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Which context matters for capturing energy needs? A multi-level analysis

A. Puranasamriddhi [a,b,c,*], P.A. Trotter [b,d], P. Parikh [c], B. Batidzirai [e], A. Brophy [b,f]

[a] Environmental Change Institute, University of Oxford, Oxford, United Kingdom
[b] Smith School of Enterprise and the Environment, University of Oxford, Oxford, United Kingdom
[c] Engineering for International Development Centre, Bartlett School of Sustainable Construction, University College London, London, United Kingdom
[d] Schumpeter School of Business and Economics, University of Wuppertal, Wuppertal, Germany
[e] African Union Development Agency, Midrand, South Africa
[f] Saïd Business School, University of Oxford, Oxford, United Kingdom

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ABSTRACT

The need for development interventions to be context-specific in the Global South has become a mantra in the academic research over the last decade. However, there is ambiguity about which type of context actually matters, using the term to either mean different countries, sub-national regions, or specific communities. Here, ordinal logistic regression models are applied to novel survey data (N = 1016) on household and small business energy needs in rural Uganda and Zambia to analyse the extent to which current and aspirational energy consumption differ at the national, regional, district, and village levels. These results indicate that domestic energy needs vary statistically significantly between the two countries, and, notably, between districts and villages. By contrast, differences in productive energy aspirations appear to differ mostly at the national and regional level, with no significant variations associated with local district and village levels within each region. These results yield two central implications that contribute to discussions on multi-scale linkages within sustainability transitions research. First, conceptually, the results suggest that a multi-level assessment is beneficial to fully understand energy consumption and aspirations of a particular location while analyses at a singular level can overlook wider disaggregated patterns that transcend one specific level. Second, the variance of local-level household energy needs means that including local-level participatory elements into energy access policy-making and implementation might be required to adequately capture and respond to these different needs. By contrast, to meet productive use aspirations, associated initiatives may benefit particularly from factoring in economic differences between sub-national regions.

1. Introduction

Off-grid electricity systems play an essential role in realising the Sustainable Development Goals (SDGs) in sub-Saharan Africa (SSA). Past studies have identified the interlinkages of dependencies between SDG 7 – universal access to affordable, reliable, sustainable, and modern energy – and other SDGs, demonstrating that increasing energy provision can create systemic impacts which link to poverty alleviation, livelihood resilience, and economic growth [1,2]. However, despite the consistent decline in costs for off-grid systems, leading them to be cost-competitive [3,4], the progress to achieve the SDGs has been uneven and, especially in SSA, too slow [5]. In recent years, this has been exacerbated by socioeconomic shocks generated from multiple crises including the COVID-19 pandemic [6,7] and armed conflict in Ukraine [8], together with persistent challenges such institutional and regulatory shortcomings [9,10], as well as limited investment in the sub-region [11–13]. Furthermore, beyond these issues, each SSA country has its own set of socioeconomic and geopolitical specificities in terms of its development objectives and energy transition trajectory to consider [14]. The diversity of contexts and characteristics of and within each country needs to be taken into account in order to address the challenges and accelerate the efforts effectively and appropriately.

The international development community has recognised that energy access issues as well as expanding renewable energy to drive energy transitions are cross-cutting and complex; departing from dominating, more uniformist approaches to development in the 1980s and 1990s driven by the World Bank and the International Monetary Fund (IMF) [15,16], there is a widespread understanding that one-size-fits-all solutions to universal electrification are highly problematic as they fail to

* Corresponding author. Environmental Change Institute, University of Oxford, Oxford, United Kingdom.
E-mail address: akaraseth.puranasamriddhi@ouce.ox.ac.uk (A. Puranasamriddhi).

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List of abbreviations

ESMAP	World Bank's Energy Sector Management Assistance Program
GDP	Gross Domestic Product
IMF	International Monetary Fund
LPG	Liquefied petroleum gas
MTF	Multi-Tier Framework
PUE	Productive use of electricity
SDG(s)	Sustainable Development Goal(s)
SHS	Solar home systems
SSA	sub-Saharan Africa
UBOS	Uganda Bureau of Statistics
USD	United States Dollars
W	Watts

take into account the critical and diverse conditions in country-specific contexts [17–22]. The lack of single universal solution is due to a wide variety of physical, socioeconomic, and political conditions and challenges, including: geography and demography dispersion [23], energy resource and potential [24], appropriate technology and delivery models to meet users' affordability and needs [10,25,26], and governance structure [27]. Implementing energy policy measures and projects to meet these challenges will therefore be more effective when efforts are context-specific, and addressing unique features of each location in which they are applied to Ref. [28].

The key research gap this study addresses is to understand exactly at which, or a combination of, geographical levels the context matters most for defining user-specific energy needs. The term 'context-specific' itself is applied very broadly across research. It can relate to salient differences on a supranational level [20,29,30], a national level between different countries [14,31], a regional level between different sub-national districts [32], as well as a district level with small-scale geographic entities within a given district [33,34]. Each of these different levels of aggregation has its own actors, characteristics, and challenges. Examining multiple levels collectively makes it possible to identify within which geographic levels current and aspired energy use are most strikingly different. The results of such analyses can help policymakers, especially where they are resource-constrained, to decide which geographic level context-specific energy access policies need to be tailored to in order to be most impactful at meeting people's individual needs through renewable energy systems. Based on novel household data from rural Uganda and Zambia as case studies, this study's novel contribution is to address this research gap by analysing the association between individual energy consumption and aspiration preferences for domestic and productive uses of several of these levels (national, regional, district, and village) in a joint manner, demonstrating the differences in across levels and therefore the importance of capturing energy needs at multiple levels simultaneously.

2. Background

2.1. Context specificity and different geographic levels in rural electrification

Current studies have presented rich empirical evidence for the need of context-specific approaches to energy access that consider the diversity of requirements in different places due to a range of socioeconomic, political, and geographical factors [17,19,21,35]. This focus on context is mirrored in the research on sustainability transitions and innovation policy, where it highlights the importance of understanding the multiple levels of decision-making and interactions relevant for policy design [36–38]. Unpacking the role of decisions and relationships at different levels is critical in explaining the success or failure of different policies for example, and in transferring these lessons to other places. Furthermore, energy infrastructure tends to be physically present at multiple levels from local through to provincial, national, and even supranational [39]. Even when infrastructure such as off-grid energy has a local physical presence, it is embedded in and affected by provincial, national, and even global policies and practices [40].

The research on energy access has focused to date on both national and local levels of context with consideration for the variety of stakeholders involved in policy design and implementation. National context has been a focus in much of the research connected to high-level frameworks such as the 2030 Agenda for Sustainable Development. For instance, the study by Nerini et al. [1], which mapped the synergies and trade-offs between energy and the other SDGs, calls for supranational- and country-specific sustainable energy system strategies. Weitz et al. [41] and Nilsson et al. [42] also argue that countries must interpret the SDGs according to their national circumstances. Similarly, Mulugetta et al. [14] recommend that acknowledging each SSA country's differences in terms of development objectives and uncertainties is key in shaping its energy transition pathway and contributing to the achievement of the African Union's Agenda 2063. This top-down perspective starting with global frameworks designed by intergovernmental organisations in collaboration with national governments views the national level as the level required to design interventions. This perspective is supported by several empirical studies on energy access analysing the salient country-specific political, economic, and demographic drivers of urban and rural electrification across countries in Africa [43–45].

The focus on local levels of context has emerged more in research in recent years. By local, this research refers to a range of sub-national geographic clusters, ranging from the administrative units within a country to small-scale geographical entities such as villages. A focus on these sub-national levels reveals important differences in the implementation of energy access policies. For instance, Trotter et al. [32] study the differences in electrification rates between the 112 different districts across Uganda, demonstrating that cheaper and more equal ways of electrification can be achieved when compared with the government's focus on grid-extension. Similarly, Munro and Bartlett [46] underline the need to address the energy inequality in Northern Uganda by measuring electricity usage in three districts. Focusing on project implementation, Muhoza and Johnson [34] explore household energy transitions in a small rural community in Northern Zambia, highlighting shortcomings of the solar mini-grid (e.g., slow and partial adoption) due to a failure to account for local socioeconomic dynamics. In another contribution, Alova et al. [47] find that the project-specific design parameters of planned on-grid and off-grid generation plants in Africa have been especially critical for their eventual success.

