pricing), and price-only auctions (instead of multi-criteria-based tenders).

Technological specificity usually brings benefits in terms of dynamic efficiency (if the least mature technologies are promoted). In general, a problem with lower neutrality is market segmentation, which could lead to few bidders and low competition in a given contingent, higher bids (higher support costs), and higher generation costs (lower static efficiency). However, in the case of SSA, technology neutrality is unlikely to lead to more participation and greater competition. The reason is that auctions in this region are particularly suitable for PV, and therefore PV is likely to concentrate most projects in a technology-neutral auction anyway. Auctions in the SSA countries analysed are for PV only. This is in contrast to the auctions in South Africa where, in addition to PV, wind, small hydro, and biomass are included, although they are also technology-specific. There are many PV project developers in these countries. According to one interviewee, this is probably due to the simplicity of these projects compared to other renewable technologies, such as biomass or hydro, where there are barely any projects being developed. Solar PV projects can be implemented more quickly and lead times are thus reduced, which make them particularly suitable for an auction, and for SSA countries which need to have additional generation sources rapidly implemented in order to cover increasing electricity demand needs in a context of power capacity deficits. For those other technology alternatives, an administratively-set FIT may make more sense. Donors have pushed strongly for auctions being based on PV in SSA.

Regarding auction type, static auctions have been the choice. Sealed bids are simpler than dynamic ones, leading to lower participation costs (Maurer and Barroso 2011). Not revealing information during the auction process becomes an advantage of sealed-bid auctions when competition is weak because bidders could use that information to coordinate their bidding, increasing the final price of the auction. Static auctions are less vulnerable to implicit collusion than dynamic ones (Haufe and Ehrhart 2015). However, the winner's curse, which occurs when bidders do not know their actual valuation for the good, is more likely under static auctions.

The pricing rule has been based on pay-as-bid in the three countries, and also in South Africa. It is also the most common choice worldwide. The uniform pricing rule (lowest rejected bid) has a main theoretical advantage: it is incentive compatible, for example there is no incentive for cost exaggeration and bidders bid their true cost. The reason is that with uniform pricing and lowest rejected bid, the bidders' own prices do not influence the price they will be paid in case of winning (Haufe and Ehrhart 2015; Kahn *et al.* 2001; Federico and Rahman 2003). However, uniform pricing leads to uncertainties regarding award prices for bidders in case of winning. Furthermore, in practice, the uniform pricing rule creates a risk of irrational behaviour (underbidding), underbuilding and, thus, ineffectiveness (see del Río 2017a). The support is not inflation-indexed in the three countries.

Two of the auctions in SSA are price-only auctions (Zambia and Ghana) whereas, in Uganda, a multi-criteria auction has been implemented, in which the price represents only 30 per cent of the criteria and technical, financial, environmental, and social parameters account for the rest. Price-only auctions would result in the lowest bidders being awarded contracts, whereas selection of the preferred bidder on criteria other than price allows for the achievement of multiple policy objectives (e.g. local employment, local environment, industrial development, etc.) (del Río, Wigan and Steinhilber 2015b). However, the least-cost bidders might not be selected in multi-criteria auctions, leading to a lower allocative efficiency and higher support costs. According to one interviewee, this was the case in Uganda, where donors decided to implement a multi-criteria analysis among other reasons to line up the selection with their own policy goals. In South Africa, the multi-criteria auctions led to some local benefits (see del Río 2016 for an overview) and a greater acceptance of the scheme, but at the cost of higher complexity (Kruger and Eberhard 2016) and lower transparency.

Pre-qualification requirements and penalties are standard measures to ensure the seriousness of bids and that winning projects are built. But, if set too stringently, they may discourage the participation of actors by increasing the costs of participation, leading to lower levels of competition and higher bid prices and policy costs. This is not the case in the three countries being analysed. According to one interviewee, the technical requirements in Ghana should have been more precise. They were set in very general terms, subject to the interpretation of participants on the required information which had to be submitted. In contrast to the lax requirements in Ghana, technical specifications may have been too strict in Uganda, setting narrow requirements for individual components, rather than for the quality of the power produced.

Finally, one country has implemented local content requirements (Ghana), whereas the other two have not. Local content requirements are a common practice in many countries around the world, with nearly half having adopted them. Their main advantage is the positive local socioeconomic impacts, as in Uganda, where local development opportunities in the rural regions have been encouraged (also due to the project size limit and the selected site). But they may restrict participation in the auction, leading to lower competition and higher bids. This design element is particularly unsuitable when there is not a local supply chain in the specific technologies being eligible to participate in the auction, because it would result in higher energy costs with very modest local benefits. According to one interviewee, the part of the supply chain which could be local was identified in Ghana and the 20 per cent local content requirement was set accordingly. Local content requirements may be in conflict with access to reliable and cheap energy, which is a main priority in SSA countries.

4.2 Assessing the success of auctions in SSA

4.2.1 Actor diversity

The auctions in SSA have attracted a considerable number of actors. In Zambia, 48 solar power developers were attracted, of which 11 were qualified and seven submitted final proposals (IFC 2016). Two companies were awarded contracts, despite the fact that a bidder submitted the lowest bids for the two sites. This is so because the Scaling Solar tender does not allow awarding both sites to the same bidder, which increases actor diversity (at the expense of higher support costs). In Uganda, 24 expressions of interest were received and nine qualified developers were invited to submit technical and price bids. Seven developers submitted their bid packages in August 2014. There were two winning bidders (Meyer, Tenenbaum and Hosier 2015). In Ghana, the auction launched in November 2015 attracted 33 developers, 18 of which were pre-qualified to submit a bid. Five applicants submitted technical and financial proposals and one bidder was recommended for negotiation (Behrle 2017).

Regarding the types of actors, mostly large, international investors have been attracted, although some local developers have participated (in Uganda). In Zambia, they were mainly large, well-established companies, with company domicile mostly in Europe. In Uganda, five of the pre-qualified companies were international solar developers and four were local companies. The high presence of local developers can be explained by the small maximum size of the projects (5MW) that reduces attractiveness for the larger international developers (Castalia LLC 2016) and the pre-existence of a FIT since 2007 that spurred local project developers. The winners of the auctions in the three countries show a combination of African and international well-established firms. In the case of Zambia, there were two winners, both international actors, a large utility from Italy (ENEL) and a PV project developer (First Solar). In the case of Uganda, there were two winners (Access Power MEA and Building Energy). Access Power is a Middle East and Africa (MEA) project developer, founded in 2012. Founded in 2010, Building Energy is one of most prominent Italian's independent renewable energy power producers. In Ghana, BioTherm Energy is Africa's leading IPP. This African-born utility has been successful in securing over 250MW of PPAs on the African continent in seven different countries.

4.2.2 Policy effectiveness

Regarding *a priori* effectiveness, the results can be deemed quite satisfactory. In Uganda and Ghana, 20MW were auctioned and they were all awarded, whereas in Zambia, 100MW were auctioned for the two projects (50MW each), and 73MW were awarded (45MW and 28MW).

It is difficult to judge effectiveness in terms of realisation rate at this stage, since the deadline for building the projects has not ended. However, there are signs that they will be built. In Zambia, the projects are scheduled to be completed in Q3 2017. The fact that the two winners are well-established international companies and the de-risking under the Scaling Solar programme are cause for optimism. One of the 10MW grid-connected solar PV plants awarded in Uganda entered into operation on November 2016. The other (also 10MW) has started construction and is expected to enter into operation in Q3 2017 (GET FiT Uganda 2017). The premium payment (a top-up to the FIT) offered by GET FiT was likely necessary for all power plants supported by the programme. Integration into the electricity system is guaranteed since the sites are preselected based on their capability to evacuate the power from the projects. In addition, investments in transmission infrastructure represent another pillar of GET FiT. In Ghana, it is too early to tell whether the 20MWp PV project awarded in November 2016 will be built. Policy effectiveness has been high in South Africa, both regarding the capacity being procured as well as the capacity expected to enter into operation (South African Government 2015).

The relatively low volumes auctioned in the three cases mean that they will contribute marginally to the countries' power mixes. However, a second round is expected in both Zambia and Ghana. In Uganda, the Electricity Regulatory Authority (ERA) will promote an additional 30MW of solar PV (GET FiT Uganda 2015). According to one interviewee, one main advantage of auctions with respect to FITs regarding effectiveness is that the sovereign guarantee to mitigate the off-taker risk (due to lack of credibility of the utility) provided by the government cannot be given to all projects applying for a FIT (due to scarce resources), and the auction allows the selection of one or two projects, the best ones, to which the guarantee can be provided. Thus, bidders winning the auction know that they will receive such a guarantee, and investors' risks are reduced accordingly. The fact that unsuccessful bidders have not complained is a sign that the processes were well developed and operated.

4.2.3 Static efficiency

Regarding the cost-effectiveness of the schemes, the results are mixed. The Zambian auction has led to remarkable low prices (winning bids of 6.02 US cents/KWh and 7.84 US cents/KWh), which can be partly related to the low risks facilitated by the Scaling Solar programme. According to USAID (2016: 6), the concessional lending provided by the World Bank made these projects commercially viable. The fact that land is provided for free by the Zambian government and the denomination of PPAs in dollars (which reduces currency risks for investors) has helped to further reduce costs. However, the pre-selection of the site has been an issue in Zambia, with Eckhouse and Hirtenstein reporting criticisms by one of the winners in the auction arguing that 'the location of the project isn't ideal… it's not flat and has rocks that will need to be removed' (2016). In addition, the sites are not in places with the highest level of solar radiation in Zambia (del Río 2017b), but they are close to a new substation (Eckhouse and Hirtenstein 2016), which facilitates grid integration in a country with an underdeveloped grid. The first geographically-neutral wind auction in South Africa led to considerable challenges for grid connection and permit approvals for the winning projects (Haffejee 2013), which suggests that the site was not optimal in terms of transmission and land use and that site-specific auctions would have mitigated these problems.

In Uganda, the wining average price was 16.37 US cents/KWh, which was higher than in Zambia and South Africa. The smaller sizes of the project (preventing economies of scale), the creditworthiness of the off-taker, being the first auction, and being a landlocked country are factors negatively affecting cost-effectiveness (Meyer *et al*. 2015). The deadline for obtaining title to land was particularly tight and turnover (revenue) requirements for the solar tender may have been too high (Castalia LLC 2016). Tender documents for the solar procurement identified preferred zones for the location of the proposed plants. Finally, GET FiT's technical specifications may have been too strict, setting narrow requirements for individual components, rather than for the quality of power produced, preventing developers from choosing the least-cost option to meet requirements (Castalia LLC 2016).

In Ghana, the preferred bidder's offer of 11.7 US cents/KWh is lower than the FIT of about 18 US cents/KWh and between the prices in Uganda and Zambia. However, in Ghana, the bidders had a 20 per cent local content requirement and concessional lending was not provided, as in Zambia and Uganda.

One of the reasons for the site-specificity of auctions in SSA is the weaknesses of grids. The limited grid infrastructure in SSA countries constrains the choice of sites. Those with the best solar resources are not chosen and, thus, direct generation costs (and bid prices) are not minimised. The sites in Ghana and Zambia were selected according to grid integration studies, which were performed to identify the amount of variable RES-E which could be fed at various substations, considering technical constraints and resource availability. Although the first auction was not site-specific in Uganda, the next round may be site-specific as the government was supported in developing a grid integration model for variable RES-E, which takes into consideration their technical constraints and economic benefit to the system. Site-specificity can be recommended in SSA given that, as stressed by two interviewees, it is quite complicated to obtain different types of permits in these countries (access to land and infrastructure, connection permit, and environmental impact assessment). Identification of these sites by the government makes it easier for project developers to obtain those permits and they usually favour this design element.

4.2.4 Impact on the local supply chain

The technological diversity provided by the projects is high regarding the electricity generation sources in three countries (since there was no solar PV connected to the grid), but low in the sense that the only RES-E supported by the auction is solar PV. The impact on the local supply chains will likely be low, since they are non-existing in the three countries and most investors are not local ones. This might be a little bit different in Ghana, where there was a 20MWp PV plant prior to the auction, and where the 20 per cent local content requirement and the fact that there will be several other rounds can be expected to positively impact the local supply chain.[14]

5 Discussion and conclusions

This article has analysed the design choices in the auctions in three SSA countries and has provided an initial assessment of their outcomes. Several lessons can be extracted from the experience with auctions in the three countries analysed. Note, however, that the experiences are nonetheless very limited and difficult to translate into general principles.

The three cases suggest that auctions can be an effective and cost-efficient way to introduce non-hydro renewable energy sources in countries with little existing experience in these sources such as those in SSA, changing the perception that cheap renewable energy projects cannot be deployed in poor countries with weak institutions and high costs for conducting business. The simplicity of PV projects makes the setting of support through auctions (rather than administratively) an appropriate choice since competition is likely to be greater than in projects with longer lead times (e.g. biomass).

Auctions for RES-E support might be useful to address some of the constraints to RES-E investments in SSA, including limited economic resources and weak grids. Their simplicity and transparency in setting remuneration levels may make it attractive for potential investors and policymakers alike. Their alleged advantage in terms of allocating efficiently the limited financial support available to RES-E is something particularly convenient in SSA countries, where economic resources are more limited, given budget constraints. They allow for the selection of good projects by experienced developers and discourage lower quality projects to go ahead. They also allow to control for the quantity of RES-E capacity connected to the grid, which is useful for purposes of grid management, particularly in SSA countries, which have weak grids.

However, auctions are not a panacea. This article has shown that, at least for SSA countries, the success of auctions depends on the choice of design elements, but it also depends on the existence of an 'enabling environment', which implies minimum institutional, regulatory, human, financial, and infrastructure capabilities. In particular, auctions need to be complemented by other instruments which directly reduce risks. Thus, auctions must be part of a more comprehensive combination of measures (policy mix) which extends over time and which addresses the barriers to RES-E deployment mentioned in Section 1. Auctions should be part of a broader package of measures aimed at de-risking and capacity building (need for technical assistance for the design and implementation of the auction processes). The experiences in SSA suggest that, in the context of those countries, the auction procedure should be combined with market-based de-risking mechanisms which directly reduce the financing costs and participation risks in order to attract potential bidders, and have appropriate competition levels and lower bid prices. This has been the case in the Scaling Solar programme in Zambia and the GET FiT programme in Uganda, which are programmes with auctions being one among other instruments. External financial support in the form of a package of de-risking/credit enhancement mechanisms has proven useful in this regard.

International institutions, such as the World Bank, and foreign governments have played and can play a very relevant role in this context. In particular, the World Bank Scaling Solar programme has contributed to mitigate international banks' concerns about political risk, reducing the costs of capital and making these emerging markets more appealing to developers. GET FiT includes a donor-financed premium to supplement the Ugandan FIT in the first five years of the project lifetime and the World Bank's PRG to mitigate the risk of default by the utility (Quitzow *et al*. 2016). The standardised PPAs and IAs (implementation agreements) offered by GET FiT reduced the time needed to finance closure and signature of the PPA and were important for lenders, because they reduced the cost of legal due diligence.

In addition to a PPA plus de-risking, the programmes have reinforced the institutional capabilities in those countries by providing technical support. Technical assistance was included in the three countries in order to develop human, regulatory, and institutional capacities, investments in technical capacities for the development of the grid, and financial mechanisms to reduce the financial risks and increase the financing capacity. According to one interviewee, technical assistance is necessary in auctions for RES-E in SSA countries, given the lack of experience in renewable energy technologies and in international tenders. It is particularly recommendable, given the capital intensity of these technologies, in order to give investors more confidence, improving selection of projects and, thus, reducing bid prices.

The governance structure is different across the experiences in the three countries. The GET FiT programme in Uganda has a broader scope in the sense that it has a multi-stakeholder governance structure, involving the ERA, governmental stakeholders, donors, and a number of energy sector and infrastructure investment experts, which monitors progress and proposes measures to address relevant challenges (GET FiT Uganda 2014; Quitzow *et al*. 2016). In this sense, the Zambian case is more 'supply-driven' (the World Bank steered the process rather than empowering local institutions to do it), whereas the cases in Uganda and Ghana are more demand-driven, with a committee with many actors, including local ones, where the respective governments played a dominant role.

Even if auctions are supplemental to other policy measures and tools, they can play an important role in supporting RES-E effectively and cost-effectively. Whether they can meet the expectations depends on the choice of design elements. Most of the design choices made in the SSA auctions are deemed standard and appropriate in order to address the constraints to RES-E investment in these countries. These include alternatives that enhance the simplicity and transparency of design, which are key aspects to attract investors in a high-risk perceived environment such as the one existing in SSA countries: technology-specific (PV), sealed-bid with PAB, and price-only auctions. Site-specific auctions address problems related to a weak grid and obtaining administrative permits, which can be particularly burdensome in SSA countries. The strong pre-qualification requirements help to avoid underbidding and improve the effectiveness of the scheme.

Finally, the transparency of the auction schemes in the three countries should be stressed. This attracts the participation of bidders, which has a positive impact on competition and, thus, on bid prices. However, an underlying problem in the SSA auctions is the lack of proper energy planning, for example documents which indicate how much capacity will be needed in the medium and long terms and which technologies would cover such capacity. This complicates the efficiency and effectiveness of tenders, given the lack of long-term signals on future volumes. Therefore, a national energy planning exercise would increase confidence of the project developers and help government to plan a schedule for the tenders. Currently, each country has only organised a stand-alone auction.

Notes

1 Faculty of Environmental Studies, York University, Toronto, Ontario M3J 1P3, Canada, hlp@yorku.ca; GREA Innovacio Concurrent, INSPIRES Research Centre, Universitat de Lleida, Pere de Cabrera s/n, 25001 Lleida, Spain, hlp1@alumnes.udl.cat.

2 Institute for Public Policies and Goods, Consejo Superior de Investigaciones Científicas (CSIC), Madrid 28037, Spain, pablo.delrio@csic.es.

3 Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), ECREEE C.P. 288, Praia, Cape Verde, mohamed.sokona@giz.de.

4 According to *The Economist* (2016), Africa requires between US$60 and US$90 billion annually to address its energy shortfall, roughly quadruple 2014 investment levels. The World Bank estimates that investments of between US$120 billion and US$160 billion are required per annum in order to provide electricity access to the entire SSA region by 2030.

5 This section draws heavily on and summarises the findings of the EU-funded Auctions for Renewable Energy Support (AURES) project. See del Río *et al*. (2015a, 2015b) and del Río (2015) for further details.

6 Full details on the description of these criteria and how they were derived are provided in del Río *et al*. (2015a).

7 According to Tietenberg (2008:18), the least cost means of achieving a target occurs when the marginal costs of all possible means of achievement are equal.

8 Balancing costs occur due to deviations from schedule of variable RES-E power plants, and the need for operating reserve and intraday adjustments in order to ensure system stability. Profile costs are mainly back-up costs, i.e. additional capacity of dispatchable

technologies required due to the lower capacity credit of non-dispatchable RES-E. Grid costs are related to the reinforcement or extension of transmission or distribution grids as well as congestion management, including re-dispatch required to manage situations of high grid load (Breitschopf and Held 2014).

9 South Africa was not included in the analysis for several reasons: (i) It is a very different country with respect to the others in fundamental aspects: economic structure and economic conditions, size, institutional capacities, etc. (ii) South Africa first implemented its auction scheme in 2011, i.e. it has a long-standing experience in RES auctions. This has likely resulted in policy learning over the years and improvements in the scheme. This is not the case in the other three SSA countries analysed. (iii) South Africa has been a well-researched country regarding RES auctions.

10 This last column is based on the analysis performed by the authors for 26 RES-E auction schemes from around the world.

11 The GET FiT premium gives small power producers FIP payments in addition to the national FIT. The costs for the already existing FIT are passed down to the consumers. However, the costs for the FIP payments are taken up by the donors. Small-scale biomass, hydro, bagasse, and solar PV plants can apply for the FIP payments.

12 This includes: enhancement of skills for FIT tariff modelling, least cost development planning, solar PV tender, project due-diligence expertise, strategic communication, and negotiation.

13 These zones were defined after a review of grid capacities, local loads, and solar radiation rates (Meyer *et al*. 2015). The tender documents also stated that projects had to be located no further than 3km from the grid and that all interconnection costs were to be borne by the bidder and included in tariff bids (Castalia LLC 2016).

14 In fact, two solar PV assembly lines have been inaugurated in Ghana (one of which was part of the winning consortium).

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Commercial-Scale Renewable Energy in South Africa and its Progress to Date*

Lucy Baker

Abstract While South Africa's electricity sector is heavily coal-dependent, the country has recently become an attractive destination for commercial-scale renewable energy investment. This article examines ongoing developments and challenges to the country's Renewable Energy Independent Power Producers' Procurement Programme (RE IPPPP), from inception as a feed-in tariff in 2007, to its launch as a competitive bidding programme in 2011. The article discusses how the programme emerged out of a set of national conditions combined with international trends in renewable energy investment and technology development. The programme's successes include progressive requirements for socioeconomic development. However, since 2016, South Africa's renewable energy industry has faced complex challenges, including resistance by the electricity utility Eskom, itself embroiled within scandals of state capture and corruption, as well as the ability of Eskom's transmission grid to integrate renewable energy generation. Subsequent delays to the programme have generated uncertainty for stakeholders and the future of the industry.

Keywords: renewable energy, electricity, South Africa, wind, solar PV, renewable energy procurement, Eskom.

1 Introduction

South Africa's electricity sector is heavily coal-dependent, accounting for 45 per cent of the country's carbon emissions.[1] However, in recent years the country has become an attractive destination for commercial-scale renewable energy investment since the launch of two key national developments in 2011: a procurement programme for utility-scale renewable energy, and a national electricity master plan which set a target for renewable energy to deliver 9 per cent of supply by 2030. Though South Africa's electricity sector is still dominated by the state-owned, largely coal-fired monopoly utility Eskom, renewable electricity generated by independent power producers (IPPs) now constitutes a small but significant contribution to the overall electricity mix.

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South Africa's Renewable Energy Independent Power Producers' Procurement Programme (RE IPPPP) and the Integrated Resource Plan for electricity (IRP) emerged after various failed attempts to liberalise the country's electricity sector in the post-apartheid era (Baker 2017). The introduction of RE IPPPP facilitated the generation of electricity from both renewable energy sources and by IPPs for the first time, and has since attracted just over R200 billion[2] in investment. RE IPPPP's trajectory and that of the industry it has generated have been influenced by a number of developments at the international and national levels, including a dramatic decline in the cost of renewable energy technologies, as a result of which solar photovoltaic (PV) has become competitive with new build coal; enormous electricity tariff hikes in South Africa in recent years; and a decline in the country's economic growth and related energy demand.

Yet despite RE IPPPP's initial successes, a complexity of political, economic, and technical challenges have led to delays which now threaten its future sustainability and have generated significant uncertainty for renewable energy investors and stakeholders. Revisions to the IRP are also severely delayed. As a result of such challenges, South Africa has fallen in the rankings of Ernst & Young's renewable energy attractiveness index and now sits in 19th place, down from 11th in May 2016 (EY 2017).[3] But as Africa's first mover in renewable energy development, South Africa's progress or lack thereof will have inevitable lessons and spillovers for other countries on the continent where renewable energy activities are currently developing, including Kenya, Ethiopia, Tanzania, and Namibia.

