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# Understanding the drivers of electricity access and willingness to pay for reliable electricity in African refugee settlements: Evidence from Zambia, Malawi, and Uganda

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ABSTRACT

This study investigates electricity access and willingness to pay for reliable electricity among refugees living in settlements in protracted situations in Sub-Saharan Africa. Field data from 1322 respondents in Dzaleka (Malawi), Adjumani (Uganda), and Meheba (Zambia) reveal varying access rates ranging from under 20 % to approximately 80 %, with older and wealthier settlements reporting higher values. Also, the level of access is low (Tier 0 to 3) and supply is unreliable. Average willingness to pay differs across locations (the household mean in Meheba is 4.5 times larger than in Adjumani and more than double that in Dzaleka) but is similar in relative terms (corresponds to about 10 % of the local monthly income). Also, the distribution of the willingness to pay within each location is left-skewed, with a significant share of respondents indicating a value of zero (28 % of households in Adjumani). Using socio-economic data collected from the field, we identify and analyse a set of potential drivers of electricity access and willingness to pay. The regression models' results confirm the crucial role of income, identify certain key end-user characteristics, and reveal the awareness of the benefits of electricity services as a significant driver for households. These findings emphasise the urgency of addressing electricity access disparities and the critical role of tailored interventions and policies promoting affordability and income-generating opportunities for refugees in protracted situations. Preliminary insights into the complex role of drivers specific to the humanitarian energy context (prior electricity access, humanitarian aid, and years spent in the settlement) suggest further research.

## 1. Introduction

One of the main challenges of Sustainable Development Goal 7 (SDG7) is providing access to affordable, reliable, and sustainable energy in the humanitarian context. Humanitarian agencies traditionally support the provision of water, sanitation and hygiene (WASH), shelter, and food but only meet a small portion of the energy needs of refugees – for example, by distributing clean fuels or solar lanterns for cooking and lighting. Hosting countries, particularly if energy access remains a challenge at the national level, can rarely justify the upfront cost of an energy intervention in a refugee settlement when settlements are considered temporary [1]. As a result, refugees remain personally responsible for collecting or purchasing biomass and acquiring fuel and other energy technologies, such as cookstoves or solar panels, from local markets [2,3].

This approach to energy access in the humanitarian domain [4] has notoriously led to insufficient results. The Global Platform for Action (GPA) [2] estimates that 94 % of forcibly displaced people living in camps lack access to electricity, and 81 % can only rely on basic fuels for cooking – typically firewood and charcoal. As these figures emerge from a modelling effort focusing on households, the reality is that, as of 2022, "we do not know how many [forcibly displaced] people have access to what type of energy, nor is there a clear figure on the progress towards Sustainable Development Goal 7" ([2], p. 11).

On the positive side, the humanitarian energy sector (intersection of humanitarian response and energy) has developed considerably in the past decade. As of today, it is relatively clear where the main challenges are and where progress is needed, from the governance and policy levels

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to strengthening the technical capacity and designing innovative financial solutions [2,4]. Notably, Rosenberg-Jansen [5] argues that to support refugees in accessing energy, a conceptual shift is necessary from energy as a technological object capable of satisfying a short-term basic need, e.g., a solar lantern, to energy as a service to be provided reliably and sustainably over the long-term, e.g., via a grid connection. Consistently, market-based solutions aligned with existing local conditions and markets would be largely preferable over the procurement and distribution of energy technologies [2,4]. Naturally, this approach requires understanding end-user priorities and their (social, cultural, environmental, and financial) context [6]. It is also aligned with the goal of supporting the inclusion and self-reliance of displaced populations, considering that refugees are often displaced "for decades and generations" ([5], p. 17).

To contribute to addressing the information gap mentioned above and supporting the broader understanding of energy access decisions, our study focuses on selected refugee communities in three countries in Sub-Saharan Africa (SSA): Zambia, Malawi, and Uganda. This geographical focus allows us to analyse access-related questions in so-called protracted situations, defined "as those where more than 25,000 refugees from the same country of origin have been in exile in a given low- or middle-income host country for at least five consecutive years" ([7], p. 22) in SSA. At the end of 2022, the United Nations High Commissioner for Refugees (UNHCR) [7] estimated that 76 % of 40.5 million refugees and other people in need of international protection were hosted in low- to middle-income countries – 1 in 5 of all refugees worldwide was hosted in SSA – and that more than 23 million people (67 % of 35.3 million refugees worldwide) lived in protracted situations.

Within the specific geographical and socio-economic framework of this study, i.e., refugees living in settlements in protracted situations in Sub-Saharan countries, we aim to address the following research questions:

1. When refugees are responsible for acquiring the energy resources they need, what is the current level of electricity access among households and businesses (run by refugees)? And how does electricity access compare across and within settlements?
2. As energy access in the humanitarian context is anchored to market-based solutions, what is the Willingness to Pay (WTP) for reliable and sustainable electricity service among households and businesses? And how does willingness to pay compare across and within settlements?
3. Moreover, what are the main drivers of electricity access among households and businesses?
4. And, finally, what are the main drivers of the willingness to pay for a reliable and sustainable electricity service among households and businesses?

To answer these questions, we take an empirical approach based on primary data from more than 1400 in-person interviews conducted in 2022 in six refugee locations in SSA. Specifically, the analyses presented in this paper rely on a number of variables and observations extracted from the primary data and consolidated in a stand-alone database (with 1322 observations: 926 households and 396 businesses) that we make openly available. To answer the first two research questions, we resort to descriptive statistics, while to address the last two, we design and estimate regression models.

Only a few studies report electricity access levels for households or businesses in protracted refugee settlements in SSA based on field data collections (e.g., van Hove and Johnson [3]). Published data (based on field observations) about willingness to pay for electricity services (different from willingness to pay for a product, such as a solar lantern) among refugees in SSA is even more scarce (e.g., Okello [8]). Hence, the first contribution of this work is new evidence that allows us to discuss the progress towards meeting SGD 7 and shed some light on the willingness to pay for improved electricity service among refugees in different protracted situations in SSA.

The academic literature on energy access in SSA countries has extensively employed regressions models to investigate the drivers of technology adoption decisions (e.g., Kizilcec et al. [9]) and, to a lesser degree, the factors affecting the willingness to pay for a reliable electricity service (e.g., Sievert and Steinbuks [10]). However, this work stream does not include displaced people residing in settlements. Hence, the second contribution of this study is methodological. The regression models used in this study align with existing academic studies (by including, e.g., income and end-user characteristics) but also differ from them by capturing potential drivers highly specific for refugees. These are based on anecdotal evidence derived from an analysis of the humanitarian energy literature on SSA (e.g., Practical Action [11]). This methodological approach allows us to study empirically, for both households and businesses, the role played by well-known (from the energy access literature) and refugee-specific drivers, e.g., prior (before displacement) access to electricity and the protractedness of the refugee situation, on both the probability of having access to electricity and the willingness to pay for a reliable electricity service. This is the third contribution of this study.

It is important to note that even though the number of interviews conducted per settlement was statistically representative, our sample and questionnaire were not designed to capture the full spectrum of socioeconomic conditions experienced by households and businesses. Hence, this work focuses on the research questions formulated above rather than on a socio-economic analysis of the settlements. Moreover, while some of our findings regarding energy access levels and aspirations might be generalised to protracted refugee settlements in SSA, our data confirms that conditions can vary significantly from one settlement to another. Hence, the results of our analysis pertain primarily to the respondents interviewed, and their generalisation to the SSA region (or other world regions) should be considered with caution.

The rest of the paper is structured as follows. Section 2 reviews prior literature, focusing on the drivers of electricity access and willingness to pay for electricity in SSA. Section 3 describes the data collection and the methods. Section 4 presents the results for both households and businesses. Section 5 discusses the limitations of this study, summarises our findings, and indicates directions for further research. Section 6 concludes and derives policy implications.

## 2. Literature

Energy within the humanitarian context is a rapidly evolving field of research and practice. While consensus exists that energy is an essential enabler of well-being and livelihood for forcibly displaced people, the literature has pointed out that displaced populations have been left behind with respect to SDG7 [4]. The scarcity of quality data within the field of humanitarian energy has also been noted in numerous papers and reports [11–13], including data about uses and preferences in the energy context [14–16]. In turn, for a few years now, publications such as the Energy Progress Report tracking SDG7 [1] and the State of Humanitarian Energy Sector report [2] have provided increasingly detailed coverage of global achievements in humanitarian energy access.

Contributions from scholars and practitioners have explored the subject of humanitarian energy on multiple fronts [17]. Several papers and reports have focused on specific refugee contexts and studied the type of energy used and the energy demand of households, enterprises and public loads, e.g., van Hove and Johnson [3] and Practical Action [11]. Others have developed techno-economic assessments of energy interventions [18–23], or critically analysed existing energy initiatives, e.g., Miller and Ulfstjernel [24]. A few studies have provided guidance on policy and governance actions necessary to provide a more comprehensive response to sustainable energy provision [25,26] and described the catalyst role of initiatives at the international level – e.g., the Moving Energy Initiative and the Global Platform for Action on Sustainable Energy in Displacement Settings [4].

Another stream of literature is concerned with analysing the economies of refugee settlements and their host communities [27–29]. Recent studies concerning refugees in SSA countries include, for example, an analysis of the economic life of refugees and the linkage with the economy of the local hosting population in Rwanda [30]. Betts et al. [31] have comprehensively analysed employment and income-generating opportunities among refugees in Kenya and Uganda and connected them with the national refugee policies of the two countries (the Ugandan model is considered one of the most advanced in the world, providing freedom of movement and the right to work).

This paper follows the steps of previous studies describing the sources of and the demand for energy in selected refugee locations. In doing this, it contributes evidence-based data and information on the progress towards SDG7 in the observed settlements. At the same time, this work tries to empirically connect the observed access levels and willingness to pay for reliable electricity to a set of socio-economic variables, also collected from the field – of course, without the ambition to describe the economies of the observed settlements. In doing this, it contributes to identifying, for the observed refugee communities, the relevant (socioeconomic) factors in electricity access decisions [6].

As detailed in this section, to build an empirical model of the drivers of electricity access and willingness to pay, we draw significantly from the rich literature on the drivers of energy technology adoption in rural and low-income settings in SSA. Also, we carefully consider (and incorporate in the models) the factors behind households and businesses' electricity adoption decisions in refugee settlements mentioned in the humanitarian energy literature – again focusing on SSA.

### 2.1. Drivers of electricity access in Sub-Saharan Africa

The literature focusing on electricity access in SSA is rich, and several authors investigated the drivers of electricity adoption decisions, especially in relation to solar technologies. In a systematic literature review, Kizilcec et al. [9] find that the primary factors influencing the adoption of SHS among households in SSA are: *(i)* the absence of a reliable supply of grid electricity (often equivalent to a rural location); *(ii)* the ability to use electrical appliances such as lights, phone chargers, radios, and televisions; and *(iii)* higher income (also captured by monthly expenditures). Other frequently mentioned drivers include *(iv)* household size, linked to larger potential savings on alternative fuels, and *(v)* the level of education, where higher education is associated with a higher likelihood of adoption. Drawing from technology diffusion theory, Eder et al. [32] confirm, although focusing on the connection to a renewable mini grid, the central role of the ability to use appliances i.e., the awareness of a technology's advantages and functionalities and its affordability.

Modern energy adoption decisions by households in SSA have also been associated with other end-user characteristics, including *(vi)* the gender of the household head, *(vii)* primary income-generating activity of the household, and *(viii)* access to credit/loans [9]. While access to credit/loans and formal employment (i.e., a non-farming family) drive adoption, the role of gender of the household head remains unclear. As many energy-demanding tasks, including cooking, washing, and collecting wood, are carried out by women, a female head can drive the adoption of modern energy. Nevertheless, households headed by women are commonly single-parent families that are less likely to have access to electricity due to lower income levels [9].

As for the humanitarian energy literature looking at SSA, anecdotical evidence suggests that "the longer people live in camps" ([33], p. 22), the more they are willing to invest in meeting more complex energy needs – e.g., there is a larger chance that refugees own an SHS. Also, it suggests that prior access to modern energy matters in increasing 'energy demand', together with the level of education, access to mobile banking and credit, and economic earning potential, potentially driven also by right-to-work and freedom of movement policies implemented in the hosting country [33,34]. The aid agencies provide in the settlement, the level of access of the host population and the settlement's size are also mentioned as potentially significant drivers, but with no specific indication about whether they would increase or decrease energy 'demand' [33]. Similarly, studying the diffusion of SHS in refugee settlements in Rwanda, Thomas et al. [35] compared results across genders, household sizes, and employment status of the adopter but found no specific patterns. In turn, income, payment flexibility, and the ability to redirect expenditures away from alternative fuels (eventually also from food expenditures) emerged as adoption drivers.

We summarise and compare the two streams of literature in Table 1. Electricity access drivers can be divided into four groups linked to location, awareness of the related benefits and advantages, income, and end-user characteristics. These are operationalised partly in the same and partly in a different manner for refugees living in settlements. For instance, awareness among refugees can be captured by prior electricity access (before the end-user was forcibly displaced) and an end-user characteristic specific to refugees is the length of stay in the settlement – one which is expected to drive access. In Section 3, we explain how these four types of drivers are captured in this work (which variables are created from the primary data) and how they enter the regression models.

