ZAMBIA

Beyond Connections

Energy Access Diagnostic Report Based on the Multi-Tier Framework

ESMAP

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MTF Multi-Tier FRAMEWORK

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ABBREVIATIONS

EA	Enumeration area
ESMAP	Energy Sector Management Assistance Program
GDP	Gross Domestic Product
HH	Household
ICS	Improved cookstove
kW	kilowatt
kWh	Kilowatt-hour
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
MTF	Multi-Tier Framework
MW	Megawatts
PSU	Primary Sampling Unit
RISE	Regulatory Indicators for Sustainable Energy
SHS	Solar Home System
SLS	Solar Lighting System
SREP	Scaling up Renewable Energy Program in Low Income Countries
W	watt
WTP	Willingness to pay
ZMW	Zambia Kwacha*

*Effective exchange rate at time of survey (8/2017) was 1 U.S. dollar = 9.1551 ZMW

EXECUTIVE SUMMARY

Zambia is a middle-income country, but the recent economic growth had benefitted only a small segment of the urban population and had limited impact on poverty (World Bank, 2019). As of 2017, the gross domestic product (GDP) per capita (in current US$) stands at $1,513.3 (World Bank, 2018a).

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 (MTF) approach. The survey's objective is to provide more nuanced data on energy access, including access to electricity and cooking solutions. The MTF approach goes beyond the traditional binary measurement of energy access—for example, "having or not having" a connection to electricity, "using or not using" clean fuels in cooking—to capture the multidimensional nature of energy access and the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[1]

ACCESS TO ELECTRICITY

The Multi-Tier Framework (MTF) defines access to electricity according to a spectrum that ranges from Tier 0 (no access) to Tier 5 (full access) through seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety.[2] The final aggregate tier for a given household is based on the lowest tier that that household attained among all the attributes.

- **Source of electricity:** The MTF survey data show that, as of 2017, 1.4 million Zambian households (42.4%) have access to electricity through either national grid or off-grid sources, while the remaining 1.9 million households (57.6%) have no access to electricity. Out of the 42.4% with electricity, most (37.7% of all households) are connected to the national grid, and the remaining 4.7% primarily use off-grid solutions. The difference in access to electricity between urban and rural areas is substantial: most urban households (74.8%) access electricity through the national grid, yet the majority of rural households (88.1%) have no access to any kind of electricity source.

- **MTF aggregate tier for access to electricity:** The MTF defines Tier 1 or above as having access to electricity based on Sustainable Development Goal (SDG) 7.1.1. Nationwide, 40.3% of Zambian households are in Tier 1 or above for electricity access. Specifically, 75.2% of urban households and 8.7% of rural households are in Tier 1 or above. Grid users are

[1] 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.
[2] For descriptions of the MTF and its attributes, see Annex 1.

mainly concentrated in Tiers 3 through 5, while user of off-grid solutions are primarily in Tiers 0 through 2.

- **Households in Tier 0:** Nationwide, 59.7% of households are in Tier 0 for access to electricity, and the majority of them do not have any source of electricity. For households without any source of electricity, it will be critical to provide either an on-grid connection or an off-grid energy solution. Addressing high connection costs and offering flexible payment plans are likely to increase the grid-electrification rate. Grid infrastructure is available in 58.4% of the enumeration areas (EAs) in the country; however, only 37.7% of Zambian households are connected to the grid. The low uptake rate of grid connection opens up the possibility to increase grid electrification rate by around 20% through connecting households that are "under the grid," that is, directly beneath existing grid infrastructure. The penetration rate for off-grid solutions can also be improved by addressing Affordability issues through payment plans.
- **Grid-connected households:** Grid-connected households are mostly in higher tiers: 97.3% of grid-connected households are in Tier 3 or above, with 56.1% being in the highest tier, Tier 5. Challenges with Availability, Quality, and Reliability are the main issues preventing grid-connected households from being in the highest tier.
- **Off-grid solutions users:** Households using off-grid solar solutions are in Tiers 0 through 3, and they are mainly constrained by Capacity and Availability issues. Although the use of solar solutions is a relatively recent phenomenon in Zambia, 77.5% of solar users are satisfied with their current service from solar devices.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

The MTF measures access to modern-energy cooking solutions as a spectrum ranging from Tier 0 (no access) to Tier 5 (full access) through six attributes: Cooking Exposure, Cooking Efficiency, Convenience, Availability of fuel, Affordability, and Safety of the Primary Cookstove.[3] The final aggregate tier for a household is based on the lowest tier that the household attained among all the attributes.

- **Primary cookstove and fuel:** Zambian households reported usage of five types of cookstoves: 46.7% of households use open fire/three-stone[4] stoves; 36.3% use a manufactured traditional stove, known as *mbaula*; 16.5% use electric stoves; and the remaining 0.5% use liquefied petroleum gas (LPG) or manufactured improved stoves. Urban and rural households rely on different cooking technologies, with a majority of urban households (60.7%) using *mbaula* while 83.6% of rural households using open fire stoves. Additionally, electric stoves are much more prevalent in urban areas (used by 32.5% of households in urban areas vs. 1.9% in rural areas).

[3] For descriptions of the MTF and its attributes, see Annex 1.
[4] The three-stone stove consists of three stones of approximately the same height on which a pot may rest over a fire built amid the stones.

- **MTF aggregate tier for access to modern energy cooking solutions:** The majority of households are concentrated in Tiers 0 and 1 (17.8% and 65.1%, respectively). A higher portion of rural households (98%) is in Tiers 0 and 1 compared to urban households (66.3%). Clean-fuel stove users tend to be in higher tiers for access to modern-energy cooking solutions.
- **The main constraint for the 82.9% of households in Tiers 0 and 1 is cooking exposure caused by the usage of open fire or *mbaula* as their primary stoves.** Possible solutions are to promote clean-fuel stoves by addressing Affordability issues; to expand the grid infrastructure or LPG network to promote the use of efficient improved cookstoves (ICSs); and to introduce Emission Tier 4 stoves, such as gasifier stoves.
- **Households in higher tiers (Tiers 3 and 4) mainly face challenges stemming from Affordability and Fuel Availability.** Overall, 53.1% of households that primarily use clean fuel stoves spend more than 5% of their total household expenditure on cooking fuel. Furthermore, 41.1% of clean-fuel stove users reported that fuel was not always available throughout the year.

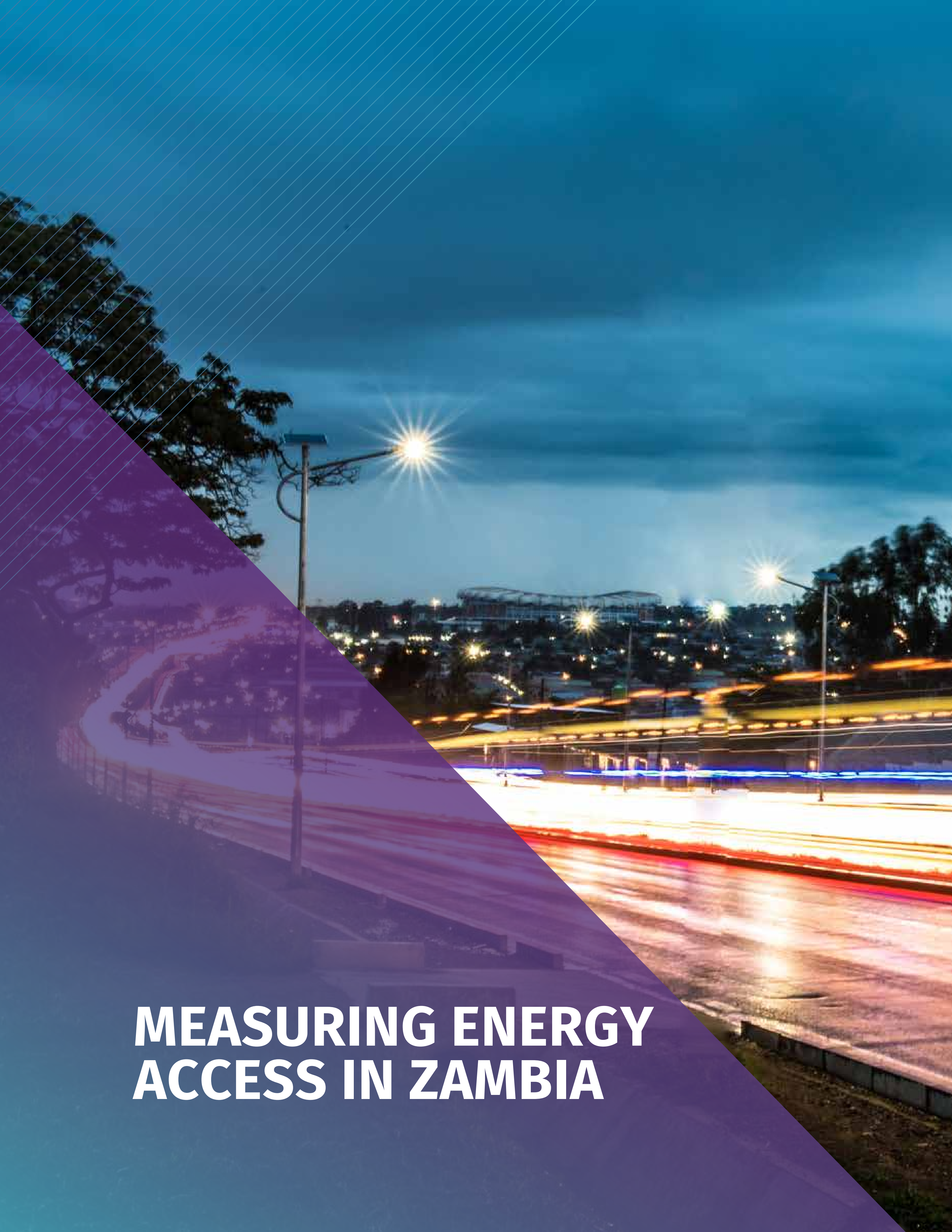
GENDER ANALYSIS

Nationwide, 76.2% of Zambian households are headed by men and 23.8% of households are headed by women. Female-headed households account for 25.4% of urban households and 22.4% of rural households.

Male household heads have higher levels of education than female household heads, with 7.2% of female household heads having never attended school, as compared with 4.6% of male household heads. Female-headed households are poorer than male-headed households, with 44.1% of them in the bottom two quintiles compared with 38.7% of male-headed households.

Nationwide, female-headed households and male-headed households have similar patterns in access to electricity, with 57.9% of female-headed households and 57.5% of male-headed households having no access to electricity. These female-headed households are more likely to be poor than male-headed households, as 42.4% of female-headed households without electricity are in the lowest expenditure quintile, compared with 29.1% of male-headed households. Similar portions of female-headed households and male-headed households are in Tier 0 for access to electricity (58.5% and 60.1%, respectively). Male-headed households appear to be more willing to pay for a grid connection or a solar home system than female-headed households.

Male-headed households and female-headed households also use similar cooking technologies. In Zambia, women ages 15 and older spend a considerably higher amount of time cooking or in the cooking area (10.6 hours per week) compared to men, girls, and boys. Women are thus much more likely to be affected by indoor air pollution. Hence, cooking solutions may have a larger impact on women compared to the other three groups.



MEASURING ENERGY ACCESS IN ZAMBIA

KEY FINDINGS AND POLICY IMPLICATIONS

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. Indeed, sustainable energy is the seventh of the 17 UN Sustainable Development Goals (SDGs): to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. The Government of Zambia, steadfastly committed to maximizing energy access benefits for its people, has therefore collaborated with the World Bank to put the Multi-Tier Framework (MTF) survey into practice and obtain guidance on setting access targets, policies, and investment strategies for energy access.

FIGURE A • **Zambia on the Africa map**

The Republic of Zambia is a landlocked country in the center of southern Africa (figures a and b). With an estimated population of 16.6 million people, the country spans 752,612 square kilometers (World Bank, 2018a). For every square kilometer of Zambian territory, there is an average of 23 people. Zambia is one of the most urbanized countries in sub-Saharan Africa, with 44% of its population living in a few urban areas, mainly in Lusaka and Copperbelt Province, whose cities represent the core economic hubs of the country, while the rural areas remain sparsely populated (World Bank, 2018a).

FIGURE B • **Provinces of Zambia**

Africa's second-largest copper producer, Zambia achieved middle-income country status in 2011, during a decade (2004–2014) of impressive economic growth (World Bank, 2019). In 2017, the GDP per capita (in current US$) amounted to $1,513 (World Bank, 2018a). Also, Zambia ranked 144 of 189 countries on the Human Development

Index (HDI) in 2017, with a value of 0.588, above the average of 0.537 for countries of sub-Saharan Africa (UNDP, 2018). However, the economic growth of 2004-2014 only benefitted a small segment of the urban population and had limited impact on poverty. As a result, the country ranks among those with the highest level of inequality globally (World Bank, 2019).

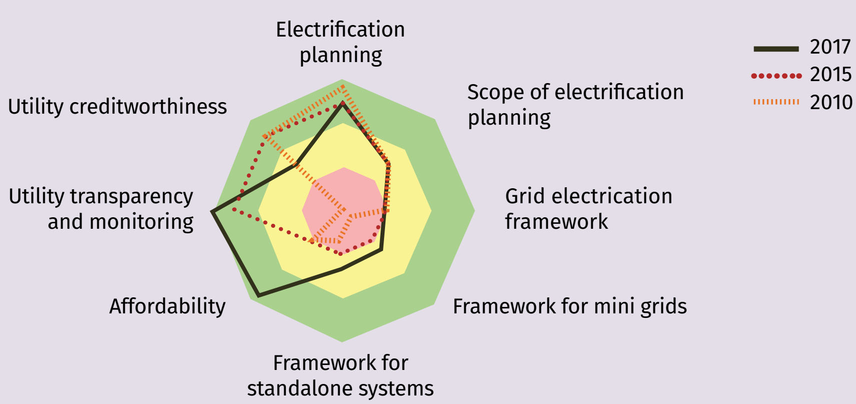
Currently, the grid supply in Zambia is dependent on hydropower (94% of electricity production). ZESCO Limited, the national utility, produces about 80% of total electricity. Zambia's grid network is interconnected with that of Zimbabwe, the Democratic Republic of Congo, and Namibia, and the main grid lines mostly follow the main road network, explaining the limited distribution into rural areas. The main issues the country has had to face concerning power have been limited resources to invest in grid expansion, low Affordability of connection fees, high unemployment, and declines in copper prices that harmed the economy until 2016 (IEA et al. 2018 and Box 1).

The government is taking steps to address several issues in the sector. Specifically, it is seeking to improve Reliability, diversify the energy mix, increase electrification rates, and encourage private sector investment. Zambia is committed to pursuing universal access to electricity under its Vision 2030 (Republic of Zambia, 2006).

BOX 1 • SUMMARY OF ELECTRICITY ACCESS INDICATORS, REGULATORY INDICATORS FOR SUSTAINABLE ENERGY (RISE) FOR ZAMBIA

Zambia has had a moderately developed policy framework for electrification since 2010. Progress on electrification planning and grid electrification development has plateaued since the country approved its Rural Electrification Master Plan in 2009. At the same time, policies for minigrids and stand-alone systems are limited. As a result of this, private developers have been investing in minigrids in the country without policy regulations. While tariffs remain relatively low by regional standards, they continue to put the electric utility, ZESCO, in financial difficulty in the absence of a cost-recovery tariff and funding for grid expansion. To address these issues, the Ministry of Energy is developing a National Electrification Program (NEP), an integrated approach to electrification that will define the role of all stakeholders in the implementation and financing of universal electricity access. It is also developing a package of sector reforms to improve the financial viability of ZESCO.

FIGURE B.1 • **Progress by indicators on electricity access, 2010, 2015 and 2017**



Source: World Bank, 2018b.

data on energy access, including access to electricity and cooking solutions. The first phase is being carried out in 16 countries across Africa (including Zambia), Asia, and Latin America. The MTF approach goes beyond the traditional binary measurement of energy access—for example, "having or not having" a connection to electricity, "using or not using" clean fuels in cooking—to capture the multidimensional nature of energy access and the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[5]

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

ACCESS TO ELECTRICITY

Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety (see table A1.1 in Annex 1).

The following describes what each of the seven attributes measures.

- ***Capacity*** ("What appliances can I power?"): The Capacity of the electricity supply (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate various appliances, ranging from a few watts for light-emitting diodes (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. First, appliances are classified into tiers based on their power ratings (see table 1). Then, each household's appliance tier is determined by the highest tier of all its appliances; that is, if a household owns multiple appliances, the highest-capacity appliance determines the household tier.[6] Capacity is measured in watts for grids, mini-grid and fossil fuel-based generators, and in watt-hours for rechargeable batteries, solar lanterns, solar lighting systems (SLS) and solar home systems (SHS). It may be difficult to determine the Capacity of the system by simple observation. An estimate of the available Capacity may be done based on the source of the supply (for example, grid is considered >2,000 watts) or appliances used (table 1).

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

- ***Reliability*** ("Is my service frequently interrupted?"): The Reliability of electricity supply is a combination of the frequency and the duration of unexpected disruptions. In this report, the Reliability attribute is only measured for households connected to the grid.

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[5] The MTF access rate includes access provided by off-grid technologies, which is often excluded by the binary rate, but excludes grid connections that do not meet the MTF criteria for a minimum level of service.

[6] Households' MTF Capacity tier, furthermore, is determined based on their appliance tier and the main source of electricity. While a household's appliance tier is the major determinant of its allocation in the MTF ranking, there is not a one-to-one correspondence, since the source of electricity plays a role too. Please note that grid-connected households are automatically assigned to Tier 5 for Capacity attribute regardless of their appliance ownership, so Capacity is discussed for off-grid households only.

- ***Quality*** ("Will voltage fluctuations damage my appliances?"): The Quality of the electricity supply refers to the absence of severe voltage fluctuations that can damage a household's appliances. Electric appliances generally require a certain level of voltage to operate properly. Low or fluctuating voltage can damage appliances, and even result in electrical fires. A low or fluctuating voltage supply tends to result from an overloaded distribution system or from long-distance low-tension cables connecting spread-out households to a singular grid. The MTF survey does not measure voltage fluctuation directly, but uses incidents of appliance damage as proxy. In this report, the Quality attribute is measured for households connected to the grid or a mini-grid.

- ***Affordability*** ("Can I afford to purchase the minimum amount of electricity?"): The Affordability of the electricity service is determined by comparing the price of a standard electricity service package (one kilowatt-hour [kWh] of electricity per day or 365 kWh per year) with household expenditure. The price of the package is determined from the prevailing lifeline tariff. If the household spends more than 5% of the household expenditure on electricity, then electricity service is considered unaffordable for that household.

- ***Formality*** ("Is grid electricity provided through a formal connection?"): If households use the electricity service from the grid, but do not pay anyone for the consumption, their connection could be defined as an informal connection. The Formality of the grid connection is important, since it ensures that the electricity authority gets paid for the services it provides, besides providing for the safety of electric lines. A grid connection is considered formal when the bill is paid to the utility, a prepaid card seller, or an authorized representative. Informal connections pose a significant safety risk and also affect the financial sustainability of the utility. Reporting on the Formality of a connection is challenging. Households may be sensitive about disclosing such information in a survey. The MTF survey, thus, infers information on Formality from indirect questions that respondents may be more willing to answer, such as what method a household uses to pay the electricity bill.

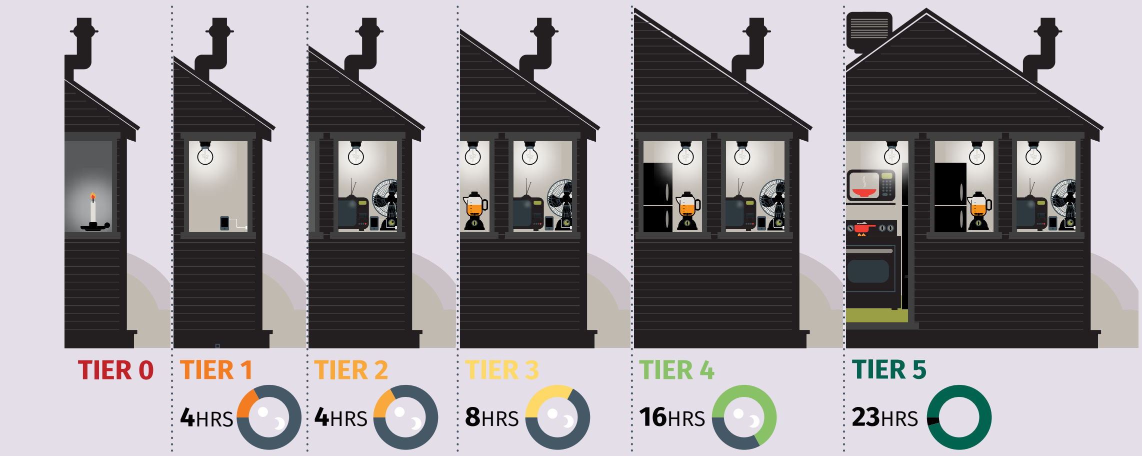
- ***Health and Safety*** ("Is it safe to use my electricity service?"): This attribute refers to any injuries to household members from using electricity service from the grid during the preceding 12 months of the survey. "Injury" could mean limb injury or even death from burn or electrocution. Such injuries can happen not just from faulty internal wiring (exposed bare wire, for example), but also from incorrect use of electrical appliances or negligence. The MTF analysis, however, does not make a distinction between the two. Electricity access is considered safe when users have not suffered from past accidents due to their electricity supply resulting in permanent injuries.

For each of these attributes, households are placed in a tier depending on the level of service as defined by the different thresholds (see table A1.1.). A household's overall tier of access is determined by the lowest tier value the household obtains among the attributes. At the national level, in the locality (urban or rural), and by the gender of the household head (man or woman household head), the distribution of the final aggregated tier and the individual attribute tier for all households as a distribution can be presented.

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 (see Box 2 for minimum requirements by tier of electricity access). Tier 0 refers to households that receive electricity for less than 4 hours per day (or less than 1 hour per evening) or that have a primary energy source with a capacity of less than 3 watts (3W). Tier 1 refers to households with limited access to small quantities of electricity provided by any technology, even a small solar lighting system (SLS) (see Box 3 for a typology of off-grid solar devices), for at least 4 hours a day, enabling electric lighting and phone charging.

Higher tiers are defined by higher 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 through 5, while Reliability, Quality, Formality, and Health and Safety attributes are applicable for Tiers 4 and 5. Access to the grid is the most likely result of achieving a higher tier, although a diesel generator or a minigrid use may also result in a similar outcome. Technological advances in photovoltaic solar home systems and direct current–powered energy-efficient appliances also make higher access to Tier 3 and even Tier 4 possible.

BOX 2 • MINIMUM REQUIREMENTS BY TIER OF ELECTRICITY ACCESS



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

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

Source: Bhatia and Angelou, 2015.

BOX 3 • TYPOLOGY OF OFF-GRID SOLAR DEVICES AND TIER CALCULATION

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

- **Solar lanterns** power a single light bulb and allow only part of the household to be classified in Tier 1 for Capacity. Under the MTF methodology, the number of household members in Tier 1 is based on the light output (lumen-hours) and phone charging capability of the solar lantern.
- **Solar lighting systems (SLS)** power two or more light bulbs and allow part or the entire household to be classified in Tier 1 for Capacity.
- **Solar home systems (SHS)** power two or more light bulbs and appliances such as televisions, irons, microwaves, or refrigerators. See table 1 for the load level associated with each Capacity tier.

Source: World Bank, 2018b.

TABLE 1 • Appliances by load level, and associated Capacity tiers

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

Source: Bhatia and Angelou, 2015.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Despite the well-documented benefits of access to clean cookstoves, about three billion of the world's population still use polluting, inefficient cooking solutions that emit toxic smoke. The inefficient use and incomplete combustion of solid fuels have significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009).[7] Fuel collection and cooking tasks are often carried out by women and girls; collection time depends on the local availability of fuel and may reach up to several hours per day (ESMAP, 2004; Gwavuya et al. 2012; Parikh 2011; Wang et al. 2013). Time spent in fuel collection often translates into lost opportunities for gaining education and increasing income (Blackden and Wodon 2006; Clancy, Skutch, and Batchelor 2003). In addition, associated drudgery increases the risk of injury and attack (Rehfuess et al., 2006).

The Multi-Tier Framework measures access to modern energy cooking solutions and is based on six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Safety of Primary Cookstove, Affordability and Fuel Availability (see table A1.2 in Appendix 1).

- **Cooking Exposure** *("How is the user's respiratory health affected?"):* This attribute assesses personal exposure to pollutants from cooking activities, which depends on stove emissions and ventilation structure (which includes cooking location and kitchen volume).[8] Thus, Cooking Exposure is a proxy indicator to measure the health impacts of the cooking activity on the primary cook. This attribute is a composite measurement of the emissions from the cooking solution, that is, a combination of the stove type and fuel, mitigated by the ventilation in the cooking area. Each of these components further has one or more subcomponents (Annex 3). The Cooking Exposure tier is assigned as a composite of emissions and ventilation tiers and is weighted by the amount of time spent on each stove, if a household relies on multiple stove types.
- **Cookstove Efficiency** *("How much fuel will a person need to use?"):* This attribute is a combination of combustion efficiency and heat-transfer efficiency. Laboratory testing of the efficiency of various types of cookstoves informs the breakdown of efficiency levels by cookstove and fuel combinations, which can be observed in the field with relative ease.[9]
- **Convenience** *("How long does it take to gather and prepare the fuel and stove before a person can cook?"):* This attribute is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and their stove for cooking. Convenience is measured through two indicators. First, the amount of time household members spend collecting or purchasing cooking fuel and preparing the fuel (in minutes per week) and the amount of time needed to prepare the cookstove for cooking (in minutes per meal).
- **Affordability** *("Can a person afford to pay for both the stove and the fuel?"):* This attribute assesses a household's ability to pay for the primary cooking solution (cookstove and fuel). Affordability is measured using the levelized cost of the fuel. A cooking solution is considered affordable if a household spends less than 5% of the total household expenditures on its cooking fuel. In this report, however, Affordability is measured using the cooking fuel expenditure only. The cost of the cookstove is not taken into account.

[7] Household air pollution has been associated with a wide range of adverse health impacts, such as increasing risk of acute lower respiratory infections among children under 5 years old and of chronic obstructive pulmonary disease and lung cancer (in relation to coal use) among adults above 30 years old. An association between household air pollution and adverse pregnancy outcomes (i.e., 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 Pruss-Ustun 2006; Smith, Mehta, and Maeusezahl-Feuz 2004).

[8] In this report, ventilation is defined as using a chimney, hood, or other exhaust system while using a stove or having doors or windows in the cooking area. The ventilation factor plays a role in mitigating pollutants from cooking. Kitchen volume was not considered for Zambia due to lack of reliable data.

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

- **Safety of Primary Cookstove** *("Is it safe to use the stove?")*: The degree of safety risk can vary by type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, or potential for fuel splatter. This attribute is measured through reported incidences of past injury and/or fire.
- **Fuel Availability** *("Is the fuel available when a person needs it?")*: The availability of a given fuel can affect the regularity of its use while shortages in the fuel can force households to switch to inferior fuel types. This attribute assesses the availability of fuel when needed for a household's cooking purposes

BOX 4 • TYPOLOGY OF COOKSTOVES IN ZAMBIA

In consultation with development partners and government officials, cookstoves in Zambia are classified into five categories (see Annex 3), as follows.

- **Open fire:** This consists of a pot balanced on three stones over an open fire or a tripod. In general, this stove uses firewood, has a low combustion temperature, and its fire is exposed to cold wind causing its heat to be lost to the ambient air.
- **Manufactured traditional stove (*mbaula*):** With this charcoal-based stove, the pot sits mostly on the fuel. It has a low combustion temperature due to poor insulation and a lot of cold excess primary air due to having too many openings. In Zambia, this is the most common manufactured traditional stove and its primary fuel source is charcoal.
- **Manufactured improved stove:** This has a higher combustion temperature due to its enclosed combustion chamber and some insulation; the pot sits above the fire, allowing more time for combustion.
- **LPG stove:** This is a clean stove that uses LPG.
- **Electric stove:** This is a clean stove that uses electricity.

Source: World Bank, 2018b.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

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

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

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

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

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN ZAMBIA[10]

MTF data collection in Zambia occurred from September 2017 to March 2018. The household survey sample selection was based on a two-stage stratification strategy, designed to be representative of the country at large. The Central Statistical Office (CSO) provided advice on sampling strategy, using the 2010 Census of Population and Housing database. CSO aggregated the Census data at the enumeration area (EA) level and provided EA maps for the team on the ground. A total of 3,612 households in 260 EAs (130 EAs each in urban and rural areas) from all the 10 provinces of Zambia were surveyed, following the stratification criteria: a 50:50 ratio of electrified and non-electrified households for the tier analysis and an equal allocation between urban and rural areas (table 2 and Figure 3). In each EA, 14 households were interviewed. The sampling strategy is provided in Annex 2.[11]

[10] The results of the MTF survey data collection and analysis were presented to the Government of Zambia's Ministry of Energy and Water Development (MEWD) and Department of Energy (DoE); and to the CSO, Rural Electrification Authority (REA), ZESCO Limited, as well as to development partners.