This article focuses on the commercial-scale, grid-connected renewable energy sector that has emerged out of RE IPPPP thus far, for which the technologies permitted are: onshore wind, solar PV, concentrated solar power (CSP), small hydro, biomass, biogas, landfill gas, small hydro, and cogeneration (from agricultural waste). Of this, 43 per cent is for wind and 42 per cent for solar PV. RE IPPPP must be differentiated from other private sector-led electricity generation activities ongoing in South Africa which go beyond the scope of this article, and include a programme for IPPs from coal, gas, and cogeneration yet to be finalised (Baker and Burton, forthcoming), and a small but growing roof-top solar PV market (Korsten 2015).

The article's structure is as follows: Section 2 situates RE IPPPP within the context of the country's electricity sector, including the state-owned monopoly Eskom. Section 3 discusses some of the key policy developments that helped to pave the way for RE IPPPP, including the 1998 White Paper on Energy Policy, the 2003 Renewable Energy White Paper, and the IRP, the country's first national planning document for electricity. As discussed, while the IRP paved the way for RE IPPPP, subsequent hold-ups in the revision of this plan have undermined gains towards a transparent and participatory planning process. Section 4 goes on to examine the emergence of RE IPPPP as a competitive bidding auction, despite original plans for a feed-in tariff. This section includes some of the impressive gains made as a result of the programme's progressive socioeconomic developments, in addition to emerging challenges as a result of delays to the programme. Section 5 explores some of the reasons behind these challenges including Eskom's resistance to the programme and the ongoing crisis within the utility which have resulted in its investment downgrade. Section 6 concludes that renewable energy procurement in South Africa cannot be understood, or resolved, without engaging with the very complex political economy in which it is embedded.

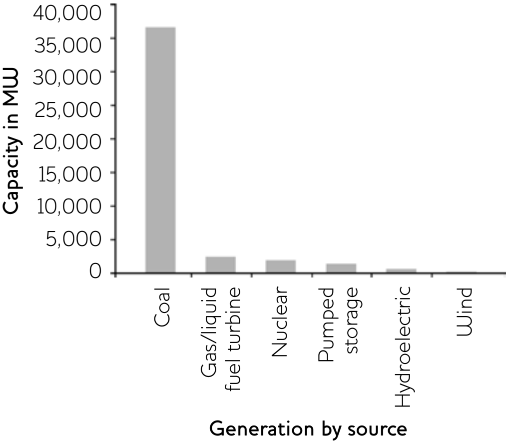
2 South Africa's electricity sector in context and the emergence of RE IPPPP

It is impossible to understand the emergence and development of South Africa's renewable energy procurement programme without examining the broader context of the country's national electricity sector, including the role of the state-owned monopoly Eskom. With a nominal installed capacity of 42.8GW, of which 85 per cent is coal-fired (Eskom 2016; see Figure 1), Eskom owns the transmission grid, generates approximately 95 per cent of the country's electricity supply, and is responsible for 60 per cent of distribution, with the remainder being sold by municipalities. Eskom is also the single buyer of power. The utility has historically focused on large-scale centralised supply, building some of the world's largest coal-fired power plants.

While coal will continue to play an important role in the electricity mix for some decades, Eskom's historical dependence on South Africa's abundant sources of formerly low-cost coal is subject to change due to reasons that include national commitments to reduce its greenhouse gas emissions and significant shifts in the coal market (Burton and Winkler 2014). As discussed in Section 5, following over a decade of periodic load-shedding,[4] Eskom is also undergoing a financial and political crisis and is front and centre of a national scandal on state capture and corruption.

South Africa's relative isolation under apartheid meant that the country avoided the global trend of electricity sector liberalisation pushed by the World Bank and other multilateral and bilateral donors as part of structural adjustment programmes during the 1980s and 1990s (Gratwick and Eberhard 2008). While Eskom retained its monopoly as a state-owned utility, there are long-standing tensions and a spectrum of ideological differences in South Africa and its ruling party the African National Congress (ANC), between those advocating for state ownership of the electricity sector at one end and those for liberalisation and market reform at the other. Eskom has long resisted the introduction of IPPs and the creation of an Independent Systems Operator for transmission as this would undermine its current monopoly control (Baker and Burton, forthcoming). As discussed in Section 3, such tensions are illustrated in the failure to fully implement measures put forward in the 1998 White Paper on Energy Policy which ultimately led to delays to the construction of new generation capacity in the early 2000s. Current delays to RE IPPPP are arguably continued illustration of such tensions.

Figure 1 Eskom's nominal capacity in MW



Source Eskom (2016: 128).

To put Eskom's generation capacity into perspective, the commercial-scale renewable energy capacity that has emerged out of RE IPPPP accounted for approximately 2.9 per cent of the country's electricity supply in 2016 (CSIR 2017a). Under RE IPPPP, 92 projects constituting just over 6,300MW of peak generating capacity have been approved under four bidding rounds and are now at various stages of development (IPPP Office 2017; see Table 2). By the first quarter of 2017, 3,052MW of electricity generation capacity from 56 IPP projects were connected to the national grid and all of the projects approved under rounds one and two of RE IPPPP were operational (IPPP Office 2017).

Alongside RE IPPPP as a programme for utility-scale projects, a small IPP programme was launched in 2013 for projects of between 1MW and 5MW. This gives bidders the option to use equipment supplied by 'South African power generation equipment manufacturers, who may not have international certification,'[5] unlike the main RE IPPPP which insists on internationally certified technologies.

Since mid-2015, electricity generated by solar PV and wind has become cost-competitive with that generated by Eskom's new build coal-fired power plants, Medupi and Kusile. Such a development follows global trends which see solar PV and wind reaching grid parity with conventional sources of energy generation (UNEP/BNEF 2015). Since the start of RE IPPPP, the tariffs at which winning projects will sell their electricity to Eskom have dropped dramatically: the average solar PV tariff has decreased by 75 per cent, wind by 50 per cent, and CSP by 43 per cent (see Table 1). RE IPPPP also accounts for one of the largest investment streams into the country in recent years (Green Cape 2017). At the time of writing, just over R200 billion[6] for both debt and equity had been committed, of which 24 per cent is foreign investment (IPPP Office 2017: 2).

Table 1 **Actual average tariffs, rounds 1–4 of RE IPPPP**

Tariffs	Round 1 (Nov. 2011)	Round 2 (March 2012)	Round 3 (Aug. 2013)	Round 4 (Nov. 2015)	Average percentage drop, Round 1–4
Wind	R 1.52	R 1.19	R 0.87	R 0.62	50%
Solar PV	R 3.65	R 2.18	R 1.17	R 0.62	75%
CSP	R 3.55	R 3.32	R 3.11	R 2.02	

Source Adapted from CSIR (2017a: 5).

Yet despite such progress, and as discussed in further detail in Section 4, the more recent bidding rounds of RE IPPPP have been beset by delays and uncertainty. Winning projects selected under round four were announced in April 2015, with a second announcement generally referred to as round 4.5, taking place in June 2015. But financial close for these projects which should have been reached by April 2016, has been stalled due to Eskom's continued refusal to sign the power purchase agreements (PPAs). A fifth round, which was slated to be announced in 2016 has been put on hold with no clarity at the time of writing. Under the small IPP programme, ten successful projects amounting to 49MW have been announced thus far but have also yet to reach financial close.

Table 2 **Project status under each bidding round of RE IPPPP rounds**

	Round 1	Round 2	Round 3	Round 3.5 (CSP only)	Round 4/4.5	Round 5	Small IPP (project size 1–5MW)
Submission date	November 2011	March 2012	August 2013	March 2014	August 2014	*Should have taken place in mid-2016. Process now stalled*	October 2013
Number of projects approved	28 projects	19 projects	17 projects	2 projects	26 projects	N/A	10 projects
Contracted capacity	1,425MW	1,040MW	1,457MW	200MW	*2,205MW procured but not signed*	N/A	*49MW procured but not signed*
Date of financial close	November 2012	May 2013	December 2014	August 2016	*Not yet signed*	N/A	*Not yet signed*
Operational	Yes	Yes	9 projects by March 2017		No	N/A	No

Source Compiled from DoE (2016), CSIR (2017a: 4), IPPP Office (2017).

3 Key policy developments

A number of national and international developments paved the way for the emergence of what is now RE IPPPP. These include, firstly, national commitments to climate change mitigation following President Jacob Zuma's pledge to reduce carbon emissions by 34 per cent by 2020 and 42 per cent by 2025 below a business-as-usual trajectory at the United Nations Framework Convention on Climate Change (UNFCCC) conference in 2009 (RSA 2015). Secondly, the 2008 global financial crisis contributed to a slump in the renewable energy markets of Europe and the US, which led developers and technology manufacturers to seek new opportunities elsewhere, including in South Africa. Thirdly, policy developments at the national level played a key role, including the 1998 White Paper on Energy Policy, the 2003 White Paper and the IRP, as is now discussed.

The 1998 White Paper on Energy Policy (DME 1998) set out the gradual liberalisation of Eskom's functions into separate generation, distribution, and transmission companies (Gaunt 2008). The subsequent Eskom Conversion Act of 2001 converted the utility from a statutory body to a public company which required that it pay tax and dividends for the first time. Eskom's stakeholder-based electricity council was replaced by a board of directors and the government, represented by the Minister of Public Enterprises, was appointed as the utility's sole shareholder. The White Paper was followed by a 2001 cabinet memo announcing that 30 per cent of electricity supply would be generated by IPPs and a subsequent ruling that Eskom no longer be allowed to build new electricity generation.

Despite these initial steps, key aspects of the 1998 White Paper were never implemented, including the creation of a separate transmission company. Indeed, the Independent Systems and Market Operator Bill that would do this has been continually postponed to date. Significantly, between 1998 and 2003 no new generation was built, reasons for which include resistance from Eskom and the unions, lack of capacity from the then Department of Minerals and Energy, and a lack of regulatory clarity that discouraged potential investors (Eberhard 2007; Baker *et al.* 2015). By 2007, the country was faced with a falling electricity reserve margin and an imminent electricity crisis so in a *volte-face*, a cabinet memo approved that Eskom should be re-allowed to construct more power plants but that 30 per cent of new generation should be built by IPPs. While the power sector reform envisaged by the White Paper was never completed, it still represents an early attempt to achieve what RE IPPPP ultimately managed to do.

A subsequent policy development was the Renewable Energy White Paper, published by the Department of Minerals and Energy in 2003 with support from Danish bilateral assistance. This paper set a target of 10,000GWh of renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar, and small-scale hydro (DME 2003). Though the paper was never formally adopted and the renewable energy commitment it proposed was minimal, it nonetheless provided a stimulus for the initial development of a feed-in tariff, which was to have created a market mechanism in order to meet this target.

Some years later, the introduction of the country's first electricity planning document in May 2011, the IRP, set a renewable energy target of 17,800MW, which if built would deliver 9 per cent of electricity supply by 2030. The IRP is significant because it represents the first time that electricity planning has taken place in South Africa and while the plan's negotiation was delayed and heavily contested, it was still considered something of a breakthrough (Baker *et al.* 2015). Not least under apartheid there was no formal process for electricity planning and policymaking and no department dedicated to it either. Instead, this role was carried out by Eskom, which took all decisions for electricity new build. It was not until the Electricity Regulation Act, introduced in 2006, that the necessary powers for the country's Department of Energy (DoE) (created in 2009 which took over the energy policy function from the former Department of Minerals and Energy) to conduct an open planning process for electricity were established. Under the Act, responsibility was formally allocated to the energy minister to approve the construction of new generation capacity and what the source of that capacity should be. Before an electricity generation project can be granted a licence by the country's electricity regulator, it must align with the technological allocations set by the IRP. The IRP also claims to be consistent with a carbon emissions constraint of 275 million tonnes of carbon dioxide annually after 2024 (DoE 2011: 6).

However, subsequent revisions of the IRP, in keeping with the requirement that the plan be updated every two years have stalled. A second revision was released in 2013 for public comment (DoE 2013) but was never formally adopted by the government. The main reason attributed to this was because the draft advised against the construction of 9.6GW of new nuclear capacity included in the original plan. There are two main reasons for this advice: firstly, due to a decline in economic growth and reduced energy intensity in the economy, the 2013 draft projected a lower electricity demand up until 2030 and by implication a reduced requirement for the construction of new capacity. Secondly, the draft questioned the high associated costs of nuclear technology, stating that 'the revised demand projections suggest that no new nuclear baseload capacity is required until after 2025 (and for lower demand not until at earliest 2035)' (DoE 2013: 8). As further discussed in Section 5, the potential nuclear programme is being pushed by the presidency and some factions of Eskom, and is an area of high political and economic controversy.

A second IRP draft was released in late 2016 for which a country-wide consultation process was held with a closing date for comments of early February 2017.[7] Key concerns expressed by the renewable energy industry and civil society about this document are that it places constraints on the uptake of renewable energy and assumes that the prices of renewable energy technologies are much higher than those reflected in the recent tariffs submitted under RE IPPPP (CSIR 2017b). By mid-2017, at the time of writing, the latest draft of the IRP had yet to be finalised. As a result of such delays, the only valid IRP document is now five years out of date and based on assumptions that no longer apply. It has been argued that despite the gains that the first IRP represented in terms of increased transparency in post-apartheid energy policymaking, the stalling of both the 2013 and 2016 versions signals a return to highly secretive decision-making, characteristic of decision-making in energy under apartheid (Baker *et al.* 2015). Such uncertainty is but one of various challenges facing the future of the country's renewable energy sector. Before exploring these challenges in greater depth, the emergence of RE IPPPP is discussed in Section 4.

4 From REFIT to RE IPPPP

The original mechanism to stimulate South Africa's utility-scale renewable energy sector was to have been in the form of a feed-in tariff, referred to as REFIT, which was originally developed in 2007 by individuals within the electricity regulatory division of the national energy regulator, supported by others from within the Treasury, the Department of Public Enterprises, and the Department of Environmental Affairs, in addition to bilateral technical assistance from Germany and Denmark (Baker 2017). One of REFIT's stated objectives was to create a market mechanism that would 'kick start and stimulate the renewable energy industry in South Africa' in order to meet the target of 10,000GWh of renewable energy by 2013, as set out in the 2003 Renewable Energy White Paper discussed in Section 3.

A feed-in tariff pays IPPs a fixed price for each unit of renewable electricity that they sell to the grid, which is set at a higher rate than the retail price of electricity generated from conventional resources. In comparison, under a competitive bidding system or auction, potential project developers bid for a renewable energy contract below a certain tariff cap. Because the latter system is more competitive, it has become the preferred global model of renewable energy procurement (EY 2014). After a number of years of protracted negotiation, REFIT was scrapped unexpectedly in August 2011 and replaced by a competitive bidding system in the form of RE IPPPP (Baker 2017).

Crucially, the launch of RE IPPPP provided the much-needed certainty to investors, not least for its 20-year government-backed, local currency-denominated PPA, which protects project developers from the risks posed by a fluctuating rand and from any potential failure of Eskom to pay for the electricity generated. Under RE IPPPP, Eskom's role is reduced to the designated buyer of power, while project selection and evaluation is carried out by the IPP-unit. The IPP-unit was set up by National Treasury's Public Private Partnership unit together with foreign technical consultants to deal specifically with RE IPPPP in light of the DoE's lack of capacity to manage a renewable energy procurement programme (more recent developments in relation to the IPP-unit are discussed in further detail in Section 5). RE IPPPP was internationally lauded for its high-quality regulatory framework, tough qualification criteria, and strong economic development and community ownership requirements, and subsequently created an investment climate that quickly became very popular with international renewable energy developers, technology suppliers, and engineering and construction companies.

A notable feature of RE IPPPP is its progressive requirements for socioeconomic development which align closely with priorities outlined in various national plans and documents on growth and industrial policy such as the National Development Plan, the New Growth Path and the Green Economy Accord. Scoring of bids is allocated 70 per cent on the tariff at which IPPs will sell electricity to Eskom and 30 per cent on economic development criteria, which includes factors such as job creation, local content requirements, participation of historically disadvantaged individuals, rural development, community ownership, and skills development. The socioeconomic development criteria must be met before the price submission will be considered with successful bids being the ones that meet the requirements at the lowest price. Such requirements are particularly significant given South Africa's high levels of unemployment, socioeconomic, and racial inequality, and a national skills deficit.

RE IPPPP also requires that project companies, most of which are special purpose vehicles set up for the exclusive purposes of developing, operating, and owning the project, have a minimum of 40 per cent shareholding by national companies, of which a minimum of 12 per cent to be held by black economic empowerment companies[8] and a 2.5 per cent shareholding by the local community within a 50km radius of the project site.

Such requirements have resulted in some impressive gains. According to Green Cape (2017: 21), over 24,000 job years have been created from RE IPPPP, including in the phase of project construction, and operation and maintenance of numerous plants and equipment manufacturing. Community shareholders in projects approved under rounds one to four of RE IPPPP are set to benefit from an income of R29 billion[9] over the 20-year duration of the projects. A number of educational initiatives have also been set up for the creation of 'green technical skills', including at various colleges across the country. For instance, the establishment of the South African Renewable Energy Technology Centre (SARETEC) in the Western Cape offers internationally accredited courses for wind turbine and solar PV service technicians.

RE IPPPP's local content requirements which require that a certain percentage of project spend be dedicated to locally procured equipment, services, and skills have helped to facilitate the establishment of a number of manufacturing and assembly plants mainly for wind towers, solar PV panels and invertors. The bulk of investment in this area has thus far gone to the Western Cape Province including the Atlantis Special Economic

Zone (Green Cape 2017: 36). Given that the local content percentage has increased with each round, by round three all wind towers should have been manufactured in-country. Studies for the potential of the localisation of wind solar PV, and CSP industries have been carried out by various different departments and/or donors and private sector institutions (DTI 2015; Ahlfeldt 2013; SASTELA 2013). This is in addition to the approval of the Special Economic Zone (SEZ) Act in May 2014 which provides financial and other incentives for investment in renewable energy manufacturing (DTI 2013). The aim of an SEZ is to keep as much of the value chain process in one place by supporting a larger manufacturer that would then allow small, medium and micro enterprises and smaller suppliers to input into the value chain through logistics, transport, and other services (Baker and Sovacool 2017).

However, despite the positive developments generated by local content requirements, delays to the programme discussed in further detail in Section 5 have had a knock-on effect on the manufacturing industry. For instance, in June 2017 the heavy manufacturing company DCD sold its share of the R536 million DCD wind tower manufacturing plant to South Africa's Industrial Development Corporation (IDC), which already owned a 20 per cent share, for a mere R1 (Allix 2017).[10] The plant has also had to lay off employees. In the solar PV industry, two leading inverter manufacturers, Germany's SMA and AEG, that both set up in South Africa in 2014 with the aim of supplying to RE IPPPP projects, shut down in 2016, citing the programme's delays as the main reason why (Hopson 2016). Others, including Trina Solar refrained from setting up a manufacturing plant in the first place (Creamer 2015).

A further contributing factor has been the manipulation of local content requirements by some developers, particularly in the case of solar PV in the first three rounds (Baker and Sovacool 2017). Because local content is measured in spend, some developers have met the requirements by purchasing non-module items such as civil works, grid connections, and inverters and importing their modules from abroad (Deign 2016), an act that violates the spirit of the requirements, if not the letter of. This has been exacerbated by the absence of import duties on solar PV modules into South Africa, which tends to give the advantage to imported PV modules which are usually cheaper (Mulcahy 2012), despite the pressure that South African manufacturers have put on the DTI.

In terms of ownership of the country's emerging renewable energy industry, there is also concern that RE IPPPP has privileged large international companies over national ones, reflecting the increasing global consolidation of the renewable energy industry. Such companies, including global majors such as Mainstream Renewable Power, Enel Green Power, Abengoa, Acciona, and Scatec Solar, have had sufficient capital to withstand the various delays in the programme's implementation and have been able to submit winning bids with very low prices in a process that has become increasingly competitive (Baker 2015). Some of the causes of such delays are now discussed in Section 5.

5 Key challenges for renewable energy in South Africa

Beyond the uncertainties in electricity planning discussed in Section 3, the stability and future development of the country's renewable energy industry is threatened by a number of challenges. These include severe delays to the programme due to the refusal by Eskom to sign 37 outstanding PPAs; the downgrading of Eskom's investment credit rating together with that of the national economy in June 2017; management scandals and allegations of corruption linked to Eskom, itself part of broader national political turmoil; and emerging evidence of state capture in relation to the nuclear programme being pushed by Eskom and the Presidency (Bhorat *et al.* 2017).

One key obstacle to the rollout of utility-scale renewable energy in South Africa is the cost of upgrading the transmission grid and substations to absorb growing levels of renewable generation. As RE IPPPP has progressed, grid constraints have become increasingly prevalent and there is now very limited capacity for project connection in areas with good wind and solar resources (Baker *et al.* 2015: 38). This is particularly the case in the Northern Cape Province where the majority of solar PV and CSP projects are located. Under RE IPPPP, Eskom is required to cover the costs of strengthening the transmission network and upgrading substations to connect projects, while IPPs pay to connect their projects to the grid. However, as Eskom is not involved in project selection, it has been unable to determine grid reinforcement needs until the winning projects have been announced and so has not been able to provide geographical incentives to IPPs. Consequently, it is likely that grid availability will be taken into account in future rounds when assessing bid submissions (Green Cape 2017: 27).

A further potential challenge to RE IPPPP is the announcement made in May 2017 by the DoE that the IPP-unit is to be incorporated into the country's Central Energy Fund, a state-owned company that currently owns PetroSA and the Strategic Fuel Fund (Creamer 2017b). This move is significant and unexplained given that the IPP-unit has been highly respected as a high-quality, transparent, and secure professional body since being established in 2011, because as Eberhard, Kolker and Leigland suggest, it 'did not start out with the level of mistrust of private business that sometimes characterises other government agencies in South Africa' (2014: 9). As discussed in Section 4, while the unit functions on behalf of the DoE, it sits outside of formal departmental governmental structures. The incorporation of the unit into the Central Energy Fund has been met with caution by industry, not least given the fund's history of poor governance (Paton 2017).

Most significantly, Eskom has refused to sign PPAs for 37 projects approved under RE IPPPP. While round five was to have been announced in 2016, by mid-2017 this was yet to happen and no capacity has been procured since 2015. Eskom's resistance to RE IPPPP began to be felt in late 2015 when it announced that it would not provide budget quotes, which indicate the potential cost for a renewable energy project to connect to the grid. The utility then announced in July 2016 that it would not sign any new PPAs with IPPs beyond those selected under the expedited round four of RE IPPPP, and refused to sign a PPA for a CSP project approved under round three. Eskom's refusal to sign PPAs is an act that goes beyond its mandate, given that it is the DoE's role to make policy on energy under the 2006 Electricity Regulation Act. The move, which represents a clear attempt by the utility to challenge the procurement of further independent power generation, was eventually condemned by the Treasury and the DoE in September 2016 (Creamer 2016). However, nearly a year later the impasse endures, despite a pledge by Jacob Zuma in February 2017 in his 'state of the nation' address that the PPAs would be signed in April 2017. The utility has not provided a formal reason as to why it has refused to sign the PPAs, though it has claimed firstly that it will make a loss on having to purchase energy from IPPs (SAREC 2017), and secondly that the country's energy supply has stabilised since the most recent round of load-shedding in 2014/15 and therefore additional capacity from renewable energy is unnecessary. In its 2016 annual report, Eskom stated that the purchase of electricity from IPPs accounts for 18 per cent of primary energy but contributes only 4 per cent of the electricity generated (Eskom 2016: 91).

