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Department of Environmental and Geographical Science

Accelerating productive energy access for the just transition among vulnerable communities; a case study of West Nile, Uganda

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ABSTRACT

Sustainable enhancement of energy security has been considered crucial for a just transition towards low carbon sustainable socio-economic development including poverty eradication, job creation and decent employment, food security, among others. Nevertheless, multidimensional energy poverty is still a widespread phenomenon, profound in low-income economies such as Uganda, more so in the rural areas. To investigate the key issues underlying productive energy access and energy-livelihood interlinkages in the context of micro and small enterprises, this research carried out a case study survey of 129 enterprises in West Nile, Uganda, where previous studies mainly focused on household energy consumption. Data were analysed based on the Multidimensional Energy Poverty Indices (MEPI) framework, capturing how the 4A's dimensions of accessibility, availability, affordability and acceptability reinforce or constrain energy choices. The study found that most enterprises rely on grid (43%), then solar PV (16%) and lastly fuel generator (10%) to meet their energy needs, while 31% are energy bricoleurs who diversified their energy sources to guarantee energy security. The prevailing source of energy used is closely associated with socioeconomic enabling or disabling factors such as gender, education, business type, and market and finance based factors. Further, the results show that several enterprises experienced severe challenges in all dimensions of the 4A's framework, and strong interlinkages existed between energy access and the livelihoods of the enterprise owners. Policies and programmes that seek to address productive energy access should be multidimensional, and should consider gender, education and capacity building, and the key types of enterprises driving the local economy. The potential of solar PV should be reinforced using innovative financial mechanisms and product design to ensure it is both affordable and suited for the needs of the local businesses. Addressing productive energy access should be considered as one of the key strategies to promote sustainable livelihoods.

Key phrases: Energy access, renewable energy, small enterprises, productive-use, livelihoods, energy security, energy security.

Table of Content

List of Figures

1. Chapter 1: Introduction

The energy sector is crucial to achieve sustainable development due to its role in driving socio-economic development. If harnessed, the energy sector also presents opportunities to drive development while combatting climate change, owing to its contribution to greenhouse gas emissions accounting for up to 75% of total global emissions (UNFCCC, 2015; IPCC, 2018; Le Quéré et al., 2019; IEA, 2021). Access and affordability of sustainable energy is particularly essential to unlock sustainable development goals (SDG) linked to poverty eradication, job creation and decent employment, climate action, food security, clean water, among others (Lema et al., 2021; Oluoch et al., 2021; Opoku, Kufuor & Manu, 2021; Koçak & Çelik, 2022). Thus, to put the world on a path toward its socio-economic development and climate goals, a transition to low-carbon and sustainable energy systems with universal access will be imperative. To achieve this, SDG 7 has been dedicated to building clean, accessible, reliable, and affordable energy systems.

Despite the recognition of the benefits and imperative of sustainable energy access, coupled with the significant investments to promote energy access and affordability in Africa, realising the ultimate benefits of a sustainable energy economy in terms of universal energy access, socioeconomic development, and transitioning to cleaner renewable energy options remains a real challenge (Dagnachew et al., 2017; Baumli & Jamasb, 2020; Antwi & Ley, 2021; Oluoch, Lal & Susaeta, 2021; Ssennono et al., 2021; IEA, 2022). The challenges to energy access and energy-driven socioeconomic development are more nuanced in Sub-Saharan Africa, which is characterised by high levels of energy poverty, with nearly 600 million people having no access to sustainable and conventional energy alternatives (IEA, 2022). Worse still, the proportion of people lacking sustainable access to energy is projected to rise by 11% by 2030 – more so in the least developed countries such as Uganda (Ssennono *et al.*, 2021). The challenges associated with ensuring energy access and transitioning to cleaner energy options provoke critical questions on the current approaches to achieve effective and sustainable energy access for all and the socioeconomic development impacts of the current energy landscape.

1.1. The Problem context

The focus of this study is on the West Nile region of Uganda. Per its National Development Plan, and pledge to shift to low carbon development pathways in the Nationally Determined Contributions (NPA, 2020; MWE, 2021), harnessing developments in the energy sector is key to shaping Uganda's development and meeting its international climate obligations. Despite these commitments, Uganda still grapples with high rates of energy poverty that pose significant challenges to unlocking the potential of the energy sector in steering sustainable socio-economic development (UBOS, 2020; Ssennono et al.,2021; Trotter, Cooper & Wilson, 2019).

Reports by UBOS (2020) indicate only 14.8% of Ugandans have access to on-grid energy sources. Additionally, about 94% of Ugandans mainly depend on biomass-based energy sources to meet their primary energy needs, which is exacerbating deforestation and other environmental challenges (UBOS, 2020). Uganda has recently adopted a more centralised and grid-extension-based approach to ensure energy access and transitions, however, studies suggest it is practically infeasible, and cost and time ineffective to get everyone onto the centralised grid system (Trotter, Cooper & Wilson, 2019).

Energy security and access is not only crucial in key sectors at the macroeconomic level, but also in driving productive small enterprises in rural microeconomies, as well as smallholder household livelihoods' sustainability and security (Mukuve & Fenner, 2015; Thomas, Williamson & Harper, 2021). The significance of energy access is highlighted by the fact that households in rural and urban areas spent approximately 15.9% and 23.6% of their income respectively on meeting energy-related needs (UBOS, 2020; van Hove & Johnson, 2021). Owing to the impetus to overcome their energy needs challenges, many smallholder households and associated small-scale enterprises are energy bricoleurs, sourcing diverse kinds of energy to meet their energy needs. However, these decisions are not sustainable to fully satisfy their energy needs in the long term (Munro & Bartlett, 2019a; van Hove & Johnson, 2021). The energy dependent needs of the smallholder households include lighting, changing electric devices, and running small-scale energy-based enterprises, among others (van Hove & Johnson, 2021).

To offer solutions to the complex challenges in the energy landscape, the national government, businesses, and development agencies have engaged in developing grant and market-based decentralised renewable energy systems (Eder, Mutsaerts, & Sriwannawit, 2015; Butu et al., 2021; MEMD, 2019). The alternatives include grid extension, solar PV projects, and improved biomass-based systems such as bagasse (Munro & Bartlett, 2019; Trotter, Cooper & Wilson, 2019). However, the uptake of these alternatives is relatively low and has not fully translated into sustainable energy access and livelihoods, especially among rural communities and energy-based enterprises (Okello *et al.*, 2013; Eder, Mutsaerts & Sriwannawit, 2015). Although national reports indicate significant gains in generation capacity and energy access (UBOS, 2020), there is a risk of masking disparities in access and socioeconomic development impact at sub-national levels such as West Nile region (Trotter, Cooper & Wilson, 2019a; Ssennono *et al.*, 2021).

1.1.1. Research Aim

The aim of this study is to investigate the key issues underlying energy access for productive end-use in the context of micro and small enterprise owners in West Nile, Uganda.

1.1.2. Main research questions

1) What are some of the key factors driving energy access for productive use among micro and small enterprises in West Nile, Uganda?
2) How does energy access impact the livelihoods of micro and small enterprise owners in West Nile, Uganda?

1.1.3. Specific objectives

1. To survey current energy access for productive end-use among micro and small enterprises (MSE) in West Nile.
2. To examine if current energy access meets the productive needs of micro and small enterprise end-users and has affected their livelihoods.
3. To investigate the factors driving the uptake of clean energy alternatives in West Nile.

1.2. Case study area: West Nile Region

Home to over 3 million Ugandans (UBOS, 2020) and over 700,000 refugees (UNHCR, 2020b), West Nile is in north-western Uganda, bordering on the Democratic Republic of Congo, and South Sudan (Figure *1.1.*) It has a largely rural population, and an economy driven by smallholder agricultural practices and several small and medium-scale enterprises that deal in various produce and merchandise.

The region faces high levels of energy poverty and is only serviced by a 3.5 megawatts mini-hydro power dam and a 1.6 megawatts thermal power plant (MEMD, 2019; Ssennono et al., 2021) which are not accessible or affordable to many of the inhabitants of the region. This situation potentially constrains socioeconomic development and the sustainability of energy-driven small enterprises.

Similar to many regions in Uganda, the energy landscape in West Nile is associated with high levels of energy bricolage and is the subject of political promises that have hardly been delivered (Trotter & Maconachie, 2018; Munro & Bartlett, 2019a; van Hove & Johnson, 2021). To meet the energy demands of the ever-increasing population and proliferating productive energy-driven small enterprises, off-grid energy solutions that are mostly dominated by solar-based systems supplied through development agencies, formal energy vending firms, or the open market are being promoted (Tröger & Tyumeneva, 2011). For a region with high poverty rates, no access to the national grid, and relatively high rates of insolation (Mubiru & Banda, 2012; UBOS, 2020), off-grid solar energy presents optimal cost-effective solutions to address the energy needs, but this has only been partially embraced.

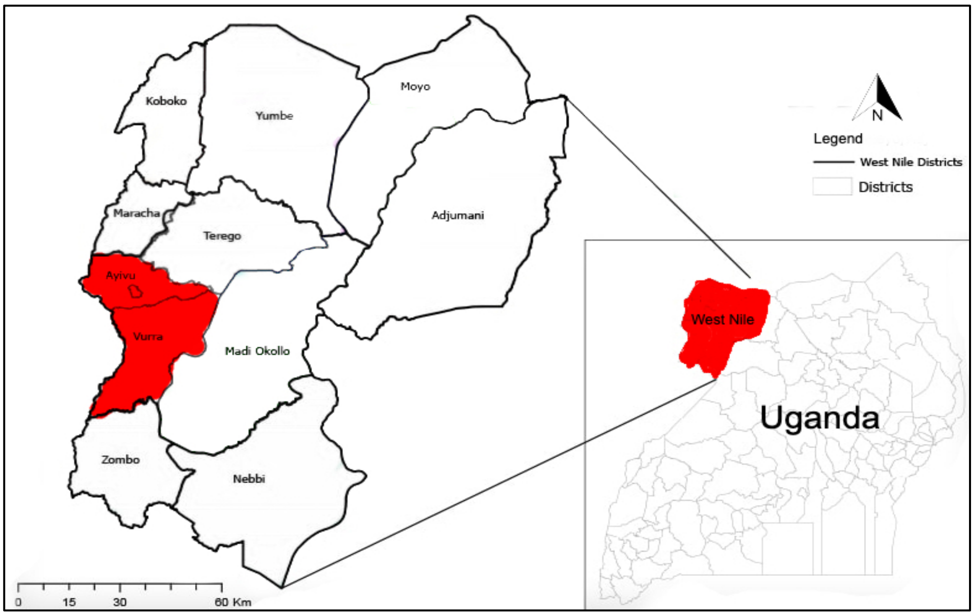

Figure 1.1 Map of Uganda showing West Nile Region.

1.3. Thesis outline

This thesis is divided into five broad chapters. Chapter one (this chapter) provides a context for the aim, research questions the study investigates, and objectives to be achieved. It also provides an outlook of the case study area. In chapter two, literature on energy access is synthesised and the research problem is presented in the context of productive enterprises, combining global, national and local scale dynamics. In the third chapter, the methodological approach for data collection and analysis of the data, together with the analytical framework are presented. Chapter four presents the results and discussions, spanning three broad areas of energy access, renewable off-grid solar PV uptake and energy-enterprise-livelihoods interlinkages. Chapter five presents conclusions, policy recommendations, and limitations of the research.

2. Chapter 2: Literature review

This chapter considers the general landscape of energy security and access in terms of how they have been conceptualised through different scholarly sources and frameworks. It also provides insights into the discourses surrounding the dynamics between energy poverty and development. It then narrows further to unpack the energy access scenarios and barriers in Uganda, looking into Uganda's overarching policy and strategic frameworks governing energy access. Additionally, it presents the emerging off-grid clean renewable energy technologies and attempts to explore the existing rationalities for the emergence of these technologies. To connect the objectives and target population of the study, this chapter offers insights into the interlinkages between micro and small enterprises and the productive use of energy. Lastly, it provides insight into the research gap in the study area, West Nile region.

2.1. The landscape of energy security and access; from global to local

The definition of the concept of energy security remains a big debate among several scholars and institutions and is a concept that has many different meanings (Kruyt *et al.*, 2009; Cherp & Jewell, 2014; Blumer *et al.*, 2015; Tutak & Brodny, 2022). Energy security traditionally was defined in terms of security of supply and availability of fuels (Sovacool, 2010). However, the emerging global trends have shifted the definition to include a more comprehensive worldview with different dimensions of energy security. Due to the multidimensional nature of energy development, the definition of energy security in several pieces of literature is being shaped by the social, geopolitical, economic, technological as well as human security and environmental demands (Sovacool, 2010; Vivoda 2010; Von Hippel 2011; Sakib bin Amin 2022; Axon & Darton, 2021).

Barton et al (2004) defined energy security as a state where a country's enterprises and all, or the majority of its population, have access to affordable energy resources for the foreseeable future without any significant risk of service disruption, a definition which brings national interests to the fore but does not pay attention to the environmental dimension of energy security. Along similar lines, Forini (2010) simply defined energy security as affordable and reliable access to energy supplies, without giving due regard to other factors shaping the energy landscape such as environmental and social sustainability. Brown and Sovacool (2007) defined energy security in terms of adequacy of energy supply and affordability of prices and social as well cultural sustainability and environmental preservation, introducing concepts of socio-culturalism and environmental sustainability. Jansen and Seebregts (2010) further defined energy security in terms of how much of a population in a defined location can obtain services for energy that are affordable, competitively priced, environmentally friendly, and of suitable quality – stressing the point of efficient service delivery and environmental acceptability. This definition is closely coherent with that of Muller-Kraenner (2007) who proposed energy security as a state of affordable, reliable, and environmentally friendly supply of energy.

This study relies on the definition by the International Energy Agency (IEA) which defines energy security as uninterrupted, reliable, affordable access to all forms of fuel and energy sources (IEA, 2021). However, the study also draws from many scholars who have moved on to conceptualise and measure energy security using the 4A's indicator framework of accessibility, affordability, availability, and acceptability which may be lacking in the IEA definition (Kruyt *et al.*, 2009; Sovacool & Mukherjee, 2011; Yao & Chang, 2014; Amin *et al.*, 2022). Some scholars have finetuned the indicators further to more discrete measurable indicators (Sovacool & Mukherjee, 2011). Nevertheless, it is important to note that there is no best-fit indicator since energy security is context-dependent and multi-dimensional.

From all the scholarly sources defining energy security, energy access stands out as a core pillar to achieve energy security. Available scholarly evidence suggests that access to sustainable, affordable, and reliable sources of energy holds the key to unlocking solutions to other global challenges of health, technology, education, and poverty among others (Roche & Blanchard, 2018; Lema et al., 2021; Wassie & Adaramola, 2021). This is especially true, at the national level, from the positive correlation between human development indices, and energy access in terms of regional per capita energy consumption (UBOS 2020).

Despite the advent of global energy policies, goals, and strategies such as the Sustainable Development Goals (in this context goal 7) and fora such as the Sustainable Energy for All initiative, coupled with the significant recognition of energy access as a global goal, universal access to sustainable, affordable, and reliable energy resources is still a big challenge. This challenge is particularly more acute in low-income economies such as Uganda which lack access to reliable, sustainable, and modern forms of energy (IEA, 2019).

To strengthen the energy security of the country, the government of Uganda made reforms to the energy sector, which include disintegrating the former state-owned Uganda Electricity Board into different agencies in charge of generation, transmission, and distribution (MEMD, 2020; Tumwesigye et al., 2011; UBOS, 2020). The reforms have yielded some positive benefits in terms of energy security, such as increased generation capacity, increased access to electricity, and proliferation of both grid and non-grid-based rural electrification in which the private sector plays a big role (MEMD, 2020; UBOS, 2020). Despite these changes, energy insecurity, particularly access insecurity, in Uganda remains considerably high (Ssennono *et* al., 2021), thus the government's challenge is to increase access to reasonably priced, consistently reliable, and sufficient energy sources.

2.2. Energy Poverty and development: a complex interlinkage

Similar to energy security, the concept of energy poverty is marred by the lack of a generally accepted definition due to its multidimensional nature and the dependence on the context of reference (Ruiz-Rivas et al., 2022; Salman et al., 2022; Sy & Mokaddem, 2022). Reddy (2000 p. 44) defined energy poverty as the:

"Absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development".

In contrast, other scholars have dived into the specifics, giving specific definitions for energy poverty. For example, Nayan Yadava and Sinha (2019) and Nathan and Hari (2020) defined energy poverty in the context of cooking, lighting, agriculture, and transport. Other scholars have defined energy poverty in terms of a threshold of the share of house income expense in meeting energy needs (Gafa & Egbendewe, 2021). It is worth noting that the definition of energy poverty also applies differently to different countries, based on the level of development. For instance, energy poverty in developed countries is framed in the context of the cost of energy relative to income to meet basic needs, whereas, in developing countries, it is framed in the context of accessibility and infrastructure (Sy & Mokaddem, 2022).

Due to the need to address the complexity of solving the energy poverty definition, different scholars have proposed a number of indicators to measure energy poverty, including single or unidimensional and multidimensional energy poverty indices (MEPI) (Abbas et al., 2022; Gafa & Egbendewe, 2021; Ruiz-Rivas et al., 2022; Salman et al., 2022; Sy & Mokaddem, 2022;

Ugembe et al., 2022). However, MEPI seems to have a better advantage of applicability due to its ability to capture diverse dimensions of energy poverty and the ability to showcase inter-country comparisons. Like energy security indicators, MEPI has been disaggregated into 13 indicators classified into 3 dimensions, that is, affordability, acceptability/cleanability, and accessibility (Salman, Zha & Wang, 2022).

Available scholarly and institutional evidence suggests that despite significant steps being taken to alleviate energy poverty, it remains widespread worldwide and is more pronounced in Africa. Particularly in Sub-Saharan Africa, it has been presented in terms of access to energy in the context of infrastructure and the capacity to afford the energy to meet basic needs dependent on energy (Abbas et al., 2022; IEA, 2021; Mahumane & Mulder, 2022; Ozughalu & Ogwumike, 2019; Salman et al., 2022; Ssennono et al., 2021; Ugembe et al., 2022). Alleviating energy poverty remains interconnected with achieving several social, economic, and environmental development agendas. For instance, Opoku et al. (2021) and Sovacool et al. (2013) cited energy access as vital in achieving gender equality. Sule et al. (2022) demonstrated the positive correlation between energy poverty and infant mortality and the negative correlation between energy poverty and inequality in education. Furthermore, a survey by the World Bank in 2018 indicated the significant losses made in production and sales due to failures in the provision of energy (World Bank, 2019). Ultimately, addressing energy poverty remains a high imperative to realise the enhanced well-being of economies and communities.

Unfortunately, there is no silver bullet to addressing energy poverty since it is linked to many multidimensional and compounding factors. These factors include government policy and strategies to alleviate energy poverty, household income and wealth that influence households' ability to meet their energy needs, and infrastructural and geographical factors among others (Trotter, Cooper & Wilson, 2019a; Gafa & Egbendewe, 2021; Ye & Koch, 2021; Wang & Lin, 2022). Wang and Lin (2022) particularly highlighted the positive correlation between household income poverty and multidimensional energy poverty, calling for policies that target the income sources of households, such as enterprises, to enhance their ability to meet their energy needs. This also partly draws on how energy access affects households' income sources, in this case, small enterprises, and how the households' livelihoods are in turn affected by energy poverty at the source of their income.

