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Rethinking energy transitions in Southern cities: Urban and infrastructural heterogeneity in Dar es Salaam

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ABSTRACT

Despite increasing attention to the complex geographies of energy supply and use in Southern cities, energy research is still largely focusing on energy transitions evolving either through homogeneous, networked electricity or heterogeneous constellations in poor neighborhoods. Central to this research are analytical concepts used to explain energy transitions in Northern cities, such as the notion of socio-technical regimes. In this paper, we argue for a better recognition of the realities of cities in the Global South, including their diverse urban development patterns. Bringing together debates on heterogeneous urban infrastructures and energy transitions, we propose a novel analytical framework that systematically captures urban and infrastructural heterogeneity to better understand energy systems and their transitions in growing Southern cities.

Drawing on a case study on Dar es Salaam, Tanzania, we develop a spatial typology of electricity constellations using three analytical dimensions: delivery channels, the neighborhood scale, and the urban scale. Based on in-depth studies of six distinct local development types, we reveal spatially heterogeneous electricity constellations and their interplay within the city. We argue that debates on urban energy transitions in academia and policy practice need to more systematically address the diverse urban development patterns within Southern cities, their co-evolution with place-based electricity constellations and their context-specific challenges and opportunities.

1. Introduction

Urban energy research has so far largely focused on transformations toward low-carbon cities based on epistemologies and policy concepts developed in and applied to Northern contexts. Most studies on urban energy transitions are based on the assumption of clearly identifiable and spatially homogenous urban energy regimes [1,2]. However, the notion of socio-technical regimes which is at the core of transition theory might not be readily applicable to Southern contexts. Here, the ideal of a "networked city" is far removed from urban realities [3]. Instead, cities and their energy constellations[1] are heterogeneous and urban coalitions that define and implement coherent policies and transition strategies are often absent [4]. The understanding of energy constellations and their transformation in Southern cities thus requires a rethinking of established epistemologies and analytical concepts guiding urban energy research.

It is in light of this limited applicability of established analytical concepts that the complex geographies and the socio-technical heterogeneity of energy provision and use in Southern cities have recently attracted more scholarly attention [5,6]. In particular, several studies have advanced our understanding of energy constellations in African cities by detailing the splintered patterns of urbanization, the critical role of incremental energy networks, heterogeneous configurations, and splintered systems in meeting energy requirements [7–9]. This growing literature across urban studies and science and technology studies has reframed and importantly expanded understandings of energy infrastructures in Southern cities. However, much of this literature strongly builds on micro-level studies and focuses primarily on poor neighborhoods [10–12]. It highlights the multiplicity of socio-technical constellations that shape and are shaped by everyday practices and experiences of the urban poor who live at the margins, in the interstices of or beyond centralized electricity networks.

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[1] We use the term 'constellation' to describe context-specific and not necessarily purposefully configured sets of various delivery channels at different scales, i.e. the neighbourhood and the urban scale. The terms of energy and electricity constellations describe the socio-technical arrangements in energy supply and use while the term infrastructure constellation captures those arrangements applicable to other infrastructure domains as well.

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Our objective is to understand different energy use patterns and forms of co-provision beyond poor individual neighborhoods and to develop a broader *urban* understanding of the heterogeneous socio-technical constellations *across individual neighborhoods*. In line with recent debates, we argue that in order to deepen our understanding of how diverse energy constellations and their interplay shape opportunities and challenges for urban energy transitions, we need to broaden our analytical focus to the diverse forms of urbanism located within cities [13].

Building on a critical review of debates on urban energy transitions and recent debates on urban and infrastructural heterogeneity in Southern cities, we propose a clearer analytical framework to apprehend the complex spatialities of heterogeneous energy constellations in Southern cities. Our paper advances current debates in two ways. First, we develop a spatial typology as an original analytical framework to capture urban diversity and infrastructural heterogeneity within a city based on three levels of analysis: socio-technical delivery channels and energy constellations at the neighborhood and urban scales. Secondly, by highlighting the multiplicity and relationality of heterogeneous energy constellations, we offer an alternative conceptual framing to the notion of energy regimes to capture the status quo of energy supply and use from which urban energy transitions emerge.

Empirically, our focus is on electricity supply and use which are key to urban energy transitions[2]. As an empirical case, we take the city of Dar es Salaam, Tanzania to investigate and capture the heterogeneity of electricity constellations at both the neighborhood and urban scale. As one of East Africa's largest and fastest-growing urban regions [14], Dar es Salaam provides an excellent case to consider how diverse patterns of urban growth and electricity provision co-evolve. Besides having splintered patterns of physical grid coverage [15], grid electricity services are poorly reliable [16] and often unaffordable for the urban poor [17]. As a result, heterogeneous socio-technical alternatives have emerged, such as individual off-grid installations, landlord–tenant arrangements or illegal network extensions. We use Dar es Salaam as a case to discern how this socio-technical heterogeneity plays out in spatially distinct forms across the city, shaped by developments such as peri-urban sprawl, rapid densification of unplanned settlements, or inner-city redevelopment. At the same time, we show how official urban energy policies in Dar es Salaam focus primarily on incrementally catching up with ideals of a uniform and universal electricity grid, yet efforts to do so tend to disregard the complex interplay with service co-provision beyond or complementary to the conventional grid.

More specifically, we investigate how electricity delivery is locally organized through multiple technical artifacts (grids, generators, solar systems, appliances, etc.) and specific structures of (co-)provision and use in six wards in Dar es Salaam. We show that the resulting electricity constellations are highly place-based and differ considerably across individual neighborhoods within the city. These constellations, we argue, fill critical service provision gaps, but also reveal substantial challenges for urban energy transitions. Our argument is that a better understanding of and an active engagement with the spatialities and socio-technical heterogeneity of urban electricity systems is essential, both for academic debates on urban energy governance and for the practice of policy makers, utility companies and international donors. We first analyze secondary empirical data, policy documents, technical reports and statistics to understand current energy developments and policies. Secondly, we examine neighborhood electricity constellations in the six wards, using a spatially explicit three-level typology of urban electricity constellations. This enables us to: (1) observe which service delivery channels can be identified within the city, resulting in (2) a rich description of the delivery channels and how they are embedded in different neighborhood settings. We then (3) interpret how these constellations and their interplay produce challenges and opportunities for future constellations.

For the in-depth study of neighborhoods across the city, we collected qualitative data between November 2018 and August 2019. Insights into user practices and institutional features of provision and use were obtained from data on technical features of electricity grids, field visits to the selected wards, participatory observation (including visual documentation through photographs) and informal discussions with residents. In addition, 62 in-depth, semi-structured interviews were conducted with the Tanzania Electricity Supply Company (TANESCO), the Energy and Water Utilities Regulatory Authority (EWURA), the energy ministry and urban planning offices, community leaders and with elected and appointed ward officials and various non-state actors (private electricity providers, donors, researchers, NGOs, lobby groups and real estate companies). Primary data gathered was supplemented by material from 20 interviews on land use and energy planning, conducted in 2017 by one of the authors. To refine our research design and to critically discuss and assess preliminary findings, workshops with key stakeholders were essential in consolidating our research.

The paper is divided into four sections: We first critically review debates on urban energy transitions in Southern contexts, focusing on analytical dimensions of transitions theory as a dominant epistemology in energy research. Section 3 introduces the case study context in Dar es Salaam, including the institutional setup and the policies in urban electricity supply. We begin Section 4 by explaining the typology of urban electricity constellations as our core contribution to advance analytical concepts for urban energy research in Southern cities. This spatial typology allows us to capture, systematize and compare heterogeneous electricity constellations across different neighborhoods. Based on this analytical framework, we then present a detailed analysis of different neighborhood electricity constellations. Section 5 discusses the relationship between them and Dar es Salaam's urban electricity constellation, including its place-based challenges and current electricity policies. Finally, the conclusion positions the findings within broader debates on urban energy research in Southern contexts.

2. Bringing urban and infrastructural heterogeneity into energy transitions debates

In the past decade, energy research in the social sciences has increasingly addressed the urban dimension of energy supply and use [18–20], focusing predominantly on pathways toward low-carbon cities. Climate change mitigation by means of renewable energies, energy efficiency and new practices of energy use are central to most research agendas [21,22], which are shaped by epistemologies and policy concepts developed in and applied to global North contexts. In such contexts, urban energy transitions are conceptualized as destabilizations and reconfigurations of an urban energy regime—understood as "relatively stable configuration of institutions, techniques and artifacts, as well as rules, practices and networks that determine the 'normal' development and use of technologies" [[23]: 1493]. Besides the presumption of a coherent regime, Northern debates also invoke other implicit assumptions about key properties of urban energy provision, use and their governance. The assumptions include a strong state capacity to plan, regulate or incentivize energy innovations through the development of socio-technical niches [24]. The implicit assumption of universal networked electricity services provided by public or state-regulated electricity companies is closely attached to this thinking, internalizing ideals of a "networked city" [3] from which energy transitions would proceed toward increased sustainability.

However, established notions and concepts such as clearly identifiable and spatially homogenous urban infrastructure regimes are detached from realities of Southern cities [4,25]. This blind spot of established epistemologies becomes particularly apparent when

[2] While electricity represents only one part of the overall energy provided and used in Southern cities, we explicitly focused on it given the growing emphasis on electrification in debates on energy transitions as well as for reasons of feasibility.

observing energy provision and use in sub-Saharan Africa's growing cities. Rapid urbanization processes, occurring mostly beyond formalized land-use regulations, generate place-based heterogeneous energy constellations and splintered network access [8]. The mostly state-owned and state-regulated electricity companies are often unable to provide ubiquitous services under those conditions and are thus regularly complemented by multiple service co-providers [12,26]. Furthermore, state authority is weak and very patchy in its reach [3], and its capacity to effectively foster energy transitions is limited by the absence of urban coalitions that define and implement coherent urban energy policies [4]. Consequently, urban realities shaped by hybrid and heterogeneous energy constellations require a rethinking of established epistemologies and analytical concepts of urban energy transitions research. Given the limited applicability of established concepts observed above, two recent trends demonstrate attention is shifting toward the importance of the complex geographies and the socio-technical heterogeneity of energy constellations in Southern cities.

First, a "spatial turn" in energy research has resulted in a number of conceptual commonalities in recent work [27]. They include an increasing focus on exploring spatial differences in energy provision and use. Furthermore, seeing energy as being both shaped by and shaping social and spatial relations is helpful when reflecting on how energy issues interact with others "such as housing, land transformations, urban design, property rights, and access to infrastructure" [5: 3]. Another crucial commonality is the emphasis on the various scales at which such differences occur. Silver and Marvin [8] have criticized existing transition concepts for their inability to capture multiple spatial scales and have called for both a more explicit incorporation of the diverse energy use and co-provision practices at the household and neighborhood scale. More attention, they argue, needs to be paid to the embeddedness of urban energy systems within national and international governance arrangements and to economic connections and investment flows. Second, an infrastructural turn in urban studies has pointed to the co-constitution of social and material dimensions of transformation processes in and of cities [28,29]. Particularly in global South contexts, this has resulted in challenging the hegemony of the "modern infrastructural ideal" [30] or that of a universally "networked city" [3]. The argument is that alternative socio-technical constellations beyond centralized urban grids should be mobilized to improve service provision [6].

Within energy research and urban studies, it is only recently that heterogeneous infrastructures in African contexts have attracted more systematic scholarly attention [4,7,8]. The literature from urban studies and science and technology studies has usefully accounted for the interplay between rapid, informal urbanization and the socio-technical constellations that most poor urbanites rely on and that are positioned "outside a conventional understanding of transition and standardized integrated and modernist notions of infrastructure configuration" [[8]: 11]. Accordingly, urban energy provision and use in Southern cities have been understood as depending on heterogeneous and hybrid arrangements with multiple combinations of networked and non-networked, public, private and self-organized, or planned and incremental infrastructures. This urban and socio-technical heterogeneity thus marks a starting point for rethinking urban energy constellations in contexts where established concepts of socio-technical regimes are hardly applicable.

According to Jaglin, heterogeneous socio-technical delivery channels have emerged in Southern cities in response to diverse urban settings—and associated user needs and capacities—as "an integral part of the material fabric of southern cities" which cannot be confined solely to poor urban neighborhoods [[31]: 435]. These channels, and their arrangements in multiple, place-based constellations, she argues, remain a cornerstone of urban service delivery, "despite policy announcements and reforms" aiming to universalize the grid [[31]: 434]. Castán Broto [7] furthermore stresses the differences in how energy constellations come about in different functional areas of a city; she draws attention not only to socio-economically stratified residential neighborhoods, but also to commercial and industrial areas.

Most empirical studies that systematically address infrastructural heterogeneity in Southern cities, however, build almost exclusively on research on individual neighborhoods, focusing primarily on everyday practices and livelihoods of the urban poor. Such studies critically explore emerging co-production schemes, pre-payment mechanisms, or slum electrification programs [10–12,32,33]. Yet, the fact that the phenomenon of socio-technical heterogeneity is not limited to poor settlements but is an equally intrinsic feature of energy constellations in middle-class, affluent or industrial areas has hardly been accounted for. Moreover, socio-technical heterogeneity is not solely a phenomenon that occurs differently and in place-based constellations *within* individual neighborhoods. At least equally important for deciphering urban energy constellations in Southern cities is an understanding of how constellations within neighborhoods relate to each other and how socio-technical heterogeneity occurs *across* the city.

Our argument is thus that we need an analytical framework to grasp this heterogeneity, and its relevance for energy transitions. This framework needs to widen our analytical focus in three ways. First, we need to understand and compare socio-technical heterogeneity across a broader variety of neighborhoods characterized by distinct socio-economic strata, urban functions and physical characteristics. Second, it is essential to adopt a multi-scalar perspective that combines the analysis of individual delivery channels and energy constellations within different neighborhoods with that of *urban* energy constellations. Such a perspective accounting for the different urban worlds within a city has the potential to uncover how energy constellations differ considerably across neighborhoods and how they relate to and mutually shape each other (for a similar argument see [9,13]). Finally, and essential for the understanding of progressive urban energy transitions[3], the social, economic and environmental externalities of heterogeneous energy constellations require further critical assessment. In particular, electricity constellations contribute fundamentally to the functioning of cities but can, at the same time, create significant sustainability challenges which differ considerably within a city. In order to systematically address these manifold analytical dimensions, we choose a typological approach based on the selection of representative neighborhoods (see section 4). This approach balances a sufficient level of detail in the analysis while ensuring a broader *urban* understanding of heterogeneous electricity constellations at the same time.

3. Electricity supply and policy in Dar es Salaam

With approximately six million inhabitants, Dar es Salaam is Tanzania's de facto capital and the largest city in East Africa. Administratively, the city is one of the nation's 31 regions; it is divided into five districts and is composed of 90 wards in total. According to the government of the United Republic of Tanzania (URT), the population is likely to double by the mid-2030s, presenting massive challenges for urban planning and infrastructure provision [34,35]. Most prominently, population growth occurs in peri-urban and some inner-city neighborhoods [36]. Settlement growth takes place mainly beyond official planning designations [37], driven by individual private households. Suburbs attract both poorer and middle-class residents aspiring to build single-family homes, resulting in socio-economically mixed neighborhoods [38]. While individuals buy land where it is cheap, which is often in locations where "infrastructure and basic services are either inadequate or non-existent" [[15]: 39], large-scale developers target the urban core and major development corridors, to use existing high quality service provision. Thus, differences in the built environment are both the result of and simultaneously impact on spatial differences in

[3] We use the term to distinguish purposeful efforts to improve the environmental, social and economic performance from other relevant transition dynamics.

electricity grid services.

The state-owned public utility TANESCO must cope with such emergent urban developments. Due to organizational and financial constraints, grid expansion is officially organized on a "first come, first served" basis (Interview 1), rather than through comprehensive plans for a proactive investment in the distribution grid. How residents are factually connected to the grid relies on negotiation with TANESCO and their mobilization of political influence or co-financing (Interview 2) [15]. Furthermore, settlement characteristics like location, size and the availability of land for grid corridors form part of the utility's commercial viability assessment (Interview 3). In its strategy to universalize grids, TANESCO relies on grants and loans from the government and international development partners.

According to government reports, Dar es Salaam has achieved universalized electricity access, which is, however, dubiously defined as households located "within 600 m from a transformer" [39]. According to a national household survey, the physical connectivity rate is 80% [40], revealing that the network does not fully cover the city's territory and that factual grid accessibility is limited. Currently, this leaves about 1.2 million urbanites unserved. Most of these non-connected households are in suburban/peri-urban settlements and some inner-city pockets. The main accessibility barrier is affordability [17]. Specifically, poor urbanites struggle to pay for initial connection fees (Interview 4), which start at 321,000 TZS (139 USD)[4] and are related to the distance to the grid. Tariffs are less frequently mentioned as a barrier to social accessibility. Urban electricity users are classified according to their consumption and there is tariff differentiation: poor residents are eligible for a subsidized lifeline tariff of 100 TZS/kWh (4.3 USD¢/kWh) up to a consumption of 75 kWh/month to meet basic household needs like lighting; all others pay 292 TZS/kWh. Large commercial and industrial users of the grid have their own, favorable tariffs [41]. Yet even for neighborhoods and users that are physically connected and can afford electricity connections and usage, service access is constrained. Despite improvements in recent years [15,42], low reliability impedes service usage [16]. The maintenance and upgrading of distribution grids are hindered by available space, financial limitations, and the difficulty of predicting increases in demand for electricity. The result is that overloading and failure of wires and transformers, or temporary plant unavailability, regularly lead to outages (Interviews 5; 6).

Partly in response to these broader challenges, the Tanzanian government has become involved in several international arrangements, such as the Paris Agreement, the "United Nations Sustainable Energy for All" initiative and the Sustainable Development Goals, ultimately influencing electricity provision and use in urban areas through e.g. policy formulation and financing [43]. Expected energy transition efforts within these agreements are renewable energy and energy-efficiency targets [44]. However, government action to encourage the transition to renewable energy remains limited: The current electricity mix is dominated by large-scale hydroelectricity and natural gas—low-carbon yet environmentally controversial sources which are domestically available and considered cheap. The Power System Master Plan does not foresee more than 10% of non-hydro renewable electricity generation [45] and as yet there is no energy-efficiency legislation. In fact, the energy transition concerning electricity is predominantly envisioned as greater generation capacity, grid connectivity and reliability, and lower grid losses. Paradoxically, even increasing consumption is framed as part of the sustainability agenda: so-called "productive uses"—business activities with electricity as a key input for goods or service production—are being promoted as part of a larger economic growth strategy [44].[5]

Although there are decentralized solar strategies for rural areas, in urban areas, national policies to achieve universal electrification have so far mostly neglected socio-technical alternatives to the conventional grid. Instead, the national government, together with TANESCO and international donors, is prioritizing a ubiquitous and uniform extension of urban grids as a key development goal. As a result, documents guiding policy do not systematically address the spatial differences in energy provision and use, the differentiated demand and payment capacities in urban areas, or social or environmental parameters like affordability, pollution, or greenhouse gas emissions [39,46].

In the following, we explore how such modernist visions of a networked city inscribed in energy policies relate to the urban realities across Dar es Salaam's neighborhoods. We begin by outlining our spatially explicit three-level typology approach to research urban electricity constellations. This typology is then applied to the case of Dar es Salaam, using the lens of urban and infrastructural heterogeneity to uncover the neighborhood electricity constellations that constitute the city's urban electricity constellation.

4. Building a typology to analyze Dar es Salaam's neighborhood electricity constellations

Before scrutinizing electricity constellations in individual neighborhoods in our case study, we describe the typology that guided our empirical study. The typology distinguishes the following three scales as the analytical dimensions from which we will draw wider conclusions for the governance of urban electricity supply and use across the city:

1) *Service delivery channels*: we analyze specific socio-technical constellations comprised of technologies in use, institutional features of the provision and use of electricity services and the actors involved, as well as the resulting externalities.
2) *Neighborhood electricity constellations*: we aim to understand how different service delivery channels together shape the socio-technical characteristics and developments of individual neighborhoods. These neighborhoods are characterized by their distinct socio-economic status, settlement patterns (e.g. densifying, influx of low-income residents, or sprawling peri-urban neighborhoods), urban functions (e.g. residential, commercial, industrial), and service levels of centralized networks. Based on these variables, we selected individual wards that represent the most relevant constellations within the urban agglomeration.
3) *Urban electricity constellations*: we investigate how the neighborhood-based constellations relate to and mutually shape each other; and how—in their multiplicity and relationality—they together form heterogeneous urban electricity constellations.

