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Injustices in rural electrification: Exploring equity concerns in privately owned minigrids in Tanzania

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ABSTRACT

Access to electricity is vital for many basic needs, but it is often unaffordable. Since 2008, there has been an increase in private companies providing electricity access in rural areas through solar minigrids in Tanzania. This paper focuses on the different tariffs used in projects in Tanzania and how they distribute costs. Data were collected over eight months of fieldwork in 2019/2020 from six rural communities through interviews, focus groups, surveys, and directly from minigrid companies. I have found that by private companies treating electricity as an economic good communities experience energy injustices. Under many tariffs poorer households pay more per unit than those with higher incomes. Poorer households are less likely to be able to connect and under some tariffs self-disconnect from their electricity service. Barriers such as lack of participation in project development, high tariffs, and high connection fees limit the benefits of rural electrification.

1. Introduction

Access to electricity is viewed by many as a basic need [1–3] – as demonstrated by it being enshrined in Sustainable Development Goal 7 (target 7.1) [4]. It can be viewed as a derived human right [5], as it is often necessary for access to good health and education. In many rural communities, the provision of electricity is driven by market forces, where it is framed as an economic good [6].

For those living in unelectrified rural areas, economic modelling suggests that minigrids or solar home systems will generally be the most cost-effective solution due to the high costs of transmission infrastructure [7]. Minigrids are often implemented outside of national infrastructure by the private sector, with multiple policy regimes. Previous work has highlighted the energy injustices and social costs of solar home systems and lanterns [9,10]. To meet national and international electrification targets, it is highly likely that private sector investment will be necessary, particularly for decentralised projects [10]. Understanding the distributional impacts of these approaches can lead to more equitable project implementation.

Policy reforms in Tanzania in 2008/9 introduced legislation that enabled private companies to implement rural electricity projects, which is why Tanzania is a good location for research into rural solar minigrids. As part of these reforms, companies can set cost-reflective tariffs, which for solar minigrids are 10–50 times higher than the national grid tariffs. The private sector has shown it can increase electricity connections [11]. However, this paper looks at who is excluded and the cost of private sector approaches for households. Approaches for delivering energy access that focus on the financial costs to governments and companies are evaluated using an energy justice lens, by also considering the social costs – such as increased inequality, exclusion of lower-income households, and distribution of costs through tariffs.

This paper highlights injustices in solar minigrid projects by drawing together approaches from different disciplines – particularly human-centred participatory approaches and economic analysis. Using ideas from both energy justice and energy ethics, it provides new insights on privately-owned solar minigrids in countries with limited rural electrification [12]. I used a multi-methods approach to collect qualitative data, through interviews, observations and focus groups, and quantitative data, including customer payment data, tariff levels and household energy use surveys. This data from fieldwork in communities with solar minigrids is used to reveal the social and economic costs of these tariffs on households. Frameworks of electricity as a social right or an economic good [13] are used to frame these costs and critique the marketisation of electrification.

2. Literature review

Many authors have found that the presence of social sciences in renewable electricity research is marginal, as research funding is focused on techno-economic approaches [14–16]. A significant gap has

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been identified around interdisciplinary evaluations of rural electrification projects, and the use of participatory and ethnographic approaches [17–20]. Yaqoot [20] has noted the importance of social barriers to implementation, particularly when considering how users value electrification [21,22]. Rahman [21] and Kumar [22] found that many rural electrification projects fail due to a lack of attention to issues other than techno-economics, further demonstrating the importance of interdisciplinary research.

Previous research has identified trade-offs between flexibility and affordability for households, and the economic performance of companies, and hence the economic sustainability of projects [23]. Ulsrud et al. [24] consider tariffs in Senegal, but focus on the perspectives of government and the private sector, rather than communities. This focus leads them to consider households' self-disconnecting allows flexibility, rather than considering the impact this has on their lives. This paper builds on this work by also considering different tariff structures and using a justice lens.

Research on minigrids has largely been focused on donor-driven projects [25], leading to research gaps surrounding the implementation of privately-owned projects and how communities are impacted. Private-sector approaches to delivering energy access increasingly dominate the landscape of electrification in low and middle-income settings [26]. Research on minigrid tariffs in developing countries is largely grey literature, such as reports from Non-Governmental Organisations and industry [4–6]. Although these sources can provide novel insights into energy access, specific aims may bias them, or a need to deliver outcomes to donors.

The increasing role of the private sector in delivering electricity access, combined with acknowledging electricity's status as a basic need, requires an interrogation of the tension between it being treated as a social right and an economic good.

