NIGERIA

NORTH-WEST GEO-POLITICAL ZONE

States of: Kaduna, Kano, Katsina, Kebbi, Jigawa, Sokoto, and Zamfara

Beyond Connections

Energy Access Diagnostic Report Based on the Multi-Tier Framework

ESMAP

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SREP

MTF Multi-Tier FRAMEWORK

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ABBREVIATIONS

EA	enumeration area
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
HH	Household
ICS	Improved cookstove
KEDCO	Kano Electricity Distribution Company
kW	kilowatt
kWh	kilowatt-hour
LED	light-emitting diode
LPG	liquefied petroleum gas
MTF	Multi-Tier Framework
MW	megawatt
N	Nigerian naira
NBS	National Bureau of Statistics
NPopC	National Population Commission of Nigeria
PSU	primary sampling unit
SHS	solar home system
SLS	solar lighting system
SREP	Scaling up Renewable Energy Program in Low Income Countries
W	watt

The average exchange rate from September 1, 2017, to March 31, 2018, was US$1 = N359.25.

EXECUTIVE SUMMARY

Nigeria is a low-middle-income country. As of 2018, the gross domestic product (GDP) per capita (in current US dollars) was $2,028.2 (World Bank 2018). The economic growth is too low to lift the bottom half of the population out of poverty, and living standards are expected to worsen (World Bank 2019). The country has one of the lowest rates of net electricity generation per capita worldwide. Electricity generation fails to satisfy demand, resulting in load shedding, blackouts, and a reliance on private generators (EIA 2016). A substantial share of the population without electricity access is in northern Nigeria, which is generally poorer and more sparsely populated than southern states. Thus, the Multi-Tier Framework (MTF) survey in Nigeria mainly focuses on the geopolitical zone of North-West Nigeria, where two distribution companies (DISCOs)[1] provide electric services. Nonetheless, notable power sector reforms are under way in the country, including plans for electrification (EIA 2016).

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the 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.[2]

ACCESS TO ELECTRICITY

The 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.[3] The final aggregate tier for a given household is based on the lowest tier it has attained among all the seven attributes.

The MTF findings for North-West Nigeria show that energy access is generally very poor and fairly polarized between urban and rural areas. The national grid is by far the most common source of electricity and households lacking connectivity tend to live without electricity. The following are particularly pertinent:

- **Source of electricity:** In 2016, 20.6 million households[4] in North-West Nigeria (42.1%) had access to electricity through either national grid or off-grid sources, while the remaining 28.3 million households (57.9%) had no access to electricity. Among the 42.1% of households with electricity, 40% are connected to the national grid, and the remaining 2.1% primarily use off-grid solutions such as electric generators. The difference in access to electricity between urban and rural areas is substantial: most urban households (78.7%) have access to electricity through the national grid, whereas only 26.7% of rural households have access to electricity through the national grid.

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1 The companies are Kaduna Electric, covering the states of Kaduna, Kebbi, Sokoto, and Zamfara, and KEDCO, covering Kano, Jigawa, and Katsina states.
2 The MTF access rate includes access provided by off-grid technologies, which is often excluded by the binary rate, but excludes connections that do not meet its criteria for minimum level of service.
3 For descriptions of the MTF and its attributes, see annex 1, table A1.1.
4 Nigeria population census, 2016, https://nigeria.opendataforafrica.org/. The combined population of the seven states that form the North-West Nigeria geopolitical zone is 48.9 million people.

- **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. In North-West Nigeria, about 40% of the households (19.3 million households) are in Tier 1 or above for electricity access, and almost none of those are in Tier 5. Electricity access is largely a rural challenge. Specifically, about three out of four rural households (35.2 million households) are in Tier 0 for access to electricity, while the remainder (26.7%) are dispersed across Tiers 1 through 5. Most urban households are in Tiers 2 and 3, and about one-quarter remain in Tier 0.

- **Households in Tier 0:** In North-West Nigeria, 60.7% of households are in Tier 0 for access to electricity, and most 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 67.9% of the enumeration areas (EAs) in the country; however, only 46.3% of North-West Nigerian households are connected to the grid. The low uptake rate of grid connection opens up the possibility to increase the grid electrification rate by around 21.6% by 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:** The performance of the grid in North-West Nigeria is not satisfactory: four in five grid-connected households are in Tiers 2 or 3. Only a few households are in Tiers 4 and 5 (6.1%), while the rest (13.2%) fall in the lower tiers (Tiers 0 and 1). Challenges with the Availability, Reliability, and Quality attributes are the main issues preventing grid-connected households from being in the highest tier.

- **Off-grid solutions users:** Over one-fifth of off-grid households falls in Tier 0 because of the limited Capacity of the off-grid solutions. About 70% are between Tiers 1 and 3, 5% reach Tier 4 and only 1.8% have access at a Tier 5 level. Although the use of solar devices is a relatively recent phenomenon in North-West Nigeria and is mainly available in the urban areas, 93.1% households that use a solar solution are satisfied with their choice.

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.[5] The final aggregate tier for a household is based on the lowest tier that the household has attained among all the attributes.

- **Primary cookstove and fuel:** North-West Nigerian households reported using six types of cookstoves: 82.8% use three-stone[6] stoves; 4.2% use a self-built/traditional stove; 6.9% use a locally manufactured stove; 2.4% use kerosene stoves, 2.6% use liquefied petroleum gas (LPG) or natural gas stoves (considered together as a category), and 0.1% use electric stoves. Urban and rural households rely on different cooking technologies, with more than half of urban households (58.2%) using stoves other than three-stone stoves while 93.4% of rural households using three-stone stoves. Additionally, LPG/natural gas stoves are much more prevalent in urban areas: used by 12.7% of households in urban areas versus 1.0% in rural areas).

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[5] For descriptions of the MTF and its attributes, see annex 1.
[6] 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:** Most households are concentrated in Tiers 0 and 1 (15.1% and 78.7%, respectively). Almost, all the rural households (97.6%) are in Tiers 0 and 1 compared to urban households (82.8%). Clean-fuel stove users tend to be in higher tiers for access to modern-energy cooking solutions.

- **The Cooking Exposure attribute as the main constraint faced by 96.1% of households in Tier 0 and Tier 1, mainly due to the extensive use of three-stone stoves:** Possible solutions are to promote clean-fuel stoves by making LPG more affordable, expanding the LPG network in rural areas, improving the grid and off-grid infrastructure, introducing payment plans of improved cookstoves (ICSs), and expanding the ICSs network.

- **Households in Tiers 1–3 mainly facing challenges stemming from Convenience.** In North-West Nigeria, 70.6% of households spend more than seven hours per week collecting and preparing fuel, or at least 15 minutes preparing a stove before each meal. Additionally, the Fuel Affordability attribute is a concern for all fuels, since more than 30% of households spend more than 5% of their total household expenditure on their primary cooking fuel.

MEASURING ENERGY ACCESS IN NORTH-WEST NIGERIA

Photo: Lucia Luzi

Without energy, promoting economic growth, overcoming poverty, and supporting human development are challenging, if not impossible. Energy access is 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 Nigeria, 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.

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COUNTRY CONTEXT

The Federal Republic of Nigeria is located in West Africa, bordering Niger, Chad, Cameroon, and Benin. A federation that consists of 36 autonomous states and the Federal Capital Territory, Abuja, Nigeria is a multi-ethnic and culturally diverse society. It is the largest economy of the African continent. A key regional player in West Africa, it accounts for about 47% of West Africa's population and has one of the largest populations of youth in the world. With an estimated population of 195.9 million people, the country spans 923,770 square kilometers (World Bank 2018), and for every square kilometer of Nigerian territory, there is an average of 215 people.

Nigeria is ranked among the world's low-middle-income countries (World Bank 2019). In 2018, the gross domestic product (GDP) per capita (in current US$) amounted to $2028.2 (World Bank 2018). Also, Nigeria ranked 157 out of 189 countries on the Human Development Index (HDI) in 2017, with a value of 0.532, above the average of 0.504 for countries in the low human development group and below the average of 0.537 for countries in sub-Saharan Africa (UNDP 2018). However, when the value is discounted for inequality, the HDI falls to 0.347, a loss of 34.7 percent. (UNDP 2018). Given that the economy is expected to grow more slowly than the population, living standards are expected to worsen.

Nigeria has abundant natural resources, which make it the biggest oil exporter in Africa; furthermore, the country has the largest natural gas reserves on the continent. Nigeria's oil production, currently the largest in Africa, is hampered by instability and supply disruptions, while its natural gas sector is restricted by the lack of infrastructure to commercialize natural gas that is currently flared (EIA 2016).

Between 2006 and 2016, Nigeria's GDP grew at an average rate of 5.7% per year, as volatile oil prices drove growth to a high of 8% in 2006 and to a low of -1.5% in 2016. While Nigeria's economy has performed much better in recent years than it did during previous boom-bust oil price cycles, such as in the late 1970s or mid-1980s, oil prices continue to dominate the country's growth pattern. However, the economic growth is too low to lift the bottom half of the population out of poverty (World Bank 2019). As a matter of fact, the weakness of the agriculture sector deteriorates prospects for the rural poor, while high food inflation harms the livelihoods of the urban poor.

North-West Nigeria is one out of six geopolitical zones in the country with both economic development and access to energy lower than those in southern zones of Nigeria (World Bank 2019). At present, oil is not produced in the north of Nigeria, nor are the proper infrastructure to process or transport oil present there. Besides, instability presents a considerable hazard to produce oil in the area (EIA 2016). The country has one of the lowest rates of net electricity generation per capita worldwide. Electricity generation fails to satisfy the demand, resulting in load shedding, blackouts, and a reliance on private generators. (EIA 2016). Overall, electricity access in urban areas of North-West Nigeria is higher than in rural areas, with a significant difference of 50 percentage points. A substantial share of the country's overall population without electricity access is in northern Nigeria, which is generally poorer and more sparsely populated than southern states. Nonetheless, notable power sector reforms are under way in the country, including plans for electrification (EIA 2016).

The overall electrification rate in Nigeria was 59% in 2016: 86% in urban and 41% in rural areas (IEA et al. 2018). The lack of access to electricity is directly affecting livelihoods, lowering quality of life, and endangering the economy. In 2016, 5% of the population had access to clean cooking solutions (IEA et al. 2018). In North-West Nigeria, only a small fraction of the population has clean cooking fuels. The MTF estimates that the portion of households in the zone with access to clean cooking solutions in 2017 was about 3.7%: 12.7% in urban and 1% in rural areas. North-West Nigerians are fully reliant on three-stone stoves for cooking, with associated health implications.

MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the MTF Global Survey, whose objective is to provide more nuanced data on energy access, including access to electricity and cooking solutions. The first phase is being carried out in 16 countries across Africa (including North-West Nigeria), 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 range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[7]

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).

7 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.

ACCESS TO ELECTRICITY

Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety (see annex 1, table A1.1). 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 diode (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. 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.[8] Capacity is measured in watts for grids, mini-grids, and fossil fuel 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 available Capacity may be based on the supply source (for example, the grid is considered greater than 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 four 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 measured only for households connected to the grid.

- **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 dispersed households to a single 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 is an informal connection. The formality of the grid connection is important, since it ensures that the electricity authority gets paid for the services provided, besides providing for the safety of electric

[8] Households' MTF Capacity Tier is 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 the Capacity attribute regardless of their appliance ownership, so the Capacity attribute is discussed for off-grid households only.

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 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.

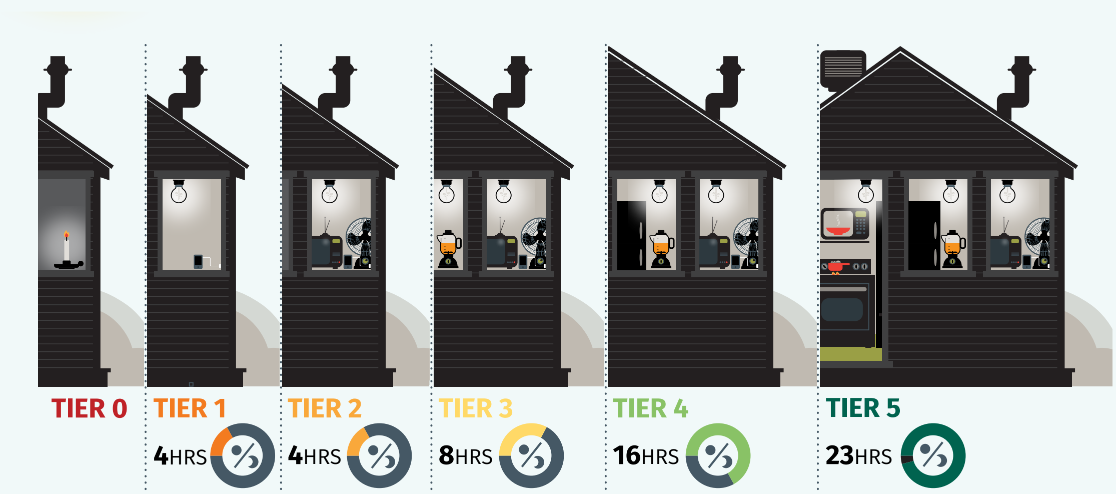
- **Health and Safety** ("Is it safe to use my electricity service?"): This attribute refers to any injuries to household members from using electricity service from the grid during the preceding 12 months of the survey. An injury could mean limb injury or even death from burn or electrocution. Such injuries can happen from faulty internal wiring (exposed bare wire, for example) and 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 or permanent injuries due to their electricity supply.

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

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

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 mini-grid use may result in a similar outcome. Technological advances in photovoltaic solar home systems and direct current–powered energy-efficient appliances can make higher access to Tier 3 and even Tier 4 possible.

BOX 1 • MINIMUM ELECTRICITY REQUIREMENTS, BY TIER OF ELECTRICITY ACCESS



Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than four hours per day (or less than one hour per evening). Households cope by using candles, kerosene lamps, or devices powered by dry-cell batteries (flashlight or radio).	At least four hours of electricity per day are available (including at least one 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 an SLS, an SHS, a mini-grid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), or the national grid.	At least four hours of electricity per day is available (including at least two 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 to meet these requirements include rechargeable batteries, an SHS, a mini-grid, or the national grid.

Tier 3	Tier 4	Tier 5
At least eight hours of electricity per day are available (including at least three 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 per year. Sources to meet these requirements include an SHS, a generator, a mini-grid, or the national grid.	At least 16 hours of electricity per day are available (including four 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 to meet these requirements include diesel-based mini-grids or the national grid.	At least 23 hours of electricity per day are available (including four 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 mini-grid or the national grid.

Source: Bhatia and Angelou 2015.

BOX 2 • TYPOLOGY OF OFF-GRID SOLAR DEVICES AND TIER CALCULATION

Solar devices are classified into three types based on the number of light bulbs 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.
- **SLSs** power two or more light bulbs and allow part or the entire household to be classified in Tier 1 for Capacity.
- **SHSs** power two or more light bulbs and appliances such as televisions, irons, microwaves, or refrigerators. (See Table 1 for the load level associated with each Capacity tier.)

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

Load level	Indicative electric appliances	Capacity tier typically needed to power the load
Very low load (3–49 W)	Incandescent light bulb, fluorescent tube, compact fluorescent lamp, light-emitting diodes (LEDs), torch/flashlight/lantern, radio/CD players/sound system, smartphone (Internet phone) charger, regular mobile phone charger	TIER 1
Low load (50–199 W)	Black-and-white television, computer, fan, flat-screen color television, regular color television, 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 or 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, around three billion of the world's population still use polluting, inefficient cooking fuels and technologies that emit toxic smoke. The inefficient use of solid fuels and the resultant pollution have significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009).[9] Fuel collection and cooking tasks are often carried out by women and girls, and collection time depends on the local availability of fuel and may take up to several hours per day (ESMAP 2004;

[9] Household air pollution is associated with a wide range of adverse health impacts, including increasing risk of acute lower respiratory infections among children under five years old, and 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 (that is, 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).

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 MTF measures access to modern-energy cooking services using six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Safety of Primary Cookstove, Affordability, and Fuel Availability (see annex 1, table A1.2).

- **Cooking Exposure** ("How is the user's respiratory health affected?"): This attribute assesses the personal exposure to pollutants from cooking activities, which depends on stove emissions and ventilation parameters (including cooking location and kitchen volume).[10] Cooking Exposure is a proxy indicator for the health impacts of the cooking activity on the primary cook. This attribute is a composite measurement of the emissions from the cooking technology and fuel combination, that is, a combination of the stove type and fuel, mitigated by the ventilation in the cooking area. Each component 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.[11]

- **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: the amount of time household members spends collecting or purchasing cooking fuel and preparing the fuel (in minutes per week) and the amount of time needed to prepare the cookstove for cooking (in minutes per meal).

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

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

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

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

[11] When the cookstove also serves as a source of heating for the dwelling, the Efficiency attribute is ignored because heat transfer efficiency becomes irrelevant.

BOX 3 • TYPOLOGY OF COOKSTOVES IN NORTH-WEST NIGERIA

In consultation with the survey firm and government officials, cookstoves in North-West Nigeria are classified into six broad categories:[a]

- **Three-stone stove:** 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.
- **Self-built/traditional stove:** The pot sits mostly on the fuel. It has a low combustion temperature due to poor insulation and much cold, excess primary air because of too many openings.
- **Locally manufactured stove:** This has a higher combustion temperature due to its enclosed combustion chamber and some insulation. The pot sits above the fire, requiring more time for combustion.
- **Kerosene stove**: A single-burner stove that uses kerosene as the main source of fuel (Kerosene is classified as a non-clean fuel).
- **LPG stove:** A single-burner stove that uses liquefied petroleum gas (LPG) for the fuel.
- **Electric stove:** A stove that uses electricity for the fuel.

FIGURE B3.1 • **Stove types common to North-West Nigeria**

a The MTF survey does not capture the variation within each stove category.

A methodology similar to the electricity framework is applied to obtain the aggregate tier for clean cooking solutions. The lowest tier of the attributes is taken as the final tier for a household. (For more information on the threshold and tier calculation, see annex 1, table A1.2.)

