LIBERIA

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

ESMAP

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SREP

MTF Multi-Tier FRAMEWORK

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Alisha Pinto, Abdul Farouk Bemba Nabourema, Bryan Bonsuk Koo, Elisa Portale, and Dana Rysankova

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1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000

Internet: www.worldbank.org

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This Energy Access Diagnostic Report details the results of the MTF survey in Liberia and provides an informed account of the status of both access to electricity and access to modern cooking services in the country. This initiative has relied on the critical support of multiple entities and individuals that the MTF team would like to acknowledge.

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ABBREVIATIONS

EA	Enumeration area.
ESMAP	Energy Sector Management Assistance Program
GDP	Gross Domestic Product.
HIES	Household Income and Expenditure Survey.
HH	Household
ICS	improved cookstove
IWA	International Workshop Agreement.
kW	kilowatt
kWh	kilowatt-hour
LED	Light-emitting diode
LISGIS	Liberia Institute of Statistics and Geo-Information Services
LPG	Liquefied Petroleum Gas
MTF	Multi-Tier Framework
MW	megawatt
SDG	Sustainable Development Goal
SHS	solar home system
W	watt
WHO	World Health Organization
WTP	willingness to pay

US$1 = Liberian $94 on June 1, 2017

EXECUTIVE SUMMARY

The Multi-Tier Framework (MTF) was developed to address the specifics of energy access needs outlined in the Sustainable Development Goals (SDGs) of the United Nations. Beyond access, the framework looks at various energy service issues. For example, it considers whether decentralized off-grid solutions (such as mini-grids and solar home systems) are viable sources of electricity in some contexts.

The World Bank's Energy Sector Management Assistance Program (ESMAP), in consultation with multiple development partners, has developed the Global Tracking Framework (GTF) to measure and monitor energy access using the attributes and tiers laid out in the MTF. Importantly, the MTF defines energy access as being adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive enterprises, and community institutions.

Among its efforts to leverage the benefits of the MTF, ESMAP launched detailed data collection activities in 16 countries, including Liberia. Situated in West Africa, Liberia is a country of 4.5 million people who recently saw their electricity resources affected by prolonged civil war. For the past decade, Liberia has experienced stability, with its government undertaking development and nation-building activities.

The World Bank carried out a nationally representative survey with the Government of Liberia from March to July 2017 to determine a baseline for Liberia's access to energy. The survey sample was selected so as to be representative of Liberia's 15 counties and urban and rural areas, and a total of 3,504 households were interviewed for this purpose. As the grid extends to Greater Monrovia, Montserrado County, the sample population from this area was further stratified into electrified and non-electrified households to understand electricity access from the national grid. The findings of this report are based on the data from that survey.

ACCESS TO ELECTRICITY

Liberia has made progress in expanding overall access to electricity. Overall, 27.8% of households have access to some source of electricity, with 6.9% of households connected to the national grid and 20.9% connected to an off-grid source. The most important off-grid sources are local mini-grids, solar lighting systems, and diesel generators. A larger share of urban households is connected to the national grid and mini-grids compared with rural households. However, 72.2% of the households in Liberia have no access to any source of electricity.

The MTF analysis shows that most Liberian households have electricity access at Tiers 1, 2, and 3. The degree of households' access is measured across a spectrum, from full access to electricity (Tier 5) to no access (Tier 0) based on the capacity of the source, and whether the electricity supply is available, reliable, without voltage fluctuations, affordable, and safe to use. To communicate these variables, the MTF uses seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety. Rural households can access only Tiers 0–1 levels with their off-grid sources: 92.2% of rural households are in Tier 0 compared with 59.5% of urban households. Urban households are commonly assigned to Tiers 1–3, while 6.2% of rural households reach Tier 1. These low rankings reflect the fact that many households simply do not have access to the grid. Thus, the Capacity attribute of the main source of electricity is brought down where households use off-grid solutions for only lighting and mobile phone charging.

For grid users, Availability, Reliability, and Affordability are the main attributes affecting access. About 70 percent of the households connected to the grid receive less than 3 hours of electricity in the evening, between 6 pm and 10 pm. Reliability is a serious issue affecting 73% of the households using grid electricity. Affordability, too, is a major obstacle, especially high tariffs (US$0.55 in 2017) and high up-front costs of connection. A standard consumption package of 365 kWh/year is unaffordable to almost 60% of Liberian households (i.e., it costs more than 5% of the household's total consumption). The most common issues that grid-connected households reported about the service were interruptions, voltage fluctuations, and supply shortages. To cope with outages and unavailable electricity supply, households use generators and mini-grid connections as backup electricity sources.

Most households connected to a local mini-grid are in Tier 2, with 16.7% reaching a Tier 3 level of access. Availability, Reliability, and Quality of electricity supply from the mini-grid are the main attributes that keep these households in the lower tiers. Mini-grid users are constrained by the overall capacity of the system, which can vary depending on its size, number of households connected to it, restrictions imposed by operators, or the appliances powered by it.

Households using solar devices for lighting are mostly limited to Tier 1. About one-third of households with solar devices fall into Tier 0, mostly due to the inability of the system to provide sufficient electricity for all household members. The most common issues households face with their solar devices are the duration of the service, poor quality of light, and limitations on capacity.

The 75.8% of households in Tier 0 without an electricity source and the 81.3% that use only dry-cell batteries would need to be connected to the grid or off-grid solutions to move to a higher tier. The unavailability of a grid network is the main reason 77.4% of households are not connected to the grid. Other issues are the costs associated with connecting to the grid, high tariffs, and administrative procedures. Most households without access to the grid appear willing to pay for access to electricity up front or with some flexibility in payment. However, Affordability is a constraint for them. Households demonstrate a much lower willingness to pay for a solar home system.

ACCESS TO MODERN ENERGY COOKING SERVICES

Liberia still has a long way to go to achieve access to modern energy coking services. The majority of households use locally made coal pot stoves (49.1%) and three-stone stoves (47.7%) nationwide. The use of improved and clean fuel stoves is extremely limited, at 1.8% and 0.1%, respectively. Correspondingly, the use of fuel is consistent with stove types: nationwide, 48.9%, 46.7%, and 4.3% of households use charcoal, collected wood, and purchased wood for cooking, respectively.

The MTF analysis shows that most households are in Tier 0 (75.2%) and Tier 1 (24.6%) nationwide. The stove and fuel combination determines their ranking across five attributes: Cooking Exposure, Cooking Efficiency, Convenience, Availability of Fuel, Affordability, and Safety. Based on these attributes, households are placed in a tier that qualifies their access to modern energy cooking services, ranging from full access (Tier 5) to no access (Tier 0). The difference in tier classifications for cooking among urban and rural households is not that significant. Only 0.1% of households in Liberia are in Tier 5 nationwide and few households are in Tiers 2, 3, or 4.

With traditional biomass stoves as common as they are, households rank low across the MTF attributes—particularly Cooking Exposure, which is closely linked to the stove and fuel combination. In Liberia, 52.6% of households spend more than 7 hours collecting and preparing fuel for cooking per week or at least 15 minutes preparing a stove for each meal. Households in rural areas tend to spend the most time preparing their fuel and stove, since most depend on collected firewood rather than the purchased charcoal common in urban areas. Since most urban households purchase their fuel, Affordability tends to be more of an issue for them than for rural households.

Households expressed a high willingness to pay for improved biomass stoves both up front and in installments over time. However, households expressed a degree of price sensitivity: higher discounts or subsidies on the prices of stoves would encourage their purchase. Those who were unwilling to pay for an improved stove noted price as an obstacle. Others indicated a lack of need for such a stove, or a lack of awareness. Thus, any effort to promote clean cooking needs to account for how Affordability affects households' decision-making, not only in terms of the stove itself but also the continued purchase of fuel.

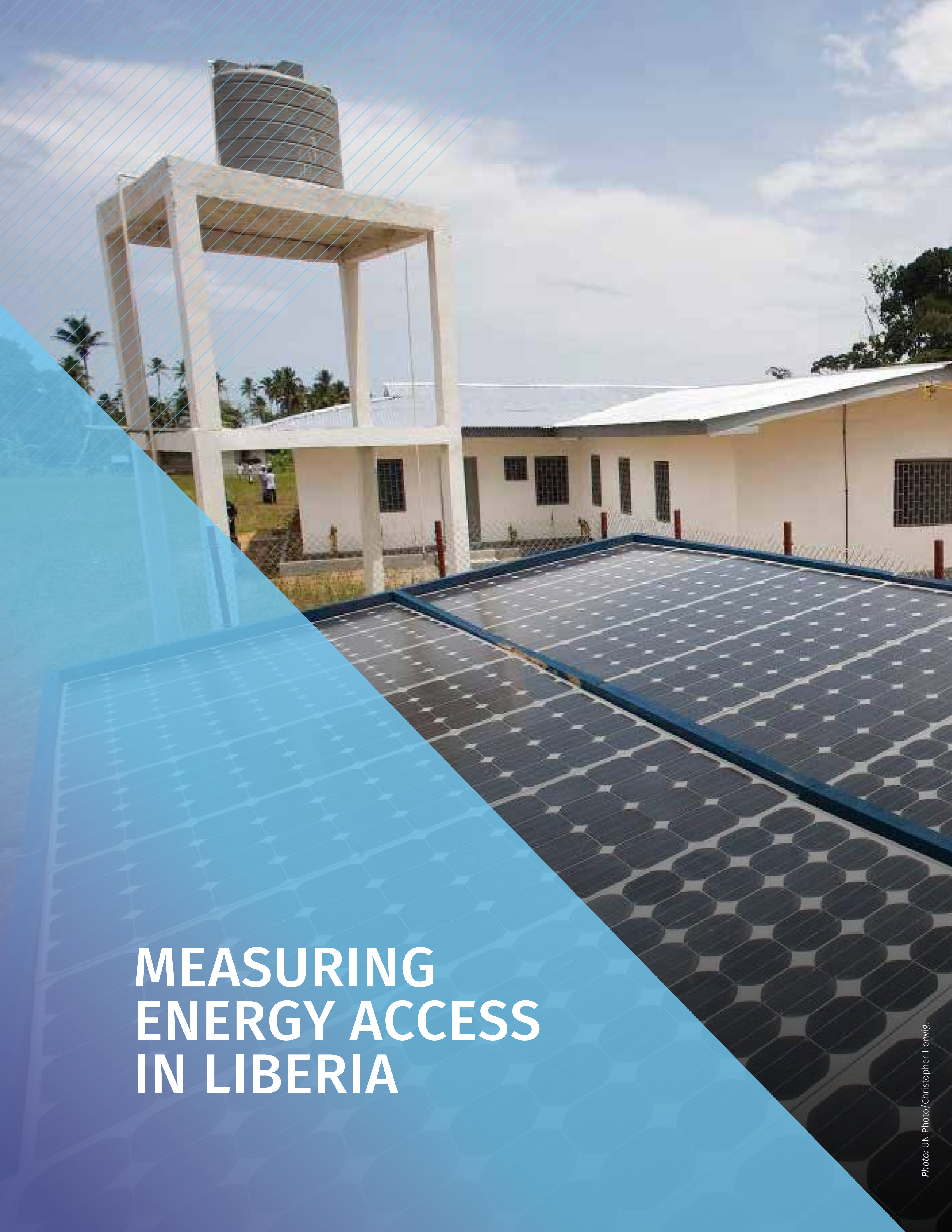
GENDER ANALYSIS

Nationwide, 76.9% of households are headed by men, while the remaining 23.1% are headed by women. The difference in the gender of the household head is similar across urban and rural areas. Male heads of households tend to be better educated than female heads. However, in terms of distribution across the expenditure quintiles, there does not appear to be a significant gender difference.

Across various sources of electricity, there does not appear to be a large difference in the level of access between male- and female-headed households. Both sets of households are comparable, in rural and urban areas, and across the different tiers.

The Cooking Tier distribution among male- and female-headed households in Liberia does not indicate any major difference between the two groups. The gender of the household head does not appear to influence the decision to acquire a self-built or clean fuel stove. However, men are willing to acquire a three-stone stove, while females prefer locally made coal pot stoves.

Women spend the most time in the kitchen. Women (above the age of 15 years) in general spend more time preparing a stove for a meal than men (above the age of 15 years), regardless of the type of stove used in the household. Cooking appears to be mainly a female activity regardless of the age of the primary cook and the type of stoves used in the household, with women and girls (below 15 years) spending substantially more time in the kitchen than men and boys (below 15 years). Meanwhile, the age, and not the gender, of a household's members decides the amount of time spent collecting stove fuel.



MEASURING ENERGY ACCESS IN LIBERIA

Photo: UN Photo/Christopher Herwig.

Without energy, promoting economic growth, overcoming poverty, and supporting human development are challenging, if not impossible. Energy access is thus a precondition to many development goals. The 7th of the 17 United Nations Sustainable Development Goals (SDGs) is to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. The Government of Liberia is committed to achieving SDG 7 to maximize energy access benefits for its population. It has worked with the World Bank on the Multi-Tier Framework Survey as well as in implementing energy access policies. This survey provides Liberia's government with guidance on how to set access targets, policies, and investment strategies for energy access.

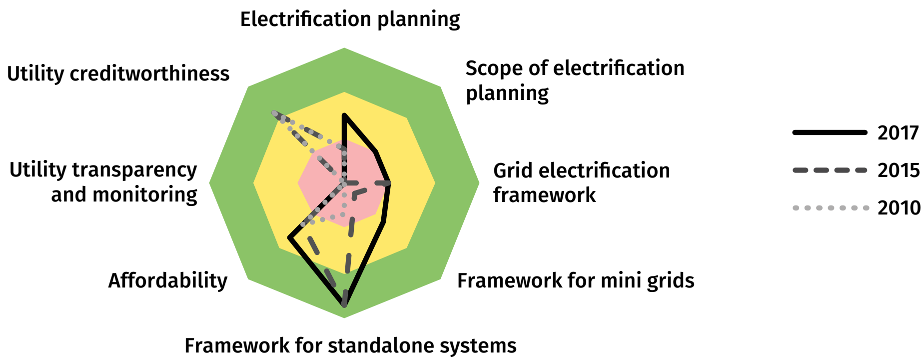
Prolonged civil war from 1980 to 2003 and the Ebola epidemic in 2014 slowed progress toward Liberia's development goals. Despite some growth and significant achievements in rehabilitating the country since the end of the conflict, poverty has remained pervasive and affects nearly 70% of Liberians. Although Liberia's Human Development index increased from 0.38 in 2000 to 0.42 in 2015, and 0.465 in 2018, it remains below the 0.541 average for Sub-Saharan Africa (UNDP 2016). Liberia's annual gross domestic product (GDP) growth rate was negative (–1.6%) in 2016 and rose to 1.22% in 2018, but is still well below the Sub-Saharan regional average of 2.4%.

Access to the national grid is substantially concentrated in Monrovia, the capital, and other urban areas. Households without access to the grid rely on private diesel and gasoline generators, and other non-efficient sources such as kerosene lamps and candles. Weak infrastructure remains an impediment to growth in the electricity sector. Globally, Liberia ranks 37th among the 190 economies included in the 2017 World Bank *Doing Business* Report (World Bank 2017), and 60% of enterprises in the country identified a lack of electricity as a major constraint.

Since the end of the civil war in 2003, the Government of Liberia has taken important steps to build its electricity infrastructure. The Government of Liberia's current priorities focus on connecting 70% of Monrovia to the electricity grid by 2030 and expanding access to 35% of rural areas through mini-grids and other isolated solutions, in particular for the rural poor (Ministry of Lands, Mines and Energy 2009). A national electrification strategy (NES) with the help of a geospatial tool is currently being developed with support from the World Bank. The strategy will identify the least-cost options (grid expansion and intensification, mini-grids, or stand-alone systems) for electrification, with the goal of achieving universal access to electricity in a reasonable time frame.

Liberia's policy framework for electricity access is nascent. Basic electrification planning and policies supporting grid electrification and stand-alone systems were instituted between 2010 and 2015, but policy development on these fronts has been stagnant since (Figure 1). On the other hand, a policy framework for mini-grids, including a national program for their development and a legal framework for their operation, has emerged since 2015. Liberia's policy apparatus faces multiple challenges: electricity connections are unaffordable, and the prohibitive cost of power has rendered even subsistence-level electricity consumption (30 kWh/month) unaffordable to most consumers. Meanwhile, the data on utilities' finances are not easily available, making it difficult to assess their financial viability.

FIGURE 1 • **Progress in electricity access, by indicator, 2010, 2015, and 2017**



Source: World Bank 2018.

Nationwide, charcoal and firewood supply 95% of energy demands for cooking for the poorest segment of the population. According to the World Bank Global Tracking Framework, only 2% of Liberian households use clean cooking technologies. Only a negligible population use liquefied petroleum gas (LPG) stoves for commercial and domestic purposes. Considering the negative environmental and health impacts of charcoal and firewood use, the government of Liberia aims to increase the share of households using modern cooking devices[1] to 95% of the population.

THE MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the Multi-Tier Framework (hereon, MTF) approach. The first phase was carried out in 16 countries across Africa, Asia, and Latin America, including Liberia. The survey's objective is to provide comprehensive data on energy access, including access to electricity and cooking services. The survey also collects household-level data on socioeconomic indicators and demographics. The study is nationally representative and incorporates urban and rural households as well as households with and without a national grid connection.

The MTF approach goes beyond the traditional binary measurement of energy access (i.e., having or not having a connection to the grid) and uses a comprehensive methodology to measure the multidimensional nature of energy access. It examines the vast range of technologies and sources that can provide energy, while accounting for the wide differences in user experience.[2]

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. Using those attributes, it then defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement. Each attribute is assessed separately for a household, and the overall tier for a household's access to electricity or clean cooking services is the lowest applicable tier attained among the attributes (Bhatia and Angelou 2015).

1 LPG, improved cookstoves (ICSs), and other technologies.
2 The MTF access rate includes access provided by off-grid technologies, which is often excluded by the binary rate, but excludes connections 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 (see Annex 1 for definitions and criteria to calculate the attributes). These attributes help determine the usefulness of electricity supply and influence the extent to which households can use electricity services.

Capacity: The ability of a system to provide a certain amount of electricity to operate different appliances, ranging from a few watts for light-emitting diode (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. (See Table 1 for load levels for Capacity and associated appliances, and Annex 2 for tier calculation of the Capacity attribute.)

Availability: The amount of time during which electricity is available. This 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: A combination of the frequency and duration of unexpected disruptions.

Quality: The absence of severe voltage fluctuations that can damage a household's appliances.

Affordability: This is determined by whether the cost of a standard consumption package of 365 kWh/year is less or more than 5% of a household's annualized expenditure.

Formality: If households use electricity service from the grid but do not pay anyone for their consumption, their connection could be defined as informal.

Health and Safety: 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.

TABLE 1 • **Load levels, indicative electric appliances, and associated Capacity tier**

Load level (in watts, W)	Indicative electric appliances	Capacity tier typically needed to power the load
Very low (3–49 W)	Task lighting, phone charging, radio	TIER 1
Low (50–199 W)	Multipoint general lighting, television, computer, printer, fan	TIER 2
Medium (200–799 W)	Air cooler, refrigerator, freezer, food processor, water pump, rice cooker	TIER 3
High load (800–1,999 W)	Washing machine, iron, hair dryer, toaster, microwave	TIER 4
Very high load (2,000 W or more)	Air conditioner, space heater, vacuum cleaner, water heater, electric cookstove	TIER 5

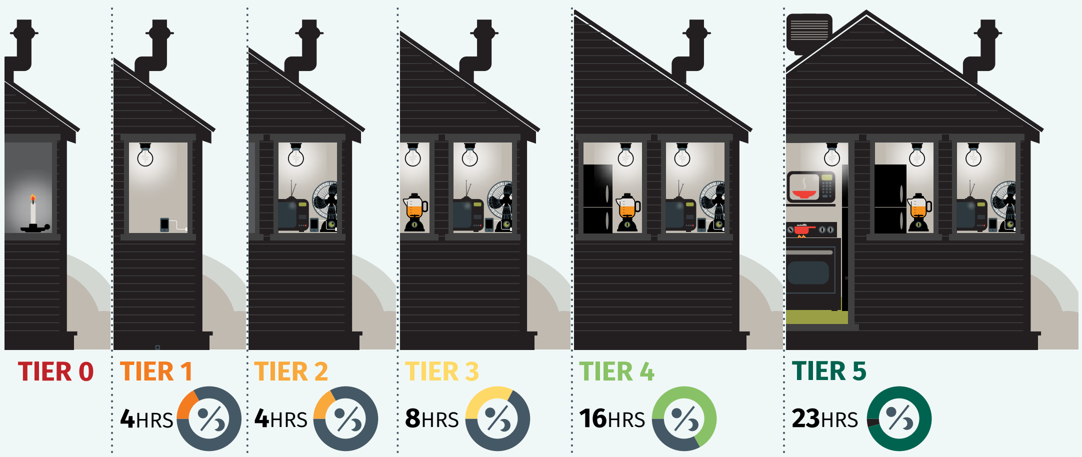
Source: Bhatia and Angelou, 2015

For each of these attributes, households are placed in a tier depending on the level of service as defined by the different thresholds (Annex 3 shows the MTF thresholds for measuring access to electricity). A household's aggregate tier or level of access is determined by the lowest tier value the household obtains among the attributes. At the national level, we can see the aggregate tiers for all households as a distribution, that is, we obtain a share of the total households that fall into each tier.

The lower tiers point to households with no electricity or sources limited by capacity. The availability of electricity supply is also a crucial determinant of whether a household is in a lower tier (Box 1 shows the minimum requirements of electricity access by tier). Higher tiers are defined by greater capacity and longer availability of supply, enabling the use of medium- and high-load appliances such as refrigerators, washing machines, and air conditioning. The Affordability attribute is applicable for Tiers 3–5 while Reliability, Quality, Formality, and Health and Safety are applicable at Tiers 4 and 5. A grid is the most likely source for a household achieving a higher tier, though a diesel generator or a mini-grid is an option. Technological advances in photovoltaic solar home systems and direct-current-powered energy-efficient appliances also make achieving Tier 3 and even Tier 4 possible. However, such systems are very rare in Liberia.

BOX 1 • MINIMUM REQUIREMENTS OF ELECTRICITY ACCESS, BY TIER

Measuring energy access: the tiers of the Multi-Tier Framework



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 (flashlights or radios).	At least 4 hours of electricity per day are available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio. Sources that can be used to meet these requirements include a solar lighting system, a solar home system, a mini-grid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and the national grid.	At least 4 hours of electricity are available per day (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances as needed during that time, such as multiple lights, a television, or a fan (see Table 1). Sources that can be used to meet these requirements include rechargeable batteries, a solar home system, a mini-grid, and the national grid.

Tier 3	Tier 4	Tier 5
At least 8 hours of electricity are available per day (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances as needed during that time, such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see Table 1). 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 a solar home system, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity are available per day (including 4 hours per evening), and capacity is sufficient to power high-load appliances as needed during that time, such as a washing machine, iron, hair dryer, toaster, and microwave. 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 and the national grid.	At least 23 hours of electricity are available per day (including 4 hours per evening), and capacity is sufficient to power very-high-load appliances as needed during that time, such as an air conditioner, space heater, vacuum cleaner, or electric cooker. The most likely source for meeting these requirements is the national grid, though in theory a generator or mini-grid might suffice as well.

Source: Bhatia and Angelou 2015.

ACCESS TO MODERN ENERGY COOKING SERVICES

Despite well-documented benefits of access to clean cookstoves, almost 3 billion of the world's population still use polluting, inefficient cooking services that emit toxic smoke (IEA et al. 2018). The inefficient use of solid fuels has significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009; World Bank 2011).[3] The consequences of inefficient energy use for cooking extend beyond direct health impacts, to socioeconomic development. For example, fuel collection and cooking tasks are often undertaken by the women and girls in a household and affect the time spent for education or income-generating activities. 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). The time spent in fuel collection often translates into lost opportunities for gaining education and increasing income and increases drudgery (Blackden and Wodon 2006; Clancy, Skutch, and Batchelor 2003). In addition, time spent in sometimes isolated areas increases the risk for injury and attack (Rehfuess, Mehta, and Prüss-Üstün 2006).

The MTF measures access to modern energy cooking services based on six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Safety of Primary Cookstove, Affordability, and Availability of the Primary Fuel (see Annex 3 for definitions and questions used to calculate the attributes).

Cooking Exposure: This attribute assesses personal exposure to pollutants from cooking activities, which depends on stove emissions and ventilation (which, in turn, depends on the cooking location and size, if enclosed[4]). The Cooking Exposure attribute is a composite measurement of the emissions from the cooking activity, that is, the combination of the stove type and fuel, mitigated by the ventilation in the cooking area. If a household uses multiple stoves, the Cooking Exposure attribute is measured as a weighted average of the time each stove is used.

Cookstove Efficiency: This is measured by looking at both combustion and heat-transfer efficiency. Laboratory testing of the efficiency of various types of cookstoves informs the breakdown of efficiency levels by cookstove and fuel combination, which can be observed in the field with relative ease.[5]

Convenience: This attribute is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and stove for cooking.

Affordability: This attribute assesses a household's ability to pay for both the 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 its total expenditure on cooking fuel.

Health and Safety: The degree of risk to life and limb can vary by type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, or the potential for fuel splatter. This attribute is measured through reported incidences of past injury and/or fire.

Availability of Primary Fuel: The availability of a given fuel can affect the regularity of its use, while fuel shortages can cause households to resort to inferior types of secondary fuel. This attribute assesses the availability of the primary fuel when needed for cooking purposes.

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[3] Household air pollution has been associated with a wide range of adverse health impacts, such as increased risk of acute lower respiratory infections among children under age 5, and chronic obstructive pulmonary disease and lung cancer (in relation to coal use) among adults over age 30. An association between household air pollution and adverse pregnancy outcomes (such as low birth weight), ischemic heart disease, interstitial lung disease, and nasopharyngeal and laryngeal cancers, may also be tentatively drawn based on limited studies (Dherani et al. 2008; Rehfuess, Mehta, and Prüss-Üstün 2006; Smith, Mehta, and Maeusezahl-Feuz 2004).

[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. We do not include data on the volume of the cooking area, since this is sparse.

[5] In cases where the cookstove also serves as a source of heating for the dwelling, the efficiency attribute should be ignored because heat-transfer efficiency becomes irrelevant.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

The MTF survey provides detailed data on household energy consumption that are valuable for governments, development partners, the private sector, non-governmental organizations, investors, and service providers. On the supply side, it captures detailed data on all energy sources that households use. On the demand side, it provides data on energy-related spending; energy use; user preferences; willingness to pay (WTP) for grid, off-grid, and cooking services; and the satisfaction of consumers with their primary energy source.

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

Governments and policy makers can benefit from the MTF findings in a number of ways. First, using MTF findings, countries can track progress toward achieving SDG 7, and set targets for universal access based on existing status, budget, and other constraints. MTF analysis can also identify the barriers to achieving energy access goals, and the government and policy makers can revise their strategies accordingly. For example, given the existing budget, governments can balance improving energy access for existing users (for example, reducing load shedding) and providing new connections. Moreover, since MTF analysis disaggregates findings by rural and urban areas, income quintile, and gender of household heads, governments can take these into account while prioritizing their energy access goals.

Second, the MTF recognizes off-grid solutions as valid sources of electricity: analysis shows that households can reach Tier 5 access with mini-grids as they can with grid access, and lower-tier access (Tiers 1–3) with low-cost solutions such as solar home systems (SHSs) or micro- or mini-hydro grids. In the medium term, governments could expand electricity access to remote or isolated areas, where the grid will not go in the foreseeable future, using SHSs or micro-hydro grids to meet households' basic electricity needs, such as for lighting, fans, radios, and TVs.

Third, MTF analysis can shed light on the linkages between energy access and its benefits. For example, it is well established that electricity access has socioeconomic benefits. By disaggregating access into different facets of electricity service, MTF analysis can identify which elements of the service (attributes) have the most impact or create barriers to reaching maximum benefits. This helps the government and policy makers focus on those aspects of electricity service that need to be improved to enhance the benefits.

Finally, the MTF findings on willingness-to-pay (WTP) may provide inputs on how to price different products meant to expand access (e.g., the connection fee for grid access, or the price of SHSs or improved cookstoves). Given the available resources, the government can subsidize or set up a financing mechanism for these components to ensure maximum access to energy.

MTF data can inform the design of interventions meant to expand access, and also the prioritization of those that are likely to have the maximum impact for a given budget. The data can be disaggregated by attribute and technology, providing insights into the variables that keep households in lower tiers and key barriers to progress, such as lack of generation capacity, high energy costs, or a poor T&D network. MTF data also provide guidance on the technologies that are most suited to satisfying the demand of non-electrified households (for example, grid or off-grid). MTF demand-side data, such as on energy spending, WTP, energy use, and appliances can also be used to inform the design and targeting of specific projects and investments.

