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Perspective

Desirable or debatable? Putting Africa's decentralised solar energy futures in context

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ABSTRACT

After decades of terrible ecological impacts, inefficiencies, corruption, and spatial injustices associated with dependencies on both centralised power generation and distribution in Africa, decentralised solar photovoltaic (PV) electrification is presented in the literature as an 'irresistible' alternative or complement necessary for a *just, development-oriented* and *low-carbon* energy transition. Affordable decentralised solar energy systems, however, currently have restrictive usage whereas systems with a larger capacity are accessible to a few richer social groups. The massive promotion of decentralised solar electrification does not even guarantee energy justice *for all*. This is due to contested notions of entitlements to and use of grid-based and off-grid electricity, relative spatial advantages or disadvantages, practical constraints linked to the pursuit of low-carbon energy solutions – particularly in situations where people/governments do not feel (morally) obliged to make commitments to climate change mitigation, and monopolistic tendencies of electricity distributors/suppliers. Furthermore, many electricity users in Africa lack the technical know-how and financial resources required for efficient self-organisation of decentralised solar PV electrification. Meanwhile, paradoxically, global north actors championing low-carbon energy technologies in Africa are sustaining their economies via massive use of fossil fuels – a behaviour referred to as 'energy bullying'. Nonetheless, these quandaries should not be taken to imply 'throwing away the baby with the bathwater'. Evidence presented from four idiographic cases suggests even that though context/country-specific conditions are decisive of the desirability of decentralised solar energy systems, certain general conditions necessary for the wider development of the technology in Africa are still discernible.

1. Africa's centralised electricity sector and the solar energy quandary

The increasing use of electrical appliances, high electricity demand for national socio-economic transformation visions and a global 'de-carbonisation' agenda in the 21st century have caused interests in the pursuit of pathways that can guarantee reliable, efficient and affordable electricity supply with low-carbon solutions. Despite the great contribution of hydropower generation to low-carbon electricity generation globally, the associated negative ecological impacts, huge financial requirements, corruption, and limited socio-economic benefits have resulted in a decline of interest in the technology in many regions of the world, including Africa [1,2]. The predominantly state-controlled, centralised provision of electricity in Africa is equally associated with inefficiencies, convoluted tariff systems, uneven spatial distribution of electrical grid infrastructure and diverse forms of spatial energy injustices [3–6]. An estimated 573 million people (of the current total population of 1.3 billion) in sub-Saharan Africa (SSA) still lack electricity access despite recent progress registered at global levels [7]. Per current policies, the World Bank [7] projects that 8% of the global population will still lack electricity access by 2030, of which 90% will be located in SSA. Public dissatisfaction with centralised electricity supply has in part driven a massive uptake of expensive diesel-fired generator sets, notably in Nigeria, to enable household and business activities that require uninterrupted power supply [8]. Furthermore, national governments of Africa and international development agencies recently provided credits to cash-strapped energy sector agencies that have accumulated debts caused by non-payment of cost-reflective tariffs, fraudulent power purchasing deals and other inefficiencies in the power sector [9,10].

Cyclical financial challenges, low-income levels and widespread inefficiencies in Africa's power sector make electrical energy either unaffordable for low-income groups or mostly accessible to richer social groups. This is the case even though tariffs are usually kept significantly

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below actual costs of power supply and life-line tariff systems[1] are well established. Meanwhile, many African governments have recently initiated ambitious energy programs to facilitate economic transformations, universal electricity access and low-carbon energy visions simultaneously. The UN 2030 Agenda for Sustainable Development Goals (e.g., Goal 7) [11], UNCTAD [12] and other recent initiatives by 'global north' actors promoting mini-grid electrification, off-grid solar photovoltaic (PV) technology and grid-connected distributed generation systems potentially offer a timely inspiration to re-configure Africa's energy sector toward the desirable end: a just, development-oriented and low-carbon energy future. Off-grid solar PV systems involve the installation of solar PV panels to generate electricity with the aid of charge controllers, batteries and power inverters (self-generation). Grid-connected distributed generation involves the use of solar PV modules, grid-tied inverters designed to export excess power to the distribution utility grid with special configurations and net-meters[2] that allow self-consumption [13]. The self-generation and self-consumption of electricity simultaneously using solar PV systems to power electrical appliances – often referred to as 'prosuming' – permits users to share excess power with co-customers, and support peak load demand management, reliable and sustainable electricity supply [14,15].

I use 'self-organisation' of electricity provision here to describe individual arrangements to access services of registered private organisations, and informal/unregistered energy providers – whether grid-connected or off-grid systems – primarily to reduce dependencies on unreliable, less efficient and sometimes expensive energy services provided by the state. Of course many national governments of Africa have, in recent times, supported or incentivised the uptake of decentralised solar PV systems but the sustainability, expansion, and maintenance of these systems have required the combined efforts of many individuals via self-funding and other self-driven initiatives [16–18]. The pace of rural electrification in Africa is still too slow despite massive Western donor funding schemes since the 1970s to facilitate economic modernisation in the periphery [19–21]. Hence, the transition to self-organised decentralised solar energy systems makes a strong appeal to modernisation narratives, climate change discourses and the rural economic transformation mantra currently driving many development policy interventions in Africa [17,22]. Such considerations overlap spatial energy justice frameworks emphasising universal access for all, fairness in electricity distribution and tariff-setting, and high-quality energy services to meet the needs of different social groups, including underprivileged persons in territorially remote locations [23–25]. It also involves equal sharing of socio-economic benefits and environmental costs of energy systems by all, including current and future generations particularly in societies aspiring to be 'fair' [26,27]. That said, the capacity of self-organised energy initiatives to deliver on energy justice visions begs many questions in African contexts given that electrical grid infrastructure and electricity distribution are predominantly centralised, organised within a state apparatus, state-run or state-owned for political expediency reasons [6,28,29,30] or for 'developmental state' agenda, as well as financial and ideological considerations [17,20,31]. Many state-owned or state-driven electricity distributors in Africa are sceptical of the promotion of decentralised self-organised solar electrification systems due to path dependence [17,20,31]. Also, grid-connected distributed solar electricity generation requires available and reliable electrical grids, while even quite 'advanced' African countries like Ghana, Nigeria, and South Africa still face challenges in the grid electricity sector [8,13,16,31].