While it is encouraging to see an increase in empirical studies that go beyond a focus on national context, what has been largely missing to date are analyses of electrification that combine multiple levels. There are two main benefits of such an integrated approach that combines national and local context. First, it can offer opportunities for resources to be coordinated between different actors in addressing the energy access challenge. As Sovacool and Brown [21] note, intervention at local and global levels has distinct costs and benefits not available to others. Local action promotes innovation and adaptation to specific circumstances and needs, while global action allows for uniformity and minimum transaction costs among actors. Examining multiple levels in detail simultaneously can provide insights in identifying the vertical disconnects between these top-down and bottom-up approaches. Finding ways for these approaches to complement each other as is critical in addressing several barriers including limited coordination between local and national public institutions and inability to transmit community demand due to lack of engagement with local stakeholders [10]. Second, an integrated analysis captures the multi-dimensional aspects of the energy challenge by recognising the relationships, factors, and influences between politics, economy, and society that transcend the distinctions between spatial levels [48]. By combining multiple levels, this research can uncover common and level-specific relationships, trends, and patterns across international, national, and sub-national levels [49]. Understanding these patterns can inform the development of policies in ways that account for differences in needs both now and in the future.

2.2. Energy consumption and aspirations for household and productive use in sub-Saharan Africa

This work focuses particularly on understanding how preferences for current and future energy use in rural areas of Uganda and Zambia differ across national, provincial, and village levels. Current energy use from traditional energy sources (e.g., kerosene and firewood) in rural communities is dominated by household use activities including lighting, cooking, water heating, and space heating [50,51]. Switching to electricity for household use plays a prominent role in improving rural livelihoods as it enables household members to use and benefit from electrical appliances. The socioeconomic benefits include potential education and health benefits, improved access to information and entertainment from radio and television, increased quality of life due to lighting and mobile phone usage, improved thermal comfort through fans or air conditioning, and increased variety and quality of diet through refrigeration [52,53]. However, many off-grid rural electrification projects and policies focus on only providing basic, minimum services, commonly electric light, and mobile phone charging, and ignore the wider benefits of electricity [54]. On-grid electrification projects similarly have the potential to capture significant socioeconomic value [52], but can be slow to do so [55].

This emphasis on prioritising basic energy services in rural areas limits the potential benefits of productive use of electricity (PUE), which integrates electricity as a direct input to produce goods and services. As research suggests, there is a direct, positive relationship between PUE and local economic development and growth of enterprises in SSA, particularly in the agricultural and industrial sectors [56–59], as it has the potential to remove energy access barriers and drive greater performance and productivity [60]. In the agricultural sector, for example, introducing PUE to business supply chains (e.g., grain milling, refrigeration, irrigation) can improve crop yields and increase post-harvesting production capacity and efficiency [50,61,62]. These benefits contribute to additional revenues and profits, and consequently strengthening of local economy.

To maximise the socioeconomic benefits, it is essential to align future energy usage aspirations with affordable and reliable energy access. Therefore, in addition to considering the current energy consumption, this research examines future energy aspirations in rural households. This provides a broader understanding of both the priority of electrical appliance ownership and energy demand [63] to enhance household and productive use activities, regardless of the present quality of energy access. While the increase (in both quality and quantity) in electrical appliance ownership does not immediately nor necessarily enhance household's socioeconomic well-being, it creates more opportunities for practice shifts to improve the overall well-being of household members [64].

2.3. Socioeconomic drivers for rural electrification in sub-Saharan Africa

To include relevant control variables into this research's models, this section briefly reviews the studies on socioeconomic drivers of rural electrification in SSA. The existing body of research has investigated the influence of socioeconomic variables on household energy choices and willingness to pay for electricity access in SSA, most notably (1) age, (2) gender, (3) education level, (4) household size, and (5) average income [65–71]. First, the impact of the household head's age on willingness to pay for electricity is inconclusive. Some studies find that an increase in age has a positive influence as older household heads are more economically well-off and tend to own more productive resources [66,69]. However, other scholars also argue that age has an insignificant to negative impact on willingness to pay for electricity as older households are less likely to accept change and consequently stay with their current energy choices [68,72].

Second, there is mixed evidence in the studies on the influence of gender on energy choices and willingness to pay for electricity. Some studies argue that women are more likely to adopt clean energy sources when compared to men [69,73]. One plausible explanation for this is that women are disproportionately exposed to indoor air pollution and responsible for the overall well-being of their households, therefore more aware of the health risks from pollution and the benefits of clean energy. Inversely, research on gender and energy needs in Ghana [74] and Tanzania [75] found that women tend to use traditional energy sources to support their food and retail enterprises, whereas men tend to use electricity for manufacturing-related activities. Other studies also discover that women have lower willingness to pay for electricity due to uneven decision-making power [70,72]. There is a consensus, however, that access to adequate electricity can enable women to operate their businesses with longer hours and exercise increased choice and control over the way in which their enterprises are run [76,77].

Third, education level is another key driver for rural energy usage in two different ways. To begin with, as households with higher education levels are associated with higher income levels, they are more likely to pay for improved electricity [65,66,70,71]. Moreover, households with higher levels of education tend to obtain greater awareness of the benefits of modern energy sources [69,72,73]. Therefore, households with higher education levels appear to be more likely to use clean and efficient sources of energy such as electricity, while households with no or limited education tend to use traditional energy sources such as firewood and kerosene.

Fourth, similarly to age and gender, the research has similarly not been clear on the effect household size has on energy usage in low-income countries. Guta [69] and Rahut et al. [73] reveal that an increase in household size has a positive impact on the adoption for clean energy sources. In contrast, Ismali and Khembo [71] and Ogwumike et al. [72] discover that household size is negatively related to electricity when compared to firewood and liquefied petroleum gas (LPG) due to expected increase in expenditure.

Lastly, households with higher average income have a higher purchasing power and, consequently, appear to have higher willingness to pay for clean energy sources, such as electricity [65,68,73]. For example, Sievert and Steinbuks [65] analyse the willingness to pay for electricity access of rural households in Burkina Faso, Rwanda and Senegal and demonstrate that households with higher income levels are more likely to pay for higher-Tier technologies like grid electricity. Inversely, households with lower income levels appear to prefer cheaper, ultra-low-cost alternatives such as solar home systems (SHS) and solar lamps [78].

3. Data and Methodology

3.1. Country contexts

Uganda and Zambia have been selected as case studies to address the research questions. Both countries are in SSA and share a similar profile in terms of electrification status. The rural electrification rates shown in Table 1 are 36 % and 15 %, respectively [79], with both countries exhibiting considerable urban to rural electrification inequality [80]. Furthermore, within Uganda and Zambia, the inequality in electricity access exists not only between urban and rural regions, but it is also evident among rural regions [46,81]. They also share similar characteristics in terms of energy access governance. According to Stritzke et al. [27], both countries have centralised, top-down energy access decision-making power structures with limited involvement from

Table 1
Energy characteristics of Uganda and Zambia.

Electricity access	Uganda	Zambia
Electrification rate, % (2022)[a]	47.1	47.8
Population without access to electricity, million (2022)[a,b]	25.0	10.4
Urban electrification rate, % (2022)[a]	72	87
Rural electrification rate, % (2022)[a]	36	15
Rural population without access to electricity, million (2022)[a,b]	22.4	9.3

[a] Tracking SDG7: The Energy Progress Report 2024 [79].
[b] World Bank data [80].

different ministries and private- and community-level stakeholders. Other shared geographic and socioeconomic characteristics are that the countries are both landlocked, a majority of the population live in rural areas, and have GDP per capita below 1400 USD.

