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Asset ownership and electricity access in the urban informal settlements of Kampala, Uganda

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ABSTRACT

Delivering on the promise of SDG7 for low-income communities will require that we appropriately measure energy access. However, common measures use narrow indicators which do not acknowledge that poor households draw on multiple assets to access electricity. Using the asset pentagon of DFID's sustainable livelihoods framework, this study investigated asset ownership in a slum in Kampala, Uganda in relation to electricity access. Data were collected using household surveys [$n = 450$], and a multidimensional index and regression models applied to deduce asset ownership with respect to electricity access. We find that asset ownership is weak, especially for financial and natural assets compared to human, social and physical assets where households are better off. Grid-connected households exhibit stronger asset ownership than the unconnected, and assets also differ between residences, businesses, and mixed-use households. Households also interact with, manage, and leverage multiple assets to access electricity, depending on the ease with which those assets can be converted or exchanged for electricity. Policy and service provision should espouse existing everyday means of accessing electricity by capitalising on the assets in which households are strongest. Further, electricity provision goals for slums should be strongly linked with asset ownership and tangible livelihood outcomes for households, and exploring the micro-politics of electricity access and provision could offer directions for actualizing this linkage. Sustainable livelihoods approaches offer a valuable entry point for understanding energy access in deprived urban settings, from a perspective that encompasses multiple priorities for sustainable and inclusive urbanisation.

Introduction

As one of the Sustainable Development Goals (SDGs), access to clean and affordable energy can unlock social and economic opportunities for the billions of people without access, and the impacts of energy access on quality of life, livelihoods and wellbeing are widely understood. Energy is also essential for delivering SDG11 (Sustainable cities and communities) to build resilient and equitable cities where every urban neighbourhood is served by appropriate infrastructure and social services (Christley et al., 2021; UN-Habitat & IUTC, 2012). By 2050, some of the world's largest cities will be in Africa, as urban populations double with some cities surpassing 15 million people (UN-Habitat, 2020). Many urban dwellers will also be living and working in slums and informal settlements where poverty is rife, asset ownership and property rights are limited, and consequently accessing services is difficult. Socio-economic, environmental and climate change shocks, risks and vulnerabilities are high in such settlements, which exacerbates the poor quality of life and compromises urban livelihood sustenance (Twinomuhangi et al., 2021). Given the uncertainties and difficulties of life in slums, slum dwellers often improvise through leveraging any available means, assets, and capitals to access basic services. There are strong linkages between household and/or business income and access to clean energy and electricity in low-income countries; energy access can improve incomes and welfare, but conversely, household/business incomes also influence energy access as observed in high-income households typically consuming more electricity than low-income households (Blimpo & Cosgrove-Davies, 2019; Moore et al., 2020; UN Economic and Social Commission for Asia and the Pacific, 2021). Wealthy households are also

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more likely to completely switch to cleaner energy sources and complement grid-electricity supply with large capacity off-grid systems, while low-income households although connected to the grid will continue to use paraffin, candles and woodfuels for instance (Bisaga & Parikh, 2018; Musango, 2014). Generally, the more income a household/business has, the higher their electricity consumption and the more likely they are to invest in alternative energy sources that can cushion them from unreliable or costly energy supply. These linkages reveal a positive relationship between incomes and access to clean, reliable, diverse energy options. There are also linkages between housing, energy access and energy poverty (Blimpo et al., 2020; Chen & Feng, 2022), especially where the state of housing, ownership, size and age impacts energy usage for cooling, insulation, and self-regulatory behaviour in energy usage. In other cases, availability and interaction between natural resources like water, land, woodlands and forests influences electricity generation, its transmission and distribution to different sectors and neighbourhoods (Hibbard et al., 2014; Sridharan et al., 2020).

Africa's urban economies (including the informal economy) are largely driven by financial assets (International Monetary Fund, 2017), therefore, accessing basic needs and social services almost always requires cash payments or access to credit. Despite eminent emphasis on income as the key determinant for energy access, for low-income neighbourhoods like slums where incomes are low and irregular, households/businesses may have to leverage other asset forms to access and negotiate access to electricity services. Equally, some asset forms may impede electricity access and consumption, and others may introduce a trade-off dynamic between different assets (de Bercegol & Monstadt, 2018). Little is known of what other asset types (other than financial assets) slum dwellers rely on to access electricity, why they rely on them, and how they enable or impede access. Understanding these aspects can inform the delivery and provision of electricity services that are more accessible to most of the urban poor or foster the uptake of diverse energy options in slums. Given that slum dwellers are typically cash-poor with low and irregular incomes, we raise pertinent questions concerning how they meet their basic needs and access social services, which assets they rely on to access electricity and which ones disenfranchise them from accessing electricity. We draw on the concept of assets and their relationship to poverty and vulnerability and use the *assets pentagon* from the sustainable livelihoods framework (Chambers & Conway, 1991; DFID, 1999) to examine how the urban poor exposed to different shocks and stresses use different assets to manoeuvre different vulnerabilities and access electricity.

Using the household as the unit of analysis, this paper examines asset ownership in slums and its relation to electricity access. We classify and stratify the household across three groups namely: residences (solely homes or places of residence), businesses (solely undertaking business activities), and mixed-use (homes which are also undertaking business activities). The objectives of the study were three-fold: 1) to determine the assets that households in slums rely on to access electricity; 2) to assess the significance of different assets in enabling access to electricity; and 3) to draw lessons from the way different assets are transformed or exchanged for electricity, to inform appropriate electricity provision. Using evidence from a slum in Kampala, Uganda, we demonstrate that while households are cash-poor or lack in material assets, they are better off in other asset types which they leverage to access electricity. We also find that electricity access in households is enabled by multiple asset forms, many of which are non-financial. To this end, we highlight the role of intangible assets like social networks and human capital in enabling access to electricity. We argue that coupled with conducive environments, different assets in the appropriate mix could bolster households' ability to convert or exchange them for electricity. Understanding the contribution of different assets can inform the provision of electricity services that are accessible to most households, through solutions that capitalise on assets in which households are strongest or for which asset exchange for electricity is easier.

The rest of the paper is organised as follows; the next section introduces the concept of sustainable livelihoods and the *asset pentagon* in relation to electricity access from the sustainable livelihoods framework (DFID, 1999); a framework that examines how poor people exposed to different shocks and stresses use different assets to manoeuvre these vulnerabilities and make a living. Next, the methods used are presented followed by the results and discussion. Lastly, conclusions and recommendations are discussed before providing directions for future work.

Sustainable livelihoods, assets, and energy access

Assets and access to social services and infrastructure are strongly linked, as assets can be directly used to meet material and non-material needs of households, or they can enable access to goods, services, and privileges. Assets (or lack thereof) have also been used as a measure of poverty, welfare and inequality (Brandolini et al., 2010; Deutsch et al., 2020; Hjelm et al., 2016), building upon earlier approaches that defined poverty using income or consumption indicators (Leipziger, 1981; OPHI, 2018; UNDP, 1990). Life in deprived settings is complex and multi-faceted – livelihoods are forged from myriad and hybridised patterns of activities, and social services are similarly sourced. Therefore, in measuring access to services and infrastructure in low-resource settings, straightforward metrics like income or expenditure can be reductionist since they may not fully capture the complexities, spatial and temporal dynamism of poor people's everyday lives (Arndt & Tarp, 2016; Batana et al., 2008). Therefore, there is need to expand measures of energy access and energy poverty beyond simply material resources (e.g., electrical connection or clean fuels) or financial resources (e.g., expenditure on energy) to measures that for example capture the quality and modality of accessing energy and its impact on social and economic wellbeing, health and wellness, prosperity and resilience, and sustained development. Sustainable livelihoods approaches offer one such avenue. Livelihoods approaches are a people-centred and holistic means for analysing the causes of poverty, access to resources, and the diverse livelihood activities that poor people engage in (Chambers, 1997, 2005), but for this paper we pay specific attention to the assets component of the framework.