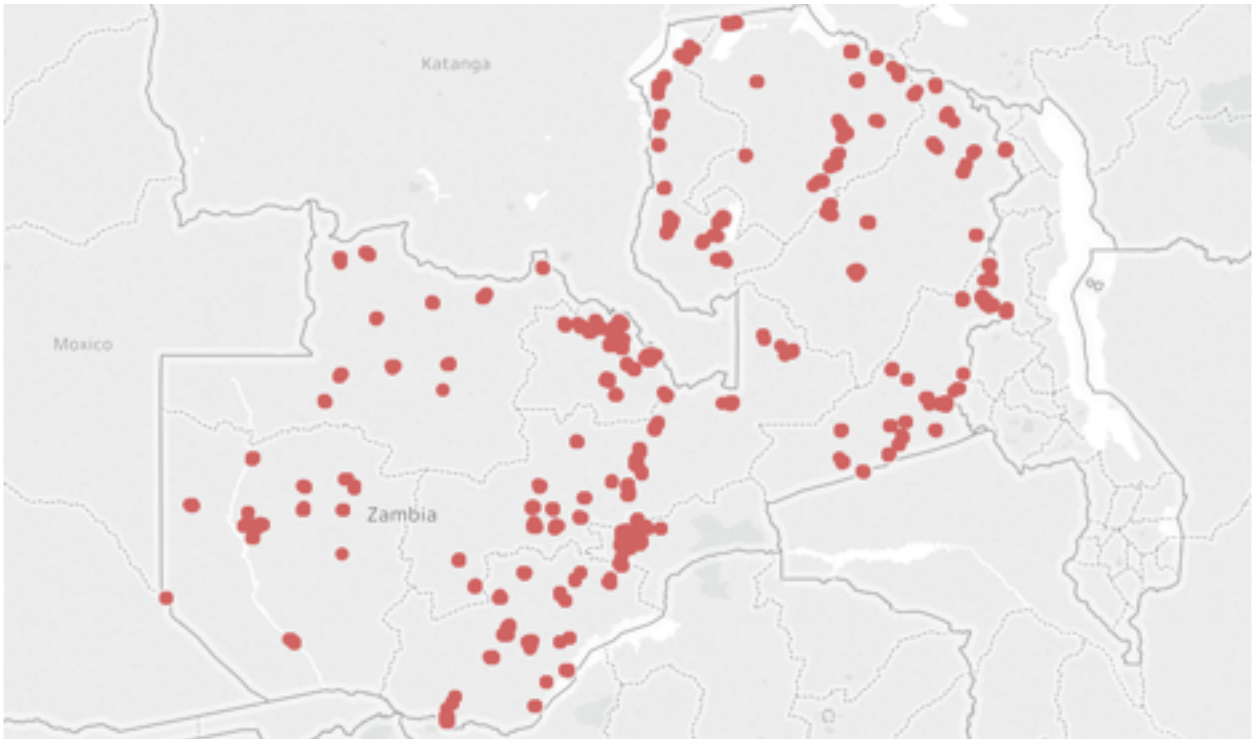
[11] Of the original sample size of 3,668 targeted households, 3,612 households were contacted, and 3,537 were effectively interviewed. The response rate was thus 96%, which is the difference between the sample of households originally targeted and those finally interviewed. The non-response was mainly due to movement out of the dwelling of respondents (43 households) and unwillingness to participate in the survey

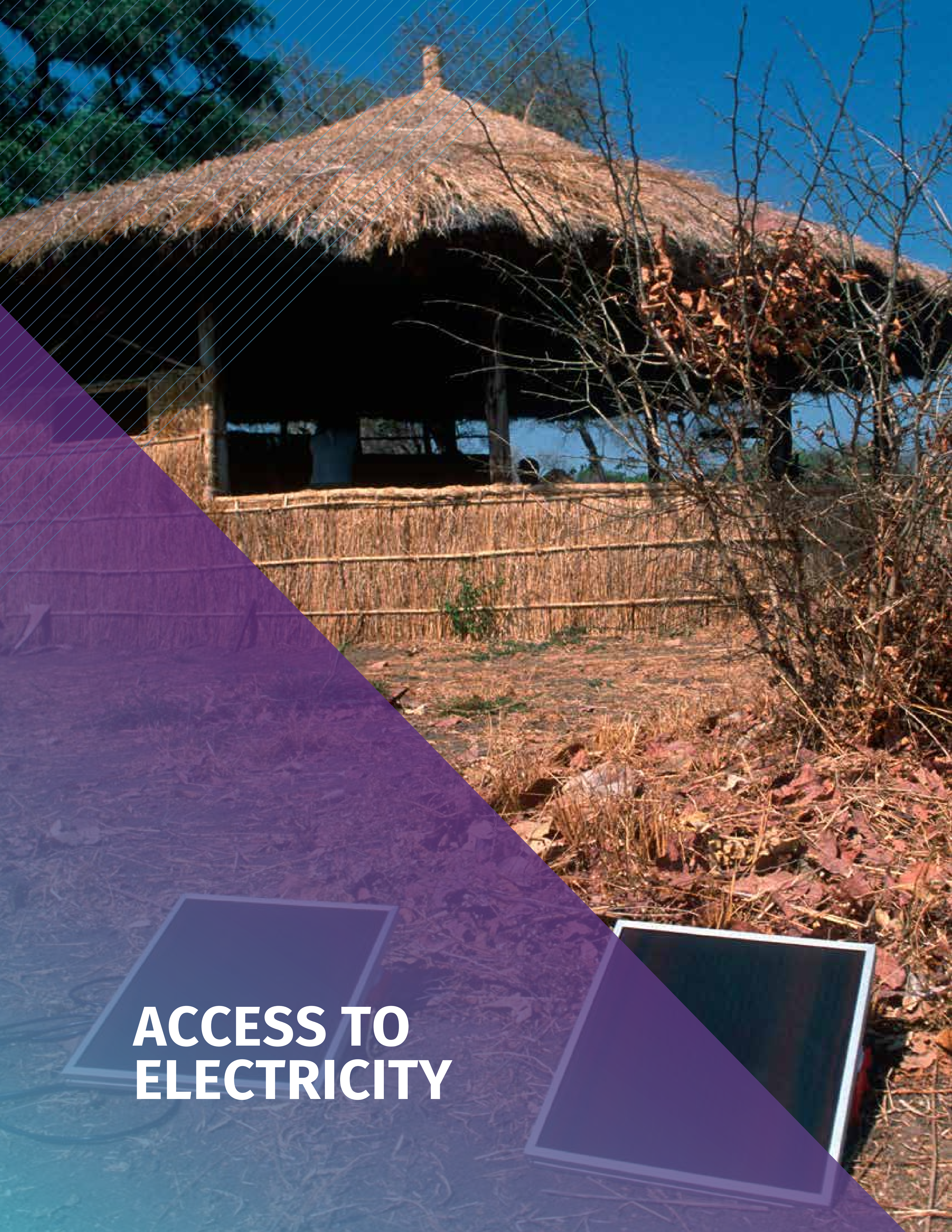
TABLE 2 • Distribution of enumeration areas and sampled households, MTF Survey, Zambia – original sample (households interviewed)

Type of fuel	Urban				Rural				Nationwide			
Province	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs
Central	69	42	111	8	18	192	210	15	87	234	321	23
Copperbelt	361	165	526	39	15	81	96	7	376	246	622	46
Eastern	37	32	69	5	7	301	308	22	44	333	377	27
Luapula	24	42	66	5	18	190	208	16	42	232	274	21
Lusaka	415	249	664	48	40	58	98	7	455	307	762	55
Muchinga	23	17	40	3	6	131	137	10	29	148	177	13
North Western	15	39	54	4	0	100	100	9	15	139	154	13
Northern	26	38	64	5	14	172	186	14	40	210	250	19
Southern	85	55	140	10	30	206	236	17	115	261	376	27
Western	21	21	42	3	0	182	182	13	21	203	224	16
Total	1,076	700	1,776	130	148	1,613	1761	130	1,224	2,313	3,537	260

Note: EA = enumeration area. HH = household.

FIGURE 1 • MTF survey, Zambia: Sample distribution





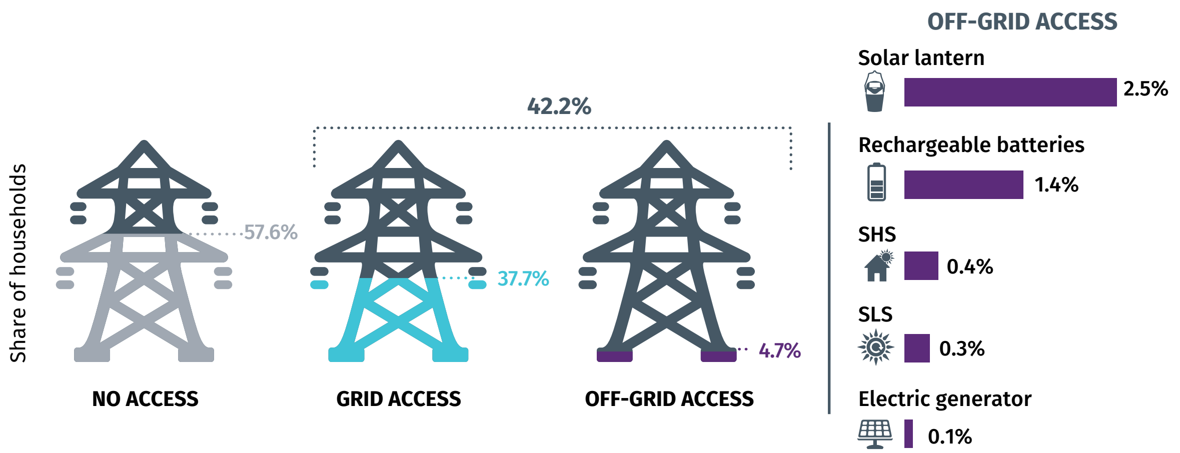
ACCESS TO ELECTRICITY

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

In Zambia, 42.4% of households have access to at least one source of electricity: 37.7% have access through the national grid, and 4.7% use off-grid solutions (Figure 2). Among the households with an off-grid solution, over half (2.5% of all households) use a solar lantern – typically providing lighting and phone charging – while a very small share use a solar home system (SHS) or a solar lighting system (SLS). None of the household sampled in the MTF survey in Zambia used mini-grid as the main source of electricity[12].

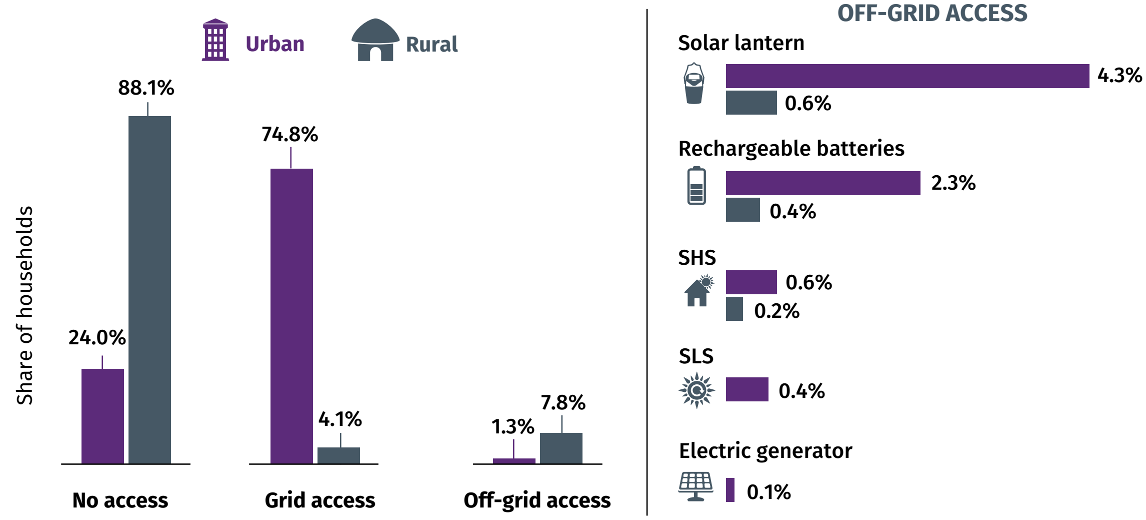
FIGURE 2 • **Access to electricity by technology, nationwide**



The discrepancy in access to electricity between urban and rural areas is substantial. In urban areas, three out of four households have access to electricity, compared to only about 1 in 10 households in rural areas (Figure 3). Grid access is the main source of electricity in urban areas (almost 75%). In rural areas, two out of three electrified households have access through an off-grid solution.

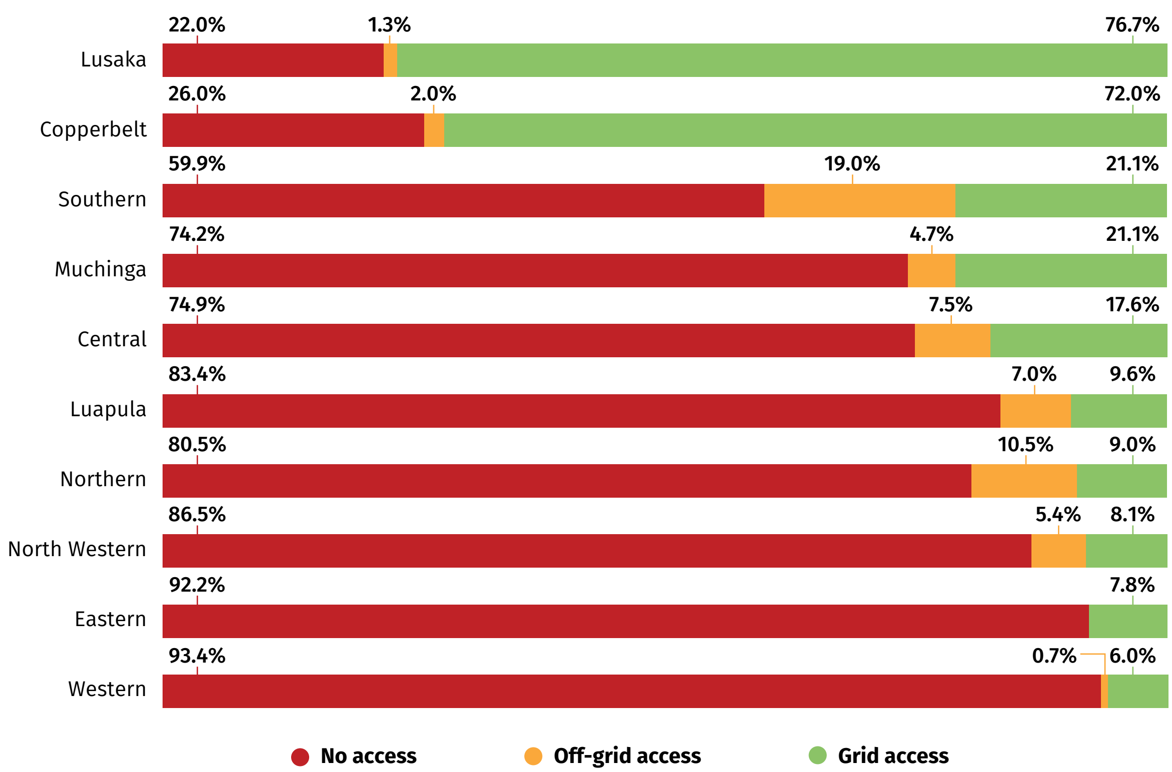
[12] ZESCO operates several diesel-based mini-grids with emerging public (e.g. through REA) and private activity in solar PV- and hydro-based mini-grids (REMP, 2009). For a more detailed description of mini-grid solutions in the country, please refer to RECP (2018).

FIGURE 3 • **Access to electricity by technology, urban vs. rural**



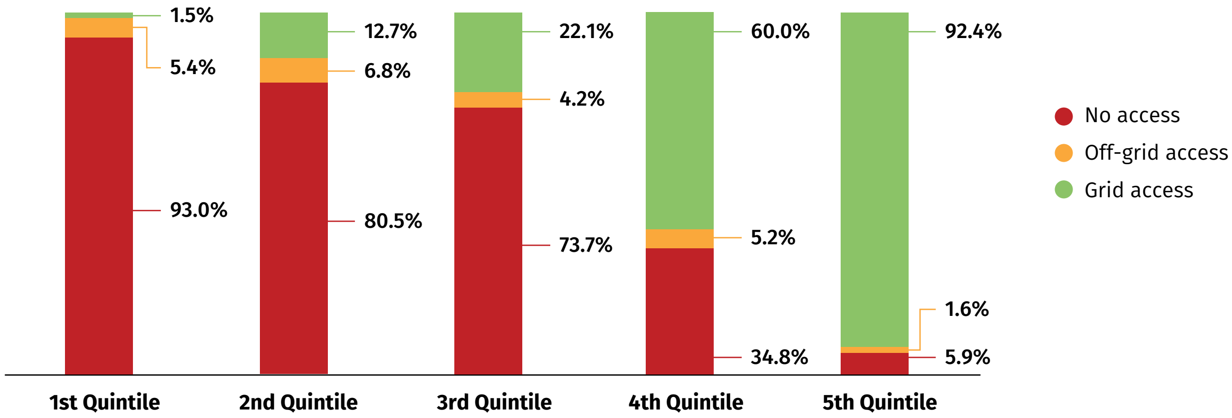
In Zambia, access to electricity varies across provinces. In the provinces of Lusaka and Copperbelt, above 70% of households are connected to the grid, whereas the rate ranges from 21% to as low as 6% in the rest of the country (Figure 4). The penetration of off-grid solutions also varies across provinces. In the Southern province, 19% of the households have off-grid access; the rate drops to 10.5% in the Northern province, while a few other provinces show a small share of off-grid households.

FIGURE 4 • **Access to electricity by technology, by province**



Access to electricity is correlated with wealth. Over half of the households in the lowest quintile lack access to electricity, while this is the case for only 3% of the households in the highest quintile (Figure 5). The grid access rate increases with the level of household expenditure. In the highest expenditure quintile, the vast majority of the households (92.4%) have access to the grid, compared to a very small share (1.5%) of households in the lowest quintile. Off-grid solutions are more common among households in the lower quintiles.

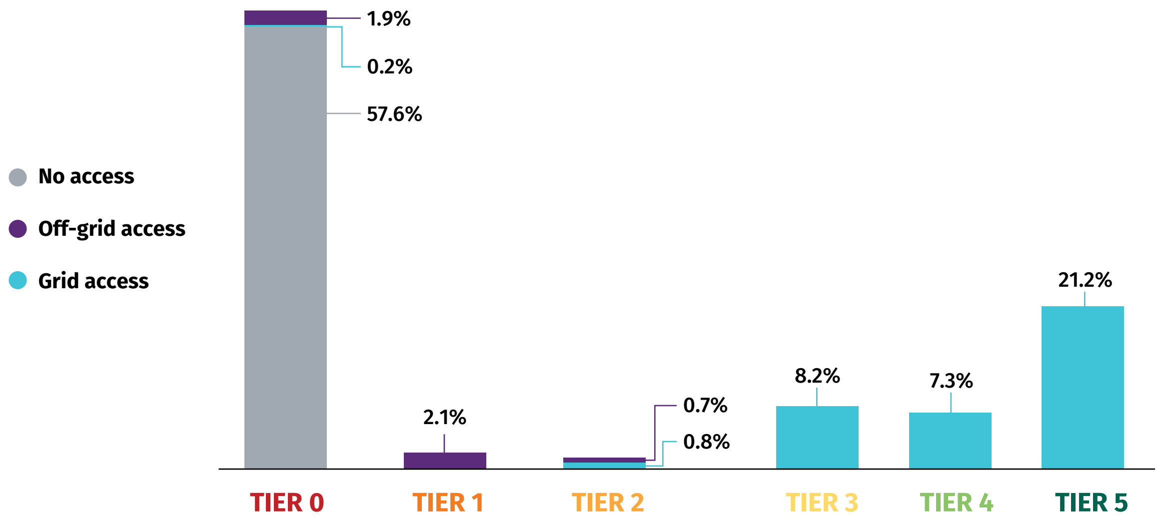
FIGURE 5 • **Access to electricity by technology, by expenditure quintile, nationwide**



MTF TIERS

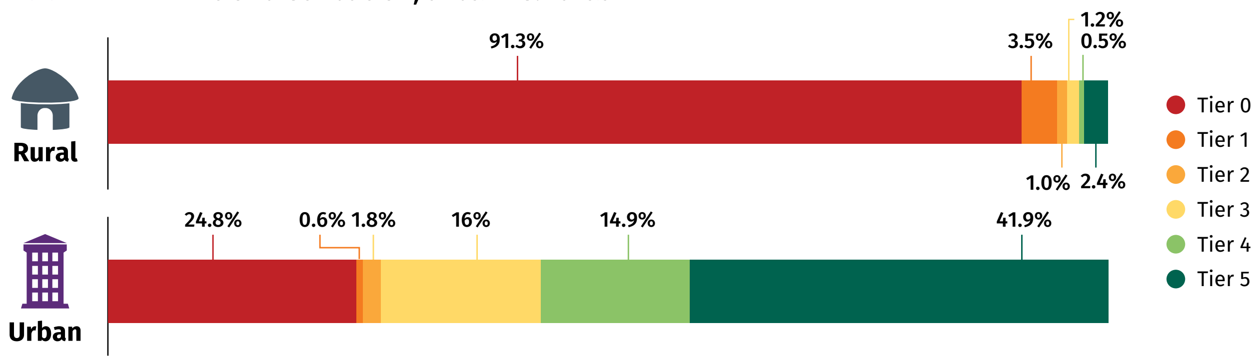
Nationwide, 40.3% (1.4 million households) of the households are in Tier 1 or above for electricity access, and over half of those are in Tier 5 (Figure 6). Among the 59.7% of Zambian households (2.1 million households) that fall in Tier 0, the large majority has no access to any source of electricity. About 1.9% of households using off-grid solutions and 0.2% of households connected to the grid still fall in Tier 0, because given that their electricity supply does not satisfy Tier 1 requirements. This is due to the limited Capacity or Availability of off-grid solutions or to the limited Availability of the grid supply. The remaining off-grid households fall in Tier 1 (2.1%) or Tier 2 (0.7%). Grid users are concentrated in Tier 3 or above, with over half of them reaching Tier 5.

FIGURE 6 • **Access to electricity by technology, by expenditure quintile, nationwide**



Electricity access is largely a rural challenge (figure 7). More than 9 in 10 rural households (1.6 million households) are in Tier 0 for access to electricity, while the remainder (8.7%) are dispersed across Tiers 1 through 5. The majority of urban households are in Tier 5, and about one-quarter (0.4 million households) remain in Tier 0. As a result, the "average" tier for urban households is 3.2, compared to only 0.2 for rural households.

FIGURE 7 • **MTF tier distribution, urban vs. rural**

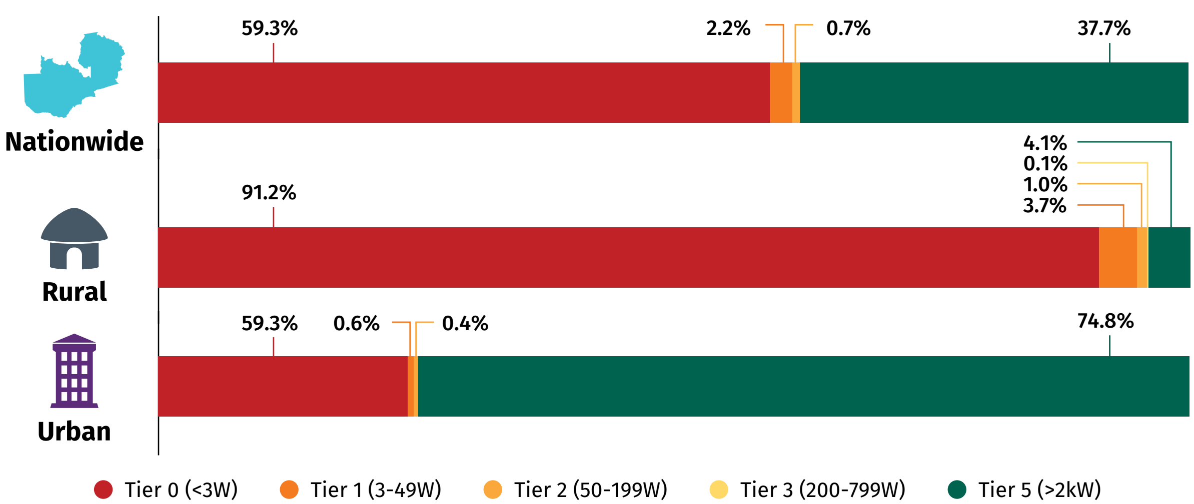


MTF ATTRIBUTES

Capacity

Capacity is the load capacity of the service that households receive from electricity connection. The MTF survey does not measure capacity of the service directly but attempts to estimate it from household appliance usage.[13] Because grid-connected households are considered to be receiving high-capacity electricity (over 2,000 watts), the share of households that receive high-capacity electricity is the same as the share of households connected to the grid (37.7%) (figure 10). The capacity of off-grid solutions typically ranges between 3W and 49W for 2.2% of the households, while only 0.7% of households have a larger off-grid solution (50W to 199W).

FIGURE 8 • **Distribution of households based on electricity Capacity, nationwide, urban and rural**

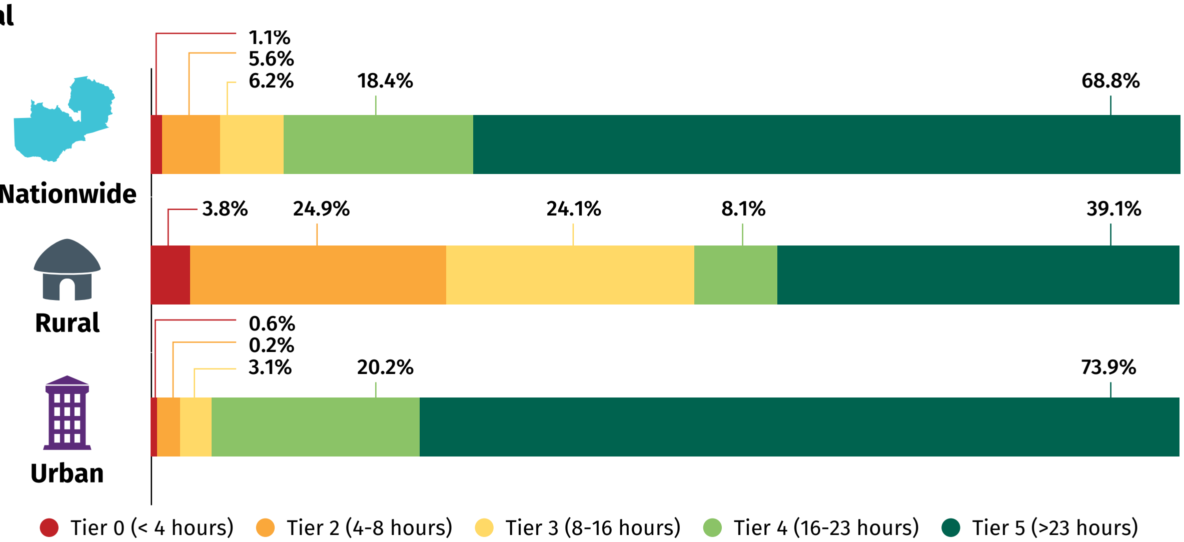


[13] The distribution of off-grid households by tiers of Capacity attribute is shown in figure 33.

Availability

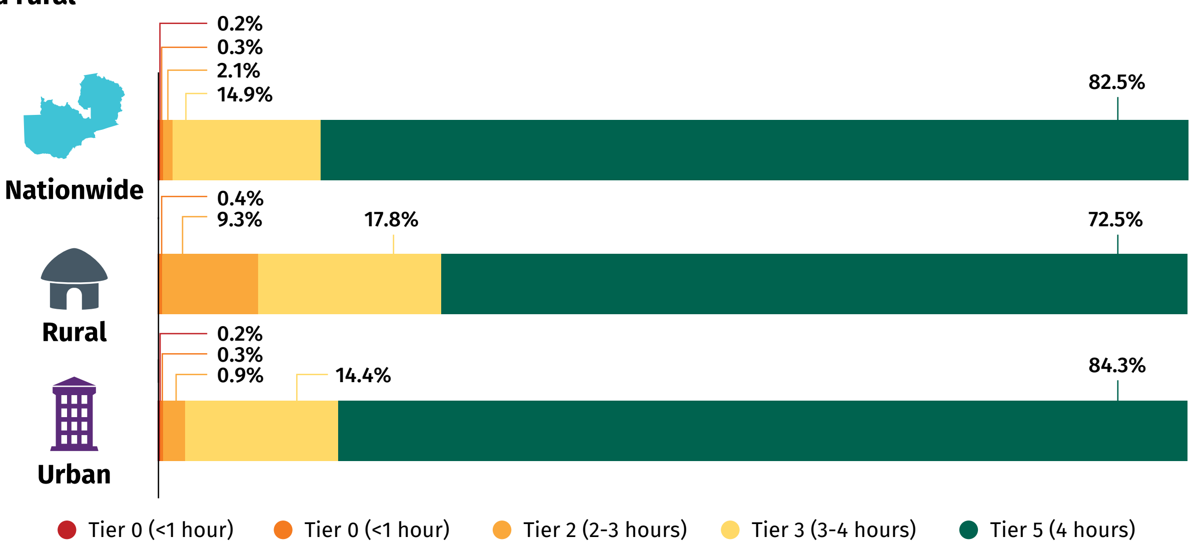
The Availability attribute corresponds directly to availability of electricity service during the day (24 hours) and in the evening (4 hours after sunset) as outlined in table A1.1 in Annex 1. Figures 9 and 10 show household distribution by availability. Availability of electricity service day and night is an important attribute. About one third of the households in Zambia have limited Availability of electricity (less than 23 hours per day) (figure 9). The share increases to over 60% in rural areas. Close to one-third of rural households receive less than 8 hours of electricity per day, compared to less than 1 in 10 urban households. Electricity supply in the evening (between 6pm and 10pm) seems to be an issue for about 2 in 10 households (figure 10).

