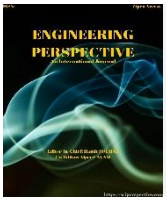

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Impact of Energy Accessibility to Household Welfare in Developing Countries: Case Study Rwanda

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ABSTRACT

Nowadays, the world's socio-economic development and well-being of society are based on energy accessibility. As the number of energy accessors increases some global problems have been highlighted including climate change and global warming. Those problems lead the developing countries including Rwanda to food insecurity and poverty. Easily accessible energy in Rwanda is biomass energy which occupies above 83% of the total energy consumption. Electrification and green energy like solar and gas energy are considerably increasingly accessed by Rwandans. Those clean energies are mostly available in the cities compared to the rural villages. Industries and other businesses are located in the city due to the energy accessibility, and youth are shifting from rural areas to the cities to look for jobs and a civilized way of living. Therefore, in this study, we assessed and analysed the impact of energy accessibility on the household's welfare. The econometric approach method with Integrated Household Living Conditions Survey 5 (EICV5) has been used to assess the country's level of energy access and the impact of energy access on the households 'welfare is identified. We used simple regression analysis's ordinary least squares test (OLS) to analyze those impacts. The data from the National Institute of Statistics Rwanda that are treated using STATA software show that access to electricity affects a household's welfare generally increasing. From the coefficient estimates, the non-farm business increased by 68.4% in rural areas. In the education sector, there is an impact of clean energy accessibility which has 52.6%. Therefore, the general consideration of the impact of energy accessibility impact to the household's welfare plays an important role at a rate of 68% in people's way of living in both rural areas and cities of Rwanda.

Keywords: Energy, Household, Electricity, Econometrics, Socio-economy

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1. Introduction

1.1 Energy Welfare in Developing Countries

Energy is necessary for the socio-economic development and well-being of society. Many of today's global issues, such as climate change, poverty, and food security, necessitate the provision of low-cost, dependable, long-term energy services. Electrification and clean energy have become both a requirement for any society's development and a symbol of civilization. Access to clean energy is essential for economic activity as well as community health and well-being [1,2]. Despite the fact that global access to electricity increased from 78 to 89% between 2000 and 2017, an estimated 800 million people remained without access in 2017. Low-income countries (especially those in Sub-Saharan Africa) and rural communities continue to face access issues. Concurrently, the quality of connections, such as electricity generation capacity, affordability, durability, safety and health, and convenience, are other factors that may influence an end user's ability to use electricity when needed [3].

In developing countries, a major impediment to rural economic growth and development is a lack of access to electricity. Along with a result, the World Bank and other development organizations have made modern energy access, particularly access to electricity, one of their top priorities. It is widely acknowledged that electrification improves household quality of life and stimulates the economy as a whole. The immediate benefit of electrification is improved lighting, which encourages long hours of study for students and, as a result, contributes to higher educational

achievement. Other household activities, such as sewing by women, social gatherings after dark, and so on, can benefit from lighting as well [4]. Rwanda's total power supply has grown by 10% since 2008, to 502,053 MWh. Year after year, total consumption has increased in a logarithmic trend. The seasonal variations in power demand are negligible. The total installed capacity of electricity generation is currently 119.6MW, with hydrological resources accounting for roughly 60% and diesel-powered generators accounting for 40%. Rwanda has a significant peak demand load between 6 and 9 p.m., which, on an annual basis, was recorded at 87.9 MW in 2013. This is because household lighting is the most common use of electricity.

1.2. Energy accession in Rwanda

Energy has a huge impact on people's lives and is a driving force behind social and economic development. Energy has aided in the transformation of societies and the advancement of human civilization over the centuries. Energy contributes to the fulfillment of some of the most fundamental human needs, such as nutrition, warmth, and light. Furthermore, there is ample evidence that having reliable, efficient, cost-effective, and safe energy carriers can directly impact productivity, income, and health, as well as improve gender equity, education, and access to other infrastructure services. The immediate applications of electricity in newly electrified households are lighting and appliances, communications, and entertainment. Public/street lighting, refrigeration, health centers, and schools, piped water, communication, and the like are among the most frequently mentioned public needs. The use of a variety of electricity-powered appliances benefits households. There is a clear progression in the energy services available to those with electricity access. The initial applications are in lighting and entertainment. Following that, thanks to appliances such as electric lamps, radios, televisions, computers, refrigerators, fans, stoves, and electric pumps, a wide range of benefits are potentially available, ranging from security, comfort, and convenience to education, health, and home productivity [5]. Bhattacharyya et al.[6], highlight levels of income are normally associated with higher levels of energy access, as expected; however, rapid improvement in access level occurs within an income band bounded by a lower threshold income level of around $1000 per person in PPP terms 2005 and an upper saturation level of around $15,000 per person in PPP terms. Those below the lower threshold clearly do not have access to clean energy, whereas those above the upper threshold do.