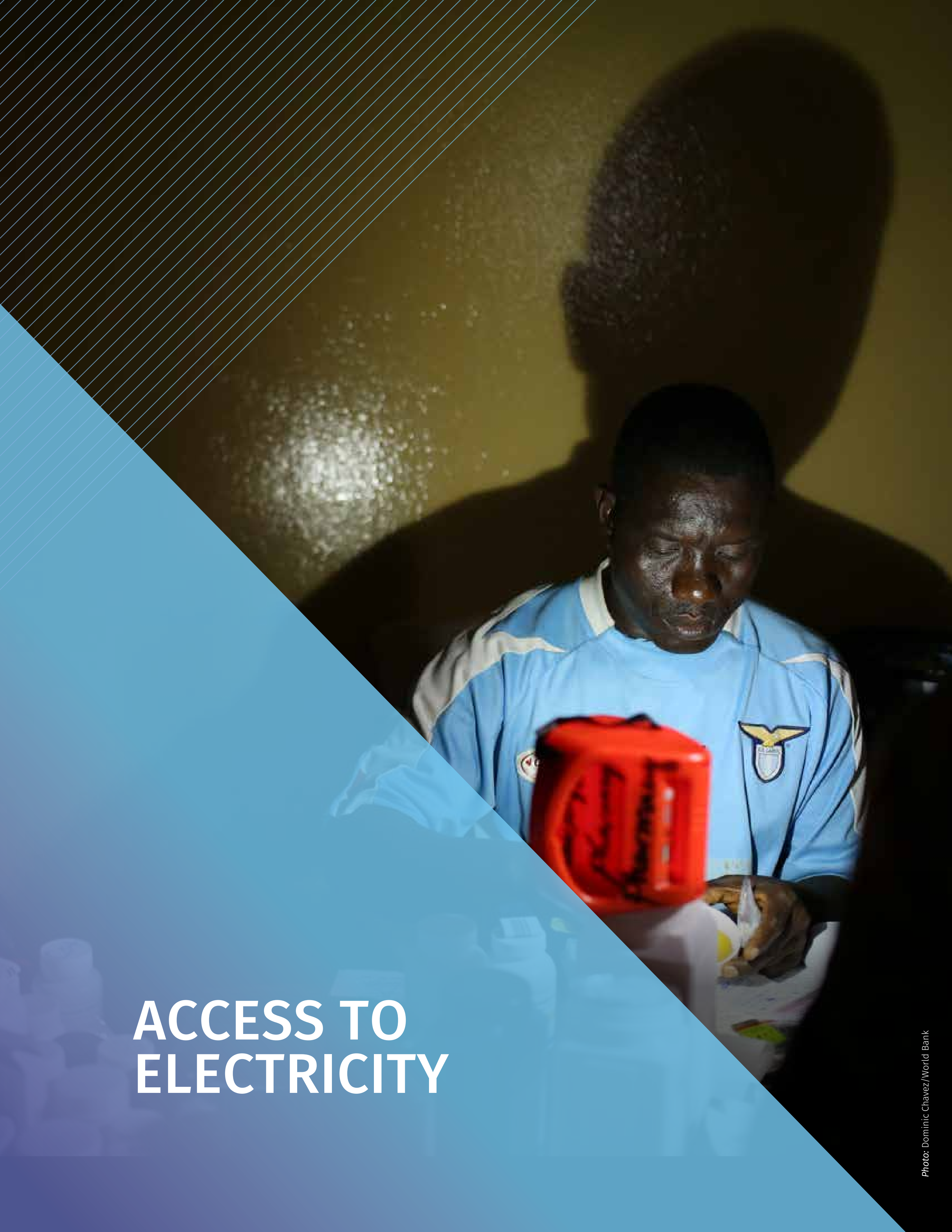
The MTF surveys provide three types of disaggregation: by urban or rural location, by expenditure quintile, and by the gender of the household head. For the gender-disaggregated survey, non-energy information such as on mobility, access to finance, and time use is also collected. Indicators such as primary energy source, tier of access, energy-related spending, WTP, and user preferences are disaggregated by male- and female-headed households. Such disaggregated analysis could add value to the planning, implementation, and financing of efforts to expand access to energy.

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN LIBERIA

The MTF data collection in Liberia began in March 2017 and was completed by July 2017. The household survey sample was based on a two-stage stratification, and aimed at being nationally representative. It was representative of the 15 counties and both urban and rural areas, with a total of 3,504 households interviewed. As the national grid extends to Greater Monrovia in Montserrado County, the sample of households was divided between electrified and non-electrified areas. A sample of 1,008 households in the urban areas around Greater Monrovia were stratified based on their electrification status, and households were selected using a 50:50 ratio of electrified and non-electrified households. Table 2 shows the number of enumeration areas (EAs) and households in each county in Liberia. The sampling frame was the 2014 Household Income and Expenditure Survey (HIES) conducted by the Liberia Institute of Statistics and Geo-Information Services (LISGIS). The survey was carried out by NRECA International, under the guidance of the Ministry of Lands, Mines and Energy and LISGIS.

TABLE 2 • **Household survey distribution of samples across Liberia**

	Urban		Rural		Total	
	Enumeration areas	Households	Enumeration areas	Households	Enumeration areas	Households
Bomi	2	24	7	84	9	108
Bong	8	96	20	240	28	336
Gbarpolu	2	24	6	72	8	96
Grand Bassa	5	60	15	180	20	240
Grand Cape Mount	2	24	9	108	11	132
Grand Gedeh	3	36	5	60	8	96
Grand Kru	2	24	4	48	6	72
Lofa	7	84	15	180	22	264
Margibi	8	96	12	144	20	240
Maryland	3	36	5	60	8	96
Montserrado			8	96	98	1,176
Greater Monrovia	84	1,008	-	-		
Other Montserrado	6	72	-	-		
Nimba	8	96	25	300	33	396
River Gee	2	24	3	36	5	60
Rivercess	2	24	6	72	8	96
Sinoe	2	24	6	72	8	96
Total	**146**	**1,752**	**146**	**1,752**	**292**	**3,504**



ACCESS TO ELECTRICITY

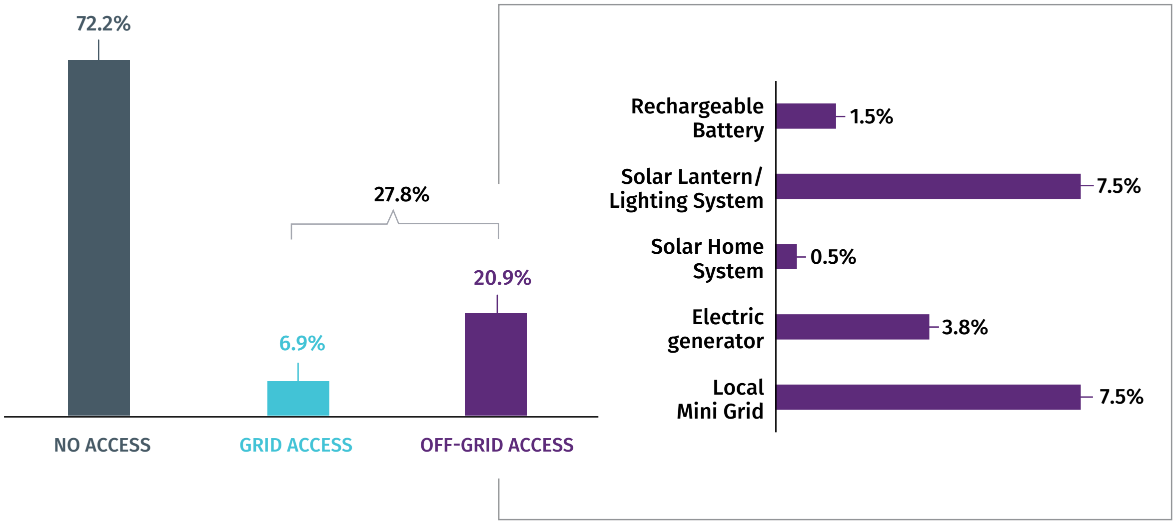
Photo: Dominic Chavez/World Bank

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

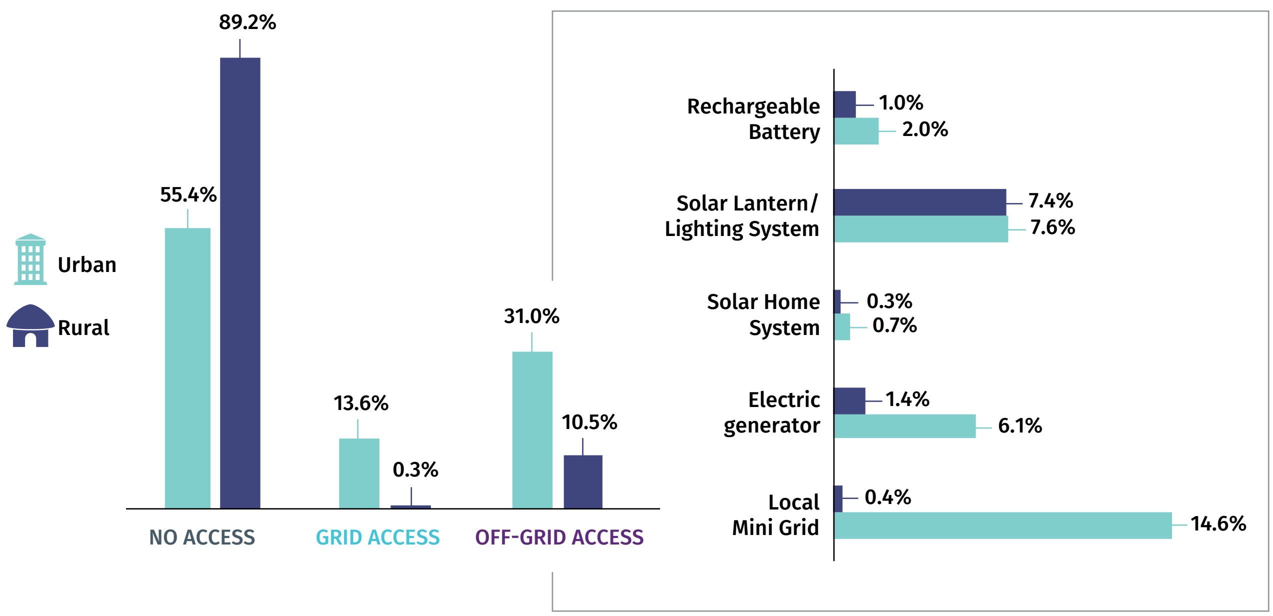
In Liberia, 27.8% of households have access to some source of electricity, with 6.9% of the households connected to the national grid and 20.9% connected to an off-grid source. The most important off-grid sources are the local mini-grid, solar lighting, and diesel generators. The local mini-grid and solar lighting each account for about 7% of the off-grid electricity used (Figure 2).

FIGURE 2 • **Access to electricity by technology (Nationwide)**



Both urban and rural households use off-grid solar devices and rechargeable batteries, but such off-grid solutions are more prevalent in urban households (Figure 3). Some 31.1% of urban households use off-grid solutions as their primary source of electricity: 14.6% use a local mini-grid, 7.6% use a solar lantern or solar lighting system. Additionally, 6.1% of urban households use a diesel generator. Rural households are still underserved by off-grid technologies: only 7.5% of these households use solar lighting systems. The use of other off-grid technologies such as an SHS, local mini-grid, or rechargeable batteries remains limited in rural areas, at between 0.3% and 1.4%.

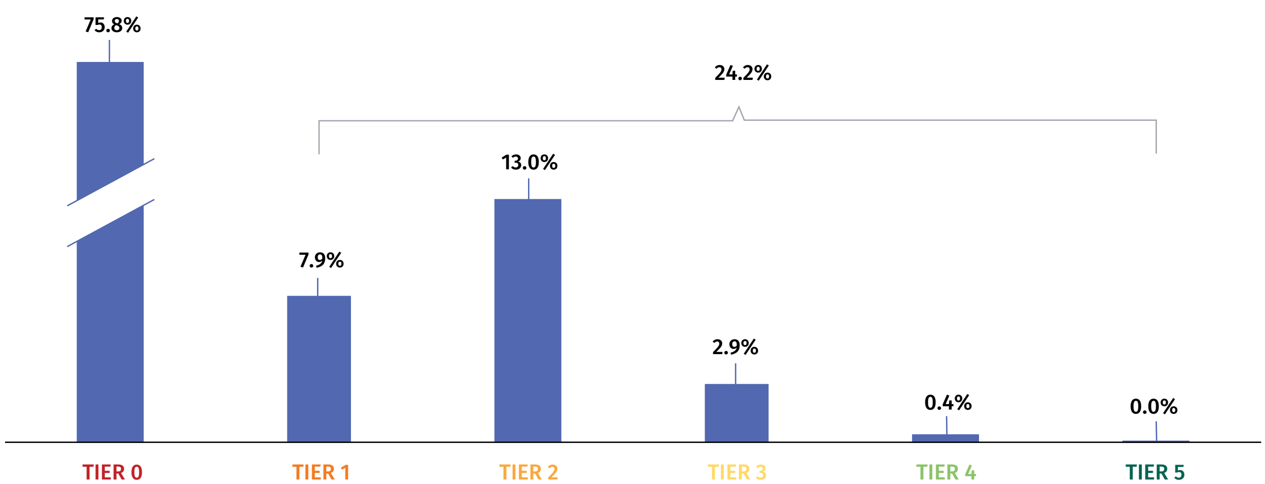
FIGURE 3 • **Access to electricity by technology (Urban, Rural)**



MTF TIERS

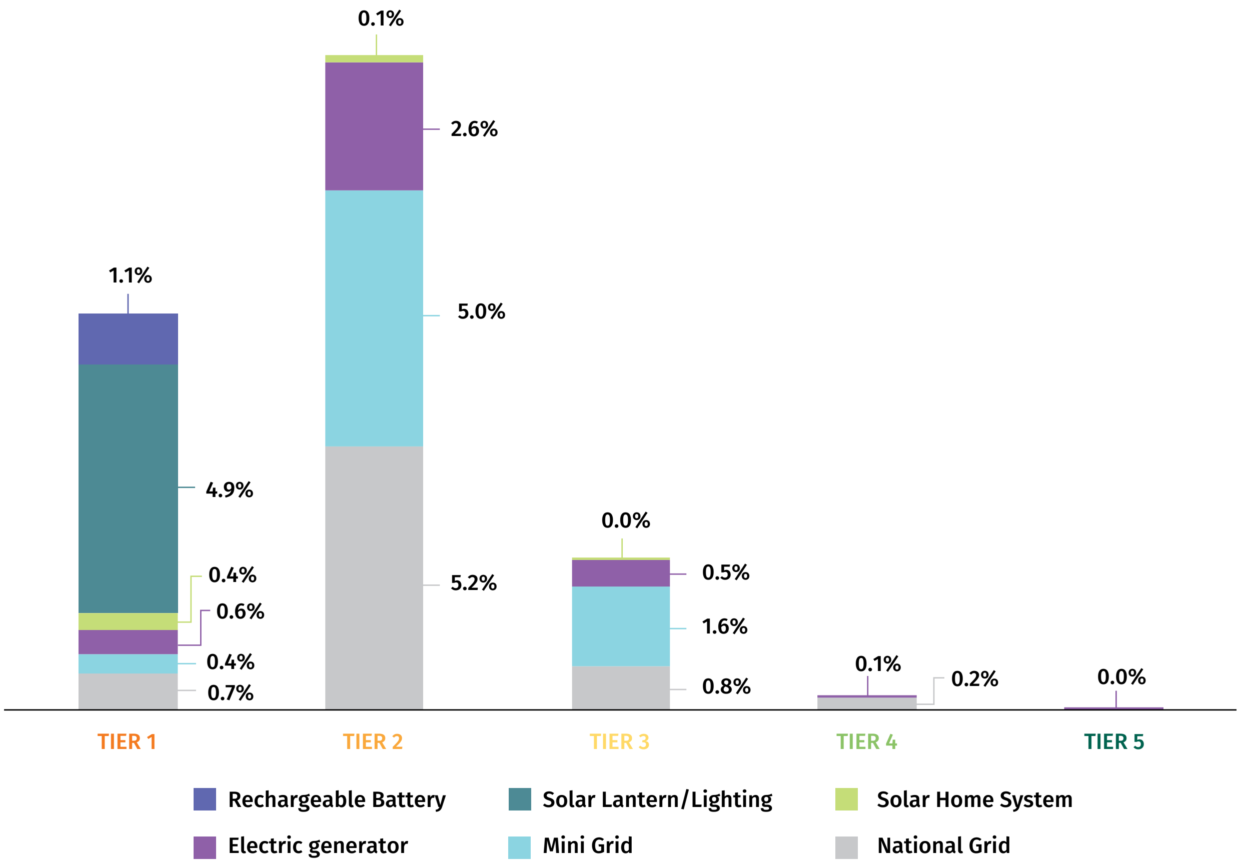
With a large proportion of the population without access to any source of electricity, 75.8% of households are in Tier 0. Tiers 1 and 2 have 7.9% and 13% of households, respectively (Figure 4). Tier 3 has almost 3% of households while less than 1 percent are in Tier 4 and none of the households reach the Tier 5 level of access.

FIGURE 4 • **MTF Tier distribution for electricity access (Nationwide)**



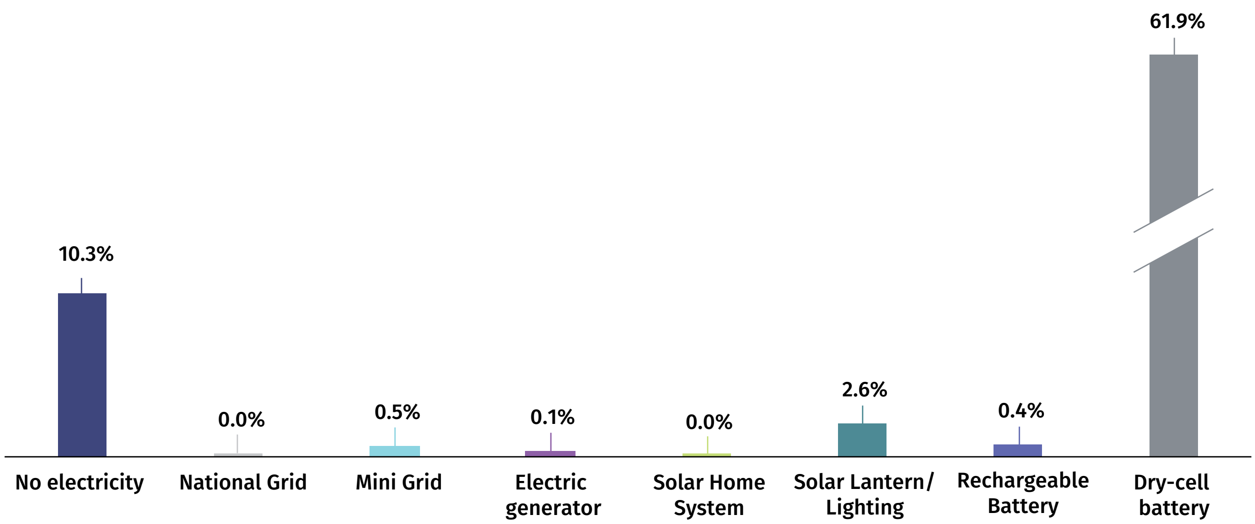
The tier distribution (excluding Tier 0), based on the main source of electricity, shows that households connected to the national grid, local mini-grid, and diesel generators might reach the higher tiers of electricity access but are mostly concentrated in Tier 2 (Figure 5). Households using solar devices or a rechargeable battery remain in Tier 1.

FIGURE 5 • **MTF Tier distribution by main source of electricity (excluding Tier 0) (Nationwide)**



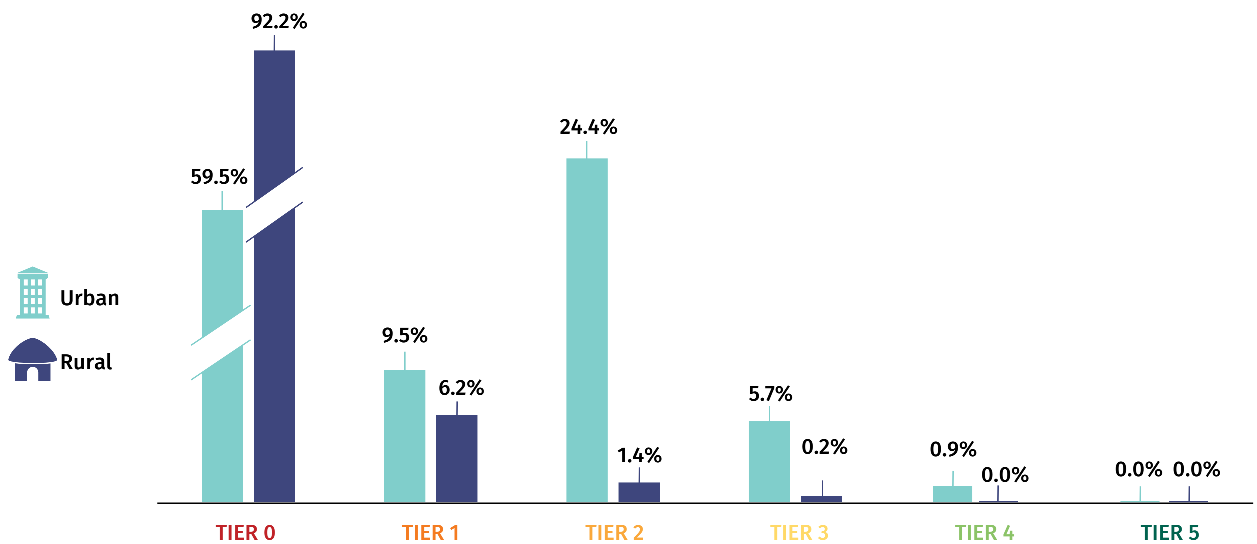
As a majority of households in Liberia (72.2%) are in Tier 0, Figure 6 shows the distribution across the different sources used by these households. Across Liberia, 10.3% of households do not have any source of electricity, whereas 61.9% of the households rely on dry-cell batteries to meet their lighting needs. Around 4% of households have different forms of electricity but they do not provide sufficient capacity for a substantial duration (less than 4 hours per day). Thus, these households are in Tier 0.

FIGURE 6 • **Tier 0 disaggregated by main source of electricity (Nationwide)**



Electricity access is a challenge for both urban and rural households as the country remains largely disconnected from the grid and the use of off-grid technologies remains limited. Rural households are the most affected, since most are in Tiers 0 or 1 (Figure 7): 92.2% of rural households are in Tier 0 compared with 59.5% of urban households. Urban households have access at Tiers 1 to 4, while 6.2% of rural households reach only Tier 1.

FIGURE 7 • **MTF Tier distribution for electricity access (Urban, Rural)**



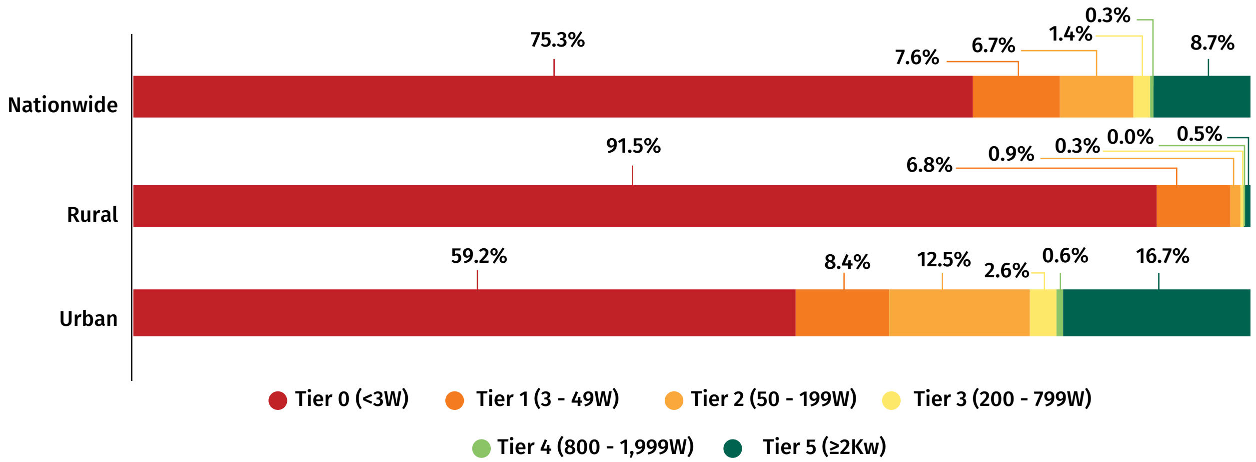
MTF ATTRIBUTES

With only 27.8% of households in Liberia having some source of electricity, this section delves into the access attributes of households powered by the grid or off-grid sources.

Capacity

Of those households having access to electricity, the majority, in both rural and urban areas, have electricity capacity levels that are less than 3 W (91.5% and 59.2%, respectively) as they use very low-capacity solutions such as dry-cell batteries and solar lighting systems (Figure 8). The rest of the households fall in Tiers 1 and 2 for the Capacity attribute, with rural areas having a smaller share of households with capacity less than 50 W compared with urban areas. Of the 8.7% of households with capacity greater than 2,000 W, most are connected to the national grid or the local mini-grid. These two sources of electricity support greater capacity.

FIGURE 8 • **Distribution of households based on Capacity (Nationwide, Urban/Rural)**



Availability

The availability of electricity supply is limited for the majority of Liberian households, both during the crucial evening hours between 6 pm and 10 pm as well as across the entire 24-hour period. About 15% of households have 23 or more hours of electricity in a day, mostly in urban areas (Figure 9). However, more than half of households overall have between 8 to 16 hours of electricity, both in urban and rural areas. Lack of availability is more acute in rural areas, where 30% of households have 4 to 8 hours and 10.2% have less than 4 hours of electricity during the day.

In the evening time, between 6 and 10 pm, over 50% of households, across urban and rural areas, have 4 hours of electricity. One-third have only 2 to 3 hours of electricity (Figure 10). About 13% nationwide, 10.2% in rural areas, and 14.6% in urban areas have electricity for 3 to 4 hours each evening.