Such resistance by Eskom takes place within the context of a long-term financial and supply-side crisis within the utility for reasons that are entrenched and complex (Baker *et al.* 2015). The latest symptoms of this crisis have resulted in periodic load-shedding since 2006 and led to unsustainably high levels of debt, despite large state bail-outs and a loan from the World Bank as a 'lender of last resort' in 2010 for the controversial Medupi coal-fired power plant. Eskom's average electricity prices increased by approximately 200 per cent between 2008 and 2016,[11] and current tariff decisions are now the subject of legal review (Baker and Burton, forthcoming). There have also been substantial cost overruns in the utility's new build programme, including in the 4.8GW Medupi and Kusile coal-fired power plants. For the time being, electricity supply has now stabilised, due to reasons that include the operationalisation of the first unit of the Medupi coal-fired plant; the introduction of renewable energy from IPPs; and perhaps most significantly, a decline in economic growth and energy demand from the country's energy-intensive industrial users in recent years.

However, Eskom is still very much in crisis and has been subject to repeated scandal over its management, and allegations of corruption and state capture. Firstly, a corruption investigation is taking place into the contracts between Eskom's power stations and their coal suppliers, in particular the irregular sale of the Optimum coal mine (which supplies to the Arnot coal-fired power station) by mining giant Glencore to a company owned by the Indian Gupta family, which has been found to have increasing influence over President Jacob Zuma and his allies. Eskom has stated its refusal and/or inability to make information public regarding its coal supply contracts and volumes burned by each power station (Creamer 2017a). A high-profile investigation into state capture by the country's Public Protector, published in November 2016, heavily implicated the then chief executive of Eskom, Brian Molefe. Molefe swiftly resigned but in several highly controversial twists was then reappointed in early May 2017 and subsequently fired again by the end of the month. In April 2017, Business Leadership South Africa called for Eskom to replace its board. In June, the Chairman of Eskom resigned. Such developments contributed to the downgrading of the country's foreign currency debt to junk status in April 2017 by both S&P Global Ratings and Fitch Ratings (Bisseker 2017) while Eskom was subsequently downgraded to junk status by all three ratings agencies in June 2017.

Despite this, Eskom, backed by the presidency, seems set to pursue its plans for a 9,600MW, state-driven nuclear fleet against all odds: President Zuma's unexpected cabinet shuffle in March 2017 removed finance minister Pravin Gordhan because of his alleged opposition to the nuclear programme and installed a new energy minister believed to be in favour of it. The revised nuclear determination of December 2016 transferred nuclear procurement responsibilities from the DoE to Eskom and the South African Nuclear Energy Corporation. In a case brought by the non-governmental organisations (NGOs) Earth Life South Africa and SAFCEI in late April 2017, the Western Cape High Court judged that the intergovernmental agreements on nuclear cooperation signed in 2014 between South Africa and five countries were unconstitutional and unlawful, particularly in the case of the agreement signed between Eskom and Russia's state-owned nuclear company Rosatom (Ensor 2017). The court further judged that the two determinations released to allow for the nuclear procurement process were irrational, illegal, and unconstitutional (Creamer 2017b). Despite this ruling, the government has since announced that the nuclear procurement programme will start afresh. Given the centralised nature of the technology, it would seem that nuclear power would serve to bolster the interests of a monopoly-controlled electricity system whilst marginalising that of renewable energy.

6 Conclusion

This article has provided an insight into some of the challenges to what was until recently deemed to be a highly successful renewable energy programme. Such challenges include resistance to RE IPPPP by the country's monopoly utility Eskom which has refused to sign outstanding PPAs; delays to the revision of the IRP which would provide certainty on the allocation of future electricity generation capacity; the downgrading of both Eskom's and the country's investment rating; related allegations of state capture and corruption; attempts by the presidency to push through a large nuclear fleet; and uncertainty over the ability of Eskom's transmission grid to integrate increasing levels of renewable energy generation.

As discussed, ownership and control over South Africa's electricity generation, transmission, and distribution remains complex, contested, and political. Decision-making and changes within the country's electricity sector are embedded within complex social, political, and economic forces and relationships. Faced with a financial and supply-side crisis and now at junk investment rating, Eskom is now challenged by a small but significant programme for renewable energy independent power production. Yet due to the utility's resistance, the future of this programme is stalled, and the IRP that has played such a key role in opening possibilities for the development of renewable energy generation is also on hold. Meanwhile, the uncertainty generated by Eskom's crisis and the broader political scandals to which it is linked have discouraged potential investors. The rapid development of renewable energy markets elsewhere, for instance in Mexico, Argentina, Chile, and Morocco, are overtaking South Africa's original successes.

In parallel, a contested and secretive process for the procurement of nuclear power looks subject to continue, despite legal rulings to the contrary. Such a programme, if it goes ahead, would be procured and paid for by the state and in turn electricity consumers, but be constructed and supplied by a foreign company. What then do such developments represent for the future of RE IPPPP, in addition to other structures of the country's electricity governance upon which the renewable energy programme depends?

While a number of Eskom's challenges are undoubtedly technical, particularly with regard to connecting growing levels of renewable energy projects to the grid, recent developments highlight the extent to which the utility has been able to subvert the procurement of renewable energy. Large-scale and successful deployment of renewable energy threatens Eskom's existing monopoly and the preferred technologies that serve to uphold it: coal and nuclear power. The introduction of nuclear power would strengthen Eskom's monopoly stronghold and the paradigm of large-scale, centralised, and state-owned supply.

The scenario examined here seems to present a dichotomy that pits a deeply entrenched, coal-fired, state-controlled monopoly utility at one end that seeks to develop nuclear in order to perpetuate its stronghold, against an emerging privately generated renewable energy industry on the other that is pushing for a shift in infrastructure towards an increasingly flexible electricity grid. While such a dichotomy may be simplistic, such dynamics illustrate long-standing national tensions as discussed in Section 2 over who should govern, generate, and control electricity. These tensions are compounded by significant and increasingly rapid innovations in the technologies that generate electricity. Indeed, the increase in generation from intermittent and variable resources such as wind and solar PV requires much greater flexibility of grid management than South Africa's current model can provide. This raises a key question with regard to the ownership and management of the country's electricity grid, with the continued failure to create an independent transmissions operator as a critical factor in this discussion.

Meanwhile, Eskom and related coalitions within the ruling party are now subject to increasing scrutiny as the networks of state capture, in which institutions of electricity governance are deeply embroiled, start to unravel. Will this scrutiny provide the opportunity that the renewable energy industry needs to overcome the political, economic, and technical obstacles currently blocking its continued development and allow it to resume its previous successes in a way that prioritises the national interest?

Notes

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1 At 215.6Mt CO2 emissions in 2015 (Eskom 2016).

2 Approximately US$15.4 billion based on July 2017 exchange rates. Note that there are differing reports of this investment, probably due to fluctuating exchange rates between the rand and the dollar. For instance, Eberhard and Kåberger (2016) state that US$19 billion was invested between 2010 and 2016.

3 Countries that have overtaken it include the middle-income economies of Morocco, now in 14th place and Argentina in 12th.

4 Load-shedding refers to planned interruption of the electricity supply in order to manage supply-side constraints.

5 www.ipp-smallprojects.co.za/.

6 Approximately US$15.4 billion based on July 2017 exchange rates.

7 www.sapvia.co.za/integrated-resource-plan-irp-consultation-workshop-dates/.

8 Black economic empowerment refers to legislation introduced in the post-apartheid era to attempt to address socioeconomic marginalisation along racial lines.

9 Approximately US$2.2 billion at July 2017 exchange rates.

10 The wind tower manufacturing plant, which opened in 2014, was a joint initiative between the DCD Group, the IDC, and the Coega Development Corporation, which manages the Coega industrial development zone in which the plant is located.

11 Calculated from Eskom's figures: www.eskom.co.za/CustomerCare/TariffsAndCharges/Pages/Tariff_History.aspx.

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The Political Economy of Investment in Renewable Electricity in Kenya

Helen Hoka Osiolo, Ana Pueyo and James Gachanja

Abstract Kenya has been hailed as a successful sub-Saharan African country in attracting private investment for renewable energy. However, energy poverty remains very high, with connectivity rates lower than the average for sub-Saharan Africa and poor quality of supply for those connected. Several constraints persist to achieve universal access to clean and affordable electricity: high system costs, including a deficient transmission and distribution infrastructure; low rural demand and inadequate planning to meet it; and local opposition to large renewable infrastructure. This article considers the political economy of these constraints, explaining how they arose, which policies can address them and which actors back or oppose these policies. The overarching message is that a prominent state role is required to fund the network components of the electricity system and to reach the less profitable segments of society, namely the rural poor. However, this clashes with a dominant private sector-led narrative in the international development community.

Keywords: renewable energy, political economy, Kenya, electricity, sub-Saharan Africa, investment, constraints.

1 Introduction

Kenya is one of the African countries with the largest share of renewables in its generation mix. In 2015, renewables supplied over 70 per cent of electricity, mainly from hydropower and geothermal plants. Hydropower was the dominant source in the past, like in many other African countries, but the government sought to diversify supply to improve energy security. Geothermal was the preferred technology, because it could generate large quantities of least-cost base load electricity, which is the type of electricity that is available all the time to meet minimum demand. To harness their vast geothermal resources located along the Rift Valley, Kenya put in place a long-term geothermal development programme, largely supported by international donors through technical assistance and concessional finance. Kenya has subsequently become the largest producer of geothermal energy in Africa. Wind has also played an increasing role in the generation basket, and the country will soon boast the largest

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wind power plant in Africa, with the 310MW Lake Turkana wind farm currently under construction.

Despite a good track record in attracting private investment for renewable energy generation, some problems still persist, which prevent the goal of achieving universal access to clean, reliable, and affordable energy in Kenya. Connectivity rates remain lower than the sub-Saharan African average, and reliability is low for those connected outside of the cities, mainly as a result of an insufficient transmission and distribution network.

Many constraints prevail to increase investment in renewable energy that improves access to affordable, clean, and reliable electricity in Kenya, but some are more important than others. In a separate publication (Pueyo *et al.* 2017), we applied the new Green Investment Diagnostics methodology to identify the most binding constraints that if tackled could deliver the biggest 'bang for the buck' of the policymaker. We followed a systematic approach using a decision tree analysis drawing from the original growth diagnostics approach (Hausmann, Rodrik and Velasco 2004) and building evidence through the collection of indicators and interviews with key stakeholders from the government, project developers, technical advisers, sectoral associations, and financial institutions. Three key constraints preventing further investment in renewables came up strongly from our analysis: low demand and inability to pay in rural areas; high system costs due to a lack of networking infrastructure and an inflexible generation mix; and serious problems of social acceptance and access to land.

Identifying the most important constraints is essential, but not sufficient. To have their predicted effect, policies need to be implemented, and this is not a technical question, but a matter of political economy. Our political economy analysis looks at the underlying interests behind each constraint, the most promising policies to address them, and the actors who may block or support suitable policies. For our analysis we interviewed ten key stakeholders from the Kenyan energy sector.[1] We posed two questions: how did each of our identified constraints come to be? And who is driving or opposing policies to address it? The political economy analysis of constraints to RE investment required first a record of the policies that exist, and the development of an inventory of stakeholders or actors who have an influence on the targets and policies to improve the investment environment for renewable energy.

These are included in Section 2. Sections 3, 4, and 5 analyse each of the key constraints to investment in Kenya and the related policies that could solve them. Section 6 concludes with a discussion of the actors that support or oppose the policies required and the political alliances that could solve the impasse.

2 Policy and stakeholder mapping for renewable energy in Kenya

The key policy documents for Kenya's energy sector are the Sessional Paper No. 4 of 2004 (Government of Kenya 2004) and the

Energy Act No. 12 of 2006. They set up the institutional framework of the power sector after a process of liberalisation that started in the mid-1990s. These have been recently reviewed through the Energy Bill 2015, to align them to the national development strategy set out in Vision 2030 (Government of Kenya 2007) and the new Constitution of 2010, which established a devolved government system.

The 2006 Energy Act succeeded the Electric Power Act No. 11 of 1997. It provided for the establishment of a number of unbundled organisations evolving from the previous centralised, vertically integrated state utility. The public utility Kengen jointly with private independent power producers (IPPs) would undertake generation, whereas the natural monopolies of transmission and distribution would be separated into two state-owned enterprises: the transmission company KETRACO and the distribution company Kenya Power. While KETRACO is fully owned by the Government of Kenya, Kenya Power is listed on the Nairobi Stock Exchange, with the government holding 50.1 per cent of shares. The 2006 Energy Act also established the Rural Electrification Agency (REA), the Geothermal Development Corporation (GDC), the independent regulator Energy Regulatory Commission (ERC) and the Energy Tribunal that would hear appeals from decisions of the ERC. The GDC is fully owned by the state, and carries geothermal exploration, drilling, and sale of steam to generators. The REA implements the (subsidised) rural electrification programme. At the top of this institutional framework, the Ministry of Energy and Petroleum (MoEP) defines energy policy and is responsible for overall planning.

The Energy Bill 2015 considers new challenges and opportunities for the energy sector, arising from the discovery of domestic fossil fuels and the political decentralisation of the country. The new Energy Bill defines the distribution of functions between national and county governments. Functions of county governments include the development of a county energy plan; the provision of land and rights of way for energy infrastructure; the facilitation of energy demand by planning for industrial parks and other energy-consuming activities; and the enforcement provisions for efficient use of energy and its conservation.

Other policies and regulations relevant for the renewable energy sector include the Least Cost Power Development Plans (LCPDPs), the Feed-in Tariff (FiT) policy and the Energy Local Content Regulations. The LCPDPs are prepared by the MoEP through inter-ministerial and industry consultations and with support from international consultancies. They include electricity demand forecasts, an assessment of energy resources, and expansion plans for generation and transmission capacity. They provide recommendations on a range of investment options, mainly taking into account their cost through the life cycle of projects, measured through the levelised cost of electricity (LCOE).

The Government of Kenya introduced feed-in tariffs in 2008 (revised in 2010 and 2012) to promote private investment in renewable energy by providing a secure long-term price and guaranteed access to the grid. The tariffs apply to grid-connected plants and are valid for a 20-year period from the beginning of the power purchasing agreement (PPA), with approval of the PPAs granted by the ERC. The FiT policy provides electricity purchase guarantees by the main power utility KPLC and includes all power generation categories.

The 2014 Energy Local Content Regulations require that companies operating in the energy sector submit a local content plan when applying for a licence. The local content plan would need to give first consideration to Kenyan services, products, and employees and commit to train Kenyans on the job. They also set minimum local content requirements for energy operations in the country, with levels increasing from the start of the project to 75 per cent of the duration of the project to reach 80 per cent of goods and services, 70–80 per cent of management and technical core staff, and 100 per cent of other staff.

We now discuss the roles of different stakeholders in the power sector. In addition to the national government stakeholders mentioned when describing the 2006 Energy Act, international governments, operating through their development agencies, play a significant role in Kenya's power sector. Donors are responsible for funding a large share of generation, transmission, and distribution infrastructure and are able to influence energy policy through their technical advisers and the conditions set for concessional finance. The MoEP chairs a donor coordination group to define support priorities. Some examples of contributions by donors to Kenya's energy sector are as follows (Tierney *et al.* 2011):

- The World Bank funded the Energy Sector Reform in 1997 and more recently the Kenya Electricity Expansion Project that includes projects in generation, transmission, and distribution.
- Japan has funded several power generation plants, including hydropower, diesel generation, and geothermal.
- France has funded transmission lines between Mombasa and Nairobi and grid extension in rural areas.
- Germany has provided equipment for the Olkaria geothermal power plant.
- Spain has funded a 430km transmission line for the Lake Turkana wind power plant, as well as rural electrification projects.
- The United Kingdom (through the Commonwealth Development Corporation) funded a share of the thermal Tsavo power plant and, lately through the Department for International Development (DFID), has provided funds for project preparation of green mini-grids and leveraging private investment.
- The African Development Bank (AfDB) has funded a transmission system improvement project as well as regional interconnections with Uganda and Ethiopia.

Table 1 **Kenya renewable energy sector stakeholders map**

Stakeholder/arenas	International	National	Local/county
Government	World Bank African Development Bank (AfDB) East Africa Power Pool (EAPP) Japan International Cooperation Agency (JICA) Department for International Development of the UK (DFID) Danish International Development Agency (DANIDA) US Agency for International Development (USAID) French Development Agency (AFD) European Commission International Cooperation and Development (DG DEVCO) Power Africa European Investment Bank (EIB)	Ministry of Energy and Petroleum (MoEP) Ministry of Environment and Mineral Resources (MoENR) The National Treasury (TNT) Ministry of Devolution and Planning (MoDP) Ministry of Water and Irrigation (MoWI) Rural Electrification Agency (REA) Energy Regulatory Commission (ERC) Kenya Investment Authority (KENINVEST)	County government County ministries of energy
Business (both private and state-owned)	Commercial banks Equity investors (i.e. Aldwych International) International IPPs (i.e. Lake Turkana Wind Power, Thika, Rabai, Orpower, Tsavo) Engineering, procurement, and construction (EPC) contractors RE technology manufacturers Private mini-grid developers (e.g. Powerhive, Powergen, SteamaCo) Private sellers of solar home systems (SHS) (e.g. BBOX, M-KOPA)	KENGEN KETRACO GDC Kenya Power KEREA KAM KEPSA Local equity investors Local IPPs Kenya Bankers' Association	
Civil society	WWF CAFOD Practical Action International universities	Nature Kenya Consumer Federation of Kenya (COFEK) National education institutions (e.g. Stanmore University, University of Nairobi) Residential consumers	Agricultural cooperatives Pastoral groups Women's groups Youth groups

Source Authors' own.

The private sector is another important player in Kenya's power sector. As of May 2016, there were 11 IPPs in Kenya, including Iberafrica, Tsavo, OrPower 4, Rabai, Thika, Imenti, Power Technology Solutions, Gulf, Triumph, Mumias, and Aggreko (as emergency power producer). Collectively, they accounted for about one third of the country's installed capacity, predominantly from thermal but also from renewable sources: geothermal, small hydro and bagasse. Further IPP generation projects are in the pipeline, most notably in the wind sector. IPPs are dominated by foreign investors, due to a lack of domestic equity for large infrastructure projects (Pueyo *et al.* 2017). At a smaller scale, several private companies operate in the off-grid market, either selling solar products (solar home systems or solar lanterns) or setting up mini-grids. Kenya is in fact the African country with the largest number of solar home systems installed as well as the largest number of enterprises providing 'pay-as-you-go' solar power (REN21 2016).

The local private sector in the renewable energy sector is represented by the Kenya Private Sector Alliance (KEPSA), the Kenya Association of Manufacturers (KAM), and the Kenya Renewable Energy Association (KEREA). Whereas KEREA mainly represents the small-scale solar industry, KEPSA and KAM represent a broader range of larger and more powerful businesses. Contradictions arise in these groups between businesses involved in the RE generation sector, seeking higher tariffs for renewable energy, and businesses as electricity consumers putting pressure on the government to further reduce electricity prices (Newell *et al.* 2014).

The Kenyan electricity system is skewed towards industrial and urban consumers. Large commercial and industrial customers represent 54 per cent of the national electricity sales but only 0.1 per cent of the total connections. On the other side, domestic consumers represent 90 per cent of the connections but only 25 per cent of the sales of electricity. Geographically, 52 per cent of electricity sales are in the Nairobi area (Kenya Power 2014). Industrial and urban consumers are therefore the most powerful actors in pressuring the government to keep electricity tariffs low.

Finally, civil society is highly influential in Kenya and is considered one of 'Africa's bravest and most vocal', contributing for example to facilitating justice and peaceful coexistence after the 2007–08 post-election violence (Allison 2016). Numerous non-governmental organisations (NGOs) operate in the country, pursuing environmental protection and poverty reduction. National and international universities are also involved in the renewable energy (RE) sector as developers of off-grid generation projects. All these stakeholders are presented in Table 1, classified according to their sector (public, private, civil society) and geographic reach (national, international, local).

3 Low rural demand and inappropriate planning

3.1 Constraints

In this section, we look more in depth at one of the key constraints to further investment in renewables in Kenya identified in Pueyo *et al.* (2017).

It refers to low rural demand and an inadequate rural electrification model that favours grid extension and large centralised generation.

Low levels of demand are due to high poverty rates (higher than the average in sub-Saharan Africa) and a lack of productive uses. According to data from a private company operating mini-grids in the country, the average monthly electricity consumption of their rural consumers is just 5KWh, compared to more than 200KWh in Nairobi. Most households do not have sufficient disposable income to acquire modern electrical appliances and use electricity for basic lighting and powering radios and TVs.[2]

The political origins of rural poverty draw on one side from marginalisation, or skewed allocation of resources for development. In Kenya, the regions with political representation in government tend to draw more economic benefits as they are prioritised for development plans. Development efforts have been concentrated in the past in the capital cities and a number of larger towns following closely the Mombasa–Kisumu railway network and its branches. Kenya's grid extension map is a clear pointer of how resources have been allocated historically. On the other side, Kenya's rural lands are generally unproductive, with some 80 per cent of the territory considered arid or semi-arid and few mineral deposits (Barnett 2016). Traditionally, these unproductive regions have been treated with less priority by the political class.

The political preference for a rural electrification model based on centralised power generation and grid extension arises as Kenyan politicians do not consider decentralised solar power as 'total electricity',[3] due to its lower capacity as compared to grid power. Several rural household surveys in Africa also show a higher willingness to pay for grid electricity than for off-grid solutions, even when consumption levels are low (Peters and Sievert 2016). Accordingly, the current president has supported wholeheartedly the development of large-scale geothermal power, as it can provide baseload power at very low costs. This allocation of priorities has displaced funds for other renewable energy technologies, especially as donors seek to be aligned with the country's development strategy.

Customers served by Kenya Power through the grid or mini-grids benefit from cross-subsidies for consumption tariffs, but must still pay a high fee to cover the costs of connection. This keeps connection rates low even for those households within reach of the grid (Lee *et al.* 2016). Grid extension to rural areas that are not able to pay for it places a heavy financial burden on Kenya's distribution utility and creates tension between the goals of universal access to electricity and financial sustainability of the power supply system.

Private off-grid alternatives providing solar home systems or solar lanterns through pay-as-you-go business models have been very successful in addressing upfront capital barriers. In this case, power suppliers also become financiers of the final consumers through a model in which they pay for the capital cost of systems and customers pay back in instalments. Access to working capital is then essential for suppliers, but it is expensive and hard to get in risky markets, which inevitably increases the price for final consumers.

Solar mini-grids with higher installed capacities allow a wider diversity of electricity uses, comparable to those provided by the national grid. However, when they are not subsidised, they are considered too expensive for most of the rural population and can only target relatively wealthy households and commercial establishments (Carbon Africa *et al.* 2015). Besides, they confront the risk of being crowded out by the cheaper tariffs of the national grid if it reaches a village before mini-grid operators are able to get a return on their investment. There has been a lot of uncertainty about when the grid would be expected to arrive to different regions in Kenya and what would be the fate of private mini-grids.

