Environment and Development Economics (2025), 1–19
doi:10.1017/S1355770X25000099

RESEARCH ARTICLE

What could explain low uptake of rural electricity programs in Africa? Empirical evidence from rural Tanzania

Remidius Denis Ruhinduka,[1]* Gunther Bensch,[2] Onesmo Selejio,[1] and Razack Lokina[1]

[1]Department of Economics, University of Dar es Salaam, Dar es Salaam, Tanzania and [2]Department of Climate and Development Policy, RWI – Leibniz Institute for Economic Research, Essen, Germany
*Corresponding author: Remidius Denis Ruhinduka; Email: rremidius@yahoo.com

(Submitted 1 May 2024; revised 21 November 2024; accepted 9 January 2025)

Abstract

Increasing electricity access remains a challenge, particularly in rural areas of sub-Saharan Africa. This study examines the case of Tanzania, where connection rates remain low even among rural households residing 'under the grid', and this despite substantial government subsidies for household connections. Using data from 1,774 rural households living within reach of the electricity grid, we investigate correlates of the low grid electricity uptake. We find that proxies for wealth are positively associated with connection status, while social network variables are less so. Capacity to pay thus appears to remain a major barrier, and in-house wiring costs emerge as a significant expense unaddressed by the existing subsidy scheme, exceeding grid connection costs sevenfold. Similar mechanisms influence the choice between grid electricity and traditional or solar energy sources. These findings inform the ongoing policy debate on subsidy design and the role of alternative energy sources in expanding access.

Keywords: electricity access; electrification; energy transition; household decision; Tanzania

JEL classification: D12; O13; O33; Q41

1. Introduction

Achieving the Sustainable Development Goal (SDG) 7 of universal access to electricity by 2030 will require additional efforts. The transition to clean energy is important to counter the local and global environmental externalities induced by the continued reliance on fossil and biomass energy sources (Balboni *et al*., 2024). Access deficits are particularly chronic in rural sub-Saharan Africa, where the number of people without access in 2021 was around 450 million, more people than in 2010 (IEA *et al*., 2023). This is despite heavy investment by several governments in the region to improve rural access to grid electricity (cf. Lenz *et al*., 2017, for example). The government of Tanzania has devoted significant effort and resources to a rural electrification program since 2007. Under this program, households are required to pay only the equivalent of US$13 to get connected to grid electricity, as opposed to the normal connection price of US$80.

Household connections have remained low even among those residing along the grid line (Chaplin *et al.*, 2017). Low grid electricity uptake has also been found in other sub-Saharan African countries, including Burkina Faso (Schmidt and Moradi, 2023) and Kenya (Lee *et al.*, 2016). Lee *et al.* (2020) later randomly allocated rural connection subsidies in Kenya and diagnosed a sharp decline in connection rates as fees increase: while almost all households connected if connection was for free, a subsidy equivalent to 57 per cent or 29 per cent increased connection rates by only 23 and 6 percentage points, respectively, with similar findings provided by Bernard and Torero (2015). Beyond connection costs as a potential driver, relatively little is known about drivers of and barriers to household grid connections (Bonan *et al.*, 2017).

This paper looks more closely into the low rural uptake of grid electricity by testing various potential correlates of uptake among households living within reach of the electricity grid in rural Tanzania. Unlike Kenya, the government of Tanzania has largely subsidised rural electricity connection fees. This raises the question of whether high connection fees contribute to the low uptake. While the running costs of electricity are another obvious and frequently cited reason for non-connection (Bos *et al.*, 2018), this paper focusses on key household-specific characteristics as potential determinants. Our data on households living within reach of the grid enabled us to better identify such factors. We argue for the importance of household-specific characteristics in addressing not only the second hurdle to connecting to grid electricity (i.e., connection fee), but also the first hurdle, the cost of inhouse wiring, which has typically not been considered in previous studies. In light of a relatively high penetration rate of individual solar photovoltaic (PV) systems, even among households living within reach of the electricity grid, we also assess the choice between grid electricity and decentralised solar energy to shed more light on this aspect of the rural energy transition.

For this analysis, we use information from both connected and non-connected households in electrified communities collected with a carefully designed sampling frame and survey instrument. The study sample comprises 1,774 households from 43 rural hamlets located in central Tanzania. Using cross-sectional data applied to simple binary and multinomial logit models, we find that household income and wealth proxies and – only selectively – social network variables play important roles in connection status, paralleling the findings of other technology adoption studies (Lewis and Pattanayak, 2012; Jaime *et al.*, 2020). These associations are found when assessing the choice between grid electricity and traditional energy sources, as well as between grid electricity and solar energy. These results hint at the importance of other cost barriers, and we briefly discuss one candidate, in-house wiring, with costs many times higher than those for grid connections in rural Tanzania.

The remainder of this paper is organised as follows. Section 2 provides contextual background on energy access in rural Tanzania. Section 3 describes the methodology of the study, including sampling and data collection and the estimation strategies. Section 4 presents the results, including both descriptive statistics and main estimation results. Section 5 concludes the study.

2. Energy access in Tanzania: trends and interventions

The household sector consumes the highest share of the country's primary energy (73 per cent) and 40 per cent of electricity (Mkoma and Mabiki, 2011; Sander *et al.*, 2013; URT,

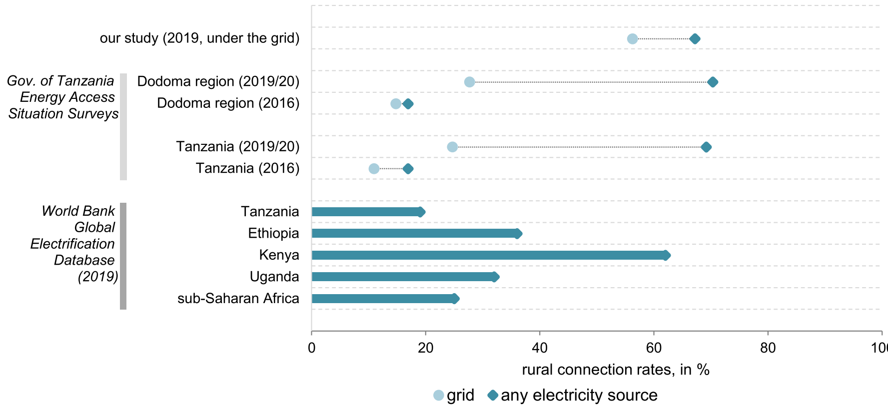

Figure 1. Rural electricity and grid electricity access rates in Tanzania and other East African countries. *Sources:* URT (2017, 2020); IEA *et al*. (2021).

