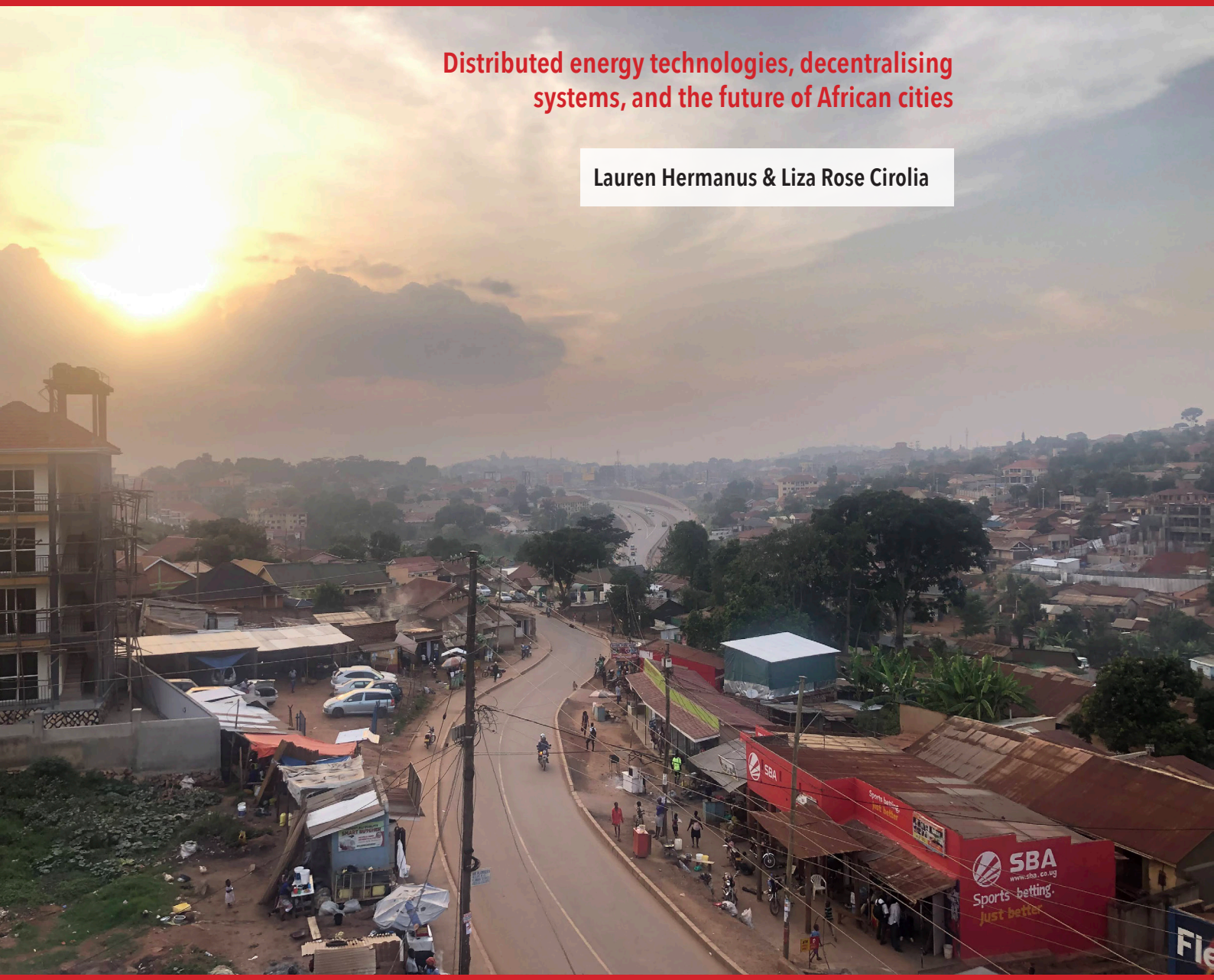
THE CABLE IS COMING

Distributed energy technologies, decentralising systems, and the future of African cities

Lauren Hermanus & Liza Rose Cirolia



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1.INTRODUCTION

According to the World Bank, Ugandan electricity access increased rapidly from a low base of less than 10% prior to 2003 to 42% in 2020 (World Bank, 2022a). Progress has not halted. In 2022, Uganda's transmission and distribution grids, the network of cables that transports electricity, is extending access to a growing number of people. This tangible progress has created optimism among decision-makers and communities alike. Despite the many challenges with grid extension, there is a hopeful discourse: "The cable is coming". When the cable arrives, the discourse goes, it brings with it new possibilities for organising households and businesses. Expanding access to those developmental possibilities is the result of ambitious planning, sector reform and restructuring, and national and international investment. Notably, the cable brings electricity not only for Ugandans, but also transports it to Kenya, Tanzania, and the Democratic Republic of Congo (DRC).

Internationally, mini-grid enthusiasm from both policy development and investor communities, across public and private spheres, has burgeoned. While mini-grids or micro-grids need not be based on renewable energy, the proliferation of renewable energy equipment and infrastructure – notably solar PV – has enabled a mushrooming of small-scale options for electricity access for household, community, and commercial applications. The flexibility of these solutions, to stand alone or be embedded in distribution grids, has been central to their framing as a key infrastructure for the advancement of the global sustainable energy transition, and for Goal 7 under the Sustainable Development Goals (SDGs) (International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division and World Bank, 2021).

Lighting up the urban periphery

The strength and importance of this emerging exactment over mini-grids in Africa generally, and Uganda in particular, can best be seen in the impressive launch of a new mini-grid in Lolwe, an island off the coast of Lake Victoria. The Ugandan national Minister of Energy and Mineral Development (MEMD) arrives at Jinja at daybreak on the morning of 14 January 2022. Formerly an industrial centre, Jinja is about 80km from the capital, Kampala. This small city is the congregation point for a party of government officials, energy professionals and researchers travelling to attend the launch of a solar photovoltaic (PV) mini-grid on Lolwe Island, a three-hour boat ride from the Jinja port.

Image: Jinja Harbour at sunrise, Uganda (Authors, 2022). Jinja District, the birthplace of the Nile, is home to three large hydroelectric power stations: Kiira Hydroelectric Power Station (200 megawatts [MW]), Nalubaale Power Station (180 MW), and Bujagali Hydropower Project (250 MW) (Electricity Regulatory Authority, 2020).

That a national minister is attending the inauguration of this small infrastructure project suggests something larger is unfolding – that the project has significance far beyond the sparsely inhabited island. Increasingly, small-scale renewable energy is presented as an opportunity on the continent, a solution to deficits in electricity access, use and investment. This is certainly the impression that development agency reports and various energy outlooks are creating. Projects like that in Lolwe are framed within this emerging opportunity space.

The launch of the mini-grid on Lolwe Island is an impressive performance of this excitement. It is only the Minister of Energy and Mineral Development's presence that lends a sense of gravity to the launch. President Museveni's endorsement is restated in the chain of speeches that commemorate this infrastructure's instantiation in Uganda's power landscape. The Chief Executive Officer (CEO) of the pioneering

private mini-grid company – Equatorial Power – references his passionate exchange with the President as a preface to plans to bring mini-grids to Uganda's other island-based communities. Questions about this wave of policy and investment enthusiasm frame Lolwe's festivities for those observers seeking to connect this project to others around the country, in the region, across the continent, and to policy emerging in the global North claiming to 'light up and power' Africa. These questions are anticipated in the Minister's address:

> *"What the President has been talking about, [is that] this government is determined to make sure that we supply power for our communities, included in the manifesto. We also included it in the National Content Plan [version] three…*
>
> *[We] are sure that we are going to have sustainable power… The question now is, is this power clean? Because this is the requirement. You know the narrative now in energy transitions. The paradigm shift: we are going green. We want clean energy. The answer a big yes… The remaining issue is affordability.*
>
> *Is this power going to be affordable? The answer is yes. You just have to change your mindset. You just have to be quick, critical thinkers… You have to get connected to electricity, [slowly, slowly]. Don't be extravagant. People become extravagant when they are using electricity, and you end up paying for almost nothing."*

After the CEO's remarks, other rhetorical offerings are made by commercial partners, foreign ambassadors, the regulator, and local government officials from the village to the district level. Local officials take the opportunity offered by their moment on stage to raise issues relevant to their constituencies. In addition to expressing thanks for the project, the platform is used to appeal to those present in the tented forum – decision-makers, investors, implementation bodies, and a few researchers – to address social and economic concerns. Finally the moment arrives and the project is 'activated', with cheers, dancing, and confetti.