### 2.2. Drivers of willingness-to-pay for electricity in Sub-Saharan Africa

A few energy access papers focusing on SSA analyse households' willingness to pay for electricity. Among these, Abdullah and Jeanty [36] find income (via the ability to afford higher payments) and several end-user characteristics to be relevant drivers. As for end-user characteristics, the level of education and the interest in starting a business are associated with a higher willingness to pay; the opposite holds for the age of the household head and the years spent in the same residence. Similarly, the study by Taale and Kyeremeh [37] reveals that monthly income and end-user characteristics drive households' willingness to pay for reliable electricity. The end-user characteristics include business ownership and prior notice of power outages on top of household size and education. Arega and Tadesse [38] confirm that household income plays a positive role, together with some end-user characteristics (older and male household head, being a taxpayer), and add access to information (awareness) and location (distance from firewood and charcoal market, living in smaller urban centres). Sievert and Steinbuks [10] also show that households' willingness to pay is associated with higher income (captured by households' monthly expenditures) and selected end-user characteristics (educational level and access to finance, while age, gender, and household size are not significant).

Focusing on urban enterprises, the study by Batidzirai et al. [39] finds several factors driving willingness to pay for a more reliable

**Table 1**
Taxonomy of the main drivers of electricity access in SSA according to the literature.

| | Drivers' type | Energy access literature | Humanitarian energy literature |
|---|---|---|---|
| (1) | Location | No grid connection (rural location) | Settlement size<br>Access level of host population<br>Refugee policies (income-generating opportunities) |
| (2) | Awareness | Advantages and functionalities | Prior access |
| (3) | Income | Affordability or monthly expenditures | Payment flexibility and ability to redirect expenditures |
| (4) | End-user characteristics | Household size<br>Education level<br>Gender<br>Income-generating activity<br>Access to credit/loans | Length of stay in the settlement<br>Household size<br>Education level<br>Gender<br>Income-generating activity<br>Access to credit/loans |

service. The type of business indicates whether they can access alternative energy sources during outages, pay lower tariffs, or work longer hours (all factors associated with a lower willingness to pay). Conversely, the fact that the enterprise earns higher annual revenues via an uninterrupted service is an important driver of the willingness to pay (because of an expected increase in competitiveness). In turn, the study found no clear role for the electricity consumed per month and the years in business.

In the humanitarian context, willingness to pay for electricity services is anecdotally linked to income and income stability (where the latter can be provided by financial or in-kind support), level of education, employment opportunities (related to the right to work), access to banking services, and awareness of the benefits (or expected benefits) of the technology [33]. With regard to the latter, a few publications report empirical data on refugees' priorities. Corbyn and Vianello [40] observe that households highly value the ability to use appliances for lighting and communication (e.g., charging phones) and the ability to cook and work at home. Van Hove and Johnson [3] confirm the importance of cooking, lighting and charging, which come before income generation and entrainment; similarly, businesses still prioritise lightning and charging but also value business operations (e.g., the ability to use fridges). The need for lighting at home (for working, studying, and safety) ranks high also in the study by Practical Action [11]. The same study observes that businesses are mostly concerned with income-generating potential, again via the use of appliances (phone chargers, TVs, radios and computers).

In sum, from the energy access literature focusing on SSA, we observe that potential drivers of the willingness to pay for grid electricity or solar technology (or, more generally, reliable and sustainable electricity) can be classified using the same four groups proposed for energy access. The same holds for the humanitarian energy literature focusing on SSA (see Table 2). In Section 3, we explain how these four types of drivers are captured in this work (which variables are created from the primary data) and how they enter the regression models.

## 3. Data and methods

### 3.1. Field data collection and the REASEP database

The selection of the locations for the field data collection was guided by the possibility of conducting in-person interviews with refugees living in settlements in SSA. To identify this opportunity, we organised, first, a webinar in collaboration with the UNHCR Division of Resilience and Solutions (DRS), aimed at collecting expressions of interest from UN Regional Bureaus and Countries Operations in SSA to host a field data collection. From the expressions of interest received, we created a shortlist of countries and settlements within these countries, where we could be given permission to enter, find help with transportation, and hire local enumerators and translators.

Considering the limits imposed by the logistical and political situations, we selected six refugee settlements in three different countries (Fig. 1): Meheba (Zambia), Dzaleka (Malawi), and Nyumanzi, Pagirinya, Ayilo I, and Maaji II (in the Adjumani district of Uganda). The data collection was officially notified by UNHCR DRS to the Regional Bureaus at the end of June 2022 and conducted between mid-July and mid-August of the same year.

Primary data was collected via 1412 structured in-person interviews conducted in accordance with the UN guidelines for participatory assessment [41] and stored using the digital KoBo Toolbox.[1] The questionnaire for the primary data collection (Annex A in Supplementary Data) was designed based on the literature [42] and our previous experience [21] and aimed at gathering reliable and usable data on the current energy supply and demand for electricity of the respondents. Additional questions around these core topics allowed us to collect also socio-economic information regarding the respondents. In this regard, the questionnaire made a distinction across three categories of end-users: households (66 % of the total number of interviews), businesses[2] run by refugees (28 %), and communal loads such as schools and health posts (6 %).

For the scope of the present work, we excluded communal loads, and were left with 1322 cross-sectional observations, which we organised in three groups, one per settlement/country:

- 252 households and 100 businesses located in Meheba (Zambia);
- 252 households and 83 businesses located in Dzaleka (Malawi);
- 422 households and 213 businesses in the four settlements in the Adjumani district (Uganda) –hereinafter referred to, for brevity, as the “Adjumani settlement”.

As summarised in Table 3, the groups differ along a few dimensions relevant to this study:

- Number of years since the settlement was established: from over 50 in Meheba to about ten for Adjumani;
- Type of location: semi-urban for Dzaleka, a mix of rural and semi-urban for Meheba, and rural for Adjumani;
- National refugee policies, i.e., the adoption and implementation of the Comprehensive Refugee Response Framework (CRRF) and the Global Compact on Refugees (GCR): restrictive in Malawi (Dzaleka), supportive in Zambia (Meheba), and proactive in Uganda (Adjumani).

Finally, from the primary data, we selected a subset of information relevant to the present study. This includes, for both households and businesses, *electricity access levels* (answers to questions regarding which energy resources and appliances are available and used) and *willingness to pay* (answers to questions regarding the minimum and maximum willingness to pay per month for a reliable electricity service, such as one provided by a mini-grid), as well as potential factors affecting these two variables as they emerged from the literature review. In this regard,

**Table 2**
Taxonomy of the main drivers of willingness to pay for electricity in SSA according to the literature.

| | Drivers' type | Energy access literature | Humanitarian energy literature |
|---|---|---|---|
| (1) | Location | Smaller urban centres<br>Distance from firewood and charcoal markets | Refugee policies (income-generating opportunities) |
| (2) | Awareness | Access to information<br>Expectation of business opportunities or improved business results | Ability to use appliances at home (lighting, charging, cooking, safety)<br>Ability to use appliances for productive applications and to improve business results |
| (3) | Income | Current income or expenditures | Income and income stability<br>In kind and financial support |
| (4) | End-user characteristics | Household size<br>Education level<br>Gender, age, years of residence<br>Income-generating activity (owning a business)<br>Access to financial services (being a tax payer)<br>Business type | Education level<br>Access to banking services |

[1] https://www.kobotoolbox.org/.

[2] The surveyed businesses were predominantly retail/wholesale shops (48 %), followed by barbers/hair salons (15 %), tailors (10 %), food and drink vendors (9 %), and phone charging kiosks (7 %).

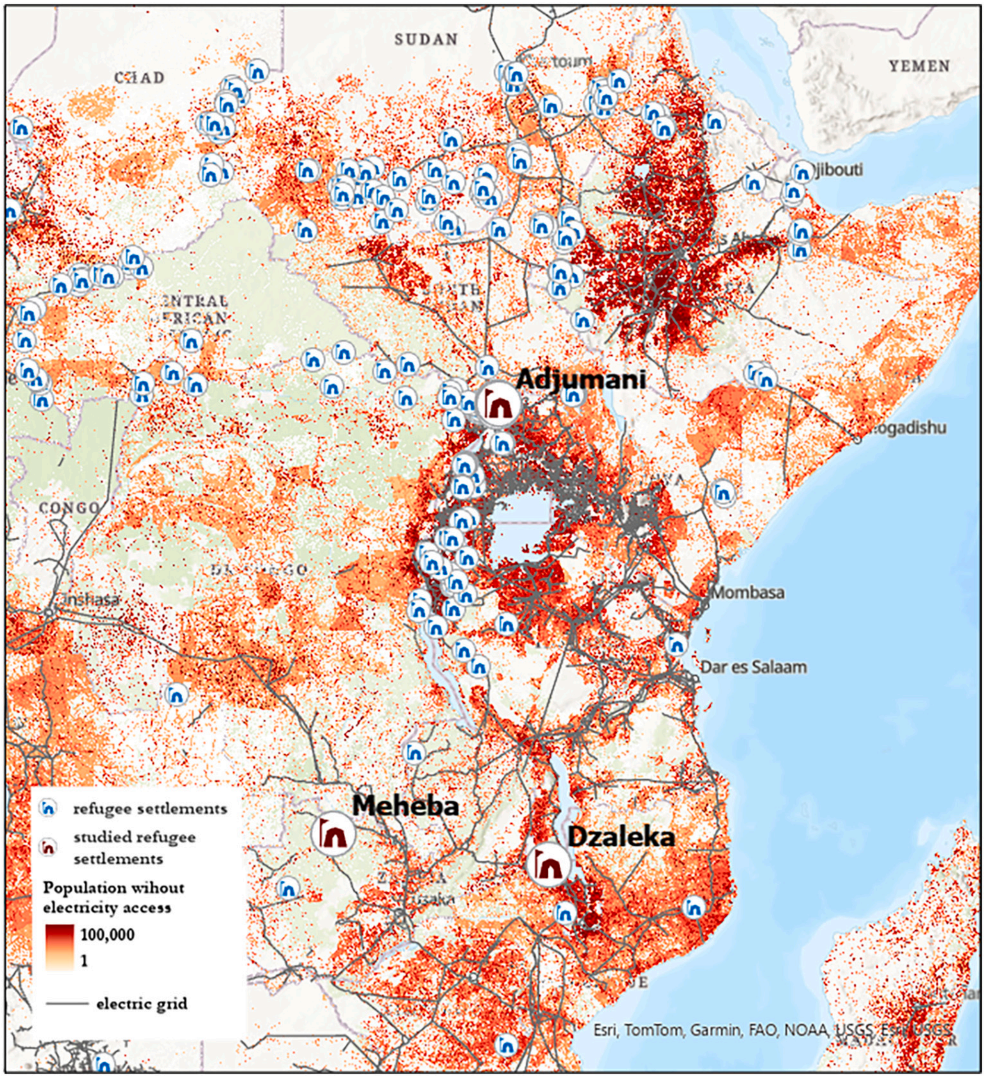


**Fig. 1.** Map of the observed settlements with the location of other refugee settlements, electric grid and population without access to electricity (people/km$^2$). (Source: Baldi et al. [21], Moner-Girona et al. [54], Falchetta et al. [55], https://africa-knowledge-platform.ec.europa.eu/energy_tool#).

the questionnaire allowed us to capture the role of:

- *Location*: the country, settlement, and administrative unit where the interview was conducted – basic information on the location (Table 3) was collected via desk research;
- *Awareness of the electricity services' benefits*: the questionnaire included questions on prior access to electricity (at home or at work) and on motivation for access (multiple choice questions including, e.g., safety, lighting, communication and entertainment, use of home/work appliances, and business improvement);
- *Income*: the questionnaire included questions on minimum and maximum monthly income, humanitarian aid (in cash or vouchers), the primary and secondary income-generating activities of the household, monthly expenditures on food (in cash), phone charging, and energy (recurring expenses, where possible, per fuel type);
- *End-user characteristics*: the questionnaire contained questions on the gender of the household/business head, the number of years the respondents had lived in the settlement, the household size and number of people working in a business, the type of business, and whether it was run from the house; in turn, we did not collect information on the level of education, access to banking and credit, and payment flexibility.

In practice, the database used in the present study contains 31 variables for households and 30 for businesses and was created following the steps indicated in Supplementary Data Annex B (Tables B.1 and B.2).[3] This so-called Refugee Energy Access and Socio-Economic Profiles (REASEP) dataset is openly available.[4]

### 3.2. Methods

To answer the four research questions stated in Section 1, we employ three different methods. First, to assess the existing electricity access levels and willingness to pay for a reliable electricity service for both households and businesses in the three observed settlements, we use descriptive statistics. We compare these values both within and across settlements and juxtapose them with comparable data obtained from

[3] Further information on the field data collection and primary data are available from the authors upon request.