2015; Lusambo, 2016). The World Bank Global Electrification Database (WB-GED) reports that, by the time of our survey in 2019, 19 per cent of rural households were connected to an electricity source, a low rate even for East African and sub-Saharan African standards (see bottom of figure 1). In the poor rural setting, lighting is the primary use of electricity. Households have clearly been moving away from kerosene, as evidenced by the sharp decline in the share of rural households using kerosene as the main source of lighting energy, from 70 per cent in 2011/12 to 9 per cent in 2017/18 (URT, 2013, 2019; see also Bensch *et al*., 2017). Cooking as the energy service that accounts for most of domestic primary energy demand is mainly done with biomass, even in households with grid electricity (Kulindwa *et al*., 2018; Alem and Ruhinduka, 2020; Bensch *et al*., 2021).

Figure 1 also presents data from the Government of Tanzania Energy Access Situation Surveys conducted in 2016 and 2019/20. There is a notable increase in the use of off-grid sources such as decentralised solar devices, both in our study region of Dodoma and in Tanzania as a whole. Separate surveys of rural areas in northern and western Tanzania over a similar period confirm this trend (Bensch *et al*., 2019). Tanzania is a hotspot for non-branded solar products imported from China, for the distribution of pico-solar lighting products and for the development of mobile-based, pay-as-you-go business models for solar products. A variety of solar products exists, ranging from smaller solar lighting systems to larger solar home systems capable of powering multiple appliances. While the data in figure 1 points to the challenge of classifying different solar energy products as electricity sources or not, the main point that emerges from the figure is the following: our study is conducted in a dynamic energy-access setting in which grid electricity is taken up only incompletely by households, even when available.

The limited improvements in the adoption of grid electricity access come despite considerable efforts to extend rural electricity grids. These efforts have been streamlined with the establishment of the Rural Energy Agency (REA) in 2008 as an autonomous body under the Ministry of Energy. REA's annual budget increased in real terms 50 times to US$239 million in 2016–17 (Godinho and Eberhard, 2018). REA in particular subsidised connection fees in recently electrified villages, and households living in proximity of distribution lines – thus requiring no extra electricity poles for household connection

– had to pay 27,000 Tanzanian Shillings (TSh), which is equivalent to US$13, instead of the regular TSh177,000 (US$80) by the research year (TANESCO, 2019). There are several challenges to promoting access to grid electricity in rural Tanzania. Firstly, rural Tanzania has a low population density and is marked by sparse settlements. This attenuates the financial sustainability of infrastructure investments such as the extension of the national electricity grid. Secondly, regulated tariff rates are below the cost of generation, also considering the substantial transmission losses of 25 per cent (Gregory and Sovacool, 2019). This makes connecting households to the electricity grid a loss-making venture for the utility (Blimpo and Cosgrove-Davies, 2019). Third, the parastatal electricity utility company, Tanzania Electric Supply Company (TANESCO) is partly perceived as being inefficiently organised with an ambivalence toward reform (Twesigye, 2022). As a consequence, even in electrified villages, household connection rates remain low. The Government of Tanzania estimates that 78 per cent of the Tanzanian population has access to grid electricity by the year 2020 in that they reside close enough to an electricity pole, but only 38 per cent of the country's population is actually connected (URT, 2020).

3. Methodology

3.1 The data

The data used in this study was collected in a large cluster in Mpwapwa district of Dodoma region in central Tanzania. This cluster includes all 43 electrified sub-villages (hamlets) from 24 villages in a radius of 35 km around the district office of TANESCO. The TANESCO district office served as a reference because technicians are sent from these offices when prospective customers request an electricity connection. The 35 km threshold ensured that there were no supply side restrictions on electrification. TANESCO confirmed being able to reach villages within this radius easily, whereas it sometimes faces difficulties with requests from more remote places. This is due to poor rural road conditions and insufficiency of physical and human resources. The sub-villages were all electrified in the context of REA's rural electrification schemes, REA I to REA III.

The survey was conducted at the household level in August 2019, with complementary data collected at the sub-village level. The primary study population comprised households living within reach of the electricity grid. After consultation with TANESCO, we defined households living at most 60 m from the nearest electricity pole as within reach of the grid or 'under the grid' as we refer to them in the remainder of the paper. Those living further away need to pay for additional poles which generally makes it prohibitive for individual households to connect. Sampling in this corridor used a census of non-connected households, which had been conducted for a prospective field experiment that was intended to focus on interventions among non-connected households. Sampled non-connected households had to meet a precondition for connection that the utility TANESCO imposes for safety reasons: their roofs have to be made of iron sheets. We also applied this criterion in our sampling so that we could better understand what other factors drive the low uptake of electricity, conditional on meeting the required criteria.[1] Connected households were additionally and randomly sampled during the census exercise, by a ratio of 1:4 or 1:5, depending on the sub-village size. Most sub-villages had between 125 and 250 households. Interviews were conducted with a

[1] With the increased adoption of modern roofing (URT, 2019), this structural requirement no longer represents the strong barrier to connection that it was a few years earlier (cf. Ahlborg and Hammar, 2014).

person who was present on the day of the interview and who knew the household and its economic situation. In 74 per cent of cases this was the head of the household.

After using GPS data to verify that non-connected households in the sample live within the 60-m threshold, our final sample comprises 1,774 households, of which 259 are connected. The actual rate of grid connection in our sample of households under the grid is on average 56 per cent, according to data provided by sub-village representatives.

3.2 Estimation strategy

We estimate two types of econometric models to study the demand factor correlates of electricity uptake using our survey data. First, we use a binary logit model, where household electricity access is regressed on a comprehensive set of predictor variables:

$$Y_{ij} = X_{ij}\beta + u_{ij}. \tag{1}$$

Y_{ij} is an indicator of connection to the electricity grid of household i in sub-village j and takes the value 1 if the household is connected to the electricity grid, otherwise 0. β is the vector of coefficients of interest and u_{ij} is the error term assuming logistic distribution. X_{ij} is a vector of explanatory variables.