As the launch comes to a close and the attendees are shuttled back to the boat, a loose constellation of ideas are left hanging in the air as the day unfolds – electrification, development, industrialisation, urbanisation, poverty alleviation, energy transition, energy access, development finance, governance, energy justice, affordability, democracy... The spectre of climate change is present too, in the rising water levels in the lake, and reports of future drying. Plenty of questions and oblique lines draw all these issues together, but the connections and causality are not so clear. Lolwe Island's mini-grid is a clear signal of shifts in the electricity landscape across Africa. It is an undeniable signal of the energy transition, but what does it signify?

The imperative: African cities and small-scale electricity infrastructure

Literature on the global sustainable energy transition includes propositions regarding the increasing prominence of cities as sites of infrastructural transition (Rutherford and Coutard, 2014). Not only cities as places, but also their governments and other local governance actors are being repositioned within infrastructure transitions. For electricity systems in particular a shift is being characterised, away from the contemporary transition; this is characterised as a shift from highly centralised modes of governance and organisation towards configurations labelled as 'decentralised' or 'polycentric' (Goldthau, 2014). Underpinning these shifts is the transformation of electricity infrastructure, particularly a change in the scale and location of generation made possible by renewable energy innovation. Connected to the sustainable energy transition, the centrality of cities is simultaneously being advanced through climate change policy and literature. Cities across the world are acting alongside, because of, or despite national policy commitments and (in)action, to address the climate crisis. The confluence of energy and climate change concerns is also shaping development support, both advisory and investment, to African cities under energy access, industrial development, climate mitigation, and climate adaptation programmes.

Focusing in on electricity interventions within this nexus of concerns, it is not clear how the realities of African urban and urbanising areas and their governance relate to both the conceptual work and the development interventions originating in the global North. This is not to claim there are no salient insights or opportunities for African cities within this policy space. However, power sectors on the continent are mostly centralised, with authority concentrated away from city administrations and other local actors with, for example, national utilities and agencies, international finance actors, and private companies in global supply chains (International Energy Agency (IEA), 2020; Silver and Marvin, 2017). Analogously, the patterns of political, administrative and fiscal decentralisation that give many cities in the global North a wide range of policy options at the intersection between energy and climate are not the same in African cities. The nature and consequences of electricity system decentralisation, poorly defined for high-income countries, are far from clear for African local authorities and city governments. In fact, in the context of a diffuse technical transformation, understandings of whether and how small, modular, energy generation and storage technologies interact with urban governance – and any modality of decentralisation – are opaque, or emergent, at best.

Scope and focus of this study

The conceptual focus of this work is on the implications of the introduction of distributed energy technologies within electricity systems for urban Africa. This paper specifically draws on the case of Uganda. It focusses on the introduction of distributed infrastructure within the national electricity system, related to what it means to be urban and networked. It is not a comprehensive characterisation of the country's electricity sector, nor does it aim to provide a normative assessment of the most appropriate interventions in Uganda or elsewhere. Rather, it considers particular instances in which distributed energy technologies are being used, and foregrounds concerns that emerge at the interface of urban governance and energy transition at these material sites. This paper reflects research conducted in Uganda in January 2022, which included 15 interviews with donors, mini-grid companies, non-governmental organisations (NGOs), start-ups, the distribution utility, and city government. Research also included reviewing national policies and secondary material (such as reports). Insights from the Ugandan case are placed in conversation with the authors' experience, conducting research and policy and institutional work related to the energy sector, urban governance, sub-national finance, and distributed infrastructures. Situated within the conversation on transition, which depends on a postulation of possible futures, this research is an exploration of what is and what could be. It is an interjection into a dense and dynamic conversation in which academic literature and policy and advocacy from governments, think tanks, NGOs, development agencies, and private sector energy and advisory actors co-mingle in sense-making spaces layered with various imaginaries and antecedents, not all benign.

2.GOVERNING AFRICA'S URBAN SYSTEMS

Contextualising energy transitions in African urbanisation dynamics

Global discourses on energy transitions have shaped donor conversations and actions in and on transition in Africa. However, there are many fundamental differences in the African context that require attention and consideration (Silver and Marvin, 2017; Tait and Euston-Brown, 2017). Key to contextualising energy transition interventions on the continent is understanding the unique ways that African cities are configured (and reconfiguring), especially in relation to centralised authority and power. There are both institutional and material reconfiguration processes underway reflecting contingent historical processes. These processes are hugely consequential for what transition pathways are possible and probable in different contexts.

Foremost among the dynamics shaping energy transitions is Africa's urbanisation, which is currently unfolding at a rapid rate. The continent's population is projected to double between 2020 and 2050, with more than two-thirds of this growth taking place in cities (Sahel and West Africa Club/Organisation for Economic Co-operation and Development [SWAC/OECD], 2020). Not only aggregate population growth but also the spatialisation of populations as they grow matters. While some cities are densifying, most are increasingly sprawling. Cities experience the rapid development of urban peripheries through piecemeal projects. This is particularly true for large metropolitan areas (such as Lagos, Cairo or Kampala), which increasingly expand beyond the boundaries of existing jurisdictions and often without clear plans for infrastructural delivery. This pattern also applies to secondary cities, particularly those connected to mega-mobility investments such as Standard Gauge Railway (SGR) or highways being built across the continent.

Second, the governance of African cities is neither homogeneous nor uncontested. Contemporary contestation can be traced back to colonial legacies. At independence, most sub-Saharan African states inherited highly centralised systems of governance, reinforced by the dynamics of complex nation-building projects. Decentralisation reforms implemented over the past 30 years have aimed to devolve power to sub-national levels of government (Ribot, 2002). These reforms include the assignment of various functions, such as planning, economic development, and service provision, to local governments[1]. The motivations for decentralisation reflected a combination of neoclassical economic theories of resource distribution (e.g. decentralisation theorem) and critiques within development studies that top-down interventions failed to attend to some of the most pressing concerns of people and places. Often driven by multilateral lenders, many African countries underwent systemic processes of fiscal, political, and administrative decentralisation in the 1980s and 1990s – contemporaneous with a wave of international power-sector reform and liberalisation. As these countervailing movements play out, cities, of course, interface with a range of other 'governing forces', such as traditional authorities, privatised utilities, and global financial actors such as the World Bank (Lindell, 2008; Marrengane et al., 2021). The outcome is that decentralisation has never been concluded, nor has governance been the sole propriety of formal state institutions. Instead, the governance of African cities reflects an ever-changing contestation between local and national, public and private, formal and informal actors.

1 In countries with federal systems, such as Ethiopia or Nigeria, authority has been centralised one level above the local, with significant powers granted to 'states' or 'provinces'.

Third, this contested and plural governance is overlaid onto partial, fragmented, and under-resourced infrastructure networks of various kinds (Cirolia, 2020; Coutard and Rutherford, 2016; Silver and Marvin, 2017). Efforts to make sense of the fragmented networks often employ a series of dichotomies – formal/informal, public/private, on-grid/off-grid, large-scale/small-scale, networked/post-networked, or rural/urban. These binary distinctions (and the spectrum of possibilities that connect these 'opposites') overlap in various ways that can be difficult to disentangle. Certainly, African urban electricity systems may reflect many configurations across multiple spectrums (Jaglin, 2013; Silver and Marvin, 2014). Moreover, the boundary of these electricity systems is fuzzy, as people supplement electricity access and use with other energy sources, such as charcoal for cooking or paraffin for lighting.

Attracting investment to African cities and infrastructure

Responding to gaps in existing networks and systems, African governments are eager to attract investment into cities. However, efforts to attract global capital often reveal contested local and international understandings of need and opportunity. For example, while most people do not have access to networked sanitation, there are mini-malls scattered across low-density and sprawling suburbs. Similarly, many new large residential buildings remain vacant while informal settlements increase in area and density. Simply put, the sorts of investments which may be most needed can be the least likely to attract finance.

While the importance of aligning finance to local priorities and planning is indisputable, in practice, financing even basic urban infrastructure in Africa, such as those in sanitation or electricity systems[2], remains appreciably challenging. Access to and allocation of finance is inextricably related to the characterisation of African cities as high-risk. This kind of pejorative characterisation frequently fills gaps in understanding resulting from a lack of data or knowledge, and the inadequacy of frameworks and ideas transposed from dissimilar contexts. These epistemic practices of legitimation interact with political-economic patterns at play. For urban actors seeking to finance local developments, capital for basic urban services comes with high costs. Where capital can be accessed and deployed, African urban actors need to design systems to respond to poverty and inequality, which, in practical terms, impacts revenue collection and operational models.

Image: Toll road between Kampala and Entebbe, where the international airport is located (Authors, 2022). Toll roads are good examples of popular infrastructure to develop, despite the fact that they often serve only small populations.

2 Africa lags far behind other regions in terms of electricity infrastructure investment, and energy poverty remains a persistent problem (IRENA and CPI, 2020). IRENA has estimated the energy finance deficit at USD 70 billion, annually, until 2030, arguing for this to be directed toward renewable energy (IRENA, 2019).