2.1. Electricity as a social right or an economic good

This paper draws upon two ways of framing access to electricity – as a social right or as an economic good. To consider electricity an economic good means it should be delivered by a market, using principles of economic efficiency [30,31]. Solar minigrid companies' main aim is to earn profits and efficiently run projects. However, to view electricity as a social right means prioritising access for people's basic needs, such as lighting and communication, and ensuring that these are accessible to the poorest in society. All framings are social constructs situated within contexts, which for literature on energy justice is largely from the global north [32–34]. However, using frameworks can facilitate comparative analysis and mean that research is more useable, such as by policymakers [35].

The two framings are not mutually exclusive – services are often provided using a combination of both. For example, Makwara [13] argue that water should be provided considering it is both an economic and social good. Water is a vital basic service and treating it as an economic good would exclude people from access. They argue that treating water purely as a social good does not encourage its efficient use and can lead to wastage. There are trade-offs between these two arguments, so it is necessary to make compromises.

In the Global North, the dominant paradigm is the privatisation of infrastructure, as shown by deregulation and privatisation of basic services such as water, energy, and public transport in the UK. This is critiqued by Bayliss et al. [36], who consider the distributional effects of this shift. They show that investors have profited through privatisation, but often not in the public interest. Lower-income households face challenges affording and accessing these basic services – such as households self-disconnecting from heating during cold winters. Poorer households self-disconnecting due to costs has also been identified in India [37]. Although there are regulations to protect vulnerable people, they do not consider this has provided adequate social protection. Systemic factors are embedded in market structures, so market-based approaches do not address these structural roots of poverty [6].

2.1.1. Energy as an economic good

The framework of basic services being provided as economic goods is an example of the marketisation of development. Prahalad [38] discussed the 'fortune at the bottom of the pyramid', arguing that businesses have great potential to profit from the poorest in the world, and that the poor are poor because they only have informal markets. However, in critique of this, Karnani [39] highlights how this approach to development provides services to those most able to pay, rather than those most in need. The focus on the private sector detracts from the failure of governments in providing basic services to citizens. Schwittay [6] argues that the marketisation approach is limited because private companies cannot tackle the systemic causes of poverty. Other issues include increased debt burdens on vulnerable people, increasing inequality in wealth distribution, encouraging unsustainable consumption and subsidising large companies, rather than local businesses.

Burgess [30] argues that electricity, particularly off-grid, should be priced as an economic good. They suggest that treating electricity as a right undermines universal access to electricity, as it encourages electricity theft and non-payment, meaning service providers are unable to cover costs. However, they start from the assumption that electricity provision should be a profitable activity, while it could be provided as a public service. Burger [31] considers that for a tariff to be *distributionally equitable or fair*, it should meet locally defined standards of justice – such as how costs are distributed between vulnerable and non-vulnerable customers.

An economic good perspective to solar minigrid development has led to a focus on minigrids for income-generating activities, or productive uses of electricity, to encourage financial sustainability [19]. However, these approaches often fail to acknowledge the broader limitations faced by communities, such as a lack of access to markets, availability of financing, quality of transport, such as roads, and skills development [40].

2.1.2. Energy as a social right

An alternative perspective is to view electricity as a social right. In this framework, the individual needs of people take priority – particularly those who are more vulnerable.

The social benefits of access to electricity have been highlighted by many scholars [41]. Benefits include improved health due to reduced air pollution from kerosene, improved household safety, better living standards, food storage, education, communication, as well as improved local services in healthcare, businesses, and education. Current discourse suggests that providing electricity to a community automatically leads to development, but in practice it is much more complex. The benefits are mediated through the local context, particularly gender and socio-economics [42].

Although no declaration or resolution explicitly claims that access to electricity is a universal human right, it can be considered a contractual right (community acknowledged rights), a derived right (necessary to protecting other rights – such as education and health) or as a human right in itself [5]. Löfquist [5] that electricity should be understood as a derived right – it is necessary for protecting basic rights to life, adequate housing, healthcare, and education.

Electrification can further exacerbate existing inequalities in communities, as those better off are more likely to afford to purchase the equipment to improve their livelihoods and pay for electricity. For example, in Bangladesh, it was found that wealthier farmers could purchase irrigation equipment to increase their crop yields [43]. In an ethnographic study of electrified communities in South Africa, Matinga [40] found that implied benefits of electrification did not materialise due to a lack of supporting services, unclear information, and existing inequalities and power dynamics. The research supported previous findings that middle income and affluent households, who had resources to exploit the benefits of electrification, were the ones who greatly

benefited [44]. This is further supported by research by the World Bank [45] found that benefits mostly accrue to non-poor households, and that productive uses of electricity were rare.

There are many examples where access to electricity is treated, at least in part, as a social good. For example, several distribution companies in India have dedicated tariffs for households below the poverty line [50]. Komives [47] identified 13 categories of electricity tariffs and 45 different subsidies provided by utilities that supported vulnerable customers ('energy safety nets'). Scott and Pickard [28] found that 'energy safety nets' exclude many poor households, and such subsidies often fail to reach those who need assistance most. The report focused on energy safety nets in middle-income countries, identifying a knowledge gap around how they are used in low-income countries.