We selected these X_{ij} variables based on factors linked to the uptake of modern energy sources as articulated in the literature on fuel switching behaviour and on the adoption of environmental technologies more generally (Van der Kroon *et al*., 2013; Pattanayak *et al*., 2018; Aguilera *et al*., 2024). In this context, we also consider the literature on appliance adoption, as the two decisions are highly interdependent.[2] The potential adoption factors mostly relate to what Van der Kroon *et al*. (2013) refer to as the household-internal opportunity set, which can be categorised into housing characteristics, demographic and socioeconomic factors, and social network related factors (see table 1). The literature on social networks, for example, asserts that the decision to adopt a new technology could be influenced by the adoption decisions of the household's network of family and friends (Bandiera and Rasul, 2006; Conley and Udry, 2010; Beaman *et al*., 2021). As we will discuss later, a cross section of these variables can also be considered as proxies of wealth as a crucial factor for electricity uptake. We additionally control for the geo-referenced distance from the sampled households to nearby electricity poles and to the nearest TANESCO district office as additional, primarily external factors potentially relevant for electricity uptake. The variables additionally have been chosen for being plausibly unaffected by an electricity connection in order to avoid confounding through an effect of the electricity connection outcome on these explanatory variables. This led us to exclude energy consumption from the studied explanatory variables, for example.

Second, we adopt a multinomial logit model (MNL), given that MNL allows the analysis of decisions across more than two types of energy sources. This is to account for the strong increase in decentralised electricity sources in rural Tanzania even among households under the grid. In our case, the response variable Y_{ij} includes three distinct main

[2]The literature associates the demand for electric appliances with income and other household characteristics (Rao and Ummel, 2017). Wolfram *et al.* (2012) and Dhanaraj *et al.* (2018) emphasise that a threshold income is necessary for purchasing durable goods and that energy consumption grows rapidly beyond this point. However, for sub-Saharan Africa, studies by Taneja (2018), Bensch *et al.* (2019), and Masselus *et al.* (2024) indicate that appliance uptake and electricity consumption remain low even over the long term, suggesting that many households have not yet reached that threshold income.

Table 1. Descriptive statistics

Variable description	Connected households		Non-connected households		Connected vs. non-connected
	Mean	SD	Mean	SD	*p*-value
Panel A: Housing and geographic characteristics					
Housing wall is made of brick/stone/cement	0.69		0.47		0.00
House is privately owned	0.97		0.93		0.03
Number of rooms in the house	4.15	1.39	3.47	1.04	0.00
Distance from the nearest electricity pole, in meters (GPS measured)	20.87	10.75	25.02	13.21	0.00
Distance to the district TANESCO offices, in km	21.14	14.96	20.55	14.52	0.55
Panel B: Demographic and socioeconomic factors					
Age of household head	44.20	12.60	45.83	16.24	0.13
Household head is male	0.78		0.66		0.00
Household head is married living with spouse	0.88		0.70		0.00
Household head completed primary education	0.75		0.66		0.00
Household head is employed or runs own business	0.18		0.11		0.00
Household size	5.60	2.13	4.68	2.08	0.00
Daily family expenditure on basic needs, in TSh	8,100	17,200	5,700	17,300	0.04
Any household member owns a bank account	0.11		0.05		0.00
Panel C: Social network related factors					
Number of years lived in the village	17.07	13.38	15.75	14.59	0.17
Number of closest neighbours connected to electricity	2.35	2.20	2.15	1.83	0.12
Number of friends/relatives connected to electricity within the village	3.51	5.08	2.52	3.21	0.00
Amount of remittance received from friends/relatives within past six months, in TSh	29,000	68,000	20,100	57,000	0.02
Panel D: Electricity access					
Main source of lighting energy					
kerosene, candle or dry-cell battery	0.04		0.74		0.00
solar energy	0.01		0.25		0.00
grid electricity	0.95		0.00		0.00
Number of observations	259		1,515		1,774

SD, standard deviation.

lighting energy alternatives k: electricity from the central grid, decentralised electricity (i.e., solar energy with solar home systems or other electricity source) and traditional non-electric sources (i.e., kerosene, candle and dry cell battery light). Accordingly, the MNL model can be specified as follows:

$$Prob(Y_{ij} = l) = \frac{\exp(X_{ij}\beta_l)}{\sum_{k=0}^{2} \exp(X_{ij}\beta_k)}, \tag{2}$$

where l is the light energy source chosen by household i from sub-village j. X_i is the same vector of explanatory variables as in equation (1). In different specifications, we use either traditional energy sources or decentralised electricity as the reference category, meaning we set the β of this reference category to zero, which turns its $\exp(X_{ij}\beta)$ equal to one. Thus, β_l represents the vector of estimated coefficients for each of the two alternative lighting energy sources l, respectively. The results of the MNL model are interpreted in terms of relative risk ratios, i.e., the probability of choosing one outcome category divided by the probability of choosing the reference category (Rahut *et al.*, 2017; Bensch *et al.*, 2018). Accordingly, a parameter above (below) 1 indicates that the probability of choosing grid electricity is higher (lower) than the probability of remaining with the reference electricity source, either traditional energy sources or decentralised electricity.

4. Results

4.1 Descriptive statistics

Table 1 presents descriptive statistics of our sampled households, differentiated by connection status. We show three sets of explanatory variables in panels A to C to underscore the different roles played by each of these sets of factors on the uptake of modern energy sources as articulated in the literature. Panel D shows descriptive statistics on the dependent variable, electricity access.

Panel A presents housing and geographic characteristics of our sampled households. Notably, connected households have bigger houses which are more often made of modern wall material according to simple bivariate t-tests on equality in means. The average distance from the nearest TANESCO office is 21 km.

Only 12 per cent of household heads are engaged in off-farm activities (panel B). All socioeconomic variables, except age of household head, show significant differences between households with grid electricity and households without the connection. For example, the average daily expenditure on basic needs over the past month[3] suggests that connected households are relatively richer (TSh8,100 or US$3.5 per day) than non-connected households (TSh5,700 or US$$2.5 per day).