FIGURE 9 • **Distribution of households based on Daily Availability (over a 24-hour day) (Nationwide, Urban/Rural)**

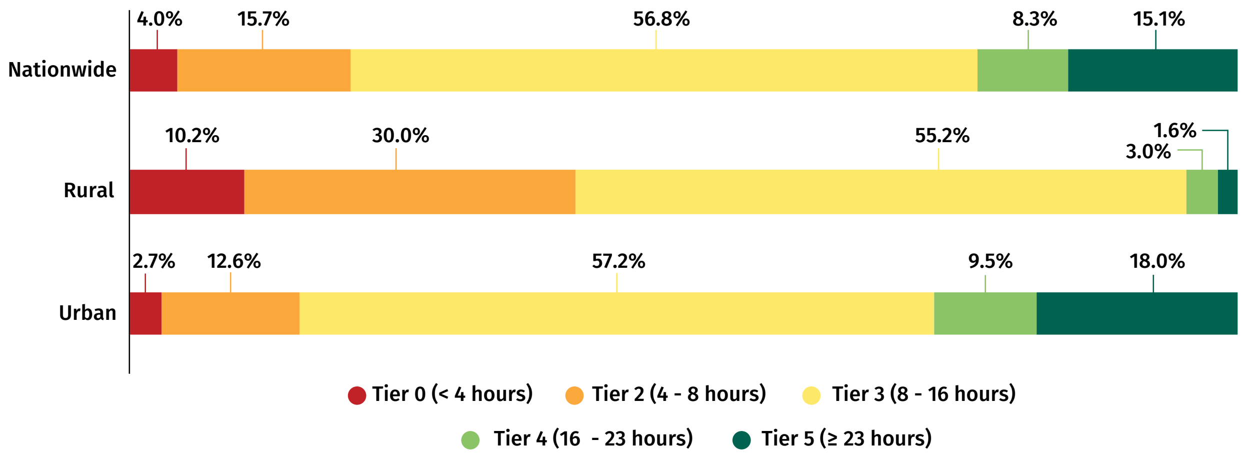
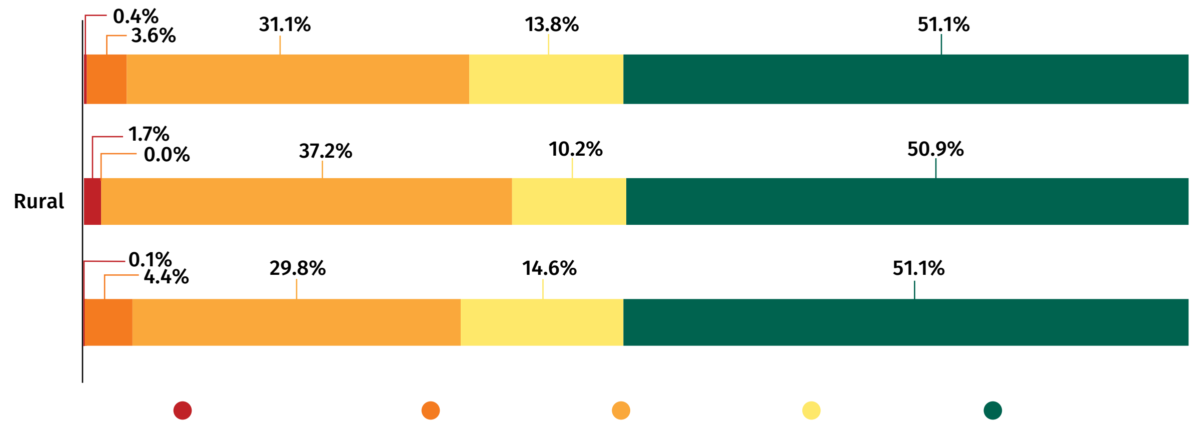


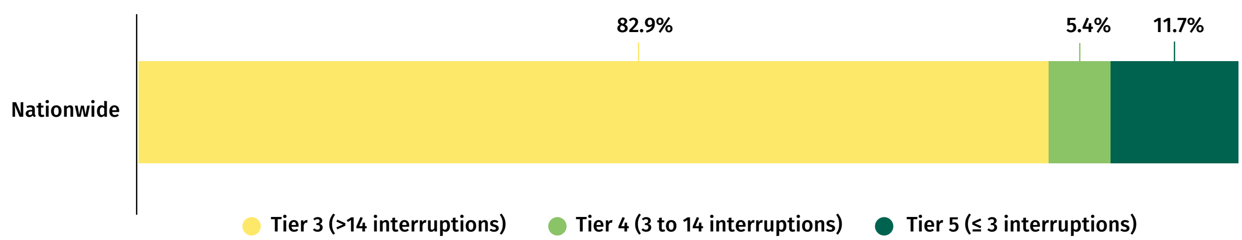
FIGURE 10 • **Distribution of households based on Evening Availability (between 6-10pm) (Nationwide, Urban/Rural)**



Reliability

In Liberia, 82.9% of households face frequent, unpredictable power outages, that is, more than 14 interruptions in a week (Figure 11). About 5.4% of households have between 3 to 14 interruptions or interruptions of more than 2 hours. Finally, 11.7% of the households have reliable electricity, equivalent to less than 3 interruptions a week with durations of less than 2 hours.

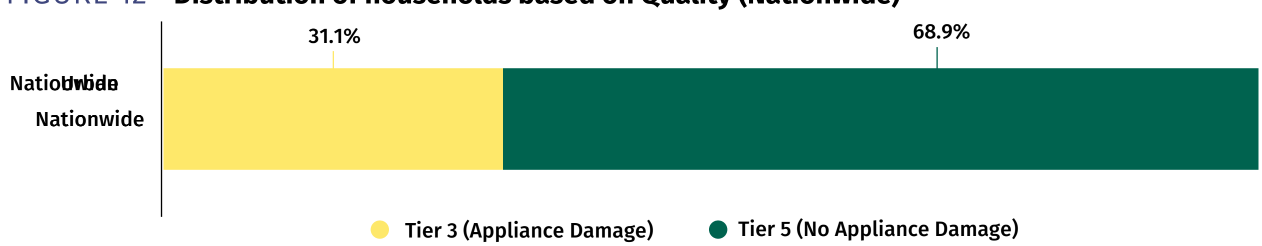
FIGURE 11 • **Distribution of households based on Reliability (Nationwide)**



Quality

In Liberia 31.1% of households face voltage issues—such as low or fluctuating services (Figure 12). Electric appliances generally require a certain voltage to operate properly, and voltage fluctuations and surges can damage electrical appliances and sometimes result in electrical fires. Low voltage is the result of an overloaded electricity system or long-distance low-tension cables connecting dispersed households to a singular grid.

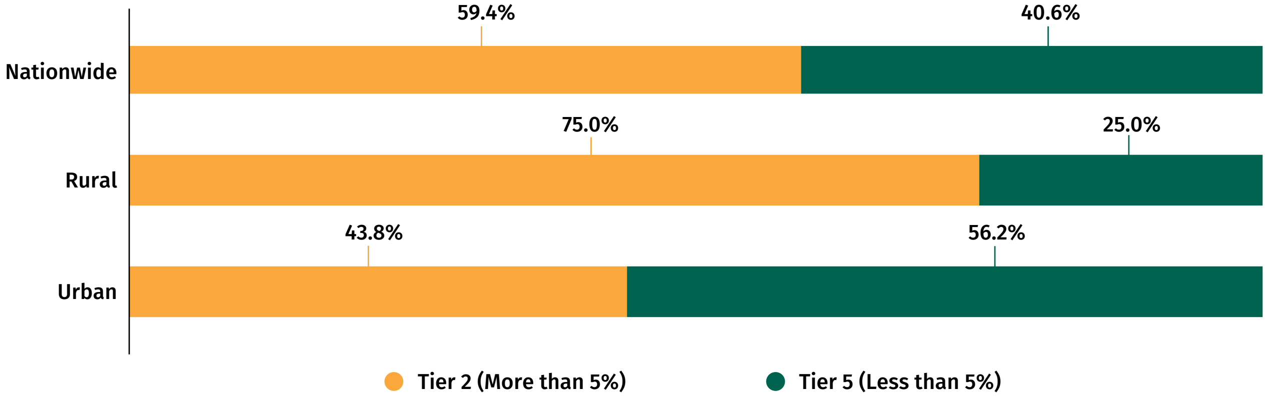
FIGURE 12 • **Distribution of households based on Quality (Nationwide)**



Affordability

The Affordability attribute is assessed for the entire population, to understand whether connecting to the grid is affordable, both for those who are already connected and those who are not. In Liberia, 59.4% of households cannot afford electricity, mainly due to the high tariffs (Figure 13). For 75% of rural households and 43.8% of urban households, the cost of a standard consumption package (365 kWh a year) would be more than 5% of their household expenditure. Affordability also manifests itself as a constraint in electricity consumption.

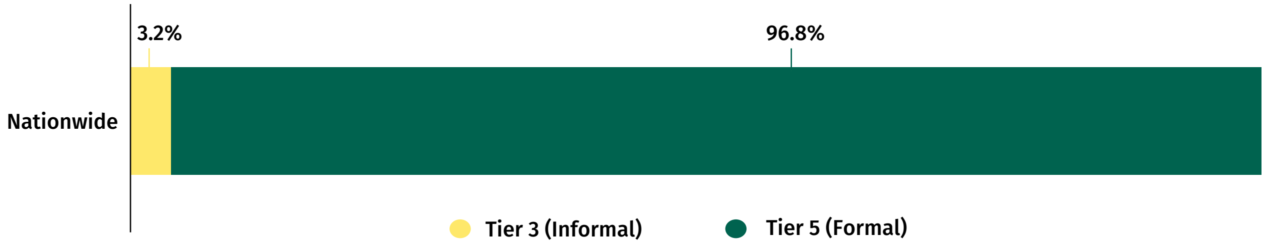
FIGURE 13 • **Distribution of households based on Affordability (Nationwide, Urban/Rural)**



Formality

Estimating the percentage of informal connections to the grid is challenging, since households may be sensitive about disclosing such information. The MTF survey therefore infers information on formality from indirect questions that respondents may be willing to answer (e.g., how does the household pay its electricity bill?—a response indicating non-payment would imply informality). Based on this method, only 3.2% of grid-connected households were identified as having an informal connection (Figure 14). Of course, the actual percentage may differ from this estimate.

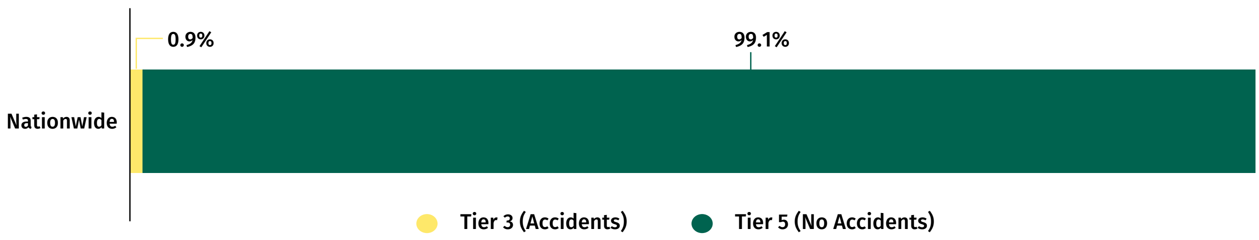
FIGURE 14 • **Distribution of households based on Formality (Nationwide)**



Health and Safety

Although only 1 percent of households reported permanent limb damage or death caused by electrocution (Figure 15), all households should be made aware of basic safety measures and ensure that wiring is installed according to national standards to prevent accidents when operating electricity under both normal and fault conditions.

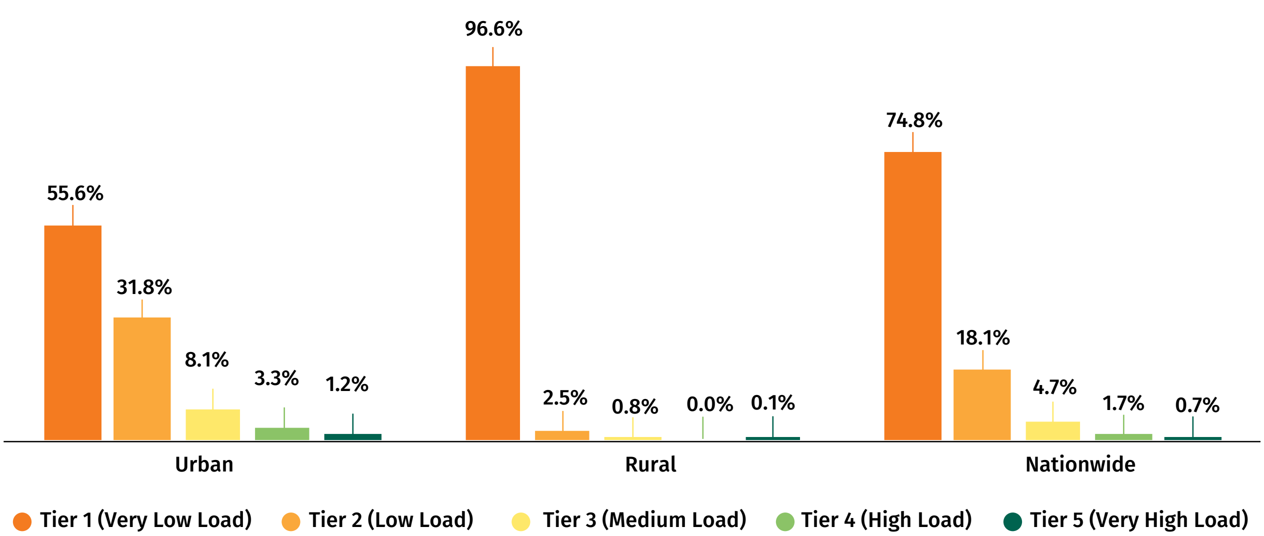
FIGURE 15 • **Distribution of households based on Health and Safety (Nationwide)**



USES

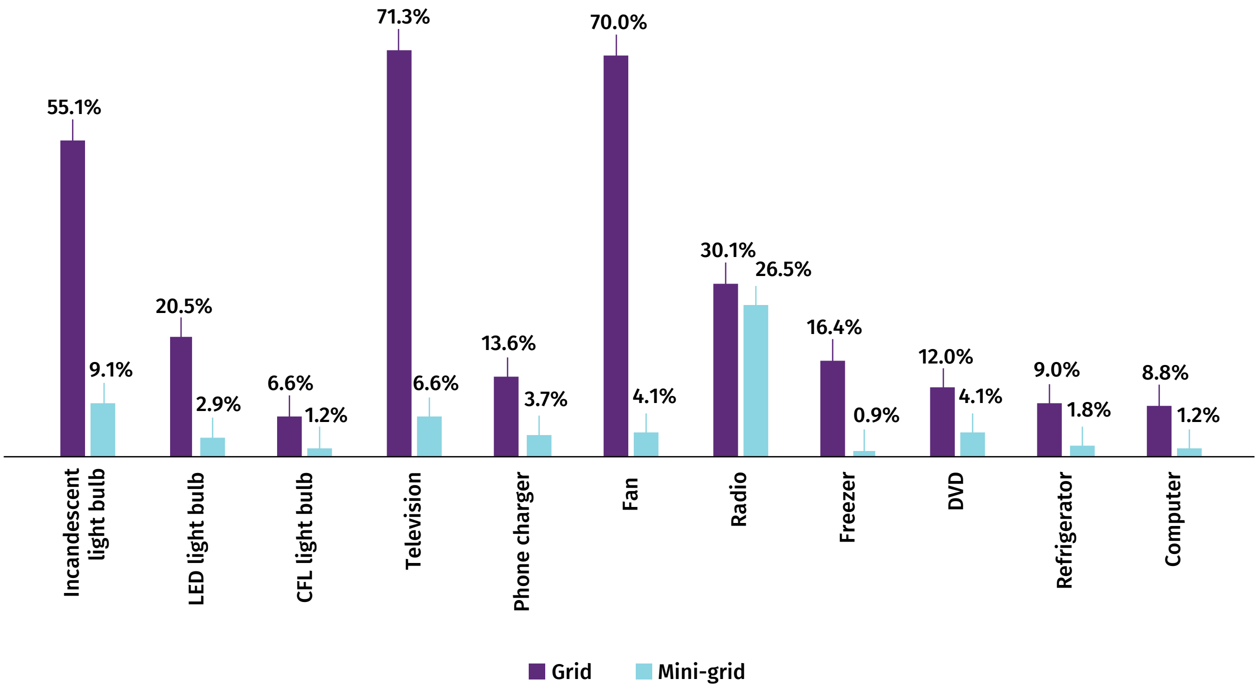
In Liberia, 74.8% of households with grid access use very-low-load appliances, such as light bulbs and mobile phone chargers (Figure 16), which are the most commonly owned appliances in rural areas. In urban areas, 31.8% of households have higher-load appliances, such as televisions, but a higher tier of electricity access is still unachievable for most due to a lack of grid infrastructure. Of urban grid-connected households, 55.6% and 31.8% use only very-low- or low-load appliances, respectively.

FIGURE 16 • **Distribution of households based on Appliance Load Level (Nationwide, Urban/Rural)**



Households connected to the national grid or a mini-grid use electricity most commonly for basic lighting, televisions, and fans (Figure 17). A larger share of grid users have higher-load appliances such as DVD players, refrigerators, and computers.

FIGURE 17 • **List of appliances for grid and mini-grid users (Nationwide)**



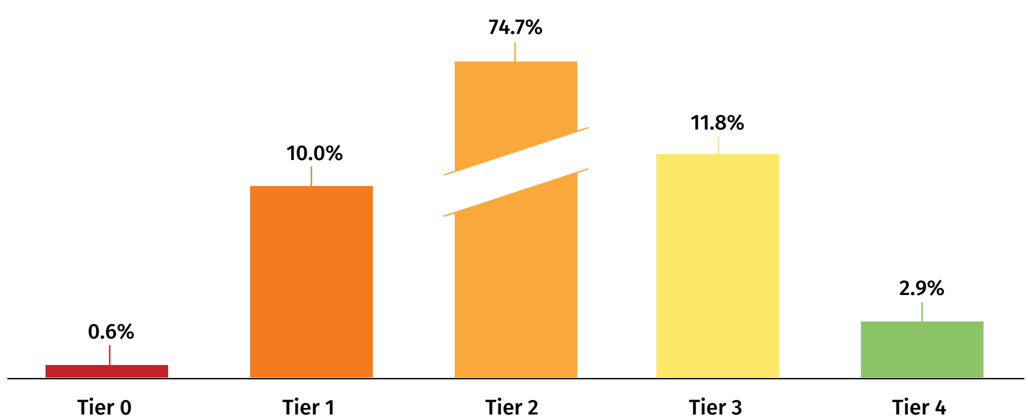
Note: CFL = compact fluorescent lamp; DVD = digital video disc; LED = light-emitting diode.

IMPROVING ACCESS TO ELECTRICITY

IMPROVING ELECTRICITY ACCESS FOR GRID-CONNECTED HOUSEHOLDS

Most grid-connected households are in the Greater Monrovia area, where grid connections have been extended to reach consumers. Households with electricity from the national grid are in Tiers 1 to 4, with the majority of households being in Tier 2. Although nearly 7% of households have access to the national grid, none have reached Tier 5 (Figure 18) due to issues with the Availability, Reliability, and Affordability of electricity supply.

FIGURE 18 • **MTF Tier distribution of grid-connected households (Nationwide)**



Though availability is problematic for households during daylight hours, it is especially so in the evening, when electricity is needed most. During a 24-hour period, 34.4% of households have 8–16 hours of electricity (Figure 19). About 70% of households receive less than 3 hours of electricity between 6 pm and 10 pm (Figure 20).

FIGURE 19 • **Distribution of grid-connected households by Daily Availability (over a 24-hour day) (Nationwide)**

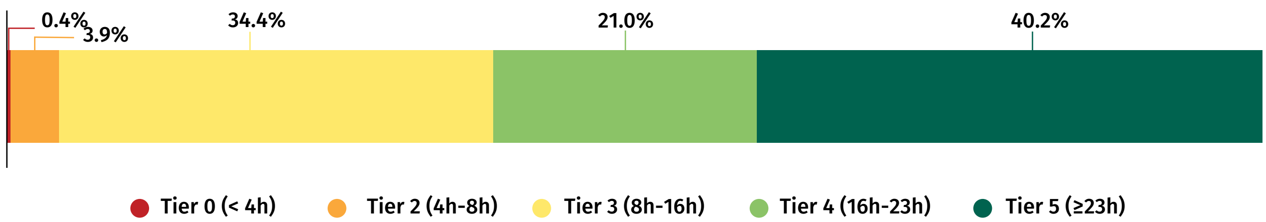
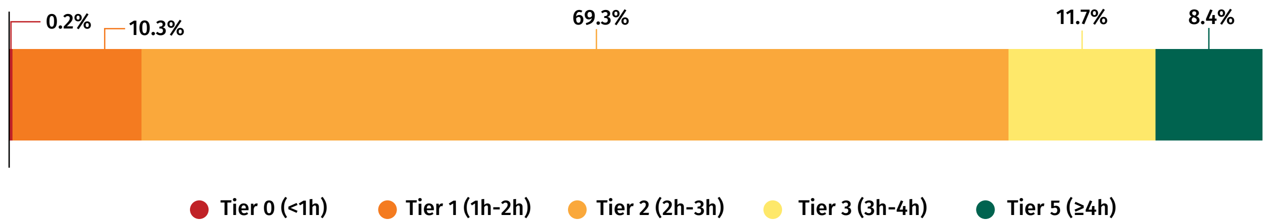
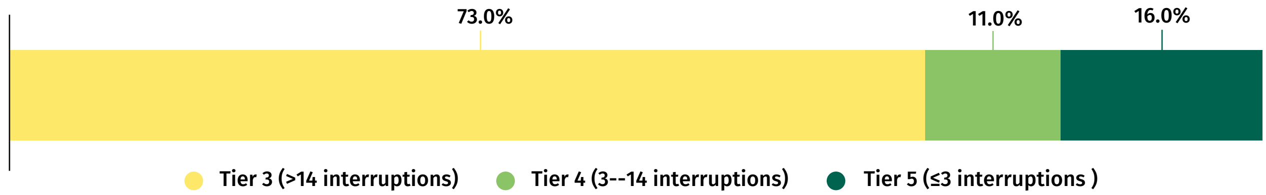


FIGURE 20 • **Distribution of grid-connected households by Evening Availability (between 6-10pm) (Nationwide)**



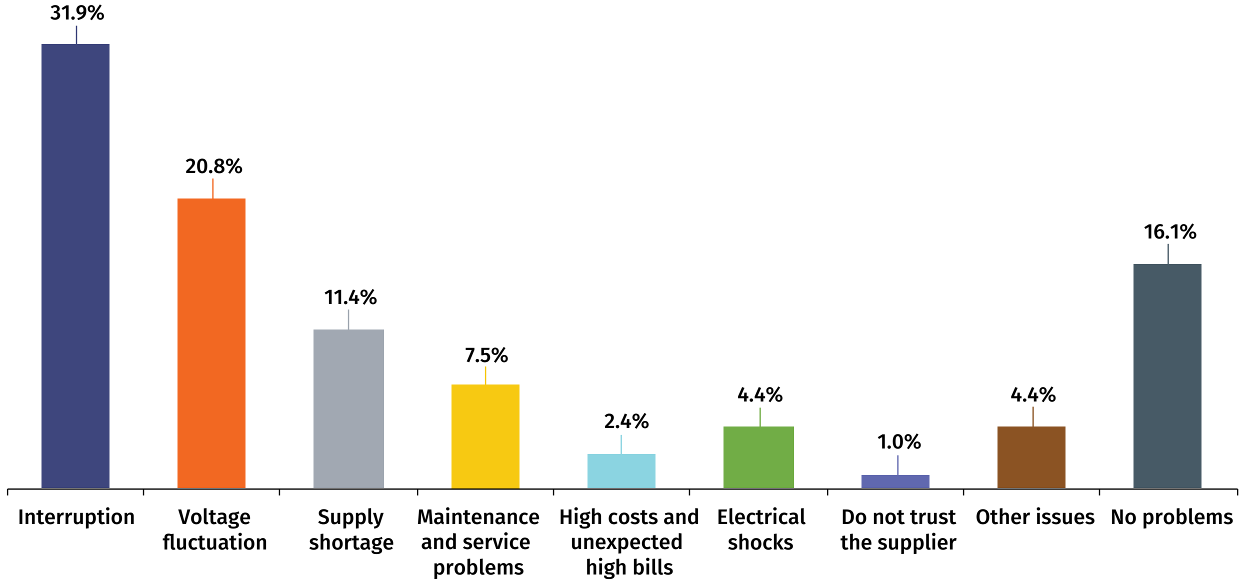
Reliability is a serious issue affecting 73% of households connected to the grid (Figure 21). These face severe disruptions in their electricity supply amounting to more than 14 interruptions a week with a total duration of more than 2 hours on average. Meanwhile, 16% of households report at most than 3 interruptions a week in their electricity service.

FIGURE 21 • **Distribution of grid-connected households based on Reliability (Nationwide)**



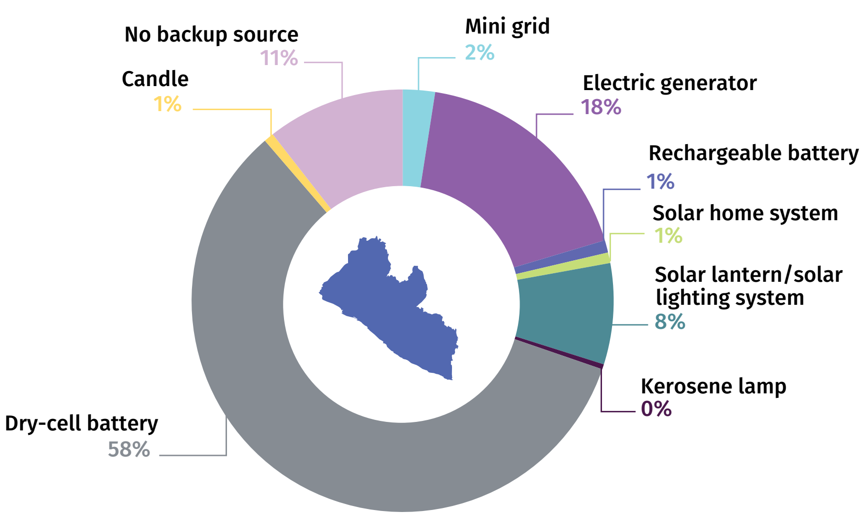
The most common service issues reported by grid-connected households were interruptions, voltage fluctuations, and supply shortages (Figure 22), which correspond to the attributes that lower the tier level for grid users. Only 16.1% of grid-connected households reported having no issues with the grid service. Meanwhile, even in the face of high tariffs—US$0.55/kWh in 2017 and US$0.33/kWh in 2020—only 2.4% of households reported having a problem with the cost of electricity. The utility, Liberia Electricity Corporation, reported high system losses, mostly due to people not paying for the electricity consumed. In 2017, stricter measures were put into place to deter electricity theft.

FIGURE 22 • **Main issues cited, related to grid electricity supply (Nationwide)**



To cope with power outages and interruptions, 18% of households use a diesel generator and 2% use a mini-grid as their backup source of lighting (Figure 23). However, 58% of households rely on dry-cell batteries for backup energy for lighting and 9% have a solar device.

FIGURE 23 • **Distribution of grid-connected households based on backup energy source (Nationwide)**



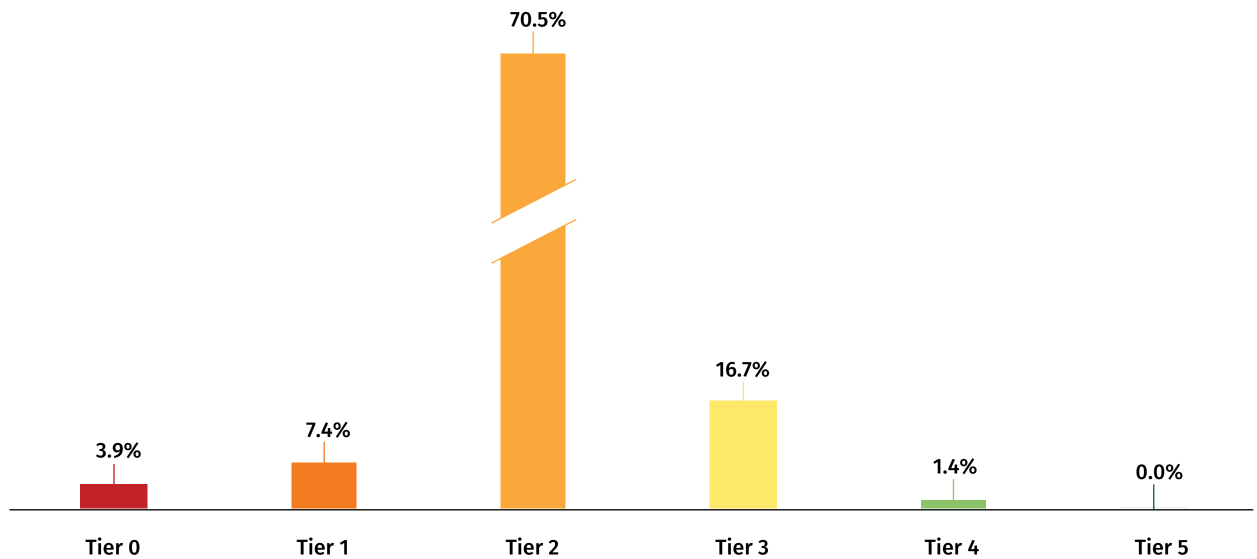
IMPROVING ELECTRICITY ACCESS FOR HOUSEHOLDS THAT USE OFF-GRID SOURCES

More households in Liberia are connected to off-grid sources than to the national grid, particularly in urban areas. In urban areas, diesel generators, local mini-grids, and solar devices are common. The proportion of solar device users is similar in both urban and rural areas. In rural areas, most households use a solar device, diesel generator, or rechargeable battery.