2.2. Energy justice and energy ethics

This work links to energy justice by drawing on three tenets of distributional, recognition, and procedural justice [34]. Distributional justice asks where injustices emerge (and how they can be solved), recognition justice asks who is impacted by injustices that exist across the energy supply chain, and procedural justice seeks to examine whether processes of decision-making, planning and participation are fair and inclusive. Compared to large-scale projects, such as coal power stations and hydroelectric dams, solar minigrids have less prohibitive justice issues, e.g., those conceptualised as 'unduly interfering' – such as land grabbing and environmental damage. However, there are significant affirmative justice issues that relate to people's derivative right to an energy service [48]. This includes putting importance on how people define their own energy needs – particularly energy sufficiency and mobility [49]. This paper draws on an energy ethics approach – looking at individuals' perceptions of justice, which allows for local ethical nuances which may be obscured by universalist approaches [55].

When looking at solar home systems and solar lanterns in Malawi, Samarakoon [8] found that a market-based approach reproduced existing inequalities. As well as distributional injustices, procedural injustices were identified, as households did not have adequate knowledge or support. Kumar [50] identified how socio-cultural processes mediate the development outcomes of energy access in India, particularly concerning education, livelihood, and health benefits. In both papers, privileged households were more able to benefit from projects delivering solar lanterns and solar home systems.

Lacey-Barnacle's 2020 [35] review of energy justice research found the use of mixed methods lacking. This work highlighted a focus on large-scale hydroelectricity projects and limited research in low-income countries. While energy justice research examining solar PV systems in Africa is emerging [8,51], there is a research gap, especially relating to the use of mixed methods and interdisciplinary concepts in energy justice research in the global south [52]. Existing research focuses on solar home systems [4,7,8] or all distributed solar [51], whereas this paper looks specifically at solar minigrids.

3. Energy context in Tanzania

In Tanzania, 37.7 % of the population (21.8 million people) have access to electricity nationally. However, this is only around 19 % in rural areas (7.2 million people) [46]. Most connections recently have been through grid connections, but as of 2016, there were 109 registered minigrids [55]. The number of minigrids in Tanzania doubled between 2008, when the government introduced policy reforms, and 2016. Most new grids used renewable generation sources. The Rural Electrification Agency (REA) has not historically monitored small-scale electrification projects, so there is uncertainty around the number of minigrids.

The Tanzanian electricity provider, TANESCO, is responsible for the production, transmission, distribution, and sale of electricity. This is predominantly delivered through the national grid, but on some islands and in remote areas TANESCO has installed minigrids powered by hydro, diesel and solar.

TANESCO uses an increasing block tariff structure, or lifeline tariff [56]. The low rate (100Ts) is available to all TANESCO's domestic customers and applies to the first 75 units of electricity per month. For demand over 75 units, households pay 350 TSh. TANESCO uses cross-subsidisation from larger users to enable poorer households (with lower consumption) to pay a lower per-unit rate. However, this tariff does not apply to people on minigrids – whose tariffs are regulated by the Energy and Water Utilities Regulatory Authority (EWURA).

The Tanzanian Government introduced a new regulatory framework for small power producers in 2008 [55]. Projects below 100 kW are classified as Very Small Power Producers. Developers propose their tariff structure to EWURA, who approve them based on cost-recovery calculations. EWURA has reviewed the tariffs of several projects, but as of 2019 had not imposed an adjustment of the tariffs [60]. The private sector often implements solar minigrids – most are owned by international companies, but Tanzanian companies own a small number, with funding from non-governmental institutions, international institutions and the Tanzanian government.

Government funding is available to support rural customers with the cost of connecting to the national grid and to minigrid projects. The Rural Electrification Agency (REA) delivers results-based financing (RBF) [57], where developers receive funding for each household connection, up to an agreed quantity. This means rural households do not have to pay the true cost of their connection (including external wires, poles and meters). This does not cover their in-home wiring. However, many minigrid developers provide financing for this and their own technicians. In contrast, most households connected to TANESCO must arrange home wiring with a local technician and pay the costs upfront.

3.1. Tariff types

Tariffs can be divided into three broad categories, as shown in Table 1. These tariffs cost between 1000 and 6000 TSh per unit of electricity, which is significantly higher than the 100 TSh per unit charged by TANESCO. For all tariffs except flat rate, the average cost per unit that customers pay depends on the time-of-use and amount of electricity used. The annual cost has been calculated for low usage – 525 Wh of lighting per week (3 lights for 5 h per night) and 45 Wh of phone charging per week.

