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Energy Efficiency Reality with Reference to the Residential Sector in Uganda

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Abstract: *This paper reviews the status of energy efficiency for the residential sector in Uganda. Energy efficiency simply means "less energy same output". It is estimated that more than 50% of households in Uganda don't have electricity grid-connection yet a lot of investment has been put in electrification programmes and construction of dams and power plants. Contrary, people usually find alternatives to grid electricity, in biomass and solar energy mostly. Majority of the households in Uganda use Charcoal and wood for cooking, and moreover in an inefficient way. Ugandan households use electricity mainly for lighting and television but still with less efficient appliances or systems. Using highly energy-efficient appliances in residences can save a lot of energy that can be used to connect thousands of new customers, instead of building new power plants. Thus, a portion of the money intended for rural electrification through new dam construction can be channeled into facilitating and subsidizing on, the acquisition of such appliances.*

Keywords: Electricity; Energy-Efficiency; Households; Power-plants

1. INTRODUCTION

More than half a billion people in Sub-Saharan Africa lack reliable access to energy and majority of them live in rural areas [1]. Demand for electricity in Uganda is steadily increasing at a rate of more than 8% every year, and this is fueled by the current economic growth and fast urbanization. Many governments in Sub-saharan Africa including Uganda adopted initiatives and thus investment to increase rural electrification rates [2]. Roughly, 25 million people per year in sub-Saharan Africa gain access to electricity [3]. The capacity to generate power in Uganda increased by five times over the past 20 years to more than 1500 MW [4]. However, that capacity is barely felt by the population, as more than 50% of Uganda's households are yet to have a grid connection, solar system or hydrocarbon generators. The ideology promoted by Uganda government that energy access can be increased by increasing supply seems not to be highly effective. The number of new grid connections is practically not corresponding to the investment in electrification projects. A lot of investments have been made in different dam projects. The investment cost per megawatt in Uganda is US$2.6 M [4], and home electricity tariffs are currently more than US $0.25 per kWh. This leaves the government in a deficit, as it is difficult to register a crossover with electrification investments. Majority of the rural people and some urban homes are running to alternative energy sources such as Charcoal, firewood, and solar energy, for domestic or residential energy needs. Grid electricity is considered expensive in terms of connection related charges, tariffs and the cost of electronic appliances. The alternative energy sources are cheap and easy to access and use. Therefore, it's necessary to think about innovative ways of increasing electricity access without necessarily investing in the costly dam projects. This paper discusses the current situation of energy efficiency in Uganda, plus its implication and limitations, with main focus on the residential sector.

2. THE CONCEPT OF ENERGY EFFICIENCY

According to the Market Business News Website [5], Energy efficiency (EE) is the practice of using less energy to provide the same amount of useful output from a service (such as heating water, lighting, or cooling in a fridge). Every year a lot of energy is wasted because of heat loss and inefficient technology. This leads to increased carbon pollution, and costs consumers and businesses money. It is important not to confuse EE with energy conservation. The main difference between the two is that energy EE does not require an individual to change or alter their behavior and habits, while that is the whole basis of energy conservation (such as turning off appliances when they are no longer in use). "Efficiency can enable economic growth, reduce emissions and improve energy security [5]. The same website reports that efficiency can cut emissions by 40% without the need for new technology.

3. BIOMASS ENERGY IN UGANDA

Majority of the African population reside in the rural areas and of these, 70% rely on traditional energy such as charcoal and firewood [6, 7]. This is contrary to goal 7 of the United Nations Sustainable Development goals which emphasizes access to modern energy for all. It is very difficult to use Charcoal and firewood in a way that ensures efficiency. This is because ensuring efficiency would translate into purchase of extra tools/facilities that would promote sustainable and efficient use of the biomass. Nalule [8] reports that dependence on this type will continue into the next decade. She also adds that 80% of the energy utilized for cooking in the urban areas is solid biomass. The biggest chunk of urban population in Uganda survive on "food-to-mouth" basis and thus there is no extra funds that can be utilized for acquiring energy saving cooking facilities or stoves.

Charcoal braziers are considered as back up to to modern energy sources for cooking according to Pesa [9]. The use of charcoal and firewood not only contributes negatively to the practice of energy efficiency but also has diverse side effects such as indoor air pollution and carbon monoxide poisoning. The latter have a potential connection to the elevated mortality in Africa [10,11].

It is simple and cheap to use charcoal for cooking; one just needs a portable stove made from clay or sheet metal (see Fig. 1-*Right*), which is protected against rusting by painting [12,8]. The maintenance costs are minimal with such cooking facilities.