3.2 Policies to address low demand constraints

Three policies could contribute to address the mismatch between low electricity demand in rural areas and a rural electrification model based on grid extension, which requires a minimum consumption to be financially sustainable:

1 Increasing rural demand through integrated development programmes that enhance the productive potential of rural areas;

2 Adapting supply alternatives to the low rural demand through integrated planning of grid extension and off-grid solutions;

3 Increasing the ability to pay of poor rural consumers through subsidies.

First, we discuss development programmes to increase demand for electricity ahead or in parallel to electrification. The imbalance between urban and rural areas has long been recognised in Kenya. The development plan of 1965–70 targeted sectoral development in rural areas to address this problem. However, redistribution goals were not realised as interventions targeted the areas with the best productive potential. The more recent Vision 2030 is currently implementing Medium Term Plan II (2013 to 2017) in order to deliver accelerated and inclusive economic growth, higher living standards, better education and health care, increased job creation especially for the youth, commercialised agriculture, an improved manufacturing sector, and more diversified exports (Government of Kenya 2007).

Secondly, on integrated planning, the current generation and transmission master plan (2015–35) highlights the importance of off-grid electrification in rural areas to supplement the national grid while progressing towards universal electrification (Lahmeyer International 2016). Several donor initiatives also point at the increasing importance of mini-grids for electrification, such as the proposed World Bank Kenya Off-Grid Solar Access for Underserved Communities, or DFID's green mini-grids facility. The MoEP has commissioned a study to inform mini-grid regulations and business models for the private sector. This study develops a clear framework for the obligations of Kenya Power when the grid reaches a village with a private mini-grid.[4] The ministry is also developing a national electrification strategy where geo-spatial mapping will be used to inform areas, resources, and strategies for electrification by grid, mini-grid, and any other distributed energy. An additional trend towards planning from the bottom-up comes from the 2015 Energy Bill that requires each county to draw up its energy plan. This will require closer collaboration between national and county governments, as well as capacity building at the county level. However, some stakeholders are critical of the benefits of devolution for energy planning, citing that it creates a new layer of transaction costs for investors and can further delay projects due to competition for political power between Members of Parliament (MPs) and county governments.[5]

Thirdly, on the introduction of subsidies for poor consumers, there are three types of subsidies commonly used to address the electrification gap: subsidies to cover capital costs of grid extension or off-grid systems; subsidies to cover connection costs; and cross-subsidies, where lower tariffs for some particular types of consumers are financed by increasing charges to other customers or regions (World Bank 2010). Kenya is currently using all three types. The capital costs of grid extension are usually financed with donor grants or concessional loans. Several programmes are in place to cover or finance the connection costs of the poor. For example, the Last Mile Connectivity project, jointly funded by the World Bank, subsidises connections for households within reach of the grid, mainly in urban slums. Kenya Power also provides credit to potential customers who require financing to pay for their connection fees. Cross-subsidies are in place through a lifeline tariff for low consumption households of up to 50KWh per month, and a uniform tariff policy through which urban consumers effectively subsidise the more expensive to reach rural consumers. However, given the very low rural electrification rate, the scale of this transfer is very low. Cross-subsidies have in fact proved to be very effective in financing rural electrification in middle-income countries that had reached a critical mass of urban connections. However, in much of sub-Saharan Africa, and Kenya in particular, providing rural access through cross-subsidies would involve highly contested price increases for urban and industrial consumers.

Donors are increasingly supporting the idea of a market-led, unsubsidised market for solar photovoltaic (PV) and this seems corroborated by the success of the Kenyan solar PV market. However, this 'unsubsidised' market has relied heavily on donor support to provide seed capital for private entrepreneurs, to enable learning and to create markets (Ockwell and Byrne 2016). This private sector-led narrative has 'ironically been a powerful tool to attract resources from donors to subsidise development that has supported the activities of private sector actors' (*ibid.*: 73).

We find, therefore, that both the subsidies-led and market-led approaches for the provision of electricity to the poor in Kenya depend heavily on donor support. However, the dominance of one model over the other results in a very different distribution of benefits. Subsidy-based approaches confer more power to the national utility and hence are prone to lobbying and rent-seeking. Profit-driven approaches could give opportunities for certain actors to gain excessive rents at the expense of the poorest. This is already the case in Kenya, where some rural consumers can pay ten times the national tariff for electricity supplied by private mini-grids (Pueyo 2015).

4 High system costs

4.1 Constraints

The second constraint we look at in more detail refers to high system costs, due to transmission and distribution infrastructure needs and to the balancing costs of intermittent renewables. Kenya has long suffered from a weak power transmission and distribution infrastructure, due to insufficient investments in upgrading the system (Sessional Paper 4 on Energy 2004, Government of Kenya 2004). A large share of system losses, outages, and voltage fluctuations are due to the poor state of the distribution network (Parsons Brinckerhoff 2013). Besides, Kenya's electrical network faces new challenges, including the long distance between some renewable energy generation resources and demand centres; the goal of universal electrification; and the growing share of intermittent generation, mainly from wind power plants (Lahmeyer International 2016). All these are likely to increase costs for final consumers.

We discuss firstly the need to invest in transmission and distribution infrastructure. The responsibility for developing the national grid lies with the government. Investment needs are detailed in a 20-year Power Generation and Distribution Master Plan, which is periodically updated. The power evacuation plans are informed by the Least Cost Power Development Plan (LCPDP) which defines the generation projects using a long-term trajectory.

After years of neglect, Kenya's grid is currently undergoing a major expansion, driven by demand growth and the increasing importance of energy for international donors. Funding for new transmission and distribution capacity comes from three sources: retained earnings of the transmission and distribution utilities; the national budget; and long-term loans at concessional rates, mainly from international development banks.

Transmission and distribution charges are calculated and approved by the ERC on the basis of performance targets (2004 Sessional Paper on Energy, Government of Kenya 2004). However, most transmission projects utilise treasury and external funding, with only one transmission line funded internally by KETRACO.[6] The government's funding of transmission projects usually focus on local costs, such as the acquisition of wayleaves (right of way for transmission lines), land for substations, and consultancy costs, whereas external partners fund infrastructure costs. The national budget has traditionally marginalised investments in the country's electricity network, as opposed to other, more visible items in the infrastructure budget line, mainly roads.[7] However, the grid is receiving increased internal and external political support. For example, the African Development Bank (AfDB), the French Development Agency (AFD) and the European Investment Bank (EIB) are behind the Last Mile Connectivity Project. The World Bank has financed an informal settlements electrification programme and the Kenya Electricity Modernisation Project (jointly with AFD), that improved the efficiency of the distribution network. Other donors, particularly the UK, are increasingly focusing their support on private sector-led off-grid alternatives.

The second element increasing system costs is the increased penetration of variable renewables, mainly wind. However, another article in this *IDS Bulletin*, by Edwards, Dent and Wade, demonstrates that the large wind projects currently being built in Kenya are likely to contribute significantly to generation adequacy of the system, thanks to the complementarity between the wind resource and demand, and between wind and hydro resources. In any case, large-scale, remote intermittent renewable generation can carry significant risks for the country, as exemplified by the 310MW Lake Turkana Wind Power (LTWP) plant. Two particular clauses in the PPA signed in August 2014 between the project owners and the off-taker, Kenya Power,[8] place a strong burden on the Kenyan counterparty. First, a monthly fine to be paid to the owners of the project in case transmission lines are not completed in time (*Standard Digital* 2017). Second, a 'take-or-pay' clause committing Kenya Power to purchase all the power generated by the wind power plant. This is problematic because wind power may be generated at times when demand in Kenya is low (e.g. at night) and when there is not enough transmission capacity. To honour this clause, Kenya Power has ring-fenced an account funded through higher power bills for consumers. This account, managed by the Treasury and the ERC, is considered crucial for maintaining Kenya's profile as a renewable investment destination (*Business Daily* 2017).

The transmission line for the LTWP is now years late, after severe delays to ensure wayleaves and financial problems of the EPC contractor (*ESI Africa* 2017). The government therefore faces the prospect of having to pay a large fine to the project owners. Whereas PPAs aim at placing the risk on the counterparty more able to deal with it, it is questionable that a country with high levels of poverty and very low electrification rates should transfer to consumers the cost of a risky private investment decision.

4.2 Policies to address high system costs

Several policies and measures could address the system constraints previously identified:

- Prioritise transmission and distribution infrastructure in the national budget, to address chronic underinvestment;

- Consider transmission and distribution (T&D) risks in new RE contracts, to limit the exposure of the national utility to these risks;
- Introduce flexibility in the system, to address the intermittency of wind and solar generation;
- Increase capabilities to manage the increasing shares of intermittent generation in the system.

The first measure proposed involves prioritising transmission and distribution infrastructure over other infrastructure-related projects. Our interview with a representative from KETRACO reveals that the background of key officials at the MoEP has an influence on the types of energy infrastructure that get prioritised. For example, the appointment of a Principal Secretary (PS) at the MoEP with an engineering background has played a part in recent increased investments in the transmission grid as compared to the previous PS, who was an economist.[9] KETRACO assesses the grid reinforcements that are required and prepares a concept note channelled via the MoEP for cabinet approval, after which development funding is sought alongside treasury funding. The PS then acts as the gatekeeper for all investment demands of the state energy agencies.[10]

The second measure proposed requires that the selection of sites for the location of renewable energy generation takes into account the risks related to T&D infrastructure. For example, transmission charges to generators should be location-specific, instead of the typical uniform rate to all network users. Locational transmission charges send the right economic signals to the market players, enabling the market to operate properly with respect to losses and possible grid connection as well as in the long term, encouraging future players to choose their locations accordingly. Nodal prices, defined as the price paid or received for the energy consumed or generated by a growth in demand, are commonly used in South American countries with long transmission distances such as Chile, Argentina, and Peru. Single pricing is the most commonly used approach in the world, but it is inefficient when the location of power generation plants has a significant impact on network costs, like in the case of renewable megaprojects located far from demand (Pérez-Arriaga 2013).

The government could also de-risk sites before power generation plants are procured, by building transmission lines before the plants are built. In this case, a centralised generation and transmission plan would define the optimal siting of generation plants taking into account the transmission costs. The selected sites would then be opened to public tender or renewable energy auctions, once the transmission infrastructure is in place. This would delay cost recovery for transmission infrastructure, which could be addressed through grace periods in the financing conditions of external donors. Some additional policies could be used to incentivise investors to site at convenient places from the transmission network viewpoint.

The third measure involves introducing further flexibility to the Kenyan system by, for example, increasing reserve capacity from hydro, gas, medium speed diesel, or flexible interconnections with neighbouring countries. A flexible interconnection with Ethiopia providing access to their large hydropower generation would be a low-cost, low-carbon option to provide flexibility to the Kenyan system. However, dependence on electricity generated in another country has political implications, 'providing one country with political power over another, involving countries in each other's internal affairs, creating opportunities for corruption, creating political costs in protecting the line, and creating political costs in the process of tariff rationalisation' (Barnett 2014: 19).

The final measure proposed involves capacity building for the system operator to be able to balance a system with a high penetration of renewables. Some programmes are in place to deal with this, such as Power Africa's Grid Management Support Programme (GMSP).[11] The government has also agreed on local content regulations for energy projects to enhance local capabilities. However, a key element is learning-by-doing, which requires time and the gradual building of renewable energy capacity. The sudden increase in intermittent generation from nearly negligible to around 15 per cent of capacity with the LTWP project will make this hard for the Kenyan system operator.

5 Social acceptance and access to land

5.1 Constraints

We finally focus on social acceptance issues, as they have proved to be the most important stumbling block for several renewable energy projects. For example, Olkaria geothermal plants faced court cases and had to disburse significant amounts in resettlement programmes for the local population. Kinangop wind power plant, which would have been the first private wind power plant using FiT had to be abandoned after local protests caused serious disruptions. The LTWP has also faced a court case about illegal land acquisition and has experienced significant delays due to the difficulty in obtaining wayleaves for a transmission line. The delay may be costly for the Kenyan government, as it is liable to compensate developers for the power they cannot sell once the plant is ready to start operations.

Social acceptance is intrinsically related to access to land, as the local population contests the right of private and government developers to use the land where they live or work. Issues of compensation and consultation are further complicated when the current users of the land do not hold formal titles, as is often the case in Kenya. The lack of clarity over land rights also creates the possibility of rent-seeking from local communities seeking compensation for land not used by them.

Previous research suggests that communities are more favourable to projects when they are given full information about their costs and benefits, when benefit-sharing mechanisms are in place, and when they are involved in consultation and decision-making (Wüstenhagen, Wolsink and Bürer 2007).

Our research in Kenya shows that the underlying causes for the problems of social acceptance and access to land are:

- Lack of clarity about land value, land property rights, and the land acquisition process;
- Imbalance between the costs and benefits for local communities (where infrastructure is located), urban residents (getting the service), and investors (profiting from it);
- Lack of clarity about consultation and compensation processes;
- Interference of local politicians seeking political or financial gain from the projects.

We discuss each of these causes in more detail, starting with access to land. There are three land ownership categories in Kenya: private land, public land, and community land.[12] Community land poses the greatest challenge for land acquisition, because it is not clear who holds rights over it. Public land on the other hand is not readily available and is often governed under conservation and environmental legislation that limits its development. There are also limitations to purchase private land, as foreign companies are not allowed to buy agricultural land in Kenya. Private investors can get around this limitation by forming a joint company with locals, but this introduces additional risks.[13] Generally, purchasing land is much harder than gaining the right to use the land for a defined purpose and timeframe through a leasing contract.[14]

The process of accessing land is mainly guided by the Constitution and the Land Act 2012. After the new 2010 Constitution, the devolved government holds public land in trust on behalf of the residents, and the national utilities have to apply to the National Land Commission for approval of valuation of land as quoted in the Land Act 2012. Such valuation is advertised for any public objections and if protested, may lead the process into re-valuation.[15] By introducing a new layer of government for land acquisition transactions, the Constitution has increased transaction costs and timeframes for project development and implementation.[16] An additional problem related to land acquisition comes from the lack of protection against speculation with land prices. When landowners and communities realise that the land is sought for use in electricity generation, prices escalate. Middlemen and political brokers insist on negotiating the price with land buyers and can use a number of tactics to increase the price, such as encouraging locals to settle in the proposed sites before or even after the transaction is completed, and demanding compensation.[17] Land cartels are also a known phenomenon, where landowners collude to increase prices for wayleaves and generation project sites.[18]

The second issue is the imbalance between the costs for local communities where infrastructures are placed and the benefits for the population getting electricity. Project developers may put in place social responsibility programmes including schools, new houses, or other social services, or also give monetary compensation, but demands from local communities often exceed what project developers are ready to offer.[19] Another source of grievance is the arrival of outsiders to work on the projects and the lack of jobs for the local population. In this respect, project developers claim that locals lack the necessary qualifications to carry out the job to an acceptable standard.[20]

The third issue is the lack of clear consultation and compensation guidelines. Project developers find it difficult to engage meaningfully with communities. They often struggle to differentiate legitimate from illegitimate demands for compensation and there has been no guidance on the acceptable level of this compensation. Speculation, encroachment, and settlement on lands demarcated for energy projects can sharply increase the cost of compensation for land since the origination of the project.[21] Several interviewees indicated that early consultations with local project stakeholders are a key element of success. When local communities and politicians are given the chance to provide inputs to the design of the project they are more likely to accept it later on. The LTWP provides an example of successful early consultation with environmentalists and the local population, which led to a change of location from close to Lake Turkana to Marsabit, to minimise damage to local birds.[22] On the other hand, environmentalists were not successful in deterring geothermal exploration around Hells Gate National Park, host to globally endangered species.

The final issue is the involvement of local politicians for political or financial gain from RE projects. The 2010 Constitution has introduced a new layer of political competition, and many expectations from locals about what the county administration can achieve for them. For example, with devolution came expectations that counties would get free electricity for their citizens.[23] The county administration can demand this, as well as jobs or shares in RE companies, and influence the acceptability of a project by locals if these are not granted.[24] The fate of Kinangop reflects the consequences of partnering with the 'wrong' politicians. In this case, project developers partnered with an ex-MP, who was a competitor of the local MP. Fearing that the success of the project would be a political gain for his competitor, the local MP mobilised community members to demonstrate against the project. Fake claims were spread about the project, including links between wind energy and infertility and unbearable noise levels. Demands for compensation and protests escalated until the project had to be abandoned. Kinangop is now seeking compensation from the government for the costs it incurred in project preparation.

5.2 Policies to address social opposition

The four constraints described previously can be addressed through four types of policies. First, land use policies that clarify who holds property rights for the land and who can purchase it; second, clear consultation and compensation guidelines that reduce uncertainty for both investors and communities; third, active participation of communities in management processes; and finally, anti-corruption measures to limit the opportunities for politicians to gain personally from projects.

Firstly, Kenya has traditionally operated without a clearly defined land use policy, with many uncoordinated institutions and pieces of legislation dealing with land use management. The government is currently developing a draft national land use policy that sets a common framework for the optimal utilisation of land resources, taking into account the goals of productivity and sustainability. Additionally, to reduce uncertainty around communal land, the recent Community Land Act 2016 provides for recognition and protection of community land rights. It requires that community lands are mapped, planned, and registered, making it simple for communities to apply for formal land titles without having to register as a legal entity. It also sets that all members of the community are allowed to benefit from it and that decision-making power with regard to the land is vested in a community assembly. County governments will hold in trust all unregistered community land on behalf of the respective communities. There are, however, two key challenges with this legislation: first, the low quorum required for decision-making in communities could be abused by elites and marginalise a large section of those communities. Second, the law is not clear on how to fairly allocate rights over land used by several communities.

Secondly, progress is also being made with regard to clearer consultation guidelines. County public participation guidelines initiated by the Ministry of Devolution and Planning inform public participation practice in county governments, in line with the County Government Act 2012. They set the approach to actively engage the public in policymaking, planning, budgeting, implementation, monitoring, and evaluation. However, these do not contemplate consultations by private investors. Private investors often follow international standards of social consultation that require free, prior, and informed consent (FPIC) from indigenous communities. The most widely followed standards are set by the International Financial Corporation (IFC) and the Equator Principles[25] and are required by multilateral development banks and export credit agencies as a precondition for funding.

Two recent policies aim at providing further clarity on compensation and land prices. The Amended 2016 Land Act introduces a bill that sets a cap on compensations required for the use of land for public purposes and limits the power held by property owners in this respect. The amendment also prohibits unlawful occupation of private, community, or public land and sets a procedure for eviction. On the other hand, the National Land Value Index (amendment) Bill 2016 seeks to create a national reference point for land values, which would help the government, investors, and landowners negotiate compensation and resist speculation. The bill also proposes that once land is officially taken and funds committed by the National Land Commission, development cannot be stopped by any court. Landowners can receive a monetary compensation, land swaps, or government bonds in return.

The previously mentioned local content regulations seek further community involvement, requiring that energy projects employ and train national Kenyans. However, there are no requirements that beneficiaries are from the local communities where the projects are located.

In spite of these recent developments, Kenya still lacks an explicit policy framework that details benefit-sharing mechanisms (BSMs) and community participation in management processes, both considered essential in the literature on the social acceptance of renewables (Hammami, Chtourou and Triki 2015). Compensation for communities should be based on independent analyses showing the distribution of costs and benefits among the different interest groups. Some frequently used BSMs include sharing revenues with the local community, creating local jobs, preferential electricity tariffs, building roads, or investing in other public services such as schools or health centres. Some of these activities are carried *ad hoc* by energy projects, but without following a systematic approach. On the other hand, community participation needs to take place from the project conception and all the way through its operation, using transparent and participatory processes (*ibid*.; Shinke and Klawitter 2015).

6 Discussion: the politics of removing constraints to investment in renewable energy

Kenya has been hailed as one of the most successful African countries in attracting renewable energy investment. However, many barriers persist that endanger the goal of universal access to clean, reliable, and affordable energy by 2030. Three particular constraints stand out: the inadequacy of generation, transmission, and distribution planning practices for the low rural demand; the high system costs; and strong social opposition to large-scale infrastructure, including renewable energy. The first two problems are shared in many other African countries and the last one is particularly acute in Kenya. This article has tried to better understand the factors that underlie these three constraints by looking at how they emerged, and what are the policies that can address them. In this section, we discuss the actors that could drive or oppose the implementation of these policies and we conclude by underscoring the role of the state.

At the heart of Kenya's problems there is a large pool of unmet needs and competition for scarce resources dominated by the ruling elite. As noted in Ng'ethe, Katumanga and Williams, '[T]he elite have generally opposed pro-poor change where this threatens their interests and sources of patronage' (2004: 4). However, '[I]n the past, reforms have usually occurred when the elite has come under sustained pressure from interest groups' (as cited in Barnett 2016: session 5, page 3). Whereas the supply of electricity has traditionally focused on large industrial customers and the urban population, increased pressure to provide access for all is now coming jointly from the international development community and the local devolved government. International donors provide finance and technical assistance, while local governments seek to provide basic services to their population and can contribute to the social acceptance of infrastructure projects. Between these two actors there are two powerful national institutions acting as gatekeepers for the allocation of funding priorities: the National Treasury and the MoEP.

International development institutions seek poverty eradication and increasing convergence with the welfare levels of developed countries, while keeping developing countries' debt under control. They increasingly follow a private sector-led narrative, where funds are provided strategically to mobilise a larger share of private finance (Pueyo, Orraca and Godfrey-Woods 2015). There is still a general perception of state-owned enterprises as being inefficient and corrupt, whereas private entrepreneurs represent efficiency through their profit-seeking behaviour and competition. Under this profit-driven approach, natural monopolies such as the network components of the electricity system, and non-profitable segments such as rural electrification often fall between the cracks.

The National Treasury and the MoEP of Kenya are driven by a growth imperative. They support investment in least-cost generation and increased energy efficiency, as these contribute to the ambitious economic growth targets set up in the Vision 2030 strategy. The least-cost narrative is very much influenced by large industry, which is the main electricity consumer.

The devolved governments, on the other hand, seek to transfer central funds to their localities, to improve development outcomes of their often-neglected communities. They are likely to oppose large infrastructure projects geared towards urban areas when their counties bear the costs but reap none of the benefits. Civil society seeks equal access to energy services, and compensation for the economic, social, or environmental costs of large infrastructure located in their native land.

The different interests of these actors can align in some specific policies. For example, policies to increase the productivity of rural areas heavily dependent on agriculture could increase rural incomes and therefore the ability to pay for electricity connections and consumption. At the same time, energy interventions could contribute to increase rural productivity through, for example, irrigation systems, and the mechanisation of agriculture, the development of agricultural processing, and other non-farm activities. A larger rural demand would improve the financial viability of public grid extension programmes or private mini-grids and reduce the cost per unit of electricity for all rural consumers. Such an approach requires close collaboration between energy planners making decisions about the most appropriate energy supply technology, and rural development planners influencing the size and composition of the rural demand. The dialogue between supply and demand should reflect on bottom-up rural electrification plans that take into account the location of customers and their current and prospective demand on the basis of realistic development opportunities. Kenya is taking steps in that direction through the increased role of the devolved government in energy planning and new rural electrification planning initiatives using geographic information.

In other cases, actors' interests clash; for example, when final consumers are asked to pay for the risks taken by private developers (like the LTWP) or for the cost of rural electrification through new items in their electricity bill. In the first case, support follows the narrative that Kenya needs to maintain its status as a desirable destination for private sector investment by keeping risks low for investors. The second case follows an energy justice narrative, where the poorer should not be made to pay more for basic services than the wealthier, even if they are more expensive to reach. The interests of local communities and large industrial and urban consumers also clash when large renewable energy infrastructure located in rural areas feeds power directly to the transmission system heading to Nairobi.

