Mobile Technologies, Digital Financing and Access to Solar Energy in Uganda

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Abstract
This study sought to examine the factors that contribute to solar energy access in Uganda. The study examined the relationships between Mobile Technologies, Digital Financing, and access to solar energy in Uganda. The researchers used a cross-sectional quantitative survey design to analyse the relationships between the variables. The study was undertaken in Mbale District; owing to the fact that it has the highest population in Eastern Uganda, and one of the highest up take of mobile phone-enabled micro-solar systems (2-20W and less). A population of 50,000 respondents, comprising of active subscribers of MTN Mobile Money and Airtel Money micro-solar systems was studied. A sample size of 384 respondents was selected using the Krejcie and Morgan (1970) table. A structured questionnaire was administered to respondents who included subscribers of micro-solar systems in the area of study. 270 usable questionnaires were collected from the field giving a response rate of .703 (70%). Data was analysed using Microsoft Excel and SPSS. The coefficients of correlation, regression, and exploratory factor analysis were used to analyse the findings. Data from the study indicated strong positive relationships between Mobile ICTs, Digital Financing, and Access to Solar Energy. Other factors that were found to be significant in accessing solar energy in Mbale- Uganda included occupation, gender, age, and the respondents' highest level of education. The researchers recommend stronger partnerships between Mobile Network Operators (MNOs), and micro-solar service providers like ReadyPay Solar and M-Kopa, to ensure higher levels of uptake of solar services in the country.

Introduction

The demand for sufficient energy sources has become a bed-rock for economic transformation in the World. The United Nations, in its Sustainable Development Goal 7 (SDG7) identifies "universal access to affordable, reliable, sustainable and modern energy for all by 2030" as an engine of international transformation (United Nations, 2015). Economies will only be able to achieve sustainable growth and development with sufficient access to affordable energy resources by their populations. Energy resources provide a means for the much-needed industrialization of developing countries, and simplification of technological transfer from the developed to developing countries. However, the worrying fact is that global household access to renewable and non-renewable energy resources is far below the required 0.92% per year (standing at 0.19%) according to the International Energy Agency (IEA, 2015). By 2015, there was a 25 million increase in Africa's population, yet access to electricity only grew by 19 million people, leaving about 6 million people off the grid of hydro-electricity (Global Off-Grid Lighting Association, GOGLA, 2015b).

Notably, the main source of energy for people in Uganda is biomass (firewood and charcoal), used by over 92% of the country's population (Ministry of Energy and Mineral Development, 2015). While the country possesses huge potential for both renewable and non-renewable sources of power, Uganda still has one of the lowest consumption per capita levels of electricity in the world, of 215 kWh per capita per year, compared to the Sub-Saharan African average of 552 kWh per capita and the World average of 2,975 per capita (Price-Water House Coopers, 2013). Most of these energy resources are only accessible in urban, peri-urban and industrialized towns, with majority of the rural population (84% of total population) not being connected to the national grid. Only about 26% of the total population have access to clean electricity resources, and these are mostly in urban areas (Uganda Bureau of Statistics, 2016). The more environmentally sustainable, cleaner sources of energy like solar energy and hydro-electricity can hardly be afforded by the majority of the country's population, and not accessible to most rural populations as they are only found along main roads (Eder, Mutsaerts, & Sriwannawit, 2015). PWC (2013) observes that the prices of electricity in Uganda are up to 60% higher than in South Africa (Africa's biggest economy). The prices have remained the same over the past five years, and this is perhaps why President Museveni directed a review of Umeme's contract (the firm that manages hydro-electricity tariffs in the country) in March 2018 (The Daily Monitor, March, 2018). Blimpo and Cosgrove-Davies (2019, pp1), citing Blimpo, Postepska, and Xu (2018) add that electricity uptake in the country remains very low with "only the central region of Uganda, which includes the capital, Kampala, having an uptake rate exceeding 50 percent". There is clear need for exploring all the existing energy potentials of the country.

Providing access and affordability to alternative sources of power can go a long way in solving the problems of limited access to hydro-electricity and the environmental damage caused by biomass in Uganda (Okello, et al., 2014). The country has a huge potential for solar energy. The Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA, *nd*) indicates that the average solar radiation of the country is around 5.1 kWh/m2/day, and this remains high throughout the year with a minimal variation (max month / min month) of only about maximum 20% (from 4.5 to 5.5 W/m2). This is principally due to the location along the equator. The market for solar solutions is dominated by larger Solar Home Systems (SHS) PV systems (50Wp-150Wp) usually installed on hotels, large homes and schools. Over 60% of the rural households can only afford micro-solar systems of 2-20W (to light lanterns, charge phones, and power radio systems), and about 30% of these rural households cannot afford solar PV systems (GTZ, 2009). This implies that for majority of people to access solar power, it is necessary for stakeholders in the energy sector to provide or support affordable sources of solar energy on the market.

Mobile based solar systems are increasingly becoming a viable solution for providing access to solar energy in Uganda. The mobile cellphone economy is one of the most important sub-sectors of Uganda's digital economy. The Uganda Communications Commission (UCC, 2020) indicates that there are 33 licensed

Telecom Operators in Uganda, of which 9 are Mobile Network Operators (MNOs), including MTN Uganda, Airtel Uganda, Uganda Telecom, Africel, K2 Telecom, Smile Telecom, Smart Telecom (formerly Sure Telecom), Lycamobile Uganda, and Vodafone). By 2015, two of the major players in the industry (MTN and Airtel) boasted of over 10 million customers each (Uganda Communications Commission, 2015). In 2018, they were 21,648,672 mobile telecom subscribers in the country (UCC, 2018). This implies that more than half of Uganda's populations (20 million people) now have access to Mobile phones. Poushter, *et al.,* (2015, pp. 3-4) observes that 93% of Ugandans with a high school education or higher own a mobile phone, and that by 2015, about "three-quarters of Ugandans who speak or read English own a mobile phone." The Pew Research Centre (2014) indicates that digital financial services, specifically making and receiving mobile payments account for about 30% of transactions undertaken by subscribers in Uganda. At least four of the MNOs (i.e. MTN, Airtel, UTL and Africel) in the country operate a Mobile Money Transfer (MMT) system. This creates potential for MMT supported financial and other value -added services.

Indeed, MMT is increasingly seen as a major engine of digital financial inclusion (Kasekende, 2017; Brookings Institute, 2011), and rural electrification (Martinez-Cesena, *et al.,* 2015; GSMA, 2012, 2017), sustainable energy access (Alsharif, 2017), and ultimately, poverty alleviation. Mobile Money payments, especially MTN Mobile Money, are now being used to purchase Solar Home Systems in Ugandan rural areas. In spite of strong demand for solar systems, 95% of households in rural areas can hardly afford the up-front cost SHS systems (Fenix International, 2018). MTN Uganda partnered with Fenix International to provide Internet enabled cell-phones on purchase of ultra-affordable ReadyPay Solar Power. By 2015, over 50,000 off-grid homes had been connected with ReadyPay Solar Power in areas including Arua, Nebbi, Pakwach, Gulu, Lira, Mbarara, Fort Portal, Mbale, Soroti and other places in Uganda (MTN Uganda, 2015). Today, over 200,000 MTN Mobile Money users network pay between 800Ugx- 1000Ugx a day to access a basic solar system that enables at least 2-3 light bulbs, a radio connection, and mobile-phone charging. Given the fact that these places (especially West Nile and Eastern Uganda) are the most severely hit by poverty (Uganda Bureau of Statistics, 2017; The Daily Monitor, January, 2018), ReadyPay solar provides an affordable and reliable system that has changed the lives of phone subscribers. Other mobile-powered solutions in the market include solar now and M-Kopa. Frangoul, (2015) observes that by 2015, M-Kopa had powered 150,000 households in Kenya, Uganda, and Tanzania. These accessed the solar energy products through its mobile App called M-Kopanet, making more than 10,000 daily mobile payments made by users on its cloud platform, and contributing to over $40 million in revenues by the end of Financial Year 2015. Subscribers of these solutions have gotten a chance to join the national off-grid electricity system, have access to information, can more effectively engage in electricity-supported economic activities like education and retail business, and have more security in their homes. One Ready Pay subscriber, Charles K., intimates in an interview, that "I bought my solar in 2014 and my life was changed. I didn't want to keep such a great product to myself and told my neighbors and friends about the kit. As I speak, over 10 houses in my village and over 30 houses in my Parish have ReadyPay" (Fenix International, 2018). Therefore, since 96% of poor people in Uganda are in rural areas (Africa Portal, 2017), and many of these people survive on less than a dollar a day, the Ready-Pay mini SHS provides an opportunity to affordably access solar solutions in the country. This study sought to examine the digital financing systems for solar home systems in Uganda.