Improving access for mini-grid households

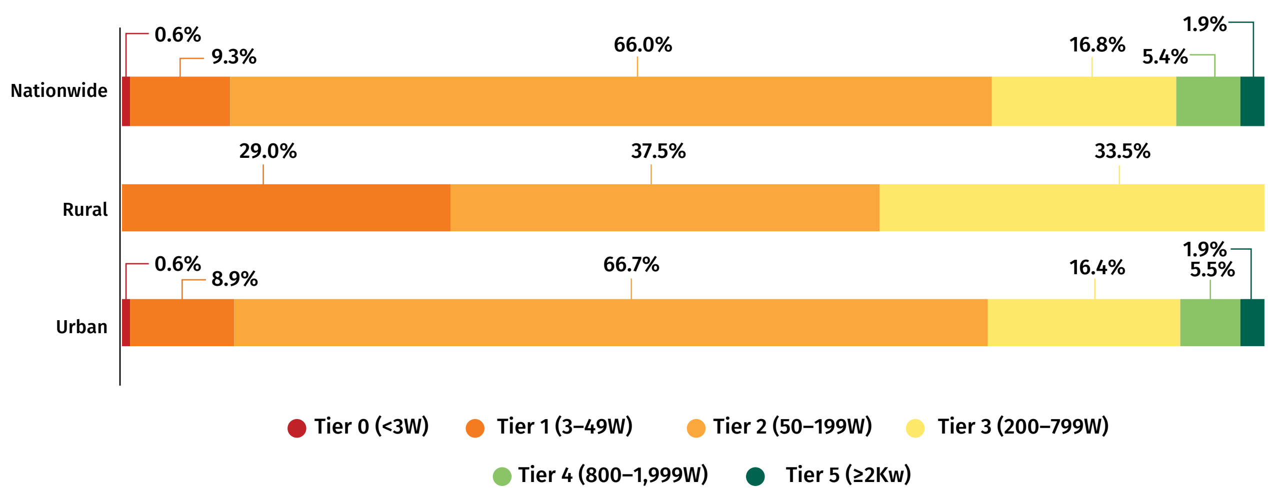
Most households connected to the local mini-grid are in Tier 2, with 16.7% reaching Tier 3 (Figure 24). The most significant factor that keeps mini-grid users in the lower tiers of access is the Capacity of the mini-grid system. Also, and as with households connected to the national grid, the Availability, Reliability, and Quality of supply are key obstacles.

FIGURE 24 • **MTF Tier distribution of mini grid-connected households (Nationwide)**



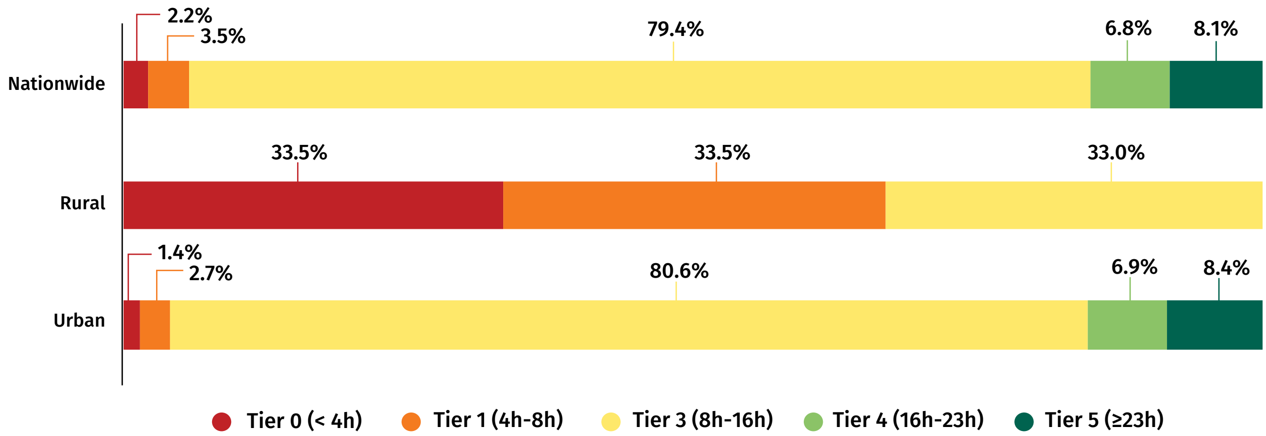
Mini-grid users are constrained by the overall capacity of the system, which can vary depending on the size, number of households connected to it, restrictions imposed by the operators, or the appliances that are powered by it (Figure 25). A majority of mini-grid households are in Tier 2 or 3 for Capacity, with less than 2% reaching Tier 5.

FIGURE 25 • **Distribution of mini grid-connected households based on Capacity (Nationwide, Urban/Rural)**



While nearly 75% of mini-grid users have electricity between 6 pm and 10 pm; the rest have less than 4 hours of electricity during these crucial evening hours. However, about 80% of these households have between 8 and 16 hours of electricity throughout the day (Figure 26).

FIGURE 26 • **Distribution of mini grid-connected households based on Daily Availability (over a 24-hour day) (Nationwide, Urban/Rural)**



The reliability and quality of electricity supply from the mini-grid affect a majority of households, preventing them from advancing to a higher tier. While 31.2% of mini-grid users experience less than 3 interruptions in their electricity supply, 66.6% of households experience between 3 and 14 interruptions each week, lasting more than 2 hours on average (Figure 27). About 56% of households face damages due to voltage fluctuations (Figure 28). To improve levels of access, the quality of service needs to be improved.

FIGURE 27 • **Distribution of mini grid-connected households based on Reliability (Nationwide, Urban/Rural)**

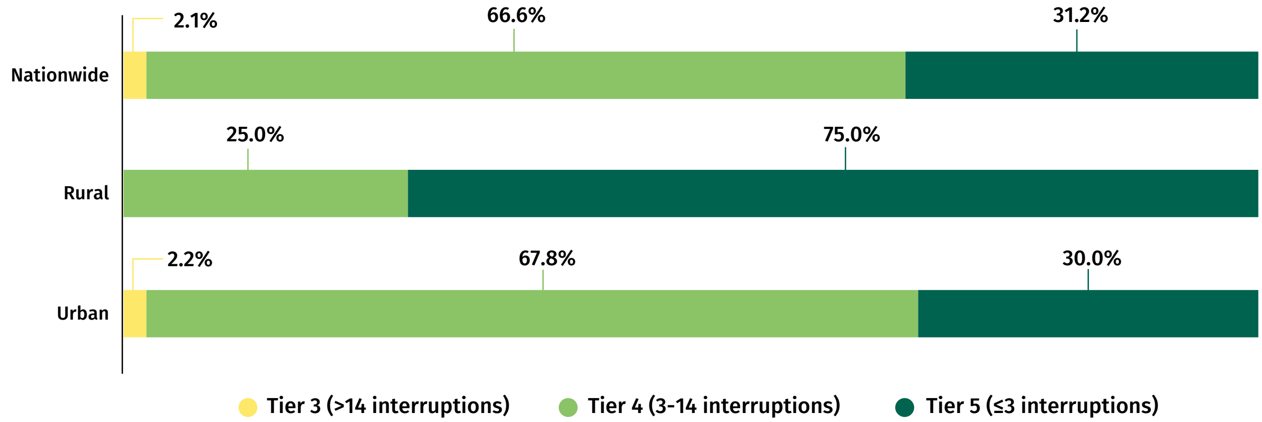
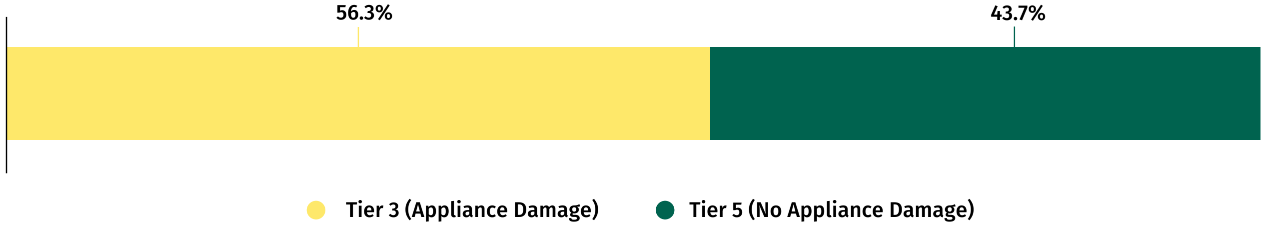


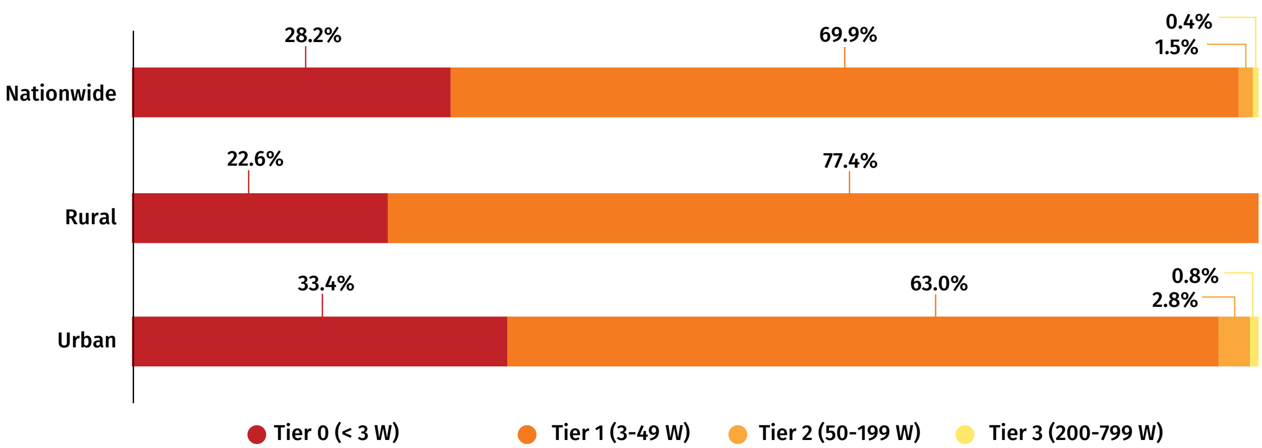
FIGURE 28 • **Distribution of mini grid-connected households based on Quality (Nationwide)**



Improving access for solar users

Households that use solar devices for lighting are mostly limited to Tier 1, with about one-third falling into Tier 0. This is mainly due to the capacity of their solar device, which may be unable to power more than 3 W (Figure 29), or may provide electricity or lighting for just a few hours and not the entire day.

FIGURE 29 • **Distribution of solar user households based on Capacity (Nationwide, Urban/Rural)**



About half of households who use a solar device have sufficient electricity in the evening hours between 6 pm and 10 pm; however, a majority (67.1% of solar users nationwide) have between 8 and 16 hours of electricity through the day, which is insufficient to meet their lighting needs (Figures 30 and 31).

FIGURE 30 • **Distribution of solar user households based on Daily Availability (over a 24-hour day) (Nationwide, Urban/Rural)**

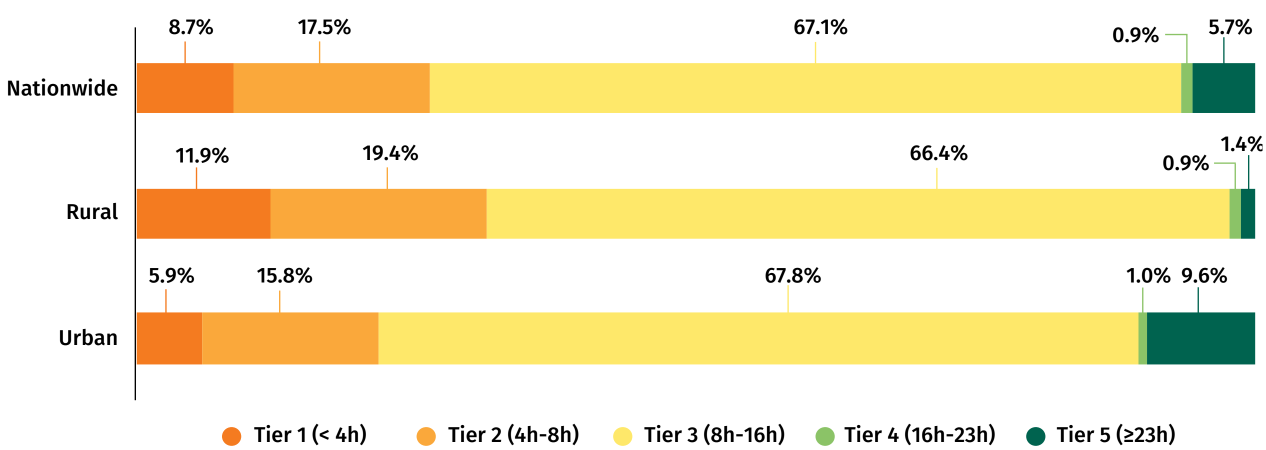
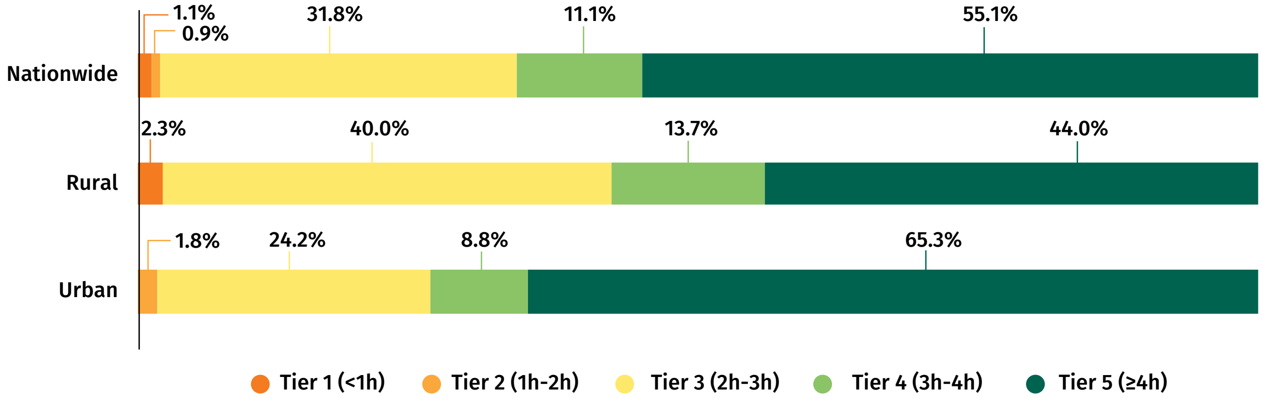
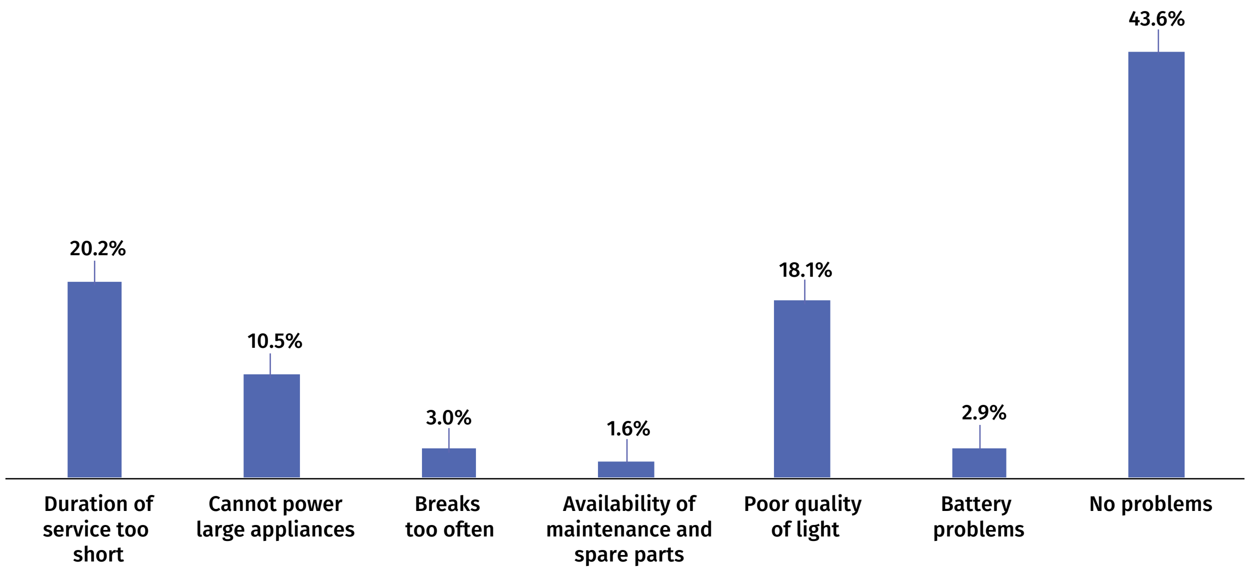


FIGURE 31 • **Distribution of solar user households based on evening Availability (between 6-10pm) (Nationwide, Urban/Rural)**



When asked about the main issues they face with their solar devices, the most common challenges reported by households were the duration of service, poor quality of light, and limitations in capacity (Figure 32). These perceptions reflect on the quality of service of solar devices.

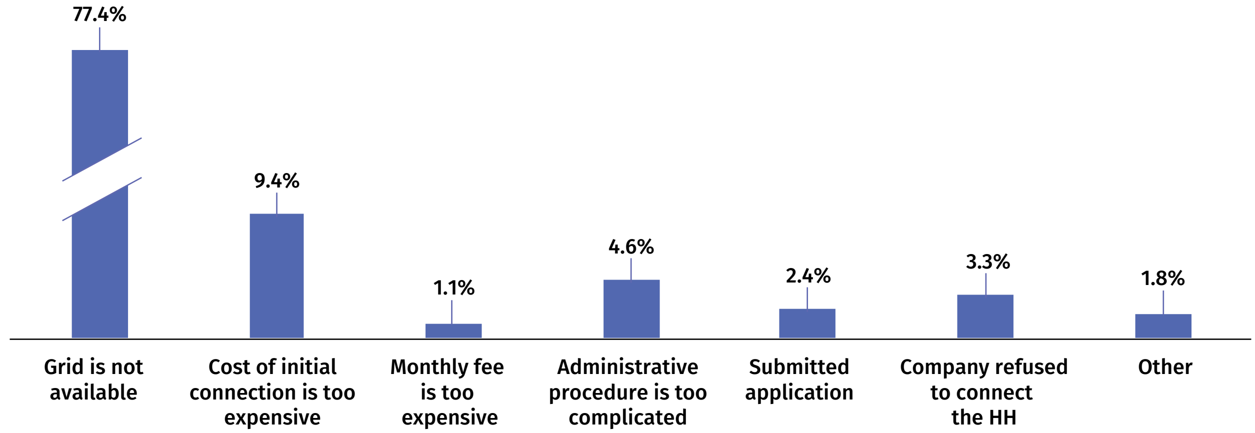
FIGURE 32 • **Main issues cited, related to solar device (Nationwide)**



PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

To move to a higher tier, 75.8% of households in Tier 0 and 61.9% that use only dry-cell batteries would need to be connected to the grid or to off-grid solutions (Figure 4). To do this, barriers that prevent these households from gaining connectivity will need to be addressed. For example, unavailability of a grid network is the main reason 77.4% of Liberian households are not connected to the grid. In Greater Monrovia, the capital, this is an issue for 39.1% of households, with the cost of the initial connection (9.4%) and complicated administrative procedures (4.6%) being others (Figure 33).

FIGURE 33 • **Barriers to gaining access to grid electricity (Nationwide)**



Note: HH = household.

Most households without access to the grid appear willing to pay for access to electricity up front or with some flexibility in payment (Figure 34); for example, 58.1% of unconnected households reported a willingness to pay (WTP) the maximum amount (US$54) up front for a grid connection. The share of households that reported that they would never pay for grid access is the highest at 15.3% when the price is US$7.56 and between 2.5%- 7.9% for the other price points. The high up-front costs are an obstacle for a majority of households, along with high tariff rates. The main constraint to WTP for a grid connection is the issue of affordability for both the wiring required and the monthly fee (Figure 35). Households need flexibility in both the payment mechanism as well as the time frame of payment; solutions like paying in installments could thus support better access.

FIGURE 34 • **Willingness to pay for the grid connection fee for non-grid-connected households, by alternative connection fee prices (Nationwide)**

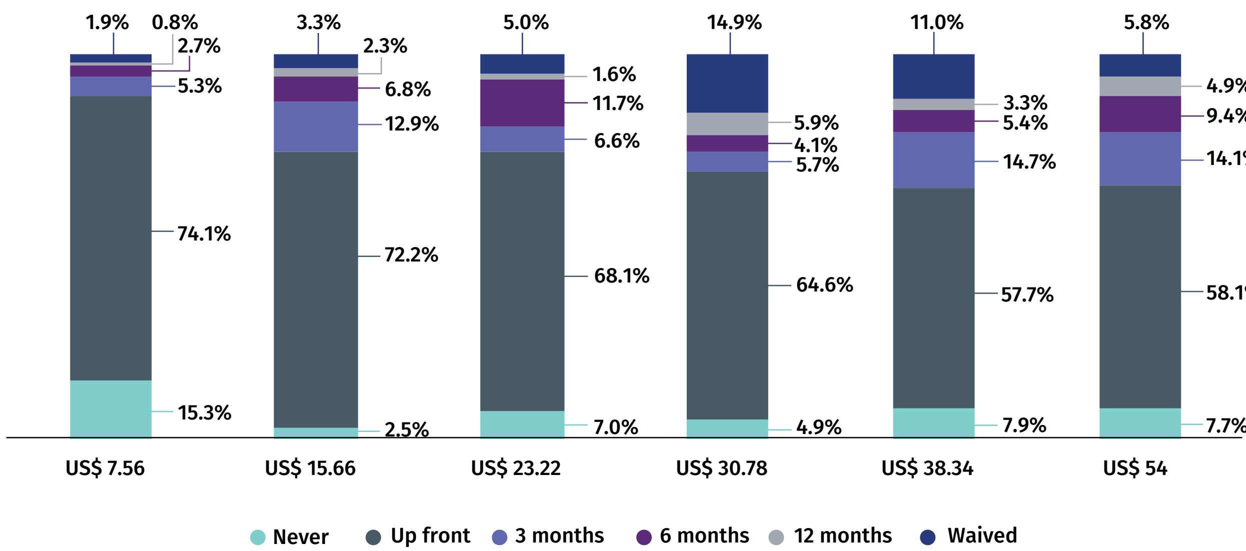
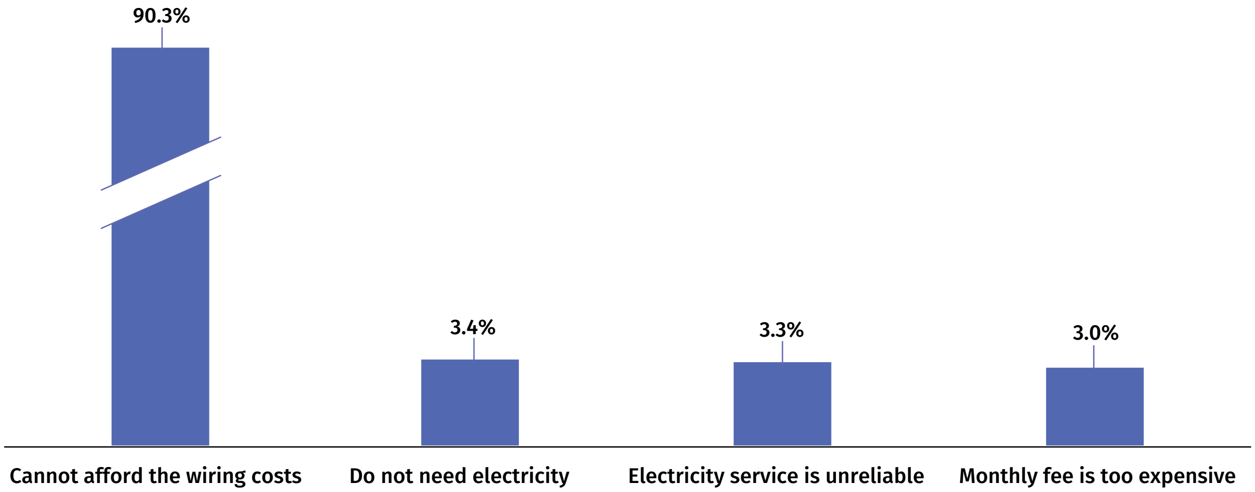


FIGURE 35 • **Reason for being unwilling to pay for grid connection (Nationwide)**



These results show that a lack of grid infrastructure and unaffordable costs are the main barriers for households with no electricity to access services.

The WTP for a solar home system is much lower than the WTP for a connection to the grid. The only price point at which a majority of households were willing to purchase a system was the lowest, US$6.85 (Figure 36). At the highest price point, US$69, 34.5% of households reported that they would never purchase a system. However, offering a payment period did significantly change the responses. At the highest price points, between US$22.77 and US$69, 23.2% to 40.5% are willing to get a system if given a 6- to 12-month payment plan. Affordability is the main issue for 88.3% of these households, while 7.4% claim that maintenance is not available for these devices (Figure 37).

FIGURE 36 • **Willingness to pay for the Solar Home System for non-grid-connected households, by alternative fee prices (Nationwide)**

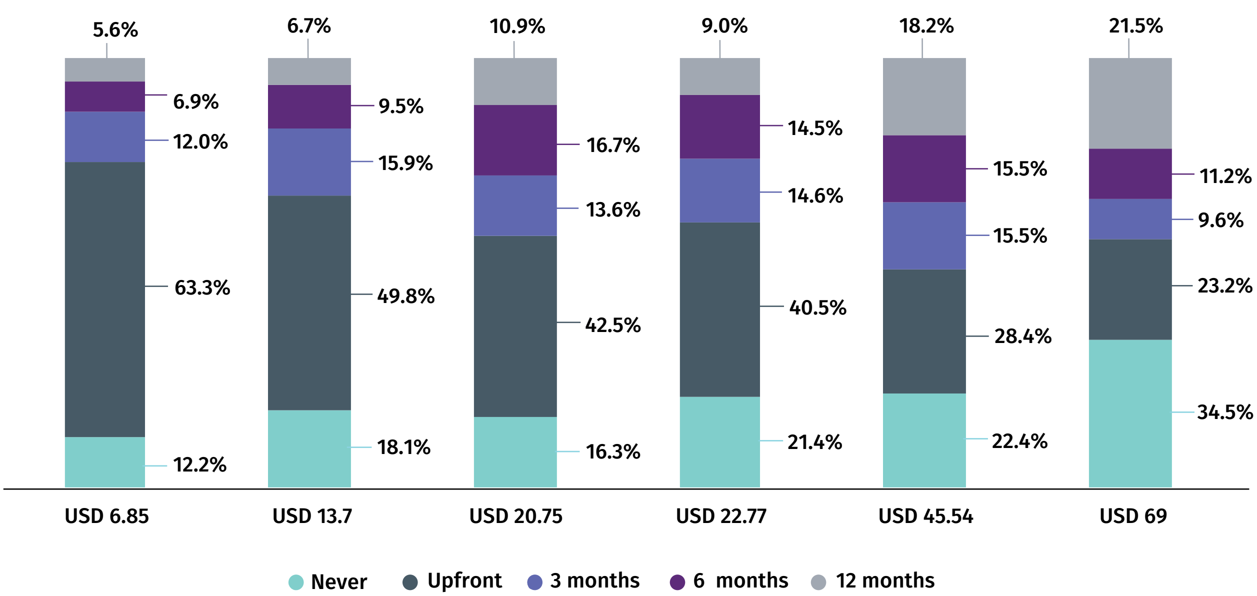
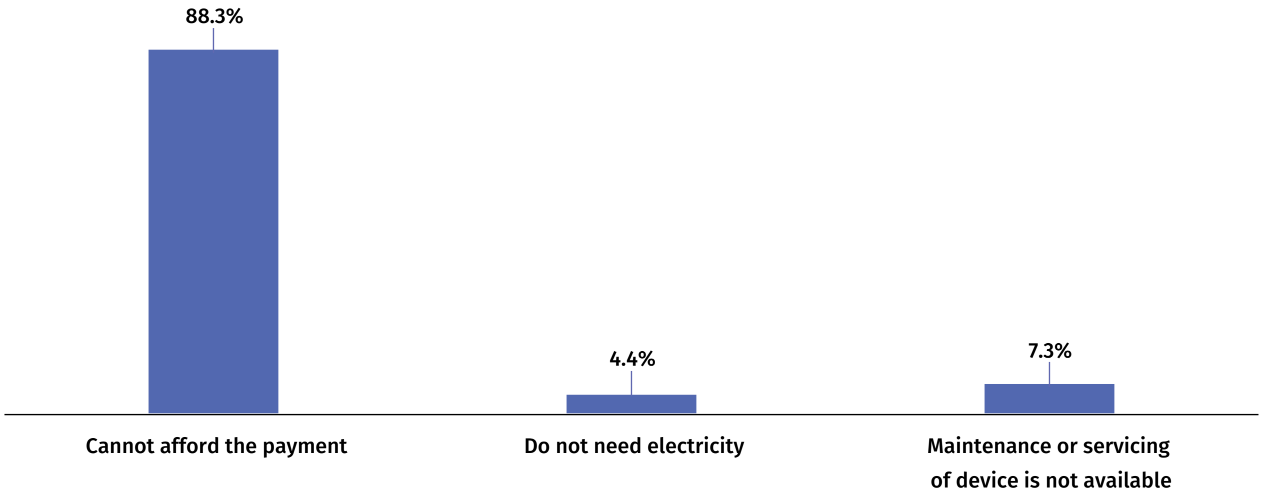


FIGURE 37 • **Reason for being unwilling to pay for solar device (Nationwide)**



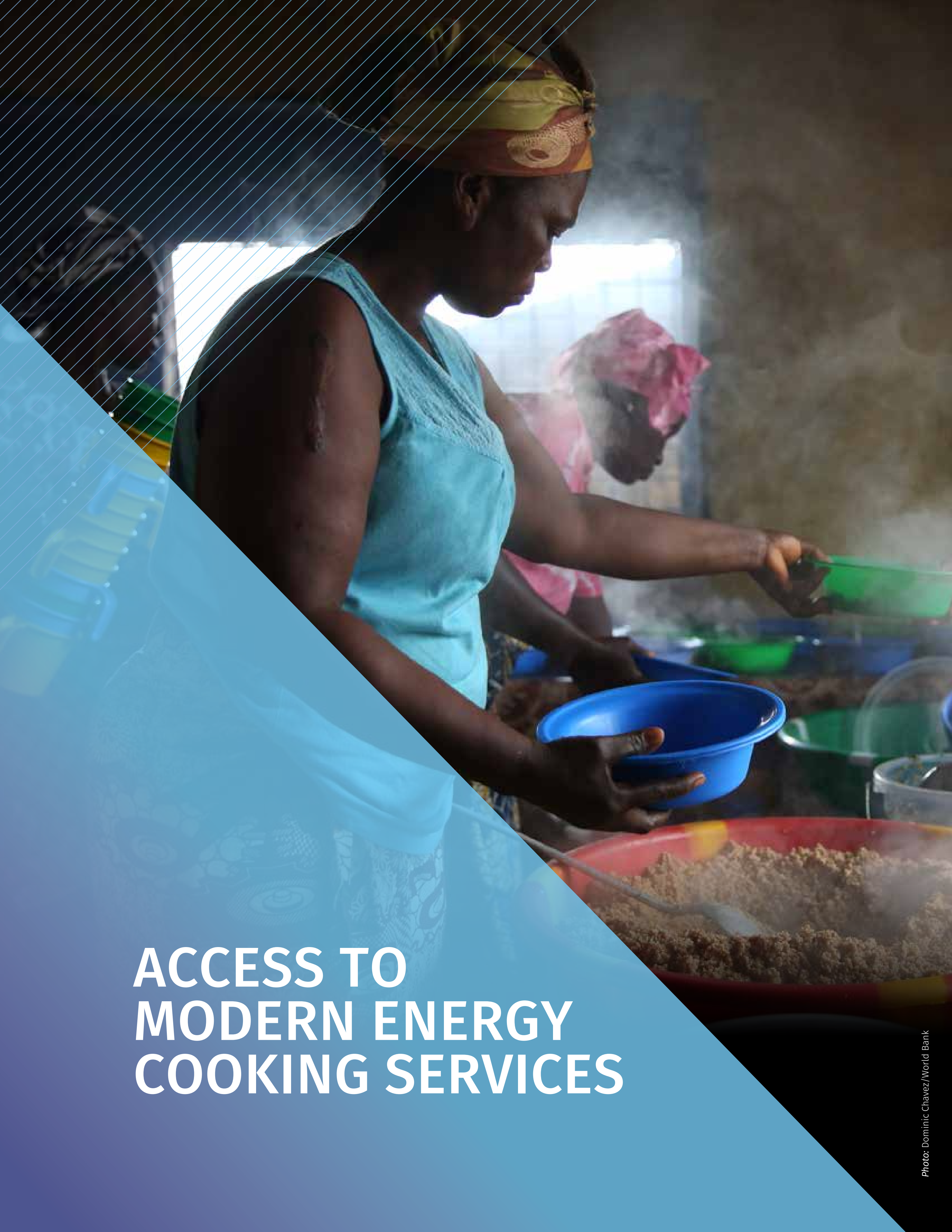
POLICY IMPLICATIONS

With only 24.2% of households across Liberia having some source of electricity, either a connection to the national grid or an off-grid solution, the country still has a long way to go to ensure sustainable, reliable, and affordable energy solutions for all households. The share of households with no access to any source is substantial, at 72.2%, and increases when taking into account the various attributes—75.8% of households across Liberia are in Tier 0. The Government of Liberia and other stakeholders need to take a multipronged approach to improving access to electricity.