The concept of assets, and more broadly the sustainable livelihoods approaches have been mostly applied to rural agrarian contexts (Adato & Meinzen-Dick, 2002; Ashley & Carney, 1999; Bernstein, 1992; Chambers & Conway, 1991; Hebinck & Bourdillon, 2002; Scoones, 1998, 2015) and to food security and disaster management work and theories (Hjelm et al., 2016; Sen, 1983; Tumaini, 2020; Yazdanpanah et al., 2021). Hunger reduction strategies recognise the importance of specific assets for reducing hunger; with land, skills, social capital and community relations all playing a key role (Cooper & Wheeler, 2017; Maxwell & Frankenberger, 1992); and in displacement and emergency settings, the available stock of assets can signal the ability of displaced communities to build resilience and bounce back from shocks and stresses (IDinsight & GiveDirectly, 2022; Refugee Self-Reliance Initiative, 2020). Although it is widely understood that energy is an enabler for improving livelihoods and wellbeing for communities, and that finances, natural and energy resources are essential for advancing energy access for poor households and communities (Angelsen et al., 2014; Mulugetta et al., 2005), few studies have directly applied livelihoods approaches or the concept of assets to energy access studies, and much less in urban settings (Beall & Kanji, 1999; Cherni & Hill, 2009; Meikle et al., 2001; Meikle & Bannister, 2003; Mukisa et al., 2020; Mulugetta et al., 2005).

Meikle and Bannister (2003) identify key linkages between urban poverty and energy, revealing that energy access and its usage impacts the livelihoods and wellbeing goals of poor urban households. Their work also demonstrates that sustainable livelihoods approaches are useful for unpacking poverty-energy-livelihoods linkages at different analytical levels. Further, there is great value in integrating livelihoods approaches in energy policies, energy technology developments and investments, particularly to benefit poor or remote, hard-to-reach populations (Cherni & Hill, 2009). Poor households, whether in cities or rural areas place importance on accessing energy for different applications, for achieving their livelihood goals and improving their wellbeing. On the other hand, policy makers can use sustainable livelihoods to measure the impact of energy policies and energy projects implemented on asset ownership, wellbeing, and resilience to shocks and stresses in households and communities (Meikle & Bannister, 2003). This study draws on the concept of livelihood assets as defined by the sustainable livelihoods framework to investigate relationships between asset ownership in urban slums and access to electricity. Different definitions of assets have been put forward as summarised in Table 1, but the common theme through them all is a recognition that the poor draw on different resources and assets to meet their needs (Small, 2007), and the utility derived from different assets varies from one setting to another. In rural areas, social capital and natural resources like arable land, livestock or natural water sources may hold more significance while in cities, financial and physical assets may be highly regarded owing to the cash-based nature of urban economies (Andersen & Kempen, 2001; Sseviiri et al., 2022). This paper operationalizes the five assets of DFID's sustainable livelihoods framework as discussed next.

The livelihood assets pentagon

The livelihood *assets pentagon* is one of the key components of the sustainable livelihoods framework (SLF) (DFID, 1999) and it considers the resources, possessions, capitals that poor people have or need to sustain an adequate livelihood. In its common application to rural agrarian contexts, the pentagon is used to assess the assets that people or households or communities possess and how they are leveraged to make livelihoods. We extrapolate this approach to electricity access in slums and consider what assets households own and how they wield them to access electricity services. In this sense, the assets pentagon sits within the broader vulnerability context within which households in slums live and work, which in turn, we argue, shapes how electricity services are accessed. Thus, through livelihoods approaches linkages between the asset pentagon and electricity access in low-resource urban settings can be established as demonstrated in Fig. 1. In general, the more assets an individual or household owns, the less vulnerable they are to shocks and stresses, the more secure their livelihoods, and the better able they are to access services like electricity (Hjelm et al., 2016). However, given that households in slums are low-income, it is worth examining what assets (beyond financial assets), they rely on to access electricity and how this can inform appropriate service offerings. The wider environment in which the urban poor live and work also determines what assets they possess, and importantly how they leverage those assets to access electricity services. Ownership of assets does not always guarantee complete conversion to electricity services, for example, having a grid connection does not always imply access and usage of electricity for households. Electricity may be costly, unreliable or its usage may be restricted, especially for productive uses.

The *assets pentagon* represents five asset categories: human, social, natural, financial, and physical. Human assets refer to people's ability to work which may include skills, knowledge, and good health. Social assets are relationships and social networks which are often built on mutual trust and understanding through bonds, bridges, and links within and between households, neighbourhoods, and institutions. Natural assets comprise natural resources such as land, forests, and water sources. Physical assets are tangible items like housing, material possessions, infrastructure, tools, and equipment; and Financial assets include cash, savings, income flows, and credit facilities. Each of asset category encapsulates specific assets that can be wielded by poor urban households to access electricity; for example, cash or savings can be directly put to purchasing electricity units, neighbourhoods may rely on social networks for lighting or cooking fuels, and physical and natural assets such as housing and land ownership determine the energy options accessible to households. Thus, different asset types have implications for how electricity is accessed and used in households. The *assets pentagon* is a suitable frame of analysis because it goes beyond financial and physical assets and considers other asset forms that informal communities like slums rely on to access electricity, and it recognizes that poor people's access to basic services is complex, dynamic and multifaceted, with people actively pursuing their livelihood goals, rather than simply being passive beneficiaries of policies or interventions. This paper uses the *assets pentagon* in this respect and examines asset ownership in households in a slum in Kampala, Uganda in the context of electricity access.

Table 1
Classification of assets and capitals by different approaches and frameworks.

Approach/framework	Definition of assets
Why are rural people vulnerable to famine? (Swift, 1989)	• Investments • Stores • Claims
Poverty and livelihoods: whose reality counts? (Chambers, 1995)	• Tangible assets (resources and stores) • Intangible assets (claims and access)
The sustainable livelihoods framework (DFID, 1999)	• Physical assets • Natural assets • Human capital • Social capital • Financial assets
The asset vulnerability framework (Moser, 1998)	• Labour • Housing • Social and economic infrastructure • Household relations • Social
Household food security: concepts, indicators measurements (Maxwell & Frankenberger, 1992)	• Productive capital • Non-productive capital • Claims • Human capital • Income

Methods

Data collection

The study took a case study approach, with Nakulabye slum, Kampala as the case study site owing to its proximity to the city centre, an existing working relationship with local partners which eased access, its established status and age, and relatively stable land tenure compared to other slums in Kampala. Data were collected between September and November 2022 using a structured survey administered to 450 households, stratified across three groups: residences, businesses and mixed-use. Nakulabye slum has 8000 households and using probability sampling (Cai & Zeng, 2004; Creative Research Systems, 2012), the sample size was estimated as 450 households obtained for 5 % confidence interval, 95 % confidence level and a 20 % error margin as time and resources allowed. Information on assets was gathered by translating the different asset categories into indicators, and then into survey questions as shown in Tables 2 and 7. Both process/direct indicators (those that reflect supply and access to a resource) and outcome/indirect indicators (which reflect resource consumption) as defined by (Maxwell & Frankenberger, 1992) were used as appropriate, depending on feasibility, relevance, and the available resources. For this study, direct indicators are those which can be transformed into or exchanged for electricity access, like household income or grid infrastructure. Indirect indicators are those which serve as proxies for electricity access and usage, like housing and electrical appliances. The indicators used were based on an extensive literature review and a pilot study (Yaguma et al., 2022) that preceded the field data collection. These data were then used to estimate asset ownership in households and relationships between assets and electricity access.