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 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, available resources, 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 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 non-electrified households (for example, grid or off-grid). MTF data on demand, such as energy spending, willingness to pay, 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, non-energy information, such as socioeconomic status, is also collected. Indicators such as primary energy source, tier of access, energy-related spending, willingness to pay, 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 NORTH-WEST NIGERIA

MTF data collection in North-West Nigeria 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 two DIStribution COmpanies (DISCOs) in the North-West region: Kaduna Electric (Kaduna, Kebbi, Sokoto, and Zamfara states) and KEDCO (Kano, Jigawa, and Katsina states). The National Bureau of Statistics (NBS) of Nigeria and the National Population Commission (NPopC) of Nigeria provided advice on sampling strategy, using the Population and Housing Census of the Federal Republic of Nigeria (NPHC), which was conducted in 2006 by NPopC. NPopC aggregated the census data at the enumeration area (EA) level and provided EA maps for the team on the ground. A total of 3,668 households (1,833 in rural and 1,835 in urban areas) in 262 EAs, equally split between urban and rural areas, from all the seven states of the North-West Nigeria 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 map 1). In each EA, 14 households were interviewed. The sampling strategy is provided in annex 2.[12]

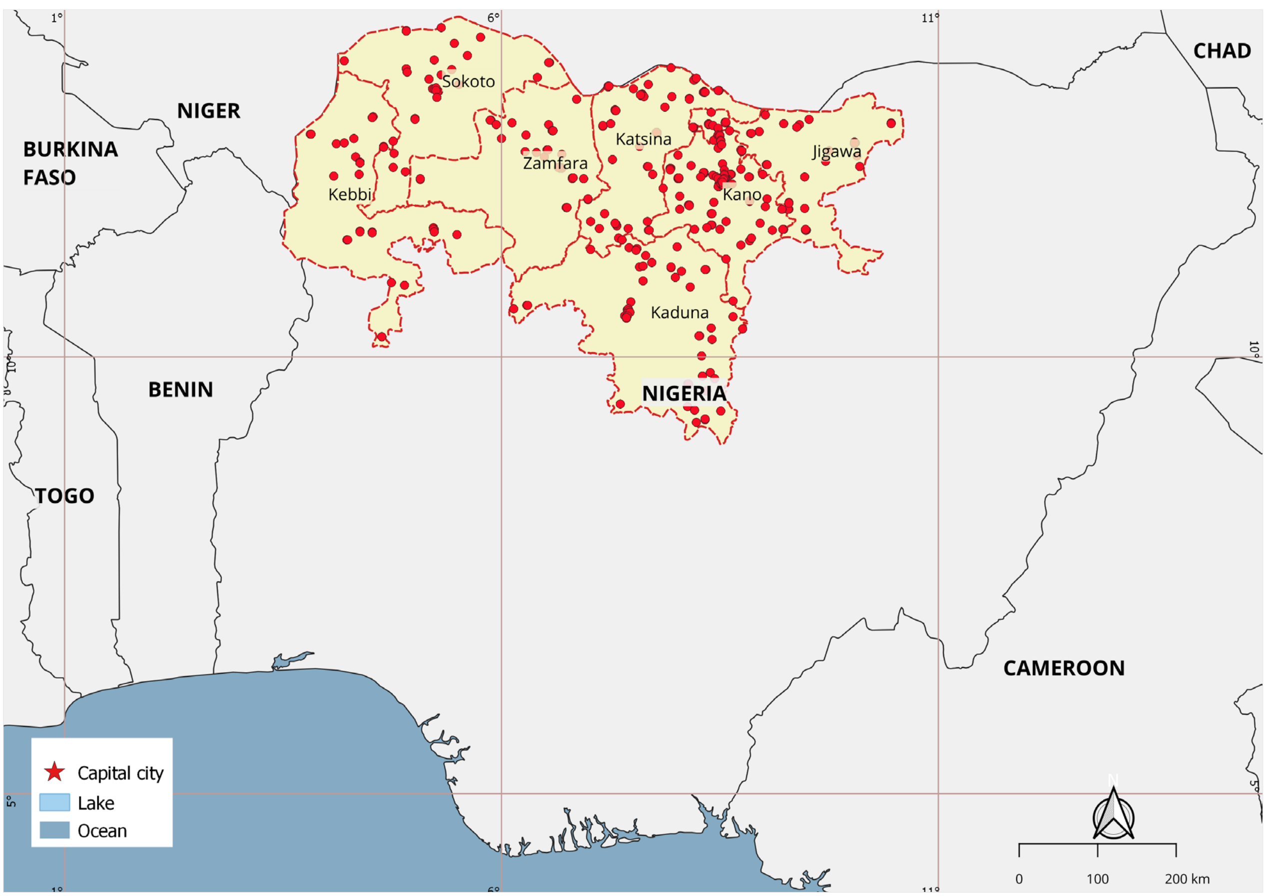
[12] Of the original sample size of 3,696 targeted households, 3,668 were effectively interviewed. The non-response rate is 0.8%, which is the difference between the sample of households originally targeted and those finally interviewed.

TABLE 2 • **Distribution of enumeration areas and sampled households, MTF Survey, North-West Nigeria (households interviewed)**

STATE	Urban				Rural				Total	
	Electrified		Nonelectrified		Electrified		Nonelectrified			
	EAs	HHs	EAs	HHs	EAs	HHs	EAs	HHs	EAs	HHs
Jigawa	11	154	5	70	6	84	10	140	32	448
Kaduna	20	271	3	42	13	182	10	140	46	635
Kano	28	387	7	98	19	265	14	196	68	946
Katsina	20	281	1	14	12	168	9	126	42	589
Kebbi	12	168	0	0	10	140	2	28	24	336
Sokoto	11	168	2	28	4	56	10	140	27	392
Zamfara	8	112	3	42	4	56	8	112	23	322
Total	110	1541	21	294	68	951	73	882	262	**3,668**

Note: EA = enumeration area; HH = household. Population = 48.9 million people (2016).

MAP 1 • **Sample distribution, MTF survey, North-West Nigeria**



Source: Authors elaboration

ACCESS TO ELECTRICITY

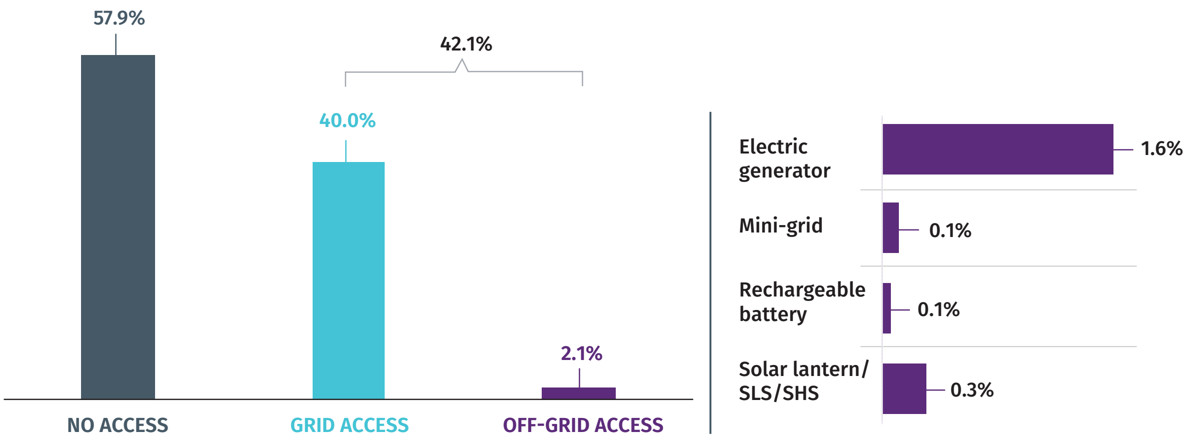
Photo: Lucia Luzi

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

In North-West Nigeria, 42.1% of households have access to at least one source of electricity: most (40%) have access through the national grid, and 2.1% use off-grid solutions (figure 1). Among the households with an off-grid solution, over half (1.6% of all households) use an electric generator—typically providing lighting and phone charging—while a very small share uses a solar system (lantern, SLS, and/or SHS), a mini-grid, or a rechargeable battery.

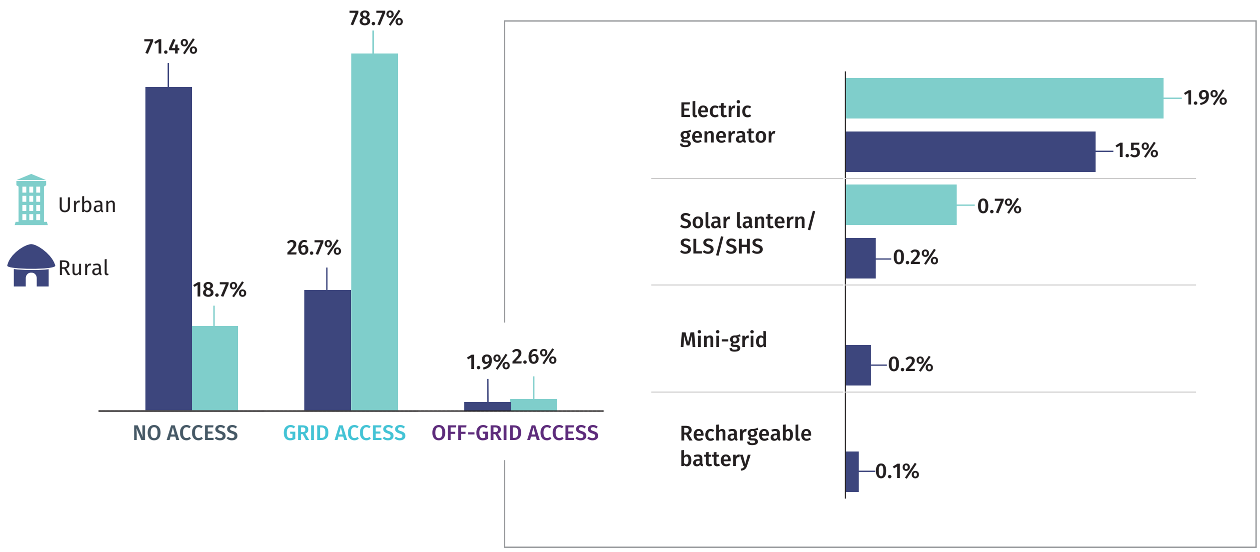
FIGURE 1 • **Access to electricity by technology, North-West Nigeria**



Note: Sample size = 3,668 households. For all other charts in the electricity section, the sample size is 3,668 households unless otherwise noted. SLS = solar lighting system; SHS = solar home system.

The discrepancy in access to electricity between urban and rural areas is substantial. In urban areas, more than four out of five households have access to electricity, compared to only slightly 28.7% households in rural areas (figure 2). Grid access is the main source of electricity both in urban areas (78.7%) and in rural areas (26.7%).

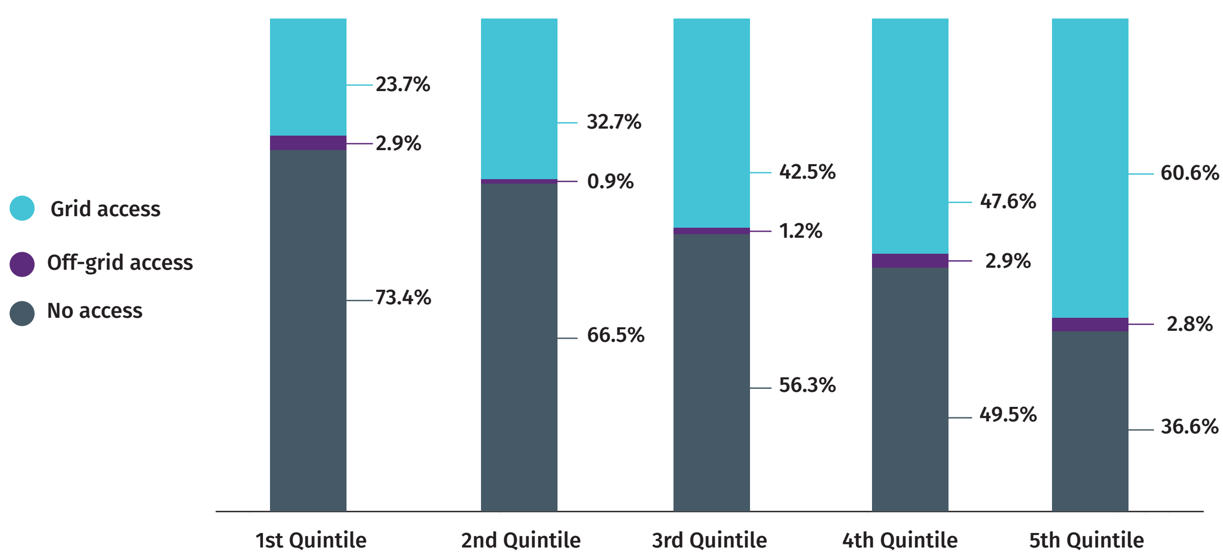
FIGURE 2 • **Access to electricity by technology, urban and rural**



Note: SLS = solar lighting system; SHS = solar home system.

Access to electricity is correlated with wealth. Almost three out of four of the households in the lowest quintile lack access to electricity, while this is the case for only 36.6% of the households in the highest quintile (figure 3). The grid access rate increases with the level of household expenditure. In the highest expenditure quintile, most of the households (60.6%) have access to the grid, compared to a small share (about 24%) of households in the lowest quintile.

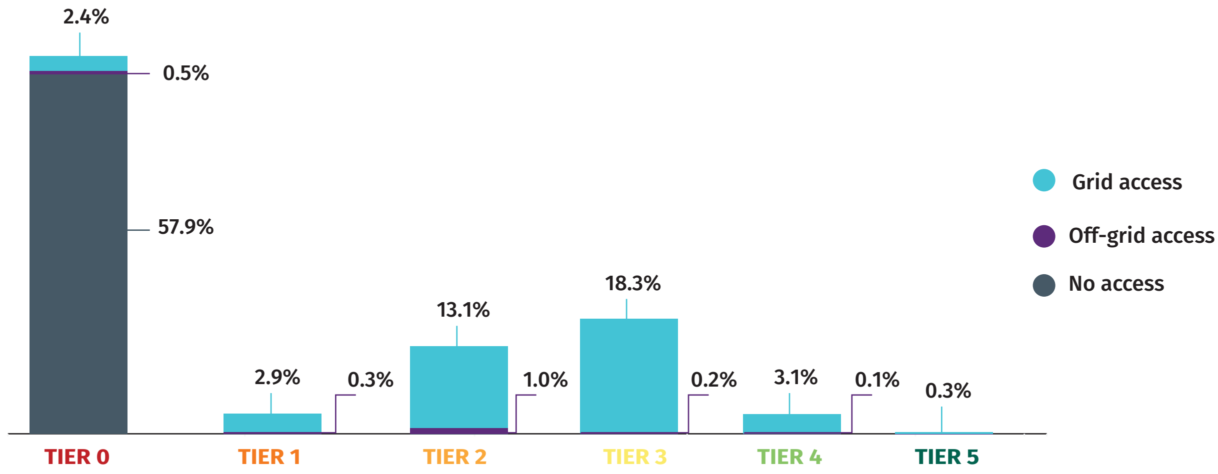
FIGURE 3 • **Access to electricity by technology, by expenditure quintile, North-West Nigeria**



MTF TIERS

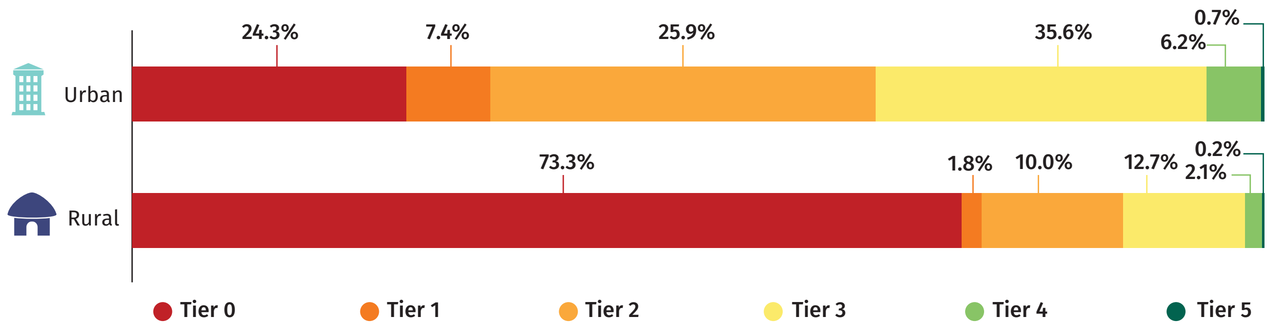
In North-West Nigeria, about 40% (19.3 million households) of the households are in Tier 1 or above for electricity access, and almost none of those are in Tier 5 (figure 4). Among the 60.7% of North-West Nigerian households (29.4 million households) that fall in Tier 0, the large majority has no access to any source of electricity. About 0.5% of households using off-grid solutions and 2.4% of households connected to the grid still fall in Tier 0, because their electricity supply does not satisfy Tier 1 requirements 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 2 (1%). Grid users are concentrated in Tiers 2 (13.1%) and Tier 3 (18.3%).

FIGURE 4 • **MTF Tier distribution, by technology, North-West Nigeria**



Electricity access is largely a rural challenge (figure 5). About three out of four rural households (35.2 million households) are in Tier 0 for access to electricity, while the remainder (26.7%) are dispersed across Tiers 1 through 5. Most urban households are in Tiers 2 and 3, and about one-quarter remain in Tier 0. As a result, the "average" tier for urban households is 1.6, compared to only 0.8 for rural households.

FIGURE 5 • **MTF Tier distribution, North-West Nigeria, urban and rural**

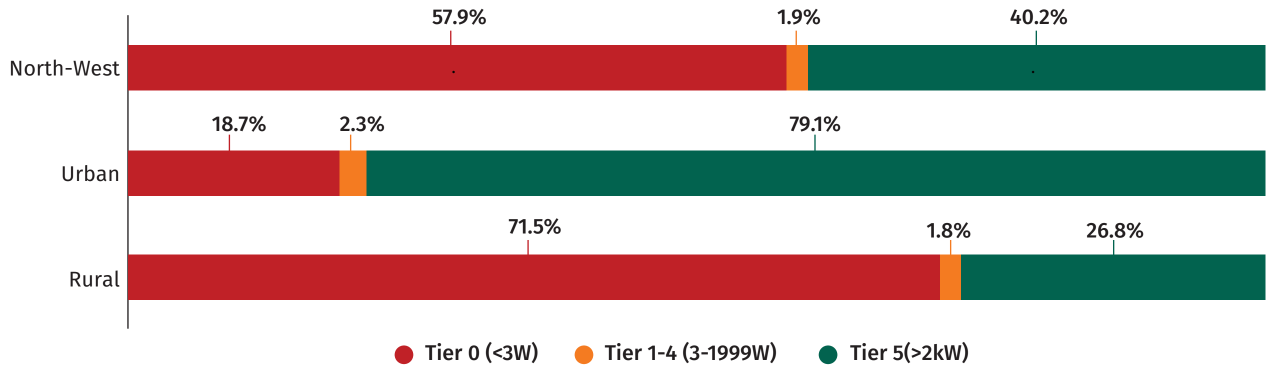


MTF ATTRIBUTES

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. Because grid-connected households are considered to be receiving high-capacity electricity (over 2,000W), the share of households that receive high-capacity electricity is the same as the share of households connected to the grid (40.2%) (figure 6). The capacity of off-grid solutions typically ranges between 3W and 1999W for 1.9% of the households.

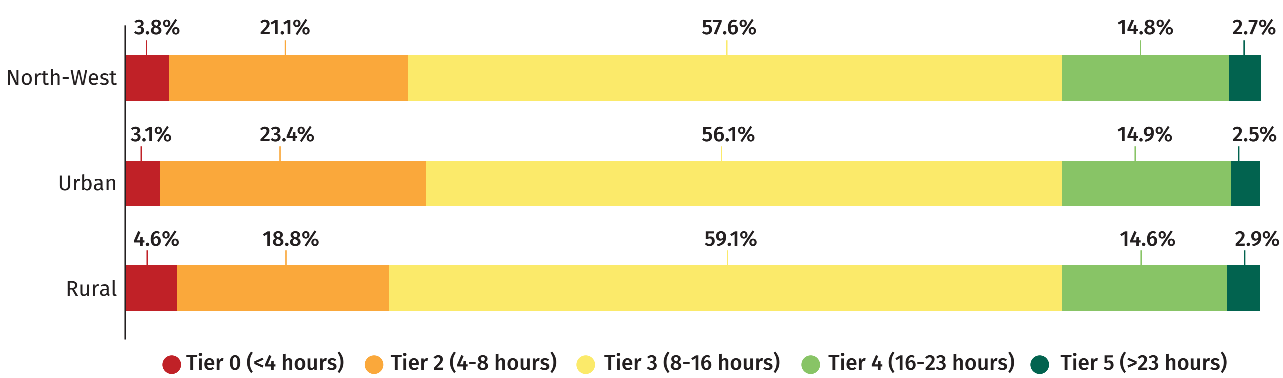
FIGURE 6 • **Distribution of households based on Capacity, North-West Nigeria, urban and rural**



Availability

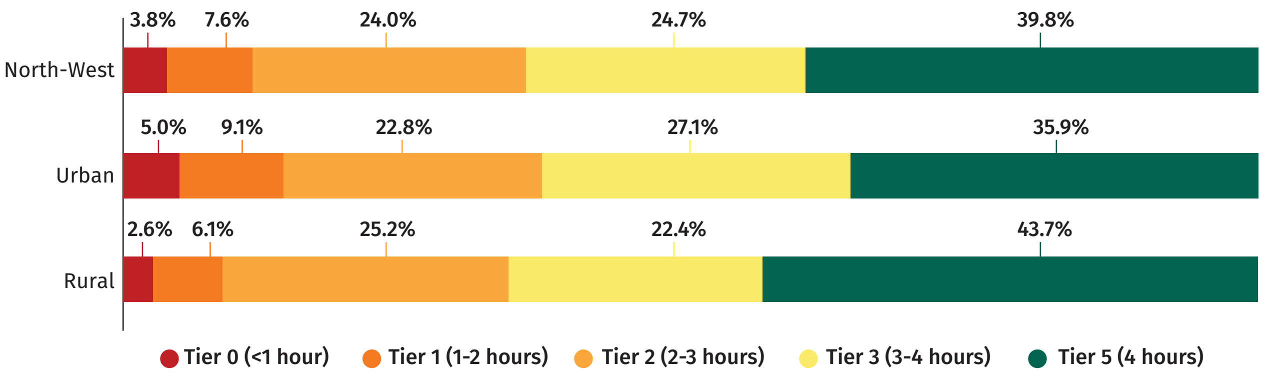
The Availability attribute corresponds directly to availability of electricity service during the day (24 hours) and in the evening (four hours after sunset), as outlined in table A1.1 in annex 1. Figure 7 and figure 8 show household distribution by availability. Availability of electricity service day and night is an important attribute. About 97.3% of the households in North-West Nigeria have limited Availability of electricity (less than 23 hours per day), and the pattern is similar in urban and rural areas (figure 7). About one out of four of households receive less than 8 hours of electricity per day. Electricity supply in the evening (between 6 p.m. and 10 p.m.) seems to be an issue for about two in five households (figure 8).