3.2. Data collection

This study uses previously unpublished and unused data from the University of Oxford's and University of Cape Town project RISE in which extensive survey data was collected with a sample size of N = 1016 from 124 different villages in Uganda and Zambia. Data collection in the project took place between 2019 and 2020, and was completed slightly before the onset of the COVID-19 pandemic. Given Uganda's and Zambia's sub-national inequality in electricity access, it was necessary to collect data across multiple geographic locations to limit selection bias [82,83]. For Uganda, the survey was conducted in all four of Uganda's main regions: Central, Eastern, Northern, and Western. In Zambia, this research randomly selected two regions: Eastern and Southern. According to the Uganda Bureau of Statistics (UBOS), the poverty estimates in 2019-20 for each respective region are 8.7 %, 25.9 %, 35.9 %, and 14.4 % [84]. Similarly, the poverty levels in 2022 estimated by Zambia Statistics Agency are 76.4 % and 63.5 % for Eastern and Southern regions, respectively [85]. The research ensured that for each region, the sample size was at least N = 100 individually. To cover different levels while maintaining adequate sample sizes within the different geographical levels, a dual approach was followed. First, to study district-level differences, one region was randomly selected in Uganda (Northern Uganda) and five different regional districts were targeted, illustrated in Fig. 1. This was done to keep regional effects constant when analysing sub-regional effects. Within Northern Uganda, one district was randomly selected and four others within close proximity of the former were chosen randomly to further limit the geographical differences of districts within the same region. Second, to study village-level differences, within three randomly selected districts, a village was randomly selected and at least four other nearby villages were randomly to limit geographical differences of villages within a given district. It is key to say that while the study considers different district-village combinations, the resulting sample size for these within-district models is comparably small, and hence is able to yield only indicative results. Individual respondents were randomly selected within their villages. In total, 465 completed surveys from Uganda, and 551 from Zambia were obtained. Table 2 presents the distribution of household survey respondents by geographic locations, comparing it its respective population size.

An extensive community survey was used to collect data on rural

Table 2
Distribution of household survey respondents by geographic locations.

Region	District (sub-region)	No. of distinct villages	Sample size	District population size[a]
Central Uganda	Kalangala	15	122	65,488
Eastern Uganda	Bugiri	8	35	449,420
	Bugweri	5	34	182,695
	Mayuge	5	34	558,297
Northern Uganda	Agago	4	22	254,977
	Amuru	7	15	216,188
	Gulu	15	44	322,833
	Nwoya	3	18	203,834
	Omoro	1	19	192,521
	Other[b]	–	2	–
Western Uganda	Kasese	14	120	795,852
Eastern Zambia	Katete	29	450	292,756
Southern Zambia	Choma	18	101	298,344
Total		**124**	**1016**	

[a] Based on population in 2018, according to the United States Census Bureau [86].
[b] A total of two respondents in Northern Uganda did not specify their sub-regional locations.

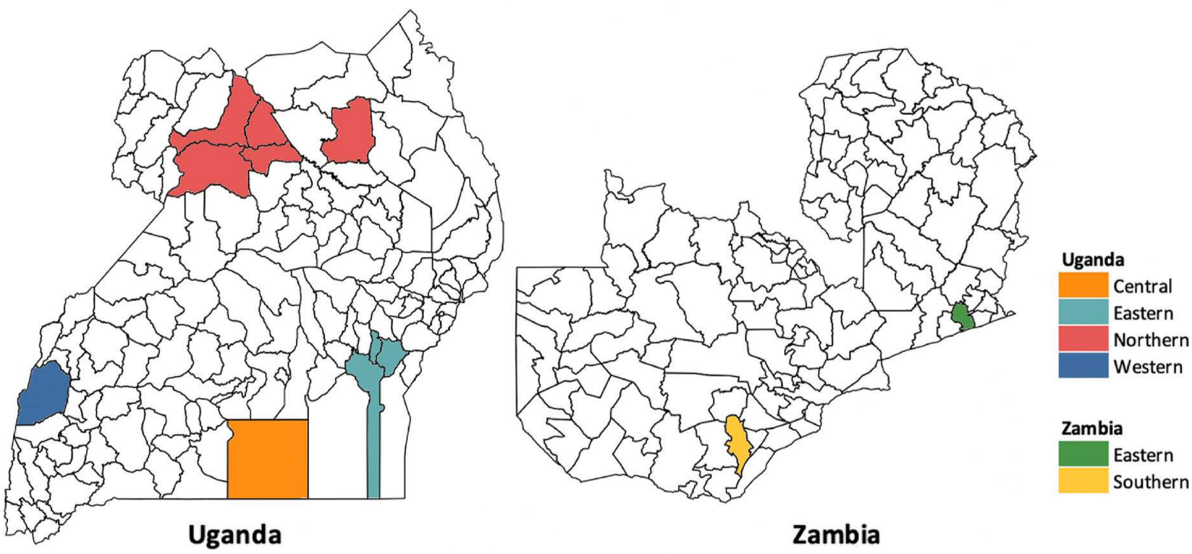

Fig. 1. Locations of the study area in Uganda and Zambia.

electrification. It had a total of 106 questions, 103 of which were closed, featuring relevant sections to this research on the socioeconomic background of the respondents, their current energy consumption, both at home and for productive use, and energy aspirations. Specifically, questions related to current energy consumption involved asking the respondents to provide information on the type of electricity supply connected (e.g., grid, mini-grid, SHS, and diesel or petrol generator), their main purposes for which they use electricity (e.g., lighting, cooking, cooling, and productive uses), and electrical appliances or machines currently owned, ranging from small devices including fans and radios to large equipment including fridges, mills, and irrigation systems. As for energy aspirations, respondents were asked to select desired electrical appliances or machines that they would like to own and use for both household and income-generating purposes but were unable to due to the lack of or unreliable power connection. All questions had an additional option to allow respondents to select “other” to specify additional appliances not on the survey list. After designing the community survey, an initial test was conducted in Katete District in Eastern Zambia to check survey duration and the relevance and consistency of questions. Once finalised, the survey was translated and provided in four local languages for authentic responses: Chichewa (for Eastern Zambia), Tonga (Southern Zambia), Luganda (Central Uganda) and Acholi (Northern Uganda).

3.3. Model specification

In this research, logistic regression (logit) has been applied extensively for analysing rural electrification at household level [69,73,87,88]. This study features multiple ordinal logistic regression models to explore the relationship between geographic and socioeconomic variables and current energy consumption and aspirations at national and sub-national levels across Uganda and Zambia. A total of 18 models were estimated and were categorised into three main sets according to dependent variables (1) Current energy consumption, (2) Household aspirations, and (3) Productive use aspirations. Each set contains six models, considering four different types of level dummy variables: country (1 model), regional (2 models), district (1 model), and village level (2 models). The results of these models were then compared and mapped based on both the statistical significance across levels for different variables (section 5). Clustering standard errors was performed at sub-regional levels.

It is critical to note that due to the fragmented nature of the data on a district and village level collected in Uganda, the resulting sample sizes used are comparably small for some of the Ugandan-specific district and village models, and are thus only able to provide indicative results. Further research is required to confirm their validity.