On the other hand, efficient use of charcoal energy would require one to invest in expensive, and bulk stoves. (see Fig. 1-*Left*)

Fig. 1 Charcoal/wood Stove. *Left*: Modern energy Saving. *Right*: Common stove [13,14]

Using electricity or gas for cooking even requires heavier investment in appliances, which is even more costly [15,16]. The size of the family, amount and type of food to be cooked, energy cost, mainly dictate the type of energy to be used for cooking. Ugandan families are always big and foods such as beans that require long cooking time are prepared [8]. These will demand cheap energy sources due to the high energy required.

In Uganda, electricity is used mainly for lighting, ironing clothes, watching television, and powering electronic gadgets. Charcoal and wood are almost the sole answers for cooking needs. Drazu et al [17] found that most consumers use electricity only for light tasks, such as lighting, ironing and watching television, turning to charcoal for cooking because electricity is relatively expensive and its availability erratic. Uganda has accelerated rural electrification in the last 10 years according to the Rural Electrification Agency [18], however, electricity consumption is still low (REA, 2020). Charcoal is second to none when it comes to household energy. The basis for investment strategies in grid electricity facilities, is that more electricity will supersede biomass [19]. Amidst the existence of grid connections in a residential setting, the still rampant low electricity consumption may be attributed to the following reasons:

- Other alternatives such as Charcoal and firewood are cheaper than grid electricity though not better.
- Inability of electricity End-user cooking appliances to serve large families, and of course the high costs of maintenance and spare parts.
- The omnipresence of Charcoal and its insusceptibility to outages and black outs
- The cultural belief where food tastes better when it is cooked with Charcoal or firewood (17, 20)
- Abundant Sunlight, an alternative to grid electricity, can be used for specific applications such as drying of agricultural produce.

4. GRID ELECTRICITY

Approximately 2.5 M additional on-grid connections in Uganda are planned by 2030, 53% of which will be urban [4]. People in residential homes in Uganda use electricity mainly for lighting (25%), Refrigeration (24%), Television (10%), Irons (9%), water heating (8%), Air Conditioning (8%), Radio (5%), Fans (4%), Cooking (4%), Kettles (2%), Computer equipment (1%). In a residential setting in Uganda, Off-Grid electricity is utilized mainly for Lighting (51%), Television (18%), Refrigeration (10%), Radio (12%), Fans (9%) [4].

An energy demand peak in Uganda exists at the end of the day for residential consumption according to ERA [21]. The peak-demand period is justified as 19:00. – 23:00, 2.2 GW of electricity is demanded daily within that time, according to UMEME [22].

5. ENERGY EFFICIENCY SETBACKS

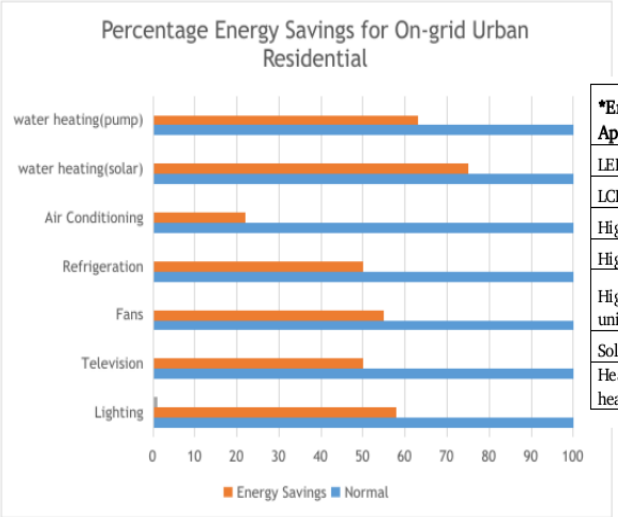
The concept of EE has not sunk so deep into the hearts of many Ugandans including, policy makers. The degree of investment in EE is not pleasing at all. Du Can et al. [4] shone a light on the different barriers to energy efficiency after consulting more than 20 stakeholders in the country. A summary of these barriers is given below:

- There are no policies and regulations to enforce and prioritize EE requirements have not been put in place.
- EE is not integrated in government resource planning
- There is no Mandate of large energy users to invest in EE
- Regulation of products or appliances sold in the market is still in vain
- There is no information to the buyers/consumers about the energy performance of technologies/appliances
- Awareness about the benefits of EE investment is still wanting
- There are no certification schemes for EE compliance
- There are no product-testing facilities for EE compliance
- Lack of access to affordable, risk-less capital and financing to energy service companies
- Lack of support for financial intermediaries to invest in energy savings opportunities.