Energy poverty in Uganda also presents itself in a similar multifaceted and multidimensional manner, ranging from domestic to commercial as well as industrial energy poverty (Ssennono et al., 2021). Energy poverty in Uganda relates to affordability associated with the high electricity tariffs, accessibility associated with the limited extension infrastructure and acceptability in terms of smoke emissions and cleanliness of the energy source with the energy sector associated with intense use of fossil fuels, and heavy reliance on biomass fuels which pose both human health and environmental sustainability challenges (Munro & Bartlett, 2019a; Ssennono et al., 2021; Trotter et al., 2019; UBOS, 2020)

2.3. A synopsis of the energy access scenario and barriers in Uganda

Uganda's energy landscape is dominated by an abundance of both renewables and fossil fuel-based energy resources (UBOS, 2020; MEMD, 2020). Efforts to enhance the potential of the energy sector through increased generation capacity has almost tripled over the past decade. The energy security prospects have been further boosted by the exploration of oil in the Albertine graben. Between 2018 and 2019 alone, energy generation capacity increased by 27.5% with the dominant sources being mini-hydro power sources and solar PV (UBOS 2020). However, the increase in generation and installed capacity has not translated into energy access for all and reduced access challenges, with over 90% of the population still reliant on traditional biomass-based energy sources such as firewood and charcoal for their basic energy needs such as cooking (Bamwesigye et al., 2020; MEMD, 2020; Munro & Bartlett, 2019a; Trotter et al., 2019). Energy-related challenges in the country include severe power shortages, rising demand, high electricity tariffs, limited grid extension infrastructure, dependence on imported fossil fuels with risk of price fluctuations, and hydro-generation threatened by climate change, which render energy security highly unstable (Marembo et al., 2018; Ssennono et al., 2021; Trotter et al., 2019; Tumwesigye et al., 2011)

A report by Uganda's Ministry of Energy and Mineral Development (MEMD, 2020) indicated that sales and purchases of electricity have increased, however, Uganda still has one of the poorest per capita consumption and reliability of electricity in the world (Meyer, Eberhard & Gratwick, 2018; Ssennono et al., 2021). Additionally, it has one of the poorest electricity access rates at 28%, which is markedly below the Sub-Saharan Africa average of 42%. In terms of expenditure-based energy poverty, Uganda has one of the highest power tariffs, which usually results in households needing to spend about 22% of their annual income on meeting energy needs – a significant factor exacerbating energy poverty (Ssennono et al., 2021; UBOS, 2020). Overall, energy poverty remains widespread in Uganda, with over 66% of Ugandans classified as multidimensionally energy poor and nearly 33% classified as severely energy poor

(Nussbaumer, Bazilian & Modi, 2012; Ssennono et al., 2021). Energy poverty is reinforced along asymmetrical lines in terms of gender, region, and residence, among others. For instance, (Ssennono et al., 2021) noted that 75% of the energy-poor population was rural and only 40% urban, with up to 70% of females suffering from energy poverty.

Owing to the multiple co-benefits that conventional energy resources accrue to end-users and suppliers, upscaling energy access is fundamental in overcoming many development challenges. At local-grassroots levels in rural areas, users are drawing from a diverse energy mixes to meet their energy demands, yet, the sustainability of these strategies is limited (Munro & Bartlett, 2019a; van Hove & Johnson, 2021). At a national level, policies and development strategies and programs such as Sustainable Energy for All (SEA4ALL) are being promoted. However, the feasibility of the national energy development strategies and frameworks that emphasise generation rather than access is highly questionable and potentially falls short of what is required to overcome the challenges of energy access (Trotter, Cooper & Wilson, 2019a).

Some of the key barriers that underpin these shortfalls may include ineffective governance and policy frameworks and their implementation; limited economic and financial capital; limited access to information; socio-cultural barriers and infrastructural barriers among others (Quansah, Adaramola & Mensah, 2016; Ikejemba et al., 2017; Guta, 2018; Bukari et al., 2021; Come Zebra et al., 2021). Population increase is likely to exacerbate the energy access challenge by outpacing grid extension, but this on one hand could also potentially be harnessed to increase access due to a potential decrease in per person cost of electrification (Trotter, Cooper & Wilson, 2019a; Nsafon et al., 2020). On the other hand, the population increase accompanied by rapid urbanization could exacerbate energy poverty by increasing the household income share used for energy purchases, limiting the capability of the households from meeting their growing energy needs.

2.4. Policy and strategic frameworks governing energy access in Uganda

A significant proportion of Uganda's overall energy ecosystem is governed by the Uganda Electricity Act 1999 which regulates the generation, transmission, and distribution, among others, of electrical energy. This is supported by the Uganda Energy Policy (GOU, 2019 p. 12), a revision of the Uganda Energy Policy 2002, that aims to:

"develop, strategically manage and safeguard the rational and sustainable exploitation and equitable utilization of energy resources for social and economic development".

At a strategic level, nationally, upscaling sustainable energy access is part of Uganda's National Development Plan III (NPA, 2020). Uganda is also part of the Sustainable Energy for All (SE4ALL) organisation and seeks to achieve increased implementation of off-grid solutions with 3.17 million new household interconnections by 2030. Furthermore, Uganda's Nationally Determined Contributions (MWE, 2016) to the Paris Climate Agreement also highlight opportunities to increase energy access through promoting increased renewable energy and generation, increasing energy efficiency, and constructing enabling infrastructure. Despite the ambitious policies, strategies, and regulatory frameworks, energy access and transitioning to cleaner energy sources is still a big challenge for most of the country (Ssennono et al., 2021; Trotter et al., 2019; UBOS, 2020).

2.5. Off-grid clean renewable energy alternatives

The growing global urgency to combat climate change and reach net zero by reducing sources of greenhouse gases has occasioned a political, financial, and socio-technical regime shift in the energy landscape (United Nations, 2015). The regime shift is characterised by a transition from fossil fuel-based inefficient energy systems to more renewable systems that emphasise efficiency (IEA, 2019).

Several discourses and rationalities invoke the imperative of a transition to cleaner renewable energy options in Uganda. Firstly, Uganda is a signatory to the strategic and political level regime shift that warrants low-carbon development pathways such as the Paris Climate Agreement and the Clean Development Mechanism under the Kyoto Protocol. Secondly, the reliance on unconventional biomass energy as a cheap source is not only destructive to the environment but also highly inefficient and with limited co-benefits for productive enterprise purposes (Tahir, Rafique & Alaamer, 2010). The reliance on these unconventional resources also renders users highly climate vulnerable (Jagger & Kittner, 2017).

Thirdly, it is likely that at the time of full-scale exploitation, Uganda's fossil resources will be less profitable due to the increasing disincentivising of fossil resources and a regime shift in finances towards renewable and cleaner energy systems. Lastly, grid-based energy systems have proven to be ineffective in exclusively achieving energy access, highlighting the value of off-grid renewable systems to complement the grid-based systems (Raisch, 2016; Trotter, Cooper & Wilson, 2019a; Probst et al., 2021)

Indeed, off-grid clean renewable energy options are necessary for energy access, a clean environment, and efficient and relatively low-cost energy (Alfaro & Miller, 2014; Baruah & Enweremadu, 2019; Wassie & Adaramola, 2021). However, these alternatives have registered a relatively low uptake among end-users in Uganda (Okello et al., 2013; Eder, Mutsaerts, & Sriwannawit, 2015).

The factors shaping the diffusion and uptake of clean renewable energy technologies include technological, economic and social factors (Eder, Mutsaerts, & Sriwannawit, 2015). The technological factors are underpinned by the relative advantage of alternative technologies in terms of robust and resilient functionality and sustainable energy generation. The economic dimension is shaped by affordability, investment costs, marketing by vendors, payment systems, and tariffs. The social dimension is shaped by cultural beliefs, involvement of local stakeholders in diffusion design, and the effectiveness of the communication of the technologies. All of the factors that shape the uptake and diffusion of clean renewable energy technologies vary at different scales from local to national level and with different uses of the renewable energy technologies, for instance, marked differences in such factors have been reported between domestic energy use and enterprise usage (Eder et al., 2015; Antwi and Ley, 2021; Oluoch, Lal, & Susaeta, 2021). It is therefore of utmost importance to investigate the factors at different scales and uses when attempting to design strategies to facilitate diffusion and effective uptake (Antwi & Ley, 2021; Oluoch, Lal, & Susaeta, 2021). The following section specifically focuses on productive energy use in the context of micro and small enterprises.

2.6. Micro and small enterprises and productive energy use

Micro and small enterprises (MSEs) are defined in different ways depending on the standards of different countries. However, the most common indicators of classification include revenues, the scale of operation and/or production, capital investment, business turnover, total assets, and the number of employees (Kayanula & Quartey, 2000; Minilek & Chinnan, 2012; Owusu et al., 2022). The Uganda Investment Authority (UIA, accessed November 2021) defines small enterprises as enterprises that employ between 5 and 49 people and have total assets between $2,800 and $28,000, while micro-enterprises are regarded as enterprises employing up to four people and total assets and annual sales not exceeding $2,800.

Small enterprises play a crucial role in economic development through providing employment, production of goods and services, and generation of revenue and income (Mbugua et al., 2013). According to the World Bank (accessed, November 2021), small enterprises coupled with medium enterprises, represent approximately 90% of businesses and more than 50% of employment worldwide. They contribute up to 40% of the GDP in emerging economies (World Bank, accessed, November 2021).

According to the UBOS (2020) and NPA (2020), the private sector, which constitutes several micro, small, and medium-scale enterprises, generates about 77% of jobs and 80% of the gross domestic product and government revenue. To further highlight the crucial role of small enterprises, the sustainable development agenda (Agenda 2030) under its 8th goal encourages the formalization and growth of micro and small enterprises for inclusive growth and equity. Furthermore, Agenda 2063 and Uganda's vision 2040 (NPA, 2020) emphasises encouraging small and medium enterprises to drive industrialisation and growth of the private sector. Whilst the crucial role of small enterprises in social and economic development cannot be ignored, they face some pervasive risks and challenges that constrain their ability to stir sustainable development (Verbano & Venturini, 2013; Asgary, Ozdemir & Özyürek, 2020). One of the key challenges is access to energy resources (Falentina & Resosudarmo, 2019; Hayelom Abrha Meressa, 2020; Pelz, Aklin & Urpelainen, 2021, 2022).

Energy access for micro and small enterprises is particularly crucial to perform a variety of operations to generate goods and services. Such energy-dependent needs of the enterprises vary in scale and intensity and they include agro-processing, cold storage, irrigation, lighting, cooking, phone charging, and other productive/manufacturing services. Without sufficient and efficient access to energy, the sustainability of such operations is highly limited. A study by Falentina and Resosudarmo (2019) and Pelz et al. (2022) indicated that blackouts hindered the performance of small enterprises by reducing average labour productivity, and losses in revenue. These findings also corroborate the findings of Owusu et al. (2022) who highlighted a positive relationship between energy access and business profitability.

Whilst it may be important to recognise that access to affordable and reliable energy may play a role in reducing the cost of doing business, Uganda has been ranked by the World Bank as

168 out of 190 in terms of accessing energy for doing business (World Bank, 2019). This has significant negative implications not only for starting enterprises to drive local economic growth and household poverty alleviation, but also for facilitating communities' access to goods and services. For example, Ssennono et al. (2021) reported that nearly 62% of Ugandans are deprived of access to at least one community service or enterprise powered by electricity, reflecting the impact of energy poverty on community development.

To address unreliable energy supply in the business and small enterprise landscape as well as to overcome their setbacks, many enterprise owners employ strategies to cope with the challenge of energy poverty. For instance, in Ghana, enterprise owners were reported to employ operation stoppage, lay off workers/forced leave, use a backup generator, reducing employee wages among others (Owusu, Agyemang & Agyeman, 2022). However, most of these strategies may not be sustainable for socio-economic development. For instance, wage reduction may have implications for income and the ability of household breadwinners to meet their basic needs, operation stoppage and layoff of workers may have implications for business productivity and the use of a backup generator may increase the cost of doing business.

Under Uganda's National Development Plan III, to unlock the potential of the energy sector to drive small-scale enterprises and productive use of energy, the government has proposed increasing access and promoting primary energy consumption practices and technology; increasing grid reliability and share of clean energy and reducing the share of biomass. If implemented well, these strategies can produce promising results. For instance, Hong et al. (2022) noted the intermediary role of clean energy resources such as solar, in promoting employment and household income while alleviating energy poverty. Furthermore, it has been recommended that strategies to enhance returns from upscaling energy access be accompanied by suitable technology to utilise the energy (Wang & Lin, 2022).

2.7. The research gap in West Nile

Energy poverty, access and security have, to some significant extent, been studied in Uganda and West Nile region. However, the majority of the studies were either limited in scope or investigated a limited theme of variables and dimensions of energy access and poverty; these studies are even more limited in the context of small productive enterprises. For instance, Qudrat-Ullah et al. (2021) explored the use of an alternative cost-effective energy billing system to lower production costs for SMEs in coffee processing only. Muhoro and Ross (2010) investigated the access and impact of energy access on micro-enterprises, but this was only limited to off-grid electricity access. Twaha et al. (2016) focused on unpacking the renewable-based energy resource potential while Mukisa et al. (2020) studied energy access in the context of sustainable livelihoods capitals as enabling factors. Ssennono et al. (2021) gave a comprehensive overview of the state of energy access and poverty in Uganda, drawing on the 4A's framework and the Multi-dimensional energy poverty indices, however, their study only utilized secondary data and remained broad in scope, potentially masking the nitty-gritties at sub-national and local levels.

In northern Uganda where West Nile is located, Munro and Bartlett (2019a) studied energy access in the context of household and non-productive use – studies of energy access in West Nile have rather followed similar patterns. In West Nile, Miller and Ulfstjerne (2020) explored energy poverty, but this was only limited to a humanitarian context, with a focus on energy for cooking. Hirmer and Guthrie (2017) studied energy access in the context of productive use, but this focused only on the benefits of energy appliances in the off-grid sector and the context of enterprises was rather implicit. This gap was addressed by a study conducted by van Hove and Johnson (2021) in which energy access in the context of SMEs was explicit, however, this was more in the context of refugees and with a sample space of only 20 respondents.

It is in this regard that this study is unique and vital for West Nile region, since its rationale is hinged on three influential and critical positions: First, the need to provide more data and understanding about energy access in the context of small enterprise and productive-use. Second, the imperative to unpack the uptake and use of off-grid renewable energy resources (Solar PV) in the context of productive-use enterprises. Third, the need to understand how the interaction between energy access and enterprises shapes the livelihoods of the business owners. This is particularly an important question to address given the role of the small enterprise in driving local economic growth and providing sources of income for households.

At a national and sub-Saharan Africa level, this study is a vital representation of energy access in the context of small enterprises. The West Nile region, located strategically bordering the Democratic Republic of Congo and South Sudan, and close to the Central African Republic, can be thought of as a microcosm of the entire region, given the diversity of socio-cultural and economic activities which have been practiced by natives and some evolving through the inflow of refugees from all the three surrounding countries.

3. Chapter 3: Methods and Data Collection

This chapter is structured into three (3) different sections; First, it provides insights into the scope and justification of the study as well as the study design. Then it provides insights into the socio demographic characteristics of the respondents and the nature of the enterprises surveyed. Lastly, it highlights the methods applied in data collection, the data analysis, and the supporting analytical framework.

3.1. Study scope and justification

This study investigated the key issues underlying energy access among micro and small enterprises in West Nile, Uganda (Figure *1.1*). The study builds on the existing body of knowledge about energy access in Uganda. It targeted informing tailored and need-responsive energy access program development and policy learning at sub-national levels to counter the "one-size-fits-all" approach which has often been used to inform energy access development policies and projects (Trotter, Cooper & Wilson, 2019a). The specific focus on micro and small enterprises and associated productive operations aimed at bringing the spotlight on energy access as a tool for poverty eradication and sustainable local economic development. Despite the focus being on micro and small enterprises, reference is also made to smallholder households since they are the main owners of the enterprises or majority of the enterprises have owners with backgrounds in smallholder work. This is to provide context on the socioeconomic dynamics behind the enterprises. Productive operations as referred here are operations that the enterprises run, this is to draw a line between energy use at enterprise level and non-productive use of energy at household level, considering that some of the enterprises were stationed at homes and so the kind of energy use needed to be differentiated based on the activity that is being run by the energy.

3.2. Study design and target respondents

The study applied mixed research methods (both qualitative and quantitative) to capture robust data from the field. The data were collected through surveys with both closed and open-ended questions designed using the KOBO Collect software, directed to respondents who were either owners or operators of the small enterprises. KOBO Collect is a web-based and mobile/tabletbased software that is used to design flexible survey forms that enables data collection both online and offline, data sharing, preliminary analysis, and visualization. The capability to function offline particularly came in handy during data collection in areas without access to internet network.

Overall, 129 small enterprises were sampled, with business lines in carpentry and joinery, welding and metal fabrication, smallholder farming and agro-processing enterprises, hotels and restaurants, salons and beauty services, Electronics, secretarial, and ICT services, among others. The enterprises were selected following conversations with the district economic officer and available knowledge of the local market. The selected enterprises were among the most common and employed a larger number of people.

3.2.1. Productive energy use perspectives from micro and small enterprises

3.2.1.1. Socio-demographic and enterprise-related data

Data collection targeted enterprises in Arua City and Vurra county, marked in red in Figure *1.1*, through purposive sampling. The gender, education and livelihood activities were the socio-demographic variables that end-users were evaluated against. The variables were selected based on available scholarly evidence that suggests their potential influence as driving factors on energy poverty and security (Mukisa, Zamora & Lie, 2020; Ssennono et al., 2021; van Hove & Johnson, 2021; Abbas et al., 2022). For instance, Pueyo and Maestre (2019) and Adom and Nsabimana (2022) reported that gender played a significant role in energy security and demonstrated how energy poverty and security are experienced differently across genders, findings that were further expounded by (Njoh et al., 2022) who observed a connection between increased energy use and improvement of women's welfare in Africa. The dynamics between gender and energy access has been well demonstrated in the domestic context, however, this study sought to bring to the fore the dynamics in the enterprise context. Lastly, a close and positive relationship has also been demonstrated between level of education and energy consumption (Adom & Nsabimana, 2022; Rhea et al., 2022), hence this study's selection of education as a socio-demographic variable.

The enterprise-related variables that were evaluated included number of employees, enterprise revenues and energy expenses, operational hours and days, type of business and operational activities, all selected on the premise of their potential to influence or be influence by the status of energy security.

3.2.1.2. Energy use-related data

Questions directly related to energy access centred around the types of micro and small enterprises, their energy needs, and energy access status. The factors influencing energy access, choices of energy types, the benefits generated, and the challenges to energy access were also explored. Furthermore, the respondents were asked questions about their energy expenditure, and how the reliability and level of energy access in their businesses affect their livelihoods and households. The study only focused on energy sources with the potential to produce electricity for enterprise operations, which included solar, grid-based electricity, and generators.

3.2.1.3. Types of enterprises surveyed.

The surveyed enterprises belong to common energy-intensive productive activities in the region. The majority of the enterprises surveyed were categorised as farming and agro-processing. This involves those engaged in aquaculture, horticulture, tree seedling business, poultry, and agro-processing and value-chain enterprises such as veterinary drug shops, maize and grain grinding mill among others.

Twenty-six (26) of the surveyed enterprises were categorised as electronics services, sales, and repair. These involved, phone and electronic appliance sales, repair and charging, computer, and ICT services, secretarial services such as graphics design, printing, scanning among others. Twenty-four (24) enterprises were categorized as metal fabrication and welding, whereas 21 enterprises were engaged in salon and beauty services and products. Thirteen (13) enterprises were engaged in carpentry, joinery, and wood works, this involved wood carving and sawmilling. Thirty (30) enterprises were engaged in farming and agro-processing. Only six (6) enterprises were categorized as hotel, catering, and hospitality services – these included restaurants, bars and lodges/guesthouses. Lastly, nine (9) businesses were placed under the ‘other’ category. These include washing bays, petrol/gas stations and inner fashion and design. It is important to note that majority of the enterprises are informal in nature which limits their access to finance and institutional incentives to make energy affordable.

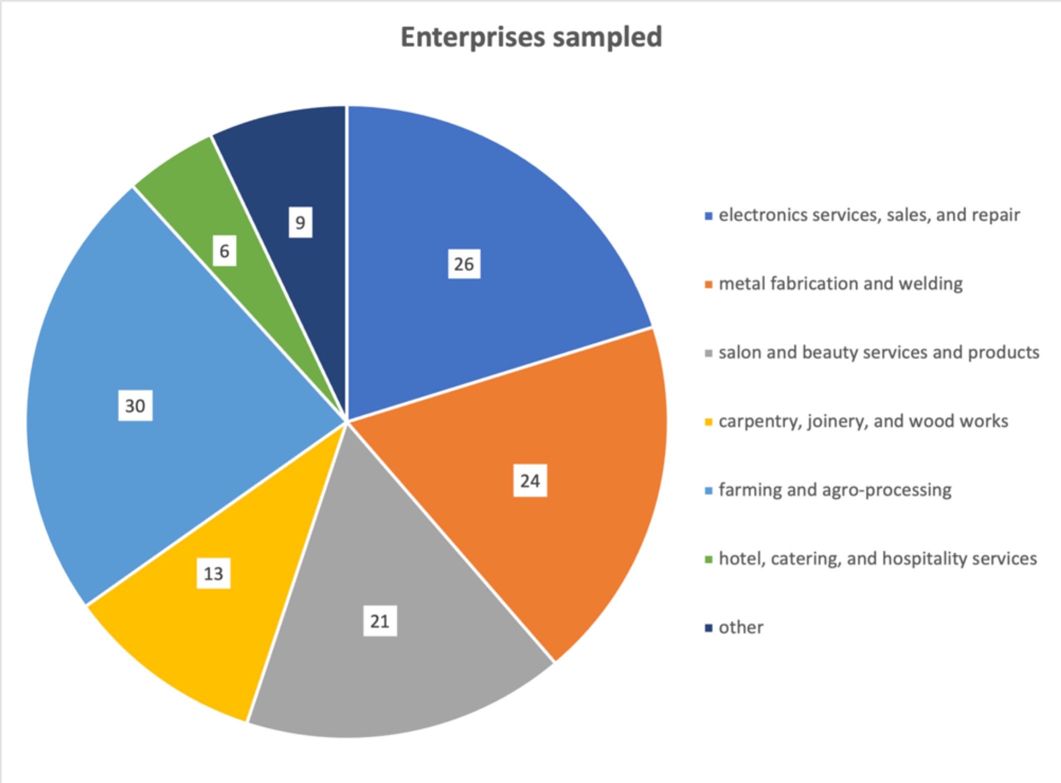

Figure 3.1. Types of enterprises sampled.