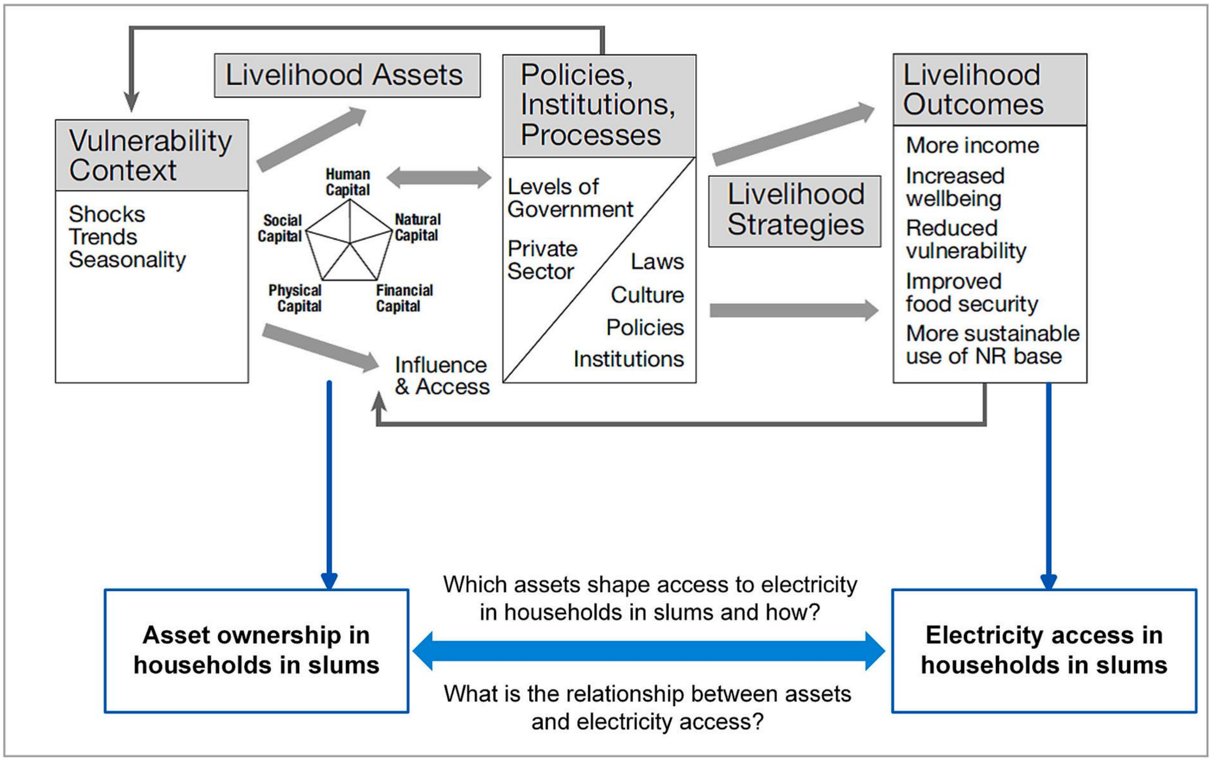

Fig. 1. Linkages between assets and electricity access and how it fits within the broader sustainable livelihoods framework.
Adapted from DFID (1999).

Table 2
Indicators and variables used to measure the different assets.

Asset type	Indicator	Variable measured
Financial assets	• Household income • Business revenue • Savings • Credit facilities	• Monthly household income or business revenue • Regularity of household income • Regularity of business profit • Ability to save • Regularity of borrowing
Physical assets	• Housing • Accessibility via roads • Electricity infrastructure • Electrical appliances • Off-grid energy sources	• Home ownership • State of permanence of housing • Size of housing • Accessibility to premises via the available access roads and paths • Formal electricity grid connection • Electric meter ownership • Applications of electricity • Off-grid, modern energy sources
Human assets	• Education • Vocational skills • Health and wellness • Employment	• Level of education • Vocational skills/training • State of physical and mental health
Social assets	• Social groups and organisations	• Membership in social groups • Support from social groups or organisations
Natural assets	• Land	• Land ownership • Type of land tenure

Defining an asset ownership index

To quantify the strength or weakness of the different assets, index scores were calculated using adaptations of livelihoods and vulnerability indices (Donohue & Biggs, 2015; Hahn et al., 2009; Hjelm et al., 2016; Ibrahim et al., 2018; Tumaini, 2020). Specifically, the multidimensional livelihoods index (MLI) as applied by (Donohue & Biggs, 2015) was adapted to measure "asset strength". The MLI uses a "Min-Max normalization method" which assigns each indicator score values between 0 and 1, where 0 is the least possible value and 1 is the highest possible value. The MLI takes a composite approach where different components contributing to a given asset can be independently analyzed and the weighted average calculated, which suits analysis for the five assets of the asset pentagon. The MLI is also a direct fit for this study whose primary data is from household surveys, and whose intention is to offer direct application to the local context in the slum. Using the five assets of the asset pentagon and a composite index approach, 20 major components and 26 sub-components were used to evaluate asset ownership in households and businesses, with respect to electricity access. Based on the indicators and variables chosen (see Table 2), responses to the corresponding survey questions were translated into index scores. Details of the assets, field survey questions and assumptions made are in the Appendix.

Estimating asset ownership using 'Min–Max normalization' scoring

The following steps were followed to calculate the asset index score for each asset category:

1) First, the major components and sub-components of each asset were identified as in Table 2 and the Appendix.
2) Next, the Index score for each sub-component is calculated using Eq. (1) (adapted from formulae used and developed by Donohue and Biggs (2015) and Hahn et al. (2009))

$$Index_{sc} = \frac{A_d - A_{min}}{A_{max} - A_{min}} \quad (1)$$

where:

- $Index_{sc}$ = sub-component score, a positive value between 0 and 1 i.e., $0 \leq Index_{sc} \leq 1$
- A_d = determined from the survey data, between A_{min} and A_{max} i.e., $A_{min} \leq A_d \leq A_{max}$

- A_{min} = minimum possible value for the asset sub-component
- A_{max} = maximum possible value for the asset sub-component

3) For major components with sub-components, the Major component score was calculated taking the average of the sub-component scores, to give the Averaged $Index_{sc}$
4) Finally, the score for the entire asset is calculated by averaging the major component scores using Eq. (2):

$$M_d = \frac{\sum_{i=1}^{n} Index_{sc}}{n} \tag{2}$$

where:

M_d = asset strength score
$Index_{sc}$ = index score of an asset's sub-component
n = number of major components used for the asset.

For the Financial assets which has four major components i.e., Household income (HI), Business revenue (BR), Savings (S), and Credit facilities (C), the asset strength score is calculated as:

$$M_{d\_Financial} = \frac{Index_{sc\_HI} + Index_{sc\_BR} + Index_{sc\_S} + Index_{sc\_C}}{4} \tag{3}$$

where:

$M_{d\_Financial}$ = asset strength score for the financial assets,
$Index_{sc\_HI}$, $Index_{sc\_BR}$, $Index_{sc\_S}$ and $Index_{sc\_C}$ = index score for household income, business revenue, Savings, and Credit facilities components respectively.