3.4. Description of variables

Traditionally, access to electricity was defined through a binary variable, relying on a single minimum threshold of energy supply or services to determine whether a household had an electricity connection [89]. However, this method fails to recognise the multi-dimensionality of energy access and is unable to consider different technical solutions. For instance, a SHS is often limited to fulfilling basic needs, while mini-grid or utility-grid connections can power more advanced appliances. Moving beyond binary metrics, the World Bank’s Energy Sector Management Assistance Program (ESMAP) has developed the Multi-Tier Framework (MTF) to capture, monitor and evaluate the multi-dimensionality of energy access [89]. The MTF categories energy access in a set of six ordinal linear tiers, ranging from Tier 0 (no access) to Tier 5 (full access). The framework consists of three energy access measurement multi-Tier matrices: (1) household energy supply, (2) household electricity services, and (3) electricity consumption. Of these, the multi-Tier matrix for measuring household energy supply is almost exclusively for measurement and policy development purposes [87]. This sub-framework in Table 3 measures electricity supply based on seven attributes: capacity, availability, reliability, quality, affordability, legality, and health and safety. The minimum requirements for each Tier also correspond with household electricity services necessary to operate their respective electrical appliances. Therefore, Table 4 illustrates the ranking of these electrical appliances by ascending power ratings. The MTF has been applied extensively in studies to measure and categorise different levels of electricity access [25,87,90,91].

The obtained community survey results were logged in a spreadsheet and coded for analysis. To measure the current energy consumption of a respondent in each location, the coding structure employed a basic binary indicator for the appliances currently owned (1) and not owned (0). Likewise for energy aspirations for both household and productive use purposes, a value of (1) was coded where a respondent would like to use the corresponding appliances, and (0) for a lack of desire to own the appliances. After the data had been coded, the appliances were categorised into a Tier level based on the MTF and assigned the final aggregated value as an ordinal linear value between 0 corresponding to Tier 0 and 5 corresponding to Tier 5. Based on these ordinal Tier levels, three different dependent variables are used for this study. First, Current energy consumption measures the degree of a respondent’s current energy consumption. Second, Household aspirations represents the energy aspirations for household purposes. Finally, Productive use aspirations describes the energy aspirations for productive use activities.

The following geographic and socioeconomic characteristics are considered as the independent variables for the ordinal logistic regression models. Country, Region, District, Village denote the categorical variables of the national, regional, district and village location in which the respondent lives, respectively. At the village level, only locations with a sample size of >15 are considered for analysis. As for socioeconomic variables, Age describes the age of the respondent, ranging from 15 to 93. Gender indicates a dummy variable which is true if the respondent is male. Education represents the respondent’s highest level of formal education, ranging from no education to college and university level. Household size describes the total number of children and adults in the household, ranging from 1 to 40. Average income denotes the monthly average income of the entire household and is categorised into five different groups. Table 5 summarises the types of dependent and independent variables used for the ordinal logistic regression models.

3.5. Descriptive statistics

Table 6 summarises the descriptive statistics by socioeconomic

Table 3
Multi-Tier matrix for measuring access to electricity supply [89].

Attribute	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	–	>3 W	>50 W	>200 W	>800 W	>2000 W
Availability (hr/day)	–	>4	>4	>8	>16	>23
Availability (hr/evening)	–	>1	>2	>3	>4	>4
Reliability	–	–	–	–	<14 disruptions per week	<3 disruptions per week
Quality	–	–	–	–	Voltage problems do not affect the use of desired appliances	
Affordability	–	–	–	Cost of a standard consumption package of 365 kWh/year <5 % of household income		
Legality	–	–	–	–	Legal payment of bill demonstrated	
Health and safety	–	–	–	–	Absence of past accidents	

Table 4
List of electrical appliances, and associated capacity Tiers [89].

Tier level	Load level	List of electrical appliances and productive use activities
Tier 1	(3–49 W)	Lighting, mobile phone charging, radio, speakers
Tier 2	(50–199 W)	Fan, television, DVD player, computer, printer, incubator, soldering machine
Tier 3	(200–799 W)	Electric kettle, electric sewing machine, refrigerator, mowing machine, popcorn machine, washing machine, oil seed/agriculture processing, blending machine, cooling
Tier 4	(800-1999 W)	Electric iron, electric oven, hair dryer/hairdressing, carpentry, electric water pump
Tier 5	(Above 2000 W)	Electric stove, electric cooker, water heating, milling, welding

Table 5
Description of variables used in the regression model.

Variables	Description
Dependent variable	
Current energy consumption	Ordered factor variable (6 levels) according to MTF's Tier levels,
Household aspirations	(0) Tier 0 (1) Tier 1 (2) Tier 2 (3) Tier 3 (4) Tier 4 (5) Tier 5
Productive use aspirations	
Independent variables	
Geographic variables	
Country	Categorical variable, Uganda and Zambia
Region	Categorical variable, regions in Uganda and Zambia
District	Categorical variable, districts and provinces in Uganda and Zambia
Village	Categorical variable, villages in Uganda and Zambia
Socioeconomic variables	
Age	Continuous variable, age in years of respondents
Gender	Dummy variable, (1) male (0) otherwise
Education	Categorical variable, (1) no formal education (2) primary education (3) secondary education (4) college and university
Household size	Continuous variable, number of people per household
Average income	Categorical variable, (1) less than 42 USD/month (2) 42–125 USD/month (3) 125–250 USD/month (4) 250–500 USD/month (5) above 500 USD/month

variables to aid the interpretation of the model estimates. The overall average age of respondents was 38 years, and 44 % were male. At the national level, the average age of Ugandan participants was slightly lower with 36 years old, but 53 % were male. Inversely, Zambian participants were 40 years old on average, and only 35 % were male. On education level, approximately 46 % of total respondents attained primary education as their highest formal education level, followed by secondary (30 %), no education (14 %), and college level (8 %), respectively. Nationally, both Uganda and Zambia also followed this trend. However, it is noted that the sample size obtained in Uganda shown to receive more formal education when compared to that by the UBOS; the Bureau estimated in 2017 that more than 45 % did not complete primary education, and only 2 % completed education at the college level [92]. The overall average household size was six people per household, and comparable to both countries nationally. For average income, the largest group at both overall and national levels earned between 42 and 125 USD per month. The main difference between Uganda and Zambia is that there were more Zambian participants in the first two brackets of average income - 38 % and 45 % compared to 31 % and 39 %, respectively - while more Ugandan respondents were in the 125–250 USD per month category.

4. Results

Sections 4.1 to 4.3 estimate a series of ordinal logistic regression models, first using Current energy consumption as the dependent variable, then switching to Household aspirations and Productive use aspirations, respectively. Section 4.4 then summarises the geographic characteristics of energy consumption and aspirations.

Table 6
Summary statistics by socioeconomic variables.

Variable	Uganda (n = 465)		Zambia (n = 551)		Overall (n = 1016)	
	Mean	Std. dev.	Mean	Std dev.	Mean	Std dev.
Age (15–93)	36.02	12.34	40.50	13.01	38.45	12.90
Gender (1 if male, 0 otherwise)	0.53	0.50	0.35	0.48	0.44	0.50
Education						
No formal education (1, 0 otherwise)	0.09	0.29	0.17	0.38	0.14	0.34
Primary education (1, 0 otherwise)	0.34	0.47	0.57	0.50	0.46	0.50
Secondary education (1, 0 otherwise)	0.42	0.49	0.21	0.41	0.30	0.46
College and university (1, 0 otherwise)	0.14	0.35	0.02	0.14	0.08	0.27
Household size (1-40)	5.80	3.75	6.48	2.90	6.17	3.32
Average income						
Less than 42 USD/month (1, 0 otherwise)	0.31	0.46	0.38	0.49	0.35	0.48
42–125 USD/month (1, 0 otherwise)	0.39	0.49	0.45	0.50	0.42	0.49
125–250 USD/month (1, 0 otherwise)	0.10	0.30	0.08	0.28	0.09	0.29
250–500 USD/month (1, 0 otherwise)	0.03	0.18	0.03	0.17	0.03	0.18
Above 500 USD/month (1, 0 otherwise)	0.01	0.08	0.02	0.15	0.01	0.12

4.1. *Current energy consumption*

The results of the regression models for analysing Current energy consumption in Uganda and Zambia at national and regional levels are shown in Table 7. For geographic variables, model (1), which captured the analysis at the national level, shows that there is almost no difference and no statistically significant association in current energy consumption between geographic variables Uganda and Zambia. On the regional level, only Central in model (2) is positively and significantly linked with the current energy consumption when having Eastern as the reference category. This indicates that households in the central region tend to own electrical appliances with higher load levels in relation to those living in other regions in Uganda.