3.3. Data analysis and presentation

The qualitative data collected such as gender, enterprise type, livelihood aspects were coded and thematic analysis was carried out using the standard statistical program STATA while quantitative data such as enterprise energy costs and revenues were analyzed directly without a need for coding. Besides being available, STATA was used because of its ability to provide a wide variety of options to do tests and its robust ability to handle quantitative data easily. The data were then analyzed to establish the status of energy access, the key factors driving energy access among productive end-use micro and small enterprises, and how the status of energy access impacts the livelihoods of micro and small enterprise owners, coherent with the research questions and objectives. The analysis sought for possible relationships and trends between various variables and display the collected data using descriptive statistics.

3.4. Analytical framework: Drawing from the Multidimensional Energy Poverty Index (MEPI) framework.

To facilitate the data collection and analysis, this study drew from the MEPI framework proposed by Nussbaumer et al. (2012), which has been widely applied as metric to measure and report on energy poverty. The MEPI framework establishes itself as a multi-criteria framework that attempts to capture the multi-dimensional nature of energy poverty and reflect that diverse deprivations that come with it.

In this study, the 4A's framework's aspects of availability, accessibility, acceptability, and affordability are drawn upon as a sub-division or breakdown of the MEPI to provide better context for measuring and reaching conclusions about the MEPI. (Salman, Zha & Wang, 2022). *Accessibility* in this research has been understood through the lens of what energy options are available to the consumers in the energy landscape and how reachable they are. *Affordability* captures the monetary capacity to purchase the desired source of energy. However, in this work, affordability has also been conceptualised in terms of the of cost of energy needs as a fraction of the total business revenues. *Availability* which is used here interchangeably with reliability explains the capacity of the accessible energy sources to last during the operational activities of the enterprises. In this study, *acceptability* is used interchangeably with *convenience of use*, drawing upon emissions, occupational health challenges and toxicity, technical and handling requirements. Furthermore, *applicability* is used interchangeably with the ability of the energy source to support all the operational activities of the enterprises.

4. Chapter 4: Results and discussions

4.1. Introduction

This chapter examines the key factors driving productive energy access among micro and small enterprises and how energy access impacts the livelihoods of the owners of the said enterprises in West Nile, Uganda. It specifically provides analysis and reports on the results from the case study by drawing primarily from the actual narratives of the respondents, that is, enterprise owners and/or operators. It also provides discussions on the meaning and implications of the results whilst drawing parallels with the existing scholarly literature in the field of energy access and development within and beyond the case study area.

Firstly, results of the analysis of general productive energy access are presented, giving insights into the existing sources of energy, potentially influencing key socio-demographic factors, business profitability under the respective energy sources, and the benefits and challenges associated with each energy source. Secondly, it presents in-depth data and discussions on the transition to off-grid solar PV for operations of small enterprises, highlighting user experiences in terms of benefits, challenges, and market factors shaping uptake. Furthermore, it also gives insights into non-user narratives about Solar PV for business operations. Lastly, the chapter reports and discusses the results of the interaction between energy access for the enterprises and the livelihoods of the enterprise owners and operators, considering the enterprise as a key source of income to meet the livelihood needs of the owners and operators.

4.2. Energy access for productive use by small and medium enterprises.

4.2.1. Main sources of energy for use by small and medium enterprises

The respondents of this study reported three sources of energy that powered the operations of their enterprises, namely grid connection, fuel generator, and solar PV. Several respondents used standalone energy sources; however, some used a composite mix of two energy sources. *Figure 4.1* and **Error! Reference source not found.** below summarise the share of energy sources powering the productive use operations. Up to 43% of the enterprises surveyed relied only on power from the grid. This was followed by energy from solar power which accounted for 16% of the energy needs of the surveyed enterprises. Fuel generators ranked last with only 10% users' reliance. On the one hand, the evidence presented here suggests that, despite the very low accessibility, the grid continues to play a central role in driving small enterprises' operations, an extension of which may be fundamental for upscaling productive energy use entrepreneurship, contrary to the suggestions of Trotter et al. (2019). On the other hand, these results affirm the impossibility of achieving universal grid access for small businesses, thus highlighting the imperative of off-grid renewables in the energy mix for secure energy futures. Furthermore, the findings highlight the emerging position of solar energy in breaking into the productive energy use sector. While 16% solar usage is significant achievement in the transition to cleaner energies, this could still be further accelerated with the right systems in the market that allow for productive use, at the expense of phasing out fossil fuel generators.

The results also revealed that a significant number of enterprises (up to 31%) relied on more than one source of energy (**Error! Reference source not found.**), a situation which may be attributed to the unreliable power supply problem expounded on in this chapter. The results corroborate with the work of Munro and Bartlett (2019) on energy bricolage in northern Uganda and suggest that more than one energy source is necessary for businesses to counter the inefficient and unreliable supply of energy in the region. It also highlights the path-dependence and lock-in effect of traditional grid and emergency fossil-based energy sources among small enterprises, with potential implications for the transition to low carbon development pathways in an energy-intensive sector, coherent with the findings of (Tenaw, 2022). Whereas, on one hand, these practices promote energy access, on another, they complicate business feasibility and service delivery due to the high costs associated with energy bricolage.

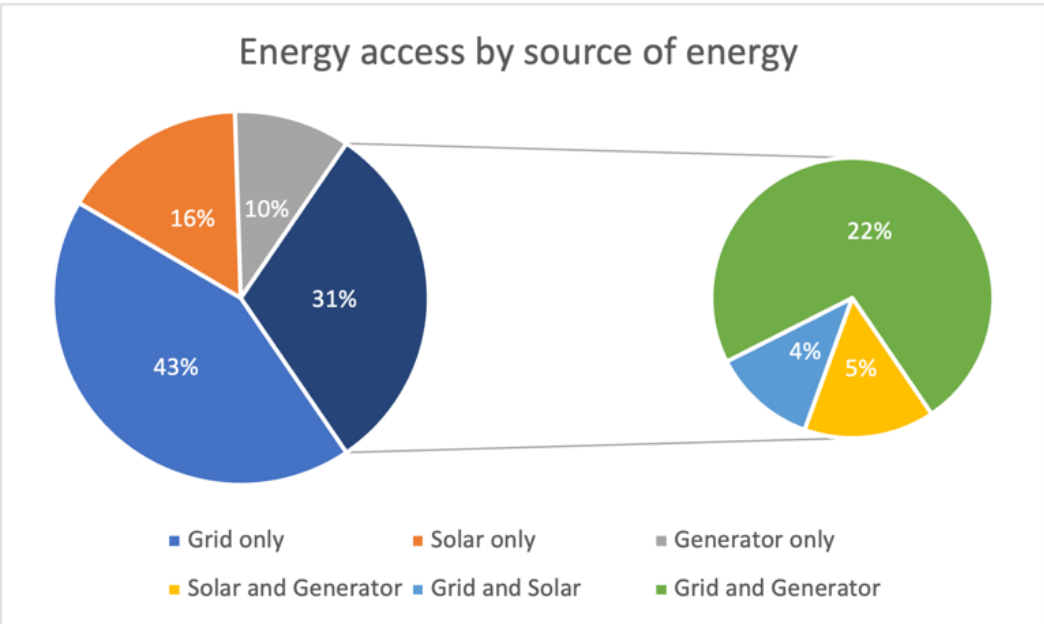

Figure 4.1 Energy access by source of energy

4.2.2. Capability of existing energy technologies to support enterprise operations.

The base load capacity of an energy source is vital in determining the extent to which it can support productive operations. The encompassing methodological approach of this study prompted the respondents about the capacity of the energy source to support all the activities of the enterprise (Figure 4.*2*). By comparison, 84% of the respondents who relied on the grid electricity indicated that when reliable, power from the grid supported all their activities, whereas only 75% of the users of fuel generators and 34% of the users of solar PV reported fuel generators and solar PV supported all the activities of their enterprises. The low capacity of solar systems to support the enterprise operations could be explained by the inability of the enterprises to afford high voltage solar systems sufficient to power their high electricity demanding operations. This rationale is further strengthened by the evidence that the users that reported solar energy as being incapable mainly operated sawmills, welding, and metal fabrication, all energy intense enterprises. Based on the information from respondents on the ground, it is sufficient to say there is a disjunct between the capacity of the available solar systems on the market, and the needs of the enterprises – available systems cannot power enterprise tools, which potentially reinforces the use of fossil generators and reliance on the grid. These deductions again emphasise the point that, for the just energy transition to be effective in the business sector, it needs to promote and make affordable renewable energy alternatives that are supportive of productive activities.

The incapability could also be attributed to solar variability by time of the year and daily sunshine hours as reported by the enterprise owners. However, though a possibility, this reason is questionable since literature suggest that West Nile receives high insolation throughout the year with a high photovoltaic potential (Soares, Brito & Careto, 2019). The users' experiences of insolation variability could be a result of limited knowledge on how solar systems work and their positioning to capture maximum insolation – a gap which could be addressed through capacity building and awareness. Alternatively, the low capacity of solar PV could be further explained by the fact that 124 of the respondents were unaware of the energy requirements of their equipment and hence possibly purchased systems that could not support the types of equipment they used. It is thus suggested that when considering energy development interventions and access programs, especially for off-grid resources such as solar PV, due consideration should be given to energy auditing through knowing the power rating of the enterprises' equipment for a more tailored energy supply.

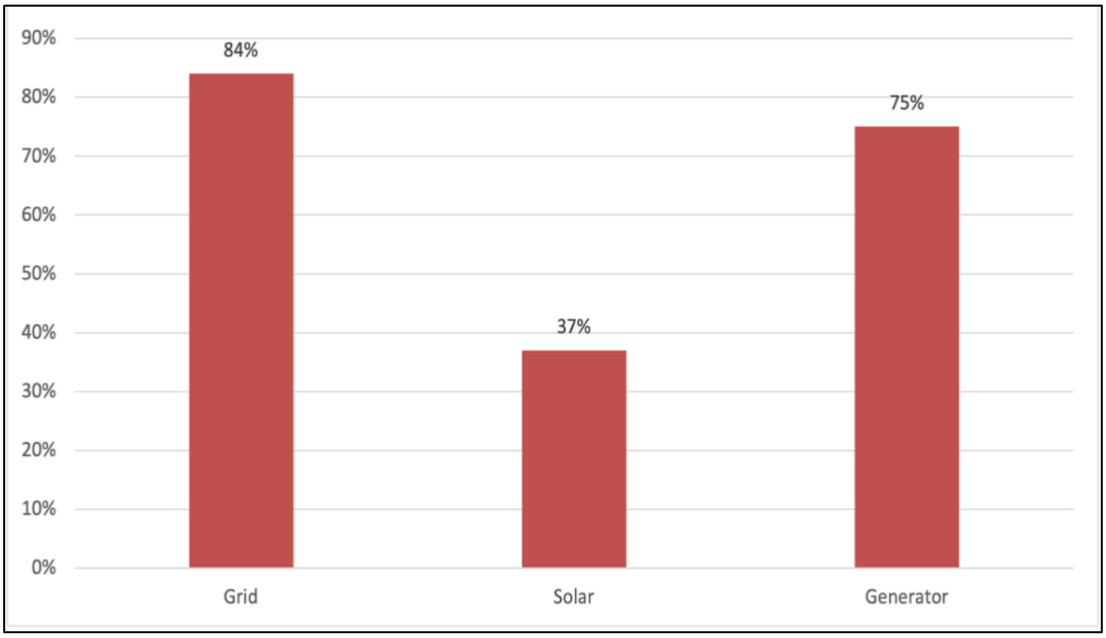

Figure 4.2 The capacity of energy sources to support all operational activities of the enterprises

4.3. Key socio-demographic and enterprise-related factors relevant to energy access.

Table 4.1 below provides a summary of the trends of the gender, education and enterprise type in relation to energy type accessible. From a **gender perspective**, 82% of female as opposed to 67% of male enterprise owners, relied more on grid energy. However, the reverse is true for generators and solar energy where more males relied on fuel generators (30%) and solar PV (23%) to run the productive operations of their enterprises as opposed to the females where 25% relied on fuel generators and only 11% relied on solar PV. Female respondents associated their low usage of fuel generators and solar systems with the technical repair demands and the need to carry especially generators around, a task which they often associated with a masculine nature. Gender plays a significant role in energy access, with women being more vulnerable to energy poverty. Hence to address energy access and facilitate the just transition, it will be important to design gender responsive programmes and policies in energy development such as providing subsidies for women entrepreneurs to access solar PV systems (Pueyo & Maestre, 2019b; Opoku, Kufuor & Manu, 2021b; Hirmer et al., 2022). Addressing the energy access-gender dynamics will also have ripple effects of empowering women and efforts to achieve the sustainable development goal on gender equality. As a mini-thesis, the aim was to provide a snapshot into the gender-energy dynamics. Further research is recommended on the gender-energy-enterprise interface dynamics.

From an **educational level** perspective, respondents with higher levels of education (post-secondary qualification) relied more on the grid, a reliance which declines with a reduction in the level of education attained. Whereas Solar PVs had the highest reliance among those with primary education, with the level of reliance relatively lower among enterprise owners with higher levels of education. The ability to innovate technologically, prudent energy use behaviour and the desire for clean renewable energies can be predicted to be strong among highly educated users, making education one of the primary socioeconomic factors influencing the demand for renewable energy (Tsaurai & Ngcobo, 2020; Özbay & Duyar, 2022; Sart et al., 2022). However, from the results of this study, energy use behaviour seems to be influenced more by the need to enhance business productivity, a need which respondents reported to be fulfilled more by the grid and fuel generator rather than solar which is not very supportive of increasing enterprise productivity (Figure 4.*2*). It can be assumed that the more educated have a stronger affinity for higher enterprise productivity, which informs their reliance on the grid.

On the other hand, to the extreme, where users had no education at all, no usage of solar PVs was recorded. This finding is coherent with the findings of (Tsaurai & Ngcobo, 2020; Özbay & Duyar, 2022) which cited education to play a role in uptake of renewable energy. Theoretically, the assumption is that the uneducated have relatively lower concerns about the cleanliness of the energy sources and are less aware about the benefits of solar PV. Furthermore, from the results, there was a near uniform spread among all levels of education regarding the reliance on fuel generators; enterprise owners with the highest level of education (post-secondary) relied more on fuel generators (32%) as opposed to energy consumers with lower levels of education. These results suggest a close relationship between education and choice of energy type, also reported in other literature (Özbay & Duyar, 2022; Sart et al., 2022). It is therefore vital to align energy access upscale programs with education programs, for users to make more informed decisions.

Enterprise type: Generally, reliance on grid energy was relatively high among all the surveyed enterprises. Farming and agricultural enterprise only scored 10% on grid reliance. This may have been due to the remoteness and distance of the farming activities from the grid transmission infrastructure. Reliance on solar PV was very low among most of the high voltage demanding enterprises such as carpentry and joinery, welding and metal fabrication, reaching down to 0%. Whereas, reliance of agricultural enterprises on solar energy was considerably high, 63%, potentially due to the feasibility of solar as an off-grid solution in the remote areas where agricultural enterprises operate. This may also have been due to farmers requirements of energy systems with low daily operational costs since the nature of their business relies on seasons and does not generate daily revenues which would otherwise be needed to meet daily energy costs associated with fuel usage. There was an equally fair spread and generally average reliance on fuel generators, with farming and agricultural enterprises scoring the highest, 33%. This could be due to the reliance on fuel generators as a backup energy source. The demand for low operational cost energy sources coupled with the limited grid extension infrastructure presents an opportunity to further reduce the usage of fossil dependent energy sources and transition towards decentralised renewables such as solar PV.

Table 4.1 Key trends of socio-demographic factors which determine energy access

Note: The findings presented refer to the number of people using a particular energy source, therefore the percentages do not add up to 100%.

Energy type	Grid	Solar	Generator	Total sample
Gender				
Female	82%	11%	25%	28
Male	67%	23%	30%	101
Education Level				
None	25%	0%	25%	4
Primary School	48%	39%	29%	31
Secondary School	76%	11%	24%	37
Post-Secondary School or Tertiary Eduation	82%	18%	32%	57
Enterprise Type				
Carpentry and Joinery	100%	8%	15%	13
Electronics Services	96%	12%	31%	26
Farming and Agriculture	10%	63%	33%	30
Salon and Beauty	86%	10%	29%	21
Welding and Metal Fabrication	83%	0%	29%	24
Restaurant and Catering	83%	0%	17%	6
Others	78%	11%	33%	9

4.4. Energy usage: challenges, benefits, and profitability through the 4A's framework

4.4.1. Grid, solar PV, and fuel generator on an energy user benefit spectrum

To investigate whether the level of energy access, including the types of energy resources, meets the needs of the consumers, this study prompted the exploration of the benefits associated with respective energy sources accrued to its users that promoted its use. To explore the benefits, the study drew on the 4A's framework (access, affordability, acceptability, and applicability) posited by Malik et al. (2020) and Amin et al. (2022), combined with other novel benefits that were found in the field but do not exist in the 4A's framework. The findings suggest a number of benefits associated with the different energy types, both unique in their own making, value, and applicability to the needs of the enterprises that reinforces the usage of the energy system.

4.4.1.1. Energy affordability for small enterprises

The results reveal that, of the enterprises that operated on grid energy, only 34% found it to be affordable (Figure 4.*3*). Affordability was weighed against the cost of first-time access/connection, electricity tariffs, and their spin-off impact on business productivity and profitability – which the respondents reported to be very high. This finding corresponds with the review by Ssennono et al. (2021) which ranks Uganda among those with one of the highest energy tariffs. Besides addressing accessibility through reach to the grid infrastructure, the evidence suggests that addressing grid affordability is crucial to unlocking the economic potential of many small enterprises that form the economic backbone of many local communities, given the number of enterprises that rely on the grid (Figure 4.*1*). Since many informal economy businesses fill the gaps left by the government's ineffective service delivery, addressing grid energy affordability is also crucial for enabling service provisioning in these locations, besides promoting the livelihoods in the local communities.

The results furthermore indicate that less than half the enterprises (47%) that operated on solar energy rated it as affordable (Figure 4.*4*). Notably, the respondents viewed affordability as strongly linked to the initial cost of acquisition and the near zero operational costs, except for where repairs had to be done in event of a breakdown. However, most of the enterprises that ranked solar PV as affordable only needed it for purposes of lighting and charging small electrical appliances like radios and telephones, whereas many of the proprietors interviewed in high voltage productive-use activities such as metal fabrication and irrigation ranked solar energy as unaffordable. This suggests that, albeit solar energy is necessary to achieve energy access and support socio-economic development as suggested by renewable energy scholars (Adenle, 2020; Mugisha et al., 2021), and by the findings of this study, its potential to spur significant economic growth, relative to other sources of energy, is significantly limited to operating in low voltage enterprises. This has significant implications for low-carbon development and complicates the promotion of solar energy as a functional energy alternative, especially where many of the fundamental services in the local communities are high-voltage services. Perhaps the perception of solar energy as a low voltage energy source explains why many of the respondents used the system in their homes for domestic lighting rather than at their enterprises. However, despite the status of affordability, affordability still ranked highest on the benefits spectrum among solar energy users, as a reason for its adoption.