6. DETERMINANTS OF ENERGY EFFICIENCY

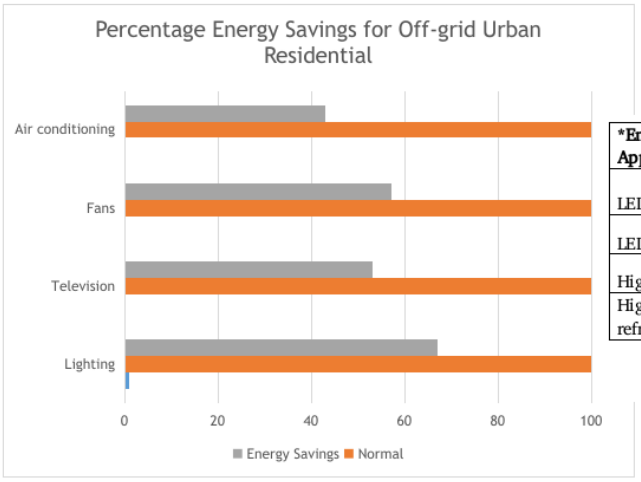
Du Can et al. [4] reports the overall EE potential in Uganda after examining close to 60 EE measures (types and associated savings). Data for the energy savings, lifetime, and cost estimates of each EE measure were gathered from different sources. For the residential sector, assumptions mainly came from Efficiency Levels of Electrical Appliances on the Ugandan Market, research championed by GIZ [23].

Fig. 2 and 3 show how much energy can be saved if highly efficient energy saving appliances replace the current ones. Fig. 4 describes the electricity consumption and potential savings if EE practice is implemented. The current annual electricity consumption for residential on grid Urban is 800 GWh and energy saving is 230 GWh now and, 500 GWh in 2030). On the other hand, the current consumption for residential on-grid rural is 190 GWh, saving 60 GWh now and 150 GWh in 2030. The total residential off-grid consumption is 105 GWh, saving 35GWh now, and 60 GWh in 2030 [4]. Total electricity consumption was 2932 GWh in 2017 and is projected.



*Energy Saving Appliance	Incremental Cost (USD/kWh)
LED lighting	0.10
LCD TV	1.58
High-efficiency fan	0.25
High-efficiency refrigerator	0.52
High-efficiency room AC* unit	0.98
Solar hot water heater	0.57
Heat-pump hot water heater	0.19

Fig.2. Energy Savings for different Electrical appliances in an On-Grid Urban residential setting (Modified from [4])



*Energy Saving Appliance	Incremental Cost (USD/kWh)
LED lighting	0.40
LED TV	1.29
High-efficiency fan	0.39
High-efficiency refrigerator	1.22

Fig. 3. Energy Savings for different Electrical appliances in an Off-Grid Urban residential setting (Modified from [4])