A small share of households (6.9%) are connected to the national grid and face multiple challenges with the quality and affordability of services available. The limited extension of the national grid and the high tariff rates (US$0.55 in 2017 and US$0.33 in 2020) are obstacles for households to connect. While affordability is a major barrier, access is further exacerbated by other supply and quality issues. The availability of electricity from the grid is variable, particularly in the evening hours. The government and the Liberia Electricity Corporation should focus on making electricity available between 6 pm and 10 pm, as one extra hour of supply in the evening could shift 70% of households up to a higher tier for availability. Closely linked to the issue of the availability of supply is the reliability of supply, or the number of outages that households experience—73% of the households report that they face more than 14 interruptions in the electricity that is available to them. Coupled with reliability is quality, in terms of the voltage fluctuations in electricity supply. Such fluctuations may damage appliances, adding additional costs and negatively affecting users' experience. Reliability and Quality substantially affect households' level of access during the limited duration in which they receive electricity. Improving transmission and distribution systems can have a positive effect on the quality of service made available to households. Affordability compounds the strain on households—for almost 60% of the households the cost of a standard 365 kWh/year package is more than 5% of their annual expenditure—and are a barrier preventing other households from connecting to the grid.

The share of households connected to off-grid solutions like mini-grids, diesel generators, and solar devices is large. However, these households face similar issues with regard to the Availability, Reliability, and Quality of electricity supply, particularly mini-grid users. Households with a solar device have an additional constraint of capacity since most devices are limited to powering light bulbs and mobile chargers at most. These households are concentrated around Tiers 1 and 2 and to move them higher would require access to the grid or mini-grid, which can provide better electricity services at affordable prices. A majority of mini-grid users have electricity during the evening hours, but about 25% of households still do not get a full 4 hours of supply between 6 pm and 10 pm. Furthermore, electricity supply is limited throughout the day and households also have to deal with outages and severe voltage fluctuations.

Most households across Liberia do not have any source of electricity and tend to rely on dry-cell batteries and torches for lighting. These households were asked whether they would pay the connection fee at either the full price or a subsidized price with the flexibility to pay in installments. Households not connected to the national grid demonstrate a high WTP for a connection up front, with a larger share of households accepting the costs at subsidized prices. Households who are unwilling to pay find the additional costs of internal wiring unaffordable. Though there is a lower acceptance to pay for a solar home system, especially the up-front costs, with flexible payment periods and at subsidized prices, households appear to be more willing to pay for these systems. Thus, efforts need to be made to provide households with affordable and reliable options to gain at least the minimum access and move them up the tiered framework.



ACCESS TO MODERN ENERGY COOKING SERVICES

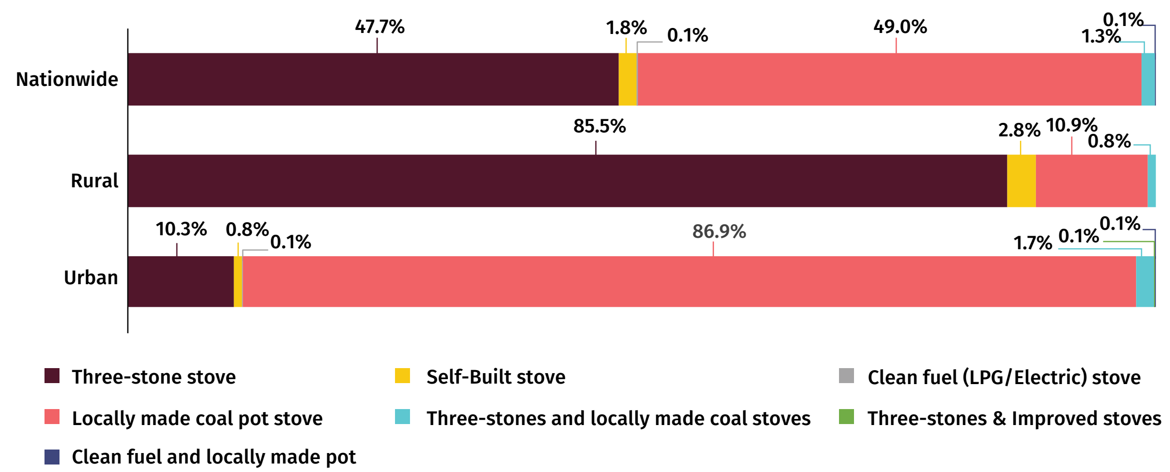
Photo: Dominic Chavez/World Bank

ASSESSING ACCESS TO MODERN ENERGY COOKING SERVICES

TECHNOLOGIES

Nationwide, many households use locally made coal pot stoves (49.1%) and three-stone stoves (47.7%). The use of self-built and clean[6] fuel stoves is extremely low at 1.8% and 0.1%, respectively. There is a disparity between the pattern of stove usage between urban and rural households. Urban households prefer using locally made coal pot stoves (86.9%), with only 10.3% urban households using three-stone stoves. Clean fuel stoves are rarely used in any area; only 0.1% of urban households reported owning a clean fuel stove, while no rural households did so. Rural households most commonly use three-stone stoves (85.5%), locally made coal pot stoves (10.9%), and self-built stoves (2.8%) (Figure 38). Stove stacking (using multiple cookstoves)—which usually reflects households' aspiration to use higher-performing cooking services in parallel to but not instead of long-standing solutions—is not a common practice in Liberia. Moreover, nationwide, only 1.3% of households that use more than two stoves prefer combining three-stone stoves with locally made coal pot stoves (Figure 38). Because the share of households that practice stove stacking is extremely low (0.08%) in Liberia, in the remainder of this report, the word "stoves" will solely refer to primary stoves.

FIGURE 38 • **Stove stacking (Nationwide, Urban/Rural)**



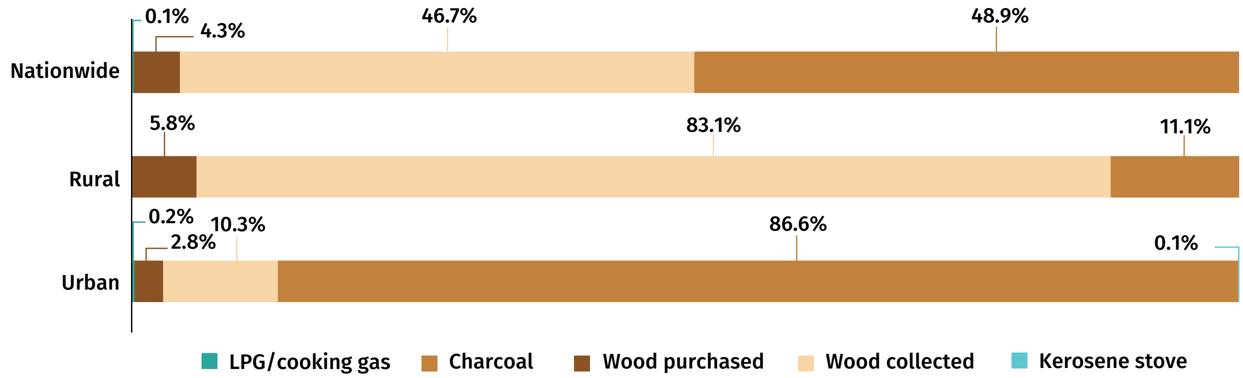
Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

Similar to the stove usage distribution in Liberia, the use of fuel is consistent with stove typology and usage. For instance, nationwide, 48.9%, 46.7%, and 4.3% of households in Liberia use charcoal, collected wood, and purchased wood for cooking, respectively, whereas only 0.1% of households

[6] In this analysis, clean fuel stoves refer to LPG and electric stoves

in Liberia use liquefied petroleum gas (LPG). Fuel usage among urban and rural households is consistent with the type of stove used daily. Thus, 86.6% of urban households use charcoal, 10.3% use collected wood, 2.8% use purchased wood, and 0.2% use LPG. Most urban households prefer to use charcoal in their stoves instead of other fuels because about 87% of them use locally made coal pot stoves. In rural areas, too, fuel usage is consistent with the stoves used: 83.1% of rural households use collected wood as fuel, and the most preferred stoves of rural households are three-stone stoves, at 85.5%. Only 11.1% and 5.8% use charcoal and purchased wood for their stoves, respectively (Figure 39).

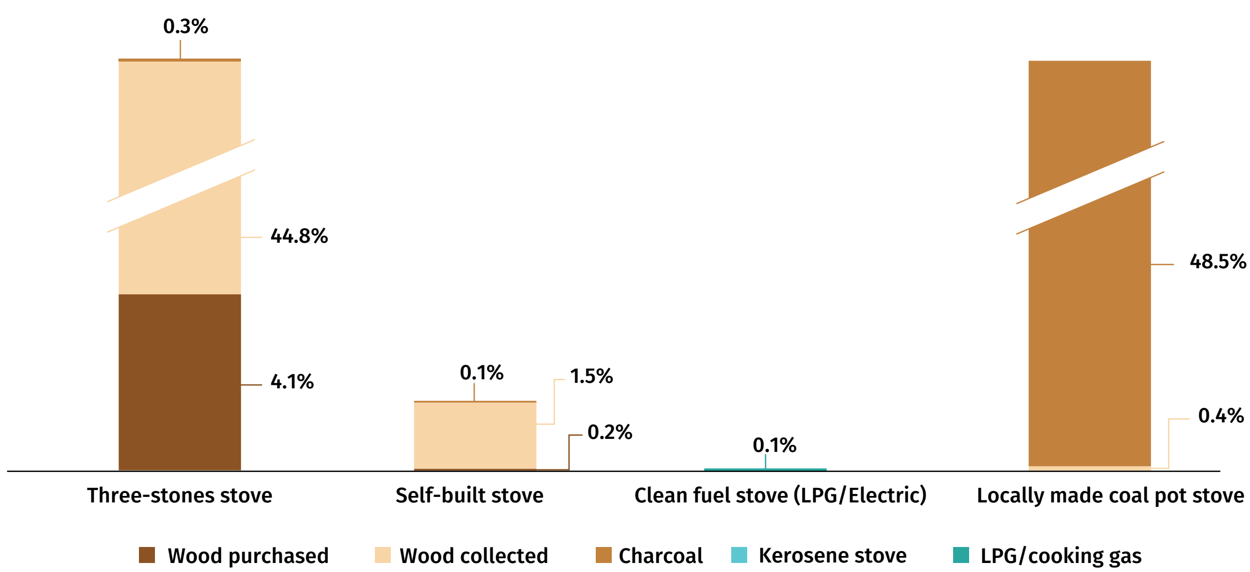
FIGURE 39 • **Cooking fuel usage (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

The distribution of primary stoves and fuel types also revealed that households in Liberia use collected wood (45%) and purchased wood (4%) with their three-stone stoves, and charcoal (48%) with their locally made coal pot stoves (Figure 40). This finding is consistent with the fact that the two commonly used stoves in Liberia are locally made coal pot stoves (49.1%) and three-stone stoves (47.7%).

FIGURE 40 • **Distribution of household by primary stoves and fuel combination (Nationwide)**

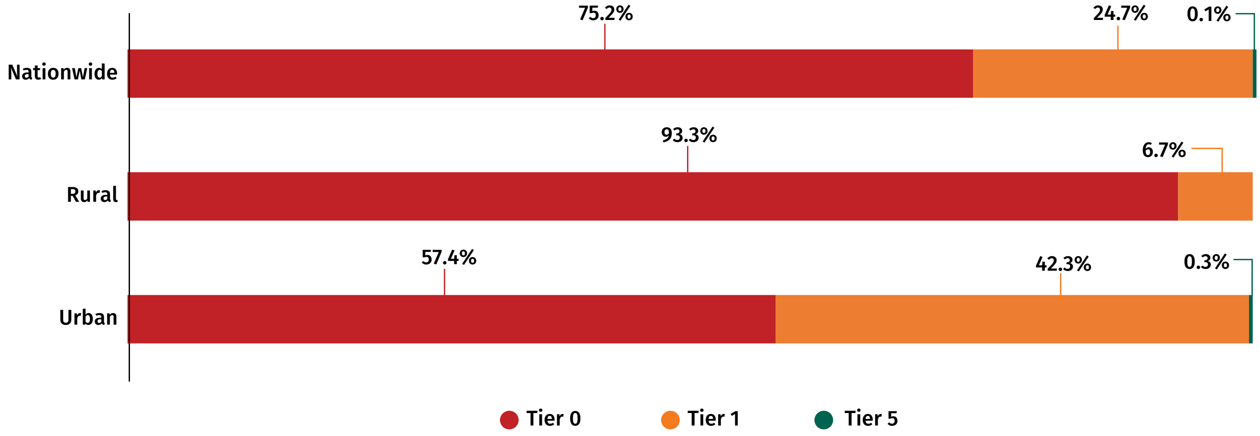


Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

MTF TIERS

According to the MTF cooking framework, only 0.1% of households in Liberia are in Tier 5 nationwide, and there are no households in Tiers 2 to 4. The majority of households are in Tier 0 (75.2%) and Tier 1 (24.7%). The disparity in tier classifications for cooking is not that significant between urban and rural households. Most rural and urban households fall in Tier 0. On the one hand, 93.3% of rural households are in Tier 0, compared with only 6.7% in Tier 1; on the other, 57.4% of urban households are in Tier 0, compared with 42.3% in Tier 1. The main difference between rural and urban households is that about 0.3% of urban households are in Tier 5 compared with none among rural households (Figure 41). That finding is not surprising because most rural households in Liberia use three-stone, self-built, or locally made coal pot stoves, and none of these has the capability to reach beyond Tier 1.

FIGURE 41 • **MTF Tier distribution for access to modern energy cooking services (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.

MTF ATTRIBUTES

Access to modern energy cooking services is measured based on six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Safety of Primary Cookstove, Affordability, and Availability of Primary Fuel. Cooking Exposure assesses personal exposure to pollutants from cooking activities, which depends on stove emissions, the ventilation structure (which includes cooking location and kitchen volume[7]), and contact time (time spent in the cooking environment). Cookstove Efficiency assesses the performance of the stove with regard to its thermal efficiency. However, due to a lack of stove testing data, the Cookstove Efficiency attribute was not considered for Liberia. Convenience measures the time spent acquiring fuel (through collection or purchase) and on preparing the stove for cooking. Safety of Primary Cookstove assesses the safety of the most used cookstove within the household. In this report, due to data limitations, the safety results will not be presented because very few households reported injuries caused by their primary stoves. Affordability assesses a household's ability to pay for fuel. Availability of Primary Fuel assesses whether it is available when needed for cooking purposes.

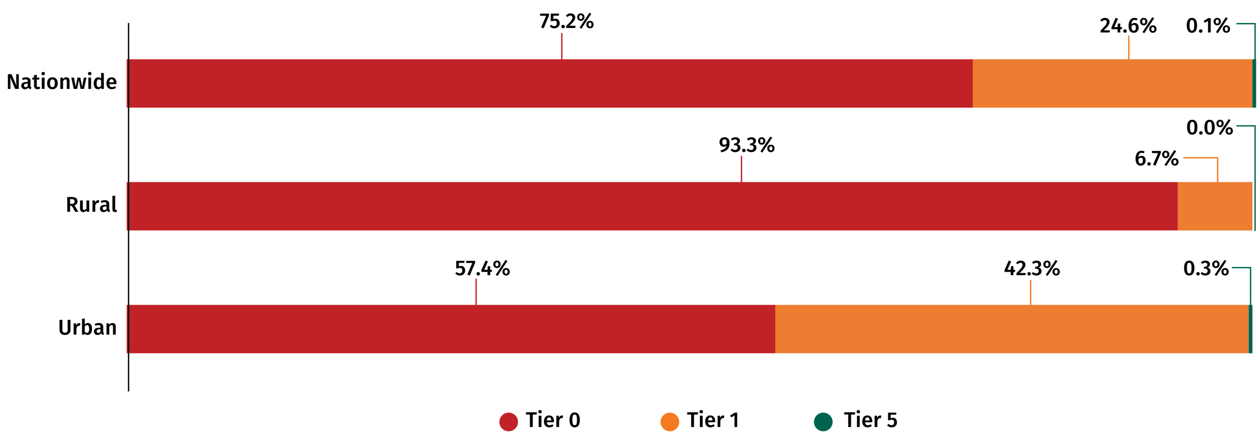
[7] Due to data limitation issues, this report did not use the kitchen volume to estimate the overall ventilation structure.

Cooking Exposure

In the MTF framework, "Cooking Exposure" is a proxy indicator to measure the health impacts of cooking activity. It is calculated, first, by determining the level of emissions based on the fuel type and stove technology, and then the ventilation of a household's cooking space (which can mitigate pollutants from cooking). The final Cooking Exposure Tier is assigned as a composite of the emissions and ventilation tiers (see Annex 1 for more details). Nationwide, 75.2%, 24.6%, and 0.1% of households in Liberia are in Tiers 0, 1, and 5 for Cooking Exposure, respectively. Moreover, nearly all cookstoves (99.9%) in Liberia fall between Tier 0 and Tier 1 for Cooking Exposure because of their stove emission levels. In fact, almost 97%[8] of households in Liberia use locally made coal pot stoves (48.9%) and three-stone stoves (46.7%), which restrict them to the lowest Cooking Exposure tiers (Figure 42).

There were no major differences between urban and rural households in terms of their Cooking Exposure. Most rural and urban stoves fall between Tiers 0 and 1 for Cooking Exposure in Liberia. In addition, there are more rural households in Tier 0 (93.3%) than urban households (57.4%), which can be explained by the fact that most rural households prefer three-stone stoves, while most urban households use locally made coal pot stoves. Moreover, only 6.7% of rural households are in Tier 1 compared with 42.3% of urban households. The other difference is that only 0.3% of urban households fall in Cooking Exposure Tier 5, but no rural households do. In fact, the use of LPG and electric stoves in rural areas in Liberia is almost non-existent.

FIGURE 42 • **Distribution of households based on Cooking Exposure (Nationwide, Urban/Rural)**



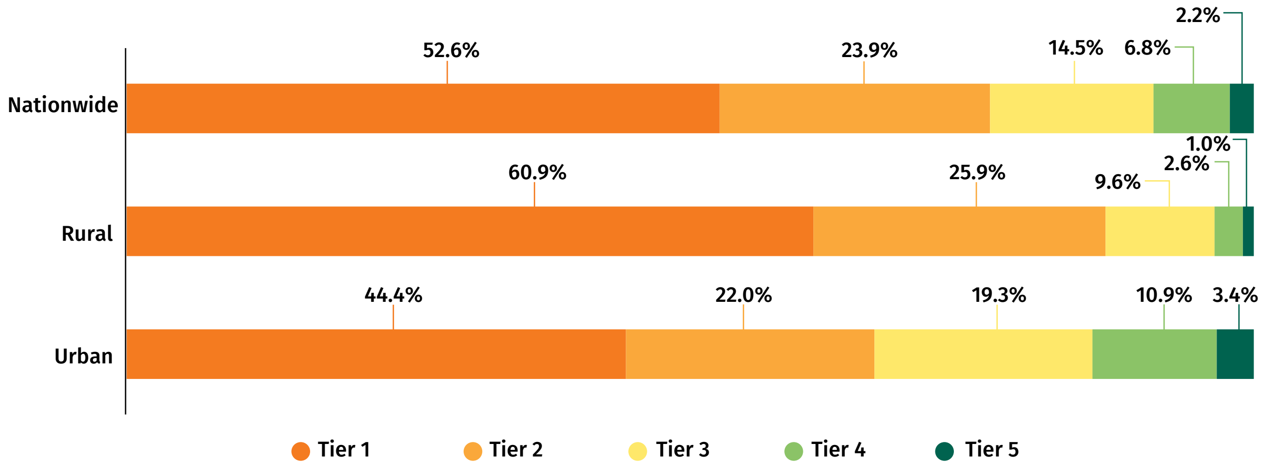
Source: 2017 MTF Household Survey for Liberia.

[8] In Liberia, 49.1% of households use locally made coal pot stoves and 47.7% use three-stone stoves. These two groups of stoves mainly use charcoal (48.9%), collected firewood (46.7%), and purchased firewood (4.3%) as fuel.

Convenience

Convenience is determined by the time spent collecting fuel and preparing the stove for cooking. In Liberia, 52.6% of households spend more than 7 hours collecting fuel per week or at least 15 minutes preparing the stove for each meal. Only 2.2% of households spend 0.5 hours collecting fuel for cooking per week or at least 2 minutes preparing the stove for each meal (Figure 43).

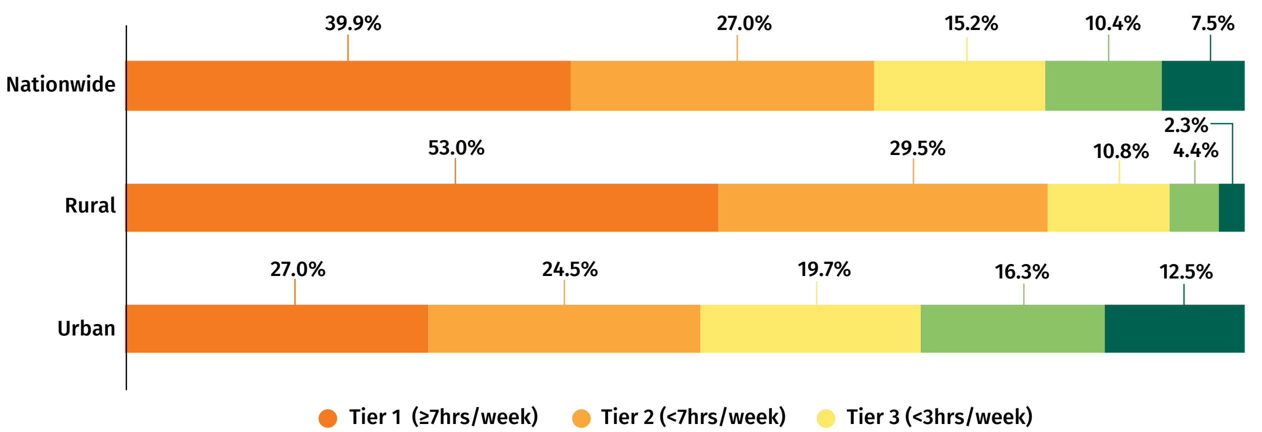
FIGURE 43 • **Distribution of households based on total Convenience (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.

More than half of rural households (53%) spend more time collecting and preparing fuel for cooking per week, while only 27% of urban households do so (Figure 44). This is because most rural households use three-stone stoves as their primary stoves, and collected firewood as the most preferred fuel for these stoves. However, urban households prefer locally made coal pot stoves and use charcoal as their main fuel.

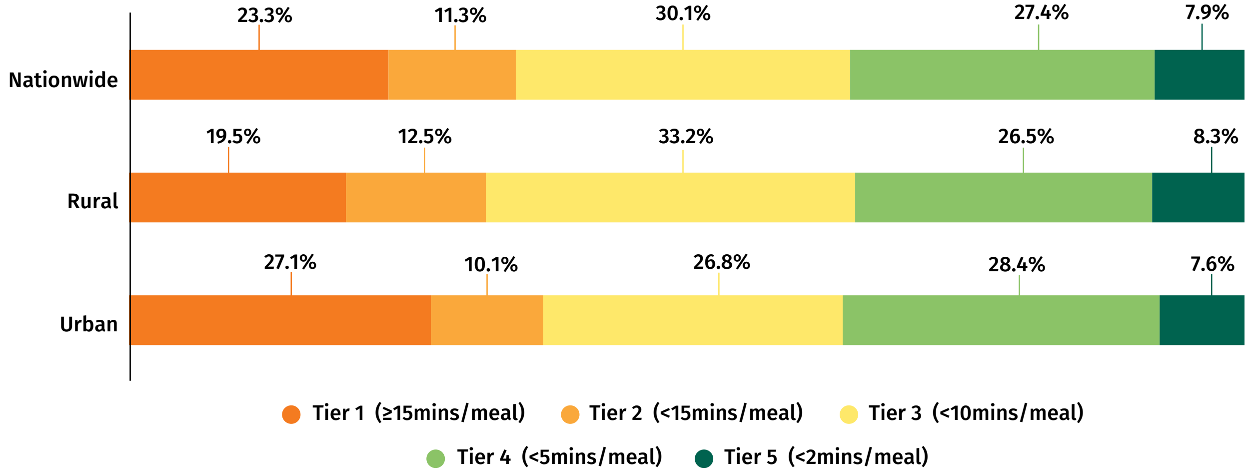
FIGURE 44 • **Distribution of households based on fuel acquisition time (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.