Rwanda is a small country in East Africa with a population of 12,089,721 people and a land area of 26,338 square kilometers. It is located between the latitudes of 1.050- and 2.84^0, and the longitudes of 28.86^0 and 30.9^0. Rwanda's economy has expanded rapidly in recent decades, and the country has substantial energy resources that have yet to be fully utilized. Despite abundant natural energy resources such as hydro, solar, peat, gas, and biomass, Rwanda currently has only about 216 MW of installed electricity capacity to serve the country. Despite encouraging economic growth, the country has a low per capita GDP of $696 and a low per capita electricity consumption (30 kWh) when compared to Uganda (66 kWh), Kenya (140 kWh), and Tanzania (85 kWh). Furthermore, when the highest regional electricity tariff of US$0.12 to US$0.18/kWh is compared to the local Rwandan electricity tariff of US$0.22/kWh, the local Rwandan electricity tariff wins (REG, 2018c). According to the research, Rwanda's electricity price is approximately 22.2 percent higher than the EAC's highest electricity tariff [7]. In 2008, the total primary energy supply was 111 PJ2, with traditional biomass accounting for the vast majority. Households consume the most energy (91%) followed by transportation (4%), industry (3%), and public services (3%) 2 percent. Households are also the largest users of electricity for lighting (51 percent). The industrial sector is the second largest consumer (42 percent of total consumption), owing primarily to motor drivers and lighting. The public sector's consumption (6 percent of total consumption) is primarily driven by public buildings, street lighting, and water pumping [7].

The energy sector is critical to the Rwandan economy because it is interconnected with almost every other sector, including transportation, housing and urbanization, manufacturing, agro-processing, mining, and information and technology services. The supply and transmission of electricity remain a top priority.

Electricity can be generated in Rwanda using a variety of technologies and natural resources, such as petroleum-based fuels, hydro, solar, methane gas, peat, geothermal, biomass, waste, and wind. Energy efficiency and conservation measures, which include both demand-side and supply-side components, are also gaining popularity [8,9]. In terms of Households (91 percent) consume the most energy, primarily using traditional fuels such as wood, followed by the transportation sector (4%), industry (3 percent), and public services (3 percent) (3%). 2% Households are also the largest consumers of electricity (51%), with lighting accounting for the majority of demand. The industrial sector (42%) consumes the most energy, with motor drivers and lighting being the primary sources. Cement, mining, textile, and agricultural companies are among the largest industrial consumers (including tea estates). Energy is required for the majority of industrial and commercial wealth creation and is essential for increased social and economic well-being [10]. It is critical for alleviating poverty, enhancing human welfare, and raising living standards. However, as important as energy is for development, it is only a means to an end. The goals are good health, a high standard of living, a sustainable economy, and a clean environment.

The Rwandan government made a clear policy decision throughout the development of the EDPRS to diversify electricity sources away from the traditional dominant grid and includes off-grid connections. As a result, households outside of the planned national grid coverage have been encouraged to use alternatively cheaper connections, such as Mini-grids and Solar Photovoltaics (PVs), to lower the cost of access to electricity while relieving constraints on previous government subsidies. Household well-being is commonly expressed in terms of real income. A rise in real output and real incomes implies that people are doing better, and thus household welfare rises [11]. Economic activity is dependent on reliable supply – not just access – because reliability affects the economic realm through income-generating activities, the ability of business operations to remain open for longer periods of time during the day, and thus increasing utilization of installed capacity. Electricity reduces the burden and time required for household work, which may influence labor supply decisions. Electricity availability has an impact on capacity utilization and

employment rates. Rwanda's government plans to transition the country from developing to middle-income status. To that end, the government intends to achieve 100 percent electricity access by 2024. Rwanda is rich in natural energy resources such as hydropower, solar power, and methane gas. It has only 218 MW of installed capacity at the moment. Rwanda's national electrification rate is estimated to be 30% by the International Energy Agency (IEA), (12%) in rural areas and 72 percent in urban areas [11].