[4] https://jeodpp.jrc.ec.europa.eu/ftp/public/JRC-OpenData/GIS-RE/EASE/REASE_Dataset_2022.xlsx.

**Table 3**
Main characteristics of the refugee settlements.

| Settlement | District (Country) | Established | Population (N.) | Administrative Units (Visited in bold) | | Urban/rural (Surface) | Population density | National refugee policy |
|---|---|---|---|---|---|---|---|---|
| Meheba | Kalumbila (Zambia) | 1971 | About 34,000 | **Block A** | Only refugees | Mix of semi-urban and rural area (720 km$^2$) | Low (with a few more densely populated areas) | Supportive (CRRF and GCR adopted)[a] |
| | | | | **Block B** | | | | |
| | | | | Block C | | | | |
| | | | | **Block D** | | | | |
| | | | | Block E | Former refugees from Angola and local population | | | |
| | | | | Block F | | | | |
| | | | | **Block G** | | | | |
| | | | | Block H | | | | |
| Dzaleka | Dowa (Malawi) | 1994 | About 50,600 | Lisungwi, Katubzya, Dzaleka Hills, Zomba, **Blantyre, Karonga, Kawale, Likuni, New Katubzya** | | Urban to semi-urban area (2 km$^2$) | High (close to the capital) | Restrictive (CFFR adopted, GCR planned but not implemented)[a] |
| Nyumanzi | Adjumani (Uganda) | 2014 | About 43,000 | n.a | | Rural area (3128 km$^2$ for the entire district) | Low | Supportive and proactive (CRRF and GCR adopted)[a] |
| Pagirinya | | 2016 | About 35,500 | | | | | |
| Ayilo I | | 2014 | About 25,200 | | | | | |
| Maaji II | | 2015 | About 17,000 | | | | | |

[a] CRRF is the Comprehensive Refugee Response Framework and GCR is the Global Compact on Refugees.

academic and grey literature.

Second, to empirically analyse the main drivers of current electricity access for both households and businesses, we apply binary logistic regressions [43]. Binary logistic regressions are designed to describe the relationship between one or more explanatory variables (i.e., factors that might affect the occurrence of an event) and a dichotomous dependent variable (i.e., the probability of that event occurring). In this study, the dependent binary variable, $Y_i$, indicates the probability, $P_i$, that end-user $i$ has access to electricity. Following [43], $P_i$ can be formulated as:

$$P_i = Pr[Y_i = 1] = \frac{e^{\alpha+\beta X_i}}{1 + e^{\alpha+\beta X_i}} \quad (1)$$

where $Y_i$ has only two outcomes:

$$Y_i = \begin{cases} 1 \rightarrow if \ \text{the end user } i \text{ has access to electricty} \\ 0 \rightarrow if \ \text{the end user } i \text{ has no access to electricity} \end{cases}$$

$\alpha$ is a constant term,
β is a vector of parameters to be estimated,
$X$ is a vector of explanatory variables for end-user $i$,
and the estimation form of the model is given after a so-called logit transformation of the probability:

$$Logit\ (P_i) = log\left(\frac{P_i}{1 - P_i}\right) = \alpha + \beta X_i \quad (2)$$

Previously utilized in the context of rural electrification to investigate the determinants of electricity adoption [44–46], the binary logit model is relatively easy to use (the regression coefficients – the β parameters – are determined via maximum likelihood estimation) and presents a straightforward interpretation. The effect of each regression coefficient can be expressed as an 'odds ratio', describing how a change in one of the explanatory variables affects the odds of the end-user having access to electricity [43].

Based on the observations in Section 2, we expect that the probability of a household having access to electricity in protracted refugee situations in SSA is driven by awareness-related explanatory variables, income-related variables, and variables describing end-user characteristics. Also, in the case of household respondents, we conjecture that the drivers of access might be different in locations characterised by different socio-economic conditions (see Section 4); hence, we estimate three separate logistic regression models, one per settlement.

Differently, we have no (socio-economic related) reasons to assume that the drivers for businesses would differ per location (see Section 4). Hence, all business observations are pooled together. However, we are still able to discuss the effect of the location, albeit indirectly. In fact, we estimate two models, one where the dependent variable is the probability of the business having electricity access (via any technology) and one where the dependent variables is the probability of the business having electricity access via a "local" technology. As discussed in Section 4, most businesses in one of the observed settlements are connected to the national grid. By estimating the second model, we aim to capture the drivers of access when the national grid does not reach the settlement – the majority settlements in SSA are located far from the national grid [21].

Third, to empirically analyse the main drivers of the willingness to pay for a reliable electricity service, we employ a linear regression model [43]. The latter is designed to estimate the relationship between a dependent variable and one or more explanatory variables. Linearity facilitates the examination of how incremental changes in the explanatory variables impact the dependent variable, providing a straightforward interpretation of the results and intuitive insights. For the purpose of this study, the continuous dependent variable $WTP_i$, captures the willingness to pay of end-user $i$ for a reliable electricity service, and the model is described by:

$$WTP_i = \alpha + \beta X_i + \varepsilon_i \quad (3)$$

where:
$\beta$ is a vector of parameters to be estimated,
$X_i$ is a vector of explanatory variables for end-user $i$,
$\varepsilon_i$ is the error term,
and an Ordinary Least Square (OLS) method is used to estimate the unknown parameters (as in Sievert and Steinbuks [10]).

Based on the observations in Section 2, we expect that willingness to pay in protracted refugee situations in SSA is affected by awareness-related explanatory variables, income-related variables, and variables describing end-user characteristics. Differently from the assumptions made for energy access, we have no strong reasons to assume that the drivers of the willingness to pay are different per location (the literature suggests that policies allowing refugees the freedom to work could drive the willingness to pay, but we already include income among the explanatory variables - Table 2). Hence, all the observations (per end-user type) are pooled together in the regression models. Nevertheless, we conjecture that drivers could be different for end-users who already have access to electricity and those who currently have no access, where the latter have a different awareness of the electricity access services. Hence, we estimate two separate models, one for those who currently have access and one for those who do not. Moreover, we employ a more detailed description of the 'awareness' than in the model used to analyse the probability of access. Finally, all models are first estimated using the maximum willingness to pay and replicated using the minimum as a robustness check.

A few practical remarks on the regression analysis are as follows. First, following Sievert & Steinbuks [10], all continuous variables in the regression models are transformed into logarithms to control for outliers; for monetary variables, a constant of one was added to variables embedding zero values. Also, to allow comparisons across settlements, all values in local currencies were converted into dollars using Purchasing Power Parity (PPP) conversion factors from the World Bank.[5] Second, to detect potential multicollinearity between the variables selected, we applied to both the binary logit and linear regression models the Variance Inflation Test (VIF); all VIF values are well below the commonly used threshold of 10, confirming the absence of strong multicollinearity among the explanatory variables. Finally, we note that variable descriptive statistics (dependent and explanatory) per settlement are reported in Table 4 (households) and Table 5 (businesses). Descriptive statistics over the entire sample are reported in Table B.3 (households) and Table B.4 (businesses) in Annex B. Pearson correlations over the entire sample are illustrated in Table B.6 (households) and Table B.7 (businesses) in Annex B.

## 4. Results

### 4.1. Analysis of current electricity access

The variable capturing electricity access in the REASEP database is dichotomous and equal to 1 if the household/business had access to electricity at the time of the interview. To distinguish access at the time of the interview from prior electricity access (before the respondent was forcibly displaced), the variable is called *current electricity access (CEA)*. Considering the Multi-Tier Framework for energy access [47], *current electricity access* captures the availability of at least basic lighting and communication services, corresponding to Tier 1 (lighting and phone charging enabled by solar lamps). As clarified below, for some end-users, the access level corresponds to Tier 2 (radio and TV supported by SHS) and, for a minority of end-users connected to a diesel generator or the national grid, Tier 3 access.

#### 4.1.1. Households

As illustrated in Table 4, we observe high heterogeneity in access rates across settlements; these are also not aligned with national electricity access rates. The highest proportion of household respondents with electricity access levels at Tier 1 or higher is found in Meheba, standing at 67 % (Fig. 2). This rate is notably higher than the national average in Zambia for the year 2021, which was 47 %. Conversely, the lowest access rate is found in Adjumani, at 16 %. This figure is considerably lower when compared to rural electricity access in Uganda, which stood at 36 % [1]. The electricity access rate in Dzaleka is 37 %, which is also lower when contrasted with the 54 % urban electricity access rate in Malawi [1].

With reference to the literature, two factors that could explain the across-settlement disparities is the number of years since the settlement was established (Adjumani is the most recent, and Meheba is the oldest) and the average household income (double in Dzaleka than in Adjumani, and twice as large in Meheba than in Dzaleka). Also, if we consider Adjumani as a single location, we observe a connection between access rates and the size of the settlement (where access rates decrease with size) and with population density (access rates are increasing with density). In turn, the link with national refugee policies needs further exploration: the most favourable policies and the lowest access rates are observed in Uganda (although open policies are expected to attract development funds on the longer term, this may not be the case of Adjumani yet).

We also observe (Fig. 3) that visible differences exist in terms of supply technologies adopted by households within and across settlements [3]. We note that in two out of three of the study areas (Dzaleka and Adjumani), off-grid solar technologies (solar lamps and SHS) are only available to a small number of households. In turn, the use of charcoal and firewood is significantly more widespread [48,49]. The same is not true for Meheba, where off-grid technologies are relatively as common as basic fuels. Moreover, it is also interesting to note that while off-grid solar technologies are found in all study areas, the presence of a few households connected to diesel generators or the national grid is specific to Meheba and Dzaleka, respectively. Meheba has a few densely populated areas, which are suitable locations for a shared diesel generator, while Dzaleka is a semi-urban site, and the national grid runs parallel to a major road tangent to the settlement. The same heterogeneity within and across settlements is also visible by observing the diffusion of electrical appliances among households (Table B.5, Annex B).

Table 6 reports published access rates for households and businesses in refugee settlements in SSA based on field data collections – from eight settlements in four countries: Burkina Faso [40], Kenya [8,40], Uganda [3], and Rwanda [11]. Household data show (as in our study) large heterogeneity in access rates (for Tier 1 and above) across settlements, with two locations scoring below 20 % and one at 80 %, while the majority is between 30 and 40 %.

#### 4.1.2. Businesses

The access rates of businesses (Table 5) present less heterogeneity across settlements and are all considerably higher than those observed for households (in the corresponding settlement) but similarly ranked. The percentage of businesses with Tier 1 or above access to electricity is the highest in Meheba (77 %) and Dzaleka (76 %) and comparatively lower in Adjumani (48 %). The link with the years since the settlement was established and the average business income continue to hold (the average business income in Adjumani is about 70 % of that in Meheba and Dzaleka), but a clear connection with national refugee policies (Table 3) and access rates (Fig. 2) does not emerge.

While businesses in Meheba and Adjumani rely on off-grid solar technologies and diesel generators, numerous businesses in Dzaleka are connected to the national grid (Fig. 3), suggesting that if a grid connection is available, it is largely used by refugees running a business. Correspondingly, the diffusion of electrical appliances such as radio and TV, fridges/freezers and computers is higher in Dzaleka than in the other two locations (Table B.5, Annex B).

When considering access rates for businesses in refugee settlements in SSA based on field data collections, Table 6 shows values around 60–70 %, which are just below the rates we observed in Meheba and Dzaleka, but above the rates in Adjumani, with two instances [40] where the observed enterprises typically had at least a solar lantern (in Goudoubo, Burkina Faso) or their own generator or diesel mini-grid (Kakuma, Kenya).

[5] https://data.worldbank.org/indicator/PA.NUS.PPP.

