

BOTTOM-UP FRAMEWORK FOR ESTIMATING APPLIANCE ADOPTION OVER TIME: IMPLICATIONS FOR ENERGY DEMAND EVOLUTION IN RURAL MINI-GRIDS

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LEAP-RE

Long-Term Joint EU-AU Research
and Innovation Partnership on Renewable Energy



The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

Context:

- Analysis of appliance ownership of mini-grid users, aiming to provide insights for better demand forecasting

Goal of the study:

- Understanding the link between household electricity access duration and appliance ownership, and creating a framework for reliable energy demand predictions.

Relevance:

- The lack of accurate electricity load prediction in rural mini-grid projects introduces uncertainty, which can negatively impact the performance and sustainability of off-grid systems.
- Accurately estimating the adoption and usage of electric appliances over time can provide valuable insights into electricity demand forecasting

- Previous Studies

- There is a general agreement about the primary factors affecting appliance adoption; nevertheless, the degree to which appliance ownership and acquisition increase or change over time is not as straightforward.
- Information and communication technology (ICT) appliances are most widely acquired appliances. The saturation of phones can be anticipated with an increasing income; however, this may not hold true for other household appliances.

CASE STUDY

Rural mini-grid (MG) in Faza Kenya
Operational since 2017

DATA

Sample: Residential sector - 192 Households

- Appliance ownership and purchase date
- Appliance usage and expenditure
- Socio-demographic characteristics

Scientific Methodology Adopted in the Study

- **Ordered Least Square Regression (OLS)** → Drivers of appliances uptake
- **T-test** → Comparison standard households and households with commercial activities
- **K-means Clustering** → Patterns in energy expenditure

APPLIANCE TIER FRAMEWORK:

Tier	Appliances Category A	Appliances Category B	Appliances Category C
1			
2		Max. 1	
3		Max. 3	Max. 1
4			