Linking assets to electricity access

The relationship between asset ownership and electricity access was deduced using tests for independence and regression models in R. Four dependent variables were chosen as proxies for electricity access: grid connection status, formality of grid connection, applications of electricity, and expenditure on electricity. Eight independent variables were selected from the asset indicators to represent asset ownership: household income, employment, education, social group membership, meter sharing, home ownership, housing permanence, and housing size. Based on the type of data collected, a binary logistic regression model was run for grid connection status and formality of connection in relation to the independent variables – see Eq. (4); and an ordinal logistic regression model was run for expenditure on electricity and applications of electricity in relation to the independent variables – see Eq. (5). The significance level was set at 5 % (0.05), and a null hypothesis (H_O) and alternate hypothesis (H_A) assumed for each dependent variable. For example, for electricity expenditure, the null hypothesis for the independent variable household income is that there is no relationship between a household's income and expenditure on electricity; and the alternate hypothesis is that there is a relationship between a household's income and expenditure on electricity. A statistically significant test result (i.e., a *p*-value $\leq$ 0.05) implies that we reject the null hypothesis and confirm a relationship between the variables. Lastly, we assume that a *p-value* $\leq$ 0.001 is highly significant; a *p-value* $\leq$ 0.01 is moderately significant; a *p-value* $\leq$ 0.05 is significant, and a *p-value* $>$ 0.05 is not significant.

$$log\left(\frac{p_G}{p_G - 1}\right) = b_0 + b_1x_1 + \ldots + b_8x_8 \tag{4}$$

$$log\left(\frac{p(Y \leq j)}{1 - p(Y \leq j)}\right) = \beta_j - (b_1x_1 + \ldots + b_8x_8); j = 1, \ldots, J-1 \tag{5}$$

where:

- p_G = probability that a household is connected to the grid (or that a household's grid connection is formal) given the independent variables
- $p(Y \leq j)$ = cumulative probability that expenditure on electricity (or applications of electricity) is less or equal to a specific category j
- $b_0 - b_8$ = coefficients
- $x_1 - x_8$ = independent variables
- J = no. categories for the expenditure on electricity (or applications of electricity) variable
- β_j = intercept or threshold values

Assumptions and limitations of the methods used

- **Asset indicators**: The asset indicators used were those considered relevant to electricity access and consumption in households/businesses. Some indicators could have been missed, and some of the survey questions could have failed to fully capture the full extent of the indicator for which they were formulated.
- **Weighting indicators**: In calculating asset strength scores, averaged equal weighting was used for simplicity and to avoid the potential subjectivity associated with assigning different weights to different components. However, indicators may not always carry equal weighting depending on the specific context, household or community being evaluated. Therefore, the shortcomings of equal weighting are acknowledged.
- **Asset ownership vs. conversion**: Livelihood assets per the sustainable livelihoods framework consider the assets that people own, and also those that they can convert. Owing to time and resource constraints, the study focused on absolute values of selected assets that could be easily measured using the survey tool and to which respondents could provide unbiased responses. For example, on whether education had helped respondents with finding employment, it was not easy to determine how and if education had contributed to employment except where it was a direct contribution or where the contribution was immediately apparent.
- **Significance of the scores**: The asset strength scores put a quantitative measure to asset ownership, but on their own, they do not paint a complete picture of asset ownership in the slum. A more accurate representation of asset ownership would likely also include qualitative narratives from focus group forums or interviews.

Results

Study population demographics

Some characteristics of the surveyed households are shown in Table 3 below.

Asset strength scores

In general, the asset strength scores are below average or just above average as shown in Table 4 and illustrated in Fig. 2. Human and physical assets are the strongest with scores of 0.552 and 0.549 respectively; while social assets are moderate with a score of 0.435, with strong contributions from shared metering and informal connections. Households are weakest in natural and financial assets (scores of 0.221 and 0.234 respectively) given that the settlement mostly sits on land owned by private landlords or institutions, and most households earn low and irregular incomes.

Asset strength scores by household type

Scores were calculated using the same indicators and sub-components for residences, businesses, and mixed-use households and results obtained as shown in Table 5 and Fig. 3. The scores are generally low (all below 0.6), regardless of the household type. Human and

Table 3
Demographics of the surveyed households.

Characteristic	Variable	Frequency (n = 450)	Percentage
Household type	Residence	211	47 %
	Business	89	20 %
	Mixed-use	150	33 %
Household head or business owner	Female	192	43 %
	Male	256	57 %
Length of stay in the settlement	Less than 5 years	199	44 %
	5 to 10 years	87	19 %
	Over 10 years	149	33 %
Household size	Single occupant	60	13 %
	2 to 5 members	211	47 %
	Over 5 members	85	19 %
Grid connection	Connected	419	93 %
	Unconnected	31	7 %
Monthly expenditure on electricity (n = 419)	Less than Ug.Shs 10,000 (<$2.7)	24	6 %
	Ug.Shs 10,000–30,000 ($2.7–$8)	238	57 %
	Ug.Shs 30,000–60,000 ($8–$16)	74	18 %
	Ug.Shs 60,000–100,000 ($16–$27)	33	8 %
	Over Ug.Shs 100,000 (>$27)	17	4 %
	Paid in the rent	10	2 %
	Do not pay	1	0.2 %
	Do not know	17	4 %
Electrical assets ownership	Grid connection	419	93 %
	Unshared electric meter (n = 419)	125	30 %
	Electrical appliances (>4)	216	48 %
	Modern[a] off-grid energy sources	166	37 %

[a] Excludes kerosene, candles or biomass based fuels.

physical assets are average and uniformly exhibited across all household types. Businesses are strongest in human and physical assets, and least strong in natural assets. Residences and mixed-use households are strongest in physical assets and least strong in financial and natural assets respectively. The different household types exhibit similar trends across the different assets, but with differences in which assets they are strongest or weakest in.

Asset strength scores by grid-connection status

The asset strength scores for grid-connected households and unconnected households are in Table 5 and Fig. 3. For this analysis, to ensure uniform comparison, only assets common to both grid-connected and unconnected households were considered as it was assumed that by default, unconnected households would not possess some assets. Therefore, physical assets excluded grid connection, metering, and electrical appliances; and for social assets, meter sharing was excluded. The results show that grid-connected households are stronger than unconnected households across all five asset categories, with stark differences in financial assets and natural assets. Both the grid-connected and unconnected households are strongest in human assets and physical assets, while the grid-connected are weakest in natural assets and social assets. Unconnected households are very weak in physical assets (score = 0.032) and financial assets (score = 0.204). All the unconnected households were also residences, and only one unconnected household had a monthly household income of at least the median household income for households in Kampala. Regarding land ownership and tenure, only two unconnected households owned land, and both had leased it from Buganda kingdom. Another stark difference between grid-connected and unconnected households was in the physical assets, notably the permanence and size of housing structures. Nearly half of all unconnected households had temporary and semi-permanent housing and over 80 % of unconnected housing structures had 1 or 2 rooms. Furthermore, the proportion of unconnected households who owned their homes was half that of grid-connected households, and one-third of unconnected households were not easy to reach using the available access roads. On the other hand, a higher proportion of unconnected households used at least one modern[1] energy source such as solar lamps or torches, or lead acid and dry cell batteries. Social capital (membership in social groups and support received from social groups) did not differ much between grid-connected and unconnected households. The differences in human assets for grid-connected and unconnected households were most pronounced in the education levels and employment, with grid-connected households having better educated household members and more household members in employment.

Linking asset ownership and electricity access

Regression models were run to estimate relationships between each of the four proxies for electricity access and eight asset ownership indicators. The results obtained are in Table 6.

Asset ownership and grid connection

Grid connection status (i.e., whether a household is connected to the grid or not) has a strong relationship with the permanence of housing ($p = 0.0001$), a moderately strong relationship with the size of housing ($p = 0.0088$) and level of education ($p = 0.0025$), and a relationship with home ownership status ($p = 0.0141$). Households were less likely to be connected to the grid if their housing was temporary or semi-permanent or small (number of rooms). Households were also less likely to be grid-connected if they did not own the home or business premises. This is as expected, because even with options to connect informally, there are practical and safety limitations to extending grid connections and installing house wiring in temporary structures with very little room. For households which do not own their premises, the other bottlenecks to acquiring a grid connection can come from landlords or insecure land ownership. Households who do not own their land are not motivated to sink heavy investments in permanent housing to begin with, or proper house wiring for fear of losing them to evictions or land grabbing. Others believe that they are staying in the informal settlement only temporarily, while they save up money to move elsewhere, so they do not invest in permanent infrastructure. Those who were born into the settlement want a better life for their children outside the settlement and those who have recently settled also see it as a temporary squatting arrangement. However, evidence shows that the cycle of urban poverty often keeps multiple generations of families in slums, with new generations now being born and migrating into them.