**Table 4**
Descriptive statistics for household respondents per settlement.

| Variable | Dzaleka (Malawi) | | | | | Adjumani (Uganda) | | | | | Meheba (Zambia) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Obs. | Mean | Std. Dev. | Min. | Max. | Obs. | Mean | Std. Dev. | Min. | Max. | Obs. | Mean | Std. Dev. | Min. | Max. |
| Access to electricity | | | | | | | | | | | | | | | |
| *Current electricity access* [binary] | 252 | 0.37 | 0.48 | 0 | 1 | 422 | 0.16 | 0.37 | 0 | 1 | 252 | 0.67 | 0.47 | 0 | 1 |
| *Prior access* [binary] | 252 | 0.52 | 0.50 | 0 | 1 | 422 | 0.40 | 0.49 | 0 | 1 | 252 | 0.53 | 0.50 | 0 | 1 |
| Willingness-to-pay | | | | | | | | | | | | | | | |
| $WTP^{max}$ [$/month] | 241 | 16.11 | 16.96 | 0.00 | 80.05 | 372 | 7.90 | 10.05 | 0.00 | 76.30 | 242 | 35.72 | 23.87 | 0.00 | 117.19 |
| $WTP^{min}$ [$/month] | 241 | 8.73 | 9.67 | 0.00 | 48.03 | 372 | 3.89 | 5.36 | 0.00 | 38.15 | 242 | 22.69 | 19.03 | 0.00 | 117.19 |
| *Income and related variables* | | | | | | | | | | | | | | | |
| *Income max* [$/month] | 169 | 160.48 | 136.00 | 16.01 | 960.58 | 261 | 78.99 | 105.62 | 7.63 | 572.26 | 218 | 303.54 | 375.99 | 15.63 | 1563.50 |
| *Income min* [$/month] | 168 | 83.77 | 70.04 | 16.01 | 320.19 | 258 | 39.45 | 61.45 | 7.63 | 572.26 | 217 | 210.25 | 336.76 | 15.63 | 1562.50 |
| *Food expenditure* [$/month] | 245 | 128.00 | 81.74 | 4.80 | 384.23 | 239 | 126.73 | 90.22 | 2.29 | 610.41 | 246 | 116.03 | 97.02 | 7.81 | 625.00 |
| *Humanitarian aid* [binary] | 252 | 0.82 | 0.39 | 0 | 1 | 422 | 0.58 | 0.49 | 0 | 1 | 250 | 0.02 | 0.15 | 0 | 1 |
| *Food insecurity* [binary] | 214 | 0.82 | 0.39 | 0 | 1 | 418 | 0.91 | 0.28 | 0 | 1 | 233 | 0.34 | 0.47 | 0 | 1 |
| *Secondary* [binary] | 252 | 0.42 | 0.50 | 0 | 1 | 422 | 0.36 | 0.48 | 0 | 1 | 252 | 0.66 | 0.47 | 0 | 1 |
| *Energy expenditure* [$/month] | 237 | 40.75 | 45.63 | 0.00 | 224.14 | 419 | 36.46 | 48.22 | 0.00 | 263.24 | 241 | 9.81 | 16.22 | 0.00 | 93.75 |
| End-user characteristics | | | | | | | | | | | | | | | |
| *Female head* [binary] | 250 | 0.39 | 0.49 | 0 | 1 | 417 | 0.82 | 0.39 | 0 | 1 | 247 | 0.36 | 0.48 | 0 | 1 |
| *Household size* [N.] | 252 | 6.40 | 3.33 | 1.00 | 15.00 | 419 | 8.41 | 3.34 | 1.00 | 15.00 | 252 | 6.21 | 3.00 | 1.00 | 15.00 |
| *Farming* [binary] | 252 | 0.29 | 0.45 | 0 | 1.00 | 422 | 0.46 | 0.50 | 0 | 1 | 252 | 0.71 | 0.46 | 0 | 1 |
| *Years* [N.] | 252 | 8.81 | 5.10 | 1.00 | 25.00 | 422 | 6.70 | 1.87 | 1.00 | 20.00 | 251 | 18.13 | 12.23 | 1.00 | 51.00 |
| Benefits of the electricity services | | | | | | | | | | | | | | | |
| *Safety* [binary] | 252 | 0.48 | 0.50 | 0 | 1 | 422 | 0.71 | 0.46 | 0 | 1 | 252 | 0.48 | 0.50 | 0 | 1 |
| *Lighting* [binary] | 252 | 0.20 | 0.40 | 0 | 1 | 422 | 0.75 | 0.44 | 0 | 1 | 252 | 0.57 | 0.50 | 0 | 1 |
| *Entertainment/ communication* [binary] | 252 | 0.52 | 0.50 | 0 | 1 | 422 | 0.72 | 0.45 | 0 | 1 | 252 | 0.71 | 0.46 | 0 | 1 |
| *Home appliances* [binary] | 252 | 0.41 | 0.49 | 0 | 1 | 422 | 0.24 | 0.42 | 0 | 1 | 252 | 0.56 | 0.50 | 0 | 1 |

### *4.2. Analysis of willingness to pay for reliable electricity*

To capture willingness-to-pay, the REASEP database contains two continuous variables, $WTP^{min}$ and $WTP^{max}$, capturing the respondent's minimum and maximum willingness to pay for electricity per month in case a mini-grid becomes available in the settlement. To put these questions in the right context, they followed a series of enquiries about the respondent's monthly income and recurrent monthly expenditures for phone charging and electricity (monthly instalments for SHS or monthly expenditures for a connection to the national grid).

#### *4.2.1. Households*

Descriptive statistics for households (Table 4) show significant heterogeneity across settlements. The highest means are recorded in Meheba, where $\text{WTP}^{\text{min}}$ is $23/month and $\text{WTP}^{\text{max}}$ is $36/month. In contrast, the lowest means are observed in Adjumani, at $4/month for $WTP^{min}$ and $8/month for $WTP^{max}$. Dzaleka falls in between, with intermediate values of $9/month for $WTP^{min}$ and $16/month for $WTP^{max}$.

One way to interpret differences in absolute values across settlements is in relation to average income. Indeed, Fig. 4. A illustrates that the average minimum and maximum income is considerably higher in Meheba ($210/month and $303/month, respectively) than in Dzaleka ($84/month and $160/month) and Adjumani ($39/month and $79/month) – as shown in Table 7 our data for Adjumani and Dzaleka is aligned with prior field evidence on household income in refugee settlements in SSA, while Meheba presents higher values.

When considered in relative terms, however, the average willingness to pay (minimum and maximum) corresponds to comparable portions of the average household monthly income in all settlements (about 10 % of the minimum and maximum income, respectively, in each settlement – see Table 4). At the same time, such percentages correspond to a sizable share of a refugee household's monthly income. By contrast, European households spend around 10 % of their monthly income on energy [50]; this includes not only electricity but also gas, petrol and other energy sources. Nevertheless, they are not unusual in the context of poor rural households in SSA. For instance, Sievert and Steinbuck [10] show that willingness to pay for electricity (in Burkina Faso, Senegal, and Rwanda) is between 12 and 15 % of total household expenditures.

Second, to reinforce the reliability of the figures in Table 4 as accurate estimates provided by the respondents, it is worth noting that they align with the observed average monthly expenditures on phone charging, which typically amount to approximately $12 per month (also reported in Fig. 4A). Phones fulfil a fundamental need for connectivity, which relies on electricity. Hence, it is rational to expect that the average household respondent is willing to allocate to electricity a budget similar to what they currently spend on charging their phones. Almost 50 % of the household respondents could indicate their phone expenditures to power their phones, making them knowledgeable of the electricity service they would be willing to pay for.

Third, looking beyond the average values, we observe that willingness to pay presents large heterogeneities within settlements (Fig. 5). Looking, for instance, at $WTP^{max}$ (similar observations can be made for $WTP^{min}$) shows that the variable distribution is left-skewed, with numerous households indicating a willingness to pay below the mean. While there are households willing to pay up to $80 per month (in Dzaleka and Adjumani) and up to $100/month in Meheba, we observe a

**Table 5**
Descriptive statistics for business respondents per settlement.

| Variable | Dzaleka (Malawi) | | | | | Adjumani (Uganda) | | | | | Meheba (Zambia) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Obs. | Mean | Std. Dev. | Min. | Max. | Obs. | Mean | Std. Dev. | Min. | Max. | Obs. | Mean | Std. Dev. | Min. | Max. |
| Access to electricity | | | | | | | | | | | | | | | |
| *Current electricity access* [binary] | 100 | 0.76 | 0.43 | 0 | 1 | 213 | 0.48 | 0.50 | 0 | 1 | 83 | 0.77 | 0.42 | 0 | 1 |
| *Current electricity access off-grid* [binary] | 100 | 0.18 | 0.39 | 0 | 1 | 213 | 0.46 | 0.50 | 0 | 1 | 83 | 0.77 | 0.43 | 0 | 1 |
| *Prior access* [binary] | 100 | 0.66 | 0.48 | 0 | 1 | 213 | 0.69 | 0.46 | 0 | 1 | 83 | 0.66 | 0.48 | 0 | 1 |
| Willingness-to-pay | | | | | | | | | | | | | | | |
| $WTP^{max}$ [$/month] | 100 | 33.56 | 26.24 | 0.00 | 128.08 | 189 | 18.82 | 30.66 | 0.00 | 228.90 | 79 | 42.19 | 22.56 | 0.00 | 93.75 |
| $WTP^{min}$ [$/month] | 100 | 18.74 | 18.44 | 0.00 | 96.06 | 188 | 10.46 | 19.41 | 0.00 | 152.60 | 79 | 26.93 | 20.49 | 0.00 | 93.75 |
| Income and related variables | | | | | | | | | | | | | | | |
| *Income max* [$/month] | 92 | 365.61 | 606.46 | 16.00 | 2401.46 | 181 | 272.74 | 220.84 | 7.62 | 572.26 | 73 | 374.04 | 404.20 | 46.88 | 1562.50 |
| *Income min* [$/month] | 92 | 230.75 | 498.12 | 16.00 | 2401.46 | 179 | 175.79 | 190.63 | 7.62 | 572.26 | 72 | 178.93 | 199.45 | 15.63 | 1562.50 |
| *Energy expenditure* [$/month] | 97 | 32.83 | 32.60 | 0.00 | 140.89 | 208 | 71.71 | 103.43 | 0.00 | 495.96 | 83 | 42.89 | 62.57 | 0.00 | 225.00 |
| End-user characteristics | | | | | | | | | | | | | | | |
| *Home business* [binary] | 100 | 0.37 | 0.49 | 0 | 1 | 213 | 0.58 | 0.50 | 0 | 1 | 83 | 0.15 | 0.35 | 0 | 1 |
| *Employees* [N.] | 100 | 2.47 | 1.31 | 1.00 | 6.00 | 213 | 2.32 | 1.69 | 1.00 | 15.00 | 83 | 2.30 | 1.56 | 1.00 | 10.00 |
| *Retail/wholesale* [binary] | 100 | 0.41 | 0.50 | 0 | 1 | 213 | 0.48 | 0.50 | 0 | 1 | 83 | 0.54 | 0.50 | 0 | 1 |
| *Female head* [binary] | 100 | 0.38 | 0.49 | 0 | 1 | 212 | 0.33 | 0.47 | 0 | 1 | 82 | 0.31 | 0.46 | 0 | 1 |
| *Years* [N.] | 100 | 7.86 | 4.90 | 1.00 | 22.00 | 213 | 5.59 | 2.58 | 1.00 | 16.00 | 83 | 13.47 | 9.56 | 1.00 | 42.00 |
| Benefits of the electricity services | | | | | | | | | | | | | | | |
| *Safety* [binary] | 100 | 0.35 | 0.48 | 0 | 1 | 213 | 0.46 | 0.50 | 0 | 1 | 83 | 0.19 | 0.40 | 0 | 1 |
| *Lighting* [binary] | 100 | 0.15 | 0.36 | 0 | 1 | 213 | 0.40 | 0.49 | 0 | 1 | 83 | 0.36 | 0.48 | 0 | 1 |
| *Entertainment/communication* [binary] | 100 | 0.54 | 0.50 | 0 | 1 | 213 | 0.65 | 0.48 | 0 | 1 | 83 | 0.69 | 0.47 | 0 | 1 |
| *Work appliances* [binary] | 100 | 0.56 | 0.50 | 0 | 1 | 213 | 0.39 | 0.49 | 0 | 1 | 83 | 0.75 | 0.43 | 0 | 1 |
| *Business improvement* [binary] | 100 | 0.50 | 0.50 | 0 | 1 | 213 | 0.71 | 0.45 | 0 | 1 | 83 | 0.31 | 0.47 | 0 | 1 |

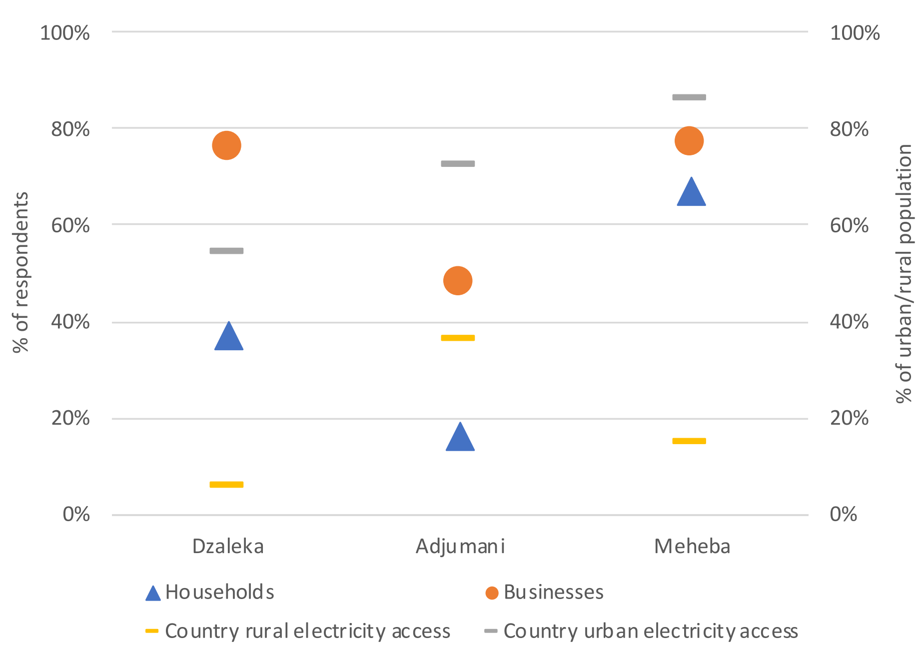


**Fig. 2.** Per settlement electricity access rates for households and businesses (left axis), compared to national electricity access statistics [1] (right axis).