We present variables related to social networks in panel C. We measure the extent of social networks by a number of variables, including years lived in the village, number of relatives and friends connected to electricity both within and outside the village, and the amount of cash transfers (remittances in TSh value) received by the households from relatives or friends living outside the village (which is obviously also a measure of ability to pay). The number of friends and relatives who are connected to electricity and the

[3]The exact formulation of the question that elicited expenditure on basic needs in our survey instrument was '*Over the past month, approximately how much has your family been spending on average per day to finance all the basic needs (food, drinks, etc)?*'. Enumerators were instructed that what falls under 'etc' would only include related expenditures such as transport costs in relation to the purchase of food.

value of remittances that households receive both show significant variations between households with and without grid electricity.

Finally, Panel D makes it clear that for virtually all connected households, grid electricity is also their main energy source of lighting. At the same time, 25 per cent of non-connected households have an alternative decentralised solar electricity source at their disposal (other decentralised sources such as diesel generators are not found in our sample) and 74 per cent rely on traditional sources of light (i.e., kerosene, candles, and dry-cell batteries).

These results suggest that social and economic differences are correlated to some degree with the uptake of electricity in rural Tanzania. A more detailed analysis of these findings is provided in the following section. While our sample was not designed to be representative of rural Tanzania, as it focuses specifically on households under the grid, household characteristics in our sample align relatively closely with national statistics, such as those in the Household Budget Survey 2017/18 (URT, 2019). For example, the national rural mean household size is 4.9 (compared to 5.1 in our sample) and the rural share of households with modern walling materials is 71 per cent (compared to 60 per cent in our sample), while the average daily expenditure on basic needs is TSh4,800 (compared to TSh6,000 in our sample).

In terms of local energy access, it is important to note that the decentralised solar energy category in panel D encompasses the variety of products referred to in section 2. This diversity means that household adoption of solar energy can vary in both functionality and cost, impacting the relative cost effectiveness of the different energy access options, household energy usage and potentially related socioeconomic outcomes. Dry-cell battery lamps are available at costs as low as US$2, while solar lamps tend to be more expensive at around US$20. Solar home systems typically cost more than US$100, with costs going up to US$700 for more powerful systems and cheaper non-branded systems entering the market at the time of our survey (Bensch *et al.*, 2019; Ankel-Peters *et al.*, 2024). Across these configurations, it appears consistent that solar energy offers greater comfort and versatility compared to traditional energy sources (such as kerosene, that would cost around US$1 per litre). At the same time, solar energy falls short of the capabilities provided by grid electricity, which allows running high-power appliances and machinery for a wider range of productive purposes. Considering that appliance uptake beyond lighting is typically low among rural people, traditional and solar energy options not only allow for lower upfront costs, but typically also have slightly lower recurrent costs (cf. also Bensch *et al.*, 2019).

4.2 Main estimation results

Table 2 presents the results from the binary logit model estimation, expressed as marginal effects. In column (1), we show the estimation results on the determinants of connection for a parsimonious model that controls only for the five housing and geographic characteristics falling under panel A of table 1. Adding further controls enables us to assess other relevant correlates of electricity connection in rural Tanzania and to test the robustness of our estimates to various model specifications.

The results suggest that distance from the TANESCO office has no association with choosing to connect to grid electricity, which supports the notion that the sampled villages are sufficiently close to that office to be served when interested in a household connection. Households located further from the nearest electricity pole are somewhat less likely to have their houses connected to grid electricity even under the restriction of

Table 2. Binary logit estimates on correlates of connection

Dependent variable:	Grid electricity connection	
Coefficients:	Marginal effects	
	(1)	(2)
Housing wall is made of brick/stone/cement	0.101 (0.022)	0.080 (0.021)
House is privately owned	0.051 (0.033)	0.038 (0.032)
Number of rooms in the house	0.047 (0.008)	0.036 (0.007)
Distance from the nearest electricity pole, in meters	−0.003 (0.001)	−0.003 (0.001)
Distance to the district TANESCO offices, in km	0.000 (0.001)	0.000 (0.001)
Age of household head		−0.001 (0.000)
Household head is male		−0.010 (0.021)
Household head is married living with spouse		0.081 (0.019)
Household head completed primary education		0.016 (0.017)
Household head is employed or running an own business		0.026 (0.029)
Household size		0.009 (0.003)
Daily family expenditure on basic needs, in TSh		0.000 (0.000)
Any household member owns a bank account		0.053 (0.040)
Number of years lived in the village		0.001 (0.001)
Number of closest neighbours connected to electricity		−0.002 (0.005)
Number of friends/relatives connected to electricity within the village		0.002 (0.003)
Remittance received from friends/relatives within past six months, in TSh		−0.000 (0.000)
Pseudo R^2	0.094	0.133
Observations	1,774	1,774

Note: Standard errors clustered at the sub-village level in parentheses.

a 60-m radius. Specifically, an extra ten m from the electricity pole reduces the likelihood of connection by 3 percentage points, other factors held constant. First, this may be due to the fact that the 60-m radius is not a sharp cutoff – for example, obstructions between the network and a house may need to be circumvented, so an extra pole may be required even within this radius. Accordingly, distance may partly drive adoption even in closer vicinity to the grid. Second, we cannot exclude that our distance measure is endogenous to a household's political influence. If that was the case, electricity poles may be strategically located closer to households whose owners are relatively more influential in the villages due to their economic or political status.

Housing characteristics as measured by the number of rooms and walling materials are robust predictors of connection status. Households with bigger houses and those with strong walling structures (i.e., brick, cement or stone walls) are more likely than their counterparts to be connected to grid electricity. While wall characteristics could put an indirect physical constraint on connection (e.g., through the convenience of house wiring), we believe that the mechanism through which housing size could influence connection is primarily as another proxy for household's ability to pay.

We present the estimation results for the broader set of potential correlates of connection in column (2) of table 2. Coefficients for the housing and geographic characteristics remain largely unchanged. Beyond that, we find that relatively older household heads are less likely than their younger counterparts to have their houses connected to grid electricity, all else equal. Married household heads living with their partners are more likely to connect, suggesting that having a stable household structure increases the incentive to invest in long-term improvements such as electricity and that these households face less severe financial constraints that discourage such investments compared to those living alone (i.e., non-married, divorced, or widowed), all else equal. A married couple is also likely to have more social interactions because of their children and relatives on both the husband's and wife's side; thus, connection to the grid electricity may be a priority to ensure stable lighting (for both the family but also for the night studies of their school-going children) and use of some appliances like television for the family and the relatives who come to visit the household. When it comes to the role of social networks, we find that remittances received from close relatives and friends and the number of social connections are not associated with the household's decision to connect, all else equal. Note that our measures may not capture all aspects related to social networks; for example, Du *et al.* (2016) suggest that the strength of relationships between individuals is more important for information diffusion related to energy decisions than the number of connections they have.