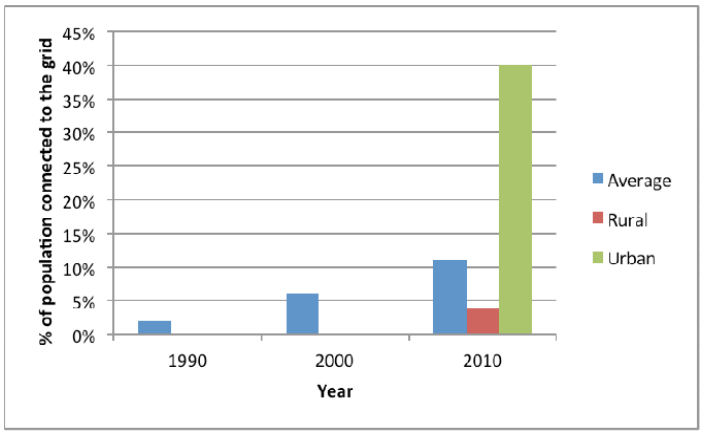

Figure 1. Percentage of Rwandan households have access to electricity (connected to the grid).

At the moment, 1.5 billion people in developing countries lack access to electricity, and 3 billion rely on solid fuels for cooking. A comparable number of people in Sub-Saharan Africa do not have access to electricity or modern fuels (respectively 560 and 625 million people). People in Asian countries may have access to electricity, but they frequently do not have access to modern fuels. Less than 200 million people in East Asia and the Pacific lack access to electricity, but nearly 1.1 billion rely on solid fuels for cooking [12]. An estimated 1.64 billion people lack access to electricity worldwide, with roughly 80% living in rural South Asia and Sub-Saharan Africa. (IEA, 2002). According to the 2001 Census of India, roughly 44% of rural Indians have access to electricity [13]. Lack of access to electricity is inextricably linked to rural poverty. This is because electricity is not only necessary for raising living standards, but it is also a necessary input for productive and economic activities. Because of the bundling of socioeconomic benefits, the positive impacts of electricity inputs for basic activities such as pumping water for drinking and irrigation; lighting for extending working and learning hours; and powering small-scale rural industry are significantly greater for vulnerable rural populations [5].

According to his book, energy has a significant impact on people's lives and serves as a catalyst for social and economic development. Energy has aided in the transformation of societies and the advancement of human civilization over the centuries. Energy helps to meet some of the most basic human needs, such as nutrition, warmth, and light. Furthermore, there is ample evidence that having access to reliable, efficient, cost-effective, and safe energy carriers can have a direct impact on productivity, income, and health, in addition to improving gender equity, education, and access to other infrastructure services. Energy issues are both serious and widespread in the developing world. Up to 90% of the population in many developing countries lacks access to adequate and sustainable energy supplies. Some 2 billion people lack access to electricity, and a similar number cook their meals with fuels such as animal dung, crop residues, wood, and charcoal. People's efforts to engage in productive activities or improve their quality of life are hampered in the absence of efficient, clean energy. People cannot farm or produce goods efficiently if they must spend a significant portion of their time traveling further and further afield in search of diminishing wood fuel. Grzegorz S et al. [14] stated that as civilization progresses, more and more energy resources are required to meet basic social needs as well as production. Inconsistent strategies and inefficient resource use result from a lack of integration in resource assessment and policy making. Electricity access has been linked to increased productivity, business creation, and employment. Businesses that are newly established and rely solely on electricity access may have the potential to improve the overall economic situation and business environment. Electricity is a critical driver of modern technology and socio-economic development, enabling industrial processing activities, value addition, export growth, and job creation for both low-consumption devices like lights and mobile phones and large users like industries. Despite accounting for only about 4% of Rwanda's primary energy consumption, Electricity consumption is expected to skyrocket in the coming years. Rwanda currently has one of the world's lowest per capita electricity consumption rates. Despite Rwanda's dense population, which should make network expansion and access to electricity easier, only 19% of Rwandan households are currently connected to the grid. Human development and modern societies are propelled forward by energy. Access to energy promotes economic and human development, as well as the transition of agrarian societies to industrial societies. As a result, industrialization increases household income, eliminates many contagious diseases, lowers child mortality rates, and extends life expectancy. Many healthcare facilities in developing countries are unable to function due to a lack of energy access, which is required for storing vaccines and performing life-saving procedures. Improved energy access in healthcare facilities will help to increase life expectancy by ensuring timely service delivery [15].