It is important to consider these tariffs in the context of household incomes. The national basic needs poverty line for 2018 was $256 UDS per adult per year (49,320 TSh per month), and the food poverty line was USD 175 per adult per year (33,748 TSh per month) [58]. In rural areas, 33 % of people live below the basic needs poverty line, and 9.7 % live below the food poverty line. The annual income distribution by quintile from 2011 is $180 (lowest 20 %), $294, $411 (middle 20 %), $574 and $1186 (highest 20 %) [59]. Annual electricity costs for basic usage (lighting and phone charging) range from $15 to $75 per year, representing a significant proportion of poorer household incomes.

As most income is from agriculture, it varies throughout the seasons and is not reliable day to day. In the case study village, daily income depended on factors such as the weather, the state of the roads, and whether buyers had come to the village. The amount of money available to spend on electricity also varies due to other costs, such as schooling, healthcare, and food.

4. Methodology

4.1. Study design and area

This research has taken a multi-method case study approach, collecting qualitative and quantitative data on minigrid tariffs in Tanzania. This approach draws on the strengths of both approaches, which provide different perspectives on complex issues [60]. Being able to consider the

Table 1
Tariff types in Tanzania.

Tariff type			Tariff description	Example residential tariff (average cost per unit low usage/mid usage)[a]	Project type	Annual cost – low usage[a] (USD)[b]
Pay per unit	Flat rate		Cost per unit (kWh) of electricity used	3500 TSh/kWh (3500 TSh/3500 TSh) 60 TSh/kWh (60 TSh/60 TSh)	Private solar minigrid Private hydro mini-grid (4 MW) [55]	$44.61 $0.76
	Time-of-use tariff		Cost per unit (kWh) of electricity varies depending on time of day	3000 TSh/kWh 10 am–6 pm 6000 TSh/kWh 6 pm–10 am (5880 TSh/5760 TSh)	Private solar minigrid (16 kW)	$74.96
	Block tariff	Increasing	Cost is set per unit (kWh) is constant for a certain quantity of units used. Cost per unit (kWh) increases or decreases as consumption increases	100 TSh/kWh – first 75 kWh per month 350 TSh/kWh – usage over 75 kWh per month (100 TSh/100 TSh)	National Grid tariff – TANESCO Residential tariff	$1.27
		Decreasing		4000 TSh/kWh – first 3 kWh per month 2500 TSh/kWh – usage over 3 kWh per month (4000 TSh/2800 TSh)	Private solar minigrid (6–16 kW)	$50.98
Pay per month	Units per day		Cost per month to receive a fixed number of units (kWh) per day	11,000 TSh per month for 275 Wh per day (4500 TSh/1320 TSh)	Private solar minigrid (48 kW)	$57.39
	Limited power capacity		Cost per month with no set limit on energy usage, but a constrained power limit (W)	3000 TSh per month for 100 W limited load (1230 TSh/200 TSh)	Community-owned solar minigrid (15 kW) [55]	$15.65
Subscription			Cost per month plus rate per unit (kWh) used	Used for business customers	TANESCO and private minigrids	

[a] Typical load profiles from household surveys – low usage (2.44 Wh per month; lights and phone charging) mid usage (15.2 Wh per month; lights, security lights, phone charging, TV, radio, and speakers).
[b] Using rate of $1 USD = 2300 TSh.

multiplicity of contributions to development outcomes using multiple methods allows an appreciation of not just what is happening, but how and why it affects people [61]. The case study approach used is intended to demonstrate the challenges facing communities, and does not have a purpose of demonstrating statistical validity.

Six communities with solar minigrids across Tanzania were visited during field visits in 2019 and 2020. Projects were selected to cover a range of regions and management companies. In these communities, 36 interviews were conducted with key informants, such as project managers, technicians, village leaders, and electricity agents. Observations were made in each village, and 16 focus groups were held, with 6–20 participants. In the main case study village (730 households), there was greater community participation in the research, including 103 household semi-structured interviews, which included survey questions on energy use and income. I worked with village leaders and local guides to select participants representative of the community.

For all projects, data were collected on the tariffs charged by the company. In the case study village, we completed surveys on appliance usage and household income, and were provided with customer payment data from the company.

The communities visited as part of this project were in remote, rural areas. All minigrids visited were solar-powered, with battery storage. Some also had a diesel backup system. Project capacity was between 16 and 100 kW, so all projects are Very Small Power Producers, and can set their tariffs. Villages visited were in the regions of Tanga, Mwanza, Pwani, Morogoro, and Dodoma. Tariffs for minigrids are a highly sensitive political issue in Tanzania, so this paper does not name specific companies or locations. This is to protect the researcher's relationship with companies while the research is ongoing. Pseudonyms have been used alongside quotes to protect individuals' anonymity.