Asset ownership and expenditure on electricity

A significant relationship exists between monthly expenditure on electricity, and meter sharing ($p = 0.0057$) and home ownership ($p = 0.0007$). Households that use shared meters pay less in electric bills than those using personal meters. Most meter sharing is governed by appliance restrictions and flat-fee payment arrangements for each household using the shared meter, typically between 10,000 shillings ($3) and 30,000 shillings ($8). However, households using personal meters are not restricted in their electricity usage except through self-limitation. Secondly, while households on shared metering pay for their energy consumption, they are also able to share the burden of non-energy costs (taxes and service fees) between all households on the meter. On the other hand, households with personal meters pay for their energy consumption and the non-energy costs (taxes and service fees) burden falls entirely on a single household. Households which own their premises

[1] Modern energy sources in this instance excludes paraffin/kerosene and candles.

Table 4
Asset strength scores and indicators related to electricity access for households in Nakulabye slum, Kampala.

Asset	Major component	Sub-component	A_d	A_{min}	A_{max}	$Index_{sc}$	Averaged $Index_{sc}$
Financial	Household income	Percentage of households with regular income flows	49.6	0	100	0.496	0.360
		Number of households whose income is at least the city household median[a]	101	0	450	0.224	
	Business revenue	Average number of profitable months in a year	1.594	0	12	0.133	0.133
	Savings	Number of households that are always able to save	126	0	450	0.280	0.280
	Credit facilities	Number of households that regularly borrow money	73	0	450	0.162	0.162
	$Md_{financial}$						**0.234**[d]
Human	Education	Number of households in which any member has attained at least primary level education	410	0	450	0.911	0.602
		Number of households in which any member has gained vocational skills & training	251	0	450	0.558	
		Number of households where education and skills have been useful in finding jobs	138	0	410	0.337	
	Health	Number of households whose members are always healthy and able to work	315	0	450	0.7	0.7
	Employment	Number of households with at least two household members employed	158	0	450	0.351	0.353
		Number of households whose employed members are always able to find work	160	0	450	0.356	
	Md_{human}						**0.552**[d]
Social	Group membership	Percentage of households with active membership in social groups	34	0	100	0.34	0.34
	Support from social groups	Percentage of households that receive or sought support from social groups, NGOs	14	0	100	0.14	0.14
	Shared metering	Percentage of households accessing electricity using shared metering	62	0	100	0.62	0.62
	Informal electricity access via neighbour	Percentage of households that informally access electricity by tapping from a neighbour	64	0	100	0.64	0.64
	Md_{social}						**0.435**[d]
Physical	Housing ownership	Percentage of households who own their home	21	0	100	0.21	0.210
	Accessibility	Percentage of households that have easy road access to premises	89	0	100	0.89	0.890
	Housing structure	Percentage of households whose housing structures are permanent[b]	87	0	100	0.87	0.533
		Number of households whose housing structures have more than three rooms	88	0	450	0.196	
	Grid connection	Percentage of households that have a formal electricity grid connection	79	0	100	0.790	0.790
	Electric meter	Number of grid-connected households that own an electric meter	313	0	419	0.747	0.573
		Number of grid-connected households that have a personal meter	125	0	313	0.399	
	Electrical appliances	Number of households that use electricity for at least four applications	216	0	450	0.480	0.480
	Off-grid energy sources	Number of households that use at least one off-grid, modern[c] energy source	166	0	450	0.369	0.369
	$Md_{physical}$						**0.549**[d]
Natural	Land ownership	Number of households that own the land on which their home or business is located	79	0	450	0.176	0.176
	Secure land tenure	Number of land-owning households that hold a leasehold, freehold or mailo-land tenure	21	0	79	0.266	0.266
	$Md_{natural}$						**0.221**[d]

[a] According to from the 2019/2020 national household survey, the median household income for households in Kampala is 667,000 shillings ($177).
[b] A permanent structure was defined as that which had a brick wall; an iron roof; and a cement, concrete, or tile floor.
[c] Off-grid "modern" energy sources here excludes paraffin, candles, and woodfuels.
[d] Asset strength score of the Asset category, calculated as the weighted average of the sub-components.

also pay more in monthly electric bills, because they are more likely to be connected to the grid and they also use electricity for more applications than households who rent.

Asset ownership and formality of electricity access

The only significant relationship with informal electricity access is meter sharing ($p = 1.9894E{-}08$), and this relationship is highly significant. Households which used shared meters were more likely to use informal electricity than households with personal meters. Shared metering arrangements made possible by strong social ties between households encouraged informal access. However, given the sensitivity of the topic (informal access), it is possible that households which used shared metering felt safer to reveal this information since they did not personally own the meter and so informal access could not be traced back to a single household. Apart from shared metering, the formality of electricity access did not depend on how many or what assets a household had. Thus, households living in permanent structures, with multiple sources of income and household income above 1 million shillings ($270) used informal connections just like the households which lived in temporary structures, had fewer sources of income, and had household incomes ten times less ($27 and below).

Asset ownership and applications of electricity

There is a highly significant relationship between applications of electricity i.e., how many applications electricity was used for and household income ($p = 0.0046$), home ownership ($p = 0.0003$), level of education ($p = 1.05E{-}05$), and membership in social groups ($p = 0.0005$). Households with higher household income used electricity for more applications, as did households which owned their premises, those whose heads had higher education levels, and who were active members of social groups. Higher income households are more likely to use electricity for more applications because they can afford to purchase a wider range of electrical appliances and pay the additional electric bills associated with using them. Those who own their premises (i.e., do not rent) are not limited on owning their appliances of choice or using electricity for different applications by landlords or landowners, therefore they can use electricity for more applications. Interestingly, meter sharing and the state of housing (permanence and size) had no significant relationship with the number of applications of electricity. One explanation for meter sharing could be that while households on shared meters are limited in their applications of electricity by meter sharing agreements, households which use personal meters may adopt self-limit their electricity usage in response to high tariffs since they are not

Natural assets - Fig. 2(a): A vacant and fenced-off piece of land in the settlement. Most land is owned by private landlords, cultural or religious institutions.

Social assets - Fig. 2(b): Shared electric meters on an electric pole. One meter is shared by multiple households, enabling those who would otherwise not have access to electricity to tap into the grid.

Physical assets - Fig. 2(c): Dense housing and narrow access paths only allow access on foot to some households, which limits grid infrastructure extension into the slum.

Fig. 2. Manifestations of different asset types in the slum.

Table 5
Asset strength scores by household type (residences, businesses, and mixed-use households), and grid-connected and unconnected households. Grid-connected households own more assets than unconnected households across all asset categories, and there are also differences in asset ownership between household types.

	Household type[a]			Grid-connection status[a]	
	Residences	Businesses	Mixed-use	Grid-connected	Unconnected
Human assets	0.559	0.568	0.565	0.587	0.483
Financial assets	0.257	0.202	0.218	0.432	0.204
Social assets	0.530	0.415	0.365	0.245	0.225
Physical assets	0.554	0.536	0.571	0.507	0.408
Natural assets	0.267	0.117	0.192	0.228	0.032

[a] The scores are on a scale of 0 to 1, where 0 is the minimum score and 1 is the maximum score.

sharing the electric bill with other households.

Discussion

Ownership and access to assets

Households rely on different assets to varying degrees, to access and use electricity. Across the board, asset ownership was mostly weak or just about average. Households were weakest in natural and financial assets given that most of the settlement sits on land owned by private landlords or institutions, household incomes are low and derived from irregular sources primarily in the informal economy, and business profitability is highly volatile and seasonal. Nakulabye is a unique settlement in Kampala in that most of the land on which it sits is owned by Buganda kingdom and it borders the Kasubi royal tombs, an important cultural site that is the burial grounds of the last four *Kabakas* (kings of Buganda). Tenants on Buganda land get tenure security by paying annual land ground rates – locally known as "*busuulu*" – of Ug.Shs. 50,000 ($13) as stipulated by the Ministry of Lands, Housing and Urban Development. Those whose occupancy status is unknown are seeking recognition through the Kingdom's initiative to register land occupants under the "*Ekyaapa Mungalo*" campaign – literally translated as "Land Title in Your Hands" at a cost of UgShs. 500,000 ($133) to secure their tenure. Although most households do not own land in the settlement, they are confident that the King would not evict them provided they abide by the Kingdom's norms on land tenure. With this perceived sense of tenure security, many have set up semi-permanent or permanent housing which although small (80 % of housing had 1 to 2 rooms), is made of solid building material. Going by the large number of mixed-use households (one-third) in the settlement, a lack of land or housing ownership has not interfered with or dissuaded the setting up and running of home-based business enterprises. Regarding electrical assets, given the high grid-connection rates in the settlement (97 %), most households owned at least three electrical appliances but their quality and efficiency was not investigated, and limitations on appliance usage may be imposed by landlords or informal providers, or through self-limiting behaviours, which impacts the value derived from electrical appliances.