According to current discourses of developmental studies, which conclude that income inequality affects educational opportunities, education is widely recognized as one of the most important components for poverty reduction. Furthermore, primary education yields the highest return on investment. Poor families enroll and complete fewer students because direct and indirect educational costs are significant burdens on them. Poor households face a lack of employment opportunities as a result of their low educational attainment [16]. Literacy levels are influenced by electricity access. Improved boarding school provision of clean water, sanitation, lighting, and cooking energy is facilitated by cleaner and more affordable energy. Rural electrification attracts qualified teachers due to the improved quality of life that comes with having access to electricity. Electricity enables learning to be digitized through the use of electronic equipment such as comput-

ers and overhead projectors for learning. Children raised in electrified homes have higher educational attainment and more study time than those rose in non-electrified homes [15]. In the work done by M. Arsene et al. [17], they demonstrated that the effect of access to electricity on educational attainment is theoretically unclear due to the possibility of multiple mechanisms at work. As one possible mechanism, increased access to electricity may increase the demand for low-skilled labor. This would increase the opportunity cost for students to stay in school, resulting in lower educational attainment. Another possibility is that manufacturing jobs are attracted by access to electricity. There are numerous other mechanisms that could influence educational attainment, complicating the impact of electricity on educational attainment uncertain. Economic activity is dependent on reliable supply – not just access – because reliability affects the economic realm via income-generating activities, the ability of business operations to remain open for longer periods of time during the day, and thus increased utilization of installed capacity. Electricity lessens the burden and time required for household chores, which may have an impact on labor supply decisions. The availability of electricity has an impact on capacity utilization and employment rates. The ability to access and use available capital resources has an impact on wages and household income. If electrification is the foundation for inclusive development, a reliable and consistent supply of electricity reduces the amount of time spent on home production, potentially increasing the labor supply of adults, particularly women, in the household. The time saved by not having to go out and buy cooking fuel can be put to better use, increasing household consumption, income, and assets.

Table1. Descriptive of variables

Variables	Description
Household age	Household age indicates the age of family members
Household size	Household size indicates the number of people living as an economic unit means that they indicate the population growth
Household expenditure	Household expenditure stands for the expenses spent on electricity, aggregate consumption, food consumption, and non-food consumption of the sample household
Household salary	Household salary is the salary gained by the household as discussed in the literature energy access impacts the household salary
Household Education	Household education stands for the general number of household heads and spouses who have primary up to university education, education, and access to energy and have a relationship
Electricity accessibility	Electricity access stands for the total population that is connected to the national grid and another source as the main focus is how it affects the household welfare
Non-farm business	Non -farm business stands for all business done by the household other than agriculture in the previous chapter discussion state that electricity access should affect the nonfarm business done by households

2. Methods and materials

2.1 Variable description of NISR with EICV5

This study's data is derived from the NISR's EICV5, which was conducted between 2016 and 2017. This data source contains information on population well-being changes Poverty, inequality, employment, living standards, education, health and housing conditions, household consumption, and so on are examples of such factors. The research framework is made up of the following components: Household income, household expenditure, household education, access to electricity, and nonfarm business, as shown in Table 1.

2.2 Econometric Approach with EICV5

This section describes the general econometric methods used in this study with EICV5 data. To avoid spurious regression, the properties of the variables must be examined in the empirical analysis. The hypothesis demonstrated that energy access has a significant impact on household welfare, including household expenditure, education, nonfarm business, and household member salary. We create an equation to investigate the relationship between energy access and household welfare. The independent variable is on the right side of the equation. "Electricity access" is explicitly used because it affects household welfare. As a result, the model specification can be written in the regression model as follows.

$$log_{hhexp} = \beta o + \beta 1 hhage + \beta 2 hhsize + \beta 3 electricityaccess + \beta 4 nonfarmbusiness + \beta 5 hhed + \beta_6 salary + \varepsilon_t \quad (1)$$

Data exploration and regression analysis of variables of interest in this study was performed to draw conclusions about the impact of energy accessibility on household well-being. The data used in the study is cross-section data which looks at information from a group of people at a single point in time. The data for this study were derived from the NISR EICV5 survey, which is conducted every three years and polled 14,580 families across the country between late October 2016 and early October 2017.