FIGURE 7 • **Distribution of households based on Daily Availability (over a 24-hour day), North-West Nigeria, urban and rural**



Note: Sample size = 1,743 households. Includes only households with access to an electricity source.

FIGURE 8 • **Distribution of households based on Evening Availability (over a 24-hour day), North-West Nigeria, urban and rural**

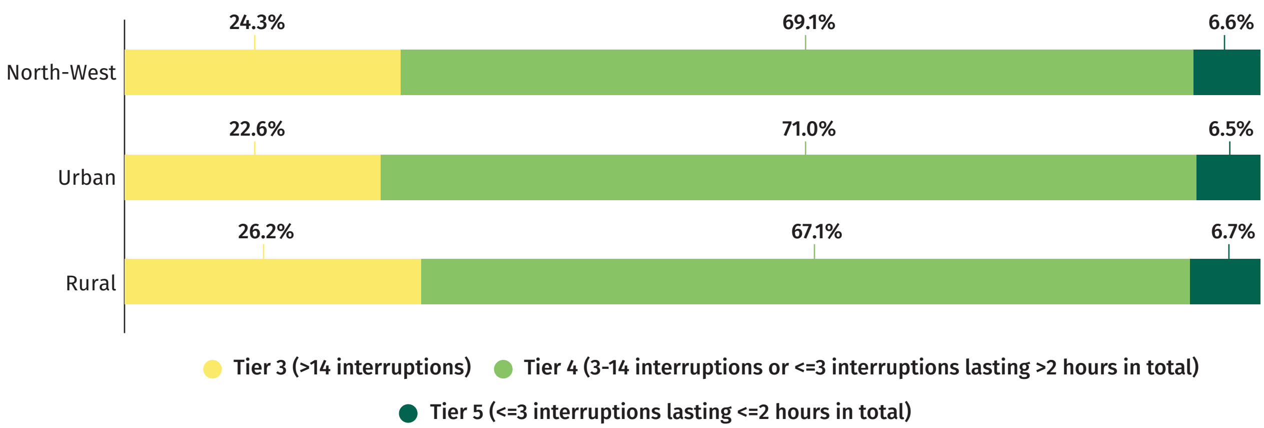


Note: Sample size = 1,743 households. Includes only households with access to an electricity source.

Reliability

The Reliability attribute captures the frequency and duration of unscheduled outages, and it applies only to grid-connected households. About 94% of the grid-connected households face frequent, unpredictable power outages (figure 9). Most suffer from 3 to 14 interruptions per week lasting over 2 hours in total. Results are similar across urban and rural households. In North-West Nigeria, the average duration of outages for grid-connected household is 40 hours in typical months. [13]

FIGURE 9 • **Distribution of households based on Reliability, North-West Nigeria, urban and rural**



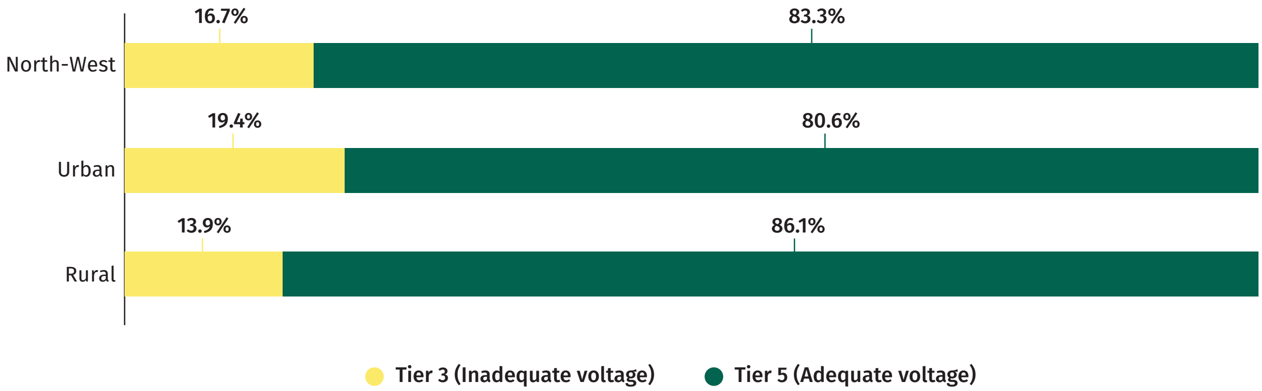
Note: Sample size = 1,679 households. Includes only grid-connected households.

[13] The worst months indicated by the interviewed households were June to September. The worst month is August.

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 North-West Nigeria, about 16.7% of the grid-connected households face voltage issues, such as low or fluctuating voltage, resulting in appliance damage (figure 10).

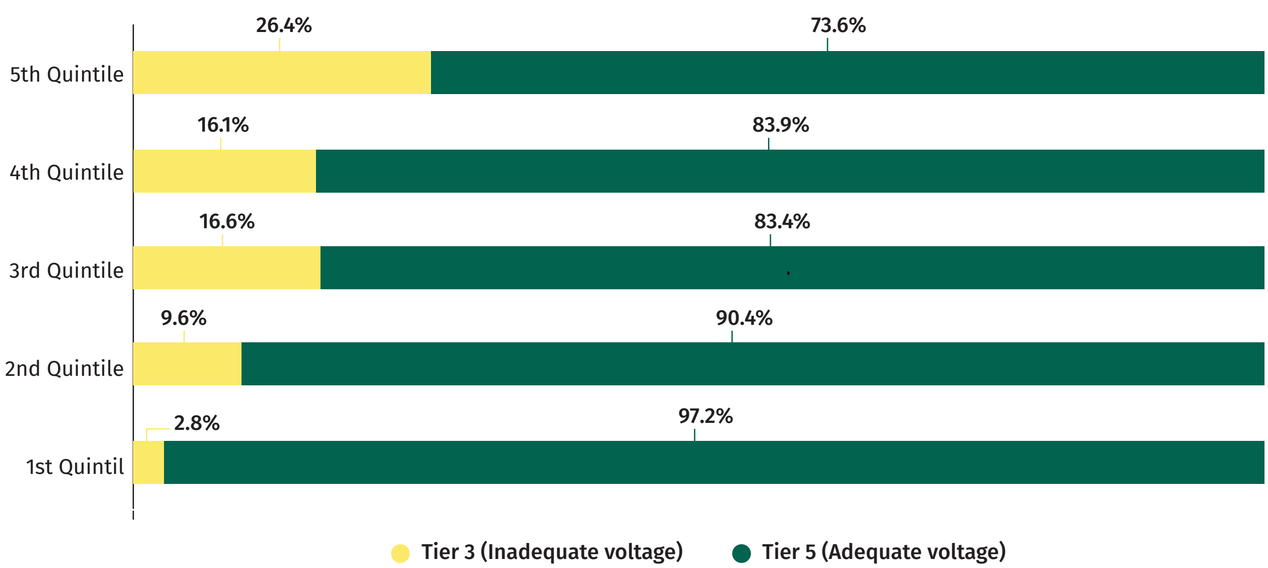
FIGURE 10 • **Distribution of households based on Quality, by locality**



Note: Sample size = 1,679 households. Includes only grid-connected households.

Almost 3% of the grid-connected households in the lowest quintile face voltage issues, while this is the case for more than a quarter (26.4%) of the households in the highest quintile (figure 11). In fact, it is likely that wealthier households own more appliances than poorer households; consequently, the former are more sensitive than the latter to the quality of electricity supply.

FIGURE 11 • **Distribution of households based on Quality, by expenditure quantile**

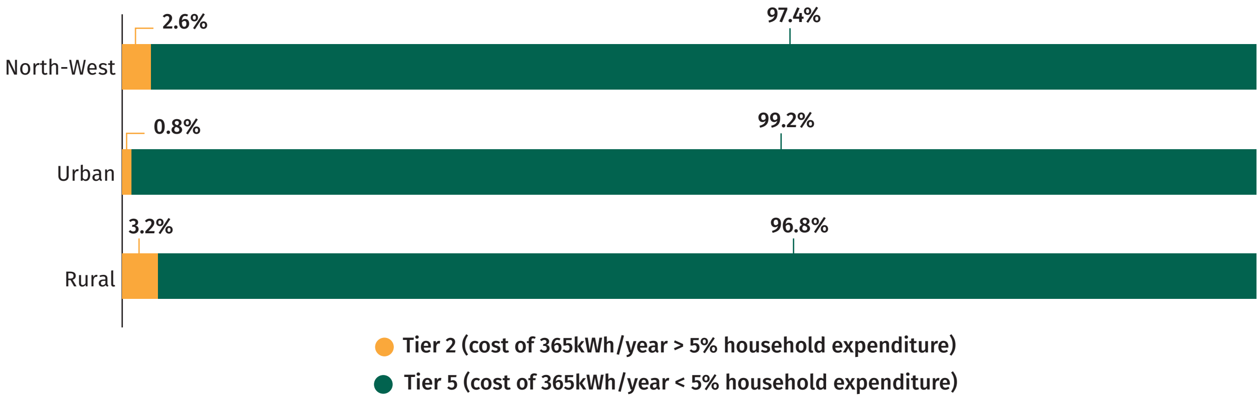


Note: Sample size = 1,679 households. Includes only grid-connected households.

Affordability

The Affordability attribute measures the percentage of households that can afford subsidized electricity. About 2.6% of North-West Nigerian households cannot afford to pay for basic electricity services, corresponding to 365 kWh per year (figure 12). The share drops to 0.8% of households in urban areas. In rural areas, 3.2% of households face Affordability issues. This suggests that the current tariff in North-West Nigeria is affordable to most households. [14]

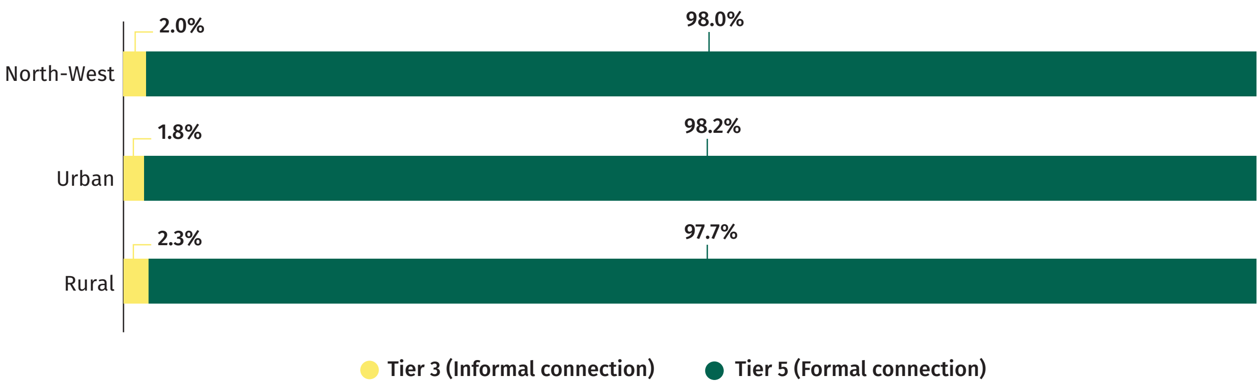
FIGURE 12 • **Distribution of households based on Affordability, North-West Nigeria, urban and rural**



Formality

Formality refers to a household's grid connection being provided and/or sanctioned by the authority.[15] Informal connections are those obtained by means not authorized by the electricity company, such as 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 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. About 98% of all grid-connected households are reported to have a formal connection (figure 13).

FIGURE 13 • **Distribution of households based on Formality, North-West Nigeria, urban and rural**



Note: Sample size = 1,679 households. Includes only grid-connected households.

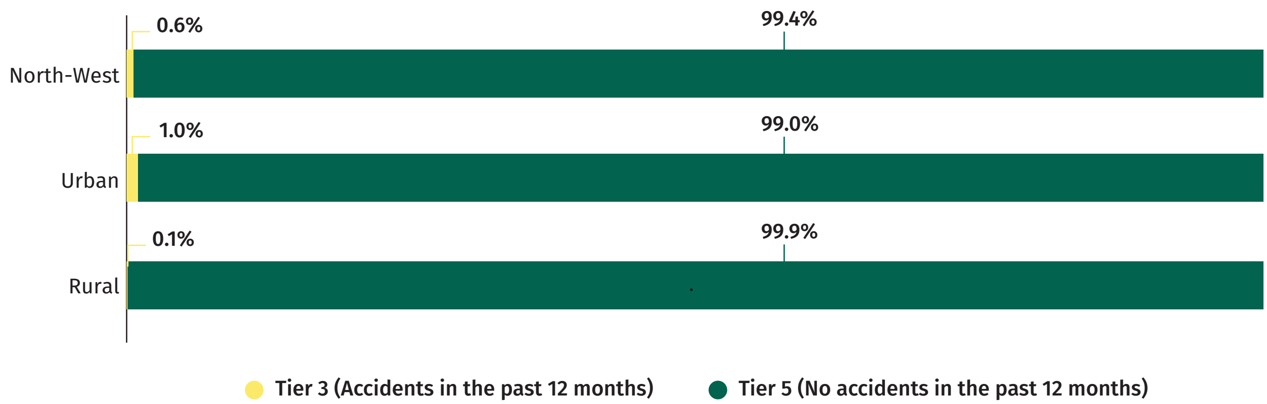
[14] The electricity tariff in North-West Nigeria is N4 per kWh for the first 50kWh consumed monthly. Above 50kWh, the two distribution companies differ. For Kaduna Electric, it is N26.4 per kWh and KEDCO is N22.5 per kWh

[15] MTF estimations consider only residential customers.

Health and Safety

The Health and Safety attribute refers to any injuries to household members from using electricity service from the grid during the 12 months preceding the survey. Electricity access is considered safe when users have not suffered from past accidents resulting in permanent injuries due to their electricity supply. Health and safety issues do not seem to occur widely in North-West Nigeria: only 0.6% of grid-connected households reported accidents causing permanent injury or death (figure 14). It is, however, 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 faulty conditions.

FIGURE 14 • **Distribution of households based on Health and Safety, North-West Nigeria, urban and rural**



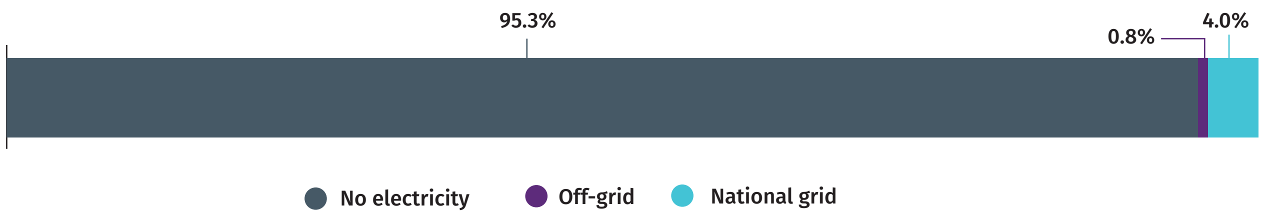
Note: Sample size = 1,679 households. Includes only grid-connected households (1,677 national grid and 2 mini-grid).

IMPROVING ACCESS TO ELECTRICITY

Most households in Tier 0 do not have access to any electricity source (figure 15): 95.3% have no electricity source,[16] about 0.8% use off-grid energy solutions, and the remaining households, about 4%, are connected to the national grid. The households that use an off-grid solution are classified in Tier 0 because their electricity does not meet the Capacity and Availability attributes criteria for Tier 1. Strategies for elevating households from Tier 0 will depend on why households are in that tier.

MTF attribute analysis shows that issues surrounding the Availability, Capacity, and Reliability attributes are the main issues for grid users Thus, improving these attributes for the national grid can raise grid users to the highest tier. 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.

FIGURE 15 • **Tier 0 disaggregation by source of electricity, North-West Nigeria**



The number of households in Tier 0 that are in non-grid-electrified EAs (enumeration areas without grid infrastructure) is much higher in rural (23.5%) than in urban (7.8%) areas. Conversely, the number of households in Tier 1 or above is much higher in urban (30.3%) than in rural (14.2%) areas (table 3). The number of households in Tier 0 that are in grid-electrified EAs is similar in urban and rural settings (11.9% and 12.3%, respectively). As indicated, 44.5% in the zone would benefit from investments to improve the quality of their existing grid or off-grid service, with most benefits accruing to urban households. About a quarter of the population (24.2%) would benefit from policies to increase the number of last-mile grid connections, benefiting both urban and rural households. A final one-third of the population (31.3%) 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.

TABLE 3 • **Distribution of households by tiers, North-West Nigeria, urban and rural**

	Households in Tier 0		Households in Tier 1 or higher	Total
	Non-grid-electrified EAs	Grid electrified EAs		
Urban	7.8%	11.9%	30.3%	50%
Rural	23.5%	12.3%	14.2%	50%
North-West Nigeria	31.3%	24.2%	44.5%	100%

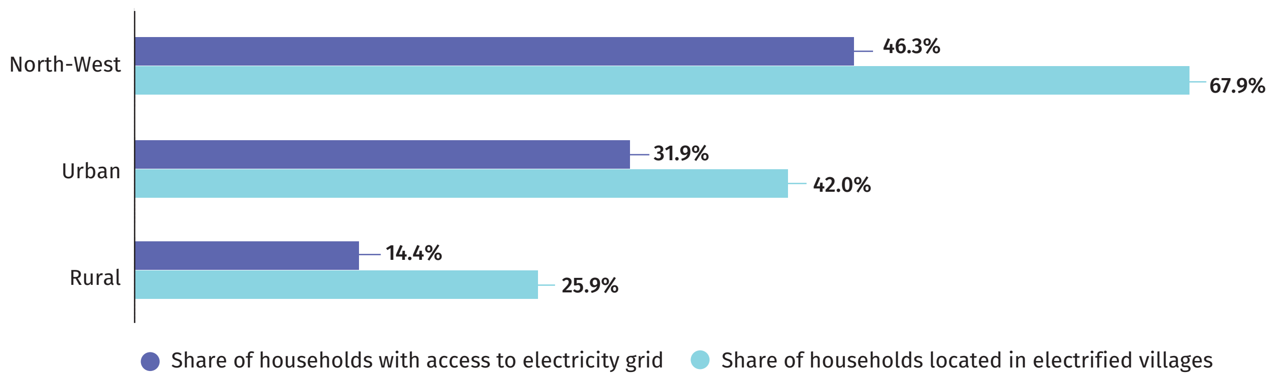
Note: EA = enumeration area.