The relatively affordable off-grid solar PV systems have rather low voltage and restrictive energy services whereas systems of higher capacity that can provide substantial energy services – including running micro-enterprises, refrigerators, water pumps, etc. – are too expensive for low-income groups [13,16,17]. The euphoria around the promotion of solar energy systems in Africa premised on declining solar PV prices is also quite simplistic. This is because a similar decline in the pace of prices has not yet occurred in the case of battery storage or inverters to make the technology readily affordable and accessible to all social groups facilitating any significant economic transformation or carbon-savings as it is often claimed [25,32,33,34] despite the emergence of flexible financing mechanisms [35–36]. It is thus, recommended that the success of off-grid solar PV electrification in Africa would still depend on financial support particularly from abroad [34] and serious attention to socio-cultural needs and views of the target communities [37–38]. Others advocate the pursuit of energy justice visions through a flexible pricing scheme and centralised system of operation capable of improving electricity access to off-grid communities with standards comparable to those depending on centralised electrical grids [25,33]. In an attempt to offer a more realistic solution, Jenkins et al. [39] emphasise that climate protection, electrification of the global south and justice ought to progress side-by-side. However, the decisive effect of local conditions in different countries is still less considered and the authors slip into the usual temptations of making *a priori* assumptions about justice/injustice.

These conundrums do not imply a dead-end in the pursuit of energy justice, low-carbon solutions and socio-economic development in Africa but rather call for a more nuanced discussion of the diversity of African cases and general conditions to show how and why decentralised energy transitions can be justifiably considered desirable or debatable. This is the core contribution of this perspective essay engaging with this overarching question: *under which conditions can self-organised decentralised solar PV electrification contribute to the making of just, development-oriented and low-carbon energy futures in Africa?*

2. Methodology and the rationale for the case selection

The current paper is based on long-term empirical fieldwork in Ghana, Namibia, and Kenya investigating conditions that support or derail the transition to decentralised solar energy systems at the domestic/household and community levels. The case of South Africa is also included, based on a review of literature on similar thematic issues. The Namibian case, in particular, was based on an inter-disciplinary project PROCEED (Pathway to Renewable Off-Grid Community Energy for Development) funded by the German Federal Ministry of Education and Research (BMBF). PROCEED[3] is constituted by four workpackages and I am part of the team conducting the workpackage: Mini-Grid Community. I draw largely on fieldwork in the mini-grid project sites in Namibia and to a lesser extent on findings presented by other project partners during a Kick-Off meeting held in Windhoek (July 2019). Arguments presented in this article are based on the analysis of policy energy policy documents, flagship initiatives on energy, renewable energy acts, minutes of project meetings, on-site visits, field interviews, surveys, and media headlines on decentralised solar PV electrification in the four countries. The design and methodological execution of the

[1] This refers to subsidies for the first 50 or 100 units of electricity consumed and varies across countries. The main target is low-income groups whose consumption is cross-financed by higher energy consumers. In some countries, life-line tariffs are financed by special funding schemes.

[2] The Net-Meter is a single bi-directional meter that tracks energy inflows from a grid network and energy outflows from the customer's renewable energy source into the grid. The customer uses his/her renewable generation to meet demand, then exports the surplus power to the grid network, earns credits to offset the subsequent consumption and hence, reduces his/her monthly tariffs. Since the system involves generating power at a local point and supplying power to a grid distribution network using Net-Meters, it is also called Net-Metering systems distributed generation. Off-grid solar PV systems are also called "stand-alone systems" or Solar Home Systems (SHS) and thus, they will be used interchangeably in the manuscript.

[3] More information about the PROCEED project is available here: https://www.bmbf-client.de/en/news/proceed-project-start.

studies and the depth of information vary since they are based on different research projects. The selection of idiographic cases is, nonetheless, based on how the quest to achieve just, development-oriented and low-carbon energy futures via decentralised solar energy systems are framed, justified and contested *in similar ways* by energy sector agencies, governments, population and energy experts in the respective four African countries. The selected cases show significant differences in terms of stages of economic development, electricity sector challenges and energy planning. Yet the mediating role of contextual conditions provides the 'litmus test' to examine *how, where* and *why* self-organised decentralised solar energy futures are desirable or debatable. The findings are likely to be transferable to African countries pursuing similar energy futures, experiencing similar electricity sector challenges, and bearing similar contextual conditions.

3. Putting self-organised decentralised solar energy systems in context

This section provides critical perspectives on self-organised decentralised electrification in Africa by presenting examples from each of the case study countries, namely South Africa, Ghana, Namibia, and Kenya. In each country, I focus on examples at the local household, national and community levels and how these interact with contextual factors including national-level policies and international initiatives.

3.1. South Africa

Structural inequalities in the South African society are evident in electricity access and energy injustice too, this is especially the case for those between rural/remote and urban locations. During the last two decades, the South African government and energy sector agencies have taken inspiration from SDG 7; as well as from national socio-economic and ecological transformation visions to accelerate the transition to universal energy access and low-carbon energy [25,31,40]. However, huge inequalities that warrant academic attention remain despite the policy interventions. South Africa's main electricity distributor, Eskom, generates over 95% of its total electricity from coal and owns most transmission networks [41]. Eskom implementing power generation and grid expansion activities between 2017 and 2024 to address recurrent power crises in South Africa [42]. Grid expansion activities are expected to bring huge costs to Eskom, part of which will have an impact on electricity consumers in the form of increased tariffs [43]. Noteworthy and paradoxical here is that Eskom has faced a steady decline in electricity consumption [43] meanwhile South African national and local governments are compelled to promote alternative electrification initiatives to achieve energy justice and low-carbon solutions. These frictions are presented in the next section.