The international development community is trying to make the narratives of energy justice and private sector-led development converge through the promotion of private mini-grids. For example, the DFID-funded Green Mini-Grid Facility (GMF) was announced in March 2017 to provide investment grants and technical assistance to leverage private investment in mini-grids in Kenya. It is certainly an attractive narrative that private entrepreneurs could target the poorest populations by offering them an affordable service that they are able to pay for. However, the prices that these mini-grids can achieve are still significantly higher than those paid by those connected to the national grid and are only affordable to a small share of the rural population (Carbon Africa *et al.* 2015). The cost of finance faced by small entrepreneurs is also much higher than that enjoyed by state-owned enterprises, and economies of scale will not materialise without common standards for grid compatibility of mini-grids.

To conclude, Kenya's goal of sustainable electricity for all requires a set of actors with conflicting interests to align their position. Donors' pressure towards decentralised, private sector-led electrification needs to align with the national government's preference towards large-scale, centralised generation, as this could generate the funds required to cross-subsidise poor and remote consumers. The dichotomy between private versus public-led electrification also needs to be solved. Private developers selling to the grid require access to the network elements of the system. On the other hand, private off-grid supply could be easily crowded out by the national grid offering electricity at a fraction of the price.

A fine balance is hence required to maintain the remarkable (and recent) financial sustainability of the Kenyan power sector. The independence of the regulator and the national distribution company are key to achieve this. The state and international donors have a crucial role in allocating funds to members of society less able to afford the full cost of electricity and to the natural monopolies of transmission and distribution. Public actors should also support structural transformation, increasing the productivity of the agricultural sector until rural areas are able to pay for the full cost of electrification. While demand remains low in rural areas, the private sector will keep focusing on the most profitable segments of the market, whether large-scale generation to supply industry and urban households connected to the grid, or small-scale solutions for rural consumers that can pay for them. Even if technological progress has improved affordability of small-scale solar solutions for an increasing number of rural consumers, public subsidies still have an important role to play for universal access to become a reality in Kenya.

Notes

1 Including two representatives from private off-grid generation developers (Powergen and Powerhive); the national transmission utility (KETRACO); one donor (Power Africa); civil society (Nature Kenya, Strathmore University); the energy regulator ERC; the Ministry of Land; an independent power producer (IPP) (Kenya Tea Development Authority – Power); and the National Environment Management Authority.
2 Interview with Powerhive, 2016.
3 Interview with ERC, 2016.
4 www.eca-uk.com/2017/01/04/kenya-mini-grid-regulatory-framework-development/.
5 Interviews with donor representative and with Ministry of Planning, 2016.
6 Interview with KETRACO, 2016.
7 Interview with Power Africa, 2016.
8 The off-taker is the counterparty in the PPA purchasing all the power from the plant.
9 Interview with KETRACO, 2016.
10 Interview with KETRACO, 2016.
11 Interview with Power Africa, 2016.
12 Interview with the Ministry of Planning, 2016.
13 Interview with Powerhive, 2016.
14 Interview with the Ministry of Planning, 2016.
15 Interview with KETRACO, 2016.
16 Interview with KETRACO, 2016.
17 Interview with Powerhive, 2016. This problem was also detailed in interviews with an international EPC contractor as detailed in Pueyo *et al.* (2017).
18 Interview with Energy Regulatory Commission, 2016.
19 Interview with National Environmental Management Agency, 2016.
20 Interview with KETRACO, 2016.
21 Interviews with ERC and KETRACO, 2016.
22 Interview with Nature Kenya, 2016.
23 Interview with KETRACO, 2016.
24 Interview with ERC, 2016.
25 The Equator Principles are a risk management framework adopted by financial institutions to assess and manage the environmental and social risks of projects. See www.equator-principles.com.

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The Political Economy of Renewable Energy Investment in Ghana

Simon Bawakyillenuo[*1]

Abstract The high level of fossil fuel consumption globally is wreaking havoc on the global climate through the emissions of greenhouse gases. Against this backdrop, there have been calls from national and international stakeholders for a transition towards renewable energy (RE). However, the investment and adoption of renewable energy technologies especially, in developing countries have been woefully inadequate. Even though various policy and legislative instruments in support of RE development abound in Ghana, the contribution of RE to the energy generation mix is notably insignificant, due to constraints that limit high investment. Using the Political Economy Analysis (PEA) approach, this article examines the deficiencies in these policy strategies, and unravels the complexity as well as the alignments of interests of stakeholders regarding policies that could provide a more favourable investment in renewables in Ghana. The article recommends that Ghana's leaders champion those policies with the highest support across all stakeholders.

Keywords: political economy, renewable energy, binding constraints, Ghana, low investment, abundant policies.

1 Introduction

Provisions for renewable energy (RE) development have featured in the energy policy regimes of Ghana for some time now. The just-ended national Medium-Term Development Policy – Ghana Shared Growth and Development Agenda Two (GSGDA II) – talks about the need to increase the proportion of RE in the energy supply mix, particularly solar, wind, mini-hydro, and waste-to-energy (NDPC 2014). The current energy policy of the country also sets a policy target of 10 per cent contribution of RE to the country's energy generation mix by 2020 (MoE 2010). In addition, there is the Renewable Energy Act, 2011 (Act 832), which gives legislative backing to the promotion and development of renewable energy technologies (RETs). The feed-in tariff (FiT), mini-grid infrastructure systems development and the RE Fund are provisions in the RE Act (Act 832) that demonstrate Ghana's quest to diversify its energy sources to take account of RE.

Notwithstanding the existence of these various policies and legislative instruments in support of RE development in Ghana, the contribution

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of RE sources to the country's energy generation mix is abysmal. At present, the share of RE in the power generation mix is about 0.1 per cent (Energy Commission of Ghana 2015) and with less than four years left, the 10 per cent share target is unlikely to be met by 2020. Paradoxically, Ghana is signatory to several international agreements, including the post-2015 United Nations Sustainable Development Goals that aim at tackling climate change and variability through environmentally sustainable development pathways such as the enhancement of RETs. In practice, however, the development trajectories being pursued are unsustainable and not in sync with these goals (UNEP 2013, 2015). Presently, about 56.5 per cent of installed electricity generation capacity in Ghana is fossil fuel-based thermal, generating about 49 per cent of total electricity (Energy Commission of Ghana 2016). What is more, the government envisions increasing thermal power generation to about 80 per cent in the next decade.[2] This raises a question regarding which pathways could lead to the development of the RE niche within the existing energy regime (Power *et al.* 2016).

This article aims to unravel the complexity of stakeholders' alignments and interests with regard to policies to support RE investment in Ghana. Moreover, this article contributes to expanding the literature on the understudied political economy of energy transitions (Power *et al.* 2016 citing Goldthau and Sovacool 2012), especially in a developing country like Ghana.

The article is structured into seven sections. Following this introductory section is Section 2, which reviews literature on the political economy of RE investment. Section 3 discusses the historical policy and institutional regimes of Ghana's energy sector. Section 4 details the Political Economy Analysis (PEA) methodological perspectives underpinning this article and how the binding constraints on RE investment in Ghana were identified, as well as the mapping of promising policies with potential to address these constraints. Discussions and analyses of the obstructing factors of the key policies and initiatives fundamental to RE investment are encapsulated in Section 5. Section 6 covers the intervention policies, while Section 7 provides the conclusion.

2 The political economy of renewable energy investment – a review

Until the twenty-first century, fossil fuel sources dominated global energy supply and consumption. They accounted for about 80 per cent of the world's total primary energy supply and 64 per cent of electricity generation in 1999 (Jacobsson and Lauber 2006). In recent times, however, there are increasing calls for a paradigm shift towards RE generation (*ibid.*). These calls are aimed at ensuring the mitigation of greenhouse gas (GHG) emissions from fossil fuel consumption. Nonetheless, the adoption of RETs is met with stiff opposition, mainly from high-profile fossil fuel energy players, who obstruct the process and subsequently promote their interest (Barnett, Stockbridge and Kingsmill 2016). Additionally, the uncertainty related to who bears the cost of the transition to clean energy landscapes, especially in developing countries, further obstructs the process (Newell and Mulvaney 2013).

A complete understanding of the reasons behind such opposition is crucial for the successful development of RE since that will help provide sustainable solutions to the root causes reinforcing the low investment in a developing country such as Ghana. A PEA approach provides the necessary scope to unearth such reasons that fuel opposition from stakeholders to investment in RE. Newell *et al*. (2014) observe that a political economy analysis creates the pathway to get beneath the formal structures in a bid to discover the underlying interests, incentives, and institutions that foster or frustrate change. It could also help to consolidate the interests of all energy players in order to facilitate the paradigm shift of accelerating the rate of development of RETs. According to Arndt (1983), the political economy (PE) concept has a broad range of applications and offers in-depth analysis of what an ordinary study may not be able to tease out. For instance, a PE application to an organisation could enhance a better understanding of the interaction between sets of major economic and sociopolitical forces that affect collective behaviour and performances within such an organisation (Achrol, Reve and Stern 1983). In the energy sector, its application aids in the understanding of the complexity surrounding clean energy transitional issues – justice, injustice, losers, and winners (Newell and Mulvaney 2013; Baker, Newell and Phillips 2014; Power *et al*. 2016). According to Isoaho, Goritz and Schulz (2016), the recent application of PEA in energy-related issues such as RE development is due to the fact that socio-technical literature failed to address adequately the complexity and dynamics of clean energy development. A PEA should therefore identify all forms of:

> competing ideas, interests, values and preferences; where specific groups and interests struggle over the control, production, use and distribution of resources; where conflict is negotiated; where bargains are struck; and where formal and informal political settlements, alliances and coalitions are made and broken (Hudson and Leftwich 2014: 6, cited in Barnett 2014).

Unequivocally, the use of PEA should help to understand why socially and economically, desirable plans and policies are regarded as being difficult to be implemented by policymakers (Barnett *et al*. 2016).

Khan (2011), using a PEA approach, studied the situation under which a ruling government or a coalition in the power sector will promote clean energy development. He documents that a change towards clean energy transition is most likely to happen if governments or ruling coalitions face pressure from powerful groups in society who either are negatively affected by current non-renewable energy sources or stand to benefit from clean energy promotion. In the study by Tsebelis (2002), which focuses on India, PEA underpins the analysis on the extent to which RE sources can be developed to their fullest capacity in the country. The study concludes that, in order to bring RE development into the policy arena, stakeholders with vested interests and veto powers – such as the mining companies, and the coal power producers – are critical to breaking strong oppositions to RE development. Other works (Newell and Mulvaney 2013), however, reiterate the need to be mindful of the justice dimension of 'clean energy' or low-carbon transition amid the quest for success.

In related studies, Fattouh and El-Katiri (2015) and Oda and Tsujita (2010) also applied PEA to study factors that prevent governments and energy players from implementing certain economic and environmental policies. Citizenry agitations for fair share of natural resources (oils and fossil resources and grid extension) and the fear of losing elections by political actors emerged strongly as factors accounting for the non-implementation of such policies. The Middle East and North Africa (MENA) region lends clear evidence to this, in which the incessant protests and agitations waged by the citizenry for social equity and fair sharing of national resources have compelled governments to subsidise fossil fuel energy sources (Fattouh and El-Katiri 2015). In Asia, Commander (2012) observes similar occurrences, as political unrest and protests forced governments to keep prices of petrol and diesel substantively lower than international prices between 2008 and 2010. Such agitations from citizens and the fear of losing political power have the effect of influencing governments and policymakers to overlook viable RE development policies. Oda and Tsujita (2010) argue that these protests and political unrest are more common in jurisdictions that lack democratic institutions. Brown and Mobarak (2009) further argue that countries without democratic political systems and institutional structures often use energy allocations and subsidies as tools for political advantage. Supporting this view, Scott and Seth (2013) submit that often, in non-democratic states, electricity distribution favours industries rather than residential areas, which becomes a source of the protest. Such motives and actions greatly affect the development of RE.

Gupta and Köhlin (2006) note that there is an opportunity cost of failing to sell energy at actual market prices, and as such, revenue can be used by government in diverse ways including the reduction of budget deficit and the size of the public debt; and increasing investment expenditure in cheaper, clean, and environmentally friendly energy technologies which can generate several socioeconomic benefits. According to Sdralevich *et al.* (2014), although these policies seek to promote social equity, in reality they actually benefit people within the middle and upper classes. Indicative of the above literature is the increasing economic and environmental costs of fossil fuel faced by many developing economies, yet RE sources in these economies remain significantly underdeveloped through inadequate investments.

3 Policy and institutional regimes of Ghana's energy sector

Electricity generation in Ghana can broadly be classified into three main phases: 'before the Akosombo era' (1914 to 1966), the 'Hydro Years' (1966 to mid-1980s) and the 'Thermal Complementation Years' (from mid-1980s to present) (ISSER 2005). The pre-Akosombo era had small-scale electricity generation from diesel-powered generators. These were owned by individuals, institutions, and towns that could afford them. The first public power plant was established in 1914 in Sekondi and was used to power the operations and activities of the then Gold Coast Railway Administration (GCRA) (*ibid*.). In 1922, small-scale public electricity was established and operated by the then public works department (PWD) to electrify major towns in Ghana. It covered the Accra township and later in 1926, coverage was extended to Koforidua. Between 1927 and 1932, the PWD undertook a restricted evening supply arrangement system to Kumasi, Swedru, Tamale, and Cape Coast townships (*ibid.*). During this era, determination of power generation was carried out solely by Ghana's colonial leaders, some public institutions (such as PWD and GCRA), and individuals who were financially sound to own and operate generator sets. Issues of climate change and RE development were non-existent in the objectives of energy generation as they were not subjects of utmost concern at the time.

Energy security and to some extent RE development, however, became more relevant in the 'Hydro Years' of power generation in Ghana. The desire to develop Ghana's huge bauxite reserves as part of having integrated the bauxite and aluminium industries marked the beginning of the hydro years (*ibid*.). This era saw a much more organised power sector, as Cabinet passed the Volta River Development Act 1961 (Act 46) for the establishment of the Volta River Authority (VRA). The VRA was mandated to foresee the construction of the Akosombo dam, its power station as well as the generation of electricity (*ibid.*). In 1967, a law (NLCD 125) was passed for the establishment of the Electricity Corporation of Ghana (ECG). This enhanced the setting up of vibrant institutions to oversee adequate production of energy that fed industries and businesses, and subsequently offered job opportunities in diverse forms. Energy security emerged as an important element under this era because other initiatives were introduced to develop more hydro sites in addition to the Akosombo Power Plant (Edjekumhene, Amadu and Brew-Hammond 2001). Unlike the pre-hydro years, this era marked the beginning of modern electricity generation in Ghana and did involve the participation of several stakeholders.

The thermal complementary phase of Ghana's power sector was highly driven by energy security issues and little about the development of other competitive energy resources. Climate change mitigation issues were of little concern as evidence shows that the development of the power sector within this era propelled the increase in the country's carbon footprint. According to Opam and Turkson (2000), this era was necessitated by the adverse effect of the prolonged drought that occurred between 1982 and 1984 in the country. On the basis of the drought, the generation potentials of the existing two hydro power plants (Akosombo and Kpong) were affected as the available water was far below the minimum operating level (*ibid.*). The shortage in electricity supply amid the growing energy demand sector necessitated the major reformation of the power sector. Thus, in 1985, the Government of Ghana commissioned the 'Ghana Generation Planning Study' (GGPS) to help identify alternative energy sources that will aid in reducing the vulnerability of the hydro power systems (ISSER 2005). The study recommended thermal as part of Ghana's energy mix.

Lack of competitiveness and private sector participation, coupled with the poor financial performance of Ghana's power sector, drove its reformation in the 1990s. According to Opam and Turkson (2000), such factors made Ghana's traditional financiers (e.g. the World Bank) reluctant in providing extra financial resources to support the thermal complementary phase of the power sector. The GGPS of the VRA estimated over US$1.5bn as the amount that was needed to finance infrastructure development at the electricity sector of Ghana (ISSER 2005). This came at the time when the World Bank was unwilling to finance non-performing energy sectors in Africa unless issues of transparency, regulation, importation of services, commercialisation and corporatisation, commitment lending, and private investment were met by energy sectors (Amoako-Tuffor and Asamoah 2015). However, the motives for undertaking this reform were not only limited to the financial challenges confronting the sector. According to Opam, UN ECOSOC and UN ECA (1995), issues of productivity losses of the overall economy as a result of the ineffective operation of the then power sector, coupled with rapid power interruptions and high cost associated with back-ups, necessitated the reform. Overwhelming debt burdens, supply-side preferences, and under-utilised energy conservation practices were other factors that influenced the decision to reform Ghana's power sector (*ibid.*). Increasing efficiency of asset utilisation, and making necessary policies and institutional changes that will ensure economic equity were other supplementary motives for initiating the reform (Sustainable Energy Regulation and Policymaking for Africa, n.d.).

The Government of Ghana, upon agreeing to the terms and requirements of the World Bank, contracted SYNEX Consulting Engineers of Chile to provide policy directions that could ensure competition and engagement of private investors (Edjekumhene *et al.* 2001; Amoako-Tuffor and Asamoah 2015). In 1994, the firm proposed a new power market with policy directions that aimed at meeting the requirements of the World Bank. Some of the policy recommendations by the firm were free entry of private investors on the power generation side as well as decentralisation of the distribution arm of the sector; establishment of an Economic Load Dispatch Centre that will be responsible for planning the operation of the system so as to minimise operating costs; and the existence of different distributors with each operating in a defined concession area (SYNEX Consulting Engineers 1994, cited in Edjekumhene *et al.* 2001).

Following these policy recommendations, the government issued a statement on 'Power Sector Policy' to serve as a framework that meets the regulatory and transparency requirements of the World Bank.

This statement also proposed the formation of the Power Sector Reform Committee (PSRC) to oversee the design and implementation of the reform (Opam and Turkson 2000; Edjekumhene *et al.* 2001). Obligations such as the assignment of mandates for power generation, transmission and distribution, promoting a competitive power market, a regulatory framework for price and tariff revision, and establishment of an institutional framework, rested on the shoulders of the PSRC (*ibid.*). The PSRC proposed a 'four-point Action Plan' to the government of Ghana in 1997 (Edjekumhene *et al.* 2001):

- Introduction of new legislation to establish a new body to replace the then existing National Energy Board (NEB) which will introduce explicit regulations, rules of practice, and standards of performance for governing the power sector;
- Introduction of 'open access' in the power sector to ensure healthy competition;
- Engineering all stated-owned private utilities into 'strategic business units' that can help improve accountability and financial management through public–private partnerships and joint ventures;
- Introduction of guidelines and procedures for transparency in tariff settings.

Arguably, the past institutional and policy regimes of the energy sector of Ghana from the pre-hydro era to the early 2000s buttressed the dominant existing hydro and thermal energy infrastructural niches in the country. Indeed, it has been argued that the energy infrastructures in most parts of the global South are connected to historical antecedents in the socioeconomic and political realms, and hence, their development is shaped by various path dependencies (Power *et al.* 2016). Moreover, the enthusiasm and contestations exuded by the two dominant political parties (the New Patriotic Party and the National Democratic Congress) in the wake of the discovery of oil in 2007 (Phillips, Hailwood and Brooks 2016), and the subsequent improved gas infrastructure development compared to the weak RE infrastructure development, vindicate the existing infrastructural dominance of thermal-led energy.

4 Methodology

The methodology used for this study is informed by the Political Economy Analysis of Climate Change Policies (PEACH) Methodology by Schmitz (2012) and the PEA framework by Barnett *et al.* (2016). The PEACH methodology focuses on answering the central question: who drives/obstructs certain policies? According to Schmitz (2012), an application of the PEA in climate change issues should be able to bring out relevant sector players who by their actions and policy priorities promote or obstruct such initiatives. Accordingly, a PEA should be capable of setting out the key challenges of which the study intends to investigate, such as 'Who drives/obstructs climate change policies in the rising powers?' (*ibid.*: 1). It examines the complexities (actors,

Table 1 **PEA framework**

1 Problem identification	For example, poor performance in the power sector
2 Diagnosis	What features of the political economy generate and contribute to the persistence of the problem?
3 Prognosis	Given the diagnosis, what is the potential for change, and what are the mostly likely pathways of change?
4 Interventions	How can particular actors help to shift the pattern of incentives in a manner that promotes desirable change?

Source Barnett *et al.* (2016).

institutions, and motivations) and is based on identifying the various stakeholders involved, including their diverse priorities. This, therefore, demands the mapping of identified stakeholders in a power priority matrix according to their direct and indirect influence on policymaking and implementation, and analysing their competing narratives. Using narratives from in-depth interviews of sector players, the PEA analysis through the PEACH lens embodies four parts: mapping stakeholders according to priority; discussions on the proponents and opponents of policies; mapping the level of influence of stakeholders on such policies; and identification of coalitions for change (Schmitz 2012).

On the other hand, the PEA framework developed by Barnett *et al.* (2016) to understand the issues of poor performance of Africa's power sector despite several years of donor support, encompasses a four-stage process: problem identification; diagnosis; prognosis; and interventions (Table 1). The problem identification stage is in synchrony with Schmitz's (2012) position of 'setting out the key challenge' from the onset. The methodology for this current study is, therefore, a hybrid of the PEACH methodology (*ibid.*) and Barnett *et al.*'s (2016) PEA framework – an adoption of elements from both approaches that are deemed pertinent to establishing an understanding of the subject matter. Thus, key elements including problem identification (already captured in Section 1 as low investment in the renewable energy sector in Ghana); diagnosis (identification of binding constraints to renewable energy investments); prognosis (mapping of promising policies); mapping of stakeholders to ascertain the varied narratives; and identification of alternative interventions, constitute the analytical framework for this study.

The identification of the binding constraints to investment in renewable energy investment in Ghana was carried out by a previous study by Pueyo *et al.* (2017). Using a framework drawing from growth diagnostics (Hausmann, Rodrik and Velasco 2004), that research accumulated evidence through the analysis of indicators and interviews to rank constraints in Ghana according to their importance, or 'binding' character. The evidence accumulated in Ghana pointed at constraints preventing sufficient returns to investment at an acceptable risk and

Table 2 **Binding constraints on RE investment in Ghana and potential policies**

Binding constraint	Policy
Off-taker risk	Privatisation of the revenue arm of the power sector
	Improved management of ECG including revenue collection (especially revenue from debtors – government and others)
	Promotion of efficient technical practices within the distribution arm of the power sector through privatisation
	Establishment of a competitive off-taker market in the power sector
Inadequate power sector regulation	Establishment of a full-time high-level independent power producer (IPP) facilitator in the power sector
	Establishment of a reliable and transparent full-cost tariff pricing system
	Full implementation of the RE Act (Act 832) and its enshrined subsidiary instruments (net-metering, mini-grid systems, and the RE Fund and levies)
Lack of access to appropriate finance	Establishment of RE financial instruments within domestic banks by government with lower interest rates

Source Author's compilation from literature sources and in-depth interviews.

also at constraints limiting the availability of adequate finance for RE investment. The four factors damaging the risk-return profile of investment relate to an unreliable off-taker, poor regulation, macroeconomic imbalances, and corruption. On the other hand, scarce domestic finance and high returns expectations for short-term loans are behind the insufficient supply of finance (Pueyo *et al.* 2017).