Average household expenditure on basic needs shows no significant relationship with electricity connection. While this measure can be seen as a proxy for income (cf. Rashid *et al.*, 2024, for example), the fact that it covers essential and thus less elastic expenditures could partly explain the observed results. In contrast, the number of years a household has resided in the village is found to be associated with connection. Given that some of the assessed variables can more broadly be viewed as different proxies of wealth, we also re-estimated the model in column (2) of table 2 collapsing these variables into a wealth index using principal component analysis (Filmer and Pritchett, 2001). This alternative specification confirms the significance of wealth while leaving the other coefficients largely unchanged (table A1 in appendix).

The MNL model results can be taken from table 3. The interpretation of the relative risk ratios (RRRs) is in reference to the base category mentioned at the bottom of the table, either traditional non-electric lighting energy sources (i.e., kerosene, candles and dry-cell batteries) or decentralised, mainly solar energy sources, allowing us to understand potential drivers of grid connection. We see that changes in the distance from an electricity pole not only makes it less likely to be grid connected compared to relying on traditional lighting sources but also compared to using solar energy sources. This implies that those further from electricity poles not only have a lower probability of connecting to grid electricity but are also relatively more likely to use decentralised electric sources. These results are robust even after controlling for additional covariates as presented in columns (3) and (4). Consistent with previous results, we find that in most cases housing characteristics correlate significantly with the probability of using grid electricity over traditional lighting sources or over solar energy. On average, households with more rooms and households with walls made of brick, stone, or cement (as opposed to lower-cost traditional building materials) are more likely to opt for grid electricity rather than using traditional energy or solar energy as main lighting sources, all else equal. Again, these results are stable and robust when controlling for other covariates.

Looking deeper into the extended set of controls in columns (3) and (4), results confirm our previous results in that married families and households that have lived longer in the village are more likely to use grid electricity as opposed to traditional sources, all else equal. Family expenditure, as a proxy for income, does have a significant but economically minimal effect on the likelihood of connection to grid electricity. The number of friends/relatives connected to grid electricity within the village and remittances now weakly increase the likelihood of using a connection to the grid as opposed to traditional energy sources or solar energy sources.

We find that for none of the assessed variables is the RRR significantly above one with traditional energy sources as the reference category, and at the same time below one with solar as the reference category, or vice versa. The results in table 3 are very consistent with those presented in table 2, suggesting that the choice of any given lighting source, including the uptake of REA electricity, is not random but rather influenced by a set of parameters. It may also help to better understand the correlates of grid electricity uptake to compare the RRRs in table 3 with those of decentralised solutions vis-a-vis traditional energy sources. These are presented in table A2 in the appendix. We see that, overall, the same variables are predictive of abandoning traditional energy sources, while correlations tend to be smaller for decentralised solutions than for grid electricity, most notably for the housing construction material as a stronger wealth measure. In line with expectations, the two distance measures are above 1 and (weakly) significant, implying that households living further away from electricity poles and TANESCO offices are more likely to switch to decentralised solutions.[4]

4.3 Exploratory analysis of the role of in-house wiring costs

Discussions with different stakeholders in the preparatory phase of our survey suggested that in-house wiring poses an additional deterrent. We therefore added questions to our survey about households' spending on in-house wiring. Indeed, these reported costs amount on average to TSh240,000 (US$115), which is about seven times higher than the grid connection fees paid to the utility for the wiring and equipment needed to connect the house to the local low-voltage distribution grid. Interestingly, expectations about in-house wiring costs among households not yet connected to the grid are only slightly below the actual costs reported by connected households, and also differ by a factor of seven. Hence, in-house wiring costs plausibly represent a barrier for many households

[4] Appendix table A2 also presents a variant of the multinomial model estimations where we include the wealth index that consolidates information from the different wealth proxies, analogous to the robustness check conducted for table 2.

Table 3. Multinomial logit estimates on correlates of lighting energy choices

Dependent variable: Coefficients:	Grid electricity connection Relative risk ratio (RRR)			
	(1)	(2)	(3)	(4)
Housing wall is made of brick/stone/cement	3.003 (0.604)	1.922 (0.419)	2.534 (0.489)	1.879 (0.412)
House is privately owned	2.044 (0.945)	1.769 (0.973)	1.797 (0.803)	1.535 (0.812)
Number of rooms in the house	1.859 (0.137)	1.232 (0.073)	1.758 (0.133)	1.189 (0.078)
Distance from the nearest electricity pole, in meters	0.975 (0.006)	0.965 (0.008)	0.974 (0.006)	0.965 (0.008)
Distance to the district TANESCO offices, in km	1.003 (0.008)	0.991 (0.011)	1.005 (0.008)	0.995 (0.010)
Age of household head			0.977 (0.006)	0.991 (0.008)
Household head is male			0.913 (0.214)	0.940 (0.239)
Household head is married living with spouse			3.466 (1.025)	1.846 (0.441)
Household head completed primary education			1.313 (0.249)	1.103 (0.244)
Household head is employed or running an own business			1.638 (0.422)	1.220 (0.335)
Household size			1.085 (0.043)	1.045 (0.035)
Daily family expenditure on basic needs, in TSh			1.000 (0.000)	1.000 (0.000)
Any household member owns a bank account			1.681 (0.556)	1.336 (0.400)
Number of years lived in the village			1.021 (0.007)	1.017 (0.008)
Number of closest neighbours connected to electricity			0.970 (0.051)	1.006 (0.051)
Number of friends/relatives connected to electricity within the village			1.049 (0.026)	1.003 (0.033)
Remittance received from friends/relatives within past six months, in TSh			1.000 (0.000)	1.000 (0.000)
Pseudo R^2	0.073	0.073	0.119	0.119
Observations	1,774	1,774	1,774	1,774
Reference category	traditional	solar	traditional	solar

Note: Standard errors clustered at the sub-village level in parentheses.

by making overall grid connection costs prohibitively expensive. In the absence of exogenously varied in-house wiring costs, our data does not allow us to assess this hypothesis in more detail.[5]

5. Discussion and conclusion

In recent years, the Tanzanian government policy has been committed to extending electricity to rural villages and providing connection subsidies. Despite these efforts, the rate of grid connection has remained very low. Our analysis shows that, despite the high level of subsidies for grid connections, household wealth status still seems to significantly influence the decision to connect, beyond other factors such as the stability of household structures. This may be partly because better-off households are more likely to be able to afford not only the connection cost but also the subsequent purchase of electric appliances (e.g., radio, television), something that can act as a motivating factor. We also find indications that in-house wiring costs present a substantive additional cost barrier typically unaccounted for. Future research could look more rigorously at this cost factor to see how much of a barrier it is to household electricity uptake, for example by randomly varying subsidies that also cover wiring costs. In addition, policy could consider technical alternatives to reduce wiring costs for low-income households such as readyboards, which are pre-assembled, compact electrical distribution boards.