The province of Western Cape suffers frequent power outages and has also been selected by the South African government to be 'the green economic hub of Africa' primarily to reduce the carbon footprint of the province [31]. Energy efficiency, tax incentives, cost reductions/income allowances for energy-saving and small-scale renewable electricity are encouraged in the province [31]. Frequent power outages and rising electricity prices have created ideal conditions for distributed generation. Municipalities were encouraged to apply for grid-connected distributed generation meanwhile the Department of Energy has failed to make the necessary regulations [31]. There was also pressure on the municipalities to implement distributed solar PV systems in ways that would prevent the potential defection of customers from the national electricity grid to decentralised/self-organised electrification systems. Cape Town, for example, was the first city in South Africa to implement feed-in tariffs for distributed generation at the household level. The National Energy Regulator of South Africa (NERSA) facilitated the installations but with structural limitations: consumers were required to be *net-consumers* but not *net-producers* per annual calculations. Also, total power generation capacity should not exceed 1 megawatt (MW) because licenses were not required for such installations. In this sense, consumers were practically compelled to use installations to offset their electricity consumption. The rationale behind these strategies of government actors was to ensure that the uptake of decentralised self-generation of renewable energy – particularly by high-end consumers – would not financially constrain municipalities and metropolises. There has been strong public advocacy in favour of private sector involvement in electricity production but this has been blocked by political elites to retain the monopoly of Eskom in electricity distribution thereby pursuing South Africa's vision for a 'developmental state' model [31]. Here, the interest of the state has constrained the freedom of prospective customers to make maximum gains from distributed generation. The reverse case could affect both the finances of Eskom and the 'developmental state' vision.

Alternative electrification systems premised on energy justice visions, such as life-line tariffs and other subsidies for low-income energy users, are equally problematic. The government introduced Free Basic Electricity (FBE) in 2004 to provide 50 kWh per month for poor households to enable cooking, lighting, and heating, and thereby address energy poverty [40,44]. However, empirical research shows that 50KWh/month is far below the energy needs of the increasing household sizes of poor homes and rural beneficiaries [44]. The households instead expected full coverage of their energy needs as well as active involvement in the project's formulation [44]. The government also subsidized SHS to provide approximately 7.5 kWh/month to off-grid rural poor households [25]. The obvious lack of uniformity in the quality of energy output and tariff standards may be considered an element of spatial energy injustice due to the wide gap in energy services between electrical grids and SHS. That said, the capacity of the final energy to address effectively energy needs and visions of different social groups – a crucial condition referred to as "practical recognition" [18] – slip out of sight.

3.2. Ghana

Power sector reforms constitute an integral part of Ghana's vision for economic transformation, energy justice, and low-carbon energy visions. The country boasts of its enviable national electricity access rate of 84% [45] and yet centralised grid electricals are still unreliable and billing systems remain convoluted [16]. The government introduced a solar PV subsidy program in 2016 to reduce load pressure on centralised grid systems and complement power generation shortfalls when power crises came to a head in 2012 [16]. Eligibility conditions favoured urban elite households that had gained the necessary experiential knowledge of solar energy technology. However, the massive use of energy-intensive/AC appliances such as refrigerators/deep-freezers, air-conditioners, TV sets and water pumps in many Ghanaian homes meant that deep cycle batteries and efficient inverters are required for effective use of solar energy services, especially during off-peak seasons or grid power outages (Author Interviews, 2019). Meanwhile, batteries and inverters currently constitute the highest costs component of solar PV systems. Gel and Absorbed Glass Mat (AGM) batteries are commonly used in Ghanaian homes due to their relative affordability but these batteries should only be discharged to 50% to increase their durability. Power storage limitations of batteries restrict the effective use of decentralised solar PV systems, and users who were oblivious to user instructions caused the breakdown of storage batteries shortly after installation. Conversely, Lithium ION batteries which are more efficient are still too expensive for lower-income households.[4] Consequently, only a few richer households can afford efficient solar energy systems that enable the performance of a wide range of social and economic activities (Author Interviews, 2019).

Thus, the promotion of 'free' decentralised solar PV systems simply

[4] For example, the prevailing market price of Lithium ION batteries with a rated power of 2.5kWh – 20kWh range between USD 456 and USD 16700 respectively.

does not address energy injustice, not even in rural areas where such systems are often considered more 'desirable' [18]. In late 2017, the Ghanaian government provided free 500 W off-grid solar PV systems to 200 households in rural locations lacking access to centralised electrical grids. Beneficiaries were required to finance maintenance costs themselves to take full responsibility for the facility. A few low-income households needing electricity to power basic appliances were satisfied with the 500 W solar PV system. The reverse was the case for local elites and higher-income rural households who claimed to have voted for the ruling government in return for electrical grids to power modern appliances (e.g., refrigerators, TVs, etc.) and also run home-based micro-business enterprises just like fellow Ghanaians living in grid-connected locations [18]. The frustrations of residents are premised on assumptions that *all Ghanaians* deserve electrical grid access regardless of their location and socio-economic status (Author Interviews, 2018). During follow-up fieldwork in 2019, many solar PV components had broken down due to poor maintenance and abuse. Village residents expressed their resolve to petition local political representatives for intervention and even threatened to vote against the ruling government in the upcoming 2020 general elections if countless promises of electrical grid extension to the village are not fulfilled (Author Interviews, 2019). These findings are similar to reports in other rural areas of Ghana where evidence of grid electricity access in adjacent locations instilled confidence in residents to be more assertive about their demands [46,47].

The Ghanaian government, with the support of "Deutsche Gesellschaft für International Zusammenarbeit" (GIZ), also piloted a net-metering policy in 2015 to drive low-carbon energy solutions, reduce frequent power outages and offer customers the opportunity to use their generation to off-set monthly tariffs (Author Interviews, 2018). During the piloting process, Electricity Company of Ghana (ECG)[5] experienced massive public interest among higher electricity consumers seeking to off-set their monthly tariffs by exporting power to the distribution network. These interested consumers included commercial institutions, small-scale processing industries, and big residential facilities, with some installing over 42 kW solar PV systems (Author Interviews, 2018). The ECG, however, feared a possible decline in revenue in-flows due to the massive uptake by its higher-level electricity consumers and argued that 1:1 units of exchange stipulated in the net-metering code was unfair. One unit of electricity exported to the grid would then equal one unit of grid electricity consumed in terms of value. ECG instead proposed a 1:04 billing system for commercial and/domestic customers and 1:06 for industrial customers that would compensate for its sunk and operational costs (Author Interviews, 2019). The ECG justifies this by stating that stepping down power for domestic and commercial consumption causes more power distribution losses in comparison to industrial entities.