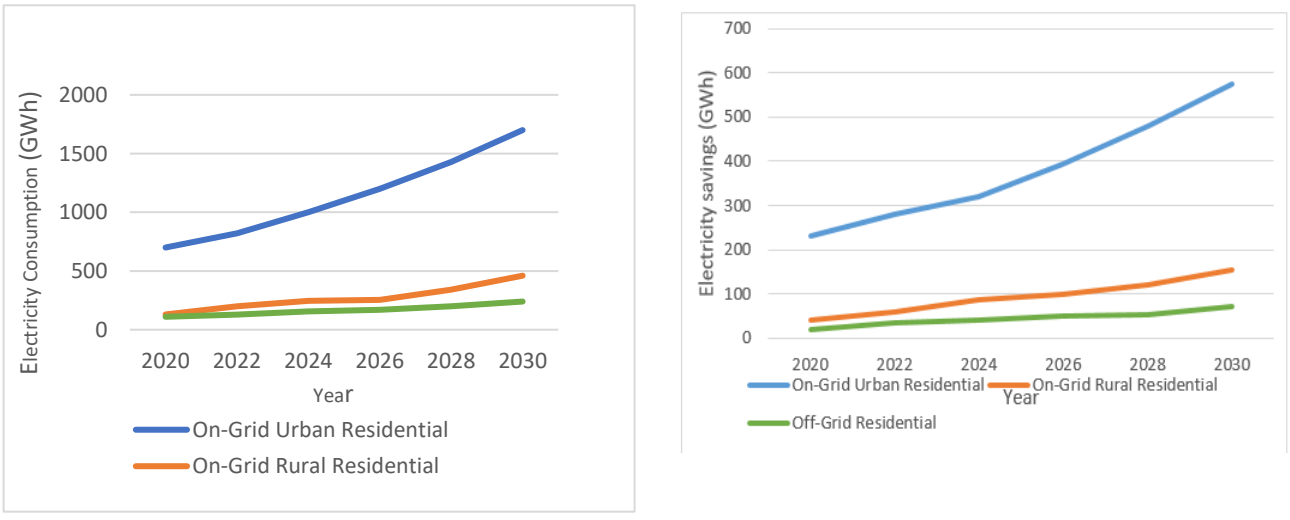


Fig.4. Residential Electricity Status in Uganda. *Left*: Energy Consumption (metre-level). *Right:* Saving Potential. (Modified from [4])

to be 7038 GWh in 2030. The current On Grid electricity consumption for residential is about 25% of the total on-grid electricity consumption. The saved electricity can cater for peak demands of energy and also provide electricity to new customers without additional power plants. Uganda's demand projections show no sign of declining in the short term, so EE offers an opportunity

to extract the maximum value from each power generation facility. The technical potential also shows
to extract the maximum value from each power plant
significant non-energy benefits, with EE measures reducing carbon dioxide (CO2) emissions by a great deal. Another non-energy benefit comes in the form of increased access to electricity. With EE helping to manage load growth, electricity capacity that is added to the grid can be used to increase access for new customers. the on-grid savings from efficiency in 2030 could allow grid access to an estimated additional 2.1 M urban
Another non-energy benefit comes in the form of increased access to electricity. With EE helping to manage load growth, electricity capacity that is added to the grid can be used to increase access for new customers. the on-grid savings from efficiency in 2030 could allow grid access to an estimated additional 2.1 M urban customers or 6 M rural customers, without adding generation capacity. Brinckerhoff [24] reported that each urban customer consumes 1060 kWh and each rural customer 370 kWh of electricity annually. In other words, including efficiency in the national planning process could mean adding the supply for 6 M rural customers without adding new generation, at a cost that is likely to be lower than the cost of building additional generation capacity.

7. RECENT ENERGY EFFICIENCY AWARENESS SURVEY

A survey was carried out in Kampala-the capital of Uganda regarding EE [25]. It is believed that the level of education perhaps has a connotation to realization of the energy efficiency measures. It is worth noting that at least over 90% of the almost 400 respondents attained high school education or more. In rural areas in Uganda the level of education is quite low (UBOS and ICF, 2018), so most probably few of them can understand the relevance of EE. The amount of electricity used during the day to some extent depends on the number of people who stays at home during day time. The survey found out that at most one person stays at home during the day and the average number of household members was 4.2. The age of the household dwellers is also significant, as different age groups have absolutely varying needs for electricity, apart from lighting. The survey found out that averagely each house used 46 kWh of electricity (Table 1) every three months which is equivalent to 200 kWh per year. This figure greatly deviates from what is reported by Brinckerhoff [24]. The deviation can be attributed to the number of household members, increase in the use of solar energy, location of the survey area, increased awareness of energy conservation or increased awarenes of energy efficiency. The latter is what this survey also discovered, and it will be discussed later in this section. The other issue for the low consumption is the current reality of tough economic times. Cost of living has gone high, yet the incomes have not necessarily increased in Uganda, and thus an urgent need to reduce expenditure on certain utilities such as electricity. This survey found out that the average monthly salary of the respondents is about Ugx. 465,000 (121 USD) as shown in table 1. Some families at times decide to keep Televisions off, go to work without ironing, refrain from using fridges or even resort to solar powered lights. Out of this study, it was found out that close to 90% of the sampled people are aware of EE (table 2). Majority of these people have been introduced to the energy efficiency via television and friends. Additionally, about 90% of these people use some of the energy efficiency measures alongside energy conservation measures. The most common measures are displayed in the table 3. It is reported that 90% of the Kampala residents use energy saving light bulbs [25], as shown in Table 3, but we cannot verify the

Table 1: Summary of Survey Statistics (Modified from Watundu [25])

Variable	Average	Min.	Max.
Number of Children	1.5	0	6
Household size	2.8	1	9
Age	4.2	0	12
Average household monthly expenditure (Ugx)	35.3 (465053)	16 (20000)	84 (6500000)
Average number of people who stay home all day	0.9	0	9
Average Quarterly electricity consumption (kWh)	45.98	7	127
Average Quarterly electricity expenditure (Ugx)	58269.9	3667	160,000