Research Gap

With the surging population in Uganda, projected at about 45.8 million people (Worldometer, 2020), and an economy growing between 3.5% and 6% per annum for the past 5 years (World Bank, 2020; Bank of Uganda 2019) , the need for sustainable energy resources cannot be over-emphasized. The World Bank's Global Solar Atlas (2019) and Uganda's Electricity Regulatory Authority (ERA) (2018) observes that Uganda enjoys 5-6 kWh M2 of solar radiation in most areas every day, with a potential of 11.98 x 108 MWh gross energy solar resources. Solar energy therefore continues to be recommended as a very potent alternative source of energy. However, the cost of and access to conventional solar systems remains remarkably high (with initial installation of a large domestic panel ranging between UGX2,500,000 and UGX3,000,000 (about USD680-780) (Fenix International, 2018). Even after installation, solar batteries have to be regularly replaced, which places another burden on the user. With the introduction of mobile-based solar payment systems, the cost of accessing solar systems has significantly been reduced. Solar providers have developed Pay as you Go systems to ease and make access to solar power more affordable. They enable users to make manageable monthly payments and access the system with much ease. MTN ReadyPay systems for example have provided an affordable and convenient means of purchasing Solar Home Systems for over 200,000 people (Hill, 2017) which has improved people's lives especially those in rural areas. Nakintu, one user from rural Uganda observes, with gratitude that, "we had never in our lives seen such light in our homes apart from the sun during daytime" (Fenix International, 2018). This digital financing solar solution can be harnessed by more people in Uganda to access conventional solar systems.

Purpose of the Study

This paper sought to examine the role of Digital financing and Mobile Technologies, in enabling access to solar energy in Uganda. It was guided by the following objectives; (i) To examine the relationship between Mobile Technologies and Digital financing, (ii) To examine the relationship between digital financing and solar energy access, (iii) To examine the relationship between Mobile Technologies and solar energy access, and (iv) To examine the mediating effect of digital financing in the relationship between Mobile Technologies and solar energy access.

Scope and significance of the Study

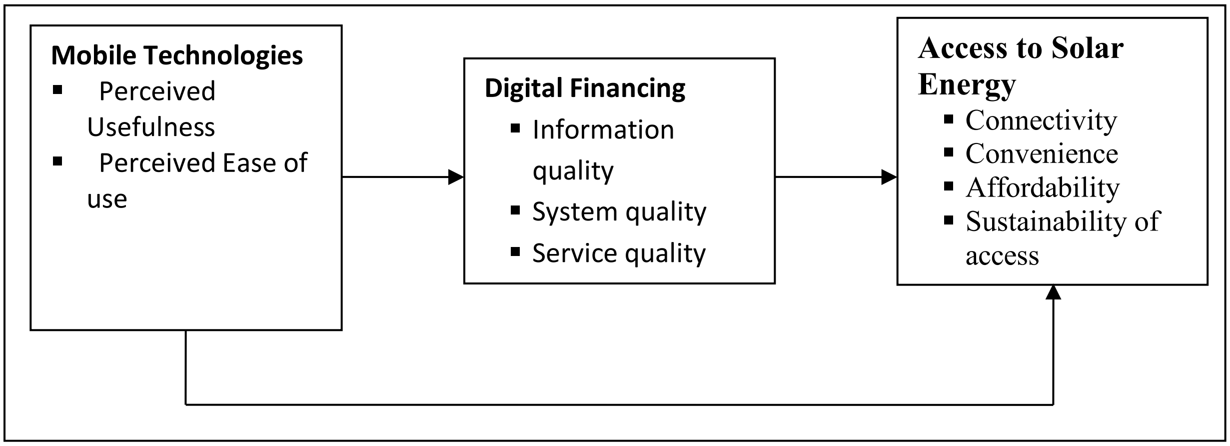
This study focused on the concepts of Mobile Technologies, digital financing and Access of Solar energy. This is because much as many studies in solar energy have in the past concentrated on access and consumption, there is a paucity of research linking ICTs to solar energy access; yet Mobile Technologies and ICTs have been earmarked by Government of Uganda as one of the 5 key major drivers of the country's economy (National Planning Authority, 2015). The study was undertaken in the Eastern Uganda district of Mbale. Mbale was chosen because it has the largest population in the region (532,100 people, UBOS, 2017), is close to the equator, is one of the districts that has people with ReadyPay (Fenix International 2018),has a considerably large population of poor people (The Daily Monitor, 2018 January) and gets a reasonable amount of radiation of solar power in the country.

This study will be significant to (a) other researchers by providing literature and in-depth analysis on the concepts of solar energy access, Mobile Technologies, and digital financing, (b) the public by providing insights into how the cost of energy access and consumption can be reduced by adopting ICT-enabled solar systems, (c) To government and Policy makers by providing an additional solution to the problem of limited access to safe, clean and environmentally sustainable energy solutions, in a country where the biggest source of energy is charcoal.

Conceptual Framework

Mobile Technologies is an independent variable, digital financing is a mediator variable, while access to solar energy is a dependent variable. For one to use digital financing; there needs to be Mobile Technology infrastructure and ability to adopt or use the infrastructure. This is because digital financing heavily depends on Mobile Technologies and specifically mobile technology. Digital financing in turn affects access to solar energy (Alstone et al., 2015). Digital financing is used as a medium to ease access to solar energy and also ensure sustainability of access. The availability of ICT specifically mobile telecommunication technologies, like Instant Messaging services and Mobile Internet has been hypothesized to facilitate convenient and affordable access to solar energy among Users (as observed by Smertnik, 2016; The United Nations Development Programme, 2012).

Figure 1: Conceptual Framework



Source: Adapted from Alstone *et al.,* (2015); Davis (1989), Davis *et al.,* 1989); Delone and McLean (1992; 2002; 2003)

REVIEW OF RELATED LITERATURE

Sustainable Development Goals

According to Adebayo et al (2018) the exigent need for a sustainable approach to global development has been a current subject of discussion at national, regional, and international levels, following the United Nations Sustainable Development Summit on the 25th of September 2015, where the world leaders adopted the 2030 Agenda for Sustainable Development. These goals include a set of seventeen sustainable development goals (SDGs) geared towards putting an end to poverty, fighting inequality and injustice, and tackling challenges associated with climate change by 2030. However, considering Africa's needs in terms of the sustainable development goals for energy (SDG7), it is likely that few African countries could achieve this goal by 2030, if proper governance and policies are put in place to develop short and long term affordable solutions to the energy needs of people living on less than $1–2 a day in rural and urban areas of Africa, where most of the people use environment-polluting kerosene lanterns to provide light at night.

Energy plays a crucial role in the development and sustainability of a nation's economy. It has a key impact on all facets of socio-economic activities in many nations of the world today. This is because energy drives all other sectors of the economy, such as food, health, the environment, water, and so on. In addition, the future economic growth of a nation is said to be guaranteed when there is a continuous energy supply that is eco-friendly, sustainable, accessible and affordable. However, the quality of life (health, education, security etc) of the citizen of any nation is closely dependent on the adequacy of the available energy supply. In general, the increasing demand for energy in the world today is linearly proportional to the rapid increase in population, industrialization and urbanization. Moreover, the success and productivity of the SDG7 depend on the quality and quantity of the available energy in the least developed countries. This implies that an increase in the accessibility of affordable and clean energy in most parts of Africa is vital to the political and socio-economic growth of the continent.

Energy Resources

The supply and use of energy have powerful economic, social and environmental impacts. Not all energy is supplied on a commercial basis. Fuels, such as fuel wood or traditional biomass are largely non-commercial. Fuel wood is playing a leading role in the developing countries, where it is widely used for heating and cooking. Universal access to commercial energy still remains a target for the future. In many countries, especially in Africa and Asia, the pace of electrification lags far behind the growing demand. It is imperative to address this major challenge without further delays, in particular taking into account the impact access to electricity has on peoples' lives and well-being, economic growth and social development, including the provision of basic social services, such as health and education.

There are currently 840 million people in the World living without access to grid energy (World Health Organisation, 2019). This situation is worse in Sub-Saharan Africa where 2 out of every 3 people lack access to electricity. Lack of access to electricity has far reaching negative impact on the economy, health and safety of those that lack due to the increased cost of production, use of alternative sources of energy that pose health risks from their emissions, and the higher risks of fire among other safety concerns. Fenix International (2017b) places the global cost of living off-grid at USD 27 billion per annum. This money is expended on alternative sources of energy such as batteries, kerosene, candles used for lighting and phone charging.