When it comes to time spent on preparing the stove for a meal, rural households tend to do better than urban households. Only 19.5% of rural households spend more than 15 minutes to prepare their stoves for a meal, while 27.1% of urban households do so (Figure 45).

FIGURE 45 • **Distribution of households based on stove preparation time, minutes per meal (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.

Safety of Primary Cookstove

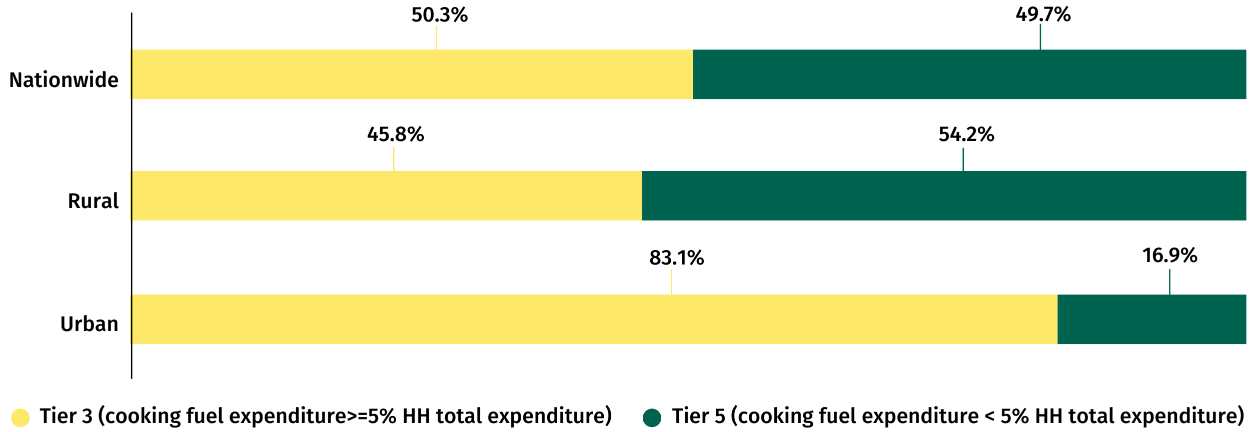
To help define safety, the International Workshop Agreements' (IWA's) methodology is adopted by the MTF in considering/referring to possible injury while using the cookstove in question. Over the past year, if household members did not experience any accidents[9] that required professional medical attention, then the cooking device was determined as "safe." However, due to data limitations, the tiers for Safety for primary cookstoves in Liberia could not be estimated.

Affordability

Affordability for cooking services is calculated using two factors: total monthly household expenditure and household's monthly expenditure on cooking fuel. If a household's expenditure on cooking fuel does not exceed 5% of its monthly budget, it is defined as being affordable according to the MTF. According to this definition, half of Liberia's households (50.3%) do not find their current cooking solution affordable. However, there is a significant difference among urban and rural households when it comes to cooking fuel affordability. The results reveal that 83.1% of urban households do not find their current cooking solution affordable compared with 45.8% of rural households (Figure 46). This is not surprising because urban households' most preferred fuel is charcoal (86.6%), which has to be purchased, while most rural households use collected firewood (83.1%), which is free, as the main fuel for their three-stone stoves (Figure 46).

[9] The list of serious accidents includes: (i) death or permanent damage; (ii) burns/fire/poisoning; (iii) severe cough/respiratory problems; and (iv) other major injury that requires professional attention.

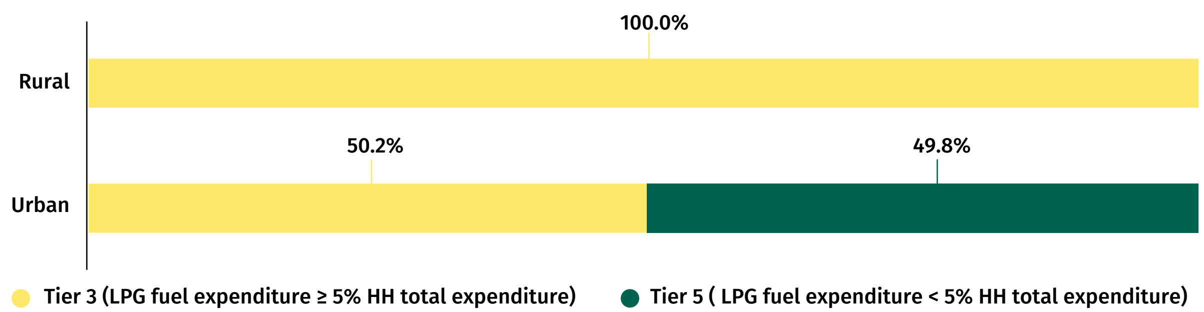
FIGURE 46 • **Distribution of households based on fuel Affordability (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.
Note: HH = household

To understand why 83.1% urban households do not find their current cooking solution affordable compared with 45.8% of rural households, we decided to research further into the Affordability Tier distribution by fuel type. Figures 47, 48, and 49 represent the Affordability Tier distribution by sector for LPG, purchased firewood, and charcoal in Liberia, respectively. Figure 47 reveals that among the 0.1% of households that use LPG stoves nationwide, 50.2% do not find their current cooking solution to be affordable.

FIGURE 47 • **Distribution of households based on LPG affordability (Nationwide, Urban/Rural)**

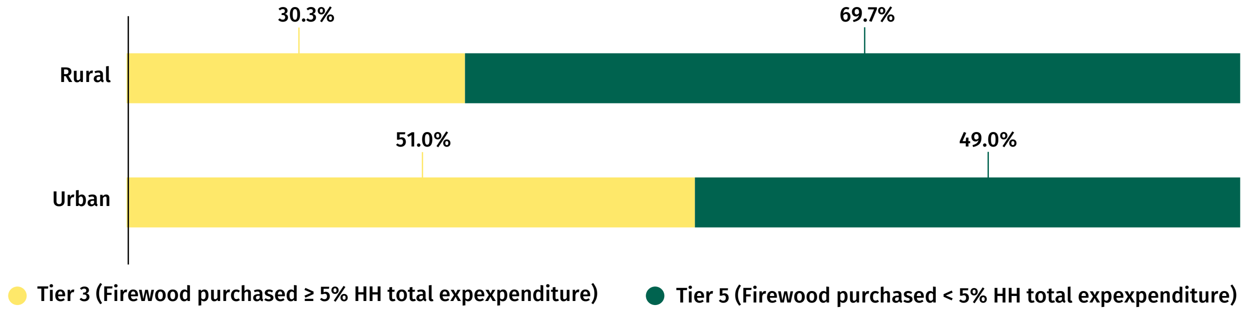


Source: 2017 MTF Household Survey for Liberia.

Note: HH = household; LPG = liquefied petroleum gas.

When it comes to purchased firewood, it appears that 51% of urban households do not find their current cooking solution to be affordable compared with only 30.3% of rural households (Figure 48). This can be explained by the fact that most rural households used collected firewood for their three-stone stoves (about 83.1%), while only 5.8% of rural households have actually paid for their firewood. Even though the proportion of households that paid for firewood in urban areas is lower (2.8%) than that in rural areas (5.8%), almost half of urban households cannot afford to pay for their firewood.

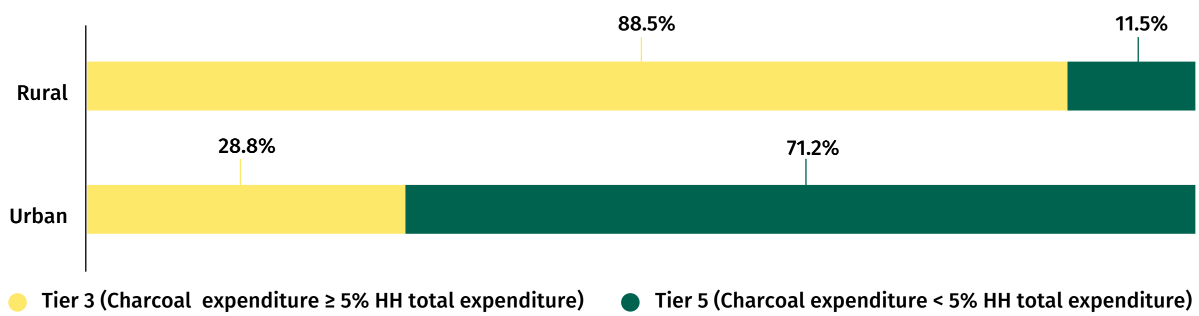
FIGURE 48 • **Distribution of households based on firewood purchase affordability (Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.
Note: HH = household.

Finally, among the 86.6% of urban households that use charcoal with their stoves, only 28.8% do not find their current cooking solution to be affordable. Among the 11.11% of rural households that use charcoal, 88.5% do not find their current cooking solution to be affordable (Figure 49).

FIGURE 49 • **Distribution of households based on charcoal affordability (Urban, Rural)**

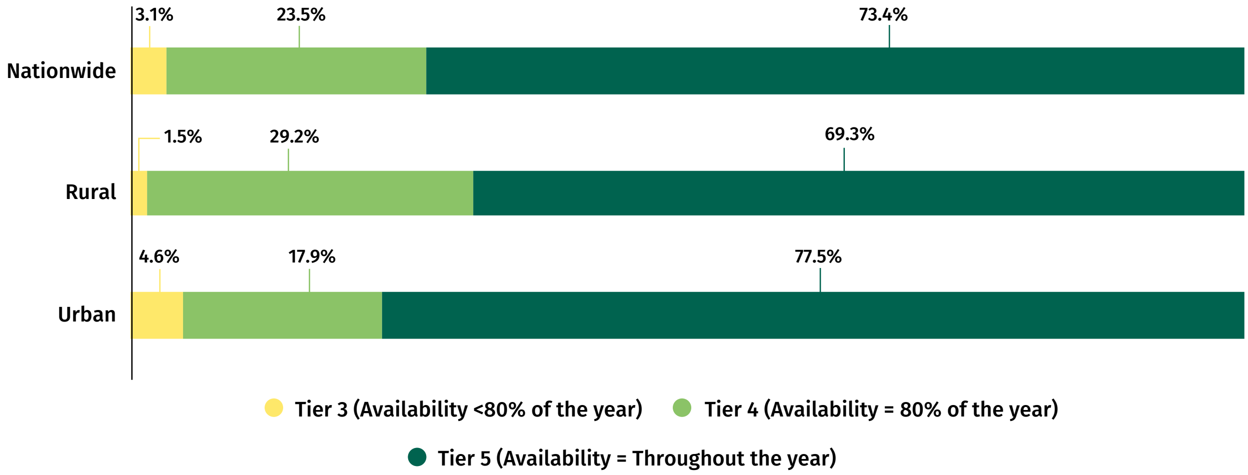


Source: 2017 MTF Household Survey for Liberia.
Note: HH = household.

Availability of Primary Fuel

This attribute measures how easily households can acquire fuel for their stoves. In Liberia, Fuel Availability does not appear to be a major constraint for households—73.4% of households nationwide responded that their primary fuel was always available; only 3.1% of households reported that it was sometimes available. There was no significant difference between urban and rural households. Over 75% of urban households and nearly 70% of rural households reported that their primary fuel was available through the year (Figure 50).

FIGURE 50 • **Distribution of households based on Fuel Availability (Nationwide, Urban/Rural)**



Source: 2017 MTF Household Survey for Liberia.

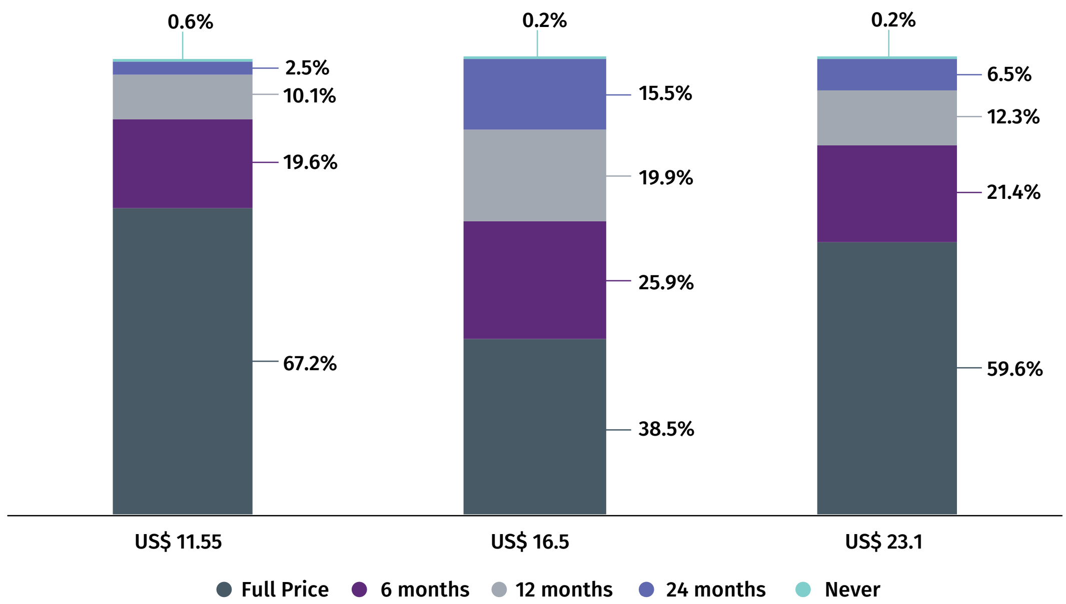
IMPROVING ACCESS TO MODERN ENERGY COOKING SERVICES

Increasing the use of improved cookstoves is the most feasible and immediate solution for households that use three-stone stoves and locally made coal pot stoves. Nearly all rural households use either three-stone (85.5%) or locally made coal pot stoves (10.9%) exclusively. Virtually all of them are in Tiers 0–1 mainly due to the Cooking Exposure and Convenience attributes.

The potential benefit of switching to an improved cookstove is substantial. Given the negative effects of indoor air pollution on health, access to higher-tier stoves should be expanded. Moreover, switching from three-stone, locally made coal pot, or self-built stoves to improved stoves can save the time households spend on collecting or acquiring fuel and preparing the stove for a meal. One way to shift households' preference toward an improved cookstove is by reducing its price or by allowing households more time to pay for it.

To investigate their willingness to pay for improved cookstoves, households were asked whether they would pay a full or reduced price for an Econochar improved charcoal cookstove that costs about US$23.10, or an Envirofit improved wood cookstove that costs about US$50.00. At full price, 59.6% were willing to pay for an Econochar cookstove up front, and 40.4% were willing to pay for it in installments of 6 to 24 months. If the price of an Econochar cookstove was reduced by one-third, from US$23.10 to US$16.50, it decreased a household's willingness to pay for it up front by 21%; however, this willingness to pay rose by 21% if the household was given 6 to 24 months to pay for it. Finally, when the price of the Econochar cookstove was reduced by two-thirds, and sold for US$11.55, an additional 7.6% of households were willing to pay for it up front (Figure 51).

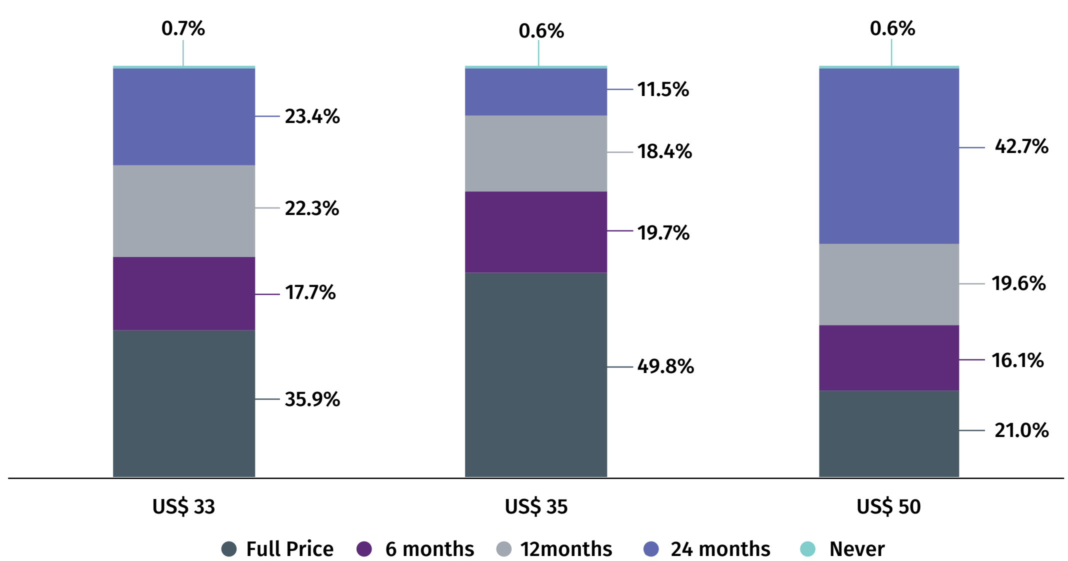
FIGURE 51 • **Willingness to pay for an Econochar improved charcoal cookstove (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.

When it comes to an Envirofit improved wood cookstove, 21% of households are willing to pay the full price of US$50 up front, and the remaining 79% are willing to pay for it in installments (of 6 to 24 months). When the price is reduced by one-third and the stove is selling for US$35, 49.8% of households are willing to purchase it at full price up front, an increase of 28.8%. However, when the price of the Envirofit cookstove is reduced by two-thirds and it is selling for US$33, 35.9% are willing to pay for it up front, or an additional 14.9% of households (Figure 52).

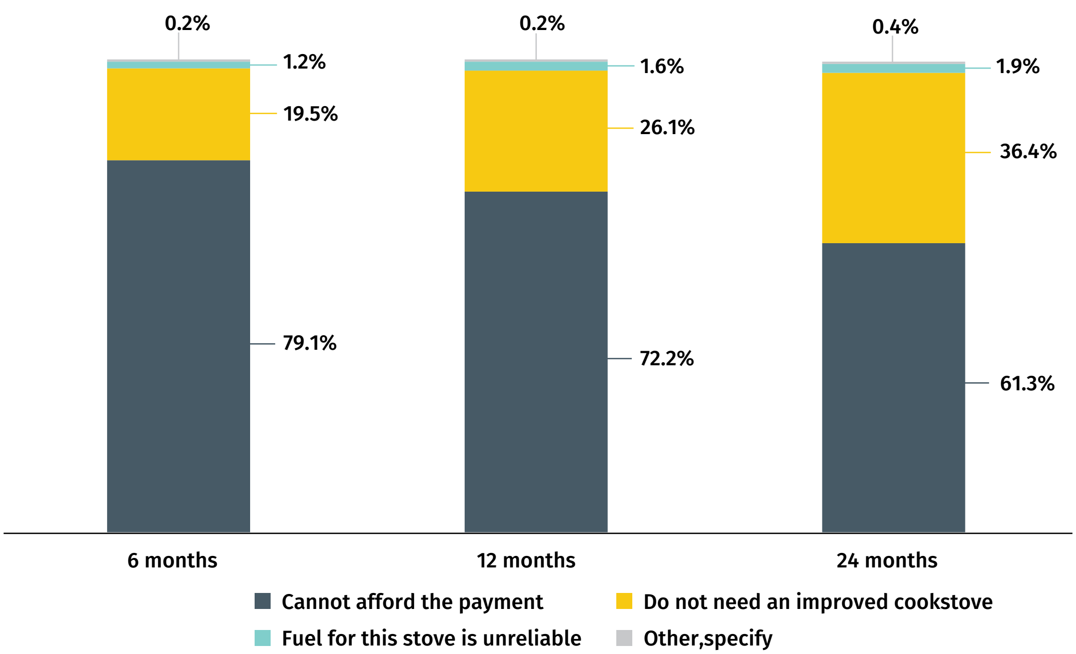
FIGURE 52 • **Willingness to pay for an Envirofit improved wood cook stove (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.

The main constraints preventing households from buying improved cookstoves are the prices of the stoves, or households not finding an actual use for them. For instance, 79.1%, 72.2%, and 61.3% of households that claimed they would never buy an improved cookstove could not actually afford it even if they were given 6, 12, or 24 months, respectively, to pay for it. This shows that price is the real obstacle, and allowing households more time to pay will not necessarily increase its affordability. Therefore, a government policy that offers a price subsidy to households that cannot otherwise afford improved cookstoves could boost their willingness to buy. The other major constraint is the fact that households do not find a real need for improved cookstoves—19.5%, 26.1%, and 36.4% of households reveal that they do not need them and would not buy them, regardless of whether they were given 6, 12, or 24 months to pay for them (Figure 53). As has been pointed out in this report several times, most households in Liberia use three-stone stoves, locally made coal pot stoves, and self-built stoves. Against this backdrop, a government program that sensitizes the local population to the potential environmental and health benefits of using improved cookstoves might be able to change people's perceptions and increase their willingness to buy.

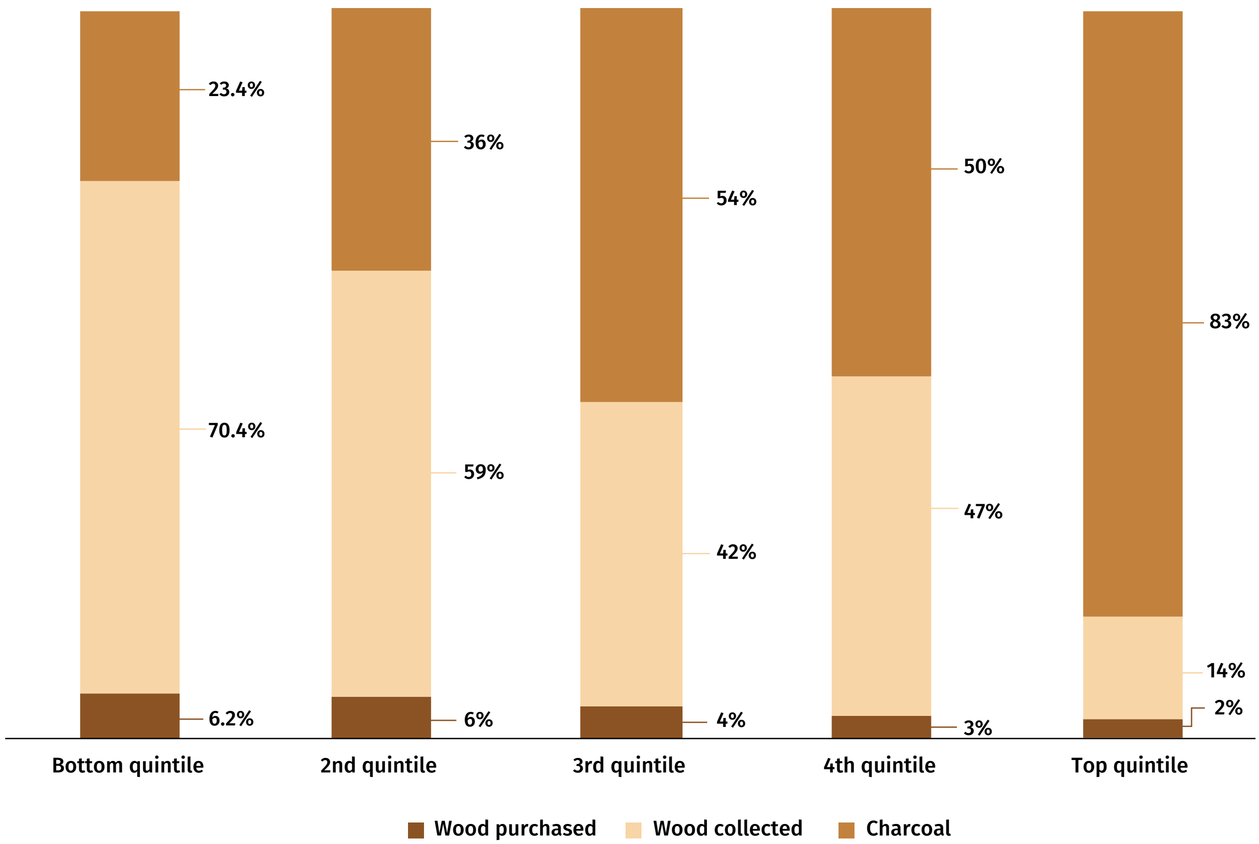
FIGURE 53 • **Reason for being unwilling to pay for improved cookstove (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.

The poorest households (i.e., those in the bottom 20% of the expenditure quintile) are more likely to collect wood for their stoves, while the richest households (those in the top expenditure quintile) prefer using charcoal. In the bottom expenditure quintile, 70.4% of households use collected wood for their stoves, and only 23.3% use charcoal; conversely, among households in the top expenditure quintile, 83.1% of households use charcoal with their stoves and only 14.4% use collected firewood (Figure 54). There is also an interesting finding about purchased firewood. One would expect the most affluent households (households in the top 20% of the expenditure quintile) to use more purchased firewood than households in the lowest quintile. However, in Liberia, it appears that 6.2% of households in the lowest expenditure quintile use purchased firewood, as compared with only 1.9% of households in the top expenditure quintile (Figure 54). Moreover, even though its usage it extremely low in Liberia, it appears that not only is kerosene used solely by urban households (about 0.1% of urban households), but it is also mainly used by urban households in the top expenditure quintile (about 0.2%) (Figure 54).

FIGURE 54 • **Distribution of Household based on Primary stove fuel usage, by expenditure quintile (Nationwide)**

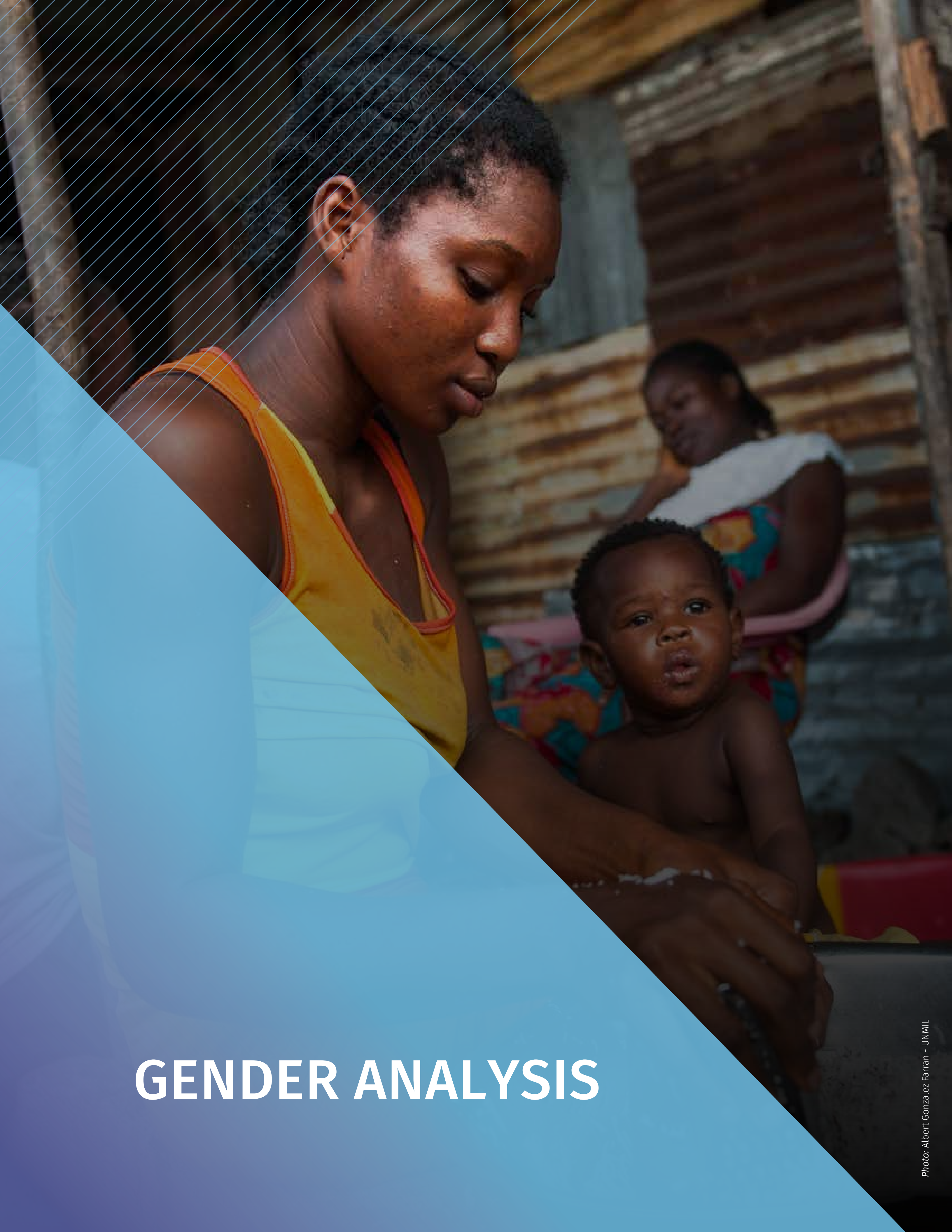


Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

POLICY IMPLICATIONS

Liberia's population is highly dependent on traditional fuels and technologies to meet their cooking needs. Firewood and charcoal persist as the main source of energy coupled with three stone fires and coal pots. It's more common in rural areas for households to rely on firewood and three stone fires while in urban areas households use of charcoal and coal pots. The combination of stove technology and fuel correlates with a household's performance on the tiered framework. The share of households in Tier 0 are about 75% across the country with 93% of rural households and 57.4% of urban households in Tier 0. Less than 1% of the households, mostly in urban areas were in Tier 5, with limited access to clean cooking solutions. Households in Liberia don't have improved or clean cooking solutions available and even the high-income households are highly reliant on traditional technology to meet their needs. While there appears to be a willingness to pay for improved stoves, there remains a large affordability gap.