Poverty and inequality are both shaped by and shape the ability of cities to attract finance. These questions cannot be divorced from those related to work and labour. The questions of how urban areas will support livelihoods and provide opportunities for work are pressing (International Monetary Fund [IMF], 2018; Webster et al., 2021). Unlike the growth of European cities, Africa's urban growth is taking place without the patterns of industrial development that characterised urbanisation (Fox and Goodfellow, 2021). To overcome centuries of structural disenfranchisement, which circumscribed African economies' contribution to global value chains, African countries are trying to attract industrial investors, offering various incentives for them to locate their factories in and around cities. Special industrial areas – industrial parks and special economic zones (SEZs) – are being linked to infrastructure development in urban areas, manufacturing zones along new transport corridors, and provisions for in-situ mineral processing facilities attached to new mining concessions. Demonstrating the revived interest in boosting Africa's manufacturing capacity, according to 2019 data, there were estimated to be 189 operating SEZs in Africa (Africa Free Zones Organisation, 2020). Green SEZs are also being explored (UNCTAD, 2021). These zones are often linked geographically to cities, which are impacted by the opportunities, costs and risks associated with these large-scale developments.

Risks and opportunities on the horizon

Across Africa, the presence of these urban governance, financial and industrial concerns shape the urban development agenda, variably characterised as sustainable, low-carbon, climate-compatible, resilient or green (Haddaoui and Gulati, 2021). The interfaces between energy transition and climate change present a range of risks and opportunities for cities; among the opportunities, there is the potential to align responses to local economic development and job creation[3]. As the COVID-19 pandemic response has ushered in green recovery frames for climate finance, several stimulus packages have included solar PV in African urban contexts (Green Economy Coalition, 2021). The International Energy Agency (IEA) has estimated that investment in distributed renewable energy technologies (mini-grids and solar home systems) could produce 900,000 job-years of employment in Africa over three years, commencing in 2020 (noting that job-years do not necessarily equate to long employment for individual workers) (International Energy Agency, 2020b).

However, challenges regarding the pace, scale and process of localisation of manufacturing opportunities related to energy are laden with assumptions that may or may not be borne out. As things stand in Uganda and across the rest of the continent, renewable energy value chains are decidedly not local. Local demand – real or latent – is being framed as an opportunity for international supply. The question raised here is 'What, in the mire of complexities outlined above, can urban governance actors do to influence the intersections between climate, energy and local economic development, to facilitate benefits for their urban environments and residents?' There is no expectation of approaching an answer. However, it is a question often skirted in the eager and even evangelical chorus of external responses to Africa's urban electricity challenges.

3.DECENTRALISED ENERGY IN AFRICAN CITIES

What does the sector mean by decentralised energy?

> *"Decentralisation is a defining feature of the ongoing energy transition."* (Brisbois, 2020)

The policy discourse on energy transitions conflates processes of changing material infrastructure networks and changes in governance under the term, 'decentralisation', and, furthermore, connects this process to sustainability and democratisation with variable rigor. A growing body of energy-transitions literature speaks to the issue of decentralisation within the current energy transition (Brisbois, 2020; Chmutina et al., 2014; Droege, 2018; De Pascali and Bagaini, 2019; Goldthau, 2014; Tait and Euston-Brown, 2017). However, there are few systematic characterisations of decentralisation, clearly articulating what it is and is not, within the transition. Additionally, within Africa's urban systems, energy system decentralisation requires further conceptual development.

With respect to electricity systems, decentralisation has posited as a break with the historical configuration of power sectors characterised by *"centralized patterns of technology, socio-economic institutions and physical infrastructure, which co-evolved over decades"* (Goldthau, 2014). At the heart of these centralised configurations are a number of large power plants (fossil fuel, nuclear power or hydroelectric) which required either state finance or massive corporate investment, and from which electricity is transported from central nodes through

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3 To illustrate: "Across the 35 major cities in Ethiopia, Kenya and South Africa, investment in more compact, clean and connected cities is expected to deliver total benefits equal to US$1.1 trillion by 2050, or as much as 250% of annual GDP in 2020, supporting hundreds of thousands of additional jobs compared to conventional fossil fuel investment" (Haddaoui and Gulati, 2021: 10).

transmission and distribution networks, to electricity loads. Additionally, planning and governance were also centralised. Juxtaposed with this centralised configuration, decentralisation refers to developments that challenge such centralised patterns, moving to a greater share of renewable energy generation and energy storage, with a significant proportion being small-scale, distributed infrastructure. The latter includes single household rooftop systems or larger mini-grids like the 600 kilowatt peak (kWp) solar PV plant on Lolwe Island. In Uganda, most of this distributed infrastructure is not embedded in distribution networks. Mini-grids are typically off-grid and are much smaller than the Lolwe Island project. Additionally, individual households can also purchase a solar home system, for example, 10 watt (W) solar home starter kits targeted at *"off grid, very low income consumers in the developing world, outdoor enthusiasts, aid organizations, green energy enthusiasts, and individuals concerned with emergency preparedness"* (Engineering for Change, n.d.: para. 9). There is also solar equipment on offer, such as solar lamps. Off-grid solutions such as these are seen as critical to the sustainable energy transitions, energy access, and decarbonisation goals. Internationally, in 2018, 171 million people were served by off-grid renewable energy solutions (from solar lights to solar, hydro and biogas mini-grids) (IRENA and Climate Policy Initiative [CPI], 2020). These solutions may be required where the grid is not yet available, in places where distribution grids cannot be extended, or where grids do not provide reliable access. There are commercial, public sector (government or public utility), community or household-owned off-grid solutions.

The above material process, which is somewhat clumsily referred to as 'decentralisation', broadly and often clumsily, invokes the urban debates on decentralisation and the role of local governments and other local governance actors, given that energy impacts urban systems from water treatment to mobility[4]. In particular, international climate policy discourse includes planning for and participating in new patterns of energy generation within an augmented role for city governments in the transition and future electricity systems. Additionally, there is a narrative connecting more localised planning and governance, together with ownership, with an additional political process of democratisation under the conceptual banner of 'energy democracy'. These debates have their genesis in the global North, and often fail to grapple with the heterogeneous contexts into which they have been transplanted in the global South. The starting conditions for African cities in the transition encompasses high levels of energy poverty, and other dimensions of poverty and inequality, which constrain the kind of participation and benefit derived from this purported energy democracy. Additionally, with limited exceptions, local governments most commonly have no electricity-related mandates, beyond perhaps the provision of street lighting, and often play a minimal role in their national electricity systems. It is in this context however – noting the other urban system challenges already examined – that city-level climate and energy planning and investment is being advanced by foreign development agencies, private companies, and NGOs. These actors interface with urban authorities and city spaces, albeit in ways that do not fit within the 'sustainable energy transition as decentralisation' narrative. To support a clearer engagement with sustainable energy transitions at the urban scale, we investigate changes to material electricity infrastructure – primarily, the inclusion of distributed renewable energy generation. In exploring distributed energy technologies, we also explore the related changes to distribution and transmission networks, as well as how these changing networks are shaped by fiscal, political and administrative governance issues at the urban scale.

How do mini-grids fit into the decentralised energy narrative?

As indicated above, within this drive for decentralisation, mini-grids are being promoted by a range of actors: foreign governments, intergovernmental organisations, NGOs, and local actors. Mini-grids are sets of electricity generators interconnected to a distribution network supplying electricity to a localised group of customers, which may also include storage. Mini-grids are often conflated with micro-grids, but some actors reserve the latter for smaller-scale mini-grids, up to 10 kW, while the former can be as large as 10 MW (typically around 100 kW) (BloombergNEF, 2020). Mini-grids can stand alone in the absence of a wider distribution network – or simply opting not to connect – or they can be 'embedded' in such a network, drawing power as needed, or feeding surplus power into the grid. As such, this infrastructure is flexible, while still providing a better and more reliable level of energy access than single solar home systems. Despite this flexibility and reliability, most of the funding for off-grid energy in Sub-Saharan Africa is still flowing into more basic solar home systems (IRENA and CPI, 2020). In Uganda, for example, the Solar Refinance Facility offers concessional finance for micro-lending for solar home systems and off-grid business solutions.

Mini-grids in Africa are often considered in the context of rural electrification in the absence of the grid – conditions like those on Lolwe Island (BloombergNEF, 2020). This is quite different from developed countries where mini-grids are motivated by a drive to match electricity to local needs and resilience, challenging the dominance of utilities without displacing them entirely, requiring upgrading of (smart) distribution grids, and advancing energy democracy (Brooklyn Microgrid, 2015). Between these applications and the off-grid rural applications, other urban African applications are also being advanced. Mini-grids are being thought of differently, as urban infrastructure, in Lagos, for example. Here, they can contribute to energy supply and reliability and provide an alternative to diesel and other fuels, as well as delivering alternative investments and other governance impacts at the local level. As mini-grid development increases in urban contexts, it remains to be seen how the relationship with existing infrastructure configurations plays out, and what end-state imaginaries shape this.