FIGURE 9 •**Distribution of households based on Daily electricity Availability, nationwide, urban and rural**



Note: Sample size = 1,413 households. Only households with access to an electricity source.

FIGURE 10 • **Distribution of households based on Evening electricity Availability, nationwide, urban and rural**

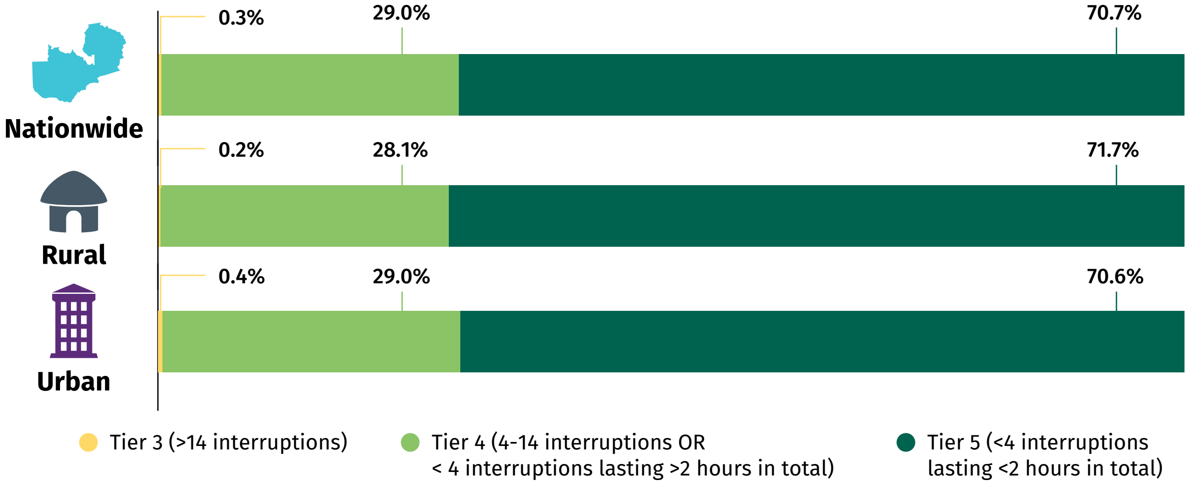


Note: Sample size = 1,413 households. Only households with access to an electricity source.

Reliability

The Reliability attribute captures the frequency and duration of unscheduled outages, and it only applies to grid-connected households. About one-third of the grid-connected households face frequent, unpredictable power outages (figure 11). Most of them suffer from 4 to 14 interruptions per week lasting over 2 hours in total. Results are similar across urban and rural households. Nationwide, the average duration of outages for grid-connected household is 7.2 hours in typical months.

FIGURE 11 • **Distribution of households based on electricity Reliability, nationwide, urban and rural**

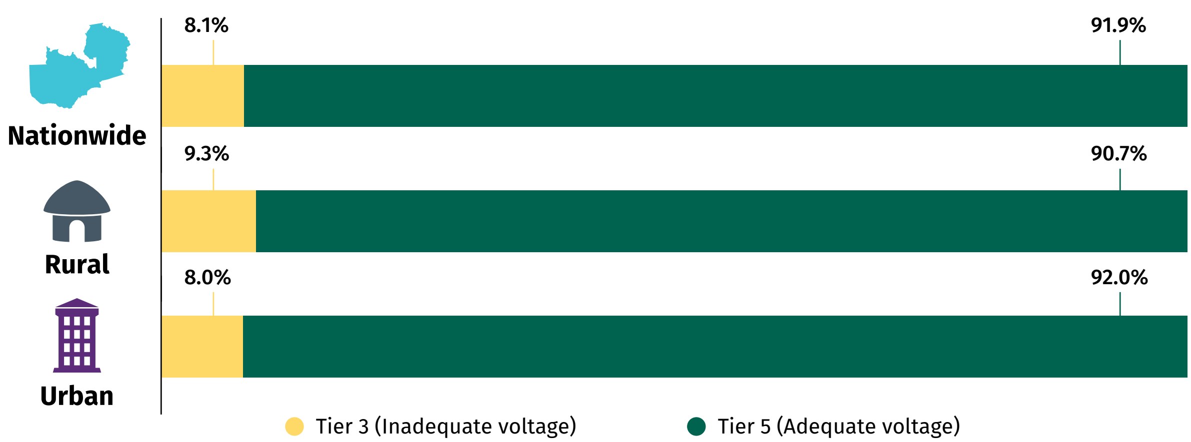


Note: Sample size = 1,224 households. Only grid-connected households.

Quality

The Quality attribute applies only to households on either the national grid or mini-grids. Electric appliances generally require a certain voltage supply to operate properly. In Zambia, about 8.1% of the grid-connected households face voltage issues, such as low or fluctuating voltage, resulting in appliance damage (figure 12).

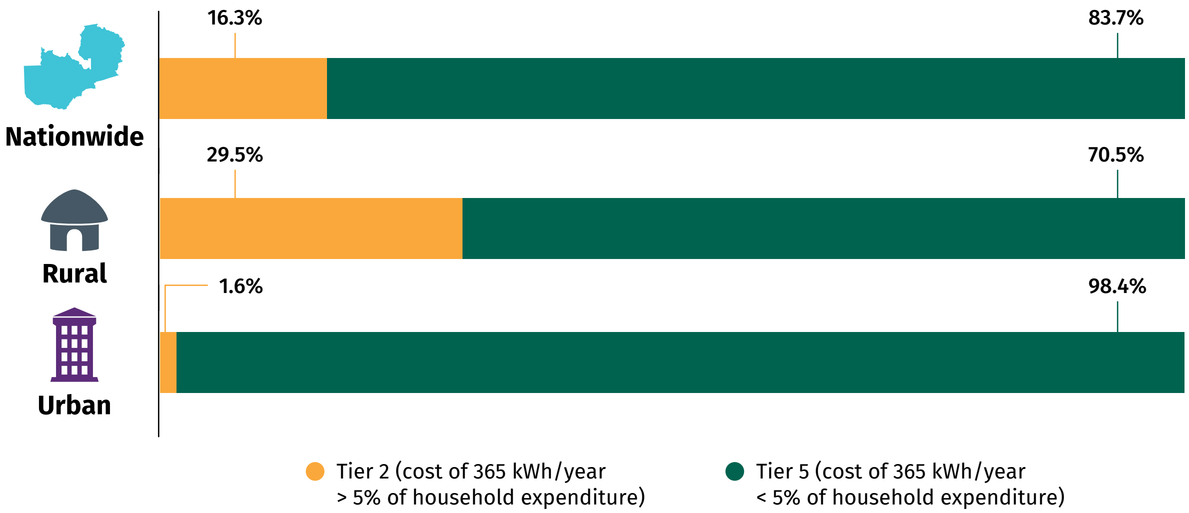
FIGURE 12 • **Distribution of households based on electricity Quality, nationwide, urban and rural**



Affordability

The Affordability attribute measures the percentage of households that can afford subsidized electricity. About 16.3% of Zambian households cannot afford to pay for basic electricity services, corresponding to 365 kWh per year (figure 13). The share drops to 1.6% of households in urban areas. Nonetheless, about one-quarter of urban households still lack access to electricity, suggesting that Affordability of basic electricity consumption may not be the main barrier in urban areas.[14] In rural areas, one-third of households face Affordability issues, while 88.1% do not have any electricity access. This suggests that the current tariff in Zambia is affordable to the majority of households.

FIGURE 13 • **Distribution of households based on electricity Affordability, nationwide, urban and rural**



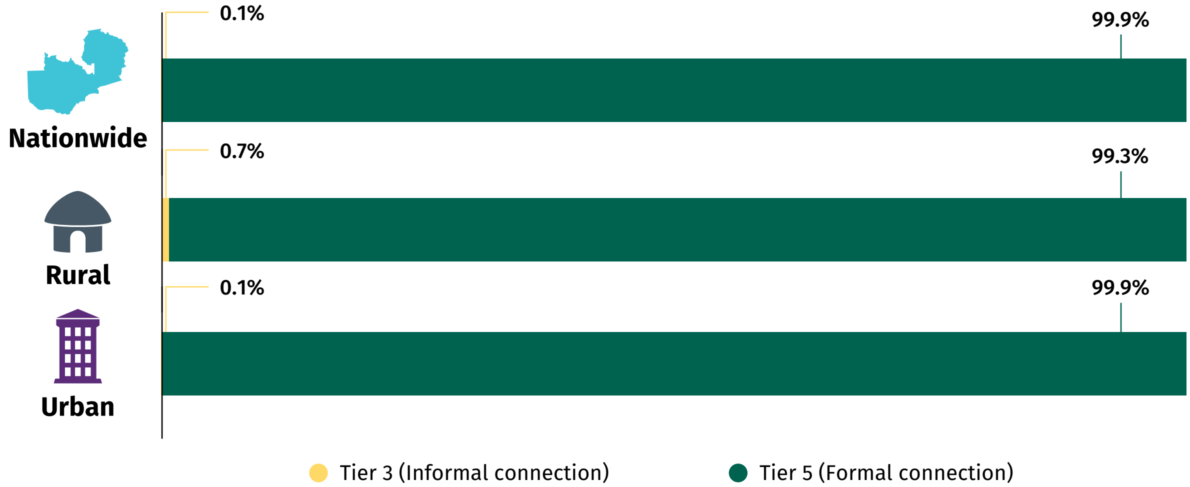
Note: Sample size = 3,537 households. All households.

Formality

Formality refers to a household's grid connection provided and/or sanctioned by the authority. Informal connections, on the other hand, are those obtained by means not authorized by the electricity company, for example those made by diverting cables from the outdoor electric line. Reporting on Formality is challenging, because households may be sensitive about disclosing such information in a survey. The Multi-Tier Framework (MTF) survey infers information on Formality from indirect questions that respondents may be more willing to answer (such as what method a household member uses to pay the electricity bill), so the actual percentage of households with an informal connection may differ from the data reported here. Almost all grid-connected households are reported to have a formal connection (figure 14).

[14] The electricity tariff in Zambia is ZMW 0.15/kWh for the first 200 kWh consumed monthly, and ZMW 0.89/kWh for above 200 kWh. It also includes a fixed monthly charge of ZMW 18.23.

FIGURE 14 • **Distribution of households based on Formality, nationwide, urban and rural**

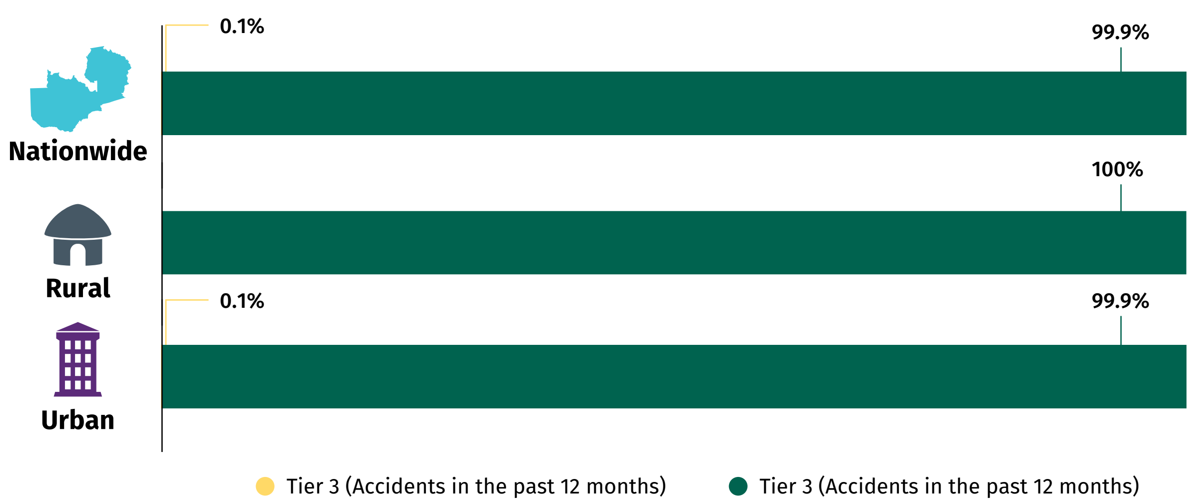


Note: Sample size = 1,224 households. Only grid-connected households.

Health and Safety

Health and Safety attribute refers to any injuries to household members from using electricity service from the grid during the preceding 12 months of the survey. Electricity access is considered safe when users have not suffered from past accidents due to their electricity supply resulting in permanent injuries. Health and Safety issues do not seem to occur widely in Zambia, as only 0.1% of grid-connected households reported accidents causing permanent injury or death (figure 15). It is however always important to ensure that all households are aware of basic safety measures and 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, urban and rural**

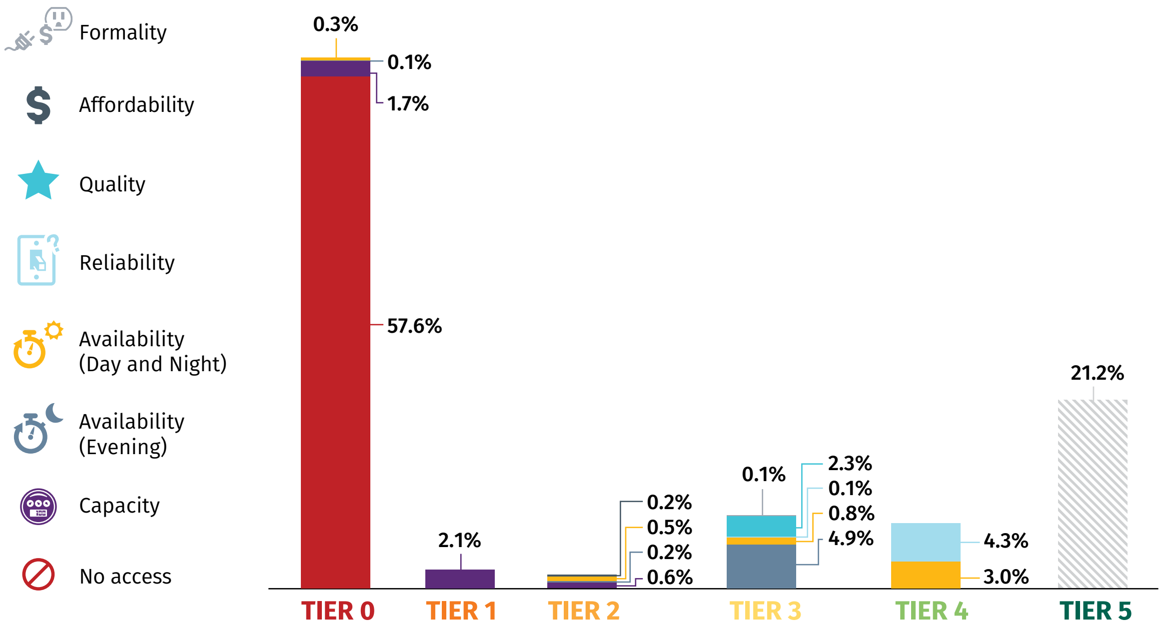


Note: Sample size = 1,224 households. Only grid-connected households.

IMPROVING ACCESS TO ELECTRICITY

The large majority of households in Tier 0 do not have access to any electricity source (Figure 16). About 2.1% of households in Tier 0 and 2.1% in Tier 1 are held back mainly because of the Capacity limitations of their off-grid system. Households in Tiers 3 to 5 (36.7%) are all grid-connected (Figure 18). Households in Tier 3 are held back mainly due to poor Evening Availability (less than 4 hours), as well as Quality issues. Households in Tier 4 suffer from poor Reliability and limited Daily Availability. Different policies are required for households that do not have access to any source of electricity, households that have off-grid access but remain in Tier 0, and households that are connected to the grid but do not reach Tier 5[15]..

FIGURE 16 • **Gap analysis for electricity access: MTF distribution by attribute, nationwide**



The number of households in Tier 0 that are in non-grid-electrified EAs (enumeration areas without grid infrastructure) is much higher in rural (38.6%) than in urban (1.4%) areas. Conversely, the number of households in Tier 1 or above is much higher in urban (35.8%) than in rural (4.5%) areas (table 3). The number of households in Tier 0 that are in grid-electrified EAs is similar in urban and rural settings (10.4% and 9.3%). Forty percent of the population would benefit from investments to improve the quality of their existing grid or off-grid service, with most benefits accruing to urban households. About 20% of the population would benefit from policies to increase the number of last-mile grid connections, benefiting both urban and rural households. A final 40% of the population would benefit from grid extension to electrify the EA, and as these households are mainly rural, that would also likely require policy support to incentivize connections.

15 Households in Tier 5 do not have any constraint as they are in the highest tiers already.

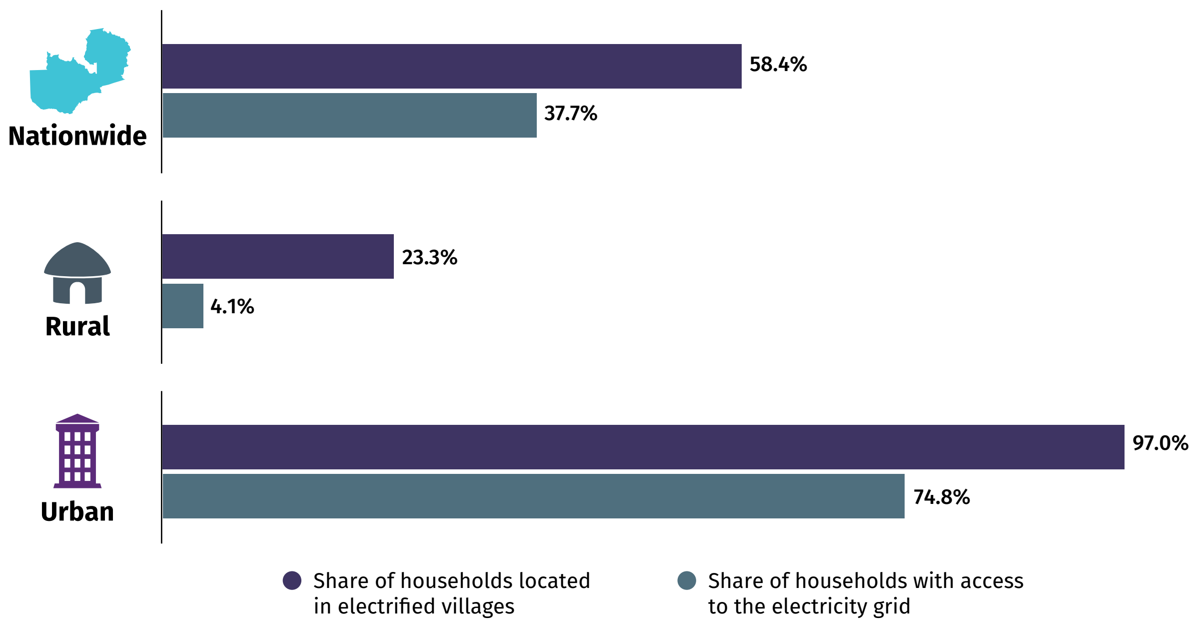
TABLE 3 • **Distribution of households by tiers, nationwide, urban and rural**

	Households in Tier 0		Households in Tier 1 or higher	Total
	Non-grid-electrified EAs	Grid electrified EAs		
Urban	1.4%	10.4%	35.8%	47.6%
Rural	38.6%	9.3%	4.5%	52.4%
Nationwide	40%	19.7%	40.3%	100%

PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

About 37.7% of households in Zambia are connected to the grid. However, 58.4% of households are located in EAs where the grid is available, that is, in EAs where at least one household is connected to the grid (figure 17). The uptake rate is the ratio between the percentage of electrified households over the percentage of electrified villages (EAs). In Zambia, the national uptake rate is 64.6%; 77.1% of urban households in proximity to the grid are connected, while only 17.7% of rural households are. Thus, densification projects may enable about 20.7% of households nationwide to get access to the existing grid.

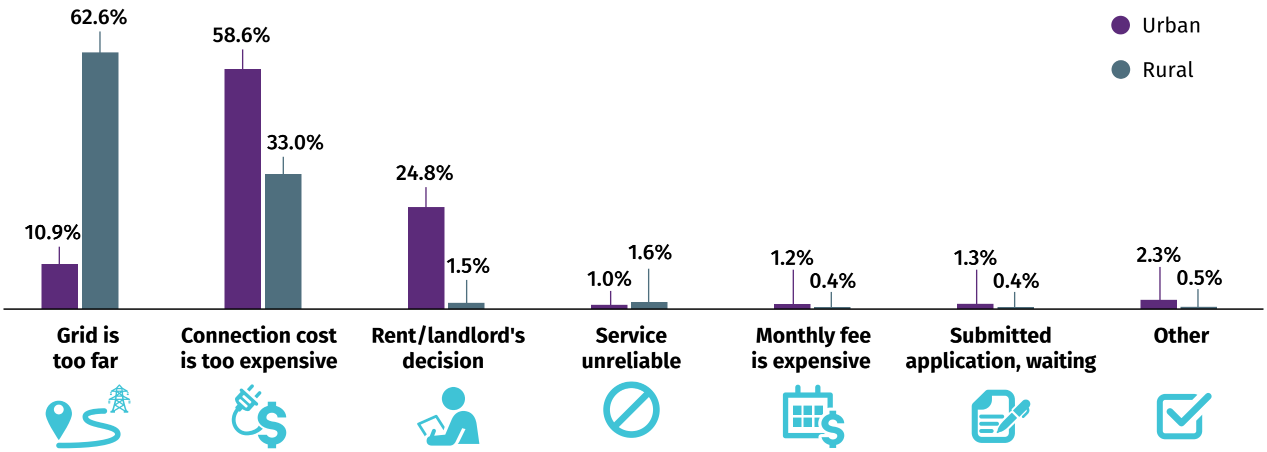
FIGURE 17 • **Comparison of electrification rate between villages (EA) and households, nationwide, urban and rural**



Note: Households living in the village (EA) where at least one household has a grid connection are defined as being under the grid.

Nationwide, the most common barrier preventing households from gaining access to the grid is the connection fee (figure 18). As mentioned earlier, households without any source of electricity tend to be poorer than households with either grid or off-grid access (see figure 5). Nonetheless, the distance of affected households from grid infrastructure is even a stronger barrier for rural households. The second most common barrier for urban households is the fact that they are renting their dwelling and the decision to obtain a grid connection lies with the landlord.

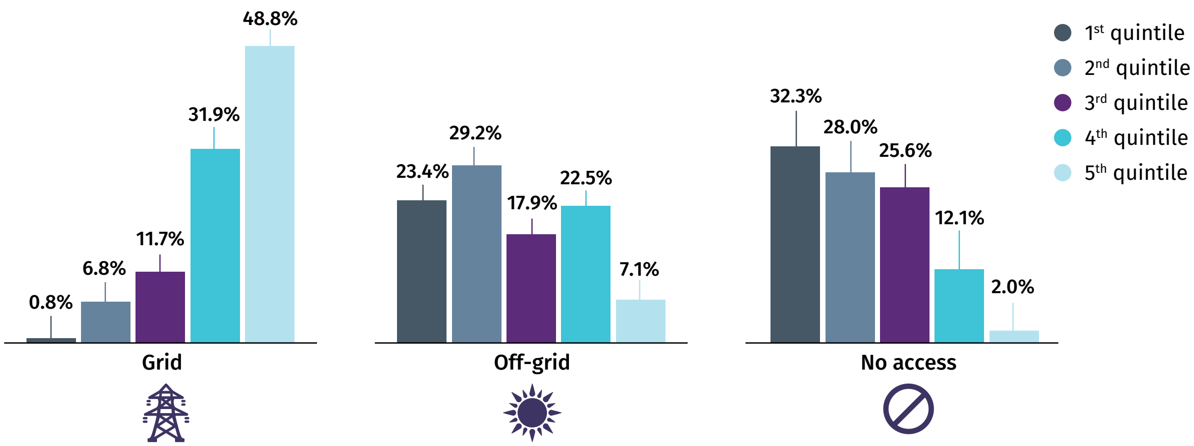
FIGURE 18 • **Barriers to gaining access to grid electricity among households not connected to the grid, urban vs. rural**



Note: Sample size = 2,313 households. Only households that are not connected to the grid.

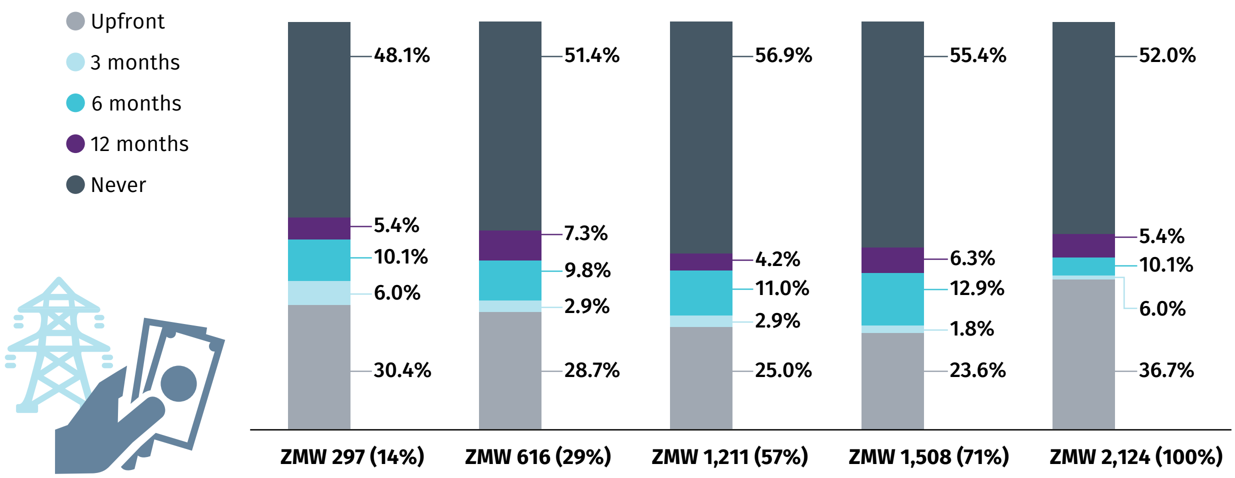
A closer look at households' total monthly expenditure shows that nonconnected households are likely to be either among the poorest households or members of a group that requires additional support to be connected (figure 19). On average, rural and urban grid-connected households spend ZMW 2,479 (US$270.8) and ZMW 3,957 (US$432.2) per month, respectively. Meanwhile, rural households without a grid connection on average spend ZMW 918 (US$100.3), while urban households without a grid connection spend ZMW1,454 (US$158.9) on average..

FIGURE 19 • **Expenditure quintile distribution for households without electricity, nationwide**



The MTF willingness to pay modules try to assess whether price reduction and flexible payment periods can increase the adoption rate of the national grid. Most rural households are not willing to pay for a grid connection under any payment plan or price suggested. Only about 23.6% to 36.7% of rural households are willing to pay for the connection cost up-front, depending on the price (Figure 20). Nonetheless, offering flexible payment options – installments paid over 6, 12, or 24 months – can to some extent address the burden of the high up-front cost of connection. Around 20% of rural households are willing to pay for the connection fee over a period of 3, 6, or 12 months, for a connection fee of ZMW 297 (US$32.4) to ZMW 1,508 (US$164.7). If the fee rises to ZMW 2,124 (US$232), only 11% of rural households are interested in a payment plan.

