KENYA

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

ESMAP

WORLD BANK GROUP

SREP

MTF Multi-Tier FRAMEWORK

KENYA

Beyond Connections

Access to electricity and clean cooking in Kenya based on the Multitier Framework survey and data analysis.

Sunita Dubey, Ehui Adovor, Dana Rysankova, Elisa Portale and Bonsuk Koo

ESMAP

WORLD BANK GROUP

SREP

MTF Multi-Tier FRAMEWORK

©2019 International Bank for Reconstruction and Development / The World Bank
1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000

Internet: www.worldbank.org

Publication date: November 2019

This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent.

The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Rights and Permissions

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

Any queries on rights and licenses, including subsidiary rights, should be addressed to World Bank Publications, The World Bank Group, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

Report and Cover design: Lauren Kaley Johnson, GCSPM, The World Bank Group
Text layout: StudioGrafik

CONTENTS

ACKNOWLEDGMENTS vii

ABBREVIATIONS ix

EXECUTIVE SUMMARY x

Access to Electricity xi

Access to Clean Cooking xiii

Gender dimension in Access to Energy xiv

Access to Electricity xiv

Scaling-up the Uptake of Clean Cooking Solutions xv

Achieving Gender Parity in Access to Energy xvi

MEASURING ENERGY ACCESS IN KENYA xvii

The Multi-Tier Framework Global Survey 4

Access to Electricity 5

Access to Modern Energy Cooking Solutions 7

Using the Multi-Tier Framework to Drive Policy and Investment 9

Multi-Tier Framework survey implementation in Kenya 10

ACCESS TO ELECTRICITY 13

Technologies 14

MTF Tiers 16

MTF Attributes 18

Capacity 18

Availability 19

Reliability 20

Quality 20

Affordability 21

Formality 22

Health and Safety 22

Use of Electricity 23

Improving Access to Electricity 28

Providing Electricity Access to Households without a Source of Electricity 28

Improving Access to Electricity among Grid-Connected Households 34

Improving Electricity Access among Households That Rely on Off-Grid Solar 37

Access to Electricity Access in 14 Under-served Counties 43
MTF Analysis for 14 Under-Served Counties 44
Improving access to Electricity 14 Counties 49
Policy Recommendations 52

ACCESS TO MODERN COOKING SOLUTIONS 55
Assessing Access to Modern Energy Cooking Solutions 56
Technologies 56
MTF Tiers 60
Improving Access to Modern Energy Cooking Solutions 64
Scaling Up the Use of Clean Fuel Stoves among Urban Populations 64
Increasing the Use of Improved Cookstoves as the Primary Cooking Solution in Rural Areas 66
Policy Recommendations 70
Scaling-Up Uptake of Clean Cooking Solutions in Urban Areas 70
Achieving Higher Tier Access for Households in Rural Areas 70

GENDER ANALYSIS 71
Access to Electricity 73
Access to Modern Energy Cooking Solutions 75
Policy Recommendations 77

ANNEX 1: MULTI-TIER FRAMEWORK 79

ANNEX 2: COOKSTOVE TYPOLOGY 81

ANNEX 3: APPROACH AND METHODOLOGY 82
Sampling Frame 82
Primary Sampling Unit 82
Figure A3.1: Sampling Frame 82
Table A3.1: Target Number of Interviews 83
Stratification 83
Household selection for the core sample 84
Oversampling 85
Selection of enumerators and supervisors 85
Regional Supervisors 86
Pre-testing survey tools and supervisors' training 86
REFERENCES 88

BOXES

BOX 1 · Kenya is One of the Top Performers in Sub-Saharan Africa on Regulatory Indicators for Sustainable Energy (Rise) 2
BOX 2 · Minimum Electricity Requirements, by Tier of Electricity Access 6
BOX 3 · Typology of Off-Grid Solar Devices based on Capacity 7
BOX 4 · Typology of Cookstoves in Kenya 9

MAPS

MAP 1 · Sample distribution 12
MAP 2 · 14 Under-served counties 44

TABLES

Table 1 ·Appliances by load level and associated Capacity tiers 7
TABLE 2 · Distribution of enumeration areas and sampled households, MTF Survey 11
TABLE A1.1 · Multi-Tier Framework for measuring access to electricity 79
TABLE A1.2 · Multi-Tier Framework for measuring access to modern energy cooking solutions 80

FIGURES

FIGURE ES1 · Access to electricity in Kenya x
FIGURE 1 · Rate of grid connection in Kenya 1
FIGURE B1.1 · Evolution of Kenya's RISE score on electricity access indicators between 2010 and 2017 2
FIGURE 2 · Increase in grid electricity connection over the years in Kenya 3
FIGURE 3 · Access to electricity, grid and off-grid based on extrapolation for 2018 (nationwide) 14
FIGURE 4 · Access to electricity and off-grid technology, nationwide 15
FIGURE 5 · Electricity access and off-grid technology, urban and rural areas 15
FIGURE 6 · Electricity access, by expenditure quintile 16
FIGURE 7 · MTF tier distribution, by source of electricity 17
FIGURE 8 · MTF tier distribution, by urban or rural location 17
FIGURE 9 · MTF tier distribution, by national grid 18
FIGURE 10 · Distribution of households based on Capacity (nationwide, urban, and rural) 18
FIGURE 11 · Distribution of households based on daytime Availability (over a 24-hour day—nationwide, urban, and rural) 19
FIGURE 12 · Distribution of households based on evening Availability (4 hours—nationwide, urban, and rural) 19

FIGURE 13 · Distribution of households based on the Reliability attribute (nationwide, urban, and rural) 20
FIGURE 14 · Distribution of households based on Quality (nationwide, urban, and rural) 21
FIGURE 15 · Distribution of households based on Affordability (nationwide, urban, and rural) 21
FIGURE 16 · Distribution of households based on Formality (nationwide, urban, and rural) 22
FIGURE 17 · Distribution of households based on Health and Safety (nationwide, urban, and rural) 22
FIGURE 18 · Number of years connected to the national grid 23
FIGURE 19 · Monthly household expenditure on and consumption of electricity 24
FIGURE 20 · Grid-connected households spending more than 5% of their household income on electricity (nationwide) 24
FIGURE 21 · Consumption in kWh among households, nationwide 25
FIGURE 22 · Power level of the appliances used among households, by urban or rural location 25
FIGURE 23 · The use of appliances among grid-connected households, urban and rural 26
FIGURE 24 · The use of appliances among grid-connected and off-grid households possessing solar devices 27
FIGURE 25 · Desirable high capacity appliances, households using off-grid solar solutions 27
FIGURE 26 · Expenditure quintile comparison of Tier 0 households 28
FIGURE 27 · Expenditure by Tier 0 households on alternative sources of electricity (on grid and off grid) 29
FIGURE 28 · Share of (monthly) expenditures on alternative sources of electricity for Tier 0 households 29
FIGURE 29 · Barriers to gaining access to grid electricity 30
FIGURE 30 · Willingness to pay for the grid connection fee 31
FIGURE 31 · Main reason for not accepting any offer to pay for grid connection 31
FIGURE 32 · Willingness to pay for a solar home systems (SHS) 33
FIGURE 33 · Reasons households are not willing to pay for a SHS 33
FIGURE 34 · MTF tier distribution among grid-connected households 34
FIGURE 35 · MTF tier distribution of grid-connected households, by urban or rural location 35
FIGURE 36 · Quality attribute, grid-connected households 35
FIGURE 38 · Main issues with the grid electricity as reported by households, by urban and rural locations 36
FIGURE 39 · Grid-connected households using a backup source for lighting, and the monthly expenditure on the backup source, urban and rural locations 36
FIGURE 40 · Off-grid technology distribution by MTF tiers 37
FIGURE 41 · Off-grid solar households, urban and rural locations 38
FIGURE 42 · Off-grid solar-grid households using solar solutions as backup source 38
FIGURE 43 · Years of using off-grid solar solutions 39
FIGURE 44 · Off-grid-solar tier distribution and product typology, nationwide 39
FIGURE 45 · Capacity tier distribution, households relying on off-grid solar solutions 40
FIGURE 46 · Distribution of the daytime Availability attribute (over a 24-hour day), households using off-grid solar solutions 40
FIGURE 47 · Distribution of the nighttime Availability attribute (6pm–10pm), households using off-grid solar solutions 41
FIGURE 48 · Expenditure quintile, households using off-grid solar solutions 41

FIGURE 49 · Main issues, off-grid solar products 42
FIGURE 50 · Expenditure on backup sources, households using off-grid solar solutions 42
FIGURE 51 · Payment plan and mode, households using off-grid solar solution 43
FIGURE 52 · Access by source of electricity, 14 under-served and Kenya's other counties 44
FIGURE 53 · MTF tier analysis, 14 under-served and Kenya's other counties 45
FIGURE 54 · Distribution of the Capacity attribute, 14 under-served and Kenya's other counties 45
FIGURE 55 · Distribution of Daytime Availability attribute (over a 24-hour day), 14 under-served and Kenya's other counties 46
FIGURE 56 · Distribution of the evening Availability attribute (4 hours), 14 under-served and rest of the counties 46
FIGURE 57 · Distribution of the Reliability attribute, 14 under-served and Kenya's other counties 47
FIGURE 58 · Distribution of the Quality attribute, 14 under-served and Kenya's other counties 47
FIGURE 59 · Distribution of the Affordability attribute, 14 under-served and Kenya's other counties 48
FIGURE 60 · Distribution of the Formality attribute, 14 under-served and Kenya's other counties 48
FIGURE 61 · Expenditure (in K Sh) by households of the 14 under-served and Kenya's other counties on alternative sources of electricity 49
FIGURE 62 · Barriers to gaining access to grid electricity 50
FIGURE 63 · Willingness to pay the grid connection fee 50
FIGURE 64 · Willingness to pay for a solar home system 51
FIGURE 65 · Payment plan and mode, households using off-grid solar solution: 14 under-served counties and Kenya's other counties 52
FIGURE 66 · Stove types: Urban, rural, and nationwide 57
FIGURE 67 · Primary cookstove type: Under-served counties 57
FIGURE 68 · Cookstove stacking: Urban, rural, and nationwide 58
FIGURE 69 · Stove stacking, by primary stove type, nationwide 58
FIGURE 70 · Primary cooking fuels: Urban, rural, and nationwide 59
FIGURE 71 · Fuel Type: 14 Under-served counties 60
FIGURE 72 · MTF tier distribution for access to modern energy cooking solutions: Nationwide, urban, and rural 60
FIGURE 73 · MTF tier distribution: 14 Under-served counties 61
FIGURE 74 · Distribution of households' Cooking Exposure attribute: Nationwide, urban, and rural 61
FIGURE 75 · Distribution of households based on the Convenience attribute: Nationwide, urban, and rural 62
FIGURE 76 · Distribution of households based on the Safety attribute 62
FIGURE 77 · Distribution of households based on Affordability attribute: Nationwide, urban, and rural 63
FIGURE 78 · Affordability tier by fuel type 64
FIGURE 79 · Expenditure quintile distribution by stove type 65
FIGURE 80 · Clean fuel stove stacking among two-stove users: Nationwide, urban, and rural 66
FIGURE 81 · Willingness to pay for improved cookstoves Nationwide 67
FIGURE 82 · Willingness to pay: 14 Under-served counties 67
FIGURE 83 · Reasons household s in 14 under-served counties unwilling to pay for improved ICS fuelwood 68

FIGURE 84 · Reasons households in 14 under-served counties unwilling to pay for improved ICS fuelwood 68
FIGURE 85 · Distribution of expenditure quintile by gender of the household head: Urban and rural 72
FIGURE 86 · Distribution of electricity sources by gender of the household head: Urban and rural 73
FIGURE 87 · MTF electricity tier distribution by gender of the household head: Urban and rural 74
FIGURE 88 · Willingness to pay for SHSs by the gender of household head 74
FIGURE 89 · Willingness to pay for a grid connection, by the gender of household head 75
FIGURE 90 · MTF Cooking tier distribution by the gender of the household head: Urban and rural 76
FIGURE 91 · Willingness to pay for improved cookstoves by the gender of the household head 76
FIGURE 92 · Time spent in the cooking space by sex-segregated ratio (minutes per day) 77

ACKNOWLEDGMENTS

The Multi-Tier Framework's (MTF) international initiative would not have been possible without the valued technical and financial support of the Energy Sector Management Assistance Program (ESMAP), which is administered by the World Bank.

ESMAP is a global knowledge and technical assistance program to support low- and middle-income countries in increasing their knowledge and their institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, the European Commission, Finland, France, Germany, Iceland, Italy, Japan, Lithuania, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and the Rockefeller Foundation, as well as the World Bank. The financial and technical support provided by ESMAP for implementation of the MTF survey is gratefully acknowledged. We also acknowledge financial support by the Scaling-Up Renewable Energy Program in Low Income Countries, which is funded by the Strategic Climate Fund (SCF), one of the two Climate Investment Funds (CIF).

This Energy Access Diagnostic Report details the results of the MTF survey in Kenya and provides the status of access to electricity and to modern energy cooking solutions in that country. The report also exclusively focuses on 14 underserved counties prioritized by the Government of Kenya for improving access to electricity and clean cooking. The initiative has relied on the critical support of multiple entities and individuals that the MTF team would like to acknowledge.

First and foremost, MTF-ESMAP would like to thank the Government of Kenya for its enthusiasm and support for this project, particularly Eng. Issac Kiva, Secretary, Renewable Energy of the Ministry of Energy (MOE), who provided valuable guidance and support throughout the process. The team is grateful to other officials of MOE, including Mr. Rodney Sultani, Eng. Kihara Mungai, and Mr. Richard *Muiru*, all of whom helped guide and gave their valuable support to the MTF team throughout the process of survey preparation, implementation, and analysis. We are also thankful to Kenya Power for data support, especially Mr. John Situma Wekesa, Mr. Simon Kamau, and Ms. Christine Tum. MTF-ESMAP's partnership with EED Advisory and the Stockholm Environment Institute, the survey firm consortium in Kenya, has been critical to the successful implementation of this national survey initiative. The insights, critical feedback, and invaluable support of Ms. Diariétou Gaye, (then Country Director), Ms. Sudeshna Banerjee (Practice Manager), Mr. Johan A. Mistiaen (then Program Lead), Ms. Kathleen G. Beegle (Lead Economist), Ms. Rose Mungai (Senior Economist/Statistician), Mr. Zubair K. M. Sadeque (Senior Energy Specialist), Ms. Laurencia Njagi (Senior Energy Specialist), Mr. Patrick Bhalla (Senor Energy Specialist), and Ms. Rhonda Lenai Jordan (Energy Specialist) have likewise made the thoughtful execution of this survey possible.

The support and contributions of the ESMAP team are gratefully acknowledged: Ms. Yabei Zhang (Senior Energy Specialist) on access to clean cooking section, Ms. Inka Ivette Schomer (Energy Specialist) on gender section, Mr. Hussain K Samad (Consultant), and Ms. Sandra Keller (Consultant) on overall report. The MTF Task Team Leaders—Ms. Dana Rysankova (Global Lead for Energy Access), Ms. Elisa Portale (Senior Energy Specialist), and Mr. Bryan Bonsuk Koo (Energy Specialist)—have been similarly vital to realizing the MTF's Kenya survey project. The MTF team would like to extend thanks to the Living Standards Measurement Study team, whose support and inputs were critical to the realization of the MTF. Additionally, the MTF team would like to thank Mr. Jay Taneja (Assistant Professor, University of Massachusetts), Mr. Dan Waddle, and Mr. Rakilbul Islam from NERCA International for their support in data and analysis. A special thanks is given to Mr. Leo Blyth (Lighting Global) for providing technical support for the MTF team in evaluating the off-grid solar market as well as in survey preparation, implementation, and analysis. Senior Energy Specialist Richard Hosier, Energy Specialist Caroline Ms. Adongo Ochieng, Ms. Alisha Pinto, Ms. Marina Brutinel (World Bank); Ms. Verena Brinkmann (Deutsche Gesellschaft fur Internationale Zusammenarbeit-GIZ); and Ms. Heather Adair-Rohani and Ms. Jessica Lewis (World Health Organization) provided comments on the section on access to modern energy cooking solutions section of this report.

ABBREVIATIONS

CIF	Climate Investment Funds
ERC	Electricity Regulatory Commission
ESMAP	Energy Sector Management Assistance Program
FGD	Focus Group Discussion
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit-
ICS	Improved Cookstove
KNES	Kenya National Electrification Strategy
K-OSAP	Kenya Off-Grid Solar Project
kWh	kilowatt hour
K Sh	Kenya Shilling[1]
LED	Light-Emitting Diode
LMCP	Last Mile Connectivity Project
LPG	Liquefied Petroleum Gas
MTF	Multi-Tier Framework
PAYGo	pay-as-you-go
RISE	Regulatory Indicators for Sustainable Energy
SCF	Strategic Climate Fund
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SHS	solar home system
SL	solar lantern
SLS	solar lighting system
UNDESA	United Nations Department of Economic and Social Affairs
VAT	value added tax
W	Watt
WHO	World Health Organization
WTP	willingness to pay

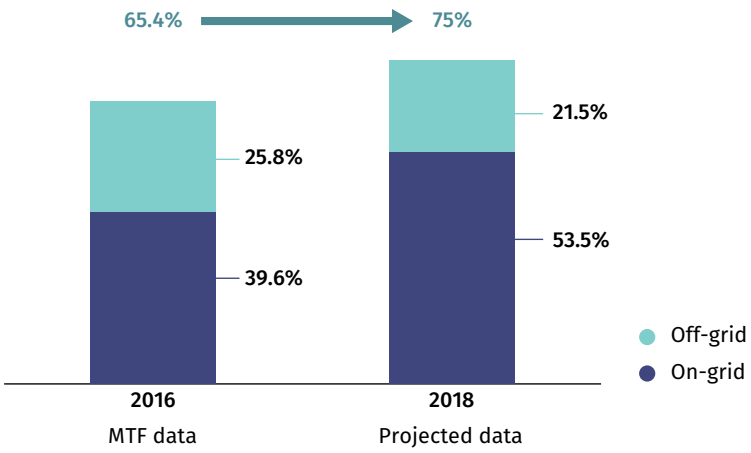
1 Exchange rate 100 K Sh~ 1USD on September, 2016

EXECUTIVE SUMMARY

Kenya has made great strides in increasing access to electricity to its population. The Multi-Tier Framework (MTF) survey has found about two-thirds of the population of Kenya having access to electricity (either from a grid or an off-grid connection) as of early 2016. Given the high pace of grid and off-grid electrification in the recent years, the MTF provided an updated estimate using extrapolation techniques, which found three-fourths of the population having access to electricity through grid and off-grid options by early 2018 (Figure ES1).

Kenya is well on its way to achieve universal access to electricity much earlier than the Sustainable Energy for All (SEforALL) goal of universal access by 2030. The Kenya National Electrification Strategy (KNES) launched in December 2018 provides a roadmap to achieving the universal electricity access goal by 2022. This initiative includes concerted efforts to increase access to electricity in the 14 under-served counties through grid, mini-grid, and off-grid options. The present report provides data on energy access from a household perspective that confirm the strategic directions taken by the government in KNES (for example, the need to provide public funding support for both grid and off-grid efforts in parallel, the already executed reformed connection policy to increase affordability of connections, and so forth). In addition, it provides additional disaggregated data that can inform implementation of KNES.

FIGURE ES1 • **Access to electricity in Kenya**



As of February of 2018, the electricity access rate stands at 75% based on the MTF extrapolated data and analysis: 53.5% have access through the national grid, while 21.5% use off-grid solutions as their main electricity source.

The Government of Kenya is also scaling-up its support to the clean cooking sector. To meet its commitment to provide access to clean cooking, the government has recently reduced the duties and taxes for clean cookstoves, raw materials, and their accessories as well as those on liquefied petroleum gas (LPG) to make the cooking technologies more affordable. The MTF survey data provide additional disaggregated information about cooking technologies and fuels (including stacking of fuels), consumer behavior, affordability, and other aspects to further guide the government's and other stakeholders' clean cooking engagements.

ACCESS TO ELECTRICITY

According to the MTF, the access rate of early 2018 in Kenya is 75%, based on the extrapolated MTF data. The main analysis presented in the report, however, is based on analysis from data collected during the survey period in 2016 and not the extrapolated numbers, as it would be impossible to extrapolate updated data for all indicators included in the report. The 2016 period is, therefore, considered "the present."

Out of 65.4% households with access, 22.7% use off-grid solar solutions as main sources of electricity, compared to 4.6% who use it as a backup.

In 2016, 65.4% of Kenyan households have access to at least one source of electricity: 39.6% are served by the national grid and 25.8% rely on off-grid sources**.** Off-grid solutions include solar home systems (SHSs), solar lighting systems, and solar lanterns that provide lighting, phone charging, and powering for devices such as TVs, radios, DVD players and other smaller domestic and productive appliances. Solar solutions are used by 22.7% of households; 2.6% of households use rechargeable batteries and 0.3% use diesel generators.

As per MTF Tier Framework for electricity access, all grid-connected households are classified as Tier 3[2] or above (37.9%), which means that they receive more than 8 hours of supply in a day (including at least 3 hours in the evening). It is noteworthy that over a third of grid-connected household are classified as Tier 5 (the highest tier), meaning they have access for at least 23 hours a day, with minimal interruptions, adequate quality, and affordable terms, confirming that for at least a third of its users the Kenya grid is capable of delivering this highest level of service. The households in Tier 1 (10.8%) and Tier 2 (4.5%) use off-grid technologies to meet their lighting and other basic electricity needs. Only a small percentage of off-grid solutions provide Tier 3 and Tier 4 access.

Nationwide, constraints to the MTF attributes of Reliability and Quality are the main factors keeping grid-connected households in Tiers 3 and 4 from reaching Tier 5. More than half the grid-connected households experience more than three outages a week, or more than 2 hours of interruptions per week placing these households in Tiers 3 or 4 for Reliability. Among grid-connected households, 17.5% have experienced appliance damage because of voltage fluctuations, placing these households in Tier 3.

To cope with power outages, households rely on kerosene lamps or off-grid solar solutions as a backup source of lighting. Six percent of rural households and 21% of urban households (out of total percentage of grid and off-grid users) use kerosene lamp as a backup source of lighting**.** About 13.1% of the grid-connected households use off-grid solar products as a back-up. Roughly 70% of the grid-connected households do not keep any backup source of lighting, and more urban households (28.5%) than rural households (5.8%) use a backup source.

The MTF survey has demonstrated that offering payment flexibility, such as payment on installment, can effectively address the burden of the high up-front cost of grid connection as well as the purchase of an off-grid solar devices. The financial burden (high cost of connection) was identified by households (urban 31% and rural 54%) as their biggest barrier to connecting to the grid. This constraint is higher than the lack of availability of the grid network (urban 16% and rural 27%), confirming that the demand side has higher connectivity constraints than the supply side. The Last Mile Connectivity Project (LMCP) has already started to address this issue by reducing the connection charges, offering payment flexibility such as payment on installment, and ready boards. The impact of new policy

2 Please see Annex 1 for details on MTF tier distribution.

changes under LMCP may not yet have been captured in the MTF survey results, as the survey was implemented in 2016, only a short time after the LMCP measures were adopted. The survey has, however, confirmed that households' willingness to pay for electricity connection increases significantly if the payment can be spread over a 12-month period. Affordability of off-grid solutions also remains an issue, although the survey has found that extended payment periods for up to 12 months increase households' willingness to pay from 43.2% to 82.3%. Further financial help, however, will likely be needed to connect all off-grid households to at least Tier 1, which is the target service level of KNES.

Out of 65.4% households with access, 22.7% use off-grid solar solutions as main sources of electricity, compared to 4.6% who use it as a backup. Urban households use off-grid solar products mainly for supplementing insufficient hours of electricity and frequent disruption of grid electricity. On the other hand, off-grid solar products are the main source of electricity in rural areas. It is noteworthy that 5.2% of households using off-grid solar solutions have high-capacity off-grid solar systems.

Households currently using off-grid solar products want to power more and higher capacity appliances: 39.4% of households using solar products want to own a TV, followed by those who want a refrigerator (16.5%) and mobile chargers (13.5%). The desire to use a refrigerator is higher among the urban solar users (32.1%), whereas among rural users the desire is higher for charging for mobile phones (14.3%) and radios (%13.9). About a quarter of all households want to have longer hours of service, and 17% want to power larger capacity appliances. These are expressed household preferences that do not reflect a willingness and ability to pay for those appliances. It is also worth mentioning that even grid-connected households do not often use larger capacity appliances. About three-quarters of rural households and even half of urban households with the grid connection mainly use the national grid electricity for lighting, mobile charging, listening to radios and DVD players, and watching television

Among households that use solar devices, over three-quarters paid for them up front, whereas 19.6% of rural households and 9.8% of urban households paid in installments. Among the households who bought solar devices through installments (14.7% households of total solar users), 50.0% of urban and 40.3% of rural households paid for their solar devices by a pay-as-you-go (PAYGo) model. The up-front payment is especially typical for smaller products, such as solar lanterns, while a payment plan is more common for SHS. In rural Kenya, a critical factor has been mobile PAYGo off-grid solar vendors' ability to leverage the popular M-Pesa mobile money and payments service for stand-alone solar products. The survey results also show that willingness to pay (WTP) increases with the length of installment period, for example, 52% households were willing to buy low capacity SHS as opposed to only 21% households with no installment offer.

A significant gap in access to electricity has been identified between 14 under-served counties and the rest of the country. These counties that are characterized by high poverty and infrastructure deficits, suffer from a lack of grid network. Grid access is significantly lower, at 20.9% compared to 42.7% for rest of the counties, reflecting the fact that grid infrastructure is less available in the sparsely populated areas of 14 under-served counties. Just 20.9% of households are connected to the grid compared to 42.7% of grid-connected households in the rest of the counties. Based on the peoples' perception, 54.3% of households in 14 under-served counties consider distance from the grid as main barrier to getting grid connection as opposed to 15.7% of households from rest of the counties. On the other hand, the off-grid penetration rate (30.5%) in the 14 counties is higher than in the rest of counties, suggesting that off-grid solar technologies are emerging as solutions to close the access gap in areas where the grid has not arrived. Despite the fact that off-grid penetration is higher in the 14 under-served counties, willingness to pay overall appears to be somewhat lower than in the rest of the country, reflecting most likely higher poverty levels in these counties, but potentially also lower awareness of off-grid technologies.

ACCESS TO CLEAN COOKING

More than two-thirds of Kenyan households (66.3%) rely on traditional biomass stoves for their primary cooking needs. Of those, the majority (59.8%) use the three-stone stove, and the remaining households (6.5%) use traditional charcoal stoves. Clean fuel stove and improved cookstove (ICS) users make up 15.6% and 10.1% of cookstove users in Kenya, respectively, while 8% of households use kerosene stoves.

Notable disparities exist in cooking technologies among rural and urban households. Eighty-four percent of rural households use traditional biomass stoves, of which 79% are three-stone stove users. **Clean fuel stove users are largely concentrated in urban areas, where 41.6% of households reported using LPG or electric stoves**. Kerosene stoves use is also predominant in urban areas, with 21% of households reporting use.

Notable disparities exist in cooking technologies among rural and urban households. Eighty-four percent of rural households use traditional biomass stoves, of which 79% are three-stone stove users. Clean fuel stove users are largely concentrated in urban areas, where 41.6% of households reported using LPG or electric stoves

Close to 30% of households nationwide reported using two or more stoves, although cookstove stacking is more popular in urban areas, where 35% of households reported using two stoves compared to 28% in rural areas. In urban areas, the most common combination is ICS-wood and kerosene stoves (7.3% of households), while in rural areas. the three-stone stove and traditional charcoal stove (7.1% of households) is the most common stacking combination.

The large proportion of households that rely on traditional biomass stoves means that many households are in low tiers according to the MTF framework: **70% of Kenyan households are classified in Tier 0, and only a fifth (19.7%) of households achieve Tier 3 or higher of the cooking aggregate tier.** Use of biomass stoves is also not necessarily cheap. The MTF survey shows that a third of traditional charcoal stove users spend more than 5% of their total expenditure on fuels—above the affordability threshold used by MTF.

More than 60% of households in Kenya spend 7.5 hours per week or more on fuel collection and preparation. The differences between rural and urban households are stark. In rural areas, about 75% of households reported spending 7.5 hours or more on fuel collection and preparation, compared to 30% of households in urban areas. Only 7% of households in rural areas achieve Tier 5 of the Convenience attribute.

Only the households in the top 20% expenditure quintile in Kenya are more likely to use clean fuel stoves and fewer biomass stoves. Thirty-six percent of clean stove users are in the top 20% quintile. However, even top quintile households revert to the use of traditional biomass stoves. For example, close to 26% of households using traditional charcoal stoves are in the top expenditure quintile. Top quintile households also account for about one-fifth of ICSs and one-fifth of kerosene stoves. These households present a clear opportunity to transition to clean fuel stoves.

The survey results also suggest that the use of ICSs could be significantly enhanced. With an installment payment extension offer from 6 to 12 months, the willingness to pay for improved cookstoves (lower tier cookstove priced at K Sh 380 (US$3.80) rose from 63%.7 to 72.0% (an 8.3% increase). The willingness increased from 57.7% to 87.4% (an increase of 30%) for a higher tier improved cookstove priced at US$41.40.

GENDER DIMENSION IN ACCESS TO ENERGY

Sex-disaggregated data of household heads reveal some disparities in electrification. Overall, fewer female-headed households have access to electricity in both urban and rural areas: 16.3% of female-headed households in urban areas do not have access to electricity, compared to 9.2% of male-headed households. Equally, a little over half (50.4%) of female-headed households in rural areas do not have access to electricity, compared to 45.3% of male-headed households. In rural areas, also, a larger proportion of male-headed households (34.3%) is likely to use off-grid solar solutions than female-headed households (23.6%).

There are fewer female-headed households in the top 20% expenditure quintile distribution in both urban (28%) and rural (10%) areas compared to male-headed households (31% urban and 16.4% rural) in Kenya. Female-headed households (26.8%) were more willing to purchase solar devices on installment periods of 6–12 months compared to 16.3% male-headed households.

Women spent more time on average in the cooking space. Women in Kenyan households reported spending on average 78 minutes per day in the cooking area, compared to about 62 minutes per day spent by male adults. Children under the age of 15 also spent on average 64 hours. These data show that while all family members are at risk of exposure to indoor air pollution, women are exposed to more indoor pollutants and are at a higher risk of respiratory illness than their male counterparts and bear a larger burden in terms of time poverty and drudgery.

POLICY RECOMMENDATIONS

MTF survey results provide several pointers to strategic policy directions. The Government of Kenya has already started integrating these recommendations, such as through the KNES and electrification programs such as the LMCP and Kenya Off-grid Solar Access Program. The disaggregated data presented in the report can provide further guidance for the implementation of these programs.

ACCESS TO ELECTRICITY

To connect the remaining quarter of the population, both grid and off-grid options would need to be pursued. The KNES, supported by the World Bank, has already identified, through geospatial tools, the least-cost options for connecting the remaining population by 2022. The grid areas identified under the KNES, and the LMCP is already addressing the affordability barrier. For off-grid areas, the World Bank–supported Kenya Off-Grid Solar Project has already started to support the least-cost technology (stand-alone or mini-grid) for providing access to electricity in the 14 under-served counties. The actual implementation of these programs, however, needs to address the number of remaining barriers. While affordability of grid connections has improved, the remaining quarter of the Kenyan population not connected to electricity typically belong to lower income quintiles, with lower affordability levels.

The MTF survey shows that Kenyan households still consider affordability of connections and of solar home systems a constraint. Offering payment plans is still the most effective financing mechanism for increasing access, but 17.7% of grid households and 48% of off-grid households would not accept the offer even with a 24-month payment plan. These households may need additional financial support to connect. The least-cost planning exercises should also consider the expected consumption levels of the newly electrified households. The MTF survey results show that the rural households typically consume low levels of electricity, and 79.9% of rural and 54.3% of urban households own only low-load appliances. For some of these households, off-grid solutions may be more cost-effective than grid connections, even if they are located relatively close to the grid infrastructure. Separately, the reasons for the limited use of appliances by grid-connected households should be investigated. Finally, while connecting everyone to at least Tier 1—as established in KNES—will be a formidable achievement, the electrification efforts should not stop there. There is no technology-inherent barrier to supplying all grid-connected households with Tier 5 service. A third of grid-connected households already receive this level of service. To bring the remaining households to this level, the government and Kenya Power will need to continue improving grid reliability (outages) and quality (voltage fluctuation). Equally, a Tier 1 off-grid system should be a start, not the end of electrification journey for off-grid households. As a starting point, the government should promote access to quality systems, which will allow households to maximize the usage of their systems and ensure longer-term functionality. The government has already taken steps in this direction by adopting the International Electrotechnical Commission's standards. As consumption of the off-grid households grows, measures should be taken to facilitate access to larger off-grid systems or to mini-grid or grid connections. Mini-grids have not yet played a significant role in Kenya's electrification, as noted in the MTF survey, but their role is expected to increase as they are becoming an increasingly cost-effective alternative to grid expansion, and their scale-up is a part of KNES and is being planned for the under-served counties under Kenya Off-Grid Solar Project (KOSAP).

SCALING-UP THE UPTAKE OF CLEAN COOKING SOLUTIONS

Nearly all Kenyan households have opportunities for improving their access to clean cooking solutions: 41.6% penetration of clean cookstoves in urban areas is a good start, but the continued use of biomass stoves and kerosene in urban areas, even among the highest expenditure quintile household, is a concern. The urban households using kerosene and ICSs present a clear opportunity to transition to clean fuel stoves—such as LPG or bio-ethanol use. This transition should be feasible for higher quintile households that are not likely to suffer from clean fuel affordability issues. For lower income households, innovative financing solutions should be devised. A PAYGo option, for example, has been cited as a good channel through which consumers can pay for limited quantities of LPG fuel without buying in bulk. These and similar innovations should be supported. The persistent use of three-stone or traditional stoves in rural areas is also a concern. The MTF survey reveals a relatively high willingness to pay for ICSs, even in rural areas. This WTP can be further enhanced by offering a payment plan. Such solutions should, therefore, be promoted more aggressively in rural areas, with a more nuanced understanding of the supply- and demand-side constraints to their adoption. To move households in Tier 0–1 to a higher tier would require promotion of high-performance biomass stoves, including biodigester stoves. In addition, public awareness about the potential benefits of clean fuels would be

useful, including fuels that are less known by households, such as bio-ethanol. Advances in electric cooking technologies also enable greater use of electric cooking in Kenya. To take advantage of this alternative, however, it is important to expand electricity access to households still without electricity and to ensure regular and reliable supply.

ACHIEVING GENDER PARITY IN ACCESS TO ENERGY

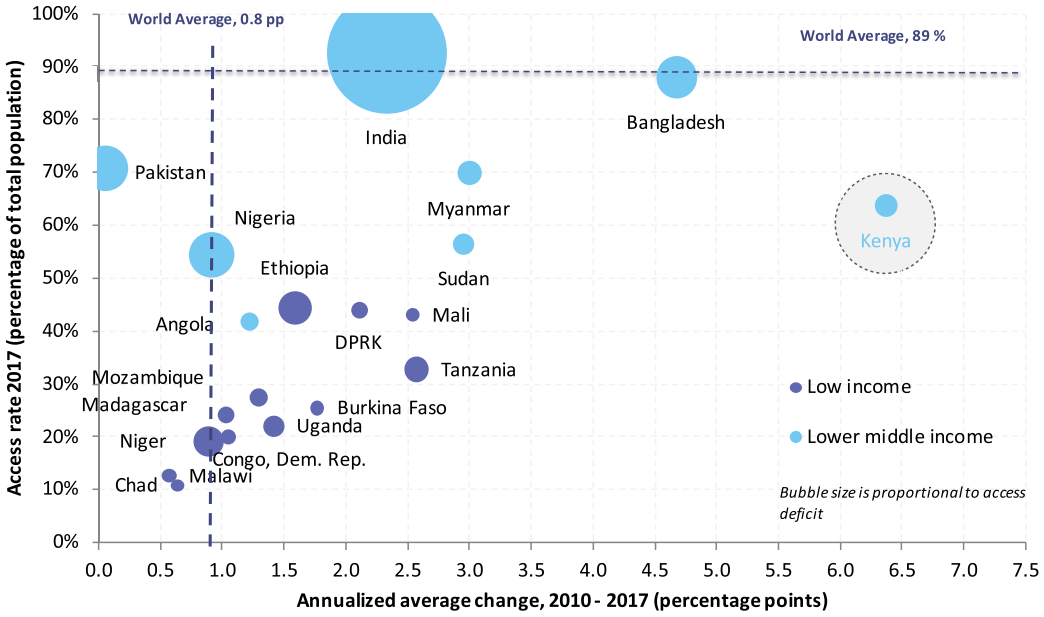
Specific financing mechanisms that enable both men and women to access energy services are required to increase grid connections for female-headed households and to enable female-headed households to benefit equally from off-grid solar solutions. This is mainly due to the observed affordability constraints, which are greater for female-headed households. More female-headed households (44.7%) than male-headed households (32.3%) are not willing to pay for grid connection (US$100 for connection fee). For ICSs, 34.7% of female-headed households and 27% of male-headed households show no willingness to pay. Thus, targeted support for a grid connection and ICSs could significantly improve access to modern energy services for female-headed households and women overall. Women and women's groups should be involved in the design of clean and improved biomass stoves, as well as of financing mechanisms and awareness and public campaigns that involve clean and improved biomass stove adoption, as women remain the primary users of the technology and are most likely to be exposed to health impacts and time poverty and drudgery.

MEASURING ENERGY ACCESS IN KENYA

Energy is vital to promoting economic growth, overcoming poverty, and buoying human development. As such, gaining energy access is a precondition to reaching many development goals. The studies analyzing data from household surveys in Sub-Saharan Africa have found positive impacts of electrification on total income ((Jimenez, 2017), agricultural productivity (Salmon and Tanguy 2016), employment (Dinkelman 2011), and education and health benefits for households (World Bank 2015). Sustainable energy has been identified as critical to enduring access to affordable, reliable, sustainable, and modern energy for all; the aim is to achieve this Sustainable Development Goal (SDG) goal by 2030. Kenya government has taken many steps in realizing their SDG 7.1 goals for improving access to electricity and clean cooking. The pace of grid electrification has accelerated significantly in recent years. Kenya is considered the global leader in the adoption of off-grid solar technology (see box 1 for details on policy efforts made by Kenya to promote sustainable energy solutions). The country has the largest, most diversified economy and the second largest population in East Africa and has become a leader in mobile money and information and communication technology. In 2017, the population of Kenya was estimated to be at 45.8 million, with an inter-censual population growth rate of 2.9 % and is expected to reach 52 million in 2020 to about 65 million by 2030 (UNDESA 2017). Despite the growing urbanization, the population remains predominantly rural. Kenya has a 73.8% rural and 27.2% urban population (World Bank 2016).

According to the latest survey carried out by the Kenya National Bureau of Statics, Kenya's electrification rate was 56% in 2016 (based on the country's Demographic and Health Survey of 2016). According to the Global Tracking SDG7 report (World Bank 2018), since 2010 Kenya has increased the electrification rate by about six percentage points annually, significantly outperforming the rest of the world (Figure 1).

FIGURE 1 • **Rate of grid connection in Kenya**

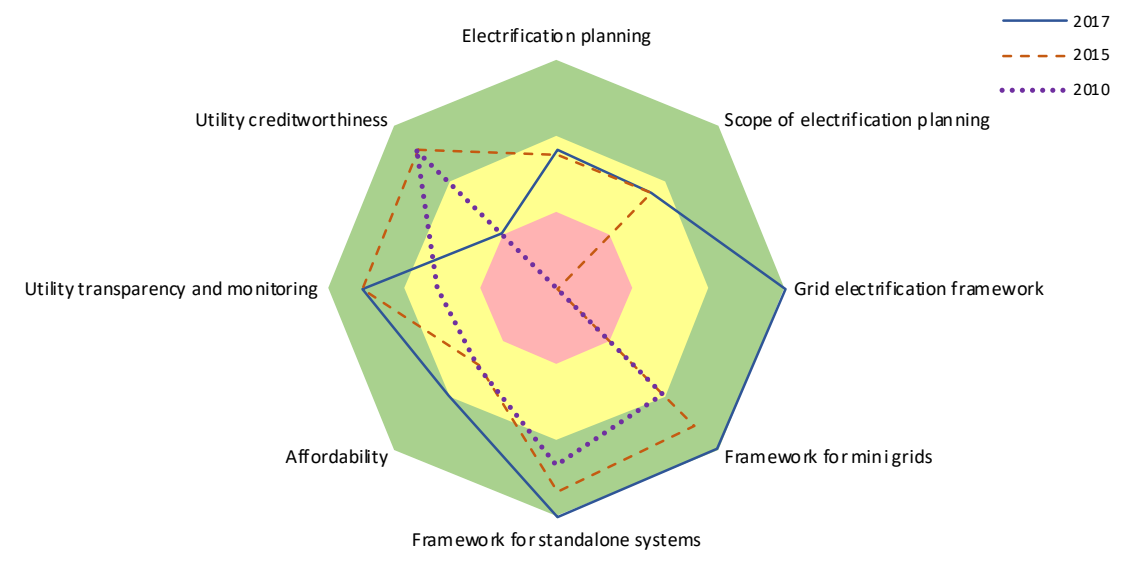


Source: World Bank 2018.

BOX 1 • KENYA IS ONE OF THE TOP PERFORMERS IN SUB-SAHARAN AFRICA ON REGULATORY INDICATORS FOR SUSTAINABLE ENERGY (RISE)

Through a series of indicators, RISE assesses policies and regulations that enhance sustainable energy—including electricity access, energy efficiency, and renewable energy—across 133 countries. The 2018 RISE update highlighted that Kenya has a thriving policy apparatus for grid electrification as well as mini-grids and stand-alone systems (see figure B1.1). Correspondingly, rural electrification policies are well designed to take advantage of grid extension and off-grid technologies, supported by a dedicated funding line in the national budget for rural electrification and connection fee subsidy to address last-mile connectivity issues. While the overall policy and regulatory framework for electricity access is robust, and most of the policies are action oriented, institutional support for laying down and enforcing targets could be strengthened. Kenya has also been able to provide affordable subsistence electricity of 30 kWh per month to the poorest 40 percent. However, the creditworthiness of Kenya's largest utility (Kenya Power and Lighting Company Ltd.) has seen a decline between 2010 and 2017.