Income in the villages visited is primarily from agriculture, which varies throughout the year depending on the season. People's total income depends on the size of harvests and the produce market. Income varies daily, depending on the availability of waged work and receiving income from crops. Road access to villages could be unreliable, particularly during the rainy season.

4.2. Methods

The collection of qualitative data was influenced by Participatory Research, which recognises the plurality of knowledge, specifically of those who have been systematically excluded [64]. For each situation, there are multiple interpretations possible, by both researchers and participants [68]. Participatory research has the potential to look at topics that may have been systematically missed through other research approaches, thus producing distinctive knowledge. Taking a critical realist approach, using various methods, leads to broader interpretations, more rooted in community experiences than the positivist paradigm often used in techno-economic research, with a focus on quantitative data [66].

Research activities took place in participants' homes and central village locations, such as school buildings. I was accompanied by a Tanzanian research assistant, who conducted activities in Swahili. Notes were made during activities, as well as recordings which were transcribed. I participated in Swahili and through translation by the research assistant.

During the fieldwork, themes were identified and investigated through an iterative approach. This included reporting back initial findings and seeking feedback from participants. The qualitative data were then imported into NVivo, and a grounded theory approach [62–64] was used to further analyse the key themes. These data were viewed through lenses of electricity as a social right and as an economic good [13] with influences from the literature on energy justice, particularly energy ethics [12].

Survey data were used to create typical load profiles for low-usage and middle-usage households. Households were grouped using criteria of what appliances they used and total demand. These characteristics were then used to create a type-profile featuring appliances used and time of use. These load profiles were used to calculate household electricity costs across different tariff types. Data on household incomes, collected in the study and from desk research, allowed us to compare the costs of tariffs to incomes. In the case study village, customer payment data were analysed to understand the proportion of households who did

not pay their electricity bill each month, or who underpaid. This provided quantitative insights into the impacts described by research participants.

4.3. Limits to methodology

The main limitation of this study is the quantity of data collected from non-case study villages, particularly a lack of information from companies. I have used insights from interviews with people involved with the project, and applied experiences recorded in the case study to other contexts, such as variation in income from agriculture. There are always challenges in human-centred research around the reliability of data collection, particularly due to researcher bias and how participants perceive the research project. For example, as I arrived in several villages with staff from the company, there were assumptions that I was employed by them. It was important to listen to participants to be aware of these assumptions and to be clear that independent research would only be reported anonymously back to the company. Challenges with language and translation were mitigated by having a good working relationship with my research assistant and triangulating ideas through multiple methods.

5. Results

Approaches to solar minigrid tariffs, and the costs that communities pay, will be analysed across four themes: project planning; getting connected; uses of electricity; and flexibility of usage. These themes are used to identify different forms of injustice that are realised in rural electrification projects.

5.1. Project planning

When planning projects, companies' priorities are to correctly size the project and ensure that customers can afford electricity. Companies identify villages that are likely to have a good level of demand, ability to pay (including potential for income-generating activities) and proximity of houses. This means that even in the early stages of project planning, poorer communities and more remote communities are excluded from electricity access.

In several villages, communities reported being told during the consultation phase that the tariff would be affordable, but no specific detail on costs or the tariff model. They were keen to get access to electricity and accept projects, as they considered it development for their village, even though they didn't have complete information. There are questions about who is included in project planning, and when. Companies target participation to potential customers, such as businesses and wealthier households in the village. This means poorer households are excluded from the consultation process.

Another challenge with private companies implementing standalone projects is a lack of holistic development [49]. As part of agreements with village leaders, companies often provide connections to healthcare and education facilities – which increases demand on the system. However, there is a disconnect between village development plans and how projects are implemented. For example, although electricity is necessary for many income-generating activities, businesses are limited by poor transport and communication infrastructure.

This demonstrates how considering energy as an economic good, with processes led by private sector actors, leads to the exclusion of poorer households in consultations and project implementation. Companies only providing limited information on tariffs at early stages in the consultation period means they are not adequately discussed, and communities don't have full information about what they are signing up for.

Once villages have been identified, companies complete surveys to understand demand and ability to pay. However, these are often flawed and overestimate both demand and ability to pay. The ability to pay is estimated by looking at households' current outgoings on energy, such as kerosene, and paying to charge phones. Poorer households, like Juma in the quote below, make sacrifices in other areas, such as education, clothing, and healthcare, to afford energy. Therefore, this figure is not a direct proxy for what they are willing or able to pay for electricity, as shown by the quote below.