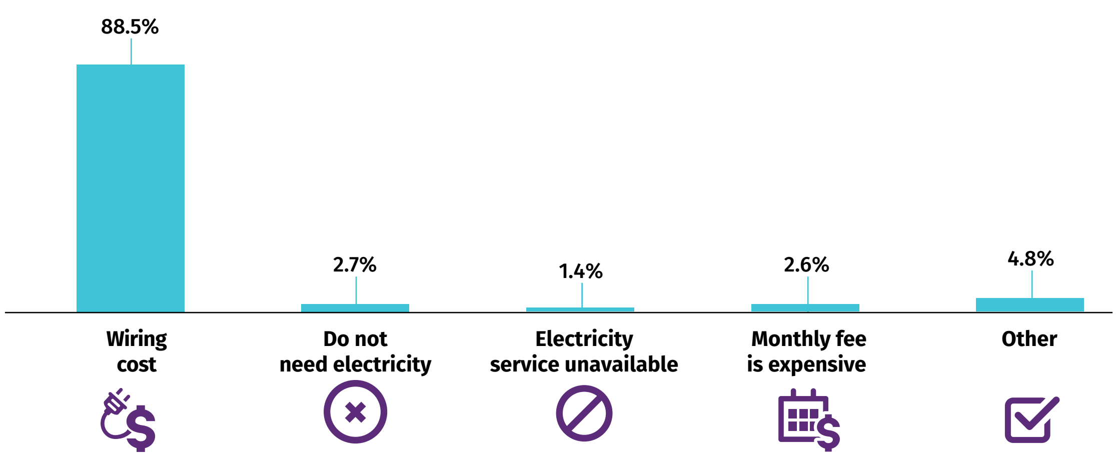
FIGURE 20 • **Willingness to pay for the grid connection fee for non-grid-connected households, by alternative connection fee prices, rural**



Note: Sample size = 1,574 households. Only rural households that are not connected to the electricity grid. Even though Zambia has different connection prices for different locations, this figure includes only the rural category, given that the urban category (urban high/low/medium cost) does not have enough observations.

About 55.9% of households stated that they would not accept any offer to connect to the grid even if the connection cost was waived. The main reason is because households cannot afford the internal wiring cost (Figure 21).

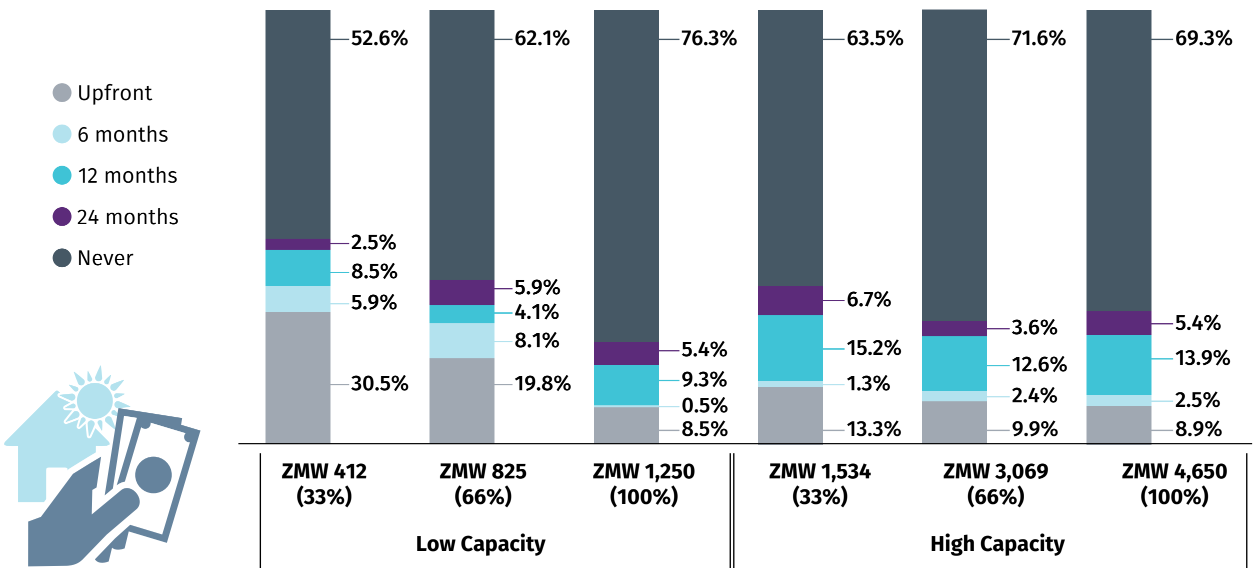
FIGURE 21 • **Reason for not willing to pay for grid connection, nationwide**



Note: Sample size = 765 households.

Willingness to pay for a solar home system (SHS) is much lower than willingness to pay for a connection to the grid, but it increases as the price drops (Figure 22). Different prices were offered to different survey respondents. The full price for a low-capacity SHS is ZMW 1,250 (US$136.5) and for a high-capacity SHS it is ZMW 4,650 (US$507.9). Apart from the full price, two other prices, 33% and 66% of the full price, were also offered to respondents. Although only 1 in 4 households are willing to pay for a low-capacity SHS at a price of ZMW1,250 (US$136.5), over half of the households are willing to pay for it at one-third of the initial price. The share of households willing to pay up-front also increases as the price lowers. As with the willingness to pay for a grid connection, for an SHS roughly 20% of households are interested in a payment plan over 6, 12, or 24 months..

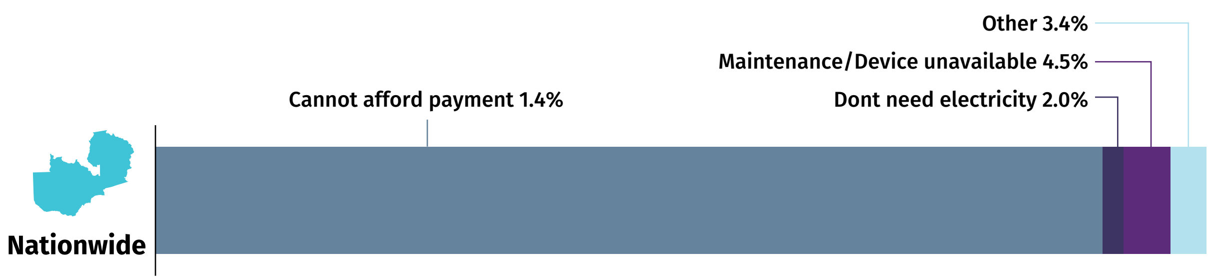
FIGURE 22 • **Willingness to pay for a solar home system, by alternative prices**



Note: Sample size = 2,109 households.

The majority of households are not willing to pay for any SHS under any price or payment plan, due to Affordability issues (Figure 23). Only 5% of households considered maintenance and the lack of availability of the system as a barrier.

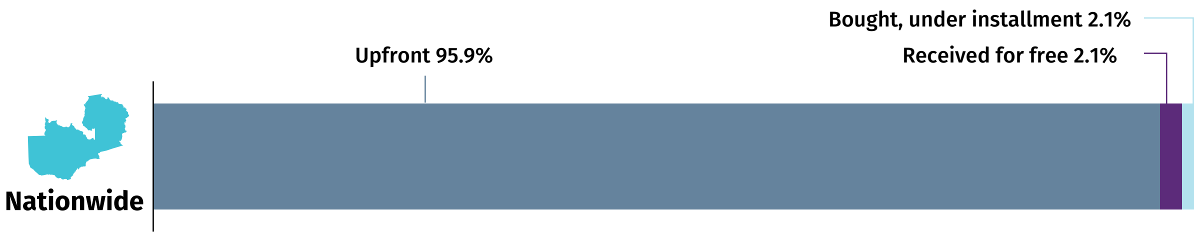
FIGURE 23 • **Reasons for being unwilling to pay for an SHS**



Note: Sample size = 1,345 households.

Among households that use a solar device, 98% purchased it (Figure 24). The majority of households that purchased a solar device paid the full price up-front (about 96%), and 2.1% paid in installments. Only 2.1% of the households received their device for free. As illustrated by the results on willingness to pay for solar products (Figure 22), and the reasons for not willing to pay for a SHS (Figure 25), the provision of a flexible payment plan would enable more households to acquire solar systems. Also, existing users of solar devices could more easily upgrade their systems and benefit from using higher-load appliances.

FIGURE 24 • **Modality of solar device acquisition among households using a device, nationwide**

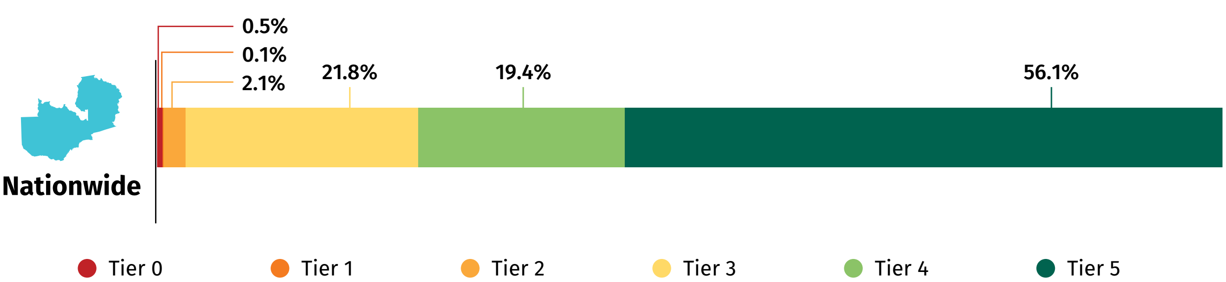


Note: Sample size = 189 households. Only households that use solar solutions.

IMPROVING ELECTRICITY ACCESS FOR GRID-CONNECTED HOUSEHOLDS

The performance of the grid in Zambia is fairly satisfactory, as 3 in 4 grid-connected households are in Tier 4 or 5 (Figure 25). The remaining households are primarily in Tier 3 (21.8%), while few (2.7%) fall in the lower tiers. On average, about 30% of grid-connected households in Zambia have been electrified for more than 10 years, while about 18.2% of these households have been electrified during the last 5 years.

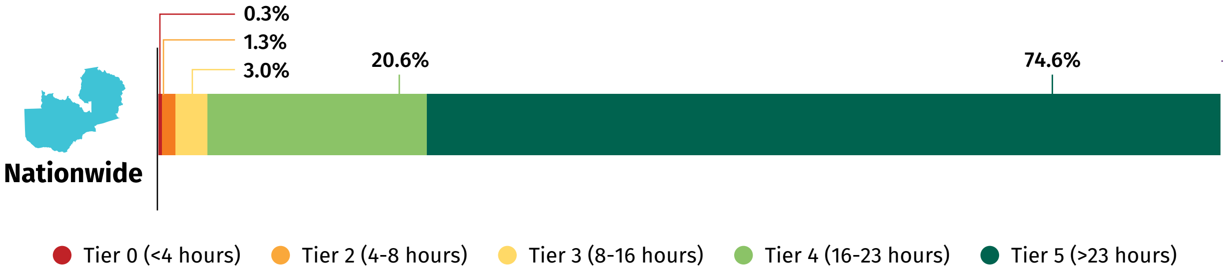
FIGURE 25 • **MTF tier distribution of grid-connected households, nationwide**



Note: Sample size = 1,224 households. Only grid-connected households..

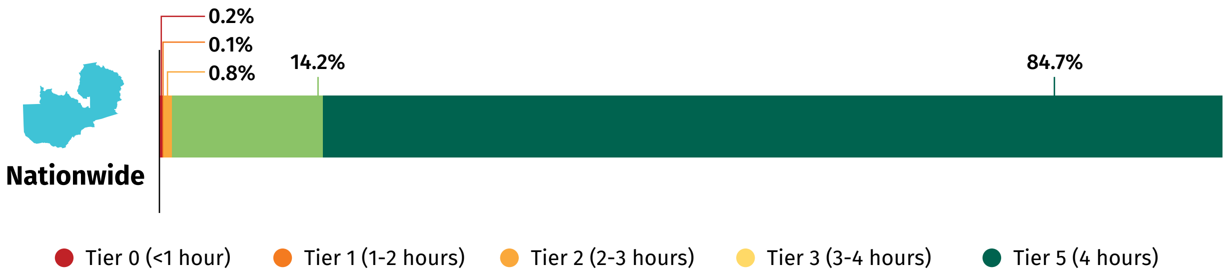
Poor Availability, Quality, and Reliability are the main issues preventing 43.9% of the grid-connected households from reaching Tier 5 access. About 1 in 4 grid-connected households has limited Daily Availability of supply (<23 hours per day), and 15.3% of them have less than 4 hours in the evening (between 6pm and 10 pm) (Figures 26 and 27). Reliability issues affect 29% of grid-connected households, as they experience between 4 and 14 power outages per week, lasting over 2 hours in total (Figure 28). Finally, about 8.1% of grid-connected households reported voltage issues resulting in appliance damage (Figure 29).

FIGURE 26 • Distribution of grid-connected households by Daily Availability, nationwide



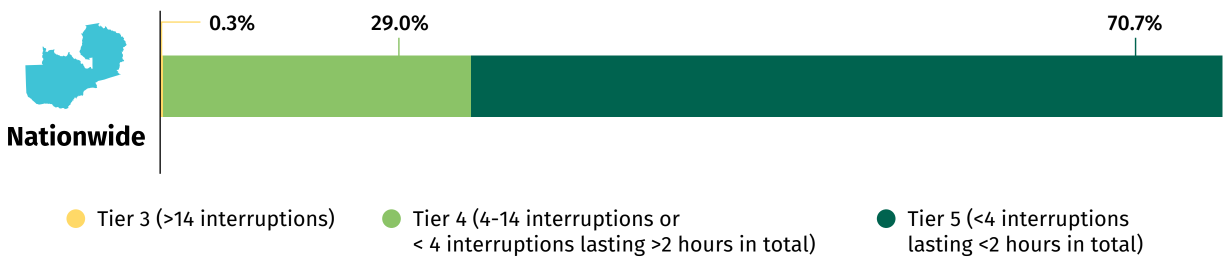
Note: Sample size = 1,224 households. Only grid-connected households.

FIGURE 27 • Distribution of grid-connected households by evening Availability, nationwide



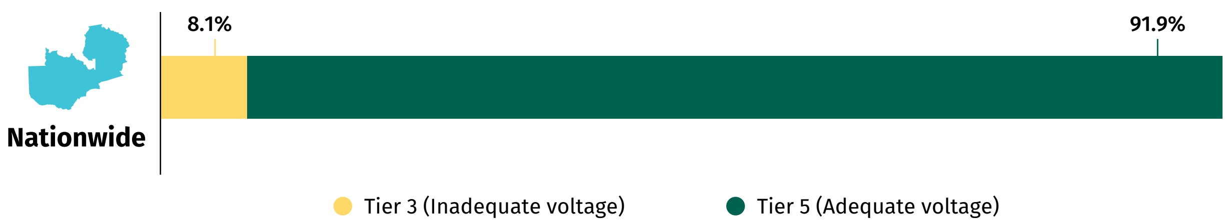
Note: Sample size = 1,224 households. Only grid-connected households.

FIGURE 28 • Distribution of grid-connected households based on Reliability, nationwide



Note: Sample size = 1,224 households. Only grid-connected households.

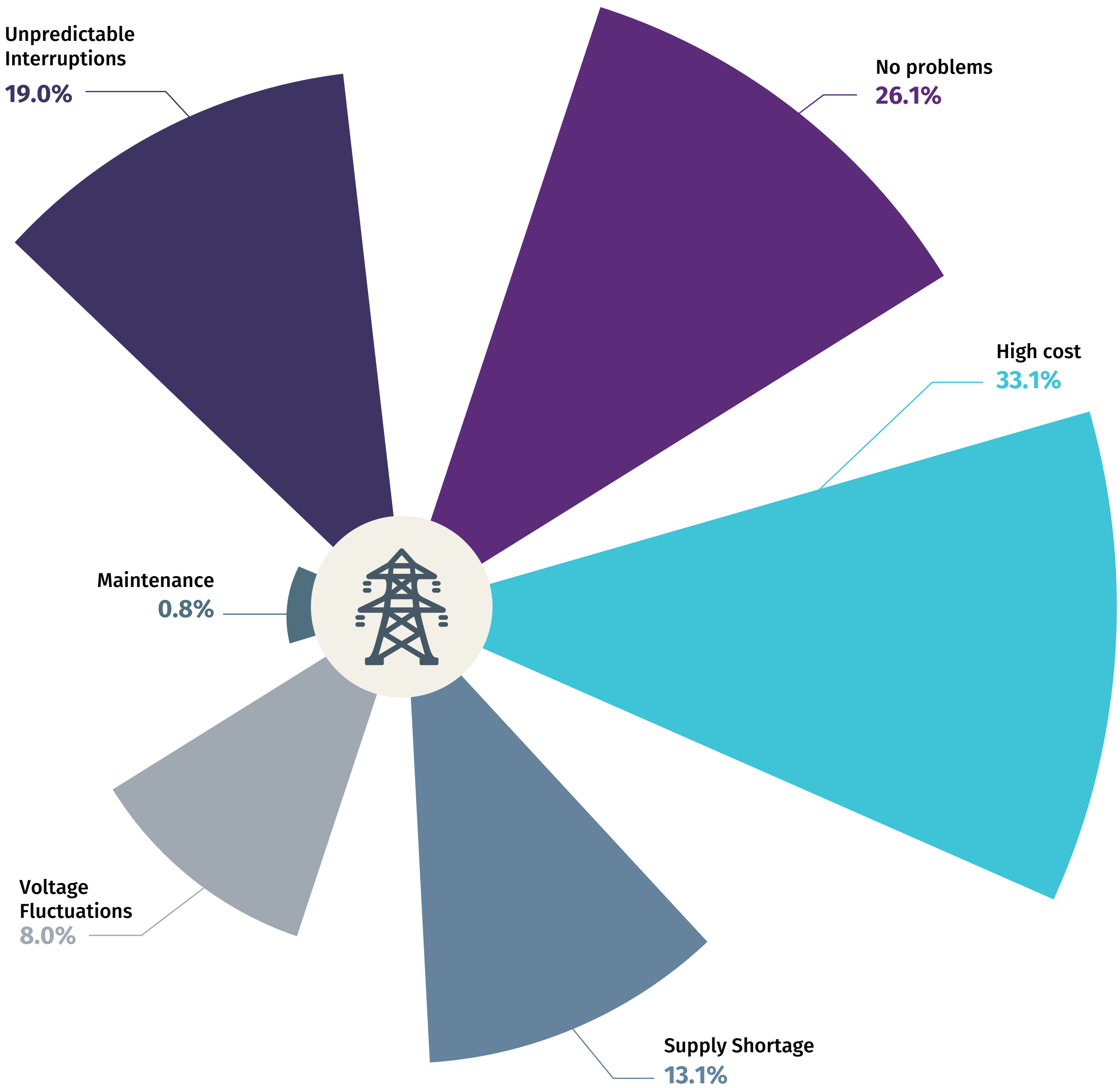
FIGURE 29 • Distribution of grid-connected households based on Quality, nationwide



Note: Sample size = 1,224 households. Only grid-connected households.

Affordability, Formality, and Health and Safety are not major issues for grid-connected households. Fewer than 1% of grid-connected households spend more than 5% of their monthly budgets to consume 1 kWh per day (or 365 kWh per year). However, 33% of grid-connected households consider that their electricity bill is too high (Figure 30).

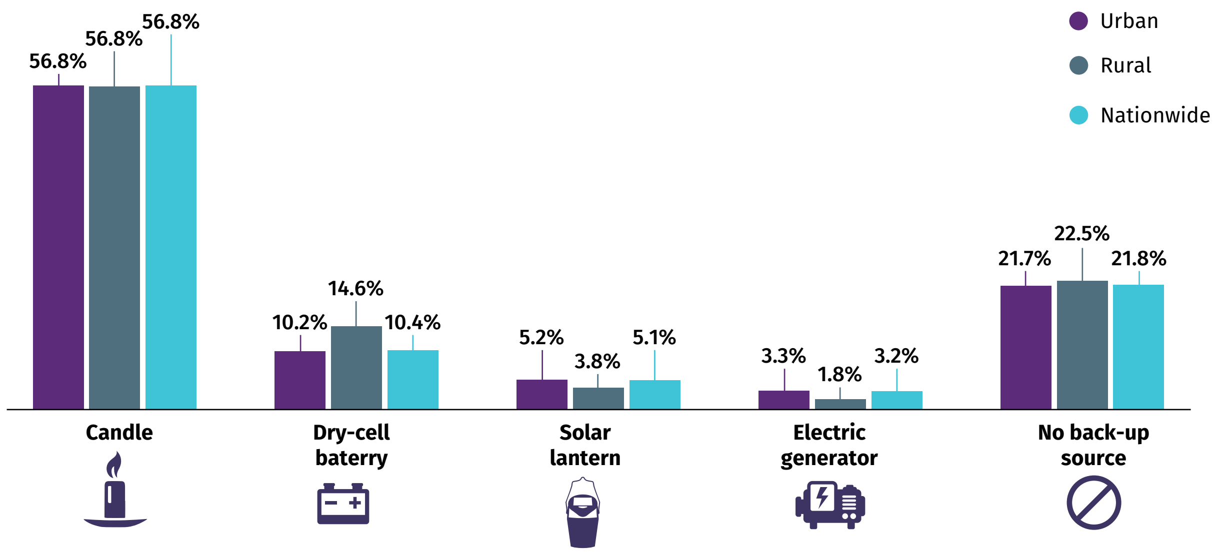
FIGURE 30 • **Main issues cited, related to grid electricity supply, nationwide**



Note: Sample size = 1,223 households.

To cope with power outages, over half of urban and rural grid-connected households use candles as a backup source for lighting. Around 10.4% of households use torches or flashlights powered with dry-cell batteries, and 5% use a solar lantern. Over 1 in 5 households has no backup at all. Backup lighting solutions represent 1.3% of household expenditure of grid-connected households (Figure 31).

FIGURE 31 • **Distribution of grid-connected households by backup energy source for lighting, nationwide, urban and rural**



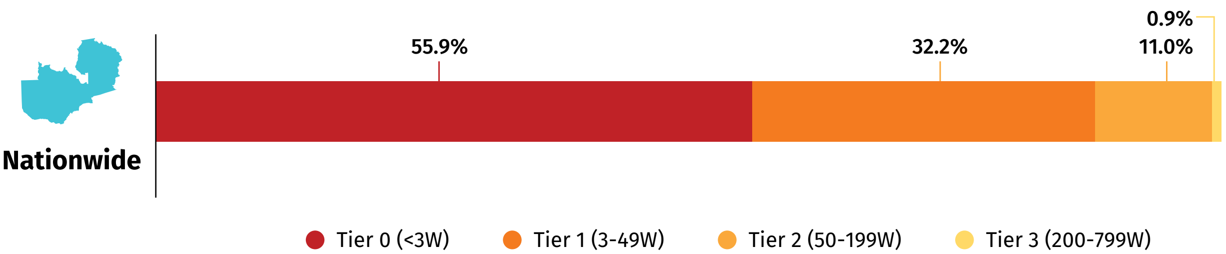
Note: Sample size = 1,222 households..

IMPROVING ELECTRICITY ACCESS FOR HOUSEHOLDS THAT RELY ON OFF-GRID SOLAR SOLUTIONS

Commonly, where grid electricity is unavailable, off-grid solutions are filling the electrification gap. In Zambia 4.7% of the households use an off-grid solution as their primary source of electricity, and 70% of those households use a solar device, mainly a solar lantern (see Figures 2 and 3). The large majority (87.2%) of off-grid solar households reside in rural areas.

Over half of off-grid solar households fall in Tier 0 because of the limited Capacity of their device. About one-third reach Tier 1, and only 11.9% have access at a Tier 2 or higher level (Figure 32).

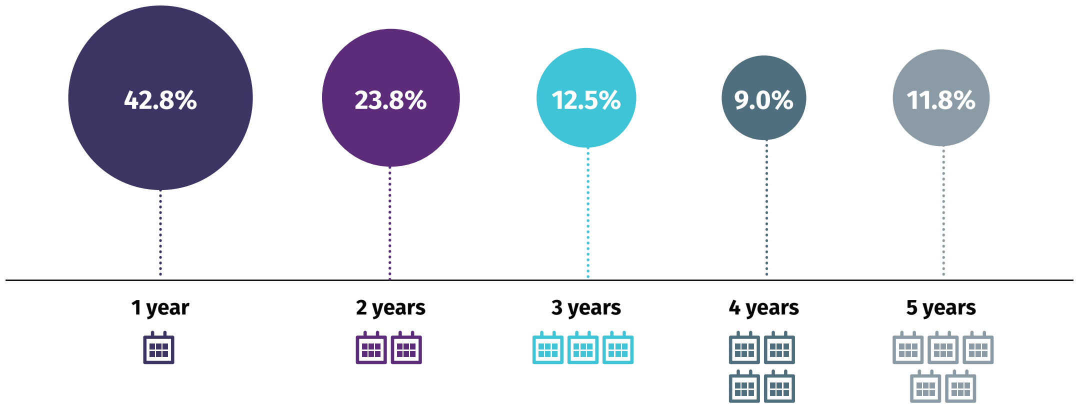
FIGURE 32 • **MTF tier distribution of off-grid solar households, nationwide**



Note: Sample size = 128 households. Only households using a solar device as their primary source of electricity.

The use of solar solutions is a relatively recent phenomenon in Zambia. About 91% of the households in the country obtained their first solar device just within the past five years, and 79.2% did so within the past three years (Figure 33)[16].

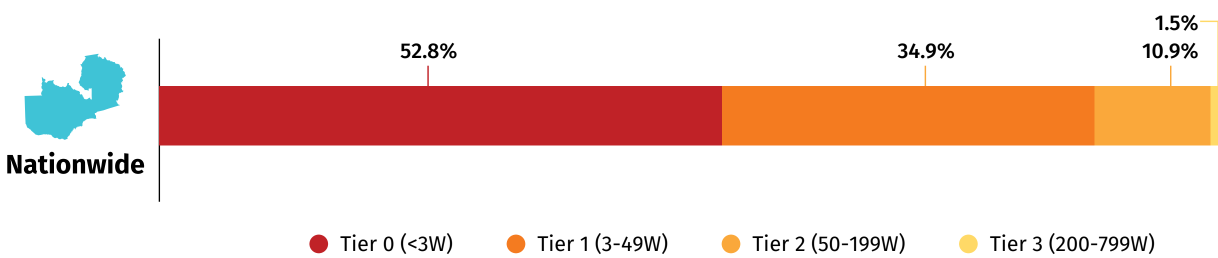
FIGURE 33 • **Number of years using solar solutions, nationwide**



Note: Sample size = 188 households. Only households that use a solar device.

Almost all off-grid solar households with Tier 0 access have Capacity constraints as their device provides less than 3 watts (or less than 12 watt-hours) per day (Figure 34). About one-third of off-grid solar households reach Tier 1 access and can power very-low-load appliances – such as lighting and phone charging – for at least 4 hours per day. Only about 1 in 10 off-grid solar households has a solution of 50 watts (or 200 watt-hours) and above, thus reaching Tier 2 or above.

FIGURE 34 • **Distribution of off-grid solar households based on Capacity, nationwide**



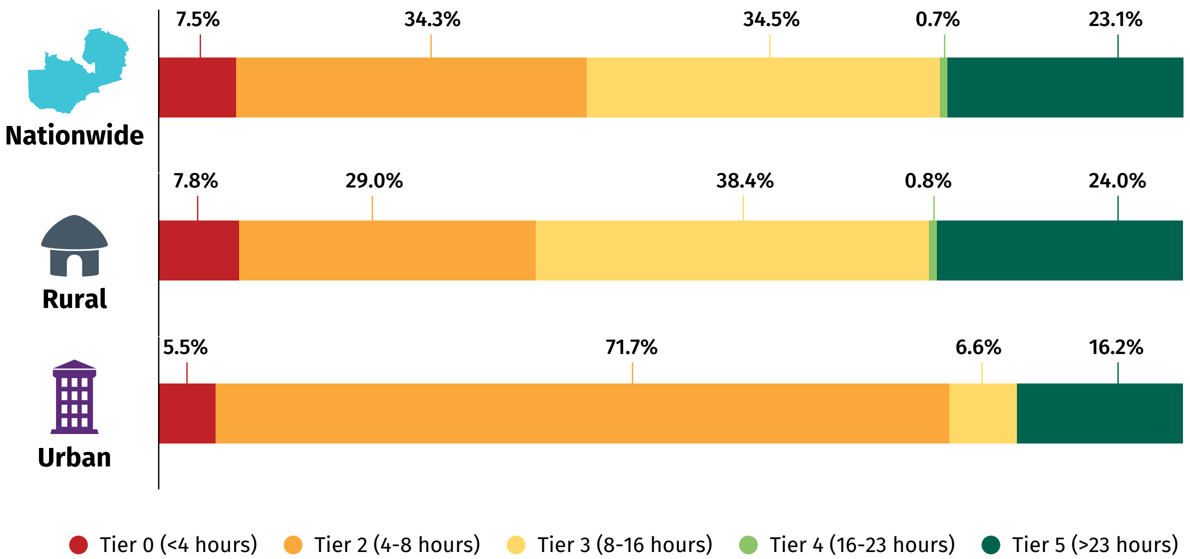
Note: Sample size = 128 households. Only households using a solar device as primary source of electricity.

Among off-grid solar users, almost 1 in 4 households receive over 23 hours of electricity per day (Figure 35). This finding suggests that about 10% of solar households have a 50- to 199-watt solution (Tier 2 for Capacity) that receives power for over 23 hours (Tier 5 for Availability). One-third of solar households receive electricity for 8 to 16 hours (Tier 3) and another third for 4 to 8 hours (Tier 2). Only 7.5% of solar users receive electricity for less than 4 hours per day. This suggests that although most solar users can

[16] Zambia's experience with decentralized off-grid solar solutions to accelerate progress towards reducing the country's energy access deficit is fast emerging. The country has a relatively developed history with stand-alone SHS, dating back to at least the 1990s, when approximately 400 55 Wp SHSs were installed in Eastern province through a Swedish International Development Cooperation Agency (Sida) supported Zambia Engineering Services Corporation (ESCO) programme (REMP, 2009). New off-grid solar solutions developments have emerged in the country recently (RECP, 2018).