3. Results and discussion

3.1 Statistical description

Figure 2 shows the descriptive statistics for the variables used in the study. The binary and discrete variables are included in the table. The binary variables have two responses (0 and 1), whereas the discrete variables have numbers such as household head age, household size, salary, and household expenditure, with the exception that the binary response variables include all of the other variables mentioned. It shows that, among the 14,580 observations, the size of the household varies from 1 to 22, and its average of 4.41, which is similar to 1, indicates that households have an average of 4 individuals, which appears to be small compared to 22. The findings show that the age of the head of households is an average of 45.2, with most heads of households appearing to approach 14 years of age than household heads who have 109.

The people who have a salary are likely to be higher than those who do not have a wage and salary the mean is 12.0 with a minimum salary of 2.08 and a maximum of 18.4. Household access to electricity has an average of about 0.25, tending to value between 0 and 1 total use of electricity, the degree of variability shows that the standard deviation of household access to electricity is 0.43 which indicates that the data is not scattered away of mean value this means that the people who are access to electricity are likely to be low than those who are not access.

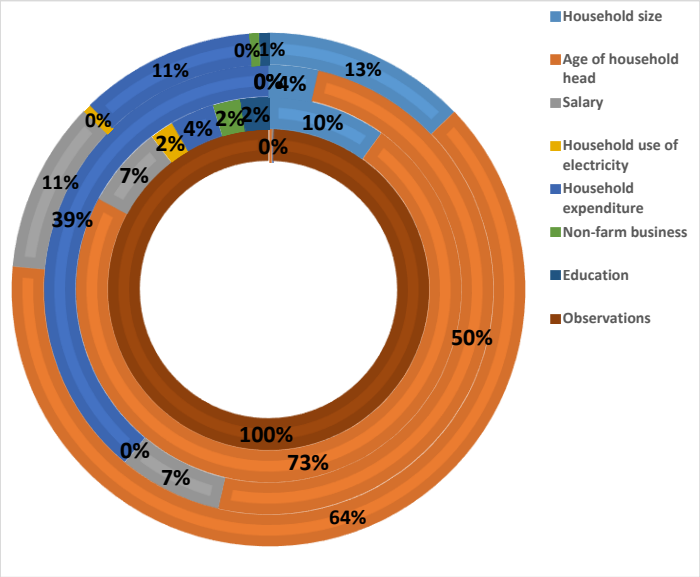

Figure 2. Descriptive statistics

The results show that the household expenditure average value is 14.5 which means that the expenditure of a household is likely to be a high value with a minimum average of 10.9 spending and maximum spending of 18.9. Non-farm business: individuals who practice non-firm business have an average of 0.52, meaning there are more people involved in nonfarm business. The findings show that the number of households who attend the class from primary to university is likely to be low means that the more household has formal education among households under consideration, the household with who have formal education have an average of 0.45.

3.2. Regression Analysis

The use of the regression analysis method allows us to conduct the different impacts of energy access on household welfare that are required to justify the economic models built. They include the impact of Electricity Access on household expenditure, the impact of electricity access on non-farm business, and the effect of access to electricity on household education.

Table 2 shows that access to electricity can affect household welfare through the expenditure of 68.7 % and acceptable at 1%, with all coefficients examined being significantly positive, implying that when the household has access to electricity, the other activities improve. Robust standard errors are represented by values in parentheses which have been defined by (*** p<0.01, ** p<0.05, * p<0.1). Other household and community characteristics, such as nonfarm business and education spending, influence household expenditure. The size of a household, for example, directly impacts expenditure at 12%, education at 26.1%, salary at 13%, and nonfarm business at 13%t. The size of a household, for example, has a direct impact on expenditure (12%), education (26.1%), salary (13%), and nonfarm business (13%): The size of a household, among other things, has a direct impact on food consumption and children's education. Community characteristics, such as rural households, appear to have a negative impact on food consumption and education spending. This finding implies that rural or remote households spend less on food and education for their children. The findings also suggest that rural households live in a subsistence economy in which their labor is not valued and they produce their own food.