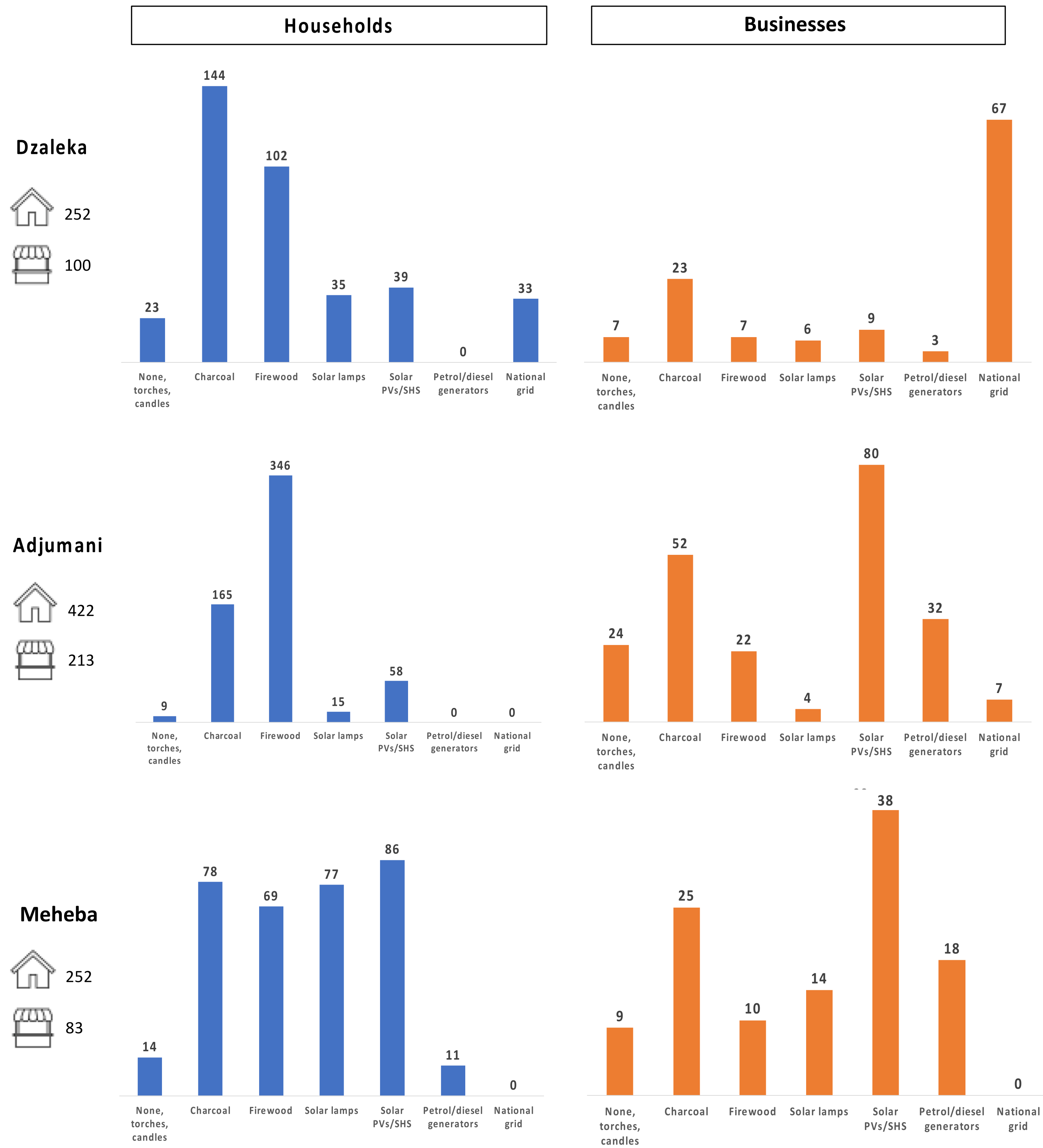


**Fig. 3.** Number of Households (blue) and Businesses (orange) using the different energy supply sources, per settlement. It is important to note that, for both end-user categories, multiple energy sources may be utilised. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

non-negligible percentage of respondents who indicated a willingness to pay equal to zero (19 % in Dzaleka and 28 % in Adjumani but only 2 % in Meheba). As 66 % of the zero values are found in Adjumani (and about 90 % were indicated by households with an income below the sample mean), we are inclined to interpret those values literally, i.e., as an indication that the household is not able to spend on electricity. Only further analysis could rule out other explanations, including that the respondents were purposively underestimating their answer or expected electricity to be provided for free (or via 'pro-poor' tariffs, as it is often the case for water).

Published data on willingness to pay for electricity services (different from willingness to pay to purchase an object, such as a solar lantern) from field data collected in refugee settlements in SSA is scarce. Shell et al. [33] report an average willingness to pay for electricity of $3/

**Table 6**
Electricity access rates: published data from field data collected in refugee settlements in SSA.

| Settlement | Country | Household electricity access[a] rate [%] | Business electricity access[a] rate [%] | Source |
|---|---|---|---|---|
| Goudoubo | BFA | 80 (solar lantern: 74) | 100 | Corbyn and Vianello [40] |
| Kakuma | KEN | 41 | 100: Tier 3 (diesel generator) | |
| Aylo I | UGA | 18 | 60 | van Hove and Johnson [3] |
| Aylo II | UGA | 27 | 60 | |
| Ghiembe | RWA | 46 | 71 | Practical Action [11] |
| Kigeme | RWA | 32 | 71 | |
| Nyabiheke | RWA | 40 | 62 | |
| Dadaab | KEN | 17.5 | n.a | Okello [8] |

[a] At least Tier 1 (solar lantern), unless specified.

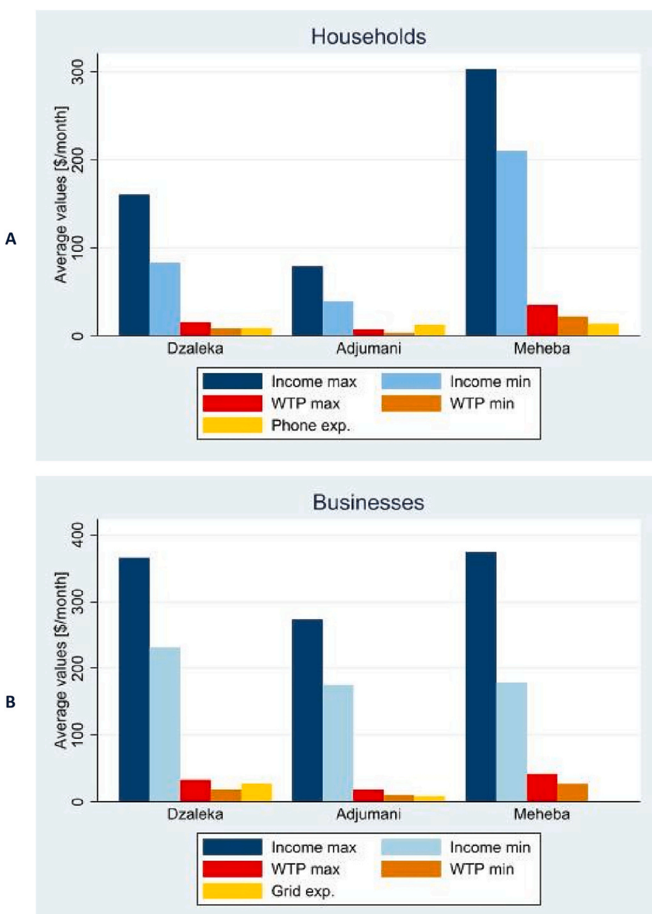


**Fig. 4.** (A) Comparison of average values of monthly Income (max and min), WTP for a reliable electricity service (max and min) and Phone expenditures of households. (B) Comparison of average values of monthly Income (max and min), WTP for a reliable electricity service (max and min) and Grid expenditures of businesses.

month in Bidi Bidi (Uganda), and Okello [8] reports $9/month for a reliable grid supply in Dadaab (Kenya). These are similar to our lower range of values.

#### 4.2.2. Businesses

Moving to business statistics (Table 5), we first observe visible differences in the average (minimum and maximum) willingness to pay

**Table 7**
Monthly income and energy expenditures: published data from field data collected in refugee settlements in SSA.

| | | Income[a] [$/month] | | Energy expenditures[a] [$/month] | | Source |
|---|---|---|---|---|---|---|
| Goudoubo | BFA | 53 | H: Median income | 8 | H: cooking, lighting and phone charging (15 % of median income) | Corbyn and Vianello [40] |
| Kakuma | KEN | 29 | H: Median income | 9 | H: cooking, lighting and phone charging (31 % of median income) | |
| Aylo I and | UGA | | n.a | 24 | H: Average recurring energy expenditures (12 % of average income) | van Hove and Johnson [3] |
| Aylo II | UGA | | n.a | 74 | B: Average recurring energy expenditures | |
| Kakuma | KEN | 96–117 | H: Median income | n.a | | Betts et al. [31] |
| Nakyvale | UGA | 53–193 | H: Median income | n.a | | |
| Bidi Bidi | UGA | 43 | H: Average income | n.a | | Shell et al. [33] |
| Ghiembe | RWA | 84 | H: Average income | n.a | | Thomas et al. [35] |
| Kigeme | RWA | 43 | H: Average income | n.a | | |
| Nyabiheke | RWA | 24 | H: Average income | n.a | | |
| Dadaab | KEN | 72 | H: Average income | 17 | H: Average energy expenditures (24 % of average income) | Okello [8] |

[a] H: household, B: business.

across settlements, although not as substantial as for households. The average valuations are also ordered in the same manner. We find the highest means in Meheba ($27 and $42/month, respectively for $WTP^{min}$ and $WTP^{max}$) and the lowest in Adjumani ($11 and $19/month), with intermediate values in Dzaleka ($19 and $34/month). Similarly, the average minimum and maximum income for businesses are higher in Meheba ($179/month and $374/month, respectively) and Dzaleka ($231/month and $366/month) than in Adjumani ($176/month and $273/month). Differences across settlements are also visible when we consider that the maximum willingness to pay corresponds to about 7 % of the average maximum monthly income in Adjumani, about 9 % in Dzaleka and 11 % in Meheba (results are similar when minimum values are considered) – see Fig. 4B.

Second, to address the robustness of the collected responses, we verify that they correspond, on average, to the local monthly expenditures for electricity currently purchased from the national grid in Dzaleka ($28/month) and Adjumani ($9/month), where this opportunity is available (Fig. 4B). Very few respondents indicated their monthly expenditures for a private or shared diesel generator, and those were

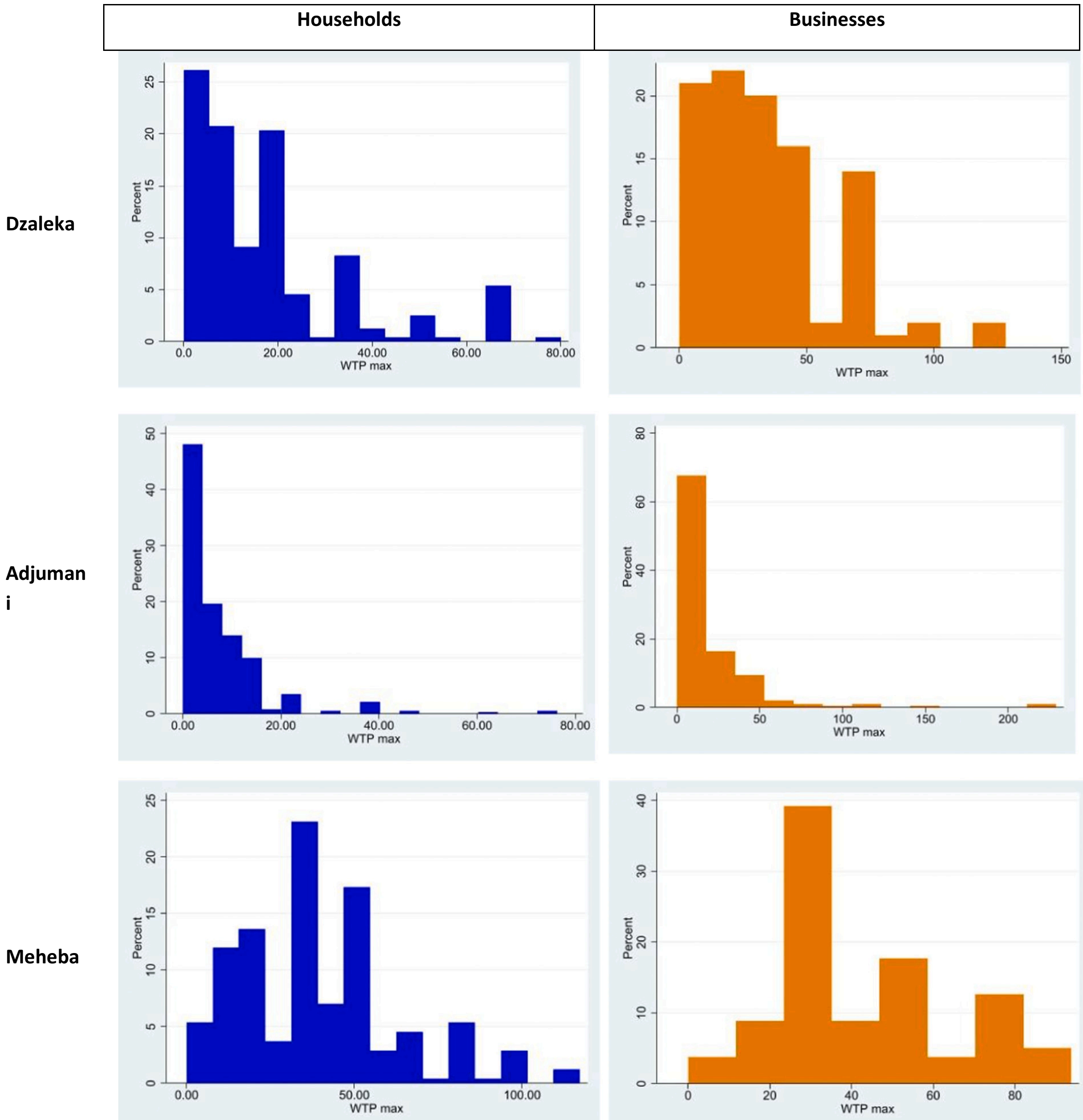


**Fig. 5.** Distribution of the maximum willingness to pay for a reliable electricity service for households (blue) and businesses (orange) per settlement. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

considerably higher (e.g., more than \$240/month in Meheba, where we collected the most answers).