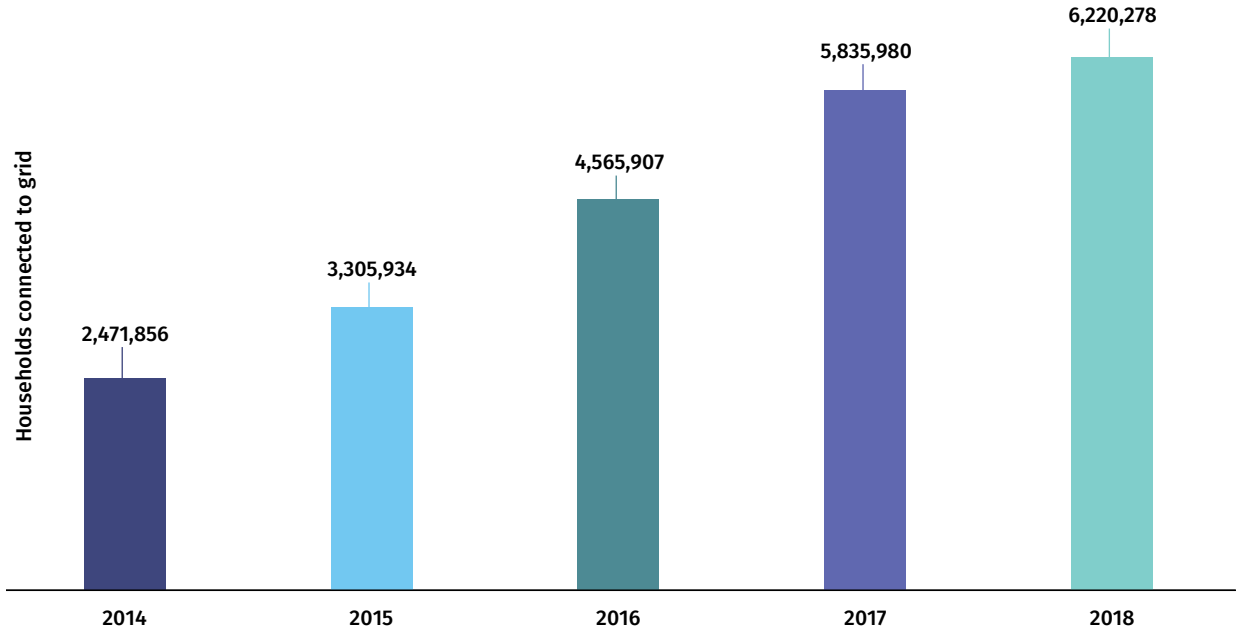
FIGURE B1.1 • Evolution of Kenya's RISE score on electricity access indicators between 2010 and 2017



Source: World Bank 2018.

The Last Mile Connectivity Program (LMCP)—a flagship effort by the Kenyan government aimed at providing affordable grid connection—has been successful in connecting millions of households since 2015. (LMCP 2016). The Kenya Power customer base has steadily increased each year, by more than 3.7 million between 2014 and 2018 (Figure 2).

FIGURE 2 • **Increase in grid electricity connection over the years in Kenya**



The Kenya National Electrification Strategy (KNES) launched in December 2018 provides a roadmap to achieving the electricity access goal by 2022 through a combination of grid extension and mini-grid and off-grid solar scale-up. The government is also acting on its commitment to provide access to clean cooking. Among other things, the Kenyan government in its 2016–17 budget announced the removal of the 16% value added tax (VAT) on liquefied petroleum gas (LPG). The government also reduced the import duty on efficient cookstoves from 25% to 10% and placed a zero-rating VAT on clean cookstoves, raw materials, and their accessories to make the cooking technologies more affordable.

Despite efforts and progress made to connect households to the grid, the 14 under-served counties, located mostly in the north and northeast of Kenya are lagging in the energy access compared to rest of the country (Map 1). These counties collectively represent 72% of the country's total land area and 20% of the country's population, including historically nomadic societies that even today continue to rely on pastoralism. Their population is highly dispersed, at a density four times lower than the national average. They present profound infrastructure deficits, including lack of access to roads, electricity, water, and social services. They have higher poverty levels than the rest of Kenya. There is also significant insecurity in certain areas, particularly those bordering conflict areas in neighboring countries, giving rise to substantial numbers of displaced persons and livelihood adaptations that further undermine economic prosperity (K-OSAP and World Bank 2017). The KNES, therefore, puts a particular emphasis on electrification of these counties, and the government has launched a World Bank–funded Kenya Off-Grid Solar Access Project (K-OSAP) to scale-up mini-grid and off-grid solutions as well as efforts to increase access to modern cooking solutions in these 14 counties.

THE MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with the support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the Multi-Tier Framework (MTF) approach. The first phase is being carried out in 17 countries across Latin America, Africa, and Asia. The survey's objective is to provide more nuanced data on energy access, including access to electricity and cooking solutions. The MTF approach goes beyond the traditional binary measurement of energy access—for example, having or not having a connection to electricity, using or not using clean fuels in cooking—to capture the multi-dimensional nature of energy access and the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[3]

The MTF approach measures energy access provided by any technology or fuel based on a set of attributes that capture key characteristics of the energy supply that affect the user experience. Based on those attributes, it then defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access) along with a continuum of improvement. Each attribute is assessed separately, and the overall tier for a household's access to electricity is the lowest applicable tier attained among the attributes (Bhatia and Angelou 2015).

3 The MTF access rate includes access provided by off-grid technologies, which is often excluded by the binary rate, but excludes energy solutions that do not meet its criteria for minimum level of service.

ACCESS TO ELECTRICITY

Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety. Tier 0 refers to households that receive electricity for less than 4 hours per day (or less than 1 hour per evening) or that have a primary energy source with a capacity of less than 3 W. (see box 2 for minimum requirements by tier of electricity access.) Tier 1 refers to households with limited access to small quantities of electricity provided by any technology, even a small solar lighting system (SLS) (see box 3 for a typology of off-grid solar devices), for a few hours a day, enabling electric lighting and phone charging.

- ***Capacity*** ("What appliances can I power?"): The capacity of the electricity supply (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate various appliances, ranging from a few watts for light-emitting diodes (LEDs) and mobile phone chargers to several thousand watts for space heaters or air conditioners (see Table 1; and Annex 1).

- ***Availability*** ("Is power available when I need it?"): The availability of supply refers to the amount of time during which electricity is available. It is measured through two indicators: the total number of hours per day (24-hour period) and the number of evening hours (the 4 hours after sunset) during which electricity is available.

- ***Reliability*** ("Is my service frequently interrupted?"): The reliability of electricity supply is a combination of the frequency and the duration of unexpected disruptions.

- ***Quality*** ("Will voltage fluctuations damage my appliances?"): The quality of the electricity supply refers to the absence of severe voltage fluctuations that can damage a household's appliances.

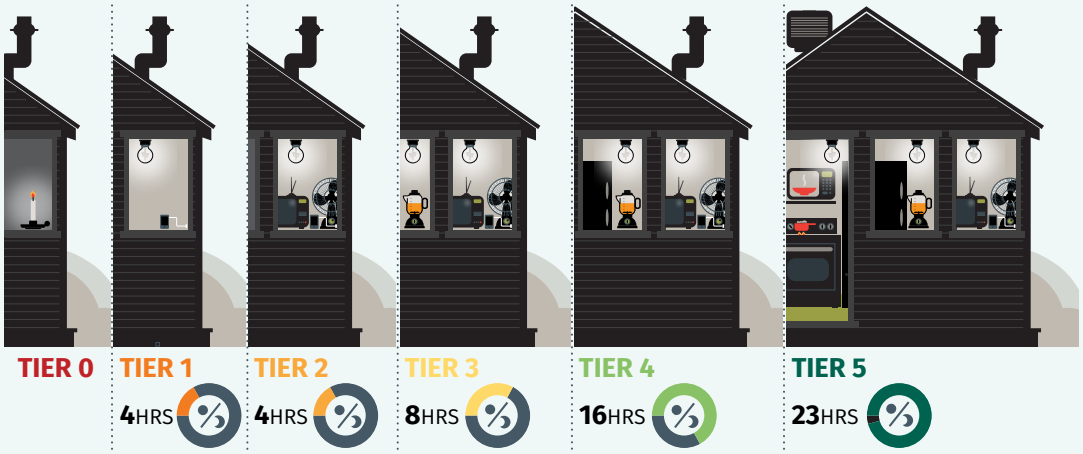
- ***Affordability*** ("Can I afford to purchase the minimum amount of electricity?"): The affordability of the electricity service is determined by whether the cost of a standard consumption package of 365 kWh a year is less or more than 5% of a household's annualized expenditure.

- ***Formality*** ("Is the service provided formally or by informal connections?"): If households use the electricity service from the grid, but do not pay anyone for the consumption, their connection could be defined as an informal connection.

- ***Health and Safety*** ("Is it safe to use my electricity service?"): The spectrum of electrical injuries is broad, ranging from minor burns to severe shocks and death. The Health and Safety attribute relates to high-risk, permanent injuries from the energy supply.

For each of these attributes, households are placed in a tier depending on the level of service as defined by the different thresholds. (See Annex 1 for thresholds in the multi-tier matrix for measuring access to electricity).

BOX 2 • MINIMUM ELECTRICITY REQUIREMENTS, BY TIER OF ELECTRICITY ACCESS



Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least 4 hours of electricity per day is available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio (see table 1). Sources that can be used to meet these requirements include a Solar Lighting System (SLS), a Solar Home System (SHS), a mini-grid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), or the national grid.	At least 4 hours of electricity per day is available (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances—such as multiple lights, a television, or a fan (see table 1)—as needed during that time. Sources that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, or the national grid.

Tier 3	Tier 4	Tier 5
At least 8 hours of electricity per day is available (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances—such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1)—as needed during that time. In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, or the national grid.	At least 16 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1)—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids or the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high–load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source for meeting these requirements is mini-grid or the national grid.

Source: World Bank, 2015

BOX 3 • TYPOLOGY OF OFF-GRID SOLAR DEVICES BASED ON CAPACITY

Solar devices are classified into three types based on the number of lightbulbs and the type of appliances or electricity services a household uses. This typology is used to assess the Capacity attribute and the related tier.

Solar lanterns power a single light bulb and allow only part of the household to be classified in Tier 1 for Capacity. Under the MTF methodology the number of household members in Tier 1 is based on the light output (lumen-hours) and phone charging capability of the solar lantern.

Solar lighting systems (SLS) power two or more light bulbs and allow part or the entire household to be classified in Tier 1 for Capacity.

Solar home systems (SHS) power two or more light bulbs and appliances such as televisions, irons, microwaves, or refrigerators. See Table 1 for the load level associated with each Capacity tier.

TABLE 1 •Appliances by load level and associated Capacity tiers

Load level	Indicative electric appliances	Capacity tier typically needed to power the load
Very low load (3–49 W)	Incandescent light bulb, fluorescent tube, compact fluorescent light (CFL) bulb, LED light bulb, Torch/flashlight/lantern, Radio/CD Players/sound system, Smartphone (internet phone) charger, Regular mobile phone charger	TIER 1
Low load (50–199 W)	Television B/W, computer, fan, flat color TV, regular color TV, VCD/DVD	TIER 2
Medium load (200–799 W)	Indoor air cooler, refrigerator, electric water pump, electric food processor/blender, rice cooker, freezer, electric sewing machine, electric hot water pot/kettle	TIER 3
High load (800–1,999 W)	Washing machine, electric iron, microwave oven, hair dryer	TIER 4
Very high load (2,000 W or more)	Air conditioner (AC), space heater, electric water heater, solar based water heater	TIER 5

Source: Bhatia and Angelou, 2015

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Despite the well-documented benefits of access to clean cookstoves, about 3 billion of the world's population still use polluting, inefficient cooking solutions that emit toxic smoke. The inefficient use and incomplete combustion of solid fuels have significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009). Fuel collection and cooking tasks are often carried out by women and girls; collection time depends on the local availability of fuel and may reach up to several hours per day (ESMAP 2004; Gwavuya et al. 2012; Parikh 2011; Wang et al. 2013). Time spent in fuel collection often translates into lost opportunities for gaining education and increasing income (Blackden and Wodon 2006; Clancy, Skutch, and Batchelor 2003). In addition, associated drudgery increases the risk of injury and attack (Rehfuess, Mehta, and Prüss-Üstün 2006).

The use of inefficient cooking fuels such as charcoal, fuelwood, and animal dung have been linked to negative environmental and socioeconomic outcomes, including pneumonia in children under the age of 5 years; premature deaths, and respiratory illnesses resulting from indoor pollution, environmental degradation, and poverty (WHO 2018). An estimated 14,300 premature deaths were reported to have occurred in Kenya in 2010 as a result of indoor pollutants resulting from cooking with traditional stoves (Pope et al. 2010). Women and girls, who bear the burden of fuel collection and cooking in Kenya due to traditional gender roles, are even more exposed to open fires and harmful substances—and lose time that could be spent in school or in productive economic activities (see box 4 for details on the typology of cookstoves used in Kenya). To this end, there are global effort to encourage households to use efficient, clean, and more sustainable cookstoves to optimize the substantial health and economic benefits related to the use of clean fuel stoves.

The MTF measures access to modern energy cooking solutions and is based on six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Affordability, Safety of Primary Cookstove, and Fuel Availability (see Table A.1.2 in Annex 1).

- ***Cooking Exposure*** ("How is the user's respiratory health affected?"): This attribute assesses personal exposure to pollutants from cooking activities, which depends on stove emissions and ventilation structure (which includes cooking location and kitchen volume).[4] Thus, Cooking Exposure is a proxy indicator to measure the health impacts of the cooking activity on the primary cook. This attribute is a composite measurement of the emissions from the cooking solution, that is, a combination of the stove type and fuel (Stove Emission indicator), mitigated by the ventilation in the cooking area (Ventilation Structure indicator). The Cooking Exposure Tier is assigned as a composite of Stove Emission indicator and Ventilation Structure indicator is weighted by the amount of time spent on each stove, if a household relies on multiple stove types.

- ***Cookstove Efficiency*** ("How much fuel will a person need to use?"): This attribute is a combination of combustion efficiency and heat-transfer efficiency. Laboratory testing of the efficiency of various types of cookstoves informs the breakdown of efficiency levels by cookstove and fuel combinations.

- ***Convenience*** ("How long does it take to gather and prepare the fuel and stove before a person can cook?"): This attribute is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and their stove for cooking. Convenience is measured through two indicators. First, the amount of time household members spend collecting or purchasing cooking fuel and preparing the fuel (in minutes per week) and the amount of time needed to prepare the cookstove for cooking (in minutes per meal).

- ***Affordability*** ("Can a person afford to pay for both the stove and the fuel?"): This attribute assesses a household's ability to pay for the primary cooking solution (cookstove and fuel). Affordability is measured using the levelized cost of the fuel. A cooking solution is considered affordable if a household spends less than 5% of the total household expenditures on its cooking fuel. In this report, however, Affordability is measured using the cooking fuel expenditure only. The cost of the cookstove is not considered.

- ***Safety of Primary Cookstove*** ("Is it safe to use the stove?"): The degree of safety risk can vary by type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, or potential for fuel splatter. This attribute is measured through reported incidences of past injury and/or fire.

4 In this report, *ventilation is defined as using a chimney, hood, or other exhaust system while using a stove or having doors or windows in the cooking area. The ventilation factor plays a role in mitigating pollutants from cooking.*

- ***Fuel Availability*** ("Is the fuel available when a person needs it?"): The availability of a given fuel can affect the regularity of its use; shortages in the fuel can force households to switch to inferior fuel types. This attribute assesses the availability of fuel when needed for a household's cooking purposes.

A methodology similar to the electricity framework is applied to obtain the aggregate tier for modern cooking solutions. The lowest tier among the attributes is taken as the final tier for the household. (For more information on the threshold and tier calculation, see Annex 1.)

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

The MTF survey provides detailed energy data at the household level for governments, development partners, the private sector, nongovernmental organizations, investors, and service providers. On the supply side, it captures data on all energy sources that households use, with details on each MTF attribute. On the demand side, it provides data on energy-related spending; energy use; user preferences; willingness to pay (WTP) for the grid, off-grid, and cooking solutions; and customers' satisfaction with their primary energy source.

BOX 4 • TYPOLOGY OF COOKSTOVES IN KENYA

Cookstoves in Kenya were classified into four categories based on existing literature and consultation with development partners and government officials during the MTF survey meetings. See Annex 2 for detailed information.

- **Three-stone stove**: A traditional biomass stove with open fires and little to no ventilation. Fuel sources is predominantly firewood. (Stove emission level is assigned as Tier 0.)
- **Traditional charcoal stove**: Mostly made from scrap metal. Open fire stove that uses charcoal as primary fuel source. (Stove emission level is assigned as Tier 0 or 1 based on features of the stove.)
- **Improved cookstove (ICS)—wood**: May have a ceramic liner and improved insulation compared to the traditional stove. It uses less fuelwood than the traditional biomass stove, releases fewer fuel emissions compared to the traditional wood stove and has openings on the side to regulate air flow. (Stove emission level is assigned as Tier 1, 2, or 3 based on features of each stove type.)
- **ICS—charcoal**: May have a ceramic liner and improved insulation compared to the traditional stove. Charcoal is the primary fuel for this stove. Compared to the traditional biomass stove that uses firewood, the ICS firewood stove is more efficient (due its insulation qualities) and uses less charcoal. It also emits fewer fuel emissions than the traditional charcoal stove. The rocket stove and multi-purpose stove are examples of the ICS charcoal stove. (Stove emission level is assigned as Tier 1, 2, or 3 based on features of each stove type.)
- **Kerosene stove**: Two main types of kerosene stoves exist, the pressure and wick kerosene stove. Both use kerosene or paraffin as their main cooking fuel. Kerosene stoves are relatively inexpensive to produce, use the most affordable cooking fuel, and are easily accessible. The fuel is, however, highly flammable and polluting. (Stove emission level is assigned as Tier 2.)
- **Clean fuel stove**: Two categories of stoves fall under this heading: the LPG stove, which uses LPG as a primary fuel, and the electric stove. (Stove emission level is assigned as Tier 5.)

Insights from MTF data enable governments to set country-specific access targets. The data can be used in setting targets for universal access based on the country's conditions, resources available, and the target date for achieving universal access. They can also help governments balance the goal of improving energy access to existing users (raising electrified households to higher tiers) and the goal of providing new connections—and to determine what minimum tier the new connections should target.

MTF data can inform the design of access interventions, in addition to prioritizing them so that they may have the maximum impact on tier access for a given budget. The data can be disaggregated by attribute and technology, providing insight into the deficiencies that restrict households in lower tiers and the key barriers—such as lack of generation capacity, high energy cost, or a poor transmission and distribution network. Access interventions can thus be targeted to maximize household access. MTF data provide guidance about what technologies are most suited to satisfy the demand of non-electrified households (for example, grid or off-grid). And MTF data on demand—such as energy spending, WTP, energy use, and appliances—inform the design and targeting of their programs, projects, and investments for energy access.

The MTF surveys provide four types of disaggregation: by urban-rural location, by quintile, by technology and by the gender of household head. For gender-disaggregated data, non-energy information such as socioeconomic status is also collected. Indicators such as primary energy source, tier of access, energy-related spending, WTP, and user preferences are disaggregated by male-headed and female-headed households. Such disaggregated analysis could add value to energy access planning, implementation, and financing. The MTF survey provides additional gender-related information, including information on gender roles in determining energy-related spending and gender-differentiated impacts on health and time use.

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN KENYA

MTF data collection in Kenya started in 2016 and was completed in 2018. The household survey sample selection was based on a two-stage stratification aimed at achieving a nationally representative sample. A total of 3,300 households was surveyed (Map 2), following the stratification criteria: 50:50 ratio of electrified and non-electrified households for the MTF tier analysis and equal allocation between urban and rural areas. The results of the MTF survey data collection and analysis were presented to the Government of Kenya on October 22, 2018.

The nationally representative core sample of 3,300 households was selected proportionally from Kenya's 47 counties combined with several over-sampled groups (Table 2). The over-sampling was done for the 14 under-served countries, which were to be supported by a new K-OSAP, supported by the World Bank, and slum areas in Nairobi, which have recently been electrified by Kenya Power with support of the World Bank and the Global Partnership on Output-Based Aid. The additional data and analysis (over-sampling) done in the 14 under-served counties aimed to understand the challenges and barriers pertaining to access to electricity and clean cooking. The survey provides key insights into supply alternatives that households are using and additional demand data on energy-related expenditure, as well as into user preferences and satisfaction with service. See Annex 3 for details.

The slum data and analysis are not included in the report and will be published as a separate report along with results from Energy Supply Monitoring Initiative project.[5]

5 The Electricity Supply Monitoring Initiative is jointly implemented in Nairobi by Prayas, India; World Resources Institute; and ESMAP, World Bank.

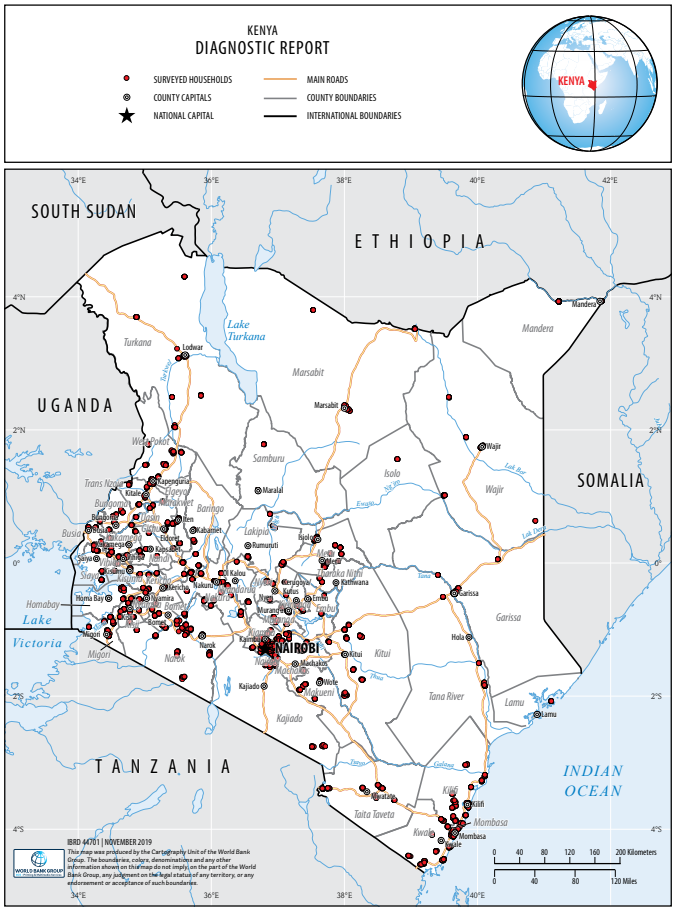
TABLE 2 • **Distribution of enumeration areas and sampled households, MTF Survey**

No. of counties	County	Households	Education facilities	Health facilities	Government offices	Worship facilities	Community (FGD6)	Total
1	Baringo	86	10	3	2	3	8	112
2	Bomet	78	9	5	4	4	4	104
3	Bungoma	77	5	2	1	7	5	97
4	Busia	47	6	2	2	2	3	62
5	Elgeyo Marakwet	42	6	2	2	3	3	58
6	Embu	41	3	1	0	1	0	46
7	Garissa	93	21	10	0	9	3	136
8	Homa Bay	91	7	1	0	4	4	107
9	Isiolo	67	5	2	3	4	3	84
10	Kajiado	74	7	0	1	6	5	93
11	Kakamega	84	5	0	1	3	7	100
12	Kericho	52	6	1	2	4	3	68
13	Kiambu	210	14	7	6	10	15	262
14	Kilifi	292	24	5	6	5	15	347
15	Kirinyaga	53	3	0	0	3	0	59
16	Kisii	131	12	2	3	6	8	162
17	Kisumu	103	11	3	3	5	8	133
18	Kitui	160	7	3	3	5	8	186
19	Kwale	156	11	6	6	12	11	202
20	Laikipia	37	7	1	2	2	3	52
21	Lamu	23	5	0	0	0	3	31
22	Machakos	106	12	3	4	9	6	140
23	Makueni	103	6	2	4	8	6	129
24	Mandera	76	4	0	1	5	5	91
25	Marsabit	80	3	4	2	3	5	97
26	Meru	109	10	0	4	4	2	129
27	Migori	75	10	3	0	0	3	91
28	Mombasa	144	10	5	1	1	10	171
29	Muranga	88	7	1	0	6	7	109
30	Nairobi core							
31	Nakuru	287	10	1	4	6	13	321
32	Nandi	66	2	0	1	6	5	80
33	Narok	239	38	12	14	12	15	330
34	Nyamira	98	7	2	1	1	4	113
35	Nyandarua	29	3	0	1	0	3	36
36	Nyeri	67	6	2	1	5	6	87
37	Samburu	46	9	3	4	5	4	71

6 FDG-Focus group discussion were conducted by the survey firm to collect information on energy access at the community facilities.

No. of counties	County	Households	Education facilities	Health facilities	Government offices	Worship facilities	Community (FGD6)	Total
38	Siaya	79	4	0	1	4	4	92
39	Taita Taveta	117	9	3	2	4	9	144
40	Tana-River	39	3	0	1	6	4	53
41	Tharaka-Nithi	41	4	2	6	3	1	57
42	Trans Nzoia	61	4	0	0	2	5	72
43	Turkana	140	11	11	11	15	6	194
44	Uasin Gishu	94	5	3	0	1	7	110
45	Vihiga	45	11	2	0	4	4	66
46	Wajir	95	3	0	0	1	8	107
47	West Pokot	152	23	6	6	5	12	204
	TOTAL	**4,473**	**398**	**121**	**116**	**214**	**273**	**5,595**

MAP 1 • **Sample distribution**



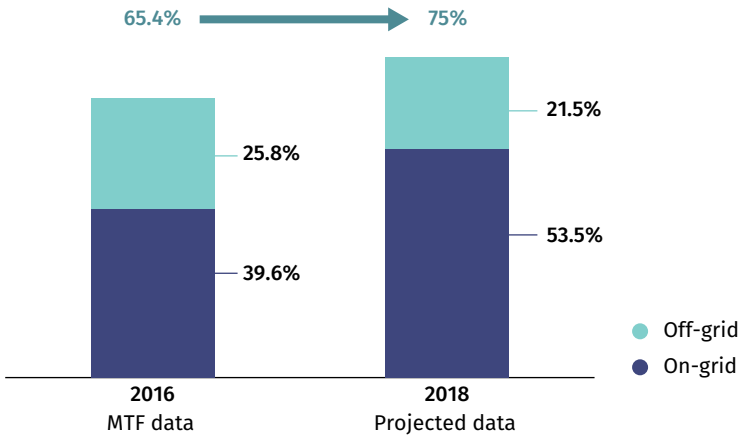
Basic MTF 47 counties
3,300 households

Over-sampling 14 marginalized counties
1,100 households

ACCESS TO ELECTRICITY

The concerted efforts by the government, development partners, and private sector in Kenya have paid off, and as of February 2018, electricity access rate stands at 75% based on the projection using MTF extrapolated data and analysis (Figure 3). In Kenya, 75% of households have access to at least one source of electricity: 53.5% have access through the national grid, while 21.5% use off-grid solutions as their primary electricity source. In addition, as per the MTF analysis, about 13.1% of the grid-connected households also use off-grid solar products. The extrapolated data provides an estimated access rate, but the rest of the data and analysis in the report is based on the data collected in 2016.

FIGURE 3 • **Access to electricity, grid and off-grid based on extrapolation for 2018 (nationwide)**

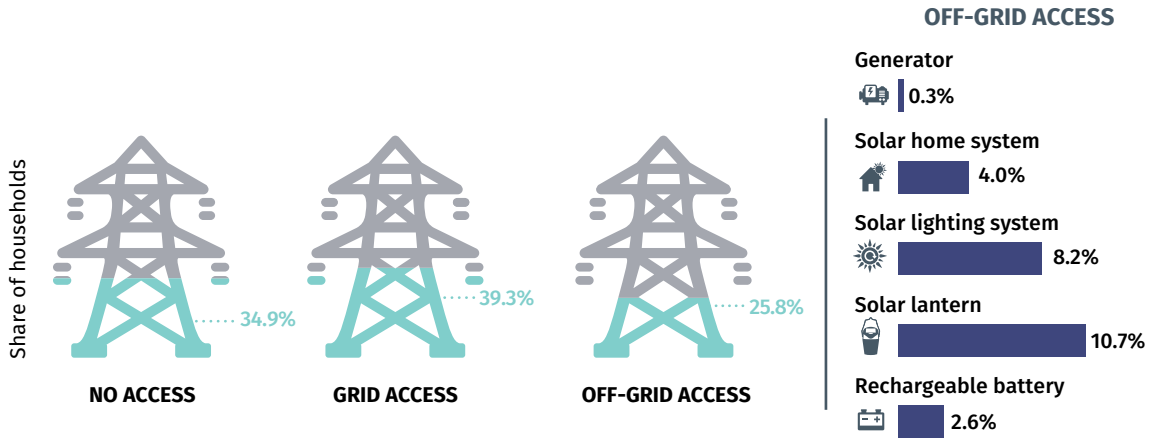


Note: The projected access rate was calculated based on the MTF, Kenya Integrated Household Budget Survey(KIHBS) data and off-grid solar data from the Lighting Global.

TECHNOLOGIES

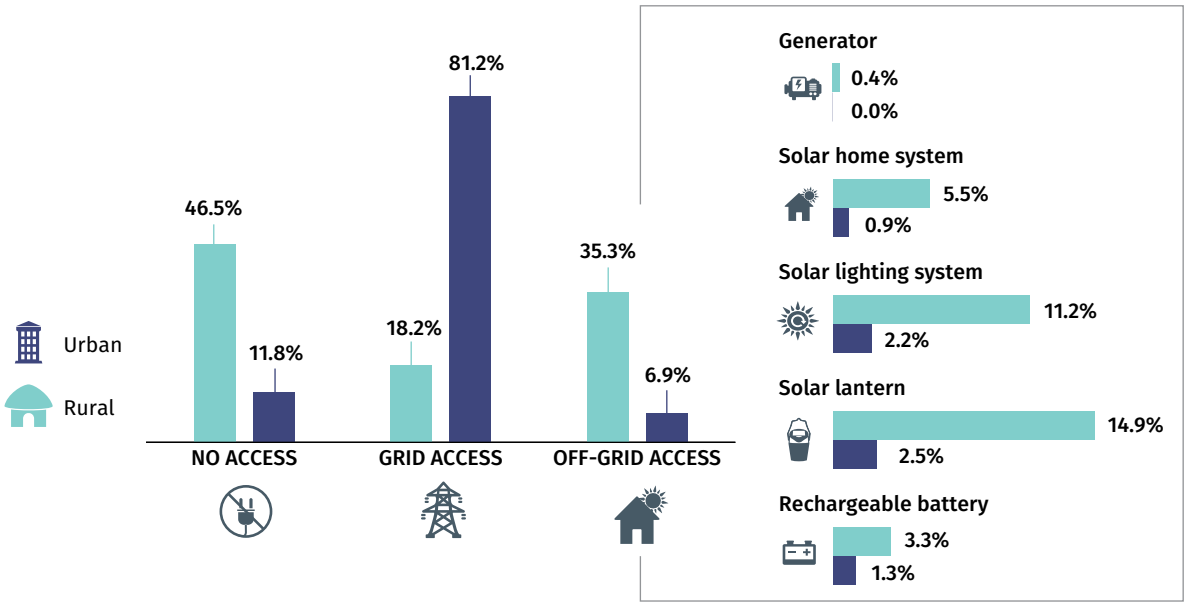
As per the MTF survey completed in 2016, 65% of Kenyan households have access to at least one source of electricity: 39.6% of households are served by the grid and 25.8% rely on off-grid sources. (Figure 4) Off-grid solar solutions are the most common off-grid source (22.9%), consisting of solar home systems (SHSs) solar lighting systems (SLSs), and solar lanterns. In addition, 2.6% of households use rechargeable batteries and 0.3% use diesel generators. During the time of survey, mini-grids were not common and therefore do not appear as a significant source of electricity in the survey results, but moving forward, the government is coming up with an ambitious plan to scale-up mini-grids, and especially in the under-served counties their contribution is expected to increase in the future.

FIGURE 4 • **Access to electricity and off-grid technology, nationwide**



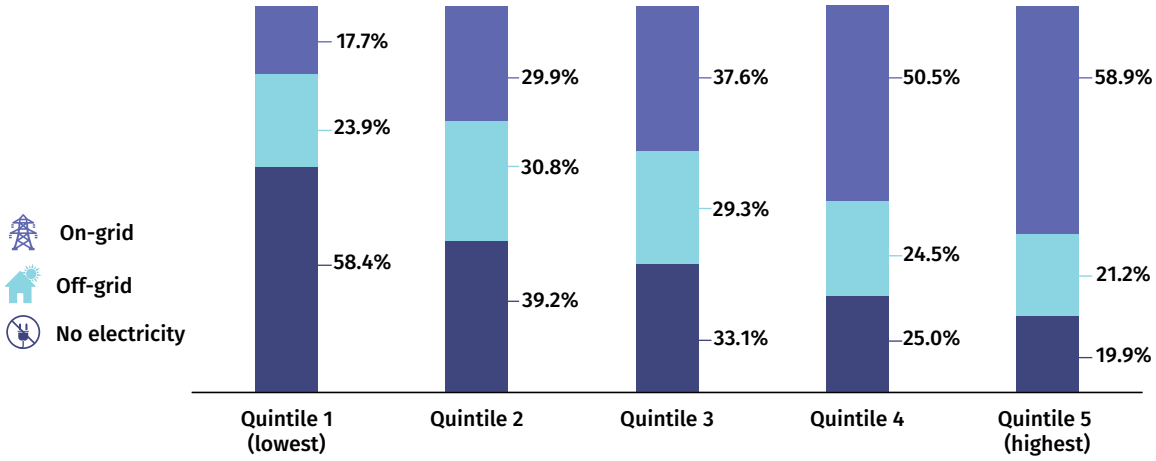
Discrepancies in electricity access among urban and rural households are wide (Figure 5). In rural areas, 46.5% of households lack access, in comparison to only 11.8% of urban households. The discrepancy is the highest for grid users. While over 80 percent of the urban population has access to grid electricity, less than 20% of the rural population has grid access. On the other hand, in the absence of grid, many rural households rely on off-grid sources, and the solar solutions occupy the most dominant space in this arena followed by rechargeable batteries and diesel generator. Thirty-five percent of rural households use off-grid solutions, compared to only 7% of urban households.

FIGURE 5 • **Electricity access and off-grid technology, urban and rural areas**



Similar disparity exists among expenditure quintiles. The national grid is the most used source of electricity by the higher quintile groups, while off-grid energy solutions are more widely used by lower expenditure quintile groups: 30% of the top spending quintile households and 9.1% of the lowest spending quintile are connected to the grid. On contrary, off-grid solutions benefit disproportionately the bottom 40% of the population. Households in the two lowest quintiles are more likely to rely on off-grid solutions than grid (Figure 6), because off-grid solutions are more affordable or are the only available electrification option for these households. Still, the majority of households in the lowest quintile has no electricity, sugesting that furhter innovations in business models and financing are needed to bring affordable grid, mini-grid, or off-grid solutions to this population segment.

FIGURE 6 • **Electricity access, by expenditure quintile**



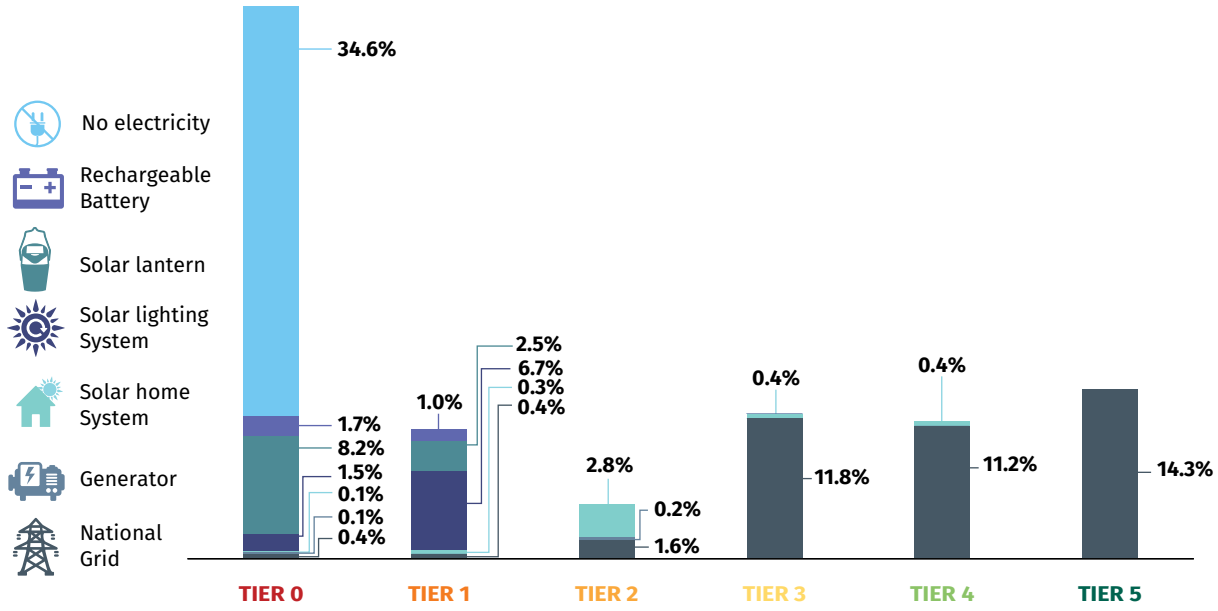
MTF TIERS

As seen in Figure 7, 65.4% of households have access to some electricity source, 53.1% have access at Tier 1 level or above. Virtually all grid-connected households are classified as Tier 3 or above, which means that they receive more than 8 hours of supply all day (including at least 3 hours in the evening). One-third of grid-connected households is placed in Tier 5, the highest level of service, meaning that these households receive at least 23 hours of supply a day, with minimum interruptions, without voltage fluctuations, and at affordable terms.

The households in Tier 1 (10.8%) and Tier 2 (4.5%) use mostly off-grid technologies such as SHSs, SLSs, and solar lanterns to meet their lighting and other basic electricity needs. A small percentage of off-grid solutions provide Tier 3 and Tier 4 access as well.

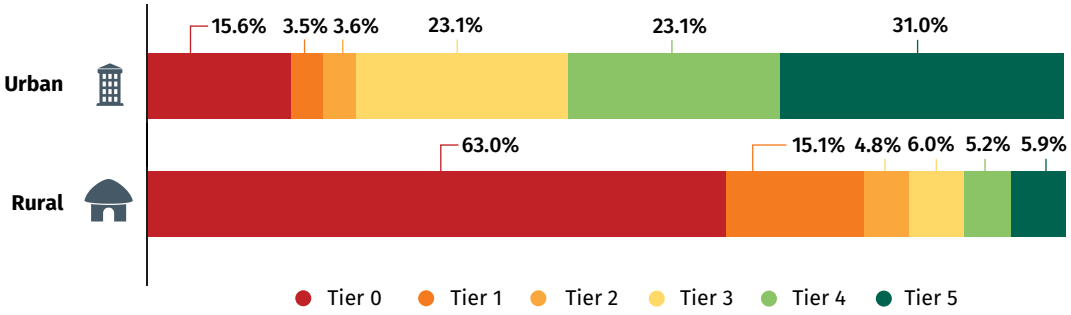
Slightly less than half of households fall into Tier 0. Tier 0 categorization does not necessarily mean that the household does not have access to an electricity source (Figure 7). Of the 46.9% Tier 0 households, 12% use energy solutions that do not provide at least Tier 1 electricity service (for example, less than 4 hours of electricity supply per day or have insufficient capacity); 9.9% use an off-grid solar device (mostly solar lanterns), 1.7% use rechargeable batteries, and 0.5% rely on grid or diesel generator as an electricity source and still have Tier 0 access. Still, 34.6% of households have no electricity at all.

FIGURE 7 • **MTF tier distribution, by source of electricity**



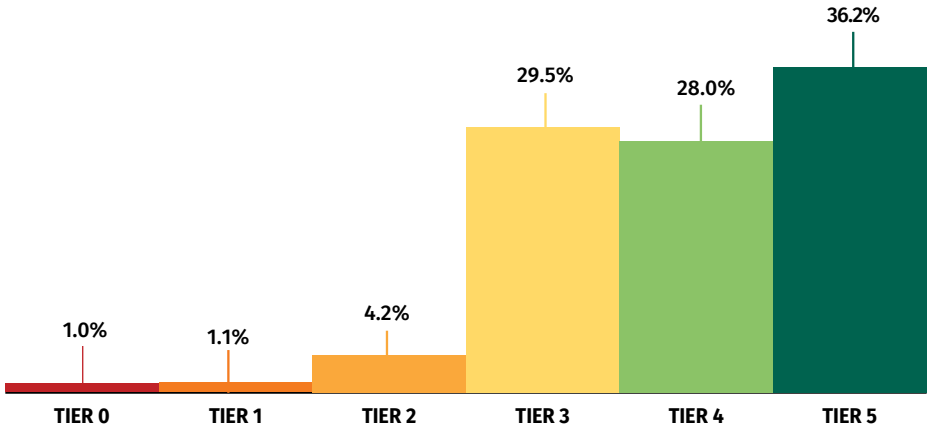
Electricity access is mostly a rural challenge: 63% of rural households are in Tier 0, while 15.6% of urban counterparts fall into this category (Figure 8). In similar fashion, 77.2% of urban households enjoy electricity of Tier 3 or higher, with largest share in Tier 5, whereas only 17.1% of households in the rural areas have access to electricity services at Tier 3 and higher, and only 5.9% of households have Tier 5 access.

FIGURE 8 • **MTF tier distribution, by urban or rural location**



In terms of electricity access by national grid, 93.7% of grid-connected households are in Tier 3 and above, and the most common is the highest Tier 5 (36.4%). These data confirm, that once the household is connected to the grid, it gets relatively good electricity supply (Figure 9), although room for improvement still exists, to move the remaining 35.8% of grid-connected households in Tiers 3 and below to Tiers 4 and 5.