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4 There are exceptions that connect these issues more explicitly (see Silver and Marvin, 2017; Tait and Euston-Brown, 2017).

4. UGANDA'S ELECTRICITY SYSTEM

Overview of the electricity system in Uganda

Uganda is a landlocked country in East Africa. It has had the same president, Yoweri Kaguta Tibuhaburwa Museveni, since 1986, with presidential elections occurring every five years through a popular vote system (most recently in 2021). The country is classified as a 'Least Developed Country' (LDC). Agriculture, forestry and fishing is a key sector, contributing 23.93% of GDP (2020 data) and employing more than two thirds of the population (World Bank, 2022b). Uganda's energy statistics are in the process of being updated, and there is currently some discrepancy in reported figures, especially given the current acceleration in off-grid generation.

TABLE 1: KEY STATISTICS

Indicator/information point	Data
Population	45,741,000 (2020)
Gross Domestic Product (GDP)	37.6 billion USD (2020)
Poverty rate as a percentage of total population	41%, at 1.90 USD (2011 PPP) (2019)
Electricity generation capacity	Total: 1237.49 MW (end 2020, according to the ERA): 1. Hydro – 1,023.59 MW 2. Thermal – 100 MW 3. Cogeneration – 63.9 MW 4. Grid-connected Solar – 60 MW
Number of mini-grids (all off-grid)	34, totalling 56.8 MW in 2019 (BloombergNEF, 2021)
Investment in off-grid renewables (2007–2019)	39.3 million USD (IRENA and CPI, 2020)
Electricity demand	Demand reaches 650 megawatts during peak hours; 67.1% of this demand is reported as residential (Lane et al., 2018).
Domestic tariffs (Ugandan Shillings, 2021)	There are four monthly domestic tariffs approved for the first quarter of 2022 (UMEME, 2022): Lifeline – First 15 Units (Ush/kWh): 250.0 Energy Units between 16 – 80 (Ush/kWh): 747.5 Energy Units between 81 – 150 (Ush/kWh): 412.0 Energy Units above 150 (Ush/kWh): 747.5
Electricity exported	Surplus is exported to Kenya, Tanzania, South Sudan and DRC through the Uganda Electricity Transmission Company Limited (UETCL)
Electricity access as a % of total population	The World Bank Reports a 42.1% electricity access rate for 2020, with urban access at 69.9%. A household survey by the Uganda Bureau of Statistics scheduled for completion in 2022 indicates that the national electricity access rate has increased to 57%, with 38% of households connected via off-grid connections (African Development Bank, 2021b).
Other energy	More than 90% of household still rely on biomass fuel (firewood, charcoal, and crop residues) for cooking (Bamwesigye et al., 2020). This is true even in urban areas with electricity access.

Source: All data in tables, unless stated otherwise, is from World Bank, 2022c.

Uganda is one of a minority of African countries to have liberalised and reformed its electricity sector in the 1990s, alongside a suit of other economic reforms, formalised through the Electricity Act, 1999 (Electricity Regulatory Authority (ERA), 2020). The formerly vertically integrated Uganda Electricity Board (UEB) was unbundled, creating separate generation, transmission and distribution industries. It would take some time before the first large independent power producer (IPP) investment would be facilitated, in the form of the Bujagali Power Project, which commenced in 2007 and began feeding power into the grid in 2012. The sizeable Bujagali dramatically increased power generation. However, it also generated controversy, with political, economic, cultural, and even spiritual opposition still being documented (African Development Bank Group, 2021a) . Notwithstanding the critique, Uganda's reform experience is presented as a best practice case study for other African countries.

5 The Government of Uganda owns a minority share in the latter project, with other private shareholders including, in order of interest: Scatec, Aga Khan Fund for Economic Development, and Jubilee Investment Company.

More recently, the sector has seen significant changes in investments and sector regulation. For example, Uganda ran the World Bank-sponsored GET-FiT IPP procurement programme, reporting:

> *"Ugandan Electricity Supply Industry continue to shine as a perfect example of how best to leverage support from development partners to attract and harness private sector capital for infrastructure development. Through the GET FiT Programme, an installed capacity of 158 MW of clean renewable energy shall be added to the National Grid from 17 projects"* (GET FiT Uganda, 2017).

The programme was designed to promote small hydro, bagasse, biomass and solar through regulatory and financing support (GET FiT Uganda, 2017). These and other changes have been overseen by the Ministry of Energy and Mineral Development (MEMD), whose mandate is to *"Establish, promote the Development, Strategically Manage and Safeguard the Rational and Sustainable Exploitation and Utilization of Energy and Mineral Resources for Social and Economic Development"* (MEMD, 2022: para. 1).

The past two decades have seen rapid electricity sector expansion off a low base of just 400 MW of generation capacity serving 180,000 grid-connected customers in 2000, increasing to 1237.49 MW serving more than 1.5 million grid-connected customers in 2020 (Umeme Limited, 2021). Uganda's Vision 2040 national plan aims to promote further energy access through both grid extension and other rural electrification programmes, implemented under the Rural Electrification Strategy and Plan (RESP), led by the Rural Electrification Agency (REA). Part of this commitment involves extending the country's transmission and distribution lines. The network is currently designed to serve urban areas in and near Kampala. Some rural districts – on the mainland and including islands – are entirely without grid connection. Grid extension remains the dominant mode for enabling electricity access, especially given what is defined as a 'surplus' of generation – Uganda generates more electricity than residential and commercial consumers buy and use (Lane et al., 2018). The rationale is that giving more people grid access will allow more of that electricity to be used locally. This, of course, depends on the affordability of that electricity, household choices, and the reliability of distribution networks. These factors – also in Kampala – affect electricity use in grid-connected households.

TABLE 2: ELECTRICITY SECTOR KEY ASPECTS (ELECTRICITY REGULATORY AUTHORITY, 2020)

	GENERATION	TRANSMISSION	DISTRIBUTION
ACTORS	Uganda has a combination of state-owned power plants (Uganda Electricity Generation Company Ltd. [UEGCL]), IPPs and PPPs)	The national transmission network is owned by the Government of Uganda through the Uganda Electricity Transmission Company Ltd (UEDCL)	Distribution includes the state-owned Uganda Electricity Distribution Company Ltd (UEDCL), as well as eight private players, including Umeme[6], the largest of these.
POLICY	The sector is led by the Ministry of Energy and Mineral Development (MEMD). In 2018, following a government reorganisation, the Rural Electrification Agency (REA) – secretariat of the Rural Electrification Board (REB) – was incorporated within the MEMD (Lane et al., 2018). The REA leads the implementation of the Rural Electrification Strategy and Plan (RESP). Uganda's SE4All policy aims for 3,000 MW of renewable energy generation by 2030. Mini-grids have been supported through the REA's Rural Electrification Fund. The government is aiming for two million new customers by 2025 and universal access by 2030.		
REGULATION	The sector is overseen by the Electricity Regulatory Authority (ERA). The ERA has five Board (Authority) Members appointed by the Minister responsible for Energy, with the approval of the Cabinet. Mini-grids are regulated through the Isolated Grid System Regulation, stipulating the same licensing requirements for mini-grids above 2 MW as for IPPs, and a streamlined process for smaller infrastructure, requiring a Memorandum of Understanding with the ERA. Mini-grid tariffs must be approved by the ERA, which can allow tariffs above the national domestic tariff (reflective of costs) (Republic of Uganda, 2020). However, a Ministerial announcement in 2019 decreed no mini-grid tariffs higher than 0.30 USD per unit.		

Source: Electricity Regulatory Authority, 2020

6 Umeme manages the "distribution network [which] consists of approximately 37,352 (2019: 35,856) kilometres of low voltage, 11kV and 33kV network lines covering all major hubs in Uganda" (Umeme Limited, 2021).

Mini-grids in Uganda's electricity system

In Uganda, policy has made provision for off-grid or standalone mini-grids, the location of which is determined through master planning, which identifies areas unsuitable for grid extension. A report released by the Sustainable Energy for All (SEforALL) Africa Hub at the African Development Bank (AfDB)[7] in 2018 estimated a total market size of $68 million (Lane et al., 2018). Mini-grid development in Uganda, particularly for solar PV mini-grids, has been promoted through a range of different state and external interventions. Capital costs for mini-grid developers remain high, with funding coming from donors and venture capital. Commercial viability is a challenge with which project-implementing partners are still grappling. Driven by costs, mini-grid end-user tariffs are typically more expensive than those offered by Umeme, the dominant private electricity distribution company. Additionally, there is no mechanism in place to manage mini-grid developers in the case of the arrival of the grid. A mini-grid that has not operated for long enough to recoup its costs could find itself unable to do so, being unable to compete with national domestic tariffs.