Table 2: EE Awareness extent and source (Modified from Watundu [25])

Knowledge of EE	**Number of Respondents**
Yes	348
No	41
Total	*389*
Source of Information	**Number of respondents**
Television	146
Radio	32
Friends	130
Posters	6
Workshop	14
Total	*389*

authenticity and standard of the bulbs. There is no organized government entity and structure to regulate, monitor, test and appraise the quality of these bulbs with so many other EE appliances. Conmen may also hide behind selling energy savings. One interesting finding is that, close to 60% of the respondents who aware of the EE concept have never seen EE labels on appliances. This points to a gap in education of the population about EE. Developing countries, including Uganda face a big shortage in energy and EE should be the way to go [27]. Among the things that the Uganda government has to do is thoroughly make the people aware of this tragedy of shortage, and the relevance of EE. However, the government of recent, has shown some glimpses of concern for EE.

Table 3: EE and Conservation measures discovered during the Survey (Modified from Watundu [25])

Efficiency measure	Number of respondents	%age
Use energy saving bulbs	309	90.35
Turn off lights	298	87.13
Turn off other electricity consuming appliances before going to bed	195	57.02
Only buy energy saving appliances	52	15.20
Use alternative cheaper sources for cooking	80	23.39
Use solar and battery storage to save electricity	9	2.63

The government of Uganda through its energy ministry distributed energy efficient LED bulbs to Kampala, but less than 50% of the respondents received these bulbs. Of those who received the bulbs, more than 40% of them claim that these bulbs had no reduction effect on the monthly electricity bill [25]. This claim warrants some serious investigation, if there was a government structure or entity to do so. These bulbs, in addition, have issues with life--about 20% of the respondents confirmed that these bulbs did not last long. Other respondents claim that these bulbs are scarce to find in shops and where present, very expensive

The policy on energy saving appliances should start from the importation and manufacture stages of these appliances. The same survey report shows that only 52 out of the 348 that are aware of EE concept surveyed population actually buy energy savings. 85% of the people choose not to buy the energy saving appliances even if they are aware possibly because of: the cost of the appliances, other competing needs, lack of awareness of EE benefits, lack of access, favourable payment strategies, bias against such appliances, and many others. In situations where the there is no electricity connection or where the electricity cost is high, people tend to resort to cheaper energy sources such as Biomass [28]. These alternatives not only violate the progress of energy efficiency practice, but also contribute to climate change.

8. CONCLUSION

The survey by Watundu [25] shows that Ugandans especially the urban population are aware of energy efficiency, and actually some of them are already implementing some of the measures, but they need more enlightment and motivation.

An enabling atmosphere for the flourishing of Energy efficiency in Uganda should be created in the energy fraternity, right from regulation, financing, investment and information flow. With energy efficiency measures in place, On-Grid Urban Residential energy saving alone can potentially provide electricity for 230,0000 new urban customers annually or 623,000 new rural customers. The On-Grid rural saving on the other hand is equivalent to 57,000 new urban customers or 163, 000 new rural customers. There is no need of a power plant to connect all those hundreds of thousands of new customers. Now you can imagine how much energy can be saved from the other sectors such as industrial and Commercial, which generally consume more than 70% of On-grid electricity in Uganda.

Biomass energy can also be utilized in an efficient manner if there is proper regulation, subsidized access to energy saving stoves, and others. Part of the finances intended for new power plants should instead be diverted into acquisition of energy saving appliances. Basing on the daily energy demand, appliances such as Light bulbs and Televisions, that are used during the peak hours should be given priority for the start. Energy saving appliances should replace the conventional ones. People should be educated on the importance of energy efficiency and its benefits in the long run.

9. REFERENCES

[1] S. Stritzke, P.A. Trotter, & P. Twesigye, Towards responsive energy governance: Lessons from a holistic analysis of energy access in Uganda and Zambia. Energy Policy (2021), 148, 111934.

[2] USAID, 2018. Power Africa 2018 Annual Report. https://www.usaid.gov/sites/default/fi
les/documents/1860/Power_Africa_AR2016-optimized.pdf

[3] United Nations, 2015. Population 2030: Demographic Challenges and Opportunities for Sustainable Development Planning. ST/ESA/SER.A/389. United Nations 58.