Energy Access in Uganda

According to the Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA), Uganda has the potential to generate 5,300 MW renewable energy power (UNREEEA, n.d). This estimation includes hydro power of 2,000 MW, geothermal power of 450 MW, biomass cogeneration of 1,650 MW and 5.1 kWh/m2 of solar energy (*ibis)*. However, Uganda's electrification rate has been quite low. Grid-connected households have grown from 5.6% in 1991 to 9% in 2006 and 10% in 2010 (energypedia, 2020). By end of 2018, access to electricity had risen to 42.65% (Trading Economics, 2020). Presently, Uganda has an energy generation capacity of 645 MW of hydro energy and 101.5 MW of thermal energy. However, only 19% of the population has access to clean energy, with 6.9 million households not having power (USAID, 2020). The grid is almost focused in urban areas and provincial towns, often only connecting a few thousand people per district. Of the rural population, approximately 8% is grid-connected, though the GoU plans to increase this to 22% by 2022 (Lighting Africa, 2018).

According to Lighting Africa (2018) Hydro-generated power is the primary source of power to the national grid and accounts for just over 70% of the 595MW installed generation capacity. Renewable energy sources, e.g. solar PV and biogas produce, contribute a negligible 0.1% of the total national energy supply. That approximately 31 million people in Uganda live without electricity has significant ramifications for the economy and quality of life. Lack of access to reliable lighting limits the productivity of about 85% of the country, hindering peoples' ability to carry out basic activities at night or in the early morning, including household chores, reading, school work, and business activities. Fuel-based lighting also has health and safety implications: chronic illness due to indoor air pollution, and risk of injury due to the flammable nature of the fuels used. Kerosene lamps emit fine particles that are a major source of air pollution. These implications also have a negative impact on the economy (lower productivity, higher health care costs) and reduced quality of life (lower life expectancy, respiratory issues)

Solar Energy in Uganda

Solar energy is the most abundant energy resource and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean etc.) forms. About 60% of the total energy emitted by the sun reaches the Earth's surface. Even if only 0.1% of this energy could be converted at an efficiency of 10%, it would be four times larger than the total world's electricity generating capacity of about 5,000 GW. The statistics about solar PV installations are patchy and inconsistent.

Uganda on average has a solar radiation of 5.1 kWh/m2/day, which is normally high throughout the year (UNREEEA, n.d). Uganda's solar market has experienced steady growth since 1994 and currently has approximately 1.1 MW of installed solar PV capacity with over 30 companies operating in the PV and thermal marketplace. The PV market has been encouraged by Government projects and donor support within the institutional (especially rural) sector and household solar systems, whilst solar water heating is in its infancy.

Opportunities within the PV sector are underlined by an ambitious target by the Government to supply 61% from a current 4% of total consumed energy from renewable sources by 2017. Solar shall be a component but a target is not specified. The greatest potential is identified in household small systems (55 MWp of a total 70MWp) but for this to materialize, credit and financing facilities are key.

However, the majority of people in Uganda live on USD 2 per day and are self-employed with unreliable sources of income (Fenix International, 2017b). This makes access to solar power very difficult to most households. According to the National Development Plan (NDP) 2010/11-2014/15, socio-economic development and rural transformation is a priority for the Government of Uganda (GoU). Whereas the NDP projected that rural electrification would increase to 20% by 2014/15, the current rural electrification stood at15% in 2015. This limited access and use of energy has significantly slowed down economic and social transformation in Uganda.

Mobile Technologies in Uganda

Sub-Saharan Africa accounts for nearly 10th of the global mobile subscriber base and it is expected to grow faster than every other region over the next 5years (Global Digital Snapshot, 2016). The mobile industry plays an important role in the social and economic development of the region as; the main platform for innovation, the driving force for greater inclusion and the mobile ecosystem contributes significantly to economic growth and jobs. For one to be able to access solar power through digital financing, they should possess the necessary technology. Digital financing is accessed through mobile phones; both GSM and smart phones and payments are made using USSD codes and mobile applications that run on smart phones.

The number of mobile phones has increased in Uganda; with about 16 million feature phones and 5.6 million smart phones (PCTech Magazine, 2020). According to Uganda Communication Commission (UCC), there are 32 million registered SIM cards in Uganda (Mpairwe, 2017). This figure includes individuals who own more than one SIM card. NITA (U) reported that 24.8 million Ugandans own a mobile phone representing 70.9% of the population (Kamukama, 2018).

Most of the mobile phone subscribers are located in the urban areas due to the supporting infrastructure such as electricity and good network. However, telecommunication providers have extended their reach by going further into rural areas in a bid to connect them. In addition, the national backbone infrastructure has also been extended (Kamukama, 2018). This has seen the number of subscribers in rural areas growing.

Out of the registered SIM cards in Uganda, MTN Uganda has the biggest number of subscribers with 46% of the subscribers (Kasemiire, 2019). Airtel has 44%, Africel 9.5%, UTL has 0.6% and Smart Telecom 0.3%. This shows that most of the subscribers use MTN SIM cards. Additionally, MTN is among the first

Telecommunication companies in Uganda and so has developed infrastructure which has enabled it provide services even in rural areas.

Telecommunication companies in partnership with supervised financial institutions began offering Mobile money services (MMS) in Uganda in 2009 (Ssettimba, 2016). MMS is regulated by the Bank of Uganda. It is a service that enables people to store money in their phones (mobile wallets) and transfer it to other recipients or use it to pay for different services among other uses. This has improved financial inclusion in a country that has the majority of people being unbanked. Gillwald, Mothobi, Ndiwalana and Tusubira (2019) state that only 2% of people in Uganda have bank accounts. This is made worse by the disparities between gender (more male account holders than females, geographical location (there are more account holders in the urban areas than in the rural areas) and education level (ibid). The number of people registered to use MMS and the value and volume of transactions has since grown from 0.6m customers, 3 million transactions and UGX133 billion in 2009 to 21.1 million customers, 693 million transactions and UGX32,506 billion in 2015 (Ssettimba, 2016). In 2018, a Finscope report (as cited in Gillwald et al., 2019) showed that Uganda registered a total of UGX63 trillion transacted via mobile money. This number decreased to UGX 866 billion and UGX475 billion in the quarters ending June 2018 and September 2018 respectively due to the mobile money tax that was introduced to collect revenue for the central Government. As of 2018, 39% of Ugandans use mobile money services to transact (Gillwald et al., 2019).

In terms of Internet penetration, Uganda was ranked by Forbes as the 7th country in Africa with highest Internet connectivity with 17.1 million users in 2017 (Internet Users increase, 2017). According to UCC, there were 23 million Internet users in the country, which represented 39.7% penetration in 2019 (PCTech Magazine, 2020). This increase can be attributed to a decrease in the data costs and availability of cheaper smart phones brought in from China (ibid*).* This growth in ICT in Uganda has and can be used to tap into many innovations to improved livelihood of people such as access to microloans and sale of various services to people both in urban and rural areas.

Digital Financing

Digital financing is a model that allows ongoing payments for a commodity of which ownership of the same commodity is transferred to the payer after a limited payment period (Alstone, Gershenson, Turman-Bryant, Kammen, & Jacobson, 2015). Digital financing works with a setup of some hardware and software to manage these payments without physical presence of the payer or seller. Digital financing has also been referred to as Pay-as-you-go (PAYG) Model. The model can be used by both owners of GSM phones and Smartphones. Digital Financing is an offshoot of wider technological development and innovation in the provision of inclusive finances to hitherto financially excluded people. This is why the term Financial Technology (FinTech) is sometimes used synonymously with Digital Financing. Digital Technologies are mainly supported by a number of technologies, including Mobile telephony, the Internet (sharing economy), Artificial Intelligence (AI), Machine Learning (ML), Big Data Analytics, Block-chain/Distributed Ledger Technology (DLT), and Cloud computing (Financial Sector Deepening Uganda, 2018).

Hasan, Yajuan and Mahmud (2020) consistent with Hill and Hill (2018) and Salampasis and Mention (2018) observe that "Internet finance" or "FinTech," refers to the provision of financial services beyond the traditional financial systems, using a wide range of platforms such as online banking, third-party payment, direct sales of funds, online insurance, crowd-funding, online banking, agent banking, mobile banking, and mobile money, and many other internet-enabled platforms. Digital financing or FinTech has consistently eliminated the need for customers and business organisations to physically go to the banking halls, by providing them with value-added financial solutions, support and services (Shin and Park 2017). These value added services which have tremendously reduced the cost of financial transactions by fostering and supporting innovation and sustainability are mainly accessed by customers through a range of internet-supported like mobile network operators (MNOs), payment service providers (PSPs), merchant aggregators, retailers, FinTech companies, neo-banks, and super platforms, among other platforms, technologies, and service providers (International Finance Corporation, 2020). Fintech enabled Digital Financial Services (DFS), have the potential to lower costs, increase speed, security, and transaction transparency and allow customization of allow financial services to serve the poor. Digital financing also addresses the problems of liquidity usually faced by SME financial services providers, and reduces the need for physical interactions among customers and service providers- as amplified by the current Corona Virus Pandemic, to ensure seamless virtual transfer of funds (Pazarbasioglu, et al., 2020). However, this may not be achieved because of the persistent challenges to accessing these services, like lack of legal and policy frameworks for FinTech, insufficient financial and digital infrastructure like telephone networks, lack of ancillary government support, user attitudes regarding the risks inherent in these systems, excessive taxation, customer ignorance among other factors (Pazarbasioglu, et al., 2020; Zollmann, et al., 2017). Addressing these challenges presents a lot of potential for financial sector growth, in terms of the numerous benefits of these services.