Third, we observe, also for businesses, heterogeneities in the willingness to pay within settlements. Looking, for instance, at $WTP^{max}$ (similar observations hold for $WTP^{min}$), Fig. 5 shows that the variable distribution is left-skewed, particularly in Dzaleka and Adjumani, where numerous businesses indicated a willingness to pay below the mean or, in Adjumani only, equal to zero (24 % corresponding to lower income businesses). At the same time, there are businesses in the same settlements willing to pay more than \$100 per month for reliable electricity. A comparison with published field data for businesses in Zambia (outside of the humanitarian context) suggests that even the highest values we observe in Meheba (above \$90/month) remain below the mean reported by [39].

### 4.3. Drivers of current electricity access

In this section, we report the results of the binary logit models employed to study the drivers of electricity access for household and business respondents. In doing so, we also provide details on the explanatory variables that enter the models.

#### 4.3.1. Households

To study the drivers of electricity access for households, we employ three types of explanatory variables. First, to capture the awareness of the benefits of the electricity services, we use *prior access,* a binary variable taking a value of 1 if the respondent had access to electricity at home or at work before living in the refugee settlement. As expected, the correlation between *prior access* and *current electricity access* is positive. Also expected is that the percentage of respondents who had *prior access* to electricity is relatively higher than the percentage of respondents who currently have access. While this is verified in Adjumani (prior access of 40 %) and Dzaleka (52 %), the reverse is true in Meheba, the oldest of the three settlements, where only 53 % of respondents had prior access.

Second, to capture income-related variables, we employ *food expenditures*, a variable measuring monthly cash expenditures for food, and *humanitarian aid,* a binary variable taking a value of 1 if the household receives humanitarian aid in vouchers or cash. In fact, while several household respondents were reluctant to provide income information (about 30 % of the respondents), missing values were only 20 % of the household observations in the case of *food expenditures*. At the same time, there is a large consensus (e.g., [51]) that household consumption is a reliable indicator of income, especially in poor economies where the informal sector is prominent (thus, the income declared by respondents may be lower than its actual value). As expected, the correlation between *food expenditures* and *current electricity access* is positive. Also, while average food expenditures are quite similar across settlements (just above $100/month), strong heterogeneities emerge within settlements (the variable ranges between $2 and $610/month).

Given the refugee status of the respondents, *humanitarian aid* is, together with work, savings and transfers from family, an important element of the household budget. At the same time, the correlation between *humanitarian aid* and *current electricity access* is negative. In other words, the variable might capture, instead, the fact that the household is poor. Notably, our data indicate strong differences across settlements. In Meheba, only a negligible percentage of respondents receive humanitarian aid. This is in contrast with 58 % and 82 %, respectively, in Adjumani and Dzaleka.

Third, as for the end-user characteristics, we include the binary variables *female head*, equal to one if the household head is a woman and *farming* equal to one if the main income-generating activity of the household is farming. We also include the continuous variables *household size*, measuring the number of family members, and *years*, indicating the number of years the respondent had been living in the settlement.

The binary variables *female head* and *farming* are negatively correlated with current electricity access (apparently capturing poorer households – see Section 2). Most households in Adjumani were headed by women (82 %), in contrast to less than 40 % in Dzaleka and Meheba. In turn, the percentage of farming households is more significant in Meheba (71 %) than in Adjumani (46 %) and Dzaleka (29 %). Correlations of the continuous variables with *current electricity access* are opposite in sign: negative for *household size* and positive for *years*. These seem consistent with the average household size being higher in Adjumani (around 8) than in Dzaleka and Meheba (around 6) and with the average time spent in the settlement being higher in Meheba (18 years) than in Dzaleka (9 years) and Adjumani (7 years).

With these remarks in mind, we look now at the findings from the logistic regression analysis (Table 8). The estimated coefficients highlight that respondents with prior access to electricity are significantly more likely to have access to electricity currently (e.g., in Meheba, the odds of having access today are 2.3 times larger for those who had prior access compared to those who did not). In line with our anticipated expectations, this result holds for all settlements and is statistically significant at the 1 % confidence level. When examining the influence of household income, it is evident that in Dzaleka and Meheba, there is a positive correlation between monthly food expenditure and the likelihood of having access to electricity; in the case of Adjumani, where respondents were fairly equally divided between those who received humanitarian aid and those who did not, the odds of having access are about 6 times larger for households receiving it over those who do not (almost all or none of the respondents received aid in Dzaleka and Meheba, respectively).

Additionally, our results indicate that end-user characteristics matter in the older settlements of Dzaleka and Meheba (but not in Adjumani). Consistent with the energy access literature, larger households in Dzaleka and Meheba exhibit an improved likelihood of having access to electricity. Also, households whose primary economic activity revolves around farming are found to have a diminished likelihood of accessing electricity, however, the coefficient is significant in Dzaleka only. Differently, the gender of the household head does not emerge as a significant driver of access in the observed refugee settlements. One specific variable for the humanitarian context is *years*: the regression analysis shows that an extended duration of residence in the settlement implies a lower probability of having access to electricity. This suggests that the households that have been displaced for longer experience more difficulties with (or lower interest in) electricity access. Note that this is a different finding from observing higher access rates in older settlements (Section 4.1).

#### 4.3.2. Businesses

To study the drivers of electricity access for businesses, we employ three types of explanatory variables. First, as done for households, we use *prior access* to capture the awareness of the electricity services' benefits. The percentage of business respondents who had *prior access* to

**Table 8**
Drivers of electricity access: logistic regression results, household respondents.

| Households | Dependent variable: *Current electricity access* | | | | | |
|---|---|---|---|---|---|---|
| | Dzaleka | | Adjumani | | Meheba | |
| | Coeff. | Odds ratios | Coeff. | Odds ratios | Coeff. | Odds ratios |
| Intercept | −4.086*** | 0.017 | −3.155* | 0.043 | −2.396** | 0.091 |
| | (1.188) | | (1.902) | | (1.062) | |
| Prior access | 0.824*** | 2.279 | 1.712*** | 5.540 | 0.563* | 1.757 |
| | (0.302) | | (0.489) | | (0.312) | |
| Food expenditure (logarithm) | 0.754*** | 2.125 | 0.204 | 1.226 | 0.853*** | 2.347 |
| | (0.231) | | (0.299) | | (0.226) | |
| Humanitarian aid | 0.214 | 1.239 | 1.836*** | 6.271 | 0.298 | 1.348 |
| | (0.440) | | (0.618) | | (1.057) | |
| Female head | −0.413 | 0.662 | −0.712 | 0.491 | −0.370 | 0.691 |
| | (0.315) | | (0.567) | | (0.313) | |
| Farming | −0.736** | 0.479 | −0.655 | 0.520 | −0.542 | 0.582 |
| | (0.365) | | (0.489) | | (0.369) | |
| Household size (logarithm) | 0.571** | 1.770 | −0.687 | 0.503 | 0.482* | 1.619 |
| | (0.266) | | (0.502) | | (0.282) | |
| Years (logarithm) | −0.642** | 0.526 | 0.113 | 1.119 | −0.433** | 0.649 |
| | (0.263) | | (0.762) | | (0.176) | |
| *Obs.* | *244* | | *236* | | *240* | |
| *McFadden's R^2* | *0.166* | | *0.205* | | *0.133* | |

*Note*: The symbols ***, ** and * indicate statistical significance at the 1 %, 5 %, and 10 % level respectively. Standard errors are reported in parentheses.

electricity is higher than for households and remarkably similar across settlements (almost 70 %); also, the variable is positively correlated with *current electricity access*, as expected.

Second, we include the continuous variable *income*, measuring a business's maximum monthly income. As expected, *income* has a positive correlation with *current electricity access*. Notably, strong within-settlement heterogeneities characterise this variable. For example, in Meheba, the variable ranges from $47 to $1563 per month. Including *income* as an explanatory variable of *current electricity access* poses a well-known endogeneity issue, as the dependent variable could support income-generating opportunities [52]. Nevertheless, alternative solutions were not available from the primary data, and, differently from the household case, we had no specific reason to question the reliability of the collected answers.

Third, to express end-user characteristics, we use three binary variables and two continuous ones. The binary variable *female head* captures the gender of the business head; the binary variable *home business* is equal to one if the business is co-located with the household, and the binary variable *retail/wholesale* is equal to one for commercial business types (at the retail or wholesale level). Consistently with the household model, the continuous variables *employees* and *years* capture the size of the business (via the number of workers) and the time spent in the settlement by the respondent, respectively.

Our data indicate that, on average, the percentage of businesses headed by a woman is between 31 % in Meheba and 38 % in Dzaleka, with Adjumani at 33 %, and the variable *female head* has a negative correlation with *current electricity access* (as in the case of households). Co-location of homes and businesses is quite common in Adjumani (58 %) but less so in Dzaleka (37 %) and relatively uncommon in Meheba (15 %). This variable is thought to influence access via a greater demand for electricity which combines business and household needs. Nevertheless, the correlation of *home business* with *current electricity access* is negative but statistically not significant. Retail and wholesale shops are the most common business types in our dataset (more than 40 % of businesses in Dzaleka and Adjumani and more than 50 % in Meheba) and are typically expected to have access (the variable *retail/wholesale* is positively correlated with *current electricity access*).

Finally, the businesses considered in our sample are of small size (the average number of workers is around 2 in all settlements), and the years of residence in the settlement for business respondents are in line with household data (the average is 13 years in Meheba, 8 in Dzaleka, and 6 in Adjumani). The correlation with *current electricity access* is positive for *years* but negative for *employees* (neither is significant).

**Table 9**
Drivers of electricity access: logistic regression results, business respondents.

| Businesses | Model 1 Dependent variable: Current electricity access | | Model 2 Dependent variable: Current electricity access (off-grid) | |
|---|---|---|---|---|
| | Coeff. | Odds ratios | Coeff. | Odds ratios |
| Intercept | −3.564*** (0.743) | 0.028 | −4.877*** (0.791) | 0.008 |
| Prior access | 0.109 (0.254) | 1.115 | 0.098 (0.258) | 1.103 |
| Income (logarithm) | 0.611*** (0.113) | 1.842 | 0.704*** (0.118) | 2.023 |
| Female head | −0.168 (0.251) | 0.846 | −0.203 (0.257) | 0.817 |
| Home business | 0.103 (0.244) | 1.108 | 0.485* (0.248) | 1.625 |
| Retail/wholesale | 0.664*** (0.247) | 1.942 | 0.565** (0.245) | 1.760 |
| Employees (logarithm) | 0.051 (0.222) | 1.053 | −0.191 (0.222) | 0.826 |
| Years (logarithm) | 0.234 (0.158) | 1.263 | 0.316** (0.158) | 1.372 |
| *Obs.* | *344* | | *344* | |
| *McFadden's R^2* | *0.102* | | *0.120* | |

*Note*: The symbols ***, ** and * indicate statistical significance at the 1 %, 5 %, and 10 % level respectively.
Standard errors are reported in parentheses.

Looking at the regression results for businesses (Table 9, Model 1), we observe that only two variables are significant to explain current electricity access. Business income shows a positive and strongly statistically significant correlation with the dependent variable. For each 1 % increase in monthly income, the odds of a business having electricity access are 1.8 times higher, holding other factors constant. Furthermore, the odds of having access are almost 2 times larger for retail or wholesale shops with respect to businesses engaged in other types of activities. Differently from what we observe for households, our analysis reveals no compelling evidence to suggest that prior access to electricity matters among business users, nor do we see a significant effect of the variable *years* and *employees* (the size of the business). The gender of the decision-maker is still not a significant driver, nor is the co-location of home and business.