Strong human assets and little difference between different household type were due to most households having healthy members who can work and be productive, and at least one member gainfully employed. The most significant contributor to human assets was that most people had attained at least primary level education, vocational skills, or apprenticeships. The high education levels among low-income populations can be attributed to Uganda's free universal primary education policy introduced in 1997 as part of the global agenda under Millennium Development Goal 2, which abolished school fees in public primary schools and saw the school enrollment rate more than double (Bategeka & Okurut, 2006). However, while most people have attained at least primary level education or vocational skills, a significant gap remains in converting these assets into income, livelihoods or basic needs due to the inflexible and rigid employment requirements in the urban economy which do not yet value vocational and life skills. In Nakulabye settlement where this study was carried out, only 31 % of educated respondents have managed to translate their education and skills into an income or consistent employment, and 40 % of respondents reported that their education or skills have never helped them to find jobs. Human assets were equally strong among grid-connected households as they were in unconnected households, meaning people in unconnected households were just as educated, skilled and of good health. Therefore, other factors like housing and incomes are likely the reasons for being unconnected to the grid.

Social support networks were moderately strong, relayed as reliance on shared metering to access electricity, informal electricity access via a neighbour or informal service providers who are widely known and based in local neighbourhoods. Only shared metering had a significant relationship with informality, therefore the financially better-off and worse-off alike all use informal/illegal connections. The use of illegal connections has become so normalized and widespread that the motivations behind it are more to do with the ease of access made possible by inter-household relationships and relationships forged with informal providers. Most households had not sought or received assistance from community-based organisations or NGOs, and they were not active members of community groups. This may be explained by the vertical relationship between slum dwellers and formal institutions, and limited inclusivity of households and community structures. Regarding seeking assistance, it may be that many households lack the security and creditworthiness required to qualify for loans or credit facilities from lenders and banks. Furthermore, most organisations deliver their assistance at community-scale and support community development projects like solar streetlighting, building drainage channels, communal sanitation blocks or water access points. These organisations rarely have a sustainability or continuity plan, so they leave when resources and funding for projects run out. An aspect of social networks that remained unexplored was the informal and often undocumented social relations that aid electricity access like phone charging at a neighbour's or kiosk during power outages, borrowing money or energy sources. Both connected and unconnected households had similar social asset profiles, so these networks could be leveraged to assist unconnected households to get connected, of course bearing in mind the reasons they are unconnected in the first place, their personal circumstances, and aspirations for electricity sourcing.

The nature and extent of the assets owned as presented in this paper vary from household to household depending on their different needs, motivations, and abilities. Assets can generally be thought to reinforce each other because available assets can be exchanged or converted into other asset types, such that the more of one asset a household has, the more of another they own or can acquire. But in deprived settings like slums, asset ownership is contested and exchanging or converting one asset for another may not be an option, or letting go of an asset through exchange or conversion may hold undesirable repercussions for households. The next section considers how different asset categories may enable or stifle electricity access in informal settlements.

How do different assets shape electricity access?

Different assets – housing, land, infrastructure, social relations, finances – make different contributions to enabling electricity access for some or disenfranchising others. This section discusses the ways in which different asset categories shape electricity access.

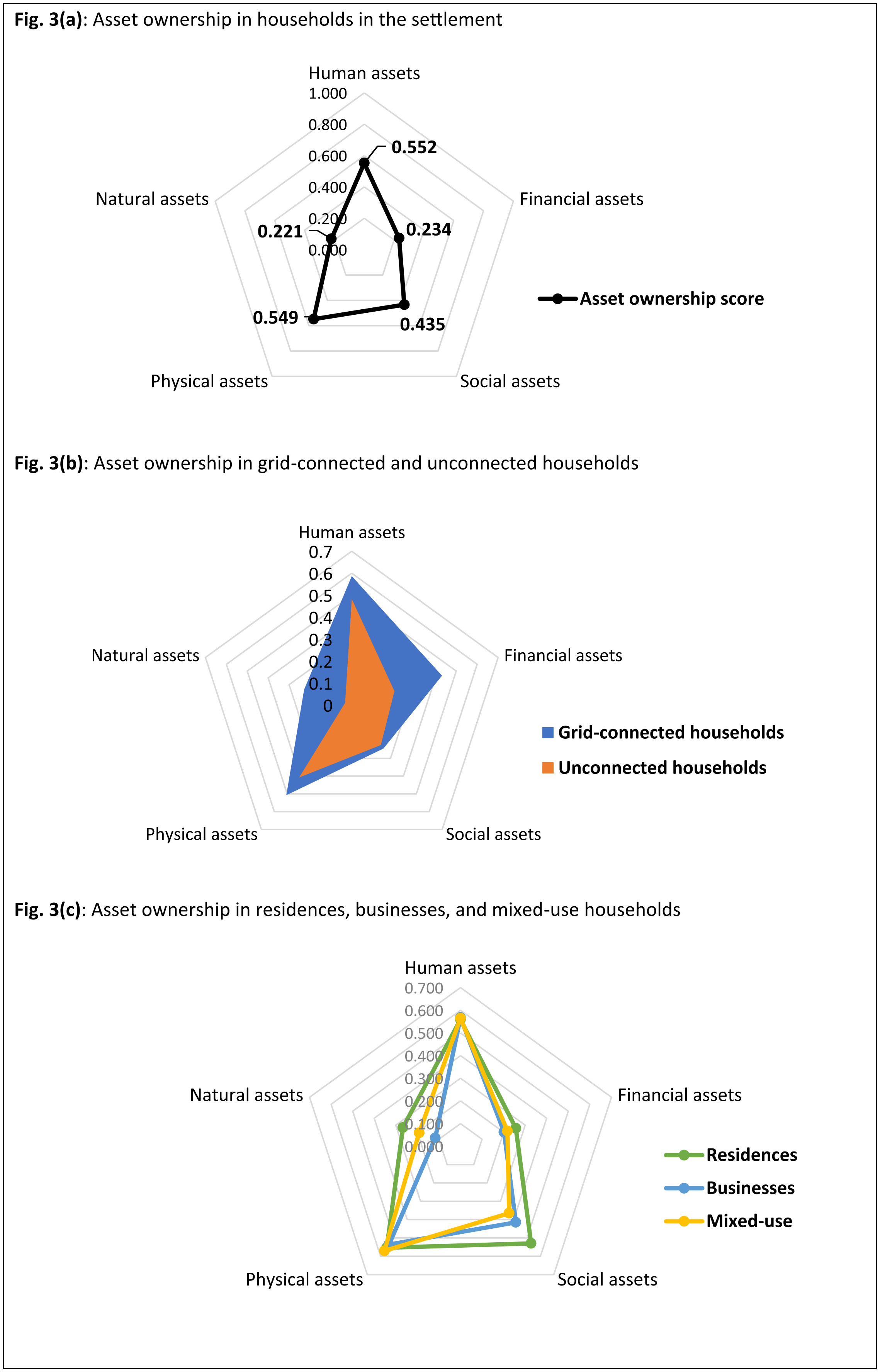

Fig. 3. Asset ownership in all households in the settlement; in residences, businesses, and mixed-use households; and in grid-connected and unconnected households.