FIGURE 9 • **MTF tier distribution, by national grid**

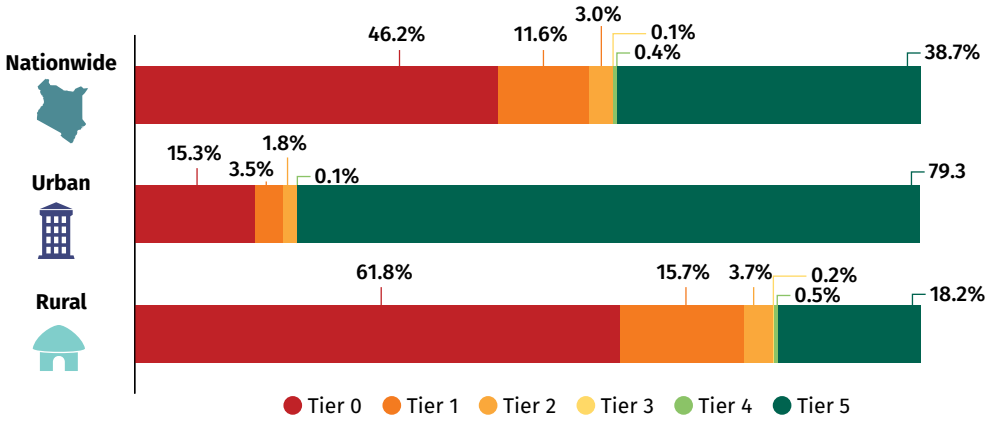


MTF ATTRIBUTES

CAPACITY

The Capacity attribute of the electricity supply (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate different appliances, ranging from a few watts for LED lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. All grid-connected households are considered to have high-capacity electricity (over 2 kW). In Kenya, even some off-grid solar systems provide Tier 4 services in terms of capacity (Figure 10). Nationwide, 38% of households are in Tier 5 for capacity, but there is disparity between rural and urban households: 79 3% of urban households are in Tier 5 compared to only 18.2% of rural households. In rural areas, 62% of households are in Tier 0, because they have no electricity access or access only to systems with very low capacity, allowing only minimum loads, such as for very basic lighting only.

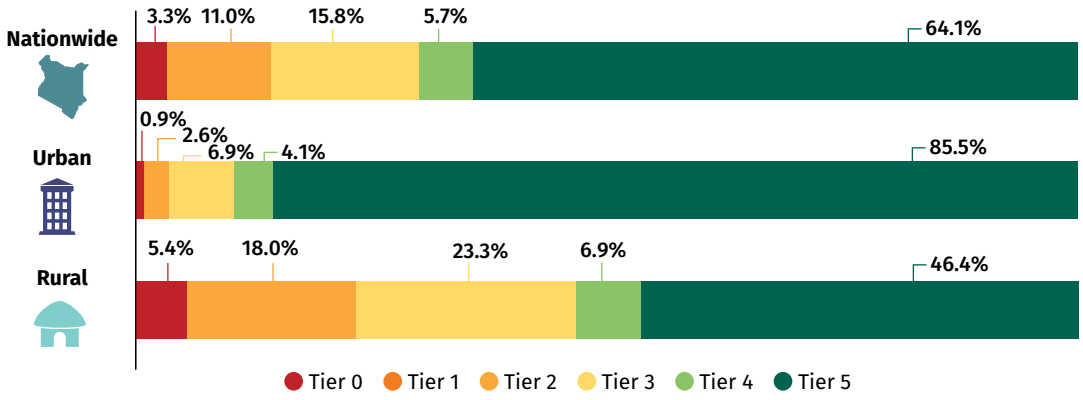
FIGURE 10 • **Distribution of households based on Capacity (nationwide, urban, and rural)**



AVAILABILITY

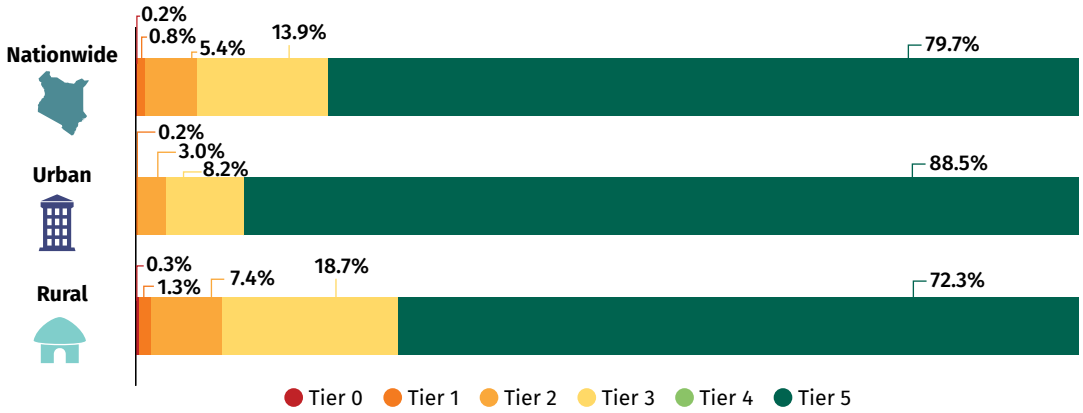
The Availability attribute consists of two components: daily (24 hours) and evening availability (4 hours between 6 and 10 pm). In Kenya, 15.1% of households have electricity for at least 23 hours a day, an additional 23.5% have at least 16 hours of electricity a day for 7 days a week, and 14.2% of households nationwide receive less than 4 hours of service per day (Figure 11). Most households that have less than 4 hours of electricity per day use off-grid solar solutions or other off-grid solutions such as rechargeable batteries and diesel generators. In rural areas, limited availability is more acute: 20.2% of rural households have at least 16 hours of electricity access a day compared to the 45.8% of urban households that have the same duration.

FIGURE 11 • **Distribution of households based on daytime Availability (over a 24-hour day—nationwide, urban, and rural)**



Evening availability of supply is less of an issue in Kenya (Figure 12): 79.7% of households have 4 hours of electricity supply during this period. Evening duration is long even for rural households, 72.3% of which have the full 4 hours.

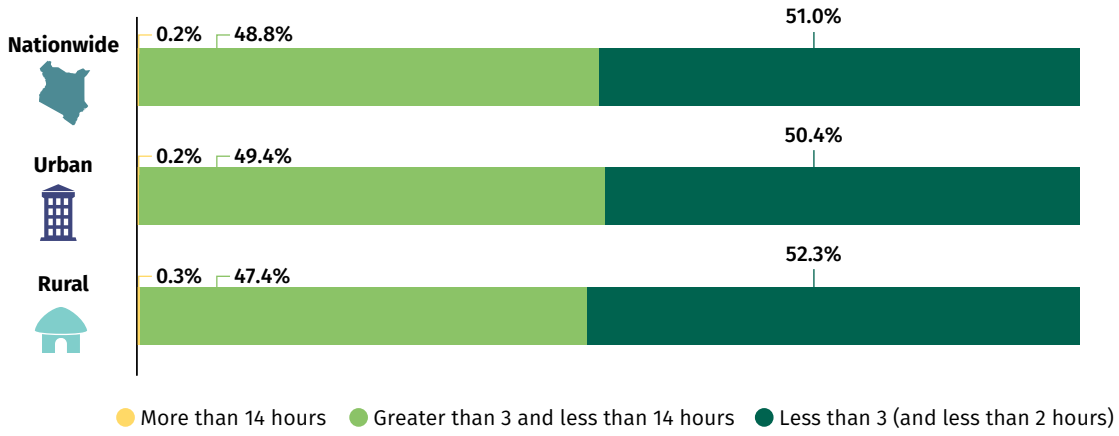
FIGURE 12 • **Distribution of households based on evening Availability (4 hours—nationwide, urban, and rural)**



RELIABILITY

The Reliability attribute captures the frequency and duration of unscheduled outages and is applied for grid-connected households only.[7] Frequent power outages are an issue for 48.8% of the grid-connected households, and they experienced outages anywhere between 3 and 14 times a week, whereas 51% of households had less than 3 or less than 2 hours of outages per week (Figure 13). The numbers are quite similar between rural and urban households and there is no major difference in Reliability between the urban and rural area. While Kenya Power has made great strides over the past decade to supply adequate electricity generation and eliminate rolling black- outs, unplanned outages persist, attributed to outdated equipment, maintenance and repair issues, as well as dynamic growth and urbanization, which put more pressures on the existing networks (Taneja 2018).

FIGURE 13 • **Distribution of households based on the Reliability attribute (nationwide, urban, and rural)**



QUALITY

The Quality attribute is also applied only for households on the national grid. Among households connected to the national grid, 17.5% face voltage issues, such as low power or fluctuating service, resulting in appliance damage (Figure 14). An overloaded electricity system that sometimes relies on long-distance, low-tension cables to connect widely scattered households to a singular grid can create erratic voltage supply. Surges can harm electrical appliances, because these generally require a certain range of voltage to operate properly. Low-voltage or fluctuating supply tends to damage electrical appliances, sometimes causing shorted wires and electrical fires. There is no major difference in the quality of electricity provided by the national grid in urban and rural locations.

7 In constructing the Reliability attribute, only frequency of outages was only considered, not duration, unlike the specification of Annex 1. This is because reported duration can overestimate the actual duration of an outage.

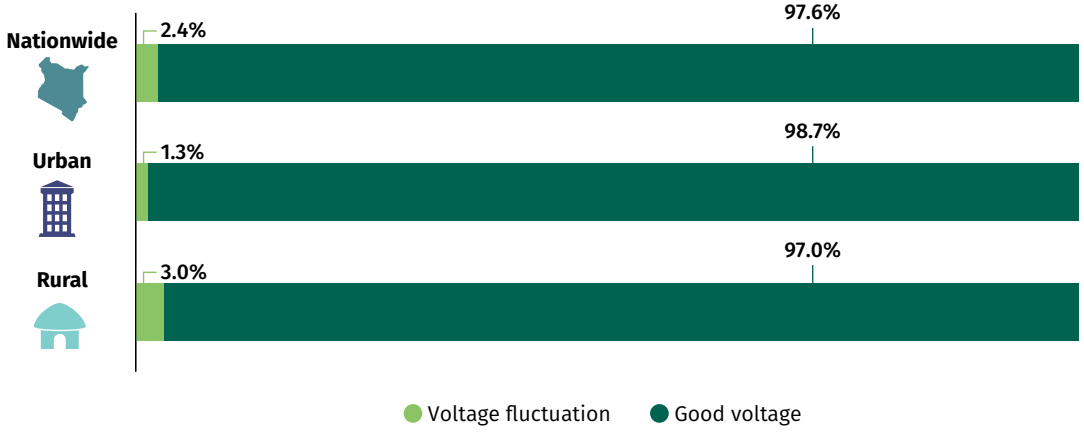
FIGURE 14 • **Distribution of households based on Quality (nationwide, urban, and rural)**

AFFORDABILITY

The Affordability attribute is also applied for grid-connected households only. It measures whether the current electricity tariff is affordable for households. If a household would spend less than 5% of the household expenditure on electricity to consume 1 kWh a day and 30 kWh a month, the electricity is assumed to be affordable. Applying this definition, the current electricity price is considered affordable to 97.6% of Kenyan households, as they would pay less than 5% of their household expenditure for a basic electricity service (at least 1 kWh a day) (Figure 15). Kenya has a differential domestic tariff structure based on electricity consumption and is divided into three categories, and until October 2017 Kenya Power customers using 0–50 kWh per month were paying a lifeline tariff of K Sh 2.50 (US$0.025) per kWh (Citizen Digital 2018). We are using those figures for our calculations as the MTF survey was undertaken between 2016 and 2017.

The Energy Regulatory Commission (ERC) released new tariff structure in 2018, and the domestic category of households with consumption between 0 and 100 kWh now falls within a new tariff band, reducing the lifeline threshold from 50 kWh to 10 kWh and removing the fixed charges of K Sh 150 (US$ 0.015) for all the customer categories. According to ERC, approximately 3.4 million customers fall under the lifeline category, consuming 0–10 units (ERC 2018).

FIGURE 15 • **Distribution of households based on Affordability (nationwide, urban, and rural)**



FORMALITY

Formality refers to a household's connection and whether it has been provided and/or sanctioned by a governing authority. In Kenya, 2.7% of the grid-connected households have an informal grid connection (Figure 16). This may be because of urban slums where informal connections are more common. Reporting on Formality is a challenge, since household responders may be sensitive to disclosing information on the nature of their grid connection in a documented survey. As a result, the MTF survey infers Formality of a connection from indirect questions that respondents may be more willing to answer (such as, which household member pays the electricity bill).

FIGURE 16 • **Distribution of households based on Formality (nationwide, urban, and rural)**

HEALTH AND SAFETY

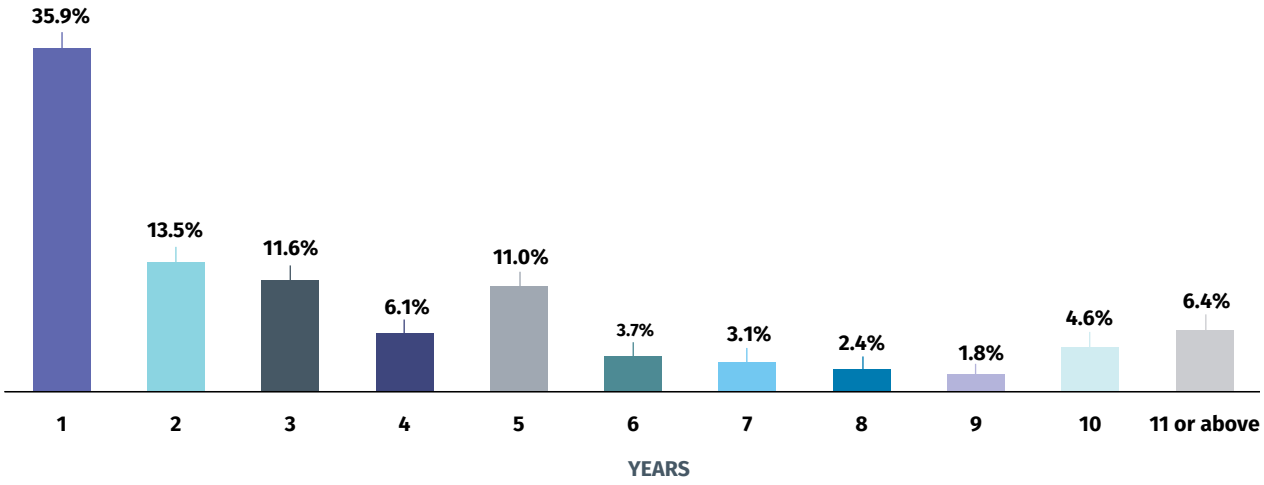
The Health and Safety attribute refers to any injuries household members experienced from using electricity service from the national grid during the 12 months preceding the survey. Electricity supply from the national grid is generally safe, and only 1.1% of households in Kenya reported any permanent damage or death due to electrocution (Figure 17). However, it is important to ensure that all household members are aware of basic safety measures; moreover, it must also be encouraged that all household wiring is installed according to national standards to prevent accidents.

FIGURE 17 • **Distribution of households based on Health and Safety (nationwide, urban, and rural)**

USE OF ELECTRICITY

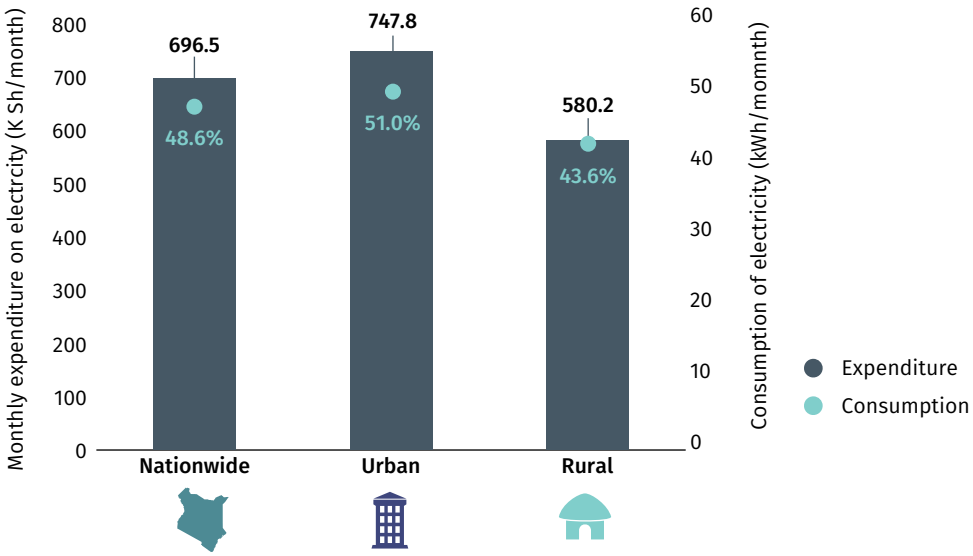
Most of the grid-connected households mainly use low or very low load appliances, such as lights, cell phone chargers, radios, TVs, and occasionally DVD players. About three-quarters of rural households and even half of urban households with the grid connection mainly use the national grid electricity for lighting, mobile charging, listening to radios and DVD players, and watching television. Fans are not very common in Kenya, nor are higher load appliances such as refrigerators, microwaves, and washing machines. When it comes to low consumption, it must be kept in mind that the grid electrification is a recent development in Kenya, and more than 60% of the national grid electrified households have used the grid electricity for fewer than three years. According to the study "Welfare Impacts of Rural Electrification: Evidence from Vietnam," households acquire appliances over time (Khandker and Barnes 2013). Although the impacts are higher during first few years after a household receives electricity, and incremental benefits leveled off after only nine years, households continue increase consumption and use of appliances. In Kenya, 35.9% of grid-connected households have been on the grid only for a year, whereas only 11% of households had grid access for 10 or more years (Figure 18). The quality and reliability of electricity supply, however, may also impact the consumption and appliance ownership.

FIGURE 18 • **Number of years connected to the national grid**



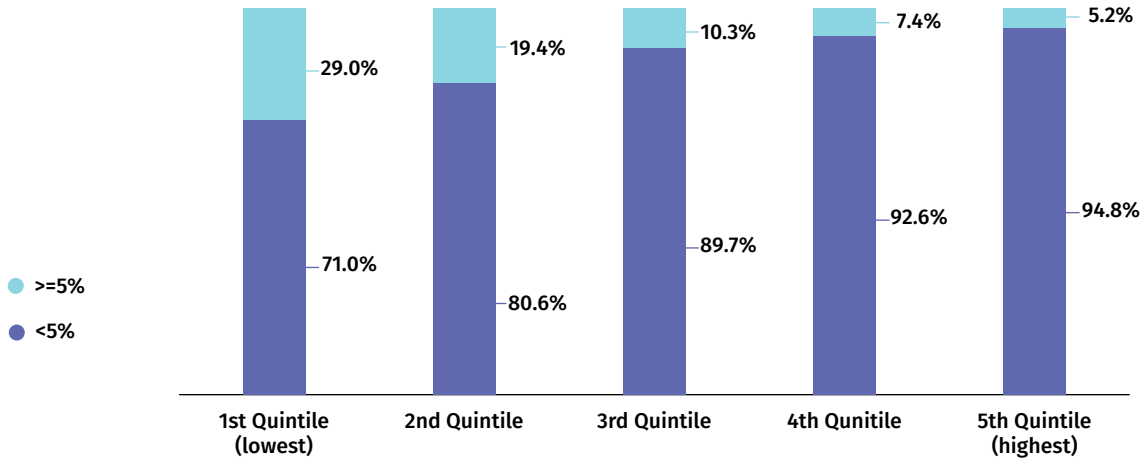
According to the MTF survey, grid-connected households consume an average of 48.6 kWh monthly. Urban households consume slightly higher than the rural households (Figure 19). Spending on electricity on average accounts for 2.8% of monthly household expenditure. The shares are slightly larger (3.1%) among urban households K Sh 747.8 (US$7.47) and slightly lower (2.7%) among urban households K Sh 580.2 (US$5.8).

FIGURE 19 • **Monthly household expenditure on and consumption of electricity**



Although, on average, households spend only 2.8% of their income on electricity, the actual percentages vary, and they are higher for lower expenditure quintiles. Overall, one-tenth of national grid customers spend more than 5% of their household expenditure on electricity, and nearly one-third of households in the bottom quintile spend more than 5% of their expenditures on electricity, suggesting that despite the existence of a social tariff, affordability of electricity can be an issue for the poorest households (Figure 20).

FIGURE 20 • **Grid-connected households spending more than 5% of their household income on electricity (nationwide)**

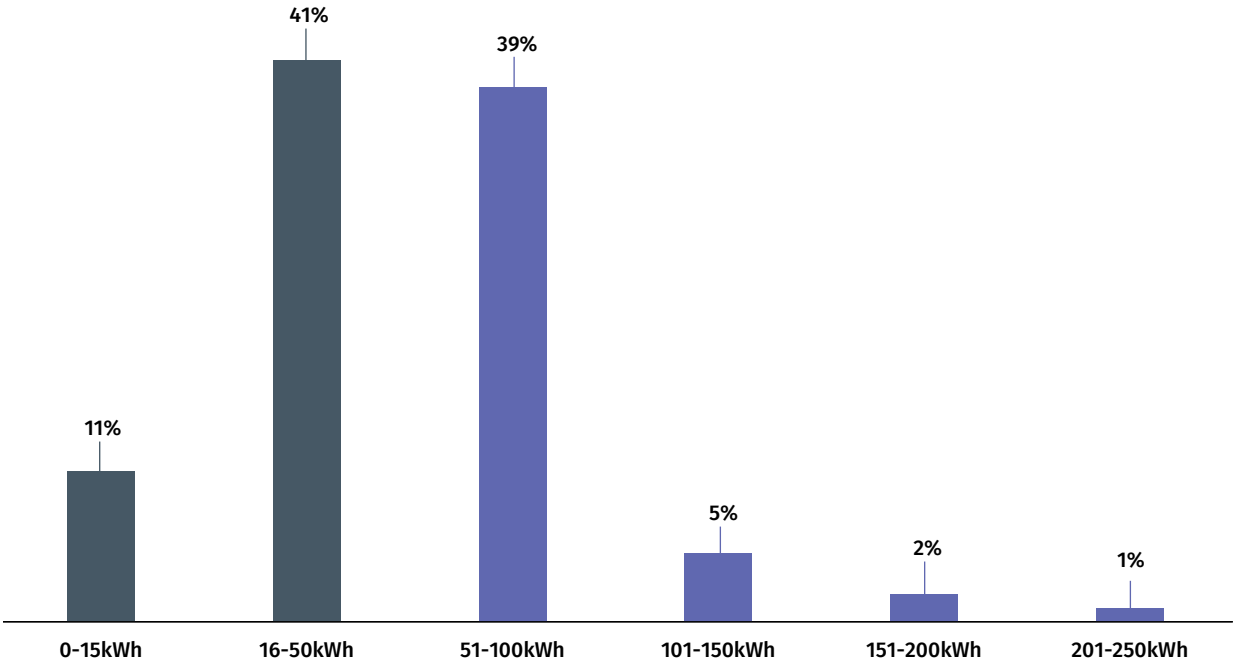


The majority of grid-connected households fall into the category of 0–100 kWh per month for electricity consumption. More than half of households consume 0–50 kWh, which are within the original lifeline tariff. ERC has since amended the lifeline tariff in 2018 to 0–100 kWh.[8] Thirty-nine percent fall within the 50–100 kWh per month category, and only 8% of grid-connected households consume more than

8 According to the new tariff structure applicable from November 1, 2018, the lifeline bracket will be from 0–100 kWh, which will be further divided into 0–10 kWh and 11–100 kWh with different tariffs for each category. See the tariff structure on Kenya Power's website: http://kplc.co.ke/img/full/rZr6LLCjVqVw_1st%20November%202018%20-%20Tarrifs.jpg.

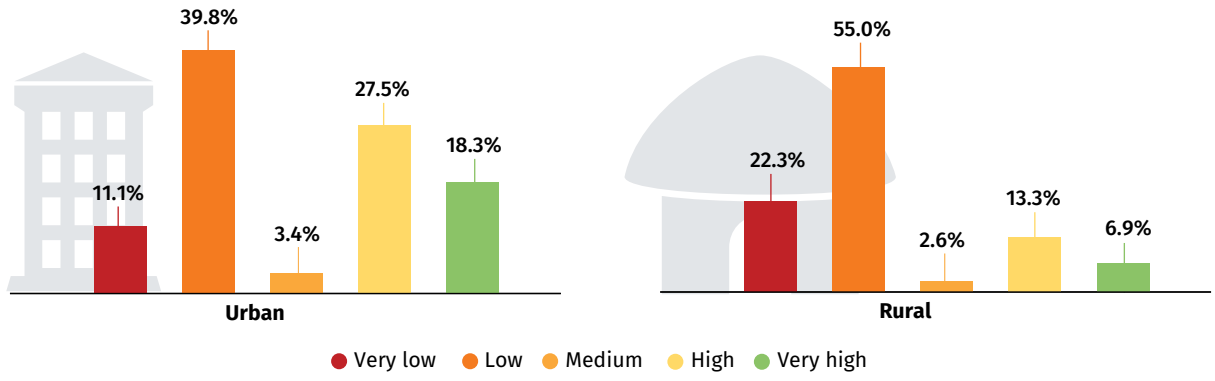
100 kWh per month (Figure 21). The energy consumption increases usually in the newly connected households, but overall consumption levels are quite low in Kenya. Administrative data from Kenya Power indicates that even in Nairobi the median connected household consumes only 2.8 kWh per month (Lee, Miguel, and Wolfram 2019). One can also see that the average residential customer now consumes only 30% of the electricity that the average residential customer consumed in 2009. One argument is that the breakneck pace of growth is tipping the balance of residential customers toward households that are newly electrified and lower consuming (Taneja 2018).

FIGURE 21 • **Consumption in kWh among households, nationwide**



Majority of the households use very low-load appliances, including urban households. However, urban households tend to use higher-load appliances compared to rural households. For example, 45.2% of urban households use higher load appliances such as irons, refrigerators, electric pumps and microwaves, whereas 77.3% of rural households use only low-load appliances such as phone chargers, radios, and TVs (Figure 22). This is likely related to lower affordability levels in rural areas—either to pay the up-front costs of an appliance or to pay for higher electricity consumption due to the appliance use. In addition, some appliances may not be readily available in rural areas.

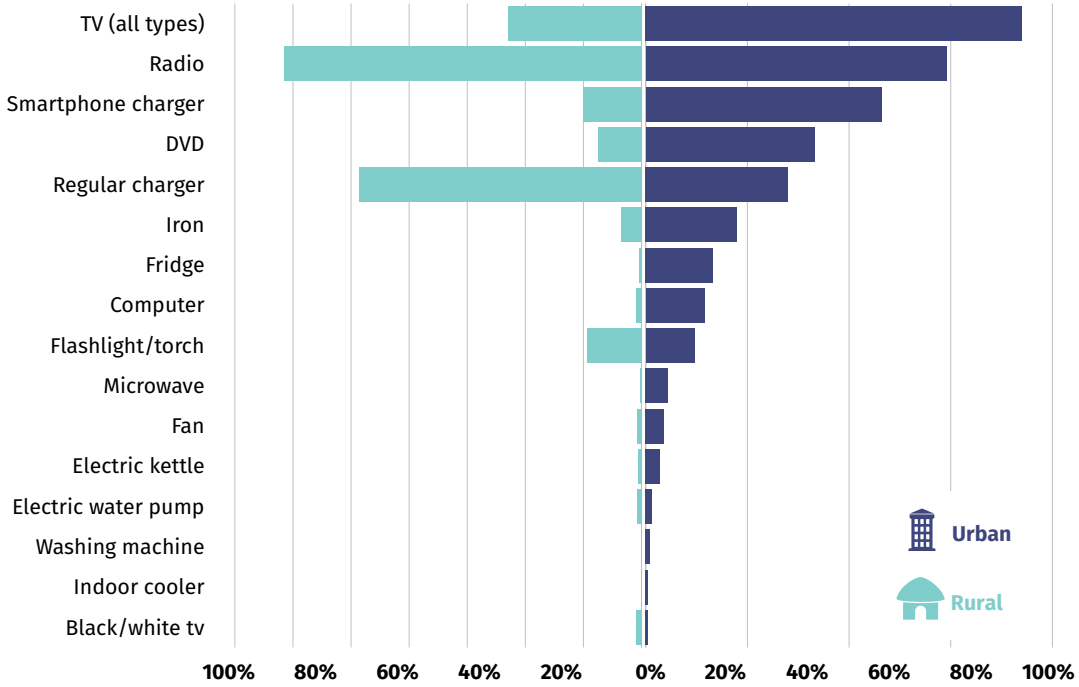
FIGURE 22 • **Power level of the appliances used among households, by urban or rural location**



The TV is the most-owned appliance among urban households (18.5%), whereas rural households (30.79%) are more likely to own a radio. This is followed by phone charger (24.7%) for rural households and smart phone chargers (11.6%) in urban households. The color TV ranks third in the appliances (Figure 23). The ownership of high-load appliances such as refrigerators is low even in urban areas. Levels of low ownership for refrigerator may reflect the high capital cost of the appliance, the relatively high electricity consumption, and the need for high reliability of electricity service to make cold storage practical (Fabini et al. 2014). Several factors thus may be contributing to the relatively low appliance ownership of grid-connected households: Affordability, Reliability and Quality of service, as well as the socioeconomic status of households.

Affordability could be enhanced through the use of energy efficient appliances. Although such appliances tend to have higher up-front costs, these are compensated by lower electricity consumption, which reduces monthly electricity bills. The use of energy efficient appliances could be increased by improving their availability (including in rural areas), improving household awareness of their benefits, and by introducing innovative financing mechanisms to overcome to up-front cost barriers (as off-grid suppliers already do through the pay-as-you-go business model). But supply-side barriers, such as quality and reliability of service, would also need to improve simultaneously to incentivize households to purchase such appliances. Efforts to increase appliance ownership and consumption will therefore need to address several demand- and supply-side barriers (Fabini et al. 2014).

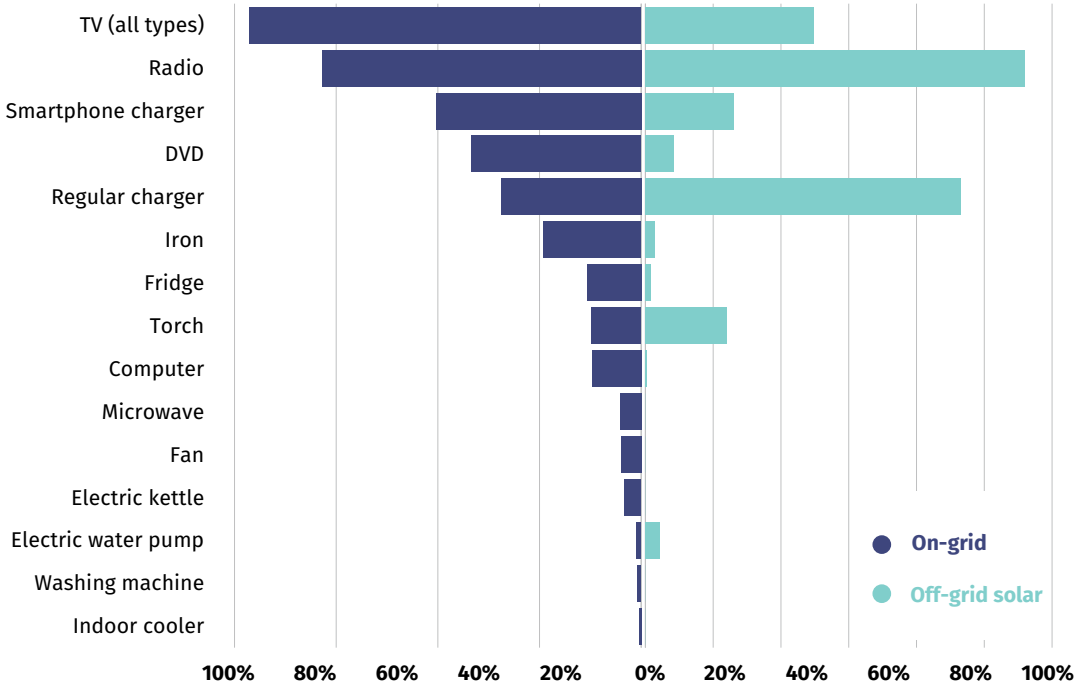
FIGURE 23 • **The use of appliances among grid-connected households, urban and rural**



Off-grid users typically own only low-load appliances such as radio, cellphones chargers, TVs, radios, and DVD players. This is the case for 95% of households serviced by solar solutions. However, there are 4.7% of households served by off-grid solar solutions who use high-load appliances such as computers, refrigerators, and iron boxes, as well as solar water pumps. While low-load appliances for lighting and phone charging have been invaluable in getting homes up the first step of the energy ladder, surveys indicate that the next priority for households tend to be TV, cooling (fans), and refrigeration—the appliances that are now expanding in off-grid markets. According to a recent study, TVs, fans, and refrigerators are among the near-to-market products that represent a significant

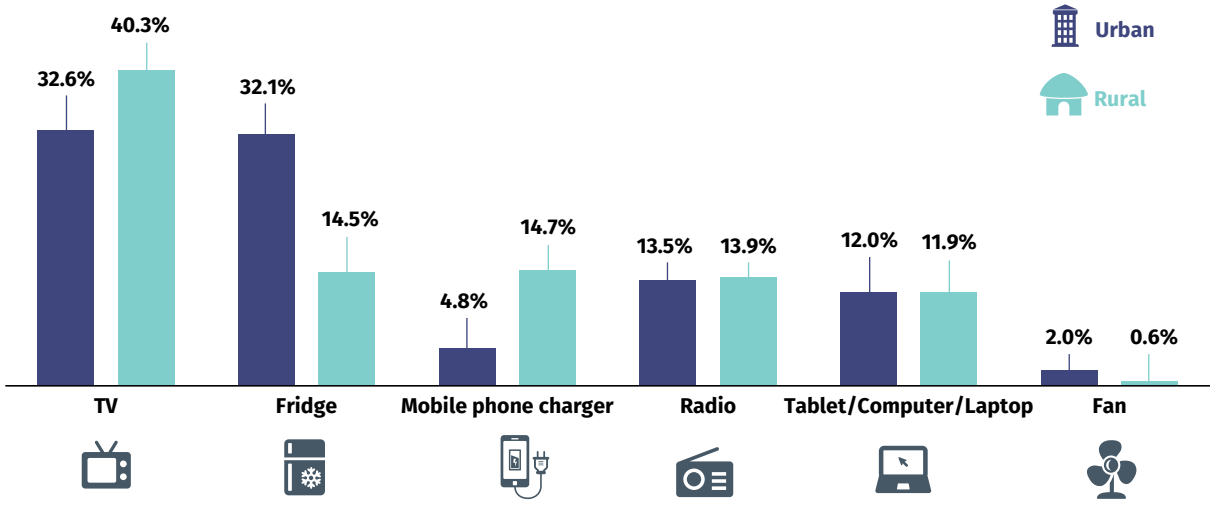
opportunity for scaling off-grid energy access However, this requires addressing such challenges as a quality assurance framework and sending a positive signal to the market (Lai, Muir, and Ruff 2019) It is also worth noting that electric water pumps are actually more common among off-grid than grid users (Figure 24).

FIGURE 24 • **The use of appliances among grid-connected and off-grid households possessing solar devices**



Households currently using off-grid solar products want to power more and higher capacity appliances: 39.4% of households using solar products want to own a TV, followed by a refrigerator (16.5%) and mobile chargers (13.5%). The desire to use a refrigerator is higher among urban solar users (32.1%), whereas 14.3% of rural solar users desire mobile phone chargers and radios 13.9% (Figure 25).

FIGURE 25 • **Desirable high capacity appliances, households using off-grid solar solutions**



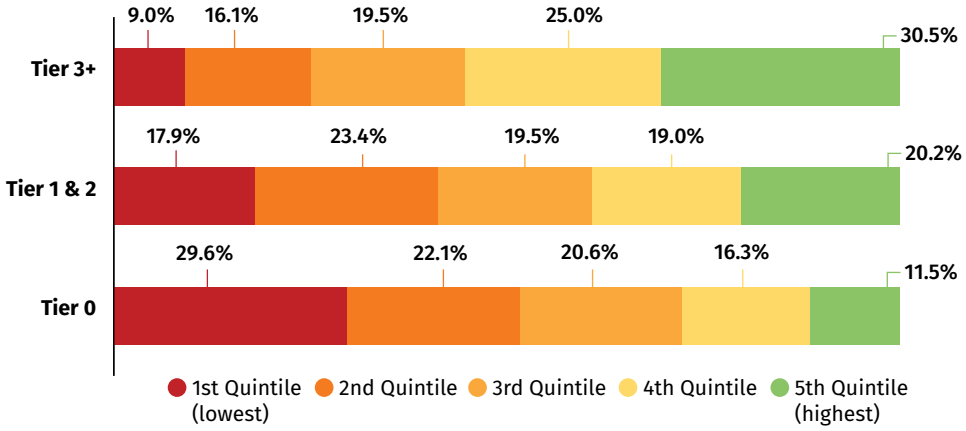
IMPROVING ACCESS TO ELECTRICITY

PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT A SOURCE OF ELECTRICITY

Households without any source of electricity (74.5%) may be disaggregated into two groups: (i) households under or near the grid and (ii) households in areas where access to the grid is not available. It is important to understand what prevents these households from becoming connected.

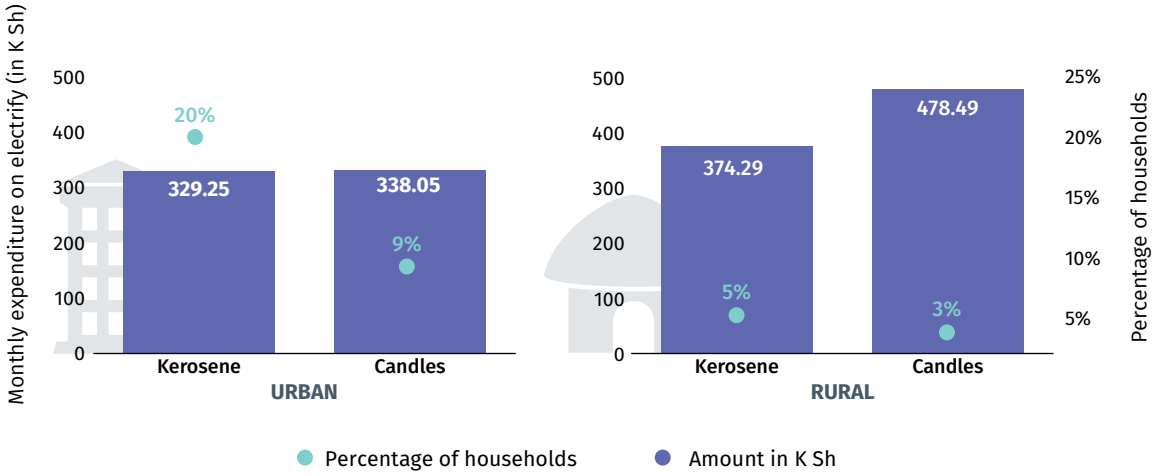
To come with up with strategies for providing access to households with no access or with Tier 0 access also requires understanding their socioeconomic status. The MTF survey doesn't investigate any direct correlation between lack of access and poverty, but it shows that Tier 0 households (with no electricity) tend to be poorer (29.6% uses belong to the bottom expenditure quintile) than households with Tiers 1 and 2 (17% in bottom quintile) and Tier 3 and higher (9% in the bottom quintile) (Figure 26). This means that affordability may play a more critical role in connecting the remaining unelectrified households.

FIGURE 26 • **Expenditure quintile comparison of Tier 0 households**



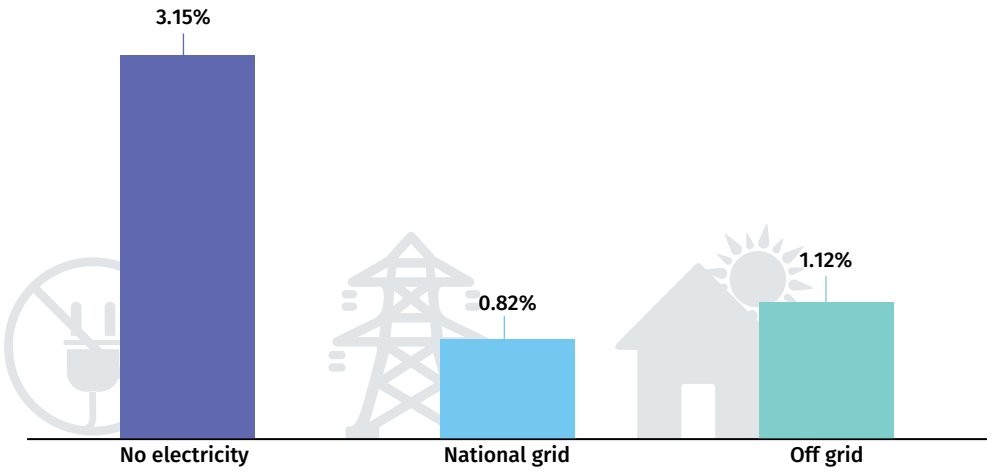
In the absence of access to electricity, households spend money on alternative sources, such as kerosene, which tend to be more expensive and polluting and can be harmful to health. Tier 0 households on average spend K Sh 400 (US$4.0) per month on candles and kerosene for lighting. According to the survey, rural households spend about 30% more (K Sh 425 = US$4.25) than urban households (K Sh 330 = US$3.30) (Figure 27).

FIGURE 27 • **Expenditure by Tier 0 households on alternative sources of electricity (on grid and off grid)**



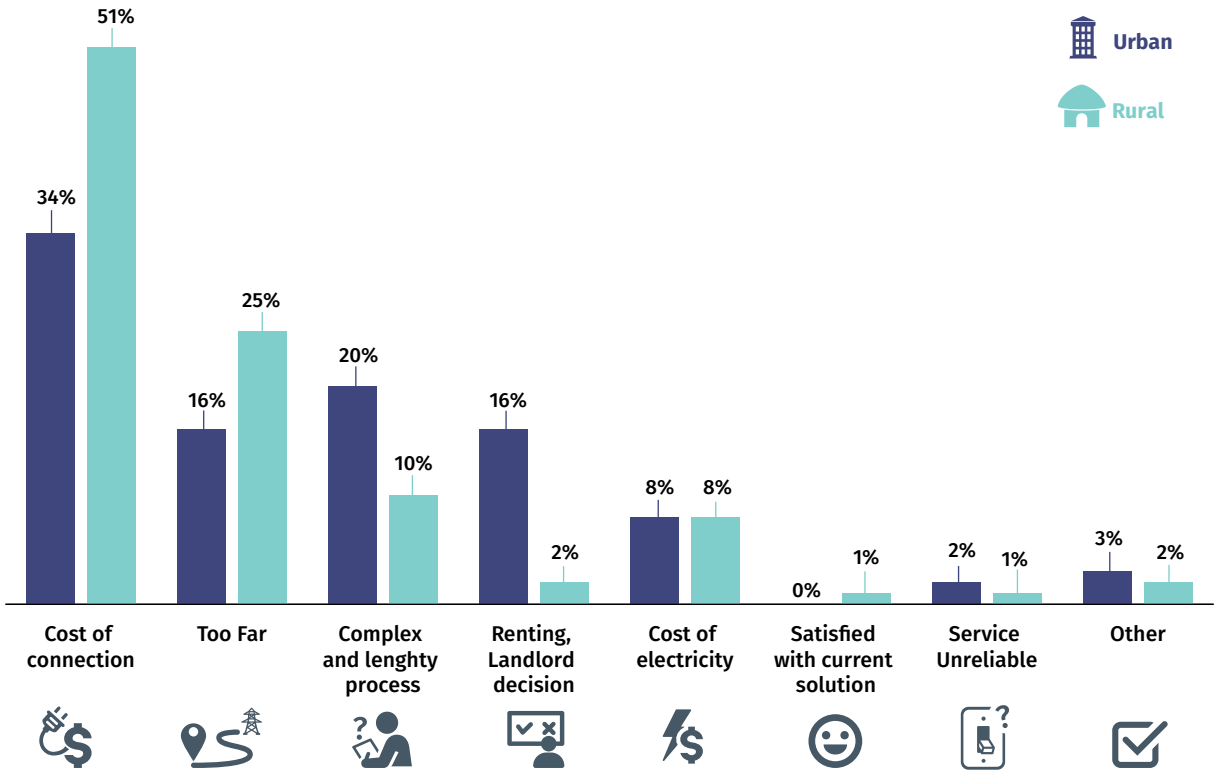
Tier 0 households spend 3.25% of their monthly household expenditure on alternative sources such as candles and kerosene for their lighting needs. The share of financial burden is more on no-access Tier 0 households compared to Tier 0 households with some off-grid or grid access, which is 1.12% and 0.82%, respectively, showing that even a very basic service, such as a solar lantern, can positively impact household finances (Figure 28). The expenditure for candles and kerosene for on-grid and off-grid households in Tier 0, however, is added on top of their expenditures for grid or off-grid electricity, so the final impact depends on the costs of their electricity supply. This also demonstrate that the grid or off-grid service they are receiving is not fulfilling all their needs—most likely due to capacity, availability or reliability issues.