As for socioeconomic variables, Education and Average income are both positively and statistically significantly associated with the dependent variable throughout all three models. For national and regional levels, the likelihood of a household owning higher-powered electrical appliances increases progressively with the increase in education and income level. For energy consumption, Gender is statistically significant for Zambia only, indicating that male-headed households appear to use more electricity than female-headed households.

Table 8 provides the results for Current energy consumption at district and village levels. District variables Amuru, Gulu, and Omoro in model (5) are strongly significantly associated (at the 1 % level) with current energy consumption in Northern Uganda, suggesting that respondents who live in these districts appear to be more likely to use either high-powered or more electrical appliances when compared to those in Agago. At the village level, only variables Kagando and Nsenyi in model (5) and Sinda in model (6) are substantially significant and show a positive relationship between the three locations and owning

Table 7
Model results: current energy consumption in Uganda and Zambia – national and regional levels.

Model	*Current energy consumption*, Tier 0-5		
	(1) - Overall	(2) - Uganda	(3) - Zambia
Geographic Variables			
Country: Zambia	−0.098		
	(0.146)		
Region: Central[a]		2.321[g]	
		(0.430)	
Region: Northern[a]		0.513	
		(0.389)	
Region: Western[a]		0.356	
		(0.403)	
Region: Southern[b]			−0.349
			(0.351)
Socioeconomic Variables			
Age	0.014[g]	0.013	0.002
	(0.006)	(0.010)	(0.007)
Gender: Male	0.075	−0.190	0.590[g]
	(0.139)	(0.210)	(0.211)
Education: Primary[c]	0.651[g]	1.372[g]	0.542[f]
	(0.200)	(0.449)	(0.217)
Education: Secondary[c]	1.424[g]	2.444[g]	0.701[f]
	(0.229)	(0.462)	(0.279)
Education: College and University[c]	2.342[g]	3.395[g]	1.915[f]
	(0.317)	(0.523)	(0.830)
Household Size	0.008	0.037	0.063[e]
	(0.021)	(0.030)	(0.034)
Average Income: 42–125 USD/ month[d]	1.031[g]	1.083[g]	0.725[g]
	(0.151)	(0.242)	(0.200)
Average Income: 125–250 USD/ month[d]	2.250[g]	2.325[g]	1.986[g]
	(0.241)	(0.382)	(0.351)
Average Income: 250–500 USD/ month[d]	1.952[g]	2.008[g]	2.062[g]
	(0.384)	(0.505)	(0.587)
Average Income: Above 500 USD/ month[d]	2.425[g]	2.360	2.615[g]
	(0.521)	(1.510)	(0.726)
Observations	870	368	502

Significance levels.
[a] The reference category is "Eastern region" in Uganda.
[b] The reference category is "Eastern region" in Zambia.
[c] The reference category is "No formal education".
[d] The reference category is "Average income of less than 42 USD per month".
[e] $p < 0.10$.
[f] $p < 0.05$.
[g] $p < 0.01$.

higher-Tier electrical appliances when compared to their respective villages in the district.

The socioeconomic control variables indicate largely similar associations compared to the national and regional models discussed in section 4.1.1; Age, Gender, and Household size indicate no clear statistically significant associations, while higher education and, with the exception of Northern Uganda, income levels are positively and statistically significantly associated with higher energy consumptions.

4.2. *Energy aspirations for household use*

Table 9 shows models (7)–(9) which analyse energy aspirations for household purposes at national and regional levels. In model (7), country variable Zambia is inversely and strongly correlated with energy aspirations for household purposes, suggesting that respondents in Zambia appear to be less likely to have energy aspirations for higher-Tier electricity provision compared to those living in Uganda. At regional level, two geographic variables, Eastern Uganda and Southern Zambia, in models (8) and (9) are both positively and statistically significant for their respective model. For Eastern Uganda, the coefficient is 1.468, meaning that respondents in the eastern region in Uganda are likely to have desires to use electrical appliances that are at least a Tier level higher when compared to respondents in Kalangala district in central region. Similarly, the coefficient of 2.927 strongly suggests that respondents in the southern region in Zambia would like to use higher-powered electrical appliances in comparison to those living in the eastern region.

Table 8
Model results: current energy consumption in Uganda and Zambia – district and village levels.

Model	*Current energy consumption*, Tier 0-5		
	(4) - Northern Uganda	(5) - Western Uganda: Kasese	(6) - Eastern Zambia: Katete
Geographic Variables			
District: Amuru[a]	3.185[h]		
	(0.818)		
District: Gulu[a]	2.281[h]		
	(0.662)		
District: Nwoya[a]	1.717[f]		
	(1.011)		
District: Omoro[a]	1.939[h]		
	(0.711)		
Village: Kagando[b]		3.952[h]	
		(1.088)	
Village: Katholu[b]		0.750	
		(0.841)	
Village: Kayanze[b]		1.016	
		(0.864)	
Village: Kisinga[b]		1.815	
		(1.096)	
Village: Nsenyi[b]		2.928[h]	
		(0.891)	
Village: Chikhutu[c]			1.157
			(0.862)
Village: Chimbalu[c]			0.633
			(0.849)
Village: Chimkule[c]			0.912
			(0.740)
Village: Luangwa[c]			1.629[g]
			(0.730)
Village: Sinda[c]			3.663[h]
			(0.797)
Village: Soweto[c]			1.594[f]
			(0.839)
Socioeconomic Variables			
Age	−0.018	0.070[g]	−0.026
	(0.019)	(0.028)	(0.021)
Gender: Male	0.346	1.202[g]	0.612
	(0.567)	(0.538)	(0.392)
Education: Primary[d]	0.695	1.258	0.408
	(1.249)	(0.918)	(0.436)
Education: Secondary[d]	1.718	1.664	0.369
	(1.192)	(1.027)	(0.584)
Education: College and University[d]	3.088[h]	2.591[g]	3.545[h]
	(1.167)	(1.199)	(0.918)
Household Size	−0.057	0.008	0.225[g]
	(0.084)	(0.134)	(0.098)
Average Income: 42–125 USD/month[e]	−0.164	1.699[h]	0.759[f]
	(0.575)	(0.551)	(0.406)
Average Income: 125–250 USD/month[e]	1.173	3.882[h]	1.771[g]
	(0.813)	(0.778)	(0.698)
Average Income: 250–500 USD/month[e]	0.983		1.766[f]
	(0.873)		(1.036)
Average Income: Above 500 USD/ month[e]	0.889		1.677[f]
	(2.891)		(1.010)
Observations	89	90	172

Significance levels.
[a] The reference category is "Agago district" in Uganda.
[b] The reference category is "Kanyanze village" in Western Uganda.
[c] The reference category is "Chimtengo village" in Eastern Zambia.
[d] The reference category is "No formal education".
[e] The reference category is "Average income of less than 42 USD per month".
[f] $p < 0.10$.
[g] $p < 0.05$.
[h] $p < 0.01$.

Table 9
Model results: energy aspirations for household purposes – national and regional levels.