Table 6
Results of regression models estimating the relationship between four proxies of electricity access (dependent variables) and eight asset ownership indicators (independent variables). Four models were run for each dependent variable, and the table is a summary of the coefficients, standard errors and *p*-values obtained for each equation ($n = 450$).

		Dependent variables (proxies for electricity access)			
		Expenditure on electricity	Grid connection status	Formality of grid connection	No. applications of electricity
		Coeff. *p-Value* (*Std. error*)			
Independent variables (asset ownership indicators)	Household income	0.0951 0.4323 (0.1210)	0.0093 0.9687 (0.2377)	0.0604 0.7559 (0.1944)	0.2956 0.0046** (0.1044)
	Employment	0.1701 0.1961 (0.1315)	0.4278 0.2468 (0.3694)	0.4761 0.1431 (0.3252)	0.1479 0.2236 (0.1215)
	Education	0.1629 0.0688 (0.0895)	0.6324 0.0025** (0.2094)	0.1398 0.3418 (0.1471)	0.3490 1.05E-05*** (0.0792)
	Social group membership	0.0746 0.7782 (0.2648)	0.0574 0.9181 (0.5587)	0.6241 0.1604 (0.4446)	0.7910 0.0005*** (0.2279)
	Meter sharing	−0.5135 0.0057** (0.1859)	(N/A)	−1.4944 1.989E-08*** (0.2662)	0.1399 0.3252 (0.1422)
	Home ownership	1.1972 0.0007*** (0.3493)	2.9747 0.0141* (1.2122)	−0.7150 0.2208 (0.5839)	1.2096 0.0003*** (0.3314)
	Permanence of housing	0.6037 0.1553 (0.4248)	1.5478 0.0001*** (0.4029)	−1.1563 0.1451 (0.7935)	0.2501 0.4884 (0.3610)
	Size of housing structure	0.2754 0.2593 (0.2442)	−1.3933 0.0088** (0.5316)	0.9491 0.0944 (0.5674)	−0.1627 0.4879 (0.2346)

Significance levels: *p-value ≤ 0.05; **p-value ≤ 0.01; ***p-value ≤ 0.001
Standard errors in parentheses.

Financial assets and electricity access

Inquiry into financial assets focused on three aspects: household income or business revenue, savings, and access to credit. Household income or business revenue can be directly exchanged for electricity services, whether that be acquiring an electricity connection or paying electric bills. Similarly, savings can be accessed to meet electricity needs while access to credit facilities like microloans or informal borrowing can be put towards meeting electricity needs. Household income as an asset was captured in absolute terms (i.e., monetary values), as the diversity of income sources, and as income regularity and consistency. With regular and consistent income flows, households are better able to exchange finances for electricity. The contribution of other household members (in addition to the primary bread winner or household head) are also an asset – 35 % of households had two or up to six household members employed or earning an income. Savings form an asset base from which finances can be drawn to supplement incoming incomes, to fill gaps left when no income or business profit is realized, or to cushion households from shocks and stresses which affect those employed in the informal sector. All the businesses reported variable and unpredictable profitability, which impacts income flows and purchasing services. While borrowing can be drawn on to meet households need in the absence of income or savings, debt can also further cripple households and send them into perpetual cycles of poverty.

Physical assets and electricity access

The quality, size, and ownership of housing directly impacts electricity access and usage. Housing quality affects eligibility for formal connection by the utility, as safety and practical considerations must be adhered to. Home ownership informs the choice of electricity sources and the installation of crucial infrastructure. Home ownership affords occupants the freedom to upgrade their homes, install infrastructure, alternative sources of energy or source electricity from a provider of their choice, while households who rent have little control over their electricity sources and little desire to invest in house wiring and metering as they cannot take it with them when they move house (Blimpo et al., 2020; Scott et al., 2003). They may then settle for the energy choices and infrastructure on offer in the rented property even if it does not meet all their needs. The size of housing matters too, as it determines appliance ownership and usage indoors. Congested living spaces pose safety risks for using certain appliances and energy sources like LPG for cooking, and there may be limited space to use or store bulky electrical appliances. Therefore, applications of electricity are limited to those which can be achieved within space and safety limitations. One-third of unconnected households in the settlement were not easy to reach using the available access roads, yet road infrastructure enables accessibility within and into settlements which is critical to the delivery and extension of grid infrastructure. Households which are close to major roads benefit from easy access to the grid, but as the density of structures increases (usually deeper into the settlement), access roads become narrow, impassable, or non-existent and accessing households to make connections or extend infrastructure becomes difficult. Accessibility may also be temporary or seasonal, depending on weather seasons and periodic road maintenance efforts from community members or other stakeholders. Electrical infrastructure and appliances are also physical assets as households rely on them to tap into the grid and use electricity, and off-grid sources also provide energy when grid-access is not possible. It is important to reiterate that having a grid connection does not necessarily mean that maximum value or any value at all is derived from it – some households had a grid connection but were not using it, while others had to limit or ration their electricity usage across space, time, and applications.

Human assets and electricity access

The human assets considered were formal education, vocational skills and apprenticeships, and health and wellness. Wide evidence shows a strong correlation between education or skills and household income and prosperity, demonstrating the relevance of human capital to achieving prosperity goals. An important dimension to these assets is the ability to convert them into productivity, therefore the ability to find employment and proportion of household members contributing to household income were considered too. Education, skills, good health, and their conversion into gainful employment contributes to household incomes which can be used to meet household basic needs, including electricity. In addition, the number of employed household members matters in pooling together resources to meet household needs. Mental and physical health directly affects people's productivity, their ability to work and keep a job, earn an income, and work in sectors that maximize their skills and abilities.

Social assets and electricity access

These are the social relations and social support mechanisms that individuals, households and neighbourhoods rely on to meet their electricity needs. Energy sources like lighting sources may be borrowed from neighbours or accessed from neighbourhood kiosks on credit, small loans from savings groups or obtained informally from friends could be used to pay rent, school fees, buy food, or pay electric bills. The volume and extent of informal borrowing in slums remains largely undocumented, but the reach and impact of these asset flows is likely significant and flows beyond the confines of specific neighbourhoods and settlements and even into rural areas, through remittances to villages or other parts of the city. This is a form of rural-urban reciprocity (Moser, 1998), where slum dwellers send remittances to their villages and in turn, relatives in rural areas send food and cooking fuels (charcoal and firewood) to cities, alleviating the most pressing vulnerabilities in either setting. Good relations within a household have an overall positive impact on access to electricity and social networks also enable multiple families to live under one roof and pool together resources to cover their rent and bills, as well as share responsibilities like household chores, childcare and care for the elderly and the sick. This frees up time for women to engage in economic activities from which they can earn an income and contribute to household expenses. In this study, 53 % of mixed-use households (where a business enterprise was running at home) were headed by women, and it is social support systems that enable women to run such enterprises and earn an income and contribute to sourcing electricity. Social support structures like informal community groups and formal organisations like NGOs, cultural and religious institutions also play a critical role, for instance in implementing community development projects or in advocating for better service delivery from city councils and municipal governments or development partners and funders (Baruah, 2015; Dobson et al., 2014; Kalpana, 2000; Slum Dwellers International, 2018).

Another vital relationship is between households that use shared metering. Shared meters enable clusters of homesteads to collectively access electricity where it would otherwise be costly or difficult to connect each household to the grid via their own meter. It is also through social networks that households enlist the services of local informal providers who typically offer a cheaper service and convenient "connect now, pay later" options to access the grid. Information exchange through word-of-mouth links households with informal providers, and during raids by the utility and law enforcement, tip-offs and warnings are shared to evade disconnection or prosecution. Lastly, landlords understand that rental value is higher for properties with good electricity connections, therefore many ensure that rental properties are connected to electricity by any means necessary. In this sense, landlords play a vital role in enabling electricity access in settlements.