Lastly, in terms of affordability among respective users, the results indicate that the users of fuel generators (both diesel and petrol) rated it as the least affordable, yet affordability ranked highest on the benefit spectrum as a reason for the adoption of fuel generators, tied with its use as a backup plan (Figure 4.5). However, users reported that the affordability of operating their enterprises using fuel generators relied mainly on the prevailing market prices of fuel, besides the cost of the generators and the repair needs. Some respondents reported countering the fuel price fluctuations with smuggled cheaper fuel from neighboring countries such as the Democratic Republic of Congo and from roadside fuel vendors who sold it cheaply relative to the price in the fuel stations. Whereas the findings suggest that fossil fuel-driven generators are crucial to energy access for the operation of the small enterprises that drive local economic development, it is critical to mention that overreliance on them may have some significant implications for sustainable economic development, particularly in an economy that relies on imported fossil fuels where the fuel prices are determined by external factors.

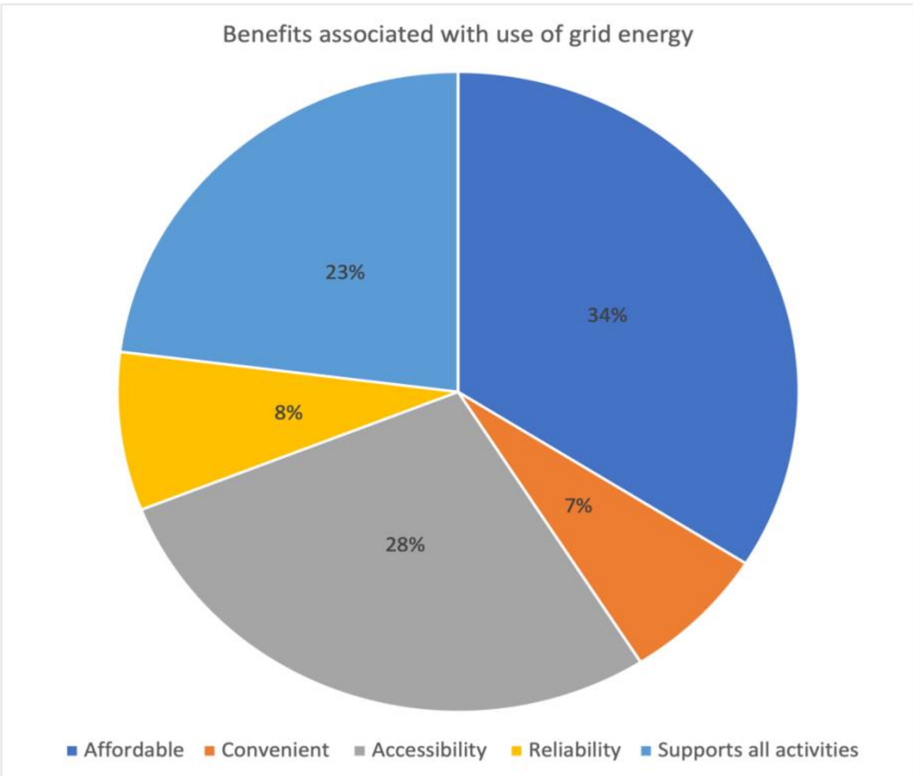

Figure 4.3 The benefits spectrum in the usage of the grid for small enterprises

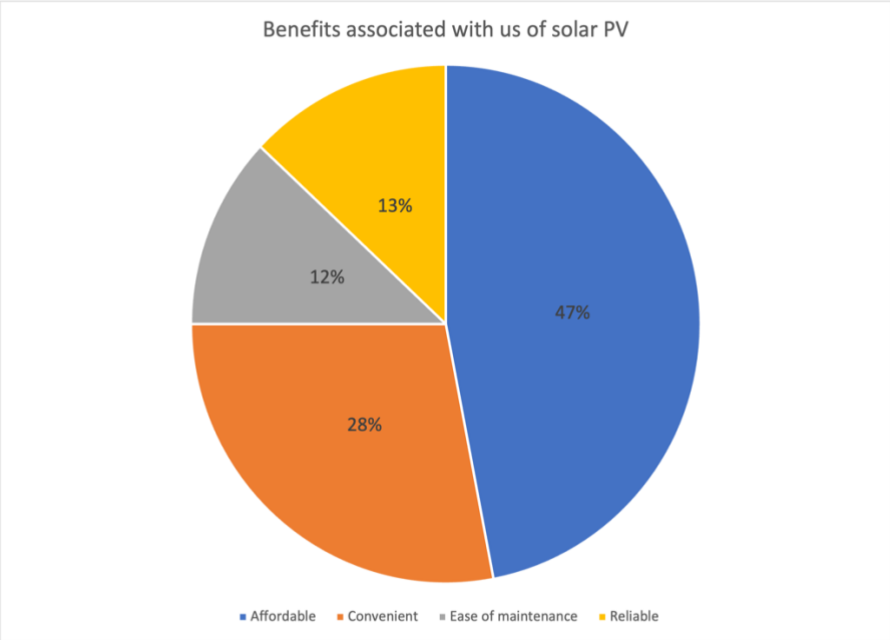

Figure 4.4 The benefits spectrum in the usage of solar energy

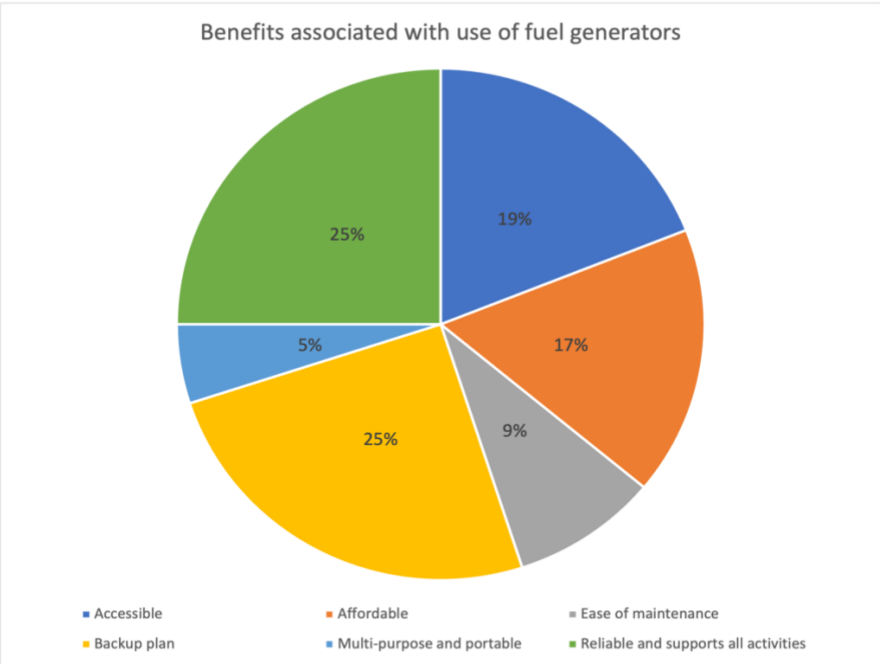

Figure 4.5 The benefits spectrum in the usage of fuel generators

4.4.1.2. Acceptability of energy

Acceptability of the types of energy has been drawn upon by various scholars as a metric for measuring both energy poverty in the MEPI framework and energy security in the 4A's framework (Malik et al., 2020; Amin et al., 2022). Available literature mainly defines energy acceptability in terms of cleanliness or emissions neutrality potential (Amin et al., 2022). However, through this study, the concept of acceptability is extended it beyond the limits of environmental acceptability to social and economic acceptability, to reflect the perspectives of the respondents. Some of the novel aspects of acceptability that underpin the basis of this analysis as reported from the survey include convenience of use, capacity to support all activities and ease of maintenance as discussed below.

4.4.1.2.1. Convenience of use of energy sources

During the survey, the respondents strongly linked convenience of use with portability, the capability of the energy source to perform multiple functions in the enterprises' operations, and the toxicity or occupational health-related issues associated with the source of energy. From the findings of the survey, convenience-of-use was ranked second highest among the users of solar PV as a rationale for its adoption, scoring 28% (Figure 4.*4*). The users associated convenience with neutral occupational health concerns, the little to no need for maintenance, and an insignificantly limited rate of breakdown. Enterprises that operated on very little energy demand, thus requiring smaller solar panels and batteries, attached convenience to the portability of the cells. Lastly, convenience was also associated with safety and security, where several solar panels were fitted on rooftops to some extent guaranteeing their security. The increasing experience of the users of solar energy presents new opportunities to promote and upscale the use of the technology whilst addressing common challenges associated with other sources of energy such as occupational health, and cost of maintenance among others. Inconvenience was largely associated with the technical knowledge required in terms of breakdowns and the limited portability of large panels used in energy-intensive enterprises such as those in irrigation farms, which often limited the use of the panels for other field-based energy-demanding activities. The findings about inconvenience-of-use reveal the need to promote more technical knowledge on the management and repair of solar energy systems or the establishment of within-reach centres of repair. On the other hand, the limited portability signifies the critical role that portable energy sources such as fuel generators will continue to play in off-site enterprise operations.

In the benefits spectrum, the users of grid energy found it to be the least convenient for use, scoring 7% (Figure 4.*3*). Convenience of use may have largely been associated with reliability; however, a significant proportion corresponds to the use of the grid only for on-site activities and is not supportive of off-site activities. The convenience of use was also associated with the anxiety of possible electrocution of electronic devices during times of fluctuating voltage.

4.4.1.2.2. Capacity of energy sources to support all activities.

The energy consumers mostly chose an energy source depending on its capacity to support all the productive use operations of their enterprises. Accordingly, 34% of users of grid energy (Figure 4.*3*) reported it to conveniently support all the activities of the enterprises during reliable times – this was also a case regarded highly among high voltage users such as metal fabrication and carpentry and wood carving works. The inability to support all activities was only noted during times of fluctuating and unreliable voltage supply.

Similarly, a significantly high proportion of users of fuel generators (Figure 4.*5*) reported it to support all their productive use activities. This was particularly true for agro-enterprises, electronic and secretariat services, and carpentry among others – this could be due to the fact the generator purchases were mostly commensurate with the power demands of the enterprise. During the engagement with the respondents, only a few, mostly engaged in metal fabrication and welding, noted generators as incapable of supporting all their productive use activities. Except for cases where an enterprise's only energy need was lighting, respondents did not appraise solar energy as an option that would support all the operational activities of their enterprises. While it is vital to recognize the role of solar energy in upscaling energy access, the empirical evidence suggests the need for caution and strategic planning of energy development in terms of an alignment between the low carbon development goals, upscaling renewable energy access, and the practical economic energy needs of the society, beyond domestic energy needs.

4.4.1.3. Ease of maintenance and repair

To explore all benefits of acceptability on the benefits spectrum, the survey also recorded responses relating to maintenance needs of the energy sources and systems as ease or complexity of maintenance. Nine percent (9%) of the users of fuel generator energy rated it as easy to maintain in terms of regular servicing and repair in case of breakdowns (Figure 4.5). Most of these were located within the urban areas where repair and maintenance services were readily available, or they had the capacity to repair the generator themselves. A closely corresponding number of users of solar energy, 12%, also commended it for ease of maintenance, however, they did not state such an ease to be applicable to repair (Figure 4.*4*). The main maintenance and repair needs for solar energy systems applied to energy storage systems, mainly for large-scale users. There were no concerns raised regarding regular maintenance needs from grid electricity. These findings suggest that achieving greater energy security, independence, and user experience will have to be aligned with availing programs to train end-users on the maintenance and basic repair of their off-grid solutions and bringing repair and maintenance services closer to them.

4.4.1.4. Accessibility

Of the users of grid energy, 28% rated it as accessible (Figure 4.*3*), however, this was often more in the urban areas, whereas many of the surveyed respondents in the peri-urban and rural areas found the grid to be inaccessible and largely relied on off-grid decentralized energy sources. This observation reaffirms the strong position of off-grid solutions in upscaling energy access, finding consilience with the suggestions of Trotter et al. (2019b) who suggested off-grid solutions in areas where the government's grid extension program has fallen short. Accessibility was often denoted by two types; primary accessibility directly from the grid and secondary accessibility, that is, accessing through a user who is connected to the grid. Most small less energy-intense enterprises relied on secondary connections while accessing the grid in rural areas remains a nightmare due to the absence of the enabling infrastructure. Although the methods make it easier for people to acquire energy, they deny the government of revenues from new connections and put end-user businesses at serious risk of electric fire breakouts due to interconnections.

Users of fuel generators ranked accessibility at 19% (Figure 4.*5*) this was also mainly in the urban areas with several electronic shops and companies within reach of users. In the rural areas accessibility is complicated not only by the distance to the market to purchase the generators but also by the lack of fuel pumps and repair services in case of breakdowns – to the extent that those who have generators cannot use them due to fuel supply shortages. Whereas fuel generators guarantee energy access in the more rural operating enterprises, they do not necessarily guarantee energy availability as this is dependent on fuel availability and access, consequently depriving the communities of constant service provision from the enterprises. To guarantee energy and fuel availability, some of the end-users purchase and store highly flammable fuel such as petrol in their homes or at the enterprise, posing severe threats of fire risks. These observations illuminate the imperative for fuel-free off-grid energy sources such as solar PV for energy access and availability, where this is not optimal, it calls for extension of energy-related infrastructure such as the grid and standard fuel storage infrastructure in rural communities.

4.4.1.5. Availability and reliability of energy

Energy reliability and availability have been conceptualized as one of the cornerstones of energy security (Amin et al., 2022). During this study, the respondents were asked questions about the reliability and availability of the energy source they use within the benefits spectrum. Only 8% of users of grid energy ranked it as reliable with an astounding 92% rating it as unreliable and/or unavailable (Figure 4.*3*). Grid reliability was measured in terms of unnotified blackouts and voltage supply fluctuations. Personal conversations with energy experts and locals noted fluctuations in river water levels as a result of climate variability at the Hydro Electricity Power station that supplies the region causing the unreliable supply. They also pointed out that fuel shortages can affect thermal generators used to sustain the grid, which results in an unstable power supply. These rationales seem popular among end-users. However, further research is recommended to provide more data on the factors influencing energy generation in the region through grid-based systems, since the current research focuses on demand side user experiences.

Some users of the grid commented that the power was sometimes available during non-business hours and to keep enterprises operational, they had to conduct their energy-demanding activities during these non-business hours. Energy programs and interventions are not only a question of economic livelihoods but also of social-livelihood relations (Adenle, 2020; Mugisha et al., 2021), hence, such unreliable and inconsistent power supply and its influence on working hours may have implications on the social livelihoods of the enterprise owners and their families. The work of Akhtar et al. (2012) demonstrated the negative impact of long work hours on social livelihoods and family wellbeing. However, we recommend more research to understand the interlinkage between energy reliability, work hours, and social livelihoods. These queries may also be responsible for the limited convenience of use of the grid energy described in the upcoming sections.

The study results also indicate that 13% of the users of solar energy for productive use operations commended it for reliability (Figure 4.*4*), with a considerably high number of users ranking it as unreliable. Unreliability was strongly linked to the dependence of the power levels on the prevailing insolation and weather conditions. It was also noted that most of the users linked unreliability to solar energy due to either limited battery storage capacity or worn-out batteries. West Nile region is among some of the regions with averagely high insolation throughout the year, and dynamic weather patterns during the wet seasons, raising questions about the problematization of insolation levels in connection to solar energy unreliability (Soares, Brito & Careto, 2019). These challenges, however, raise the need for new approaches and programs of upscaling solar energy use in running high voltage enterprise operations that focus on strengthening energy capture and storage capacity, to guarantee energy availability during periods of unfavorable weather and low insolation. The dynamic nature of the weather in the region also calls for aligning weather and climate variability prediction services with efforts of upscaling solar energy usage.

The findings further indicate a significant percentage of users of fuel generators found it as reliable (Figure 4.5) relative to other benefits on the benefits spectrum, especially in areas with ready access to fuel. Reliability was also strongly linked to the convenience of use, in terms of discretion of operation time and voltage supplied, which gave the enterprise the flexibility of business hours. The rating of fuel generator reliability in terms of provision of energy for enterprise operations ahead of Solar PV may pose significant threats to efforts to promote solar energy since consistency and reliability of energy availability are core to the operation of many enterprises.

4.4.1.6. Energy sources as a backup plan

During the survey, some of the respondents also noted certain energy sources for the beneficial role they play as a backup plan in the event of power outages from the grid or bad weather that hinders sufficient energy production from solar. However, the use of energy sources as a backup plan was only reported by users of fuel generators, 25% of whom stated that they acquired and commended their generators as a backup plan to maintain productivity during times of power outages from the grid (Figure 4.5). This information alludes firstly to the level of trust the consumers have in the reliability of supply from the grid energy suppliers. Secondly, it highlights the preference of enterprises for fuel generators rather than solar, spelling difficulties in shifting the perception and narratives around the potential of solar energy for productive-use purposes.

4.4.1.7. *Multipurpose and portability*

Closely related to the convenience of use was the concept of portability and the ability to perform several, non-enterprise-related activities, as highlighted by the respondents. This was a benefit reported only among the users of fuel generators, with 5% noting it as a rationale for the adoption of the fuel generator (Figure 4.5). They described this benefit through the ability to easily transport the generator off-site to perform other functions such as lighting at home, supporting public address systems at domestic functions and gatherings, and hiring the generator out to other people among others. However, this was only reported by businesses that were using small and light-duty generators. The ability of an energy source to perform several non-enterprise-related tasks is vital to the owners of the enterprises since they have energy needs beyond the enterprise. Whereas being able to hire the energy generation systems for other users and uses, may provide the enterprise owners with an extra source of income which is vital when the grid energy supply is stable or when the enterprise operations are down during periods of limited labor or raw materials.

4.4.2. Enterprise profitability under specific energy scenarios: revenues versus energy expenses

To investigate the impact of the type of energy on enterprise profitability the survey launched inquiries into the daily energy expenditure and business revenues. Where operational costs were associated with only periodic maintenance and/or capital investments, per month were calculated by dividing periodic maintenance costs in a month by the number of days. Overall, at lower levels of investment, solar PV users realized higher daily revenues – this could be explained by the minimal operational costs of solar PV. However, users could only invest on solar PV up to a certain limit, potentially due to the high costs of high-voltage solar systems (Figure 4.6). In terms of returns per energy expenditure, grid ranked second after solar PV. This can be explained by the ability of the grid to supply sufficient energy load to support all enterprise activities as highlighted in *Figure 4.4.* hence maintaining higher enterprise productivity. Nevertheless, this ability was limited due to energy supply reliability from the grid, where enterprises experienced losses during downtime associated with power blackouts.

Composite energy sources where business operators combined more than two sources of energy ranked third in terms of revenue-energy expenditure ration. Having more than one source of energy guarantees reliability and availability of energy with one acting as a substitute where the other is down. This allows businesses to remain operational and productive for most of the time, however, it also implies higher costs associated with operation as energy expenses go higher. Fuel generators ranked last in the revenue-energy expenditure comparison i.e., much higher energy expenditure was required to fetch higher revenues as opposed to other energy sources. Owners of enterprises that operate on fuel reported that they kept the generators running for most of the time which increased fuel expenditure regardless of whether the business was receiving customers or not. The findings further suggest that, at the lowest rate of investment/expense and near-zero operational energy costs, solar energy yielded the highest revenues.

Albeit solar energy helps businesses save money by reducing energy imports from the grid, its capacity to generate higher revenues at low expenses is only limited up to a certain level of investment. This observation which could be strengthened by the limited capacity of solar energy to support all the productive use activities of the enterprises, goes back to the challenges associated with solar energy for productive use purposes. An observation has also been made by previous scholars who observed that including more modern renewable energy sources into the final energy mix was not conducive for economic growth (Tsaurai & Ngcobo, 2020; Tenaw, 2022).

Much as these findings may be challengeable due to the several factors that influence business profitability, such as marketing and location, the energy share of enterprise costs is fundamental to business profitability since energy is one of the biggest production factors for enterprises – these findings should there for serve as a pointer among other factors in unlocking the profitability of productive energy-driven enterprises. Furthermore, these results demonstrate the imperative for solar-for-business strategies to better support all or most of the fundamental productive operations of the enterprises, other than lighting. Such a strategy will help the small enterprises realize higher revenues even at higher levels of energy investment, which is fundamental for the enterprises that are at the forefront of service provision and driving local economies and livelihoods. When businesses are provided with high-capacity solar systems at low cost, the businesses can compete in terms of productivity with other businesses driven by other high voltage energy systems such as the grid. Low capital investment in high voltage solar systems coupled with low operational costs and higher productivity can make businesses that operate on solar energy more competitive and profitable in terms of productivity.

