Solar energy's potential to mitigate political risks: The case of an optimised Africa-wide network

Philipp A. Trotter\textsuperscript{a,⁎}, Roy Maconachie\textsuperscript{b}, Marcelle C. McManus\textsuperscript{a}

\textsuperscript{a} Mechanical Engineering Department, University of Bath, Claverton Down, Bath BA2 7AY, UK
\textsuperscript{b} Department of Social and Policy Sciences, University of Bath, Claverton Down, Bath BA2 7AY, UK

\textbf{A R T I C L E   I N F O}

Keywords:
African development
Renewable energy
Regional electricity trade
Multi-criteria linear programming
Generation and transmission expansion planning
Political risk management

\textbf{A B S T R A C T}

Electricity generation expansion planning in Africa has focused almost exclusively on minimising costs. Yet infrastructure projects in Africa have been frequently shown to fail because planners have neglected their socio-political realm. Using the social science literature, this paper derives six political factors that are crucial for African electrification, and incorporates them into a linear, renewable-energy focused bi-criteria optimisation planning model of the African electricity network. The results reveal a significant degree of preventable political risk in the network if the only optimisation criterion is cost minimisation. This cost-minimal solution highly depends on large-scale exports from some of Africa’s most politically volatile countries, such as hydroelectric energy from the Democratic Republic of Congo and wind energy from Sudan, Somalia, Chad and Mauritania. However, the model demonstrates that raising the levelised cost of electrification in 2030 by 4% allows to cut preventable political risks of the network by 50%. Crucially, the optimal, most cost-effective risk mitigation strategy is to gradually replace large-scale exports with domestic solar energy abundant in most African countries. High solar energy shares increase national energy sovereignty, meet international climate commitments, and decrease the network’s dependence on politically unstable and/or ineffectual countries for generation and transmission.

1. Introduction

The 7th United Nation’s Sustainable Development Goal (SDG) aims to ensure access to affordable, reliable, sustainable and modern energy for all by 2030. While this objective is challenging in a number of world regions, it seems most significant in Africa. Roughly 650 million people in sub-Saharan Africa alone are without electricity access, a number paralleled by no other region in the world (International Energy Agency, 2015). The associated overall electrification rate in sub-Saharan Africa was 35% in 2015 (World Bank, 2017).

A multitude of donor countries and international organisations have set up African energy programmes. These policy efforts are convinced of the developmental benefits of African electrification (Cook, 2011; Tiwari et al., 2015), acknowledge the necessity of a joint effort to accumulate sufficient capital to meet demand, and agree that renewable energy technologies will play a considerable role in Africa’s electricity future (Sustainable Energy for All Initiative, 2012; United States Agency for International Development, 2015; World Bank, 2010). However, they suffer from an increasingly complex coordination requirement, and lack multi-faceted quantitative decision support analyses regarding where to optimally install which technologies exactly across Africa.

In helping to specify a suitable supply mix able to meet future African demand, the recent quantitative academic planning literature has focused almost entirely on minimising cost, in some cases for a discrete set of environmentally different scenarios (Gnansounou et al., 2007; International Renewable Energy Agency, 2015b; Mentiis et al., 2017; Ohiare, 2015; Ohijeagbon and Ajayi, 2015; Ouedraogo, 2017; Rose et al., 2016; Sanoh et al., 2014; Taliotis et al., 2014; Taliotis et al., 2016; Zeyringer et al., 2015). While the relevance of environmental, technological and social decision criteria have been well documented (Bhattacharyya, 2012; Loken, 2007; Mirakyan and De Guio, 2013; Pohekar and Ramachandran, 2004; Rojas-Zerpa and Yusta, 2014; Trotter et al., 2017a; Wang et al., 2009), it seems imperative that policy makers also consider the politics of African electrification in energy planning (Trotter et al., 2017b). For instance, favourable cost and environmental factors have led to appraisals of large-scale electricity export projects such as hydroelectric energy from the Democratic Republic of Congo (DRC) to power significant parts of sub-Saharan Africa (International Renewable Energy Agency, 2015b; Sanoh et al., 2014; Taliotis et al., 2014; Taliotis et al., 2016; Tshombe et al., 2007). South African development Renewable energy Regional electricity trade Multi-criteria linear programming Generation and transmission expansion planning Political risk management

⁎ Corresponding author.
E-mail address: p.trotter@bath.ac.uk (P.A. Trotter).
Africa has signed an agreement with DRC, two countries separated by 3000 km and multiple other countries, to supply 2500 MW peak from DRC's Grand Inga dam to South Africa by 2021. Yet politically, overly relying on a highly volatile country marred by dysfunctional political institutions and violent conflict involving at least 81 different armed groups (Stearns and Vogel, 2015) appears to be a sub-optimal choice. Other political aspects influencing African electricity trade are unfavourable political dependencies from overly relying on imports (for example, the Swazi dependence on imports from South African), or politicised land access which is holding up crucial transmission line construction (for example in Uganda).