FIGURE 28 • **Share of (monthly) expenditures on alternative sources of electricity for Tier 0 households**



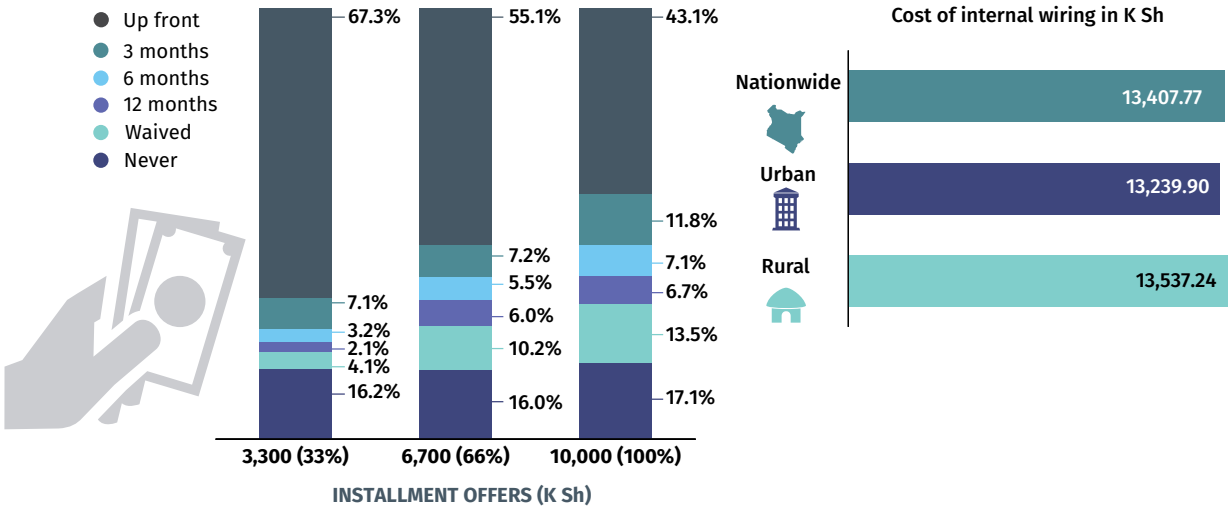
The barriers preventing Tier 0 households from gaining a connection are as follows: cost of grid connection (urban 39.6% and rural 45.6%), the grid infrastructure availability (urban 16% and rural 27%), cost of electricity (urban 7.5% and rural 6.8%), and complex and long administrative processes (urban 18% and rural 11%). Noteworthy is that 12. 3% of urban and 6.3% of rural rental households identify the decision taken by the landlord on grid connection as their main barrier to electricity access (Figure 29). Low levels of demand to get connected to the grid may be partly attributable to the lengthy and bureaucratic process of obtaining an electricity connection. As per the research done by the Poverty Lab at the University of Berkeley, the sample households waited a staggering 188 days after submitting their paperwork before they began receiving electricity. The delays were mainly caused by time lags in project design and contracting, as well as in the installation of meters (Lee and Wolfram 2016).

FIGURE 29 • **Barriers to gaining access to grid electricity**



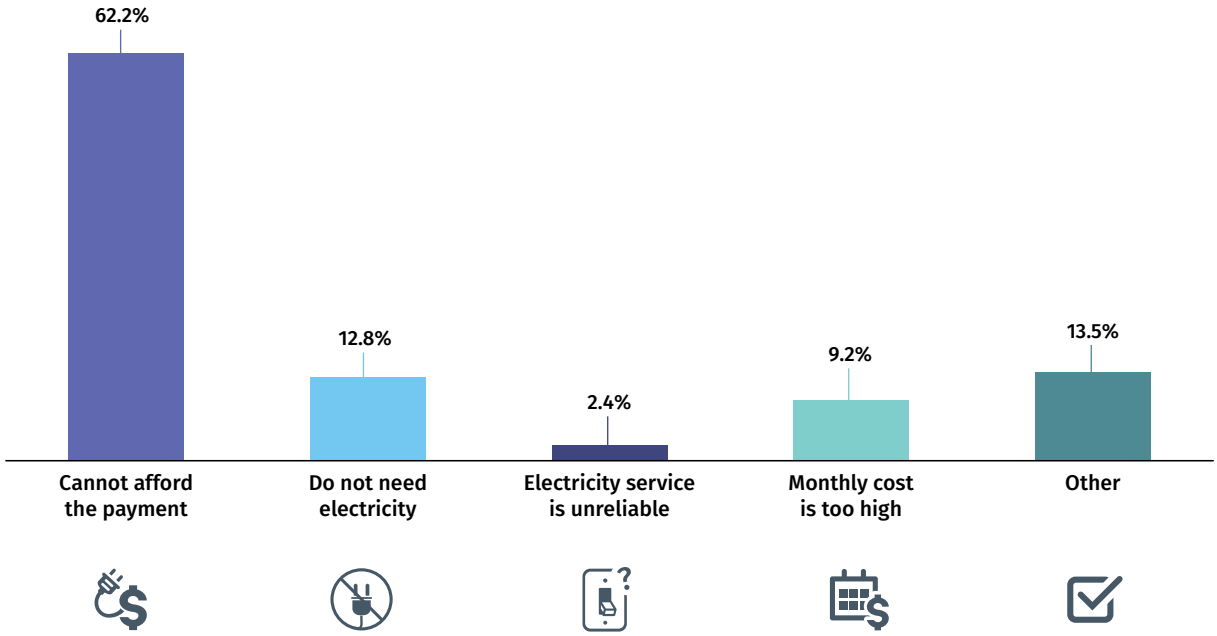
Payment flexibility, such as payment on installment, can effectively address the burden of the high up-front cost of connection. Most unconnected households that were asked if they were willing to pay for access to the national grid showed willingness to pay (WTP) if the connection fee could be paid in installments. Among these households, 43.2% were willing to pay the maximum amount (K Sh 10,000 or US$100) up front. However, an additional 39.1% were willing to pay the full amount based on an installment plan (Figure 30). Offering payment flexibility to potential users could increase the uptake of the national grid. However, it should be noted that the grid connections are long lived but their long-term benefits may not be fully reflected in WTP if households have limited information about their future income or broader social benefits of electrification, or if there is imperfect within-household altruism, for instance, if children stand to gain the most from indoor lighting in the evening (if it boosts learnings and future earning) but their parents do not fully understand these gains or incorporate them into decision-making (Lee and Wolfram 2018).

FIGURE 30 • **Willingness to pay for the grid connection fee**



However, 17.7% of households would not connect even if a financing plan was offered. Surprisingly, this percentage of households unwilling to connect to electricity changes little even if the connection fee is reduced to one-third (Figure 31). These households have identified the key reasons for not being interested in accepting an offer to connect: high connection costs (62.2%), which not only include a connection fee but also internal wiring, the costs of which can be significant, especially in rural areas); followed by no need for electricity (12.2%); and the electricity usage (tariff) being too expensive (9.2%). These findings point to the need to design and implement more comprehensive policies to realize grid densification. This must include financing options, with improved targeting to the poor, to help these households not only afford the official connection fee but also pay any other cost associated with grid connection. The electrification efforts also need to incorporate awareness campaign to educate households on the benefits of electricity.

FIGURE 31 • **Main reason for not accepting any offer to pay for grid connection**



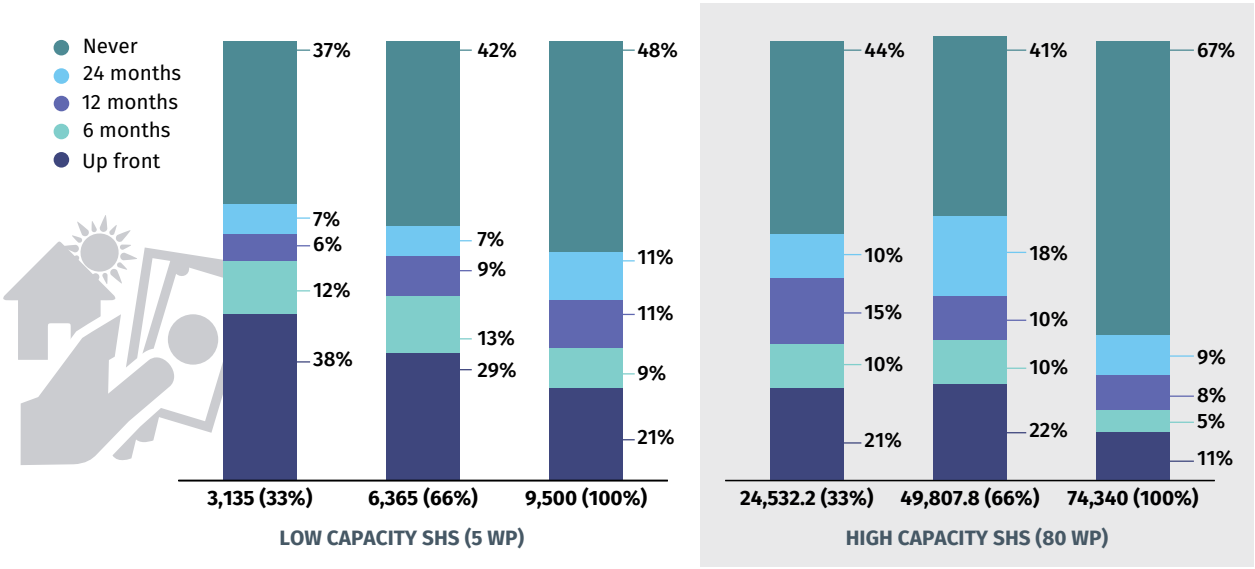
The Kenyan government has already taken many steps to overcome these challenges, such as lowering the cost of internal connection and lifeline tariffs and providing ready boards. The Kenyan government in 2015 introduced a subsidized connection fee of K Sh 15,000 (US$150) to connect households within 600 meters of 5,320 targeted transformers countrywide; the fee was previously K Sh 35,000 (US$350). Kenya Power also allows the customers to pay the fee over 36 months, removing the cost hurdles for poor homes. They are now approaching potential customers in neighborhoods with transformers and offering to hook them to the grid (Daily Nation 2017). This was done through the Last Mile Connectivity Program (LMCP), and in one year this installment-based payment plan led to a 30-fold increase in legal electricity connections in impoverished neighborhoods (World Bank 2015). Internal wiring can also be a barrier for some households to get electricity access, and per our research rural households spend K Sh 13,537 (US$135) and urban households spend K Sh 13,405 (US$134) on internal wiring. The Ministry of Energy has also come up with designs that will enable households that do not have internal wiring to use electricity by providing a "ready board." The ready board has switches, sockets, and bulb holders, and those who do not have wiring in their houses will be able to use electricity as soon as they are connected (Presidential Office, Kenya 2015).

WTP for SHS is somewhat lower than for the grid connections. The survey assessed WTP for two types of SHS—low capacity SHS of 5 watt peak (Wp) bundled with two LED lights, two mountable switches,[9] and a portable LED solar lantern (for appliances), retailing at around K Sh 9,500 (US$95), and high-capacity SHS (80 Wp), bundled with four LED solar lights, 19-inch DC TV, portable radio, and portable LED solar lantern (appliances), retailing for K Sh 74,340 (US$743.4).[10] The surveyed households were offered hypothetical installment packages for SHSs and were asked their willingness to pay based on 33%, 66%, and 100% of the cost. As in the case of the grid connection fee, the WTP increases with the payment period—only 21% of households would be willing to purchase a low-capacity SHS at full price. Offering a payment plan would increase acceptance of the system to more than a half of respondents. Lowering the price (even to one-third of the full price) is less effective than offering a payment plan for a low-capacity SHS.

The WTP for a high-capacity system is more limited, with only a third of respondents willing to purchase a system at full price, despite an offer of a financing plan. The WTP, however, increases rapidly if the price drops to 66% (about K Sh 50,000 US$500) and if a payment plan is offered (59% of respondents say they would be willing to purchase the system) (Figure 32). Promoting business models that allow customers to pay over time, such as pay-as-you-go, is therefore likely to be an effective mechanism to increase access to at least Tier1 off-grid solar systems. Further strategies, including targeted subsidies, are, however, likely to be needed to eventually reach all off-grid households with at least Tier 1 systems.

9 "DLight D20 Powerful Solar Home System Kit," https://dhause.com/p/solar-home-system-kit-d20.
10 (proxy, Mobisol Premium Buffalo-Nyati).

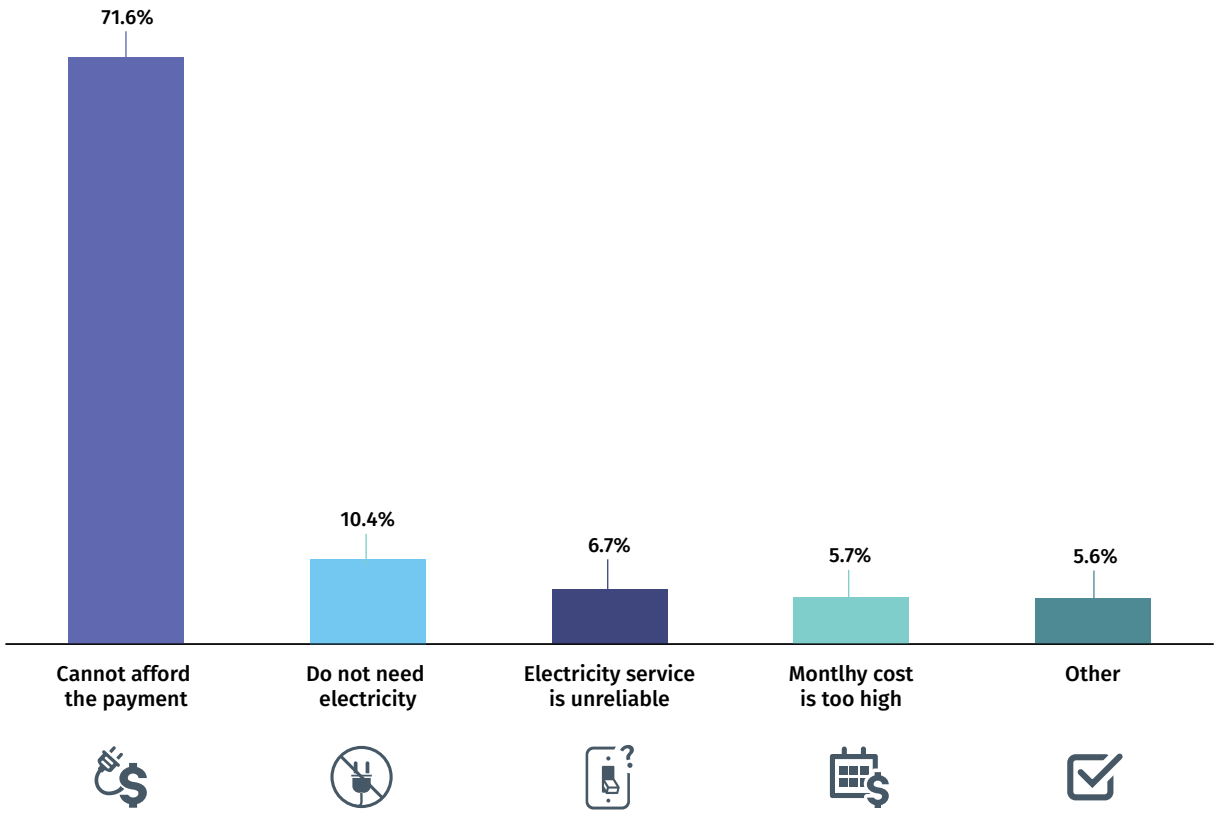
FIGURE 32 • **Willingness to pay for a solar home systems (SHS)**



Installment offers (K Sh)

Three main reasons were provided by households to explain why they were not willing to pay: the high cost of purchasing an SHS, an unclear value of electricity access, and the quality of lighting from solar products (Figure 33). This indicates that offering financial incentives is important, but also that non-financing barriers must be tackled, including improving quality of products on the market, ensuring that warranties and after-sales services are provided, and educating consumers about their choices.

FIGURE 33 • **Reasons households are not willing to pay for a SHS**

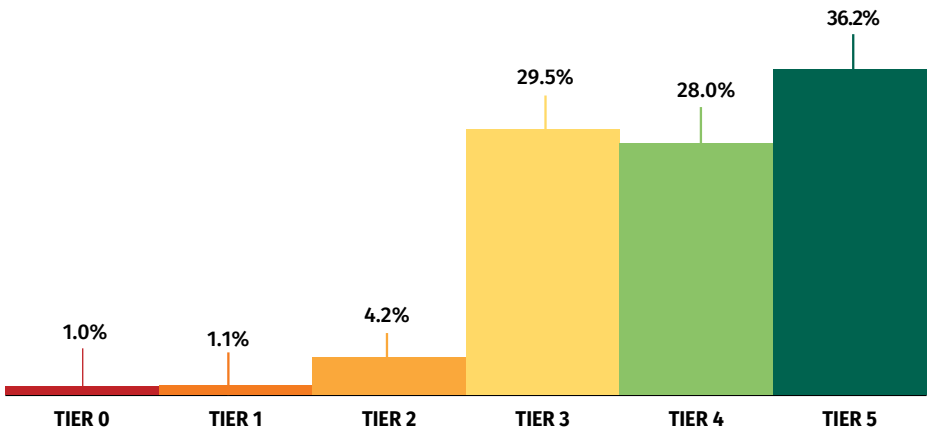


To make off-grid solar more accessible, the Kenyan government has provided exemption from the value-added tax, which applies to all solar photovoltaic (PV) equipment, such as solar panels, batteries, and controllers. This reduces the cost of PV systems by 16% and increases the chances that they will be adopted. While the reduction in price helps, the survey results also show that it is even more important to ensure that customers can spread payments over time. Promoting such solutions, such as pay-as-you-go (PAYGo) and/or microfinance and making them available and affordable for the remaining unconnected households is therefore very important. Awareness campaigns may further increase uptake, as 10.4% of households do not see any need for electricity, along with the assurance of quality and service. However full universal access will likely require some subsidization for those who cannot afford the system even with payment installments. The *Lighting Kenya II* program has built some useful examples for addressing these issues, such as showcasing the potential of partnering with financial institutions, including microfinance institutions, promoting financing schemes like the PAYGo model, and involving women and youth as last-mile distributors (Lighting Kenya 2018).[11]

IMPROVING ACCESS TO ELECTRICITY AMONG GRID-CONNECTED HOUSEHOLDS

The national grid provides an electricity service in higher tiers than off-grid (Figure 34). Nationwide, 93.7% of grid-connected households are in Tier 3 or above. The largest share of grid-connected households is in Tier 5 (36.3%). The median household has been connected for about six years, and a majority of households have been connected in the past 2 –3 years. The government is working with different development partners to increase the expansion and densification of grid to connect more households in urban and peri urban areas and less remote rural areas. Efforts are being made to improve grid infrastructure, such as adding more transformers and extending transmission lines.

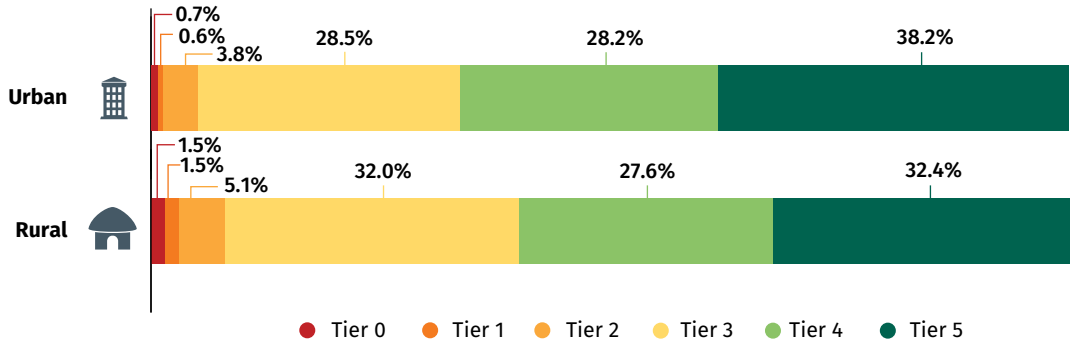
FIGURE 34 • **MTF tier distribution among grid-connected households**



Most of urban and rural households once connected to the grid are concentrated in higher tiers (Tiers 4 and 5). More urban households than rural households are in Tier 5 (38.2% versus 32.4%) and Tier 4 (28.5% versus 27.6%). Correspondingly, a higher share of grid-connected rural households is in Tiers 0–2 (8.1%, compared to urban households (5.1%) (Figure 35).

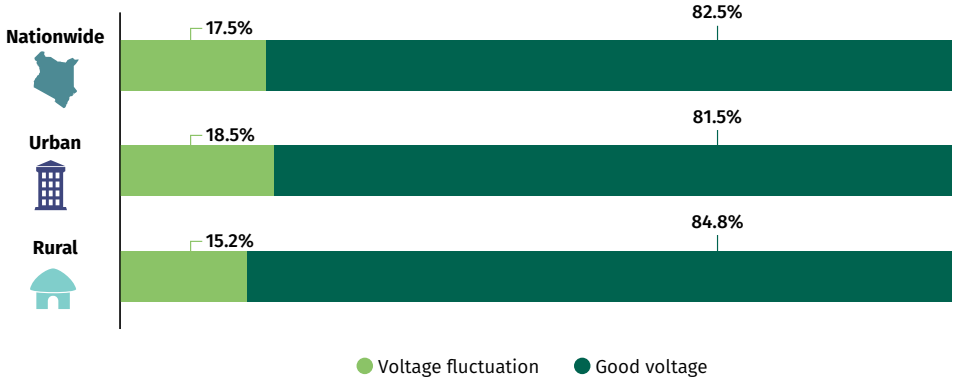
11 The Lighting Kenya program has been closed.

FIGURE 35 • **MTF tier distribution of grid-connected households, by urban or rural location**



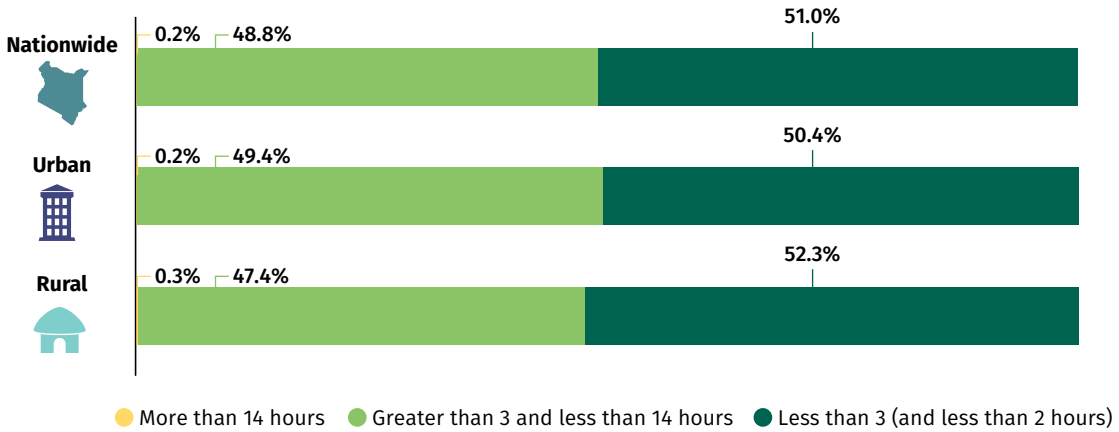
Nationwide, the Reliability and Quality attributes are the main constraints keeping grid-connected households in Tiers 3 and 4 from reaching Tier 5. Among grid-connected households, 17.5% have experienced appliance damage because of voltage fluctuations, placing these households in Tier 3 (Figure 36). Availability, Reliability, and Affordability attributes keep many households in Tier 2 or below. These attributes are also reflected in Figure 38, as most of the households perceive outages and quality as major challenges.

FIGURE 36 • **Quality attribute, grid-connected households**



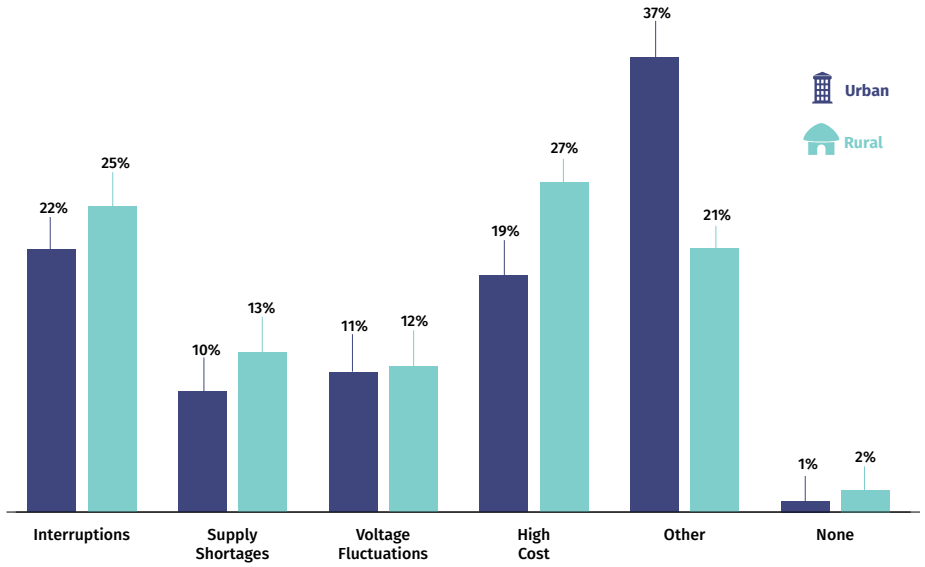
Almost half of grid-connected households experience more than three outages a week, or more than two hours of interruptions thus placing these household in Tiers 3 or 4 for Reliability (Figure 37). Slightly fewer than half grid connected households are in Tier 5 and reducing number or duration of outages can help move many households to higher Tiers.

FIGURE 37 · **Reliability attribute, grid-connected households**



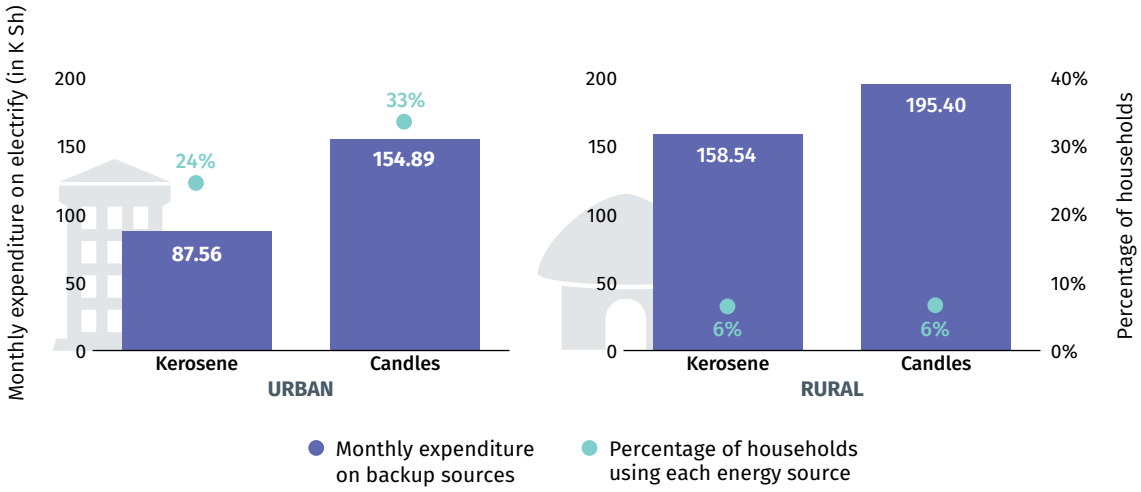
The most common issues directly reported by grid-connected households as key concerns were service interruptions, high cost, and voltage fluctuation (Figure 38). Twenty-five percent of rural and 21% of urban households rate power outages as the most serious problem with the grid, followed by 27% of the rural and 19% of the urban respondents complaining about the high cost of electricity. These findings are based on consumer perceptions of key issues and are therefore more subjective than those analyzed in the case of MTF attributes. The number of rural households (21%) are less than the urban households (37%).

FIGURE 38 • **Main issues with the grid electricity as reported by households, by urban and rural locations**



To cope with power outages, 6% of rural households and 21% of urban households use kerosene lamp as a backup source of lighting; 6% of rural households and 33% of urban households use candles (Figure 39). Roughly 70% of the grid-connected households do not have any backup source of lighting, and more urban households (28.5%) than rural households (5.8%) use a backup source; 13.1% of households use off-grid solutions as backup.

FIGURE 39 • **Grid-connected households using a backup source for lighting, and the monthly expenditure on the backup source, urban and rural locations**



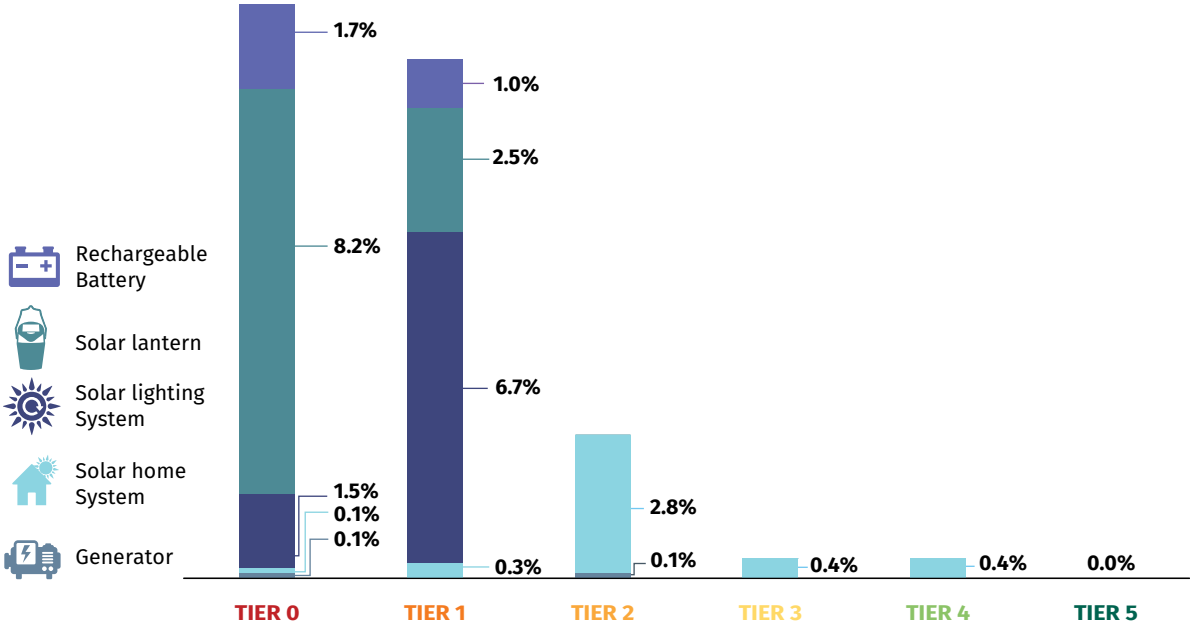
IMPROVING ELECTRICITY ACCESS AMONG HOUSEHOLDS THAT RELY ON OFF-GRID SOLAR

Wherever the national grid is unavailable, off-grid solar devices are the most commonly used systems, and rechargeable batteries are helping fill the electrification gap. More than 90% of households rely on off-grid solutions, and the reliance on generator and rechargeable batteries is very low.

Most of all households using off-grid solutions are in Tiers 0–2; fewer than 2% are in Tier 3 or above (Figure 40). Households depending on off-grid energy solutions are mainly constrained by the Capacity and daily Availability attributes.

FIGURE 40 • **Off-grid technology distribution by MTF tiers**

Households Using Off-Grid Solar Products



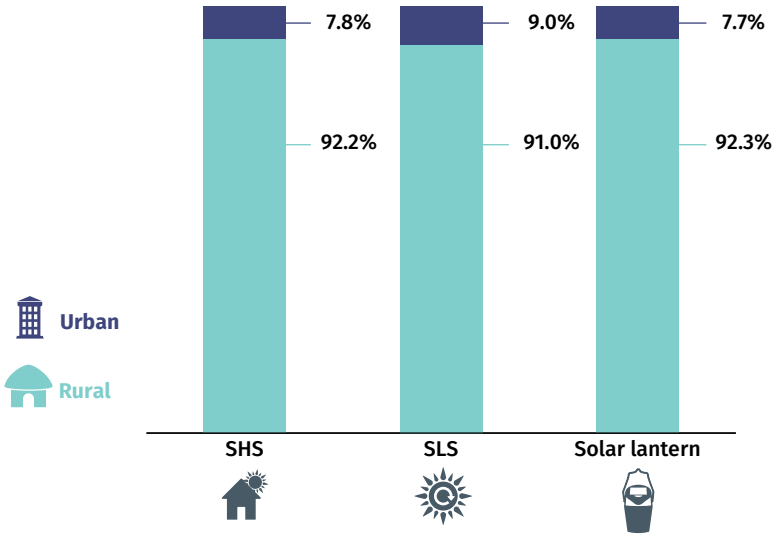
Off-grid energy's tremendous impacts—and the potential for more—have been recognized in the newly launched (December 2018) Kenya National Electrification Strategy (KNES). Kenya has long been the global leader in adoption of off-grid solar technology. From the time Lighting Africa's[12] first pilot kicked off in Kenya in 2009 to today, the achievements have been remarkable. In 2009, consumer awareness was extremely low, solar lanterns represented cutting-edge technology, and usage of these products was at only 2%. In contrast, nearly 10 million Kenyans are now meeting their basic electricity needs with quality-verified products that can do much more than task lighting, and 4.7 million certified quality products were sold between 2009 and 2018 (Lighting Africa 2018).

12 Lighting Africa is part of the World Bank Group's contribution to Sustainable Energy for All (SEforAll). It is implemented in partnership with the Energy Sector Management Assistance Program (ESMAP), the Global Environment Facility (GEF) and the governments of Australia, Austria, Canada, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Lithuania, the Netherlands, Norway, Sweden, the United Kingdom, and the United States of America. https://www.lightingafrica.org/about/

Kenya's private sector players have developed innovative business models to reach more customers over the past several years, including developing efficient supply channels for cash sales of portable lanterns and SHSs; pioneering the rollout of technological approaches such as pay-as-you-go (PAYGo) systems that enable customers to pay for their solar products in small. affordable installments, often through mobile money. The new industry is attracting private equity and debt capital to fund fast-growing businesses. The MTF survey also confirms that solar-based solutions play significant roles in providing electricity access in Kenya and especially in rural areas.

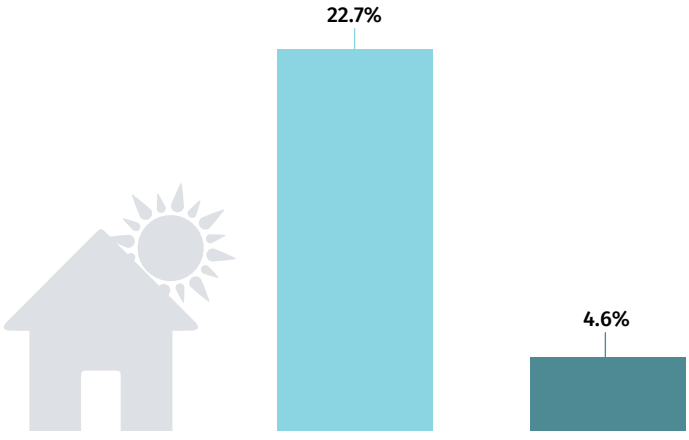
The off-grid solutions are mostly popular in rural areas as opposed to the urban areas. Across different solar products such as solar lanterns, solar lighting systems and solar home systems, approximately 91.5% household using these reside in rural area (Figure 41).

FIGURE 41 • **Off-grid solar households, urban and rural locations**



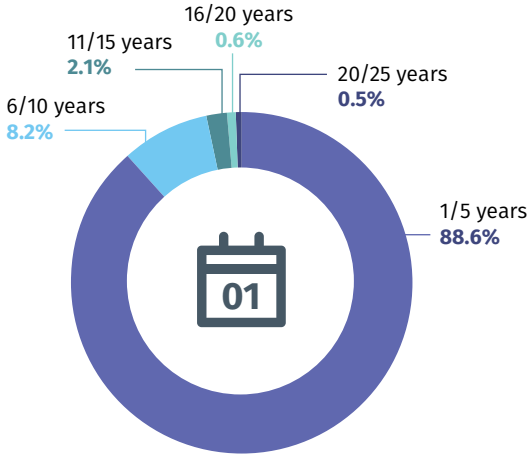
Out of 65.4% households with access, 22.7% use off-grid solar solutions as main sources of electricity, compared to 4.6% who use it as a backup**.** Urban households use off-grid solar products mainly for supplementing insufficient hours of electricity and frequent disruption from the grid electricity. On the other hand, off-grid solar products are the main source of electricity for users in rural areas (Figure 42).

FIGURE 42 • **Off-grid solar-grid households using solar solutions as backup source**



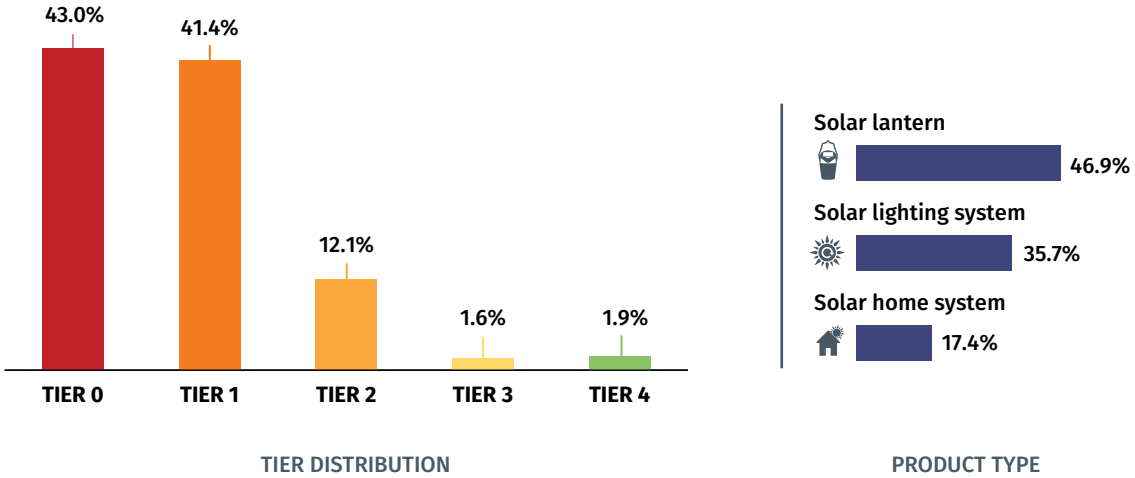
The rapid scale-up of off-grid solar electrification is mainly associated with the past five years. Among households that apply these solutions, most obtained their first off-grid solar device within the past five years (86.7% of all off-grid solar users), although 11.4% did so before that (Figure 43)

FIGURE 43 • **Years of using off-grid solar solutions**



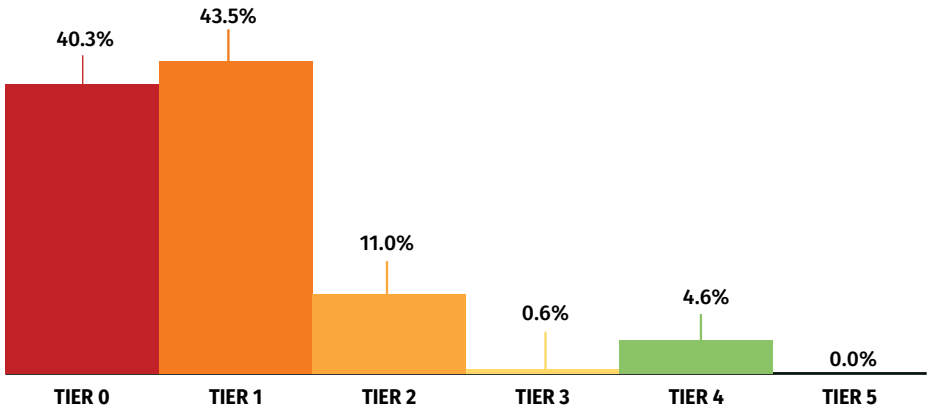
More than half of households using off-grid solar devices as their primary source are in Tier 1 or above; 43% are in Tier 0. Of those in higher tiers, 41.4% are in Tier 1, meaning that they can power a very low-load appliance, such as lights, a phone charger, or a radio, and 12.1% are in Tier 2, meaning that a low-load appliance can be powered, such as a television or a fan. Only 3.5% of households get Tier 3 and Tier 4 access, allowing them to power high-load appliances such as refrigerators and computers (Figure 44). Products that provide less than 1,000 lumen hours per day, or do not provide mobile phone charging, are counted as meeting some fraction of a household's needs. These products are measured at between Tier 0 and Tier 1, depending on their level of services, to evaluate their impact. On the other hand, SHSs that provide enough general lighting for a household and can also power a television and/or fan reach Tier 2 in the MTF (Lighting Africa 2016).