[16] Dry-cell battery is not counted as a source of electricity.

PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

About 46.3% of households in North-West Nigeria are connected to the grid. However, 67.9% of households are in EAs where the grid is available (i.e., in EAs in which at least one household is connected to the grid) (figure 16). The uptake rate is the ratio between the percentage of electrified households over the percentage of electrified villages (that is, the EAs). The uptake rate in North-West Nigeria, is 68.2%, but this combines the urban uptake rate of 75.9% and the rural uptake rate of 55.7%. Thus, densification projects may enable about 21.6% of households in North-West Nigeria to get access to the existing grid.

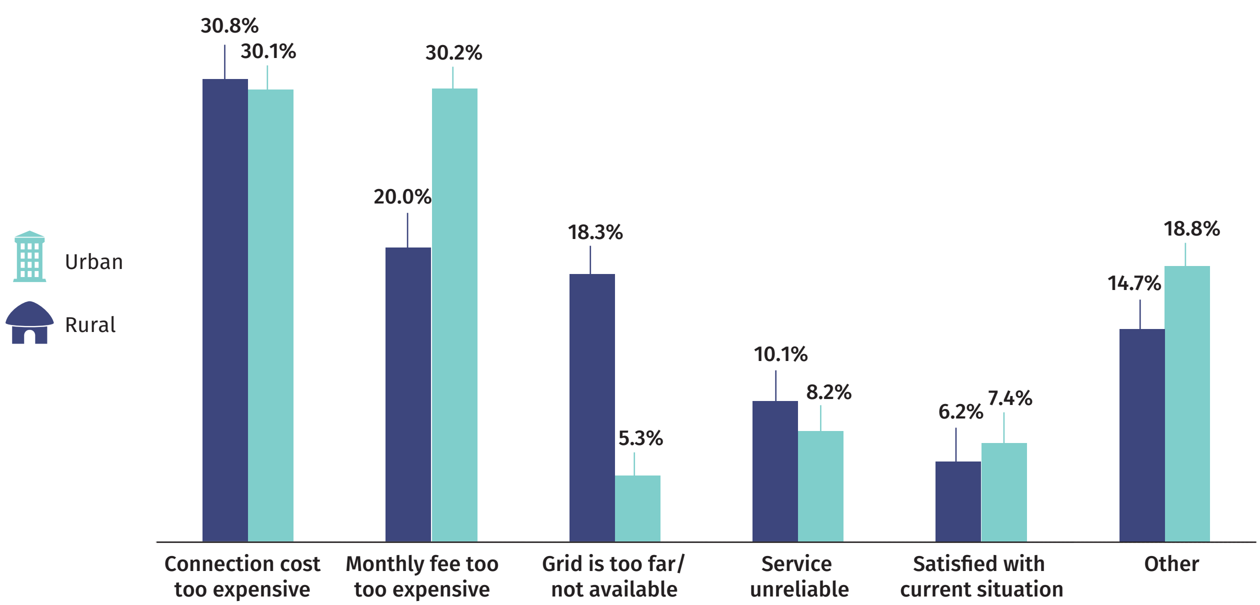
FIGURE 16 • **Comparison of electrification rate between villages (EAs) and households, North-West Nigeria, urban and rural**



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

Addressing the affordability of up-front connection fee is critical in increasing the uptake rate. A closer look to urban and rural households in proximity to the grid shows that the most common barriers preventing these households from gaining access to the grid are both the connection and the monthly fee, the latter being even a stronger barrier for urban households (figure 17).

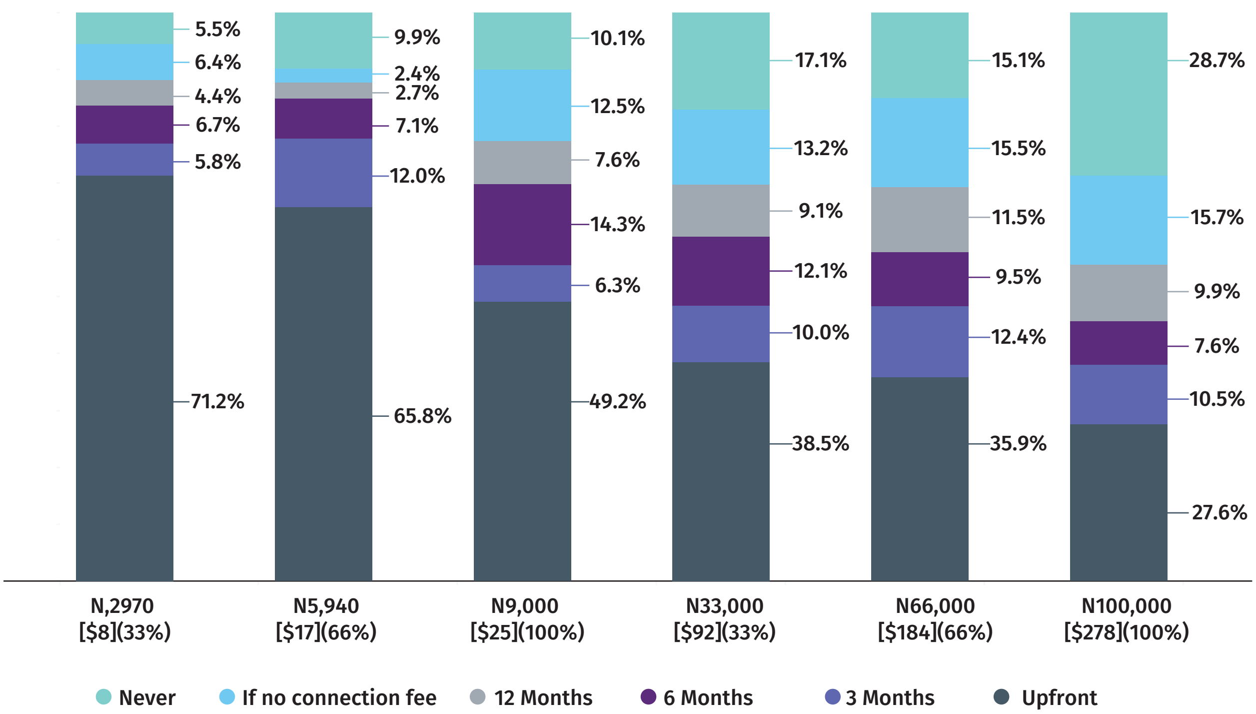
FIGURE 17 • **Barriers to gaining access to grid electricity among households not connected to the grid in electrified villages, urban and rural**



Note: Sample size = 792 households.

The MTF willingness-to-pay modules try to assess whether price reductions and flexible payment periods can increase the adoption rate of the national grid. The higher the payment plan or price suggested, the lower the percentage of households than are willing to pay for a grid connection. Specifically, about 27.6% of households are willing to pay the highest suggested payment for connection up-front, and 71.2% of households are willing to pay the lowest suggested payment (figure 18). Offering flexible payment options—installments paid over 3, 6, or 12 months—can to some extent address the burden of the high up-front connection cost. About 17% to 22% of households are willing to pay for a connection fee of N1,400 (US$4) to N2,900 (US$8) over a period of 3, 6, or 12 months. This percentage increases for the higher price suggested; about 28% to 33.5% of households are willing to pay a connection fee of N4,300 (US$12) to N10,000 (US$28) over a period of 3, 6, or 12 months.

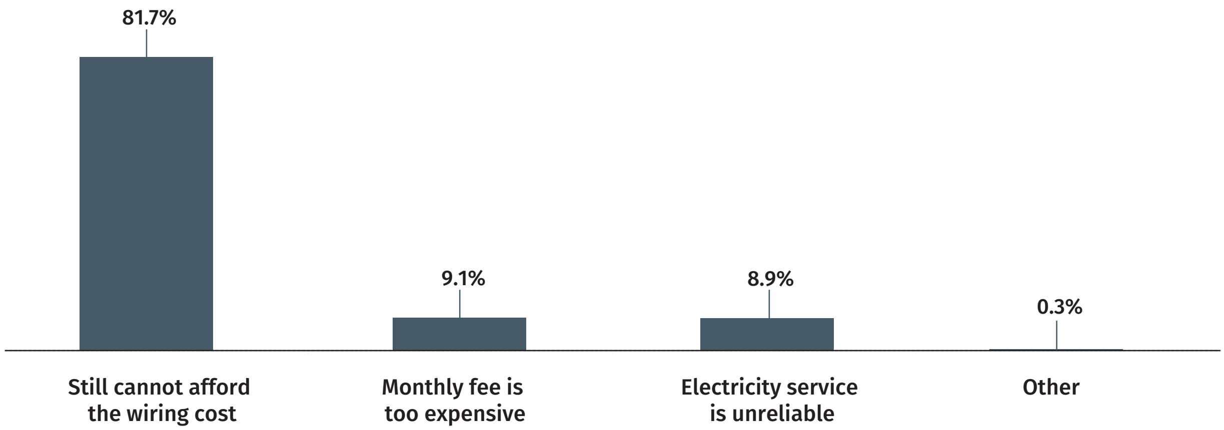
FIGURE 18 • **Willingness to pay for the grid connection fee for non-grid-connected households, by alternative connection fee prices, North-West Nigeria**



Note: Sample size = 1,816 households.

Several households that stated that they would not accept any offer to connect to the grid even if the connection cost was waived (captured by the "Never" category in figure 18). The main reason for those households is because households cannot afford the internal wiring cost (figure 19).

FIGURE 19 • **Reason for being unwilling to pay for grid connection, North-West Nigeria**

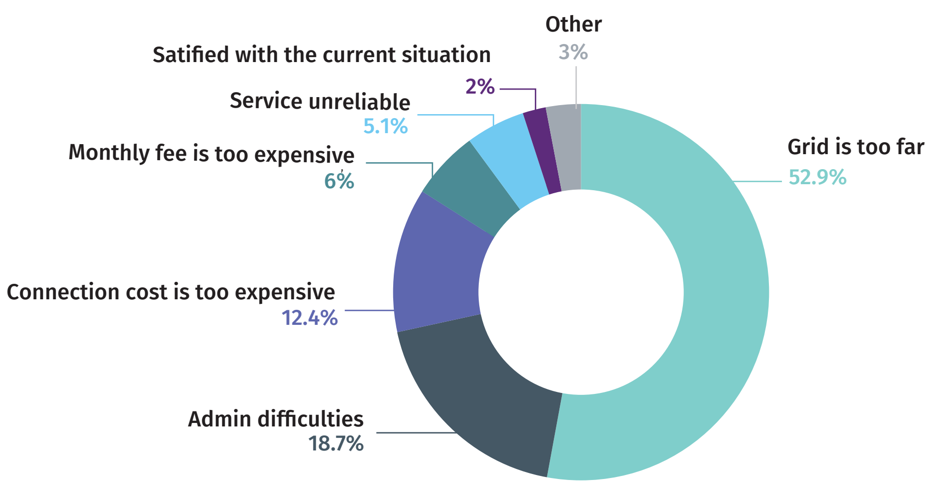


Note: Sample size = 286 households.

Along with the grid densification, off-grid energy solutions can provide the energy solutions to those households that currently do not have any source of electricity.

In North-West Nigeria, the most common barrier preventing households from gaining access to the grid is the distance to grid infrastructure (figure 20). Extending the grid to these areas can provide an opportunity for more households to gain access to grid electricity. As mentioned earlier, households without any source of electricity tend to be poorer than households with either grid or off-grid access (see figure 3). The second most common barrier is related to administrative difficulties.

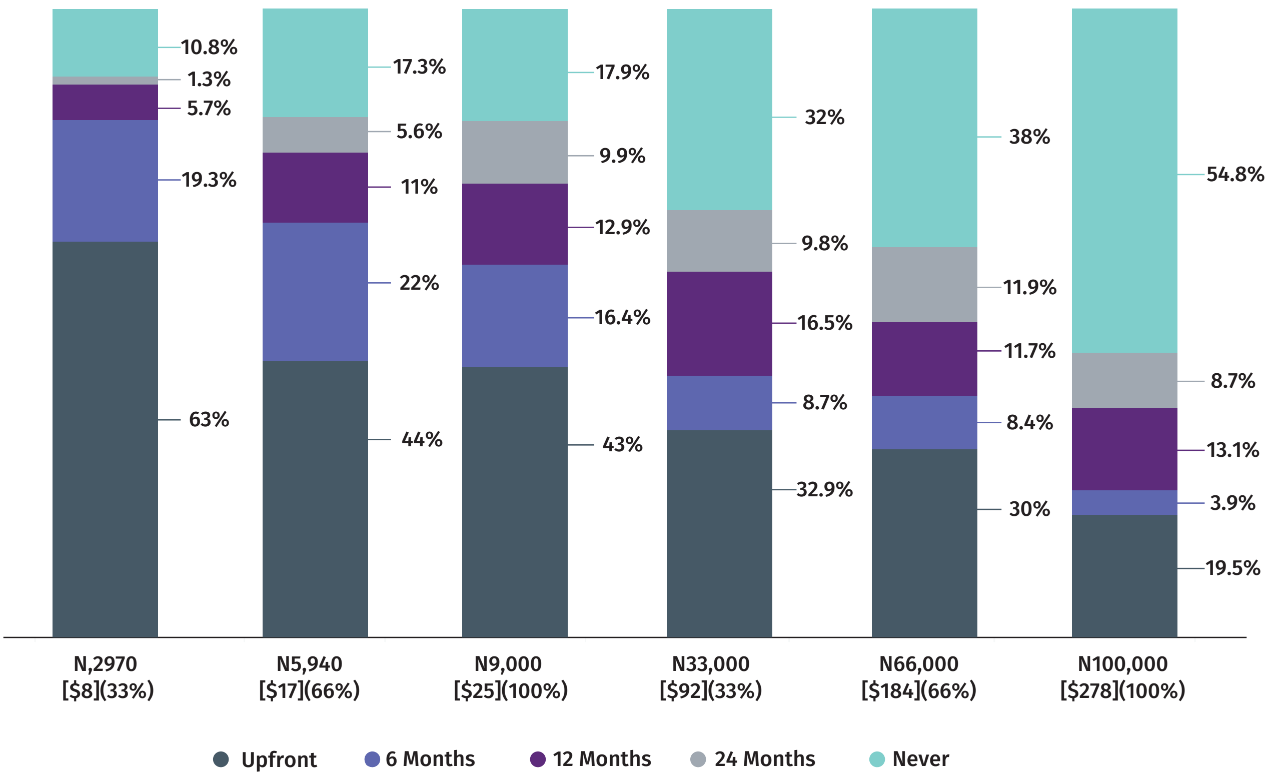
FIGURE 20 • **Barriers to gaining access to grid electricity, North-West Nigeria**



Note: Sample size = 1,968 households. Includes only households not connected to the grid.

Willingness to pay for an SHS is much lower than willingness to pay for a connection to the grid, but it increases as the price drops (figure 21). Different prices were offered to different survey respondents. The full price for a low-capacity SHS is N9,000 (US$25) and for a high-capacity SHS it is N100,000 (US$278). Two other prices, 33% and 66% of the full price, were also offered to respondents. Although only about 82% of the households are willing to pay for a low-capacity SHS at a price of N9,000 (US$25), about 90% 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. About 45% of the households are willing to pay for high-capacity SHS at a price of N100,000 (US$278), while 68% 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. Similarly, to the willingness to pay for a grid connection, roughly 26% to 39% of households are interested in a payment plan for an SHS over 6, 12, and 24 months.

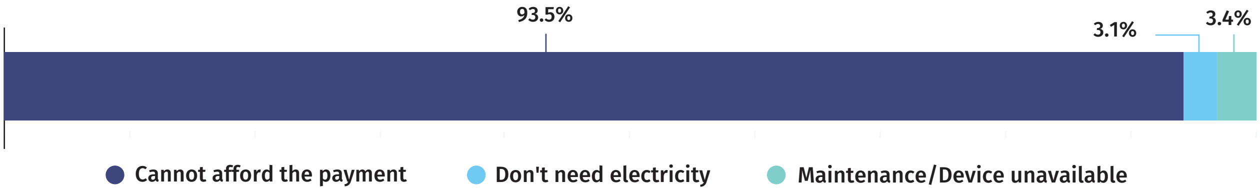
FIGURE 21 • **Willingness to pay for a solar home system, by alternative prices, North-West Nigeria**



Note: Sample size = 1,968 households.

Affordability is the biggest barrier to obtaining an SHS (figure 22). Only 3.4% of households, however, considered maintenance and the lack of availability of the system as a barrier.

FIGURE 22 • **Reasons for being unwilling to pay for an SHS, North-West Nigeria**

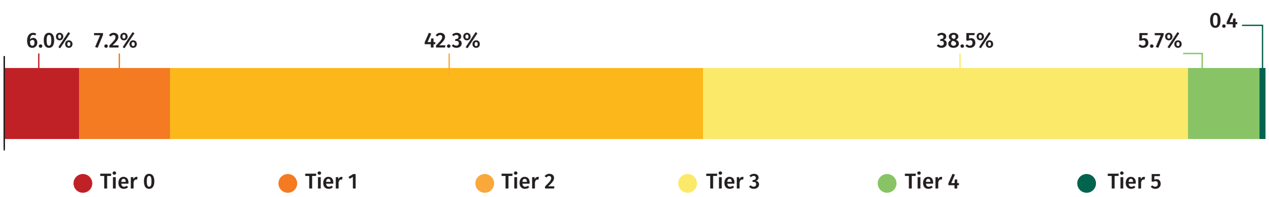


Note: Sample size = 1,016 households.

IMPROVING ELECTRICITY ACCESS FOR GRID-CONNECTED HOUSEHOLDS

The performance of the grid in North-West Nigeria is not satisfactory: four in five grid-connected households are in Tiers 2 or 3 (figure 23). Only a few households are in Tiers 4 and 5 (6.1%), while the rest (13.2%) fall in the lower tiers (Tiers 0 and 1). On average, about 30% of grid-connected households in North-West Nigeria have been electrified for more than 10 years, while about 18.2% of these households have been electrified during the past 5 years.

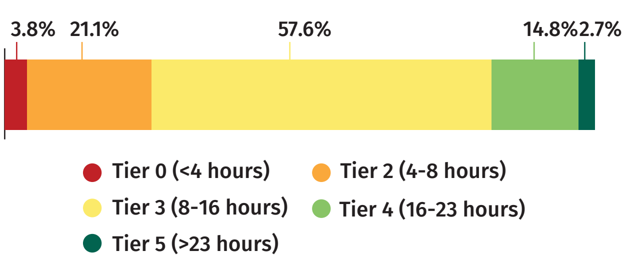
FIGURE 23 • **MTF Tier distribution of grid-connected households, North-West Nigeria**



Note: Sample size = 1,679 households. Includes only grid-connected households.

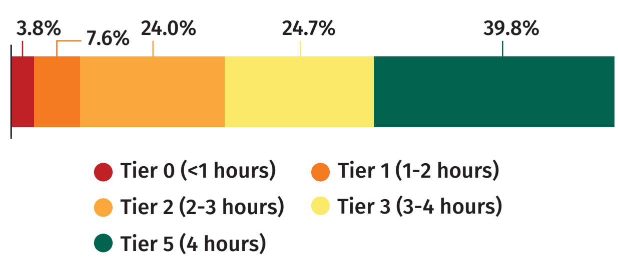
Poor availability, reliability, and quality are the main issues preventing 99.6% of the grid-connected households from reaching Tier 5 access. About 97% of grid-connected households has limited daily availability of supply (less than 23 hours per day), and around 60% of them have less than four hours in the evening (between 6pm and 10pm) (figure 24 and figure 25). Reliability issues affect 94% of grid-connected households, because 69.8% experience between 4 and 14 power outages per week, lasting more than two hours in total, and 24.3% experience more than 14 power outages per week (figure 26). Finally, about 16.7% of grid-connected households reported voltage issues resulting in appliance damage (figure 27).