The investment risk management literature has convincingly demonstrated the relevance of political risk assessment for investment decisions in general. Countries have been found to receive more foreign direct investments when political risks are low (Asiedu, 2006; Barry, 2016; Busse and Hefeker, 2007; Erb et al., 1996; Jensen, 2008; Kooijaroenprasit, 2016), with investors often ranking political concerns as their main investment risk in developing countries (Al Khatib et al., 2008; Komendantova et al., 2012). In terms of electrification, the merits of political risk insurance for risk-laden projects have been pointed out (Chowdhury et al., 2015), and renewable energy investments have been argued to increase energy security due to their de-central applicability (Frances et al., 2013). Yet despite these achievements, a formalised incorporation of the political dimension of electrification, including a discussion on which political risk factors are actually important, is absent from the quantitative electricity planning literature.

This paper makes three novel contributions. First, based on relevant social science research and various agency reports in Africa, it distils six specific political factors that matter for electricity planning. As this is based on a systematic review of the larger African electricity planning literature elsewhere by the authors (Trotter et al., 2017b), the frequency with which the these factors are discussed indicates their relative importance. Second, the paper illustrates how these six political factors can be integrated into a generation expansion planning model using entirely linear constraints. The resulting bi-criteria model is able to quantify the optimal trade-off between cost and political risk minimisation. Third, using this model, this paper is the first to present a continuous optimisation of the African generation and transmission network with multiple decision criteria, extending the previous work focused on cost-minimisation (in some cases for a discrete number of different environmental scenarios). Its cost minimisation solution, a specific case where no political risk constraints are active, corrects and remedies the multiples flaws present in Sanoh et al.’s (2014) original work (see Trotter, 2017 for a discussion). Political factors of electrification are particularly salient on a continent-wide scale, where some of the greatest potential for cost-effective renewable energy is located in some of the most politically risk-laden countries in Africa. The model results challenge hasty recommendations for large-scale export-driven projects in politically highly volatile countries, and identify increased solar energy shares as the optimal political risk mitigation strategy.¹

Section 2 develops the six different political factors relevant for electricity planning in Africa, illustrating the strong link between political risk and electricity in the region. Section 3 discusses the methods and data sources necessary to incorporate the six political factors into a bi-criteria linear electricity planning optimisation model. Modelling results for the Africa-wide network and risk mitigation strategies are presented in Section 4, while Section 5 offers a conclusion and policy implications.

2. Political factors of African electrification for energy planning

Political science and policy research on African electrification, often qualitative in nature, has detailed a large set of cases where politics have crucially influenced technology choice and implementation. Table 1 categorises these works along six different political factors, sorted from macro to micro-level politics. It is based on a systematic literature review described in detail by (Trotter et al., 2017b), involving all African countries as well as regional power pools and a combination of different relevant keywords such as “energy” and “electricity” with full-text searches of the stem of the word “politics”. International, national and project-level politics were all included, whether of structural or agency-related nature. Imposing a limit of five journal articles per country and region, as well as only including peer-reviewed journal articles published in English, the search identified 84 relevant papers and 21 agency reports on electrification in Africa that have addressed political factors. While the list in Table 1 is not exhaustive, it offers an insightful evidence base. Its bottom-up approach avoids over-generalisation of political risks and goes considerably beyond generic country-level risk indices such as the International Country Risk Guide (ICRG) (Erb et al., 1996), or one-dimensional proxies to evaluate general political risks frequently used in the investment risk management literature (see for instance (Henisz, 2000; Kooijaroenprasit, 2016; Kucukali, 2011)), Sections 2.2–2.6 briefly discuss each political factor.

2.1. External political pressure/commitments

All African countries except Libya have submitted their Intended Nationally Determined Contributions (INDCs) on climate change to the UN following the 2016 Paris agreements (see Appendix A). While several intended contributions were entirely conditional on receiving international financial support, the majority of countries described at least part of their contributions as “unconditional” in the INDCs, implying a firm commitment to realise them. Apart from the inherent political motivation of such worldwide agreements for all signees to do their part, many INDCs submitted by developing countries have been found to be strongly influenced by international development organisations (Energising Development Initiative, 2016).

External influence on African electrification is not new. Neoliberal ‘conditionality’s associated with international loans have considerably influenced energy policy in Africa. For instance, following its 1991 Structural Adjustment Programme (SAP), Zimbabwe gradually changed its electrification strategy from a socialist “electricity-for-all” paradigm to a market-focused financial self-sufficiency approach (Söderholm, 2014). The World Bank effectively decided which generation technologies to use (Rowlands, 1994). A 2012 World Bank report corroborates this finding, stating that generation installations in general are subject to international financial institutions’ viewpoints (The International Bank for Reconstruction and Development, 2012). Several scholars have criticised the effects of neoliberal policy on Africa’s power sector (Pineau, 2002, 2007; Wamukonya, 2003). Issues of external political commitments tend to multiply in the case of multinational electricity transmission where severe political complexities can arise depending on the history of different countries involved in the network (United States Agency for International Development, 2015). For instance, Namibia’s committed greenhouse gas savings in its INDC are likely to have an effect on coal-fired electricity imports from South Africa which are responsible for a major part of greenhouse gases in Namibia’s electricity consumption.

2.2. National energy security/sovereignty

In a politically volatile environment, using domestically resources to meet energy demands increase both national energy and political implications.

¹ This paper does not attempt to present modelling approaches that capture all political aspects of electrification. On the contrary, the complexity of African electrification politics makes it virtually impossible to capture all relevant aspects through quantitative modelling alone. However, by including some fundamental political factors in quantitative energy planning models, there is much greater potential for more resilient energy initiatives to be developed, which includes important qualitative discussions focusing on infrastructure decision-making.
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات