Journal of Urban Technology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cjut20

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To cite this article: Joyce A. Eledi Kuusaana, Jochen Monstadt & Shaun Smith (2023) Toward Urban Resilience? Coping with Blackouts in Dar es Salaam, Tanzania, Journal of Urban Technology, 30:2, 79-101, DOI: 10.1080/10630732.2022.2153318

To link to this article: https://doi.org/10.1080/10630732.2022.2153318

Published online: 16 Jan 2023.

JOURNAL OF URBAN TECHNOLOGY
2023, VOL. 30, NO. 2, 79–101
https://doi.org/10.1080/10630732.2022.2153318

Toward Urban Resilience? Coping with Blackouts in Dar es Salaam, Tanzania

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ABSTRACT
The seamless and ubiquitous supply of infrastructure services such as electricity is usually seen as a critical backbone of modern urban societies. Yet electricity supply in Dar es Salaam, Tanzania, like many other infrastructure services in cities in the Global South, is unreliable and unpredictable, with urban power cuts being everyday occurrences. Major challenges in electricity supply have resulted in severe crises leading to spatially uneven rationing of electricity. Amid such insecurities, however, the criticality of such infrastructure services and the shortfall of reliable networked services are met with innovation, creative maneuvering, and the building of adaptive systems that allow cities to continue to function. Based on debates on urban and infrastructure resilience and heterogeneous infrastructures, this article examines the coping mechanisms of urban residents in response to electricity blackouts in Dar es Salaam. It identifies the different energy constellations that function either complementarily or alternatively to networked services. Pointing to the adaptive capacities of urban dwellers that enable them to be prepared for power cuts but also highlighting their unequal access to infrastructure services, it argues for a more critical reassessment of debates on urban and infrastructural vulnerability and resilience from a Southern perspective.

KEYWORDS
urban resilience; infrastructure resilience; heterogeneous infrastructures; electricity blackouts; Tanzania

Introduction

Electricity is one of the infrastructural "life-support systems" providing the fundamental background to modern everyday life in cities (Graham, 2010). The disruption of these systems' critical services can therefore trigger dramatic urban crises. One issue that has been ignored in these debates is the place-based vulnerability and resilience of technical infrastructures in cities in Africa and, more generally, in the Global South. Contrary to what hegemonic models like the "modern infrastructural ideal" (Graham and Marvin, 2001) or the "networked city" (Coutard and Rutherford, 2015) suggest, the

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universalization of infrastructure networks through publicly owned and/or state-regulated service providers has never been achieved in many cities of the South (Jaglin, 2014; Monstadt and Schramm, 2017). Instead, these cities are characterized by an unequal provision of infrastructure services, low access rates of the urban poor to networked services, a diversity of service (co-)providers, and differentiated services. Studies in water supply and governance, for example, point to the self-help initiatives of individual residents in accessing water (Dakyaga et al., 2021; Nhamo et al., 2019). Moreover, regular infrastructure interruptions, breakdowns, and failures of centralized networks are the norm rather than the exception.

The above is also true for electricity systems in Dar es Salaam, Tanzania's economic engine and East Africa's largest and rapidly growing conurbation. Since its foundation in 1964, the Tanzania Electric Supply Company Limited (TANESCO), together with national governments and international donors, has sought to universalize electricity supply. Several challenges, however, have restricted TANESCO's ambition to ensure a universal, reliable, uninterrupted supply of electricity. Among these challenges are, mobilization of investment funding, increasing connectivity and accessibility to the network, ensuring the affordability of power supply, reducing technical and non-technical system losses, and diversifying resources for electricity generation (Muhongo, 2014). Researchers have typically explained power interruptions as a supply-side issue (Growth, 2018) related to the poor technical functioning of the grid (due to an overloaded or aging technical infrastructure), financial constraints and mismanagement within TANESCO, and the overreliance on hydropower generation, which is prone to environmental impacts such as droughts. Furthermore, rapid population growth and unplanned and sprawling urbanization have thwarted TANESCO's efforts to ensure a ubiquitous supply of electricity. This has led not only to spatially uneven access to, and varied quality of, electricity services but also to frequent power shortages and blackouts. Consequently, the situation in Southern cities like Dar es Salaam is often described as calamitous (McLees, 2012). The precarious access to networked services and the frequency of their disruption have reinforced perceptions of these cities as vulnerable and deficient. However, as we argue, such views primarily focus on the vulnerability of centralized, networked infrastructures while disregarding the heterogeneous modalities of urban service co-provisioning in Southern cities. Southern cities and their residents habitually "cope" with functional crises of centralized networks through multiple modalities of co-provision. Concerning water, evidence in Dar es Salaam points to the dependence on individual access initiatives due to deficiencies of centralized water networks, particularly on the urban periphery (Dakyaga et al., 2021; Kyessi, 2005; Wamuchiru, 2017). Such systems can often be characterized as more flexible and adaptive than their counterparts in the Global North as these co-provision arrangements have backup systems in place which enable the maintenance of core functionality in the event of disturbances.

However, how the heterogeneous and hybrid constellations that characterize energy supply and use in Dar es Salaam ensure the continuity of core urban functions amid splintered landscapes of centralized networks, therefore, merits study. Recent advances have highlighted that how diverse communities build resilience is spatially contingent (Chelleri et al., 2015). Moreover, several authors have recently critiqued "post-political" notions of resilience which focus on the status quo of maintaining system "functioning" often disregarding certain communities (perceived as "resilient") or failing to address structural inequalities (Golubchikov and de Verteuil, 2021; Ziervogel et al., 2017).

Building on this recent work, we argue that while heterogeneous "responses" to crises/disruptions in electricity systems may be considered (highly) resilient, traditional resilience frameworks disregard uneven infrastructural access, the highly uneven time and resources needed by different groups to mitigate, and prepare for, service interruptions, and fail to address underlying structural inequalities.

We make this argument by exploring the socio-spatial diversity of how urban stakeholders maneuver and "respond" to habitual disruptions in electricity supply. Concretely, this article assesses the resilience capacities—i.e. the capacities to resist, absorb, and transform—to electricity blackouts in Dar es Salaam. We identify how multiple energy constellations operate either complementarily or as alternatives to centralized electricity networks, and likewise, how residents adapt their infrastructural use/access practices. We begin by engaging literature on urban and infrastructure vulnerability and resilience, positioning them in relation to debates on heterogeneous infrastructures in Southern cities. We proceed by presenting an overview of the spatial dynamics in Dar es Salaam, its relation to the production of heterogeneous infrastructures and lastly uneven exposure to blackouts. Finally, we present an empirical assessment of Dar es Salaam's resilience capacities, using a socio-technical approach. In our conclusion, we recognize that urban residents employ multiple adaptive strategies which reflect strong resilience capacities. However, we also discuss the limitations of conventional resilience assessments and argue for a critical reassessment of debates on urban and infrastructural vulnerability and resilience.

We deploy a largely qualitative approach based on primary data collected through semi-structured interviews with officials of TANESCO, local authorities (urban planners and ward executives), NGOs, and residents of specific communities and secondary data from reports and planning documents from TANESCO, statistical data, media materials, and literature. Respondents were selected using a snowball method beginning with initial contacts from TANESCO, Dar es Salaam City Council, and local planning authorities. Respondents were selected to gather the perspectives of different departments within TANESCO (e.g., generation, transmission, and distribution), as well as other actors involved in spatial development issues and resilience responses. Interviews were conducted in English and Swahili with the help of a research assistant/translator. A key aim was to gather the perspectives of residents. We, therefore, also conducted neighborhood visits, where we conducted observations, transect walks, and interviews with residents, from July–September 2018 and May–July 2019. Over 50 interviews were conducted altogether in the process. For this study, we categorized the selected wards into six different spatial clusters: the inner city, peri-urban, high-income, middle-income, low-income, and industrial areas. Considering the evidence of disparity associated with accessing infrastructure services for different population groups within the city (Luo et al., 2021; Kombe et al., 2015), we aimed to capture the difference in responses and socio-technical options across neighborhoods. Data analysis was done by first documenting and collating the adaptive strategies of respondents. These strategies were then clustered into groups of similar strategies and then assigned to the three resilience capacities based on what manner of capacity the particular strategy provides.

Urban and Infrastructural Resilience

The early twenty-first century has witnessed a growing interest in the twin concepts of urban vulnerability and resilience as approaches to understanding, mitigating, and preparing for the risks confronting modern cities, particularly in terms of safeguarding urban systems and key urban functions (Meerow and Newell, 2019). As geographical nodes in the infrastructurally mediated flows of water, energy, waste, communication, people, goods, and services, cities are highly dependent on the smooth functioning of multiple interconnected networked infrastructures (Monstadt and Schmidt, 2019). Yet although networked infrastructures facilitate urban processes, they can also make cities vulnerable in the event of failure. Paradoxically, cities with more "reliable" infrastructures often become more vulnerable to interruptions, what is sometimes called the "vulnerability paradox" (Folkers, 2012). Relatedly, scholars contend that only by being vulnerable can a system show its inherent resilience properties, such as the capacity to learn, adapt, and innovate (Reghezza-Zitt et al., 2012). Conversely, studies in fields as diverse as psychology, social sciences, and climate change also point to "resilience paradoxes." This includes instances where the lack of negative effects of extreme weather events, for example, lead to fewer incentives and motivation to undertake climate change mitigation measures (Ogunbode et al., 2019) or where the resilience of individuals could conflict with that of an entire group or community (Freedom Lab, 2020). However, these paradoxes of resilience are less known in critical infrastructure research, and it is unclear how such paradoxes manifest. This section draws on debates on urban and infrastructure resilience and vulnerability as a basis for assessing the resilience to blackouts in Dar es Salaam.

Assessing Urban Vulnerability and Resilience

The concepts of urban vulnerability and resilience have been used widely across different disciplines to study the susceptibility of urban infrastructure systems to threats or disturbances. Whereas urban resilience is considered to be a system's coping capacity (cf., Adger, 2006; Christmann and Ibert, 2012), vulnerability is traditionally perceived as a weak disposition of a system, which can be assessed by the degree of the system's exposure to internal and external threats, its sensitivity to them, and its adaptive capacity (IPCC, 2012: 33). More recently, scholars have questioned earlier inherently negative understandings, highlighting that vulnerabilities can stimulate openness to learn, optimize, and transform (Bijker et al., 2014; Gallopín, 2006) following disruptions and failures.

Simultaneously, scholars' understanding of resilience has shifted from an earlier focus on a system's capacity to absorb shocks and perturbations to "return to an equilibrium or steady-state after a disturbance" (Davoudi, 2012: 300) to, instead, a system's ability to learn, adapt, and transform (Folke, 2006; Christmann and Ibert, 2012). Instead of focusing primarily on a system's robustness and stability to failures, system attributes such as pro-activity, adaptability, and flexibility have received greater attention (Christmann and Ibert, 2012). Meerow et al. (2016: 39) define urban resilience as "the ability of an urban system—and its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." Accordingly, researchers have analyzed and assessed urban and infrastructure resilience through three distinct resilience "capacities": (1) a system's resistance to shocks and disturbances; (2) a system's capacity to recover and restore previous conditions; and (3) a system's capacity to learn and adapt (Alexander et al., 2016; Huck, 2020).

The *capacity to resist shocks* can be defined as the ability to not be adversely affected by an event (Hegger et al., 2016). Alternatively, it is considered as a system's capacity to withstand disturbances through preventive actions and initiatives that enhance its capacity to reduce the likelihood and/or magnitude of failures (Alexander et al., 2016). For our assessment of resilience to blackouts, we address the capacity of mitigating the likelihood or magnitude of blackouts. This capacity may be most important before and during a disruptive event.

The *capacity to absorb and recover* is defined as the ability of a system affected by an event to continue to function and to cope with, respond to, and recover from the event's impact (Hegger et al., 2016). The assessment of this capacity considers what happens during and after a disruption, particularly in the coping mechanisms that enable primary system functions to be maintained and to recover quickly and bounce back from disruptions to ensure the restoration of functions.

The *capacity to adapt and transform* embodies learning and changing processes. It is a continuously reflective process that fosters transitioning over time to new states (i.e. bouncing forward) and adjusting to changing conditions. Hegger et al. (2016) believe that this capacity manifests in improvements in the capacities to resist, absorb, and recover by implementing "lessons learned." Of particular importance to this capacity are elements of diversification, innovation, and experimentation which develop over an extended period.

Assessing Urban and Infrastructure Resilience in the Global South

Many conceptualizations of urban vulnerability and resilience have emanated from Northern contexts, where certain themes, such as cyber security, climate adaptation, and the protection of critical infrastructures have featured strongly. In Southern contexts, urban vulnerability and resilience research has centered predominantly on climate change, its impacts on cities and the ways to adapt to, reduce, and manage the associated climate risks (Allen et al., 2017; Herslund et al., 2016). Of particular interest have been flood risks, rising temperatures, droughts, water resources management, food security, coastal flooding, and erosion (Silver et al., 2013; Pelling and Wisner, 2009; Birkmann et al., 2016). As such, both policy and research focus on natural disasters and their direct impacts on human societies and environments, e.g., on the loss of lives and properties, health impacts, and human livelihoods.

However, perspectives focusing on technical infrastructures as a cause of urban vulnerabilities and/or as a site of resilience have received less attention. Many perspectives have taken a developmentalist view centered solely on large-scale, centralized, and networked infrastructures and their breakdown. Several authors have thus pointed to the insufficiencies, inefficiencies, and constraints of these systems in Southern cities (Eberhard and Shkaratan, 2012; Kebede, 2019; Peng and Poudineh, 2017). Here, Southern cities are often uncritically framed as vulnerable predominantly in relation to Western norms and frames (Silver, 2015), a view which may compound the vulnerability of cities, specifically that of poor neighborhoods and residents (Hardoy and Pandiella, 2009). The problem is that the alternative socio-technical practices and constellations that co-provide energy (and other services) are largely disregarded in assessments of vulnerability and resilience to infrastructure failures and breakdowns. Our argument is thus that resilience assessments must take into account the splintered character of infrastructure networks in African cities, the unequal access to critical infrastructure services, and the often unreliable and rationed supply.

We, therefore, concur with McLees (2012) that rather than viewing Southern cities and their infrastructures in terms of how they fail, more attention should be placed on understanding the multiple practices and socio-technical constellations that constitute how infrastructures work (and persist). At the same time, we also agree with Ziervogel et al. (2017) that this requires reorienting resilience to consider "endogenous forms of resilience."

Accounting for Heterogeneous Infrastructure Configurations in Resilience Debates

Recently, many scholars have studied how infrastructures in Southern cities work through a multiplicity of socio-technical constellations that complement or replace networked services. While a unitary, orderly city integrated by universal networks has been the primary ambition of decision-makers in utility companies, governments, and international funding organizations since colonial times (Jaglin, 2014; Monstadt and Schramm, 2017; Lawhon et al., 2018), such a modernist ideal of a "networked city" has never been achieved and is far removed from urban realities in the South. Instead, Southern cities are regularly characterized by an unequal provision of infrastructure services, low access rates of the urban poor to networked services, a diversity of service providers, and differentiated service levels (Lawhon et al., 2018).

For electricity, rapid urbanization, mostly occurring beyond formalized land-use planning, has driven heterogeneous energy constellations and splintered network access (Silver, 2014). State-owned or state-regulated electricity companies are often unable to provide ubiquitous services and their services are regularly complimented by multiple service co-providers (Munro, 2020; Silver, 2014). Furthermore, state authority is weak and partial in its reach, and its capacity to effectively shape the universalization of electricity services is limited by the absence of urban coalitions that define and implement coherent urban energy policies (Jaglin and Verdeil, 2017). As a result, authors have highlighted the heterogeneity of energy provision and use in Southern cities defined by the multiple hybrids of networked and non-networked services, diversity of public, private, and self-organized modes of service delivery and the incremental nature of infrastructure production (e.g., Jaglin, 2014; Munro, 2020; Lawhon et al., 2018).

Given the considerable heterogeneity of energy systems in cities such as Dar es Salaam, empirical analyses and assessments of urban and infrastructure vulnerabilities need to be reconsidered and broadened. Thus, the approach of this article is to examine urban resilience through the lens of heterogeneous infrastructures, specifically, who "copes" or is vulnerable to networked electricity disruptions, what are the diverse socio-technical "responses" to habitual electricity disruptions, and can socio-technical heterogeneity provide fair and equitable redundancies and protections for diverse urban populations. To do this, we re-focus the evaluative notion of the three resilience "capacities" outlined earlier solely from the unitary system functioning of "the" electricity network, to the heterogeneous nature of energy systems.

Socio-Spatial Dynamics, Heterogeneous Electricity Constellations, and the Uneven Vulnerability to Blackouts in Dar es Salaam

Before assessing how heterogeneity affects the resilience of urban residents, it is crucial to first situate and understand the drivers and socio-spatial conditions which give electricity provision/use its "heterogeneous" character. This is done by firstly tracing the relations between urban growth and infrastructure provision, outlining the spatial contingency of infrastructure heterogeneity, and finally analyzing the uneven exposure to electricity disruptions across different settlement types. Dar es Salaam is the largest city in Tanzania, with an estimated population of approximately 6.7 million (*World Population Review, 2020*). The population continues to increase at a rapid pace of 5.4 percent per annum and is estimated to reach 10.7 m by 2030 (UN, 2018). Dar es Salaam served as Tanzania's capital until 1974, which was when Dodoma became the official capital city but remains both the economic and industrial hub of the country and a de facto hub for many governmental departments.

Urban Growth and Infrastructures in Dar es Salaam

Urban growth in Dar es Salaam is characterized by the expansion of predominantly low-density neighborhoods (Kironde, 1995, 2006), and is marked by various inequalities. Such spatial inequalities have their roots in the colonial period when racial segregation was institutionalized through laws excluding poor people from habitation in cities and the establishment of racially segregated residential land use patterns. In Dar es Salaam, this took a threefold form through neighborhoods designated "European" (Oyster Bay, Masaki), "African" (Kariakoo, Illala) and "Asian" (Kironde, 1995; Todd et al., 2019). Todd et al. (2019) argue that settlement classifications within Dar es Salaam to date mirror this pattern through, high-, middle- and low-income settlements. Alternatively, Mercer (2020) contends that such distinct classifications of settlements according to income are less visible on the urban periphery. In her view, the incremental, expansion of the city has culminated in a relatively mixed spatial distribution of social classes, thus presenting a different dynamic from the earlier planned neighborhoods in the city.

Planning has been a fundamental challenge in Dar es Salaam, particularly, ineffective master plans and inadequate official planning practices (Kombe, 2005; Todd et al., 2019). It has been argued that Tanzanian cities developed informally because of poor development machinery in the post-independence era when national priorities shifted from cities to rural areas through villagization (*Ujamaa*) policies (Todd et al., 2019). While several urban master plans were drawn—1949, 1968, and 1979—the influence of these plans on urban growth was minimal, if any at all (see Armstrong, 1986) and infrastructure planning remained disconnected from spatial planning, particularly in the case of electricity planning. Since the 1980s, rapid population growth far outstripped housing provision and land allocation resulting in two out of every three housing units being "unplanned" (Armstrong, 1986). Additionally, planning for the provision of critical services was sectorialized and disconnected from urban planning—except in part for transport. While earlier plans provided for social amenities like hospitals and schools, no specific provisions were made for networked services. Although the 1949 master plan dedicated a chapter to public utility services including water supply, drainage, electricity, and postal services, only brief comments were made on them while the detailed plans were to be prepared by the specific sectors following the circulation of the master plan (see Gibb and Partners, 1949). Similarly, the 1979 master plan, made stipulations to the effect that, where unavailable, water, sewage, electricity, and telephone services must be privately arranged by residents themselves (Armstrong, 1986: 51). Currently, a fourth master plan, finalized in 2016, is in place and some strategies/priorities have been implemented, including a Bus Rapid Transport (BRT) system. While detailed plans are included for water and transport, only sectoral electricity polices exist with very little generic information and no spatially situated strategies for the provision of electricity. This disconnect is also visible in the administrative structure of the city government which has planning responsibilities for other critical infrastructures like water, transport and sanitation but not for electricity provision.

The period between 1979 and 2016 when plans were largely ineffective, also witnessed deepening informality, where many parts of the city developed without recourse to formal planning schemes, regulations, or plans for the provision of basic services including electricity (Interview 11, 2018). As of 2015, close to 80 percent of the city's residents were reported to reside in informal settlements (Kombe et al., 2015), posing significant challenges to the provision of critical services (also see Kyessi, 2005). More recently, several initiatives (e.g. the 20,000 Plots Project of 2003) have been designed to make formally planned lands available for development to private individuals—as a means of spearheading more formal urban growth patterns. However, such initiatives have been criticized for the lack of coordination with service providers including TANESCO, Tanzania Road Agency (TANROADS) and Dar es Salaam Water and Sanitation Authority (DAWASA), leaving the owners of such lands to devise their own means of access to such critical services (Kironde, 2015). The initiative was further criticized for being spearheaded by the Ministry of Lands and not the urban planning or local government authorities (Kironde, 2015).

Due to the rapid and informal urban growth dynamics in Dar es Salaam, there has also been a mismatch between urban expansion and critical infrastructure provision. Amid limited resources, city authorities and utilities are constrained in their capacity to adequately deliver infrastructure services to residents (Kombe et al., 2021). As such, low-income and peri-urban neighborhoods/settlements are frequently saddled with poorer access to critical infrastructure services (Kasala et al., 2016; Kyessi, 2005). Such gaps are often filled with individual or community self-help interventions such as voluntary household contributions of funds, labor, and material for the construction of water wells, maintenance of roads as well as supervision of operation and maintenance of community water supply systems by local leadership, among others (Kyessi, 2005). For electricity, low-income residents resort to individual off-grid installations (e.g., Solar), tapping from neighbors (e.g. subscriber retail) or illegal grid extensions (Koepke et al., 2021).

Socio-Spatial Development and the Heterogeneity of Electricity/Energy Infrastructures

From the above, it is clear that socio-spatial development is related to the development of infrastructure provision and service delivery. Studies of water (Monstadt and Schramm, 2017), housing (Mercer, 2020), and transport (Mkalawa and Haixiao, 2014) in Dar es Salaam have shown the inextricable link between fragmented urban growth dynamics and uneven access to infrastructures/services. In electricity, such relations have been less well studied (as exception: Koepke et al., 2021), even though the city has had a splintered supply since the colonial period.

To begin with, access to electricity is defined by the Tanzanian Government as the "percentage of the population living within 600 meters from a transformer" (URT, 2015). According to this definition, electricity access in Dar es Salaam is 85.7 percent (URT, 2020), much higher than the national average of 37.7 percent (URT, 2020). This highlights the city's economic and political importance, with a relatively higher dependence upon electricity, and consuming approximately a third of all the electricity generated in Tanzania (Interview 3, 2018). Many ongoing electricity generation and rehabilitation initiatives are focused on Dar es Salaam (World Bank, 2016). Although the official figures for "connected" households seem high, they conceal that many residents cannot afford the connection fee to the grid, or that those who are connected only use electricity selectively (See Table 1). Additionally, the low reliability of electricity supply and regular outages impede users' reliance on TANESCO's supply. As a result, the socio-technical constellations in electricity, and more broadly, energy supply and use are diverse (e.g., stand-alone solar, hybrid on-off grid systems, backup systems, etc.).

Furthermore, households without formal access to the grid typically rely on alternative forms of energy (most prominently charcoal and paraffin) which supplement off-grid solutions such as solar power (NBS, 2017), or on illegally tapping the grid. Moreover, electricity access is driven by selective user practices and overlapping supply sources (See Table 1). In practice, the energy sector in Tanzania continues to be dominated by biomass, which accounted for 89.7 percent of the total energy use in 2018 (NBS, 2019). Moreover, in recent periods, the "proportion of households in Dar es Salaam using charcoal has increased and is now above 70 percent" (RVO, 2018: 6).

Such "heterogeneity," however, is not limited to the mix of energy sources but includes the multiple socio-technical constellations and co-provision channels that have developed in Dar es Salaam's differentiated electricity landscapes (Koepke et al., 2021). Networked electricity coverage and reliability are generally considered to be better in wealthier neighborhoods than in low-income and peri-urban areas. A crucial issue here is affordability. TANESCO has consistently increased tariffs, at times by as much as 30 to 40 percent per annum, largely to pay for power generation and maintenance costs (Degani, 2017). Thus, while connection rates are high, actual availability is differentiated between those who can generally afford "uninterrupted" supply and those who use electricity selectively or intermittently.

Table 1. Selective household energy use in Dar es Salaam

Lighting	Electricity	Solar	Kerosene Lanterns and Wick Lamps	Candles	Paraffin Lamps	Torches/ Rechargeable Lamps	Acetylene and Other
	80%	5.4%	4.8%	1.2%	0.4%	6.8%	1.3% & 0.2%
Cooking	Electricity	Charcoal	Gas	Paraffin		Firewood	Other
	7.8%	58.9%	13.3%	6.5%		5.9%	7.7%

Source: NBS, 2019

Also important is the spatiality of urban growth dynamics and functions. In peri-urban areas such as Chamazi and Mabwepande, urban growth precedes networked electricity provision. In such areas, solar power is typically the first source of electricity generation for residents. The extension of the grid to such areas often results in interesting modes of co-provision and selective practices of energy use, depending on which devices are "connected" to the grid (Interview 12, 2018). Meanwhile, residents in wealthier neighborhoods typically use more electricity than those in low-income and peri-urban neighborhoods because of their higher demand for and use of "modern" electric appliances such as air conditioners (Interview 12, 2018; Interview 14, 2018).

Table 2 summarizes these spatial dynamics across Dar es Salaam, based on the neighborhoods we sampled. Also shown in this analysis are the various electricity/energy socio-technical constellations which have developed across divergent spatial conditions. The following discussion presents a more detailed analysis of the different urban typologies identified (also see Koepke et al., 2021).

The *inner city* comprises the central business district in Dar es Salaam. Here, Kisutu is a compact, built-up area, with predominantly high-rise, mixed-use developments. This neighborhood was officially "planned" and has universal coverage of networked electricity. Coupled with its role as the central business district, performing key functions such as administrative services, hotels, hospitals, commerce, a characteristic feature of Kisutu is the high prevalence of diesel backup generators and other backup systems.

High-income residential areas include the Masaki and Oyster Bay neighborhoods. These are typically modest density, low-rise, residential developments. Such areas were formerly occupied by colonial administrators and white settlers but are now inhabited by foreign diplomatic missions, international agencies, hotels, and national and urban

Table 2. Socio-spatial electricity use and energy constellations

Ward	Settlement Type	Built Environment and Functionality	Electricity Use	Socio-Technical Constellations
Kisutu	Inner-city	Dense, high-rise center of business, administration, and commerce	High	1 2 3 4 5 6 7 8 9 10
Msasani (Masaki, Oyster Bay)	High-income	Moderate density, mixed developments, Residential, high-end business, embassies	High	1 2 3 4 5 6 7 8 9 10
Sinza	Middle-income	Dense, low-/medium-/ high-rise buildings. Mixed functions; residential retail and services.	Moderate	1 2 3 4 5 6 7 8 9 10
Ubungo	Middle-income	Low-rise, medium density. Functions: residential, industrial, educational, retail, and services	Moderate	1 2 3 4 5 6 7 8 9 10
Mbagala	Low-income	Moderately built-up, low-rise developments. Residential with commercial activities.	Low	1 2 3 4 5 6 7 8 9 10
Chamazi	Peri-urban	Sparsely built-up, low-rise developments, ongoing horizontal expansion and densification, Residential, low–middle income	Low	1 2 3 4 5 6 7 8 9 10
Vingunguti (Nyerere Road)	Industrial	Industrial area, moderately dense, factory establishments. Manufacturing and industry and residential.	High	1 2 3 4 5 6 7 8 9 10

Legend: (1) Networked electricity; (2) diesel generators; (3) automation and synchronization; (4) solar power; (5) Uninterruptible Power Supply devices; (6) alternative energy sources; (7) meter sharing; (8) manual technology; (9) installation of own transformers; (10) alternative and rescheduling activities
Source: data collected during fieldwork in 2018 and 2019.

elites. Once again, networked electricity is ubiquitous in such areas and there is a high prevalence of backup generators, UPS devices, and electricity storage systems.

Sinza and Ubungo are *middle-income* neighborhoods with mixed urban dynamics. As long-standing residential areas, these neighborhoods are dense and consolidated. Whereas Ubungo consists predominantly of low-rise residential developments, Sinza includes a mix of low- to medium-rise developments. Urban development here is largely in the form of infill developments of pockets of greenfield areas or redevelopment of brownfield areas.

Low-income neighborhoods, exemplified by Mbagala, have largely developed outside official planning documents/regulations. This neighborhood is primarily residential, with small-scale commercial activity along major streets. The neighborhood is compact, dense, and consolidated through predominantly low-rise residential buildings.

Peri-urban areas like Chamazi and Mabwepande serve predominantly residential functions and have few commercial activities. Built-up densities here are relatively low and the areas are home to a mix of low- and middle-income residents. Peri-urban settlements in Dar es Salaam are largely unplanned. Grid infrastructure here is largely incomplete, often requiring network extension works.

As the name implies, *industrial areas,* such as Vingunguti, primarily harbor manufacturing plants and industrial activities. This is a "planned" area, earmarked solely for industrial purposes.

From the spatial typology outlined above, it is clear that electricity demand, use, and the materialization of different socio-technical electricity/energy constellations are strongly related to socio-spatial conditions and dynamics. Generally, in higher-income neighborhoods, almost all households are connected to the grid using independent metering systems, whereas in lower-income neighborhoods meter-sharing is a common phenomenon (Koepke et al., 2021). The relation between electricity access and socio-spatial dynamics also affects electricity use practices. Meter-sharing allows low-income households to access electricity by pooling their resources but also dictates how electricity is used because it restricts the types and number of appliances allowed (Interview 11, 2019). One resident in a low-income neighborhood, for example, stated that "I use only fan and light. Irons and electrical cookers use a lot of electricity, which causes problems with other tenants" (Interview 11, 2019).

Infrastructural bypassing is also observable across the city and includes street vendors positioned beneath overhead power lines, often without grid electricity. Backup generators can also be seen in lower-income neighborhoods, but typically only to enable retailers to continue business operations at night, mainly to provide lighting and charge cell phones (Interview 5, 2019). Concerning urban functions, in higher-income neighborhoods (and those which serve "key" economic functions), "backup" generation, storage, and surge protection systems are common methods of electricity co-provision. In higher-income neighborhoods, however, electricity consumption is typically higher and is used for a broader range of devices, with many uses tied to socio-spatial demands, e.g., electric fences for security and air conditioning (See NBS, 2017).

Unpacking Power Interruptions in Dar es Salaam

Power interruptions are an enduring feature of electricity access in Dar es Salaam. Interruptions do not have one single cause. They are neither experienced ubiquitously nor do different socio-spatial groups "respond" in the same way. Interruptions must, therefore, be contextualized and situated within the differentiated socio-spatial dynamics discussed above. Figure 1 shows various causes of power interruptions in a certain illustrative period, where interruptions occurred for two broad categories of reasons: (a) "unplanned" (e.g., technical faults such as "overcurrents"); and (b) "planned" (network maintenance and load-shedding). For the current analysis, "load-shedding" is a particularly interesting frequent cause of interruptions. Load-shedding (or "rolling blackout") is essentially demand-side management, through TANESCO selectively disconnecting certain areas/services and not others to avoid a total collapse of the grid.

Focusing on supply-side dynamics, as dominant approaches tend to do, critically fails to take account of the divergent experiences of interruptions across different neighborhoods and social groups. Figure 2 shows that across the five municipalities of Dar es Salaam, the total length or outages varies considerably. *Temeke,* the municipality mainly inhabited by low-income residents (where Mbagala is located), records the highest number of hours of blackouts in a typical month while *Kinondoni*, the municipality inhabited mostly by high-income residents and many high-end businesses (where Msasani is located) and *Ilala,* the municipality housing the central business district and erstwhile administrative hub of Tanzania (where Kisutu is located) record significantly lower figures in comparison—up to 50 percent fewer blackouts.

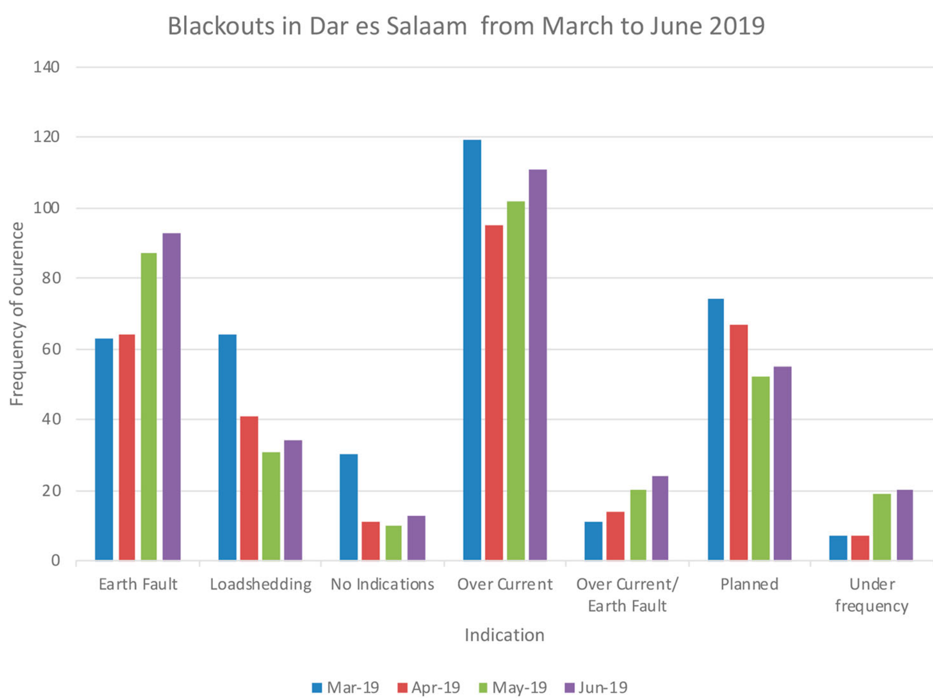

Figure 1. Occurrence of power interruptions in Dar es Salaam over an illustrative four-month period, according to cause
Source: Own figure based on data from TANESCO

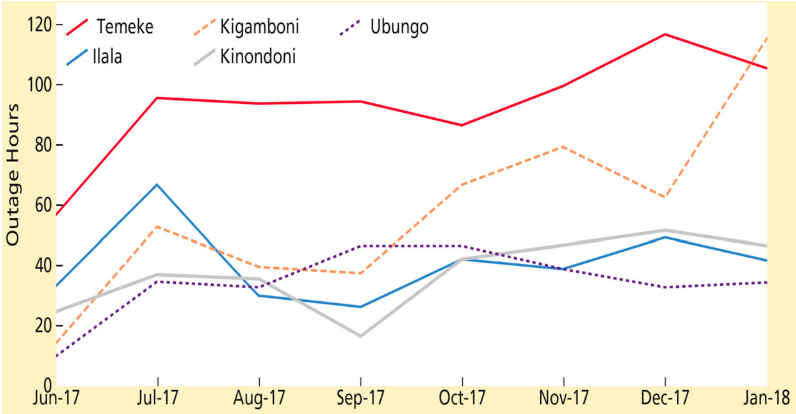

Figure 2. Power outage (blackout) hours per month across the five municipalities in Dar es Salaam over an eight-month illustrative period
Source: IIED, 2018

Although sometimes based on technical considerations, load-shedding decisions involve socio-economic and political decisions. Our interviews with TANESCO employees revealed that load-shedding decisions generally consider the available supply capacities, "critical" sectors of the economy, and considerations of least impact (e.g., in terms of concentrations of people and "key" activities). Areas such as presidential residence, the prime minister's residence, health institutions, key businesses, and industry, are considered "high priority" areas/functions and are typically not disconnected. These areas, however, are not always served on dedicated lines, meaning that cables serving an industrial area or a hospital, for instance, may simultaneously service other consumers en route to these priority locations, hence allowing other customers to enjoy fewer interruptions as well.

Interviews with TANESCO employees revealed that load-shedding is considered a matter of finance because of the revenue required to keep the system running. Therefore, TANESCO aims to ensure that its largest paying customers are seldom cut off (Interview 3, 2018; Interview 30, 2019). Industries are generally given preference, for economic reasons. In some cases, individual organizations, such as the Tanzania Revenue Authority (TRA), have negotiated with TANESCO to receive more protection from blackouts (*Daily News*, 2011). This implies, therefore, that low-income residential communities are likely to suffer more load-shedding incidents than high-income neighborhoods. Our discussions with TANESCO did indeed reveal that higher-income areas such as Masaki seldom recorded any load-shedding outages, whereas, in a typical month, low-income areas like Mbagala recorded several load-shedding incidents. Additionally, a 2017 report published by Japan International Cooperation Agency found that most grid failures occurred in the Temeke district of Dar es Salaam (i.e. the district with many low-income neighborhoods, including Mbagala). The reason given for these interruptions was that "equipment has fallen into a state of deterioration" (JICA, 2017: 5–25).

Furthermore, many "technical" (i.e. unplanned) faults are strongly related to socio-technical dynamics, i.e., the interactions between critical infrastructures and electricity users and their co-evolution through time. In Masaki, it was observed that 65 percent of all outages in a typical month were the result of "overcurrents" (based on data from TANESCO, 2019). This results from the high demand (from higher-income consumers) in such areas exceeding the capacity of the technical systems (Interview 30, 2019). Moreover, the inner-city area is experiencing vertical growth and expansion through redevelopment and infill of existing green spaces, thereby overloading existing electricity infrastructures and causing interruptions that have knock-on effects on the system. Peri-urban areas were also found to experience interruptions for similar technical reasons, related to the extension of networked electricity in those areas failing to keep pace with population growth. A TANESCO official described the situation as follows:

> When we installed that transformer … we had 20 houses. Now after five years maybe we have 100 houses, or we have 50 houses. Obviously, the conductors that we used before, due to poor planning also, we used small conductors, we did not anticipate the load. So, we use small conductors, they are overloaded, and if we don't replace them in time, they break. Or the joints between the section of the lines, they break, you know, because of the overload. (Interview 6, 2018)

From a resilience perspective, this situation highlights two points: firstly, TANESCO is generally limited in its capacity to address divergent socio-spatial dynamics of power shortages. What also results from this, through the experience of frequent interruptions, are divergent "responses"—including changing of functions, alternative practices, and alternative constellations—among different socio-spatial groups. Given the frequent nature of interruptions, such responses can be understood as resilience capacities. The temporality of electricity interruptions is also important here. TANESCO was found to supply power where it was most "needed" at different times during the day—supplying residential neighborhoods in the evenings and early mornings and industrial and commercial areas during the day to facilitate business operations (Interview 3, 2018). Despite regulations stipulating that residents should be informed of "planned" outages, a key problem is that many residents do not receive such information in time (Interview 4, 2019). Thus, responses from urban dwellers emerge, in many senses, in anticipation that blackouts might occur. The "synchronicity" allowed by diesel backup generators becomes a clear advantage for higher-income groups and key functions, while the responses from lower-income groups are often to build forms of resilience outside the central grid.

Secondly, such findings show how the "exposure" to blackouts and other interruptions is fundamentally uneven across the city. The experience of interruption events relates to the causes of blackouts, the underlying socio-spatial conditions, urban dwellers' immediate capacity to respond, and the more enduring forms of capacity embodied in the different socio-technical constellations. It is, therefore, crucial to understand and situate "resilience" both beyond the confines of the central electricity network and as a highly differentiated set of "responses" or adaptive capacities that exist among heterogeneous infrastructure systems.

Building Resilience Through Heterogeneous Infrastructure Systems?

Given the divergent socio-spatial conditions, uneven exposure to blackouts, and the different socio-technical electricity constellations detailed above, the following sections discuss how resilience can be better understood in such contexts and how urban actors build (or do not build) resilience through such heterogeneity. The triadic distinction between different resilience "capacities," outlined previously, offers a useful framework to approach this question. In the assessment that follows, we draw upon the heterogeneity that characterizes the adaptive capacities in response to "blackouts," which serves as a useful reference point from which to assess how (and why) resilience emerges (See Table 3). Some of these strategies provide multiple resilience capacities and as such, may appear under more than one capacity. The spatial distribution of some of these adaptive capacities in the city is presented in Table 2 above under socio-technical constellations.

Capacity to Resist

This capacity is predominantly considered as the ability and means to prevent the occurrence of blackouts and ensure a reliable, uninterrupted supply of electricity. In practice,

Table 3. Resilience capacities in Dar es Salaam

Resilience Capacity	Resilience Strategies	Actors (Institutions and User Groups)
Capacity to Resist	Increased electricity generation capacity through direct investment in power generation, engaging Independent Power Producers (IPP's) and Emergency Power Producers (EPP's)	TANESCO
	Diversification of power generation sources from a hydropower base to include power generation based on diesel, natural gas, and other fossil fuels.	
	Improved repair and maintenance practices	
	Demand-side management to prevent total system collapse	
Capacity to Absorb and Recover	Co-production of electricity through self-generation using backup generators and solar power.	High-income residents, large-scale businesses, public organizations
	Automation and synchronization of backup generators to interruptions in grid electricity supply.	Hospitals, hotels, embassies, large-scale businesses, public administrations
	Complementing electricity with the use of alternative forms of energy like solar, gas, charcoal, firewood, etc.	Residents (mixed incomes)
	Load-shedding	TANESCO
	Use of bridging devices for specific energy services (e.g., rechargeable lamps, solar lamps, torch lights, kerosene lanterns)	Residents (mixed incomes), small-scale businesses
	Coping technologies: Buffer technologies like Uninterruptible Power Supply (UPS) devices, electricity storage systems.	High-income residents, large-scale businesses, public institutions
	Coping practices: Rescheduling/switching of activities, living without electricity, use of manual equipment	Low-income residents, small-scale businesses
Capacity to Adapt and Transform	Alternative electricity generating technologies (Open market and engineering expertise for diesel generators, solar panels, UPS systems)	High-income residents, large-scale businesses, public institutions
	Social Preparedness to respond to blackouts	Residents (mixed)
	Investments in dedicated transformers by private actors	Factories, large apartment buildings
	Social arrangements and initiatives at the community level (e.g., electricity sharing initiatives)	Communities
	Socio-technical systems supporting alternative fuels (distribution networks, local sellers, devices such as stoves and lights)	Low-medium-income residents
	Installation of hybrid (solar-grid) and co-provision systems	International organizations
	Flexible working patterns	Small-scale businesses

Source: Data collected during authors' fieldwork much of this capacity lies with TANESCO. Driven by political pressures and "energy for all" policies but also by international donors and their conditionalities, the utility company has sought to address interruptions by addressing generation deficits, which have been a major cause of power cuts. Thus, the primary strategy has been to increase supply-side capacity by increasing generation capacity and diversifying the energy base for power generation (Interview 3, 2018). Notable ongoing investments in power generation include the state-funded Julius Nyerere Hydropower Station with a planned capacity of over 2000 MW, which has given rise to considerable controversy among environmentalists, international donors, and NGOs. This Tanzanian flagship development is expected to cost US$2.9 billion. So significant is this investment that it accounted for 65.54 percent of the Ministry of Energy's budget in 2020/21 (*The Citizen, 2020*). Although such initiatives have the potential to increase electricity supply, the overreliance on centralized hydropower arguably leaves the grid vulnerable to the same climatic (primarily droughts) and technical (high maintenance costs) threats that currently exist. Partly noting this challenge, TANESCO and the Tanzania government have sought to diversify the fuel base for electricity generation by investing in fossil-fuel-based power plants. However, the cost of fossil fuels for thermal power presents other financial challenges.

Part of the strategy to build resilience here is financial. Key institutions have attempted to move away from the sole dependence on traditional avenues of investment in generation infrastructure. Rather than direct investments through revenues, government initiatives, and international development partners/donor agencies, TANESCO has increasingly engaged Independent Power Producers (IPPs) and Emergency Power Producers (EPPs) to supplement electricity generation capacity. These initiatives have been controversial, however, as the purchase costs of electricity are high (JICA, 2017; Gratwick et al., 2017). Those affordability challenges have perpetuated the uneven electricity access and the differentiated user responses to interruptions discussed above. To maintain revenue flows into TANESCO, available electricity is directed toward those who can pay promptly for their consumption—namely high-income customers.

Measures have also been implemented to improve the maintenance of the existing electricity network, such as the "Whole Maintenance Project," which pursues a holistic approach to the maintenance of chains/groups of infrastructures, relating to specific feeders (Interview 6, 2018). Financed by the government of Finland and limited to Dar es Salaam, this project aims to reinforce the distribution network within the city through close monitoring and proactive maintenance of network components (i.e., clearing the network path of trees and vegetation, substation refurbishment, replacement of circuit breakers, replacement of rotten poles, replacement of conductors, proper joint connections with high tension lines, etc.). However, given that maintenance operations are one of the biggest causes of interruptions, and interruptions are experienced unevenly across the city, maintenance projects are failing to address resilience systematically. This exposes the fact that there is a lack of redundant capacity within the distribution networks, which prevents maintenance works from proceeding without the disruption of energy flows. As a result, although maintenance practices prevent the infrastructure from deterioration and breakdown, they also contribute to the divergent exposure to blackouts and uneven responses of different urban socio-spatial groups.

In summary, therefore, although much has been done to prevent the occurrence of blackouts, electricity supply is still susceptible to frequent disruption. The spatially differentiated exposure to blackouts within the city and the differentiated access to the network (e.g., between inner city and peri-urban or planned and unplanned areas) as discussed above (also see Koepke et al., 2021), means that not all residents enjoy the benefits of this capacity equally.

Capacity to Absorb and Recover

Although the capacity to resist/prevent interruptions mostly lies with TANESCO, the capacity to absorb and recover from blackouts is much more dispersed among multiple stakeholders. Urban dwellers, businesses, and public administrations have developed their own adaptive capacities to respond to blackouts beyond or in tandem with the grid itself (See Table 3). The socio-technical constellations presented in Table 2 above also indicate areas of concentration of these response mechanisms. As discussed, some of these adaptive capacities are synchronized in anticipation of electricity interruptions. It is common to do so using UPS devices, which prevent equipment from shutting down abruptly because of power cuts or power fluctuations (Interview 25, 2019). Likewise, in areas like Kisutu for example, many backup generation systems are automated to ensure supply continues after a blackout occurs, thereby ensuring certain urban functions continue unaffectedly or in a slightly more limited form (Interview 18, 2019). Co-provision mechanisms (e.g., solar power, alternative fuels) similarly build capacity, by allowing residential, commercial, or public users to switch power supply to preserve the most critical functions.

It was observed that such absorption and recovery capacities vary considerably between different social income groups, neighborhoods, and functions across the city (see Table 2 above). This translates into highly splintered forms of resilience at various levels, individual, household, neighborhood, and organizations. Although multiple "coping" mechanisms are well established, economic factors restrict many residents of Dar from accessing certain strategies. It was observed and reported in interviews with residents that higher-income neighborhoods like Masaki and Oyster Bay exhibit a higher affinity for electricity backup generators, while lower- and middle-income residents rely heavily on alternative energy sources and changing user practices to reduce electricity dependency/consumption. In summary, therefore, there is a high capacity to absorb the shocks of a blackout and recover from them through the interventions and creativity of urban residents and electricity users. Primarily because of high costs, this capacity differs considerably.

Capacity to Adapt and Transform

The capacity to adapt and transform involves learning and changing processes over time: that is, more durable forms of capacity embodied in socio-technical systems and responses to blackouts. Despite several interventions by TANESCO, the network continues to lack the capacity necessary to ensure a more secure and reliable electricity supply. Moreover, the utility company, regulator, and government departments continue to ignore the innovations and interventions of urban residents/actors (outlined in the previous sections) as viable alternatives for building resilience. Our data, however, suggests high levels of social transformations in response to the repeated experience of blackouts (See Table 3).

Dar es Salaam has witnessed increasing electricity co-provision by residents, and in some circumstances, private actors have indeed intervened directly in the grid itself (e.g., industries pay for new/separate transformers [Interview 22, 2019]). Consumers continuously invent avenues to enable access through meter-sharing in multi-family homes in poorer neighborhoods and other communal initiatives. Private actors have also filled gaps left by public utility services such as generator operators who sell power for as low as 500–1,000TSh to street vendors at night (Interview 5, 2019). Moreover, alternative technologies such as UPS devices, generators, solar panels, and solar-related devices have become accessible and more affordable. For example, former slum dwellers who relocated to Chamazi were found to have installed solar power through loan facilities (Interview 12, 2018), while simple solar lamps can be as low as 2,500TSh on the market, depending on their quality and what other ancillary energy services are needed—e.g., radio, USB charging ports, etc. Such innovations have significantly elevated the resilience capacity of Dar es Salaam's residents and the level of social preparedness to respond to interruptions.

We thus argue that despite the shortcomings of centralized networked systems, the heterogeneity of infrastructures emanating from such circumstances in cities like Dar es Salaam, serve not only to create access to critical services but it also enhances the adaptive capacities of residents against the frequent disruptions of critical services. However, there are two significant barriers to many of these capacities: the failure of the government/utility provider to legitimize such practices/constellations, and the lack of regulation and appropriate governance structures to support this complex energy environment. Key stakeholders such as TANESCO have been slow to learn from such heterogeneity due to their refusal to acknowledge such co-provision channels and their limited financial and technical capacity. TANESCO's focus has predominantly been on increasing centralized supply, extending the grid, and improving its financial sustainability. There are lessons to be learned, however, in harnessing the capacities that reside in the individual responses to power outages and using them to assure a more sustainable service delivery. Simultaneously, such adaptive capacities must also be fairly assessed and evaluated. Alternative fuel sources such as diesel generators, for example, are often environmentally unsustainable and come with huge costs of continuous electricity supply. In summary, there are high levels of social adaptation and transformation as a direct result of learning from repeated experiences of blackouts, yet the centralized electricity provider and governments lack the capacity to systematically acknowledge, make use of, and regulate such user-driven resilience capacities.

Conclusion: Toward Urban Resilience?

In this article, we assessed the resilience of urban user groups to habitual electricity disruptions through the heterogeneous nature of socio-technical infrastructures in Dar es Salaam. This study first situated the production of heterogeneous energy infrastructures in the socio-spatial dynamics of the city. Our findings indicate that poorer communities are generally more exposed to electricity blackouts than wealthier neighborhoods, and generally have poorer access to networked services. Similarly, inner-city neighborhoods are less exposed to blackouts than neighborhoods on the urban periphery and there is a spatially differentiated sensitivity to blackouts based on underlying economic, social, and cultural practices/conditions.

When assessing the resilience of heterogeneous electricity systems, networked electricity systems exhibit a low capacity to "resist" blackouts. However, there is a much higher capacity to "absorb" and "recover" from disruptions. Undoubtedly, much of this capacity is held by user groups and is due to the practices, resourcefulness, innovations, and investments of different groups in response to disruptions. Concerning the transformative capacity, this is much more ambivalent, as while there are some lasting socio-technical innovations through users' and co-providers' activities to produce socio-technical hybridities and alternatives, there is also low levels of learning among TANESCO and the central government to both address underlying causes of blackouts and better coordinate decentralized backup and co-provision channels.

This leads us to a nuanced and "double-sided" conclusion that while resilience is, to some degree, a useful concept it is also limited in its explanatory value. On the one hand, for cities like Dar es Salaam, often framed as vulnerable despite the widespread knowledge of the "vulnerability paradox," this research shows that there are considerable resilience capacities embedded within the heterogeneous socio-technical systems and "responses" of local user groups—both of which emerge not only due to uneven spatial conditions but partly due to the habitual experience of electricity disruptions. As demonstrated by our case, the repeated exposure to the vulnerabilities of centralized electricity provision results in what could be termed another "resilience paradox"—which is increased adaptive capacity through socio-technical innovations and initiatives that allows urban societies to cope with disruptions. On the other hand, however, conventional approaches to resilience largely fail to acknowledge and address how divergent underlying socio-spatial conditions and uneven capacities shape these responses. For example, lower-income user groups often have considerable burdens (time, resources, etc.) associated with shifting practices or "waiting" and generally have much lower (financial, physical) access to socio-technical alternatives such as backup systems, which afford particular benefits to high-income user groups.

We thus agree with Golubchikov and de Verteuil (2021) that traditional resilience assessment frameworks applied in this research are post-political in nature. There is a severe risk that ubiquitously portraying all user-groups as resilient in Dar es Salaam legitimizes the lack of political action to address the uneven exposure and experience to blackouts among (typically) poorer communities therefore leading to the "abandonment of impacted communities" (Golubchikov and de Verteuil, 2021: 72) perceived as more "resilient." It also depoliticizes the negative "externalities" associated with such responses, such as environmental damage caused by backup diesel generators and economic burdens on lower-income groups. This suggests that debates on resilience must indeed move beyond maintaining the status quo, and "future proofing" existing infrastructure arrangements, towards more critical, alternative notions of resilience (Ziervogel et al., 2017).

Therefore, while this article has accentuated the importance of heterogeneous energy systems for urban resilience (rather than solely focusing on centralized power grids), further research is needed on the complex governance challenges of heterogeneous infrastructures and how they can contribute to urban resilience in more sustainable and equitable ways. Recognizing and legitimizing these heterogeneous infrastructures by the state and utility providers would be a crucial first step as they are frequently ignored in existing policies and strategies. In addition, further research is needed on how the potentials of these heterogeneous infrastructure constellations could be better harnessed through proper regulations and governance mechanisms.

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