Since not all businesses run by refugees have the opportunity to be connected to the national grid, we run the model also using as a dependent variable off-grid access, *current electricity access off-grid*.[6] The results (Table 9, Model 2) validate the significance of income and engagement in retail/wholesale activities as factors that increase the likelihood of electricity access. Furthermore, two additional end-user characteristics now matter. First, the co-location of homes and businesses (a factor seldom mentioned in the literature) plays a significant role, with the odds of having access being 1.6 times later for business activities co-located with the households compared to those located outside the household. Second, an extended duration of respondent's residence in the settlement is positively associated with an increased probability for the business of having electricity access (the odds ratio equals 1.4).

### 4.4. Drivers of willingness to pay for reliable electricity

In this section we report the results of the linear regression models estimated to study the drivers of the willingness to pay for reliable electricity among households and businesses. Before presenting the results, we introduce the explanatory variables used in these models.

#### 4.4.1. Households

The awareness of the benefits of electricity services is captured, first, by the binary variable *prior access* (which is positively correlated with the willingness to pay). *Prior access* is complemented by a set of binary variables articulating the benefits associated with electricity (Table 4). In this regard, our data indicate that benefits are valued differently across settlements. Carrying out activities after dark (variable *lighting*) is considered important in Adjumani (75 % of respondents), together with improving safety (variable *safety*, 71 %) and using communication appliances (variable *entertainment/communication*, 72 %). The most valued benefit in Meheba and Dzaleka is linked to communication appliances (respectively 70 % and 52 % of respondents), and relatively higher percentages of respondents (respectively 56 % and 40 %) indicate the need to use other domestic appliances (variable *home appliances*), such as fridges and electric stoves (the value of this variable is only 24 % in Adjumani). Overall, these numbers (and the correlation coefficients of these variables with $WTP^{max}$ and $WTP^{min}$) suggest that where access rates are lower, respondents are concerned with the more fundamental benefits of electricity, namely lighting and safety, while interest in the

[6] The binary variable, *current electricity access off-grid* is equal to one if the business has access to electricity via an off-grid solar technology (e.g., a solar lamp) or is connected to a private or shared diesel generator, and zero otherwise. The off-grid access rate is 18 % in Dzaleka, 46 % in Adjumani and 77 % in Meheba (Table 5).

use of communication and other appliances emerges where access rates are higher.

To capture the role of household income, we employ three binary variables and a continuous one. One of the binary variables, *humanitarian aid*, was already described and is negatively correlated with the willingness to pay (with respect to willingness to pay it appears to capture the fact that households receiving humanitarian aid are less willing to spend on electricity due to their disadvantaged economic status).

In addition, we measure whether the family suffers severe food insecurity (if this is the case, the variable *food insecurity* takes a value of one) and whether the household can rely on a secondary economic activity to generate income (when this is true, the variable *secondary* is equal to one). While the second is a signal of better economic conditions that increase the family's ability to pay for electricity, the first can be interpreted as a measure of poverty. We observe that 66 % of the families in Meheba can rely on a secondary income source, and the food insecurity indicator has the lowest value (34 %) across the three settlements. In turn, only less than half of the households in Dzaleka (42 %) and Adjumani (36 %) can rely on a secondary income-generating activity. More importantly, the share of households experiencing food insecurity in Adjumani (91 %) and Dzaleka (82 %) indicate that access to enough nutritious food is a challenge for most refugees. As expected, the correlation with willingness to pay is positive for the variable *secondary* and negative for the variable *food insecurity*.

Finally, we add *energy expenditures*, a continuous variable measuring monthly energy expenses in (only recurring costs, such as, for instance, fuel, including cooking fuel, and/or monthly charges for a grid connection). In fact, this variable is included in the regression model mainly to control for the 'quantity' of the electricity needs of the household – recall that the willingness to pay is measured in $ per month, not per unit of energy. Comparing average energy expenses across settlements, we note that Meheba has the lowest value (around $10/month), which can be explained by the high adoption rate of solar technologies, compared to Adjumani ($37/month) and Dzaleka ($41/month). As shown in Table 7, our data for households (and businesses) are aligned with prior evidence from the field in the same geographical area.

Third, the variables capturing the end-user characteristics are four: two are binary (*female head* and *farming*), and two are continuous (*household size* and *years*). They were all described before. Two are negatively correlated to the willingness to pay (*female head* and *household size*), and two are positively correlated (*farming* and *years*).

The linear regression results for household respondents are reported in Table 10. Model 1 and Model 2 for the dependent variables $WTP^{max}$ include respondents with and without current access, respectively. Consistently with the literature and the above discussion, in both models the $WTP^{max}$ is significatively influenced by the variables capturing household income: humanitarian aid (negative sign), food insecurity (negative sign), secondary economic activity (positive sign). In Model 2, in addition to income, we observe that monthly energy expenditure, exhibits statistical significance and a positive correlation with $WTP^{max}$.

In terms of the awareness of the benefits, we note that prior access to electricity does not emerge as a statistically relevant predictor of $WTP^{max.}$ However, safety is found to be statistically significant and has a positive effect on $WTP^{max}$ within the group of respondents who do not currently have access to electricity (Model 2). Conversely, for those with electricity access (Model 1), the significance lies in the potential use of home appliances, which is positively associated with $WTP^{max}$.

As for the end-user characteristics, the significant variables are the protractedness of the refugee status (positive sign); moreover, in Model 2, households headed by a female demonstrate a significant negative association with the dependent variable. In turn, farming and size are not significant drivers.

As a robustness check, we run both models using $WTP^{min}$ as the dependent variable. Significant coefficients remain the same, confirming the robustness of the results. The only exception is the variable related to the use of home appliances, which now becomes significant in both models.

**Table 10**
Drivers of willingness to pay for reliable electricity: linear regression results, household respondents. Model 1: Respondents with electricity access; Model 2: Respondents without electricity access.

| Households | Dependent variable $WTP^{max}$ | | Dependent variable $WTP^{min}$ | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 |
| Constant | 2.541*** | 2.506*** | 1.915*** | 1.877*** |
| | (0.337) | (0.301) | (0.306) | (0.251) |
| Prior electricity access | 0.051 | 0.027 | 0.090 | 0.044 |
| | (0.140) | (0.099) | (0.127) | (0.083) |
| Safety | −0.060 | 0.260** | −0.064 | 0.228*** |
| | (0.141) | (0.105) | (0.128) | (0.088) |
| Lighting | −0.185 | −0.094 | −0.101 | −0.095 |
| | (0.141) | (0.108) | (0.127) | (0.090) |
| Entertainment/ communication | 0.178 | −0.057 | 0.194 | −0.060 |
| | (0.155) | (0.115) | (0.141) | (0.096) |
| Home appliances | 0.392*** | 0.162 | 0.377*** | 0.201** |
| | (0.151) | (0.106) | (0.137) | (0.089) |
| Humanitarian aid | −0.957*** | −0.885*** | −0.805*** | −0.663*** |
| | (0.188) | (0.105) | (0.170) | (0.087) |
| Food insecurity | −0.424*** | −0.758*** | −0.334** | −0.784*** |
| | (0.150) | (0.128) | (0.136) | (0.107) |
| Secondary | 0.449*** | 0.207* | 0.488*** | 0.244** |
| | (0.169) | (0.121) | (0.153) | (0.101) |
| Energy expenditure | 0.030 | 0.102*** | 0.027 | 0.067*** |
| | (0.040) | (0.027) | (0.036) | (0.023) |
| Female head | −0.031 | −0.317*** | −0.058 | −0.255*** |
| | (0.132) | (0.106) | (0.120) | (0.088) |
| Household size (logarithm) | −0.185 | −0.057 | −0.130 | −0.038 |
| | (0.127) | (0.091) | (0.115) | (0.076) |
| Farming | −0.035 | −0.037 | 0.051 | −0.052 |
| | (0.158) | (0.120) | (0.143) | (0.100) |
| Years (logarithm) | 0.325*** | 0.203** | 0.253*** | 0.223*** |
| | (0.089) | (0.081) | (0.081) | (0.068) |
| *Obs.* | *273* | *496* | *273* | *496* |
| *R-squared* | *0.467* | *0.298* | *0.470* | *0.323* |

*Note*: The symbols ***, ** and * indicate statistical significance at the 1 %, 5 %, and 10 % level respectively. Standard errors are reported in parentheses.

### 4.4.2. Businesses

In the case of business, the awareness of the benefits is captured by the binary variable *prior access* (which is positively correlated with the willingness to pay), plus a set of binary variables capturing the benefits associated with electricity (Table 5). These include variables that were introduced before: *lighting, safety, entertainment/communication,* and use of *(work) appliances.* In addition, we include a variable equal to one if the respondent values electricity for the possibility that it will bring *business improvement*. All these variables (apart from *safety*) are positively correlated with the willingness to pay. Respondents across settlements value, in particular, the use of appliances (for communication/entertainment and work) together with business improvement. Lighting and safety emerge as particularly relevant in Adjumani.

The regression models include business *income* (already discussed) and *energy expenditures* (as a control for the electricity needs of the business). As expected, *energy expenditures* are positively correlated with willingness to pay and present strong heterogeneities within settlements, particularly in Adjumani (ranging from $0 to $496 per month), and across settlements: the variable mean is more than double in Adjumani ($72/month) than in Dzaleka ($33/month), with Meheba at $43/month.

The variables capturing the end-user characteristics are five: three are binary (*home business*, *retail/wholesale*, and *female head*), and two are continuous (*employees* and *years*). They were all described before. The three binary variables are negatively correlated with the willingness to pay, and the continuous ones are positively correlated.

**Table 11**
Drivers of willingness to pay for reliable electricity: linear regression results, business respondents.

| Businesses | Dependent variable $WTP^{max}$ | Dependent variable $WTP^{min}$ |
|---|---|---|
| | Coeff. | Coeff. |
| Constant | 0.234 | −0.075 |
| | (0.371) | (0.359) |
| Prior access | 0.053 | 0.100 |
| | (0.131) | (0.127) |
| Safety | −0.029 | −0.039 |
| | (0.129) | (0.125) |
| Lighting | −0.079 | 0.047 |
| | (0.228) | (0.221) |
| Entertainment/ communication | −0.038 | −0.007 |
| | (0.134) | (0.130) |
| Work appliances | 0.220 | 0.116 |
| | (0.148) | (0.144) |
| Business improvement | −0.151 | −0.099 |
| | (0.132) | (0.128) |
| Income (logarithm) | 0.428*** | 0.383*** |
| | (0.055) | (0.053) |
| Energy expenditure (logarithm) | 0.102*** | 0.063** |
| | (0.032) | (0.031) |
| Home business | −0.494*** | −0.523*** |
| | (0.127) | (0.123) |
| Employees (logarithm) | 0.119 | 0.111 |
| | (0.118) | (0.115) |
| Retail/wholesale | −0.226* | −0.204* |
| | (0.128) | (0.124) |
| Female head | −0.123 | −0.173 |
| | (0.133) | (0.129) |
| Years (logarithm) | 0.234*** | 0.271*** |
| | (0.081) | (0.078) |
| *Obs.* | *317* | *316* |
| *R-squared* | *0.316* | *0.291* |

*Note*: The symbols ***, ** and * indicate statistical significance at the 1 %, 5 %, and 10 % level respectively.
Standard errors are reported in parentheses.

The regression results for businesses are reported in Table 11. Here, we observe that, as expected, income and monthly energy expenditures are positive and significant determinants of $WTP^{max}$ and $WTP^{min}$. As for end-user characteristics, the number of years in the settlement has a positive and significant effect on the dependent variable, while co-location of home and business and being in the retail/wholesale sector present a significant negative relationship with it. None of the variables capturing the benefits of the technology are significant.

## 5. Discussion

In this section, we delve into our main findings concerning *current electricity access* and willingness to pay for a reliable electricity service. We also examine the limitations and constraints of the data and methods employed in this research. Finally, we suggest directions for further research.

### *5.1. Main findings*

Our investigation reveals considerable heterogeneity in electricity access rates when refugees are responsible for acquiring their own energy supplies. Interestingly, our field data are in line with previous field studies, suggesting that access rates in protracted refugee settlements in SSA can span considerably, from less than 20 % to about 80 % (and even more in the case of businesses). The motivations for such disparities are important to understand in view of addressing them.

As for differences in access rates in the three locations of Dzaleka, Adjumani and Meheba, we were able to connect them to the years since the settlement was established, as well as to the average income level of the end users, confirming that older and wealthier settlements are characterised by higher access rates for both households and businesses. In turn, it was not possible to establish a clear connection between observed access rates and the rural/urban electricity access rates of the hosting country or the support offered by national refugee policies. In this regard, it would seem logical to find wealthier communities and higher access rates in countries where open policies are granted and refugees are able to move freely and access livelihoods; at the same time, this effect would be visible only on the longer term.