> "*When we don't have money, we have porridge instead of breakfast, we just boil bananas, it will be bland food. We were told about the health insurance, but we don't have it because we don't always have the money. We just take the children to school… they can have porridge, they don't always have a comfortable life, they know the income that we have, we are all used to it.*"
>
> Juma - farmer with electricity connection

Project planning is important both when considering electricity as an economic good and a social right. Across all tariff types, there are challenges in estimating demand. This often leads to oversized projects and higher costs. On pay-monthly tariffs, it can be easier to plan future demand, as each customer has either a fixed capacity or a fixed quantity of units per day. However, demand will still vary depending on the number of customers. Using time-of-use tariffs can reduce the need for storage on the system.

There are issues of procedural injustice in solar minigrid planning, as poorer households can be excluded from planning processes, and companies provide limited information to communities. This demonstrates how the cost of increased private sector involvement is broader than just financial impacts, but households can be excluded in other ways.

5.2. Getting connected

Minigrid developers providing rural electrification in Tanzania receive financing from the government for each connection delivered [57]. This means they can provide subsidised connections to a set number of customers. The cost of connections can be prohibitive, so subsidies that reduce this are often needed [28].

A certain number of connections are funded per project, which means households who can connect early are more likely to get this benefit. Developers are encouraged to connect customers with higher electricity demand, as this will provide them with higher income. Wealthier households who can connect, or choose not to, are more likely to afford alternatives, such as solar home systems. Companies will identify larger and wealthier villages to implement projects, meaning poorer communities miss out as a whole [23].

Developers will plan the distribution network for the system based on concentrations of customers who can pay, so customers who live further from the village centre can be less likely to connect, particularly if they have lower incomes. Households who are fearful about costs or have expectations that the grid will arrive can lose out on the subsidised connections. Grass houses are deemed unsafe for mains electricity due to the fire risk.

> "*I want electricity, but the poles aren't close to my house. What will I gain?*"
>
> Ahmad - farmer without electricity connection

Most companies provided financing for household wiring, so customers did not have to pay upfront. However, having to pay a monthly contribution towards their wiring costs on top of electricity costs meant they viewed electricity as much more expensive.

This study found that households may be connected to the minigrid, but self-disconnect at times of the year when they can't afford to pay. A common issue with the fixed monthly cost was that customers' income varies throughout the year due to harvesting seasons. This means around 50 % of customers, such as Musa in the quote below, went some months without electricity, as they couldn't afford the monthly fixed costs. On other types of tariffs, customers can reduce their usage without having to

go completely without electricity (and use batteries, kerosene and pay to charge phones). A further issue with income is that customers' income varies daily, so they may not have the full amount to pay at once.

"*It can last a month. In a year can happen three times or more depending on the earning we get. We use kerosene lamp and we charge phones from our neighbours*"

Musa - farmer with electricity connection

This demonstrates how there are distributive injustices regarding who gains connections within communities. A further issue is self-disconnection, which was particularly prevalent on pay-monthly tariffs, where customers would go several months without an electricity service due to lack of income.

5.3. Uses of electricity

In rural communities, electricity is used for lighting, phone charging, and entertainment appliances in households. Common businesses using electricity include hair salons (mainly for men), TV showrooms, shops with fridges, as well as businesses such as restaurants using lighting to increase operating hours. Energy is used in health centres, village offices and schools. Some communities have larger electricity users, such as small industry and telecommunications towers.

Lighting was a key use of electricity in all households in this study – and it can't be switched to daylight hours. Many households did not benefit from the lower costs during the day because of a lack of income and capital to buy other appliances. Most households in this study were primarily farmers, such as Hadija in the quote below, who spend the daylight hours working their land. This means other activities, such as phone charging, occur at night.

"*I wish to see the same tariff for day and night because there is a lot of cost to use electricity at night, the night price is too high.*"

Hadija - farmer with electricity connection

As well as lighting, people value using electricity for communication, entertainment, personal presentation, education, and healthcare. People reported that having access to radio and television enabled them to be more active citizens, as they could follow what was happening in their country and across the world. Members of the community pride themselves in having electricity – both because of the direct impacts (such as clothes being cleaner than when using kerosene lights), but because it is a symbol of development. Most households not connected to the grid reported benefits to their community, such as improved healthcare and education provision, community lighting, and an increase in businesses in the village, as shown by the quote from Zainab. However, others, such as Asha, did not see how they had benefited at all.

"*In the past, if I went to the hospital, I had to go with my lamp, but now there is light. There are salons - I don't have to have my kids using razors. I see so many changes. When I visit my friend's house, I see light, I feel happy.*"

Zainab - farmer without electricity connection

"*Electricity has not affected my life.*"

Asha - farmer without electricity connection

Households that have been able to obtain a connection are still limited in how they can use electricity. A lack of access to financing and affordable appliances means they are often limited to using electricity just for lighting and mobile phone charging. When companies use pay-monthly and decreasing block tariffs, poorer households pay more per unit of electricity, as they do not own appliances to use all their electricity allowance or to reach higher levels of demand with lower unit costs (Table 1).