Any such policy efforts have to consider both the financial sustainability of subsidy schemes and the cost effectiveness of on- versus off-grid solutions. It is key that the marginal fixed and operational costs of the electric utility company to connect and service a new household justify the size of marginal subsidy per household. Like most African electricity utilities, the Tanzanian utility, TANESCO, seems to struggle with covering costs when connecting low-consuming households. For future research, it therefore seems relevant to link information on operational costs and on electric appliances adoption with the intensity of electricity usage to explore these crucial questions on the financial sustainability in the electricity sector.

Existing literature recognises the transformative potential of grid electricity, but also highlights the limited environmental and productive impacts in rural areas of recently electrified areas (Peters and Sievert, 2016; Bos *et al.*, 2018; Lee *et al.*, 2020), suggesting that smaller-sized and cheaper off-grid solutions may be the more cost-effective solution for certain regions and population strata (Ankel-Peters *et al.*, 2024). We also find indications for a shift of user preferences from on-grid to smaller and cheaper off-grid technologies, considering that a notable share of households opt for individual solar energy even in our study sample of households living within reach of the electricity grid. In this context, we furthermore find that the mechanisms that lead households to choose electricity over traditional energy sources seem to work in a similar way when it comes to choosing between electricity and decentralised solutions such as individual solar energy sources.

[5]In appendix table A3 we present results for the estimations in table 3 where we add in-house wiring costs as an additional explanatory variable, using both actual wiring costs for connected households and expected wiring costs for non-connected households. Wiring costs turn out to be positively correlated with connection status. Since wiring costs are likely subject to stronger endogeneity and measurement error compared to other explanatory variables, this positive correlation should be rather understood as reflecting two confounding factors: (i) households that are more capable and willing to pay for higher wiring costs have already decided to connect, making observed wiring costs a reflection of their financial capacity and willingness to invest rather than a direct barrier to connection, and (ii) non-connected households tend to expect lower wiring costs than the actual wiring costs incurred by connected households, which may reflect an underestimation of the financial burden by non-connected households.

Data. The Stata data and code that support the findings of this study are available at https://doi.org/10.7807/ruhindukaetal25-ede:v1.

Acknowledgements. We thank Jörg Ankel-Peters, Mats Hoppenbrouwers, and Elisabetta Di Vito for their valuable support. We are also grateful to two anonymous referees and the guest editors for enriching comments and suggestions.

Competing interest. None.

References

Aguilera F, Reyes R, Schueftan A, Zerriffi H and Sanhueza R (2024) Understanding the role of people's preferences and perceptions in the analysis of residential energy transition: a meta-analysis. *Energy for Sustainable Development* **82**, article 101534.

Ahlborg H and Hammar L (2014) Drivers and barriers to rural electrification in Tanzania and Mozambique–grid-extension, off-grid, and renewable energy technologies. *Renewable Energy* **61**, 117–124.

Alem Y and Ruhinduka RD (2020) Saving Africa's tropical forests through energy transition: a randomized controlled trial in Tanzania. Ruhr Economic Papers 885.

Ankel-Peters J, Bensch G, Moull K, Rauschenbach M and Sievert M (2024) Cost-effectiveness of rural energy access strategies. DEval Discussion Paper 1/2024. Bonn: German Institute for Development Evaluation (DEval).

Balboni C, Dobermann T, Greenstone M, Reguant M and Ryan N (2024) Energy and environment. IGC Evidence Paper. London, UK: International Growth Center.

Bandiera O and Rasul I (2006) Social networks and technology adoption in northern Mozambique. *The Economic Journal* **116**, 869–902.

Beaman L, BenYishay A, Magruder J and Mobarak AM (2021) Can network theory-based targeting increase technology adoption? *American Economic Review* **111**, 1918–1943.

Bensch G, Peters J and Sievert M (2017) The lighting transition in rural Africa – from kerosene to battery-powered LED and the emerging disposal problem. *Energy for Sustainable Development* **39**, 13–20.

Bensch G, Grimm M, Huppertz M, Langbein J and Peters J (2018) Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews* **90**, 1060–1068.

Bensch G, Cornelissen W, Peters J, Wagner N, Reichert J and Stepanikova V (2019) *Electrifying Rural Tanzania. A Grid Extension and Reliability Improvement Intervention*. The Hague: Netherlands Enterprise Agency.

Bensch G, Jeuland M and Peters J (2021) Efficient biomass cooking in Africa for climate change mitigation and development. *One Earth* **4**, 879–890.

Bernard T and Torero M (2015) Social interaction effects and connection to electricity: experimental evidence from rural Ethiopia. *Economic Development and Cultural Change* **63**, 459–484.

Blimpo MP and Cosgrove-Davies M (2019) *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact*. Africa Development Forum. Washington, DC: World Bank Group.

Bonan J, Pareglio S and Tavoni M (2017) Access to modern energy: a review of barriers, drivers and impacts. *Environment and Development Economics* **22**, 491–516.

Bos K, Chaplin D and Mamun A (2018) Benefits and challenges of expanding grid electricity in Africa: a review of rigorous evidence on household impacts in developing countries. *Energy for Sustainable Development* **44**, 64–77.

Chaplin D, Mamun A, Protik A, Schurrer J, Vohra D, Bos K, Burak H, Meyer L, Dumitrescu A, Ksoll C and Cook T (2017) *Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation*. Princeton, NJ: Mathematica Policy Research.

Conley DT and Udry CR (2010) Learning about a new technology: pineapple in Ghana. *America Economic Review* **100**, 35–69.