Ghana's Energy Commission and Public Utilities Regulatory Commission (PURC) advised the ECG to submit proposals for amendment and so the policy was put on hold. The ECG justifies the temporary hold-up because it was a pilot project and hence, contracts with customers regarding a suitable unit of exchange, sizing of their solar PV systems and other related practical issues must be clarified before the policy becomes fully operational. For example, the sizing of solar PV systems would be determined based on customers' average loads so that only the excess power from households would be exported to the grid network during periods of absence from home or when the systems are under-utilised. This is intended to prevent potential over-sizing of systems by enabling prospective customers to become net-producers instead of net-consumers. This is understandable given that currently, Ghana has almost doubled its power generation capacity to 5000 MW which considerably exceeds peak electricity demand (2400 MW). The embattled net-metered customers, however, continue to export surplus power to the grid without being 'credited' by the utility distributor. Some of these customers have, in response, defaulted on monthly tariffs claiming they are owed by ECG – claims of unfairness related to allegations of misinformation and verbal promises to credit them even though no generation license existed[6]

ECG's proposal has been reportedly by the PURC and so a full policy implementation is expected anytime soon. Meanwhile, frequent power outages persist in Ghana despite its excess power generation of over 2500 MW. The erratic power supply may thus erode the supposed benefits of net-metering systems since the distribution network serves as 'storage battery'. Given Ghana's current dependence on fossil fuels to generate about 70% of its power, the net-metering policy could be considered an avenue for low-carbon energy solutions. However, energy sector agencies are not encouraged to promote renewable energy technologies until they are considered cost-effective. because Ghana does not consider itself morally or politically obliged to make any serious commitment to low-carbon energy solutions. Interviews with renewable energy experts in Ghana regarding low-carbon energy visions in Africa showed their scepticism with one comment being particularly instructive: 'Why should a poor person in Africa seeking to meet his/her basic needs worry about green energy or climate change? That must be a foreign [global north] concern. … systems here are so chaotic, self-interest first'.[7] Similar viewpoints were expressed during communication with over 20 energy experts and some even justified such scepticism towards low-carbon energy technologies as the 'bitter-truth' given the challenges and other competing priorities of Africa (Author Interviews, 2019).

3.3. Namibia

Namibia seeks to facilitate nation-wide economic transformation and low-carbon energy visions through strategic electricity planning as enshrined in its Vision 2030 and Harambee Prosperity Plan (2016–2020) .[8] Namibia is a signatory to the Paris Climate Agreement of 2015 [48]. Its Vision 2030 targets self-sufficiency in the generation of at least 70% of the country's energy needs from renewable sources and economic transformation by 2030 through the development of an effective electricity distribution industry [48]. NamPower has a monopoly in the generation and importation of electricity, but since early 2000s the Nambian government has established private asset-based companies, Regional Electricity Distributors (REDs) to improve efficiencies and reduce costs, unify tariff structures, and incentivise private sector investments.[9] REDs are established through private companies with all initial shareholding by government-owned or public entities who are responsible for operating distribution assets and ensuring efficient electricity supply to all customers within their distribution areas or specific geographical regions in Namibia.

National energy visions and the increased involvement of private-sector agencies in electricity provision energy are intended to address spatial energy injustices [46], create economic opportunities for all – particularly poor social groups in the periphery,[10] whilst driving the

[5] . . In late February 2019, Ghana's electricity distributor leased its assets to an investment company by the name of Power Distribution Services (PDS) under a 20-year concessionary agreement. The contract has been currently suspended pending the outcome of corruption investigations.

[6] Research report by my Master's student researching on Net-Metering Systems and energy justice in Accra (June 2019).

[7] A private communication during fieldwork in Ghana in February 2019. The quotations are anonymous at the request of the sources

[8] ""Harambee" is a Kiswahili word meaning "to pull together in the same direction". As the term suggests, Harambee Plan is the government's 'Action Plan towards Prosperity for All'. Achieving improved energy access for all is an essential aspect of the development plan.

[9] This information was accessed from a series of short reports published by Namibia's Electricity Control Board. It is available here: https://www.ecb.org.na/index.php/documents2/regional-electricity-distributors.

[10] For example, Namibia has a national average population density of 2.8 persons/sq. km and this ratio are much lower in rural or remote locations. Of the 55% of the population lacking access to centralised electrical grids, 71% of these are urban residents. About 52% of the population live in rural areas compared to the 48% urban population.

transition to low-carbon energy solutions. Namibia records estimated annual power imports via Southern African Power Pool (SAPP) worth NAD 3 billion[11] (Author Interviews, 2019). Between July 2017 and June 2018, approximately 73% of Namibia's power was imported from SAPP and figures reach staggering levels whenever complementary supplies from the Ruacana hydro-power station is affected by drought (Author Interviews, 2019). Long distances between urban and rural locations also affect the cost and timely delivery of diesel for diesel-fired power generation as alternatives to centralised electrical grids. The electricity supply in Namibia is thus expensive, fossil fuel-dependent and could be considered unjust toward low-income groups particularly in remote locations.

Namibia officially introduced a net-metering policy in 2016 which has been effective since 2017 [49]. It was introduced to reduce dependencies on power imports and fossil fuels, and to facilitate 'prosuming' in grid-connected locations. Yet there are still structural restrictions including;

- Prospective net-metered customers will be connected on a first-come, first-served basis until 15% of the maximum demand of the main feeder line serving a specific group of customers is reached.
- A Time-of-Use (TOU) tariff system[12] is used in the estimation of the cost of power generated by net-metered customers – i.e. solar power generated during the day (being off-peak hours) is credited at a lower rate whilst customers pay higher rates during evening hours when they use power from the utility. Per the 2018 approved tariffs in Namibia, net-metered customers are credited NAD 0.96/kWh (during off-peak hours), NAD 1.44/kWh (standard hours) and NAD 2.40/kWh (during peak hours) and yet pay significantly higher tariffs for the same units of power supplied by distributor licensees during the same periods [50].