Companies aim to stimulate income-generating activities, such as shops, manufacturing, and other services. The economic benefits of this are that these businesses are likely to have higher demand and ability to pay than households. They are likely to be able to vary their demand, using electricity during the day when it is cheaper to produce. This was observed in communities through companies providing financing for appliances and lower business tariff rates. In practice, many businesses still struggle, as access to electricity is not their only limitation. They are held back by a lack of accessible markets, skills, financing, and poor road networks. This can mean that these activities do not increase the income of the community, but change the distribution of wealth within them, increasing local inequality. This quote from Mariam demonstrates how households are limited not by their production of crops, but by having available markets.

"*Money stays within [the village] – there is barter trading within the village, but not much money coming from outside. We have a lot of crops, but nowhere to sell them*"

Mariam - farmer with electricity connection

When electricity is considered an economic good, companies use tariffs to maximise their profits. Decreasing block tariffs incentivise higher electricity usage, but increases costs per unit for lower usage (often poorer) households. Households with lower usage pay more per unit on pay-monthly and subscription tariffs. Time-of-use tariffs only benefit those who can vary their demand. Households who use electricity for lighting and phone charging pay a higher cost per unit. These are examples of distributional injustice, as the costs are a greater burden on lower-income households. Companies preferentially connect customers with higher demand, particularly where there are a fixed number of subsidised connections. This leads to recognitional injustice, where lower usage households are excluded from access.

5.4. Flexibility of usage

On solar minigrids, it is cheaper to provide electricity during daylight hours, as night-time usage increases the capacity of batteries needed, and they degrade over time. For tariffs to be more economically efficient, load shifting is incentivised through time of use tariffs, as discussed in Section 5.3.

Income from farming varies throughout the year, depending on harvests and crop yields. It varies daily, depending on when buyers come to the village. This means households' ability to pay for electricity varies throughout the year. Tariffs with a fixed monthly cost pose a challenge, as, during these months especially, households must decide whether to spend money on electricity or other needs. In the case study village with this tariff, 50 % of households self-disconnected for at least one month a year. During this time, they use a combination of battery-powered lighting, kerosene, and paying to charge their phones. Using kerosene causes air pollution and is damaging to people's health, as well as being less bright and making clothes dirty. In villages with pay-as-you-go tariffs, people would reduce their usage, but would still be able to make small payments.

On pay-as-you-go tariffs, customers can monitor their usage, receiving an alert when their credit is running out. This can be a challenge, as agents are not always available, particularly later in the evening – when electricity is most often used, or at weekends.

Another issue is the minimum amount that customers can top up, which was set at 1000 TSh (0.43 USD) across most of the projects visited. As income varies daily, several participants, such as Gordon, suggested a lower minimum top-up would be more suitable for their incomes. This had a larger impact on customers with lower or less certain incomes, as they were more likely to run out of electricity and need to top up more regularly. If they were not able to top up, households would need to resort to previous sources of light, such as kerosene or solar appliances. These provide a lower quality of light, and kerosene can be unsafe.

"*Currently the system has changed, the minimum amount to pay is 1000 TSh. It is too big, people want to pay 200, 300, 500 TSh.*"

Gordon - teacher with electricity connection

Representatives from companies explained that a lower minimum top-up would increase their overheads, as there is a cost per transaction. This would mean an increase in the cost of electricity. They suggested encouraging customers to top up larger amounts encourages them to use more electricity.

People dislike that they must use their units over a fixed duration. This can be an issue, particularly if they leave the village for some time, such as to visit family or go to the hospital. Customers noticed they had units left in the meter at the end of the month, but they would lose them if not used.

> "*The electricity bundle being like voucher is not good, even if you have not used it, units run out at the end of the month, it is not okay*"
>
> Ally - businessman with electricity connection

In all the projects visited, the communities were happy with the reliability of the service – it was generally available 24/7, with occasional short outages. This contrasts with local villages on the national grid, which report outages lasting days or weeks.

As companies have fixed monthly costs, it is economically beneficial to have a regular reliable income, such as through pay-monthly or subscription tariffs. However, these present challenges for both households and businesses, as their income is variable, and they value being able to change their usage depending on income.

6. Discussion

The main argument in this paper is that current market-led approaches lead to injustices in access to electricity. Low-income households are often excluded from both planning processes and access to connections. Low-income households who can connect experience higher per-unit costs and barriers due to minimum top-up amounts. Going forward, energy access projects, particularly minigrids, need to consider how to improve justice and fairness. This includes meaningful participation at all stages of project and policy development, and consideration of the distributional impacts of projects and their tariffs.