FIGURE 24 • **Distribution of grid-connected households by daily availability, North-West Nigeria**



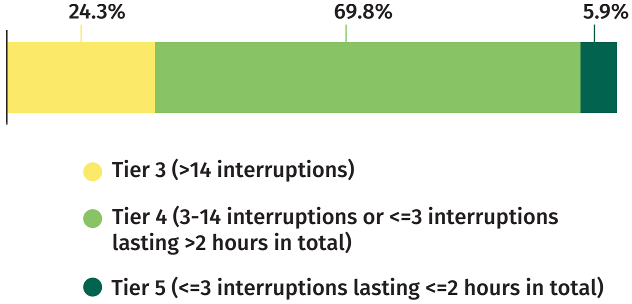
Note: Sample size = 1,679 households. Includes only grid-connected households.

FIGURE 25 • **Distribution of grid-connected households by evening availability, North-West Nigeria**



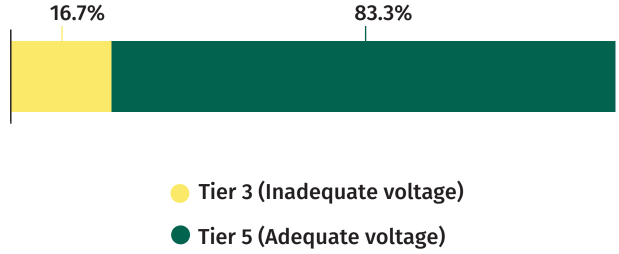
Note: Sample size = 1,679 households. Includes only grid-connected households.

FIGURE 26 • Distribution of grid-connected households based on reliability, North-West Nigeria



Note: Sample size = 1,679 households. Includes only grid-connected households.

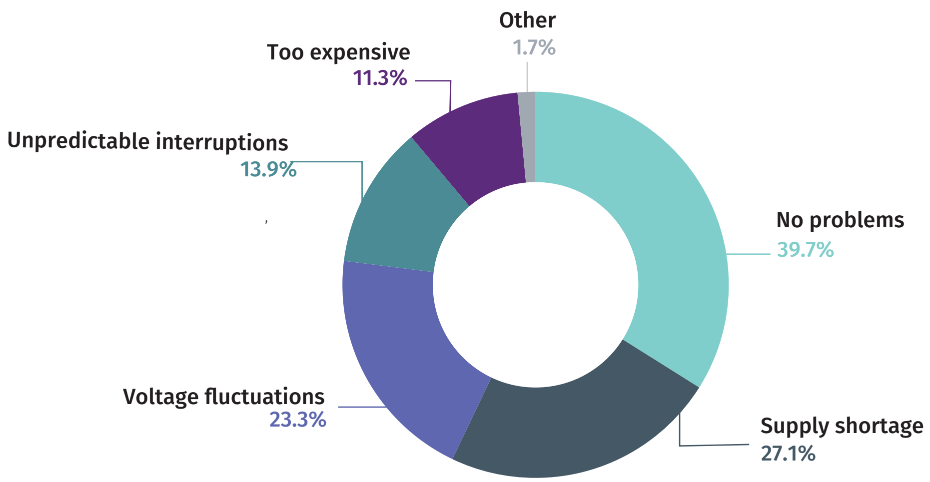
FIGURE 27 • Distribution of grid-connected households based on quality, North-West Nigeria



Note: Sample size = 1,679 households. Includes only grid-connected households.

Affordability, formality, and health and safety are not major issues for grid-connected households. These issues also arise when households are asked questions outside of the MTF attribute categories. The most frequent problem reported by the households is Availability, given that 27.1% of grid users experience supply shortage. Grid users experience unpredictable interruption (13.9%), affecting Reliability (figure 27). Finally, the Quality of the supply represents another issue, because 23.3% of grid-connected households experience voltage fluctuations (figure 28). Even though these findings are based on consumer perception of key issues, and are, therefore, more subjective than those analyzed in MTF attributes, the responses are consistent with the MTF findings. Finally, 11.3% of grid-connected households consider that their electricity bill is too high (figure 29).

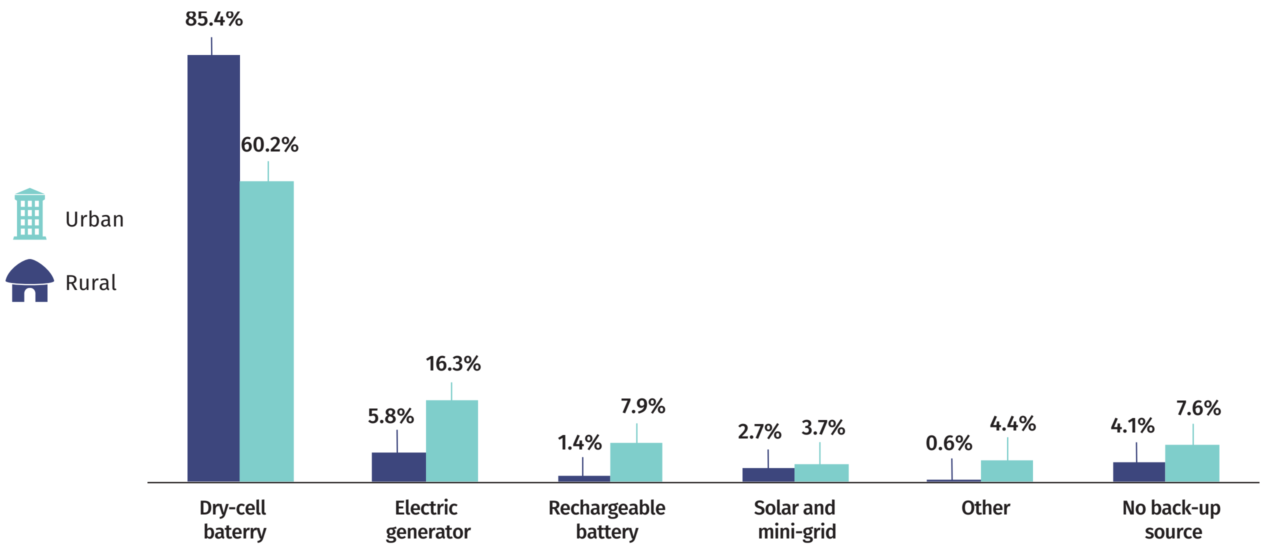
FIGURE 28 • Main issues cited, related to grid electricity supply, North-West Nigeria



Note: Sample size = 1,679 households.

A further analysis of the household data shows that a large number of households use backup electricity sources. To cope with power outages and supply shortage from the grid, 60.2% of urban and 85.4% of rural grid-connected households use candles as a backup source for lighting. Electric generator usage is almost 16.3% in urban households as backup source for lighting, which can increase the fuel cost for the households (figure 29). Rechargeable battery and solar appliances also contribute to backup sources for lighting. Only about 6% of households in North-West Nigeria, do not use any source of backup power for lighting.

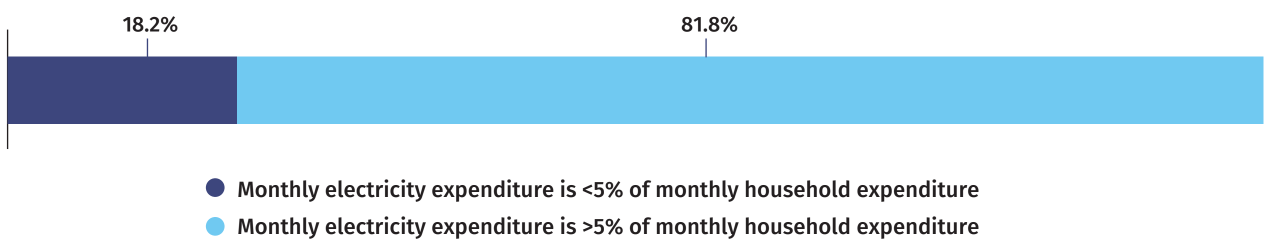
FIGURE 29 • **Distribution of grid-connected households by backup energy source for lighting, urban and rural**



Note: Sample size = 1,679 households.

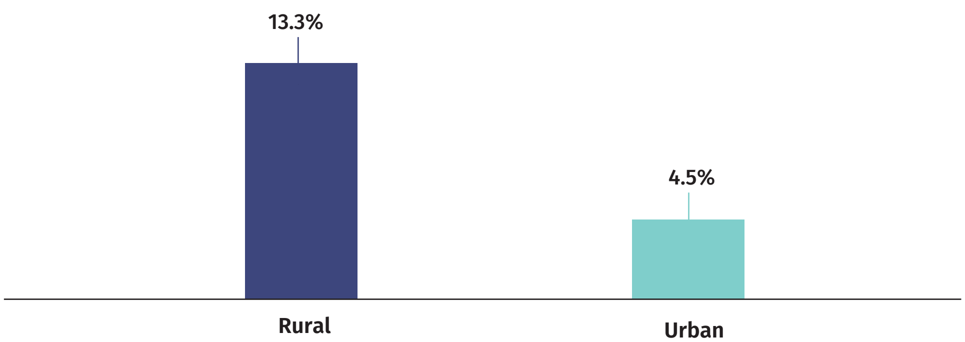
Improving the availability of the electricity supply could help reduce the burden of energy spending, and shift spending on backup sources toward higher consumption of electricity. Although the MTF Affordability Tier shows that basic electricity is affordable, we find that 18.2% of grid-connected households spend more than 5% of their monthly budgets on electricity (figure 30). Spending on a backup source of lighting accounts for 8% of North-West Nigerian household monthly spending. Since households already spend a substantial amount on electricity, even a small increase in that spending would put a strain on a household's budget. This is particularly true for rural households, for which 13.3% of the monthly spending goes to backup sources, compared with 4.5% for the urban households (figure 31).

FIGURE 30 • **Share of grid-connected households spending more than 5% of monthly household expenditure on electricity, North-West Nigeria**



Note: Sample size = 1,679 households.

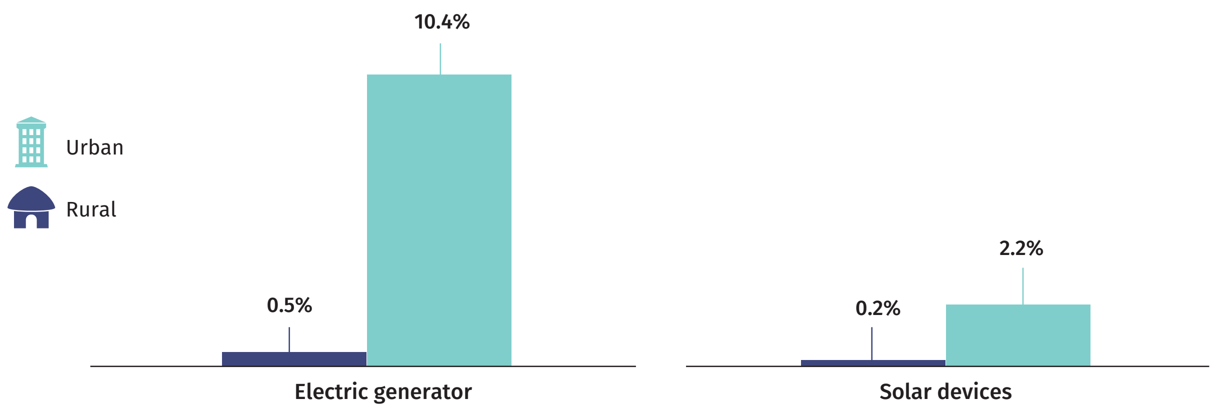
FIGURE 31 • **Monthly expenditure on backup lighting**



Note: Sample size = 1,679 households.

Off-grid solutions—particularly electric generators—are more commonly used as backup source rather than as primary source of electricity. In North-West Nigeria, the option of using off-grid solution as backup is relatively more common in urban than in rural areas; urban households rely more on electric generators (10.4%) than on solar devices (2.2%) as main backup source of electricity (figure 32).

FIGURE 32 • **Reliance on off-grid solution as backup source, by locality**



Note: Sample size = backup electric generator 198 households; backup solar device 29.

IMPROVING ELECTRICITY ACCESS FOR HOUSEHOLDS THAT RELY ON OFF-GRID SOLUTIONS[17]

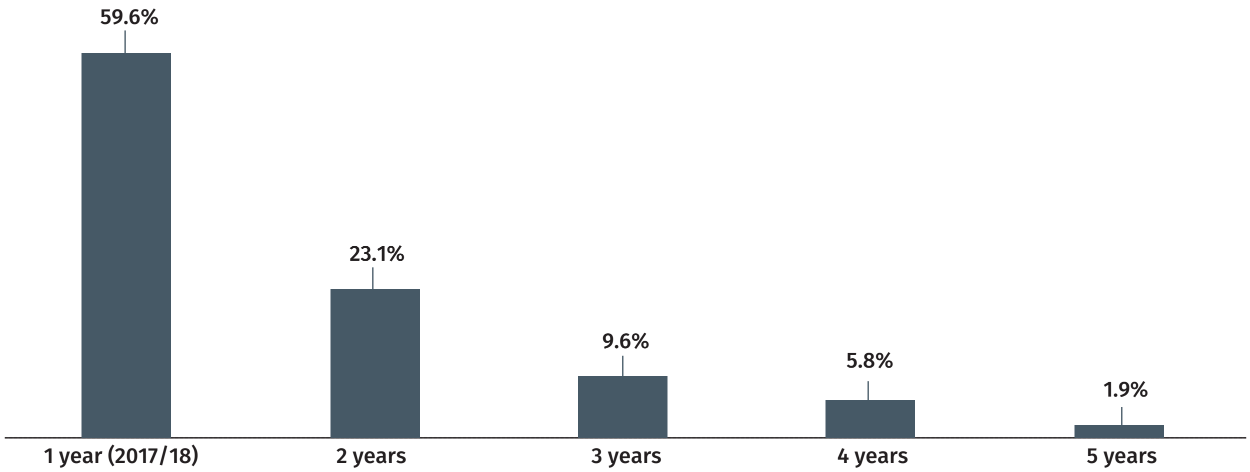
Off-grid solutions tend to fill the electrification gap when grid electricity is unavailable. However, the penetration of off-grid solutions in North-West Nigeria is low: 2.1% of the households there use an off-grid solution as their primary source of electricity, and 1.6% of those households use an electric generator (see figure 1). Only 0.3% of the households use solar devices as their primary source of electricity. The difference between off-grid usage as primary source of electricity between urban and rural is not significant (figure 2).

Despite the current low penetration of off-grid solar solutions, off-grid energy solutions can provide electricity to those who do not have electricity now. The use of solar devices is a relatively recent

[17] The sample size for households that rely on off-grid solutions as a main source of electricity is low. Therefore, the analysis presented in this section cannot lead to any conclusive inferences. Nonetheless, some of the analyses are here presented to help form future hypotheses in research of the off-grid sector.

phenomenon in North-West Nigeria and is mainly available in the urban areas (figure 32). As a matter of fact, the households obtained their first solar device just within the past five years, and 92.3% did so within the past three years (figure 33).

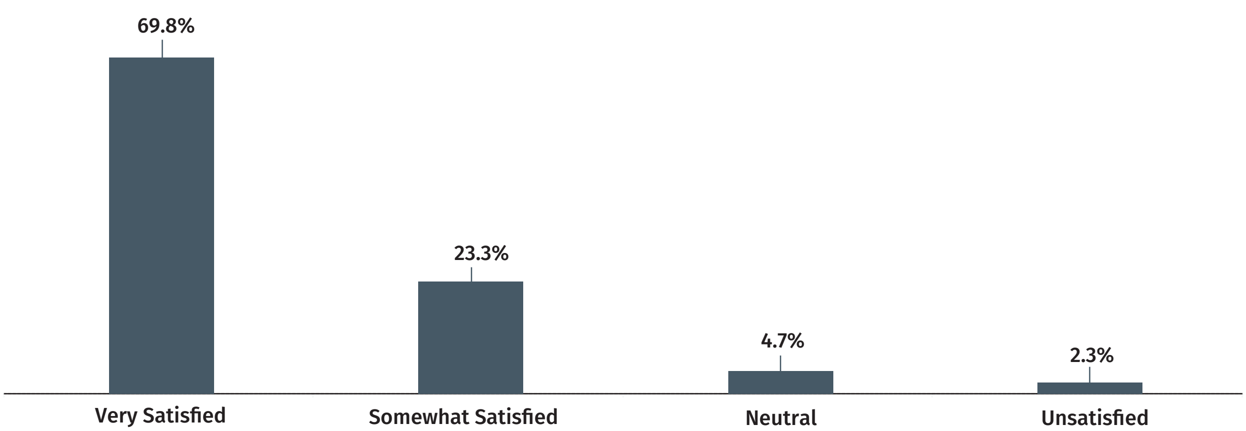
FIGURE 33 • **Number of years using solar devices, North-West Nigeria**



Note: Sample size = 41 households. Includes only households that use a solar device.

Among households that use a solar solution in North-West Nigeria, 93.1% are satisfied with their choice (figure 34), suggesting that even solar users in Tier 0 consider their solution satisfactory. High satisfaction levels compared with the recent adoption of the solar devices makes it important to support the growth of solar devices as a viable source of electricity.

FIGURE 34 • **Satisfaction levels of solar device users, North-West Nigeria**



Note: Sample size = 43 households. Includes only households using a solar device

POLICY RECOMMENDATIONS

About four out of ten (40%) of households in North-West Nigeria are connected to the national grid. More than 80% of grid-connected households are in Tiers 2 or 3, only a few households are in Tiers 4 and 5 (6.1%), while the rest (13.2%) fall in the lower tiers (Tiers 0 and 1). Improvements in availability (increasing the amount of time during which electricity service is available), reliability (reducing the number and duration of outages), and quality (reducing voltage fluctuation) of the grid can shift these households to the highest tier.