This article goes beyond the identification of key constraints to analyse the political economy of their solutions. High-profile representatives of 31 organisations,[3] belonging to private and public sectors; civil society organisations; academia; the utilities; and research thinktanks that have key interest, as well as playing significant roles in the energy landscapes and regimes development in the country, were sampled randomly after all relevant stakeholders were mapped, for both the administration of in-depth interviews and questionnaires from June to October 2016. Drawing on the data from the in-depth interviews, three binding constraints to RE investment in Ghana were unearthed through prioritisation by interviewees: off-taker risk; inadequate power sector regulation; and lack of access to appropriate finance. Similarly, relevant potential policies that could have been used to help unlock these binding constraints, but did not, were mapped through a review of various literature sources and the in-depth interviews (Table 2).

The next section explores the alignment of Ghanaian stakeholders with respect to the potential policies that could solve the constraints to investment in RE.

5 Analysis and discussion

Having identified policies that could have been used to address the binding constraints to RE investment in Ghana, the analysis and discussion focus on why such policies have been ineffectual in the past. The proponents and opponents of these policies are teased out from the in-depth interview scripts. Our interviews were not able to gauge the extent of the power of each of the stakeholders to achieve their goals when these conflict with those of other stakeholders.

5.1 Off-taker risk constraint

The non-existence of a credible off-taker in Ghana's power sector remains a key disincentive to investment in energy and especially in renewables as this typically has higher upfront costs. The inability of the present off-taker (ECG) to maintain a credible and resounding financial balance sheet as a result of low electricity prices and bottlenecks with revenue collection underscores investment risks. Narratives from stakeholders underpinning why the credit-unworthiness of the present off-taker dissuades investors from investing in Ghana's power sector resonate with findings by *African Energy* (2014).

> *An important constraint is that the off-taker is not financially credible. They are unable to pay their bills.* (A senior officer at Renewable Energy Promotion, Energy Commission of Ghana)[4]

> *We can't call ECG a credible off-taker. So now, it is a major bottleneck… who would buy the power I'm generating and can pay at the end of the month? Most of the people who have got PPAs* [power purchasing agreements] *from ECG are asking for further guarantees because of their notorious track record of being unable to pay*. (A senior officer at KITE)

The policies counting with the highest support in our interviews included the privatisation of the revenue arm of the power sector and the improved management of the national distribution company.

5.1.1 Privatisation of the revenue arm of the power sector

One of the key policy interventions that could help to unlock the off-taker risk in the power sector is the privatisation of the revenue arm of the power sector. This policy has been strongly supported by donors, and particularly by the United State's Millennium Challenge Corporation. A private, competitive retail market would be solely driven by the objective of profit maximisation. Accordingly, it would not be subject to political interference demanding, for example, lower tariffs, or exemption from paying their bills for public administration consumers. Such private retailers would also be more likely to implement innovative monitoring and metering systems resulting in higher revenue collection, the narrative goes (Eberhard *et al.* 2008).

Several counter-narratives oppose the privatisation approach, mainly the fear of tariff escalation; ideological perspectives of ECG as a national identity; and job uncertainty.

According to Hall, Lobina and Motte (2005), initiatives towards privatisation of essential national assets such as the energy sector are never without oppositions for the fear of price increment. Privatisation in most cases widens the affordability gap, increasing the population who cannot afford services that used to be provided by the public institutions (*ibid.*). Hall *et al.* (2005) and Nellis (2003), dwelling on the negative implications associated with privatisation, note that it increases the cost of living, deepening poverty. Such fears by citizenry have negative effects on governance due to the 'patron–client relationship' practices in developing countries in which there is a trade market for cost of electricity and votes (Barnett *et al.* 2016). Narratives from the in-depth interviews indeed attest to the fact that the fear of increase in tariff has been pursued by various stakeholders over time to block the implementation of this intervention as this one shows:

> *I think the stakeholders that are kicking against this are basically the final consumers who in effect have witnessed tremendous increase in electricity tariffs. The fact is you are bringing a third party, which we see will be more efficient and more effective. The fact too, however, is that we also have information about the cost of electricity being higher than how much we are paying and it means that a third party who is coming in with a business motive or private motive will need to break even or make profit for that matter through high cost of electricity tariffs. So, consumers would then try to fight against those things*. (A senior officer at KASA-Ghana)

Second, the belief that ECG is a national asset and should stay as such also emerged strongly as a reason against privatisation. According to this narrative, the government has no moral right to either sell or give out ECG's function to a foreign private entity since that will be tantamount to weakening the country's sovereignty.

> *Looking at what is happening and the attempt by government through MiDA to give ECG to a company to manage as a concession for 25 years, it's on a large scale and taking it from the hands of Ghanaians to a foreign company.* (A senior officer at KASA-Ghana)

> *Ownership should be Ghanaian. It should be listed on the Ghana Stock Exchange so that every Ghanaian will be a shareholder. In that way, it will still be for Ghanaians but it will mean government cannot take out anything from the ECG.*[5] (Chief policy analyst, Ghana Institute for Public Policy Options (GIPPO))

Concerns about job security and the possible creation of jobs for only a few elites are the third most frequent arguments against the policy instrument of privatising the revenue arm of ECG. While assurance has been given in the MiDA Compact II deal, emphasising that no ECG worker would be laid off in the first five years[6] of the concession, opponents of the initiative, including ECG workers, are not entirely convinced about the provision, since they are unsure of their retentions after the first five years. This uncertainty has triggered a series of strike actions[7] by ECG workers against government. Birdsall and Nellis (2003) observe that privatisation unfairly disenfranchises workers.

> *They* [ECG workers] *have legitimate concerns because they are afraid of job securities and are not sure what the private entity would do*. (A senior officer at ACEP)

> *I think it's really job security, first of all. Maybe pride a little bit, but job security and mistrust of whoever is coming in, that they are simply coming to make money on top of their labour*. (A senior officer at Solar Light Ghana)

5.1.2 Improved management of ECG

As an alternative to privatisation, the improved management of ECG would result in a more efficient revenue collection from debtors – government and others. Authors (Hall *et al.* 2005; Barnett *et al.* 2016) argue that the privatisation of the energy sector in Africa would not be necessary if there were mechanisms in place to avoid governments' interferences. The inability of Ghana's power sector off-taker to function effectively is attributable to long-standing interferences by various governments. Unsurprisingly, the government itself is identified as the main obstruction for the improved management of ECG.

> *I will say that the reason why some people are kicking against it* [privatisation] *is because they feel that government is the cause of the problem so don't blame it on ECG. Government owes ECG so much and they feel if government can put in place measures to curtail this, then ECG can operate efficiently*. (A senior officer at Renewable Energy Promotion, Energy Commission of Ghana)

> *But we do know that what has crippled the ECG is not that we don't have people with brains to deliver but it has been the interference of government to just cripple them and the solution is to either make them independent or to give it to a private entity to handle, which also brings the independence that is required.* (A senior officer at ACEP)

It has been argued that Ghana's government seems powerless to resist external pressures requiring privatisation as a precondition for financial assistance, mainly through the Millennium Challenge Corporation Compact II. Hence, its inability to support the initiative of improved management of ECG. For instance, Mehrotra and Delamonica (2005) observe that in most privatisation initiatives in developing countries, donor partners and international organisations strongly push governments to accept the deals, with a lot of them being done behind the scene without proper consultation.

> *When something is coming from outside Ghana we are going to push back easily, good or not. So, what would have been nice is for us to recognise that the way we run these parastatals over the years has been wrong. So we need a government that is mature enough to step out and say no*. (A senior officer at Solar Light Ghana)

Another critical intervention to unlock the off-taker binding constraint is the provision of guarantees for power producers in Ghana. However, the government cannot commit to high levels of debt and a lack of financial resources.

5.2 Inadequate power sector regulation constraint

Effective regulation of the power sector with incentivised strategies tailored towards RE development are paramount to boosting investment in RE sources. All over the world, different countries are formulating and implementing such policies on RE, to enhance energy security and climate change mitigation drives. Although Ghana's power sector regulatory regime aims at diversifying energy portfolios in order to enhance the green economy, it is still fraught with challenges that undermine RE investors' confidence. Three policy interventions that could have addressed the inadequate regulatory constraint in Ghana, had an RE agenda been attended to seriously, were unearthed: establishment of a full-time level facilitator in the power sector; establishment of a reliable and transparent full-cost tariff pricing system; and full implementation of the RE Act (Act 832) and its subsidiary instruments.

Regarding the setting up of a full-time level facilitator in the power sector, opposers have argued that it is unnecessary and will only bring about extra cost, since current practices in the power sector already take account of that. Concerning the setting up of a reliable and transparent full-cost tariff pricing system, opposers have gone against it on the basis that electricity prices will increase; and secondly, electricity is regarded as a public good. The lack of full implementation of the RE Act (Act 832) is attributable to the non-incentivisation approach to RE development in Ghana; RE is not considered as an immediate priority by policymakers compared to thermal energy and lack of political will. The following narratives give credence to the weaknesses of the regulatory environment as a result of the energy regimes and infrastructure niches supported by state:

> *We have the key issue as being the Renewable Energy Act, which says that the tariffs cannot be changed before 10 years. But then for investment like this, we are looking at a lifespan of 20 to 30 years. So if an investor is only guaranteed for 10 years then what happens to the 10 or 20 years left? So, these are some of the issues that hold back some of these investors.* (A senior officer at ECG)

> *The truth of the matter is that when it comes to the renewables, the approach has always been different even in matured democracies and matured countries like the UK and the US. There were incentive mechanisms through the FiT with the obligation to pay. We cannot do otherwise because our scenario is even more complicated.* (A senior officer at KITE)

> *You have one arm of government or ministry promoting a green agenda and the other doing something that contradicts it. Ghana signed up to the Sustainable Energy for All initiative and our president chaired a session in the UN on sustainable energy, but we are talking about coal. So there is a disconnection between various government agencies leading on policies on energy and environmental sustainability.* (A senior officer at KITE)

> *I don't even think the minister* [former minister of power] *ever thought of the renewable option whenever as a credible option. His thoughts were all about how to get fuel and thermal plants running, whereas you don't need fuel for renewables.* (A senior officer, ACEP)

5.3 Lack of access to appropriate finance

Financial instruments remain essential ingredients for the development of RE. It is therefore not surprising that governments and policymakers in developed countries create economic and financial incentives to facilitate the development of renewable energy technologies. According to Painuly (2001), credit subsidy was introduced in Denmark to finance RE development for a ten-year period. Other financial instruments such as tax exemptions, credit facilities, and third-party financing mechanisms are also introduced in other jurisdictions in developed economies to boost RE investment (IEA Renewable Energy Working Party 2002).

A fundamental factor sustaining the lack of appropriate finance in Ghana, which in turn affects RE investment is the low financial portfolios of domestic banks. Despite its positive effect on RE development, current financial portfolios of domestic banks cannot make the policy implementable. The high risk of doing business coupled with the low portfolios of domestic banks makes it difficult for entrepreneurs to access loans. This affects the pricing of electricity from RE sources, which also affects consumers' willingness to appreciate the usefulness of the technology, as it is perceived to be expensive relative to other technologies.

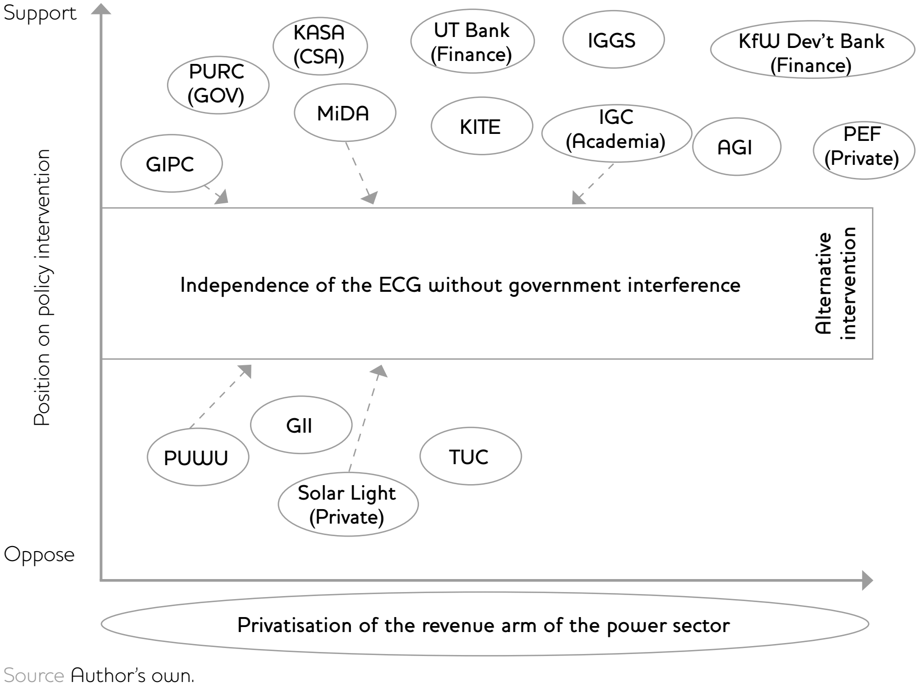
> *The technology is still a bit expensive and you need to get a good feed-in tariff before you can make good business. Unfortunately, we also don't have flexible financing schemes. We still have to deal with the same commercial banks and they don't understand the investment aspect in the renewables. They are still doing short-term loans with 30 per cent to 35 per cent interest rates.* (A senior officer at KITE)

6 Emerging interventions for change

Our interviews[8] revealed institutional patterns of support or opposition as well as alternative policies that could gather more support than those opposed. However, the article could not establish clear-cut coalitions for or against policies due to insufficient information on how stakeholders exert power differently. The majority of these stakeholders have not evolved from the mere expression of support for or opposition to the policies, to building coalitions, and exertion of different influences to bring about these changes. In the view of a key stakeholder: 'Networking and advocacy for RE development by civil society organisations and allied groups have been weak in Ghana' (a senior officer, ACEP). The graphs included in this section depict the group of stakeholders that support (upper part) and those that oppose (lower part) the potential policies that could boost RE development in the country. The policy proposed is presented under the horizontal axis and the dominant suggested alternative is presented in the centre.

The privatisation of the revenue arm of the power sector policy received high-level support from the majority of the institutions, with only PUWU, GII, TUC, and Solar Light opposing this policy (Figure 1).

Figure 1 **Stakeholders' support or opposition to privatisation of the revenue arm**



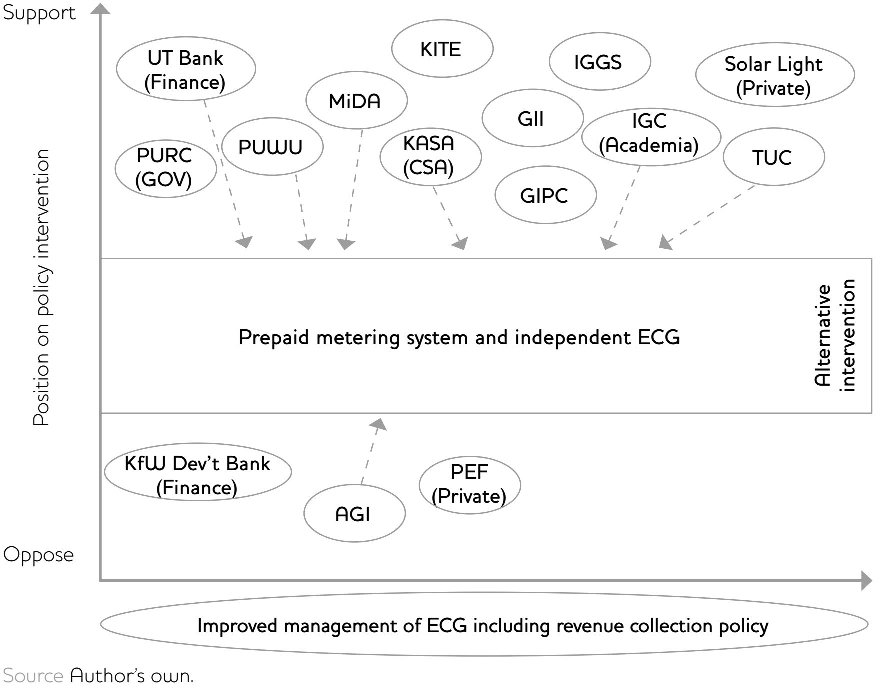
Source Author's own.

Various alternative policies have been proposed by these stakeholders as being capable of addressing the off-taker risk constraint. However, only stakeholders from GIPC, MiDA and IGC, who support the policy, and PUWU and Solar Light Company, who oppose the policy, have proposed a common alternative policy intervention. This alternative policy intervention to the privatisation of the revenue arm of the power sector entails guaranteeing the independence of ECG, including government non-interference, since it will facilitate the expansion of the prepaid billing system to maximise revenue collection.

Similar to the privatisation of the revenue arm of the power sector policy, the improvement in the management of ECG is widely accepted by a majority of the interviewed stakeholders (Figure 2) as an important solution to the off-taker constraint. Only AGI, PEF, and the KfW Development Bank oppose this policy, considering it insufficient to improve the creditworthiness of the off-taker. The proposed alternative policy option is a prepaid metering system and independence of the ECG.

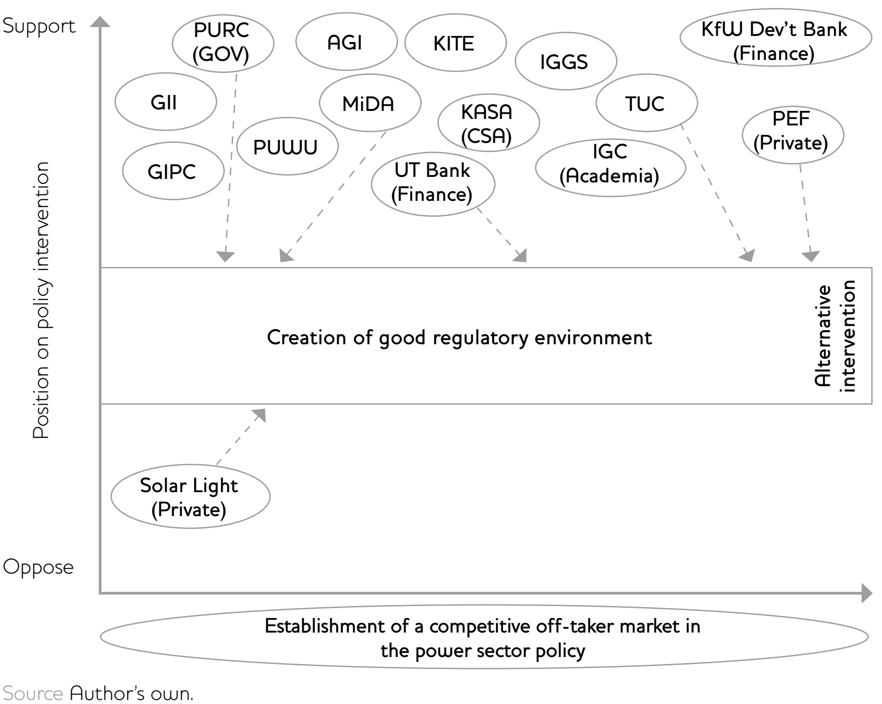
While all but one (Solar Light Company, Ghana) gave maximum endorsement to the establishment of a competitive off-taker market in the power sector, PURC, MiDA, UT Bank, TUC, PEF, and Solar Light were of the view that the creation of a good regulatory environment, with independent regulators and independent distribution and retailing could achieve similar results (Figure 3).

Figure 2 **Stakeholders' support or opposition to improved management of ECG policy**



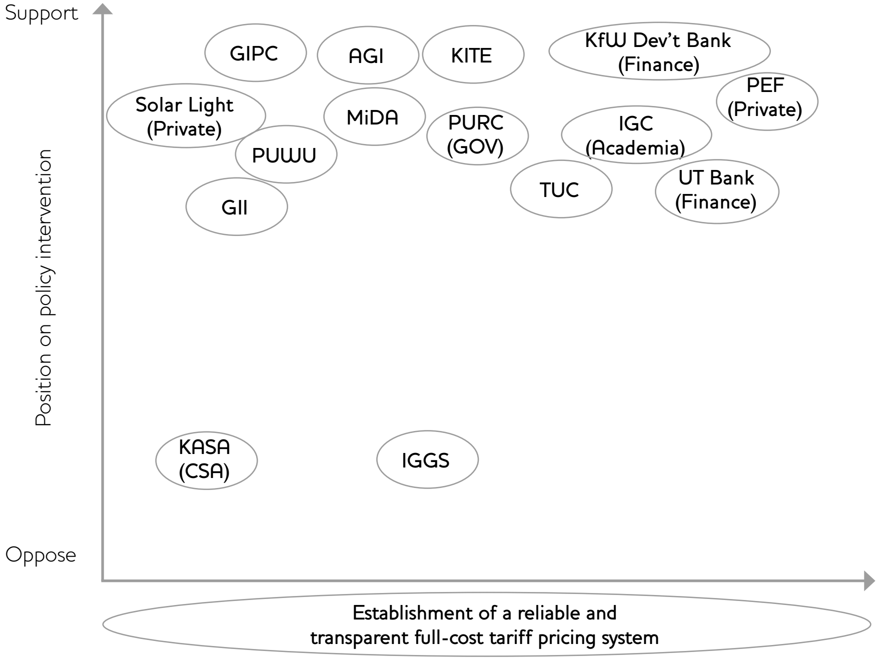
Source Author's own.

Figure 3 **Stakeholders' support or opposition to the establishment of competitive off-taker market policy**



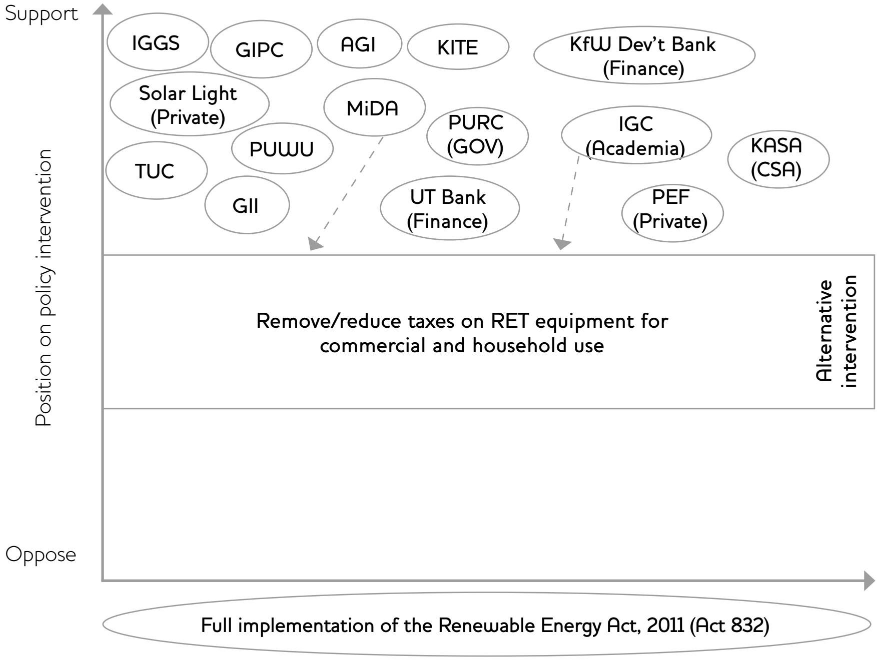
Source Author's own.