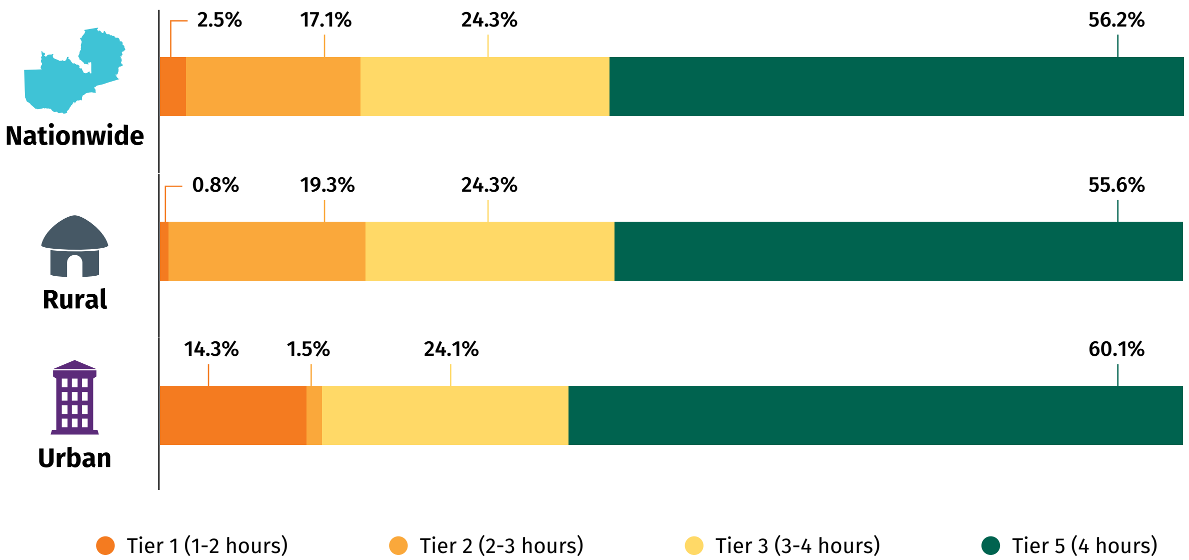
only power very-low-load appliances with their systems, the majority of them can use electricity for 4 to 16 hours. Evening Availability is not an issue for 56.2% of solar users (Figure 36). This suggests that households receiving electricity for less than 8 hours a day, are those that tend to suffer from poor Evening Availability as well.

FIGURE 35 • **Distribution of off-grid solar households based on Daily Availability, nationwide, urban and rural**



Note: Sample size = 128 households. Only households using a solar device as primary source of electricity.

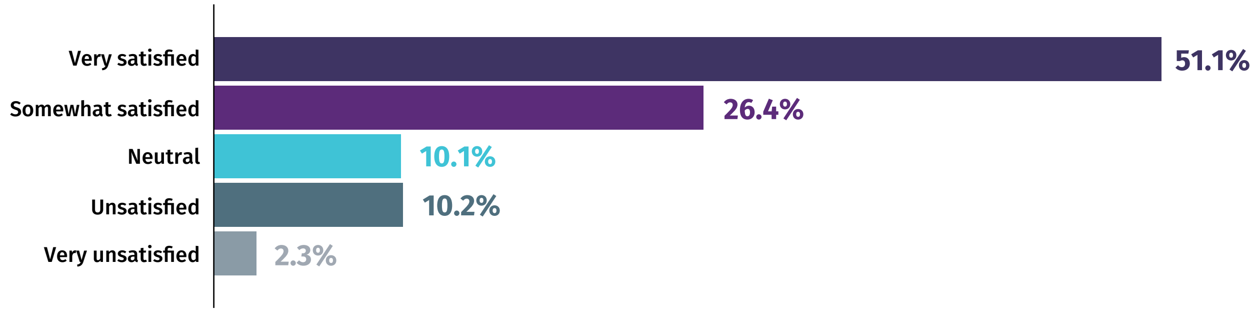
FIGURE 35 • **Distribution of off-grid solar households based on evening Availability, nationwide, urban and rural**



Note: Sample size = 128 households. Only households using a solar device as primary source of electricity.

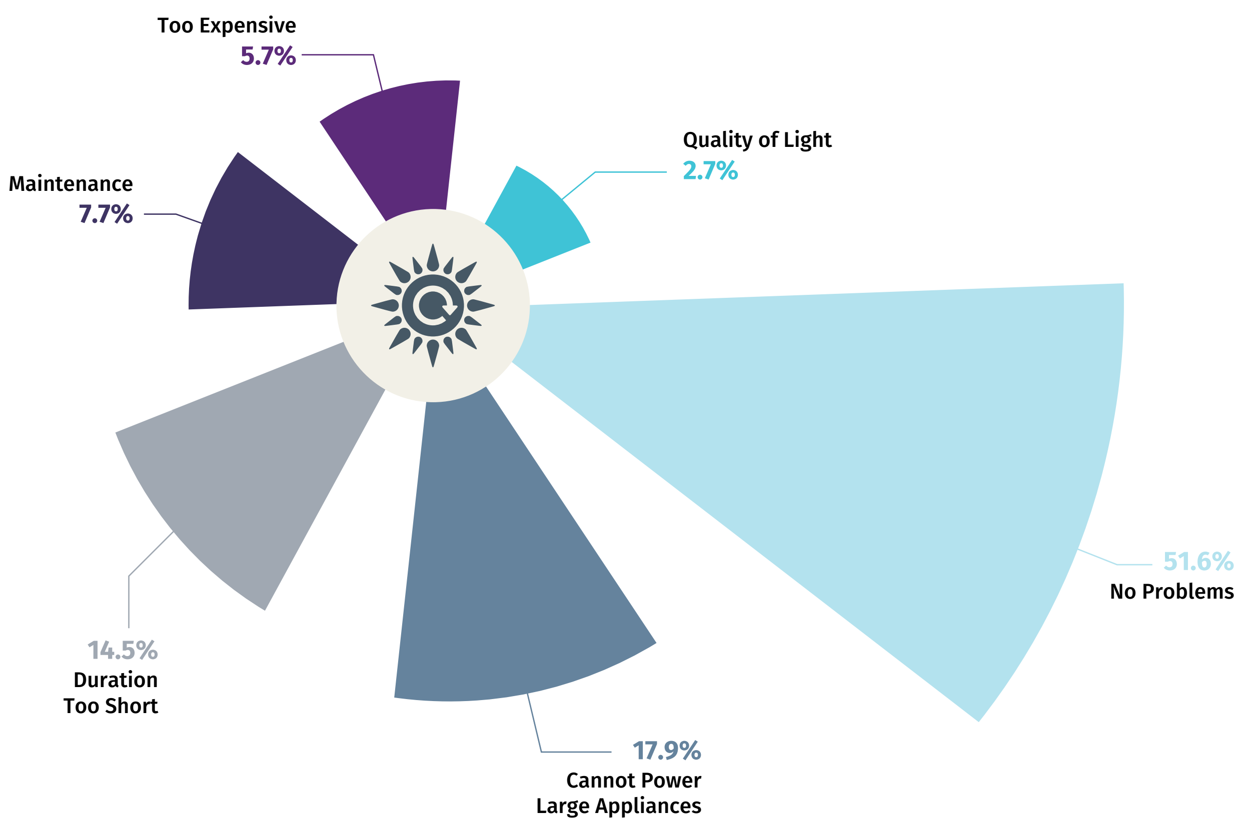
Among households that use a solar device, about 77.5% are satisfied with their solution (Figure 37), suggesting that even solar users in Tier 0 consider their solution satisfactory. Over half of the solar users reported no issues regarding their device (Figure 38). About 18% complained that they could not power large appliances and 14.5% felt limited by the short duration of electricity.

FIGURE 37 • **Satisfaction levels of solar device users, nationwide**



Note: Sample size = 189 households. Only households using a solar device (as primary or secondary source of electricity).

FIGURE 38 • **Main issues for households using solar solutions, nationwide**



Note: Sample size = 189 households. Only households using a solar device (as primary or secondary source of electricity).

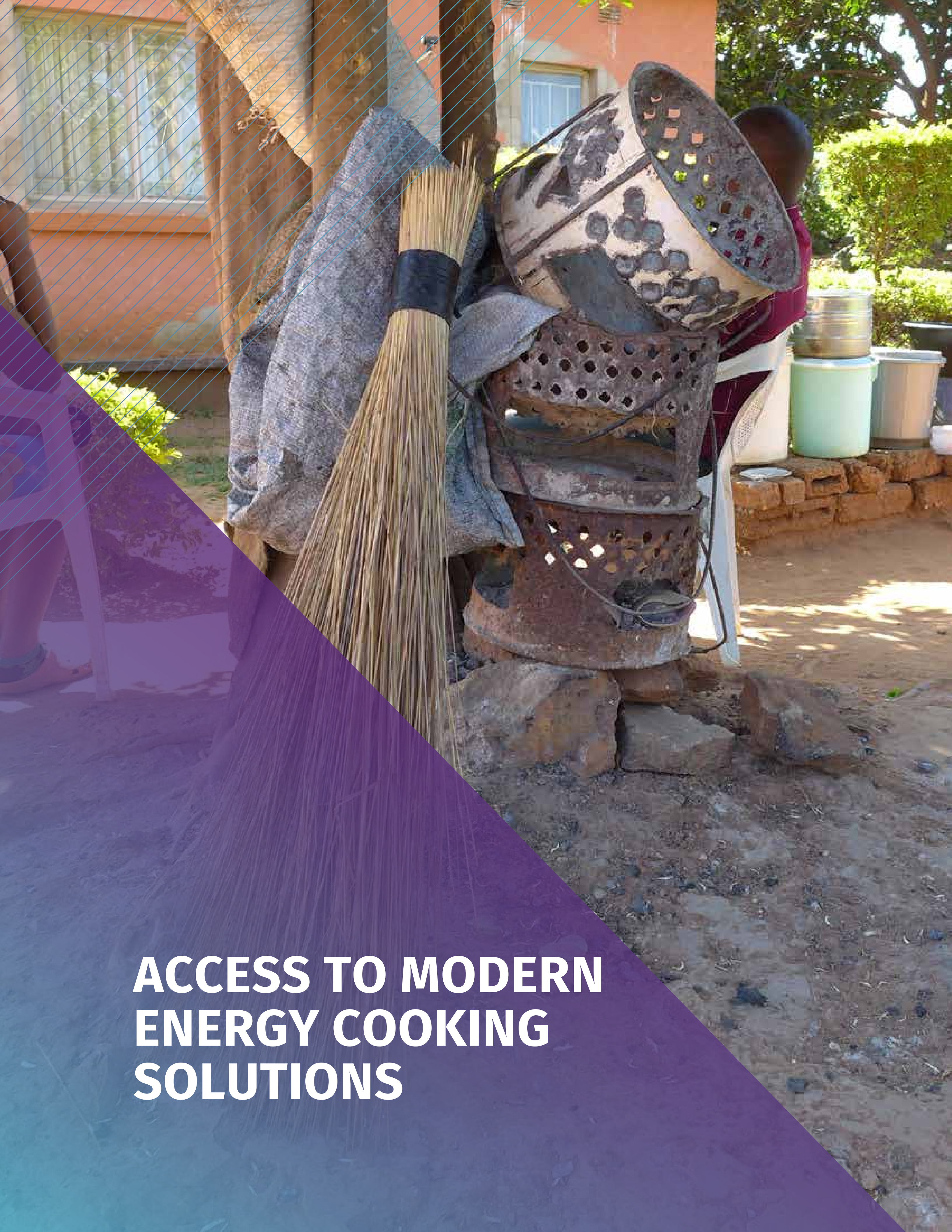
POLICY RECOMMENDATIONS

More than one-third (37.7%) of households in Zambia are connected to the national grid. Among them, about 58% are in Tier 5. The remaining grid-connected households are either in Tier 3 or Tier 4. Improvements in Availability (increasing the amount of time during which electricity service is available), Quality (reducing voltage fluctuation) and Reliability (reducing the number and duration of outages) of the grid can shift these households to the highest tier.

Only 4.7% of households use off-grid solutions, and most of them use solar devices. The majority of off-grid solution users are concentrated in Tiers 0 and 1 (85.3%) for access to electricity. Capacity and Availability are the main constraints solar users face. Thus, dissemination of larger off-grid solar systems could shift them into higher tiers.

About 57.6% of Zambian households have no access to any electricity source. Moving them to higher tiers would require the provision of either grid or off-grid access. Below are the policy recommendations to provide electricity to those without any:

- **Extend the grid:** Connecting households to the national grid could shift them to Tier 3 or above. Connecting households in non-grid-electrified areas would require grid extensions and possibly financing schemes to make grid connections affordable. Connecting households "under the grid" -directly beneath existing grid infrastructure, and potentially increasing grid electrification by over 20 percentage points, would require additional financing schemes and payment plans over time to reduce upfront cost and make connections affordable. In addition, allowing tenants to apply for a grid connection may also improve grid access rates.
- **Provide off-grid access:** Off-grid solar products may often be a more feasible solution for households living in areas where the grid infrastructure is not available. Although Zambian households have only started using solar devices in recent years, the majority of these solar users seem to be satisfied with the current service. Furthermore, the cost of purchase of a low capacity off-grid solution is lower than the grid connection fee. Thus, providing off-grid access through solar devices of at least 3 watts (or 12 watt-hours) can move Tier 0 households to higher tiers (most likely Tier 1 or 2) for access to electricity. Strengthening quality assurance systems coupled with microfinance and leasing opportunities could increase the adoption of solar devices. Consumer awareness programs could help potential customers choose products of adequate quality and use them more sustainably.



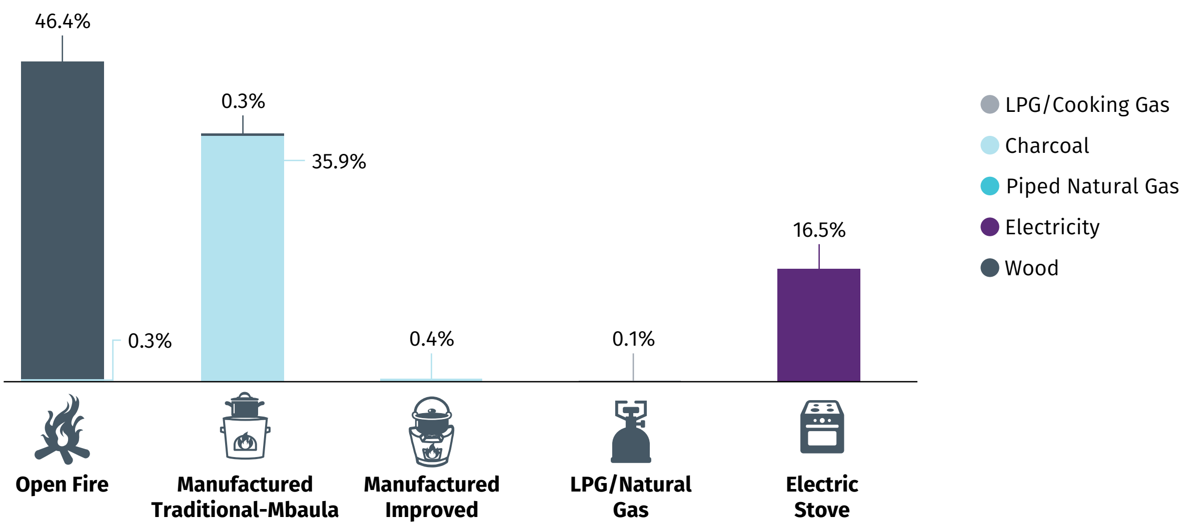
ACCESS TO MODERN ENERGY COOKING SOLUTIONS

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

TECHNOLOGIES

In Zambia, 83.4% of households cook with biomass (figure 39). Over 46% of the households use a three-stone, open-fire stove as their primary cooking solution, mainly burning wood, and over 36% use traditional stoves (*mbaula*), mainly with charcoal.[17] Only a negligible part of the population (0.4%) use improved stoves. About 16.5% of households cook with clean fuel stoves, mainly electric stoves.

FIGURE 39 • **Access to modern cooking solutions, by technology, nationwide**

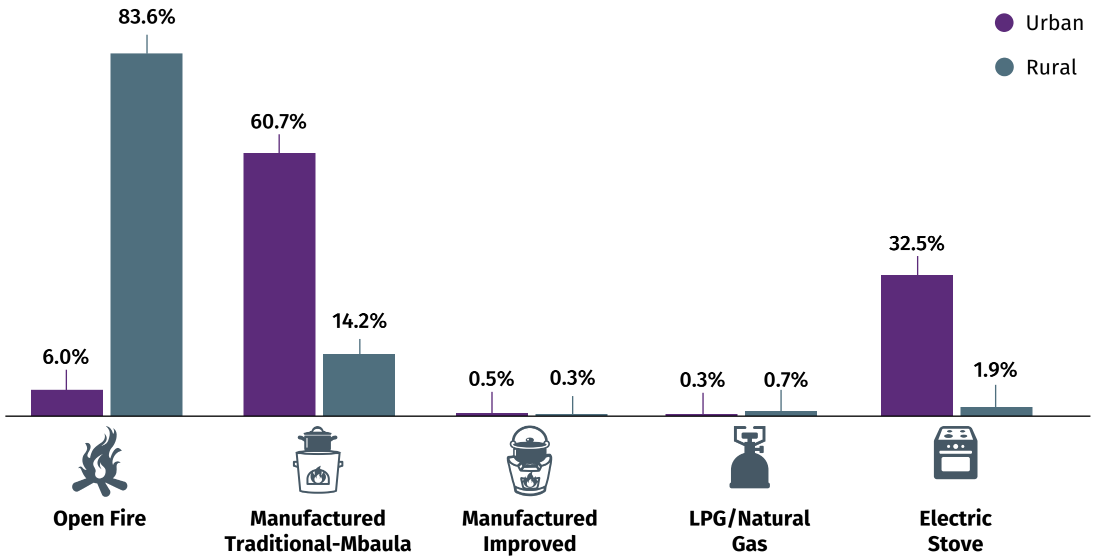


Urban and rural households have different cooking patterns (Figure 40). Urban households cook predominantly with traditional stoves (*mbaula*) (60.7%), while 83.6% of rural households use open fire. Electric stoves are much more prevalent in urban areas: 32.5% of urban households use an electric stove (the second-most-used stove in urban areas), whereas the penetration of electric stoves is very limited in rural areas (1.9%).

Analysis into stove "stacking" was not conducted due to data limitations, however, according to fuel consumption data, 47.3% of Zambian households use a combination of electricity and charcoal, suggesting that these households are likely to use both electric stoves and *mbaula*.

[17] For more details about each type of cookstove, see Annex 3.

FIGURE 40 • **Access to modern cooking solutions, urban vs. rural**

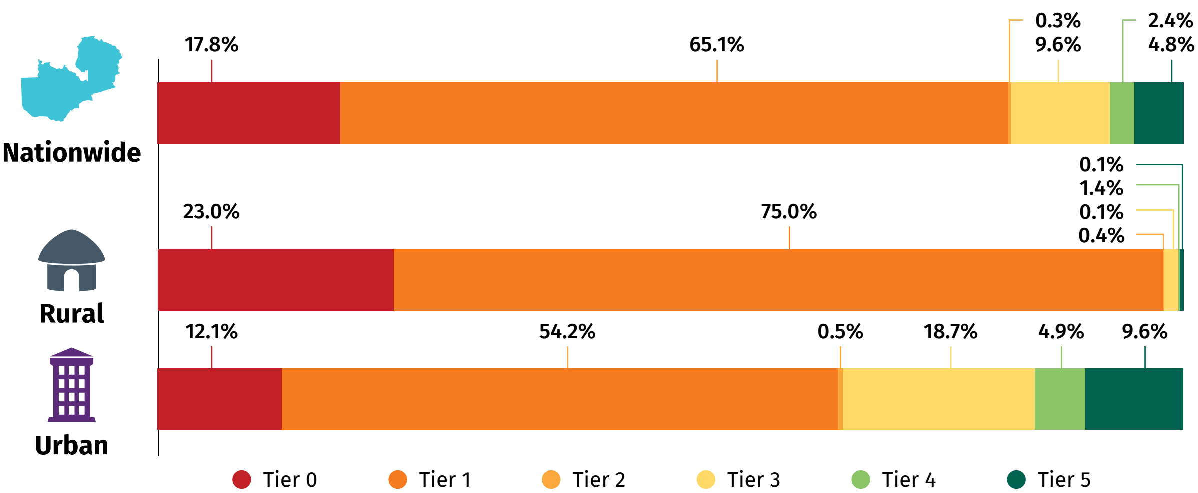


Note: Sample size = 3,518 households. For all other charts in the cooking section, the sample size is also 3,518 households unless otherwise noted.

MTF TIERS

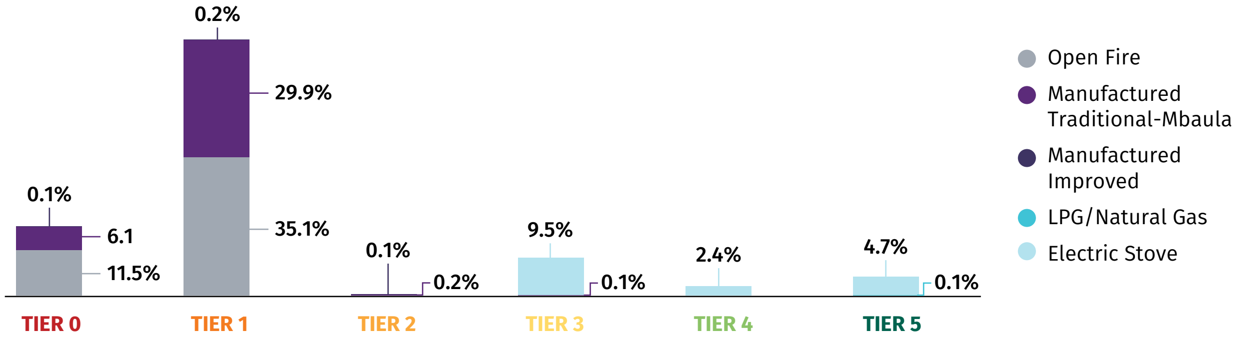
In Zambia, most households are concentrated in Tiers 0 and 1 (82.9%), due to the high share of open-fire and *mbaula* stoves (Figure 44). A higher percentage of rural households (98%) are in Tiers 0 and 1 compared to urban households (66.3%). By contrast, more urban households fall in higher tiers for access to modern cooking solutions. Of urban households, 4.9% are in Tier 4 and 9.6% in Tier 5, compared with 0.1% of rural households in Tier 4 and 0.4% in Tier 5. This is mainly because clean fuel stoves are mostly used in urban areas. However, using a clean fuel stove does not automatically categorize these households into higher tiers. For instance, 32.8% of urban households and 1.9% of rural households use a clean-fuel stove as their primary stove, but only 14.5% of urban households and 0.5% of rural households are in Tier 4 or 5 for access to modern energy cooking solutions. Possible reasons will be discussed later.

FIGURE 41 • **MTF tier distribution: access to modern-energy cooking solutions, nationwide, urban and rural**



Households that primarily use open fire or *mbaula* stoves are concentrated in Tiers 0-1, while almost all households that mainly rely on electric stoves are in Tiers 3 through 5. Thus, clean-fuel stove users are more likely to be in higher tiers for access to modern energy cooking solutions (Figure 42). The large gap in access to modern cooking solutions between urban and rural area can be explained by different use of primary cooking solutions, since a larger portion of rural households than urban households use open fire or *mbaula* stoves.

FIGURE 42 • **MTF tier distribution by primary stove type, nationwide**

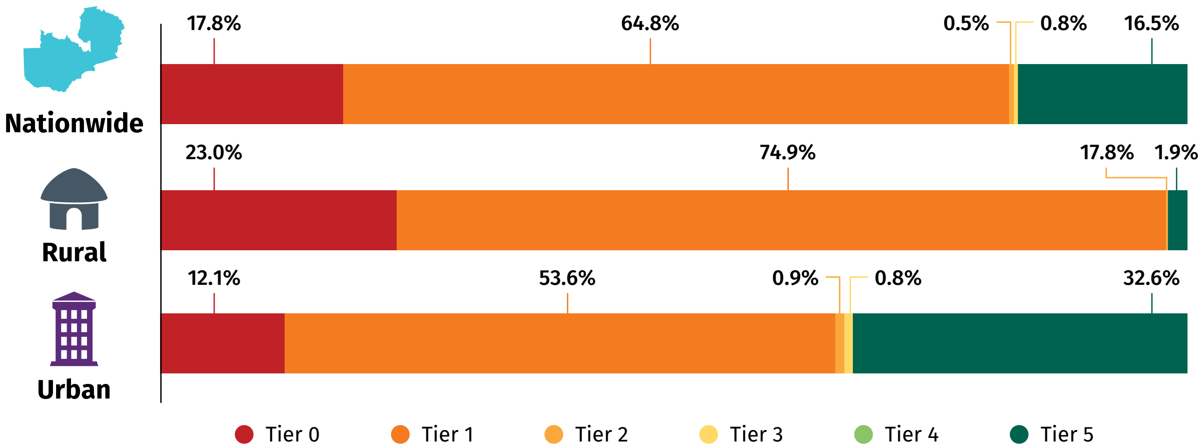


MTF ATTRIBUTES

Cooking Exposure

Nationwide, the majority of households (82.6%) are in Tiers 0 and 1 for the Cooking Exposure attribute, which represents an estimate of personal exposure during cooking activities based on the emissions of cooking and the ventilation, due to the use of open fire and *mbaula* stoves. About 16.5% of the households are in Tier 5 as they use-clean fuel stoves. Nearly all rural households (97.9%) are in Tiers 0 and 1, compared with 65.7% of urban households (Figure 43).

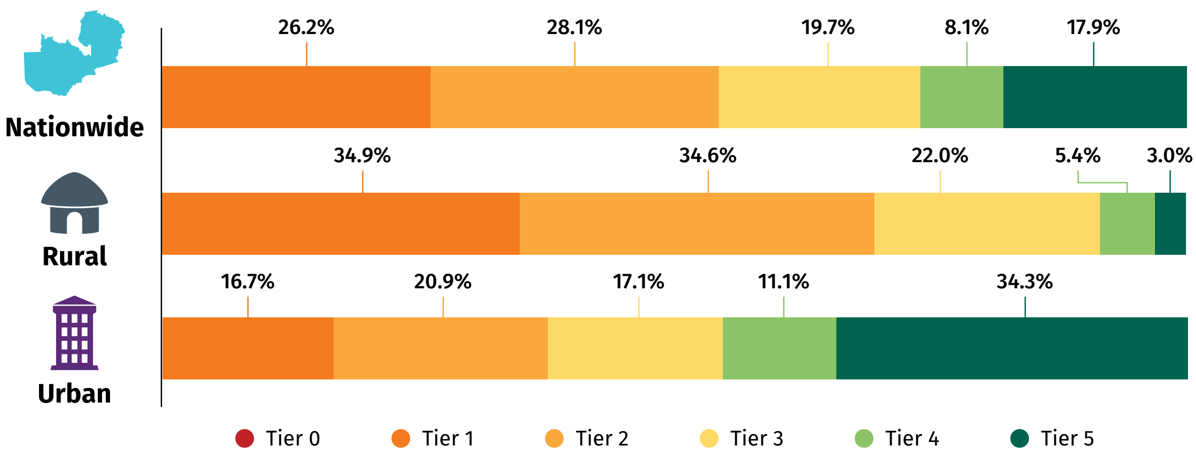
FIGURE 43 • **Distribution of households based on Cooking Exposure, nationwide, urban and rural**



Convenience

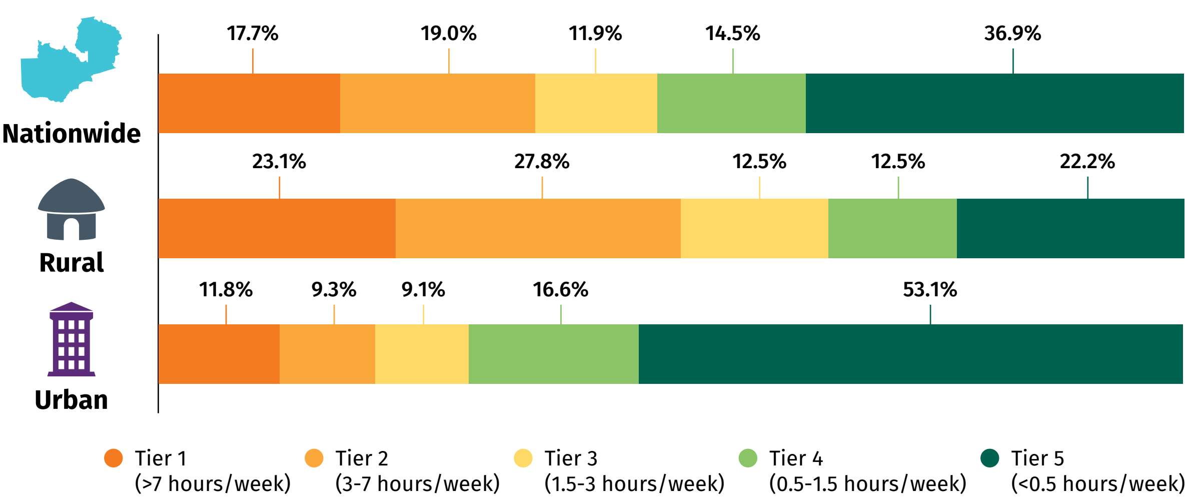
The Convenience attribute is composed of two parts: the first is the amount of time a household spends acquiring and preparing fuel each week; the second is the amount of time a household spends preparing a stove for cooking before each meal. Nationwide, 26.2% of households spend more than 7 hours per week collecting and preparing fuel, or at least 15 minutes preparing a stove before each meal (Figure 44). Households in lower convenience tiers primarily use three-stone stoves or *mbaulas*, which require more effort and are less efficient than clean-fuel stoves.