Digital financing has the advantage of cutting the cost of transaction and management of microloans (Alstone et al., 2015). The costs of servicing a microloan such as transport costs to go and pay, supply chain costs and other operation costs of the seller that would otherwise be transferred to the buyer are drastically cut because payments are made using the payers' phones. The authors found other advantages are; it helps build trust among customers because they can suspend payment before the full payment if the service is found inadequate, it provides newer consumer insight since they can monitor their consumption, increases access to solar energy as the customer can expand their service over time, it is easy to maintain and monitor since one can use a GSM phone and it enables connection of supply chains by providing jobs to different people.

Uganda's Vision 2040 fronts ICT as one of the main enablers of development and business opportunities. This is seen with encouragement of people to utilize secure ICT in business and service delivery (Gillwald et al., 2019). The GoU has also engaged in the formulation, improvement and enforcement of cyber laws to enhance information security through Government organs such as National Information and Technology Authority - Uganda (NITA-U) and Uganda Communications Commission (UCC) (ibid*).* This has created an enabling environment for telecommunication companies and banks to offer digital financing.

Digital Financing, FinTechs and Mobile Banking Institutions in Uganda

There are a number of digital financing and Fintech service providers that are operating in Uganda. These include traditional commercial banks, microfinance and microcredit deposit taking institutions, agent banking institutions, insurance firms, and mobile network operators. FSD Uganda (2018) identified over 71 FinTechs in Uganda, contributing a total market volume of approximately USD 16 million in 2017. The number has certainly grown now. These are divided into five major service segments digital payment providers, banking infrastructure services, investment services, savings and lending providers, and digital markets. Digital payments service providers in Uganda include the 9 MNOs, over 31 commercial banks, micro-credit financial institutions, digital payment service providers like *Xente-* a cross-platform mobile app that allows anyone with a mobile phone and a mobile number to transact with each other customers; *Yo! Payments*, which provides businesses with a secure and convenient interface through which customers can manage mobile payments from multiple providers; *DusuPay-* a payment gateway that enables businesses to accept and make payments in Africa; and *Ezeemoney* (payment aggregator that facilitates payments into customer mobile wallets). Digital lending service platforms include *Numida* (digital loans to entrepreneurs), *Borrocracy* (links borrowers to lenders), *Akellobanker* (rural farmers credit providers), and JUMO (offers a digital credit product, *Wewole,* in collaboration with an *Airtel* Uganda). Insurance service providers include

MTN's aYo Uganda, *Mazima Retirement Plan* (MRP), *WeFarm* Limited (farmer-to-farmer knowledge sharing network of insurance providers), and *Money Duka,* among others (FSD, 2018).

Digital Financing for solar energy through Pay As you Go (PAYG)

Digitally financed off-grid solar has transitioned from pilot scale to a diverse and substantial sub-sector of the global off-grid energy market. Over the past five years, digital financial services providers in Africa have leveraged remote lockout mobile technologies to provide micro payments for solar home systems for low-income customers (Zollmann et al., 2017). Customers pay for their units over time with small, high-frequency payments, often on terms that are more flexible than traditional lending models and microfinance.

Today nearly 30 companies operating in at least 32 countries provide access to consumer capital for off-grid solar using digital finance, opening access to vital electricity services. Building on the burgeoning pico-power and solar home system (SHS) progress of the last decade, ICT systems are accelerating and reshaping the dynamics of off-grid electricity access by providing financing and increasing connectivity throughout the supply chain (Alstone et al. 2015). Uganda has a number of companies such as ReadyPay, D-Light, M-KOPA, PAYG System, Lumeter Customer Meter, Angaza Embedded PAYG that use the PAYG Model.

PAYG systems catalyze increased energy access through financing and through increased connectivity across the supply chain, from head offices to end users operating remotely monitored systems. While the full measurable benefit of PAYG has not yet been rigorously established, early indications are that PAYG dramatically increases levels of access through consumer markets for off grid power. The most obviously valuable feature of PAYG systems is the opportunity to lower transaction and management costs on loan and energy service payments, thus enabling consumer financing for loan sizes that are much smaller than previously possible. This access to consumer-level financing had long been recognized as a critically important factor for increasing energy access for cash-poor buyers, and it was noted as an important and valuable opportunity by the people our research team heard from in the field.

Kenya, using Pico-power and Solar home system (SHS) has been offering digital financing for off-grid energy since 2014 and has realized a lot of growth and success. Kenya has seen an exponential growth of Mobile Money Transfer which has helped spur the DESCO. Even though studies on PAYG in Kenya is still in its infancy, it has seen the sale of solar study lamps in schools growing at 20-50% compared to 10-15% growth before the introduction of PAYG (Alstone et al., 2015)

Theoretical framework

A number of theories and models have been promulgated to explain adoption and success of technology. Among them the Technology Acceptance Model (TAM) (Davis 1989), DeLone and McLean (D&M) IS Success model by DeLone and McLean (2002), Unified theory of acceptance and use of technology of Vankatesh et al (2003) among others. This study adopts constructs from TAM of Fred D. Davis and IS Success model of William H. Delone and Ephraim R. McLean.

The Technology Acceptance Model (TAM) models how users come to accept and use a technology (Davis, 1989). A number of factors influence users of information systems on whether to adopt and use it or not. The theory models the factors that may lead to intention to use and actual use of information systems. These factors include Perceived usefulness (PU) and Perceived ease-of-use (PEOU) (Davis, 1989, Davis et al., 1989). PU is the extent to which a user believes that using an information system will improve his or her performance. This is measured in terms of how much better the user feels his/her performance will be due to the application of the information system. PEOU on the other hand is the extent to which a person believes that use of the information system is possible with minimal effort. This is measured by the amount of effort; especially technical effort a person has to put in order to be able to navigate the information system. These two factors are considered to affect the attitude of a user and ultimately influence their intention to adopt and actual use of an information system (Davis et al., 1989). This study adopts the constructs of Perceived usefulness and Perceived ease-of-use to measure how these factors enable the use of ICT in Uganda.

The Information Systems success Model (also known as the Delone and McLean IS success model was developed by Delone and McLean (Delone and McLean, 1992; 2002; 2003) to explain IS success by identifying, describing, explaining and evaluating how six dimensions related in order for a successful information system. This theory has been used in over 300 articles in refereed journals (Delone and McLean, 2003). The theory modeled how information quality, system quality and service quality affect usage intentions/system use and user satisfaction that ultimately affect net system benefits (Delone &McLean, 1992). According to the authors, information quality is evaluated according to the quality of information the system is able to store, deliver or produce. System quality is measured according to the quality of the system in terms of reliability and availability. Service quality measures the quality of the service that is provided by the information system. These factors enable or hinder the use of information systems. This study adopts information quality, system quality and service quality to measure adoption of digital financing.

Mobile Technologies, Digital Financing and Solar Access

Mobile phone penetration in Sub-Saharan Africa has grown. For most telecommunication companies in Sub-Saharan Africa, energy is the next biggest thing after airtime, data and mobile money (Fenix International, 2017b). Alstone et al. (2015) fronted ICT as a provider of financing medium for off-grid electricity. They also posit that ICT enables connectivity throughout the off-grid supply chain. Distributed energy service companies (DESCO) provide an agreed amount of energy services with an on-going payment. It is considered as asset financing. There is need for Telecommunication Companies to partner more with Solar Power providers to tap into the opportunity of growth in energy access using ICT and more specifically mobile technology (Fenix International, 2017b). There are currently 30 companies offering Digital Financing for energy access in 32 countries across Africa (Alstone et al., 2015). A survey by Alstone et al. (2015) established that over 80% of the PAYG customers they had preferred to expand their solar energy service using PAYG rather than paying cash.

Despite the opportunity to access solar power afforded through Digital financing, there are a number of challenges that have been faced. These include; technology costs vis-à-vis the income of potential customers, difficulty to access off-grid customers, lack of infrastructure in some areas with poor network connectivity, poor perception of solar power by many people and lack of government policies and support for example through tax exemptions (Fenix International, 2017b).