Figure 4 **Stakeholders' support or opposition to the establishment of a reliable and transparent full-cost tariff pricing system**



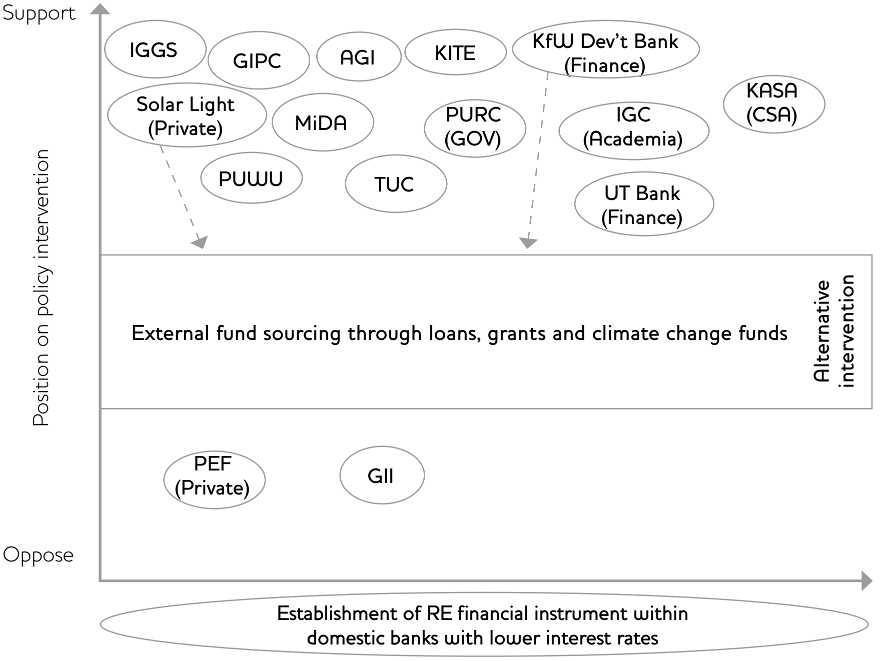
Source Author's own.

Figure 5 **Stakeholders' support or opposition to full implementation of the Renewable Energy Act, 2011 (Act 832) policy**



Source Author's own.

Figure 6 **Stakeholders' support or opposition to RE financial instruments**



Source Author's own.

The majority of the stakeholders support the establishment of a reliable and transparent full-cost tariff pricing system devoid of government intervention to overcome the faulty power sector regulatory constraint (Figure 4). The opposing stakeholders did not propose an alternative policy. The dominance of the supporting group, however, shows that many stakeholders want this policy to be implemented.

There is total support for the full implementation of the Renewable Energy Act, 2011 (Act 832) by all institutions interviewed. This is considered by all the institutions as a means to overcome the faulty power sector regulatory constraint. Nevertheless, MiDA and IGC were of the view that reducing or removing taxes on RET equipment is equally imperative (Figure 5).

The establishment of RE financial instruments within domestic banks with lower interest rates is a potential policy that could overcome the binding constraint on access to appropriate finance. All the institutions except GII and PEF are in support of this policy (Figure 6). Solar Light Company and the KfW Development Bank, however, proposed external fund sourcing as an alternative means to improving access to finance for RE projects. Clearly, there is not a mutually proposed alternative policy by the opposing and supporting stakeholders. The dominance of the supporting group, however, shows that many stakeholders want the establishment of RE financial instruments within domestic banks with lower interest rates to be implemented.

7 Conclusion

The discussion in this article has underscored the critical role political economy dynamics have played as part of the elements influencing the underinvestment within the RE landscape in Ghana. While several factors may constrain investment in the sector, previous research using the Green Investment Diagnostics framework and further in-depth interviews with key stakeholders unearthed three binding constraints: off-taker risks, inadequate power regulation, and lack of access to appropriate finance. The permanence of these binding constraints is caused by dominant institutional, regulatory, and policy regimes on energy in the country, which are more fossil fuel inclined. While several policies or strategies could enhance RE in the country, inertia from the country's leadership coupled with the weaknesses of advocates, have precluded implementation. Ghana's political leaders should champion those RE policies that already attract overwhelming support from stakeholders for renewables to have a chance in a fossil fuel-dominated paradigm.

Notes

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1 ISSER, University of Ghana (bawasius@hotmail.com; bawasius@isser.edu.gh).

2 www.ghanaweb.com/GhanaHomePage/NewsArchive/Gov-t-projects-80-of-power-plants-to-be-thermal-430382; www.urbanafrica.net/urban-vocies/15378/.

3 Association of Ghana Industries; Ghana Investment Promotion Council; Ghana Integrity Initiative; International Growth Centre; Institute of Green Growth Solutions; Kasa Initiative Ghana; Kumasi Institute of Technology and Environment; Millennium Development Authority; Private Enterprise Federation; Public Utilities Regulatory Commission of Ghana; Public Utilities Workers Union; Solar Light Co. Ltd; Trade Union Congress; UT Bank Ghana Ltd; Energy Commission; Ghana Investment Promotion Centre; Africa Centre for Energy Policy (ACEP); Biogas Technologies Africa Ltd; Electricity Company of Ghana; IMANI Ghana; Institute of Fiscal Studies; Integrated Social Development Centre; African Energy Consortium; African Energy Consortium; Sahel–Sahara Bank; Blue Energy Company; Lekela Power; Ghana Capital Partners; NEK–Ghana; Volta River Authority; International Growth Centre.

4 The interviews took place between June 2016 and October 2016. Dates of interviews were: 10 June 2016; 19 July 2016; 20 July 2016; 22 July 2016; 12 August 2016; 19 August 2016; 8 September 2016; 9 September 2016.

5 www.ghanaweb.com/GhanaHomePage/business/Tarzan-disagrees-with-ECG-workers-over-privatization-465173 (accessed 15 August 2016).

6 'For the first five years we are telling whoever comes as a concessionaire that you cannot reduce the level of employment within ECG. It is a way of guaranteeing people's jobs at least for the next five years' (Chief executive officer, Millennium Development Authority).

7 www.africanews.com/2016/01/20/ghana-labour-groups-protest-increase-in-utility-and-taxes/ (accessed 15 August 2016).

8 The definitions of the acronyms for these organisations are as follows: AGI – Association of Ghana Industries; GIPC – Ghana Investment Promotion Council; GII – Ghana Integrity Initiative; IGC – International Growth Centre; IGGS – Institute of Green Growth Solutions; KASA – Kasa Initiative Ghana; KITE – Kumasi Institute of Technology and Environment; MiDA – Millennium Development Authority; PEF – Private Enterprise Federation; PURC –Public Utilities Regulatory Commission of Ghana; PUWU – Public Utilities Workers Union; Solar Light – Solar Light Ghana; TUC – Trade Union Congress; UT Bank – UT Bank Ghana Ltd.

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The Political Economy of Aid for Power Sector Reform

Neil McCulloch, Esméralda Sindou and John Ward[1]

Abstract Recent literature on the effectiveness of donor programmes points to the importance of understanding the political context within which reforms are taking place. The characteristics of the power sector make reform intensely political in almost all countries and donor projects have sometimes failed because of an inability to navigate the local politics of reform. This article reviews what is known about how donors have taken politics into account in designing and implementing power sector reform programmes in sub-Saharan Africa. It illustrates the challenges which donors have faced with reference to a case study of donor attempts to support power sector reform in Tanzania. The article draws on documentary evidence from major donors as well as a set of qualitative interviews with experienced project supervisors to provide a set of lessons for donors about how to incorporate political context into the design and implementation of power sector projects.

Keywords: political economy, aid, power sector reform, electricity, Tanzania, donors.

1 Introduction

There has been a resurgence of interest in recent years, amongst both practitioners and the academic community, in the political economy of donor engagement in reform processes (Carothers and de Gramont 2013). A series of studies has suggested that projects that take a flexible and adaptive approach to reform have been more successful. For example, Andrews, Pritchett and Woolcock (2012) and Andrews (2014) have argued that programmes should focus on problem-solving through an iterative process; whilst Pritchett, Samji and Hammer (2013) have argued that projects should 'crawl the design space' for solutions. Similarly, Booth (2015) argues for the need to 'think and work politically', whilst Levy (2014) provides a theoretical framework for how reform can 'work with the grain' of the domestic political reality. There is also a growing literature of comparative case studies (e.g. Booth and Unsworth 2014) that argues that aid programmes which are flexible, long-term and locally owned are likely to be much more effective in achieving sustainable change than more traditional 'linear' programmes.

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Donors have been paying attention to this literature and are increasingly recognising that an appreciation of the politics of the sectors and countries in which they are operating is essential for successful and sustainable reform. One of the consequences of this work has been considerably greater interest and uptake by donors in 'political economy analysis' (PEA) (Fritz, Levy and Ort 2014). Many donors now routinely conduct a PEA as part of the preparation of a project and some embed regular sectoral or issue-based PEAs into the operation of projects. Some have gone even further – for example, the Department for International Development (DFID) has sent several hundred of its staff on a training course about politics and institutions in order to try to change the mindset of technical staff about the importance of political considerations in projects. What is less clear is the extent to which such analysis is translating into different designs and different approaches to the implementation of projects. A recent review of DFID experience suggested that, whilst PEAs have been mainstreamed in many areas, this has resulted in relatively little change in the types of projects that are actually implemented (Piron *et al.* 2016).

This article examines how donors have tried to take political context into account in their support of reform efforts in one particular area and region – power sector reform in sub-Saharan Africa. In most countries, power systems are centralised, mainly based on a national grid, and although electricity is part of the development narrative of most countries, it tends to be controlled by a domestic elite, and is a significant source of rents. Thus, although there is politics associated with reform in all sectors, the characteristics of the power sector make accounting for political considerations particularly important.

There is already a literature on the political economy of power sector reform. Numerous papers have looked at the politics of reform (see Gratwick and Eberhard (2008) and Eberhard *et al.* (2016) for descriptions of reform in sub-Saharan Africa; Dubash and Rajan (2001) and Tongia (2006) describe the political economy of reform in India; Victor and Heller (2006) describe the politics of reform in five major developing economies; Scott and Seth (2013) provide a literature review of reform of electricity distribution in developing countries; Kojima, Bacon and Trimble (2014) review the literature on reform of power sector subsidies). However, this literature focuses on the political economy of the reform process within individual countries, where the main actors are government, business, and voters.

By contrast, rather little has been written about the role of donors and the extent to which they have taken knowledge about the politics of reform into account in the design and implementation of their programmes in Africa. Our research questions are: to what extent have donors analysed the underlying political constraints that they face? Have donors significantly shifted the nature of the power sector reform programmes which they implement as a result of a better understanding of the political context? Are they taking on board the lessons from recent research on 'thinking and working politically' and, if so, how? Are there general lessons that can be learned about what sorts of approaches to power sector reform are more, or less, successful and how this varies by context?

This article reviews the existing studies – both published and, where available, donor evaluations – looking at how donors have navigated the political economy of power sector reform. It complements this by collecting documentation on power sector reform projects implemented by the major donors in Tanzania over the last decade or so. This is supplemented with qualitative analysis based on a set of interviews with experienced donor officials responsible for the implementation of power sector reform projects. We conclude with a summary of the lessons, from the literature and our case study, about how donors might respond more effectively to the political challenges associated with power sector reform.

2 Methodology

Our methodology has three components.

First, we examine the literature about the political economy of aid in the power sector (including reviews conducted by donors such as Deloitte Touche Tohmatsu Emerging Markets (2004); Besant-Jones (2006); and Deloitte (2015)). We limit the scope of this review to studies that have examined the role of donors in power sector reform in developing countries and how they have designed and implemented such programmes in the prevailing political context in the countries of operation. Thus, we do not review all studies on the political economy of power sector reform, but focus on synthesising available literature on how this has influenced donor programming in sub-Saharan Africa in particular.

Second, we have attempted to obtain information and documentation about the power sector reform projects supported by donors over the last decade (or longer where appropriate) in Tanzania. Tanzania was chosen because of the length and intensity of donor engagement in power sector reform, providing a literature and experience to draw on. The documentation for these projects was then used to answer a set of questions including: how political considerations were taken into account in the design of the project; how challenges and blockages were handled during the course of implementation; what the overall performance of the project was; and what lessons were learned in terms of project design and implementation.

Third, we conducted a series of qualitative interviews with experienced project supervisors from the major donors who were supporting power sector reform for Tanzania. This was in order to obtain their views about the critical success factors for power sector reform projects and, specifically, how projects have attempted to take into account the politics of sector reform.[2]

3 A brief history of donor engagement in power sector reform

Although donors have been involved in supporting power sector investments since the 1950s, the nature of development partner involvement in power sector reform in developing countries is rooted in the transformations that affected the sector in Organisation for Economic Co-operation and Development (OECD) countries in the 1980s. During that time, a combination of political, financial, and technical factors triggered power sector reforms in the UK, Chile, and Norway (Gratwick and Eberhard 2008). These countries' experiences appeared to demonstrate the benefits of such reforms, which were then followed by several other industrialised and some developing nations from the early 1990s. Since then, power sector reform has been advocated by the development community, including the World Bank, the Inter-American Development Bank, the European Bank of Reconstruction and Development, as well as other international agencies, such as the World Energy Council (Bacon and Besant-Jones 2002). Thus, donors have played a major role as the architects of reforms in the power sector, and have often attempted to initiate reform through the provision of technical assistance and capacity-building programmes in developing countries (Wamukonya 2003; Dornan 2014).

At first, most development partners typically implemented a somewhat uniform approach to power sector reform. The approach taken in OECD countries crystallised into a 'standard' or 'textbook' approach to restructuring the sector, which aimed at fully unbundling and liberalising the power sector following a logical sequence of distinct steps: corporatisation, commercialisation, legislation, regulation, restructuring, privatisation, and competition (Gratwick and Eberhard 2008; Joskow 2006; Littlechild 2006; Hunt 2002).

The development community promoted power sector reform out of a belief that the standard 'model' would enable the transformation of poorly performing energy systems in developing countries, promoting growth and improving access for poor populations. It was felt that the recommended structure and regulation of the sector would benefit consumers by allowing their participation in the market and by ensuring consumer protection (United States Government Accountability Office 2005). In the words of one former senior donor official from a major multilateral donor, 'there was, in the early 1990s, a strong belief that one size did actually fit all.'

However, the application of the 'standard model' of reform in developing countries yielded rather modest results, as it faced significant political barriers (Besant-Jones 2006; Choynowski 2004). The consensus in the literature is that the standard model failed for three main reasons.

First, it often failed to take account of the vastly different circumstances prevailing in developing countries from those in the OECD countries where it was first implemented. For example, the textbook model for power sector reform did not make sense in many small African countries, where the necessary degree of competition in the generation segment cannot be obtained due to the small size of the power system and insufficient generation capacity (Barnett 2014).

Second, the model struggled to map out a feasible pathway for reform. As Victor and Heller summarise, '[T]he standard textbook for reform focuses on the end point, namely an unbundled, privately owned and competitive power sector, not on the steps that governments need to take towards that end' (2006: 21). In practice, governments tried a wide variety of approaches to reach the end point, not all of which were successful (Chikuni *et al.* 2011).

Third, and perhaps most important, many reform attempts failed to understand or, at least, to take account of, the underlying political constraints facing decision-makers. In almost all countries, reform of the power sector is an extremely sensitive area. Electricity is part of the development vision of all countries and therefore brings significant political benefits to leaders who can control the price of and access to a key developmental service. Economies of scale mean that large financial flows are involved in procuring power production, transmission, and distribution systems. The centralised nature of the technology concentrates control in the hands of relatively few powerful individuals.[3] As a result, the location of transmission and distribution lines can be driven by electoral considerations, power may be rationed to influence voters, and power generation may fluctuate with the election cycle (Tripp 2012; de Mesquita and Smith 2009). Utilities have historically been used to serve the broader patronage system and became large employers (Barnett 2014). As reforms often emphasise restructuring utilities, they have faced strong resistance from labour unions (Eberhard 2004; Dubash and Rajan 2001). Reforms also encouraged cost-reflective pricing, but the associated price increases have resulted in popular uprisings in several countries including Argentina, India, Indonesia, Ghana, and South Africa (Dubash and Rajan 2001).[4]

Thus, rather than the 'standard model', the reforms of the last two decades have generated a wide variety of 'hybrid' structures (see Eberhard *et al.* (2016); Trimble *et al.* (2016) for a recent classification of different systems in Africa). In each case, these reflect the outcome of a complex and context-specific contestation both between domestic actors (utilities, independent power producers, regulators, finance ministries, energy ministries, and political leaders) and between domestic and international actors (independent power producers, donors, and other financiers).

Donors responded to the challenges of implementation in different ways. Some development partners had considerably more leverage than others due to the scale of the resources which they were providing. The literature points to examples, predominantly from the 1990s, where countries were effectively forced to implement the reforms suggested by donors because of the conditions included in loan packages (Wamukonya 2003; Lefevre and Todoc 2000).

There is also evidence that pressure to implement the recommended reforms was strengthened by coordination amongst donors. The World Bank, for example, refused to fund more capital investments until specific reforms had been implemented and most other donors would only support programmes that the Bank had approved (Barnett 2014).

Some donors also responded by attempting to insulate reforms from politics. For example, Bouille, Dubrovsky and Maurer (2002) describe how in Argentina, a small group of politically powerful bureaucrats, supported by multilateral agencies, designed the reforms without engaging with other relevant public agencies or civil society. However, this opaque process created political opposition and resulted in a lack of ownership of the reforms by key stakeholders.

By the early 2000s, the donor community was conscious of the difficulties being encountered in the implementation of power sector reform in developing countries. The World Bank commissioned a major review of its power sector operations which has been extremely influential in shaping the approach taken by most development partners over the last decade (Besant-Jones 2006). It concluded that 'the most important lesson from reforming power markets in developing countries is that "cookbook" solutions for reforming their power markets are ruled out by the extensive range of economic and institutional endowments of these countries' (*ibid*.: 1).

The consequence of this reappraisal was the abandonment of the 'one-size-fits-all' approach. The World Bank issued new Operational Guidance to its staff (World Bank 2004), which emphasised context specificity and the importance of the political dimensions of reform. In particular, a stronger focus was put on identifying 'stakeholders with the incentive and influence to press for improved performance' and 'top-level political decision makers', who will be able to champion the reform process (Fritz *et al.* 2014: 134; Levy 2007).

The last decade has therefore seen a considerable amount of experimentation by development partners and closer attention to understanding the political context. But donors still face considerable challenges in navigating the complex politics of power sector reform and it is not clear whether the deeper understanding of context has yet translated into donors undertaking different interventions in the countries that they support. Thompson and Bazilian (2014) assert that donor-funded technical assistance and capacity-building activities still avoid 'the fundamental political issue of who wields political power and how that power is wielded'. And Naqvi (2016), in examining the role of development actors in power sector reform in Pakistan, highlights how awareness of the complex political problems associated with reform is not sufficient to avoid them, pointing to a higher order of structural obstacles within development partners that remain unaddressed.

To understand these obstacles further and assess how donors have addressed them, the next section examines reforms in Tanzania and the role of development partners in the process.

4 Power sector reform in Tanzania

4.1 The Tanzanian reform experience

The Tanzanian power sector is dominated by a state-owned and vertically integrated utility, the Tanzania Electricity Supply Company (TANESCO), which has been struggling financially for many years. Its precarious financial situation has led to chronic underinvestment in the sector, from both public and private investors, which in turn resulted in significant underperformance for decades, both in terms of quality of supply and coverage. The lack of reliable electricity supply has been identified as one of the three major constraints to growth in the country (Partnership for Growth 2011).

Reforms began in the 1990s, when the country's structural adjustment programme supported by the International Monetary Fund (IMF) and the World Bank, was expanded to the power sector through the inclusion of sector-specific conditions in general budget support. Restructuring and privatisation were deemed the solution to TANESCO's financial deficits and the generation segment was opened to independent power producers (Ghanadan and Eberhard 2007). In the mid-1990s, reflecting the expectations that the private sector would fill the investment gap in the generation segment, donors mostly withdrew their direct support to the development of power projects. Unfortunately, the relatively rapid reduction in donor funding for power supply and technical investments worsened the investment gap in the sector, as private capital failed to pick up.

Despite the changes associated with the reforms, neither TANESCO's financial situation nor the quality of supply improved. This led to the management of TANESCO being outsourced to a private company from 2002 until the end of 2006. The management contract placed an overwhelming emphasis on increasing the utility's short-term revenues, which may have deterred long-term investments. The results of this were also unconvincing – whilst commercial performance improved, there was little improvement in service quality or transmission and distribution losses. In 2005, the newly elected government terminated the management contract at the end of 2006 and de-specified TANESCO for privatisation.

Consequently, between 1997 and 2006, the utility suffered from a critical lack of investments, in its workforce, systems, and infrastructure, reflecting the view that long-term investments would not benefit the government or the managing entity, as TANESCO was expected to be privatised. The 'generation gap' left in TANESCO by the lack of recruitment in the last decade is still a major concern for the utility. The utility also requires a technological turnaround and related capacity building, as its systems have not kept speed with the revolution in industry-specific technologies.

Notwithstanding the difficulties in reforming TANESCO, the 2000s saw significant changes in the legal, regulatory, and institutional environment. The Energy and Water Utilities Regulatory Authority (EWURA) Act was passed in 2001 (although it only came into being in 2006). On paper, the institutional structure and governance of the sector is excellent, as the legislation guarantees the autonomy of the regulator and the participation of the public. However, in practice, the Ministry of Energy and Minerals can exercise political pressure and intervenes on regulatory issues, in particular, tariff setting. Other changes included the creation of a Rural Electrification Agency in 2005, to focus on extending access. And in 2008 an Electricity Act was passed that encourages private participation in the sector.

Whilst these legislative and institutional changes might signal a renewed commitment for creating a conducive environment for private investments (Kapika and Eberhard 2013), the deals struck with private investors have not always been transparent, which has heightened suspicion about private sector investments. For example, the lack of planning in the sector, combined with severe droughts, forced TANESCO to resort to emergency power producers in 2006 and 2011. The absence of competitive and transparent tendering resulted in one of the largest scandals in the country's history (Kapika and Eberhard 2013) and put TANESCO on the verge of bankruptcy, as the negotiated cost of electricity with emergency power producers significantly exceeded the tariff. This experience demonstrates that strong negotiation skills and an in-depth knowledge of competitive procurement in the utility are paramount to enable private sector participation in the long term.

In 2013, the Government of Tanzania, through 'Big Results Now', a programme aimed at fast-tracking projects of national importance in key sectors of the economy, including energy, promised a reform of the sector (Government of Tanzania 2013) including unbundling, commercialisation, and sale. This has been followed by a new Roadmap which was approved by the Cabinet in 2015. However, the latter was funded by the African Development Bank and was undertaken by a Western consultancy company. Its recommendations bear a strong resemblance to the 'standard model', promising to unbundle and liberalise the power sector by 2025. The election of President Magufuli in 2015 led to the dismantling of the Big Results Now programme. In January 2017, the managing director of TANESCO was removed and a tariff increase was reversed; more recently, the director-general of the regulator was suspended. Both moves point to the continued influence of political considerations in the management of the power sector.

4.2 The role of donors

Traditionally, the dominant approach to influencing power sector reform in Tanzania has been through general budget support. Combined commitments from donors were substantial and represented a potentially influential tool, since some donors have made the disbursement of their loans conditional on the adoption of reforms.

Since the Busan Partnership agreement on development cooperation in December 2011, 'a lot of donors were going for low-hanging fruits' to yield measurable 'results' quickly, 'instead of thinking of the long term,' according to one interviewee.[5] Also, despite some willingness amongst donors to develop a common Performance Assessment Framework to measure the effectiveness of aid, there has been a lack of alignment between the framework and the conditions of disbursement of further loans. This was due to both the complexity of the results framework and competing donor interests and approaches.