Model	*Household aspirations*, Tier 0-5		
	(7) - Overall	(8) - Uganda	(9) - Zambia
Geographic Variables			
Country: Zambia	−0.656[c] (0.139)		
Region: Eastern Uganda[d]		1.468[c] (0.337)	
Region: Northern[d]		0.094 (0.330)	
Region: Western[d]		0.487[a] (0.273)	
Region: Southern[e]			2.927[c] (0.292)
Socioeconomic Variables			
Age	−0.001 (0.005)	−0.0001 (0.008)	0.004 (0.008)
Gender: Male	0.341[c] (0.129)	0.215 (0.198)	0.409[b] (0.181)
Education: Primary[f]	0.552[c] (0.184)	0.333 (0.323)	0.449[b] (0.225)
Education: Secondary[f]	0.603[c] (0.209)	0.167 (0.340)	0.506[a] (0.300)
Education: College and University[f]	0.021 (0.298)	−0.547 (0.403)	0.319 (0.794)
Household Size	0.078[c] (0.020)	0.018 (0.025)	0.040 (0.045)
Average Income: 42–125 USD/month[g]	−0.112 (0.135)	0.192 (0.209)	0.243 (0.185)
Average Income: 125–250 USD/month[g]	−0.054 (0.224)	−0.085 (0.399)	1.367[c] (0.312)
Average Income: 250–500 USD/month[g]	0.738[b] (0.367)	1.005 (0.709)	1.162[b] (0.484)
Average Income: Above 500 USD/month[g]	1.203[b] (0.501)	1.189[c] (0.409)	2.020[c] (0.702)
Observations	870	368	502

Significance levels.
[a] $p < 0.10$.
[b] $p < 0.05$.
[c] $p < 0.01$.
[d] The reference category is “Central region” in Uganda.
[e] The reference category is “Eastern region” in Zambia.
[f] The reference category is “No formal education”.
[g] The reference category is “Average income of less than 42 USD per month”.

Table 10
Model results: energy aspirations for household purposes – district and village levels.

Model	*Household aspirations*, Tier 0-5		
	(10) - Northern Uganda	(11) - Western Uganda: Kasese	(12) - Eastern Zambia: Katete
Geographic Variables			
District: Agago[a]	1.179 (1.098)		
District: Gulu[a]	1.163 (0.733)		
District: Nwoya[a]	0.893 (0.834)		
District: Omoro[a]	0.992 (0.953)		
Village: Kagando[b]		1.481 (1.252)	
Village: Kanyanze[b]		2.486[h] (0.830)	
Village: Katholu[b]		0.213 (0.929)	
Village: Kayanze[b]		2.793[h] (0.865)	
Village: Kisinga[b]		2.369[g] (1.034)	
Village: Chikhutu[c]			0.427 (0.528)
Village: Chimbalu[c]			0.288 (0.581)
Village: Chimkule[c]			0.739 (0.491)
Village: Chimtengo[c]			0.839 (0.604)
Village: Luangwa[c]			0.431 (0.510)
Village: Sinda[c]			2.200[h] (0.573)
Socioeconomic Variables			
Age	0.003 (0.023)	−0.016 (0.016)	0.014 (0.016)
Gender: Male	0.431 (0.602)	−0.279 (0.429)	−0.037 (0.381)
Education: Primary[d]	−0.515 (0.797)	1.017[f] (0.521)	0.338 (0.349)
Education: Secondary[d]	−0.083 (0.943)	1.549[h] (0.528)	0.410 (0.549)
Education: College and University[d]	−0.433 (0.996)	−0.239 (0.783)	1.840[g] (0.743)
Household Size	−0.030 (0.090)	0.016 (0.078)	0.105 (0.083)
Average Income: 42–125 USD/month[e]	1.842[h] (0.640)	0.560 (0.466)	0.942[g] (0.410)
Average Income: 125–250 USD/month[e]	2.269[h] (0.640)	0.125 (1.060)	1.486[g] (0.595)
Average Income: 250–500 USD/month[e]	3.057[h] (0.964)		0.923 (0.789)
Average Income: Above 500 USD/month[e]	3.090[h] (0.890)		0.857 (1.277)
Observations	89	90	172

Significance levels.
[a] The reference category is “Amuru district” in Uganda.
[b] The reference category is “Nsenyi village” in Western Uganda.
[c] The reference category is “Soweto village” in Eastern Zambia.
[d] The reference category is “No formal education”.
[e] The reference category is “Average income of less than 42 USD per month”.
[f] $p < 0.10$.
[g] $p < 0.05$.
[h] $p < 0.01$.

For control variables, Table 9 also reveals that similarly to the case of electricity usage in section 4.1, men appear to have higher energy usage aspirations at the household level in the Zambian sample, but not in the Ugandan sample. While high income levels are statistically positively associated with household energy aspirations, similar to the findings from current energy consumption in Table 7, higher education levels are statistically insignificant for household energy aspirations in the sample.

Models (10)–(12) in Table 10 present the regression results for energy aspirations for household use at district and village levels. While no coefficient values are statistically significant at the district level, the village level variables Kanyanze and Kayanze in the Kasese district, Western Uganda, are positively and strongly associated with energy aspirations for household use. The coefficients of 2.486 and 2.793 (at the 1 % level) suggest that respondents living in these villages have a higher likelihood of having desire to own high-powered household electrical appliances when compared to those living in the Nsenyi village. As for the Katete district, only village variable Sinda is positively and statistically significant, meaning that in comparison to those in Soweto village, households in Sinda village tend to have a higher desire for purchasing high-Tier electrical appliances for household purposes.

As was the case for energy consumption discussed in section 4.1, the associations of the socioeconomic control variables are similar in the national and subnational models; Age, Gender, and Household size are all statistically insignificant while both higher education and higher income levels appear to be at least somewhat statistically significantly associated with household energy aspirations.

4.3. Energy aspirations for productive use

The results for analysing energy aspirations for productive use purposes in Uganda and Zambia at national and regional levels are illustrated in models (13)–(15) in Table 11. Showing a positively and strongly significant coefficient of 1.911 (at the 1 % level), the country variable Zambia indicates that respondents living in Zambia have a higher likelihood of wanting to own high-powered electrical appliances for income-generating purposes when compared to those in Uganda. For the regional level, Eastern Uganda is positively and heavily associated with energy aspirations for productive use. This follows the same pattern as that of aspirations for household use in model (8). As for regions in Zambia, the coefficient for Southern is negative and significant (at the 5 % level), denoting that households in the southern region in Zambia appear to be less likely to have desires for owning electrical appliances for productive use in comparison to those in eastern region.

Furthermore, the results in Table 11 suggest that control variables Age, Household size, Education and Average income variables are statistically insignificant with respect to Productive use aspirations across models (13)–(15). Gender, however, notably, is strongly positively and statistically significant at both national and regional levels. This finding suggests that men appear more likely to desire using higher-powered electrical equipment to support their income-generating activities compared to women in the sample.

Table 11
Model results: energy aspirations for productive use of energy – national and regional levels.

Model	*Productive use aspirations*, Tier 0-5		
	(13) - Overall	(14) - Uganda	(15) - Zambia
Geographic Variables			
Country: Zambia	1.911[c]		
	(0.152)		
Region: Eastern Uganda[d]		1.321[c]	
		(0.320)	
Region: Northern[d]		0.239	
		(0.279)	
Region: Western[d]		0.022	
		(0.273)	
Region: Southern[e]			−0.539[b]
			(0.245)
Socioeconomic Variables			
Age	−0.006	0.012	−0.013[a]
	(0.005)	(0.009)	(0.007)
Gender: Male	0.872[c]	0.570[c]	1.266[c]
	(0.139)	(0.194)	(0.216)
Education: Primary[f]	0.271	0.125	0.436[a]
	(0.187)	(0.292)	(0.245)
Education: Secondary[f]	−0.007	−0.218	0.295
	(0.213)	(0.350)	(0.312)
Education: College and University[f]	−0.162	−0.155	0.578
	(0.309)	(0.445)	(0.541)
Household Size	0.022	−0.026	0.039
	(0.020)	(0.025)	(0.033)
Average Income: 42–125 USD/month[g]	−0.078	−0.012	−0.026
	(0.139)	(0.214)	(0.198)
Average Income: 125–250 USD/month[g]	−0.010	−0.530	0.863[b]
	(0.240)	(0.420)	(0.352)
Average Income: 250–500 USD/month[g]	0.097	0.357	−0.142
	(0.414)	(0.992)	(0.493)
Average Income: Above 500 USD/month[g]	−0.295	−1.600	−0.097
	(0.503)	(1.067)	(0.525)
Observations	870	368	502

Significance levels.
[a] $p < 0.10$.
[b] $p < 0.05$.
[c] $p < 0.01$.
[d] The reference category is “Central region” in Uganda.
[e] The reference category is “Eastern region” in Zambia.
[f] The reference category is “No formal education”.
[g] The reference category is “Average income of less than 42 USD per month”.