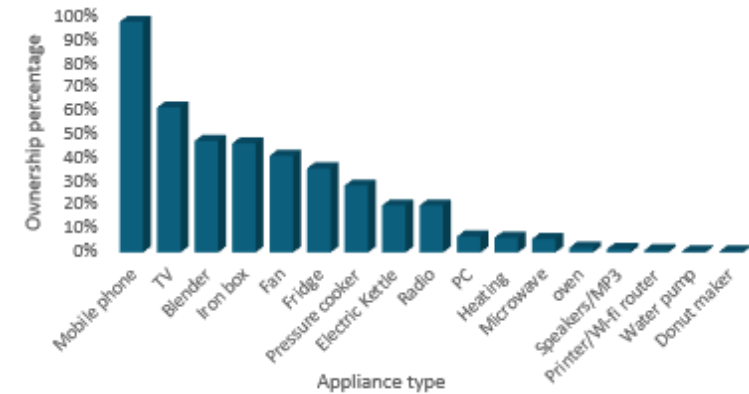
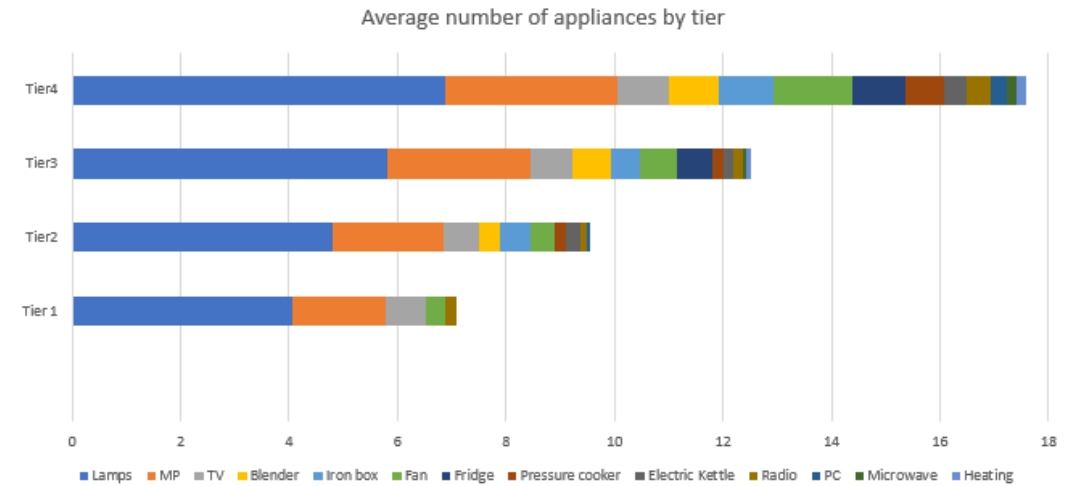
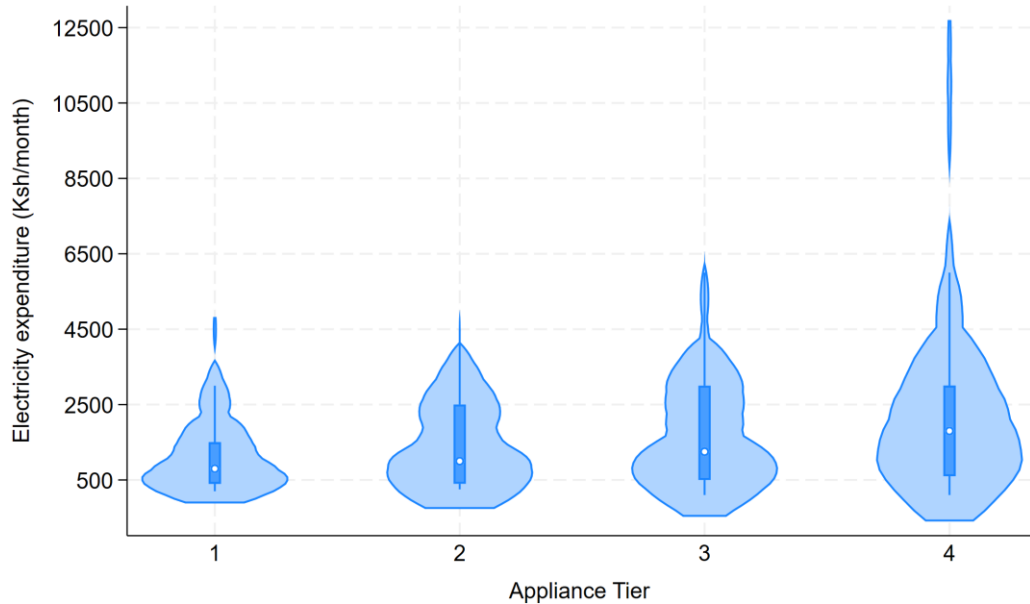
Category	Appliances
A	Bulbs
	mobile phone charger
	TV
	Fan
	Radio/Speakers/Mp3
B	Pc/Printer/Wifi
	Blender
	Iron box
	electric kettle
	Pressure cooker
C	Donuts maker
	Microwave
	Water pump
	Oven
	Heating
	Fridge

Preliminary results



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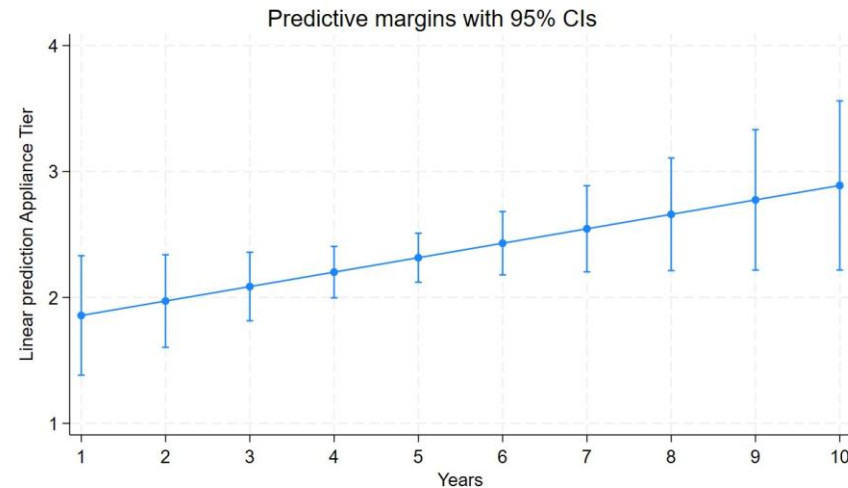
Descriptive statics