The current approach to subsidies in Tanzania encourages companies to target wealthier households for connections. It reduces a barrier to connections, but the cost-reflective tariffs and connection costs charged are too high for many households. This means wealthier households benefit more from funding from government and other sources, as found by Samarakoon [8] in the context of off-grid solar in Malawi. Another issue found in solar appliance markets by Samarakoon [8] and Cross [9] is the availability of poor-quality appliances, including counterfeits, and poor customer service for repairs and faults. Although minigrids present similar issues with distributional injustice [34] both among and between communities, customers were generally satisfied with the quality of the service they received.

Private companies are driven by economic principles, so they often implement tariffs that mean poorer households pay a higher price per unit of electricity than wealthier ones – such as time-of-use tariffs, decreasing block tariffs and pay-monthly tariffs (Table 1). Although TANESCO, the national electricity provider, provides an increasing tariff (where lower usage is charged at a lower rate), there is no incentive for private companies to follow suit. This aligns with Pedersen [65], who found that although rural electrification companies claim to be driven by social values, commercial approaches dominate their actions.

The benefits for poorer households could be improved by solar minigrids providing an increased variety of energy services. However, these households are less likely to be involved in the planning of projects, so can be excluded from decision-making – an example of procedural injustice [34]. Although companies implementing minigrids often provided local benefits, such as connections to schools and health centres, they were unable to act on other community needs, such as improved roads or access to water. A further challenge is the capacity of solar minigrids, particularly for providing alternatives to cooking with firewood. This lack of holistic development limits the wider benefits of electrification [66], particularly for those who are unable to connect.

There are often conflicts between considering electricity as a social right [5] versus an economic good [31]. Electricity connection costs and tariffs play a big role in this. For example, time-of-use tariffs encourage efficient use of the system, but force people to pay higher costs for lighting their homes. Increasing the minimum payment amount reduces company overheads and may encourage usage, but means poorer households struggle to pay for, and therefore use electricity. This supports findings by Bayliss et al. [36] that privatisation increases inequality. Burger [31] suggests the optimal method to resolve this inequality is through means-tested rebates for vulnerable customers, as they are likely a small proportion of customers. Low incomes compared to electricity tariffs across the community mean most customers would require rebates, which would not be sustainable without government support.

As these projects are delivered by the private sector, they need to cover their costs and strive to make a profit. Even with the subsidies provided, this is proving difficult, which leads to further questions about whether the private sector is best placed to provide electricity necessary for people's basic needs. Another approach could be to have increased regulation to protect lower-income customers. However, the reason for the current low regulation policy for Very Small Power Producers (below 100 kW) is to reduce the costs of regulatory burden on companies, which may increase costs for households [31].

Another important factor is communities' perspectives of fairness and justice [12,67]. Several respondents raised the philosophical idea of Ujamaa [68], in which Nyerere argued that the ideal society must have equality, freedom and unity. His socialist ideals were grounded in African principles of family-hood and communalism [69]. These principles are seen in the affordable lifeline tariff offered to households connected to the national grid, but caused frustration to communities with minigrids as they felt they were not being treated as equals to their fellow citizens. Other communities may value different principles, such as individual liberty, which demonstrates the importance of understanding local interpretations of fairness and justice.

7. Conclusions

This paper presents the impacts of a wide range of tariffs used in solar minigrid projects. It highlights key questions that should be asked about policy and practice around tariffs, including whether it is right for the private sector to play such a large role in delivering basic services. In Tanzania, the responsibility for delivering electricity infrastructure is being passed from the Government to the private sector, leading to poorer households being burdened with high costs, or being excluded from access to electricity.

The private sector can access different streams of funding and implement projects faster than the state, as demonstrated by the increase in solar minigrid projects in Tanzania following policy reforms [55]. However, the connections they provide are generally to those most able to pay in rural areas, rather than more inclusive approaches that don't leave households and communities behind. When combined with a lack of holistic development [32], richer households benefit most from these projects, and poorer households miss out.

One way to reduce the costs of solar minigrids is through targeted subsidies [37,45] – but how they are currently being provided to the grid maintains the exclusion of poorer households through cost-reflective tariffs. This reflects the conflict between energy being seen as a basic need, and the dominant role of the private sector in delivering electricity in rural areas.

The arguments in this paper contribute to wider discussions about the role of the private sector in energy for development. The findings support the idea that marketised solutions reach those who are most able to pay, rather than those who are most in need [39]. This leads to the poorest in communities, and poorer communities overall, being left behind on progress towards the Sustainable Development Goals.

This paper adds to the existing literature by bringing together approaches from different disciplines – particularly human-centred participatory approaches and economic analysis. Further research is needed into alternative models of service delivery, and policies that create a more just situation.

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Declaration of competing interest

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Data availability

The author is able to share data on minigrid tariffs, however the data from interviews is confidential.

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