FIGURE 44 • **Off-grid-solar tier distribution and product typology, nationwide**



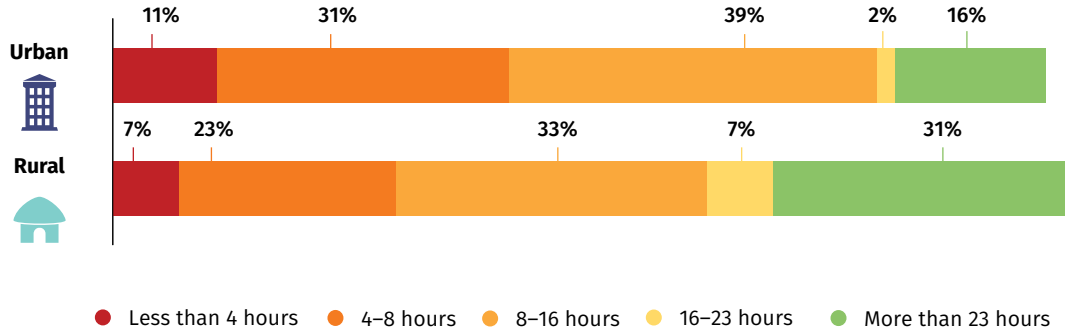
The majority of households using off-grid solar devices as their primary source (84.4%) are still in Tier 0 or Tier 1. To get these households to higher tiers, it is important to deal with Capacity and Availability attribute issues. Insufficient capacity is the main reason why households are classified in lower tiers. Among households that use off-grid solar devices, 40.3% are in Tier 0 for the Capacity attribute; 43.5% are in Tier 1—meaning that they can power a very low-load appliance, such as lights, a phone charger, or a radio—and 11.0% are in Tier 2. It is noteworthy that 5.2% of households have high-capacity (Tiers 3 and 4) off-grid solar systems (Figure 45).

FIGURE 45 • **Capacity tier distribution, households relying on off-grid solar solutions**



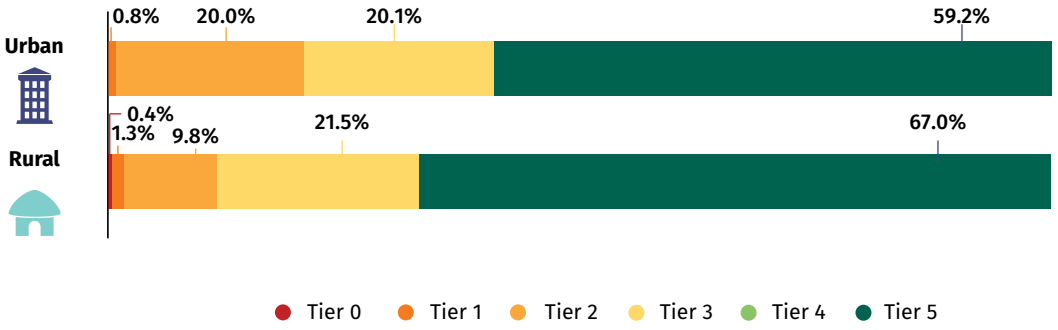
Availability (number of hours that the system can operate each day) is also an issue for some households in low tiers. The rural households get longer service from their off-grid solar systems than urban households; 31% of rural households enjoy 23 hours and more availability compared to 16% of urban households, whereas only 7% of rural households have less than 4 hours, compared to 11% of urban households. This may be related, however, to rural households using fewer appliances. Nearly 70% get to at least Tier 3 availability for the day and 87% for the night (Figure 46).

FIGURE 46 • **Distribution of the daytime Availability attribute (over a 24-hour day), households using off-grid solar solutions**



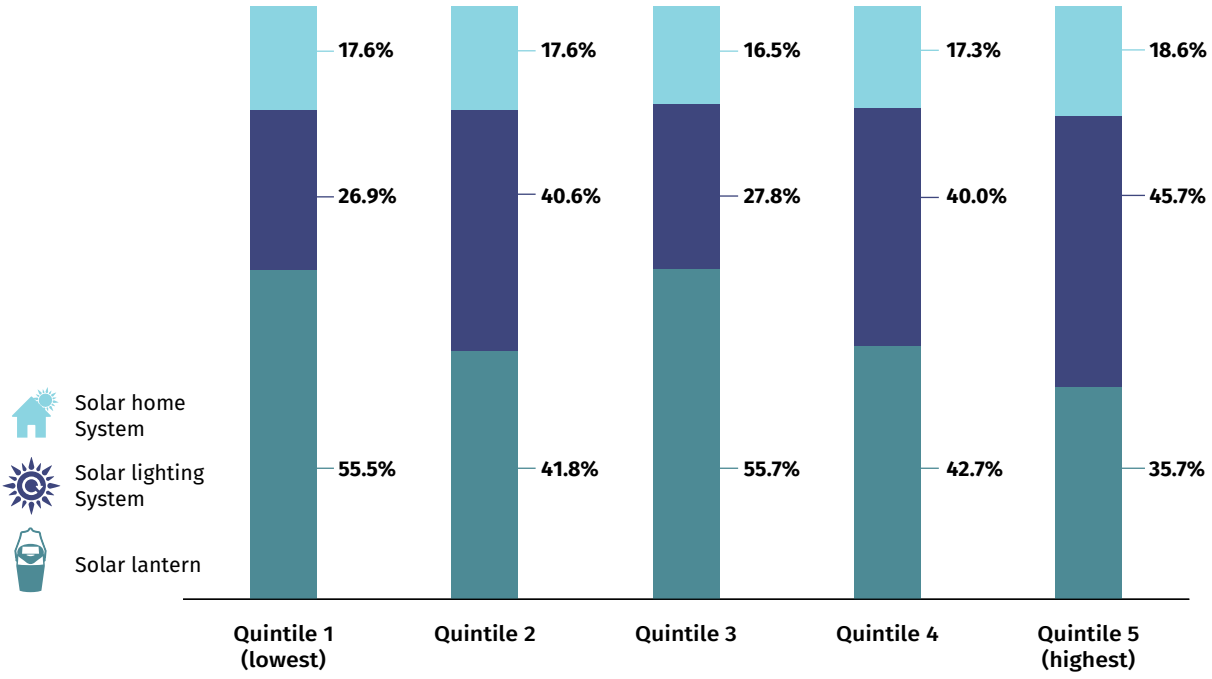
As can be seen in Figure 46, the off-grid solar solutions fall under higher tier classification in the evening hours: 59% of urban and 67% of rural households using solar off-grid solutions in Tier 5 for evening time availability.

FIGURE 47 • **Distribution of the nighttime Availability attribute (6pm–10pm), households using off-grid solar solutions**



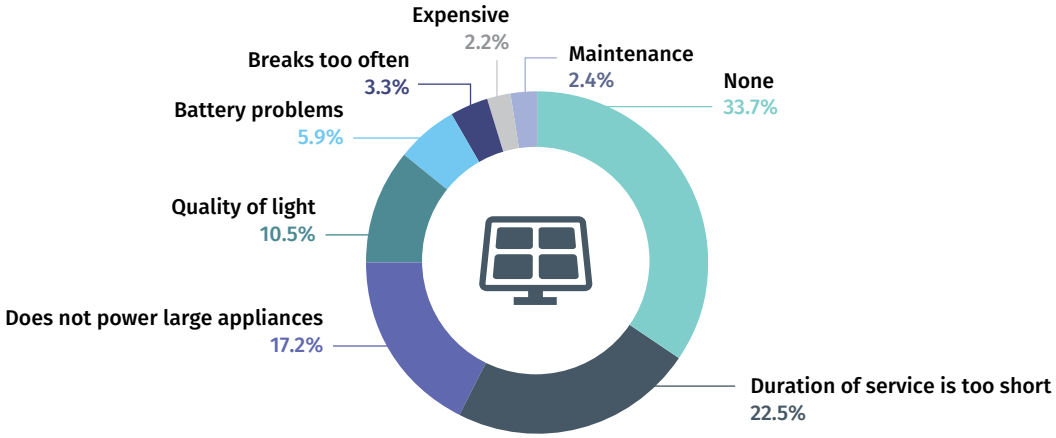
Off-grid solar solutions benefit all expenditure quintiles. While solar lanterns are more common in the lower expenditure quintiles, SHS use cuts across all income quintiles quite equally, showing that even poor households see value in accessing better off-grid solar service and are willing to invest in larger solar off-grid systems (Figure 48).

FIGURE 48 • **Expenditure quintile, households using off-grid solar solutions**



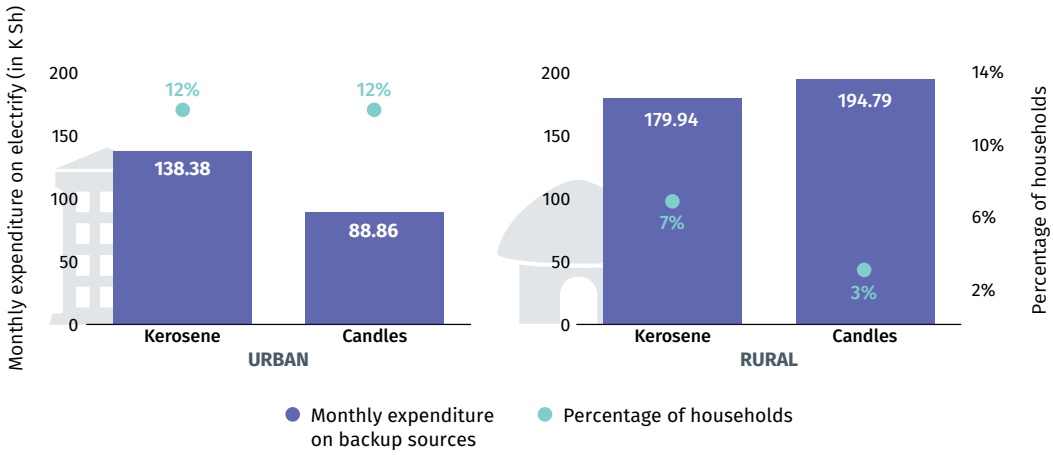
One third (34%) of households using off-grid solar products had no issues with the systems; 23% of households want to have longer hours of service, 17% want to power larger capacity of appliances. The others find challenges with the maintenance, quality of light, and battery problems when it comes to off-grid solar products (Figure 49).

FIGURE 49 • **Main issues, off-grid solar products**



To cope with limited capacity or availability of off-grid solar devices, 7% of rural households and 12% of urban households use kerosene as a backup source of lighting: whereas 3% of rural and 12% of urban households use candles. The rural households on an average spend more money (K Sh 187.5) than the urban households (K Sh 113.5 US$11.4) on back-up fuels (Figure 50).

FIGURE 50 • **Expenditure on backup sources, households using off-grid solar solutions**

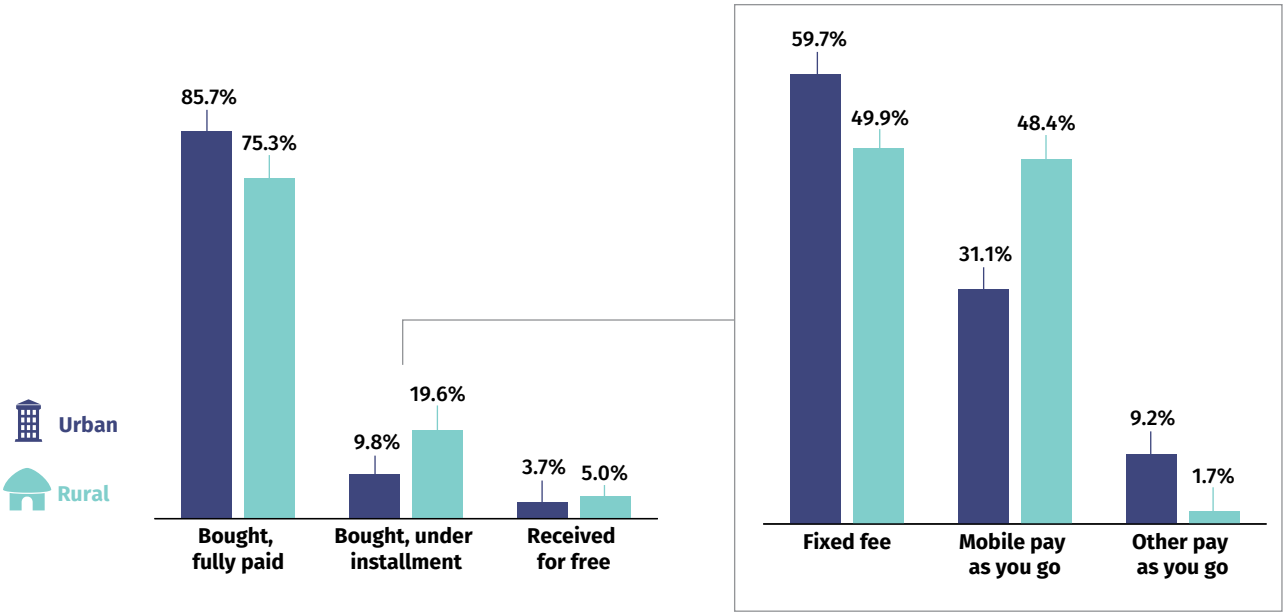


The priority in solar energy is to ensure that households relying on solar can achieve at least Tier 1 and above in access. This would mean that adequate and affordable off-grid solar products are available on the market. A solar device is adequate if the system can be used to power appliances for extensive amounts of time without such problems as failing batteries. Raising the awareness among non-electrified households about the benefits of such devices is important. Moreover, households should be able to upgrade the system as their needs and their ability to pay increase. Households without electricity and households with poor-quality solar systems would profit from financing options enabling them to upgrade.

The increasing number of PAYGo users in Kenya should facilitate the availability of financing options for upgrading off-grid solar systems. Among households that use solar devices, 75.5% of rural and 85% of urban households paid the full up front. In addition, 19.6% of rural and 9.8% of urban households paid in installments, and only 4.2% of households received the devices from local governments or the national government for free (Figure 51).

Of the households that bought solar systems under installments (19.6% rural and 9.8% urban), nearly half used the PAYGo model. Overall, 50% of urban and 40.3% of rural households using solar systems paid for their solar devices by the PAYGo model. In Kenya, a critical factor has been mobile PAYGo off-grid solar vendors' ability to leverage the popular M-Pesa mobile money and payments service for stand-alone solar products.

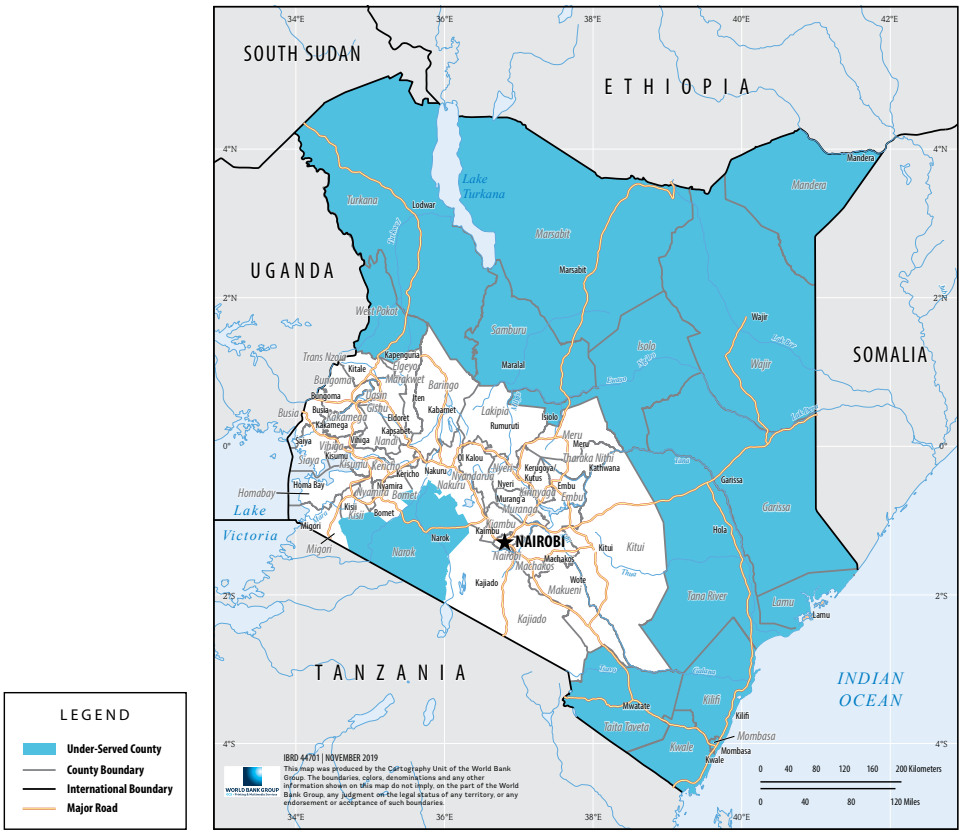
FIGURE 51 • **Payment plan and mode, households using off-grid solar solution**



ACCESS TO ELECTRICITY ACCESS IN 14 UNDER-SERVED COUNTIES

The 14 under-served counties include Mandera, Wajir, Garissa, Tana River, Samburu, Isiolo, Marsabit, Narok, West Pokot, Turkana, Taita Taveta, Kwale, Kilifi and Lamu (Map 3). They collectively represent 72% of the country's total land area and 20% of the country's population, including historically nomadic societies that even today continue to rely on pastoralism (K-OSAP and World Bank 2017). Their population is highly dispersed, at a density four times lower than the national average. They present profound infrastructure deficits, including lack of access to roads, electricity, water, and social services. There is also significant insecurity in certain areas, giving rise to substantial numbers of displaced persons and livelihood adaptations that further undermine economic prosperity (Wilcox and Cooper 2018). The region also scores much lower than rest of the country on several development indices: for example, poverty levels are at 70% (Lighting Africa 2018).

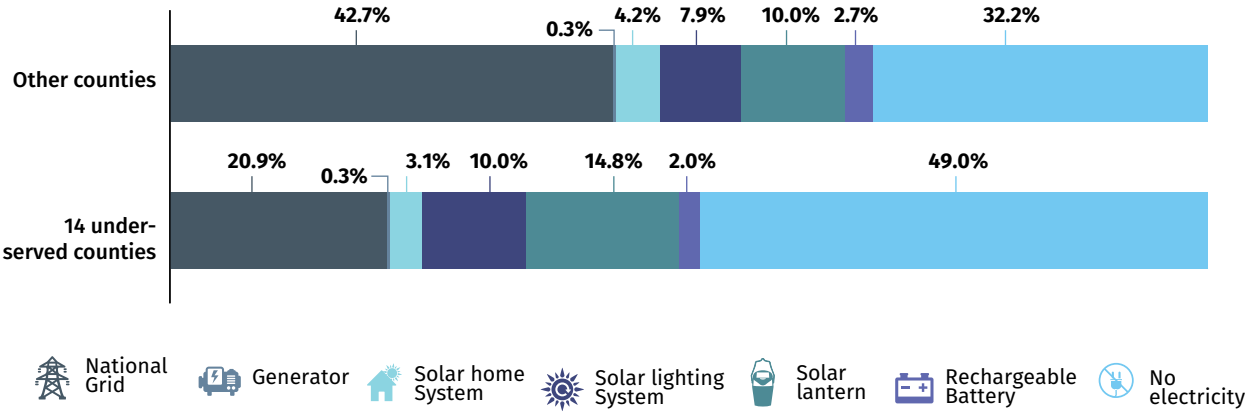
MAP 2 • **14 Under-served counties**



MTF ANALYSIS FOR 14 UNDER-SERVED COUNTIES

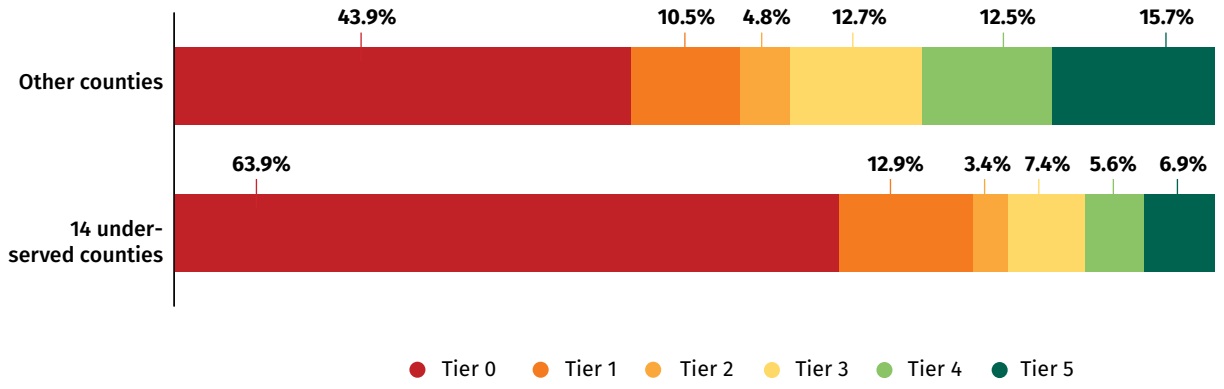
A significant gap in access to electricity is identified between the 14 counties and the rest of the country**.** Almost half (49%) of the households in the 14 counties do not have any source of electricity. The households connected to the grid are just 20.9% compared to 42.7% of grid-connected households in the rest of the counties. On the other hand, the off-grid penetration rate (30.5%) in the 14 counties is higher than in the rest of counties (Figure 52).

FIGURE 52 • **Access by source of electricity, 14 under-served and Kenya's other counties**



The electricity access gap and level of service are also low in these 14 under-served counties compared to the rest of the country: 63% of households in the 14 counties are in Tier 0 compared with the rest (43.9%). Only 29.7% of households are in Tier 3 and above compared to 51.3% of households in the rest of the counties (Figure 53)

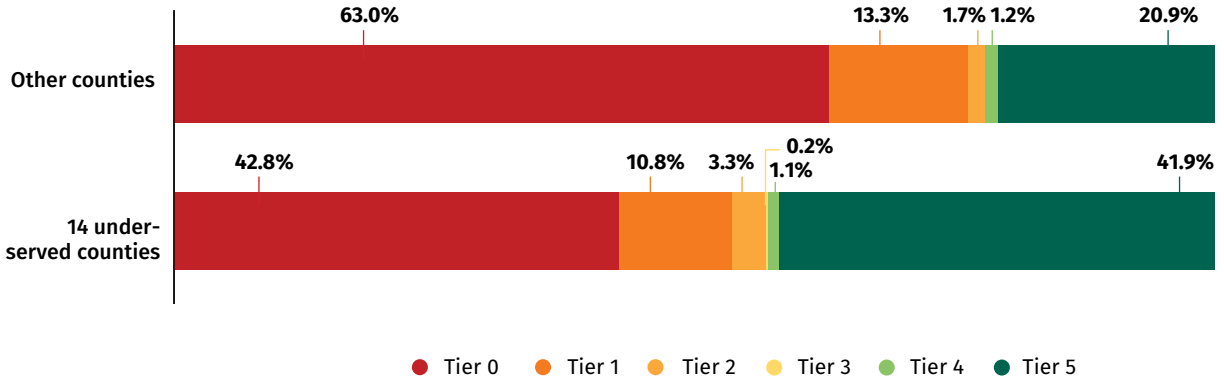
FIGURE 53 • **MTF tier analysis, 14 under-served and Kenya's other counties**



Capacity

All grid-connected households are considered to have high-capacity electricity (over 2 kW), but the grid infrastructure is limited in the 14 under-served counties, resulting in higher penetration of lower capacity off-grid solutions (Figure 54). Sixty-three percent of households in the 14 under-served counties fall in Tier 0 for the Capacity attribute compared to 42% of households in rest of the counties, whereas 20.9% of households in the 14 counties fall into Tier 5 compared to double the numbers (41.9%) for rest of the counties.

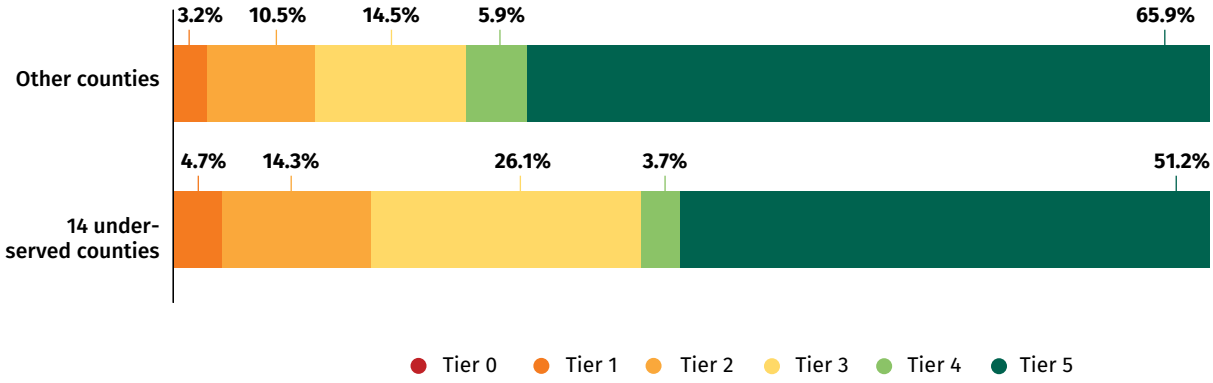
FIGURE 54 • **Distribution of the Capacity attribute, 14 under-served and Kenya's other counties**



Availability (over a-24 day)

In the 14 counties, 51.2% of households have electricity for at least 23 hours a day, and an additional 29.8% have 16 hours of electricity a day for seven days a week (Figure 55), This is less than the rest of the counties, as 65.9% of those households have 23 hours of electricity access per day. In the 14 counties, limited availability is more acute: 19% of rural households have less than 16-or-more hours of electricity access a day compared to 13.5% in the rest of the counties households that have the same duration.

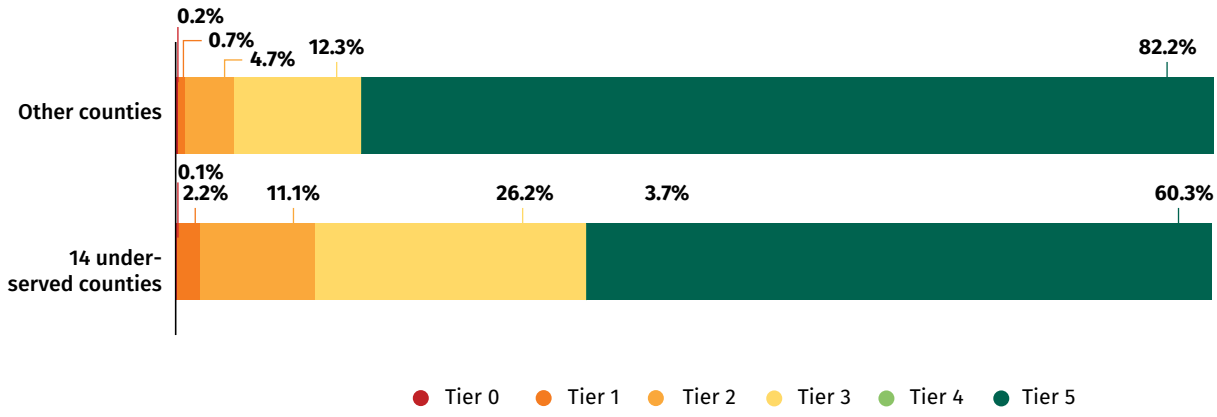
FIGURE 55 • **Distribution of Daytime Availability attribute (over a 24-hour day), 14 under-served and Kenya's other counties**



Availability (evening time)

Households in the 14 counties have more electricity supply during the evening (Figure 56) than do households elsewhere: 82% of households have 4 hours of electricity supply during this period. Evening duration is shorter for households in the rest of the counties, 60% of which have the full 4 hours. The 14 counties' better evening time access can be attributed to prevalent use of off-grid solar solutions compared to rest of the counties.

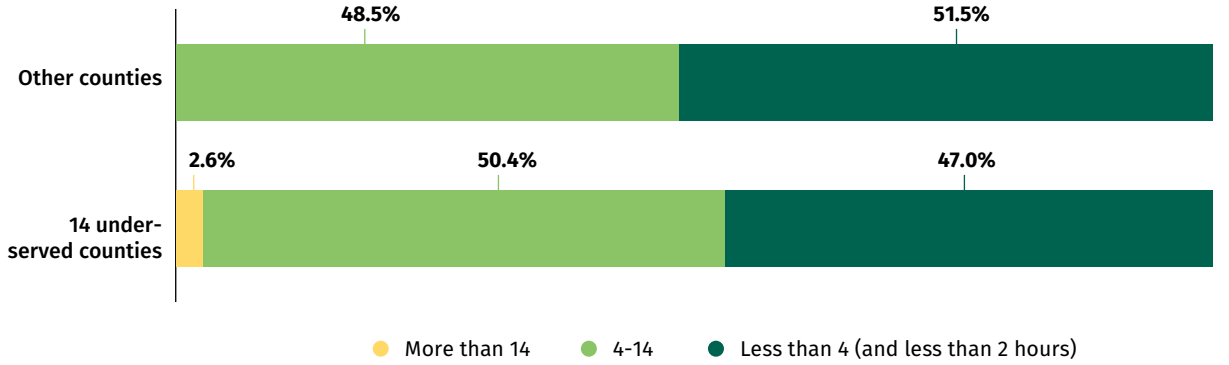
FIGURE 56 • **Distribution of the evening Availability attribute (4 hours), 14 under-served and rest of the counties**



Reliability

The Reliability attribute applies only to households on the national grid. Frequent power outages are challenging for 53% of the grid-connected households in the 14 under-served counties, and they experienced outages anywhere from 4 to 14 times a week. The other 47% of households had less than 4 or less than 2 hours of outages per week. Only 2.6% of households have more than 14 outages in under-served counties. Grid access is a challenge in these counties (Figure 57).

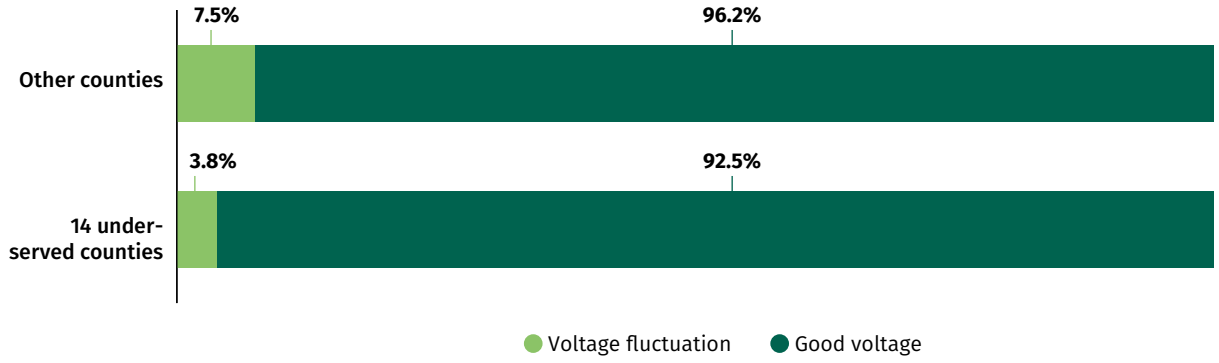
FIGURE 57 • **Distribution of the Reliability attribute, 14 under-served and Kenya's other counties**



Quality

The Quality attribute applies only to households on the national grid. Among households connected to the national grid, 3.8% face voltage issues, such as low power or fluctuating service, resulting in appliance damage in the 14 under-served counties. This is, however, slightly better than for the rest of the counties (Figure 58).

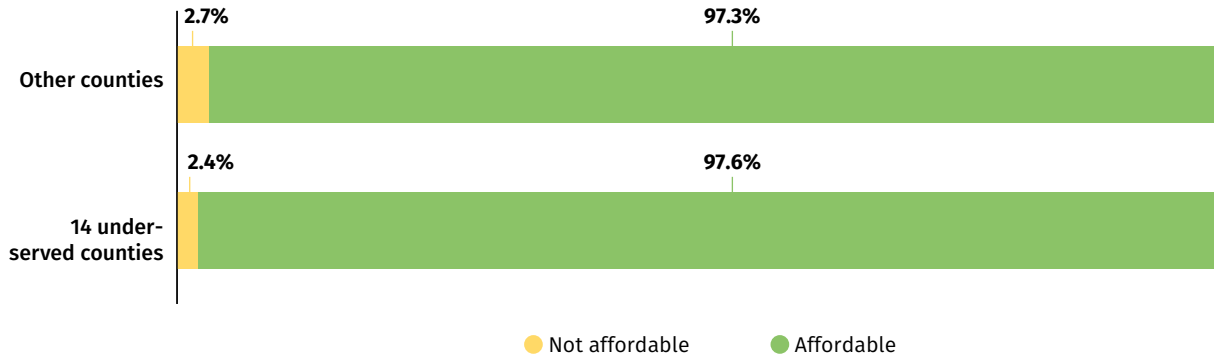
FIGURE 58 • **Distribution of the Quality attribute, 14 under-served and Kenya's other counties**



Affordability

The Affordability attribute is also applied for grid-connected households only. It measures whether the current electricity tariff is affordable for households. If a household would spend less than 5% of the household expenditure on electricity to consume 1 kWh hour a day and 30 kWh a month, the electricity is assumed to be affordable. Applying this definition, electricity was found affordable to most of the households in the 14 under-served counties. Only 2%, households find it unaffordable (Figure 59).

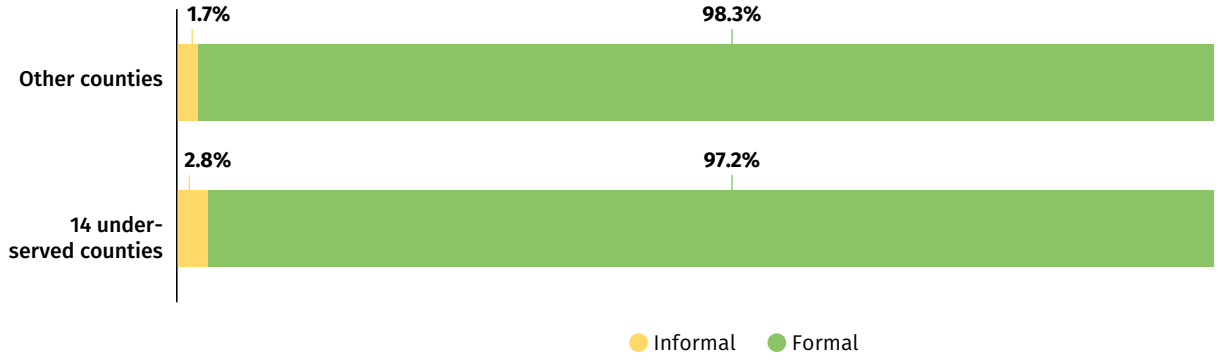
FIGURE 59 • **Distribution of the Affordability attribute, 14 under-served and Kenya's other counties**



Formality

In the 14 under-served counties, 3% of the grid-connected households have an informal grid connection compared to 2% of households in rest of the counties (Figure 60).

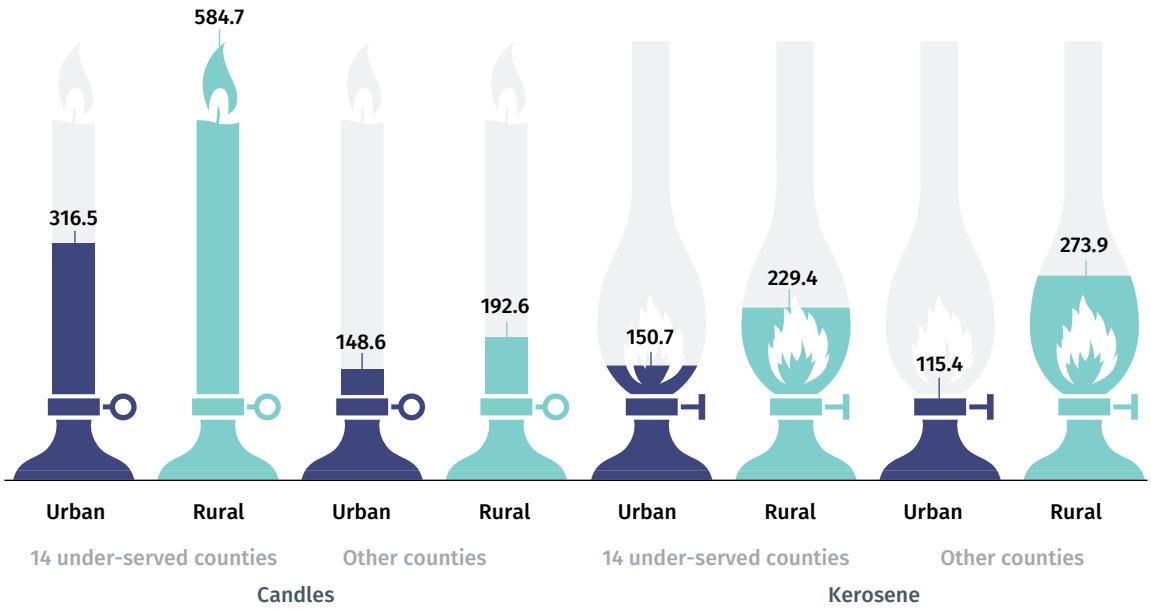
FIGURE 60 • **Distribution of the Formality attribute, 14 under-served and Kenya's other counties**



IMPROVING ACCESS TO ELECTRICITY 14 COUNTIES

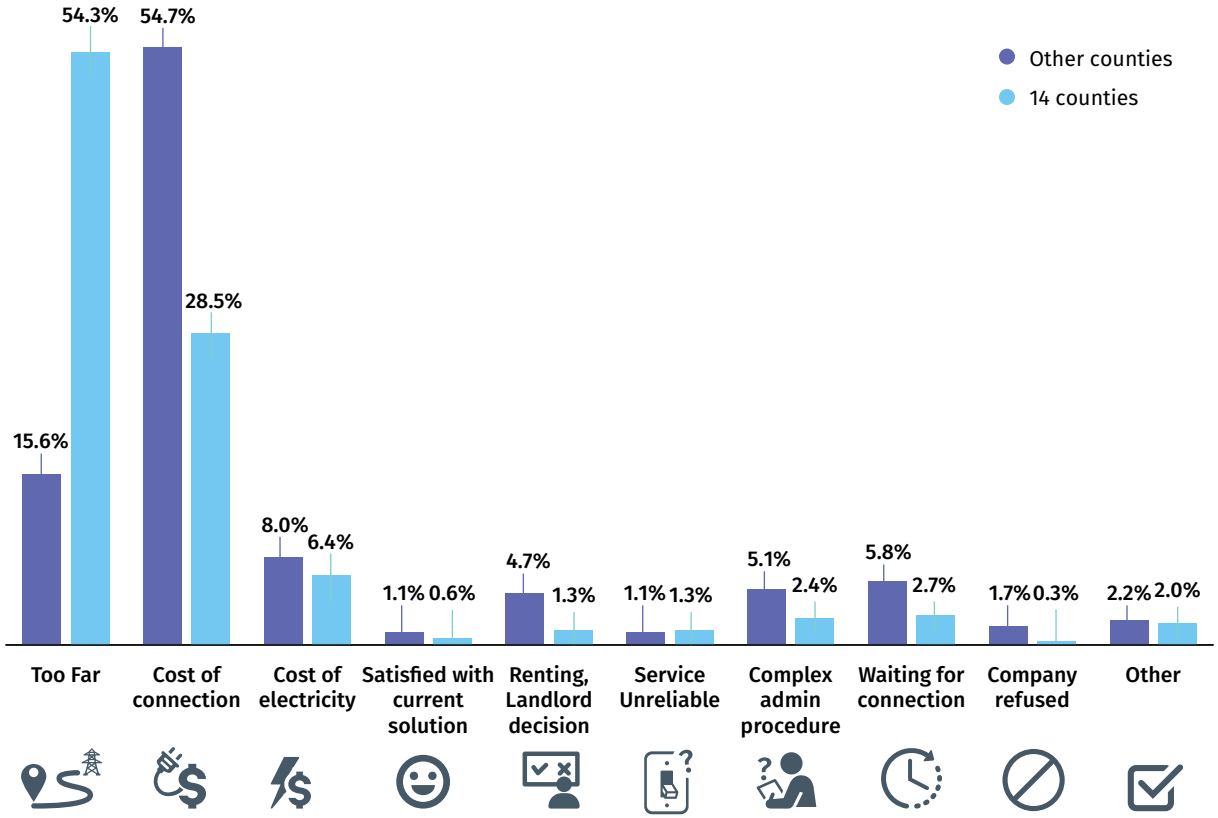
Households in the 14 under-served counties spend 3.25% of their monthly household expenditure on alternative sources such as candles and kerosene for their lighting needs. The share of financial burden is more on no access Tier 0 household compared to households with some off-grid or grid access which is 1.2% and 0.82% respectively (Figure 61).

FIGURE 61 • **Expenditure (in K Sh) by households of the 14 under-served and Kenya's other counties on alternative sources of electricity**



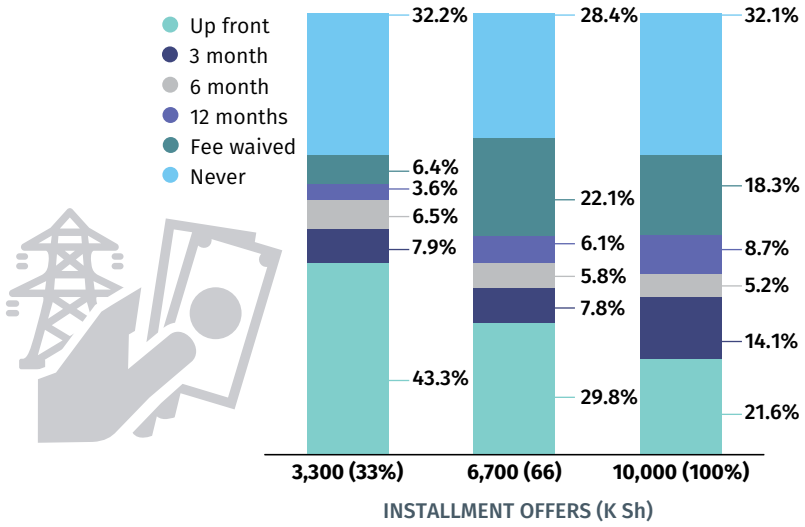
Based on peoples' perceptions, 54.3% of households in the 14 under-served counties consider distance from the grid as the main barrier to getting grid connection. This was considered a barrier by only 15.7% of the households from rest of the counties. In addition, 28.6% of households in the 14 under-served counties see cost of connection as a barrier, which is a lower rate than the 54.7% of the rest of the counties—for a large number of the under-served county households, the cost of connection is less relevant if the grid is not available in the area. Cost of electricity as a barrier doesn't differ much between the 14 under-served and rest of the counties (Figure 62).