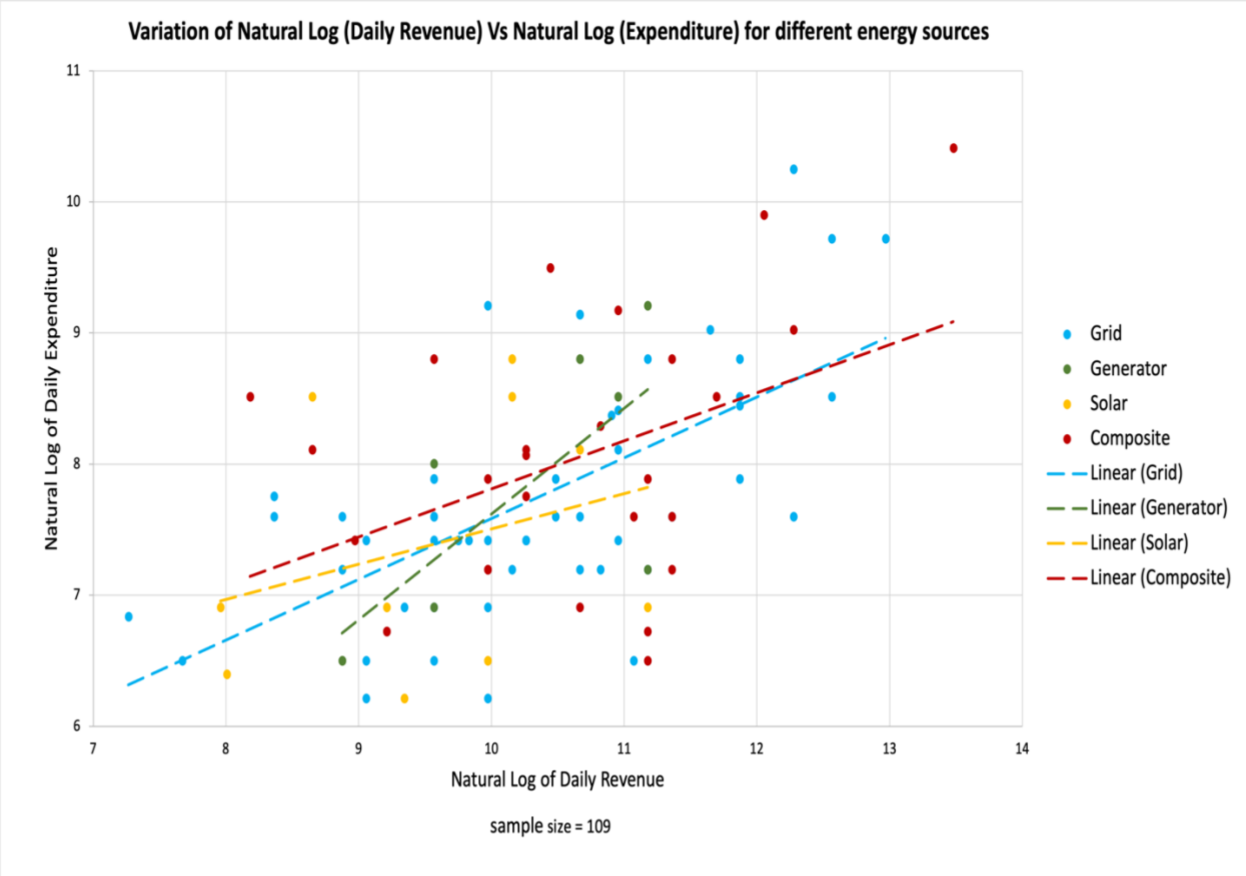

Figure 4.6 Relationship between enterprise revenue and energy expenditure

4.4.3. Challenges in the energy landscape for productive enterprises.

Through the survey, this study also explored the prevailing challenges existing in the energy security landscape for productive use operations. From the results, three categories of challenges are observed: access challenges, use-related challenges, and challenges associated with payment and recharge or purchase of the energy system, which are discussed in the upcoming sections.

4.4.3.1. Challenges associated with grid energy for productive purposes.

The results summarized in Figure 4.*7* as per the survey indicate that 66% of the users of grid energy raised concerns around use-related challenges while the remining 34% of respondents in this challenge category did not report any challenges. 34% of the respondents raised challenges about recharge and payment, and only 14% reported challenges about accessibility to the grid. A comparison of the three patterns reveals that it is possible to preliminarily hypothesize that while the government has made efforts to upscale energy access through the grid, a number of issues related to the efficiency of the access in terms of user experience remain at large. It is important to note that each bar in Fig. 4.8 represents the fraction out of 110% of respondents under that particular category.

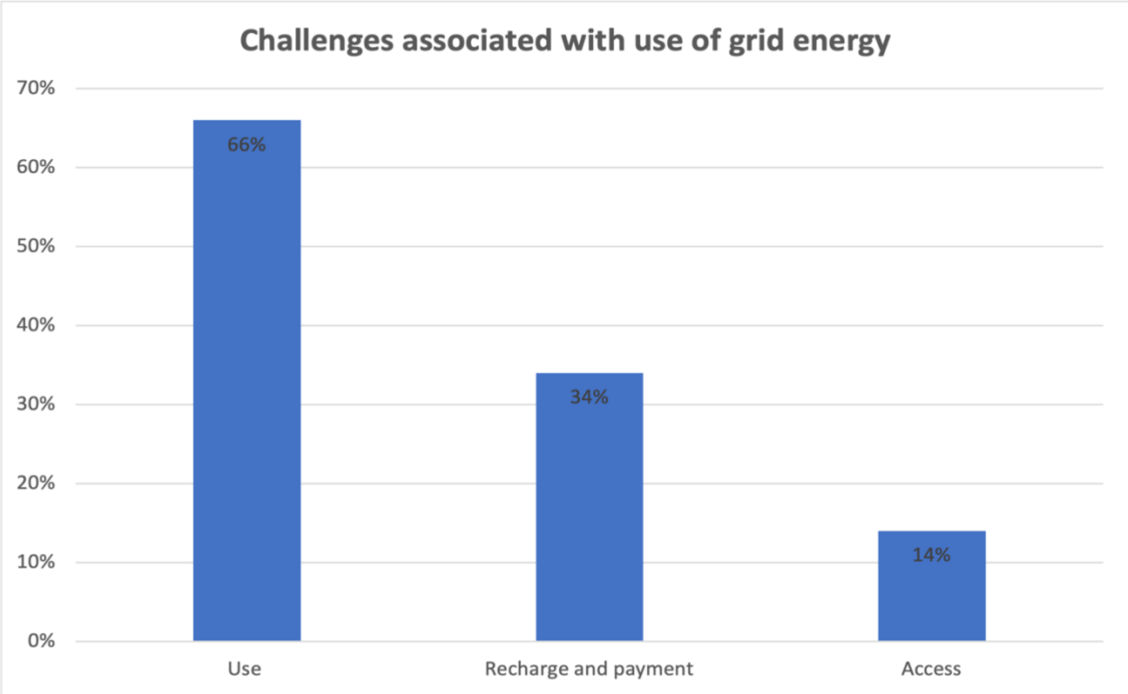

Figure 4.7 Categories of challenges associated with grid energy

4.4.3.1.1. Grid access challenges

From the study, several challenges were raised under the category of access-related challenges. The results demonstrate that delays associated with getting an initial connection to the grid account for the majority of the undesirable access experience (Figure 4.*8*). Respondents mainly raised concerns about the bureaucracy associated with getting an appointment with the energy supplying body, that is West Nile Rural Electrification Company Limited (WENRECo). Some also noted delays in connection due to the distance of the existing extension infrastructure from the points of use.

The results in Figure 4.*8* also indicate that high initial connection fees are one of the access-related challenges faced by users, ranked second by respondents, accounting for up to 28% of the undesirable access-related experiences. Respondents' complaints about the high initial connection costs were particularly more substantial for those who were far away from the main grid electricity supply lines. Such connection fees, coupled with the low net worth of most businesses, may explain why a number of users resorted to pursuing secondary connections through neighbours to save costs. Only 11% of the users raised concerns about power supply line breakdowns which affect their business operations, shedding light on the quality of the electricity extension infrastructure. The findings add to the understanding of the challenges associated with the government's approach to grid extension for energy access, in line with previous studies by Trotter et al. (2019b). Based in the findings, it is suggested that such grid extension programs must be further streamlined to address the stated challenges to achieving universal energy access for driving local and rural economies.

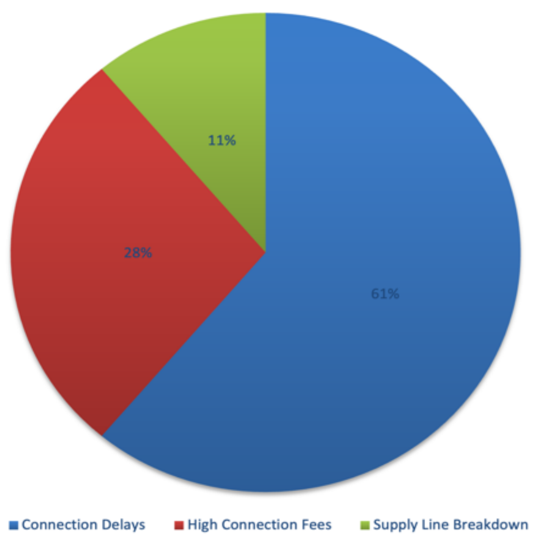

Figure 4.8 Challenges associated with access to grid energy

4.4.3.1.2. Recharge and payment challenges

An array of challenges was raised under the payment and recharge category (Figure 4.9). Service provider system failure was the most recorded challenge, accounting for up to 59%. The respondents noted that the challenge presented in the form of network failures to load power units and to carry out purchase transactions at the points of sale. Furthermore, respondents noted the few numbers of recharge/unit purchase shops or the distance to them as the second most common challenge, accounting for 18% of recharge-related challenges. Some of the respondents reported that they often had to travel long distances to purchase the power units. Our study did not dive further into the supply side approaches and factors, however, these findings suggest significant inefficiencies in the supply chain of the energy sector causing undesirable demand-side user experiences. For a better end-user experience, the results point toward the need for complementing the grid extension infrastructure with better service delivery in terms of streamlining payment and purchase of energy.

Eighteen percent (18%) of the respondents also reported the challenges of price fluctuation and high tariffs on the electricity units (Figure 4.9). They particularly raised concerns about their lack of knowledge on the determinants of the price of the power units and some demonstrated their eagerness to audit and understand the factors that influenced the cost of the units. Three percent (3%) of the users raised the concern of limited recharging knowledge and noted that they had to rely on knowledgeable people to help with the recharge. Lastly, 2% of the respondents reported the challenge of recharging point time restrictions. They observed that often, recharging points only worked for 8 to 9 hours per day, yet their enterprises worked for more than 9 hours a day. If their power units got used up during the non-working hours of the available recharging points, it would cause an operation paralysis as they would have to wait for the recharging points to re-open. This not only negatively impacts the revenues and productivity of the enterprises but also deprives the local communities of the services of the enterprises during the downtimes. The challenges associated with payment and pricing build on the reports by Ssennono et al. (2021) noting Uganda is among the countries with one of the highest tariffs. Albeit the study did not investigate issues around energy pricing in-depth, transparency between the energy sector supply side actors (government) and the demand side users in terms of energy units pricing is a necessary condition that would enhance user experience and potentially promote a more positive attitude towards the grid uptake.

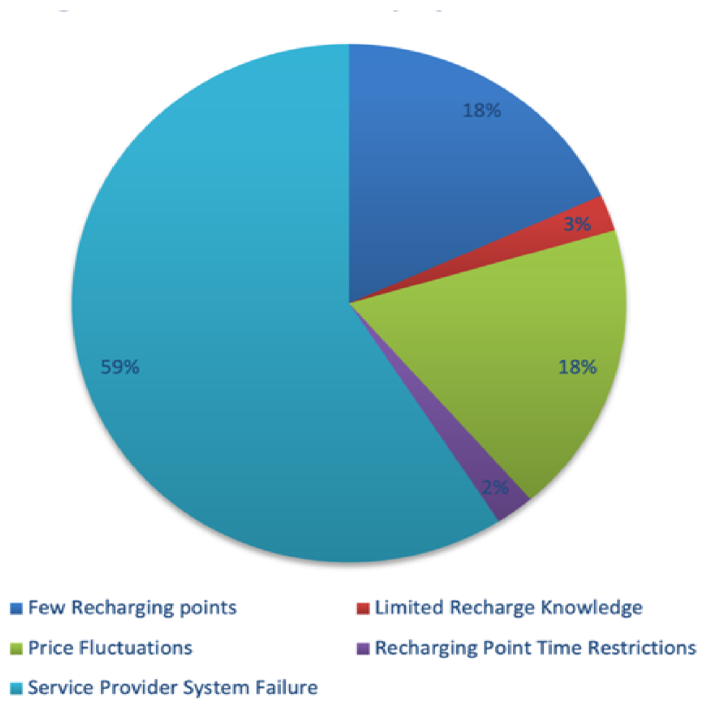

Figure 4.9 Challenges associated with access to grid energy

4.4.3.1.3. Grid use challenges

The respondents reported three main categories of challenges associated with usage of energy from the grid and these are reconnection delays, technical troubleshooting delays, and unreliable supply of electricity (Figure 4.*10*). Unreliable or unstable supply accounts for up to 98% of the challenges – this includes blackouts and power voltage fluctuations which often posed a threat to the consumers' electrical appliances. Reconnection delays and technical troubleshooting delays each accounted for 1% of the challenges. Respondents reported a time lag between the purchase of the power units and when they get the power, often affecting their business operations. These challenges highlight the reduced value for money that the services of the grid energy supply sector are rendering to the demand-side end-user enterprises. Besides, the reduced value for energy investment, these challenges also pose threats to the productivity of the enterprises. These challenges, unaddressed, could potentially sabotage the government's efforts to upscale grid-based consumption by skewing the demand-side preference towards off-grid energy alternatives. Further research is recommended to explore the underlying causes of the voltage fluctuations and the impacts of the foretasted challenges on business productivity.

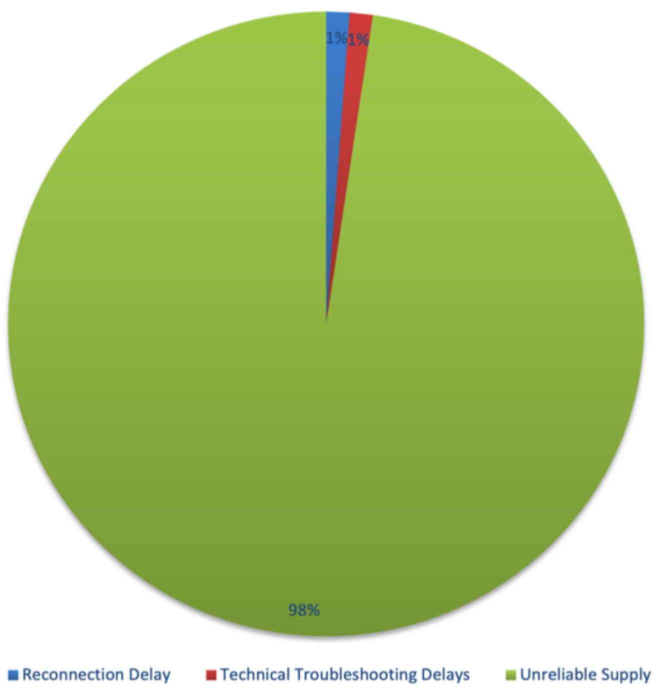

Figure 4.10 Challenges associated with the usage of grid energy

4.4.3.2. Solar energy challenges for productive use enterprises

From this study, it is apparent that the majority of the challenges raised about solar energy pertain to access. The results in Figure 4.*11* indicate that 41.2% of the users' raised concerns about the high initial investment costs they encountered while purchasing their solar PV. Some respondents rated acquiring solar energy for their enterprise's productive use operations as completely economically infeasible given the energy intensity of their business and low capital, even though they would wish to invest more into solar energy. According to respondent reports supported by secondary data, several affordable solar energy programs are being rolled out through the region; however, these mostly seem to benefit domestic usage since the evidence obtained from this study seems to suggest that solar affordability for several productive-use enterprises is still a challenge. Similar respondent reports suggest that new suppliers are attempting to provide alternatives to make solar more affordable for enterprise operations, however, these are still faced with several challenges, which are discussed later in this chapter. Unaddressed, this finding has severe implications for the efforts dedicated to building more low-carbon enterprises and enhancing the productivity of the local economy through energy access. As part of the governments low carbon development plan and upscaling energy access, it may be appropriate for the government to establish incentive and subsidy schemes to incentivise and subsidise solar PV prices for businesses, a strategy which has been proven to lift adoption barriers among small and medium enterprises (Sher & Qiu, 2022).

The second most encountered challenge was the difficulty of finding authentic solar products in the market (Figure 4.*11*). This was mainly reported by users who got their solar systems from either informal market vendors or electronic shops and companies. 23.5% of the users raised the concern of distance to the market to purchase solar systems – this was particularly for those that were far away from the town. Meanwhile, the informal vendors and electronic shops and companies are playing a vital role in bringing solar energy products closer to the users, it is vital to ensure that they are providing standard and authentic products and services. Reports of counterfeit products were raised by some of the respondents, confirming the findings of Groenewoudt et al. (2020) about the existence of fake solar in the market. These observations suggest that the government needs to establish a streamlined process of certifying the solar energy products that are imported and made available on the market. This could be further strengthened by certifying professional firms to train consumers on judging the authenticity of the products available in the market. Such strategies will protect energy users from cheap counterfeit products.

Lastly, the respondents reported challenges associated with the use of solar systems to operate their business; only 30% reported low power output to support their business operations. Some noted this as a result of low insolation during days of bad weather, however, some reported this insufficiency due to the high voltage nature of their business, rendering solar PVs incapable of supporting all the operational activities. The provision of affordable and more efficient energy storage products will be vital to overcoming this challenge. It is also suggested that producers produce similar equipment that is customized to operate on solar energy for small enterprises.

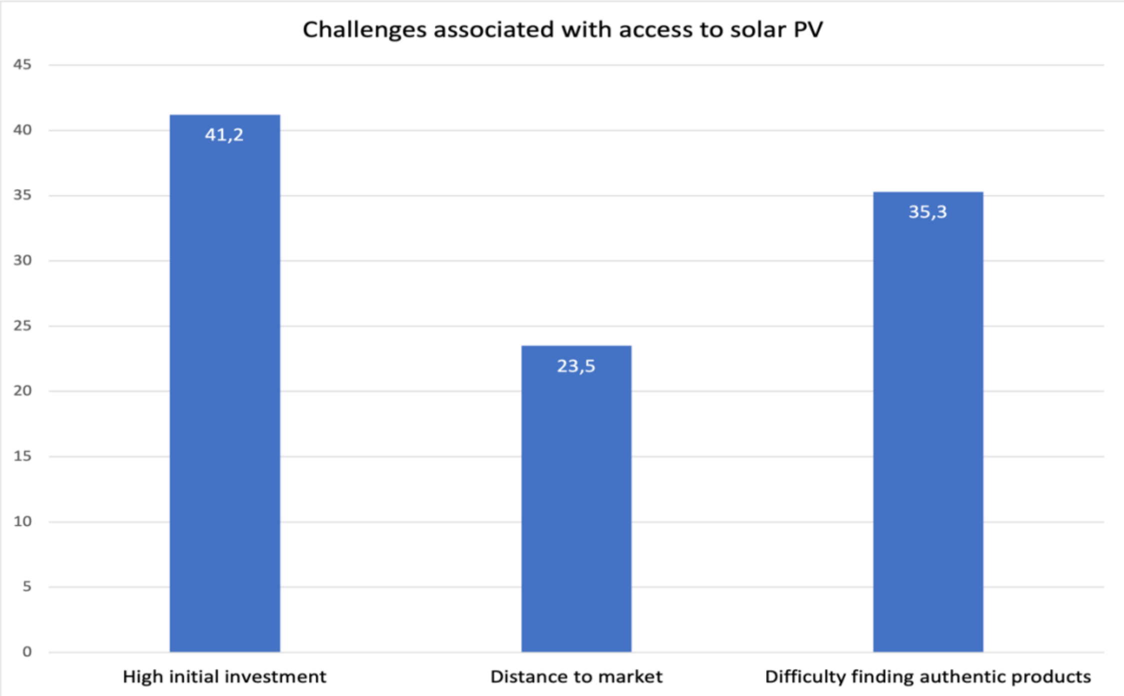

Figure 4.11 Categories of challenges associated with access to solar energy

4.4.4. Response strategies to the challenges associated with energy usage.

The results of this study tie well with the previous studies done by Munro and Bartlett (2019) and Owusu et al. (2022) about the multiple strategies employed by energy consumers for coping with energy poverty, such as energy bricolage, worker layoff, operation stoppage, switching livelihood strategies and business times among others. The respondents of this study reported that to address the several challenges associated with the access, payment, and usage of energy sources for productive enterprise operations, they employed more than one strategy all with significant negative implications for the productive potential of their businesses. For instance, 24 out of the 129 enterprises surveyed reported varying prices of their goods and services based on the type of energy used at the time the service is rendered. Prices were often increased when the enterprises were operating on fuel generators during a grid electricity blackout. Such price variations may have significant budgetary implications that may affect the capacity and bargaining leverage of the consumers to purchase the goods and services during periods of high prices. On the other hand, it makes the small enterprises lose their competitive leverage to capture the local market, against well-established large-scale enterprises with higher capital base and investment, providing the same goods and services, consequently presenting risks for the livelihoods of the small enterprise owners.