For households to transition to better cooking solutions, technology and fuel options should be available and affordable to households. Liberia has a nascent market, which will need to be developed and include solutions that are adapted for the local context and local cooking needs. Liberia will need a systems approach by considering whole system of interactions of the cooking technologies (the stove and fuel combination) with human behavior (e.g what to cook, how to cook, for how long) and household conditions (e.g. kitchen location, ventilation, kitchen size). Local innovation and localized solutions can help support the long-term sustainability of providing access. To move the needle, this issue should be prioritized on the government's agenda, particularly integrated at the energy planning stage. The issue of access to modern energy cooking services is a development issue and progress towards it needs to bring together the different players within this sector, not only in energy but also health, gender and the environment, including policy and decision makers, the private sector and enterprises, and civil society.

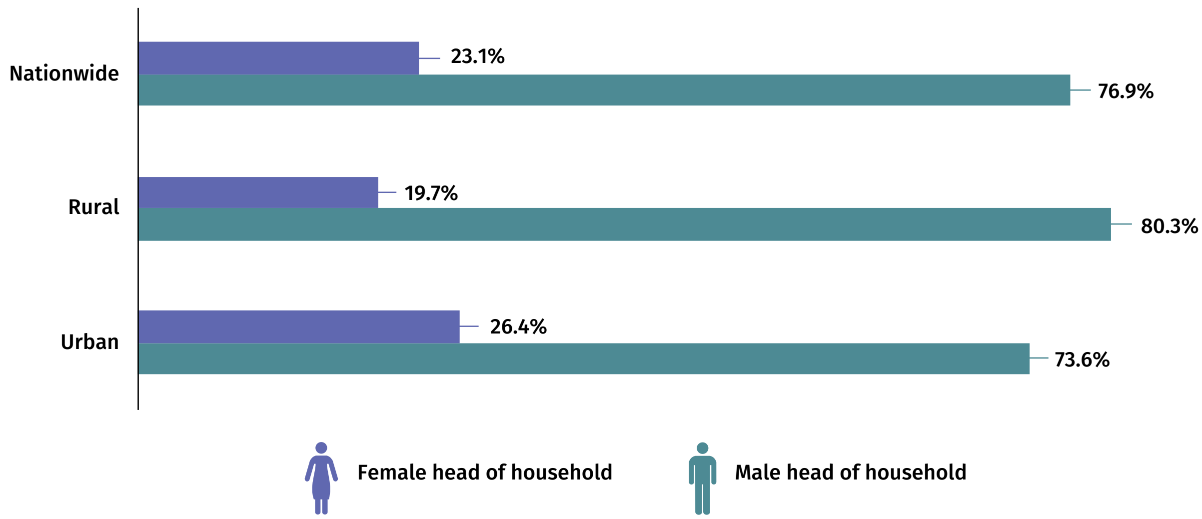


GENDER ANALYSIS

Photo: Albert Gonzalez Farran - UNMIL

Nationwide, 76.9% of households are headed by men, while the remaining 23.1% are headed by women. A similar trend is observed in both urban and rural areas, where 73.6% and 80.3% of households are headed by men, respectively (Figure 55).

FIGURE 55 • **Distribution of households by gender of the household head (Nationwide, Urban/Rural)**

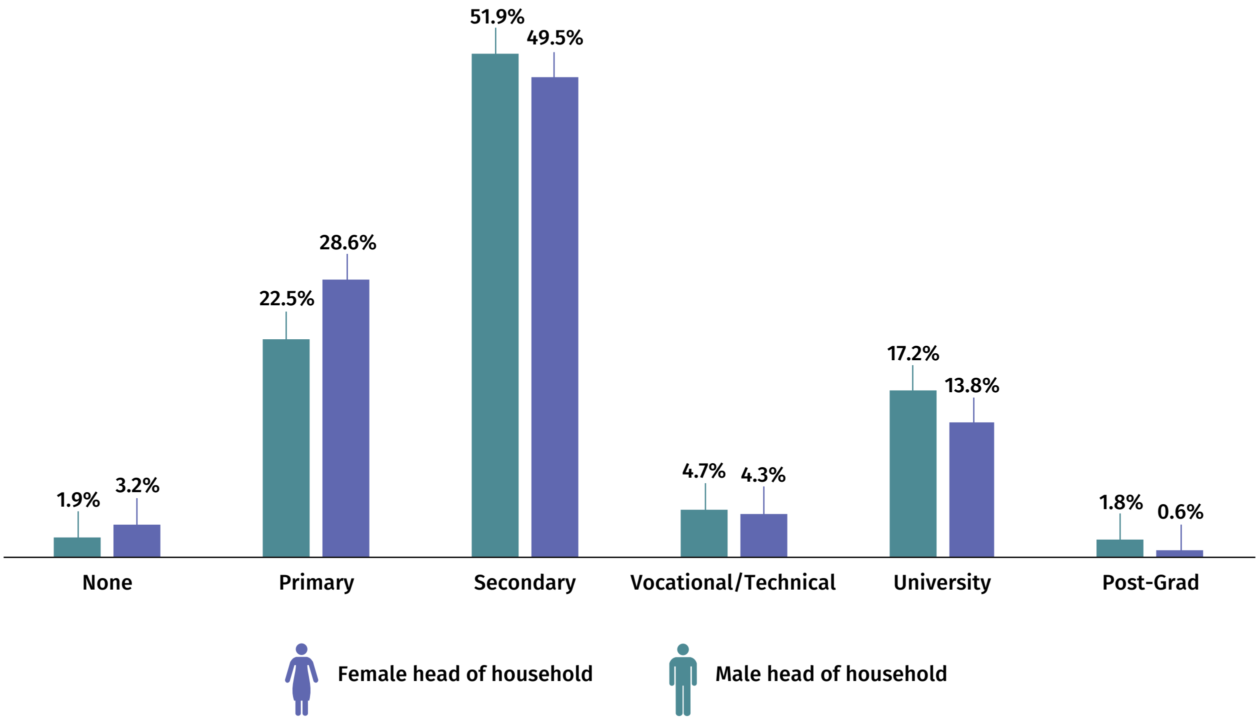


Source: 2017 MTF Household Survey for Liberia.

The average age of female household heads is 46 compared with 47 years for male household heads. Female-headed households are a bit smaller (4.6 members) than male-headed ones (5.4 members).

Male household heads have completed a higher level of education than their female counterparts nationwide: 22.5% of male household heads have completed primary school compared with 28.6% of female household heads; 51.9% of male household heads have completed secondary school education compared with 49.5% of female household heads; 4.7% of male household heads have completed vocational or technical school compared with 4.3% of female household heads; and 17.1% and 1.8% of male household heads have a university degree and a post-graduate degree compared with only 13.8% and 0.6% of female household heads, respectively (Figure 56).

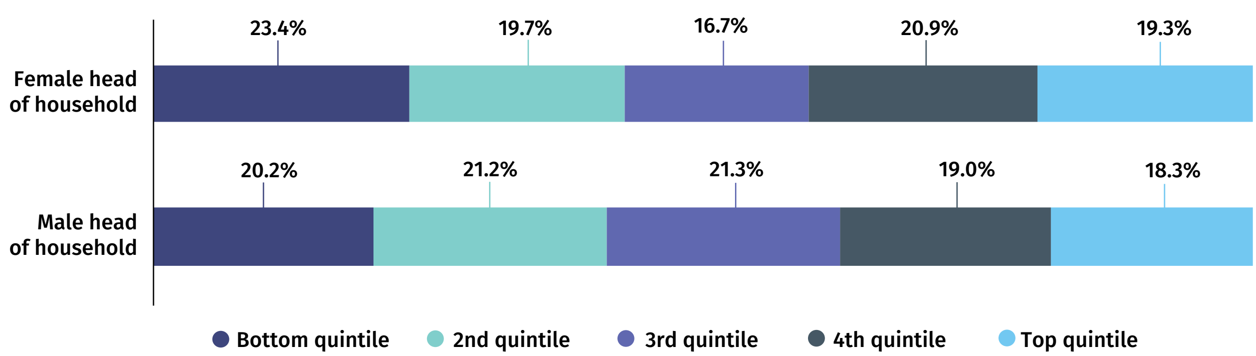
FIGURE 56 • **Distribution of households by education level of gender of the household head (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.

Nationwide, there is no major difference between households in the top expenditure quintile in Liberia by gender of household head: 19.3% of female-headed households are in the top expenditure quintile as compared with 18.3% of male-headed households. However, it appears that there are more female-headed households than male-headed households in the lowest expenditure quintile in Liberia: 23.4% of female-headed households are in the lowest expenditure quintile as compared with 20.2% of male-headed households (Figure 57).

FIGURE 57 • **Distribution of households by expenditure quintile, by gender of the household head (Nationwide)**

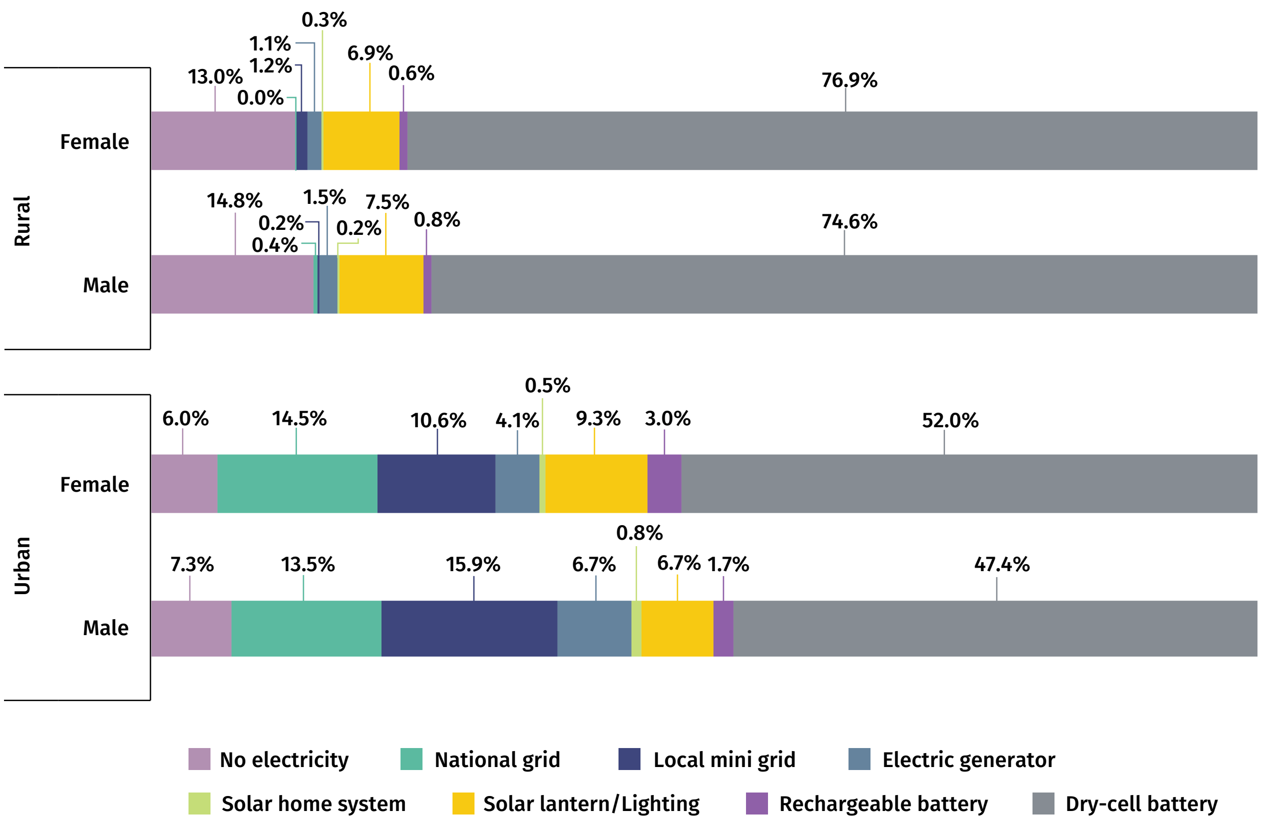


Source: 2017 MTF Household Survey for Liberia.

ACCESS TO ELECTRICITY

When it comes to the demand for and use of electricity in Liberia, there is no major difference between households with respect to the gender of the household head. We find that the proportion of male-headed households in rural areas that have no electricity or use dry-cell batteries is similar to the proportion of female-headed households: 13.0% and 76.9% of female-headed households, respectively, have no electricity or use dry-cell batteries in rural areas, as compared with 14.8% and 74.6% of male-headed households, respectively. The same trend is observed among urban households, where the share of female-headed households that do not have access to electricity or use dry-cell batteries is almost similar to the share of male-headed households. The use of the national grid and mini-grids among rural households is extremely low compared with their usage among urban households, and there seems to be no correlation between grid and mini-grid technology adoption and the gender of household heads in Liberia. We find that only 0.4% and 0.2% of male-headed households in rural areas use a grid or mini-grid, respectively, compared with only 1.2% of female-headed households in rural areas that have a mini-grid. The adoption of grid and mini-grid technology is higher among urban households, and the share of female-headed households using a grid (14.5%) in urban areas is higher than the share of male-headed households (13.5%). Moreover, 10.6% of female-headed households in urban areas use a mini-grid compared with 16% of male-headed households. The share of male- and female-headed households using solar lanterns and solar lighting systems is about the same among rural households in Liberia. However, the share of female-headed households using solar lanterns and solar lighting systems (9.3%) in urban areas is larger than the share of male-headed households (6.7%) using the same technology (Figure 58).

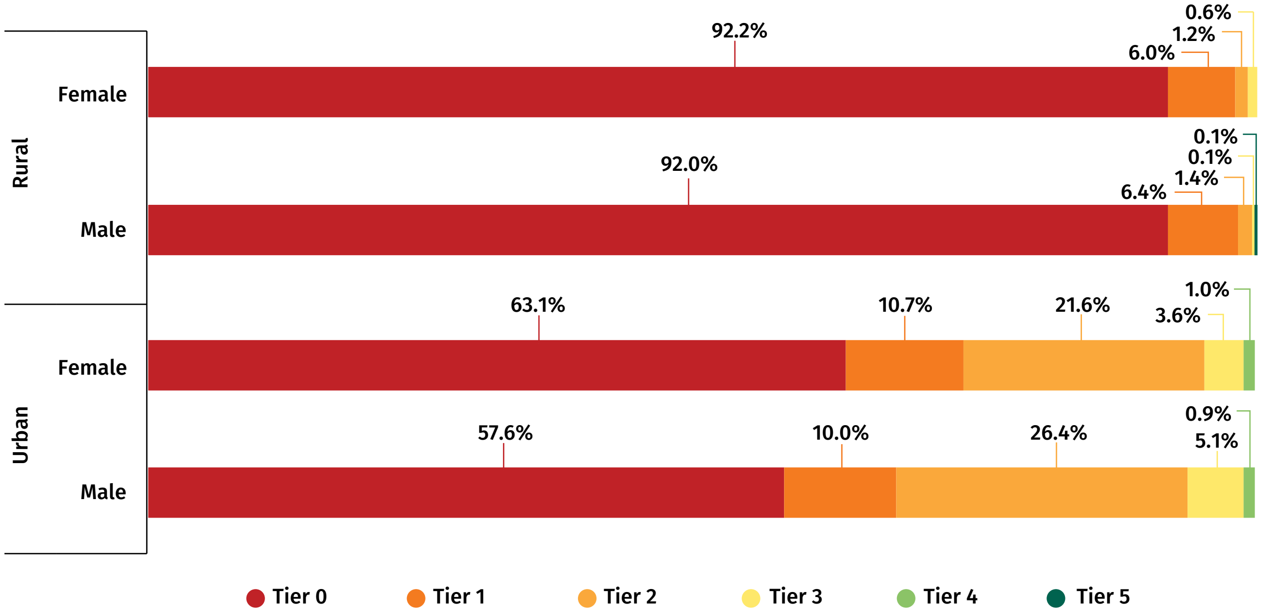
FIGURE 58 • **Distribution of households by source of electricity, by gender of the household head (Urban, Rural)**



Source: 2017 MTF Household Survey for Liberia.

The share of male- and female-headed households falling in Tier 0 is about the same, meaning that the gender of the household head does not have any significant impact on the household's source of electricity (Figure 59).

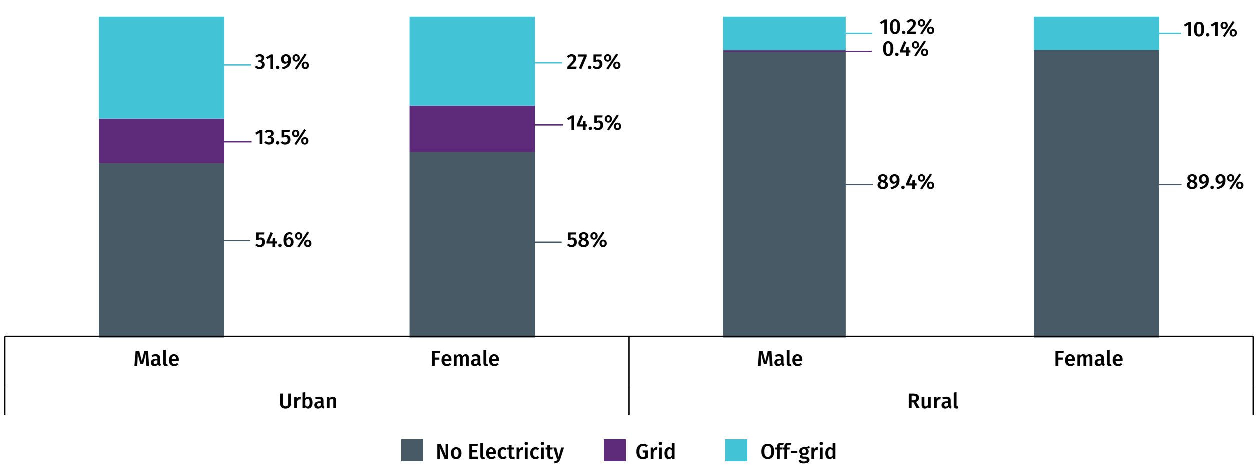
FIGURE 59 • **MTF Electricity Tier distribution by gender of household head (Urban, Rural)**



Source: 2017 MTF Household Survey for Liberia.

Only 10.1% of households in rural areas rely on off-grid solutions,[10] and there is no major difference between the share of male- and female-headed households residing in rural areas that use off-grid solutions. However, the use of off-grid solutions among urban households is quite high compared with the use of the grid. In fact, 31.9% and 27.5% of male- and female-headed households use off-grid solutions in urban areas, respectively, compared with 13.5% and 14.5% of male- and female-headed households using the grid, respectively (Figure 60).

FIGURE 60 • **Share of non-grid-connected households using off-grid solutions by gender of household head (Urban, Rural)**



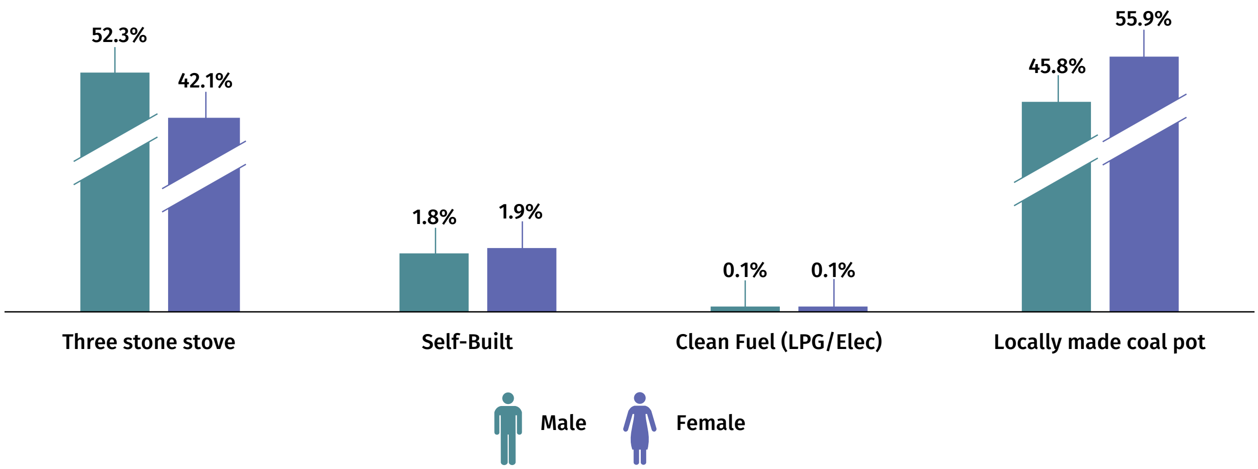
Source: 2017 MTF Household Survey for Liberia.

10 Off-grid solutions refer to the use of mini-grids, diesel generators, rechargeable batteries, solar home systems, and solar lanterns/solar lighting systems.

ACCESS TO MODERN ENERGY COOKING SERVICES

The gender of the household head does not appear to influence the decision to acquire cookstoves in Liberia when it comes to self-built stoves and clean fuel stoves. However, it seems like more men are willing to acquire a three-stone stove, while females prefer locally made coal pot stoves: 52.3% of men made the decision to purchase or acquire a three-stone stove compared with 42.1% of women. This can be explained by the fact that these stoves can be built easily and manually without any technical skills, and men in general are tasked with these activities. When it comes to locally made coal pot stoves, the reverse pattern is observed: 55.9% of women made the decision to buy a locally made coal pot stove, as compared with 45.8% of men (Figure 61).

FIGURE 61 • **Distribution of households by gender of decision makers to buy the cook stoves (Nationwide)**

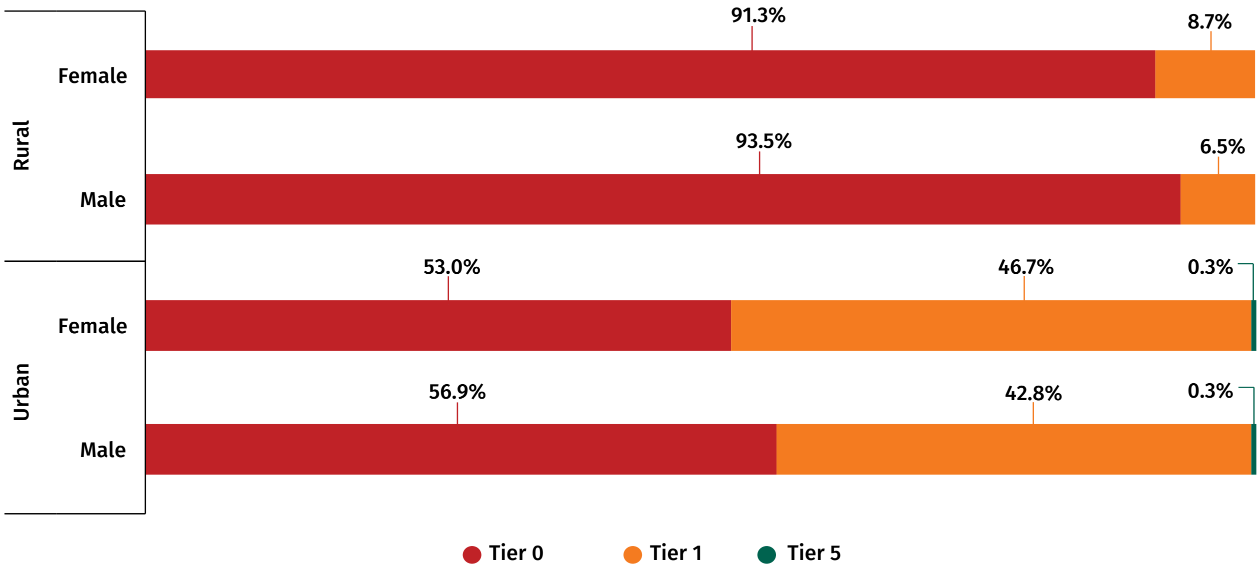


Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

The distribution of cooking tiers among male- and female-headed households in Liberia does not show any major difference, except for the fact that there are more rural households in Tier 0 than urban households. More than 90% of both male- and female-headed households in rural areas, and more than 50% of male- and female-headed households in urban areas are in Tier 0. This is because three-stone stoves and locally made coal pot stoves are the most common in Liberian households.

When examining the distribution of cooking tiers between male- and female-headed households in urban and rural areas, no significant distinction is observed. In rural areas, over 90% of both male- and female-headed households are in Tier 0, mainly due to the use of three-stone or traditional stoves for which the stove emission tier is 0. Moreover, there seems to be no significant difference among the share of male- and female-headed households that fall in Tier 1. However, when we look at the distribution by locality, it appears that there are more male- and female-headed households in Tier 1 living in urban areas than there are in rural areas: 46.7% and 42.8% of female- and male-headed households in urban areas, respectively, are in Tier 1, compared with 8.7% and 6.5% of female- and male-headed households in rural areas, respectively (Figure 62). The share of households in Tier 5 is almost non-existent because few households, 0.3% to be precise, use clean fuel stoves (LPG/electric stoves) in the entire country. Since more households in urban areas use either an electric or LPG stove as their primary cookstove, they are placed in Tier 5.

FIGURE 62 • **MTF Cooking Tier distribution by gender of household head (Urban, Rural)**

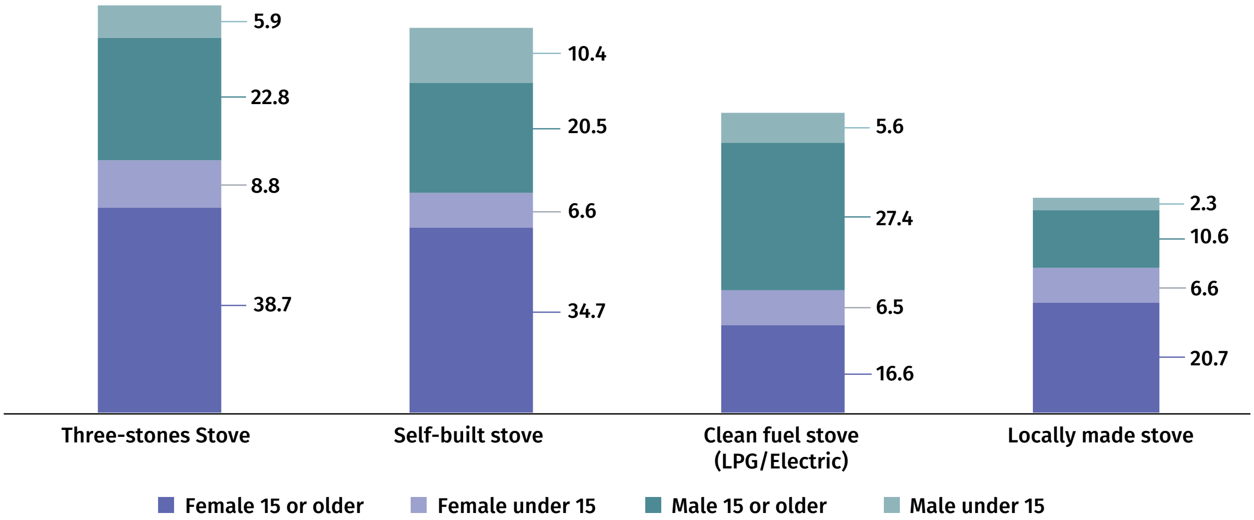


Source: 2017 MTF Household Survey for Liberia.

TIME USE ANALYSIS

In Liberia, when it comes to household chores related to cooking, the age and not the gender of household members most affects the amount of time they spend collecting fuel for their stoves. In fact, in Liberia, men and women over the age of 15 spend between 16 and 39 minutes a day, respectively, collecting fuel for their primary stoves; household members below or equal to the age of 15 spend no more than 11 minutes a day. The amount of time household members spend on collecting fuel for clean fuel stoves is also smaller than the amount of time they spend gathering fuel for three-stone, self-built, and locally made coal pot stoves (Figure 63). Moreover, women over the age of 15 spend more than 30 minutes a day collecting fuel for their three-stone and self-built stoves, while men over the age of 15 spend at least 20 minutes a day collecting fuel for the same stoves. When it comes to clean fuel stoves, it seems like men over the age of 15 spend more time (27.45 minutes per day) collecting fuel for their stoves compared with 16.63 minutes for women over the age of 15.