Dhanaraj S, Mahambare V and Munjal P (2018) From income to household welfare: lessons from refrigerator ownership in India. *Journal of Quantitative Economics* **16**, 573–588.

Du F, Zhang J, Li H, Yan J, Galloway S and Lo KL (2016) Modelling the impact of social network on energy savings. *Applied Energy* **178**, 56–65.
Filmer D and Pritchett LH (2001) Estimating wealth effects without expenditure data – or tears: an application to educational enrollments in states of India. *Demography* **38**, 115–132.
Godinho C and Eberhard A (2018) *Power Sector Reform and Regulation in Tanzania – Tanzania Institutional Diagnostic. Chapter 7: Power Sector Reform and Regulation in Tanzania*. Oxford, UK: Economic Development and Institutions. Available at https://edi.opml.co.uk/wpcms/wp-content/uploads/2018/09/07-TID_Power-sector.pdf.
Gregory J and Sovacool BK (2019) The financial risks and barriers to electricity infrastructure in Kenya, Tanzania, and Mozambique: a critical and systematic review of the academic literature. *Energy Policy* **125**, 145–153.
IEA, IRENA, UNSD, World Bank, and WHO (2021) *Tracking SDG7: The Energy Progress Report*. Washington, DC: World Bank.
IEA, IRENA, UNSD, World Bank, and WHO (2023) *Tracking SDG 7: The Energy Progress Report*. Washington, DC: World Bank.
Jaime MM, Chávez C and Gómez W (2020) Fuel choices and fuelwood use for residential heating and cooking in urban areas of central-southern Chile: the role of prices, income, and the availability of energy sources and technology. *Resource and Energy Economics* **60**, article 101125.
Kulindwa YJ, Lokina R and Ahlgren EO (2018) Driving forces for households' adoption of improved cooking stoves in rural Tanzania. *Energy Strategy Reviews* **20**, 102–112.
Lee K, Brewer E, Christiano C, Meyo F, Miguel E, Podolsky M, Rosa J and Wolfram C (2016) Electrification for 'under grid' households in rural Kenya. *Development Engineering* **1**, 26–35.
Lee K, Miguel E and Wolfram C (2020) Experimental evidence on the economics of rural electrification. *Journal of Political Economy* **128**, 1523–1565.
Lenz L, Munyehirwe A, Peters J and Sievert M (2017) Does large-scale infrastructure investment alleviate poverty? Impacts of Rwanda's electricity access roll-out program. *World Development* **89**, 88–110.
Lewis JJ and Pattanayak SK (2012) Who adopts improved fuels and cookstoves? A systematic review. *Environmental Health Perspectives* **120**, 637–645.
Lusambo LP (2016) Household energy consumption patterns in Tanzania. *Journal of Ecosystem and Ecography*, S5:007. Available at https://www.omicsonline.org/open-access/household-energy-consumption-patterns-in-tanzania-2157-7625-S5-007.php?aid=72902.
Masselus L, Ankel-Peters J, Gonzalez Sutil G, Modi V, Mugyenyi J, Munyehirwe A, Williams N and Sievert M (2024) 10 years after: long-term adoption of electricity in rural Rwanda. Ruhr Economic Papers 1086.
Mkoma SL and Mabiki FP (2011) Theoretical and practical evaluation of Jatropha as energy source biofuel in Tanzania. In Bernardes MA (ed.), *Economic Effects of Biofuel Production*. Rijeka, Croatia: InTech, pp. 181–200.
Pattanayak SK, Pakhtigian EL and Litzow EL (2018) Through the looking glass: environmental health economics in low and middle income countries. In Dasgupta P, Pattanayak SK and Smith VK (eds), *Handbook of Environmental Economics*, Vol. **4**. Amsterdam, Netherlands: Elsevier, pp. 143–191.
Peters J and Sievert M (2016) Impacts of rural electrification revisited–the African context. *Journal of Development Effectiveness* **8**, 327–345.
Rahut DB, Behera B, Ali A and Marenya P (2017) A ladder within a ladder: understanding the factors influencing a household's domestic use of electricity in four African countries. *Energy Economics* **66**, 167–181.
Rao ND and Ummel K (2017) White goods for white people? Drivers of electric appliance growth in emerging economies. *Energy Research & Social Science* **27**, 106–116.
Rashid FN, Sesabo JK, Lihawa RM and Mkuna E (2024) Determinants of household food expenditure in Tanzania: implications on food security. *Agriculture & Food Security* **13**, article 13.
Sander K, Gros C and Peter C (2013) Enabling reforms: analysing the political economy of the charcoal sector in Tanzania. *Energy for Sustainable Development* **17**, 116–126.
Schmidt M and Moradi M (2023) Community effects of electrification: evidence from Burkina Faso's grid extension. Available at SSRN: https://ssrn.com/abstract{\mathsurround=\opskip$=$}4523234 or http://doi.org/10.2139/ssrn.4523234.

Taneja J (2018) If you build it, will they consume? Key challenges for universal, reliable, and low-cost electricity delivery in Kenya. Center for Global Development Working Paper 491.

Tanzania Electric Supply Company (TANESCO) (2019) Service Line Application. Available at https://www.tanesco.co.tz/customer-services/service-line-application.

Twesigye P (2022) Structural, governance, & regulatory incentives for improved utility performance: a comparative analysis of electric utilities in Tanzania, Kenya, and Uganda. *Utilities Policy* **79**, 101419.

United Republic of Tanzania (URT) (2013) Tanzania Mainland Key Indicators Report, 2011–12 Household Budget Survey. National Bureau of Statistics, Ministry of Finance and Planning. Available at https://microdata.nbs.go.tz/index.php/catalog/18/related-materials.

United Republic of Tanzania (URT) (2015) *National Energy Policy 2015*. Ministry of Energy. Available at https://www.nishati.go.tz/uploads/documents/en-1622283004-National%20Energy%20Policy%20(NEP),%202015.pdf.

United Republic of Tanzania (URT) (2017) *Energy Access Situation Report, 2016. Tanzania Mainland*. Government report prepared by National Bureau of Statistics (NBS) and Rural Energy Agency (REA). Available at https://www.nbs.go.tz/nbs/takwimu/rea/Energy_Access_Situation_Report_2016.pdf.

