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# Impact of political and economical barriers for concentrating solar power in Sub-Saharan Africa

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ABSTRACT

Sub-Saharan Africa (SSA) needs additional affordable and reliable electricity to fuel its social and economic development. Ideally, all of this new supply is carbon-neutral. The potentials for renewables in SSA suffice for any conceivable demand, but the wind power and photovoltaic resources are intermittent and difficult to integrate in the weak electricity grids. Here, we investigate the potential for supplying SSA demand centers with dispatchable electricity from concentrating solar power (CSP) stations equipped with thermal storage. We show that, given anticipated cost reductions from technological improvements, power from CSP could be competitive with coal power in Southern Africa by 2025; but in most SSA countries, power from CSP may not be competitive. We also show that variations in risk across countries influences the cost of power from CSP more than variations in solar resources. If policies to de-risk CSP investment to financing cost levels found in industrialized countries were successfully implemented, power from CSP could become cheaper than coal power by 2025 in all SSA countries. Policies to increase institutional capacity and cooperation among SSA countries could reduce costs further. With dedicated policy measures, therefore, CSP could become an economically attractive electricity option for all SSA countries.

## 1. Introduction

The electricity systems of Sub-Saharan Africa (SSA) face a number of serious challenges. Electricity demand is increasing rapidly, and is likely to at least double in the next 25 years (EIA, 2013; IRENA, 2015a). Simultaneously, only one-third of the population has electricity access, and current progress on electrification is merely keeping up with the population growth (IEA and World Bank, 2015). There is thus a need to expand the electricity generation faster than today: need estimates range from 7000 MW/year to 14000 MW/year, corresponding to 5–10% of the currently installed capacity; presently, some 4000 MW/year are installed in SSA (EIA, 2015). Blackouts are common because of capacity shortages and unreliable infrastructure, forcing consumers to rely on expensive and inefficient diesel-fueled backup generators. In some countries, diesel generators represent half the installed capacity, despite their very high cost of 50 US¢/kWh or more, greatly exceeding the cost of grid power (Briceño-Garmendia and Shkaratan, 2011; Eberhard et al., 2011; Eberhard and Shkaratan, 2012; Gallup, 2010; Mukasa et al., 2015).

The electricity production must be completely decarbonized by the second half of this century, also in SSA (IPCC et al., 2014; UNFCCC, 2015a). This means that all new long-lived infrastructure must be based on carbon-neutral technologies (IPCC, 2011; Rogelj et al., 2015). To meet the objectives of sustainable development and poverty eradication defined under the Millennium Development Goals (MDGs) and the Paris Agreement (UN, 2016; UNFCCC, 2015a), however, new electricity generation in SSA also needs to be affordable, not increasing costs beyond what consumers can afford. Currently, three-quarters of the sub-Saharan countries have average power generation costs exceeding 10 US¢/kWh, and one third exceed 15 US ¢/kWh (Eberhard et al., 2011). Hence, if new carbon-neutral electricity is to be considered “affordable”, it must be at least competitive with the existing power mix and have generation costs of less than 10–15 US ¢/kWh. If it is to be competitive with the largest electricity system carbon emitter – coal power – then it must have generation costs of less than about 8 US¢/kWh (IRENA, 2013c).

In the sub-Saharan context, the search for additional generation is further complicated, as the weak electricity grids south of the Sahara would struggle to integrate large-scale additions of new intermittent power (Mukasa et al., 2015). Hence, either the grids must be reinforced to integrate fluctuating renewables, or ways could be sought to smooth the renewable electricity on the generation site and make the feed-in

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predictable and controllable so as to minimize the added strain on the grid. Dispatchable and economical renewable power would therefore be particularly valuable for the electricity supply of SSA.