Connecting to the urban in Uganda

Despite considerable efforts to attend to data gaps, we can speak with only degrees of certainty about statistics at the urban scale in Africa. There are many factors shaping this – not least of which is the rapid and often undocumented changes which take place annually. It is costly, and often very difficult, to account for the often informally driven changes taking place in and around cities. These unknowns are further complexified by the lack of clarity on what constitutes 'the urban', both geographically and substantively.

The likely inaccuracy of existing data does not militate against its usefulness in providing a high-level overview of what is taking place. As the World Bank data below indicates, Uganda is urbanising at a rate of just over 5.3% per year. Its urban population is likely now over 25% of the total population.

TABLE 4: URBAN DATA

Urban Population (2021)	12,041,476 (approx. 25% of total Uganda population)
Urban population growth, annual (2021)	5.3%
Proportion access to electricity, urban (2020)	69.9%
Population living in slums, urban (2018)	48%
Population in largest city (2021)	3,469,510 (approx. 28% of total urban population)

Source: World Bank Statistics, see https://data.worldbank.org/indicator

Like most African countries, there is only one very large city in Uganda. Kampala, the capital city and largest urban conurbation, has wildly different estimates of its growth rate and size. This may be due to very different boundaries used for estimation, as well as different assumptions used in the modelling. The table below provides an overview of the five largest cities in Uganda, based on 2022 estimates from the World Population Review.

TABLE 5: POPULATION ESTIMATES FOR CITIES AND TOWNS

Name 2022	Population
Kampala	1,353,189
Gulu	146,858
Lira	119,323
Mbarara	97,500
Jinja	93,061

Source: https://worldpopulationreview.com/countries/cities/uganda

7 Other active development agencies include: United States Agency for International Development (USAID); Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); UK Foreign, Commonwealth & Development Office (FCDO); KfW; and the World Bank.

As the above table indicates, Kampala is upward of five times larger than the next largest cities, and over ten times larger than cities like Jinja. While smaller towns are growing rapidly (albeit off lower bases), this explains why one of our informants told us "All of Uganda is in Kampala." (Personal communication, Economist in Jinja, 2022). The Kampala Capital City Authority (KCCA) has published claims that up to 60% of the country's economic output is generated in the city. While service industries (telecoms, finance) are indeed located here, these claims have been disputed. What is unarguably concentrated in the capital is most of the country's networked infrastructure. The electricity transmission and distribution networks are designed to facilitate urban energy access. As the urban periphery expands – driven by both formal and informal peri-urban development – the distribution cables are expected to extend outward too, into surrounding jurisdictions and areas.

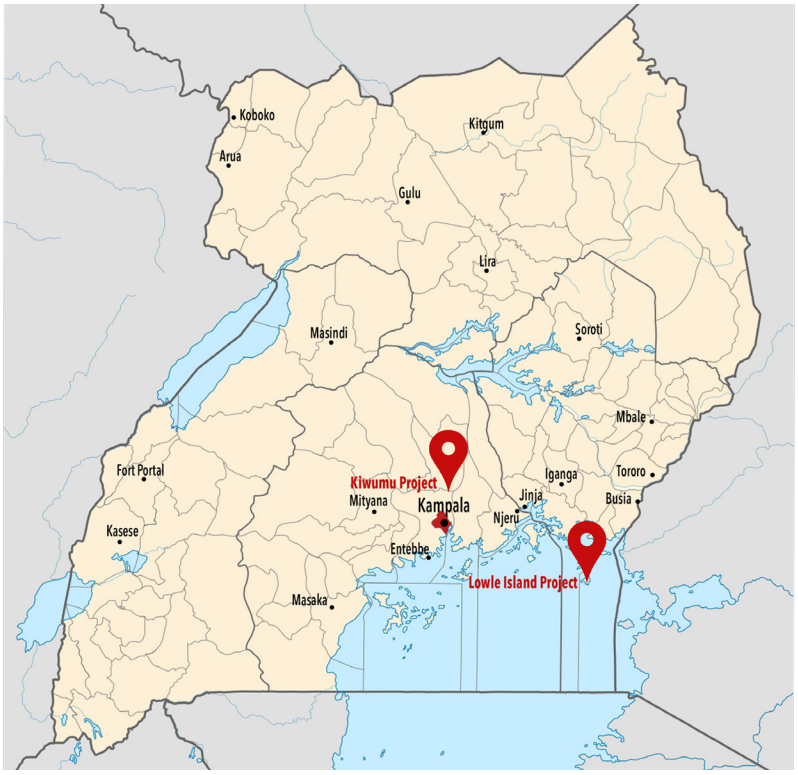
Despite the high levels of electricity access in Uganda's urban areas overall (and Uganda's generation surplus), there are distributed energy technologies, solar home systems, and commercial installations in and across urban areas. These technologies compensate for reliability issues due to maintenance challenges and infrastructure damage. Additionally, most of Kampala's residents use charcoal for cooking, motivated by cost as well as preference (Bamwesigye et al., 2020), a likely case for cities across the country.

Compared to many parts of the country, Uganda's urban areas have decent urban networks – with Kampala's being both the strongest and most in-demand. However, significant levels of capital are needed to ensure that the network is maintained and upgraded to keep pace with demand and deterioration. Distributed technologies of various sorts are being developed to fill the gaps in the network – attending to areas that are yet to be reached, and supplementing grid access where it is unable to deliver consistent supply. It is against this backdrop that we look in more detail at the distributed technologies that are being tried in and around cities.

5. CASES OF DECENTRALISED ENERGY PROVISION

This section explores several cases of distributed energy services in the context of Uganda's national electricity system. These cases are suggestive of different service typologies being explored and developed in Uganda, and more widely in Africa. These cases are, of course, illustrative. They are not presented as fully developed project categories. The first two cases are mini-grids, aimed at extending the urban network (Kiwumu) or creating a standalone network in the absence of distribution network connectivity (Lolwe). The second two cases focus on the city of Kampala, first looking at how start-ups are creating distributed energy solutions in the city, and how the city government itself is engaging with distributed energy solutions (KCCA). Image 1 shows the locations of the projects.

IMAGE: MAP OF UGANDA, KAMPALA, INDICATING THE CASE STUDY LOCATIONS/MINI-GRID SITES



Source: Authors, 2022

Peri-urban connectivity – the Utilities 2.0 Twaake Project at Kiwumu

> *"In a country like Uganda, stimulating electricity demand within the customer base is critically important. The country has leveraged its access to low-cost hydropower to develop new supply that is already more than double the current peak demand. Demand growth is imperative to the power sector's long-term financial sustainability."* (Mahomed et al., 2020)

> *"Neither centralised or decentralised energy can end energy poverty alone. However, through partnership and leveraging comparative strengths, traditional utilities and innovative DRE companies can create a new frontier in the fight to end energy poverty."* – Kristina Skierka, Power for All CEO (Rockefeller Foundation, 2021)

Under the RESP, the distribution company, Umeme, has been forging ahead with the extension of distribution infrastructure, and many eagerly await its arrival. Operating under a concession that is soon up for review, pressure is mounting to keep the grid and customer base growing in line with national development plans. However, once the grid arrives and as the urban edge of Kampala moves outward, there is still the matter of getting electricity connected to businesses and homes and getting people to use the electricity – to pay for the 'last mile' connection, as well as appliances they have not had before, and the power to use them. Within this 'last mile' of connection, according to project partners, there is work to be done to raise awareness and facilitate 'productive uses of power' to make it worth the while of end users to sign up for access. For Umeme, whose tariffs are tightly regulated by ERA, there is a significant risk in extending the grid to areas where people are not able or willing to pay for electricity. In 2021, the effective tariff for a household using less than 100 kWh a month would have been less than 0.20 USD per unit. Nonetheless, affordability is a challenge. In the absence of last connections or without electricity usage, there is effectively no means of cost recovery for the utility. To say that Uganda has an energy access problem is thus too simple a diagnosis. Umeme's balancing act between covering its costs and striving for affordability of electricity is a seemingly intractable problem in a country with significant levels of poverty. The situation was worsened by the impact of COVID-19, and severe lockdown measures only eased in January 2022. Indeed, across sub-Saharan Africa, COVID-19 led to a decrease of at least 6% in basic energy access due to loss of income (International Energy Agency (IEA), 2020b).

Images: (left) Kiwumu Mini-grid, Uganda; (right) Distribution Pole, Kiwumu, Uganda (Authors, 2022).