Table 2. Regression analysis of household expenditure

Variables	Household expenditure
Household use of electricity	0.687***
	(0.0159)
Household size	0.123***
	(0.00277)
Salary	0.130***
	(0.00551)
nonfarm business	0.119***
	(0.0119)
Education	0.261***
	(0.0111)
Constant	12.00***
	(0.0624)
Observations	11,253
R-squared	0.518

Table 3. Regression analysis of non-farm business

Variables	Nonfarm business
	0.526***
Household use of electricity	(0.0352)
	(2.67e-06)
Household size	-0.00926
	(0.00627)
Age of household head	-0.0111***
	(0.000815)
Household expenditure	0.587***
	(0.0216)
Non-farm business	0.684***
	(0.0247)
Education	0.118***
	(0.0247)
Constant	6.661***
	(0.621)
Observations	11,253
R-squared	0.359

Table 3 lists the coefficient estimates of non-farm businesses. It increases in access to electricity by 1% will impact non-farm businesses by 52.6% means that when the electricity is more accessible will increase the investment of businesses other than farm businesses for the people because the small and big industries' production needs electricity. Access to electricity is supposed to improve socioeconomic well-being and poverty reduction. These benefits are expected to be realized through a variety of mechanisms. Domestic and economic productivity has increased, as well as the creation of new economic opportunities, many of which are

not related to agriculture, are expected as a result of new and/or improved access. Positive externalities could result from potential increases in household and corporate wealth.

Table 4 shows that access to electricity can impact education at 52.6% this means that more people's access to electricity encourages people to study by expanding the hour of study which may yield the desired results. Electricity is frequently assumed to improve educational outcomes, and there are several potentials and theorized causal pathways by which this may occur. The main mechanism highlighted in the studies included new and/or improved lighting, which would allow for an extended effective school day and flexible home study. The primary point is that having access to electricity leads to improved educational outcomes, which implies more and better human capital accumulation, which translates into increased labor supply and household incomes. Access to electricity, in particular, appears to promote women's economic participation by relieving them of tasks such as biomass collection and, more broadly, by allowing them to make better use of their time. In this vein, increases in female employment are primarily the result of increased small-scale self-employment. Increased nighttime light intensity. In terms of mechanism, in addition to overall electricity access, does not contribute to increased average years of schooling. This finding implies that having access to electricity during the day, rather than just at night, benefits household cluster educational attainment. This discovery implies that the impact of electricity on education may have occurred through channels other than illumination, such as labor savings.

Table 4. Regression analysis of household salary

Variables	Salary
Household use of electricity	0.526***
	(0.0352)
Hhid	-1.58e-05***
	(2.67e-06)
Age of household head	-0.0111***
	(0.000815)
Household size	-0.00926
	(0.00627)
Household expenditure	0.587***
	(0.0216)
Non-farm business	0.684***
	(0.0247)
Education	0.118***
	(0.0247)
Constant	6.661***
	(0.621)
Observations	11,253
R-squared	0.359

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

According to the coefficient estimates of electricity access on salary, the household is likely to increase their salary by 52.6% for every 1% increase in access to electricity. This indicates that every percentage point of electricity access has an effect on household earnings, same as non-farm business and education also can impact the household salary by 68.4% and 11.8%

Household income increased as access to electricity improved, Non-farm income has a larger effect size, as reported. Despite the fact that separating farm and non-farm income produced no statistically significant effect sizes for either source of employment [18], farm employment increased only marginally.

3. Conclusions

In this research, EICV5 data from Rwanda's National Institute of Statistics have been used to conduct a more detailed assessment of the impact of energy access on household expenditure, salary, non-farm business, and education. However, simple Ordinary Square regression analysis was used to investigate the impact of electricity on household expenditure, salary, education, and non-farm business. The findings revealed that access to electricity directly impacts expenditure via various channels such as salary generated from non-farm business and increasing the level of study up to the university level. The results indicate that access to electricity has a positive and statistically significant impact on household expenditure, which plays a critical role in household welfare at a rate of 68%. This means that access to electricity has a significant impact on household life. Additionally, the findings show that electricity access continues to play a vital role in household welfare and where positively impacts the salary, education, and non-farm business at a significant level. This means that as the government continues to increase the level of energy connectivity, especially rural electrification will increase the well-being of people as well as economic growth occurs.

Nomenclature

EDPRS	Economic Development and Poverty Reducti on Strategy
PPP	Purchasing Power Party
GDP	Gross Domestic Product
EAC	East African countries
KWH	Kilowatt-hour
REG	Rwanda Energy Group
MW	Megawatt
IEA	International Energy Agency
USAID	United States Agency for International Deve lopment
EICV	Integrated Household Living Conditions Sur vey
NISR	National Institute of Statistics
OLS	Ordinary Least Square
%	Percentage
MININFRA	Ministry of Infrastructure

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

U. Redempta: Conceptualization, Data curation, investigation, Software, Writing-original draft, Validation, Formal analysis, **U. Julie:** Writing-original draft, Validation, **T. Pacifique:** Writing review & editing.

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