United Republic of Tanzania (URT) (2019) *Tanzania Mainland Key Indicators Report: Tanzania Household Budget Survey 2017–18*. National Bureau of Statistics, Ministry of Finance and Planning. Available at https://www.nbs.go.tz/nbs/takwimu/hbs/2017_18_HBS_Key_Indicators_Report_Engl.pdf.

United Republic of Tanzania (URT) (2020) Energy Access and Use Situation Survey II in Tanzania Mainland, 2019/20. Summary of Key Findings. Government report prepared by National Bureau of Statistics (NBS) and Rural Energy Agency (REA). Available at https://rea.go.tz/Articles/energy-access-and-use-situation-survey-in-tanzania-mainland-april-2020.

Van der Kroon B, Brouwer R and Van Beukering PJ (2013) The energy ladder: theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews* **20**, 504–513.

Wolfram C, Shelef O and Gertler P (2012) How will energy demand develop in the developing world? *Journal of Economic Perspectives* **26**, 119–138.

Appendix A. Complementary estimation results

Table A1. Binary logit estimates on correlates of connection, alternative specification

Dependent variable: Coefficients:	Grid electricity connection Marginal effects (1)
Housing wall is made of brick/stone/cement	-#-
House is privately owned	-#-
Number of rooms in the house	-#-
Distance from the nearest electricity pole, in meters	−0.003 (0.001)
Distance to the district TANESCO offices, in km	−0.000 (0.001)
Age of household head	−0.001 (0.001)
Household head is male	−0.002 (0.021)
Household head is married living with spouse	0.079 (0.019)
Household head completed primary education	0.008 (0.017)
Household head is employed or running an own business	0.008 (0.028)
Household size	0.008 (0.003)
Daily family expenditure on basic needs, in TSh	-#-
Any household member owns a bank account	-#-
Number of years lived in the village	0.001 (0.001)
Number of closest neighbours connected to electricity	−0.002 (0.005)
Number of friends/relatives connected to electricity within the village	0.003 (0.002)
Remittance received from friends/relatives within past six months, in TSh	-#-
Wealth index based on PCA	0.049 (0.009)
Pseudo R^2	0.135
Number of observations	1,774

Notes: -#- refers to the six variables collapsed into the wealth index based on principal component analysis (PCA) listed at the bottom of the table. In line with standard practise, the PC scores for the first component are used to create the index, with a mean of 0 and standard deviation of 1. Standard errors clustered at the sub-village level in parentheses.

Table A2. Multinomial logit estimates on correlates of lighting energy choices, alternative specifications

Dependent variable: Coefficients:	Grid electricity connection Relative risk ratio (RRR)		Connection to solar Relative risk ratio (RRR)	
	(1)	(2)	(3)	(4)
Housing wall is made of brick/stone/cement	-#-	-#-	1.563 (0.267)	1.349 (0.218)
House is privately owned	-#-	-#-	1.156 (0.325)	1.168 (0.309)
Number of rooms in the house	-#-	-#-	1.509 (0.084)	1.478 (0.081)
Distance from the nearest electricity pole, in meters	0.971 (0.006)	0.963 (0.008)	1.011 (0.006)	1.010 (0.006)
Distance to the district TANESCO offices, in km	1.006 (0.008)	0.994 (0.010)	1.012 (0.007)	1.010 (0.006)
Age of household head	0.979 (0.006)	0.991 (0.008)		0.986 (0.007)
Household head is male	0.933 (0.214)	1.062 (0.279)		0.972 (0.207)
Household head is married living with spouse	3.506 (1.018)	1.751 (0.397)		1.884 (0.397)
Household head completed primary education	1.199 (0.241)	1.062 (0.242)		1.191 (0.167)
Household head is employed or running an own business	1.269 (0.337)	1.184 (0.337)		1.338 (0.225)
Household size	1.068 (0.044)	1.046 (0.037)		1.039 (0.032)
Daily family expenditure on basic needs, in TSh	-#-	-#-		1.000 (0.000)
Any household member owns a bank account	-#-	-#-		1.259 (0.344)
Number of years lived in the village	1.023 (0.007)	1.017 (0.008)		1.004 (0.007)
Number of closest neighbours connected to electricity	0.964 (0.050)	1.003 (0.052)		0.964 (0.041)
Number of friends/relatives connected to electricity within the village	1.048 (0.024)	1.011 (0.033)		1.047 (0.028)

Continued.

Table A2. *Continued.*

Dependent variable: Coefficients:	Grid electricity connection Relative risk ratio (RRR) (1)	(2)	Connection to solar Relative risk ratio (RRR) (3)	(4)
Remittance received from friends/relatives within past six months, in TSh	-#-	-#-		1.000 (0.000)
Wealth proxy based on PCA	2.132 (0.166)	1.226 (0.076)		
Pseudo R^2	0.121	0.121	0.073	0.119
Number of observations	1,774	1,774	1,774	1,774
Reference category	traditional	solar	traditional	traditional

Notes: -#- refers to the six variables collapsed into the wealth index based on principal component analysis (PCA) listed at the bottom of the table. In line with standard practise, the PC scores for the first component are used to create the index, with a mean of 0 and standard deviation of 1. Standard errors clustered at the sub-village level in parentheses.

Table A3. Multinomial logit estimates on correlates of lighting energy choices, specifications including wiring costs

Dependent variable: Coefficients:	Grid electricity connection Relative risk ratio (RRR) (1)	(2)	(3)	(4)
In-house wiring costs, in TSh	1.0000 (0.000)	1.0000 (0.000)	1.0000 (0.000)	1.0000 (0.000)
In-house wiring costs, in log	1.956 (0.506)	1.809 (0.482)	1.981 (0.489)	1.923 (0.522)
Set of additional controls	Table 3, columns (1) & (2)		Table 3, columns (3) & (4)	
Pseudo R^2	0.081–0.082		0.128–0.129	
Number of observations	1,573	1,573	1,573	1,573
Reference category	traditional	solar	traditional	traditional

Notes: The table presents results for separate estimations including either wiring costs as a continuous variable or in logarithmic terms. Standard errors clustered at the sub-village level in parentheses.

Cite this article: Ruhinduka RD, Bensch G, Selejio O, Lokina R (2025). What could explain low uptake of rural electricity programs in Africa? Empirical evidence from rural Tanzania. *Environment and Development Economics* 1–19. https://doi.org/10.1017/S1355770X25000099