Social networks can also be detrimental to electricity access particularly where there are hierarchical or coercive relationships with considerable power asymmetry. In shared metering arrangements, tensions can arise as households navigate and manage the complexities of using a shared meter; for example, agreeing on a flat-fee payment structure, enforcing electricity usage limitations, or handling non-payments. Tensions in meter sharing are so prevalent that a good number of households which accessed electricity via a shared meter desired to have their own electricity meter and control over their electricity usage. Some social support may also be temporary, short-term, or unsustainable, for example an NGO discontinuing support or ending a community project, or unreliable financial support from kin and friends. Inter-household tensions can also result from misunderstandings in obtaining wayleave agreements from neighbours to install electricity poles and overhead wires. The relationship between informal electricity providers and households is also hierarchical, as illegal electricity is unregulated and not governed by any formal contract. Therefore, the quality of supply is not guaranteed, and limitations are placed on appliance usage. Often, landlords are the only direct interface between end-users (households) and the utility or informal providers. In this regard, landlords may gatekeep electricity access options, bill payment modalities, and appliance usage, all to the detriment of households.

Natural assets and electricity access

The natural assets in the settlement were related to land and agricultural activity. Very few residents own land in the settlement, which has implications for how and who provides services, and how electricity infrastructure is extended. On one hand, as alluded to earlier, a lack of ownership over land and fragmented plots can make extending electricity infrastructure into the depths of slums particularly challenging. Wayleave permissions may have to be obtained from multiple landowners, or there may be no vacant lots to install infrastructure, which limits electricity provision. On the other hand, proximity to an important cultural site, a university and the city center may mean more secure land tenure for the community. With this, landowners and landlords are more inclined to invest first and foremost in constructing more permanent housing, and then in extending electricity infrastructure to their properties. This sense of tenure security then promotes access to electricity services.

Conclusions

This study used the *assets pentagon* of the sustainable livelihoods framework to investigate asset ownership in a slum settlement in Kampala, Uganda with respect to electricity access. The findings show that slum dwellers manage and interact with multiple asset forms, and asset ownership is weak, especially financial and natural assets but households are better off in human and social assets. Accessing electricity in households and businesses is enabled by different asset forms, and the contribution of less-understood, non-financial asset categories is evidently strong. Social assets and social support networks in particular play a vital role and although African cities are more socially fragmented than rural areas (World Bank, 2017), in slum settlements, social capital and social cohesion are strong, with people often relying on relationships with neighbours, kin, friends and informal electricity providers to meet their electricity needs. Some assets also create coercive or exclusionary dynamics that stifle electricity access and usage, therefore further work is needed to explore the micro-politics of electricity access and provision in slum settings. Asset ownership and electricity access are strongly related, therefore understanding the contribution of different assets can inform appropriate policy and electricity services that are accessible to most, through provision mechanisms that capitalise on the assets in which households are strongest and service provision that considers broader metrics for enlisting consumers. Identifying the ways in which slum dwellers wield different assets for electricity access could inform the formulation of impactful interventions that do not erase or undermine existing everyday means of accessing electricity but rather espouse easy asset-conversion or exchange. It is also useful for identifying asset types that constrain or pose potential roadblocks to accessing and using electricity in households, to inform solutions that remove or minimise these. Further, stronger asset ownership in grid-connected households than in unconnected households is evidence of the enabling and transformative potential of electricity for prosperity and wellbeing in low-resource communities. Ultimately, the relationship between asset ownership and electricity access is a bi-directional feedback loop. With more assets, households can access grid electricity affordably, safely, and efficiently; and conversely, electricity access can facilitate asset acquisition, particularly where electricity is put to productive uses. Given that different assets shape electricity access in different ways, city councils, policy makers and development partners designing slum upgrading initiatives or electrification policies should be cognizant of this fact. Uganda's lifeline-tariff subsidy for instance, should consider that in most poor urban communities, electricity is accessed via shared metering which exceeds the subsidy's threshold, and slum upgrading projects should consider that accessibility, housing and social spaces, and inter-household relations are vital for extending infrastructure and accessing services in slums. Electrification initiatives should have strong linkages with people's livelihoods and prosperity goals and be geared towards strengthening the assets in which households are weak, thereby delivering tangible livelihood gains for people and encouraging wider uptake of any proposed solutions. In this sense, sustainable livelihoods approaches offer a valuable entry point for understanding energy access in deprived urban settings, from a perspective that encompasses multiple SDGs and overarching priorities for sustainable and inclusive urbanisation, reduced inequalities, and prosperity for the urban poor.

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.

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Ethics statement

The research study was conducted in accordance with the principles embodied in the Declaration of Helsinki and in accordance with local statutory requirements. Ethics approvals and permissions were obtained from Uganda (Uganda National Council for Science and Technology, Ethics ID number: SS1036ES and Mbarara University of Science and Technology, Ethics ID number: MUST-2022-98) and the UK (University College London, Ethics ID number: 20673/003). All participants gave written or verbal informed consent to participate in the study. Permissions were also sought from local council chairpersons of all the nine administrative zones in Nakulabye slum.

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Appendix A

Table 7
Livelihood assets, indicators used (major component) and the corresponding survey questions posed to respondents.

Asset	Major component	Unit of measure	Survey question(s)	Assumptions/limitations
Financial	Household income	Percentage No. households	• What is the monthly household income or business revenue? • Does your household have a regular or consistent source of income?	Given the irregular nature of livelihoods in slums, it was difficult to specify what regular or consistent was in this case, therefore it was left up to the respondent to determine, based on their personal livelihoods arrangements and circumstances
	Business revenue	Average no. months	In which months of the year does the business make profit?	
	Savings	No. households	Does your household/business have any savings?	
	Credit facilities	No. households	Do you borrow from a savings group or elsewhere?	Difficult to measure informal borrowing from friends, family, neighbours
Human	Education	No. respondents	• What is your level of education? • Do you have any vocational skills? • Has your education or skills helped you find jobs?	Difficult to measure the indirect impacts of education/skills on employment prospects e.g., social capital gains or the application of skills gained
	Health	No. respondents	Are you healthy, physically and mentally able to work?	
	Employment	No. households	• How many people in the household (including yourself) are employed or earn an income? • Are the employed household members always able to find work or jobs?	Regardless of the household size, it was assumed that a household with at least two employed or income-earning members was strong in this sub-component
Social	Group membership	Percentage	Are you an active member of a social or community group?	
	Support from social groups	Percentage	Have you ever received or sought support from a community group or NGO or community-based organization?	
	Shared metering	Percentage	Do you share your electric meter with any other household?	
	Informal electricity via neighbour	Percentage	Was your informal connection made by tapping from a neighbour?	
Physical	House ownership	Percentage	Do you rent or own your home/business premises?	

(*continued on next page*)

Table 7 (*continued*)

Asset	Major component	Unit of measure	Survey question(s)	Assumptions/limitations
	Accessibility	Percentage	Is it always easy to reach your home or business using the available roads and access paths?	The question did not account for the time or season- e.g., access roads during the rainy season or at night
	Housing structure	Percentage No. households	• What materials is the structure constructed out of (i.e., roof, walls, and floor)? • How many rooms does the housing structure have?	The permanence of most structures lay on a spectrum or was a mixed state for walls, roofing, flooring in different conditions. For uniformity the definition was maintained, and it was left up to the enumerators to ascertain a structure's state of permanence
	Grid connection	Percentage	Do you have a (formal) grid electricity connection?	Only formal connections were considered
	Electric meter	No. households	• Do you have an electric meter? • Do you share your meter with any other household?	
	Electrical appliances	Percentage	• What do you use electricity for in your household?	Households that used electricity for at least 4 distinct applications
	Off-grid energy sources	No. households	• What other sources of energy do you use?	
Natural	Land ownership	No. households	Do you own the land on which your home/ business is located?	
	Land tenure	No. households	What type of land tenure do you hold?	Freehold, Leasehold and Mailo land tenure were considered the more secure tenure types as owners own the land in perpetuity

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