The protection of revenues of utilities is cited to justify restrictions placed on net-metered customers, – gestures which contradict energy justice claims and the strong stance of self-styled low-carbon energy advocates. A Solar Revolving Fund (SRF) was launched in 2011 to incentivise solar energy adoption in remote locations and facilitate rural development [51]. The project provided a loan range of NAD 6000 – NAD 35000 for Solar Home System (SHS); NAD 50000 for Photovoltaic Pumps (PVP) and NAD 30000 for Solar Water Heaters (SWH) at a simple interest rate of 5% per annum with a repayment period of five years [51]. By late 2018, a total of 3563 systems had been financed at the cost of NAD 98 million. Three months of bank statements, recent payslips of prospective applicants and at least a 5% initial deposit of loan are required. Three issues are noteworthy here. First, the maintenance of solar energy systems is the sole responsibility of owners, and the availability of competent personnel to provide user instructions and system maintenance has been challenging. Second, the loan packages cannot finance large capacity systems that can enable appliances for economically productive activities, except for powering only basic lights, phone charging, and TV. Finally, the strict eligibility criteria for accessing loans simply disqualifies low-income groups and informal sector workers.

Furthermore, the government has developed hybrid solar mini-grid systems in the two largest off-grid communities –Tsumkwe and Gam in the Otjozondjupa region – and hopes to replicate it in other off-grid communities if successful [22]. The systems are classified as a hybrid because diesel-powered generator sets provide back-up power systems to support storage batteries and solar PV systems. Domestic customers pay NAD 1.8 per kWh whereas commercial entities (e.g. shops, guest houses, and fuel refilling stations) pay NAD 4 for the same unit of energy. The domestic users here refer to customers who use electricity not-for-profit or commercial purposes, and therefore pay lower tariffs because they considered low-income groups whereas those using energy for business or income-generating activities pay higher for the same units of power consumed. This tariff system is similar to life-line tariffs and it is hence intended to be reflective of the financial conditions of different customers (Author Interviews, 2019). Customers located within a radius of 80 km from the power source were prioritised and hence, paid a grid connection cost of NAD 2500 whereas those located further away paid a much higher fee (Author Interviews, 2019).

Maintenance and operational costs, as well as the reliability of electricity supply, remained key challenges under the management of Namibia's Ministry of Mines and Energy [22]. In late 2017, a regional electricity distributor, Central Northern Electricity Distribution (CENORED), took over the management of the facilities to ensure more efficient operation of the systems and introduce measures that would, at least, meet operational and maintenance costs (Author Interviews, 2019). Field visits to gain insights into the history, livelihood patterns, social classes, and energy needs of the two project communities showed interesting findings. The mini-grid system in Tsumkwe had been upgraded from 202 kWp to 303 kWp and serves 260 customers. This system was supported by two sets of 200 kW diesel generators (operating four hours per day) and 3.8 MWh storage batteries to meet the increasing electricity demand driven by more intensive socio-economic activities. In Gam, on the other hand, the total energy consumption is considerably below the installed power generation capacity because residents are predominantly cattle herders who pursue less energy-intensive activity patterns. Gam is served by a 292 kWp solar PV system and a 2.6 MWh storage battery for 224 customers. It was found during the fieldwork that a large part of the generated power is wasted after 11:00 when batteries become fully charged. This is an indication of the under-utilisation of the facility.

Before the CENORED take-over, the ministry restricted domestic electricity users to a load limitation of 5 AMP in Tsumkwe and 10 AMP in Gam to discourage the use of energy-intensive appliances (e.g. electric iron, hot-plates, and microwave) because their consumption is considerably subsidised relative to other users. Elite or higher-income groups, however, defied user instructions, thereby causing the occasional break-down of their meters. CENORED increased the load capacity to 40 AMP to somehow address the energy demand of customers and also increase revenue in-flows. This intervention did not generate corresponding financial gains because of tariff defaulting and rampant power thefts in the villages – a situation largely driven by financial challenges. CENORED officers confirmed their inability to cover even the maintenance and operational costs, let alone make profits. I observed over 400 pending mini-grid connection applications in Gam meanwhile applicants had limited resources to finance electrification costs. The current draft of off-grid electricity policy [48] provides an enabling environment to stimulate investments into mini-grid electrification via grants, subsidies, loans, and tax incentives but there is no serious attention to the creation of income-generating activities in the remote locations that would drive the demand for energy to be supplied. Furthermore, the efficiency of mini-grid electrification systems was constrained technical challenges, notable among them include the following: periodic break-down of generator sets, poor maintenance of PV modules (or defective modules), defective batteries, and loose terminal screws of batteries to receive charging power, etc. due largely to poor monitoring of the facility by responsible operators and the lack of local technicians.[13] This suggests that huge power distribution losses could be avoided to meet the soaring energy demand in Tsumkwe if

[11] Namibia Dollar (NAD). NAD 15 is equivalent to USD1.

[12] The TOU concept is intended to incentivise customers to use more energy at off-peak times to create a useful balance between energy demand and supply. Therefore, tariff charges vary at different times of the night or day according to energy demand and supply patterns. That is, lower tariffs are charged when demand is correspondingly low and the reverse case happens at peak demand hours, especially during the day. Power export to the distribution network during peak demand hours are thus valued higher than exports in the off-peak seasons, hence the difference in tariff estimates for net-metering systems.

[13] These findings were shared by the technical team of the PROCEED project during the Kick-off meeting in Windhoek, Namibia (July 2019).

local technical capacity existed. The Technical Team therefore recommended to CENORED the following: proper monitoring of the facility, regular on-site trainings in battery and mini-grid technology, regular training of PV modules by security staff, the transfer of redundant batteries from Gam to Tsumkwe, the need for at least 2 back-up generators for Tsumkwe, spare kit for generators, and replacement of damaged PV modules.[14] Based on these examples from Namibia, the capacity of solar PV systems to achieve just, development-oriented and low-carbon energy futures seem to depend on the type of community and the extent to which the dominant lifestyles/livelihoods require electricity use, local technical capacity, settlement patterns and spatial distribution of residential facilities in relation to mini-grid infrastructure.