The Kiwumu Mini-grid responds to challenges in the 'last mile', particularly seeking to unlock solutions where the urban edge and the distribution grid are expanding in tandem. The project is being implemented as part of the Twaake Pilot under the Utilities 2.0 project. This wider pilot has two sites in Uganda (the second operating in parallel to the Umeme grid at Nyenje). In Mukono District in Kiwumu, the 40 kWp solar PV mini-grid is a short walk from the residential area. Its first customer is a maize mill with the ability to mill five tonnes of maize a day, a productive use off-taker which shares premises with the mini-grid. In January 2022 the project, now seven months old, is the sole electricity option for the 300 local households and 60 businesses (micro-enterprises); 35% of the electricity generated is going to households.

The Twaake project is an initiative of Power for All, a 501(c)3 non-profit organisation registered in the United States of America (USA), which focuses on decentralised renewable energy solutions to the global energy access challenge. It is funded by the Rockefeller Foundation.

Rather than operate where Umeme is not or cannot operate, this project aims to work with the utility and the government's plans for electrification, working in proximity to the grid. In fact, Umeme is a lead partner. The project team's ambition is to be the country's first successful interconnection of a mini-grid. The distribution lines that run from the power plant are erected by Umeme, and smart metering is also to the utility's specifications, to make sure that there will be no compatibility issues in the event of the grid arriving.

Other project partners include the Africa Mini-Grid Developers Association (AMDA), CLASP, CrossBoundary, East African Power, EnerGrow, Equatorial Power, NXT Grid, the Rocky Mountain Institute (RMI), the University of Massachusetts Amherst, and Duke and Makerere Universities. EnerGrow's role is to simulate electricity demand by providing access to appliances. The start-up provides productive asset financing and financial literacy awareness and training. More than half the assets purchased are financed – microfinance in Uganda is expensive, and Energrow reports interest rates around 35%, reportedly only achievable because of donor support for their business. The pilot is still learning lessons. COVID-19 definitely impacted people's ability to repay debts. Some still-new fridges are half empty. But for at least two entrepreneurs in Kiwumu, electricity has meant a near-doubling of services they offer their local community. The Kiwumu project has achieved unprecedented rates for uptake of electricity from a mini-grid, and this partnership is credited with some of this success.

The Director of Power for All Uganda navigates a complex institutional environment. She has worked through unclear regulations, convenes technology partners, and connects with research partners to develop an evidence-based case for the often-recited energy-for-development narrative motivating much of the donor involvement in energy access. The fragmented policy and institutional context for mini-grids has been cited by some as a significant barrier to investment by developers. However, the view from the site is different: "We don't need more policies, because the policies are sufficient. Let's help these industries to speak to one another." (Official interview, 2022). While local government did not have a clear role in the project, they were important for getting access to the land and being able to convene groups of people and build interest in the project's offerings.

Umeme employees working on this project are positive in their assessment of the project. They are keenly aware of the financial constraints that make the government's plans a currently intractable problem for the utility. Regardless of the myriad layered challenges, replication is being pursued. There are more than a million potential customers between one and two kilometres from the grid. For them the mini-grid solution might well be an interim fix before the cable arrives. And when it does arrive? There are four options: (1) all the infrastructure is handed over with compensation for future anticipated income, and the developer starts again in the next location; (2) the developer hands over the distribution network and applies for a small power producer licence and keeps selling power; (3) the developer hands over generation and operates the distribution under a licence; or (4) the developer keeps generating and distributing power under two licenses. Under the fifth option – and here the modularity and mobility of this solution comes into play – the developer works with Umeme to move the power plant to the next spot on the utility's long list. The generation infrastructure was imported from South Africa particularly because of its flexibility in this regard. The benefit for Umeme is that its grid arrives to an already stimulated demand.

High capital costs mean that a cost-reflective tariff for a project like this would be 0.60 USD. That is well beyond the affordability of Kiwumu's residents and more than three times the 2021 national tariff. However, the Minister's limit for land-based mini-grids to 0.30 USD came as a surprise to the mini-grid industry. Reportedly, achieving such a tariff would require full subsidisation of distribution costs. If the Twaake pilot were to achieve sufficient scale, says the project director, a cost-reflective, unsubsidised tariff would be 0.35 USD – significantly higher than Umeme, but workable under the right conditions. If subsidies come into play, the mini-grid would be competitive with Umeme's supply, with fewer grid reliability issues anticipated by some project stakeholders.

As the current phase of the Kiwumu project draws to a close, the practicability of the pilot as a replicable model for grid extension will be tested. It certainly appears to have the potential to respond to some of Umeme's challenges in its government-mandated network expansion, but barriers to replication, notably tensions between cost recovery and affordability, remain without any easy solutions.

Isolated island project – Lolwe (Dolwe) Island mini-grid

> *"We have brought [the] Rural Electrification Agency back in the Ministry for quick monitoring. You know some of those guys... they are disconnected from the Ministry… Even if you put poles down there, people will know that electricity is coming… Our plan is to take power to every sub-county… We must be in Sigulu quickly, as we are discussing. If the cable is delaying that, we go with the mini-grids. If it is too expensive, the cable has issues, we want to connect to people by 2023."*
> – Minister of Energy and Mineral Development, Lolwe Island mini-grid launch

Images: Solar Power 600 kWp power plant, Lolwe, Uganda (Authors, 2022).

Departing from Jinja and its large infrastructural endowment, the journey to Lolwe requires a three-hour ferry trip across the lake, or a more efficient chopper ride for the Minister, for whom a private tour has been arranged. Looking for Lolwe Island on maps can cause confusion. It is also called Dolwe Island or Lolui Island. Whether its name begins with an L or a D, whether it ends in 'we' or 'ui', is a matter of both linguistics and of politics. It depends on who is speaking and whether they are from here (Namayingo) or from there (Kampala). The island is one of nine that can support people within Namayingo District. Three quarters of the district's land comprises 16 islands on Lake Victoria. Until 2022, Namayingo's geography had kept it beyond the reach of the country's expanding electricity distribution networks. However, Lolwe Island's future changed dramatically between 2021 and 2022, with the construction of the solar PV mini-grid, or "fully integrated clean energy multi-utility, from electricity to rural service delivery" (Alliance for Rural Electrification, 2022). The project is described as the first of its kind. It is an example of Uganda's embrace of technological and regulatory change.

Insofar as the Lolwe mini-grid is located away from existing distribution networks, it is more typical of mini-grid deployment on the continent than the Kiwumu case. One of the government officials speaking at the Lolwe Island mini-grid launch mentions the submarine cables that had been promised as a way of bringing power to Uganda's island residents – and their failure to materialise. The Minister responds, assuring everyone that Lolwe is the first of the Bukooli Islands – but not the last – to receive power. And mini-grids are the way. Unlike the Kiwumu site, the island seems a world away from the closest urban node at Jinja. Although some of Jinja's residents bemoan its decline from the industrial hub that it was, and COVID-19 has emptied many of the resorts that line the shores of the Nile, its infrastructure is observable, and its businesses from small to large are visibly bustling. The physical and conceptual distance between Jinja and Lolwe seems an unlikely one for the cable to overcome. The problem set out at this launch is the cost and complexity of connecting places like Lolwe to both power and economic opportunities, to address the two-sided challenge of enabling electricity access and creating electricity demand.

The Lolwe Island mini-grid is the result of a partnership between the foreign-owned Equatorial Power and French multinational utility company Engie. The two companies have formed a joint venture – Engie Equatorial – to undertake this project, the first of its scale and design, an island mini-grid. At the launch the CEO of Equatorial Power assures everyone that – based on his understanding with the President – there are more than 20 other sites that can look forward to similar electricity-productive use infrastructure. Unlike the Kiwumu site, Umeme is not a key partner at Lolwe.

There are 15,000 people living on Lolwe Island. The island is visibly deforested, and there is little visible commerce. The project has, however, mapped businesses and fuel use that could be replaced with solar energy. On the island, the economy of which has hitherto been dominated by small-scale fishing, the overland trip from the ferry to the launch site takes everyone past the medium and low-voltage distribution network that connects the power plant (600 kWp solar PV and 600 kWh battery storage) to a productive use off-taker. The project is remarkably large compared with other mini-grids around the country. The off-taker is framed as both an anchor consumer and as an economic development investment. It comprises an ice-making and fish-drying facility, both part of the mini-grid project, and positioned as an 'integrated productive hub'. The idea is that fishers can either use the ice to keep their catch fresh, or to dry their catch, to be sold on the mainland. Fishers pay a fee for the ice and the drying, which is already underway by the time the grid is launched. There is a range of other potential applications for this new power, with several demonstrated on the day. Bodawerk (a company introduced below) has electrified

motorbikes and a boat, both on display. Energrow, the productive use partner at the Kiwumu site, is also present at the launch. If people have access to power, they will need appliances to use it. They will need finance to access the appliances. Communications materials promise that a programme is forthcoming to support 200 entrepreneurs to develop local 'productive usages of energy'.