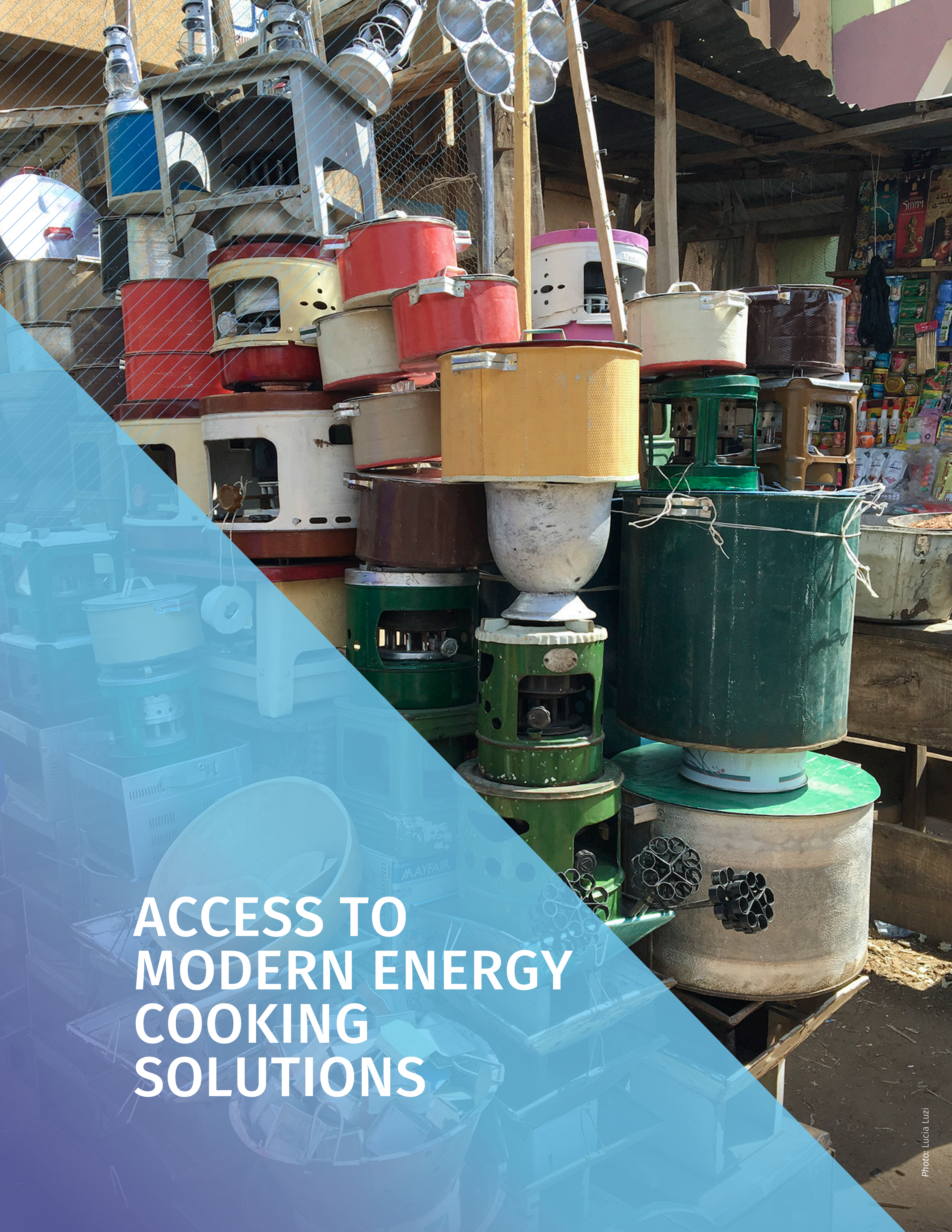
Only 2.1% of households in the zone use off-grid solutions, and most of them use electric generators. Over one-fifth of off-grid households falls in Tier 0 because of the limited capacity of their device. About 70% are between Tiers 1 and 3; 5% reach Tier 4 and only 1.8% have access at a Tier 5 level. Thus, dissemination of larger off-grid systems could shift them into higher tiers.

About 57.9% of North-West Nigerian households have no access to any electricity source. Moving them to higher tiers would require the provision of either grid or off-grid access. Policy recommendations to provide electricity to those without it are as follows:

- **Extend the grid:** Connecting households in North-West Nigeria 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. Households that live in villages that do not have access to grid electricity cite distance from the grid as major barrier for connection. Most of these are in rural areas, and therefore the government can consider extending the transmission and distribution lines to rural parts of the region.

- **Grid densification:** Connecting households "under the grid," directly beneath existing grid infrastructure, would require additional financing schemes and payment plans over time to reduce up-front 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 products may often be a more feasible solution for households living in areas where the grid infrastructure is not available. Although North-West Nigerian households have only started using off-grid devices in recent years, most of these off-grid users seem to be satisfied with the current service. Furthermore, the price of a low capacity off-grid solution is lower than the grid connection fee. Thus, providing off-grid access through off-grid devices of at least 3W (or 12Wh) 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 off-grid devices. Consumer awareness programs could help potential customers choose products of adequate quality and use them more sustainably.



ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Photo: Lucia Luzi

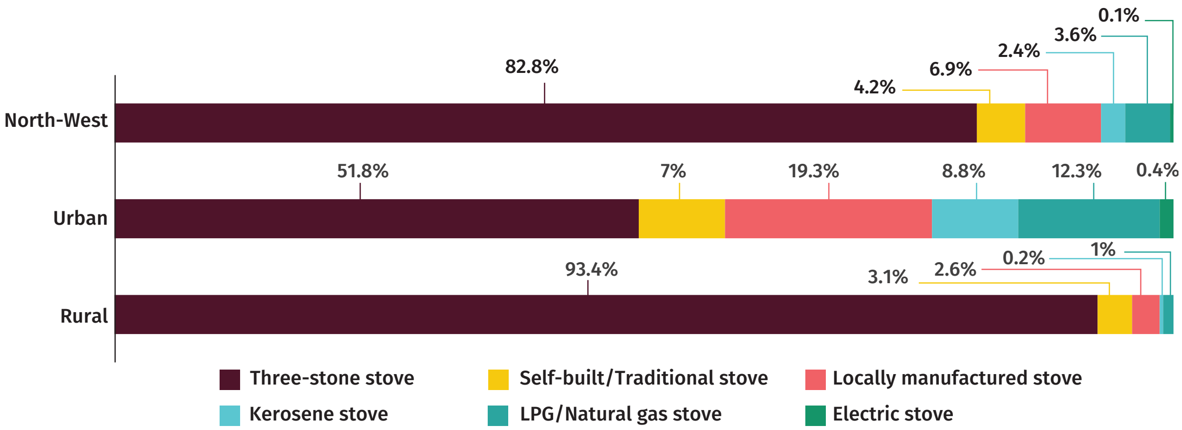
ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

TECHNOLOGIES

In North-West Nigeria, over 82.8% of the households use three-stone stoves as their primary cooking solution[18] (figure 35), and wood is the main source of fuel (figure 37). Only 4.2% use self-built/traditional stoves, and 6.8% of the population uses locally manufactured stoves with wood and charcoal as their main fuels (figure 37). A meagre 3.7% of households cook with clean-fuel stoves, mainly liquefied petroleum gas (LPG) or natural gas stove (figure 35).[19]

Urban and rural households have different cooking patterns. 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 three-stone stove. Three-stone stove is used to cook by almost half of the urban households, while it is more widely used (93.4%) by rural households. Locally manufactured and kerosene stoves are much more prevalent in urban areas: 19.3% of urban households use locally manufactured stoves and 8.8% of households use kerosene stoves compared to 2.6% and 0.2% of rural households, respectively. Clean stoves like LPG are very limited in rural areas (1%), while in urban areas they are found in 12.3% of households. Electric stoves are not used in rural areas and are used only by 0.4% of urban households. Overall, LPG stoves are the more dominant clean-fuel stove.

FIGURE 35 • **Access to modern cooking solutions, by technology, North-West Nigeria, urban and rural**



Note: Sample size = 3,632 households. For all other charts in the cooking section, the sample size is also 3,632 households unless otherwise noted.

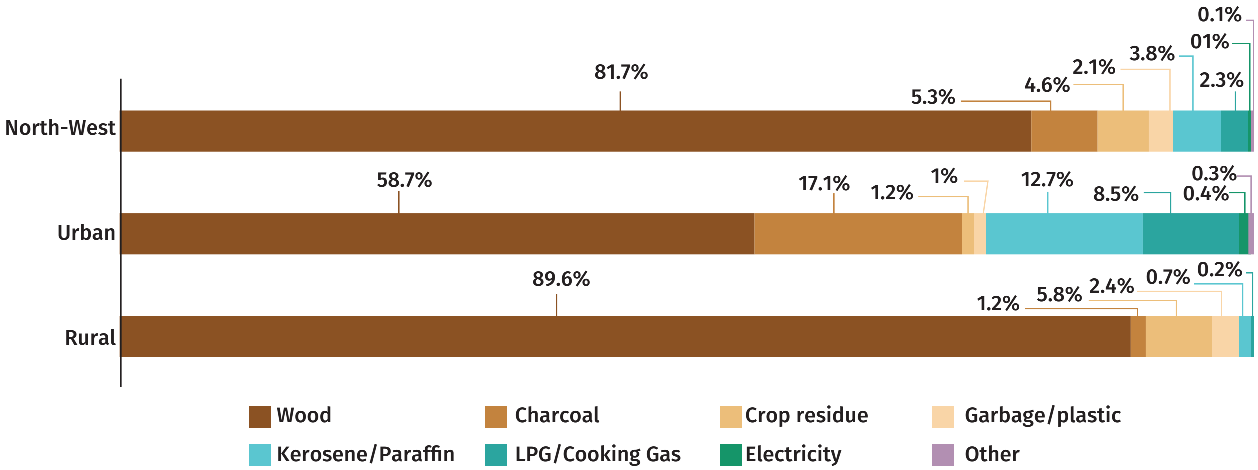
Almost four out of five North-West Nigerian households (81.7%) still heavily rely on wood as their primary cooking fuel to meet their cooking needs (figure 36). The use of charcoal increases

[18] Primary cookstove is defined as the one used most of the time in the household. Households were asked to identify their primary cookstove if they use multiple stoves. From the MTF perspective, a household must have only one primary cookstove.

[19] For more details about each type of cookstove, see annex 3.

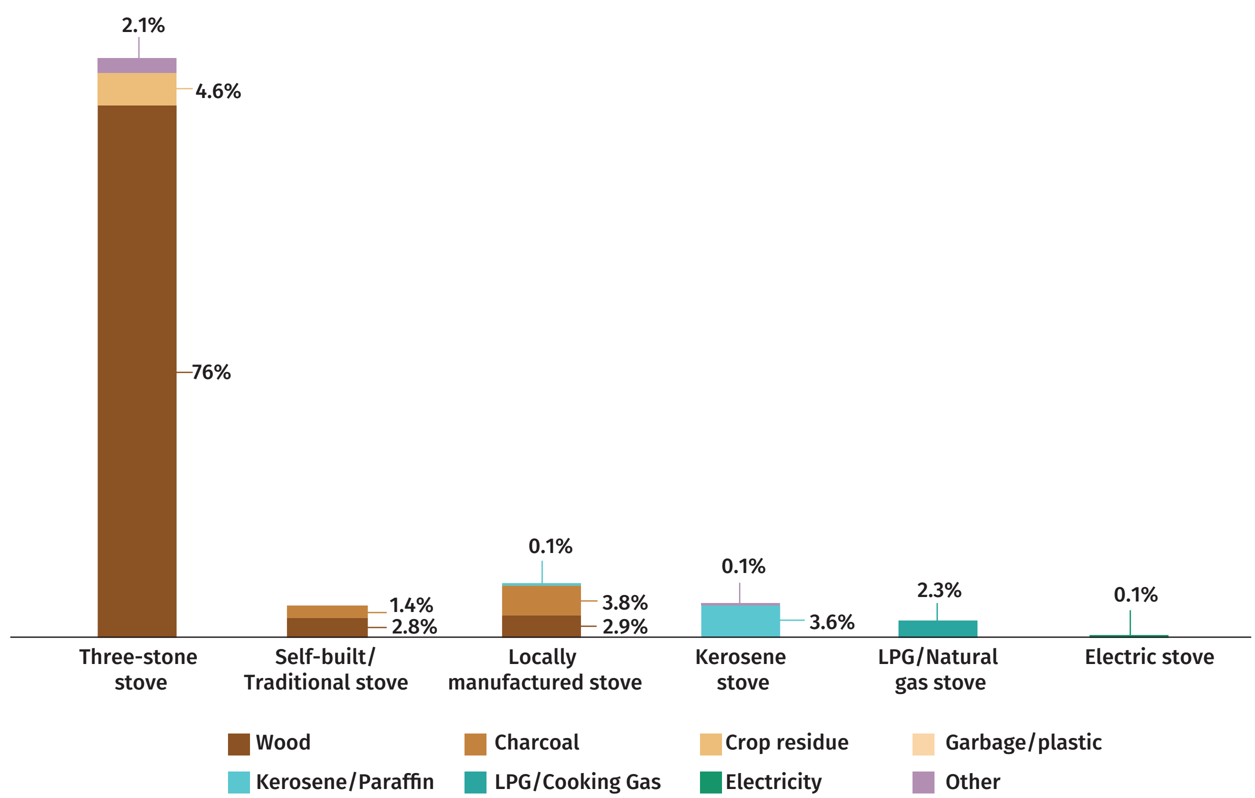
to 17.1% in urban areas compared to 1.2% in rural areas. Overall, charcoal is used mostly in self-built/traditional and locally manufactured cookstove (figure 37). Similarly, 12.7% of the urban households use kerosene fuel, while only 0.7 % of the rural households use kerosene. Clean fuel is mainly used in urban areas, although only 8.5% and 0.4% or urban households use LPG and electricity, respectively, as fuel (figure 36).

FIGURE 36 • **Access to modern cooking solutions, by fuel, North-West Nigeria, urban and rural**



Households that use a three-stone stove often mainly use three sources of fuel: wood, crop residue, and garbage and plastic. Households burn wood and charcoal mainly on traditional and locally manufactured stoves.

FIGURE 37 • **Distribution of cookstoves and fuel used, North-West Nigeria**



Stacking

Stacking refers to the practice which households use more than one type of stove or fuel to meet their cooking needs. There are two types of stacking in North-West Nigeria: stove stacking and fuel stacking.

While 88.1% of the households use only one stove in North-West Nigeria, 9.9% use two types of stoves for cooking, while 1.9% of the households use three types (figure 38).

In North-West Nigeria, one out of three households use two types of fuels to meet their cooking energy needs (figure 39). This indicates the dependency of these households on different fuel types. Further analysis is required to analyze the main reasons behind the choice of stacking fuels.

FIGURE 38 • Stove stacking, North-West Nigeria

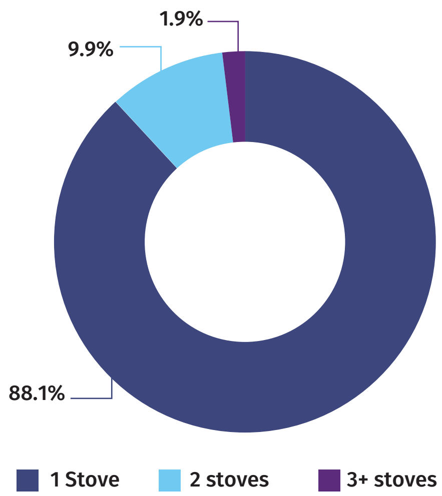
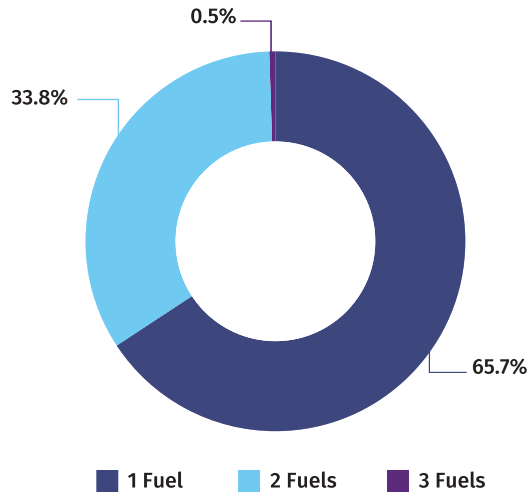


FIGURE 39 • **Fuel stacking, North-West Nigeria**



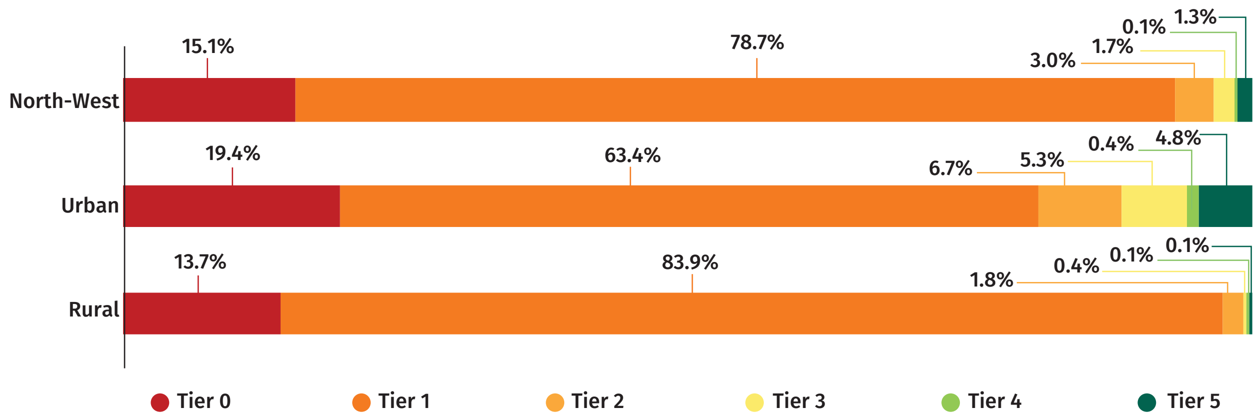
Note: Sample size = 3,573 households

MTF TIERS

In North-West Nigeria, most households are concentrated in Tiers 0 and 1 (93.8%), due to the high share of three-stone stoves (figure 40). Almost all rural households (97.6%) are in Tiers 0 and 1 compared to urban households (82.8%). By contrast, relatively more urban households fall in higher tiers for access to modern cooking solutions. Of urban households, 4.8% are in Tier 5, compared with 0.1% of rural households in the same tier level; this is mainly because clean-fuel stoves, such as those using LPG and natural gas, are mostly used in urban areas. However, using a clean-fuel stove does not automatically categorize these households into higher tiers. For instance, 12,7% of urban households use a clean-fuel stove as their primary stove (figure 35), but only 5.2% of urban households are in Tier 4 or 5 for access to modern-energy cooking solutions.

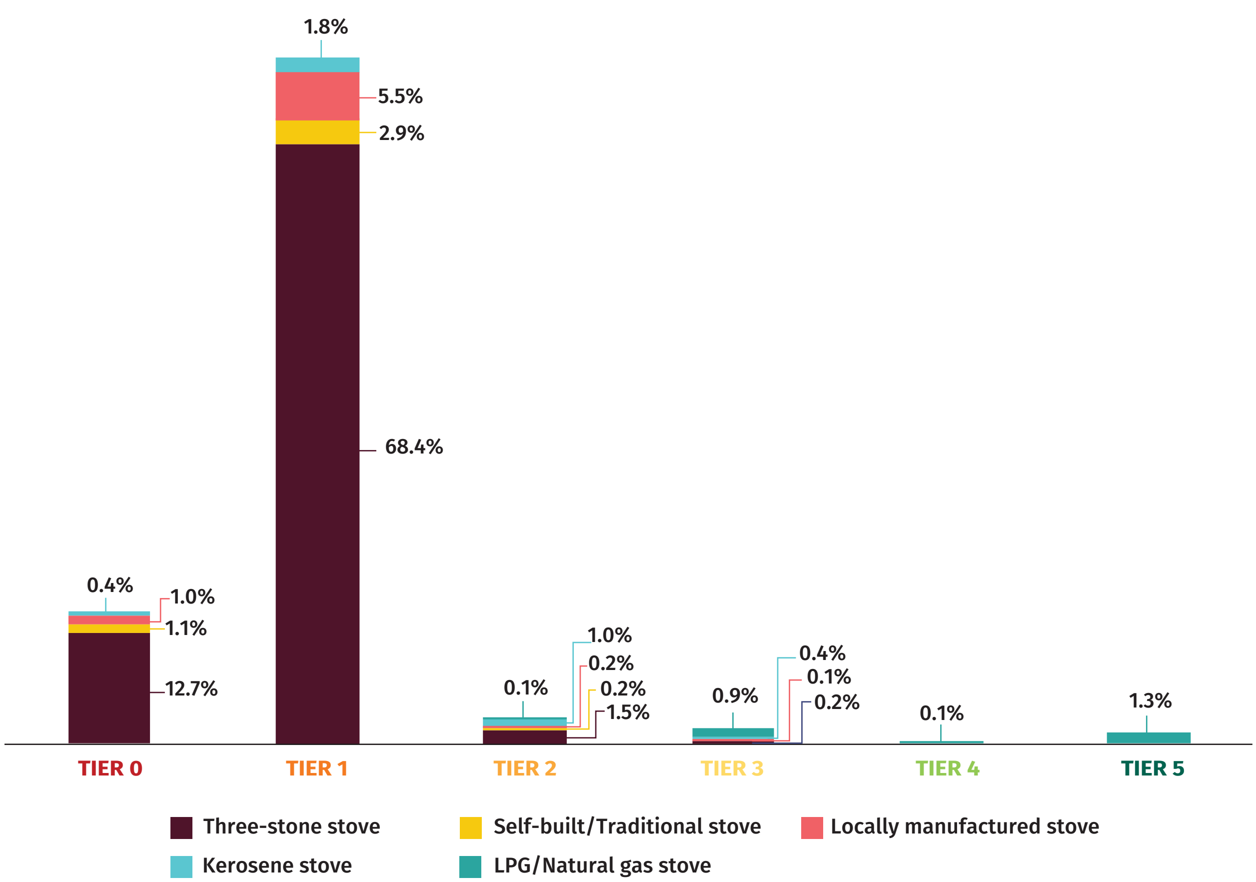
The large gap in access to modern cooking solutions between urban and rural areas can be explained by lower use of clean cooking solutions in rural households, because a larger portion of rural households than urban households use three-stone stoves (figure 35). Urban households tend to be in higher tiers mainly because kerosene (classified as Tier 3), LPG or natural gas, and electric stove (classified as Tier 5) are used mostly in these areas. Rural households use of kerosene and clean-fuel stoves as their primary stove is negligible; only 0.2% of the rural households are in Tiers 4 and 5 (figure 40).