METHODOLOGY

Research Design

The research adopted a quantitative analytical survey research methodology. The quantitative methods elicited numerical data and increased generalisability of the findings (Creswell, 2007). Cross-sectional design was adopted to enable the researchers collect data at one point in time.

Population

Fenix International (2018) reports that there are currently 20,000 ReadyPay users across Uganda. D-Light, M-Kopa (2015) indicated it was lighting over 20,000 off grid homes in Uganda with affordable solar power, and expected the number to increase to 50,000 more homes by the end of 2015. The Ministry of Energy and

Mineral resources adds that there are more than 30,000 people connected to other micro-solar systems providers like D-Light and Solar Now. The Population of this study was therefore 50,000 respondents, comprising of active subscribers of MTN Mobile Money and Airtel Money micro-solar systems subscribers.

Sampling procedure and size

Two stage cluster sampling was adopted with respondents clustered according to those that already have access to solar power using MTN ReadyPay and those that haven't yet accessed the service. Issues of trustworthiness were ensured by gathering data from many participants for the quantitative data. A sample size of 384 respondents in Mbale district, at a confidence level of 95% and margin of error of 5.0% was selected (Bartlett, Kotrlik & Higgins, 2001; Krejcie & Morgan, 1970) for the study.

Data collection method

The data collection method was a self-administered survey using a questionnaire. A questionnaire was chosen as the data collection instrument because it enables the collection of many responses at an affordable cost. A questionnaire, if well developed, pretested and correctly administered elicits accurate data. The questionnaire was first pretested for face validity, content validity using content validity index (CVI) and reliability using Cronbach Alpha's coefficient. Only items with CVI and Cronbach Alfa's coefficient greater than .7 were used. A Cronbach Alpha's coefficient of .836 was realized meaning that the questionnaire was reliable.

Measurement of variables

Constructs of the independent variable (Mobile Technologies) were adopted from Davis (1989) and Davis et al (1989). These included measuring the perceived usefulness and perceived ease of use of the Mobile technology infrastructure. The study also measured the Mobile technology infrastructure available to the respondents. The mediating variable (digital financing) was developed by adopting constructs from the Information System model (Delone and McLean, 1992; 2002; 2003). These included measuring whether the quality of digital financing information, the quality of the system it runs on and the quality of digital financing service. Lastly, the dependent variable (access to solar energy) was measured according to its connectivity, convenience, affordability and sustainability of access (Alstone et al, 2015).

Coding and data analysis

Data Coding for the questionnaire was done by assigning key numbers or values to each response. In order to clean the data before analysis, Exploratory analysis was done using SPSS 20.0 statistical package. These included descriptive analysis using frequencies to check for wrong data entry, univariate analysis using Z-scores to check for and transform outliers. Diagnostic tests were also run to check if the model fits the data well. These included tests for normality, linearity, multicollinearity and homogeneity of variance. Correlations and regressions were estimated to test the relationship between the variables. Quantitative results in this report are presented using graphs, charts and tables.

Ethical consideration

This study adopted the utilitarianism ethical position; the actions of the researchers are evaluated according to the consequence. The goal of the research is to promote a positive consequence to benefit a big number of people. Utilitarianism enables generalization of the findings. Respondents were requested to participate in their free will and confidentiality and anonymity of the respondents were maintained.

Data were collected and analysed using the most appropriate methodology as discussed above. Findings of the respondents are reported without distortion. Care has been taken to separate researcher bias by adopting a realism ontological perspective and objectivism epistemological stance.

RESULTS

This study sought to establish the effect of ICT (in particular mobile technologies) have affected solar energy usage. Only respondents who were using mobile technologies to access solar energy were considered. The Response rate was 88% however, only 270 questionnaires were found usable. Both the unit of inquiry and unit of analysis were individuals. Data were cleaned prior to analysis. Pre-estimation tests of normality, linearity, Multicollinearity and Homogeneity of variance were estimated.

An Exploratory Factor Analysis (EFA) was run for validation of measurement scales. It was done with the purpose or establishing the most important factors among the list of factors in the questionnaire to use for further analysis. Less important items were eliminated and these included all items with communalities less than 0.5. The Kaiser-Meyer-Olkin (KMO) was used to verify the sampling adequacy for factor analysis.

Sample Characteristics

In order to establish representativeness of the sample, we tested characteristics such as gender, age group, education level, occupation. These were found to be representative of Uganda's population of people using solar energy. The results show that most of the respondents were male (58%) compared to females who were 42%. For the age groups, 18-25 years were 14%, 26-35 years were 54%, 36-45 years were 21%, and those above 46 years were 12%. In terms of education level, most of the respondents had attained Primary level education (38%), followed by Secondary level (32%). The other respondents were of Tertiary level (12%), Primary level (12%) and lastly University level education (7%).

We also elicited data on mobile phone usage in solar energy consumption. We established that 99.6% of the respondents owned a mobile phone and 0.4% did not. Mobile phone penetration has grown allowing even people without a mobile phone to access it through those around them. A total of 266 (98.5%) respondents indicated that they pay for solar energy using mobile money transfer against 1.5% who use other means. The results further reveal that most of the respondents (81.1%) pay for solar energy for self-consumption, 16.3% for other people like their extended family and 2.6% for both self-consumption and other people.

On solar energy usage, respondents were asked what they use solar energy for. The question was multivariate and therefore a respondent would select more than one option. The results show that most of the respondents (96.7%) use solar energy for lighting followed by 69.3% for phone charging, 57.0% for radio, 20.0% for TV and only 1.5% for other uses. These results reveal that solar energy usage, while is growing, is still not used for many domestic purposes beyond lighting.

We posed questions to elicit information about the service providers of solar energy and facilitators. MTN telecommunication company has the highest number of subscribers who use telecommunication companies to pay for solar energy with 81.1% of them. Only 18.9% of the respondents use Airtel, while the other telecommunication companies did not have any respondents. Consequently, ReadyPay, which partners with MTN was the most used solar service provider with 49.2% of the respondents. M-Kopa has 24.4%, Solar Now with 23.7%, D-Light with 1.1% and others with 1.5%. The question had some missing values occasioned by the respondents not selecting any of the responses. The respondents stated that they finance their solar energy as follows; 89.5% pay in installments through monthly mobile money transfer, 6.7% use one-time payments while 3.7% used loans.

Correlation Results

According to Field (2009), Correlation is used to measure and describe the direction and strength of the relationship between variables. We undertook correlation analysis to determine if there were associations

between the variables. Because the data were normally distributed, Bivariate Pearson correlation was run. Field (2009) further states that the correlation coefficient lies between −1 and +1, with a coefficient of +1 indicating a perfect positive relationship, a coefficient of −1 indicating a perfect negative relationship and a coefficient of 0 indicating no linear relationship. This implies that the strength of the relationship increases as figures move towards +1. In a 5 point Likert Scale therefore, values of ±.1 represent a small effect, ±.3 is a medium effect and ±.5 is a large effect.
The table below presents the correlation analysis results.

	1	2	3	4	5	6	7	8
Mobile Technologies (1)	1							
Perceived Ease of Use (2)	.944**	1						
Perceived Usefulness (3)	.932**	.759**	1					
Digital Financing (4)	**.757****	.671**	.752**	1				
Information Quality (5)	.628**	.549**	.634**	.840**	1			
Service Quality (6)	.707**	.638**	.690**	.908**	.607**	1		
Systems Quality (7)	.668**	.588**	.668**	.904**	.635**	.776**	1	
Access to Solar Energy (8)	**.582****	.536**	.556**	**.633****	.542**	.543**	.599**	1

**. Correlation is significant at the 0.01 level (2-tailed).

The results in the table above reveal that mobile technologies are positively and significantly correlated to digital financing with a coefficient of r=.757. Digital financing is positively and significantly correlated to access to solar energy with a coefficient of r=.633. Lastly, mobile technologies are positively and significantly correlated to access to solar energy with a coefficient of r=.582. All the three associations were found to be having large effects (Field, 2009) and are significant at 0.01.

Regression Results

Hierarchical linear regression was run to predict the effect of the independent variables on the dependent variable. Three models were run; with the first model testing the predictive effect of control variables on access to solar energy. The second model included mobile technologies and the third added the cumulative predictive effect of the control variables, mobile technologies and digital financing on access to solar energy. The results are shown in the table below;

Model Summary											**ANOVA**	
					Change Statistics						**F**	**Sig**
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change			
1	.237[a]	.056	.042	.45890	.056	3.921	4	264	.004		3.921	.004[b]
2	.599[b]	.359	.347	.37883	.303	124.402	1	263	.000		29.484	.000[c]
3	.663[c]	.440	.427	.35478	.081	37.858	1	262	.000		34.323	.000[d]

Model Summary

a. Predictors: (Constant), occupation, gender, highest level of education, age group

b. Predictors: (Constant), occupation, gender, highest level of education, age group, Mobile Technologies

c. Predictors: (Constant), occupation, gender, highest level of education, age group, Mobile Technologies, Digital Financing

ANOVA

a. Dependent Variable: Access to Solar Energy

b. Predictors: (Constant), occupation, gender, highest level of education, age group

c. Predictors: (Constant), occupation, gender, highest level of education, age group, Mobile Technologies

d. Predictors: (Constant), occupation, gender, highest level of education, age group, Mobile Technologies, Digital Financing

The results in the table above reveal in Model 3 that occupation, gender, level of education, age group, Mobile Technologies, Digital Financing account for 42.7% of the variability in access to solar energy. The model is useful for predicting access to solar energy with F-ratio (F) of 34.323 which is significant at $p<0.001$ (significance is .000).