FIGURE 62 • **Barriers to gaining access to grid electricity**



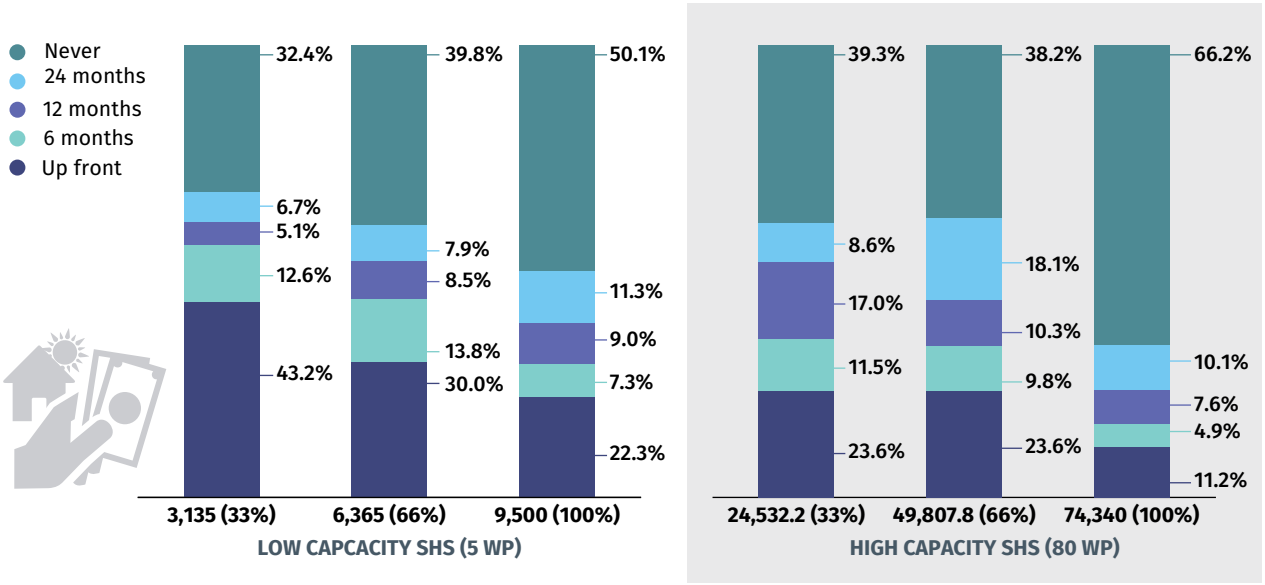
Slightly more than 49% of households from the 14 counties would be willing to pay for the grid connection in full over time. Hence, installment periods and flexible payment can be used to provide grid connectivity for those households that can be connected to the grid. However, a larger share of households in the 14 counties (38.6%) would not be willing to pay for a grid connection, even if the price was reduced to one-third and a payment plan offered (Figure 63). Thus, understanding the financial and other constraints of these households will be necessary to achieve universal electricity access in these 14 counties.

FIGURE 63 • **Willingness to pay the grid connection fee**



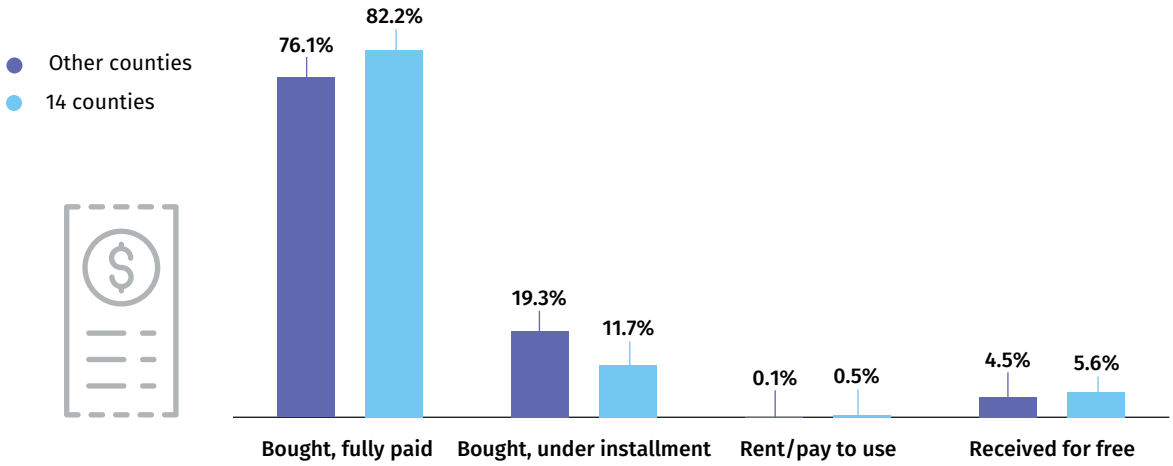
Given the lack of expansive grid infrastructure in the 14 under-served counties, the off-grid solutions such as SHSs and mini-grids can provide low-cost and timely access. However, up-front cost can be a barrier, which can be mitigated through flexible installment payments. Almost 33.6% of households are willing to pay the full cost of a low-capacity SHS, and 23.6% of households are willing to pay for high-capacity SHS if provided with some installment scheme (Figure 64). The majority of households, however, would not be willing to pay for a low-capacity SHS, even with installments. The WTP, however, increases if the price is reduced and a payment plan is offered. Understanding financial and other constraints of households that were unwilling to pay will be critical for devising a plan that will connect everyone in the 14 countries to at least Tier 1. Targeted assistance for poorer households is likely to be needed.

FIGURE 64 • **Willingness to pay for a solar home system**



Among households that use solar devices, 82.3% of the 14 under-served counties' households paid the full price up front, 11.7% bought an SHS on monthly installment schemes, and 0.5% of households had pay-to-use or rent schemes. Only 5.2% received an SHS for free as part of the government schemes. The high rate of households buying SHSs up front and fully paid shows a willingness to get electricity access through off-grid solar solutions in the 14 under-served counties. The numbers for rest of the counties follow similar trend (Figure 65).

FIGURE 65 • **Payment plan and mode, households using off-grid solar solution: 14 under-served counties and Kenya's other counties**



The 14 under-served counties are spread out; some are nomadic in nature and it might be difficult for their population to afford off-grid solar systems or grid connections. Many of these households have also not used electricity before and do not have any reference point on the benefits of electricity, including information on PAYGo schemes to access SHS. It would make sense to provide flexible payment schemes and coupled with an awareness campaign on the benefits of electricity access.

POLICY RECOMMENDATIONS

Electricity Access to Tier 0 Households: About 34.5% of households are in Tier 0 for electricity access, out of which 74.4% have no source of electricity whereas 25.6% have an electricity service that does not meet the Tier 1 Capacity or Availability attributes thresholds. Moving households without any source of electricity up from Tier 0 would require connecting these households to the grid or providing them with off-grid solutions. A Least-Cost Geospatial Electrification Plan developed under KNES guides government decisions on which households could be cost-effectively connected to the grid and which will require mini-grid or off-grid connections.

- **Connecting households within the grid catchment:** As part of the "last mile" approach, some of the Tier 0 households can be connected through the grid, which would involve extending low voltage lines to reach consumers in proximity of existing lines and transformers. These are low-cost connections that would increase the share of households in Tier 3 and above. This will, however, also require tackling the administrative issues and complex processes for getting a connection that 15% of households identified as the main reason for not being connected. On the other hand, the least-cost electrification considerations should also carefully examine the expected demand from these households. Given the low consumption and low appliance ownership of grid-connected rural households, some of these households may be more cost-effectively connected to off-grid solutions, despite their relative proximity to the grid.

- **Overcoming demand-side constraints:** Even if households reside in close proximity to the grid, they may not be connected due to affordability constraints Offering payment plans for the connection costs and a variety of financing options and low-cost wiring options (such as ready boards), as already practiced in LMCP, should effectively address the financial barrier for the majority of the

households. The WTP survey shows that extending the payment period is still the most effective measure to increase grid and off-grid affordability. It should be noted, however, that affordability constraints are likely to increase, as the unelectrified households are disproportionately represented in the lowest expenditure quintile. Additional financial support may be needed for poorer households to achieve universal electricity access, particularly in the 14 under-served counties, where more than a third of households would not connect despite the offer of the financing plan. The government and Kenya Power should also investigate the reasons for low consumption and low appliance use of newly connected grid households. Measures to increase consumption and support use of appliances, in particular for productive uses, may be appropriate.

- **Promote the adoption of off-grid solutions:** Off-grid solar products could help households in areas where grid infrastructure is not available, or where it is not economically viable to connect the household due to the low consumption levels. Distance from the grid remains one of the main issues for many households. These households can be better served with mini-grid or off-grid solutions, and conducive policies and private sector participation can help this sector grow faster and bridge the access gap. Supporting quality products and making them more affordable, for example, through the provision of microfinancing and payment plans such as PAYGo, should boost the adoption of solar devices. In parallel, the government should investigate the reasons why 48% of households would not purchase a low-capacity SHS even with the provision of the payment plan. Additional financial incentives and complementary measures (such as awareness campaigns) may be necessary to ensure that everyone has access to at least Tier 1 service level. Mini-grids are not prevalent in the survey, but moving forward they are one of the options for unelectrified households, especially in areas where the main grid is too far and there is potential high to medium demand. Scaling up mini-grids would requires clear policies and regulations along with the capacity building efforts within the sector.

Improving Access for Grid-Connected Households: More than half the grid-connected households experience outages, thus placing these households in Tiers 3 or 4. Less than a quarter (17.5%) have experienced appliance damage because of voltage fluctuations, placing these households in Tier 3. Improvement in the Quality and Reliability attributes of the grid electricity service would shift two-thirds of grid-connected households to higher Tiers 4 and 5. The Quality improvement would involve reducing voltage fluctuation. The Reliability enhancement would require reducing the number and duration of outages.

Improving Access for Off-Grid Households: One-fourth of households use off-grid solutions, including stand-alone solar devices, rechargeable batteries, and generators. Of these households, 40.3% are in Tier 0, and the main constraints these households face are in the Capacity and Availability attributes. The improvement in these attributes could shift a third of households relying on off-grid solutions to higher tiers. Off-grid solutions are the main source of electricity for 22% of households, and many households want to power higher load appliances, showing willingness to upgrade their existing solar systems. Availability of affordable, quality solar systems and appliances, including availability of financing options or installment payments for such systems and appliances, is key to moving these households to higher tiers.

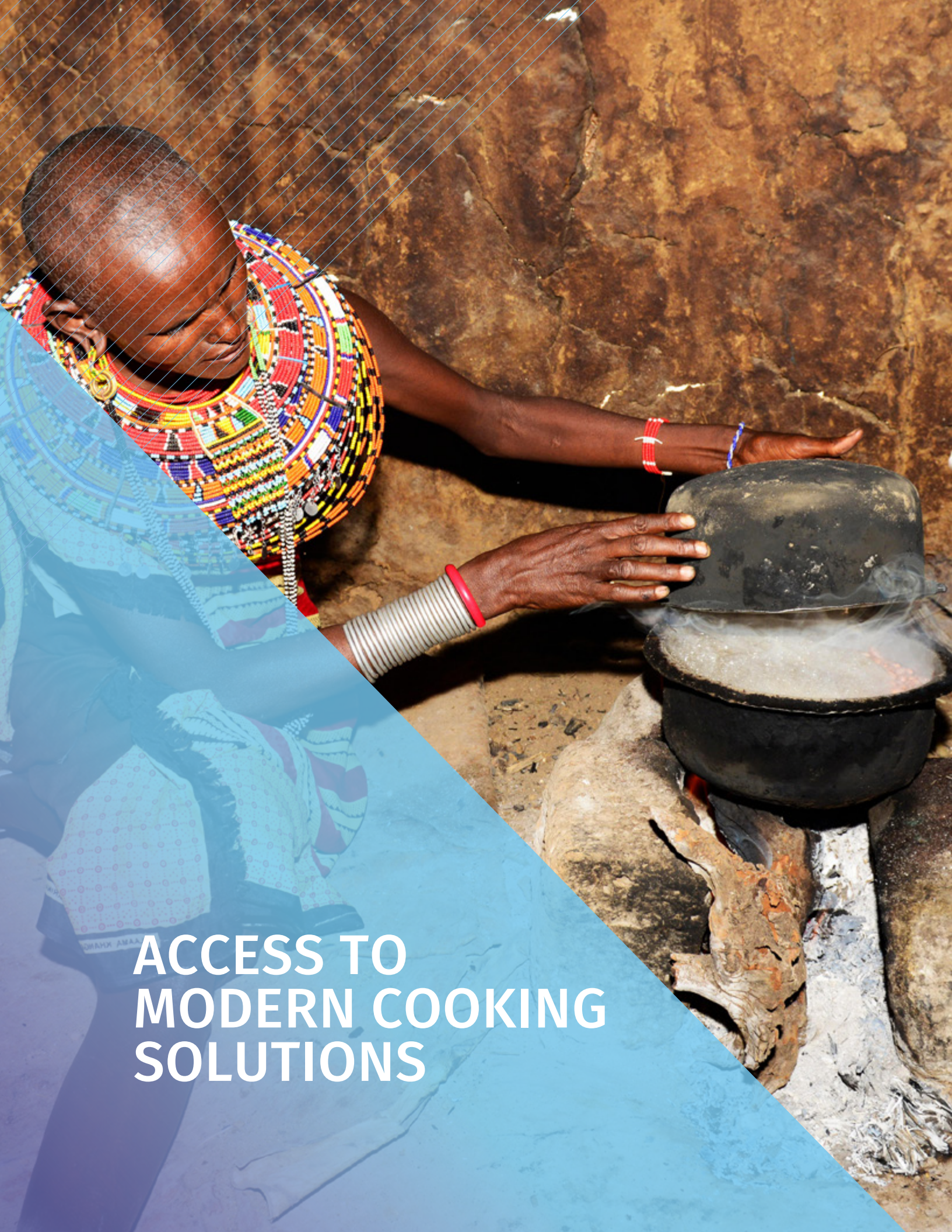
Promoting quality solar products and off-grid solar appliances would be critical in expanding the solar market. As noted from the MTF survey, 34% of households using off-grid solar products cite that they have no issues with their systems, but many complain about challenges with the maintenance, quality of light, and battery problems. The Government of Kenya has already taken positive steps by adopting International Electrotechnical Commission standards for off-grid systems—which should lead to higher penetration of quality products on the market.

Improving Access in the 14 Under-Served Counties: The level of access in the 14 under-served counties is lower than in the rest of the counties, and these counties might need a customized approach to improve and increase electricity access. As for the grid-connected 20.9% of households, only 6.9% are in Tier 5 and by improving the Quality and Availability attributes many of the grid-connected households can be moved to higher tiers. Also, given the remoteness and sparsely populated areas in these counties, off-grid solar products and mini-grids would serve as a timely and low-cost solutions. The use of off-grid solar is prevalent in the 14 counties, as 30.5% of households rely on such a solution. Sustainable access to at least the Tier 1 level will, however, require strengthening and expanding off-grid solar market and improving the quality of the products. Under the World Bank–supported K-OSAP, the government is already putting measures in place to increase off-grid solar product penetration and identifying communities for mini-grid development

Capacity and Skills Development: A comprehensive capacity- and skills-building program is critical for improving access to grid and off-grid solutions. The expansion of grid infrastructure and connection would require the training of electricians, especially for the Quality and Affordability attributes in internal wiring. As per the MTF, many grid households would benefit from good internal wiring and better maintenance of grid infrastructure. Expanding or creating mini-grids would also require trained solar technicians and installers, along with company skill development on software and business management, especially in the 14 under-served counties where off-grid solutions can play important role in achieving access.

Awareness Campaign: Many households complain about the quality of service, cumbersome grid connection processes, and lack of knowledge about the benefits of electricity access and quality off-grid solar products. An awareness campaign should be part of any access strategy to ensure that households understand the grid connection process, are aware of the benefits of electricity and the availability of new technologies and options, can recognize and understand the benefits of quality off-grid products, and are aware of financial support available to them. This can help potential grid customers apply for connection and avail themselves of installment schemes offered by the government. The off-grid solar users can then make informed choices that are best suited to meet current and future needs: for example, the option to use modular systems for households who plan to buy higher load appliances.

Monitoring Progress: A repeat of the MTF survey would allow the government to monitor the progress and impacts of measures already introduced, such as LMCP, reduced connection fees, availability of ready boards, and off-grid electrification initiated nationwide and 14 under-served counties.



ACCESS TO MODERN COOKING SOLUTIONS

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

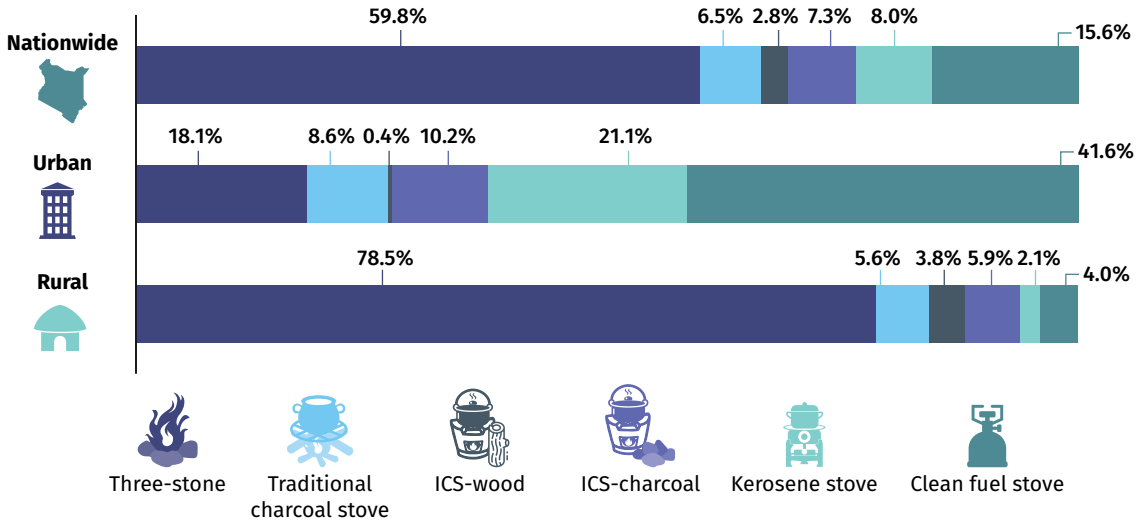
TECHNOLOGIES

Kenya has made notable strides in encouraging the use of clean and improved cookstoves in Africa (Teodoro 2008; Winrock International 2011). According to MTF survey results, however, over 65% of households still use traditional biomass stoves and cooking fuels to address their primary cooking needs, due to the slow penetration of improved and clean fuel stoves among Kenyan households.

Almost two-thirds of Kenyan households (59.8%) reported using the three-stone stove as their primary cookstove—although significantly large variations exist between rural and urban households that use the three-stone stove. Notably, while more than three-quarters (78.5%) of rural households use three-stone stoves, only about 18.1% of urban households use them. Similarly, we observe variations in the use of clean-fuel stoves—liquefied petroleum gas (LPG) and electric stoves—with 41.6% of urban households reporting their use, compared to only 4% that reported using clean-fuel stoves in rural Kenya. We also observe the wide use of kerosene stoves in urban areas of Kenya, confirming previous studies which note the increasing use of kerosene stoves among lower- and middle-income households in urban areas across Africa (DHS 2015). Our results reveal that the kerosene stoves are the second most reportedly used primary stove in urban areas in Kenya—used by 21.1% of urban households.

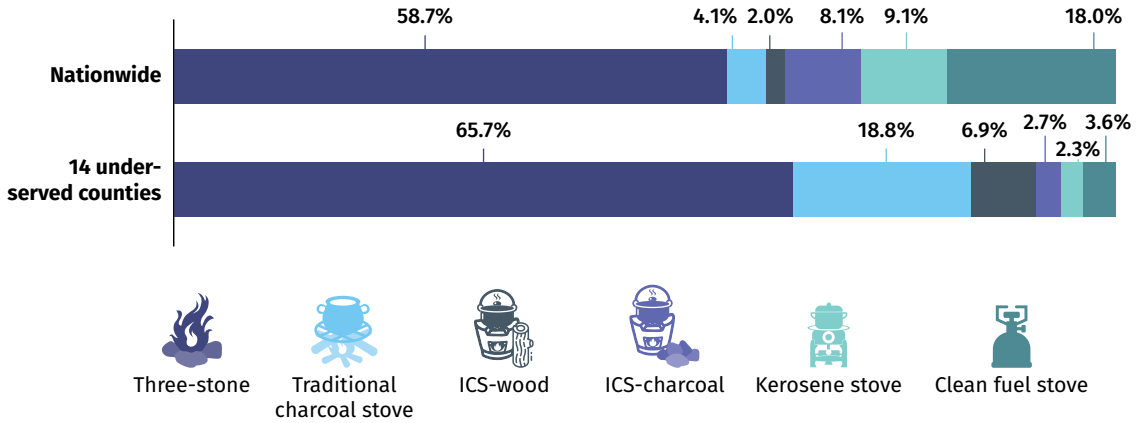
Nationwide, 6.5% of households in Kenya also use the traditional charcoal stove, while about 10% reported using improved cookstoves (ICSs). ICS-wood stove use is more prevalent in rural areas than urban areas of Kenya—where 3.8% of households reported using the ICS-wood stove, compared to less than 1% in urban areas (Figure 66) The low penetration rate of ICSs confirms previous studies, which find that while Kenya enjoys success in the manufacture of cost-effective and fuel-efficient ICSs, the uptake and usage are still modestly low, particularly in rural areas (Government of Kenya 2013; Karanja and Gasparatos, 2019).

FIGURE 66 • **Stove types: Urban, rural, and nationwide**



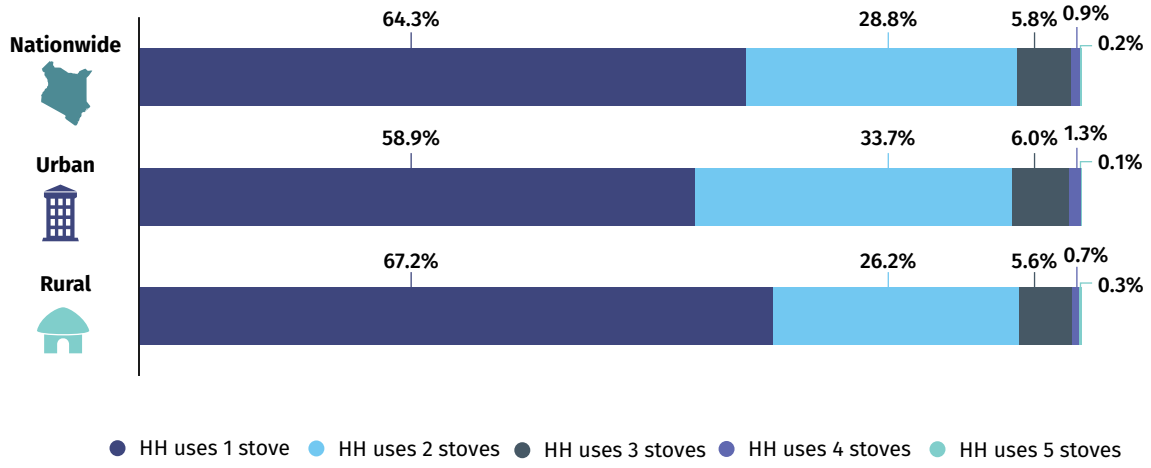
We analyze cooking solutions in the 14 under-served counties and highlight striking differences that exist within these counties and the rest of the country. The vast majority of households (85%) in the under-served counties use traditional biomass stoves, compared to about 62.8% in the rest of the country. Clean fuel stoves are less common. In fact, less than 4% of households in the 14 under-served counties use clean fuel stoves, compared to 18% in the rest of Kenya. There are also differences in ICS usage, with households in the 14 under-served counties being more likely to use improved wood-stoves (7%, as opposed to 2% in the rest of Kenya). On the other hand, they are less likely to use improved charcoal stoves (2.7% in the 14 counties) than is the rest of the country (8.1%). There are, therefore, significant potential gains from time use, productivity, and health benefits that could accrue to these households by encouraging the use of cleaner stoves (Figure 67).

FIGURE 67 • **Primary cookstove type: Under-served counties**



The use of multiple stoves by households (stove stacking) is quite prevalent in Kenya and may be based on a host of factors, including the price of cookstove fuels, the household's budget, personal preferences, and convenience. Our analysis reveals that nationwide close to 30% of households use secondary or multiple stoves, with stacking more prevalent in urban than rural households; about 35% of urban households use more than one cookstove, compared to about 28% in rural households (Figure 68).

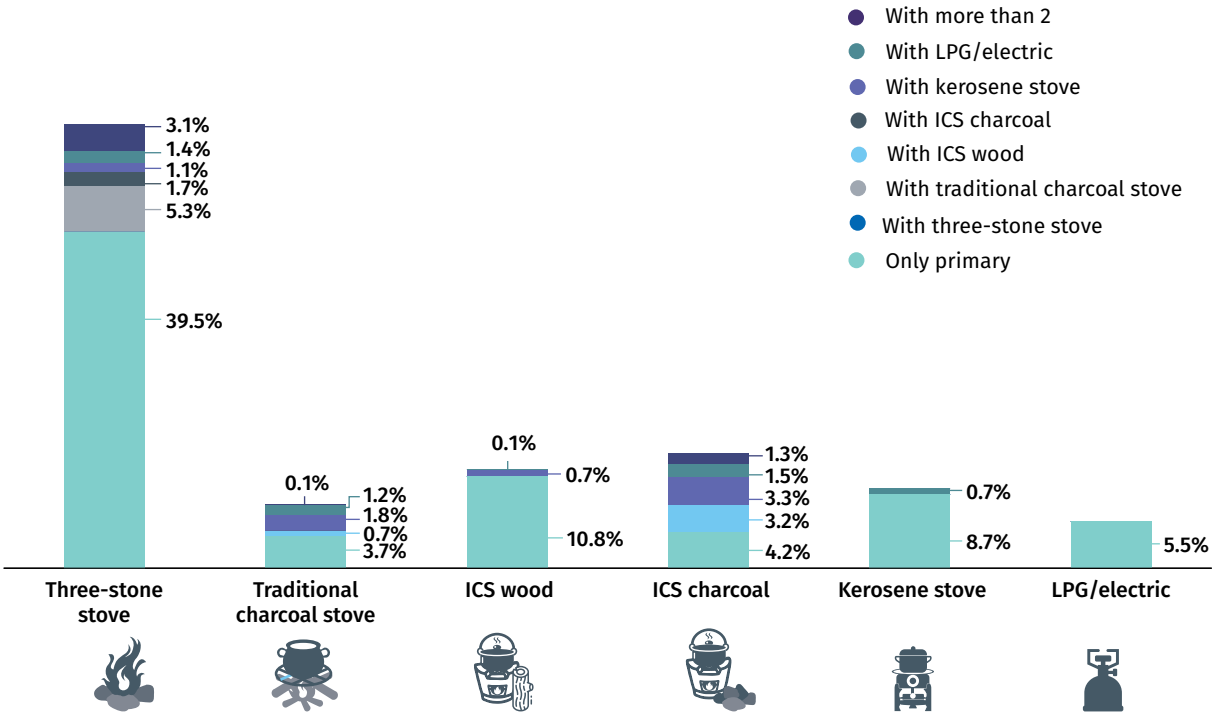
FIGURE 68 • **Cookstove stacking: Urban, rural, and nationwide**



Note: Fuel stacking refers to the practice of a household using more than one type of fuel to meet its cooking energy needs. For additional explanation on the origins and reasons behind fuel stacking, please refer to Bhatia and Angelou (2015, 46). HH = household.

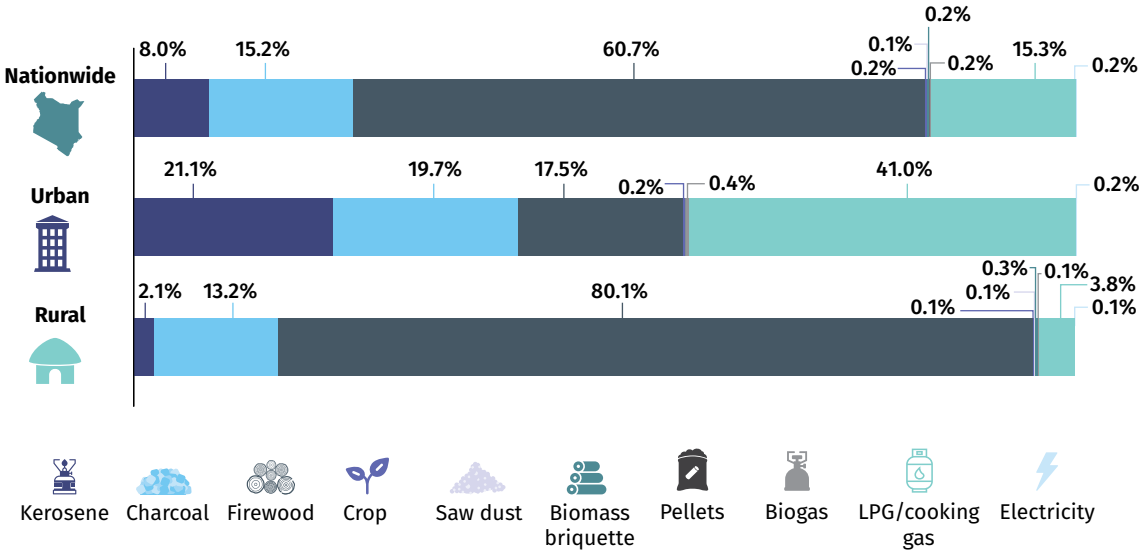
Among households using multiple stoves concurrently, the combination of the three-stone and traditional-charcoal stoves are most popular (5.3% of households), revealing that even when rural households use multiple stoves, the combination of stoves used is still primarily biomass stoves. Households that use a combination of biomass stoves and clean fuel stoves reported using biomass stoves (both three-stone stove and traditional stove) with LPG electric stoves (2.6%); and ICSs with LPG stoves (1.6%) (Figure 69).

FIGURE 69 • **Stove stacking, by primary stove type, nationwide**



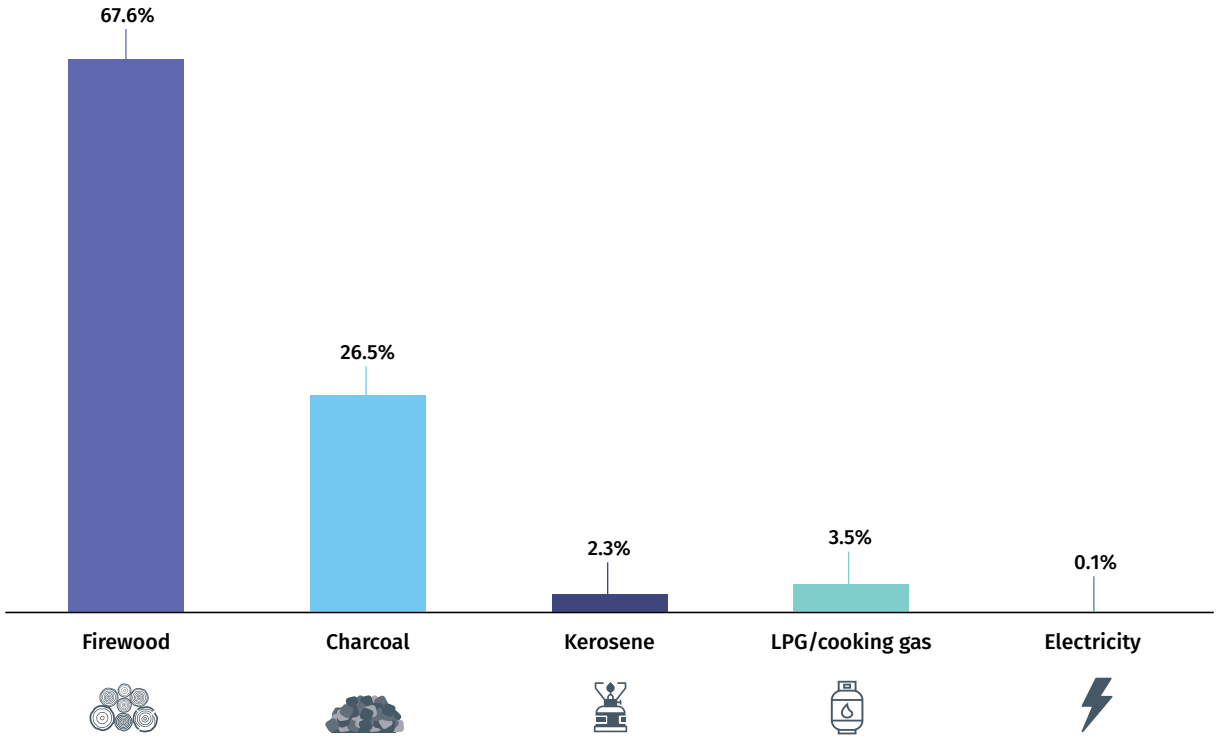
Nationally, the most common fuel is firewood, followed by LPG and charcoal equally, and then kerosene. Stark contrasts, however, exist between urban and rural areas. Firewood is the most widely reported cooking fuel used by households in rural Kenya (80%). By contrast, a little less than a fifth (18%) of households in urban areas use firewood for cooking. Instead, urban households use LPG/cooking gas (41%) and kerosene as a primary fuel (21%). The use of LPG cooking gas in rural areas is relatively small –with only about 4% of rural households reporting using LPG. Charcoal use by households across Kenya confirms studies that find charcoal is still considered an important cooking fuel source for many households—especially in urban areas across Africa (IEA 2010). In Kenya, charcoal is common in both urban (19.7%) and rural (13.2%) areas. Kerosene is the second most widely reported fuel source in urban areas in Kenya (after LPG), most likely because of its relative affordability and availability. About a fifth of urban households (21%) use kerosene to fuel their stoves primary stoves (Figure 70).

FIGURE 70 • **Primary cooking fuels: Urban, rural, and nationwide**



Given that most households in the 14 under-served counties use traditional biomass stoves, fuelwood is the most popular fuel source for households. Combined, firewood and charcoal make up 94% of the fuel source for households in the 14 under-served counties. Clean fuel use remains low at 3.6%—with only 0.1% of households using LPG/electric stoves. The low use of clean-fuel stoves may be as a result of low population densities in the 14 under-served counties, which may make the distribution to these areas unlikely, and high poverty levels, which make it unlikely for households to be able to afford LPG as a primary fuel source. Electrification rates in the 14 counties (21%) are also lower compared to the 43% average rate for the rest of the country—therefore households are even less likely to rely on electricity as a fuel source (Figure 71).

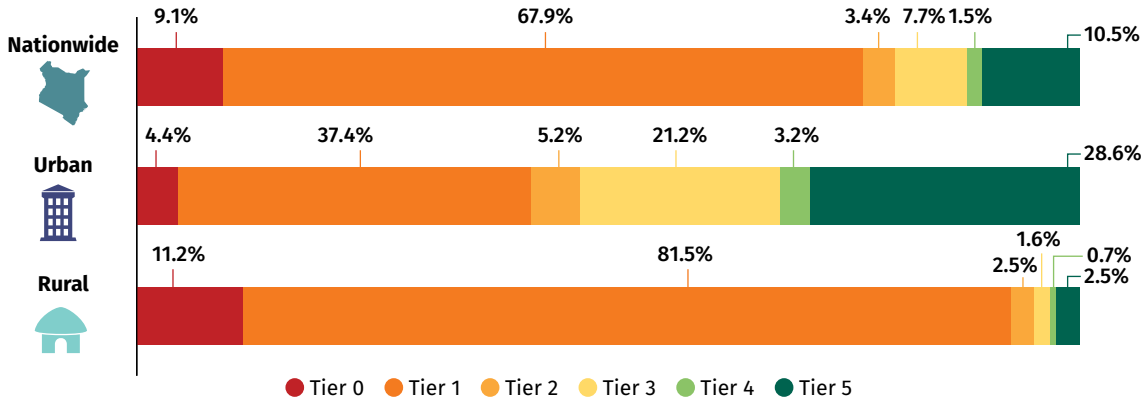
FIGURE 71 • **Fuel Type: 14 Under-served counties**



MTF TIERS

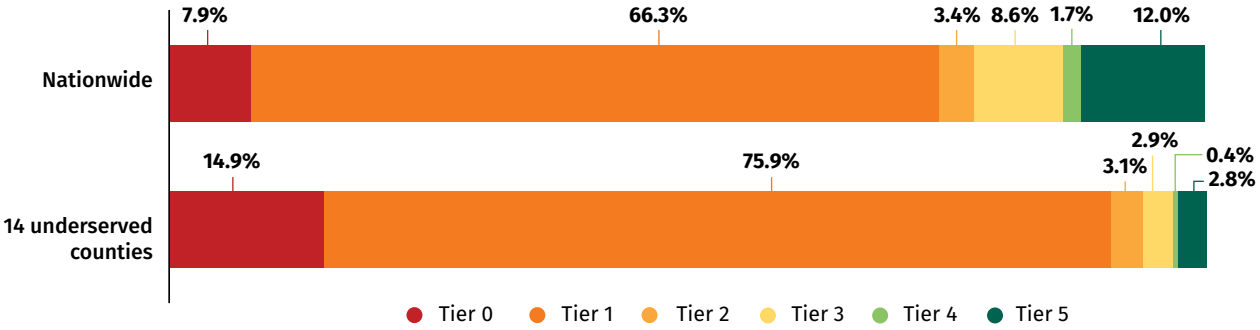
Slightly less than a fifth (19.7%) of households are in Tier 3 or higher of the Cooking Aggregate Tier (Figure 72)—with only 12% of households in Tier 4 and Tier 5. A closer look at the tier distribution in rural and urban areas reveals significant disparities between distributions. Urban households in Tier 0 and 1 account for a little over two-fifths (41.8%) of the distribution, whereas in rural areas, Tier 0 and Tier 1 users account for more than double of that amount (92.7%). A significant gap also occurs between the highest tier users. Close to 30% of households in urban areas are in Tier 5, compared to only 2.5% of rural households in Tier 5. The smallest variation between the tier distribution occurs in Tier 2; which has a slightly higher percentage of households in urban areas (5.2%) than rural areas (2.5%).

FIGURE 72 • **MTF tier distribution for access to modern energy cooking solutions: Nationwide, urban, and rural**



Given the variation in cookstove types used in the 14 counties and the rest of Kenya, we expect to find notable differences between the aggregate tier distribution in the regions as well. Our results reveal that a significantly higher proportion (90%) of households are found between Tier 0 and Tier 1 of the Cookstove Aggregate Tier distribution in the 14 counties—compared to 74% in the rest of the country. Only a small number of households (3.2%) reach Tiers 4 and Tier 5 of the aggregate tier distribution in the 14 under-served counties (Figure 73).

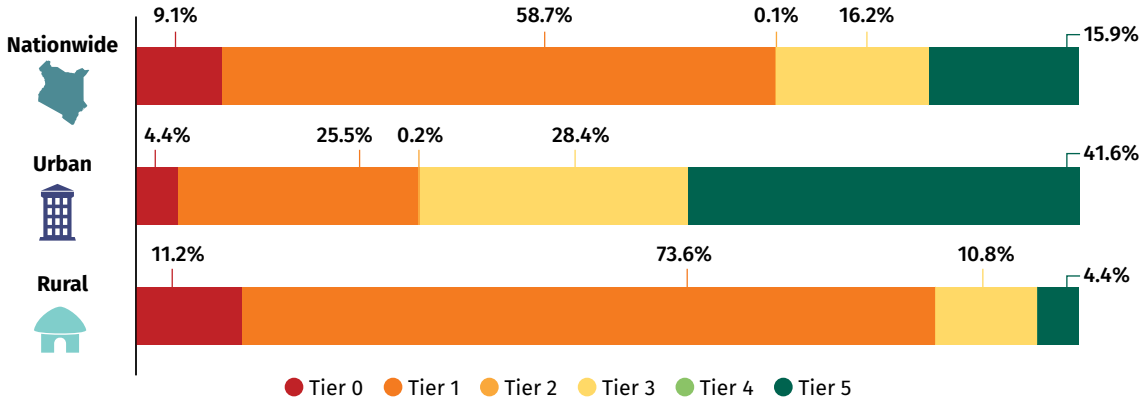
FIGURE 73 • **MTF tier distribution: 14 Under-served counties**



Cooking Exposure

The Cooking Exposure attribute, which represents an estimate of the level of personal exposure from cooking activities, reveals that almost two-thirds of Kenyan households (67.8%) are in the Cooking Exposure Tiers 0 and 1, due to higher exposure to emissions, which are a function of the use of traditional biomass stoves in poor ventilation structure. The use of solid-fuel stoves is typically associated with particle emissions, which expose the primary cook to both short- and long-term respiratory diseases. By contrast, 15.9% of households in Kenya are in Tier 5 of the Exposure Tier attribute (Figure 74).

FIGURE 74 • **Distribution of households' Cooking Exposure attribute: Nationwide, urban, and rural**

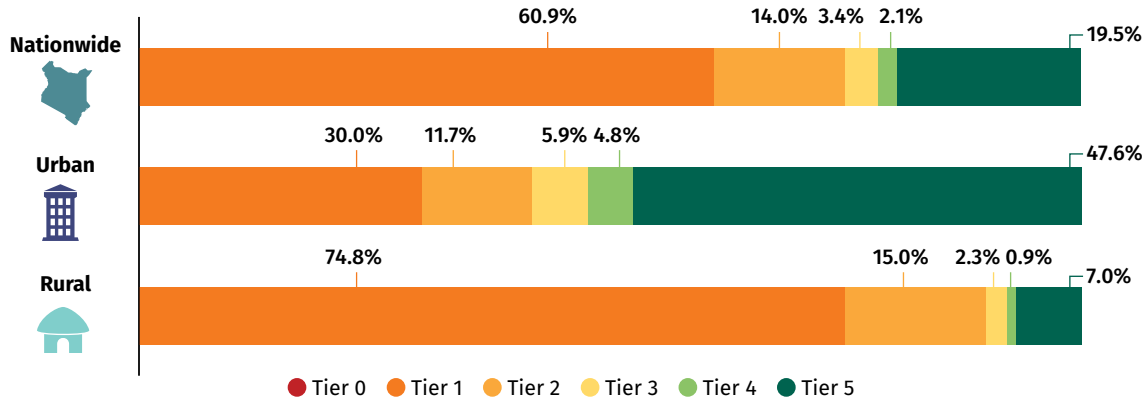


Convenience

Convenience is determined by the time spent collecting and preparing fuel per week and preparing the stove for cooking per meal. More than 60% of households in Kenya spend more than 7.5 hours for fuel collection and preparation per week. In rural areas, the inconvenience of meal preparation is even more stark, with almost 75% of households pending more than 7.5 hours on stove preparation per week. This may be due to the large number of biomass stoves, which are generally associated with longer cooking times and less efficiency, requiring long hours gathering fuels (Figure 75). By

contrast, on average, about a fifth of Kenyan households spend less than 1.5 hours for fuel collection and preparation per week, with a significantly larger number of households (48%) in Tier 5 of the Convenience attribute. Wide differences occur in the Convenience Tier for rural and urban households. Most households in rural areas (75%) are in Tier 1 for Convenience, in contrast to about 30% of urban households. Only 7% of rural households reach Tier 5 for Convenience in Kenya, while almost half (48%) of households in urban areas reach Tier 5, due to their use of improved and clean fuels stoves.