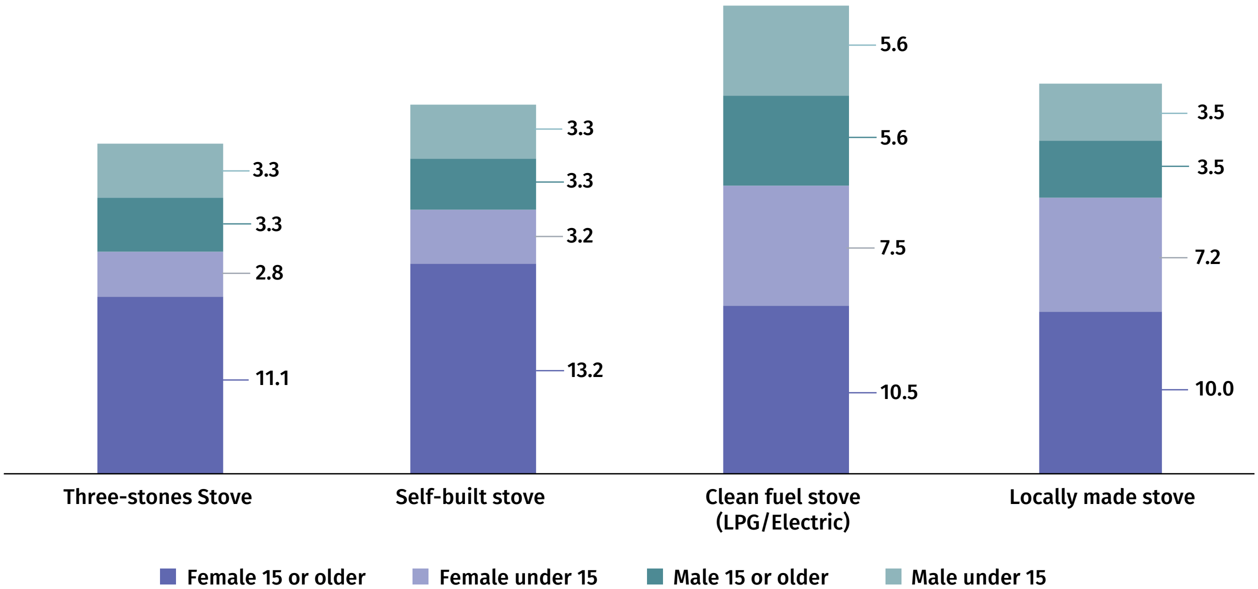
FIGURE 63 • **Average fuel collection time (minutes per day) for the primary stove, by gender and age (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

It appears that women in general spend more time preparing a stove for a meal than men in Liberia, regardless of the type of stove used. On average, women above the age of 15 spend between 10 and 14 minutes a day preparing a stove for a meal, while females below the age of 15 spend between 3 and 7 minutes. Males, regardless of their age, spend less than 6 minutes a day preparing a stove for a meal, regardless of the type of stove used. Also, household members regardless of their gender or age spend more time on average preparing clean fuel stoves (LPG/electric stoves) for meals (Figure 64). This is because, unlike three-stone stoves or locally made coal pot stoves (which used firewood or charcoal), household members need to be more cautious while handling the hazardous nature of the fuel (gas) that clean fuel stoves use.

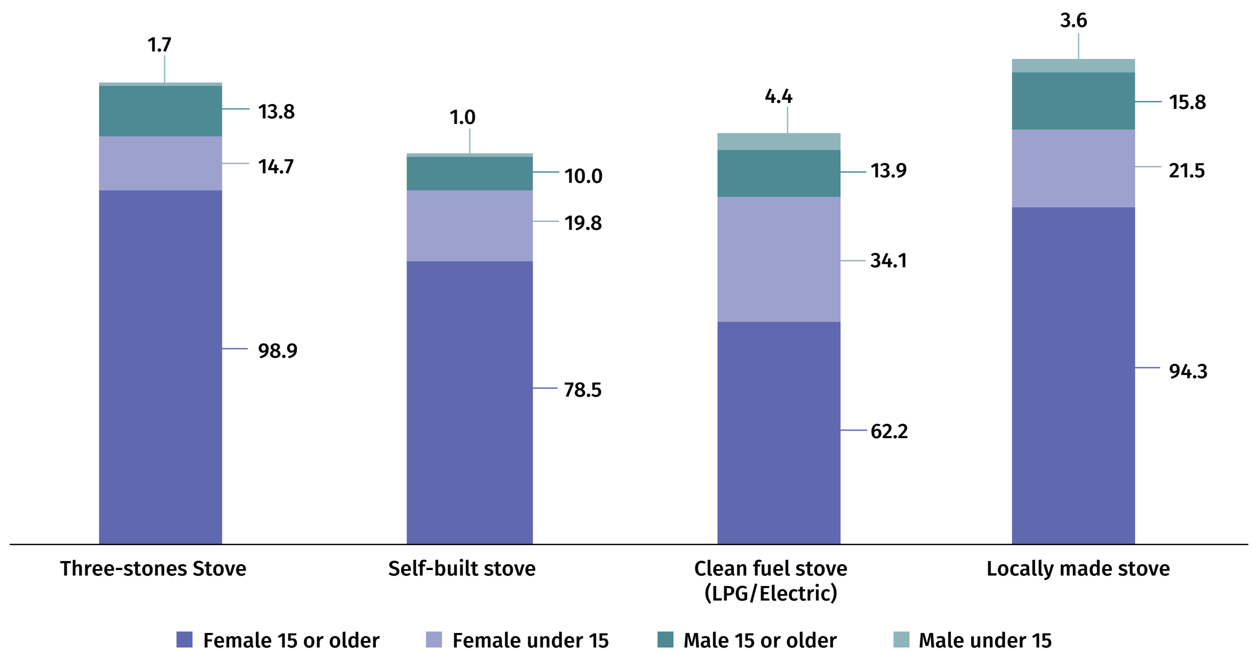
FIGURE 64 • **Average stove preparation time (minutes per meal) for the primary stove, by gender and age (Nationwide)**



Source: 2017 MTF Household Survey for Liberia.
Note: LPG = liquefied petroleum gas.

However, cooking appears to be mainly a female activity regardless of the age of the primary cook and the type of stoves used. In general, females, especially those above the age of 15, spend between 60 and 94 minutes a day cooking meals compared with those below the age of 15 who spend between 15 and 34 minutes (Figure 65). This finding is not surprising because females, at a very young age, are trained to help their mothers in the kitchen and do household chores such as washing the dishes, sweeping the compound, and fetching water. However, males, regardless of their age, spend less than 20 minutes a day preparing meals.

FIGURE 65 • **Average cooking time (minutes per day) for the primary stove, by gender and age (Nationwide)**



Source: 2017 MTF Household Survey For Liberia.
Note: LPG = liquefied petroleum gas.

POLICY IMPLICATIONS

In Liberia, the gender analysis does not show wide disparities in energy access overall as the levels of access across the country are relatively low for the majority of the population. The initial analysis shows that female-headed households are at a slight disadvantage compared to male-headed households on socio-economic aspects relating to education levels and expenditure quintiles. Female-headed households have lower levels of education particularly, secondary and tertiary education compared to their male counterparts. However, on electricity access there is no substantial difference in the sources of electricity or the tiers that female- and male-headed households fall into. Households in urban and households in rural areas have similar patterns of access regardless of the gender of the household head.

ANNEX 1.
MULTI-TIER FRAMEWORK MATRIX AND THEORETICAL BACKGROUND

Attribute	Definition	Question from the short module
Capacity	The Capacity 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 light-emitting diode (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. Thus, it establishes what types of appliances may be used with the given supply. Capacity is measured in watts for grids, mini-grids, and fossil-fuel-based generators, and in watt-hours for rechargeable batteries, solar lanterns, and solar home systems (SHSs).	What source of electricity is used most of the time in this household? What appliances are powered using this household's solar device/system? How many light bulbs can be powered using this household's solar device/system?
Availability (duration)	Availability of supply refers to the amount of time during which electricity is available. It is measured through two indicators: (i) the total number of hours per day (24-hour period), and (ii) the number of evening hours (the 4 hours after sunset) during which electricity is available.	In the last 7 days, how many hours of electricity were available **each day** on average from [name main electricity system]? ***(Maximum 24 hours)*** In the last 7 days, how many hours of electricity were available **each evening** on average, from **6 pm to 10 pm from** [name main electricity system]? ***(Maximum 4 hours)***
Reliability (unscheduled outages)	The reliability of electricity supply is a combination of two factors: (i) frequency and (ii) duration of disruption. When electricity supply goes off unexpectedly it means that the grid is unreliable and needs backup generators as a coping mechanism.	In the last 7 days, how **many times** were there unscheduled outages or blackouts from [name main electricity system]? What is the total duration of all the unscheduled outages or blackouts in the last 7 days?
Quality (voltage)	The quality of the electricity supply is defined in terms of voltage. Most electricity applications cannot be operated properly below a minimum level of supply voltage.	In the last 12 months, did any of this household's appliances get damaged because the voltage was going up and down in the [name main electricity system]?
Affordability	If households spend less than 5% of their monthly expenditure (or consumption) to consume 30 kilowatt-hour (kWh) of electricity per month, it could be defined as being affordable.	Expenditure/consumption aggregation. Monthly expenditure to consume 30 kWh per month.
Formality	If households use electricity service from the grid but do not pay to anyone, their connection could be defined as informal connection.	Who does this household currently pay for [name main electricity system]?
Safety	An attribute of energy supply that relates to the risk of injury from the energy supply. The spectrum of electrical injuries is broad, ranging from minor burns to severe shocks and death.	In the last 12 months, did anyone using [name main electricity system from HE1] die or have permanent limb (bodily injury) damage?

ANNEX 2.
MULTI-TIER FRAMEWORK FOR MEASURING ACCESS TO ELECTRICITY

TABLE A1.1 • **The 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.

ANNEX 3.
DEFINITIONS AND QUESTIONS USED TO CALCULATE THE MODERN ENERGY COOKING SERVICES ATTRIBUTES

Attribute	Definition	Question from the short module
Cooking Exposure	**"Cooking Exposure"** attribute is a composite measurement of the emissions from the cooking activity, i.e., the combination of the stove type and fuel, and mitigated by the ventilation in the cooking area. If a household uses multiple stoves, the cooking exposure attribute is measured as a weighted average of the time each stove is used.	What does this household use for cooking **most of the time**, including cooking food, making tea/coffee, and boiling drinking water? What is the brand of the cookstove or device?
Emissions—Stove		
Emissions—Fuel		What type of fuel or energy source does this household use most of the time in this cookstove or device for cooking food, making tea/coffee, and boiling drinking water?
Ventilation		Is the cooking usually done in the house, in a separate building, or outdoors? Does the cookstove have a chimney or hood?
Contact time		**Yesterday**, how much time was this cookstove used for cooking food, making tea/coffee, and boiling drinking water?
Stove stacking		
Convenience	**Convenience** is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and the stove for cooking.	On a single trip, how long does it take for this person to go to collect the fuel, get the fuel, and come back? **In the past month (the last 30 days)**, how many times has this person collected this fuel for household cooking? **Yesterday**, how much time in total was spent preparing the [cookstove] and fuel for cooking, including setting up the fuel and lighting/turning on the cookstove, but not including time for gathering fuel or cooking?
Affordability	**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 household expenditure on their cooking fuel.	How much did this household pay for this fuel or energy source **last month** for cooking (the last 30 days)? (in local currency)
Fuel availability	**Fuel availability** measures the availability of the primary fuel over the last 12 months.	In the **past 12 months**, how often was this fuel or energy source unavailable in the quantity you desired?
Health and Safety	**Safety of the primary stove** accounts for any serious injuries from the stove over the last 12 months.	In the **past 12 months**, did any harm or injury happen from using this cookstove, device, or fuel?

ANNEX 4.
MULTI-TIER FRAMEWORK FOR MEASURING ACCESS TO MODERN ENERGY COOKING SERVICES

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

CHANGES IN CALCULATING THE ATTRIBUTES ON COOKING EXPOSURE AND COOKING EFFICIENCY

This report applies an updated framework of the attributes to the household data on cooking behavior, in particular, the attribute on "Indoor Air Quality" is now measured through "Cooking Exposure." The negative health impacts of household air pollution caused by traditional cooking activities are a key driver in promoting clean and efficient cooking. According to the World Health Organization (WHO 2014) guidelines for indoor air quality, average annual PM2.5 concentration should be less than microgram per cubic meter (10 µg/m3), and 24-hour exposure to carbon dioxide concentration should be less than 7 µg/m3. The WHO guidelines and interim targets have been a reference for the Multi-Tier Framework (MTF).

The measurement of direct exposure on the body of the cook would be the most accurate methodology. However, this process is very costly and not practical to implement through a large-scale household survey. One alternative is to calculate exposure based on simulation through mathematical models that consider key factors contributing to indoor air quality, such as indoor fuel combustion, ambient air pollution in the area, and kitchen volume and air exchange. Indoor emissions depend on the characteristics of each cooking solution (to account for stacking), along with its use, duration, and pattern. Emissions also depend on fuel quality, device maintenance, and users' adherence to specifications.[11] Another alternative is to use proxy indicators that do not provide measured or estimated exposure data, but classify different real-life situations in the sense of "contributing more or less to exposure." By including a broad variety of factors, the overall assessment still presents a comprehensive picture of exposure.

Much like the Cooking Exposure attribute, Cookstove Efficiency can be quite complicated to measure directly. The thresholds for the efficiency tiers are set using a technical report, *Clean Cookstoves and Clean Cooking Services: Harmonized Laboratory Test Protocols, Part 3: Voluntary Performance Targets for Cookstoves Based on Laboratory Testing*, published by the International Organization for Standardization (ISO 2018). Stoves with less than 10% thermal efficiency are in Tier 0, those with 10%–20% thermal efficiency are in Tier 1, those with 20%–30% thermal efficiency are in Tier 2, those with 30%–40% thermal efficiency are in Tier 3, those with 40%–50% thermal efficiency are in Tier 4, and those with 50% or higher thermal efficiency are in Tier 5. The survey did not measure stove efficiency directly. Households that were interviewed in the survey provided limited information that could accurately identify all the models and makes of the improved biomass stoves in use. Not all the stoves identified through the survey had testing data available to match the stove on the efficiency level. To consistently apply the Efficiency Attribute across the sample, we would require information on each stove's efficiency level, particularly for the solid biomass improved cookstoves. Without these detailed data, this report presents a version of the Multi-Tier Framework that does not include the Efficiency Attribute but calculates the aggregate tier for access to modern energy cooking services with five attributes.

A key question about cookstoves and their use is "*what constrains a household from moving up to the next tier?*" Equipped with the answers, policy makers can target fuel and stove design interventions to remove barriers. Answering the question begins with the analysis of attributes that defines the value of access to modern energy cooking services and fuels for the customer. A similar methodology to the electricity framework is applied to obtain the aggregate tier for modern energy cooking services. The lowest tier of the attributes is taken as the final tier for a household. Attributes directly related to the cooking solution, cookstove, and fuel, such as Cooking Exposure, Cookstove Efficiency, and Safety of Primary Cookstove, are the main concern in the lower tiers. Convenience, measured as time spent acquiring (through collection or purchase) and preparing fuel, is applicable in Tiers 2–5. Additional attributes—such as Affordability and Fuel Availability—are applicable in the higher tiers.

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[11] This approach is under development; its validity has not been verified by comparing the wide range of simulated data and direct measured exposure data with the WHO guidelines.

ANNEX 5.
Sampling Strategy for Liberia

The sample size proposed for the selected country is designed to get sufficiently precise estimates of each tier at the national level as well as the zonal (urban and rural) level. This section, at first, presents a discussion on the factors that should be taken into consideration in the determination of sample size calculation (1.1) and provides a justification for the proposed sample size for the selected countries (1.2). Then, it explains the criteria for stratification process (1.3).

ISSUES DETERMINING A SURVEY'S SAMPLE SIZE

The major issues considered to determine the appropriate sample size for a survey are:

1. The precision of the survey estimates (sampling error);
2. The quality of the data collected by the survey (non-sampling error); and
3. The cost in time and money of data collection, processing, and dissemination.

The following sub-sections discuss each of these issues in turn.

1. The precision of the survey estimates

The concept of the precision of a sample survey estimate is crucial in determining the sample size. By definition, a sample from a population is not a complete picture of it. However, an appropriately drawn random sample of reasonable size can provide a clear picture of the characteristics of that population, certainly sufficient for policy implication or decision-making purposes. From a sample of households, one can collect data and generate a sample (or survey) estimate of a population parameter. The population parameter value of characteristics of interest is generally unknown.

The formula to calculate the sample size is:

$$n = \frac{z^2 r(1-r) fk}{e^2} = \frac{z^2 r(1-r)[1+\rho(m-1)]k}{e^2} \qquad (1)$$

where:

n = Sample size in terms of number of households to be selected.

z = z-statistics corresponding to the level of confidence desired. The commonly used level of confidence is 95% for which z is 1.96.

r = Estimate of the indicator of interest to be measured by the survey.

f = Sample design effect. This represents how much larger the squared standard error of a two-stage sample is when compared with the squared standard error of a simple random sample of the same size. Its default value for infrastructure interventions is 2.0 or higher, which should be used unless there is supporting empirical data from similar surveys that suggest a different value. The sample design effect has been included in the sample size calculation formula (1) and is defined as: $f = 1 + \rho (m - 1)$.

ρ = Intra-cluster correlation coefficient. This is a number that measures the tendency of households within the same Primary Sampling Unit (PSU) to behave alike in regards to the variable of interest. ρ is almost always positive, normally ranging from 0 (no intra-cluster correlation) to 1 (when all households in the same PSU are exactly alike). For many variables of interest in LSMS surveys, ρ ranges from 0.01 to 0.10, but it can be 0.5 or larger for infrastructure related variables.

m = Average number of households selected per PSU.

k = Factor accounting for non-response. Households are not selected using replacement.[12] Thus, the final number of household interviewed will be slightly less that the original sample size eligible for interviewing. For most developing countries, the non-response rate is typically 10% or less. So, a value of 1.1 (= 1 + 10%) for k would be conservative.

e = Margin of error, sampling errors or level of precision. It depends very much on the size of the sample, and very little on the size of the population.

2. The quality of the data (Non-sampling error)

Besides sampling errors, data from a household survey are vulnerable to other inaccuracies from causes as diverse as refusals, respondent fatigue, measurement errors, interviewer errors, or the lack of an adequate sample frame. These are collectively known as non-sampling errors. Non-sampling errors are harder to predict and quantify than sampling errors, but it is well accepted that good planning, management, and supervision of field operations are the most effective ways to keep them under control. Moreover, it is likely that management and supervision will be more difficult for larger samples than for smaller ones (Grosh, M. E., & Muñoz, J., 1996, p56). Thus, one would expect non-sampling errors to increase with sample size.

3. The cost of data collection, processing, and dissemination

The sample size can affect the cost of the survey implementation dramatically. It will also affect the time in which the data can be collected, processed and made available for analysis. The availability of the firm conducting the survey and cost for each country would also affect the total cost of survey implementation. Thus, the cost of data collection, processing, and dissemination should be considered when determining the sample size for each country.

SAMPLE SIZE CALCULATION

Sample surveys are appropriate for the collection of national and relatively large geographic domain level data on topics that need to be extensively explored. The main purpose of this survey is to identify and analyze the energy access tiers (Tier 0 to Tier 5) both at the national level and at the zonal (urban and rural) level. Equation (1) in the previous section indicates the formula to calculate the sample size. Given that the concept of the MTF has been recently introduced and the aim of this global survey is to establish the baseline of monitoring energy access globally, the indicator of interest (r) is unknown. Thus, the sample size for each selected country is calculated using the prevalence rate of 50% as the most conservative choice and to achieve the minimum margin of error (standard errors are inversely proportional to the square root of the sample size: $e=z*\sigma/\sqrt{n}$). Since the non-response rate is typically

[12] The sample size should be calculated to reflect the experience from the country in question. Hence, we will introduce the possibility of replacement of certain households in particular countries, if needed. In this case, a different weight will be considered when preparing the estimates.

under 10% in developing countries (United Nations, 2011), a value of 1.1 for k (non-response rate) would be considered a conservative choice (United Nations, 2011, p42). The number of households selected per PSU (m) is 12 (DHS normally visit 20-35 households per PSU, while socioeconomic surveys rely on 6-16 households per PSU); however, it can be modified depending on the level of homogeneity in a given PSU and community. Due to the characteristics of infrastructure variables/indicator, we select 0.45 for intra-cluster relation coefficient (ρ), consequently, the design effect (f) will be equal to 6 ($f = 1 + \rho (m - 1)$) (Grosh, M. E., & Muñoz, J., 1996, p59).

The number of analytic domains also has a large impact on the sample size and strategy. An analytic domain can be defined as the analytic sub-groups for which equally reliable data is required for the analysis. The sample size is increased by a factor equal to the number of domains desired, because it does not depend on the size of the population itself.

While defining a strategy to calculate the sample size for the selected countries, we have considered two approaches: one calculating, at first, the national sample size as one analytic domain and allocating the sample size proportional to urban and rural population; the other is calculating, at first, the sample size using the distribution between urban and rural as two analytic domains and adding these two values to obtain the national sample size. These two approaches have taken into consideration data on sample size by a margin of error, ranging from approximately 4% to 5.5% at the national level and from nearly 5% to 11% at the zonal level. Considering the results obtained, we have chosen to keep those of the second approach, which for a margin of error of 6% at urban and rural levels gives a national sample size of roughly 3,300 households with an error of 4.2%.

Within each cluster/state, PSUs are selected with probability proportional to its measure of size (PPS) and households are selected with equal probability within each PSU (the definition of this approach is reported in United Nations, 2011).

STRATIFICATION

Once the sample size is determined, we develop a stratification strategy, which is the process of dividing households into homogeneous smaller groups called strata and then sampling separately for each stratum following certain rules. Stratification often improves the sample's representativeness by reducing sampling error. Each stratum is treated as an independent population. Sampling weights need to be used to analyze the data reflecting the stratification strategy adopted. This section provides guidelines on stratification for the MTF Global Survey.

The guidelines provided in this section are general, and ideally, this is what we aim to achieve in the stratification of the sample for the selected countries. However, these guidelines may not apply identically to all 16 countries where MTF surveys will be implemented as these countries may well vary in their geographical structure and population distribution within and across geographical units. That is, country-specific modification of the guidelines is likely, and such modification will be covered in the country-specific data collection reports.

It is useful to review the criteria that will guide the overall stratification strategy. This stratification is important for the tier analysis and capturing the diversity in different energy solutions and services. Such criteria are:

1. Equal allocation between urban and rural areas. This is established during sample size calculation. This will help conduct disaggregate and in-depth analysis for urban and rural areas, which are statistically sound.

2. While the parameters of interest for the MTF study are access to grid electricity and access to non-solid fuel, the prior will be used in the stratification. However, to make the analysis representative of the underlying population, sampling weights will be applied to reflect the actual distribution of both grid users and non-solid fuel users in the population.
3. A sample will have 50-50 distribution of grid users and non-users. This will help us conduct in-depth analysis of both groups. As mentioned, sample weights will be used in the analysis to compensate for oversampling of either group.
4. Twelve households will be sampled from each village or urban block (PSU).

SAMPLING FRAME

A sampling frame is a complete list of all sampling units that entirely covers the target population. The sampling frame was the 2014 Household Income and Expenditure Survey (HIES) conducted by the Liberia Institute of Statistics and Geo-Information Services (LISGIS).

TABLE 1 • **Distribution of Enumeration Areas (EAs) and households by County and Locality**

	URBAN		RURAL		TOTAL	
	EA	Households	EA	Households	EA	Households
Bomi	54	4,113	219	16,395	273	20508
Bong	256	20,729	671	49,081	927	69810
Gbarpolu	15	1,640	133	12,893	148	14533
Grand Bassa	129	12,214	339	35,226	468	47440
Grand Cape Mount	23	1,925	255	22,140	278	24065
Grand Gedeh	74	6,925	102	11,218	176	18143
Grand Kru	9	604	121	8,365	130	8969
Lofa	136	14,695	365	34,947	501	49642
Margibi	146	17,813	285	27,282	431	45095
Maryland	64	7,650	107	11,604	171	19254
Montserrado			182		182	0
Greater Monrovia	1967	100,626		-	1967	100625.5
Other Montserrado	101	12,847		18,804	101	31651
Nimba	173	19,300	608	61,434	781	80734
River Gee	27	2,552	81	7,270	108	9822
Rivercess	5	487	147	13,494	152	13981
Sinoe	23	2,594	195	13,235	218	15829
Total	**7012**	**327,339**	**3810**	**343,388**	**10822**	**570101.5**

Note: The sampling frame is the 2014 Household Income and Expenditure Survey (HIES) by the Liberia Institute of Statistics & Geo-Information Services (LISGIS);

Structure of the sample

The sample for the survey will be a stratified sample selected in two stages. The first stage will be selecting 292 enumeration areas (EA) in the sampling frame; the second stage is selecting 12 households in each sample EA. It is important to divide the sampling frame of EAs into strata in which households are homogeneous. Stratification can increase the efficiency of the sample for the survey. Stratification is achieved by separating in each county the urban and rural villages, and electrified and non-electrified villages; the urban and rural, and electrified and non-electrified villages in each province forms each a sampling stratum. In total, 32 sampling strata have been created. Samples were selected independently in each sampling stratum, by selection of one stage.

The sampling procedure

In the first stage, a random probability proportional to size (PPS) sample of EAs was selected from each county and urban-rural area. The sample was selected without replacement. At least two EAs were selected from each urban and rural area in each county. In the first stage, 292 EAs were selected using the PPS selection procedure for the entire country (Table 2).

In the second stage of sampling, a random sample of 12 households were selected from all EAs selected in the first stage of sampling. With a low grid electrification rate, particularly outside of the capital of Monrovia, the survey team adapted its sampling approach. The county of Montserrado, where the capital of Monrovia is, was divided into two regions – the Greater Monrovia area and the rest of the county, 'Other Montserrado. The EAs in each county (excluding Greater Monrovia) were divided based on their urban and rural classification. Then a random sample of enumeration areas was drawn based on a probability proportional to size (PPS) from each county and urban-rural area. Within each EA's geographic limits, NRECA International digitized all visible structures using existing GIS data from LISGIS and available satellite imagery. Each structure was digitized as points to represent a household. In each selected EA, once all the points were digitized, 12 structures were selected using a sampling design tool in GIS.

In the Greater Monrovia area, the sample selection used a two-stage stratification approach. In the first stage, 84 enumeration areas were selected in the Greater Monrovia (proportionate to the population). Each enumeration area was further divided into electrified and non-electrified households through a listing process. Enumerators carried out a listing of households to identify which were electrified and unelectrified.

In cases where the EA was too large to inspect, it was subdivided into subsections. One or more subsections were randomly selected and inspected. In cases where the team was unable to select six electrified and six unelectrified houses, for any of the selected EAs because there were fewer than six of either category, a sample of 12 homes of a single category (electrified or unelectrified) was randomly selected. Any shortfall was made up in other EAs.

At the second stage, in each selected EA, a fixed number of 12 residential households were selected among the residential households listed. A total of 3,504 households were selected to be enumerated, 1752 from rural and urban areas respectively.

TABLE 2 • Household survey distribution of samples across Liberia

	URBAN		RURAL		TOTAL	
	Enumeration areas	Households	Enumeration areas	Households	Enumeration areas	Households
Bomi	2	24	7	84	9	108
Bong	8	96	20	240	28	336
Gbarpolu	2	24	6	72	8	96
Grand Bassa	5	60	15	180	20	240
Grand Cape Mount	2	24	9	108	11	132
Grand Gedeh	3	36	5	60	8	96
Grand Kru	2	24	4	48	6	72
Lofa	7	84	15	180	22	264
Margibi	8	96	12	144	20	240
Maryland	3	36	5	60	8	96
Montserrado			8	96	98	1,176
Greater Monrovia	84	1,008	-	-		
Other Montserrado	6	72	-	-		
Nimba	8	96	25	300	33	396
River Gee	2	24	3	36	5	60
Rivercess	2	24	6	72	8	96
Sinoe	2	24	6	72	8	96
Total	**146**	**1,752**	**146**	**1,752**	**292**	**3,504**

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