Factors affecting the highest appliance tier reached

Dependent variable: Highest appliance tier reached				
Model	(1)	(2)	(3)	(4)
Years of electricity	0.16*** (0.05)	0.14*** -0.05	0.099* (0.05)	0.11* (0.05)
Number of rooms	0.289** (0.12)	0.26* -0.13	0.251* (0.144)	0.46*** (0.17)
Education	0.602*** (0.18)	0.56*** 0.18	0.38** (0.18)	0.51** (0.25)
Female decision maker	0.198 (0.23)	0.195 0.22	0.138 (0.22)	0.325 (0.29)
Income per capita	0.133*** (0.046)	0.122*** 0.04	0.173*** .049	0.183*** (0.05)
No children		-0.062 0.06	-0.034 (0.05)	-0.476 (0.07)
No people earning salary		0.31* 0.17	0.19 0.18	0.321 (0.2)
Age of household head		-0.011* 0.006	-0.013** (.005)	-0.022*** (0.007)
Marital status			0.061 (0.15)	-0.152 (0.18)
Access to finance			0.55** (0.2)	0.602** (0.26)
Household location			-0.018 (0.1)	-0.050 0.12
Business at home			0.98*** (0.16)	
Constant	1.41*** (0.395)	0.68 (0.66)	0.948 (0.69)	0.998 (0.88)
N	172	172	172	121
R2	0.1984	0.2192	0.3614	0.3261

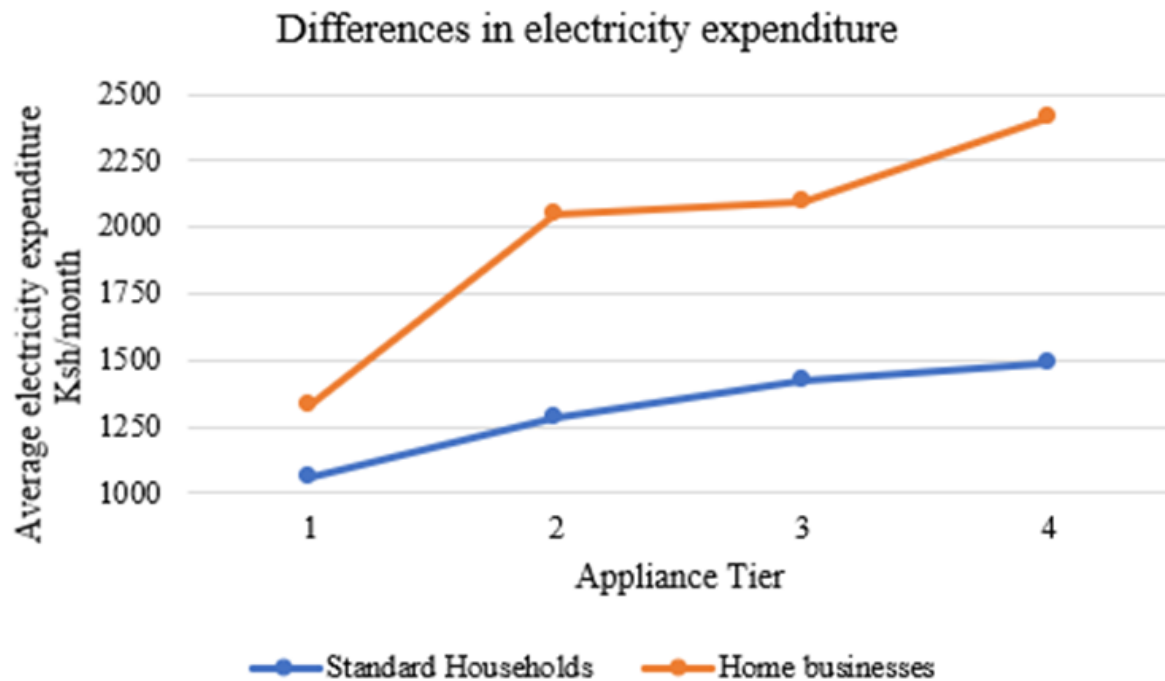
* p<0.1, **p<0.05, ***p<0.01.