Table 12 provides the results of the regression model estimation for analysing energy aspirations for productive use at district and village levels. None of the geographic variables are statistically significant, suggesting no detectible differences in productive use of energy aspirations between districts in the same region, or villages in the same district. This contrasts the findings from section 4.3.1 where statistically significant differences between Uganda and Zambia are found, as well as within the different regions of Uganda in terms of aspirations to use energy for productive means.

Similar to the findings for energy consumption and household use aspirations, the socioeconomic variables at district and village levels exhibit similar associations to those at the national and regional levels. The Age, Household size, Education, and Average income variables are again statistically insignificant at both district and village levels, but Gender is positively and statistically significant at the sub-regional level, with the notable exception for Northern Uganda. Hence, except for the context of Northern Uganda, positive associations between higher productive use of energy aspirations and being male across different geographical levels are identified.

4.4. Summarising the geographic characteristics of energy consumption and aspirations

Summarising the regression models results, the heat map matrix (Fig. 2) is produced to unpack the influences of geographic characteristics on energy consumption and household and productive use aspirations at national, regional, and sub-regional levels. The matrix, which illustrates the statistical significance patterns of locations across levels, demonstrate that in the sample, different types of levels appear to matter for (1) current energy consumption and (2) household energy use aspirations, while only levels at national and regional levels appear to be associated with (3) productive energy use aspirations. It is noted that the matrix only shows one district and two village levels across both Uganda and Zambia. It is due to a research limitation of having an insufficient number of respondents in several districts and villages for analysis. They are therefore excluded in the matrix. The future research should consider increasing the number of respondents, ensuring a more balance distribution of respondents at sub-regional levels, and including additional regions as the study area.

On current energy consumption, the national level variable does not have a strong association with current energy consumption, suggesting that rural energy consumption in the Ugandan and Zambian sample is similar. However, while different regions in Zambia are not statistically significantly associated with energy consumption, different sub-national regions in Uganda are strongly associated with differences in energy consumption. This means that there are salient differences in energy consumption levels between the respondents from Uganda’s Central, Western, Eastern, and Northern regions. Examining further, both the district and village-level dummy variables in both countries are also strongly associated with energy consumption, indicating that locations at district and village levels in their respective region might play a differential role. Crucially, this implies that while energy consumption is not associated with national-level differences, it may significantly vary in different district and/or village levels, and, in the case of Uganda, within different regions (which are characterised by large developmental differences).

With respect to household energy aspirations, the results indicate that locations appear to be salient across all levels, suggesting significant energy aspiration differences at national, regional, and sub-regional levels. One exception worth noting is the district level in Northern Uganda where aspirations appear to be more uniform across districts.

Table 12
Model results: energy aspirations for productive use of energy – district and village levels.

Model	*Productive use aspirations*, Tier 0-5		
	(16) - Northern Uganda	(17) - Western Uganda: Kasese	(18) - Eastern Zambia: Katete
Geographic Variables			
District: Agago[a]	1.221		
	(0.802)		
District: Amuru[a]	0.504		
	(0.861)		
District: Gulu[a]	1.104[f]		
	(0.645)		
District: Nwoya[a]	0.214		
	(0.841)		
Village: Kagando[b]		1.397	
		(1.140)	
Village: Kanyanze[b]		0.807	
		(1.155)	
Village: Katholu[b]		0.405	
		(1.080)	
Village: Kayanze[b]		0.493	
		(1.141)	
Village: Nsenyi[b]		0.929	
		(1.220)	
Village: Chikhutu[c]			1.440[f]
			(0.753)
Village: Chimbalu[c]			0.321
			(0.594)
Village: Chimtengo[c]			0.071
			(0.703)
Village: Luangwa[c]			0.469
			(0.593)
Village: Sinda[c]			0.619
			(0.455)
Village: Soweto[c]			0.551
			(0.485)
Socioeconomic Variables			
Age	0.017	0.031[f]	−0.016
	(0.025)	(0.016)	(0.014)
Gender: Male	−0.197	1.290[g]	1.455[h]
	(0.446)	(0.394)	(0.374)
Education: Primary[d]	1.850	0.404	0.433
	(1.542)	(0.424)	(0.396)
Education: Secondary[d]	1.707	−0.360	−0.350
	(1.530)	(0.816)	(0.496)
Education: College and University[d]	1.254	−0.401	0.337
	(1.460)	(1.069)	(0.595)
Household Size	0.004	−0.150	0.104
	(0.079)	(0.097)	(0.104)
Average Income: 42–125 USD/month[e]	0.200	0.097	−0.309
	(0.440)	(0.569)	(0.417)
Average Income: 125–250 USD/month[e]	0.331	0.964	0.860
	(0.740)	(1.067)	(0.529)
Average Income: 250–500 USD/month[e]	1.158		1.008
	(1.025)		(1.063)
Average Income: Above 500 USD/month[e]	−0.787		1.170
	(1.531)		(0.746)
Observations	89	90	172

Significance levels.
[a] The reference category is "Omoro district" in Uganda.
[b] The reference category is "Kisinga village" in Western Uganda.
[c] The reference category is "Chimkule village" in Eastern Zambia.
[d] The reference category is "No formal education".
[e] The reference category is "Average income of less than 42 USD per month".
[f] $p < 0.10$.
[g] $p < 0.05$.
[h] $p < 0.01$.

According to Rafa et al. [93], six of the ten poorest districts are located in Northern Uganda, a region with high interregional, but lower intraregional economic inequality. High poverty rates in these locations may imply that most households prioritise other needs over higher-Tier household appliances. This aligns with the results from the 2016 Uganda national census asking respondents which reasons improved their living conditions compared to three years ago. It revealed that the improvement in access to roads, peaceful environment, and provision of safe drinking water were the top three reasons, while the provision of electricity ranked second last [94]. In addition, overall, energy consumption aspirations differ more starkly across all different analysed levels than energy consumption, suggesting the need for tailored national, regional, and local energy access policy interventions to best capture these different residential needs.

For productive use aspirations, the evidence suggests that locations play a crucial role at national and regional levels for both Uganda and Zambia. However, neither district nor village level variables were statistically significant. This suggests that in the sample, the national and regional levels matter more than the sub-regional level for productive use aspirations. Thus, to capture individual productive use needs, tailoring policy interventions at a national and regional level appears to be most critical, whereas local-level approaches might be limited in their potential of capturing additional customised value.

Finally, while not the focus of this study, the results suggest that there could be different socio-economic driving forces of energy use and aspirations within households vis-à-vis for productive use; while there are some evidence for higher education and higher income levels being positively associated with both higher energy use and higher aspirations for future use in households, aspirations for productive use of energy do not appear to differ markedly by income or education, but appear to be significantly higher for men than for women.

5. Discussion and conclusion

Using ordinal logistic regression models, this study has presented evidence suggesting the importance of different geographic levels of context for explaining differences in residential and productive use of electricity in Uganda and Zambia. The results revealed that all levels appear to have an impact on energy needs and household aspirations, while the national and regional levels were most salient for productive use aspirations. There are two main implications from this work, one conceptual and the other in terms of needs-based energy policymaking.