Images: (left) Electricity distribution network, Lolwe Island, Uganda; (right) Productive Hub, Lolwe Island, Uganda (Authors, 2022).

At the time of the launch, none of the 3,783 potential electricity users (3,026 households and 757 businesses) are connected to power yet, and it is also unclear who will cover the connection costs. According to project partners, the REA, now within the Ministry, has paid for the distribution infrastructure and will cover the 'last mile' from the pole to the house, too. These state contributions amount to about 40% of the project being subsidised. This is not quite in line with the Minister's address, which suggests that this cost is for households to cover themselves.

The rest of the capital and operational costs are for the developer to cover and recover through the tariff – in this case, an amount of about 0.30–0.40 USD per unit is outstanding. The gap between this tariff and the national tariff presents the same financial and political challenge for developers as at the Kiwumu site. The differences between Lolwe and Kiwumu include a wider spatial disconnection of the urban economies at Jinja and Kamapala for the former, along with the absence of any electricity alternatives. Project stakeholders know this. Rural and peri-urban communities need energy access, but they also need economic opportunities to use, pay for, and hopefully reap benefits from safe and sustainable energy access. Affordability, as the Minister mentions, is a question with answers that are context-specific, relative to local incomes, and often qualified: 'It depends.' Affordability is a persistent challenge. Even if the cable were ever to arrive from Jinja, presumably it would bring in electricity sold in line with the national domestic tariff structure. It would be significantly cheaper than the electricity the mini-grid can generate, but likely still unaffordable for many.

Lolwe Island residents have joined the 19% of Ugandans that are being served through off-grid electricity installations. Replicability is clearly part of the plan for project partners. This is true for Uganda, and beyond its borders. In the mini-grid launch crowd, there are visitors from the DRC – a UETCL power customer. These visitors are there to understand the potential for replication. Uganda's electricity innovation looks like it could be replicated again – the GET FiT programme has already been exported by the World Bank to Zambia. The Lolwe project is an example of a common trend, wherein small-scale utilities operate in place of connection to the national grid. While discourses locally may still suggest that the cable will, eventually, come, in reality such isolated mini-grid projects reflect an alternative, rather than an interim, strategy of electricity provision.

Urban service retrofit: e-mobility

> *"A dispute over COVID-19 testing fees for truckers has created a fuel crisis in Uganda, highlighting an economic impact of the pandemic in a landlocked country with virtually no fuel reserves of its own… With little movement at the border, many fuel stations across Uganda ran empty. Motorists lined up at the few still operating, creating anger when prices eventually rose sharply."*
> (Associated Press, 2022: para.1–3)

While impacts of COVID-19 story are contemporary and perhaps also temporary, petrol shortages are not new for people living or working in African cities. International market dynamics result in price hikes and kilometre-long queues at fuel stations, with a grinding impact on urban economies relying on the movement of vehicles in, through and around cities. Volatile petrol costs amplify calls for investment in electric vehicles. These calls resonate around the world, dovetailing with a plethora of global goals related to air pollution and carbon emissions-reduction targets. A move away from petrol and diesel engines would shift the mobility sectors of cities, increasing electricity demand, and directly impacting the local network – straining, supplementing, or displacing it with alternative distributed provision and energy and storage.

In the context of Kampala, these calls for electrification of mobility centre around the (in)famous motorcycle taxi ('boda boda') sector. Motorcycles dominate movement in Kampala, in particular for shorter trips around the city, and last-mile logistics (for example, for companies such as Jumia or Glovo). As with electricity access, the last mile is the final distance between the customer and the larger supply chain. Motorcycles outcompete other mobility modes through their agility in the face of traffic, dirt roads, and urban sprawl. According to the IGC (2018), they accounted for 42.4% of the vehicles on the roads of Kampala in 2018. Several companies are attempting to shift boda bodas from diesel dependence towards rechargeable batteries. These companies argue that such a shift not only improves the livelihoods of motorcycle taxi operators (lowering the operational cost of providing their services), but also contributes to a range of climate objectives. There are two important and complementary Kampala-based companies that have made it their mission to transition the boda boda sector: Bodawerk is a Ugandan start-up that focuses on developing rechargeable lithium-ion 'smart' batteries. These batteries can be integrated with the existing motorcycle taxis used by the vast majority of Kampala operators. A modified Bajaj Boxer – an Indian-designed, Chinese-manufactured and now Ugandan-retrofitted – motorcycle enables riders to reduce both their emissions and operational costs. Bodawerk is complemented by another start-up, Zembo, with headquarters in France. Zembo imports electric motorcycles (frames and batteries) and establishes charging stations where riders can exchange batteries for a fee. Zembo's vision is to develop charging stations all over Kampala, using solar charging wherever possible to supplement the energy provided by the utility. In the digital mobility debates across Africa there is ongoing debate over the most viable 'model'; a plethora of variations have been developed to test different ownership, finance, and management configurations. Central to all of these is the question of data, particularly its contribution to lowering the risks of investing in the sector.

Communicated in pitch decks that estimate the future value and impact of e-mobility innovations, both Bodawerk and Zembo have attracted the attention of international donor organisations. Donors have funded much of the research and development of both organisations, hoping that the programmes will grow to attract larger funding from venture capital or development finance institutions. Both organisation have also attempted to partner with the government, Zembo having sold four bikes to the KCCA and Bodawerk having been allocated a contested share in one of Kampala's industrial parks. The companies see themselves as 'start-ups', and they have ambitious hopes of scaling their operations. For Zembo, scale looks like a city full of charging stations, with riders able to recharge (at an affordable rate). Despite its name, Bodawerk's scalable innovation is not limited to (or even focussed on) the boda boda sector. After all, the retrofit is an expensive process, given the short lifespan of motorcycles (estimated at around four years) and the marginal gains of riders (to whom limited credit is available). The battery offering which the company has been refining for the past four years can be used to power home systems (enabling uninterrupted power supply in the context of regular cuts) or other vehicles, such as tractors or boats. The batteries are manufactured locally from imported components, offering customers the convenience of easily accessible service in the event of a problem.

Images: (left) Zembo Recharging Station, Uganda; (right) Bodawerk battery development (Authors, 2022).

Returning to the cable, what do these cases reflect? To start with, Zembo and Bodawerk are both working to expand the ways in which the existing electricity grid is used. The electrification of mobility increases local electricity applications and demand within the dense networked areas of urban agglomeration. At the same time, they are making investments which enhance the usability of the grid. Private investment in Bodawerk's home batteries can compensate for network downtime and accompany solar home systems seen atop some homes in the city. These companies in Kampala, and many more across the continent, challenge linear notions and concepts of decentralisation. These innovations do not seek to weaken the centralised grid or diminish its importance, but rather add to it in terms of network supplementation and the augmentation of electricity demand.

KCCA projects

Kampala is undeniably the largest urban area in Uganda; what happens in this city will have implications for smaller towns, the country, and the region at large. Despite the importance of Kampala in the country and region, there is considerable confusion over the (urban) governance of Kampala. According to documentation:

> *"In 2009, and in realisation of the need to reverse the deteriorating City status, a study on transforming Kampala City from a Local Government to a corporate entity was initiated under the Kampala Institutional and Infrastructural Development Programme (KIIDP). A Bill for an Act of Parliament was presented following a lengthy consultative process. It was debated, amended, and finally passed in 2010 by Parliament as the Kampala Capital City Act, 2010… The Act was amended in 2019… to streamline and strengthen the governance of the Capital City in accordance with article 5(4) of the Constitution; to clarify the roles of the Lord Mayor and Deputy Lord Mayor; and to provide for related matters."* (KCCA, 2019)

Based on this review, in 2011 the affairs of Kampala were brought under the direct supervision of the central government through the Ministry for Kampala Capital City and Metropolitan Affairs (there is also a separate national directorate for planning in Kampala). The KCCA was established as a corporate entity, and remains in charge of the management and development of Kampala. This is not dissimilar to many other capital cities in Africa, which are governed by authorities established exclusively for this purpose. The Lord Mayor is the political head of the Capital City, forming part of the KCCA. So too are the mayors of the five geographical divisions within the city area. The relationship between the elected politicians and the appointed technical team which forms the bulk of the KCCA is not entirely clear. Within the KCCA there are several directorates. The directorate of engineering is responsible for planning, designing, and managing the construction of city roads, city drainage systems, traffic and street lighting, parking, and city public transport. The KCCA total budget in 2018/2019 was 130 million USD. Over a third of this budget came from national government grants and transfers. According to the International Growth Centre (IGC) (2018), the KCCA spent 54% of its 2018/19 budget on engineering services.