FIGURE 44 • **Distribution of households based on total Convenience, nationwide, urban and rural**



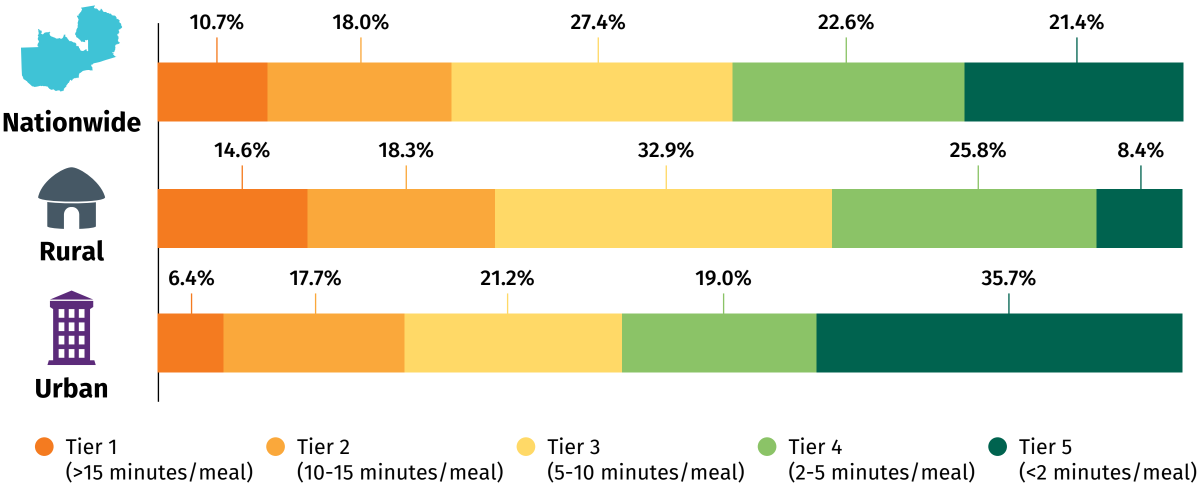
Nationwide, 17.7% of the households spend more than 7 hours per week acquiring and preparing fuel, while almost 37% spend less than 30 minutes (Figure 45). Close to two-thirds of rural households spend over 1.5 hours per week acquiring and preparing fuel, while over two-thirds of urban households spend less that 1.5 hours per week

FIGURE 45 • **Distribution of households based on fuel Convenience (time spent for fuel collection and preparation), nationwide, urban and rural**



Over 56% of households spend more than 5 minutes to prepare their stove before each meal (Figure 46). Only 1 in 5 households spends less than 2 minutes for each stove preparation. In urban areas, the share reaches 1 in 3.

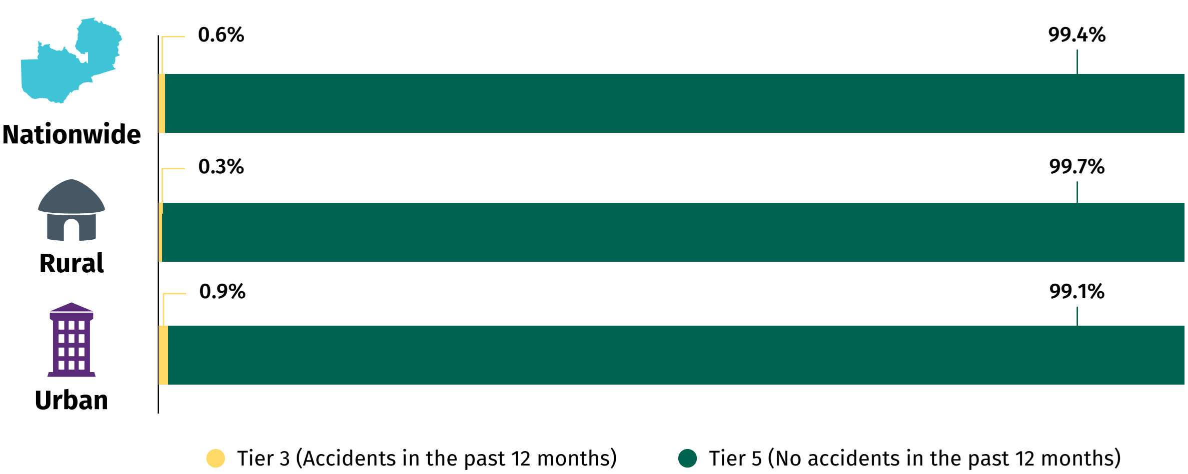
FIGURE 46 • **Distribution of households based on stove Convenience (time spent for stove preparation), nationwide, urban and rural**



Safety of Primary Cookstove

The attribute of Safety of Primary Cookstove is a yes-no attribute, determined by the incidence of serious injuries from the use of the main cookstove for one year preceding the survey. Households are assigned Tier 3 if they report any such incidents, and Tier 5 otherwise. Most households did not recall a major injury over the last 12 months (Figure 47); only 0.6% of households (29 households in total) nationwide reported serious injuries, including permanent health damage, burns/fire/poisoning, severe cough or respiratory problem, or even death of a household member within the past year, resulting from the use of their primary cooking device or fuel. Out of all the households that reported accidents, two thirds use an *mbaula* stove as their primary cookstove.

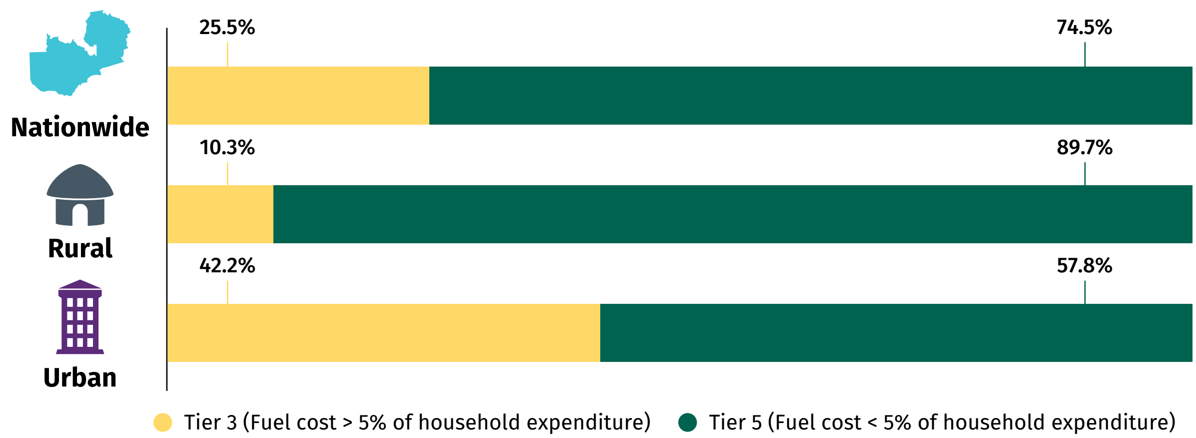
FIGURE 47 • **Distribution of households based on Safety, nationwide, urban and rural**



Affordability

Affordability is also a binary (yes-no) attribute and is measured by the levelized cost of the cooking solution (both stove and fuel). A household is assigned Tier 5 if the cost is less than 5% of its annual general expenditure, and Tier 3 otherwise. Assessing the cost of the stove, which is subject to depreciation, is not straightforward; so, in this analysis, the cost of fuel only is taken into consideration. Nationwide, 74.5% of households spend less than 5% of their total household expenditure on cooking fuel (Figure 48). Fuel is considered unaffordable for more than 4 in 10 urban households, compared with only 1 in 10 rural households. This gap is due to the fact that the large majority of rural households cook with wood, and 72.5% of them collect their fuel for free. Conversely, urban households mainly use charcoal and electricity.

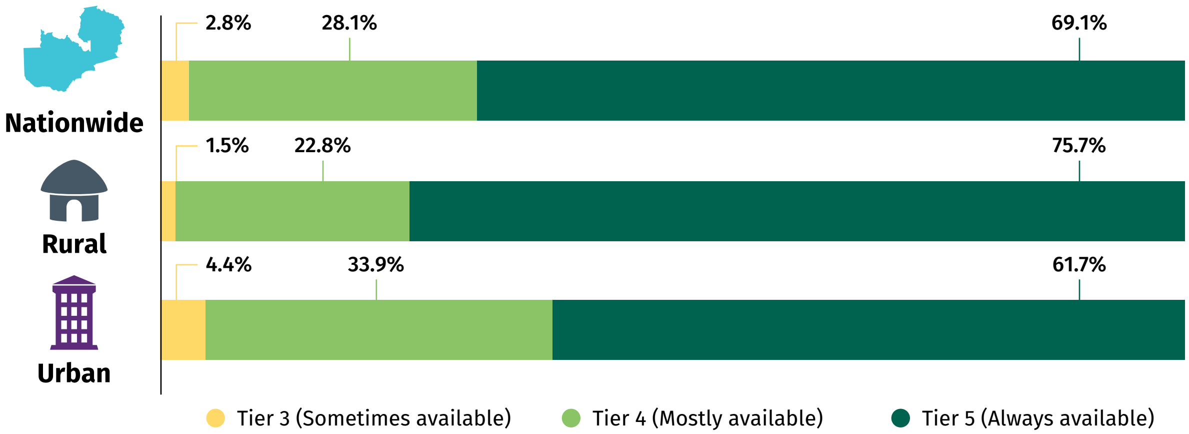
FIGURE 48 • **Distribution of households based on Affordability, nationwide, urban and rural**



Fuel Availability

This attribute is determined by the availability of the main fuel. A household is assigned to Tier 3 if the primary fuel is not available at least 80% of the time, to Tier 4 if it is available at least 80% but not 100% of the time, and to Tier 5 if it is always available. About 3 in 10 households reported that fuel was not always available (Figure 49). Fuel was mostly available for most of those households, while only 2.8% of households reported that fuel was only sometimes available. In urban areas, fuel availability tends to be less adequate than in rural areas.

FIGURE 49 • **Distribution of households based on Fuel Availability, nationwide, urban and rural**

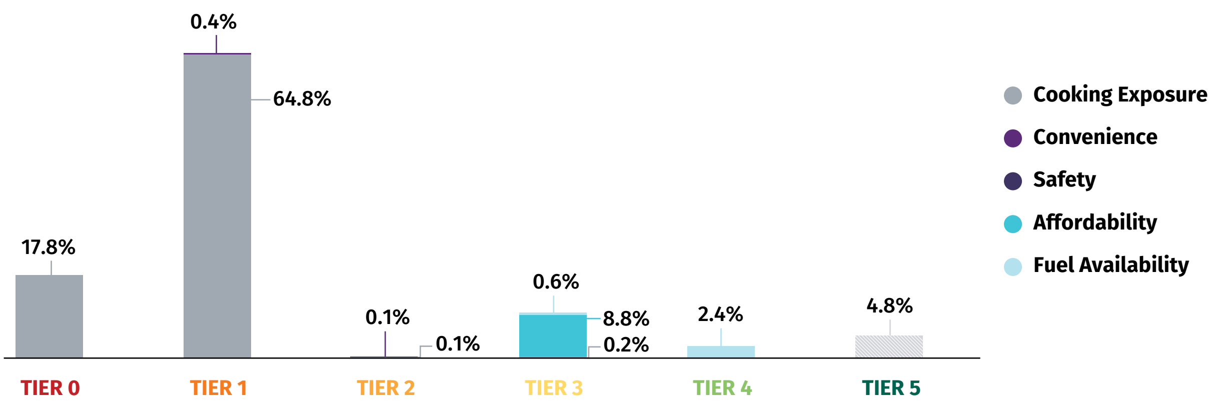


IMPROVING ACCESS TO MODERN COOKING SOLUTIONS

The ultimate objective of improving access to modern energy cooking solutions should be to facilitate access among all households to cooking solutions that are clean, convenient, efficient, affordable, safe, and available. An increase in the rate of adoption of clean fuel stoves could move households to the highest tier. In addition to clean fuel stoves, the promotion of improved cookstoves (ICSs) could help shift households, particularly Tier 0 households, into higher tiers.

Nearly all households in Tier 0 or Tier 1 are primarily constrained by Cooking Exposure (see Figure 50). Households in Tier 3 mainly face Affordability issues, and Fuel Availability is mainly an issue for households in Tier 4. Most Tier 3 and Tier 4 households cook with electric stoves (see Figure 42). Most of them cook with electric stoves.[18]

FIGURE 50 • **Gap analysis: MTF tier distribution, by attribute, nationwide**



[18] Households in Tier 5 do not have any constraint as they are in the highest tiers already.

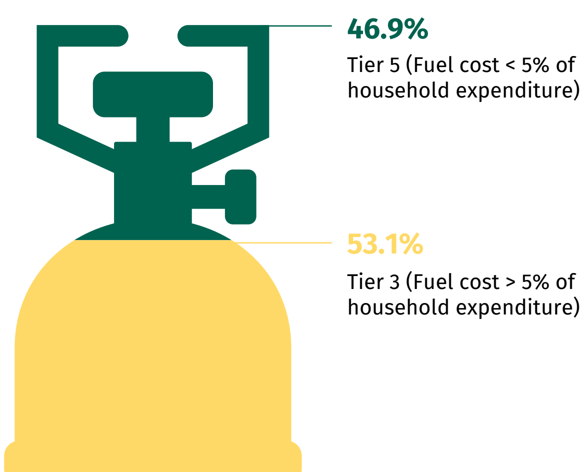
Furthermore, the breakdown of aggregate tier by primary stove type, as shown in Figure 42, indicates that clean fuel stoves are typically in higher tiers, while open-fire or manufactured stoves are in lower tiers. Given these considerations, policy recommendation can target two different groups. First, for households that use open-fire or *mbaula* stoves, since Cooking Exposure is the main issue that prevents them from moving up to higher tiers, the ideal solution would be to promote clean fuel stoves such as electric or LPG stoves. However, because LPG penetration in Zambia is limited, coupled with the impression that African households are concerned about the safety issues of LPG stoves, it is unclear whether promoting LPG stoves is a realistic approach. Therefore, increasing the use of electric stoves, while addressing Affordability and Fuel Availability issues, is critical.

INCREASING PENETRATION OF CLEAN FUEL STOVES

Since the majority of households in Zambia rely on an open fire or *mbaula* stove, promoting clean-fuel stoves such as electric stoves among these households obviously would be an option. However, promoting clean-fuel stoves is a complex transformational change challenge and requires good insights into the country-specific conditions and potentials.

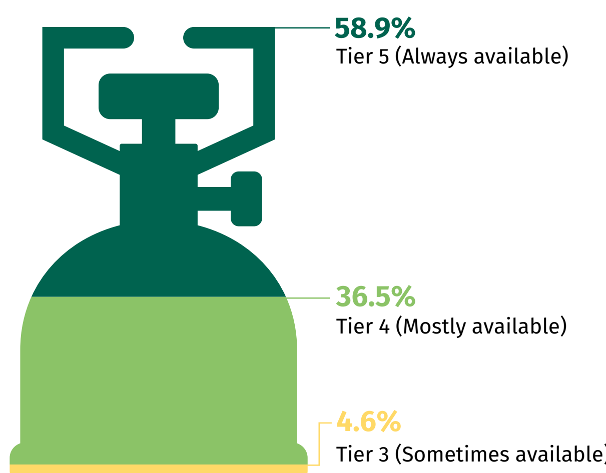
Examining the challenges that clean-fuel stove users are already facing and avoid these problems in the future could make the promoting process more efficient and successful. MTF data show that Affordability and Fuel Availability are two main issues. Over half of the households cooking primarily with clean-fuel stoves (mainly electric stoves) spend over 5% of the household expenditures on cooking fuel[19] (Figure 51). Over 40% of clean-fuel stove users report that cooking fuel (mainly electricity) is not always available, suggesting that they experience Availability or Reliability issues with their electricity supply (Figure 52).

FIGURE 51 • **Distribution of households cooking with clean-fuel stoves based on Affordability, nationwide**



Note: Sample size = 451 households.

FIGURE 52 • **Distribution of households cooking with clean- fuel stoves based on fuel Availability, nationwide**



Note: Sample size = 451 households.

[19] The MTF questionnaire collects information about the amount of money households spend on each kind of fuel.

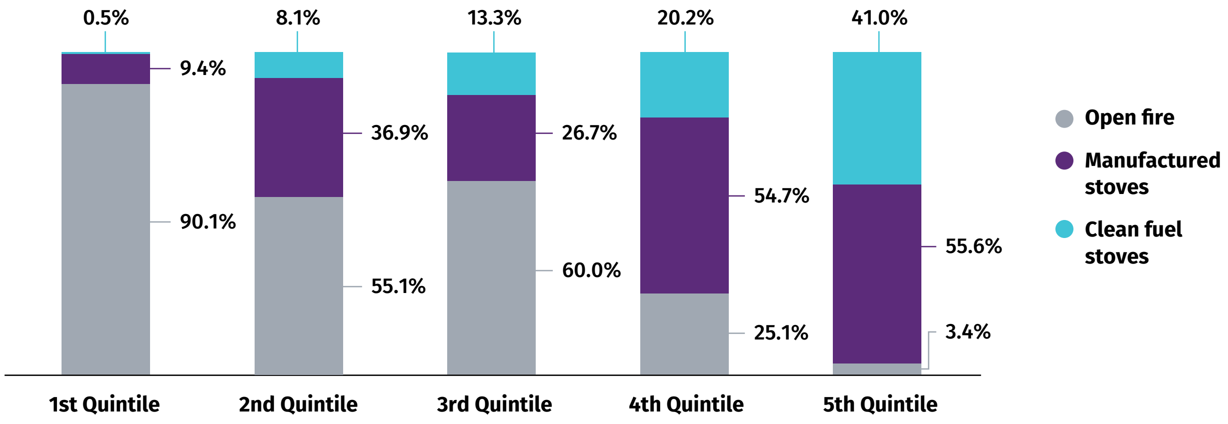
Other possible constraints to promoting clean-fuel stoves include the following. First, 74.5% of households that primarily use an open-fire or *mbaula* stove do not have grid connection. Increasing the penetration of electric stoves would first require the extension of grid connection. Second, according to cooking specialists from the World Bank, African households seem to be concerned about the safety issues of LPG stoves. Thus, more analysis into the feasibility of promoting LPG stoves would need to be conducted using other sources.

Furthermore, for households that are already connected to the national grid, only 43.1% of them use electric stove as their primary stove, so urging them to mainly cook with electric stoves is going to shift them to higher tiers.

INCREASING ADOPTION OF IMPROVED COOKSTOVES AS PRIMARY COOKING SOLUTIONS

While promoting clean-fuel stoves is a long-term goal, a short-term solution would be to increase adoption of improved biomass cookstoves as primary cooking solutions. As mentioned earlier, 82.9% of Zambian households cook with a three-stone stove or a *mbaula* stove. Most of them (74.5%) do not have grid connection and are overrepresented in the lower quintiles (Figure 53). Thus, improved biomass cookstoves may be the most feasible cooking solutions able to move such households in higher tiers (most likely Tiers 1 through 3). Improved cookstoves result in minimal disruption in cooking practices and households can rely on existing fuel (wood or charcoal). Thus, adoption rates can increase faster than for clean-fuel stoves.

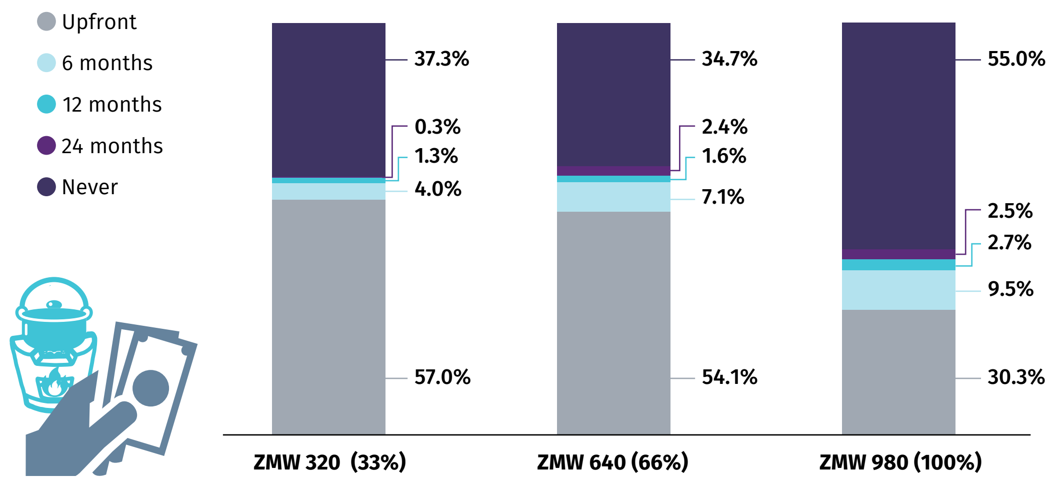
FIGURE 53 • **Primary stove type, by expenditure quintile, nationwide**



In order to find out if households' willingness to pay for an improved cookstove is affected by payment plans or reductions in price, the MTF survey incorporated a willingness to pay section, in which each household was presented with one type of improved cookstove, an upfront price, and then different payment plans.

In Zambia, respondents were asked if they would be willing to pay for a gasifier stove, which is an affordable cookstove designed to burn locally produced biomass such as wood pellets in a cleaner and more efficient way. The MTF analysis shows that payment plans and reductions in price will effectively increase Zambian households' willingness to pay for a gasifier stove. Adoption of improved cookstoves could be facilitated by reducing the price of the stove and offering payment plans over time. Although 55% of households were not willing to pay for the stove at its full price (US$107 / ZMW 979.6), the share dropped to 34.7% in the scenario where the stove was priced at US$70 (ZMW 640.9) (Figure 54). Most households interested in an improved cookstove are willing to pay up-front, particularly in the scenario where the stove is priced at US$35 (ZMW 320.4). Payment plans increase the share of households willing to pay for the gasifier stove from 6% to 15%, depending on the price. The higher the price, the more households are interested in payment plans.

FIGURE 54 • **Willingness to pay for an improved cookstove, nationwide**

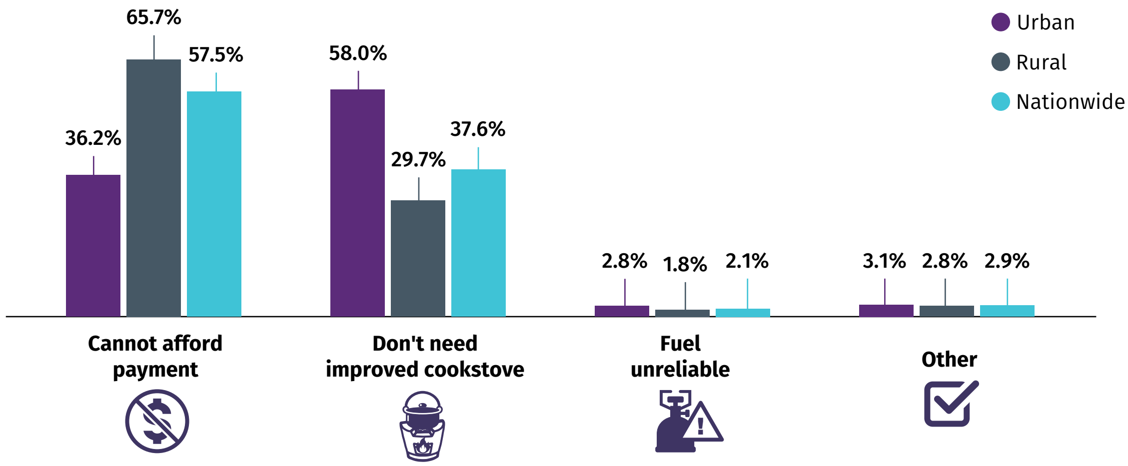


Note: Sample size = 2,904 households.

According to Figure 55, among households unwilling to accept an improved cookstove, the majority of urban households reported that they do not need the improved cookstove and most of rural households reported that they could not afford the payment. Therefore, improving public awareness of the benefit of using improved cookstoves is also critical. However, since the improved stove offered to respondents in the willingness to pay section was a pellet gasifier stove, in order to promote such stoves, it is also important to look further into the pellet supply chain and other potential issues, which were not addressed by MTF data. As discussed earlier, biomass such as firewood and charcoal is widely used by Zambian households already, so promoting improved cookstoves that use firewood or charcoal would be a more feasible and realistic solution in Zambia.

About 57.5% of households not willing to pay for an improved cookstove under any price or payment plan reported that they cannot afford it, while 37.6% believed they did not need an improved cookstove (Figure 55). Affordability is an even larger issue in rural areas, where close to 2 in 3 households cannot afford an improved cookstove, while close to 6 in 10 urban households report that they do not need an improved stove.

FIGURE 55 • **Reasons for not being willing to pay for an improved cookstove, nationwide, urban and rural**



POLICY RECOMMENDATIONS

In Zambia, 83.3% of households primarily use open-fire or *mbaula* stoves. Cooking Exposure (personal exposure to pollutants from cooking activities) is thus the main constraint for these households in moving up the tiers. In order to shift these households to higher tiers, switching to improved or advanced biomass stoves or clean-fuel stoves would be critical.

- **Promote clean-fuel stoves:** Clean-fuel stove users are more likely to be in higher tiers due to the Cooking Exposure attribute. Promoting clean fuel stoves such as electric stoves while addressing Affordability and fuel availability issues could shift these households to higher tiers.

Households that primarily use clean-fuel stoves mainly face challenges from Affordability (the ability of the household to pay for both the cookstove and fuel) and Fuel Availability (availability of fuel when needed for the cooking purposes of the household). Addressing the high cost and availability issues from electricity can shift these households to the highest tier for access to modern energy cooking solutions.

However, since almost all open-fire users and 43.4% of manufactured stove users are not connected to the national grid, coupled with the fact that clean fuel is relatively expensive in Zambia, a more feasible solution is to promote improved or advanced biomass stoves. Furthermore, LPG use is negligible in Zambia and African households seem to be concerned about the safety issues of LPG, so the impact of promoting LPG stoves remain unclear.

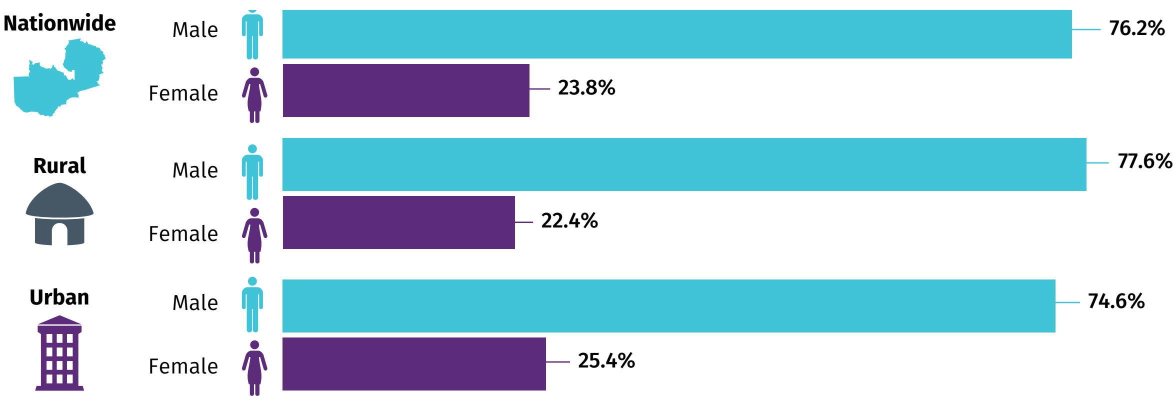
- **Promote improved or advanced biomass stoves:** Zambian households are more used to biomass such as firewood and charcoal. Moreover, households that primarily use open fire or mbaula stoves are much poorer than clean-fuel stove users, therefore the cost of clean stoves and clean fuel would probably be too high for these households. Promoting improved or advanced biomass stove along with payment plans and a public awareness campaign could increase households' adoption rate of such cookstoves. Improved cookstoves have higher performance at a more affordable price compared to advanced biomass stoves, so promoting improved cookstoves is critical given the Affordability issues in Zambia.

GENDER ANALYSIS

HOW DO HOUSEHOLDS DIFFER BY GENDER OF THE HEAD?