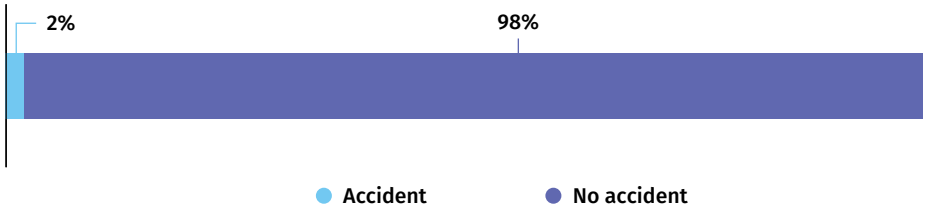
FIGURE 75 • **Distribution of households based on the Convenience attribute: Nationwide, urban, and rural**



Safety of Primary Cookstove

The degree of safety risk can vary by the type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, and the potential for fuel splatter. In defining this attribute, reported incidences of past injury and/or fire are used to measure safety. Over the past year, if a household's members did not experience any accidents that required professional medical attention, then the cooking device was determined as "safe." Ninety-eight percent of Kenyan households reported not having experienced an accident that required any professional attention within the past 12 months (Figure 76).

FIGURE 76 • **Distribution of households based on the Safety attribute**

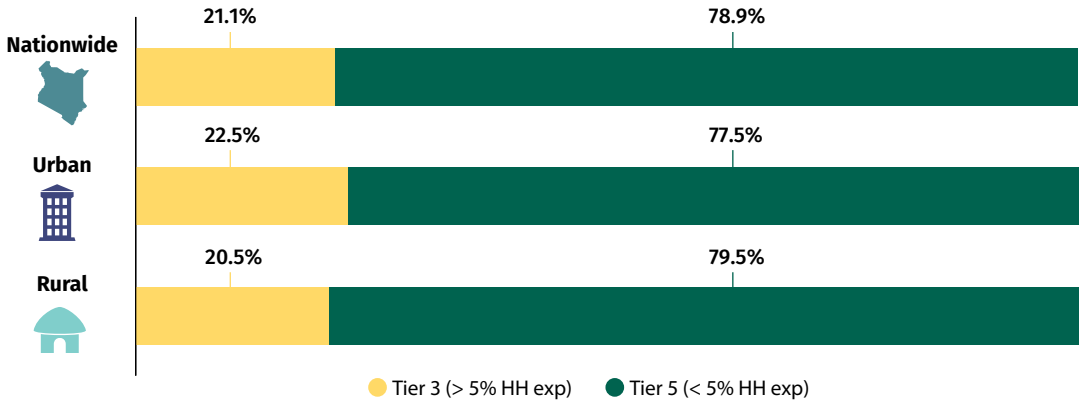


Among households that reported an accident or injury that required professional medical attention, the largest proportions were reported by three-stone-stove users (2.6%) and ICS-charcoal users (1.8%) respectively. Approximately 1.4% of kerosene users also reported accidents related to the use of their cookstoves, confirming findings that poorly made kerosene stoves may cause accidents and injury through explosions and the accidental ingestion of fuels by children (Peck et al. 2008).

Affordability

The Affordability attribute is calculated using two factors: total monthly household expenditure and a household's expenditure on cooking fuel. If a household's expenditure on cooking fuel doesn't exceed 5% of its monthly expenditure, it is defined as being affordable. Almost three-fourths (78%) of Kenyan households spend less than 5% of their household expenditures on cooking. Thus, more than one-fifth of Kenyan households do not find their current cooking solution to be affordable. No notable differences are observed between rural and urban households in the Affordability attribute (Figure 77).

FIGURE 77 • **Distribution of households based on Affordability attribute: Nationwide, urban, and rural**

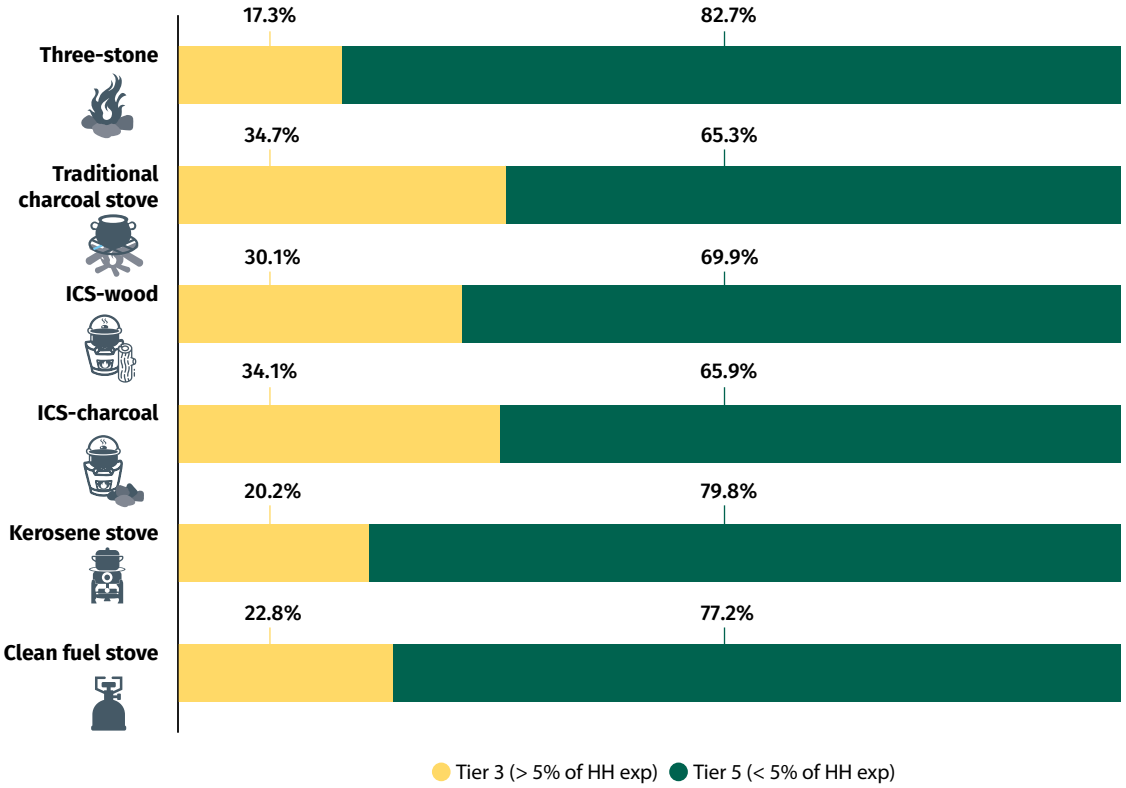


Affordability has been well-documented in the literature, which has established that for low-income households, liquidity constraints may serve as a barrier to adopting improved and clean fuel stoves (Hewitt et al. 2018). Overall, affordability appears to be a constraint among traditional charcoal stove users in Kenya, with a larger proportion of households (35%) reporting spending more than 5% of their household expenditures on the cookstove than any other stove. For these households, switching to even more expensive clean fuels would unlikely be affordable. On the other hand, use of ICSs may help them reduce charcoal consumption, and therefore also cooking expenditures.

About 32% of ICS users, however, also reported spending more than 5% of their household expenditures on fuels for their cookstoves, as do 23% of clean-fuel stove users. In contrast, only 17% of three-stone stove users reported spending more than 5% of their household expenditures on cooking fuels. This is likely because three-stone stove users gather their cooking fuels for meal preparation.

Affordability may not be the only barrier to the uptake of improved cookstoves in Kenya. However, it may slow the adoption of improved and clean fuel stoves for those households that are liquidity constrained. Households currently spending more of their household budget on charcoal, for instance, may find it difficult to switch to a cleaner fuel stove due to even higher fuels costs for LPG (Figure 78).

FIGURE 78 • **Affordability tier by fuel type**



IMPROVING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Efforts to promote the use of improved biomass stoves have yielded some results in Kenya. The introduction of the Kenya Ceramic Jiko stove, which is an ICS, and subsequent improved cookstoves that are manufactured locally are considered modest milestones in Kenya's progress toward access to modern cooking energy solutions. However, given the growing evidence of negative health impacts of indoor air pollution caused by biomass stoves, and limited evidence that ICS eliminates health risks (GACC 2011), the current goal is to encourage the use of clean, convenient, efficient, affordable, and safe cooking solutions across the country. We offer two overarching policy recommendations targeted toward improving access to modern energy solutions in Kenya.

SCALING UP THE USE OF CLEAN FUEL STOVES AMONG URBAN POPULATIONS

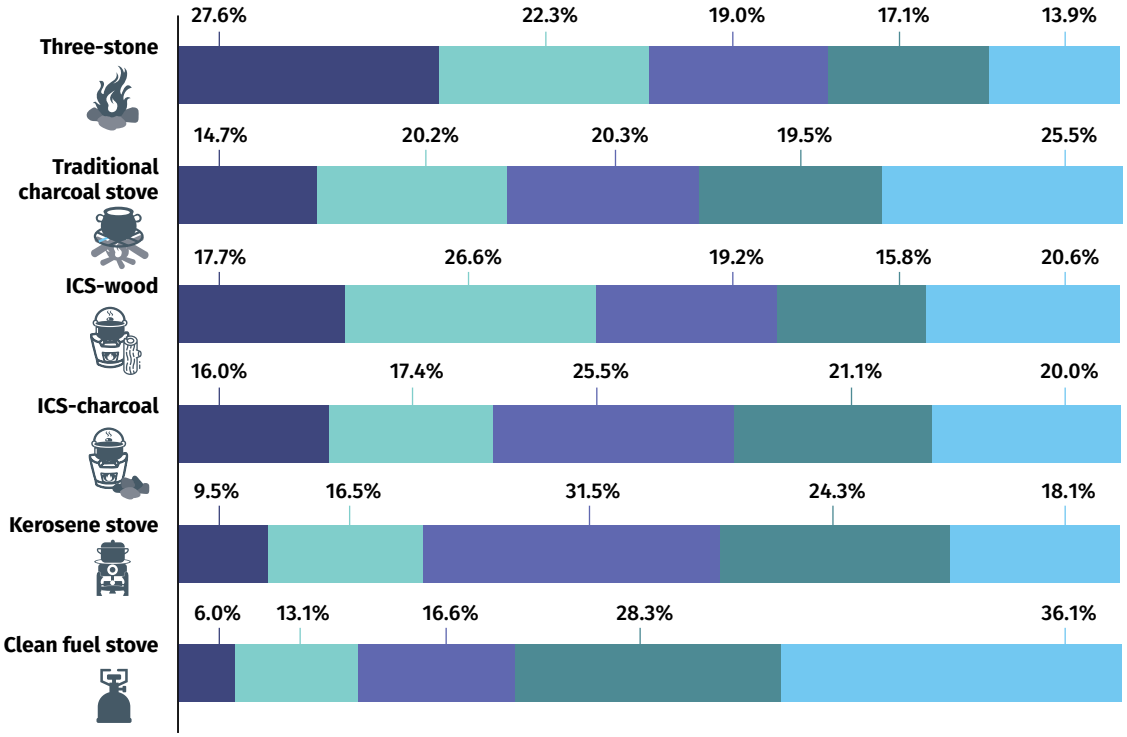
Our first critical policy recommends scaling-up the adaptation and use of safe and clean cooking technologies such as LPG, electric or bioethanol stoves for households that can afford the stove switch. Two segments of this group should be targeted: those households that can afford the switch and those that can afford clean fuel stoves but are faced with liquidity constraints.

Our analysis reveals about 21% of urban households currently use kerosene stoves in Kenya, which may be due to kerosene's wide accessibility, availability, and affordability. While kerosene stoves may be improved substitutes to biomass stoves with relatively lower emission tiers, cost-effective, and easily accessible to large segments of the urban population, kerosene stoves have been noted to be polluting, hazardous, and poorly designed and are estimated to cause 2,000 to 3,000 avoidable

deaths per year in Kenya (Dalberg 2018). Another 11% of urban dwellers use ICSs, which may also be an improvement to traditional biomass stoves but are not considered clean fuel stoves.

We further observe that households in the top 20% expenditure quintiles in Kenya are more likely to use clean fuel stoves and less biomass stoves (36%). However, it is also striking to observe that close to 26% of households using traditional charcoal stoves are in the top quintile. Similarly, about 20% of households that use ICSs (both wood and charcoal) are in the top 20% quintiles. Kerosene stove users round up the top 20% expenditure quintile, with about 10% of households. Thus, households in the top quintiles using kerosene, ICSs, and traditional charcoal stoves present a clear opportunity to transition to clean fuel stoves (Figure 79).

FIGURE 79 • **Expenditure quintile distribution by stove type**



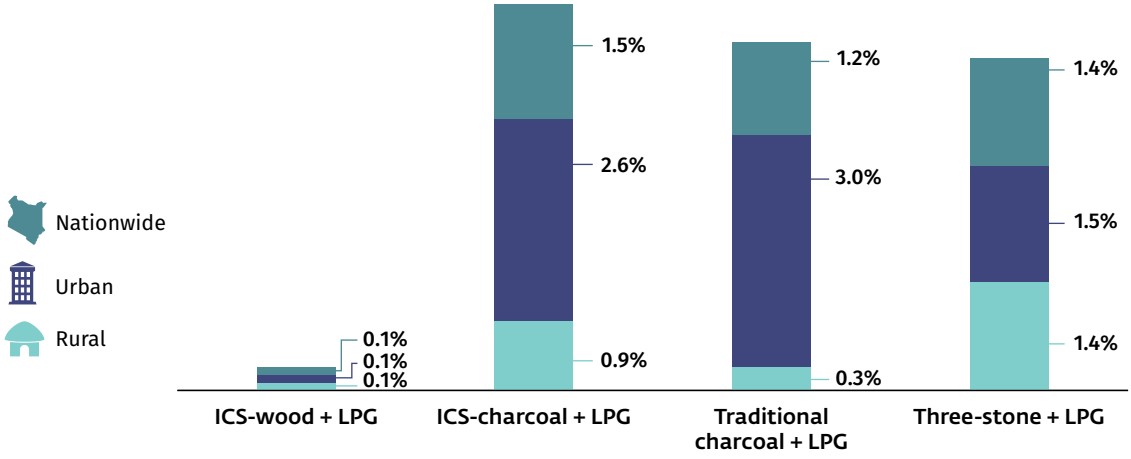
In the short-to-medium term, households in the top expenditure quintiles that can afford to switch to clean fuel stoves areas provide the best opportunity to expand the use of LPG and bioethanol as a clean-fuel cooking alternative. These households are likely to be in urban areas, where 36% of households are already using LPG or electricity as their primary stove energy source. This paves the way for encouraging households to switch to LPG stoves, as the fuel is widely available in urban areas of Kenya, with projected increases in supply from the Kenya Pipeline Company and other private stakeholders to increase production over the next few years.

The use of bio-ethanol stoves also presents an opportunity to increasing clean fuel use in Kenya. Bio-ethanol has been known to have low emission levels and to reduce indoor emissions. Bio-ethanol also has flame characteristics like LPG stoves, and estimates suggest that average annual costs per household for bio-ethanol use using the innovative and decentralized KOKO Networks in Nairobi K Sh 22,000-23,000 (US$220–230) are comparable to kerosene K Sh22,400 (US$224) and cheaper than LPG K Sh 23,300 (US$233) (Dalberg 2018). The fuel is currently produced in Kenya on a limited scale and mainly available in limited quantities in urban areas but could be an alternative to kerosene with increased awareness of its benefits to consumers if a viable supply chain is encouraged in the private sector.

Second, for households that are in the top quintiles but face liquidity constraints, offering innovative financing mechanisms could increase the demand and uptake of clean fuel stoves. For instance, PAYGo Energy Limited and KOKO Networks[13] offer a digital PAYGo platform that sells clean fuel such as ethanol and LPG in small quantities to households who otherwise have to purchase clean fuel up front. Similarly, Equity Bank Kenya offers financing through its ECOMOTO program to enable the purchasing of clean fuel stoves.

It is also important to consider the combination of cookstoves used in households in cookstove stacking, as previous evidence suggests that even with increased incomes, households may stack their stoves as a coping mechanism to deal with price fluctuations in clean fuels or to meet different cooking needs (World Bank 2014; Ruiz-Mercado and Masera 2015). Among households using a combination clean fuel and biomass stoves stove, we find the combination of ICSs and clean fuel stoves are observed among urban households, where 2.6% use a combination of ICS-charcoal and LPG stoves (Figure 80). Prior research suggests that the benefits for using clean fuel stoves (time saved, health benefits) are minimal when households combine them with traditional stoves. Thus, promoting a cleaner fuel stacking by replacing traditional fuels with more efficient fuels will enable households to meet their multiple energy needs, as relying on a single clean fuel may leave households vulnerable to fuel price and supply shocks.

FIGURE 80 • **Clean fuel stove stacking among two-stove users: Nationwide, urban, and rural**



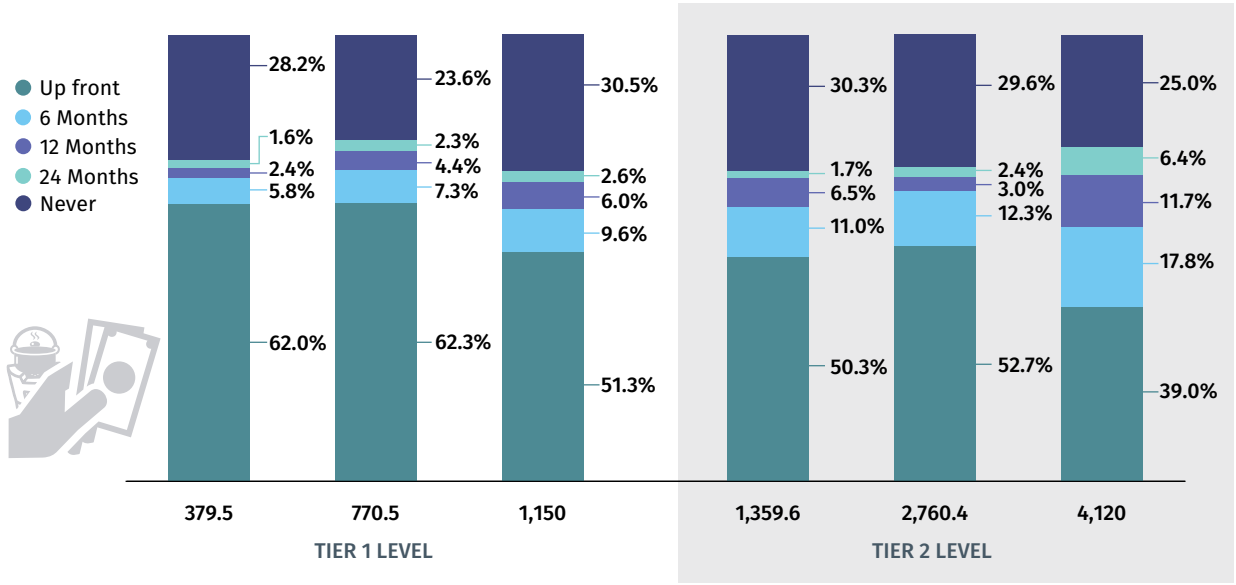
INCREASING THE USE OF IMPROVED COOKSTOVES AS THE PRIMARY COOKING SOLUTION IN RURAL AREAS

Promoting the use of energy efficient improved cookstoves is an immediate solution for rural and the 14 under-served county households that are in Tiers 0–1 for Cooking Access, who primarily rely on three-stone or traditional stoves. The goal here is to move these households to a higher tier by promoting cookstoves with improved performance and increasing the tier access for households. A report published by Dalberg (2018) estimates that rural households purchase only about 20–30% of their fuels. Encouraging clean fuel stove use therefore may not be feasible in the short term, as rural households are likely to be resource poor and may not have access to cleaner cooking fuels. Addressing this challenge would require encouraging and promoting the use of lower-cost options that meet the needs of rural households without the need to switch fuels and that correspond to the WTP to pay options of the households. In addition, encouraging low-cost behavioral change to reduce contact time for vulnerable populations is important.

[13] More about KOKO Networks can be found on the company's website, https://kokonetworks.com.

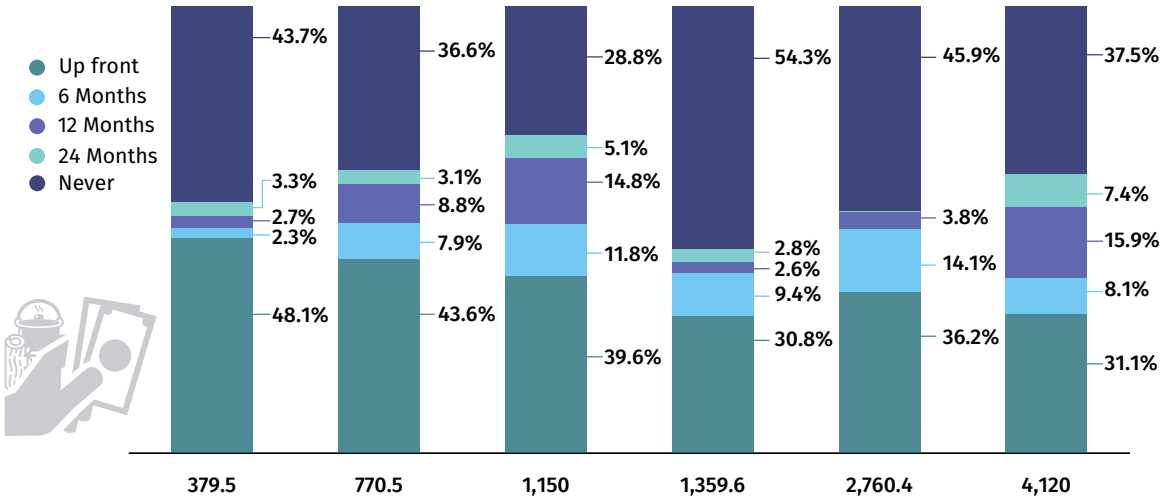
Our WTP model gives insight into how much households are willing to spend on an improved cookstove (Figure 81). Households were offered a SCODE JikoStar/Jikokoa (charcoal users) stove and a SCODE Kuni Mbili or Upesi/EnviroFit SuperSaver GL Wood (wood users) stove with prices ranging from K Sh 379.5- K Sh 4.120 (US$3.80-US$41.20). We find that offering flexible payment options eased the willingness to pay for a cookstove as the offered price increased. For instance, at a price offer of K Sh 380 (US$3.80), an additional 6% of households were willing to accept the offer if there was a six-month payment period. Once the price of the cookstove increased to K Sh 4,140 (US$41.40), an additional 18% of households said they would accept the offer if there was a six-month repayment period.

FIGURE 81 • **Willingness to pay for improved cookstoves Nationwide**



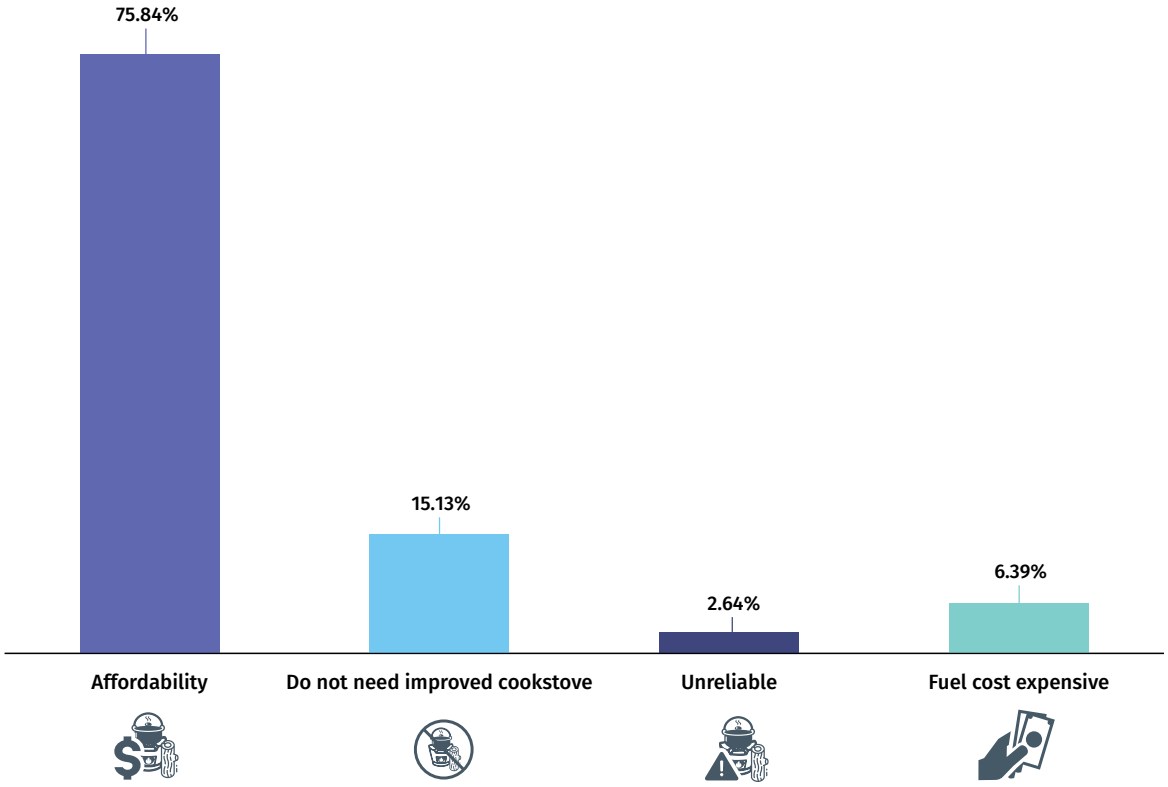
In the 14 under-served counties, when an improved fuelwood stove was offered at a price of US$3.80, 48% of households stated they would pay an up-front cost. The number of households willing to accept a six-month payment option increased from 7.9% to 14.1% between prices K Sh 770 (US$7.70) and K Sh 2770 (US$27.70)but declined when the offer price increased to K Sh 4.120 (US$41.4). Even more intriguing is the 44% of households who would never accept the offer price of K Sh 380 (US$3.80)—revealing that affordability may be an even bigger constraint in the 14 under-served counties (Figure 82).

FIGURE 82 • **Willingness to pay: 14 Under-served counties**



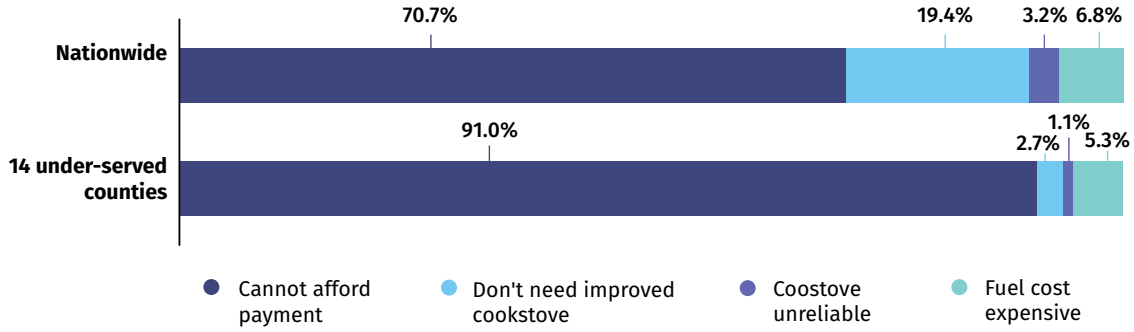
Among households not willing to accept any offer, a majority of households (76%) stated they could not afford an improved stove-- but 15% of households also reported they do not need an ICS, which may reveal that cultural values and practices and lack of knowledge and awareness may be the reasons that prevent the adaption and sustained use of improved fuel stoves in Kenya (Figure 83).

FIGURE 83 • **Reasons household s in 14 under-served counties unwilling to pay for improved ICS fuelwood**



Addressing affordability in the adoption of an ICS is critical for those in the 14 under-served counties. The majority of households in the 14 under-served counties (91%) stated an unwillingness to purchase the stove regardless of the payment conditions, compared to 71% in the rest of the country (Figure 84).

FIGURE 84 • **Reasons households in 14 under-served counties unwilling to pay for improved ICS fuelwood**



The WTP model reveals that regardless of the actual price of the stove, repayment and financing modalities would be accepted by over 70% of households for an improved cookstove Thus, the availability of financing options over at least 6 months increases affordability more than does reducing the price of the stove by one-third. Longer financing plans (up to 24 months), thus become more important for high-value stoves. Offering innovative and appropriate financing and promotion initiatives through community savings and loans organizations and local financial institutions is encouraged to ease the financial burden of rural households in adapting higher performing cookstoves. For those households that are unwilling to accept the offer price, even with longer repayment options, additional incentives might include trials of new products to help households understand better the products and increase their willingness to pay.

The lack of access to clean fuels in addition to costs is a major deterrent to households in rural areas. Encouraging the transition to sustainable fuels by switching to products that meet a higher standard of emissions is encouraged for rural populations. Biomass pellets have been identified as viable option, especially in helping rural farming communities transition households to more fuel efficient and cleaner stoves. The Kenya Biogas Project, a private-public partnership to increase digesters in targeted communities, was reported to have reduced the energy expenditures of households by more than 50% (Ogara, Ayieko, and Odindo 2017), while reducing the amount of cooking preparation and cooking time and showing improved health risks from respiratory diseases (World Bank 2019). Scaling-up the production of biogas in Kenya will require sustained partnerships from the private sector in addition to financing options to both producers and end users.

The lack of awareness about the health, time, and savings benefits of improved stoves serves as a detriment to the adaption and continuous use of stoves. It is, therefore, important to prioritize a dedicated education and awareness campaign about the potential health risks of biomass stoves as well as to promote better fuels, which will reduce indoor air pollution for those market segments that can afford switching to the cleaner fuels. Evidence suggests that educational campaigns that target changes in cooking behavior, including encouraging households to cook outside, keep children away from smoke, and use better ventilation, could be advocated. Sensitizing communities to the health and economic impacts and savings of improved fuel stoves through influential community leaders has been documented as effective (Rosenbuam, Derby, and Dutta 2015), as has influencing behavior change through social networks. Person, Loo, and Cohen (2012) find that the adaptation of improved cookstoves was facilitated most effectively by using people in the community who were already familiar with the technology to raise awareness.

Low grid electrification in rural areas and the 14 under-served counties prevents households from accessing new emerging cost-effective electric energy solutions. With current electrification rates of 18% for rural areas and 21% for the 14 under-served counties, high connectivity costs and distance to the grid prevent households from benefiting from advances in electric cooking solutions. Mini-grids present a viable opportunity to power households in rural communities and address energy needs in the 14 counties. Along with technological advances in energy efficient products including pressure cookers and slow cookers, electric cooking solutions may be a viable option in Kenya in the future. Even with slightly higher up-front costs, solutions powered by SHSs and mini-grids can provide substantial long-term benefits and savings for households at estimated costs comparable to cooking with traditional fuels (World Future Council 2019). Taking advantage of advances in electric cooking, however, will require expansion of electricity service to under-served households and ensuring a sustained and reliable electricity supply to these communities.

POLICY RECOMMENDATIONS

SCALING-UP UPTAKE OF CLEAN COOKING SOLUTIONS IN URBAN AREAS

- **Transitioning kerosene and traditional stove users to clean fuels:** While we observe that a large proportion of households (36%) using clean-fuel stoves make up the top 20% income quintile, it is striking to see close to 20% of both kerosene and ICS users' households in the top 20% expenditure quintiles. These households present a clear opportunity to transition to clean fuel stoves—to LPG or bio-ethanol use. They are also mostly located in urban areas, where LPG and bio-ethanol may already be available.

- **Providing innovative financing options and increasing public awareness about clean fuel stoves:** Stakeholders should offer innovative financing mechanisms to increase uptake of clean fuel stoves. A PAYGo option, for example, has been cited as a good channel through which consumers can pay for limited quantities of LPG fuel without buying in bulk. In addition, the country should embark on public awareness about the potential benefits of clean fuels, especially bio-ethanol, which may be a cost-effective solution to replace kerosene, and may not be as familiar to the potential users.

ACHIEVING HIGHER TIER ACCESS FOR HOUSEHOLDS IN RURAL AREAS

The goal is to move households in Tier 0–1 aggregate, primarily in rural areas, to as high a tier as possible. Therefore, where possible, higher performance biomass stoves should be promoted. These include promoting improved biodigester stoves as well.

- **Offering flexible financing options:** Our WTP model suggests that offering a payment plan to households in Tier 0–1 energy access could increase the purchase of ICSs that have higher energy performance than traditional stoves. We observe that offering flexible payment options with longer periods of repayment may ease willingness to pay for a cookstove even with price increases. Thus, offering repayment and financing modalities to pay across different categories is more likely to influence a household's decision to purchase an improved cookstove. Households that are unwilling to accept any offer price, even with longer repayment options, should be offered incentives including trials of new products to help them better understand the products and increase their willingness to pay

- **Increasing consumer awareness and knowledge about improved cookstoves:** The refusal of some households to purchase a new and improved cookstove, irrespective of the price offered and the flexibility of payment plan offered, may be due to the lack of awareness about the health and savings benefits of improved cookstoves. Forty-six percent of households who said they would not be willing to purchase the cookstove, even with a financing plan, reported they would not purchase an improved cookstove because they do not need one. To move these households to a higher tier access, a targeted public awareness campaign is needed to change the perceptions and behaviors of households. In addition, campaigns to improve cooking behavior, including cooking in spaces with proper ventilation and targeting network behavior change, have proven effective in changing behavior.

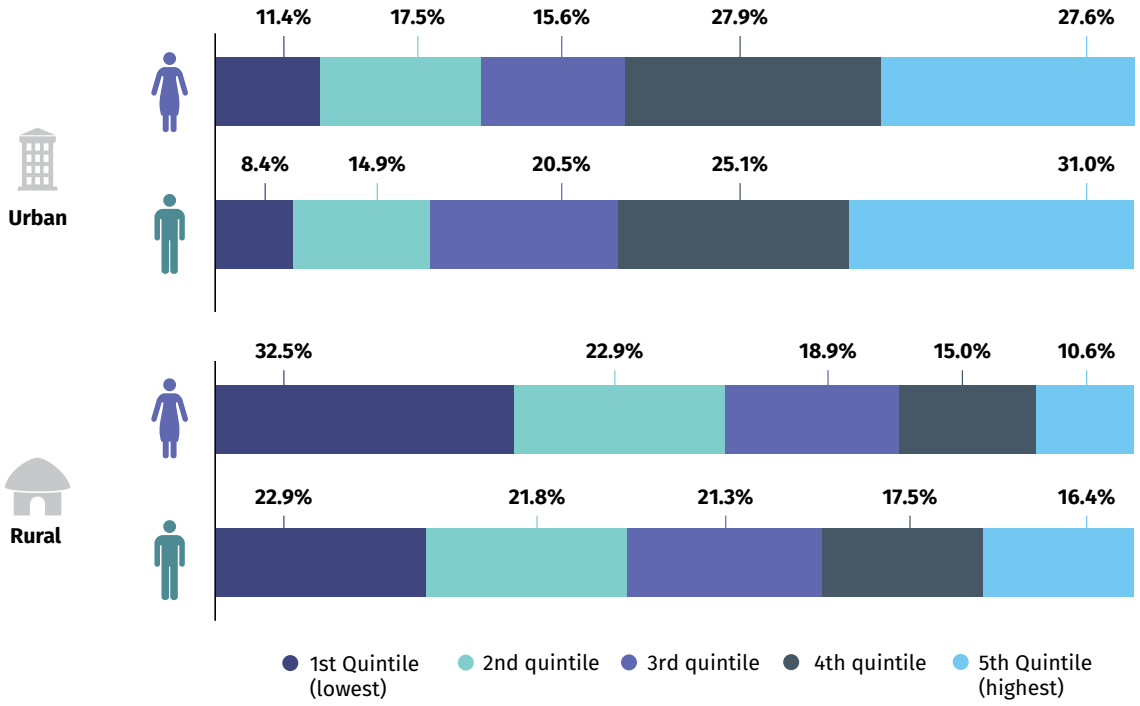
- **Expanding electricity access, such as through mini-grids:** Low electrification rates in rural areas and the 14 under-served counties due to high connection costs and distance to the grid do not encourage the use of clean fuel stoves such as electric stoves. Advances in electric cooking technologies through the mini-grid that are highly efficient and cost-effective make this a viable alternative in Kenya. To take advantage of this alternative, however, it is important to expand electricity access to households still without electricity and to ensure regular and reliable supply.

GENDER ANALYSIS

In Kenya, about 16% and 12% of rural and urban households, respectively, are headed by females. The socioeconomic characteristics of households show that the average size of female-headed households (2.4 members) is smaller than that of male-headed households (4.4 members). Female-headed households, on the other hand, tend to be older (30.5 years) than male-headed households (26.9 years). Education rates also reveal that while more male household heads (0.35%) have no education than female household heads (0.19%), only 2% of female-headed households are tertiary educated, compared to the reported 13% of male-headed households. Gender disparities also exist at the primary and secondary level of education, with fewer female household heads having both primary (8.9%) and secondary (5.4%) education than their male counterparts (35% average for both primary and secondary education).

We find modest variations in the expenditure quintiles of male- and female-headed households. For instance, close to half (44%) of female-headed households are in the bottom 40% of the expenditure quintiles—compared to 38% of male-headed households. Also, there are more male-headed households (21%) than female-headed households (18%) in the top 20% expenditure quintile. Among rural households (Figure 85), a significantly larger population of female-headed households (33%) are in the bottom 20% expenditure quintile, compared to 23% of male-headed households. In urban areas also, the disparities are largest among female- and male-headed households in the lowest quintiles.

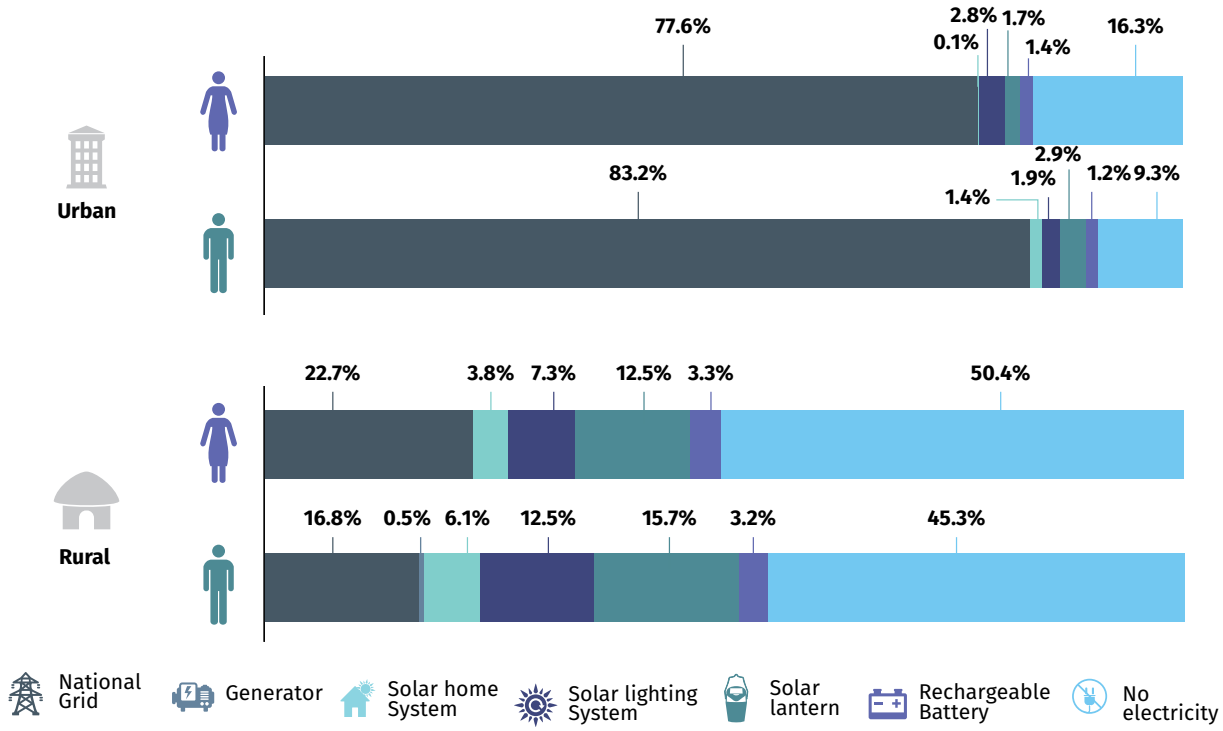
FIGURE 85 • **Distribution of expenditure quintile by gender of the household head: Urban and rural**



ACCESS TO ELECTRICITY

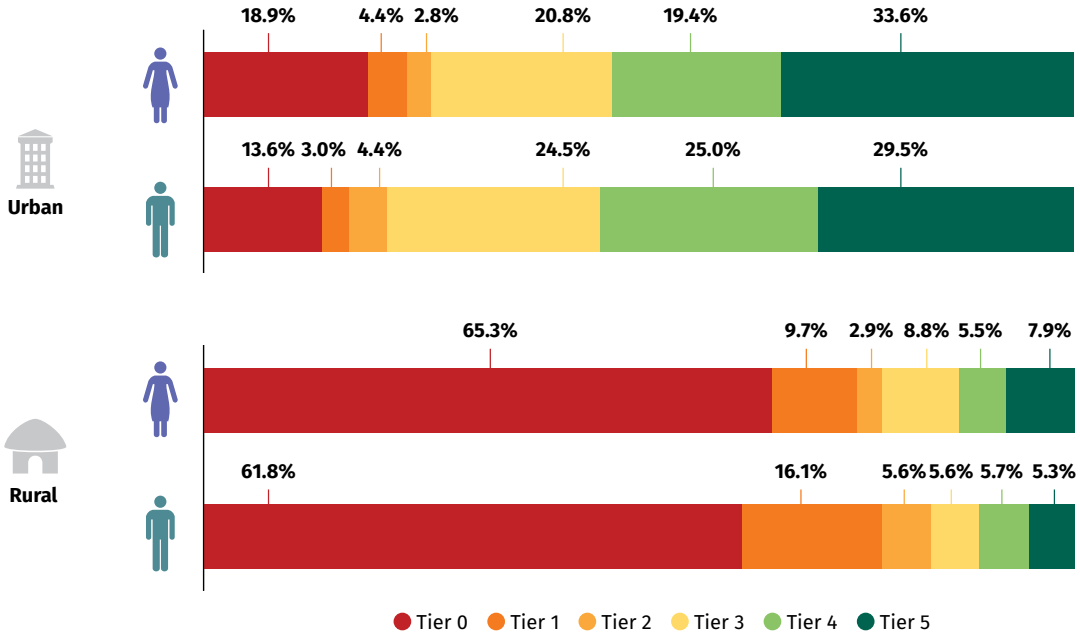
Slightly more female- than male-headed households have no access to electricity: 16.3% and 50.4%, respectively, of urban and rural female-headed households do not have any source of electricity compared to 9.3% and 45.3% of male-headed households. In urban areas, a larger portion of male-headed households have access to the grid network than female-headed households. In rural areas, interestingly, more female-headed households have access to the grid network than male-headed households. However, in rural areas, male-headed households are more likely to use off-grid solar solutions than female-headed households: 34.3% and 23.6% of rural male-headed and female-headed households use off-grid solar solutions, respectively (Figure 86).