3.4. Kenya

Kenya's economic transformation vision ('Vision 2030′) and universal electricity access vision (Vision 2020)[15] are centred on the spatial expansion of the electrical grid. A predominantly donor-funded electrification program called 'Last Mile Connectivity Project' and complementary rural electrification initiatives subsidise grid connection costs for residential facilities located within 600 metres radius from existing transformer stations and remote locations are least favoured. There are Power Purchase Agreements (PPAs) for 68 existing operational power generation plants from both KenGen (Kenya's main power generator) and independent power producers, with contract duration spanning from 10 to 25 years. Kenya recorded a peak electricity demand of 1700 MW and installed generation capacity of 2336 MW by December 2017, suggesting at least 600 MW of excess power. Kenya Power and Lighting Company (KPLC) is thus sceptical of self-organised private sector-led decentralised electrification systems, as it hopes to prevent defection of customers from electrical grids, avoid potential revenue losses, protect its monopolistic agenda given the huge sunk investments and excess power generation [19,20]. In 2017, World Bank and GIZ recommended net-metering systems to incentivise the uptake of renewable energy technologies but KPLC declined the recommendation due to its revenue generation shortfalls. For example, a revenue requirement of KES 10.1 billion compelled Kenya's Regulatory Commission (ERC) to increase tariffs in August 2018 contrary to an earlier court verdict [52,53]. The tariff increase created tensions in Kenya until the Electricity Consumers Association of Kenya petitioned the High Court to revoke the decision in October 2018. During fieldwork in 2018, some urban-based KPLC customers were disgruntled by alleged unfair, exorbitant and unclear monthly tariffs. They had installed decentralised solar PV systems in their residential facilities in native remote villages and expressed interest in using self-generation of solar electricity to off-set monthly tariffs in their rented apartments in urban areas.

After persistent campaigns by renewable energy investors (particularly solar energy providers), GIZ and grid-connected solar PV users, the 'Net-Metering System' has finally been signed into law since March 2019 [54]. This policy is expected to allow solar PV service providers to expand the market for solar systems from off-grid customers to include grid-connected customers. The electricity exchange or credit system is not yet determined. Electricity sales reports by ERC (as of 2017) and informal discussions with KPLC officers about Kenya's power market shows a long-term upward growth trajectory and that net-metering system implementation may not lead to significant reductions in grid electricity consumption (Fieldwork Interviews, 2018). It is also reported that domestic customers consume less than 30% of the overall power supply and so electricity demand losses to home-based distributed generation would still be marginal compared to the overall demand.[16] Although these claims suggest limited or even no potential tensions between distributed generation and the centralised, state-driven electricity provision, there are still structural contradictions. Clause 162 of the Energy Act [54] prohibits potential domestic net-metered customers from sizing their solar PV system above 1 MW. It is assumed that the power demand of even large middle-class households rarely exceeds 400 kWh per month (i.e. average load of 0.55 kW) and that 1MW cap is considered 'fair' by KPLC and ERC because approximately 40% of their generation can be traded to off-set monthly tariffs. Feed-In-Tariff power generation companies are capped at 100 MW. The limitations on the total of power supplies via net metering are intended to protect the market share of existing power producers to fulfil the terms of their PPAs, whilst accommodating proposed future least-cost power generation projects.[17] Recording an increased power generation capacity of 2700 MW and peak demand of 1880 MW (as of April 2019) implies a current excess power in Kenya of almost 1000 MW. Also, Kenya generates 85% of its power from renewable sources (Geothermal, Hydro, and Wind) and so the promotion of the net-metering system, premised on low-carbon energy solutions, is considered needless by the energy sector agencies. Here, the government's financial considerations potentially discourage customers seeking to off-set 'unfair' tariffs through 'prosuming' and it is doubtful that the electricity unit exchange system will be different from those of Ghana and Namibia described above due to cyclical financial challenges of KPLC and the government's treatment of the electricity sector as its "cash cow" to meet certain revenue requirements [52,53].

Stand-alone systems have their flipsides too. Despite recent great strides in the electricity access rate of 75% (as of April 2019), electrical grids are predominantly concentrated in densely populated areas. Dispersed settlement patterns, red-tape in rural electrification programs, convoluted billing systems, and corruption scandals have incentivised a massive uptake of solar PV systems in remote areas of Kenya [35]. Apart from a few richer households in the periphery owning off-grid solar systems above 1 kW, more common sizes of systems are 100 to 500 W for middle-income groups and 20 to 80 W for poorest households. These cannot enable bigger electrical appliances and home-based micro-enterprises due to their low energy output. The most widespread solar PV systems in Kenya and East Africa today are small plug and play systems. These are accessible to lower-income groups through pay-as-you-go (PAYGO) and other financing and payment arrangements that allow incremental payments, sometimes displacing or reducing the use of kerosene lamps and fossil-fired generators particularly in remote locations where such liquid fossil fuels are either expensive for the poorest households or not readily available [17]. Also, the small plug and play systems are affordable for large groups that could not afford solar PV systems before and yet still residents of remote rural villages cannot afford such systems of useful quality [17,55,56]. These smaller systems are neither cost-effective/affordable for all nor sufficient to support micro-business enterprises necessary for the socio-economic development of rural locations [17]. The most common systems provide energy services like powering cell phones, lights, radio sets, and small-sized TV sets. Furthermore, households that accessed M-KOPA[18] Plug-&-Play solar PV systems usually pay between KES 50 and KES 125 daily for 400 days before owning the systems. This translates into a monthly tariff range of KES

[14] Unpublished Technical Report by Workpackage-3: Mini-Grid Technology for the PROCEED Project in Namibia.

[15] The government's plan to achieve universal electricity access by 2020. Recording a current electricity access rate of 75%, it is pretty clear that achieving 100% access by 2020 (i.e. 25% more within a year) is not realistic and so the vision has been recently revised to 2030. Therefore, until clarification is made Vision 2030 applies to both the economic transformation vision and universal access for all by 2030.