Applying this multi-dimensional approach, comprising comparative, relational, and multi-scalar perspectives requires a careful delimitation of the scope of analysis. While urban and neighborhood developments are linked to transnational, national and regional governance arrangements, investments, technological design or management choices, our analytical focus is on the comparative analysis of different neighborhood types. Furthermore, a sufficiently in-depth analysis of neighborhoods

[4] This is about six times the monthly basic needs poverty threshold, below which 8% of the population in Dar es Salaam lives [40].

[5] Planned increases in electricity generation as one of the major national goals of an "Energy for All" agenda have recently led to beginning construction of the Julius Nyerere Hydropower Station. The large dam project has been criticized internationally for its likely detrimental environmental and climate impact and the destruction of an important wildlife reserve and UNESCO World Heritage.

requires a meaningful selection of representative types of settlement and urban development patterns. Our selection builds on Kombe's typology of contemporary land-use patterns across Dar es Salaam [37]. Together with local researchers and through stakeholder workshops we further incorporated and systematized this typology to cover the most relevant neighborhood electricity constellations. We took into account settlement variables such as the built environment, history, socio-economic status and urban functions, as well as socio-technical features such as the physical connectivity and social accessibility to electricity grids, reliability of supply, and demand growth. Six representative wards were selected as cases that illustrate phenomena that we could also identify in other neighborhoods with similar characteristics, development patterns, and challenges in electricity provision and use. Table 1 provides an overview of the six wards and their characteristics.

To identify relevant service delivery channels in each ward, we draw on a classification proposed by Jaglin [31] and adapt it to the context of Dar es Salaam based on expert interviews and field observations. In addition to the conventional electricity grid, the service delivery channels include individual installations, subscriber-retailer arrangements, premium grid access modalities, and illegal network extensions (Fig. 1).

These channels and their place-specific arrangements shape neighborhood electricity constellations. In the following sub-sections, we illustrate how the constellations fill electricity service gaps in each of the wards and thus constitute a reaction to the more or less contingent conventional service in specific spatial contexts.

Fig. 2 is a schematic map of the wards' locations and the constellations' diverging degrees of socio-technical heterogeneity. Starting with the case wards that represent where most people in Dar es Salaam live and which are still attracting residents, we analyze the neighborhood electricity constellations in the following order:

(1) Kilakala: low-income settlement with high levels of co-provision;
(2) Mabwepande: peri-urban area with splintered networks and individual off-grid installations;
(3) Kariakoo: congestion of consolidated networks by vertical redevelopment and densification;
(4) Msasani: wealthy neighborhood requiring premium electricity services;

Table 1
Diverse urban settings and associated grid characteristics in the six selected wards.

	Kilakala	Mabwepande	Kariakoo	Msasani	Mikocheni	Kisutu
Settlement type and key development	Rapidly densifying, unplanned settlement to the southeast of the center, rapid infill	Unplanned greenfield/ *peri*-urban expansion area with uncoordinated incremental building activities	Commercial/ business center and central market place, undergoing vertical redevelopment	Consolidated, wealthy residential area, housing political and economic elites, limited building dynamics	Consolidated industrial district with mainly light industries; surrounded by "up-class" residential buildings	Commercial/ administrative center with (government) offices, high rise undergoing further redevelopment
Pop. density (1000/km^2) and growth[1]	29.0 Very high	0.5 High	32.8 Medium	4.3 Low	4.3 Low	18.9 Medium
History	Established some decades ago; currently consolidating	Recently established settlement	Colonial period, originally planned for African residents	Colonial period "European" residences	Long-established area for non-residential purposes	Colonial center
Income status	Low–middle	Low–middle	Middle	Very high	High	High
Built environment	High density, single-story buildings	Low–medium density, single-story buildings	Very high density, multi-story buildings	Low density, medium height	Medium density	High density, multi-story buildings
Key function	Residential	Residential	Commercial and residential	Residential	Industrial, some residential	Commercial, administrative
Electricity grid supply and demand	Low demand, incomplete grid coverage, frequent outages	Very low demand, limited grid coverage, frequent outages	Medium to high demand, good coverage but frequent outages	Medium demand, very good grid coverage and quality	High demand, very good grid coverage and quality	Medium to high demand, good grid coverage and quality

Data from [36]. The classification of annual growth rates from [36] is used without changes: low (<2.7%), medium (2.7% – 5.8%), high (5.8% – 10%) and very high (greater than10%).

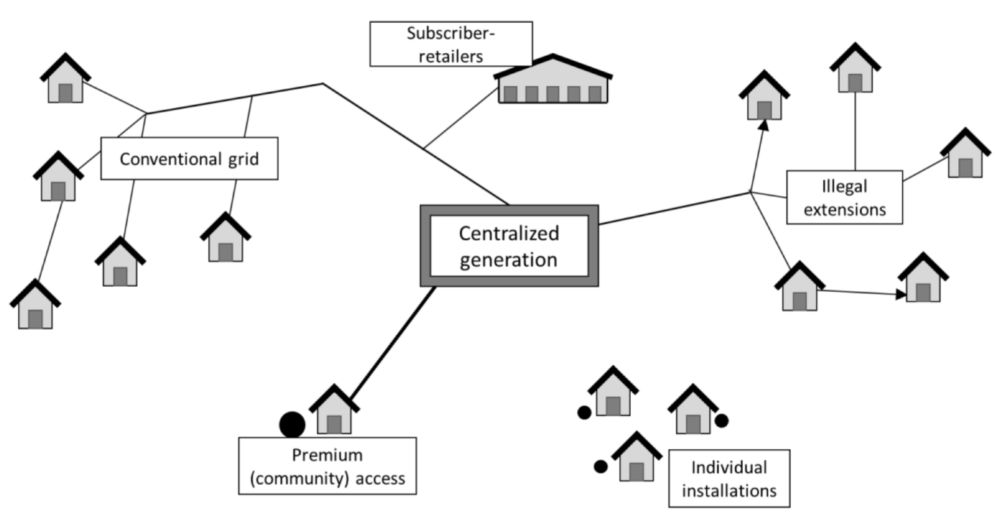

Fig. 1. Electricity delivery channels in Dar es Salaam, based on own field work, adapted from [31].

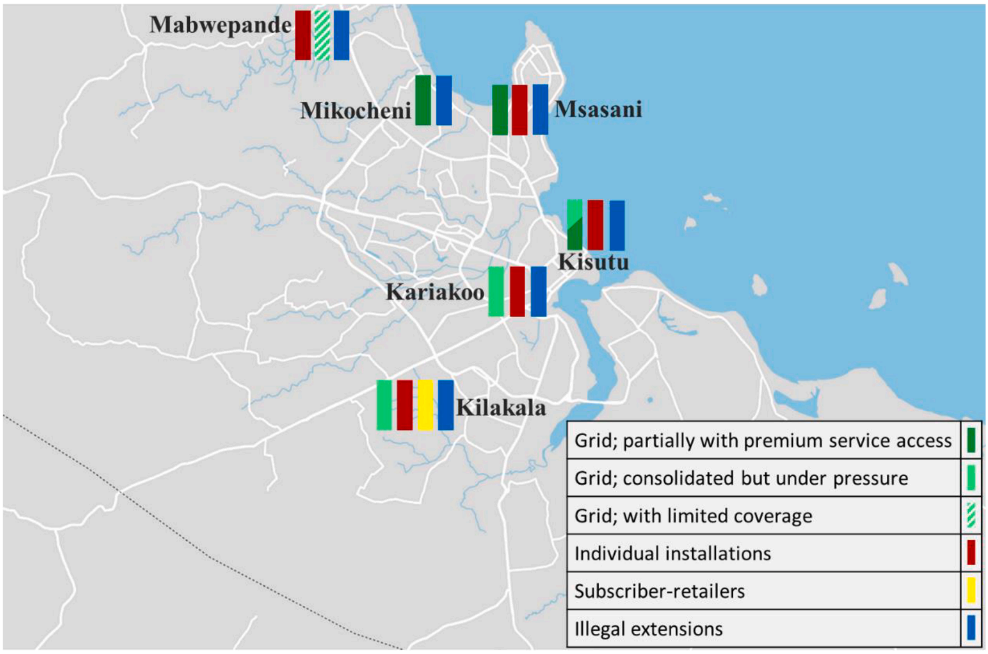

Fig. 2. The case study wards in Dar es Salaam and their main service delivery channels.

(5) Mikocheni: industrial area demanding high reliability; and
(6) Kisutu: area with de facto consolidated networks and mixed requirements.

4.1. Kilakala: Low-income settlement with high levels of co-provision

Kilakala ward, an unplanned residential settlement in the Temeke District southwest of the city center, attracts many low- and middle-income residents since housing costs are low and the (low-quality) infrastructure services are less of a financial burden [15]. It is typical of the many settlements in which most residents live: it is a medium distance from the city center and has a high density population that is growing rapidly [36]. Recently, donor-financed road upgrades have improved its accessibility, fueling its growth. New houses are built under a quasi-customary or informal land tenure regime. The subdivision of already small land plots and consequent infill of empty spaces between single-story houses is the prevailing mechanism to accommodate newcomers.

Grid electricity is rather unreliable, and affordability poses a barrier to physical connectivity and electricity consumption (Interview 7), with residents resorting to alternative delivery channels. Despite high political pressure to extend grid connections, the incrementally built settlement structure and its development pose major restrictions for TANESCO. The dense and unplanned structure results in disputes over grid corridors and land access that can delay this process (Interview 3). Rapid growth in consumption means that there is also a constant need for upgrading which outpaced grid capacity beyond original plans. A substation that reached its full capacity in two years instead of the originally projected ten years illustrates how the planning and financing of electricity grids is struggling to keep up with growth (Interview 8).

In response to the situation described above, Kilakala's residents themselves co-organize electricity provision in various ways: by negotiating terms of grid access with their landlord, by setting up illegal connections, or by using small individual solar devices when they cannot afford grid-based services.

Small-scale tenancy is common in this settlement. Households dwell in single rooms in compounds with simple single-story buildings. They access the grid jointly through subscriber-retailer arrangements in which, in contrast to apartment building complexes, the landlord or building owner registers only one (shared) meter and then organizes regular payments from all users. Individual contributions depend on estimates of consumption or of appliance type and number. Disputes over non-payment and cost-sharing are frequent. Their resolution can include practices such as limiting and prohibiting appliance use as part of the rental agreement, or internal disconnections (Interview 7). Increasingly, the installation of private consumption meters allows for demand-based billing which is perceived as fair by users and is more affordable than registering separately with TANESCO. Despite the advantage of avoiding connection fees, tenants suffer from considerable cost burdens: the cumulative usage of several households exceeds the maximum consumption allowed to benefit from the subsidized "lifeline" tariff. The associated subsidy is therefore ineffective, and users end up paying unit prices similar to those paid by wealthier households in other areas, but for inferior service. Unaffordability and the dense built environment increase the risk of users stealing electricity by tapping wires. Some residents have reported that others opt for accommodation without an electricity connection. In such cases, people might rely on single solar devices with a small panel, a battery, and outlet sockets (Fig. 3). These only provide lighting and mobile phone charging, for comparatively high cost per consumption unit. There are a few back-up systems in Kilakala, such as generators owned by small processing companies for running equipment like grain mills.

The various ways in which users and landlords as co-providers mobilize different service delivery channels reveals the pressures that they—and TANESCO—face in rapidly growing low-income settlements. This constellation shows the affordability challenges of electricity services in most neighborhoods like Kilakala, and how socio-technical heterogeneity is an "answer to commercial imperatives of adaptation to demand, based on finely segmented customer groupings" [[31]: 441]. However, practices like meter-sharing and the associated challenges are largely unknown to public decision makers and, consequently, are hardly addressed by energy policies. Since the conventional mode of accessing grid electricity from the individual household's connection plays only a marginal role here, progressive energy transition efforts need to acknowledge existing practices and how they meet affordability requirements yet also produce questionable outcomes concerning e.g. social equity.

Fig. 3. Solar lantern charging in Kilakala—a typical individual system to cover basic electricity needs.

4.2. Mabwepande: Peri-urban area with splintered networks and individual off-grid installations

Mabwepande is a relatively recent, mostly unplanned ward in the Kinondoni District at the margins of the city's northern expansion. Its low but rapidly rising population density is representative of many similar peri-urban areas in Dar es Salaam. The coverage of the distribution grid is splintered across the ward. Two issues particularly complicate the efficient roll-out of electricity connections: first, low- and medium-income residents build houses incrementally, inducing slowly increasing demand for electricity services, which start out from low levels. Secondly, the scattered settlement structure, resulting from unplanned incremental housing, makes it costly to provide new distribution lines and transformer stations. When deciding about grid expansion, TANESCO considers commercial viability (Interview 3): New connections are added reactively and in piecemeal fashion, mostly in response to individual applications from new homeowners able to afford the connection fees. Occasionally, neighbors apply jointly to save costs. Fees generally depend on the distance to the nearest pole and can be up to 697,000 TZS (300 USD) within 90 m but can reach millions of TZS when the distribution grid lies outside this radius. This frequently leaves applicants without grid connection for a considerable time, until they have saved enough money, or a much nearer pole is erected because neighbors can pay for it, or because the utility proactively invests in its grid.

Long waiting times and high connection fees trigger illegal network extensions: people may informally and temporarily supply neighbors who have not yet been connected by the utility. TANESCO's poor service encourages people to look for cheaper and more efficient services provided by self-employed technicians who illegally establish connections: "Demand for illegal connections is big. These technicians exist because, first of all, they're trusted by customers. They're faster, they can move faster than TANESCO" (Interview 9).

In settlements like Mabwepande, solar and, although less common, fuel-powered individual installations covering electric base load are more prevalent than elsewhere in the city. Individuals invest in solar home systems (Fig. 4) which can power lights, mobile charging, fans, radios, and TV sets. However, the investment these systems entail is substantial. The interaction of already acquired individual installations with the slow grid expansion produces a noteworthy path dependency: even after being connected to the grid, users keep and run their systems as parallel delivery channels or as back-ups complementing the grid. This consolidates low-carbon solutions in the case of solar systems, but it also perpetuates the pollution and noise emissions of fuel-based systems. It highlights the importance of strategies to avoid a potential lock-in into fuel-powered generators as back-up systems. Both the illegal connections and stand-alone installations reveal the importance of timely provision of electricity access, which some individuals are able and willing to pay for.

4.3. Kariakoo: Congestion of consolidated networks by vertical redevelopment and densification

A more consolidated network for larger-scale consumption is observed in Kariakoo in the Ilala District. In this central market area of the city, shaped by small-scale businesses, physical grid connectivity is almost universal, yet reliability and affordability remain problematic. Once planned in colonial times, Kariakoo has since experienced both planned and unplanned forms of rapid vertical redevelopment [37].

Fig. 4. Individual solar installations as common service delivery channel in peri-urban wards.

Increasingly affluent residents are using more electricity, putting the distribution grids under additional pressure (Interview 10). Blackouts can be traced to lagging reinforcement of wires and transformers, which—according to local government officials—is partly attributable to the limited availability of space for reinforcement in the densely occupied streets. The ever-increasing demand for space is illustrated in Fig. 5, which shows multiple transformers on a pole construction, surrounded by street vendors not complying with the statutory minimum distance to such poles.

Outages are often compensated by users' small fuel-powered generators. Due to the high density and resulting number of generators as well as the absence of centralized back-up providers, noise and air pollution, and usage of sidewalk space are serious problems. Yet generators are essential for the functioning of the neighborhood, specifically for the many small businesses. Political priorities can also inhibit potential action against generator usage. A public official mentioned the importance of a national government's instruction to not hinder small-scale traders, which has led to conflicting interests with the municipal authority, which is more concerned with the local repercussions of generator use. The only requirement placed on back-up generators is that they comply with the manufacturer's stipulations; no energy-efficiency regulations are applied (Interview 11). Complaints to EWURA about air and noise pollution are rare, as there is general understanding of the need to use back-up generators, with TANESCO—and the state at large—being blamed for unreliable grid services (Interview 12). This situation has implications for the ongoing development of Kariakoo: though new buildings increasingly have centrally organized and more efficient back-up systems, people are likely to continue to use equipment they have bought, perpetuating environmental externalities.

Electricity theft is also a common phenomenon in Kariakoo, adding to unreliability and regular blackouts. Affordability is one key reason for engaging in illegal practices, because some low-income households are unable to pay the connection fees. TANESCO officials report a clustering of theft incidents in lower-income and higher-density neighborhoods. These neighborhoods are regularly visited by the utility's Revenue Protection Units. However, there is no clear spatially differentiated strategy for these visits, nor is there a focus on more affluent—and thus more electricity consuming—neighborhoods, even though these could be more effective ways of limiting revenue losses.

Fig. 5. Density as a key challenge in Kariakoo.

4.4. *Msasani: Wealthy neighborhood with demand for premium electricity services*

Msasani (Kinondoni District), located on the peninsula in the Indian Ocean, is one such affluent neighborhood with higher electricity consumption. Physical grid connectivity and reliability are high and affordability is not a hurdle for its population. Msasani's sub-wards Oyster Bay and Masaki are particularly synonymous with "up-class" residences and high-end hotels. The ward was planned in the colonial era and still today is home to the country's elites. Development takes place modestly in this low-density area. In Oyster Bay, wealthy residents have enforced a local redevelopment plan to restrict vertical growth. Alongside the main roads, however, there have been massive changes in the built environment, fueled by international investments [47].

Although Msasani's planned structure and limited growth are easy to manage for TANESCO, there are political and economic pressures to ensure premium power availability and reliability (Interview 13). Such premium demands are satisfied by prioritizing the smooth operation of the conventional grid, but such service quality differentiation is neither backed by official policies, nor publicly communicated by TANESCO. The utility provides premium network services to secure revenue and to accommodate powerful interests (Interview 14). As many wealthy and influential individuals within the administrative apparatus—or closely tied to it—reside and work here (Interview 15), service deficiencies pose a problem for TANESCO and are thus deliberately avoided. The comparatively larger economic loss from power outage here is another reason for TANESCO's prioritization. This privileged position concerning grid investment and operation modalities ultimately skews resource allocation at the expense of other areas and clients.

Despite this prioritization, outages still occur [16]. Msasani shows that limited exposure to blackouts can be accompanied by great vulnerability to them: here, users rely on electricity as their key energy source more than elsewhere (Interview 16). Consequently, high-end generators and battery-inverter systems are used because they can complement the grid, providing the seamless experience expected in wealthy residences, offices, or shopping malls.

Contrary to the framings of electricity theft as a phenomenon confined to the urban poor, illegal practices also occur, often in the form of manipulated meters.

4.5. *Mikocheni: Industrial area with high reliability demands*

As another neighborhood with consolidated grids, Mikocheni (Kinondoni District) has a very high electricity demand. Several industrial consumers require a steady high supply of electricity, which decentralized back-up systems can hardly provide. This makes them specifically vulnerable to instabilities and blackouts. Such techno-economic vulnerability of some of the country's largest businesses puts enormous pressure on TANESCO to provide premium services. Uninterrupted supply is considered essential for Tanzania's ambitious industrialization targets [48]. The monofunctional nature of Mikocheni Light Industrial District has resulted in less socio-technical heterogeneity, since grid power is the only viable technical solution. Providing premium quality services is the direct response to this vulnerability and lack of alternatives. Nevertheless, prioritized distribution lines do not exclusively connect to the targeted industrial clients. According to TANESCO (Interview 5), these clients connect to feeders which also supply neighboring residential areas. This attracts investors who build offices and apartments, contributing to vertical growth and socio-economic upgrading.

Besides this locational advantage for investors through the operational and managerial favoritism of the utility, investors themselves contribute to ensure premium grid services. New real estate developments and business establishments have upgrading needs that TANESCO can sometimes not provide alone (Interview 3). Investors also provide such upgrading measures—sometimes even at the request of the utility—to relieve the stress they have put on the distribution grid (Interview 6), with the result that the improved grid conditions that originally attracted these companies become even better, widening the gap in service quality with other neighborhoods in favor of neighborhoods that are wealthier, better connected, and centrally located.

Illegal network extensions play a role here, too. The high consumption of many clients incentivizes them to manipulate or bypass meters—a practice that is particularly detrimental to TANESCO's revenue collection: "When many factories are in full production, this is when cheating happens. […] They want to maximize profits" (Interview 17). In response, the utility has introduced real-time, automatic meter readings to enable rapid follow-up of irregularities.

4.6. Kisutu: Area with near consolidated networks and miscellaneous requirements

Kisutu ward in Ilala District is the dominant commercial and administrative urban center and attracts similar levels of political and economic attention as Msasani. Here are located many current and former government offices, corporations and hotels. Residential and mixed-use buildings blend in. The multi-story, dense environment results in concentrated electricity demand. Despite a recent slowdown, vertical redevelopment continues. Many newly added buildings aspiring to a "modern" look with glass-and-steel structures are ill-suited to cope with the tropical climate. The electric appliances in most apartments—air conditioners and other modern equipment—thus create a local hotspot of electricity demand.

In Kisutu, TANESCO also needs to satisfy the demand for premium service which results from Dar es Salaam's aspiration to be a regionally competitive hub for innovative business and trade [35] and is illustrated by the density of businesses and government offices in the ward. However, here the demand for premium service is less than e.g. in Msasani, due to the more mixed socio-economic structure including street vendors, small shop owners and residents in old social housing units. The majority of Kisutu's users, however, do not face an affordability challenge in accessing grid electricity.

How back-up power is organized and used, though, reflects the different economic capabilities and needs within the settlement: There are individual, off-grid installations which mainly include pull-string generators and to a lesser degree battery-inverter systems used by smaller businesses. As in Kariakoo, street-side generators create environmental problems that raise concern in local authorities and communities: "Some generators make noise, and some are being pulled in the pedestrian side. When you are in the ground floor or the first floor and someone starts the generator, the smoke enters the house. That's a big challenge." (Interview 10).

Small generators are usually owned and operated by private individuals. Smaller popular solutions range from rechargeable torches and power banks to solar equipment acquired by households (figure 6). Largely unregulated markets with multiple traders sell these imported products, which meet users' needs and are affordable but whose quality is often poor. In contrast, middle to higher income residents and businesses in multi-story buildings have larger power demands and require the ability to switch seamlessly to off-grid power provided by building operators (Interview 18). To curb pollution and also to ensure faster equipment amortization, building operators as exclusive back-up providers may regulate or prohibit the use of other generators. Users of their services either pay a flat fee on top of their rent or pay according to the power consumed, at prices that are currently unregulated. Decentralized provision of back-up generators temporarily complementing the grid makes users less dependent on the fluctuating power supply. However, the high investment and running costs entailed mean that important issues of reliability of supply are left to market forces.

Fig. 6. Solar equipment, rechargeable torches, and appliances in a market.

5. Heterogeneous urban electricity constellations revealing contextual transition challenges

The six neighborhood electricity constellations described above show how a variety of delivery channels are arranged in heterogeneous, place-based ways. These constellations reflect the different urban functions, settlement patterns and conventional grid service levels across the city; they do not stand isolated but relate to and depend on each other—together forming Dar es Salaam's *urban* electricity constellations. In this section, we discuss the implications of understanding this urban dimension through the multiplicity and relationality of neighborhood constellations for current epistemologies of energy systems and their transitions.

Taking stock of the various electricity constellations across representative neighborhoods confirms our original contention that Dar es Salaam's urban electricity constellations defy assumptions made in much of the established energy transition literatures: TANESCO's networked services are complemented and partially replaced by other delivery channels organized by users and service co-providers. From an urban perspective, the city's electricity constellation appears multi-segmented and highly heterogeneous, if not fragmented. This can firstly be observed in regard to the different demands for electricity services across neighborhoods and the different characteristics of electricity users. For example, users' reliability requirements and their capacity to pay for services is highly differentiated across the urban area.

Secondly, from the (co–)providers' side, the varying demands are met by differentiated services —networked, non-networked, or combinations of both. In the case of networked electricity supply, this differentiation is not socially balanced: customers in affluent neighborhoods and poor neighborhoods often factually pay the same tariffs for diverging service qualities and the lifeline tariff is ineffective due to landlord–tenant arrangements in poor neighborhoods. The provision of socio-technical alternatives is equally diverse and predominantly follows market mechanisms. Users make use of a service combination that fits their needs and situation, e.g. the type of building they live in, to their ability to pay. Overall, this multi-segmentation of the city's urban electricity constellation shows that to ascertain which socio-technical constellations are dominant it is important to look at individual neighborhoods and take a comparative perspective to understand their relationality.

Here, it is crucial to acknowledge the ambivalent character of the heterogeneous neighborhood electricity constellations, which pose both challenges and opportunities for understanding and fostering progressive urban energy transitions. On the one hand, the heterogeneous electricity constellations readily respond to rapid growth, widespread poverty, or the service needs of businesses by providing extra reliability or affordability and thus contribute to the functioning of the city. The occurrence of specific delivery channels therefore signals in which places the conventional grid is unable to meet these needs. On the other hand, socio-technical alternatives give rise to place-based negative environmental, social and economic externalities (see Table 2). Whereas some of these (emission of pollutants, greenhouse gases and noise from generators) are more severe in specific (e.g. dense) areas, others occur across the city (health and safety risks from ad-hoc electrical work for illegal extensions). A grounded understanding of urban energy transitions thus needs to acknowledge the highly place-based solutions and challenges as their starting point.

However, in the case of Dar es Salaam, current energy sector policies stand in stark contrast to how neighborhood electricity constellations fill existing service gaps and the place-based challenges they reveal and generate. The existing strategies and dominant discourses focus almost exclusively on the ambition to incrementally universalize electricity grids. This approach relies on more electricity generation and transmission capacity, reflected by the investment priorities of the utility (Interview 19). The subsequently rising demand is increasingly met by gas, coal, and highly contested large-scale hydro power plants, all of which are questionable from an environmental sustainability perspective. Given the *urban* repercussions of solely grid-focused strategies, it is clear that such strategies are unsuitable for understanding and exploiting the opportunities for heterogeneous socio-technical alternatives and their importance for providing tailored solutions beyond conventional grids. By the same token, grid-based policies also fail to consider the negative externalities caused by the alternatives and their challenges. Since challenges to universalize the grid in the context of massive and diverse urban growth will likely persist in the near future, so will the ambivalent character of these alternatives. Alongside efforts to universalize and manage the conventional grid, decision makers should more systematically address opportunities and challenges posed by the urban and socio-technical heterogeneity.

Efforts to address heterogeneity would also help to achieve policy goals, such as TANESCO's commercial viability, hence decreasing its financial dependence on state and donor funding [43]. In this case, more account needs to be taken of the place-based reliability requirements of customers so that customers using premium networked services could be required to pay higher tariffs. As the case in Msasani has shown, many of them already use and pay for expensive individual back-up solutions, indicating their willingness to pay. The resulting increase in revenue could allow the utility to improve network quality elsewhere: e.g. through upgrading in poor settlements like Kilakala or more timely, planned and proactive grid expansions in peri-urban neighborhoods like Mabwepande. Another way in which addressing heterogeneity could help achieve policy goals is to broaden the view on user practices "behind the meter". The current blindness to the spatially different user practices outside the conventional model have led to the lifeline tariff being ineffective as the key policy instrument for addressing basic electricity needs of the poor. In addition, economic growth and small traders could both be better served by addressing decentralized back-up systems like fuel-powered generators, rather than by considering them a matter for private individuals. Closer regulation of such individual installations or their replacement with less decentralized systems could reduce inefficiencies and environmental impacts.