Nationwide, 17.7% of the households spend more than 7 hours per week acquiring and preparing fuel, while almost 37% spend less than 30 minutes (figure 56). Close to two-thirds of rural households spend over 1.5 hours per week acquiring and preparing fuel, while over two-thirds of urban households spend less (that) than 1.5 hours per week..

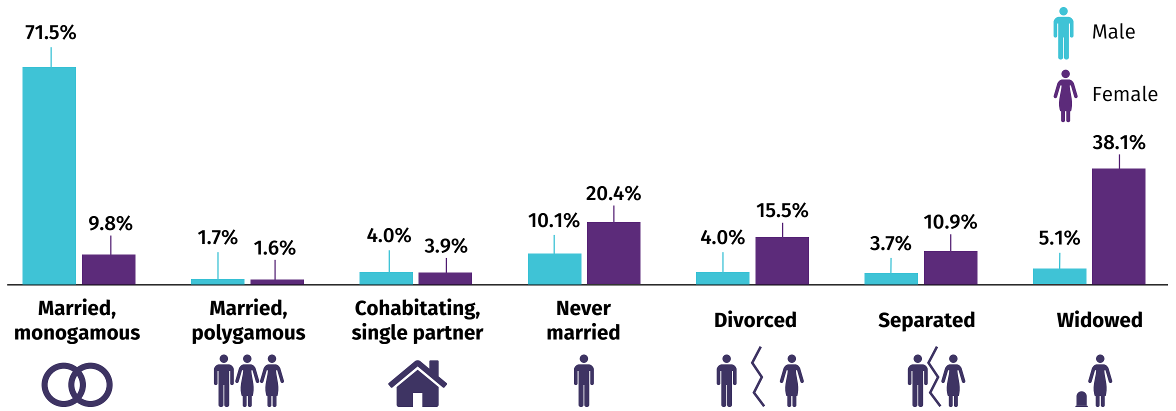
FIGURE 56 • **Distribution of households by gender of household head, nationwide, urban and rural**



Note: Sample size: 3,537 households

The average size of female-headed households is three members, compared with four members for their male-headed counterparts. Widowed women make up the majority of female household heads (38.1%), while most male household heads are married (71.5%) (Figure 57).

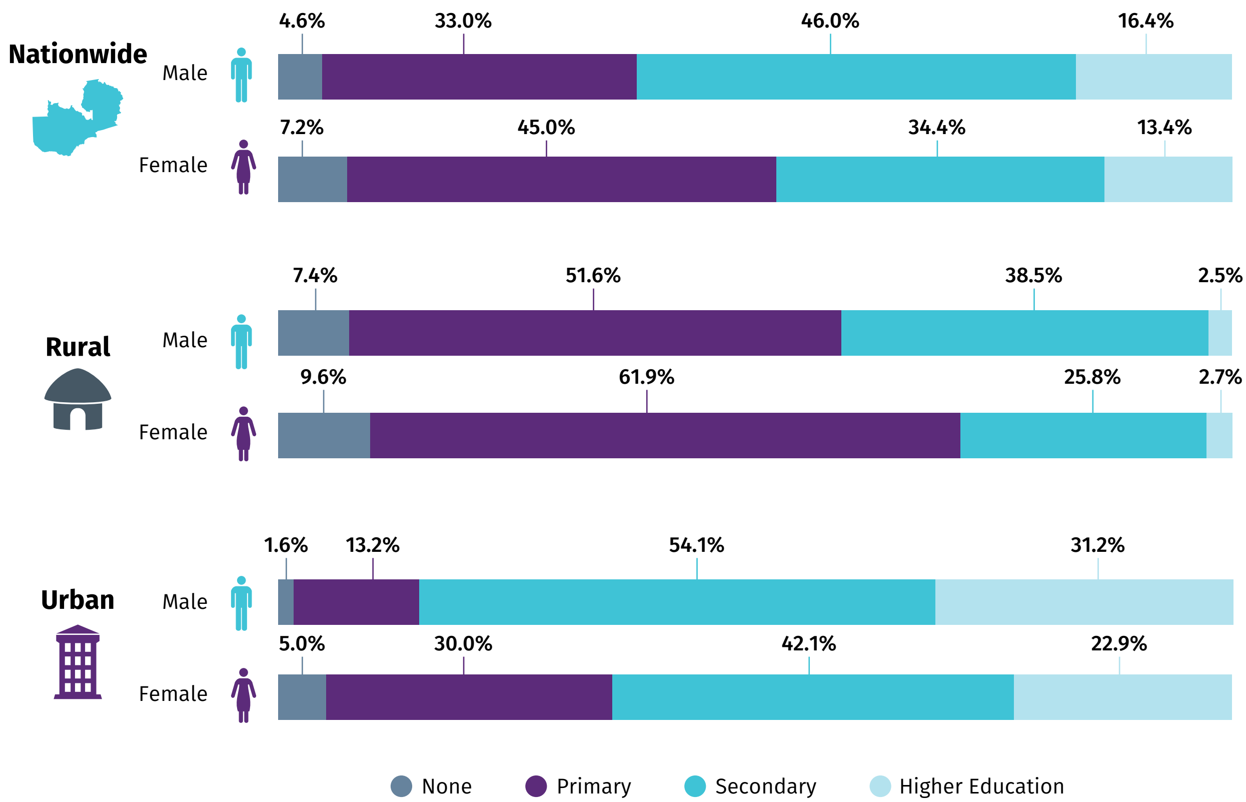
FIGURE 57 • **Marital status of household head, by gender of household head, national**



Note: Sample size: 3,537 households.

Male household heads are more likely to complete a higher education than female household heads (Figure 58). Nationwide, 13.4% of female household heads received a higher education, compared with 16.4% of male household heads; likewise, 7.2% of female household heads have never attended school, while this is the case for 4.6% of male household heads. Educational disparities between female and male household heads remain in both urban and rural areas. In rural households, 9.6% of female heads and 7.4% of male heads did not attend school. In urban areas, 5% of female heads did not receive any formal education, compared to 1.6% of male heads.[20]

FIGURE 58 • **Education level by gender of household head, nationwide, urban and rural**

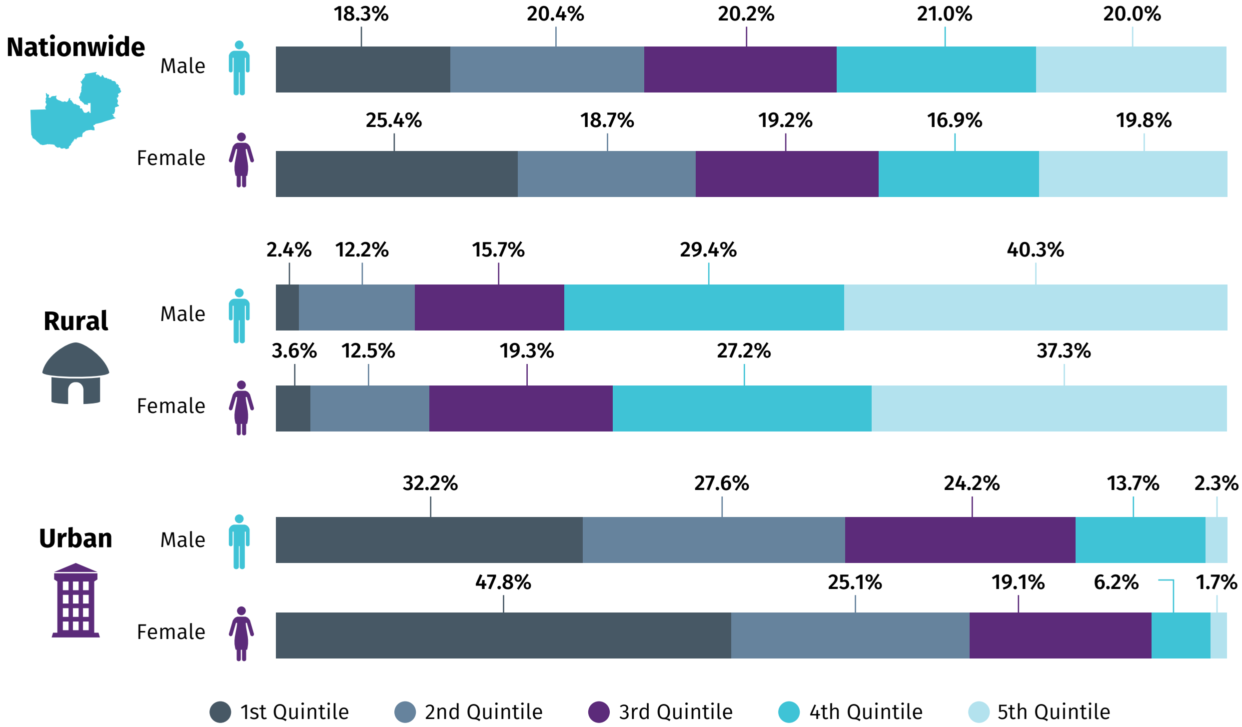


Note: Sample size: 3,203 households.

Nationwide, female-headed households spend ZMW 417 (US$46) less per month than male-headed households. The average monthly expenditure for female-headed households and male-headed households is ZMW 1,780 (US$194.4) and ZMW 2,197 (US$240), respectively. Overall, 44.1% of female-headed households are in the bottom two quintiles compared with 38.7% of male-headed households. The gap is bigger in rural areas, where 72.9% of female-headed households are in the bottom two quintiles, compared with 59.8% of male-headed households. In urban areas, the percentage of households in each quintile is similar (Figure 59). Breaking down the expenditure quintiles by household head gender reveals that, nationwide, female-headed households are poorer than male-headed households.

[20] Secondary education includes junior secondary and senior secondary. Higher education refers to trade school, college, and university.

FIGURE 59 • Distribution of households by expenditure quintile, by gender of household head, nationwide, urban and rural



Note: Sample size: 3,537 households.

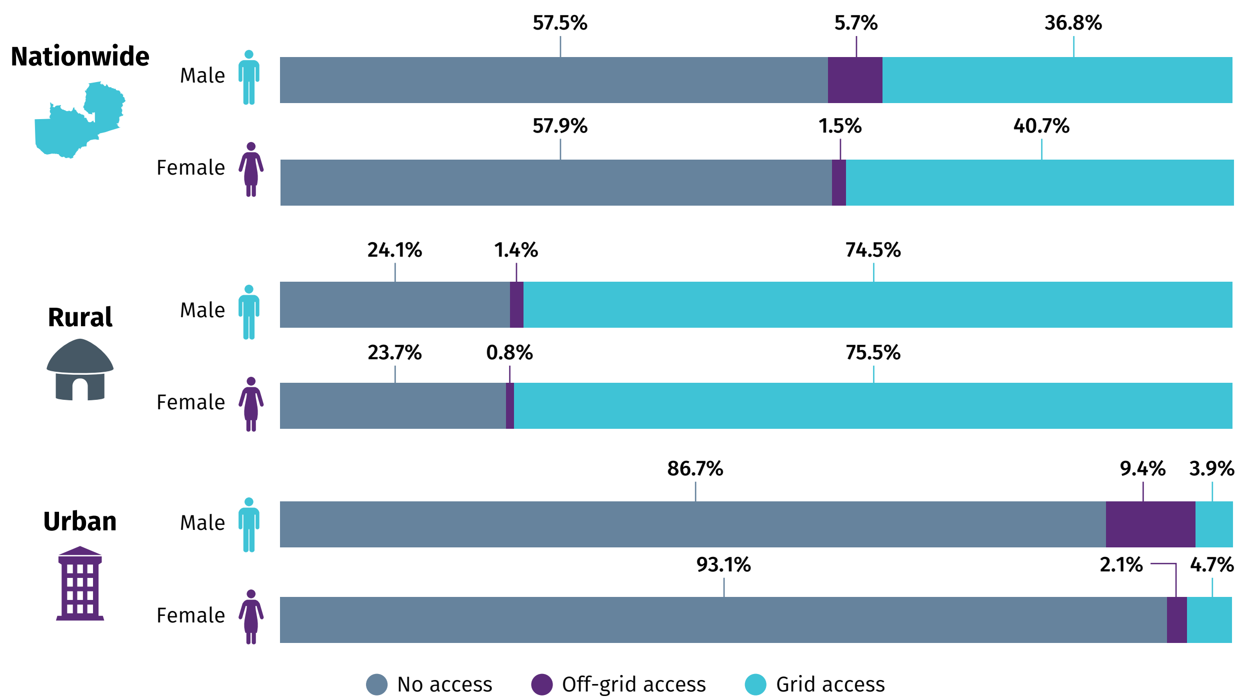
Only 63.2% of female-headed household reported that they had access to loans or credit, compared with 67.9% of male-headed households. When access is compared within urban areas, the gender gap increases. Only 65.1% of female-headed households had access to loans or credit compared with 73.4% of male-headed households. In rural areas, 61.2% of female-headed households have access to loans or credit compared with 63.1% of male-headed households (Figure 60).

FIGURE 60 • Access to finance (loan/credit) by gender of household head, nationwide, urban and rural

ACCESS TO ELECTRICITY

Nationwide, the percentages of male- and female-headed households that have access to electricity are similar: around 57% of households have no access to electricity. At the national level, the percentage of female-headed households who are connected to the national grid is higher than that of male-headed households. However, this is partly driven by the fact that female-headed households are slightly more likely to be located in urban areas, where the electrification rate is high. In addition, among households with no access to electricity, female-headed households are poorer than male-headed households, as 42.4% of female-headed households without electricity are in the lowest expenditure quintile, compared with 29.1% of male-headed households. The difference in access to electricity between rural and urban areas is substantial. In rural areas, more female-headed households have no electricity source (93.1%) compared with male-headed households (86.7%) (Figure 61). Access to the grid is low for all households, but male-headed households are more likely to use off-grid solutions compared to female-headed household. In urban areas, the gender gap does not remain.

FIGURE 61 • **Access to electricity by technology, by gender of household head, nationwide, urban and rural**



Note: Sample size: 3,537 households.

Female-headed and male-headed households have similar distributions of the MTF aggregate tier for access to electricity. Nationwide, 58.5% of female-headed households and 60.1% of male-headed households are in Tier 0. The situation differs between rural and urban areas, but regardless of area female-headed households are in lower tiers compared to male-head households. For instance, Figure 62 shows that:

- In rural areas, 94.3% of female-headed households are in Tier 0, compared with 90.5% of male-headed households; and
- In urban areas, 39.8% of female-headed households are in Tier 5, compared with 42.6% of male-headed households. The higher concentration of female-headed households in Tiers 3 and 4 is due to Availability issues.

FIGURE 62 • **MTF electricity tier distribution, by gender of household head, nationwide, urban and rural**

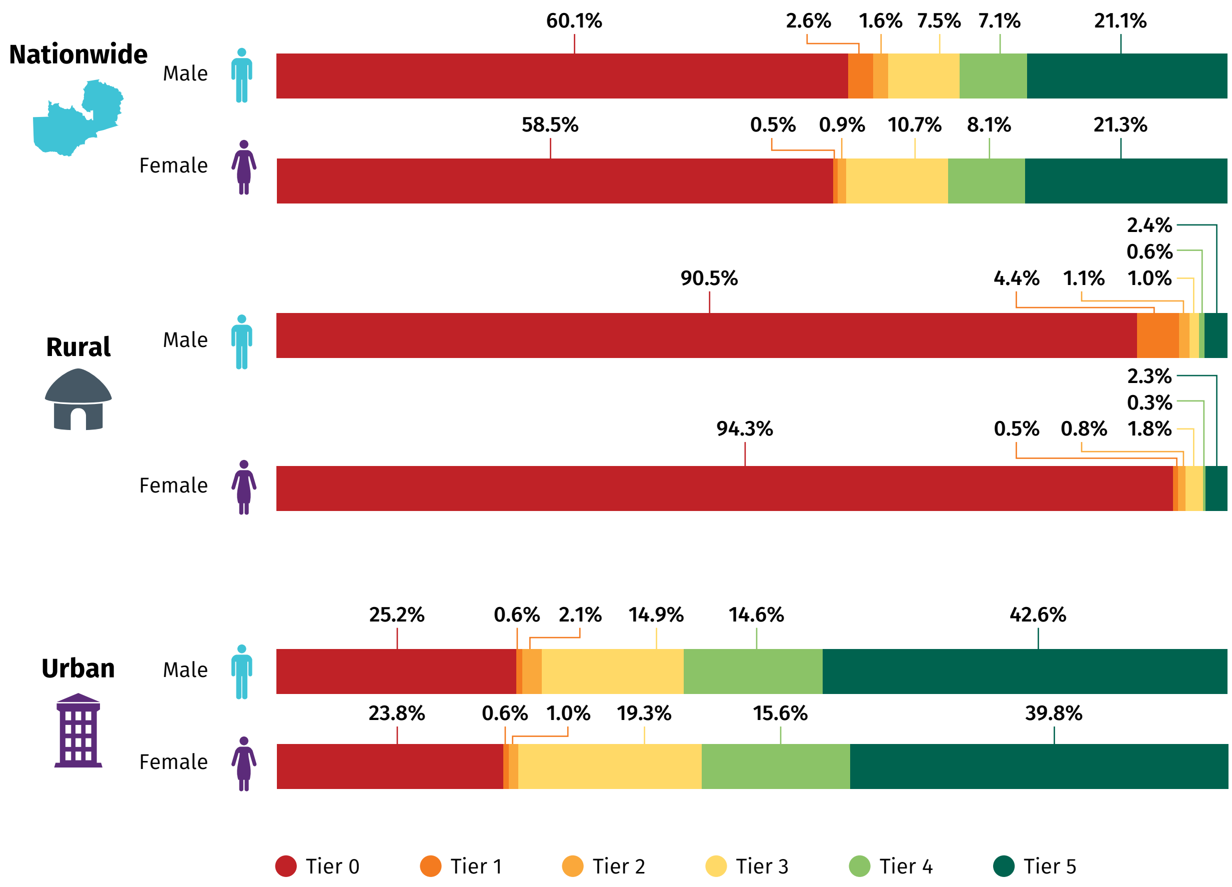
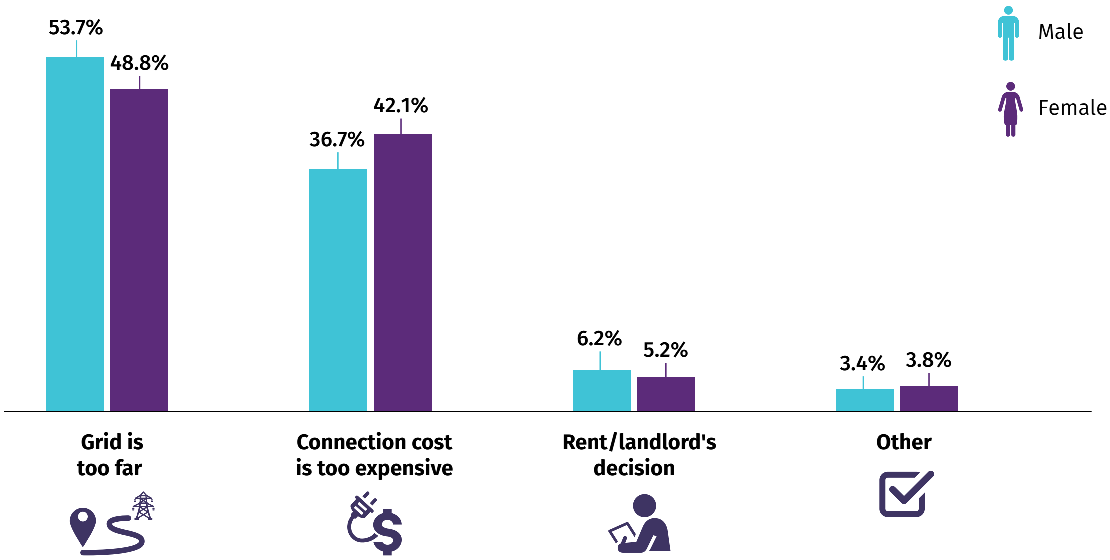


Figure 63 shows that both male-headed households and female-headed households identified "grid too far or unavailable" as the main reason they were not connected to the grid. Compared to male-headed households (36.7%), a larger portion of female-headed households (42.1%) reported that high connection cost was also a major barrier. Among households that identified high connection cost as the main barrier, more female-headed households (42.9%) are in the lowest expenditure quintile compared to male-headed households (27.6%).

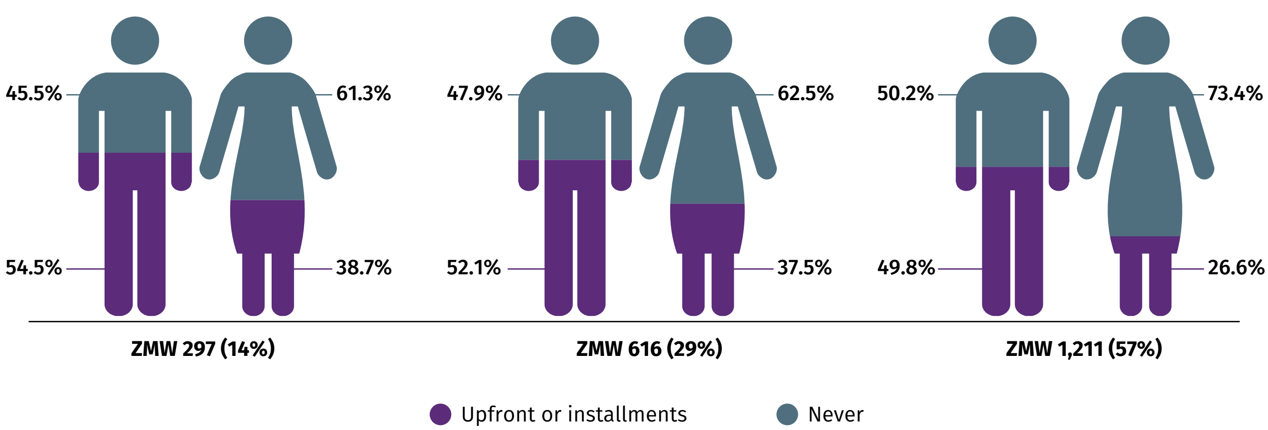
FIGURE 63 • **Barriers to gaining access to the electricity grid, nationwide**



Note: Sample size = 2,313 households. Only households that are not connected to the national grid.

Among unconnected households, the percentage of female–headed households that are willing to pay for a grid connection is lower than that of male-headed households. Over half of male-headed households are willing to pay ZMW 297 (US$ 32.4) for a grid connection, compared to only 4 in 10 female-headed households (Figure 64). Both shares decrease slightly as the fee increases to ZMW 616 (US$ 67.3). The willingness to pay among female-headed households drops dramatically, to 27%, as the connection fee soars to ZMW 1,211 (US$132.3).

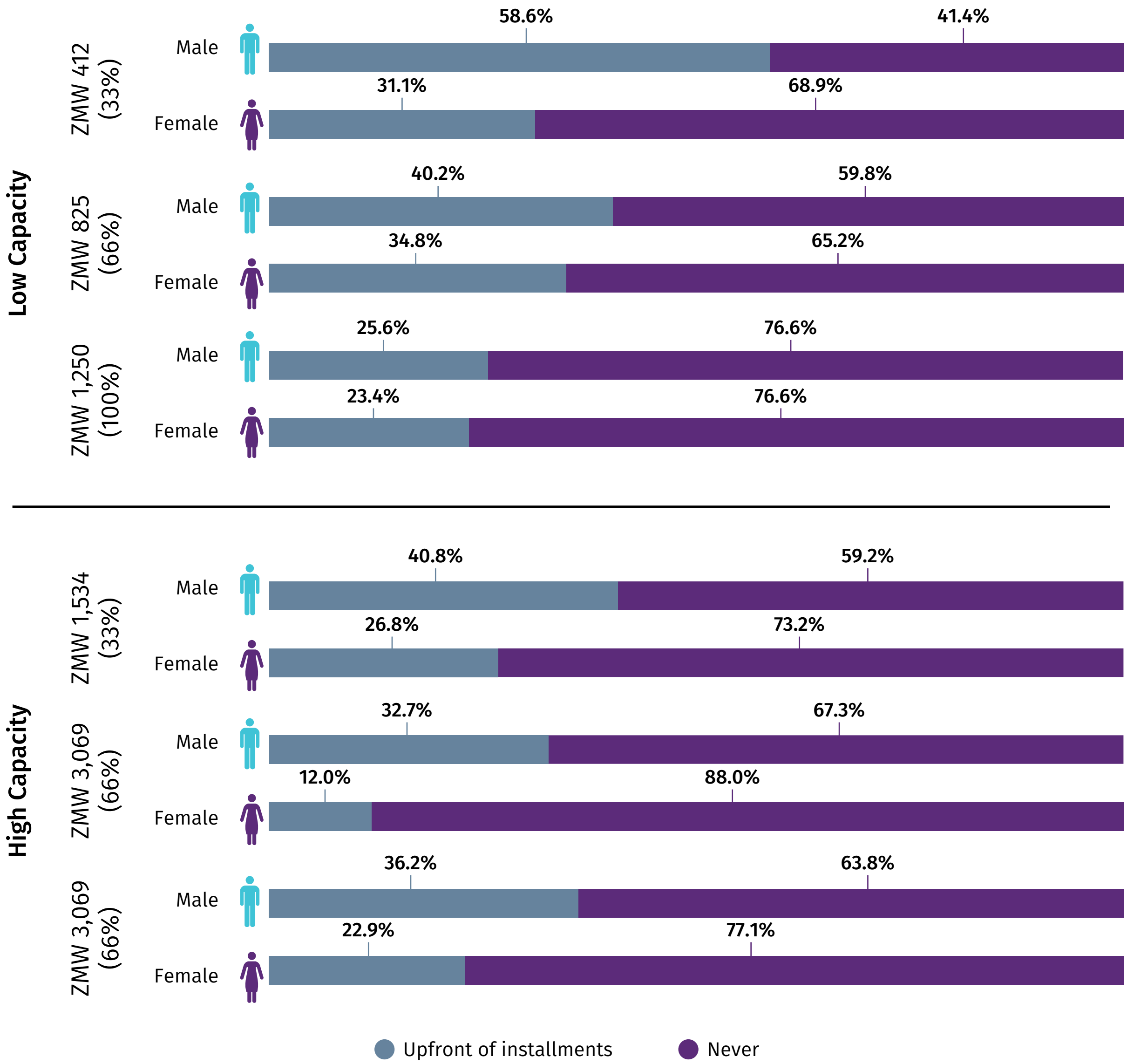
FIGURE 64 •**Willingness to pay for grid connection, by gender of household head, nationwide**



Note: Sample size: 1308 households.

Nationwide, a large percentage of female-headed household are never willing to pay for a solar home system at any cost. For a low-capacity solar home system, 68.9% of female-headed households are never willing to pay if the price of the system is ZMW 412 (US$ 45) (Figure 65). For a high-capacity system, 73.2% of female-headed households are never willing to pay at ZMW 1,534 (US$ 167.6). Male-headed households are more willing to pay for a solar home system at lower prices, while most female-headed households are still unwilling to adopt even if the price drops. The gender gap in willingness to pay remains for both grid connection and home solar system. If no measures are taken, the willingness to pay gap is likely to increase the difference in access to electricity in the future.

FIGURE 65 •**Willingness to pay for a solar home system, by gender of household head, nationwide**

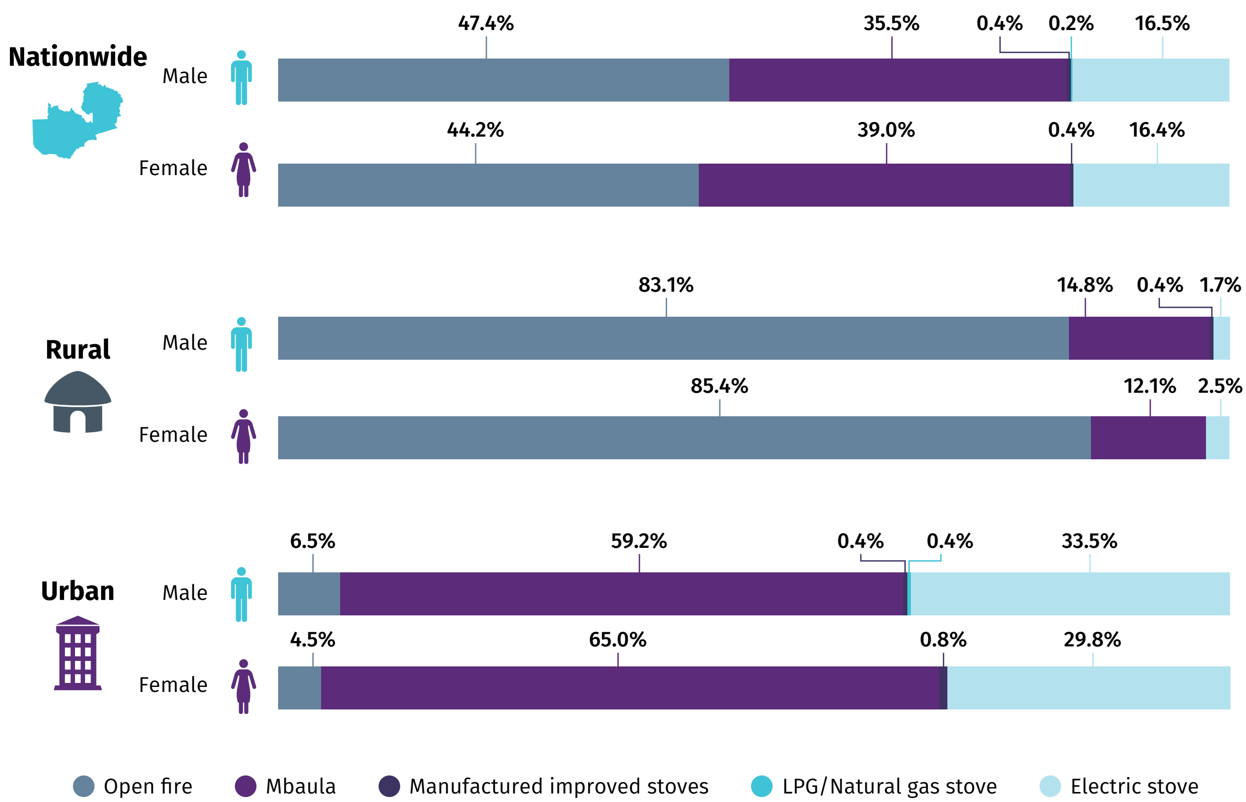


Note: Sample size = 2,260 households.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Nationwide, male-headed households are more likely to use open fires and less likely to use manufactured stoves than female-headed households, while there is no gender gap in the use of clean-fuel stoves. In rural areas, female-headed households are more likely to use open fires and less likely to use manufactured stoves, compared to their counterparts, and in urban areas they tend to have less access to clean cooking solutions (Figure 66).