In terms of electricity, the majority of Kampala is covered by the Umeme-operated distribution network. However, as the city has grown and densified, investments to upgrade (and even maintain) transmission and distribution investments have not been consistent. For Umeme – a private company – retaining its concession means keeping tariffs in line with regulated 'developmental' levels and meeting expansion targets; meeting its operational and shareholder expectations means recovering its full costs with profit. The tension between these two imperatives is not easy to navigate. Many parts of the city experience regular power failures. Consequently, households and business that can afford it create backup systems to supplement their reliance on the grid. The same is true for the city authority.

In attending to the energy question, the relationship between Umeme and KCCA is incoherent. The 'Lord Mayor' of the city has, on many occasions and in many public fora, expressed concern for the climate agenda and the importance of centring cities in global development. His speeches and social media accounts reflect his related advocacy efforts on behalf of Kampala. Despite this, KCCA overall has little engagement with the energy system in Kampala. The KCCA interfaces with the electricity system as a consumer. While some energy-intensive urban functions (such as water treatment) are not managed by the KCCA, the infrastructure which the KCCA does operate requires energy. For example, the KCCA office and government buildings, the street lighting, the traffic lights which mediate intersections and crossings, and the schools and clinics which fall under city jurisdiction, all require electricity services. As new projects come online (such as the proposed Bus Rapid Transit), the authorities may find themselves requiring more energy to run and manage these services. KCCA's functions are subject to the prevailing grid conditions. The cost of electricity is also an operational burden at 180–200 million shillings per year. Delayed transfers from the national government have contributed to large outstanding debts to the utility company.

An expressed desire to lower the cost of electricity to the city, improve the consistency of services, and work with enthusiastic French funding partners has resulted in a series of interventions in the city. These interventions include installing solar-powered streetlights; upgrading school buildings to support rooftop solar panels; and purchasing four Zembo motorcycles to be used by the KCCA. The hope is that these

minor improvements will reduce the operational costs carried by the city, creating savings that go toward repaying the loan that funds the project. Regarding its collaboration with the French Development Agency (AFD), the KCCA reports:

> *"KCCA is in the process of acquiring funding of approximately Euros 77 million from the French Development Agency after GOU clearance. Through this project, KCCA will increase street lighting in Kampala from 8% to 100%. A total of 35,000 lights will be installed. The Euros 70 million is a loan, whereas 7 million is a grant from the European Union."* (Source: KCCA, 2021: para. 11)

Images: (left) Kampala Capital City Authority Depot; (right) Kampala 'mini mall' (Authors, 2022).

While the KCCA, and some of the political actors involved in urban governance, are indeed interested in the energy transitions underway, the role that they play in transforming the city's electricity system is minimal. Even as a relatively powerful African urban authority, the KCCA is implementing small-scale projects, largely focussed on changing their own electricity uses and supplementing their grid access. This begs the question: if the KCCA is not a key player shaping the energy transitions in Africa, what does this mean for other (less supported and resourced) city governments? What of the global North narrative and development agency plans placing cities at the centre of interconnected climate and energy planning?

6. CONCLUDING REFLECTIONS

The fossil fuels energy transition irrevocably altered Africa's social, political, economic, ecological and other trajectories, driving the interconnected exploitation and dislocation of people, places and resources. How will this 'sustainable' energy transition reshape the continent and its various systems? And how will this transition interact with burgeoning, dynamic cities and their overstretched infrastructure networks in the context of already serious climate change and related policy regimes?

The sustainable energy transition narratives offered within entrenched development paradigms make bold assertions connecting the material transformation of infrastructure and technologies – lower-carbon, smaller, more flexible – to constellations of normative ideals, such as energy access, energy-poverty alleviation, energy justice, energy democracy, good governance, green industrialisation, green economy… the list continues. But what are the connections between changes in physical infrastructure and profoundly different – and proposedly better – social outcomes? How do we interrogate purported causal linkages and intervening mechanisms when policies also do not clearly articulate a theory of change laying bare their assumptions? The aim of this discussion has not been to answer these questions but to raise them, as others have, in relation to concrete instances of transition projects. Transition policies share the feature of many speculative stories oriented by propositions about a fundamentally unknowable far future: The issue is not with the act of speculation itself, but in its presentation as self-evident, shaping and legitimising policies, actions and investments now. This presentation matters to African urban governance actors needing to develop low-carbon energy pathways that make sense for them in context, many of whom are offered various modes of external development support for this purpose.

It is clear that sustainable energy transition research and policy advocacy is infused in the rationale and resource mobilisation for distributed electricity technologies in Uganda. These cases show how what is, is being changed by ideas about a very different electricity system that

could be. Normative ideas about the future are guiding planning and investment through pilot projects, all aiming for scale through extension or replication. Given the reality of energy access and energy poverty as well as actual poverty rates, the distributed infrastructure and technologies offer relatively basic solutions aiming to achieve some measure of poverty alleviation. This access is complicated by issues of affordability, coupled with little chance of significant local manufacturing. What development agencies, NGOs and private companies say could be in that far future, at the end of the sustainable energy transition, is sustainable, inclusive development powered by various renewable energy solutions. The mini-grid projects, however, show just how puzzling connecting electricity and development is. The complexity is clearly illustrated in the ERA's and Minister's challenge of tariff-setting to cover mini-grid developer costs, incentivising additional investment, and simultaneously incentivising electricity use to enable both revenue collection and energy-poverty alleviation.

In this paper we focus on concrete projects that can be interrogated and measured. We offer four vignettes examining differing distributed electricity solutions in Uganda being implemented during 2022, more than two years into the COVID-19 pandemic. We looked at innovations within Kampala's dense urban fabric, its meandering peripheries, and in spaces noticeably disconnected from urban infrastructure and economy. These examined cases challenge us to critically engage with distributed electricity infrastructure in relation to patterns of urbanisation: its presence, absence, arrival, and its governance. They display distinct relationships between project leads, their commercial backers/employers, project teams, different government actors, utility staff, and other international development, foreign government, non-governmental and commercial actors, as well as researchers. The international sustainable energy community of actors in Uganda notably includes a host of foreign for-profit energy companies of different sizes that operate and also access donor funding and mobilise public spending under the auspices of SDG7 and related (inter)national policies. Thus the binary distinction between public and private is blurred. Each project has a different relationship to incumbent infrastructure networks. The vignettes clearly illustrate how distributed investments can extend the grid (Kiwumu), supplement the grid (KCCA and e-mobility projects), and create new grids (Lolwe). In the context of failing networks, for those few who can afford it, new technologies can also supplant the grid, removing those most able to pay from the pool of customers contributing to the cost of delivering electricity access to everyone. Clearly, understanding these projects needs an analytical shift away from simplistic binaries including on-/off-grid, or networked/non-networked.

Similarly, 'decentralisation' does not appear an apt characterisation of what is happening in the governance of Uganda's electricity system in response to the incorporation of distributed electricity solutions. Distributed electricity technologies are being deployed, funded, and governed by existing centralised institutions and processes. The KCCA's energy mandate does not appear to be significantly expanding through their innovative energy projects. As more mini-grids, e-mobility, home systems and solar equipment are integrated into the national electricity system, it also remains to be seen how they will typically relate to existing infrastructure networks, how this is motivated, and whether electricity governance arrangements are meaningfully challenged.

The deployment of distributed technologies – and the financial and governance arrangements that shape them – interface with the medium- and long-term material and institutional development of cities, regions and countries. The extension, supplementation, supplanting and 'operating in place of' existing networks is motivated by 'better' services underpinned by 'better' infrastructure, compared to current service levels given resource constraints. It is possible, however, that short-term improvements will not necessarily add up to long-term viable configuration. Thus, the incipient electricity infrastructural palimpsest may lock in particular trajectories and exclude others without the benefit of knowing where the transition will lead. More attention is needed to chart alternative urban transition pathways and planning, combining growing evidence-based sense-making with explicit speculative reasoning.

These cases are not definitive of a project type. They are merely snapshots of specific projects at particular locations, contextualised within a multi-level change that is being implemented through national and international decisions. These four vignettes provoke more questions than they answer. Insofar as each project ventures an answer to the question 'How will the transition advance?', they are critical sites of experimentation that matter to more than just the refinement of Ugandan electricity policy. They could function as case studies in the local benefit of the global sustainable energy transition and its accompanying urban policy focus to African countries. Tracking these kinds of projects and scaling plans over time will be invaluable in understanding what kind of future is being seeded through the transition as a policy package, layered over the transition as a complex, multilevel technological and social transformation. Significant additional work is required to understand how, under what conditions, and with what support these material interventions will and will not advance local energy plans and other local developmental objectives – at the country level and within urban and urbanising areas.

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