[16] Statistical analysis supplied by ERC and KPLC officers via e-mail communication (March 2019).

[17] These updates were accessed from my research contact persons at the KPLC and ERC via e-mail (June 2019).

[18] A solar energy company providing off-grid solar PV electrification services to rural locations in Kenya, Tanzania, and Uganda.

1500 to KES 3750, meanwhile average monthly tariffs paid by low-income groups seldom exceed KES 500. So-called flexible financing mechanisms have thus become avenues for the exploitation of unsuspecting customers in remote locations. Rural households with high energy demand and also needing grid electricity for business enterprises resort to paying bribes to grid electricity contractors to expedite grid connections or benefit from rural electrification programs [52,53].

4. Just, development-oriented and low-carbon energy visions for whom, how and why?

The electricity regimes of the selected countries suggest that 'injustice' is deeply embedded in the energy system, sometimes for strategic reasons. For example, the limited commitment to low-carbon energy solutions, as explained above, is sometimes justifiably necessary to sustain the energy sector, at least financially, due to unbridled power thefts costly, social interventions, and other system losses which are inevitable. Deliberate limitations placed on the units of power that can be traded by net-metered customers, and advocacy against 1:1 unit of exchange for net-metering systems to prevent financial losses to electricity distributors may be considered perverse from the perspective of energy justice. This is because levies and standard charges are indirectly integrated into monthly electricity tariffs to cover grid infrastructure maintenance costs and so customers might have already paid for sunk costs over the years. This seemingly 'strange' stance on revenue protection, on the other hand, appear justifiable due to practical constraints – including tariffs which ought to be held significantly below actual costs of power supply, deliberate defaulting of tariffs by customers, unbridled power theft, social interventions like life-line tariffs and other financial losses which are usually beyond the control of energy sector agencies. Therefore, non-payment of cost-reflective tariffs, the promotion of life-line tariffs and net-metering systems without the establishment of special funding schemes to offset financial contingencies would place additional financial burdens on state-owned electricity distributors in contexts characterised by such obscurities and uncertainties.

It is also important to scrutinize the motivation of global north actors championing solar energy adoption in Africa. In the global north context, distributed generation ensures reliable energy supply, sustainable energy practices, and energy autonomy [57–59]. Financial and relevant technical information are also provided by the state to facilitate such self-organised energy initiatives. Self-organised electrification initiatives in Africa, on the other hand, emerged out of despondency: they are consequences of state neglect, unbridled corruption and other 'injustices' associated with dependencies on centralised electricity provision. Self-organisation of energy, according to this logic, provides avenues for 'self-governance' of energy realisable through defection from, or reduced dependencies on, state-controlled centralised systems. In other circumstances, self-organised energy initiatives imply citizens who are almost fully fending for themselves via self-financing of power back-up systems, the making of direct negotiations with private sector energy providers at exorbitant costs, and/or depending on mini-grid systems with tariffs significantly higher than that of conventional electrical grids.[19] The vision to ensure uniform tariffs to provide just electricity services *for all groups* in different territories, and enhance the territorial reach of the state by way of producing certain intended outcomes throughout the country may be constrained. In either way, self-organisation of electricity provision could generate mixed outcomes: it provides avenues to address spatial injustices or grant energy autonomy on the one hand, and smacks of a 'denial of relationship' with the state and thus potentially constrains state capacity on the other hand [60].

Another paradox is the continued championing of these renewable energy technologies in Africa by global north actors who are sustaining their economies via massive use of fossil fuels – referred to as 'energy bullying' [33]. Kerne and Rogge [61] have predicted much faster future energy transitions because they will be 'problem-driven' (e.g. by climate change and scarcity) than previous transitions which were predominantly 'opportunities-driven'. Undeniably, the fact that different regions find themselves at different stages of development suggests that what may be considered an 'opportunity' or 'problem' in the low-carbon energy transition process is practically "perspectived" or context-specific. The current conceptualisation of energy justice equates justice (or fairness) with *equal* co-sharing of outcomes of energy transitions between different people, groups and geographical regions, often without reference to energy entitlement notions and practical energy visions of socially and spatially differentiated actors [18], and different moral/political obligations to climate change mitigations and development priorities of different countries. Put more provocatively, promoting decentralised solar energy as an "unquestionable good" in Africa without paying serious attention to local conditions smacks of engaging in 'energy bullying' – which is an injustice manifesting itself in subtle ways. Self-organised decentralised solar PV electrification cannot contribute to just, development-oriented and low-carbon energy futures in Africa unless sufficient information, technical knowledge and financial resources are available. Also, a thorough understanding of the specific circumstances in each country's energy sector, including the spatial distribution of population, electrical grid infrastructure, livelihood patterns, income levels as well as public perceptions toward dependencies on and use of grid-based and solar PV electricity are required to determine the desirability of decentralised solar energy transition in Africa. In this sense, the direction of an energy transition process cannot be considered unilinear for all geographical regions and social groups and hence an analysis of timing and contextual conditions in specific geographies is crucial [18,62]. I will explain this by referring back to the country-specific examples described above, and present general recommendations for the way forward.

In Ghana, distributed generation offers many benefits but realities and national energy priorities suggest that its implementation may be premature, at least in the meantime. Ghana's main electricity distributor is already struggling financially. Electrical grid outages persist too. Investments in storage batteries for a hybrid distributed generation would be too expensive for most customers, particularly the low-income groups. Although Ghana currently generates approximately 70% of its power from fossil fuels, the country does not have urgent (moral or political) obligations toward carbon-savings nor does it have acute power generation shortfalls to warrant the implementation of a net-metering policy. Given its current high installed power generation capacity, Ghana might instead want to ensure a more reliable/stable power supply, initiate innovative measures to ensure efficiency in the power sector, extend the electrical grid to new locations and provide an enabling environment for people to choose between off-grid solar PV and centralised electrification systems. Promoting decentralised solar energy systems in remote/rural areas as an alternative to centralised electrical grids may address certain energy needs and reduce poverty but leaves much to be desired. At best, the dissemination of free or state-subsidized off-grid solar PV systems in remote/rural areas would be suitable for hamlets or homesteads where farmers and extremely poor people need electricity to power light and a few other basic appliances. Solar PV systems may also be particularly useful for well-to-do households (especially urban residents) that usually need 'surplus' energy to sustain luxurious lifestyles and/or energy-intensive practices because they have financial resources to pursue energy visions which are essentially driven by self-actualisation, elitism, and quests for social recognition [18].