Most significant factors:

- Creation of commercial activities
- Use of microfinance
- Education Level
- Number of rooms
- Income per capita

Comparison standard households and home businesses



T- test results

Group	Expenditure Mean	Standard Deviation	N
0	1279.1	1149.3	138
1	2142.6	1378.2	69

Group	Tier Mean	Standard Deviation	N
0	2.23	1.2	136
1	3.23	.89	69

Group 0 → Standard Households

Group 1 → Home businesses

Standard households spend about 60% less on electricity compared to households with commercial activities

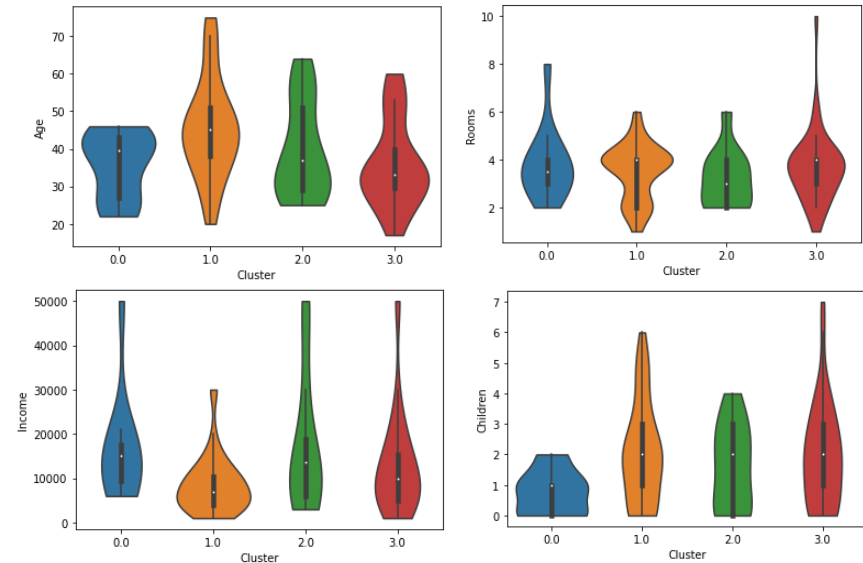
Patterns energy expenditure and appliance uptake in standard households

K-Means Cluster Centroids				
Cluster	1	3	2	0
Electricity expenditure (Khs/month)	703	825	3115	1800
Number of appliances owned	0,93	4,1	2,4	7,8
Observations	39.5%	32.3%	18.5%	9.7%

- Group characteristics are highly heterogeneous
- Clusters 3 and 2 lack correlation between appliances and energy expenditure
- Cluster 0, with very low expenditure and number of appliances, has the oldest population

Other findings:

- Households led by a male as the financial head exhibit higher expenditure compared to households led by a female financial head
- Groups 3 and 0 have the highest expenditures on other energy resources



Conclusions and implications



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Households with commercial activities

- There is a discernible time lag in acquiring appliances in a household, with notable increase both in appliances owned and energy expenditure associated with having a home business
- A distinct user category for households involved in business activities is required to better estimate electricity demand growth across rural households

Standard households

- Even when households own several appliances, electricity usage still might remain low. This might be explained by the relatively high use of traditional fuels, even after having access to electricity.
- The optimal categorization of standard households can be challenging, even when accounting for socio-demographic characteristics.
- There is a need to incorporate a usage behavior component that complements appliance ownership, to define residential customer archetypes.

Future research

Definition of optimal categorization of standard households, grounded in electricity expenditure patterns



Utilize cross-sectional data with temporal information about appliance acquisition in each household



Identify patterns of appliance uptake over the years



Combine findings of appliance uptake patterns and appliance usage patterns to deepening our understanding of electricity demand evolution during the initial years of electricity access within the context of rural mini-grids.

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