FIGURE 40 • **MTF Tier distribution: Access to modern-energy cooking solutions, North-West Nigeria, urban and rural**



Households that primarily use three-stone stoves are concentrated in Tiers 0 and 1, while almost all households that mainly rely on LPG or electric stoves are in Tiers 3 through 5 (figure 41). Households that use kerosene stoves (classified as Tier 3) are in Tier 1 or 2 due to Availability and Convenience Tiers of kerosene fuel.

FIGURE 41 • **MTF Tier distribution by primary stove type, North-West Nigeria**



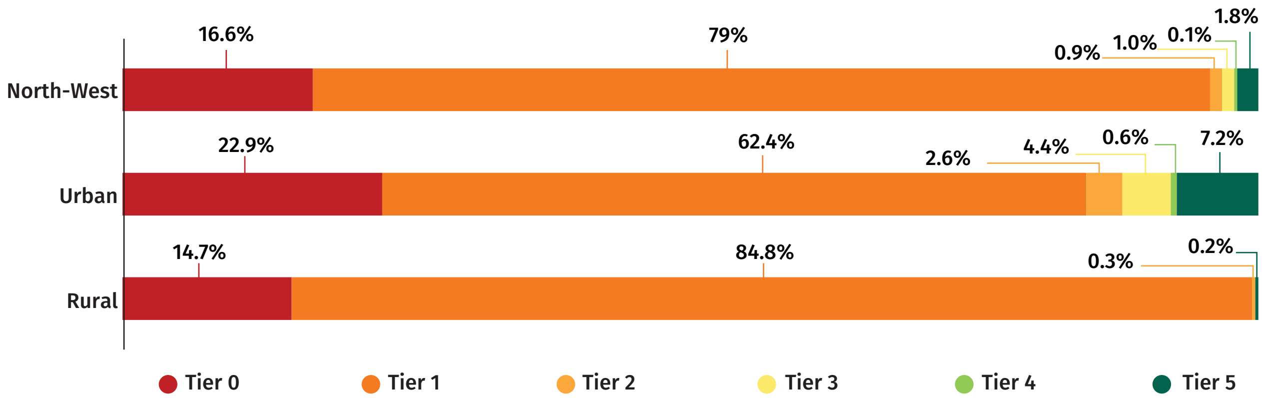
MTF ATTRIBUTES[20]

Cooking Exposure

In North-West Nigeria, most households (95.6%) 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 from three-stone, self-built/traditional, and locally manufactured stoves. The reason more households are in Tier 1 than Tier 0 is that most of the households cook outdoors and therefore have ventilation. one result is that a higher rate of urban households (22.9%) are in Tier 0 than rural households (14.7%).

A mere 1.8% of households are in Tier 5, as they use clean-fuel stoves. Nearly all rural households (99.5%) are in Tiers 0 and 1, compared with 85.3% of urban households (figure 42).

FIGURE 42 • **Distribution of households based on the Cooking Exposure Tier, North-West Nigeria, 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. In North-West Nigeria, 70.6% 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 43). Households in lower convenience tiers primarily use three-stone stoves, which require more effort and are less efficient than clean-fuel stoves. Rural households spend more time on collecting fuel (firewood) rather than purchasing fuel (firewood).

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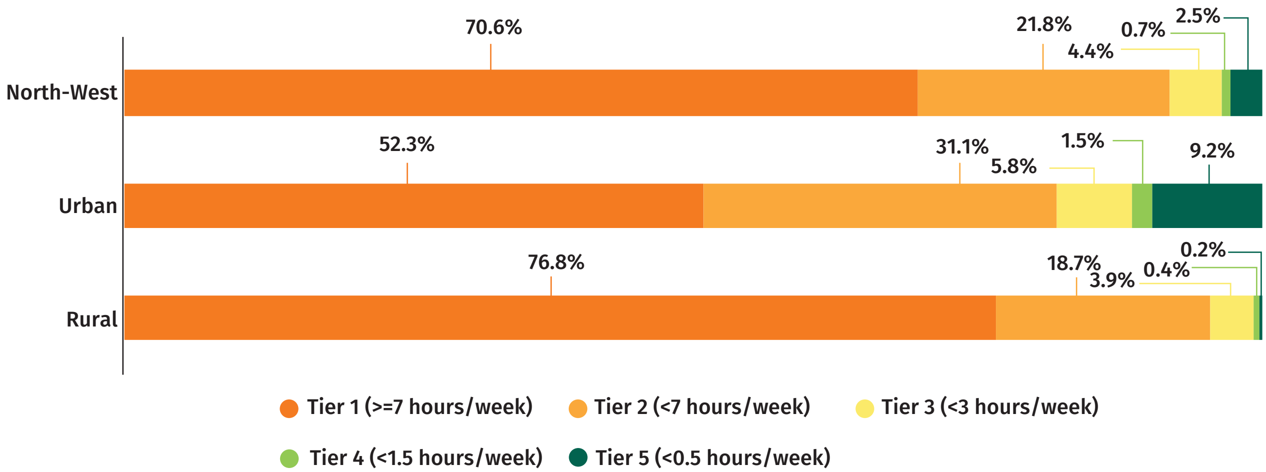
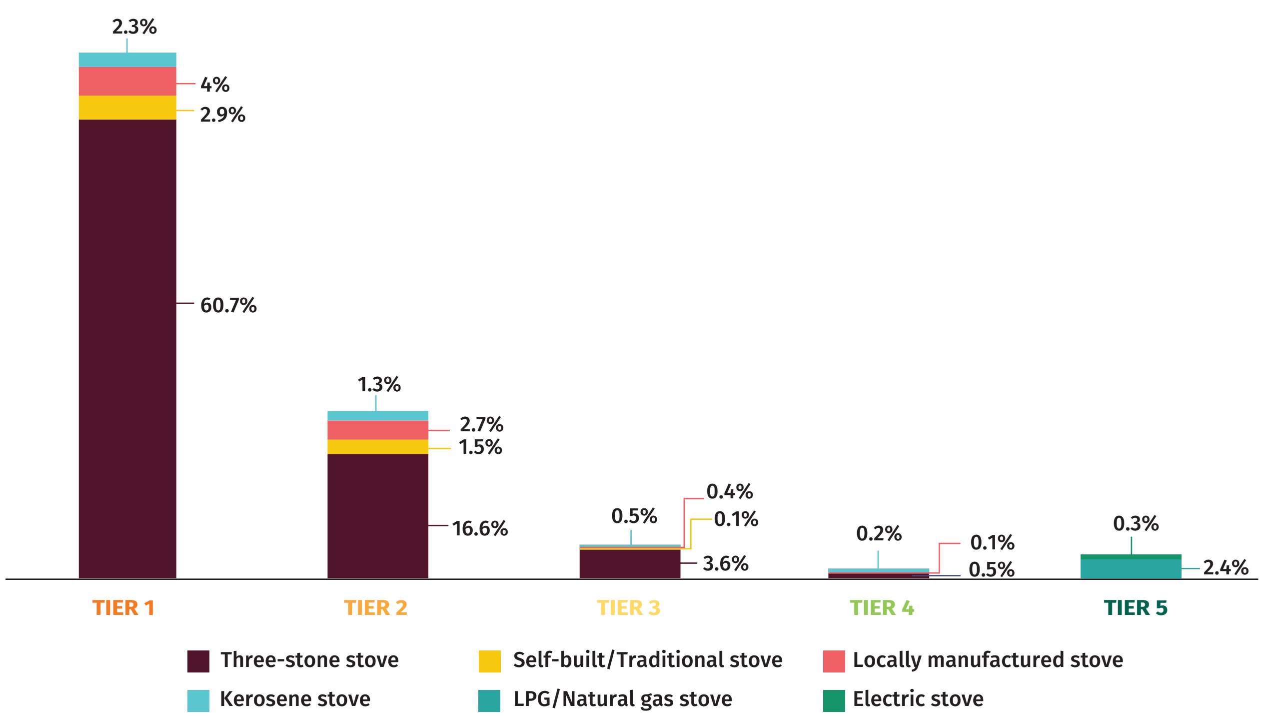
[20] The Cookstove Efficiency attribute is missing in this analysis.

FIGURE 43 • **Distribution of households based on total convenience, North-West Nigeria, urban and rural**



Tier 5 households in the Convenience attribute are clean-fuel stove users (figure 44). This shows that the fuel acquisition and stove preparation time for these households are very low. Kerosene stoves also fall between Tiers 0 and 2 of the Convenience attribute, hinting at greater fuel acquisition and preparation and greater stove preparation time, similar to wood and charcoal. Therefore, households that use stoves that require wood and charcoal are mainly in Tier 0.

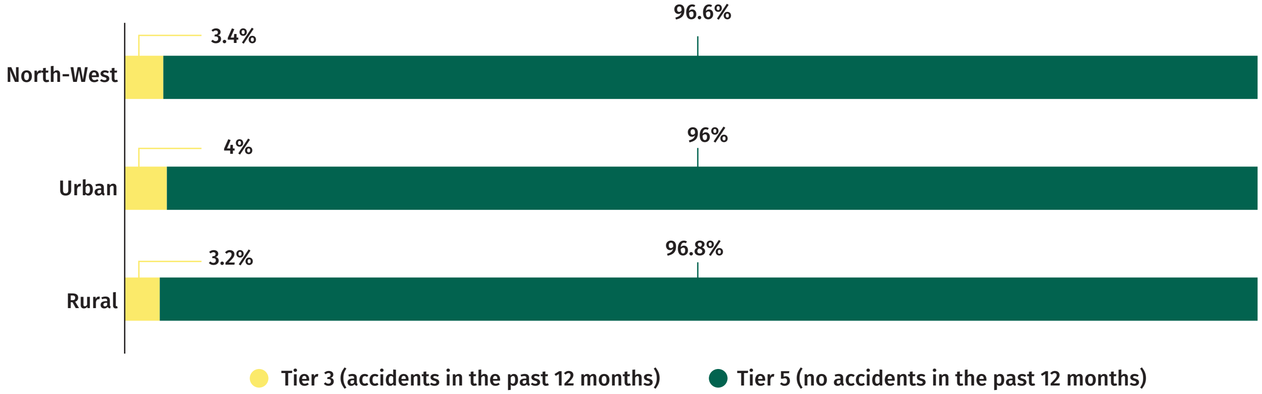
FIGURE 44 • **Distribution of the Convenience Tier by stove-type, North-West Nigeria**



Safety of Primary Cookstove

The attribute of Safety of Primary Cookstove is a binary (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 previous 12 months (figure 45). In North-West Nigeria, only 3.4% of households reported serious injuries, including permanent health damage, burns/fire/poisoning; or even death of a household member within the past year, resulting from the use of their primary cooking device or fuel.

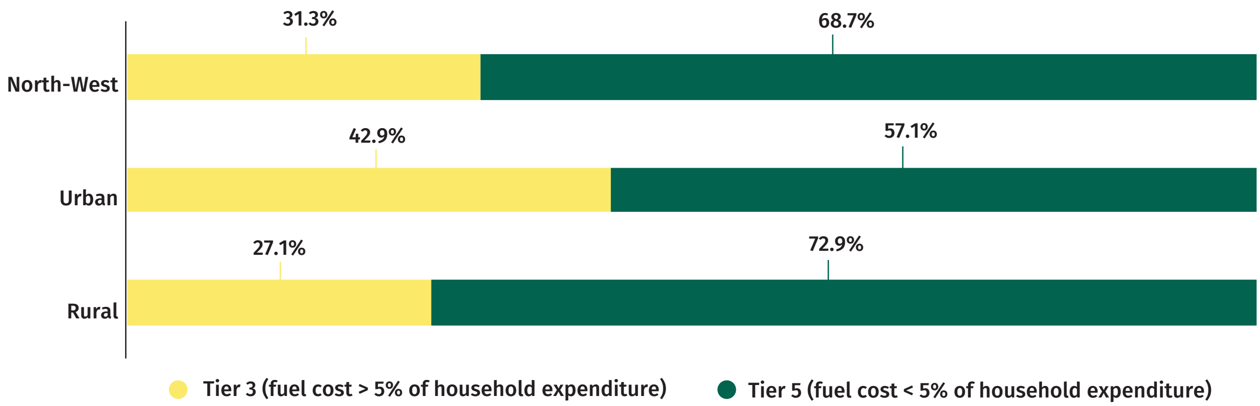
FIGURE 45 • **Distribution of households based on Safety, North-West Nigeria, urban and rural**



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. In North-West Nigeria, 69.2% of households spend less than 5% of their total household expenditure on cooking fuel (figure 46). Fuel is considered unaffordable for 42.8% of urban households, compared with only 26.8% rural households. This gap is because most rural households cook with wood, and most of them collect their fuel for free. Conversely, urban households purchase wood and 90% of charcoal is used in urban areas which is purchased.

FIGURE 46 • **Distribution of households based on affordability, North-West Nigeria, urban and rural**

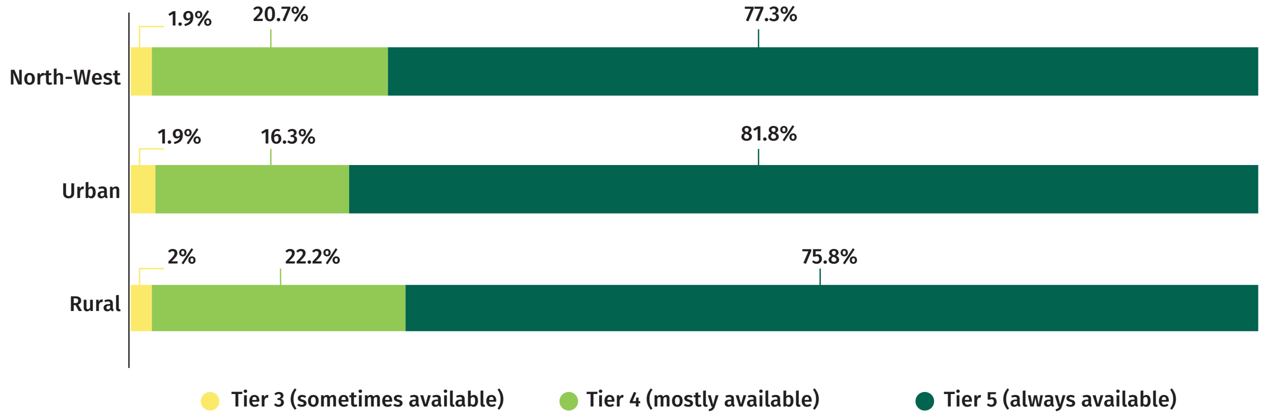


Note: Sample size = 3,621 households.

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 77.3% of households reported that fuel was always available (figure 47). Fuel was mostly available for 20.7% of households, while only 1.9% of households reported that fuel was only sometimes available. In urban areas, fuel availability tends to be slightly better than in rural areas.

FIGURE 47 • **Distribution of households based on availability, North-West Nigeria, 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 access of clean-fuel stoves could move households to the highest tier. In addition to clean-fuel stoves, the promotion of locally manufactured or kerosene stoves could help shift households, particularly Tier 0 households, into higher tiers. However, due to health issues with kerosene and the inefficiency of the locally manufactured stoves, more efficient products with lower smoke emission need to be introduced to the market.

The primary constraint for households in Tier 0 and Tier 1 for moving toward higher tiers is the poor quality of stoves as highlighted by Cooking Exposure attribute (figure 42). Apart from this, several households in Tier 1 and Tier 2 are constrained by convenience, which is a factor of fuel acquisition and preparation time and stove preparation time. Safety and fuel availability are not major concerns relative to cooking exposure and convenience. Solving the cooking exposure issue can lead to health benefits by reducing the amount of indoor air pollution.[21]

Furthermore, the breakdown of aggregate tier by primary stove type, as shown in figure 41, indicates that clean-fuel stoves are typically found in higher tier households, while open-fire or manufactured stoves are in lower tiers. Given these considerations, policy recommendation can target two different groups. First, households that mainly use three-stone stoves must move to higher tiers by using clean-fuel stoves. Due to poor LPG availability in rural areas (figure 37), there should be greater emphasis on improved cookstoves (ICSs) for rural areas since willingness to pay for ICSs is high among these households (figure 49). Second, the households using three-stone, locally manufactured and kerosene

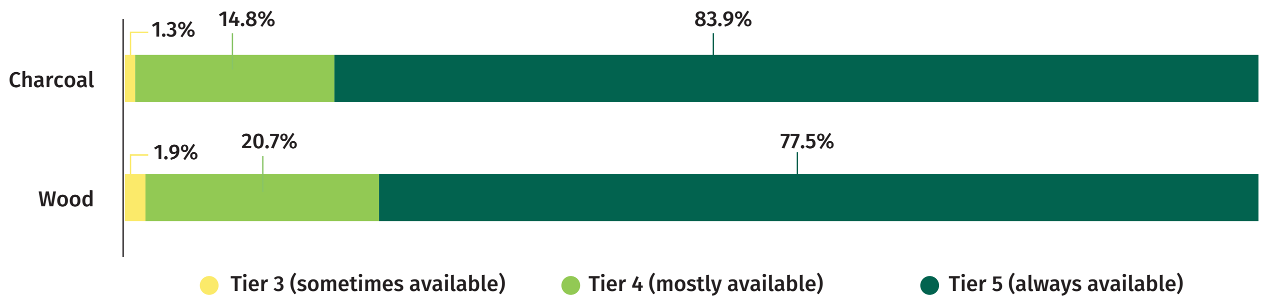
[21] Households in Tier 5 do not have any constraint, as they are in the highest tiers already.

stoves can be directly transitioned to clean-fuel stoves, especially in urban areas where LPG fuel (figure 52) and electricity are available (figure 2).

INCREASING SWITCHING TO IMPROVED COOKSTOVES FROM TRADITIONAL STOVES

The presence of ICSs such as locally-manufactured and kerosene stoves in lower tiers (figure 35) highlights two problems. First, the low-grade technology of traditional cookstoves through the Cooking Exposure attribute (figure 42) means that access to and adoption of ICSs is necessary to achieve cleaner cooking solutions. Second, the Convenience attribute (figure 43) shows that households face inconvenience with high fuel-acquisition time and stove preparation time, which must be reduced. Figure 48 shows that both wood and charcoal are easily available throughout the year. Therefore, when the quality of the cookstoves increases, there is fuel available to use these cookstoves.