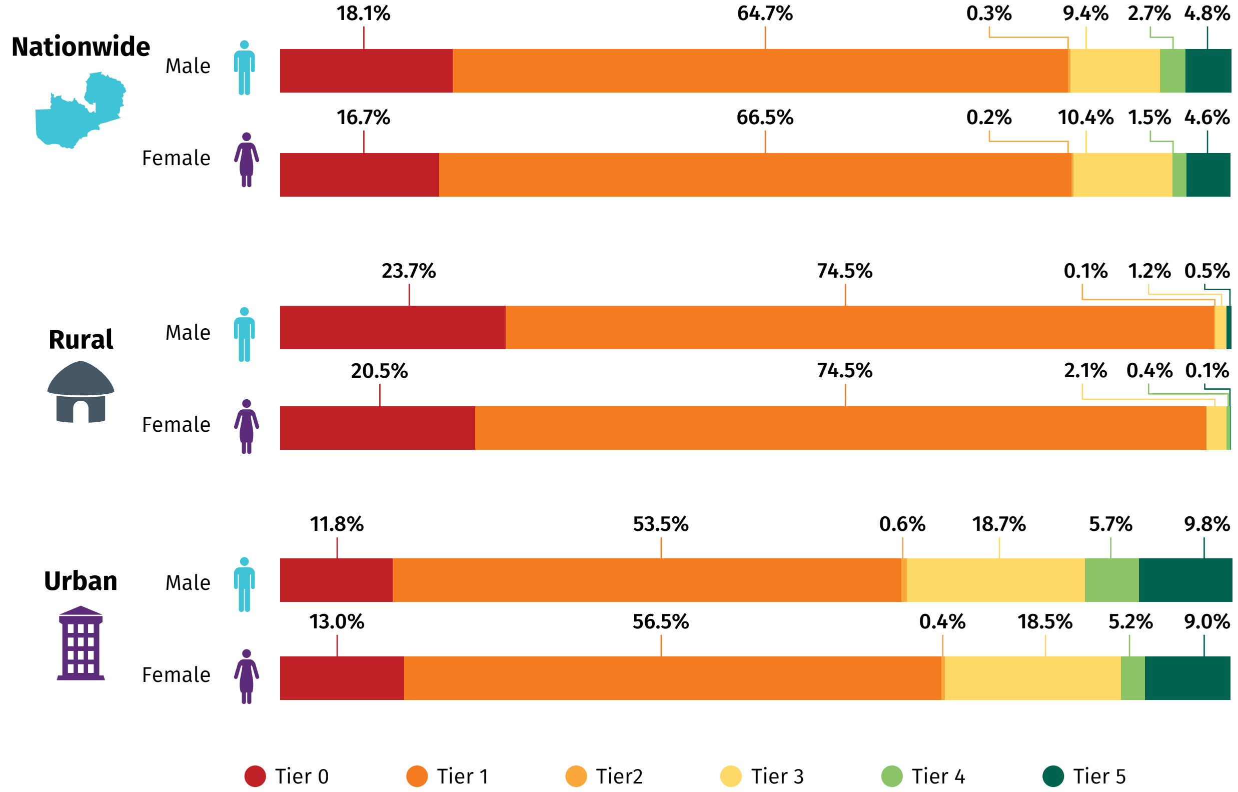
FIGURE 66 • **Access to cooking solutions, by type of primary cookstove, by gender of household head, nationwide, urban and rural**



Note: Sample size: 3,518 households.

Figure 67 indicates that male-headed and female-headed households also have similar access to modern energy cooking solutions. Nationwide, 83.2% of female-headed households are in lower tiers (Tier 0 and 1) and 82.8% of male-headed households are in those two tiers, while 4.6% and 4.8% of female-headed and male-headed households, respectively, are in the highest tier for access to modern energy cooking solutions. Although the amplitude is low, a small gender gap is observed in the use and access to a modern energy cooking solution.

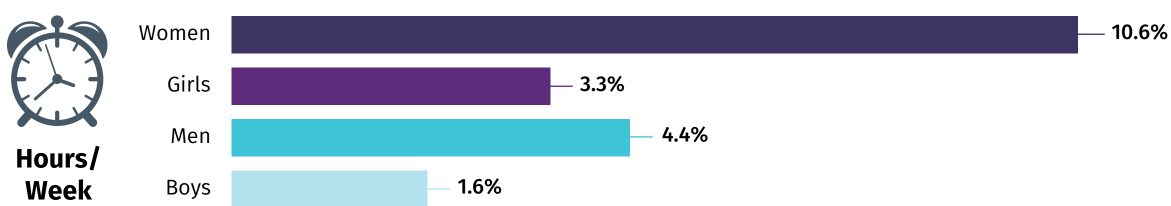
FIGURE 67 • **MTF tier distribution, by gender of household head, nationwide, urban and rural**



Note: Sample size: 3,518 households.

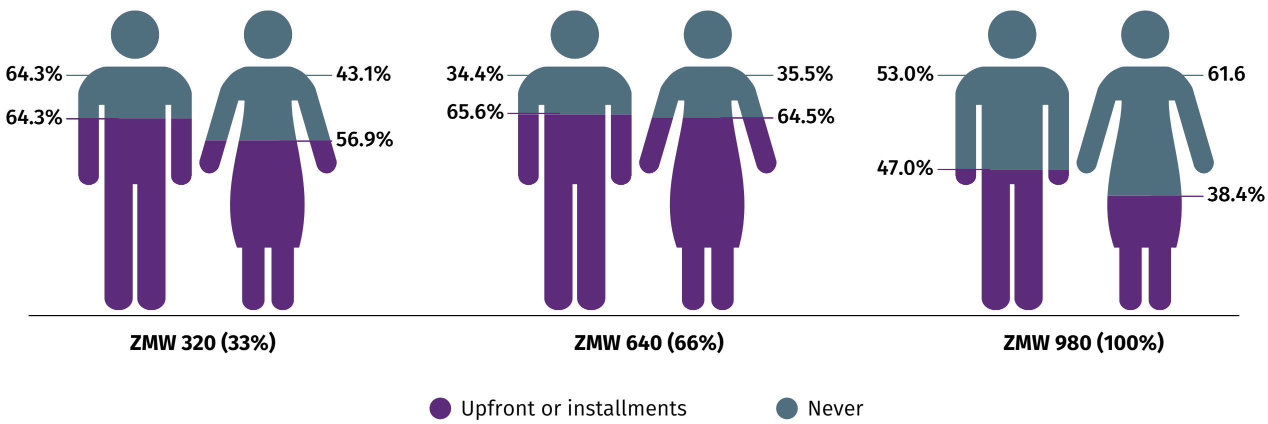
In Zambia, women age 15 and older spend a considerably higher amount of time cooking or in the cooking area (10.6 hours per week) compared to the other three groups (girls, boys, and men) (Figure 68). Therefore, women and girls are thus much more likely to be affected by indoor air pollution and are more likely to benefit from cleaner cooking solutions, compared to men and boys. The gender gap also exists for youth: girls spend 3.3 hours per week cooking, compared with 1.6 hours for boys.

FIGURE 68 • **Time spent in the cooking area (contact time), by hours/week, nationwide**



Male-headed and female-headed households show similar patterns regarding their willingness to pay for an improved cookstove. At the full price US$107, more than half of both male-headed households and female-headed households are unwilling to pay for an improved cookstove. While more households are willing to adopt an improved cookstove upon price reduction, the differences in willingness to pay between these two groups remain insignificant even at the lower price points of US$35 and US$70 (Figure 69).

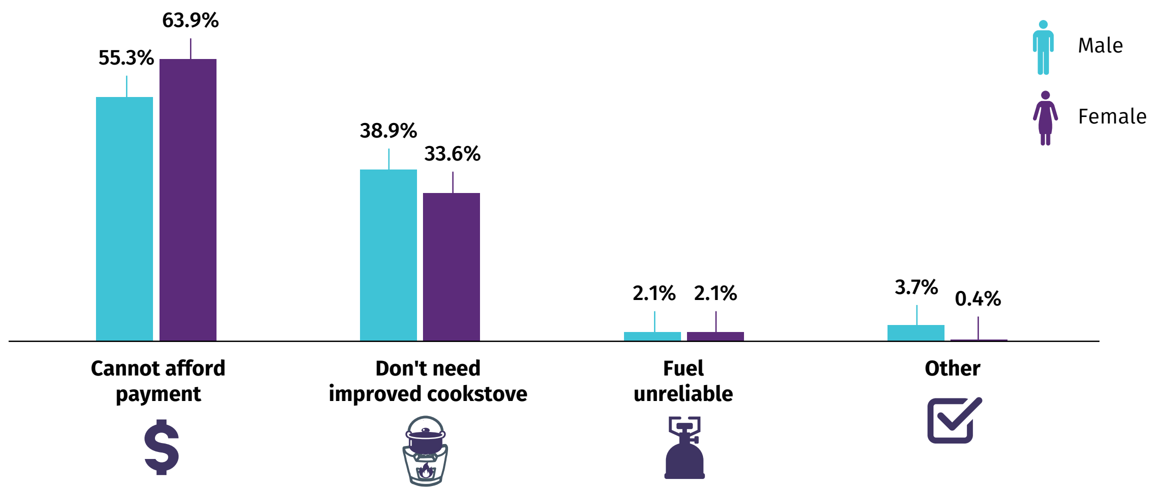
FIGURE 69 • **Willingness to pay for an improved cookstove, nationwide**



Note: Sample size: 2,151 households.

Both male-headed households and female-headed households identified high payment (Affordability) as the main reason why they would not adopt an improved cookstove, and the percentage is relatively greater for female-headed households (63.9%) than male-headed households (55.3%) (Figure 70).

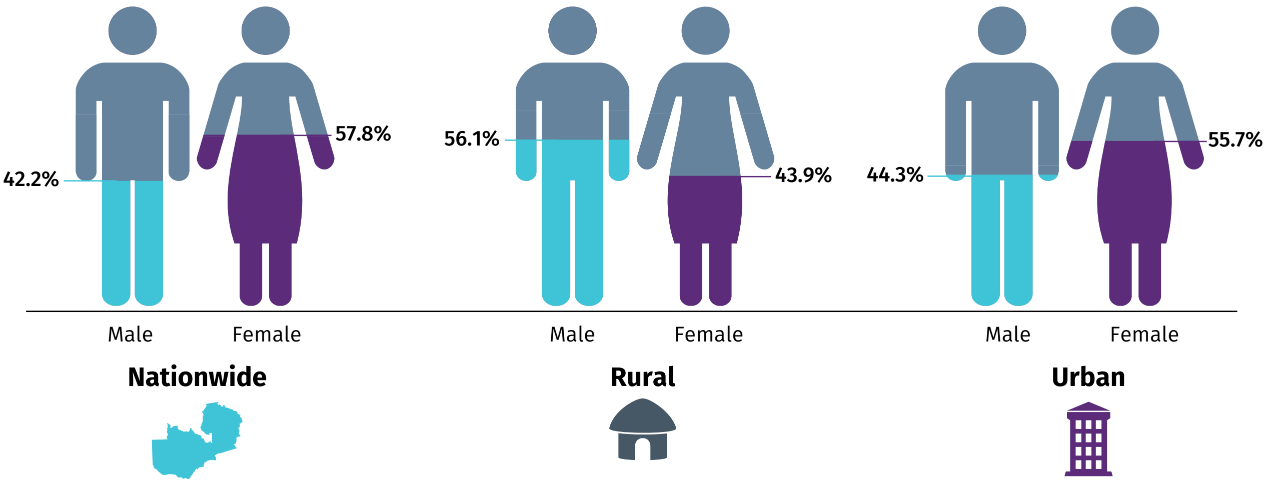
FIGURE 70 • **Reasons for not willing to pay for an improved cookstove, by gender of household head, nationwide**



Note: Sample size: 1,019 households.

Among households who purchased cookstoves, there is a substantial difference between urban and rural areas regarding decision making. Specifically, in urban areas female members (57.8%) tend to make decisions regarding purchasing cookstoves, while in rural areas male members (56.1%) usually make the decision (Figure 71).

FIGURE 71 • **Who decided to purchase cookstoves, nationwide, urban and rural**



Note: Sample size: 1,874 households..

POLICY RECOMMENDATIONS

Female-headed households appear to be more vulnerable than male-headed households: over half of them are widows or divorced, they tend to be poorer - especially in rural areas, are less educated, and less likely to have access to credit. Although female-headed households tend to have similar electricity access rates with male-headed households at the country level, in rural areas they tend to suffer more from lack of electricity compared to their male counterparts. They are more likely to be unable to pay for a grid connection or a SHS. Therefore, further research should be carried out to identify their needs and priorities, and possible ways to overcome barriers to energy access. Several pro-poor targeting actions, whereby female-headed households may be automatically eligible, may be considered, including interest-free credit for the purchase of energy equipment, credit schemes allowing payment of connection fee in affordable installments, subsidized connection costs, and lifeline tariffs.

Access to modern cooking solutions tend to be similar for male- and female-headed households at the country level. However, female-headed households tend to have less access to electric stoves in urban areas. Female-headed households are also less willing to pay for an improved cookstove, especially for highly priced stoves. Female-headed households are more likely to face Affordability constraints while male-households are more likely to believe that they do not need an improved cookstove. Women and girls in Zambia spend much more time in the cooking area compared men and boys. They are thus much more likely to be affected by indoor air pollution and thus more likely to benefit from cleaner cooking solutions. Therefore, Affordability constraints should be addressed for poor households and female-headed households, for example through targeted financing mechanisms. Education campaigns are also recommended to raise awareness on the benefits of clean and efficient cooking solutions targeting both men and women.

ANNEX 1: Multi-Tier Frameworks

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

<table>
<tr><th colspan="2">ATTRIBUTES</th><th>TIER 0</th><th>TIER 1</th><th>TIER 2</th><th>TIER 3[b]</th><th>TIER 4</th><th>TIER 5</th></tr>
<tr><td rowspan="3">Capacity</td><td rowspan="2">Power capacity ratings (W or daily Wh)</td><td>Less than 3 W</td><td>At least 3 W</td><td>At least 50 W</td><td>At least 200 W</td><td>At least 800 W</td><td>At least 2 kW</td></tr>
<tr><td>Less than 12 Wh</td><td>At least 12 Wh</td><td>At least 200 Wh</td><td>At least 1 kWh</td><td>At least 3.4 kWh</td><td>At least 8.2 kWh</td></tr>
<tr><td>Services</td><td></td><td>Lighting of 1,000 lmhr per day</td><td>Electrical lighting, air circulation, television, and phone charging are possible</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Availability[a]</td><td>Daily Availability</td><td>Less than 4 hours</td><td colspan="2">At least 4 hours</td><td>At least 8 hours</td><td>At least 16 hours</td><td>At least 23 hours</td></tr>
<tr><td>Evening Availability</td><td>Less than 1 hour</td><td>At least 1 hour</td><td>At least 2 hours</td><td>At least 3 hours</td><td colspan="2">At least 4 hours</td></tr>
<tr><td>Reliability</td><td></td><td colspan="3">More than 14 disruptions per week</td><td>At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours”</td><td>(> 3 to 14 disruptions / week) or ≤ 3 disruptions / week with > 2 hours of outage</td><td>At most 3 disruptions per week with total duration of less than 2 hours</td></tr>
<tr><td>Quality</td><td></td><td colspan="4">Household experiences voltage problems that damage appliances</td><td colspan="2">Voltage problems do not affect the use of desired appliances</td></tr>
<tr><td>Affordability</td><td></td><td colspan="3">Cost of a standard consumption package of 365 kWh per year is more than 5% of household income</td><td colspan="3">Cost of a standard consumption package of 365 kWh per year is less than 5% of household income</td></tr>
<tr><td>Formality</td><td></td><td colspan="4">No bill payments made for the use of electricity</td><td colspan="2">Bill is paid to the utility, prepaid card seller, or authorized representative</td></tr>
<tr><td>Health and Safety</td><td></td><td colspan="4">Serious or fatal accidents due to electricity connection</td><td colspan="2">Absence of past accidents</td></tr>
</table>

a. Previously referred to as “Duration” in the 2015 Beyond Connections report, this MTF attribute is now referred to as “Availability,” examining access to electricity through levels of “Duration” (day and evening). Aggregate tier is based on lowest tier value across all attributes

Source: Bhatia and Angelou 2015.

Note: Color signifies tier categorization.

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

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	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	≤ 10%
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 than 80% of the year				Available 80% of the year	Readily available throughout the year

Note: Cookstove Efficiency not used as an attribute to calculate the final tier in Zambia. Volume of kitchen not used to calculate the tier for sub-attribute Ventilation for the attribute Cooking Exposure due to data limitations which hindered making this calculation.

ANNEX 2:
Sampling Strategy

A. SAMPLE SIZE CALCULATION PARAMETERS

The sample size proposed for Zambia is designed to get sufficiently precise estimates of each tier at national as well as urban and rural level. A much smaller sample size would have been adequate to produce precise estimates at the national level within those domains. This section discusses the factors that should be taken into consideration in the determination of sample size calculation and provides a justification for the proposed sample size for each country. The major issues considered in determining 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 subsections 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 the population. 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 purpose. 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 a characteristics of interest is generally unknown. Sampling errors (or margin of errors) depend very much on the size of the sample, and very little on the size of the population. To maximize the sample size and to reduce the sampling error the prevalence rate in this calculation is 50%. The formula to calculate the sample size is as below:

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

where:

n = Sample size to be determined.

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

r = Estimate of the indicator of interest (50%).

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 regarding 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. Thus, the final number of households interviewed will be slightly less that the original sample size eligible for interviewing. The sample size should be calculated to reflect the experience from the country in question. 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 or level of precision. We apply various level of margin of error from 1% to 5.5% to the calculation.

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

Beside 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 and Muñoz 1996, p. 56). Thus, one would expect non-sampling error to increase with sample size and we would like to limit the sample size to less than 5,000.

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 survey firm and cost for each country would affect the total cost of survey implementation, too. Thus, the cost of data collection, processing, and dissemination should be considered in determining the sample size for each country.

B. SAMPLING APPROACH

In this study, stratified random sampling technique is used. The first stratification involves stratifying into urban and rural strata. The second stratification is based on electrification status of the enumeration areas (EAs) in the study population.

Urban and Rural stratification

The primary sampling units (PSUs) in this study are EAs, selected randomly from the list of EAs in Zambia obtained from CSO Zambia. The EAs were stratified into rural and urban strata. For each stratum, random numbers were allocated to each EA and these EAs were arranged in ascending order. The first EAs to satisfy the sample quota of each province were picked. The number of EAs picked in each province for either rural or urban stratum were dependent on the sample size of each province. A total of 14 households were sampled in each EA, so the sample size of each of the province was divided by 14 to get the total number of EAs to be sampled. An equal split of the sample between rural and urban stratum was done at the national level.

Electrified or non-electrified stratification

Listing was conducted only in the sampled EAs to determine whether to classify an EA into either electrified or non-electrified stratum. EAs with at least 3% of households that were connected to the national grid were classified as electrified while those with less than 3% of households connected to the national grid were classified as non-electrified. A 50-50 ratio of distribution of sample between grid and non-grid users was achieved.

Household selection

During the listing process, information on electricity connection (the number of households with or without electricity in a sampled EA) were collected. Random numbers were allocated to each household and arranged in ascending order for each stratum.

C. SAMPLE SIZE CALCULATION

Sample size calculation is done using this formula:

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

where n is the sample size in terms of number of households to be selected and z is standardized z-score (normal variate) corresponding to a 95% confidence interval. Estimate of the indicator of interest to be measured by the survey is denoted by r and is taken to be 0.5 using the MTF suggested prevalence rate so as to achieve minimum margin of error and the intra-cluster correlation coefficient ρ=0.45 selected using knowledge of the characteristics of infrastructure. The number of households to be selected per EA, m, and 14 households are proposed. The factor accounting for non-response, k, is calculated to be 1.1 considering that in developing countries the non-response rate is typically 10% or less. The margin of error, e, is taken to be 0.044 (96% confidence). Using these values, the sample size was 3,658 households. Due to the fact that the sample quota allocated to some EAs was not divisible by 14, a slightly higher sample size of 3,668 was covered.

Listing was done for only sampled EAs in all provinces. The number of EAs listed in a given province was calculated as follows:

$$\text{Number of EAs} = \frac{\text{sample quota for both rural \& urban strata for the province}}{14}$$

All households selected were listed during the listing exercise. A unique identification (ID) that identifies the EA, rural/ urban stratum and connection status was given. In this survey, for a person to be considered a member of the household, he/she must be a member of the immediate family who normally lives in the household and has eats meals together for the last 6 months. Exceptions that were considered in the study were:

- newborn children who were members of the household, even if they were less than six (6) months of age;
- women who had entered a marriage were considered as members of the household, even if they had not lived six (6) months in their new household; and
- students who had attended school during the school year were considered as members of the household in which they lived during the school year.

Of the original sample size of 3,668 targeted households in 262 EAs (130 EAs in urban and 132 EAs in rural areas) (table A2.1), 3,612 households in 260 EAs were contacted (table A2.2), and 3,537 in 260 EAs were effectively interviewed (table A2.3).[21] The response rate is thus 96%, which is the difference between the sample of household originally targeted and those finally interviewed. As explained in paragraph 4, the non-response was mainly due to movement out of the dwelling of respondents (43 households) and unwillingness to participate in the survey.

The following tables (tables A2.1 through A2.3) summarize the number of sampled EAs and household sample distribution. The sample is split into rural and urban strata and is further split between electrified and non-electrified strata.

[21] The sample of 3,537 was used to calculate the weight.

TABLE A2.1 • Distribution of EAs and households in Zambia sampled for the Multi-Tier Framework survey – original sample (households targeted)

Province	Urban				Rural				Nationwide			
	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs
Central	70	42	112	8	19	191	210	15	89	233	322	23
Copperbelt	359	187	546	39	16	82	98	7	375	269	644	46
Eastern	35	35	70	5	6	316	322	23	41	351	392	28
Luapula	26	44	70	5	22	202	224	16	48	246	294	21
Lusaka	410	262	672	48	40	58	98	7	450	320	770	55
Muchinga	27	15	42	3	7	133	140	10	34	148	182	13
North Western	14	42	56	4	0	126	126	9	14	168	182	13
Northern	35	35	70	5	2	208	210	15	37	243	280	20
Southern	81	59	140	10	29	209	238	17	110	268	378	27
Western	21	21	42	3	0	182	182	13	21	203	224	16
Total	**1,078**	**742**	**1,820**	**130**	**141**	**1,707**	**1,848**	**132**	**1,219**	**2,449**	**3,668**	**262**

TABLE A2.2 • Distribution of EAs and households in Zambia sampled for the Multi-Tier Framework survey – original sample (households contacted)

Province	Urban				Rural				Nationwide			
	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs
Central	69	42	111	8	18	192	210	15	87	234	321	23
Copperbelt	361	165	545	39	15	81	98	7	376	246	643	46
Eastern	37	32	70	5	7	301	308	22	44	333	378	27
Luapula	24	42	67	5	18	190	211	16	42	232	278	21
Lusaka	415	249	671	48	40	58	98	7	455	307	769	55
Muchinga	23	17	42	3	6	131	140	10	29	148	182	13
North Western	15	39	56	4	0	100	126	9	15	139	182	13
Northern	26	38	68	5	14	172	190	14	40	210	258	19
Southern	85	55	140	10	30	206	237	17	115	261	377	27
Western	21	21	42	3	0	182	182	13	21	203	224	16
Total	**1,076**	**700**	**1,812**	**130**	**148**	**1,613**	**1,800**	**130**	**1,224**	**2,313**	**3,612**	**260**

TABLE A2.3 • **Distribution of EAs and households in Zambia sampled for the Multi-Tier Framework survey – original sample (households interviewed)**

Province	Urban				Rural				Nationwide			
	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs	Electrified HHs	Non-electrified HHs	Total HHs	Total EAs
69	42	111	8	18	192	210	15	87	234	321	23	23
361	165	526	39	15	81	96	7	376	246	622	46	46
37	32	69	5	7	301	308	22	44	333	377	27	28
24	42	66	5	18	190	208	16	42	232	274	21	21
415	249	664	48	40	58	98	7	455	307	762	55	55
23	17	40	3	6	131	137	10	29	148	177	13	13
15	39	54	4	0	100	100	9	15	139	154	13	13
26	38	64	5	14	172	186	14	40	210	250	19	20
85	55	140	10	30	206	236	17	115	261	376	27	27
21	21	42	3	0	182	182	13	21	203	224	16	16
1,076	**700**	**1,776**	**130**	**148**	**1,613**	**1761**	**130**	**1,224**	**2,313**	**3,537**	**260**	**262**

C.1 SAMPLE WEIGHTING CALCULATIONS

Sample weights are important in analysing household survey data. Due to this fact sample weighting was executed to reduce bias due to imperfections in the sample. Since we used two-stage stratification, the sample design weight was calculated as $w_i = 1/p$, where p is the probability of a unit to be included in the sample. The focus is on design weight, weight attributable to the compensation for non-coverage, and weight attributable to compensation for non-response. Calculation of the design weight was done as follows.

- First the probability of selecting a certain EA in rural and urban strata was established, which was the first stage calculated as the number of EAs selected in a stratum multiplied by the measure of size of the EA. The total number households in that stratum were then divided into the result. A 88-12% electrification ratio between urban and rural areas respectively was used to calculate the probability of electrification status of an EA. The 88-12% electrification status split was obtained from the CSO of Zambia.
- The probability of selecting the household within the EA, which is stage 2, was then established. This was simply the number of households selected in the EA in a certain stratum divided by the total number of households listed in the EA in that stratum considering the electrification status.
- We then calculated the overall selection probability of each household in an EA of a certain stratum as a product of values found in (i) and (ii) above.

- We computed the design weight for each household in an EA of a certain stratum as the inverse of the overall selection probability.

Correction for non-response was done at EA and household levels. EA response rate was calculated as the number of EAs interviewed divided by the number of EAs selected in each stratum. Household level response rate was calculated as the design weight multiplied by the sum of households interviewed in a stratum divided by the design weight multiplied to the sum of households listed in a stratum.

D. FIELDWORK CHALLENGES

The study was carried out successfully, although some challenges were met during the course of the fieldwork. Fieldwork challenges included:

- Inaccessible EAs: A total of 8 sampled EAs were in the wetlands and, thus, difficult to reach because of the rainy season. This delayed fieldwork, as enumerators used a primitive mode of transport. A total of 2 out of 8 EAs were totally inaccessible by any form of transport.
- Overall, about 4% of the sampled households were not interviewed because they were unwilling to participate; furthermore, 43 households moved out of the dwelling after listing.
- Electrification status discrepancies between listing and fieldwork: About 1% of the sampled households recorded as connected during listing were then identified as not connected to electricity during the fieldwork, and this problem was solved by recording the connection status during the fieldwork.
- Permission to interview facilities: The authorization letter from Ministry of Energy was received on time, while the letters from Ministries of Health and Education delayed to the end of the survey.
- Challenges in locating some households in the compound residential areas.

ANNEX 3:
Cookstove Typology

Open fire: A pot balanced on three stones over an open fire or a tripod. In general, this stove uses firewood, has a low combustion temperature, and its fire is exposed to cold wind causing its heat to be lost to the ambient air.

Manufactured traditional stove (*mbaula*): The pot sits mostly on the fuel. It has a low combustion temperature due to poor insulation and a lot of cold excess primary air because of too many openings. In Zambia, this is the most common manufactured traditional stove.

Manufactured improved stove: This has a higher combustion temperature due to its enclosed combustion chamber and some insulation. The pot sits above the fire, allowing more time for combustion

LPG stove: A clean stove that uses LPG.

Electric stove: A clean stove that uses electricity.

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