Further, the table below shows the coefficients from the regression analysis

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.655	.174		26.742	.000
	What is your gender?	-.141	.057	-.148	-2.460	.015
	What is your age group?	-.045	.034	-.081	-1.327	.186
	What is your highest level of education?	.028	.027	.064	1.064	.288
	What is your occupation	-.115	.046	-.151	-2.473	.014
2	(Constant)	2.279	.257		8.871	.000
	What is your gender?	-.103	.047	-.108	-2.170	.031
	What is your age group?	-.038	.028	-.069	-1.386	.167
	What is your highest level of education?	.023	.022	.053	1.054	.293
	What is your occupation	-.041	.039	-.054	-1.051	.294
	Mobile Technologies	.499	.045	.561	11.154	.000
3	(Constant)	1.665	.260		6.391	.000
	What is your gender?	-.090	.044	-.095	-2.023	.044
	What is your age group?	-.021	.026	-.038	-.812	.417
	What is your highest level of education?	.031	.021	.070	1.487	.138
	What is your occupation	-.014	.037	-.018	-.377	.706
	Mobile Technologies	.208	.063	.234	3.295	.001
	Digital Financing	.409	.066	.441	6.153	.000

a. Dependent Variable: Access to Solar Energy

According to the results above in Model 3, a person's gender negatively changes access to solar energy by 9.5%; and is significant at $p<.05$ (significance is .044). For every change in age group, access to solar energy decreases by 3.8%; and is not significant at $p<.05$ (significance is .417). For every increase in the level of education, access to solar energy increases by 7.0%; but is not significant at $p<.05$ (significance is .138). One's occupation decreases access to solar energy by 1.8%; and is not significant at $p<.05$ (significance is .706). Mobile technologies facilitating conditions increase access to solar energy by 23.4% and was found significant at $p<.05$ (significance is .001). Finally, digital financing also increases access to solar energy by 44.1% and was found significant at $p<.01$ (significance is .000).

Test for mediation

Hayes test was run to test for the mediating effect of digital financing in the relationship between Information Communication Technology and solar energy access.

Test for mediation

Y: Mobile Technologies (MobileTe)
X: Access to Solar Energy (AccesSE)
M: Digital Financing (DigitalF)

Sample
Size: 270

****

OUTCOME VARIABLE: Digital Financing

Model Summary

R	R-sq	MSE	F	df1	df2	p
.7566	.5725	.1096	357.5378	1.0000	267.0000	.0000

Model

	coeff	Se	t	p	LLCI	ULCI
Constant	1.1164	.1681	6.6427	.0000	.7855	1.4473
MobileTe	.7253	.0384	18.9087	.0000	.6498	.8008

****

OUTCOME VARIABLE: Access to Solar Energy

Model Summary

R	R-sq	MSE	F	df1	df2	p
.6521	.4252	.1273	98.4022	2.0000	266.0000	.0000

Model

	coeff	Se	t	p	LLCI	ULCI
Constant	1.4781	.1955	7.5620	.0000	1.0933	1.8630
MobileTe	.2141	.0632	3.3870	.0008	.0896	.3385
DigitalF	.4180	.0659	6.3386	.0000	.2881	.5478

**************** DIRECT AND INDIRECT EFFECTS OF X ON Y *****************

Direct effect of X on Y

Effect	se	T	p	LLCI	ULCI	c'_ps	c'_cs
.2141	.0632	3.3870	.0008	.0896	.3385	.4567	.2408

Completely standardized indirect effect(s) of X on Y:

	Effect	BootSE	BootLLCI	BootULCI
Digital Financing	.3410	.0684	.2103	.4779

********************** ANALYSIS NOTES AND ERRORS ***********************

The results above show that the regression model of digital financing on access to solar energy was found to have a significant positive effect on digital financing (Beta = .7253, p= .000). In the regression of mobile technologies on both access to solar energy and digital financing; digital financing was also found to have a significant effect on mobile technologies (Beta = .2141, p=. 0008). Digital financing had a significant positive effect on mobile technologies (Beta = .4180, p = .0000). Since both the a-path and b-path were found to be significant, bootstrapping method was run to test mediation effect with the bias corrected confidence interval (Hayes, 2018). The mediation analysis results confirmed existence of a mediation effect of digital financing on the relation between mobile technologies and solar energy access (Beta = .3410, CI = .2103, .4779). Consequently, since the direct effect of mobile technologies and access to solar access when controlling for digital financing was significant, it means that mediation effect was partial. Therefore, the effect of mobile technologies and access to solar access is partly direct and partly indirect through digital financing.

DISCUSSION OF RESULTS

Findings from the study indicated that mobile technologies were positively and significantly correlated to digital financing; digital financing is positively and significantly correlated to access to solar energy, and that mobile technologies were positively and significantly correlated to access to solar energy. All the three associations were found to be having large effects and are therefore significant. This discussion is based on the four objectives of our study.

The relationship between Mobile Technologies and Digital financing

In this study, majority of respondents strongly agreed with a number of statements that affirm a significant positive relationship between mobile technologies and digital financing; for example, the fact that their mobile service providers offers them expert help in case they have problems with solar connection, that they save money that they would have spent on hydro-electricity by using solar energy, and that the telecom networks that they use to pay for solar reach their areas. These findings have major implications for research and policy. There are for example numerous studies in the area of financial inclusion that support the strong association between mobile technologies and digital financing.

The Organisation for Economic Co-operation and Development (OECD, 2018) for instance observes that financial technologies as “Fintech”, which encompasses finance enabled by new technologies, digitally enabled financial innovations, newly emerging digital technologies innovative business models and emerging technologies that have the potential to transform the financial services industry. These fintech innovations according to the OECD are facilitating an efficient storage of wealth, exchange of domestic payments, exchange of currencies between countries; and providing a means by which financial and other risks can be managed. The findings of this study show that mobile money is a fintech technology that is facilitating digital financing innovations, through the transfer of domestic payments of solar energy in Uganda.

The findings that mobile technologies are positively related to digital financing are also supported by Stewart, Yaworsky, and Lamont (2018) who reveal that mobile technologies facilitate digital lending as one of the key applications of digital financing. This is done through emerged increasing access to digitized customer data, improving analytics and machine learning, lowering the cost of digital channel design, and enabling the remote delivery of digital products in a matter of seconds to an increasingly connected global clientele. Bank of Uganda (2018) indicates that mobile technologies continue to become a key player in the financial sector, providing digital financing solutions, principally because of the improved network availability and reliability and more than 99.7% of network uptime (the time that mobile money network do not encounter any major interruptions). This means that mobile network technologies are a strong contributor to digital financing as reported in this study. Biscaye *et al.,* (2017) observes that half of the financially excluded people have access to mobile phones, and therefore provision of Digital Financial Services (DFS) through mobile money technologies that they already have access to. The findings that mobile technologies are significantly and positively related to digital financing are therefore strongly supported by research in the field of financial inclusion.

The relationship between digital financing and solar energy access

The study also found a strong positive relationship between digital financing and access to solar energy. Solar energy has been earmarked as one of the strongest promises to access to clean, sustainable and efficient energy resources, especially among developing countries. Ozili (2018), in agreement with Rizzo (2014) indicates in his study that digital financing can enable the extension of financial services to non-financial sectors (like the energy sector in this case), to nearly 50% of people in the developing world who already own mobile phones. Access to solar energy has been a challenge to many people in developing countries, given the high cost of installation conventional solar sources, and the additional cost of replacement of batteries after some time.

Mobile financing solutions facilitate solar energy access through a number of ways, including providing ability to pay for solar services using fintech (digital technologies), ability to access solar products using digital financial loans (Allet, 2016; Goyal and Jacobson, 2018). The findings in this study affirm the fact that digital financing facilitates access to solar energy in a number of ways, including providing plug-and-play mobile systems that are very easy to use, the simplicity of mobile systems that do not require expert knowledge, the fact that solar energy is remarkably clean, the provision of warranties on purchase of solar systems using mobile money, the opportunity to save money that would have been spent on hydro-electricity, savings of alternative energy resources like charcoal and hydro-electricity, the affordability of solar systems bought on mobile phones, and the reliability of mobile money networks whenever someone needs to access solar energy.