[4] S. D. L. R. Du Can, D. Pudleiner & K. Pielli, K. (2018). Energy efficiency as a means to expand energy access: A Uganda roadmap. Energy Policy, 120, 354-364.

[5] https://marketbusinessnews.com/financial-glossary/energy-efficiency/ (Accessed Jul 21 2022 15:50)

[6] V,R. Nalule, V. R. (2020). Transitioning to a Low Carbon Economy: Is Africa Ready
to Bid Farewell to Fossil Fuels? In The Palgrave Handbook of Managing Fossil
Fuels and Energy Transitions (pp. 261–286). Cham: Palgrave Macmillan.

[7] A. Khellaf, Overview of economic viability and social impact of renewable energy deployment in

Africa, Africa-EU Renewable Energy Research and Innovation Symposium. Springer, Cham, 2018.
[8] V. R. Nalule, How to Respond to Energy Transitions in Africa: Introducing the Energy Progression Dialogue. Energy Transitions and the Future of the African Energy Sector. Palgrave Macmillan, Cham (2021). 3-35.
[9] I. Peša, Sawdust pellets, micro gasifying cook stoves and charcoal in urban Zambia: Understanding the value chain dynamics of improved cook stove initiatives. Sustainable Energy Technologies and Assessments, 22, (2021)171-176.
[10] D. G. Fullerton, N. Bruce, & S. B. Gordon, Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. Transactions of the Royal Society of Tropical Medicine and Hygiene, 102(9), ((2008)) 843-851.
[11] De Koning, H. W., Smith, K. R., & Last, J. M. (1985). Biomass fuel combustion and health. Bulletin of the World Health Organization, 63(1), 11.
[12] Nabukalu, C., & Gieré, R. (2019). Charcoal as an energy resource: Global trade, production and socioeconomic practices observed in Uganda. Resources, 8(4), 183.
[13]https://www.newvision.co.ug/news/1416911/mugerwa-earns-living-energy-saving-charcoal-stoves Accesed 11:21 July 26 2022
[14] https://www.pinterest.com/pin/113856696799563002/ accesed 11:29 July 26 2022
[15] Maria de Fatima, S. R., Zahran, S., & Bucini, G. (2010). On the adoption of electricity as a domestic source by Mozambican households. Energy Policy, 38(11), 7235-7249.
[16] Akpalu, W., Dasmani, I., & Aglobitse, P. B. (2011). Demand for cooking fuels in a developing country: To what extent do taste and preferences matter?. Energy Policy, 39(10), 6525-6531.
[17] Drazu, C., Olweny, M. R., & Kazoora, G. (2015). Household energy use in Uganda.
[18] Rural Electrification Agency. (2020). Large scale schemes implemented through REA under GoU. Retrieved from www.rea.or.ug: https://www.rea.or.ug/completed-projects.html.
[19] Owen, M., van der Plas, R., & Sepp, S. (2013). Can there be energy policy in Sub-Saharan Africa without biomass?. Energy for sustainable development, 17(2), 146-152.
[20] R. Bailis, C. Rujanavech, P. D. Dwivedi, H. Chang, & R. de Miranda, Innovation in charcoal production: A comparative life-cycle assess-
ment of two kiln technologies in Brazil. Energy for Sustainable Development, 17 (2), (2013) 189–200.
[21] Electricity Regulatory Authority (ERA), 2016. Demand side management strategy.
[22] UMEME, 2016. 2015 Electricity Consumption Data for Top 200 Customers in Each Tariff Class.
[23] GIZ, 2014. Efficiency levels of electrical appliances on the Ugandan Market.
[24] P. Brinckerhoff, Power Sector Investment Plan. Kampala: Uganda MEMD (2011).
[25] S. Watundu, L. Senyonga, R. Atuhaire, C. Ashaba, B. Kyasiimire, A. Asiimwe, G. Nkurunziza, and O. Bergland. Drivers of Energy Efficiency among Households using Grid Electricity in Kampala, Uganda, ORSEA JOURNAL 11, no. 2 (2022).
[26] UBOS and ICF, Uganda Demographic and Health Survey 2016. Kampala, Uganda and Rockville, Maryland, USA (2018).
[27] M. Sultan, Investigating energy efficient air-conditioning options for agricultural and livestock applications, In Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), no. 6, pp. 21-22. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, 2020.
[28] S.C. Karmaker, M. M. Rahman, S. Hosan, and B. B. Saha, The impact of biomass energy consumption on human development: evidence from Asian countries. Sciences (IEICES) 6 (2020): 204-211.