South Africa's promotion of distributed solar PV systems is premised on 'ecological guilt' and measures to avoid defection of customers from the conventional grid. Given huge investments in grid infrastructure, frequent power outages and massive interest in distributed solar power generation, the transition to just, development-oriented and low-carbon energy futures would depend on the following conditions: legal and

[19] This observation was made through personal research visits to mini-grid sites in SSA and research interviews with energy experts.

regulatory frameworks to incentivise distributed generation, removal of restrictions on the amount of power that can be exported to the grid and the introduction of a unit exchange regime that gives Eskom precedence. Such initiatives could help raise sufficient revenues to compensate Eskom for any financial losses caused when customers off-set their monthly energy consumption via distributed generation whilst increasing the penetration of low-carbon energy solutions to off-set coal-based generation. This could provide funds to finance life-line tariffs for the poor population in both grid-connected and off-grid communities, according to their respective energy visions.

The realisation of just, development-oriented and low-carbon energy visions in Namibia would require strategic 'prosuming' in rural and urban areas. In remote rural locations where existing mini-grids are available, the government might provide financial support to higher-energy consumers (or those hoping to increase energy demand in the future) who are located within the 80 km radius from the power source to size their roof-top solar PV systems above their average monthly electricity consumption and then export the excess power to the mini-grid distribution networks. Conversely, groups needing electricity to power basic appliances would continue to depend on the mini-grid. In this sense, only those living in dispersed settlement patterns and located beyond the 80 km radius from the mini-grids would be eligible for the SRF. This spatial energy planning would allow higher-energy users to freely produce and consume electricity cost-effectively without restrictions, reduce (or even avoid) dependencies on diesel-powered generators and pre-empt expensive mini-grid expansion unless it becomes particularly necessary in the future. Operational and maintenance costs of mini-grid electrification, as well as the cost of mini-grid infrastructure expansion which would drive tariff increases, could be kept at the barest minimum. Cost-effective mini-grid electrification would make electricity affordable and accessible to almost all social groups. In communities like Gam where mini-grid electricity supply exceeds demand substantially, affordability of electricity services and the creation of new income-generating activities would drive rural socio-economic development. In grid-connected urban locations, attractive rebates for net-metered customers would speed up the penetration of renewable energy technologies to off-set both monthly tariffs and fossil-based power imports from South Africa, for example. The fulfilment of these conditions can facilitate the pursuit of just, development-oriented and low-carbon energy futures in Namibia.

In Kenya, excess power generation, huge financial obligations of KPLC and massive use of renewable energy suggest that the initial rejection of World Bank and GIZ's recommendations for a distributed generation could not be more apt. Restrictions on the newly implemented net-metering systems may, on the one hand, affect KPLC customers seeking energy autonomy. On the other hand, KPLC's ambivalence concerning possible future outcomes of the policy seems justifiable given that the power sector is characterised by structural uncertainties bundled with numerous financial obligations. It is not intended here to deride the enthusiasm of champions of decentralised solar energy but rather show that given Kenya's circumstances, the net-metering system is not urgently needed and neither would it guarantee energy justice for the population. Kenya might rather expedite on-going rural electrification programs and considerably subsidise stand-alone systems for predominantly off-grid communities. This may enhance universal energy access and help rural households to expand decentralised systems to enable economically productive activities and social practices in cost-effective ways. Alternatively, part of the funding for centralised grid expansion could be re-directed into the development of solar mini-grid systems for subsidised electricity provision in the periphery, so that small-scale solar PV systems would serve as back-up power systems – these measures would enable business activities in such deprived locations.

The foregoing analysis suggests that blueprints for Africa's solar energy futures would be problematic because envisioning energy justice, ecological sustainability and economic development via decentralised solar energy systems remains amorphous when framed, justified and contested without reference to a set of relevant contextual conditions. Seeking to break from path dependence produces opportunity costs, and inevitably harms or benefits certain people/social groups, the environment and economic development visions unequally in different geographies. In any case, justice/injustice and desirability terminologies remain speculative without reference to contexts. Therefore, an analysis of whether decentralised solar energy futures are desirable or debatable cannot be divorced from the fulfilment of sufficient contextual conditions. Noteworthy here is that, despite the decisive role of context/country-specific conditions in the determination of the desirability of solar PV systems, a more general conclusion can be reached from the kind of conditions which are particularly important and essentially applicable to many African countries – especially those bearing characteristics similar to the four cases. Notable among these general conditions that are essentially decisive of the desirability of decentralised solar PV systems in Africa include the following:

- substantial funding (e.g. via Clean Development Mechanism) and technical support from advanced countries with emission-reduction or emission-limitation commitments to improve the competitiveness of decentralised solar PV systems in terms of cost and energy output (relative to dependencies on centralized electrical grids), particularly in favour of 'poorest' households in territorially remote and sparsely populated locations, and/or to compensate for financial and technical constraints of net-metering systems.
- Financing mechanisms that would cause a significant reduction in prices of storage batteries – particularly Lithium ION batteries which are more efficient – to facilitate the maximum storage and efficient use of solar energy even in evening hours or under cloudy weather conditions.
- an improved financial strength of power sector agencies, or stringent measures to reduce cyclical financial challenges of grid-based electricity distributors, the state's willingness to liberalise the electricity markets, and an improved commitment to low-carbon energy solutions.
- a thorough understanding of spatial and social differences in economic circumstances and notions of entitlements to and public perceptions about electrical grid access.
- technical training and other informal public education to facilitate effective self-organisation of decentralized electrification.
- Public education to change mindsets of people towards a massive uptake of solar energy technology especially in geographically remote locations that are not likely to be served by centralised electrical grids anytime soon.

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I hereby declare that there was no conflict of interest in the writing of this article.

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