These findings are a further re-affirmation of earlier findings by Alstone et al., (2015), who indicates that digital financing systems provide a number of scale economies that facilitate access to off-the-grid solar systems. Such economies include down payment or installment opportunities, affordability and quality which are bred by competition and the growing mobile money market, standardized pricing, access to working capital for investors in the new "pay-as-you-go" solar sub-sector, social and financial returns, increased trust and data privacy among other advantages. These findings are also supported by GOGLA (2015a), who indicated that out of an anticipated 315 million people in the world that will gain access to electricity by 2040, 25% of these households will most likely use off-grid, mobile phone-enabled solar systems. All of these attract more citizens to join mobile-enabled solar systems, and thus higher access levels. Therefore, numerous earlier findings affirm the fact that digital financing is indeed positively and strongly related to access to solar energy in Uganda.

The relationship between Mobile Technologies and solar energy access

The other important finding in the study was that mobile technologies were positively and significantly correlated to access to solar energy. Mobile technologies here encompass the mobile phone itself, mobile network applications like mobile money and mobile payments, and mobile financial services. Respondents indicated that the growth and omnipresence of mobile technologies was instrumental in enabling access to solar energy. These findings are supported by the USAID (2018) which did a study in Nigeria, and finding that mobile financial services, which include a combination of bank-led and MNO-led applications provided by startup energy enterprises, such as M-KOPA, PEG, BBOXX, and Mobisol, are providing an opportunity to reduce cost of energy, increase access to solar energy, saving the country up to USD4.4billion p.a. in energy expenses. This is because such applications are built on innovative mobile payment solutions that reach a wider customer base than previously accessible through traditional sales and distribution models.

Energypedia (August, 2018) indicates that mobile enabled Fee-For-Service (FFS) or Pay-As-You-Go (PAYG) photovoltaic solar systems like ReadyPay Solar, Foundation Rural Energy Services (FRES), M-KOPA, and Mobisol are enjoying increasing popularity in Africa, Asia and Latin America, and this is because of the increased mobile phone penetration in these developing and less developed regions. As access to mobile technology deepens in the “southern third world”, it is estimated that Off-grid Energy Companies (OECs) will sell around 3 million solar home systems in 2015-2020. The findings in this study therefore have strong empirical foundations in earlier studies in the area of mobile technologies-enabled access to solar energy.

Conclusion and Recommendations

This study sought to examine the factors that determine access to solar energy in Uganda, and the relationships among them (mobile ICTs, digital financing, and access to solar energy). Mobile ICTs and digital financing were found to be key factors in ensuring more access to off-grid electricity in the country. Digital financing was found to be the strongest predictor of solar energy access. The regression model also confirmed the above findings. Specifically, it was found that occupation, gender, highest level of education, age group, Mobile Technologies, Digital Financing account for the highest variability in access to solar energy in the areas of study. Therefore, government and stakeholders in the energy sector have to build stronger partnerships with Mobile Network Operators, and financial institutions to enable increased access to digital finance that can be used to purchase solar energy among communities that are not on the national hydro-electricity grid. In addition, government needs to offer more support to firms that provide mobile network enabled solar energy, for the people to access it at a lower cost.

REFERENCES

Allet, M. (2016). Solar Loans through a partnership approach: lessons from Africa. Journal of Field Actions. *Field Actions Science Reports,* Special Issue 15, pp.128-137.

Alsharif, M.H., (2017). A Solar Energy Solution for Sustainable Third Generation Mobile Networks. *Energies 2017*, 10, 429.

Alstone, P., Gershenson, D., Turman-Bryant, N., Kammen, D.M., & Jacobson, A. (2015). Off-grid power and connectivity. Pay-as-you-go financing and Digital supply chains for Pico-solar. Lighting Global Market Research Report. *World Bank Group, International Finance Corporation*.

Bank of Uganda (2018). Financial Stability Report, June 2018. Kampala-Uganda.

Bank of Uganda (2018). State of the Economy, September 2019. Kampala-Uganda.

Biscaye, P., Fowle, M., Knauer, J., O'Brien-Carelli, C., Orlebeke, A., Reynolds, T., & Anderson, C.L. (2017). Digital financial services & gender: An analysis of correlates of awareness, adoption, and use. *Evans School Policy Analysis And Research* (EPAR) Technical Report No. 317.

Blimpo, M.P., & Cosgrove-Davies, M. (2019). Electricity Access in Sub-Saharan Africa Uptake, Reliability, and Complementary Factors for Economic Impact. *Africa Development Forum*, Wolrd Bank Group.

Blimpo, M.P., Postepska, A., & Xu. Y. (2018). Why is household electricity uptake low in Sub-Saharan Africa?" Working Paper, *World Bank*, Washington, DC. [Cross Reference].

Brookings Institute (2011). Mobile Financial Services and Financial Inclusion, May 16-17, 2011.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MIS Quarterly*, 13 (3): 319–340, doi:10.2307/249008

Davis, F.D., Bagozzi, R.P., Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models, *Management Science*, 35: 982–1003, doi:10.1287/mnsc.35.8.982

DeLone, W.H., & McLean, E.R. (1992). Information systems success: the quest for the dependent variable. *Information Systems Research*. 3 (1): 60–95. doi:10.1287/isre.3.1.60.

DeLone, W.H., & McLean, E.R. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems*. 19 (4): 9–30.

DeLone, W.H., McLean, E.R. (2002). Information Systems Success Revisited. Proceedings of the 35th Hawaii International Conference on System Sciences (HICSS), Big Island, Hawaii, 238-249.

Eder, J., Mutsaerts, C., & Sriwannawit, P. (2015). Mini-grids and renewable energy in rural Africa: How diffusion theory explains adoption of electricity in Uganda. Energy Research & Social Science, *Special Issue on Renewable Energy in Sub-Saharan Africa: Contributions from the Social Sciences*, 5: 45-54.

Electricity Regulatory Authority (2018). Renewable Energy Opportunities. Kampala Uganda. https://www.era.or.ug/index.php?option=com_content&view=article&id=214:renewable-

Energypedia (2018). Fee-For-Service or Pay-As-You-Go Concepts for Photovoltaic Systems. Available online at: https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems

Energypedia (2020, May 24). Uganda Energy Situation. Available online at: https://energypedia.info/wiki/Uganda_Energy_Situation#toc

Fenix International (2017a). Pay-to-own Solar Energy System Doubles Off-Grid Customer Base in Just 12 Months. Retrieved from https://www.fenixintl.com/blog/pay-to-own-solar-energy-system-doubles-off-grid-customer-base-in-just-12-months/

Fenix International (2017b). Pay-to-own Solar Energy System Doubles Off-Grid Customer Base in Just 12 Months. Retrieved from https://www.fenixintl.com/blog/pay-to-own-solar-energy-system-doubles-off-grid-customer-base-in-just-12-months/

Fenix International (2017c). Off-Grid Solar: the Next-Generation Energy Solution for Africa. Retrieved from https://www.fenixintl.com/blog/off-grid-solar-next-generation-energy-solution-africa.

Fennix International (2018). Power to rise. https://www.fenixintl.com.

Financial Sector Deepening Uganda, (2018). FinTech in Uganda: Implications For Regulation, November, 2020.

Frangoul, A. (2015). Pay-as-you-go solar power takes off in Africa. CNBC, February 25, 2015.

Gillwald, A., Mothobi, O., Ndiwalana, A., & Tusubira, T. (2019). The State of ICT in Uganda. *Research ICT Africa.*

Global Digital Snapshot (2016). A snapshot of the World's key digital statistics indicators.

Global Off-Grid Lighting Association (2015a). Providing Energy Access through Off-Grid Solar: Guidance for Governments. Utrecht, the Netherlands

Global Off-Grid Lighting Association (2015b). Global Solar Off-Grid Semi-Annual, *Market Report*, July – December, 2015.

Goyal, R., & Jacobson, A. (2018). Energy access and off-grid solar use in Uganda examining solar adoption and the role of flexible payment mechanisms as a driver for energy access. *Schatz Energy Research Center & the UNCDF CleanStart Programme*.

GSMA (2016). Mobile for development utilities feasibility study- Assessing the opportunity for pay-as-you-go solar in Pakistan.

GTZ (2009). Uganda's Solar Energy Market.

Hasan, M., Yajuan, L,, & Mahmud, A. (2020). Regional Development of China's Inclusive Finance Through Financial Technology. Information Technology , Financial Economics , Political Science, Sage Open Access Journals. Available Online at: https://us.sagepub.com/en-us/nam/open-access-at-sage.