6. Conclusion

In this paper, we have explored a novel perspective that allows us to rethink concepts in urban energy transitions research beyond established epistemological and conceptual framings anchored in Northern contexts. Despite the infrastructural turn in urban studies and spatial turn in energy studies, few analytical frameworks and methodologies incorporate Southern cities' urban *and* socio-technical heterogeneity (as exceptions, see [7,9,31]). The key analytical and methodological contribution of our study is a typological approach that aims to systematically apply intra-urban comparative and multi-scalar perspectives in an individual city. Based on our three-scale analysis applied to the case of Dar es Salaam, we have demonstrated that heterogeneous *urban* electricity constellations are shaped by spatially distinct constellations in each neighborhood. Our typology integrates urban and infrastructural heterogeneity at different scales and thus provides an analytical framework that captures the variety of socio-technical constellations occurring *within the city and across different neighborhoods*. This provides a useful conceptualization of the status quo from which urban energy transitions take place, rather than the often used, yet misguiding regime concept. To better understand socio-technical heterogeneity, we thus argue for a multi-scalar approach to embrace the various service delivery channels, how they are arranged in distinct electricity constellations in selected neighborhoods and how these together form urban electricity constellations.

To test and refine our analytical framework and typological approach and its findings, further case studies in other cities and comparative work are needed. Further research also bears the potential to expand the framework for scales and places beyond city boundaries, and thus to consider transnational and trans-local linkages more explicitly. Equally, the typology provides essential insights for the study of other urban infrastructure domains in the global South as well as in Northern contexts, where urban infrastructures are becoming more heterogeneous driven by technological and environmental change and market dynamics.

At the same time, our case study contributes to a better

Table 2
Overview on the diverse, localized challenges for urban energy transitions.

	Kilakala	Mabwepande	Kariakoo	Msasani	Mikocheni	Kisutu
Supply and demand side challenges	Affordability, reliability under rising load	Affordability; grid expansion and stability, low profitability for utility	Grid overload, space for equipment	Premium demand, high reliance on electricity	Premium demand, limitations of back-up systems	Premium demand, increasing loads
Place-specific social, environmental, and economic externalities	Suppressed use; economic losses and environmental damage from non-electric alternatives	Lock-in to expensive and polluting stand-alone systems; environmental damage from non-electric alternatives	Space usage; local pollution and climate impact from inefficient back-up generators	Back-up systems' overall economic cost; climate impact from many individual back-up generators	Further "splintering" due to differentiated supply; profitability of the utility	Space usage; local pollution and climate impact from inefficient back-up generators

understanding of the situated opportunities and challenges for progressive urban energy transitions which differ considerably within a city and must be tackled by tailored socio-technical solutions and policies. Our conceptualization of heterogeneous electricity constellations provides important insights for energy transition policies where notions of niche development and regime destabilization seem inappropriate. This unpacking of the status quo requires further research to reconceptualize how progressive energy transitions can evolve in contexts such as in Dar es Salaam—a challenging task given the frequent limitation of energy transition policies to the universalization of networked electricity while environmental issues remain relatively unattended. Taking urban *and* infrastructural heterogeneity within cities seriously, our approach can thus inform both empirical studies and conceptual debates on how energy transitions emerge from heterogeneous constellations in Southern cities and how policy makers, utility companies and international donors could engage in pursuing and promoting progressive agendas.

Seeing infrastructural heterogeneity within cities not as an interim stage toward a "modern" networked city but as a potentially enduring phenomenon and a contextually creative response of a rapidly urbanizing society [49] raises several questions for future research and transition policies: firstly, unsolved questions of *technical consistency, functionality, and alignment* arise, with urban infrastructure systems being fundamentally composite in technical terms [[31]: 444] and thus highly complex in their design and operation. Answering these questions requires novel engineering solutions for managing grid stability and technological interfaces for aligning centralized networks with semi-centralized and off-grid solutions. Secondly, acknowledging the enduring heterogeneity of energy constellations provokes multiple *challenges in the design and management of service provision.* On the one hand, it challenges the formal monopoly of public utility companies which are under increasing political pressure to universalize their services and to recover their costs. On the other hand, effective mechanisms of contracting/subcontracting and licensing with co-providers are yet to be developed to guarantee minimum standards in service quality, price and environmental sustainability and to enable both the remuneration of co-providers and the recovery of costs by public utilities. Thirdly, the implementation of differentiated service standards, tariffs, and socio-technical solutions that are tailored to local user needs and capabilities raises questions of *spatial justice and political legitimacy*. While tackling the energy challenges in differentiated ways might be the most pragmatic way forward, such spatially differentiated transitions can intensify the splintering of urban infrastructures. Moreover, the question is whether and, if so, to what degree differentiated service standards could be politically legitimized in contexts where the overcoming of the stark socio-spatial inequalities and equal access to infrastructure services is a priority in political agendas. Finally, the spatial, institutional, and technological granularity and fragmentation of urban electricity systems evoke enormous *governance complexities* of progressive energy transitions. The challenge is not only to design plans, regulations, and legal standards that take account of particular needs and capabilities of specific places and acknowledge existing forms of co-provision. Equally challenging is the limited reach of state authority in many African cities in shaping market- and user-driven forms of co-provision as well as the limited knowledge and attentiveness of key decision makers in utilities, governments and international donors regarding alternative delivery channels. First and foremost, this knowledge can be attained through greater engagement with local actors who are confronted with the realities we presented on a day-to-day basis. Managing and governing progressive energy transitions in African cities is thus far from simple—technically, economically, institutionally, and politically. It involves heterogeneous technical challenges, complex actor arrangements and power relations, and limited institutional and financial resources of the state and public utilities. Further research is thus needed to better understand and guide the governance of heterogeneous urban energy constellations to improve service levels and promote sustainability.

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Appendix

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3. Distribution engineer, TANESCO. 11 December 2018.
4. Advisor, local energy NGO. 27 June 2019.
5. Operations engineer, TANESCO. 22 August 2019.
6. CEO, private construction company. 30 July 2019.
7. Chairwoman, Kilakala ward. 8 July 2019.
8. Senior manager, TANESCO. 12 December 2018.
9. Customer protection organization. 14 December 2018.
10. Councilor, Kisutu ward. 8 July 2019.
11. Manager, EWURA. 5 August 2019.
12. Former municipal planner. 21 August 2019.
13. Former manager, EWURA. 08 August 2019.
14. Engineer, Regional Office, TANESCO. 19 December 2018.
15. Chairwoman, Oyster Bay. 11 July 2019.
16. Stakeholder Meeting. 18 July 2018.
17. Manager, TANESCO. 12 December 2018.
18. Manager, private back-up sales company. 5 July 2018.
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