First, conceptually, this work suggests the importance of being more explicit about what the study considers "context matters" [17,19,21,35]. The results suggest that a multi-level assessment is beneficial to fully understand energy consumption and aspirations of a particular location while analyses at a singular level can overlook wider or more disaggregated patterns that transcend one specific level. Specifically, these results suggest that capturing context-specificity requires to factor in at least two dimensions, namely different levels of geographic aggregation and different nuances in the dependent variable. Analysing the case of rural energy usage and aspirations in Uganda and Zambia, this study finds that different geographic levels of aggregation can have statistically significant impacts. Strikingly, while energy consumption levels can look similar when aggregated at the national (i.e., no statistically significant differences between Uganda and Zambia on a national level in the sample), there might be salient regional, district-level and, while only indicative here, potentially even village-level differences that are masked when aggregating at the national level. This finding supports the notion that context-specificity can be most salient at different scales of aggregation [39]. Moreover, the results show that even seemingly small differences in research questions and dependent variables can imply notable differences regarding which context matters. In this case, while both household energy consumption and aspiration patterns are most saliently different on sub-regional levels, there is much clearer regional patterns when asking specifically about productive use of energy

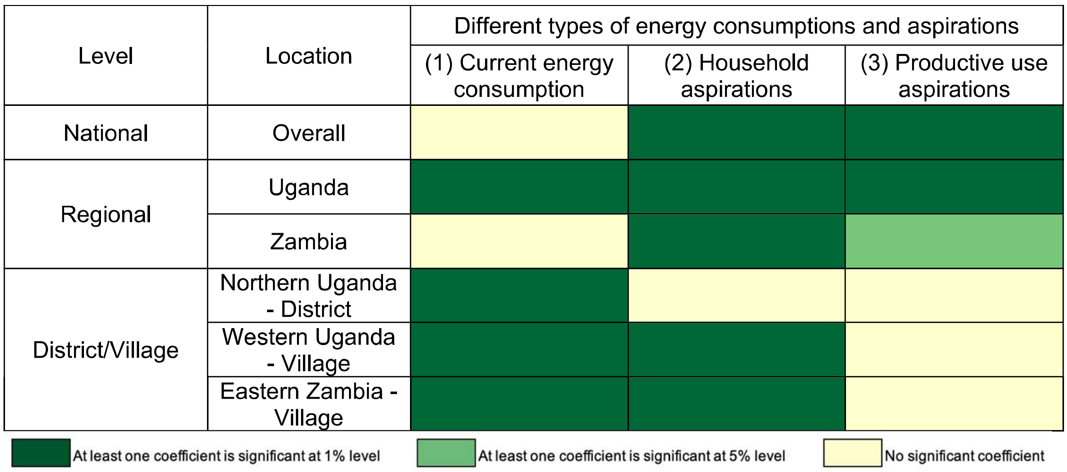

Fig. 2. Significance of geographic variables on dependent variables.

aspirations. All these dependent variables map onto the same SDG7 realm. This underlines the multi-facetted nature of the context construct in the energy space, where a specific geographical level of aggregation can have significant implications for some energy-related use aspirations while they may be limited for others. More research is needed to fully unpack the drivers and causal mechanisms of how context influences achieving SDG7.

Second, the findings appear to challenge energy access policymaking realities in Uganda and Zambia by both the governments as well as by the international donor community. Both the Ugandan and Zambian government, as well as key energy access initiatives in Uganda and Zambia such as the European Union's Energising Development Partnership, U.S. Agency for International Development's Power Africa as well as the World Bank's and GIZ's off-grid energy access programmes have been described as being top-down and centralised in terms of their institutional setup, planning, implementation and governance [10,27]. In the case of the international donor community, their energy access programmes are frequently designed with high levels of standardisation across different countries, let alone sub-national constituencies [16]. Research has suggested that examples of involvement from regional or local-level representatives are rare in both countries, along with a paucity of regional or local-level policy strategies or specific policy instruments to tailor energy access initiatives to these contexts [27, 95–97]. However, the results suggest that domestic energy needs, both in terms of the present and future aspirations, can vary considerably between regions, districts, and villages. As village-specific energy policymaking is unlikely to be sensible, adequately capturing these different needs likely requires including participatory elements into energy access policymaking and implementation. By contrast, to sufficiently meet productive use aspirations of small enterprises, initiatives targeting Uganda and Zambia would appear to benefit from factoring in national and regional differences, suggesting the merits of regional-over local--specific productive use of energy policymaking in an environment where energy access institutions and governance are resource-constrained. What is more, while this issue requires more research, this study finds some evidence that especially women have been left behind in terms of aspiring to use energy for productive means, a finding that held true largely independent of context. There has been a general lack of focus on productive of energy by policymakers in Uganda and Zambia [98,99]. Instead, household energy access has been the clear priority within national governments and the international donor community, where electricity connections for basic services are the main success indicator for rural electrification [100]. This focus on electricity access for basic services has been suggested to underestimate energy aspirations for productive use and limit relevant policy options [101,102]. Inferring from the results, a stronger policy focus on productive use of energy aimed at benefitting women appears to hold significant potential for productive energy use uptake and wider rural development. Existing research points to the need of complementing such targeted energy access and use strategies with building skills as well as with access to finance to enable communities to derive the most tangible development benefits from energy access [14].

This study's multi-level assessment further contributes to the discourse within the sustainability transitions research, especially on the dilemmas surrounding key methodological approaches, as outlined by a state of the art review from Kohler et al. [38]. These dilemmas include (1) case studies: in-depth particularity and generic insight and (2) micro-macro levels of analysis. Case studies provide detailed attention to a country's context and policy landscape in order to recognise complexities and draw out patterns and differences. Extracting insights from these case studies and producing new cases by considering new domains, including regions, actors, technologies, and governance structures [38], are necessary in forming a strong foundation for aggregated research. Meanwhile, accumulating generic lessons by connecting common relationships and trends across cases can inform overarching policy development and theory-building [38,103]. This study links the two perspectives by producing country-specific insights, while also presenting comparative case studies that explore countries with similar energy characteristics, specifically in relation to centralised energy access governance and significant urban-rural electrification disparities.

In terms of the micro-macro levels of analysis, the focus on sub-national levels of context is to reveal important niches and differences and seek out the central causes (e.g., interaction proximity) and actors responsible for these differences [36,104–106]. Conversely, discussions on wider systems and collective change tend to emerge from analysis at the national and supranational levels [38]. The main challenge remains in bridging these two levels of analysis. The findings from this study suggest that both levels can be navigated simultaneously through understanding the energy-related salience across geographical levels in a holistic way. For instance, in terms of policymaking, this could involve considering the need to capture the complexities and important sub-national differences, while at the same time ensuring its feasibility given broader fiscal, governance, and other macro-related structures and constraints. Given the merits in both micro and macro levels of analysis, research should find a better balance between the two levels, rather than considering them as a binary choice. This ability to observe across scales aligns with the current state of the art frameworks like the multi-scalar multi-level perspective framework proposed by Raven et al. [107] which involves multi-level linkages of networks and institutions to unpack the relationships among locality, proximity, structures, and environments.

In addition to highlighting these methodological approaches, this study also addresses several challenges within the sustainability transitions research. For instance, much attention on a micro-level analysis is focused on a city level, meaning smaller-scale administrative levels or entities including district and beyond are largely ignored [108]. As such, this study emphasises the importance of delving into district and village levels as a mean to uncover variations across these particular levels and highlight vertical disconnects between top-down and bottom-up approaches. Moreover, on the role of geography and place specificity at the local levels, rural regions tend to be overlooked in the analysis, as the research is more inclined towards urban settings due to their rapid nature in policy responses [38,105]. Similarly, there is a strong need for more case studies in the Global South, with much research on the multi-level perspective for example being concentrated in the Global North [109,110]. This study directly responds to these gaps by providing case studies from SSA that encompass a range of sub-regions with diverse economic contexts, illustrating the value in applying a more holistic and inclusive view.

CRediT authorship contribution statement

A. Puranasamriddhi: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **P.A. Trotter:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **P. Parikh:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **B. Batidzirai:** Data curation, Writing – original draft, Writing – review & editing. **A. Brophy:** Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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