Hill, J. (2017). Fenix International's Pay-To-Own Solar Doubles Ugandan Off-Grid Customer Base. https://cleantechnica.com/2017/01/24/fenix-internationals-pay-solar-doubles-ugandan-off-grid-customer-base/

Hill, J., & Hill, J. (2018). Fintech and government regulation. In Fintech and the remaking of financial institutions (pp. 285–314). https://doi.org/10.1016/B978-0-12-813497-9.00015-9

International Energy Agency- IEA (2015). International Energy Agency. *World energy outlook* 2015.

International Finance Corporation (2020). Digital Finance. IFC- World Bank Group, 2020. https://www.ifc.org/wps/wcm/connect/Industry_EXT_Content/IFC_External_Corporate_Site/Financial+Institutions/Priorities/Digital+Finance/.

Kamukama, E. (2018). More Ugandans now own mobile phones. Daily Monitor. Retrieved from http://www.monitor.co.ug/Business/Technology/-Ugandans-mobile-phones--National-IT-Survey-NITA/688612-4334138-2fb1ruz/index.html

Kasekende, L. (2017). Remarks by Dr. Louis Kasekende, Deputy Governor, Bank of Uganda at the 2017 Annual Dinner for the Uganda Bankers' Association (UBA), November 24, 2017. *Bank of Uganda*. https://www.bis.org/review/r180117b.pdf.

Kasemiire, C. (2019, March 7). Mobile phone users grow to 23.2 million. *The Daily Monitor.* Available online at: https://www.google.com/amp/s/www.monitor.co.ug/Business/ Technology/Mobile-phone-users-grow-23-2-million-/688612-5012688-view-asAMP-13h2qb7/index.html

Lighting Africa (2018). Uganda enabling a market-led approach. Available online at: https://www.lightingafrica.org/country/uganda/

Martinez-Cesena, E.A., Mancarella, P., Ndiaye, M., & Schläpfer, M. (2015). Using Mobile Phone Data for Electricity Infrastructure Planning. *Physics and Society*. https://arxiv.org/abs/1504.03899.

Ministry of Energy and Mineral Development (2015a). Uganda's Sustainable Energy for All (SE4ALL) initiative action agenda. June, 2014. Kampala-Uganda.

Ministry of Energy and Mineral Development (2015b). National Charcoal Survey for Uganda 2015, Final Report. June, 2016. Kampala-Uganda.Ministry of Energy and Mineral Development (2016). Ministerial Policy Statement for FY 2015/16. Republic of Uganda, Kampala-Uganda.

M-Kopa, 2015. M-kopa solar lights up over 20000 homes in Uganda. Available online: http://www.m-kopa.com/ m-kopa-solar-lights-up-over-20000-homes-in-uganda/.

MTN Uganda (2015). MTN and Fenix partner to offer free Internet enabled phones on purchase of ultra-affordable ReadyPay Solar Power. Media Release, 16th November, 2015.

Mugume, P. (2017). November 6. UCC Report: Number of Mobile Phone Subscribers in Uganda Drops. *PCTech Magazine*. Retrieved from https://pctechmag.com/2017/11/ucc-report-number-of-mobile-phone-subscribers-in-uganda-drops/

Ozili, P.K., 2018. Impact of digital finance on financial inclusion and stability. Borsa Istanbul Review Vol 18, Issue 4, Pp. 329-340.

Pazarbasioglu, C., Mora, A.G., Uttamchandani, M., Natarajan, H., Feyen, E., & Saal, M. (2020). Digital Financial Services. World Bank Group, New York, USA, April 2020.

PCTech Magazine (2018). Over 54% of mobile money customers in Uganda use MTN – Report Retrieved from https://pctechmag.com/2018/03/54-mobile-money-customers-uganda-use-mtn-report/
PCTech Magazine (2020, February 3). Uganda: Internet Penetration Stands at 37.9%, with 23M Users. Available online at: https://pctechmag.com/2020/02/uganda-internet--penetration-stands-at-37-9-with-23m-users/
Poushter, Cuddington, D., Deane, C., Devlin, K., Drake, B., Keegan, M., ...Kent, D.(2015). Cell Phones in Africa: Communication Lifeline Texting Most Common Activity, but Mobile Money Popular in Several Countries, *Pew Research Centre (2015).* Global Attitudes survey, Spring 2014.
Price-Water House Coopers (2013). Creating Certainty: Uganda's FY 2013/14 Post Budget Analysis. https://www.pwc.com/ug/en/assets/pdf/uganda-budget-2013.pdf.
Rizzo, M. (2014). Digital finance: Empowering the poor via new technologies. *World Bank Features*. April 10. Available at: http://www.worldbank.org/en/news/feature/2014/04/10/digital-finance-empowering-poor-new-technologies.
Salampasis, D., & Mention, A.-L. (2018). FinTech: Harnessing innovation for financial inclusion. In Handbook of blockchain, digital finance, and inclusion, Volume 2, 1st edition.
Shin, D.H., & Park, Y.J. (2017). Understanding the Internet of Things ecosystem: Multi-level analysis of users, society, and ecology. Digital Policy, Regulation and Governance, 19(1), 77–110. https://doi.org/10.1108/DPRG-07-2016-0035.
Ssettimba, I.J. (2016). Mobile Money in Uganda. Bank of Uganda. Presented at the Mission to Foster price stability and a sound financial system, held on March 11-14, 2016 in Kampala. Retrieved from https://www.theigc.org/wp-content/uploads/2016/03/3.-Ivan-Ssettimba-Bank-of-Uganda.pdf.
Stewart, A., Yaworsky, K., Lamont, P. (2018). Demystifying digital lending: How digital transformation can help financial service providers reach new customers, drive engagement, and promote financial inclusion. *Accion Insights*, April, 2018.
The Daily Monitor (January, 2018). Poverty level increases to 21.4 per cent, says UBOS. http://www.monitor.co.ug/News/National/Poverty-level-increases-per-cent-UBOS/688334-4268774-format-xhtml-ubneas/index.html.
Trading Economics (2020). Uganda: Access to Electricity Percentage of Population. Available online at: https://tradingeconomics.com/uganda/access-to-electricity-percent-of-population-wb-data.html
Uganda Bureau of Statistics (2016). Statistical Abstract for 2015. Kampala Uganda.
Uganda Communications Commission (2015). Mobile Network Access for MVNOs. Market Assessment, 30 January 2015. Kampala-Uganda.
Uganda Communications Commission (2018). Annual Market Industry Report 2016-17 FY. Kampala-Uganda.
Uganda Communications Commission (2018). Post, Broadcasting and Telecommunications Market & Industry Q2 Report, 2018. Available Online at: https://www.ucc.co.ug/wp-content/uploads/2017/09/Communication-Sector-Performance-for-the-Quarter-ending-June-2018.pdf.
Uganda Communications Commission (UCC, 2020). List of Telecom Providers. Accessed on September 2, 2020, at: https://www.ucc.co.ug/list-of-telecom-providers/
Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA). (n.d). Overview of Uganda's Renewable Energy Potential. Available online at: https://unreeea.org/resource-center/overview-of-Ugandan-energy-sector/
United Nations (1987). Our Common Future. World Commission on Environment and Development/ Brundtland Commission Report. October, 1987. New York, USA.
United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. United Nations – Sustainable Development knowledge platform. New York, USA.

United States Agency for International Development [USAID] (2018). The digital financial services landscape in Nigeria: enabling market conditions for Pay-As-You-Go solar Executive Summary. Available Online at: https://www.usaid.gov/sites/default/files/documents/1860/Enabling_Market_Conditions_for_Pay-As-You-Go_Solar_Executive_Summary.pdf.

USAID (2020, April 16). Uganda Power Africa Fact Sheet. Available online at: https://www.usaid.gov/powerafrica/uganda

World Bank (2019). Global Photovoltaic Power Potential by Country. Global Solar Atlas, Version 2.0, as at 23-Oct-2019. Available online at: https://globalsolaratlas.info/download/uganda

World Bank (2020). Uganda Economic Update: Strengthening Social Protection to Reduce Vulnerability and Promote Inclusive Growth. *World Bank Group*, 14th Edition February 2020. Africa Region Office.

World Health Organisation (2019, May 21). Tracking SDG7: The Energy Progress Report. Chaired by the International Energy Agency. Available online at: https://trackingsdg7.esmap.org. Worldometer (2020, July 27). Uganda Population (2020) - Worldometer. Available online at: https://www.worldometers.info.

Zollmann, J., Waldron, D., Sotiriou, A., & Gachoka, A. (2017). Escaping Darkness: Understanding Consumer Value in PAYGo Solar. Access to Finance Forum Reports by CGAP and Its Partners No. 13, December 2017.