Furthermore, 35 of the surveyed enterprises reported running two businesses simultaneously to maximize electricity use and boost revenue. In many cases, the dual nature of the business implies that one was entirely dependent on energy and the other did not need energy, thus allowing for the businesses to remain operational during blackouts. This strategy not only helps the businesses maximise energy use and get through downtimes, but it also allows for minimal impacts of power blackouts on the livelihoods depending on the business. As discussed in the upcoming section, many businesses were the only source of income for the owners, whose livelihood needs such as food and daily commuting depended on the daily profits generated at the enterprise or operated on a hand-to-mouth basis. Hence maintaining functionality in times of energy downtime was vital for the livelihoods behind the enterprises.

Additionally, many of the enterprises were open several hours a day and several days a week to account for energy-related downtime. For instance, 72 of the surveyed enterprises worked for 7 days a week. The average daily operational hours of the surveyed enterprises were 9 hours and 52 enterprises operated for over 10 hours daily. Such long working hours and days may have productivity implications ranging from physical productivity issues due to worker fatigue, to mental health challenges. Furthermore, such times also infringe on the time available to the workers to engage in other social activities beyond work as well as time to pursue other livelihood and income strategies, potentially limiting their social satisfaction and livelihoods and income streams and strategies.

Workers/employees layoff was also reported, but only by a few enterprises, as the majority preferred employing few people, less than half of the maximum number employable under small enterprises. This report finds consonance with the findings of Owusu et al. (2022). A strategy that creates unemployment, risks the livelihoods of workers' families, and limits the productivity of the small enterprises. This is even riskier since many of the enterprises were operating in the informal sector, without any social security and safeguards for the workers.

An extreme coping strategy reported was where some respondents that chose anonymity reported relying on cheap illegally smuggled fuel to run their fuel generators, thus meeting their energy needs cost friendly.

4.5. The key factors driving the uptake of renewable energy for productive enterprises.

Decentralised solar PVs have been suggested by several scholars as vital for ensuring energy access, recommendations which have been implemented by several energy vendors and organizations. However, several reports have emerged about the low uptake and feasibility of the current distribution and enrollment approaches. This study also investigated the uptake of renewable solar PV in the business ecosystem, the findings are reported and discussed in the upcoming section.

4.5.1. Affordability

From the study, several respondents reported near impossible use of solar PV for their operational activities due to the high voltage nature of their activities which requires several solar panels and storage batteries. As much as 47% of the users found it affordable, but this was only in terms of operational costs rather than initial costs, and mainly among those that only mainly needed the energy for lighting. The analysis also found that 53% of the respondents found solar energy unaffordable due to the high initial investment. Some further reported that they used solar PVs at home since this was only required for lighting and therefore not much initial investment was required. These results cast light on affordability as a big challenge to the uptake of solar PV, coherent with the findings of Adenle (2020) where respondents noted financial constraints and affordability as a barrier to adoption. Addressing affordability will be important for energy access upscale, but also, most importantly, accelerating the transition to low carbon development in the business ecosystem.

4.5.2. Need and ability to support all activities.

The findings also indicate that the need for energy in the face of intermittent grid supply or limited access to the grid, as well as the necessity to sustain all business activities, had a significant impact on the decision to adopt solar PV. Several of the respondents stated that they acquired Solar PV because of its perceived benefits that are relevant to some of the functions of their enterprises' operations. For instance, respondents in farming enterprises noted the ability to pump water for irrigation at very low operational costs. Whereas farming enterprises engaged in poultry production reported the need for low-cost lighting for their brooder houses influenced their uptake of solar PV since their thermal needs were already being met by using charcoal, a need too costly to be fulfilled by the purchase of solar PV. This was also the case in enterprises that operated low-voltage electronic appliances such as televisions and entertainment systems as well as lighting influence. However, most respondents in the enterprises that required high voltage of electricity to operate, such as welding, and metal fabrication reported that they did not purchase Solar PVs due to their perceived incapability to meet the energy requirements for the productive use operations such as metal plate cutting and grinding. This perception could be true or false since all the surveyed respondents were unaware of their actual energy needs. Hence there is a need to do research involving an energy audit for the types of enterprises where the negative perception of the capability of Solar energy is prevalent and tailoring solar production capacity to their needs. However, such tailored supply will have to be accompanied by prices perceived as reasonable by the users.

4.5.3. Source of information on solar PV

Access to information and awareness has been reported as one of the factors that influence the uptake of solar PV (Roger, 2003). To explore the role information access plays in uptake in the West Nile region, solar users were prompted about where they heard about the use of solar PV for running their enterprises. The sources are indicated in Figure 4.*12*. The results indicate that the highest source of information was from the formal solar marketing companies where 37% of the respondents got their information. This highlights the role the private sector and marketing are playing in accelerating energy access and a transition to low-carbon economies. Given the level of trust consumers have in these formal companies, their regulation and certification are necessary to protect consumers from potentially counterfeit products and unreasonable prices. Evidence from our analysis also indicates that 22% of the users got to know about the potential of solar PV to support their enterprise activities through recommendations from family and friends, highlighting the role social relations play in influencing the uptake of solar PV. This finding also agrees with the findings of Sigrin et al. (2022) that reported peer referrals and social networks to play a big role in motivating adoption. Lastly, worth noting is the role informal solar PV street vendors play in promoting information about the use of solar PV for business operations, ranking at 3.7% as indicated in the analysis in Figure 4.*12*.

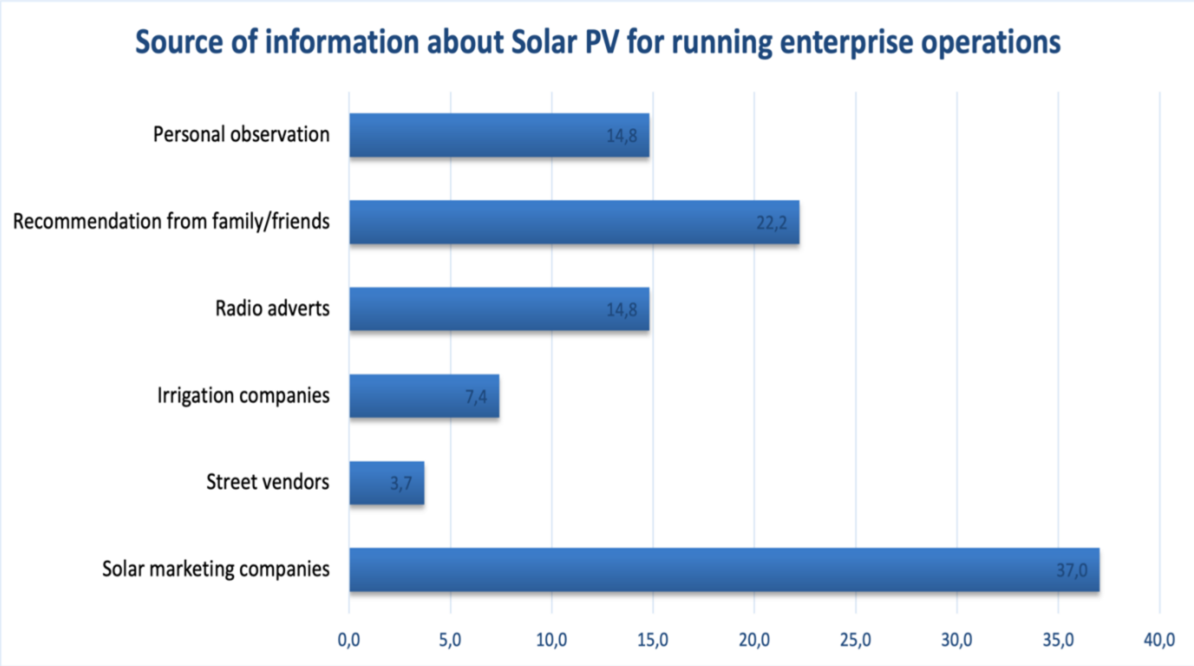

Figure 4.12 Source of information about solar PV

4.5.4. Market access and payment dynamics

4.5.4.1. Point of purchase

Market access and payment dynamics also play an important role in the access to and uptake of solar energy systems. These are presented in terms of the point of purchase of solar systems and the modality of payment. As per the results in Figure 4.*13*, several users, 52%, obtained their solar from formal solar marketing companies, potentially due to associated benefits such as warranty and any after-sales services, or just due to the security associated with formal companies. This finding also corresponds with the finding in the previous section where the formal solar marketing companies played the biggest role in promoting information about solar PVs. The results also indicate that licensed electronic shops play a big role in the dissemination of solar PVs accounting for up to 37% of user purchases. For productive purposes, the informal street vendors played the least role (11%), as a point of purchase of Solar PVs to the enterprises, also corresponding to the role they play in disseminating information about the use of solar PV, which could be since most vendors only do it as a source of livelihood rather than an intent to roll out renewable energy access. The findings provide evidence for the big role the private sector is playing in upscaling energy access through decentralised renewable energy technologies. There have been reports of the government's role in upscaling energy access through decentralised renewable technologies, however, there was no evidence of the government's role in directly promoting decentralized solar PV among the surveyed respondents. Since available scholarly suggestions indicate the government's approach to upscaling energy access centrally through the grid is infeasible (Trotter, Cooper & Wilson, 2019a), the results of this study suggest the government should actively take a direct role in rolling out decentralised energy solutions to achieve its vision of sustainable energy for all.

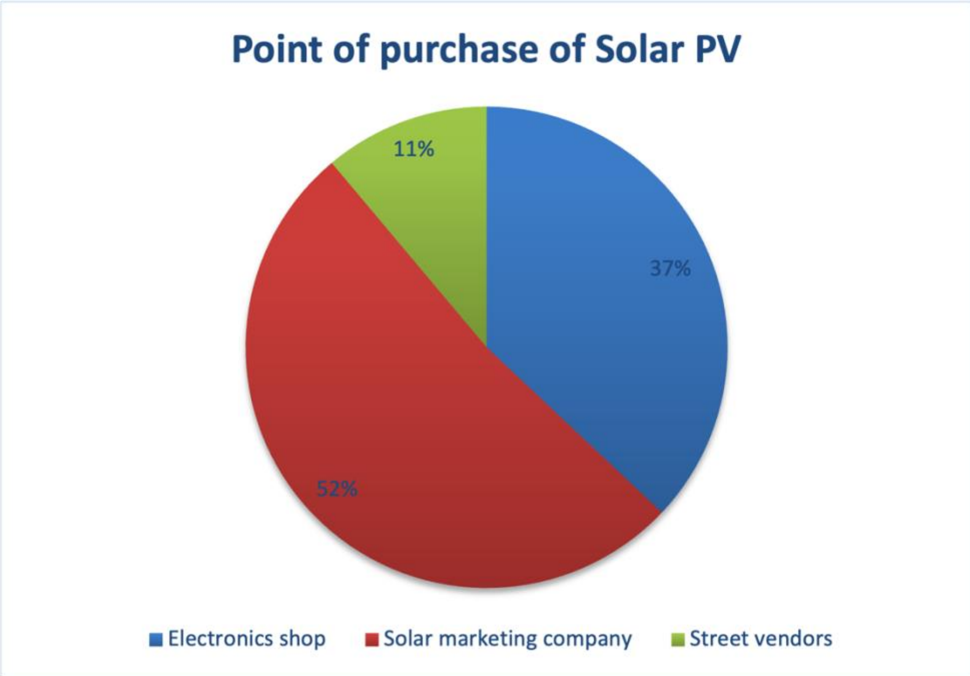

Figure 4.13 Common points of purchase of solar PV

4.5.4.2. *Modality of payment*

The survey also engaged the respondents with questions about the methods they used to pay for their solar PVs (Figure 4.*14*). A majority, 59.3%, of the users made upfront payments in cash at the point of purchase. This was followed by payments in installments or solar loans, through which 33.3% of the users purchased their solar PVs. Only 7.4% of the users subscribed to prepaid solar, a relatively reasonable amount given that prepaid solar is still novel to the region. This study suggests evidence for a stable number of people engaged in installment and loan payments. Respondents who engaged in this method of payment applauded it for enabling them to acquire solar PVs, given that they were incapable of making upfront payments due to the low capital investment of their enterprises.

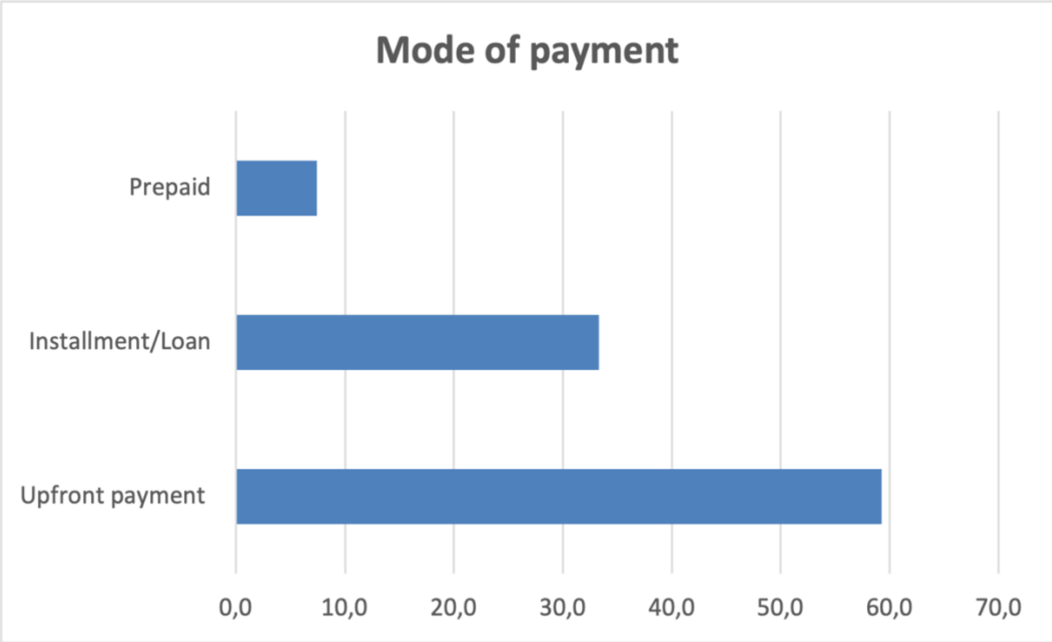

Figure 4.14 Common modes of payment for solar PV in the market

4.5.4.3. The convenience of payment versus source of purchase

Since affordability was outlined as one of the key dimensions of measuring energy poverty, to further explore the concept of affordability, the study investigated how convenient the existing payment modalities were in influencing the choice of the end users (Figure 4.*15*). The modality of payment has been indicated by available scholarly evidence as vital in the adoption of renewable energy technologies (Yadav, Heynen & Palit, 2019). From this study, 55% of the total users who purchased their solar PV systems for electronic shops reported the terms of payment to be inconvenient. Sources of inconvenience included the lack of standard pricing, implying that the prices depended on one's negotiating capability. Given the low educational levels of some of the respondents, they claimed that they were prone to being exploited since they were not aware of the actual value of the products. Another source of inconvenience was associated with the fact that most of the electronic shops required payments upfront, this often rendered several enterprises that have little capital investments and very narrow profit margins, bankrupt. Some of the survey respondents stated that they would wish to make payments upfront, but this was not possible due to their capital limitations. These findings point toward an existing opportunity for the vendors to explore other payment modalities such as payment by installment or loans.

As opposed to purchases from electronic shops, forty-five percent (45%) of the total users who purchased their solar systems from solar marketing companies, reported the terms of payment as inconvenient. The respondents reported high-interest rates as a main source of inconvenience in terms of paying for solar loans, an option that was presented by many of the solar companies. Some respondents reported inconveniences arising from business-related shocks with periods of low revenue or even business shutdown, which often affected their enterprises' capacity to pay the installments and solar loans, consequently leading to loan default, and accumulation of interests, thus rendering solar costlier. Some of the respondents simply stated that they were not fully familiar with the contractual terms under which they obtained the solar loans and had no security in event of a breach of contract for instance where the solar breaks down after a short term. The respondents who obtained their solar from informal street vendors did not report inconveniences with payment. Taken together, these findings merit the need for, firstly, educating the users on issues involving payment such as understanding contracts, this is particularly important in a region where several small enterprises operate in the informal economy associated with little education. Secondly, they point toward the need for auditing the suppliers and price regulation to protect less educated customers against exploitation.

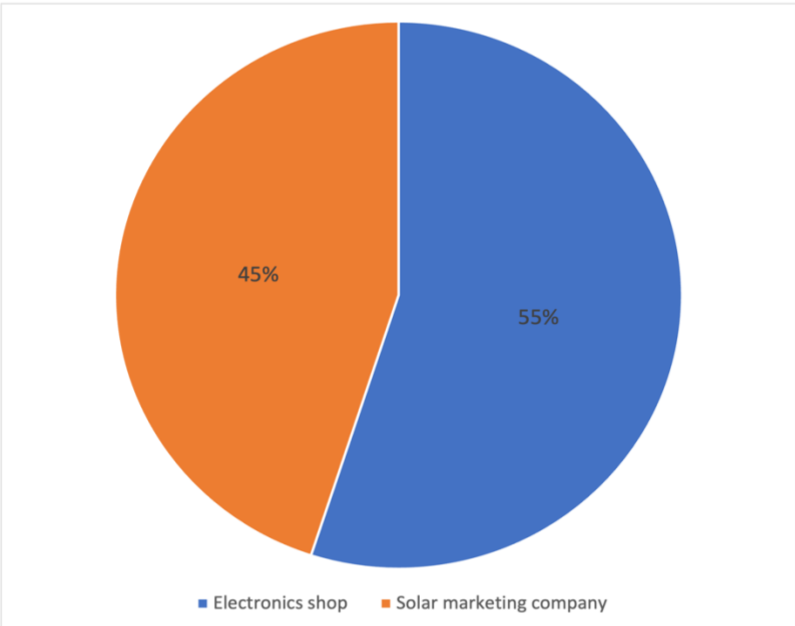

Figure 4.15 Comparison between the point of purchase of solar PV and inconvenience of payment method

4.5.4.4. The convenience of the method of payment

The respondents of this study were also asked about their convenience or inconvenience regarding the method of payment that they used to purchase their solar PV (Figure 4.*16*). For upfront payment, 50% of the users found it inconvenient, while the other 50% found it convenient. The inconvenience of payment may be strongly linked to the limited capital investment and revenues of the enterprises, which affects the capability of the small enterprises to make the initial payments. Of the majority of the users who paid in installments or obtained solar loans, 67% found it convenient, while only 33% found the payment modality inconvenient, mainly due to contractual terms regarded as unsuitable, especially the interest rates. Interestingly, all the surveyed respondents who subscribed to prepaid solar found it a convenient payment model. An interpretation of these results is an invitation for the suppliers to consider the promising installment payment with improved terms of payment and the prepaid solar, as viable modalities to serve the customers' needs and enhance their purchasing power, while maintaining the suppliers in the business.