These multiple policy objectives of carbon-neutrality, dispatchability and affordability are not easily compatible, for several reasons. Current costs of renewable power still exceed those of most fossil technologies, although this gap has closed substantially through substantial technological development: the cost of solar photovoltaic (PV), for example, has decreased by 50% over the last four years (IPCC, 2011; IPCC et al., 2014; Rogelj et al., 2015). Solar PV and wind turbines are the least-cost renewable technologies, and both could be competitive on a levelized cost basis in many SSA countries: today, wind power costs some 6–9 US¢/kWh, on par with new fossil generation, while PV costs some 10–12 US¢/kWh in America and Europe, depending on solar resource and market situation, down to 6 US¢/kWh in the United Arab Emirates with very good solar resources (IRENA, 2015b). On the other hand, there are not many options for supplying dispatchable renewable power at large scale. Dam hydropower and biomass power have limited potentials and are questionable for a very large-scale expansion because of their environmental impact (IRENA, 2012b, 2014). Wind power would need bulk storage for large amounts of power, such as pressurized air storage, to smooth the wind farm output on-site, and such storages are currently not commercially available at scale (Budt et al., 2016). Solar PV, which is modular and easy to quickly install also in remote places, can be equipped with batteries in a decentralized setting, making the supply to the grid more – or even fully – predictable, or enabling consumers to be fully autarkic (Baurzhan and Jenkins, 2016). The last option – the one we investigate here – is concentrating solar power (CSP) with thermal storage, which offers the potential to provide fully predictable renewable bulk power (Pfenninger et al., 2014). The potential for CSP in SSA is vast, and would in principle suffice to cover any conceivable future SSA demand (Hermann et al., 2014; Trieb et al., 2009b). However, CSP is lagging behind and is not expanded as fast as PV – there are 5 GW of CSP world-wide, compared to 230 GW PV (NREL, 2016; SolarPowerEurope, 2014) – also because of PV's rapid cost development. Indeed, several projects have seen a shift in technology, from CSP to PV, because of the lower costs of PV. For example, this happened at the 250 MW Beacon project in the US (CSP World, 2013) and the 10–30 MW Erfoud, Zagora and Missour projects in Morocco (World Bank, 2014): in these cases, the CSP plants were planned without storage, so that the CSP power would have been similarly fluctuating as that of the final PV projects. Today, most recent CSP projects and those under construction are equipped with thermal storage to leverage this advantage, including all CSP stations built or under construction in Africa (Morocco and South Africa) (NREL, 2016). When comparing CSP with thermal storage and PV with lithium-ion (Li-ion) batteries on a levelized cost of electricity (LCOE) basis, CSP with storage emerges as the lower-cost alternative: using current and projected costs (2020), the LCOE of CSP is lower than of PV with the same hours of storage for peak and intermediate power coverage (Feldman et al., 2016). When comparing CSP with thermal storage and PV with Li-ion batteries on a net system cost basis, the projected costs (2020) of both technologies are similar but with high uncertainties especially for PV with batteries (Mehos et al., 2016).

Here, therefore, we examine the competitiveness of CSP with thermal storage as one possible policy option for supplying dispatchable renewable power to SSA and compare it with typical cost of coal power, which in most cases is the currently cheapest dispatchable electricity supply option. In this article, we investigate the potential for and cost of CSP with thermal storage in SSA. In particular, we explore how dispatchable solar power could be traded, and investigate how the current political, institutional and economic situation in SSA with its far-reaching effects on financing costs, technological capacity, and international cooperation on infrastructure development affect the prospects of this technology, and what it would take in terms of policy to solve key problems and make CSP with thermal storage a viable electricity option in SSA.

## 2. Background

### 2.1. Concentrating solar power

Concentrating solar power collects the heat of the sun through large mirrors, which focus the light on a focal line (parabolic trough, Fresnel) or a focal point (solar towers), to generate steam and drive a turbine. The aspect that sets CSP off from other renewables is the option of equipping it with thermal storage. The thermal storage is charged during the sunny hours of the day and allows the power station to operate after sundown, at night, or during periods of adverse weather. Recent analyses suggest that with the proper system coordination, CSP with thermal storage can be operated in the Northern and Southern African deserts to provide both a constant and a dispatchable power supply (Pfenninger et al., 2014; Trieb et al., 2014).

Today, there are almost 5 GW of CSP in the world, mainly in Spain and in the US, and further CSP stations stand in another 8 countries, including South Africa, Morocco, China and India. This is less than expected during the CSP hype a decade ago, but CSP continues to develop and expand, albeit at a much lower pace than wind and solar PV. Some 2 GW of CSP are currently under construction, almost all of which outside the industrialized world, mainly in Morocco, South Africa, Chile, China and India (NREL, 2016).

One reason for the slow expansion pace is that optimal conditions for CSP are found in areas with high direct normal solar irradiance (DNI). Such areas are typically found in deserts and arid regions, and most deserts are not in the industrialized countries traditionally driving renewables development and expansion (IRENA, 2012a; Lilliestam et al., 2012). Even in countries with good CSP sites, such as the US or South Africa, large cities and densely populated areas are often located far away from such dry places, so that long power lines are needed for CSP to reach the main grid and the consumers. This makes CSP projects more complicated than other renewables to be expanded near demand, but CSP projects can be cost-effectively connected to demand-centers with high-voltage power lines (Trieb et al., 2015).

### 2.2. Renewable energy investments and finance in Sub-Saharan Africa

Renewable power technologies have high upfront investment costs but low operation costs compared to fossil alternatives, as they have no fuel costs (except biomass power). The investment and the financing costs[1] are therefore the dominant drivers of the LCOE for renewables, making them very different investment cases than, for example, gas and coal power stations.

Investment costs are commonly higher in developing than in developed countries due to factors such as poorly trained labor forces, a need to bring engineers from abroad, and weak transportation infrastructure (IRENA, 2015a; Ondraczek et al., 2015). The financing costs are also commonly much higher in developing than in developed countries, as they represent the extra reward required by investors and lenders to compensate them for the high risks. These risks arise because of perceived or factual political, regulatory, financial and administrative barriers, long and uncertain permission processes, and other general investment risks (Backhaus et al., 2015; Ondraczek et al., 2015; UNDP, 2013). Given that renewables are capital-intense investments, renewable energy projects are especially sensitive to financing risks driving up the cost of capital (Williges et al., 2010). To address

[1] Throughout the article, we use the terms weighted average cost of capital (WACC), financing cost and discount rate interchangeably, as they refer to practically the same financial concept in the context of our study.