FIGURE 86 • **Distribution of electricity sources by gender of the household head: Urban and rural**



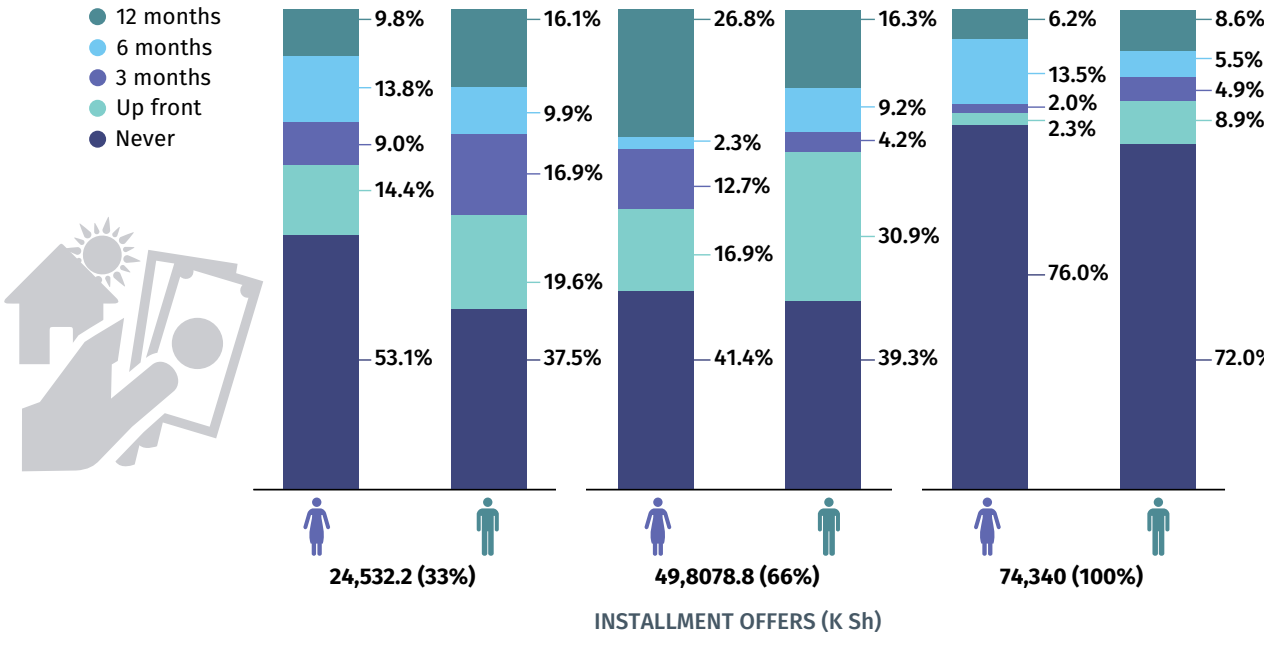
Marginal differences exist between female- and male-headed households in Tier 0. A little under a fifth (19%) of female-headed households in urban areas are in Tier 0 access, compared to 14% of male-headed households. In rural areas, 65.3% of female-headed households are in Tier 0, compared to 61.8% of male-headed households. At the same time, however, female-headed households have slightly higher rates of Tier 5 access (33.6% in urban and 7.9%in rural areas, compared to 29.5% in urban and 5.3% in rural areas for male-headed (Figure 87).

FIGURE 87 • **MTF electricity tier distribution by gender of the household head: Urban and rural**



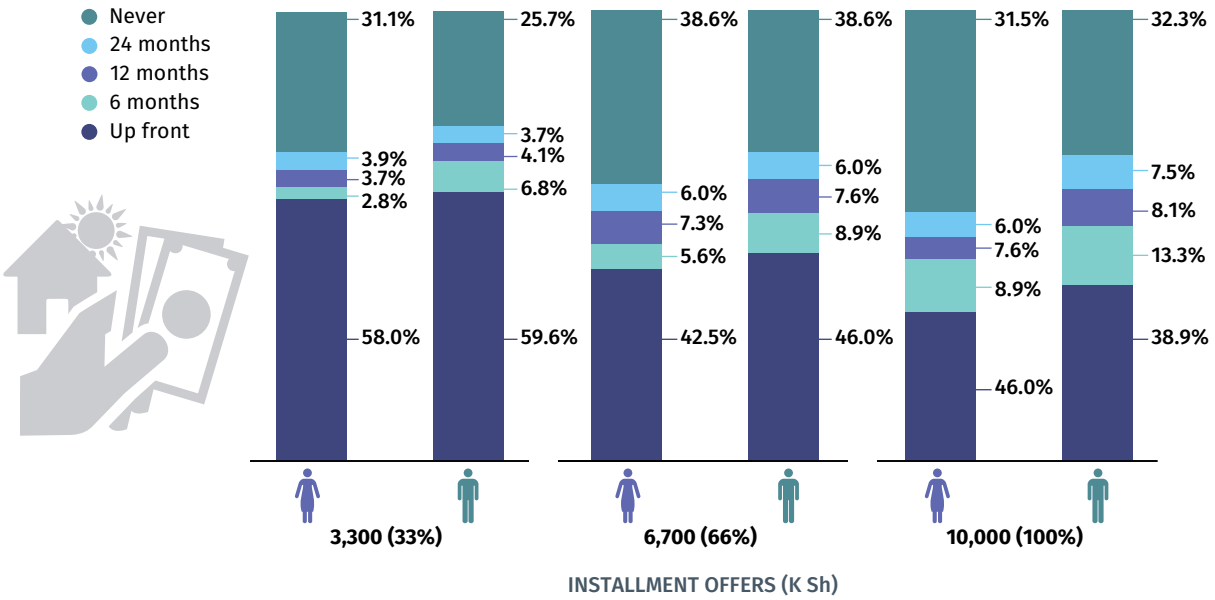
Across Kenya, households where women are primary decision makers are generally less willing to pay for off-grid solar solutions up front (Figure 88) but were more willing to purchase a solar solution if the repayment period was over a longer period of time (6–12 months). For instance, when offered a 12-month payment plan to repay K Sh 49,807 (US$49.8) for an off-grid solar-solution, only 17% of female-headed households would be willing to pay up front, compared to 31% of male-headed households. However, when a payment plan of 12 months was offered, more female-headed households (26.8%) than male-headed households (16.3%) were willing to pay for solar home systems. This could be due to the gaps in access to education, employment, and job opportunities, as well as access to finance available for males and females in Kenya.

FIGURE 88 • **Willingness to pay for SHSs by the gender of household head**



For households not connected to the grid, the differences between male- and female-headed households in WTP for a grid connection are most stark when households were offered a connection fee of K Sh 10,050 (US$100.50): 44.7% of female-headed households said they would not accept the offer, regardless of the terms, compared to 32% of male-headed households that declined (Figure 89).

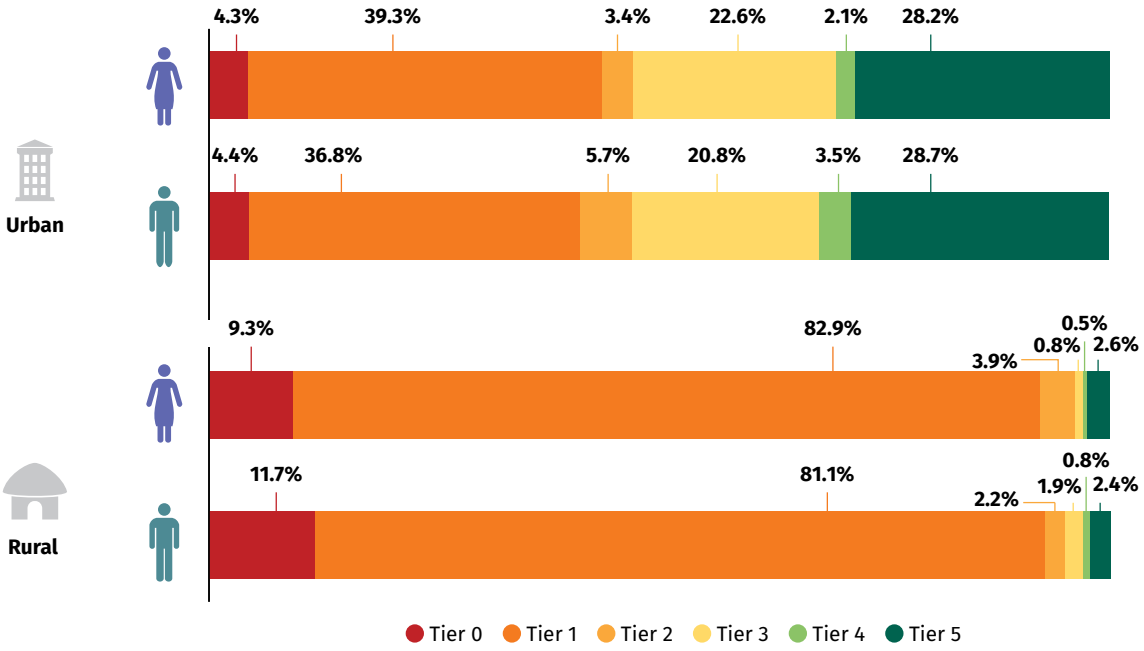
FIGURE 89 • **Willingness to pay for a grid connection, by the gender of household head**



ACCESS TO MODERN ENERGY COOKING SOLUTIONS

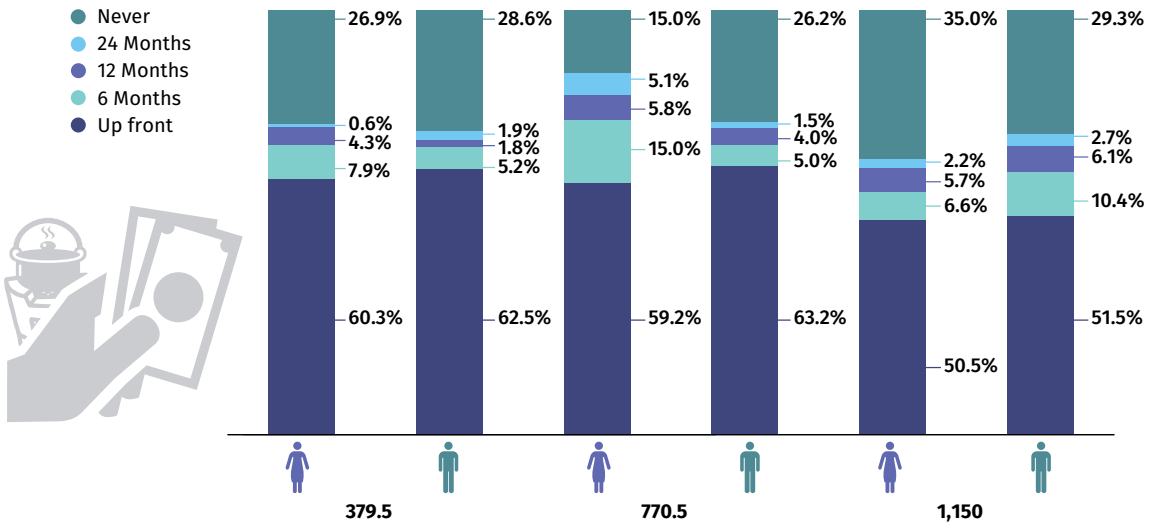
No significant distinction is observed in Cooking Tier distribution between male- and female-headed households in urban and rural areas. In urban areas, since more households use either an electric or LPG stove as their primary cookstove, 43% and 43.1% of male- and female-headed households, respectively, are in Tier 5. In rural areas, more than half of both male- and female-headed households are in Tier 0, mainly due to the use of a three-stone or traditional stove (Figure 90).

FIGURE 90 • **MTF Cooking tier distribution by the gender of the household head: Urban and rural**



Regardless of the gender of the household head, more than a fifth of them were not willing to pay for an improved cookstove, irrespective of the payment option offered. There are no significant differences when an improved cookstove is offered at a price of K Sh 380 (US$3.80), to both male- and female-household heads. About 61% of household heads would accept the offer, with slightly more males accepting. However, when the higher price of K Sh 1,115 (US$11.55) is offered, 35% of female-headed households would never accept the offer irrespective of payment terms, compared to 29% of male-headed households (Figure 90). This may be due to income disparities between females and males based on economic opportunities in terms of education, employment, and pay gaps which have been well documented in the literature.

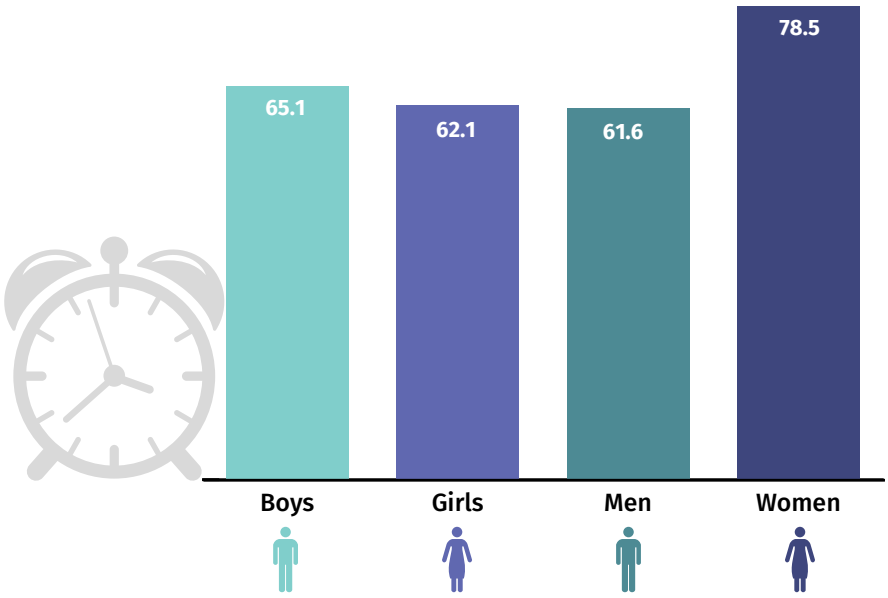
FIGURE 91 • **Willingness to pay for improved cookstoves by the gender of the household head**



Primarily women and younger children are tasked with gathering fuel and cooking within households in Kenya. The health risks are well established, as are the opportunity cost of time unavailable for education and income-generating activities. In comparing the amount of time household members spent in the cooking area, women in the household spent on average 78.5 minutes per day, almost 17 minutes more than male adults. Children under 15 also spent on average 64 minutes per day in the cooking area. Women are thus exposed to more indoor pollutants and are at a higher risk of respiratory illness. The long average times spent in the cooking area by female children under the age of 15 may result in the opportunity cost of unavailable time for school.

The use of clean fuel stoves decreases the average time households spend in the cooking area. Women especially stand to reap immense time-saving benefits by using modern and clean fuel stoves for cooking (Figure 92)

FIGURE 92 • **Time spent in the cooking space by sex-segregated ratio (minutes per day)**



POLICY RECOMMENDATIONS

A small gender gap exists in access to electricity, with male-headed households having slightly higher electricity access in both urban, and rural areas. Male-headed households tend to have their highest access to electricity in urban areas, while female-headed households have their higher access in rural areas. Among households without a grid connection, fewer female-headed households use off-grid solar solutions than male-headed households. WTP analysis reveals that female-headed households are less willing to pay a full price for grid connection or an SHS up front, but more willing to accept a financing offer of up to 12 months. In addition, more female-headed households (34.7%) than male-headed households (27%) are unwilling to purchase an ICS at full price.

Gender-targeted financing mechanisms are required to increase grid connections for female-headed households and to enable female-headed households to benefit equally from off-grid solar solutions. Thus, gender-targeted support for a grid connection, an SHS, and improved biomass stoves could significantly improve access to modern energy services to female-headed households.

Women and women's groups should be involved in the design of ICS stoves as well as in awareness and public campaigns that involve ICS adoption and use, since they spend the most time in the cooking area and are exposed to the highest risks.

ANNEX 1.
Multi-Tier Framework

TABLE A1.1 • **Multi-Tier Framework for measuring access to electricity**

Attributes		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Capacity (power capacity ratings)		< 3W	3W–49W	50W–199W	200W–799W	800W–1999W	≥ 2kW
Availability	Day	< 4 hrs	Min 4 hrs		Min 8 hrs	Min 16 hrs	≥23 hrs
	Evening	< 1 hr	Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	
Reliability	(Frequency of disruptions per week)	> 14				4–14	≤ 3
	(Duration of disruptions per week)					> 2 hrs (if frequency ≤ 3)	≤ 2 hrs
Quality (voltage problems affect the use of desired appliances)		Yes				No	
Affordability (cost of a standard consumption package of 365 kWh/year)		≥ 5% of household expenditure (income)			< 5% of household expenditure (income)		
Formality (bill is paid to the utility, pre-paid card seller, or authorized representative)		No				Yes	
Health and Safety (having past accidents and perception of high risk in the future)		Yes				No	

Source: Bhatia and Angelou 2015.
Note: Color signifies tier categorization.

TABLE A1.2 • **Multi-Tier Framework for measuring access to modern energy cooking solutions**

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking Exposure	ISO's voluntary performance targets (Default Ventilation) PM2.5 (mg/MJd) CO (g/MJd) gn	>1030 >18.3	≤1030 ≤18.3	≤481 ≤11.5	≤218 ≤7.2	≤62 ≤4.4	≤5 ≤3.0
	High Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>1489 >26.9	≤1489 ≤26.9	≤733 ≤16.0	≤321 ≤10.3	≤92 ≤6.2	≤7 ≤4.4
	Low Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>550 >9.9	≤550 ≤9.9	≤252 ≤5.5	≤115 ≤3.7	≤32 ≤2.2	≤2 ≤1.4
Cookstove Efficiency	ISO's voluntary performance Targets	≤10%	>10%	>20%	>30%	>40%	>50%
Convenience	Fuel acquisition and preparation time (hours per week)	≥7		<7	<3	<1.5	<0.5
	Stove preparation time (minutes per meal)	≥15		<15	<10	<5	<2
Safety		Serious Accidents over the past 12 months				No serious accidents over the past year	
Affordability		Fuel cost ≥5% of household expenditure (income)				Fuel cost <5% of household expenditure (income)	
Fuel availability		Primary fuel available less then 80% of the year				Available 80% of the year	Readily available throughout the year

Source: Bhatia and Angelou 2015; ISO 2018

Note: Colors signify tier categorization

Note: ISO = International Organization for Standardization; PM = ; mg/MJd = ; CO = ; g = .

ANNEX 2:
Cookstove Typology

3-Stone Stove

Traditional Stove

ICS

ICS

ICS

ICS

Kerosene Stove

Clean Fuel

ANNEX 3:
APPROACH AND METHODOLOGY

SAMPLING FRAME

Based on the requirements of the Terms of Reference (ToR) and following discussion with the ESMAP – World Bank Team, a nationally representative core sample of 3,300 households (HHs) was selected proportionally from Kenya's 47 counties combined with several oversampled groups. The oversampled groups were pulled from the marginal counties and specific World Bank intervention areas. The intervention areas initially included KEEP and KEMP focus areas and slum areas. However, KEMP areas were yet to be defined at the time of the study and were not included in the sample as initially planned. The core sample and over-sampling are shown in Figure 1.

FIGURE A3.1: SAMPLING FRAME

Basic MTF Sampling	Oversampling	Notes
47 Counties 3,300 HHs[1]	14 marginalized counties 1,100 HHs[2]	1) Originally enumeration areas belonging to KEEP and Nairobi slum areas were to be pulled out from 47 counties and treated as three separate strata. However, the target areas of these programs were not defined in terms of geographic administrative units, and they could not be readily matched to specific enumeration areas
	Nairobi — Slum Area: Intervention 600 HHs[4]	2) 14 marginalized counties oversample was summed up with the core sample thus concurrent data collection and non-differentiating selection of enumeration areas. The marginalized counties include Garissa, Isiolo, Kilifi, Kwale, Lamu, Mandera, Marsabit, Narok, Samburu, Taita Taveta, Tana River, Turkana, Wajir and West Pokot.
	Nairobi — Slum Area: Non-Intervention 600 HHs[4]	

The survey was administered using 7 survey instruments (questionnaires): (i) households, (ii) institutional – schools, (iii) institutional – health centers, (iv) institutional – places of worship, (v) institutional – government offices, (vi) community focus group discussion and (vii) mini-grid developers. The questionnaires were drafted by the World Bank ESMAP team and revised by the Consulting team based on extended discussion and feedback from pretesting exercises done in Kajiado and Narok towns. Table 1 summarizes the target number of interviews per survey instrument.

PRIMARY SAMPLING UNIT

The team had originally planned to use PSUs defined by KNBS in the most recent National Sample Survey and Evaluation Program V (NASSEP V). After several rounds of discussions between KNBS, ESMAP, and the implementation team, the team decided to develop a separate sampling frame, which is described below. One disadvantage of the NASSEP V sampling frame was seen to be its limitation in

TABLE A3.1: TARGET NUMBER OF INTERVIEWS

No.	Questionnaire	Comment	Target No.
1	Household	A person or a group of persons, related or unrelated, who live together in the same dwelling unit, who make common provisions for food and regularly take their food from the same source.	6,300
2	Education	This includes primary, secondary and tertiary education institution. The aim was data collection from all primary and secondary schools in each selected enumeration area but capped at 4 units. It was suspected that some enumeration areas may not have schools while others may have more than 5.	
3	Health institutions	In order of size, these are divided into dispensaries, clinics, health centers, nursing homes, sub-district hospitals, district hospitals and national hospitals. We proposed to collect data from all the health institutions from clinic upwards but capping this at 2 units per enumeration area.	
4	Places of Worship	These include places of worship operating within permanent structures e.g. mosques, churches, temples, synagogues and traditional religions.	
5	Government office	These include both county and national government offices/installations that provide services available to the residents of that area. For example, a chief's office facilitating issuing of identity cards would be covered but a Ministry of Water office doing research on river flow rates would not apply (as it does not offer services directly to the residents). Government offices include post offices, AP camps, lands office, chief's office, county government offices among others. Total of government offices interviewed was capped at 2.	
6	Community FGD	Administered through a focus group discussion setting, these interviews include more than one respondent, preferably with the sub-location chief.	370

adequately covering the KEEP and slum (GPOBA) sub-regions targeted by this survey, as the NASSEP V frame's enumeration areas are representative of statistics only at the national and county level.

To define and select enumeration areas, a publicly available gridded mapping of Kenya's population produced by NASA's Socioeconomic Data and Applications Center (SEDAC) was used. The SEDAC mapping estimates are consistent with Kenya's 2009 national censuses, and have been updated to match the 2015 Revision of UN World Population Prospects (CIESIN, 2016). This data is presented as a continuous raster surface with each pixel (1Km by 1Km) representing the population density of that area. Using these population estimates as a starting point, GIS experts from the National Autonomous University of Mexico (UNAM) worked to develop a spatial algorithm that defines discrete population enumeration areas bounded by Kenya's 7,149 sub-locations. Each enumeration area is continuous in space and contains roughly 200 households, which is similar in size to the PSUs defined by NASSEP V. Enumeration areas were then selected following the stratification plan described. The gridded population estimates, and population enumeration areas are shown in Figure 2: Gridded population based on UN estimations (left) and enumeration areas with roughly 200 HHs (right)

STRATIFICATION

Stratified random sampling was used in household selection for the core sample and marginal counties. Stratification was by county, rural/urban residence and electrification status.

County - HH selection for the core and marginal county samples was proportional to each County's population based on the 2009 census.

Rural/Urban - Counties were divided equally between urban and rural areas, based on definitions in the 2009 census resulting in a 50-50 rural-urban split at the national level.

Electrification status - Once selected, rural and urban enumeration areas within each county were categorized by electrification status and the sample divided in half between electrified and non-electrified enumeration areas. Electrification status is defined based on the location of KPLC step-down transformers. Detailed maps of transformer locations were provided by KPLC. 600m buffers were drawn around each transformer to simulate the distance that electrified households are typically located from transformers. Clusters that lie fully or partially within the 600m buffer were considered electrified (even if some of the enumeration area lay outside the 600m radius). Clusters that do not overlap with the buffer are considered unelectrified. Clusters were randomly selected from the categorized clusters with a bias given to electrified clusters. This provided for a balance between the electrified and non-electrified households as the possibility of having non-electrified households within electrified clusters was high as compared to the non-electrified clusters where 100% of the households in these clusters are not connected. In areas where the split between electrified and non-electrified clusters was uneven, then the category with fewer clusters was given priority where all the clusters in that category were picked with the remaining clusters selected from the other category.

Based on this stratification process, there were 4 possible characterization of the enumeration areas: Urban/electrified, Urban/unelectrified, Rural/electrified and rural unelectrified.

HOUSEHOLD SELECTION FOR THE CORE SAMPLE

To select households, the team followed one of two options described below.

Option 1) High resolution satellite imagery that allow dwellings within the enumeration area to be readily identified

The team used Google Earth images to geo-reference, list, and randomly select 12 household structures from within the enumeration area. Where the selected structure turned out to something other than a household (e.g. commercial buildings), the enumerator selected the nearest household by distance. This approach was applied in areas with high population densities: urban areas and, sometimes, rural areas with an even and dense distribution of households This method was unsuitable in dense slum areas, middle income urban areas with many multi-family dwellings (flats and apartments) and sparsely populated pastoral areas, where EAs occupied several hundred square kilometers and individual dwellings were difficult to identify from remotely sensed images.

Option 2)

Options 2 was the application of random walks and was applied in areas where Option 1 was not applicable. This method was viewed as being non-probabilistic and was applied for a greater majority of the interviews. In this approach, enumerators were trained to randomly select houses within their enumeration area ensuring that the respondent houses were spread across the entire area.

OVERSAMPLING

Underserved counties

14 underserved counties, listed in Figure 1, were oversampled by 1,100 HHs. This is in a*ddition to the HHs from these counties included in the core sample*. These underserved counties consist of mainly rural populations and therefore sample selection for oversampling did not follow the 1:1 urban-rural stratification applied to the core sample. Similarly, electrification is much lower than national average and a 1:1 ratio was also not possible, particularly in rural areas. The result of this oversampling on the distribution of enumeration areas was fewer or no rural electrified areas in a county and majority of the electrified EAs falling within urban centers and outskirts of major administrative towns.

KEEP and Nairobi slum areas (GPOBA areas and non-GPOBA areas)

Two areas with current or soon-to-be implemented World Bank Supported energy access projects were oversampled. These were KEEP and GPOBA intervention areas. Discussions at proposal and inception stage also included KEMP intervention areas. These were, however, not included in the survey implementation due to lack of data on the specific target areas.

For KEEP, a listing of target areas was provided by KPLC. The listing included the size of the target population. This allowed for proportional distribution of respondents across 31 randomly selected target intervention areas. A total of 351 KEEP area surveys were carried out. Oversampling for GPOBA slum intervention and non-intervention areas focused on slums within Nairobi county. Respondents were randomly selected in both areas for a target of 1,200 households. The KEEP areas did not have clear geographic demarcations and even some of the local KPLC staff could not clearly distinguish the boundaries. Most of the local teams were not familiar with the term “KEEP” but understood these to mean the GPOBA areas.

SELECTION OF ENUMERATORS AND SUPERVISORS

EED Advisory has developed an expansive database of over 130 enumerators spanning the various counties. This database consists of enumerators that EED-A has worked with directly on previous engagements, as well as enumerators from the KEFRI and Kenya Red Cross Society (KRCS) database and partner clients and organizations. Enumerator selection tapped into this list. KRCS vehicles and volunteers (who were recruited to work as enumerators) were used for high-risk counties including Mandera, Tana River, Garissa, Wajir and Nairobi’s slum areas. EED Advisory signed a memorandum of understanding with KRCS in this regard.

The following criteria was applied in enumerator selection. Enumerators had to:

- Be conversant with (preferably resident in) the area in which they were conducting the interviews. Understand and speak the local language in the area they would be conducting the interviews.
- Be familiar with the political and administrative boundaries of the survey areas.
- Be fully available for the entire duration for which the interviews would be carried out.
- Provide a valid original Kenyan National Identification Card.

- Provide proof of graduation from a University recognized in Kenya. Diploma holders with substantial data collection experience were considered especially in the underserved counties.
- Provide their current telephone contact.
- Attend an enumerator training session before undertaking any survey interviews.
- Demonstrate ability to collect data using CAPI.

Selected enumerators were trained and tested. The training program was over a duration of two days where enumerators were trained on the questionnaires including definition of terms, interviewing etiquette and best practices in asking questions. They were also trained on the survey tools including ODK and SW Maps (elaborated on later). Mock interviews and a pre-test exercise were integrated in the training program. Each enumerator was assigned a unique identity number and a supervisor.

The enumerators were under the leadership of regional supervisors who reviewed submitted data and performed random checks to certify that the information collected was accurate.

REGIONAL SUPERVISORS

9 regional supervisors were drawn from EED-A and SEI staff and were responsible for training and coordinating survey teams, checking the work done by enumerators and leading introduction meetings with the relevant authorities before embarking on the data collection. They were the first contact point in case of any technical and logistical challenges faced by the data collection enumerators. The supervisors participated in a pre-survey training before being deployed to a region. They carried out a series of checks on every survey to ensure that the data collected was consistent and realistic. The supervisors provided the enumerators with reports of any errors observed in verified submitted data to ensure errors were not carried forward. Enumerators received feedback from a team of about 15 data verifiers also contracted by EED-A to check data uploaded on ODK over the first two days of field data collection in each county.

PRE-TESTING SURVEY TOOLS AND SUPERVISORS' TRAINING

Pre-testing was done in Kajiado county and Narok county between 21/09/2016 – 22/09/2016 and 09/11/2016 and 10/11/2016 to assess the expected duration of an interview, respondents' comprehension of the questions, logical flow of the questionnaire and structure of each question, appropriateness of the answer options, use of CAPI, sampling strategy assumptions among other issues. This process also helped detect problems with the questionnaire design, highlight sensitive questions, and identify redundant and ambiguous questions.

The supervisors' training was done on the 16/11/2016 and 17/11/2016 in Karen, on the outskirts of Nairobi. A process map to standardize the data collection process was developed

Computer Aided Personal Interview

Open Data Kit

In carrying out the tablet-based surveys, we used Open Data Kit (ODK). We developed the necessary scripts required on ODK built from the provided questionnaires. The platform provided both data

collection and data analysis capabilities, automatically uploading the data onto a central server, facilitating GPS positioning of the survey point and inputting a timestamp. ODK had been pre-tested and had proven capable of delivering data to the standard and intention of the Client. It was uploaded on all the tablets prior to distribution to the enumerators and supervisors. The set-up software is cross-compatible on Windows, Mac and Linux platforms. Detailed training on using ODK for this survey was provided to the supervisors and enumerators during the pre-testing period. Once the data is entered, the team would carry out a detailed analysis and provide a full array of descriptive statistics for all indicators of interest. Descriptive statistics will be disaggregated to indicate regional trends and contrasts between urban and rural sub-populations, as well as other socio-demographic groups (e.g. female-headed households). As expected, certain sites did not have access to power to charge the tablets therefore the enumerators being dispatched to these areas were given portable power sources to ensure their tablets were always charged during the interviews.

SW Maps

The randomly selected enumeration areas, county sub-locations, and randomly selected households per county were overlaid on SW Maps, a GIS android application that can collect, present, and share geographic information. The App enabled enumerators to navigate to the enumeration areas in real time and provide live maps of the enumeration area, sub-locations, and the randomly selected households. Information (electrification status, rural urban status, and administrative information) on each enumeration area was also visible on the App. SW maps can also record GPS tracks and measure distances.

GIS Database

The survey questionnaires were set up to collect the GPS coordinates of all the interviews carried out. To do this, each tablet's inbuilt location services was switched on to automatically record the GPS coordinates onto the ODK questionnaire. The tablet's location services and SW Maps facilitated the movement of enumerators and supervisors in the field as they could locate and plan for transport based on distances and accessibility. All the surveys with the correct spatial information (County name, District, Division, Location, Sub-location and Cluster Unique Id/EA Id) can be presented in shapefile(. shp) and Google Earth (. kml/.kmz) format.

REFERENCES

Bhatia and Angelou. 2015.Beyond Connection-Energy Access Redefined, Technical report, ESMAP http://documents.worldbank.org/curated/en/650971468180259602/Beyond-connections-energy-access-redefined-technical-report

Blackden, M., and Wodon, Q. 2006. *Gender, Time Use, and Poverty in Sub-Saharan Africa*. Washington, DC: World Bank.

Citizen Digital. 2018. "ERC Mulls Uniform Tariff for Prepaid Customers." January 9. https://citizentv.co.ke/business/erc-mulls-uniform-tariff-for-prepaid-customers-187484.

Clancy, J. S., Skutsch, M. M., and Batchelor, S. 2003. The Gender-Energy-Poverty Nexus: Finding the Energy to Address Gender Concerns in Development. London: UK Department for International Development.

Daily Nation. 2017. "Longer Wait for Cheaper Sh 15000 Power Connection." February. https://www.nation.co.ke/business/Longer-wait-for-cheaper-Sh15-000-power-connection/996-3821722-hx3u6s/index.html.

Dalberg Advisors. 2018. "Cleaning up Cooking in Urban Kenya with LGP and Bio-Ethanol." Cape Town: South-South North.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101 (7): 3078–3108.

DHS. 2015. Kenya Demographic and Health Survey 2014 https://dhsprogram.com/pubs/pdf/FR308/FR308.pdf

Ekouevi, K., and Tuntivate, V. 2012. *Households Energy Lessons for Cooking and Heating: Lessons Learned and the Way Forward*. Washington DC: World Bank.

ERC (Electricity Regulatory Commission, Government of Kenya). 2018. "Clarification of the Retail Electricity Tariff Review for the 2018/19 Tariff Control Period (TCP)." Nairobi. https://www.erc.go.ke/wp-content/uploads/2018/08/Clarification-on-the-Retail-Electricity-Tarrif-Review-for-the-2018.19-tarrif-Control-Period.pdf.

ESMAP. 2004. The Impact of Energy on Women's Lives in Rural India. The World Bank

Fabini, D. H., D. P. Baridó, A. Omu, and J. Taneja. 2014. "Mapping Induced Residential Demand for Electricity in Kenya." *Proceedings of the Fifth ACM Symposium on Computing for Development*, ACM DEV-5 14. doi:10.1145/2674377.2674390.

GACC (Global Alliance for Clean Cookstoves). 2011. *Igniting Change: A Strategy for Universal Adoption for Clean Cookstoves and Fuels*. Washington DC. GACC.

Government of Kenya (and United Nations Development Program). 2013. *Kenya National Development Report: Climate Change and Rural Development*. Nairobi.

Gwavuya, S. G., S. Abele, I. Barfuss, M. Zeller, and J. Muller. 2012. "Household Energy Economics in Rural Ethiopia: A Cost-Benefit Analysis of Biogas Energy." *Renew Energy* 48: 202–209.

Hewitt, J., C. Ray, S. Jewitt, and M. Clifford. 2018. "Finance and the Improved Cookstove Sector in East Africa: Barriers and Opportunities for Value-Chain Actors." *Energy Policy* 117: 127–135.

IEA (International Energy Agency). 2010. *Energy Poverty: How to Make Modern Energy Access Universal*. Special Early Excerpt of the World Energy Outlook 2010 for the UN General Assembly on the Millennium Development Goals. Paris: IEA.

Jimenez, R. 2017. "Development Effects of Rural Electrification." IDB Policy Brief, InterAmerican Development Bank, Washington, DC

Karanja, A., and A. Gasparatos. 2019. "Adoption and Impacts of Clean Bioenergy Stoves in Kenya." *Renewable and Sustainable Energy Reviews* 102: 285–306.

Khandker, Shahidur, and Douglas Barnes. 2013. "Welfare Impacts of Rural Electrification: Evidence from Vietnam". The World Bank https://www.researchgate.net/publication/46444109_Welfare_impacts_of_rural_electrification_evidence_from_Vietnam

K-OSAP (Kenya Off-Grid Solar Project) and World Bank. 2017. The Project Appraisal Document, Republic of Kenya for an off-grid solar access project for underserved countries. http://documents.worldbank.org/curated/en/212451501293669530/pdf/Kenya-off-grid-PAD-07072017.pdf

Lai, Elisa, Stewart Muir, and Yasemin Erboy Ruff. 2019. "Off-Grid Appliance Performance Testing: Results and Trends for Early-Stage Market Development." *Energy Efficiency* (May 22). doi.org/10.1007/s12053-019-09793-z.

Lee, K., Miguel, E., and Wolfram, C. 2019. "Experimental Evidence on the Demand for and Costs of Rural Electrification." Cambridge, MA: National Bureau of Economic Research. doi:10.3386/w22292.https://www.povertyactionlab.org/sites/default/files/publications/Experimental-Evidence-on-the-economics-of-rural-Electrification_February2019.pdf.

Lee and Wolfram. 2016. Experimental Evidence on the Demand for and Costs of Rural Electrification. CEGA Working Paper Series WPS-057. Center for Effective Global Action. University of California, Berkeley.

Lee and Wolfram. 2018. Experimental Evidence on the Economics of Rural Electrification. University of California, Berkeley and NBER.

Lighting Africa. 2016. "Improving the Accuracy of Our Impact Reporting through the Multi-Tier Framework." The World Bank Group. Lighting Africa. https://www.lightingafrica.org/improving-accuracy-impact-reporting-multi-tier-framework/.

Lighting Africa. 2018. "A Thriving Off-Grid Market—With a New Focus on Underserved Areas." The World Bank Group. Lighting Africa. https://www.lightingafrica.org/country/kenya.

LMCP (Last Mile Connection Program). 2016. "Kenya Last Mile Connection Factsheet." Nairobi: Ministry of Energy. http://kplc.co.ke/img/full/AtNquN6B7LWP_Last_Mile%20Frequently%20Asked%20Questions.pdf.

Parikh, Jyoti. 2011. "Hardships and Health Impacts on Women Due to Traditional Cooking Fuels: A Case Study of Himachal Pradesh, India." *Energy Policy* 39: 7587–7594. https://irade.org/Parikh.pdf.

Peck, M. D., G. G. Kruger, A. E. van der Merwe, W. Godakumbura, and R. B. Ahuja. 2008. "Burns and Fires from Non-electric Domestic Appliances in Low- and Middle-income Countries: Part I. The Scope of the Problem." *Burns* 34 (3): 303–11.

Person, B., J. D. Loo, and A. L. Cohen. 2012. "It Is Good for My Family's Health and Cooks Food in a Way That My Heart Loves: Qualitative Findings and Implications for Scaling-Up an Improved Cookstove Project in Rural Kenya." *International Journal of. Environmental. Research and Public Health* 9: 1566–1580.

Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M, et al.2010. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. Epidemiol Rev. 2010; 32:70–81. pmid: 20378629

Presidential Office, Kenya. 2015. "Cost of Installing Electricity Drops to Ksh 15,000 with Option of Instalments." Press release, Nairobi. http://www.president.go.ke/?s=Cost+of+Installing+Electricity+Drops+.

Ogara, W., J. Ayieko, and T. Odindo. 2017. "Carbon Monitoring and Biogas User Survey 2016." Nairobi: Biogas Partnership Programme.

Rehfuess, Eva, Sumi Mehta, and Annette Prüss-Üstün. 2006. "Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals." *Environ Health Perspectives* 114 (3): 373–378.

Rosenbaum, J., E. Derby, K. and Dutta. 2015. "Understanding Consumer Preference and Willingness to Pay for Improved Cookstoves in Bangladesh." *Journal of Health Communication* 20 (sup1): 20–27.

Ruiz-Mercado, I., and O. Masera. 2015. "Patterns of Stove Use in the Context of Fuel–Device Stacking: Rationale and Implications." *EcoHealth* 12 (1): 42–56.

Salmon, Claire, and Jeremy Tanguy. 2016. "Rural Electrification and Household Labor Supply: Evidence from Nigeria." *World Development* 82: 48–68.

Taneja, Jay. 2018. "If You Build It, Will They Consume? Key Challenges for Universal, Reliable, and Low-Cost Electricity Delivery in Kenya." CGD Working Paper 491. Center for Global Development: Washington, DC. https://www.cgdev.org/publication/if-you-build-it-will-they-consume-key-challenges-universal-reliable-and-low-cost.

Teodoro, S. 2008. *Lessons from Project Implementation on Cookstoves and Rural Electrification: The Practical Action Experience.* Nairobi: United Nations.

UNDESA. 2017. United Nations, Department of Economic and Social Affairs, Population Division (2017a). Household Size and Composition 2017.

UNDP, and WHO (World Health Organization). 2009. The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub Saharan Africa. New York: UNDP and WHO.

Wang, X., J. Franco, O.R. Masera, K. Troncoso, and M.X. Rivera. 2013. What Have We Learned about Household Biomass Cooking in Central America. ESMAP Report No. 76222. Washington, D.C.: The World Bank.

WHO (World Health Organization). 2018. "Household Air Pollution and Health—A Factsheet." Geneva: WHO. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. zWillcox, Mary, and David Cooper. 2018. *NAE Case Study: Kenya, Off-Grid for Vision 2030*. Washington, DC: National Academy of Engineering.https://energypedia.info/wiki/NAE_Case_Study:_Kenya,_Off-Grid_for_Vision_2030.

Winrock International. 2011. *The Kenyan Household Cookstove Sector: Current State and Future Opportunities.* Washington, DC: Winrock International.

World Bank. 2014. ASTAE (Asia Sustainable and Alternative Energy Program). "Clean Stove Initiative Forum Proceedings." Beijing, China, April 26–29. East Asia and Pacific Clean Stove Initiative Series, World Bank, Washington, DC.

World Bank. 2015. "Bringing Electricity to Kenya's Slums: Hard Lessons Leads to Great Gains." Blog entry, April 20. Washington, DC: World Bank. http://www.worldbank.org/en/news/feature/2015/08/17/bringing-electricity-to-kenyas-slums-hard-lessons-lead-to-great-gains.

World Bank Data. 2018. United Nations Population Division. World Urbanization Prospects. The World Bank. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=KE

World Bank. 2018. *Tracking SDG7: the energy progress report 2018 (English)*. Washington, D.C. World Bank Group. http://documents.worldbank.org/curated/en/495461525783464109/Tracking-SDG7-the-energy-progress-report-2018

WORLD BANK GROUP

ESMAP

SREP

MTF
Multi-Tier
FRAMEWORK