Coordination is also made more difficult by the large number of development partners working in Tanzania; and this is reinforced by the limited ability of the Tanzanian government to coordinate them. In an attempt to address this, donors have formed the Energy Development Partners' Group, intended as a sector-wide platform for dialogue with government. However, as each country's presence in Tanzania is founded on bilateral diplomatic relationships, the government has no incentive to deal with development partners as a united block of donors.

Commercial interests have not been absent from the considerations of bilateral donors when promoting reforms. In the words of one senior donor official[6] from a major bilateral donor, the 'dialogue with the main sector stakeholders started very good, and development partners managed to affect them in many many areas, until a number of development partners wanted to promote their interests more than that of the Tanzanians. Then the relationship became difficult.' This has undermined trust between the government and donors, since it is not always clear to the government that the approach being promoted is in the long-term interest of Tanzania.

Furthermore, some development partners have a particular ideological position about unbundling and liberalisation, despite the limited number of actors in the sector, which makes it difficult to achieve enough competition in the market, and the lack of high-level expertise necessary to manage the independent system operator required. In other cases, the relatively rapid rotation of staff in donor agencies can mean that there is an insufficient understanding of the country's politics combined with a lack of skill in supervising and monitoring reform recommendations produced by independent consultants to ensure that they are consistent with the local context. This might also be amplified by the fact that consultants are often contracted by donors, with limited inputs from the government, and, in turn, frequently recycle the standard model with relatively little modification for country context.

The experience of donor engagements in Tanzania exemplifies some of the key challenges faced by external actors in promoting power sector reform. Frequent changes in government policy and attitude towards reform, combined with a mistrust of the motives of foreign partners and an historical antipathy towards the private sector make it hard for development partners to support a reform process. For their part, a lack of serious analysis of the underlying political constraints, combined with rapid turnover of donor officials, has resulted in a reliance on a standard model of reform with seemingly little attempt to tailor this to Tanzania's context. The result has been *de jure* reforms which satisfy the donors and release funding, but little *de facto* reform in the way in which the sector operates. However, the efforts of specific individuals to build trusting relationships with key government counterparts and tailor interventions accordingly have yielded important practical reforms in some areas.

5 Lessons learned

Our analysis of the academic literature and documentation from donor projects, along with our interviews with donor officials suggest some general lessons for policymakers, both in development partners and developing country governments.

5.1 Analysing the underlying politics of change in a country is valuable – but only if used

One of the surprising findings that emerged from our interviews was the absence of any significant formal analysis of the political context, in which reforms were being undertaken. Reforms were viewed as technical with the result that the only analysis undertaken prior to the implementation of projects were assessments of the different technical aspects of the project, rather than assessment of the wider political context and the incentives facing the various stakeholders.[7] Even where assessments are done, there seems to be little connection between the theoretical assessments provided by political economy analysis and operational programmes implemented on the ground (Levy and Palale (2014) provide an exception for Zambia). There is also a tension between those that believe that developing a deep understanding of the local political context is essential to success and others who believe that remaining politically 'neutral' requires focusing only on technical aspects.

Notwithstanding this, almost all donor officials interviewed displayed a detailed understanding of the political context in which they operated, with many arguing that success depended far more on intensive engagement with counterparts in government than any formal analysis of the context. As one respondent put it, '[H]aving key staff and development partners work intensively and over a long period of time [with the government] is important.'[8] However, the instruments at their disposal, the pressure to disburse, and the processes with which they had to comply seemed to, at best, discourage taking a slower and more reflective approach to engagement. For all donors, it appears to be difficult to *not* pursue reform, even if there is evidence that the particular pathway being proposed is unlikely to be successful.

Indeed, most projects provide an optimistic view about what will be achieved and only mention political interference as a potential risk to implementation. This is despite the fact most donor officials accepted that political interference in the power sector was a near certainty, and that many previous projects had cost two or three times as much as originally anticipated and taken two or three times longer than originally planned. It is not entirely clear why development partners are driven to pursue reforms; this may relate to the 'mental model' adopted by the donor (see Section 5.4), or to the belief that funds are only likely to be effective if reforms take place. However, it would appear that the internal approval processes for such projects may sometimes discourage honesty about the practical political challenges that they entail.

There would also appear to be a reluctance to apply such analysis *ex post* as well. With the exception of the World Bank, no other development partner had readily available project completion reports for power sector projects (including those supporting policy reforms) and virtually no donors appear to have assessed in a systematic fashion the political factors that determined success or failure. There would appear to be a strong case for more systematic *ex post* evaluation of power sector projects.

5.2 Flexibility is important – but there are reasons why it is difficult

Much of the recent mantra about project design is that donor programmes (in all sectors) should be flexible and adaptive (Andrews *et al.* 2012). Indeed, some of the successes reflect the ability for development partners to act in a flexible and opportunistic way. Flexibility also allows donors to shift focus to take account of changes in government and key personnel in counterparts, as well as enabling implementing partners to experiment with alternative approaches to solving problems.[9]

However, respondents also pointed to significant structural and procedural reasons as to why flexibility is difficult. For example, USAID receives funding from Congress that is allocated by sector and by country, inhibiting the flexibility to shift resources from less effective to more effective areas. Internal structures can also matter – complex reforms often require multidisciplinary approaches, but donor staff are often arranged by sector and discipline, making building a multidisciplinary team difficult. Different types of donors can also work with different counterparts. Bilateral donors generally have the capability to work with a range of counterparts in developing countries, including sometimes, the private sector and civil society and to work through contractors. Multilateral organisations, by contrast, are typically constrained to work through government which can restrict the nature of programmes that they can operate. This is a particular problem in the power sector, where projects often must work through the Ministry of Energy, even where political influence by the ministry is a key constraint in progressing reform.

Flexibility is particularly difficult when it comes to stopping ongoing initiatives. Once approved, the obligation on donor officials and implementers is to make a success of a project. This provides strong incentives to continue activities, even when external, often politically induced, changes have made the chances of success slim. Conversely, officials have greater flexibility to add components to programmes, with the result that programmes evolve by growth rather than by re-allocation.

Flexible programmes are also perceived to be more difficult to evaluate. Building a good relationship may be key to achieving reform, but is hard to assess in a results matrix. Flexible programmes typically consist of multiple initiatives which are not known in advance, making it much harder to design a monitoring and evaluation framework for such programmes.[10]

Donor programmes are evolving to address some of the challenges created by flexible programming, but difficulties remain. For example, some of the recent programmes designed by DFID in other sectors have deliberately built-in flexibility to allow a response to changing and emerging needs of the host country government. This may be easier in larger programmes, especially those backed by a long-standing relationship between donors and host country governments. At the same time, the monitoring and evaluation can be facilitated by retaining a clear sense of the overall outcomes that the donor programme is seeking to effect. But the stakeholders interviewed for this case study suggested that, despite some progress towards more flexible programme design, the structural and procedural constraints outlined previously remain a significant barrier to more flexible and politically informed ways of working.

5.3 Dialogue, trust, and personal relationships are of critical importance for reform

Perhaps the most consistent message from our interviews related to the critical importance of dialogue, trust, and personal relationships with key decision-makers. Again, this is true for all sectors, not just the power sector[11] – but the long-term nature and sunk costs of power sector reforms make the issue of particular salience. Respondents often attributed programme failures to a lack of trust between the government and donors. Almost every instance of successful reform was related to the construction of an effective working relationship through intensive and repeated interaction, often over a long period of time. A number of respondents pointed to the need to understand the nature of the constraints facing policymakers and the need to 'listen more and lecture less'. One respondent argued that loan conditionality was only effective when the conditions were suggested by the government as a mechanism to help them to handle domestic resistance. Overall, there was a consensus that 'there is no substitute for an experienced and credible [donor] staff member who has the trust and confidence of the key decision-maker.'[12]

Notwithstanding the almost universal support for the importance of building trust, there was a sense from some respondents that donor structures and training are making this more difficult than before. Some officials highlighted the burden of process compliance taking time that might otherwise be spent engaging key stakeholders. Some related the bureaucratic burden to risk aversion associated with (donor country) domestic political concerns; others pointed to the results agenda as a source of additional administrative work to 'prove' that aid is working.

A number of respondents suggested that the frequent rotation of donor staff undermines the ability to build long-term relationships with key government counterparts and noted the difficulty of maintaining institutional memory as well as a good understanding of the country's recent history. For example, one official suggested that the reticence of Tanzanian officials to pursue certain types of reform was rooted in the experience of reform attempts in the early 1990s; failing to understand this might result in pursuing reform models which, although technically sound, were politically unfeasible.

5.4 Mental models matter

As noted in the literature review, the application of the standard model for power sector reform has not generally been successful in developing countries. Notwithstanding the growing body of evidence supporting this, the core elements of the standard model – unbundling, commercialisation, privatisation, competition – still appear to hold sway in the thinking, both of development partners and some government officials. However, some senior donor officials argue that this view is mistaken, firstly because the standard model was rarely actually implemented in practice and so cannot be deemed to have failed; and secondly, because adherence to the model was abandoned in the early 2000s, notably by the World Bank, as evidence of its unsuitability came to light.

Although both of these are true, our research leads us to believe that the 'standard model' still holds considerable sway as a 'mental model'. The standard model is clear, coherent and logical. It was generally regarded as a success in England and Wales, Chile and Norway. Despite accepting the need for context specificity, development partners have struggled to adjust because there is no other compelling 'mental model' to which to refer. Rather, a set of path-dependent 'hybrid' models has begun to develop (Gratwick and Eberhard 2008) based on local experimentation within different political contexts. However, most international consultants, on whom donor officials depend, are still most familiar with the standard model. As a result, it has been difficult for donors to shift their advice, whilst developing countries have found it hard to gain donor acceptance of the somewhat expedient and path-dependent approaches that have been implemented in practice.

5.5 There may be an opportunity to build domestic demand for reform

One of the surprising findings from the project documentation and interviews was that development partners have put relatively little effort into building a wider domestic constituency for reform in the countries in which they operate. In general, donors appear to have interpreted the 'country ownership' principle of the Busan Partnership for Effective Development to mean government ownership. None of the projects reviewed in Tanzania included activities to build support for reform outside of government.

There are several reasons for this. First, in some countries donor projects are tightly controlled by the government, which may be unsympathetic towards activities that attempt to support advocacy activities. Moreover, many donors, particularly the multilateral development banks, typically work directly with government counterparts, making work with other stakeholders more challenging. Indeed, some respondents argued that, in certain countries, it was neither possible nor necessary to engage with wider civil society since all the key decisions were taken by a narrow group centred on the government.

Second, several donor officials said that engaging groups outside of government in favour of support was not possible because there simply was not a constituency of support for reform. For example, large industrial customers, who constitute the majority of electricity demand, can have significant influence over policy – but their interest is primarily in maintaining low prices. Small businesses without electricity might be expected to support improvements in access, but generally do not wish to pay a significantly higher tariff to obtain it. And the majority of households in Tanzania are poor and are not believed to support cost-reflective tariffs that would significantly increase the price of access and supply.

This lack of interest in building coalitions in support of reform is nonetheless surprising, given the growing literature on the importance of building broader coalitions to achieve sustainable reform (see Faustino and Booth 2014; Buckley, McCulloch and Travis 2017). Whilst no one is likely to be in favour of price increases in the short term, there are constituencies that would benefit from reform in the longer term (e.g. businesses that obtain more reliable supply; households and communities that can be connected because the utility is able to invest in expansion; civil society groups campaigning against corruption in the sector, etc.). There are strong parallels with the literature on fuel subsidy reform, where effective communication about the issue to build a wider constituency of support has been an essential part of successful reforms (Beaton *et al.* 2013; Kojima *et al.* 2014).

6 Conclusion

Our central finding is that, whilst development partners are often fully aware of the political nature of reform of the power sector, they appear to devote much less attention to the analysis of these political constraints and that what analysis there is has little or no influence on the nature of programmes that are put in place. Moreover, many development partners appear to be unaware of the emerging aid modalities for engaging with such dynamic political contexts or, for structural or political reasons, are unable or unwilling to adopt them.

We suggest that, at a minimum, future programme designs should start with a detailed analysis of the underlying motivations of the key actors and institutions in order to identify reform pathways that are politically feasible, rather than just those that are technically desirable. In general, donor interventions in this field should be based around the concept of 'politically feasible and technically sound' rather than the present approach of proposing technically sound solutions with the lack of political feasibility treated as a risk to be mitigated. Our work also suggests that development partners face a difficult choice between two rather different principles. One the one hand, where the political analysis indicates that certain reforms are likely to be impossible, they must find ways to 'work with the grain' (Levy 2014), i.e. to identify useful activities that are consistent with the current political equilibrium to maximise the chances of success. On the other hand, sometimes long-term sustainability requires a change in the political equilibrium. This suggests that development partners should consider ways in which they can support legitimate, credible domestic actors to challenge the *status quo*. Such interventions are common in the wider governance field, but rare in power sector reform.

Finally, our work poses an empirical challenge. Our theory is that new, more politically savvy approaches may help development partner interventions on power sector reform to be more successful. Insofar as such approaches are adopted going forward, there is a need to test this empirically to see whether such programmes are actually more effective and how their success or failure depends on the nature of the political context and the way in which they are implemented.

Notes

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2 Donors interviewed include: DFID, USAID, Power Africa, Millennium Challenge Corporation (MCC), the Swedish International Development Cooperation Agency (Sida), the World Bank and the African Development Bank.

3 There is, of course, a live debate about how developing countries might 'leapfrog' Western centralised power systems by adopting technology which allows a more distributed form of production, transmission, and distribution.

4 Hall, Lobina and de la Motte (2005) document civil society opposition to water and electricity privatisation in developing countries; Wood (2005) notes that fundamentally different understandings of public participation amongst stakeholders have stunted meaningful dialogue around reform.

5 Interview, September 2016.
6 Interview, September 2016.
7 It is possible that donors may undertake these assessments but not publish them because of their sensitivity. Whilst this may be true, our interviews suggest that formal assessments of this kind are rare and that these issues, if tackled at all, are typically addressed informally through discussions around assumptions and risks.
8 Interview, September 2016.
9 This said, flexibility is not always seen as positive – one experienced donor official commented that 'flexibility in reform tactics is often necessary, whereas flexibility in reform strategy is seldom advisable' (interview, September 2016).
10 Although not impossible – see Ladner (2015) for recent work in this area.
11 Indeed, one of the challenges in building these relationships can be that work in the power sector may be a small component of the overall work of some donors and so resources are devoted to building relationships elsewhere.
12 Interview, September 2016.

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Glossary

ACEP	Africa Centre for Energy Policy [Ghana]
AEECT	Applied Electrical Engineering and Computing Technologies
AEG	Allgemeine Elektricitäts-Gesellschaft [General Electricity Company, Germany]
AFD	French Development Agency
AfDB	African Development Bank [Côte D'Ivoire]
AGI	Association of Ghana Industries
AICD	Africa Infrastructure Country Diagnostic
ANC	African National Congress [South Africa]
APEC	Asia–Pacific Economic Cooperation [Singapore]
AURES	Auctions for Renewable Energy Support [Denmark]
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit [Federal Ministry for Economic Cooperation and Development, Germany]
BNEF	Bloomberg New Energy Finance [USA]
BSM	benefit-sharing mechanism
CAFOD	Catholic Agency for Overseas Development [UK]
CGE	Computable General Equilibrium
COFEK	Consumer Federation of Kenya
CPI	consumer prices index
CSIC	Consejo Superior de Investigaciones Científicas [National Research Council of Spain]
CSIR	Council for Scientific and Industrial Research [South Africa]
CSP	concentrated solar power
C-SIREA	Capacity for a Successful Implementation of the Renewable Energy Act in Ghana
DANIDA	Danish International Development Agency
DEFRA	Department for Environment, Food & Rural Affairs [UK]
DFID	Department for International Development [UK]
DG DEVCO	European Commission International Cooperation and Development [Belgium]
DME	Department of Minerals and Energy [South Africa]
DoE	Department of Energy [South Africa]
DTI	Department for Trade and Industry [South Africa]
EAPP	East Africa Power Pool [Kenya]
EBRD	European Bank for Reconstruction and Development [UK]
ECG	Electricity Corporation of Ghana
ECOWAS	Economic Community of West African States [Nigeria]
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency [Cape Verde]

EENS	expected energy not served
EIB	European Investment Bank [Luxembourg]
EMPD	Energy Management and Power Delivery
EnCG	Energy Commission of Ghana
EPC	engineering, procurement, and construction
EPSRC	Engineering and Physical Sciences Research Council [UK]
ERA	Electricity Regulatory Authority [Uganda]
ERC	Energy Regulatory Commission [Kenya]
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility [Germany]
EWURA	Energy and Water Utilities Regulatory Authority [Tanzania]
EY	Ernst & Young
fFIP	fixed feed-in premium
FIP	feed-in premium
FIT/FiT	feed-in tariff
FPIC	free, prior, and informed consent
GAA	generation adequacy assessment
GAMS	General Algebraic Modelling System
GCRA	Gold Coast Railway Administration [Ghana]
GDC	Geothermal Development Corporation [Kenya]
GDP	gross domestic product
GFPPM	the GET FiT Premium Payment Mechanism
GGDA	Green Growth Diagnostics for Africa [UK]
gGmbH	gemeinnützige GmbH [limited non-profit company]
GGPS	Ghana Generation Planning Study
GHG	greenhouse gas
GII	Ghana Integrity Initiative
GIPC	Ghana Investment Promotion Council
GIS	Geographic Information Systems
GIZ	Gesellschaft für Internationale Zusammenarbeit [German Corporation for International Cooperation]
GLSS	Ghana Living Standards Survey
GMF	Green Mini-Grid Facility
GMSP	Grid Management Support Programme [Kenya]
GoG	Government of Ghana
GSDRC	Governance and Social Development Resource Centre [UK]
GSGDA	Ghana Shared Growth and Development Agenda
GSS	Ghana Statistical Service
GTAP	Global Trade Analysis Project [USA]
GW	gigawatt
GWh	gigawatt hour
GWS	Gesellschaft für wirtschaftliche Strukturforschung [Institute of Economic Structures Research, Germany]
HFFP	high fossil fuel price

IASS	Institute for Advanced Sustainability Studies [Germany]
IDA	International Development Association [USA]
IDC	Industrial Development Corporation [South Africa]
IDE-JETRO	Institute of Developing Economies-Japan External Trade Organization
IEA	International Energy Agency [France]
IEEE	Institute of Electrical and Electronics Engineers [USA]
IET	Institution of Engineering and Technology [UK]
IFC	International Finance Corporation [USA]
IFPRI	International Food Policy Research Institute [USA]
IGC	International Growth Centre [Ghana]
IGGS	Institute of Green Growth Solutions [Ghana]
ILO	International Labour Organization [Switzerland]
IMF	International Monetary Fund [USA]
IPP	independent power producer
IRENA	International Renewable Energy Agency [UAE]
IRP	Integrated Resource Plan for Electricity [South Africa]
ISSER	Institute of Statistical, Social and Economics Research [Ghana]
IZA	Institut zur Zukunft der Arbeit [Institute for the Study of Labor, Germany]
JICA	Japan International Cooperation Agency
KAM	Kenya Association of Manufacturers
KENGEN	Kenya Electricity Generating Company
KENINVEST	Kenya Investment Authority
KEPSA	Kenya Private Sector Alliance
KEREA	Kenya Renewable Energy Association
KETRACO	Kenya Electricity Transmission Company
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KITE	Kumasi Institute of Technology and Environment [Ghana]
KLEM	Capital (K), Labour, Energy, Materials
KPLC	Kenya Power and Lighting Company
KPMG	Klynveld Peat Marwick Goerdeler [Netherlands]
KWh	kilowatt hour
LCOE	levelised cost of electricity
LCPDP	Least Cost Power Development Plan [Kenya]
LOLE	loss of load expectation
LTWP	Lake Turkana Wind Power Plant [Kenya]
MCC	Millennium Challenge Corporation [USA]
MEA	Middle East and Africa
MENA	Middle East and North Africa
MiDA	Millennium Development Authority [Ghana]
MoDP	Ministry of Devolution and Planning [Kenya]
MoE	Ministry of Energy [Ghana]

MoENR	Ministry of Environment and Mineral Resources [Kenya]
MoEP	Ministry of Energy and Petroleum [Kenya]
MoWI	Ministry of Water and Irrigation [Kenya]
MT	multi-technology
Mt	metric tonne
MW	megawatt
MWh	megawatt hour
MWp	peak megawatt
NDPC	National Development Planning Commission [Ghana]
NEB	National Energy Board [Ghana]
ODI	Overseas Development Institute [UK]
OECD	Organisation for Economic Co-operation and Development [France]
PAB	pay-as-bid
PDIA	problem-driven iterative adaptation
PE	political economy
PEA	political economy analysis
PEACH	Political Economy Analysis of Climate Change Policies
PEF	Private Enterprise Federation
PPA	power purchasing agreement
PPIAF	Public–Private Infrastructure Advisory Facility [USA]
PRG	Partial Risk Guarantee
PS	Principal Secretary
PSRC	Power Sector Reform Committee [Ghana]
PURC	Public Utilities Regulatory Commission of Ghana
PUWU	Public Utilities Workers Union [Ghana]
PV	photovoltaic
PWD	public works department [Ghana]
R&D	research and development
REA	Rural Electrification Agency/Authority [sub-Saharan Africa]
RECAI	Renewable Energy Country Attractiveness Index
REF	Rural Electrification Fund
REFIT	Renewable Energy Feed-In Tariff
RE IPPPP	renewable energy independent power producer procurement programme
REMP	Rural Electrification Master Plan
RES-E	renewable energy sources of electricity/renewable electricity
RETs	renewable energy technologies
RoK	Republic of Kenya
SAFCEI	Southern African Faith Communities' Environment Institute
SAM	social accounting matrix
SAPVIA	South African Photovoltaic Industry Association
SAREC	South African Renewable Energy Council

SARETEC	South African Renewable Energy Technology Centre
SEZ	Special Economic Zone [South Africa]
sFIP	sliding feed-in premium
SHS	solar home system
SIDA	Swedish International Development Cooperation Agency
SPDSS	Spatial Decision Support Systems
SREP	Scaling-Up Renewable Energy Programme
SSA	sub-Saharan Africa
SUT	supply-and-use table
SWER	Single Wire Earth Return
SWERA	Solar and Wind Energy Resource Assessment
T&D	transmission and distribution
TA	Technical Assistance
TANESCO	Tanzania Electricity Supply Company
TFP	total factor productivity
TN	technology-neutral
TNT	The National Treasury [Kenya]
TS	technology-specific
TUC	Trades Union Congress [Ghana]
TWh	terrawatt hour
UNDESA	United Nations Department of Economic and Social Affairs [USA]
UNDP	United Nations Development Programme [USA]
UNEP	United Nations Environment Programme [Kenya]
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistical Division [USA]
UNU-WIDER	United Nations University World Institute for Development Economics Research [Finland]
USAID	United States Agency for International Development
USDA	US Department of Agriculture
VG	variable [renewable] generation
VRA	Volta River Authority [Ghana]
WBCSD	World Business Council for Sustainable Development [Switzerland]
WFP	World Food Programme [Italy]
WIDER	World Institute for Development Economics Research [Finland]
WWF	World Wildlife Fund [Switzerland]

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Editors **Ana Pueyo and Simon Bawakyillenuo**

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