Large disparities are evident in the available energy technologies across the different locations. While one semi-urban location (Dzaleka) is reached by the national grid, a rural location (Adjumani) has limited electricity access, with only three households out of twenty having access to a few hours of light per day and the possibility to charge a phone or use a radio/TV. Indeed, the level of electricity access observed in our study is generally low, falling within Tier 1 and Tier 2 for the majority of households having access and Tier 2 and Tier 3 for business users. However, even in locations where informal diesel mini grids are available, issues such as reliability and lack of sufficient capacity remain significant challenges (about 80 % of our business respondents declared to be unsatisfied with the current level of service).

The regression analysis looking into the drivers of access among households and businesses (Fig. 6) has highlighted that the likelihood of having access is driven, first and foremost, by income. This underscores the importance of affordability in determining access to electricity. Notably, household income can be derived from different sources, and we observe that humanitarian aid can serve as a catalyst for enhancing electricity access. Additionally, and for households specifically (though not for businesses), prior access, i.e., the awareness of the benefits of having access to electricity services/technologies, plays a significant role.

With respect to the energy access literature focusing on SSA, our study does not find evidence supporting a significant role for the gender of the household head. However, our data corroborate that households relying on farming as their primary economic activity face disadvantages in accessing electricity, while larger households tend to have an increased probability of access. Furthermore, our analysis reveals a novel insight: while electricity access rates are higher in older settlements, households with longer residency in these settlements may have a lower probability of accessing electricity compared to those who have been displaced for shorter durations.

As for business characteristics, our analysis indicates that the type of activity, in our case, retail and wholesale shops, may play a role in enhancing the probability of electricity access. In turn, size, gender of the business head, and years spent in the settlement do not emerge as relevant drivers. Interestingly, when we exclude end-users connected to the national grid (which is a minority in the humanitarian context), we find that the co-location of home and business enhances the probability of access. This aspect is often overlooked but proves to be important in enhancing electricity access.

The analysis of the willingness to pay for reliable electricity reveals similar trends to those observed in electricity access rates, with significant variations in average values across different locations, particularly among households. For instance, when considering the maximum willingness to pay, the mean value in Meheba is 4.5 times larger than in Adjumani and more than double that in Dzaleka. Staying with the absolute values, households and businesses that are in settlements that are older and wealthier tend to exhibit a higher average willingness to pay values. The data also suggest that more supportive national refugee policies, such as those existing in Uganda, do not necessarily correspond to higher average willingness to pay for reliable electricity. This finding underscores the complex interplay between policy frameworks, socio-economic factors, and individual preferences when it comes to energy access and affordability within refugee settlements.

When considered in relative terms, willingness to pay corresponds to a sizable share of household income (10 %) and to increasing shares of business income (from 7 % to 11 %) in increasingly wealthier


**Fig. 6.** Drivers of *current electricity access* and *willingness to pay* for reliable electricity for households and businesses.

settlements. Respondents appeared to anchor their monthly willingness to pay for reliable electricity to current, easy-to-recall electricity expenditures for phone charging (households) and electricity from the national grid (businesses). These could be used to infer the average willingness to pay of refugees where no field data is available.

Particular attention should be paid to the fact that the distribution of the willingness to pay within each settlement is highly skewed, and for relatively few respondents willing to spend more than $80/month, most answers were below the settlement mean. Also relevant is that the share of zero values, which we interpret as the inability to pay for electricity, was considerably larger in lower-income settlements.

The regression analysis looking into the drivers of willingness to pay for reliable electricity among households and businesses (Fig. 6) confirms income as a relevant driver. As for households, income is captured via proxies that are specific to the context of this work. Households experiencing food insecurity and receiving humanitarian aid are associated with a lower willingness to pay for electricity, while households having a secondary source of income exhibit a higher willingness to pay.

Among the end-user characteristics, we now find a relevant role for the gender of the household head (negatively correlated with the willingness to pay) and observe that, for both households and businesses, the longer the time spent in the settlement, the higher the willingness to pay for reliable electricity. Also, we note that lower willingness to pay is associated with a co-location of the home and business and a business activity in the retail/wholesale sector.

In turn, our results only weakly support the idea that the awareness of the benefits is a significant driver of the willingness to pay. While prior access plays no role, we observe, for households only, that concerns for safety and the ability to use home appliances increase the willingness to pay among those who currently have and do not have access, respectively. Notably, apart from the latter difference, the drivers of the willingness to pay for electricity do not differ across the two household groups (those who have and those who do not have access).

### 5.2. Limitations

The data used in this paper is based on an extensive field data collection and, with its 1322 observations, is quite large within the humanitarian energy literature. Nevertheless, the questionnaire designed to conduct the interviews prioritised the collection of data necessary to estimate the settlements' latent demand for electricity and conduct techno-economic analyses of energy interventions. In other words, it was not specifically tailored to conduct a socio-economic analysis of current levels of access and willingness to pay for electricity (such as, e.g. [31]). For instance, the sample was not a priori designed to capture the full range of socio-economic conditions experienced by refugees. Accordingly, even though the number of interviews per settlement is representative (the size of the sample, assuming a 95 % confidence level, gives a 4 to 5 % margin of error, depending on the country), the results of our analysis are to be interpreted as outcomes concerning only the respondents.

Also, we are aware that eliciting information on willingness to pay is prone to cognitive and strategical biases [10]. Although we approached these questions by providing plenty of context and we thoroughly discussed (in Section 4) the reliability of the collected answers, we cannot exclude that the respondents underestimated their true valuation (or overestimated it to signal how much they need electricity).

Finally, assumptions were made to clean the primary data. As a typical example, minimum income values were recorded in place of maximum values; while two researchers always double-checked each change to ensure it reflected the intended meaning of the collected answers, we cannot entirely exclude that this activity might have affected our findings.

As for the empirical models used to analyse the drivers of electricity access and willingness to pay for electricity, they were designed to capture the types of potential drivers known from the literature on energy access and humanitarian energy studies in SSA. Still, not all the explanatory variables identified in previous work were available from our primary data. Hence, potentially relevant effects could not be tested (e.g., the level of education of the end-user, or the ability to redirect expenditures from other basic needs, such as food). Still, using the available explanatory variables, we were always able to observe if the driver's type (e.g., the end-user characteristics in general) emerged as a significant determinant of access or willingness to pay.

In our logistic analysis, we addressed the issue of potential endogeneity for household income by employing well-established proxies based on the literature, thereby reducing the likelihood of reverse causality between income and the dependent variable. This approach allowed us to mitigate the impact of endogeneity in the models for households. However, for businesses, our dataset presented constraints that limited our ability to utilize similar proxies for income. Consequently, we cannot entirely rule out the presence of endogeneity, as *current electricity access* may, in turn, influence business *income*. This interdependence underscores a limitation in our analysis, highlighting the need for caution in interpreting the results for businesses.

Finally, our sample combines evidence from three locations which differ considerably from one another in terms of contextual factors (e.g., refugees hosted at the national level and national refugee policies, costs and availability of a grid connection, proximity to local markets, socio-economic conditions of the hosting population). These external conditions were not the focus of the data collection and were not included in the empirical models (where the unit of observation was the end-user, not the settlement). Although they would deserve greater attention, they were, at least, briefly discussed when comparing data across settlements. Other potentially important factors, such as the availability of development support, donor interests in funding certains refugee situations, or the inclusion of refugee settlements in national development plans (through advocacy efforts made by UNHCR or other humanitarian agencies) also remain to be explored.

### 5.3. Research directions

Altogether, our findings provide preliminary insights into the complex role of a few variables that are peculiar to the humanitarian energy literature and deserve to be further analysed. The *years* spent in the settlement drive the willingness to pay for a reliable electricity service for both refugee households and businesses. Refugees residing in the settlement for a longer time might have a stronger sense of electricity as an enabler of economic development. In turn, while the variable *years* increase the probability of “off the national grid” access for a business, they decrease the probability of access for a household. Also, *prior access* significantly drives the probability of households currently having access to electricity but plays no role in driving the willingness to pay for a reliable service (neither for households nor businesses). Further inquiries into the dynamics of electricity access decisions over time could clarify these findings.

The co-location of *homes and businesses* (quite frequent in the observed settlements) and the business being a *retail or wholesale* shop (also a quite common business activity) are associated with an increased probability of access but a lower willingness to pay for a reliable electricity service. Further analysis could shed light on the specific motivations for electricity acquisition of these households and businesses.

The variable *humanitarian aid* emerged as a driver of access and of a lower willigness to pay for a reliable eletricity service - it was interpreted as 'additional' income and as a signal of difficult economic conditions or limited livelihood opportunities which entail insufficient income). This divergence calls for a deeper exploration of the complex relationship between aid and energy access.

By using *food expenditures* (a driver of *current electricity access*) and *food insecurity* (a barrier to the willingness to pay) as proxies of income, this study had only indirectly touched upon another very important topic that we leave for future research: the nexus between electricity access and food security - and more generally between access and other primary needs, such as health, and education.

Altogether, this discussion underscores not only the role of additional empirical analysis based on quality data but also the role of qualitative research methods, which are crucial in revealing the complex socio-economic dynamics behind the adoption of energy solutions and identifying solutions and best practices to increase access to safe, sustainable, and affordable energy [5,6]. Improved energy solutions should not only address immediate needs but also play a pivotal role in enhancing security, nutrition, education, livelihoods, health, and the environment [53].

Finally, we note that while publicly available data from field assessments is scarce and not systematically collected, field evidence in SSA indicates higher access rates with respect to global estimates – "94 % of displaced people in camps do not have access to electricity?" ([2], p. 10). Significant work is needed to address this information gap.

## 6. Conclusions

Access to sustainable, affordable, and reliable energy in humanitarian settings is widely acknowledged as a key enabler of self-sufficiency and development. At the same time, the consensus is that while the number of forcibly displaced people globally increases due to conflicts and climate change, access rates might be declining over time [2].

To contribute, at least in part, to understanding the actual situation and potential direction for change, this work focuses on forcibly displaced populations living in settlements in protracted situations in three SSA countries (Malawi, Uganda, and Zambia). Relying on data from the field from three specific locations (Dzaleka, Adjumani, and Meheba), we estimate and analyse the current level of energy access and the willingness to pay for reliable electricity, as well as their main drivers among refugee households and businesses. These evidence-based insights are valuable as they contribute to the identification of some of the specific socio-economic challenges of meeting SDG7 in the observed locations and context.

Heterogeneity in the electricity access and willingness to pay for reliable electricity within and across the surveyed refugee settlements has identified the importance of supporting policies aimed at facilitating refugee access to work as a key source of income, the one variable that emerges as relevant across all the analyses in this work. At the same time, planning for higher levels of access should also be a key concern because current access levels are low, the quality of the electricity service matters, and the local availability of different technological options is also heterogeneous.

Always in relation to income, great attention is needed in establishing financial support mechanisms tailored to refugee settlements. These mechanisms would potentially enable economically vulnerable groups to obtain electricity access. Specifically, they might mitigate the disparity between larger and smaller households, between families relying on income from formal employment and those depending on farming as their primary economic activity, and between those relying on multiple rather than single income-generating activities.

The awareness of the benefits of electricity access emerged as a relevant issue in the case of households. Therefore, addressing a potential information gap between those who have and those who have no experience with electricity access becomes relevant. More generally, it is important that refugees can make well-informed decisions when purchasing an electricity technology or service.

The disparity in the willingness to pay for reliable electricity highlights a gender gap which does not appear elsewhere in our analysis. The same holds for businesses co-located with the household, as co-location might signal smaller or nascent enterprises with higher barriers to paying for electricity. Further inquiries would be necessary before designing gender-specific interventions or small/new business-specific policies. We recall that this work has not looked into access to banking services or the level of education of the decision maker, while both factors could already enhance the willingness to pay and the ability to make an informed decision for the refugees.

The protractedness of the refugee situation also emerges as a specific concern when households living in the settlement for longer appear to have a lower probability of having access to electricity. In this regard, tailor-made policies might be necessary to support these families. More generally, in light of this result, planning for energy access solutions should receive higher priority after a forced displacement.

The role of national refugee policies (CRRF and GCR) in meeting SDG7 in the humanitarian context via market based solutions deserve greater attention. Policies defining the right to work and freedom of movement play a key role in addressing self-sustained economic development, which is enabled, among other things, by energy access. At the same time, greater self reliance might drive energy access via higher income levels.

Finally, to avoid potential conflicts, planning for electrical energy service needs to be informed by and target the needs of the local hosting population alongside those of the refugees. Possibly because we used national instead of local information on electricity access, this work offers little guidance on the nexus between access rates in refugee settlements and energy access of the hosting population and how they connect with national electrification strategies. This important topic should be addressed by further research.

## CRediT authorship contribution statement

**Paola Casati:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. **Elena Fumagalli:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. **Duccio Baldi:** Data curation, Project administration, Writing – original draft. **Magda Moner-Girona:** Conceptualization, Investigation, Resources, Supervision, Writing – original draft, Writing – review & editing.

## 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

I have shared the link to my data within the manuscript

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## Appendix A. Supplementary data

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