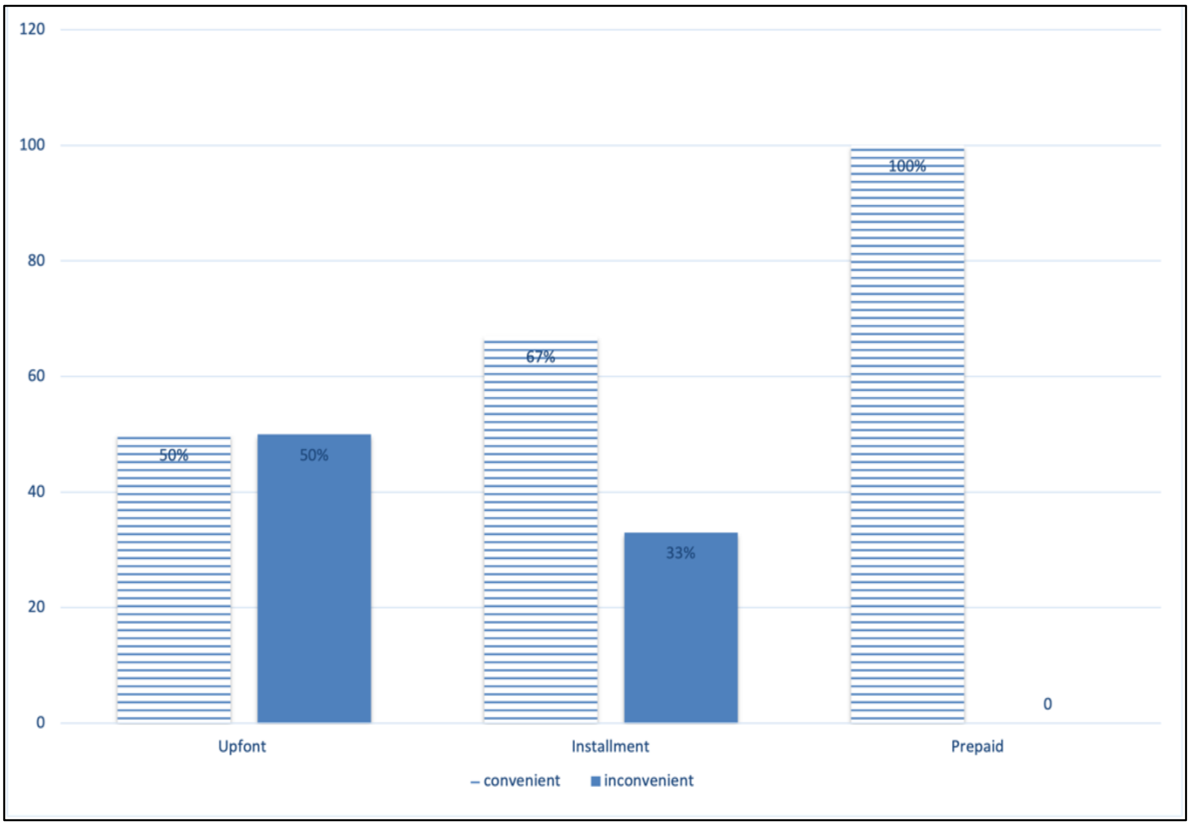

Figure 4.16 Comparison of convenience among the different methods of payment for solar PV

4.5.4.5. After-sales experience

Some of the respondents who used solar energy also reported the availability of and guarantee for after-sales services to have significantly influenced their choice (Figure 4.*17*). However, this was an advantage mainly realised by the users who obtained their solar from formal solar marketing companies, with up to 85% of the users reporting after-sales services such as repair and replacement under the warranty period as well as training and directives on use. Only 15% of the users who purchased their solar from electronic shops reported the existence of aftersales services. The ability of after-sales services to boost end-user satisfaction presents new opportunities to expand the uptake of solar energy systems and grow business for the suppliers.

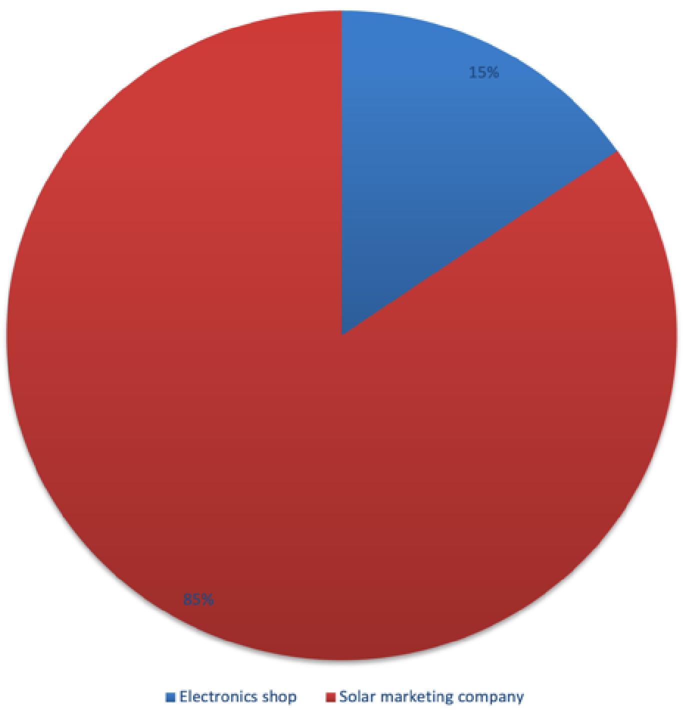

Figure 4.17 Percentage of after-sales services as a function of where the system was purchased.

4.5.4.6. Breakdown

From the study, the rate of breakdown of the solar system also influenced user experience and uptake. During the survey, a number of the users reported that they used solar systems due to their perceived wear and breakdown resistance. However, some users also reported that high breakdowns affected their perception of solar systems. Reported breakdowns included breakage of the wires, wear of storage batteries, and breakage of the solar panel, especially for smaller non-roof fitted panels that have to be carried in and out of the enterprise buildings daily. The majority, of up to 50% of the breakdowns were reported by users who purchased their solar systems from formal solar marketing companies (Figure 4.*18*). This was proceeded by those who purchased from licensed electronic shops, 36%. Surprisingly, the least rate of breakdown, 14%, was recorded among users who purchased from informal street vendors. Likely, this is because most of the solar systems available from the street vendors are small and only mainly used for less energy-intensive operations such as lighting and are easy to take care of. This study did not investigate the cause of breakdown; however, two possible causes may be applicable; firstly, natural wear of the batteries over time; secondly, careless user handling; and thirdly, the use of counterfeit products which have a low wear and breakdown resistance. There are two possible solutions to these problems, firstly, training the users on the handling of solar products, and secondly, regulating and certifying the products of the suppliers to get rid of counterfeit products.

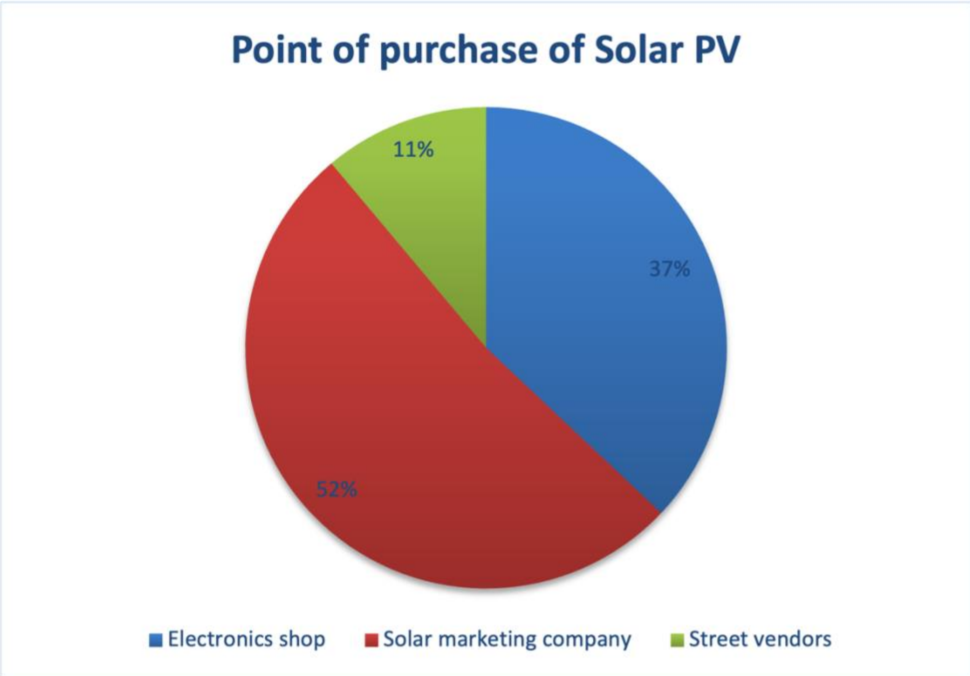

Figure 4.18 Percentage of people who reported breakdowns as a function of where the solar PV system was purchased.

4.6. Non-Solar PV users' knowledge about solar energy systems

This case study also engaged productive energy use enterprises that relied on other sources of energy (grid and fuel generator) except solar energy. This was to help establish their level of awareness about solar energy, and their willingness to adopt solar energy to run their enterprises' operational energy-demanding activities.

4.6.1. Awareness about the benefits of solar

When asked about their knowledge of the use and benefits of solar energy as an alternative energy source (Figure 4.*19*) 48% percent of the respondents were aware of the benefits of solar energy, while 52% of the respondents were not aware. The respondents were further prompted with questions about their awareness of the potential of Solar PV to run their enterprises' operational activities (Figure 4.*20*), of which, 69% responded with a "No" and 31% responded with a "Yes". However, some of the users who responded with a "Yes" outrightly stated that solar PV could not support their activities due to their energy-intense nature, this was particularly the case for enterprises with business lines in welding and metal fabrication. The failure of the awareness to translate into adoption could also be a result of the affordability of the technology, or the perceived incapability of solar PV to support certain activities. These findings warrant the need to upscale information dissemination about the benefits of solar PV and a demonstration of its potential to run high voltage enterprise operations.

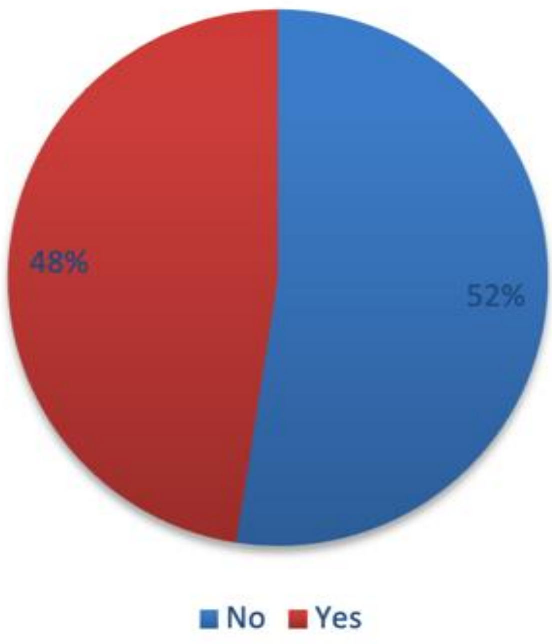

Figure 4.19 Level of awareness of the benefits of solar energy

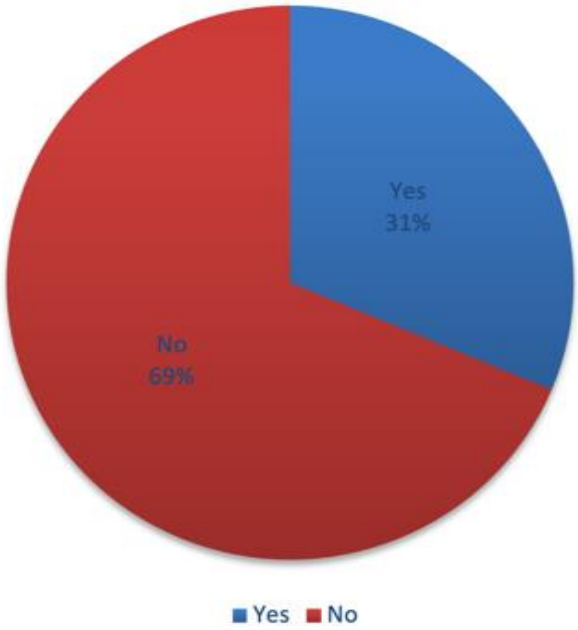

Figure 4.20 Level of awareness about the potential of solar energy to run business operations

4.6.2. Source of awareness about solar PV

To understand the sources of information about the use and benefits of solar PVs, the respondents were asked to share where they obtained the information (Figure 4.*21*). The majority, 24 respondents of the 48% who were aware of the benefits observed the benefits and use from other users such as neighbors, and friends, again pointing towards the potential role of social relations in facilitating information access about solar PV. Seven (7) of the respondents obtained the information from solar marketing companies, while 6 got it from NGO training. At the tail end were users who obtained the information from school, 3, radio adverts, 4, or were previous users of solar energy or use it at home for domestic purposes. The findings provide evidence that a diverse set of actors ranging from the business-oriented private sector, non-profit civil society actors, and development agencies as well as the academia and mass media all play a role in brokering knowledge and information dissemination about solar PV. However, there was no evidence of the direct role of the government in facilitating information access about solar PV among the respondents, except through academia, which is not the most effective approach since it is non-audience specific and fails to capture the needs of potential users outside the academia.

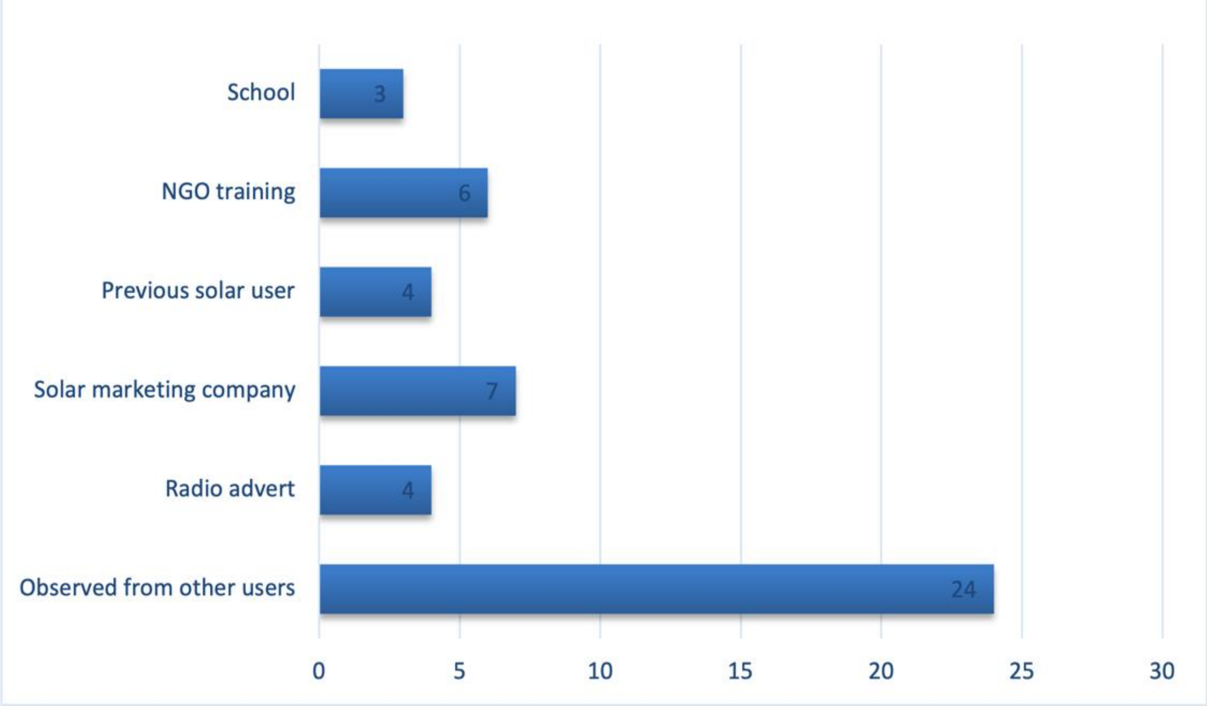

Figure 4.21 Comparison among the different sources of information about the awareness of solar energy benefits

4.6.3. Purchase of Solar energy systems

4.6.3.1. Willingness to pay and adopt.

Through the survey, the study also investigated the willingness of the enterprise owners and/or operators to acquire solar energy to run their operations. During the survey, most of the respondents had high expectations of receiving a solar system from the survey administrator, signifying an eagerness to adopt solar energy. When all the respondents were asked about their willingness to pay to obtain a solar energy system or upgrade their existing one to meet the needs of their enterprises' productive use activities, 53 responded with a willingness to pay while 46 were not positive about purchasing or obtaining solar PVs for their business, with some unrecorded number willing to change their opinion and purchase in event of stronger guarantees for energy supply. The study did not prompt respondents further on why they were unwilling to pay, however, suggestion is that this could be due to the perceived or experienced unaffordability of the Solar PV technology. This could also be due to the perceived or experienced limited capacity of solar PV to run enterprise operations, especially among previous users of solar PV.

4.6.3.2. Preferred modalities of payment

Both categories of respondents who expressed their willingness to pay and those who were not positive about adoption were also asked about their potentially preferred payment modality in case they changed their opinion in light of new information and guarantees (Figure 4.*22*). Up to 50 of the respondents preferred payment in installments or loans. This was mainly preferred due to the window of time it would give them to meet the high initial investment costs. Eleven (11) respondents preferred to make upfront purchases while only 8 preferred prepaid solar. A significant number, 30, belonged to the other category, who indicated that their preferred payment modality would depend on a number of factors such as the actual cost, the terms of payment, and the associated guarantees. Though preliminary and based on limited sample size, these results confirm that suppliers need to approach the market with more than one payment modality to meet the contexts and preferences of the different clientele.

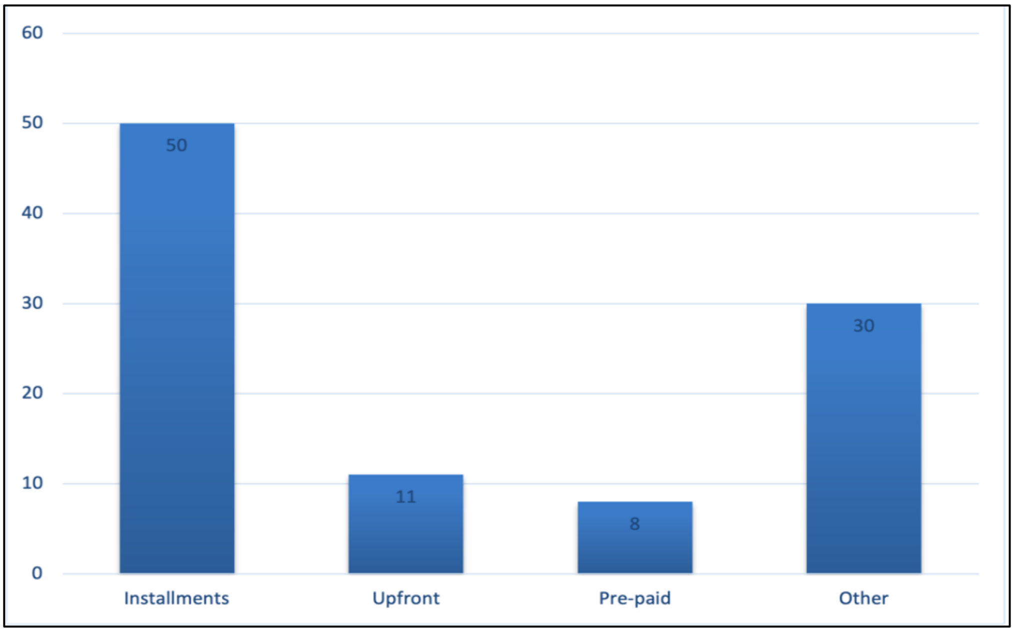

Figure 4.22 Comparison of preference among the different methods of payment for Solar PV

4.7. Extent to which energy-enterprise interlinkages affect livelihoods of business owners.

Small enterprises energy access and security have a profound influence on the capability of local communities to meet their livelihood needs. To explore the interconnection between the two factors, this study also attempted to investigate the impact of the status of energy access, particularly focusing on the reliability of supply in the enterprises on the livelihood sustainability of the enterprise owners. Respondents were asked whether their livelihoods were affected by energy-related downtime at the enterprises. 118 respondents responded in the affirmative, while only 11 reported that energy-related downtime did not significantly affect their livelihoods (Figure 4.*23*). Most of the respondents that reported the effects of energy downtime on their livelihoods only operated one enterprise as their main source of income (Figure 4.*24*). Contrastingly, those that reported not being affected had more than one source of income. The high level of impact of energy-related downtime on livelihoods could also be explained by the fact that most of the enterprises operated on a hand-to-mouth modality running on daily revenues without significant savings, thus affecting livelihoods when daily revenues are lost due to energy-related downtime.

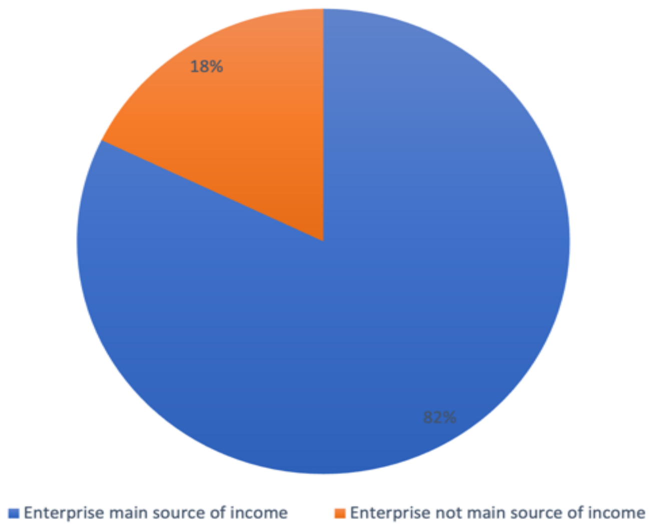

Figure 4.23 Enterprise operated as the sole source of income

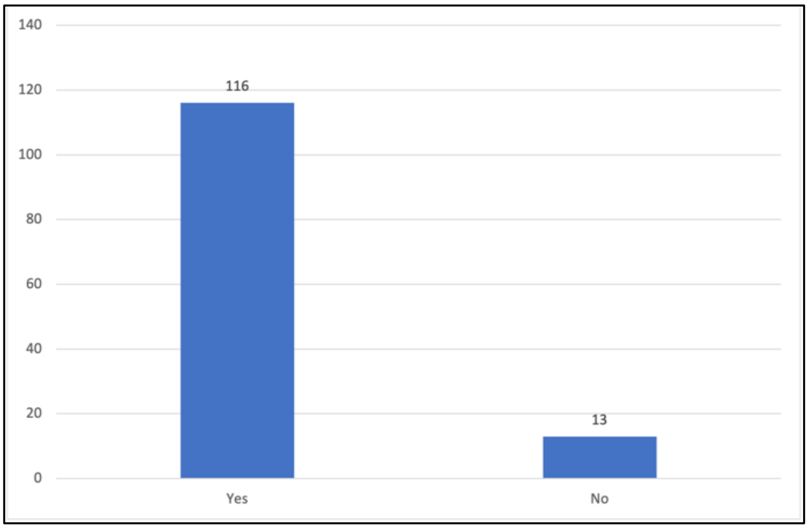

Figure 4.24 Comparison of the effect of energy-related downtime on livelihoods

4.7.1. Aspects of livelihoods most affected.

The aspects of livelihoods reported here are the key aspects of livelihoods as reported in the National Household Survey of 2020. From the study, thirty-four percent (34%) of the respondents reported that their ability to purchase food at home was compromised during periods of long energy downtime (Figure 4.*25*). This is expected of the nature of the enterprises that only provide daily revenues small enough to run the enterprise and meet household needs, hardly extending to savings for unforeseen periods of revenue loss or enterprise downtime. Furthermore, 31% of the respondents reported that their ability to pay school fees for their children's education was compromised due to limited revenues as a result of low enterprise productivity associated with an unreliable supply of energy. Additionally, 28% of the respondents reported that energy-related downtime sometimes compromised their ability to meet medical bills in event that such medical emergencies occurred concurrently with energy-related downtime in their enterprises. Only 7% of the respondents reported other livelihood compromises associated with energy-related enterprise downtime and these include the ability to meet daily commuting costs, the ability to engage in leisure activities, and the ability to pay for domestic utility bills.

This brings to light the fact that unreliable energy supply occasions losses beyond the boundaries of the enterprises to the livelihoods of the enterprise owners. Therefore, any attempts towards improving health care access, alleviating poverty, creating employment, enhance food security, and education should be met with enhanced and reliable energy access and supply for the enterprises which will reduce energy-related downtime and contribute to improving the purchasing power of the end users to afford the social services. These results merit more research on the social justice implications of energy-related downtime among the end-users.

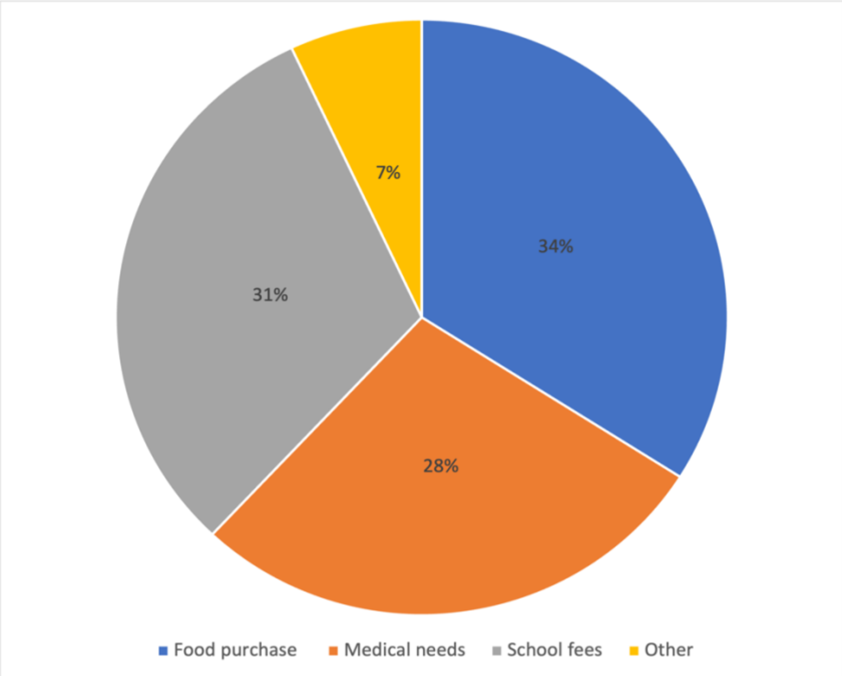

Figure 4.25 The different dimensions of livelihood affected by energy-related enterprise downtime

4.8. Summary of the findings

The discussed findings of this study have highlighted the consumption status, key socio-demographic trends, challenges, and benefits associated with productive use energy in West Nile. The discussions have also unpacked the status of uptake and transitions towards renewable energies and opportunities for the development of the different energy types for productive use.

Firstly, results indicate that much as the grid is the most preferred energy type, other energy sources continue to play a significant role in averting energy poverty in the productive use sector – a role which can be further optimized if the perceived or experienced challenges associated with the alternative energy sources are addressed. The main challenges fall within the 4As framework of affordability, acceptability, applicability, and accessibility. Secondly, though preliminary, the results indicate trends between energy type and socio-demographic and enterprise-related variable such as education, gender and, business type, observations which warrant further research. Thirdly, the results also highlight the emerging position of solar PV as a renewable technology in the productive use energy sector. This position can be further enhanced if the cost ineffectiveness of solar PV in terms of affordability as well as the limits it imposes on productivity due to insufficient voltage supply, are addressed. Lastly, the results indicate that energy access for productive use is interlinked closely with the capability of households to meet their basic livelihoods needs and therefore any upscaling productive energy access should be approached as one of the solutions to achieving sustainable livelihoods.

5. Chapter 5: Conclusions and recommendations

This chapter concludes the study by summarising the key research findings and discussions in relation to the research aims and questions. It also discusses the value and contribution towards the body of knowledge in the field of energy and development necessary for policy and programme development. Additionally, it gives insights into the limitations of the study and recommendations for future research.

This study investigated some of the key issues underlying productive energy access for micro and small enterprise owners in West Nile, Uganda, in terms of the drivers of energy access and the implications for livelihoods of enterprise owners. To achieve this, data were obtained through surveying and interviewing the owners and operators of small energy-driven enterprises and the data were analysed using both quantitative and qualitative tools. The findings of this study provide insights into the status of energy access for productive use, the energy access-livelihood interlinkages, and the transitions towards renewable energy alternatives.

To meet their energy needs, small enterprises draw from diverse sources of energy, choices mainly influenced by the business type and activities, and the capacity of the energy type to support the business' operations. The findings of this study demonstrate that the grid is the most used energy source because it supports all the productive operations of several businesses, however, its accessibility is very limited, with only 43% standalone users. Nevertheless, other energy sources such as solar PV are emerging to play a significant role and traditional fossil-based generators have persisted in promoting energy access for the small enterprises. During the study, there was evidence of other sources of such as biomass-based energy and liquified natural gas (LGN), which were not the focus of this study, that seemingly played a role in sustaining mainly the heating energy needs of the small enterprises. Further studies will be necessary to investigate the role of non-electric sources of energy that play a bigger role in the energy ecosystem of the region, in the context of small enterprises to devise strategies to optimise them.

Beyond business type, enterprises make choices on the type of energy based on the realised or perceived benefits related to the 4A's framework in terms of affordability, acceptability, applicability, and accessibility discussed in section 4.4.1. Accessibility is less of a matter of choice since this depended on the suppliers. However, affordability, acceptability and applicability played a bigger role in consumer choices and satisfaction since they corresponded to the prevailing circumstances of the small enterprises. The findings thus suggest the 4As framework as an important tool that energy developers should draw upon when designing energy development programmes and businesses, coherent with the suggestions of (Nussbaumer et al., 2012). Overall, the current level of energy ecosystem falls short of meeting the productive needs of the small enterprises. This study did not quantify the actual economic cost of such a limitation; however, it is likely that there are severe economic losses due to these circumstances, which have to be further investigated.

The findings also support the existence of a strong trends between key socio-demographic factors including gender and education and the level and type of energy used. This builds on existing literature which has reported trends between these factors and energy access. The finding points towards the proposition that considering these gender, education and prevailing business types when planning energy development will be vital to achieve sustainable and acceptable energy access for all. For instance, education and capacity building is particularly important for users to inform their choices about the existing energy sources and optimising them for the best outcome, as highlighted in section 4.34.3. However, it will be necessary to fully understand the interplay between the 4A's as actual influencers of energy choice and the socio-demographic factors that shape the enabling environment to meet the 4A's for a sustainable energy access.

Throughout this study, there was a profound evidence that small enterprises in West Nile region face severe challenges associated with energy access, which not only significantly affects the productivity of the enterprises, but also livelihoods dependent on the enterprises as discussed later in paragraph 5.8 of this section. Similar to the benefits, the main challenges fall within the 4A's framework which constrains the energy choices of the small enterprises and contributes to energy poverty, and consequently limited productivity and service provision. Noteworthy, several energy-related challenges mainly correspond to supply side constraints and miscalculations as discussed in section 4.4.3, even though some of the challenges are purely due to the demand side incapability and circumstances. For instance, many informal enterprises only made marginal revenues which constrains their ability to afford their energy needs, warranting the alignment of the supply side approaches with the demand side circumstances and capabilities.

Solar PV is emerging to lend itself as an off-grid renewable solution for business, whose uptake is mainly influenced by business types, market, and financial factors. Nevertheless, the transition to solar energy is limited by mainly the types of systems available which have a limited capacity to support high voltage operations, coupled with the limited affordability. To quicken the transition to solar PV it is imperative to design systems that are supportive of the needs of the businesses using them and to establish innovative financing mechanisms that will make Solar PV cumulatively affordable. Capacity building and awareness raising will also be very fundamental to promote uptake and positive user experiences. The findings also suggest that the government need to invest more in the region, in terms of off-grid renewable energy access alternatives such as Solar PV. The government could play a role in setting regulatory standards for energy products that enter the market to curb counterfeit products. Additionally, the government could offer subsidies for private sector firms deploying renewable energy technologies to attract more investors and reduce the cost of the products, thus ensuring affordability for consumers. Lastly, to facilitate uptake of renewable energy technologies, the government should deploy financial incentives and subsidies that make the renewable energy technologies more affordable for the small enterprises.

This study provides empirical evidence of the close interlinkage between productive energy access and households basic livelihoods needs. The results indicate that limited productive energy access and reliability negatively affects the capacity of households to meet their basic livelihood needs such as food purchases, medical needs, education among others. This might have been due to that fact that most of the enterprises were an only source of income to the households and only operated on daily revenues fetched, without significant savings; therefore, any energy-related downtime limited productivity and daily revenues and income. Ensuring affordable and reliable energy access for small enterprises can support with expediting the government's efforts to alleviate poverty and enhance living standards. Therefore, strategies of upscaling productive energy access should be approached as one of the solutions to achieving sustainable household livelihoods.

Focus on energy access in West Nile region has mainly been on domestic use or energy access in the humanitarian context, with little exploration of the business context. This thesis has provided a comprehensive, yet inexhaustive status of energy access, the transition to Solar PV as a renewable energy option and the interconnection between energy access and livelihood sustainability in the business context in West Nile. In doing so, it challenges the energy development strategies and illustrates the imperative of multidimensional approach in energy development.

While the sample size and the mainly qualitative nature of the study may limit the generalizability and use of the results in designing energy development strategies in West Nile, it offers broad insights into some of the primary issues shaping energy security in the business sector. Further quantitative-oriented research is suggested to model the energy needs for the small enterprises to plan energy development with better precision. This will be particularly vital for the development of off-grid renewable technologies, since there is an urgent need for technologies supportive of business operations in the market. A research focused on quantifying the economic losses as a result of the challenges in the energy access and model the economic development such as business profitability under different energy scenarios will be vital to planning energy development. Furthermore, studies that comprehensively address the gender-productive energy use interface are necessary to provide better policy and strategic recommendations for specific groups. Future research extending beyond proof of concept towards driving solutions and impact will be necessary for developing tools to avert the technology use related challenges associated with the current energy types. This study did not explore in-depth the non-electric sources of energy, this is recommended for future research as these sources of energy are important especially in such low-income communities.

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Appendix

Survey questionnaire for micro and small enterprises

1. OWNER INFORMATION

1.1. What is your age?

a) 18-25 b) 26-35 c) 36-45 d) Above 45

1.2. What is your gender?

a) Male b) Female

1.3. What is your highest completed level of education

a) None b) Primary School c) Secondary School d) Post-secondary school or tertiary education

1.4. What is your marital status?

a) Single b) Married c) Separated/Divorced d) Widowed

1.5. Do you have a family?

a) Yes b) No

1.6. What is the size of your family?

2. BASIC INFORMATION – Productive end-users

2.1. What is the enterprise's approximate age?

a) Less than 1 year b) 1-5 years c) 5-10 years d) Above 10 years

2.2. What is the enterprise's line of business or business type?

2.3. How many people are directly employed by the enterprise right now?

2.4. How many days per week is the enterprise usually in operation?

2.5. What are the daily operational hours of the enterprise?

2.7. Do these hours depend on or are they impacted by energy access?

a) Yes. b) No

2.8.If yes, please explain

2.9.Has the enterprise been in operation in all of the last 12 months?
a) Yes b) No

2.10. If not, how many weeks or months was it not in operation?

2.11. Are any of the reasons for the enterprise not being in operation energy related?
a) Yes b) No

2.12. If yes, what were the reasons?

2.13. What is the enterprise's average weekly revenue?

3. Energy needs/access

2.6.How important is energy access to the operation of this enterprise?
a) Not important b) important c) very important d) Essential

2.7.What are the productive use operations of the enterprise that require energy access?

2.8.What type/sources of energy does the enterprise use?

2.9.How much on average does this enterprise spend in a month to meet its energy needs?

2.10. Does the energy type used at a point influence the price of the services you render?

a) Yes b) No

2.11. If yes, please explain

3. Grid-based systems

3.1.Is the enterprise's main source of energy grid based?
a) Yes b) No

3.2. If source of energy is not grid based, why not?

If the participant answered yes, the following follow-up questions will be asked:

3.3. For how long has the enterprise been using the grid system?

a) Less than a year b) 1-5 years c) 5-10 years d) More than 10 years

3.4. Does the grid connection support all of the enterprise's activities?

a) Yes b) No

3.5. What are the main activities that rely on the grid connection?

3.6. What are the benefits associated with using the grid system that influenced you to choose it?

3.7. Are there any challenges you encountered in getting access to the grid system?

a) Yes b) No

3.8. If yes, what are the challenges?

3.9. Are there any challenges associated with paying re-charging your electricity from the grid system?

a) Yes b) No

3.10. If yes, what are the challenges?

3.11. Are there any challenges associated with using energy from the grid system for your productive use operations?

a) Yes b) No

3.12. If yes, what are the challenges?

3.13. In the past week, how many times did you experience unforeseen blackouts?

3.14. Did the blackouts stall the enterprise operation?

a) Yes b) No

3.15. If yes, what operations were stalled with the energy blackout?

3.16. Were there any equipment damages due to electricity fluctuations?

a) Yes b) No

4. Solar systems (Off-grid).

4.1. Do you use solar PV systems? If not, why not [end of question – skip to questions on those that do not use solar]?

a) Yes b) No

4.2. How did you know about the use of Solar PV system?

4.3. For how long has the enterprise been using the PV system?

a) Less than a year b) 1-5 years c) 5-10 years d) More than 10 years

4.4. Does the PV support all of the enterprise's activities?

a) Yes b) No

4.5. What are the main productive use operations that run on Solar PV?

4.6. What are the benefits/advantages associated with the usage of the solar system that influence your choice of it?

4.7. Are there any challenges you encountered acquiring the solar system for your operations?

a) Yes b) No

4.8. If yes, what are the challenges?

4.9. Are there any challenges you encountered using the solar system for your productive use operations?

a) Yes b) No

4.10. If yes, what are the challenges?

4.11. Have there been any breakdowns since the purchase of the solar system?
a) Yes b) No

4.12. If yes, did the breakdown stall the enterprise operations?

4.13. Are there any after sales services provided by the suppliers?

a) Yes b) No

4.14. If yes, what are the services?

Set of questions for those not using solar systems

4.15. Are you aware about solar PV systems?

a) Yes b) No

4.16. Are you aware about the benefits of Solar PV systems?

a) Yes b) No

4.17. How did you know about the benefits of the Solar PV systems?

4.18. If you have used solar for your operations before, what made you stop using it?

4.19. Do you use solar at home other than the business?
a) Yes b) No

4.20. Are you aware about the potential of Solar PV systems to run your enterprise?
a) Yes b) No

4.21. Do you know other businesses that use Solar PV?

a) Yes b) No

4.22. Would you be willing to pay for a solar system if it is more operational cost and energy effective?

a) Yes b) No

4.23. Given the cost of solar systems for productive use, if you were provided with a payment plan, what payment plan would you prefer?

a) Paying upfront b) Paying in instalments c) Pre-paid solar d) Other (please specify

5. Fuel generators (Off-grid).

5.1. Does your enterprise use a fuel generator system? If not, explain why [end of question]?

a) Yes b) No

5.2. For how long have you been using the generator?

a) Less than a year b) 1-5 years c) 5-10 years d) Above 10 years

5.3. Does the Generator support all of the enterprise's activities?

a) Yes b) No

5.4. What are the main productive use operations that run on the Generator?

5.5. How many hours per day do you use the generator?

5.6. How many litres of fuel is that per day?

5.7. What influenced your choice of the Generator system?

5.8. What are the benefits associated with the usage of the Generator system?

5.9. Are there any challenges you have encountered using the Generator for your productive use operations?

a) Yes b) No

5.10. If yes, please explain.

5.11. How many times a week do you experience breakdowns in the generator?

5.12. Do these breakdowns stall the enterprise operation?

a) Yes b) No

5.13. If you experienced breakdowns in the generator, did this stall the enterprise's operations?

5.14. For how long does the said breakdown stall the enterprise's operation?

5.15. How much did you spend to service the Generator over the past one month?

6. Other sources of energy.

6.1. What are the other sources of energy used to run your enterprise's productive use operations?

6.2. What influenced your choice of this energy system?

6.3. For what specific purposes do you use these sources of energy?

6.4. What are the benefits associated with the use of the mentioned energy source?

6.5. Are there any challenges associated with the use of this energy source in relation to the operation of your enterprise?

a) Yes b) No

6.6. If yes, what are the challenges?

7. Livelihood impact of current energy access (only for small enterprise sole proprietors).

7.1. Is this business the main source of income for your family?

a) Yes b) No

7.2. What other businesses does your family run as a source of income?

7.3. If this enterprise is the only source of income for your family, is your family usually affected by energy related downtime of the enterprise?

a) Yes b) No

7.4. What aspects of your family are affected by enterprise's energy related downtime?

a) Ability to purchase food	b) Ability to meet medical needs	c) Ability to pay school fees	d) Others. Please specify

7.5. What are the direct effects of the current energy type you are using on your household (domestic enterprises)?