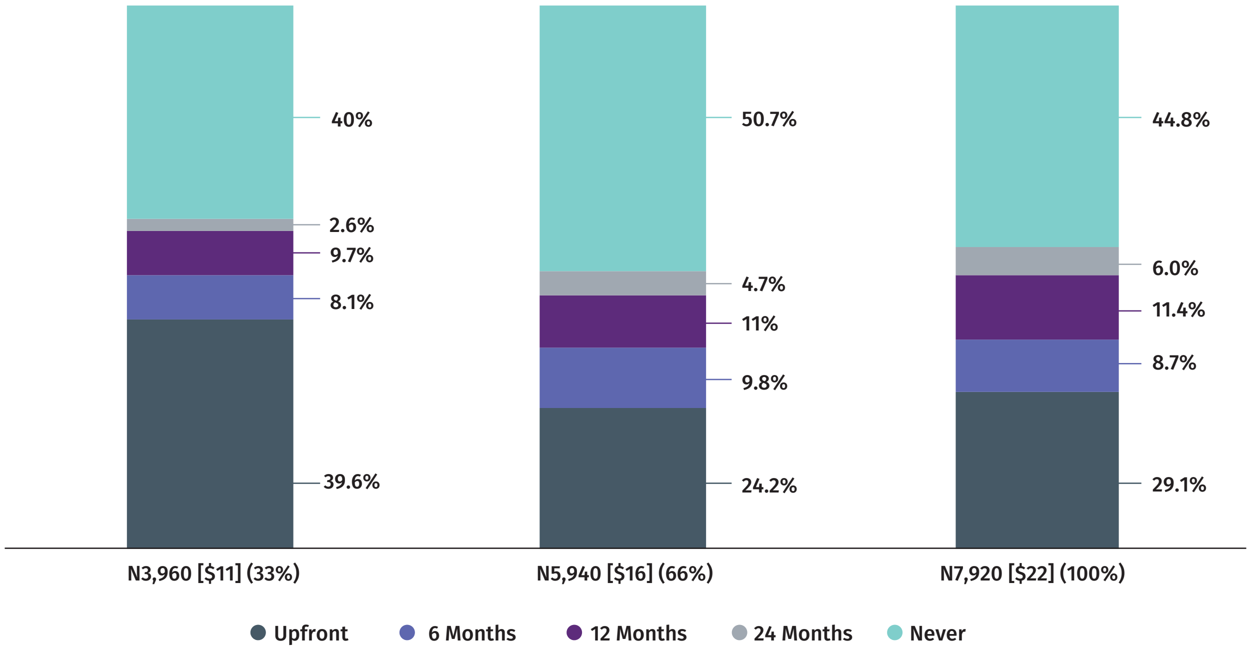
FIGURE 48 • **Distribution of households cooking with biomass stoves based on fuel availability, North-West Nigeria**



In North-West Nigeria, respondents were asked if they would be willing to pay for an improved stove.[22] (An improved stove is an affordable cookstove available in the market that burns biomass fuel in a cleaner and more efficient way.) The MTF analysis shows that payment plans and reductions in price will effectively increase North-Western Nigerian households' willingness to pay for an improved stove. Willingness to pay for an ICS up front is high for the households. Different prices were offered to different survey respondents. The full price for an ICS is N7,920 (US$22). Apart from the full price, two other prices, 33% and 66% of the full price, were also offered to respondents. At 33% of the price, N3,960 (US$11), 39.6% of the households are willing to pay up front; at full price of N7,920 (US$22), more than one out of four households are willing to pay up front (figure 49). When payment periods are offered of 6, 12 and 24 months, several more households are willing to pay. For the full price of N7,920 (US$22), one out of four more households is willing to pay with payment periods. Therefore, the adoption of ICSs can increase by more than 50% if payment options are introduced.

[22] Households were randomly offered a charcoal- or wood-fueled efficient cookstove that is available in the market. Households then responded whether they are willing to purchase this cookstove at the different prices (33%, 66% and 100% of the market price for the offered stove). This ICS is a manufactured cookstove with higher fuel efficiency and lower emissions than a three-stone and locally manufactured cookstoves. Households were shown pictures and explained the benefits of this ICS.

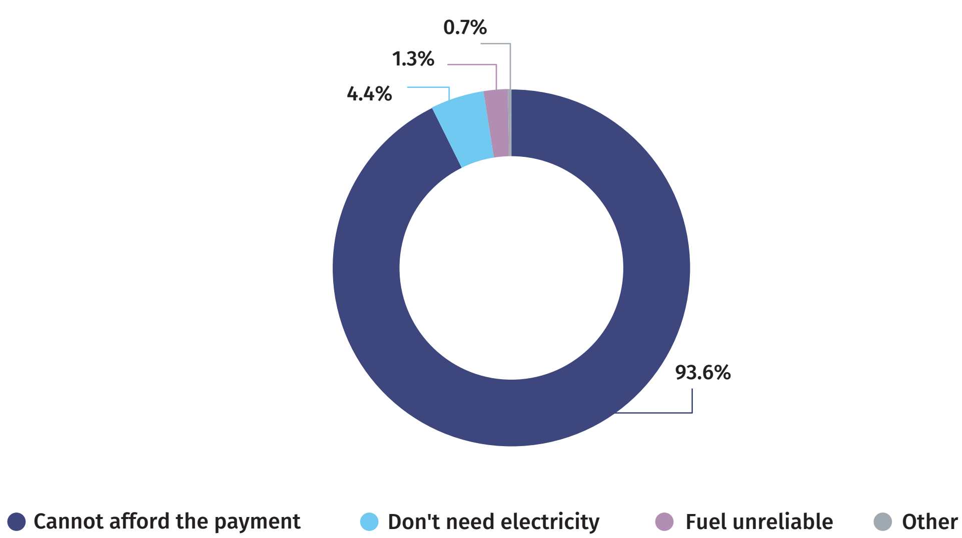
FIGURE 49 • **Willingness to pay for an improved cookstove, North-West Nigeria**



Note: Sample size = 2,367 households.

For the full price of N7,920 (US$22), 44.8% of households that are never willing to pay for the ICS, irrespective of the payment periods. According to figure 50, among households unwilling to pay for an ICS under any price or payment plan, most of them (92.8%) reported that they could not afford the payment (which represents Affordability issue for cookstoves). Besides, 4.7% of households not willing to pay for an ICS believed they did not need an ICS.

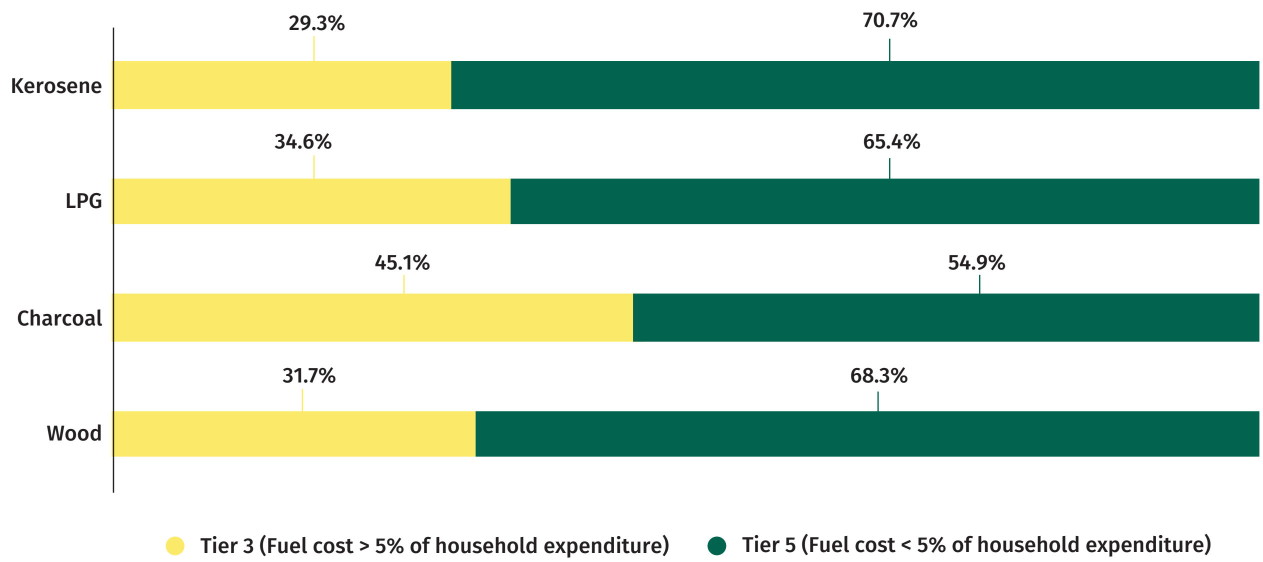
FIGURE 50 • **Households unwilling to pay, North-West Nigeria**



Note: Sample size = 355 households.

Further analysis shows that many households spend over 5% of their monthly expenditure on fuel, and this includes every kind of fuels available (figure 51).[23] Therefore, a combination of fuel affordability and cookstove affordability need to be addressed to improve access to modern cooking solutions.

FIGURE 51 • **Distribution of households cooking with biomass stoves based on fuel affordability, North-West Nigeria**



INCREASING PENETRATION OF CLEAN-FUEL STOVES

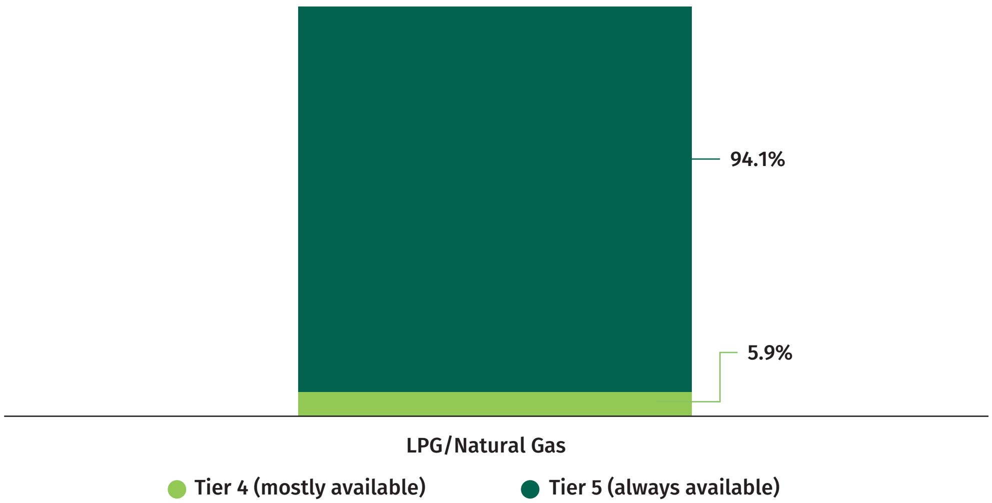
Clean-fuel stoves are of two types: LPG stoves and electric stove. Since most households in North-West Nigeria rely on a three-stone stove, promoting clean-fuel stoves such as electric stoves among these households can be further explored. However, promoting clean-fuel stoves is a complex transformational change challenge and requires good insights into the country-specific conditions and potentials. As a matter of fact, given that the electric availability is only 40% (figure 1) electric cookstoves can be a reliable source only for those 40% households for which reliability is not a concern. When the electricity is not reliable, it can lead to higher stacking, as households might purchase backup stoves during days when electricity is not available

Examining the challenges that clean-fuel stove users are already facing and avoiding these problems in the future can make the promoting process more efficient and successful. Clean-fuel like LPG has very low fuel acquisition and preparation time and low stove preparation time (figure 44). With these benefits, LPG stove adoption in urban areas can increase, since LPG fuel is easily available throughout the year, particularly in urban areas (94.1%) (figure 52). Although, LPG fuel is still missing in rural areas of North-West Nigeria, a future possibility can be to stimulate the rural market for LPG fuel, which can lead to a spillover effect by creating the market for LPG stoves.

Other possible constraints to promoting clean-fuel stoves include the following. First, 57.9% of households do not have grid connection (figure 1). Increasing the penetration of electric stoves would first require the extension of grid connection. Second, safety issues of LPG stoves exist in areas with lack of standards and regulations for quality of LPG stoves (Puzzolo et al. 2019).

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

FIGURE 52 • **LPG fuel availability, urban**



Note: Sample size = 111 households.

POLICY RECOMMENDATIONS

The MTF survey in North-West Nigeria finds that more than 4 out of every 5 households still use three-stone stoves as their main cooking stove. These stoves generally use firewood, which leads to higher emissions; 81.7% of households use firewood as their main cooking fuel. Thus, cooking exposure (personal exposure to pollutants from cooking activities) due to type of stove is the main constraint for these households in moving up the MTF tiers. To shift these households to higher tiers, switching to improved or advanced biomass stoves and clean-fuel stoves is critical.

Promote improved or advanced biomass stoves: For households in areas with high biomass availability and lower penetration of clean fuels, ICSs can be a viable option. Presenting a higher quality ICSs and offering payment periods on the cookstoves can lead to higher adoption of these kinds of stoves.

ICSs have the added advantage of better exhaust systems and being more energy efficient than such traditional stoves as three-stone or self-built biomass stoves. Most of the households use three-stone stove due to affordability issues. Therefore, a public awareness campaign and payment plans for improved biomass stoves can significantly increase the use of these cookstoves in North-West Nigeria. MTF data show that urban households are transitioning to kerosene stoves due to increased availability and the affordability of kerosene in these areas.

Promote clean-fuel stoves: Clean-fuel stove users are more likely to be in higher tiers due to the lower emissions. Clean fuels like LPG can be promoted and potentially lead to higher adoption of LPG stoves, as evident in urban areas of North-West Nigeria. However, the main constraint to LPG adoption is fuel affordability (the ability of the household to pay for both the cookstove and fuel). Additionally, MTF data explore the reasons for lack of LPG stove diffusion in rural areas; a transition to LPG stoves must consider the household affordability and LPG stove diffusion across North-West Nigeria.

Among the clean-fuel stoves available in North-West Nigeria, penetration of electric stoves is extremely low. Fuel affordability for electricity and higher cost of electric stoves can be a barrier for households that have access to electricity, while unavailability of electricity in more than half the population will not allow for adoption of electric stoves. Additionally, electricity reliability issues in North-West

Nigeria make electric stove an unattractive proposition. Electric stoves, therefore, can be a medium- to long-term solution assuming improved access to electricity. Urban areas have lower disruptions and benefit from a reliable and constant supply of electricity, which increases the probability of adoption of electric stoves. However, improving grid access and off-grid solutions like solar, electric stove, and solar-powered electric stoves can be near-term to medium-term possibility in rural areas.

According to the Nigeria Cookstove Program, established in 2014, clean cooking fuels will be promoted through a market-based approach in Nigeria. Additionally, a biomass ICS effort is heavily focused on rocket wood stove promotion (for example, Save80 and Envirofit). MTF data on willingness to pay for ICSs demonstrates a high willingness to buy such improved biomass cookstoves with reduced up-front costs and payment flexibility options. Therefore, a multi-level approach for promoting improved and clean-fuel stoves can help transition North-West Nigeria to a modern-energy cooking region.

ANNEX 1.
Multi-Tier Frameworks

TABLE A1.1 • **Multi-Tier Framework for Measuring Access to Electricity**

Attributes				Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
	1. Capacity	Electricity	Power		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Daily supply capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
			Typical source		Solar lanterns	Solar home systems	Generator or mini-grid	Generator or grid	Grid
	2. Duration of daily supply				Min 2 hrs	Min 4 hrs	Min 50% of working hours	Most of working hours (Min 75%)	Almost all of working hours (Min 95%)
	3. Reliability							Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
	4. Quality							Voltage problems do not affect the use of desired appliances	
	5. Legality							Energy bill is paid to the utility/pre-paid card seller/authorized representative/legal market operator	
	6. Safety							Energy supply solutions have not caused any accidents over the last one year	

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

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

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

Note: Cookstove Efficiency not used as an attribute to calculate the final tier in North-West Nigeria. 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

SAMPLE SIZE CALCULATION PARAMETERS

The sample size proposed for MTF countries is designed to get sufficiently precise estimates of each tier at national, urban, and rural levels. 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 to consider in determining sample size calculation and provides a justification for the proposed sample size for each country. Major issues in determining the appropriate sample size for a survey are the following:

- Precision of survey estimates (sampling error)
- Quality of data collected by the survey (non-sampling error)
- Cost in time and money of data collection, processing, and dissemination

Precision of 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 purposes. From a sample of households, one can collect data and generate a sample (or survey) estimate of a population parameter. The population parameter value of 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 (B.1) to calculate the sample size is as follows:

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

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 Living Standards Measurement Study (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 than 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. Therefore, a value of 1.1 (= 1 + 10%) for k would be conservative.

e = Margin of error or level of precision. The World Bank applies various levels of margin of error from 1% to 5.5% to the calculation.

Quality of data (nonsampling 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 nonsampling errors. Nonsampling 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, 56). Thus, one would expect nonsampling errors to increase with sample size, and we would like to limit the sample size to less than 5,000.

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.

SAMPLING APPROACH

For this household survey, the target sample was 3,696 households spread across 264 enumeration areas (EAs). The sample was split equally between urban and rural areas, which were treated as analytical domains (1,800 household in urban and rural areas respectively). The sample size was based on the formula and assumptions below. The following formula was used to determine the sample size per state:

$$n \quad \frac{z^2 * r(1-r) * f}{}$$

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, which yields the maximum sample size. The design effect, *f*, describes the loss of sampling efficiency due to using complex sampling design, and it is assumed to be equal 6. The factor accounting for the anticipated response rate, R, is calculated assuming 90% response. The margin of error, *e*, is assumed to be 6% at urban/rural level; this is equivalent to about 4% margin of error for the study area overall.

The sample was distributed across the seven study states according to their populations based on available data from the Census 2006. Urbanity split was not available at state level.

SAMPLE DESIGN

The sample design adopted a stratified, cluster sampling approach to select the household survey sample. The sample was stratified by region and electrification status. The sample was selected using the following steps:

Firstly, the firm selected primary sampling units (PSUs). The administrative unit used as PSUs was census enumerations areas (EAs). In rural areas this was equivalent to villages and in urban areas this was wards. EAs were then selected with probability proportional to population size within each state. A fixed number of households (14) was selected within each EA, meaning each household had the same probability of selection. Note that while this number was in principle fixed, a little flexibility was allowed in practice. Thus between 12 and 14 households was an acceptable number within each EA.

The National Population Commission (NPopC) provided population data at EA level and electrification status.

The sample of electrified and non-electrified EAs within each state was drawn from two separate lists of EAs reflecting the two electrification strata. At EA level, villages or wards where 97% or more of households are connected to the grid was classed as electrified. Conversely, EAs where 3% or less of the households are electrified was treated as non-electrified.

The sample was evenly distributed between electrified and non-electrified areas. Given the different possible scenarios, EAs were selected as follows:

The State has both villages with electricity and villages without electricity. Where an uneven number of EAs was selected, the larger number was allocated to electrified EAs.

> *Special case I (Number of electrified PSUs in the State is less than the number of electrified EAs allocated to the State):* When this was the case, the firm selected all the electrified PSUs in the State and oversampled non-electrified EAs. To keep the ratio between on-grid and off-grid users to less than 1.1, the firm oversampled electrified EAs in other states.

> *Special case II (Number of non-electrified PSUs in the States is less than the number of non-electrified EAs allocated to the State):* the firm selected all the non-electrified EAs in the state and oversampled electrified EAs. If the ratio between on-grid and off-grid users was less than 1.1, there was need to oversample non-electrified EAs in other States.

All the villages in the State have access to electricity (or only few villages do not have access to electricity - e.g. if less than 2% of villages do not have access to the grid in the state the firm adjusted the threshold in consultation with the World Bank team). This was a special case. In this case, all the EAs were randomly selected from the list of the enumeration areas.

No villages in the State have access to electricity: In this case, all the EAs were randomly selected from the list of EAs. The firm then attempted to pair this state with another state where all sampled villages have electricity.

Within each EA the firm aimed to interview 7 electrified household and 7 non-electrified households. Electrified households were defined as household who are connected to the grid while non-electrified households are those who are not connected to the grid. The number of EAs per state ranges between 23 and 67, giving a total of 258 EAs with an additional 6 spare EAs to take care of contingencies.

The EAs have approximately 200 households. Census 2006 block maps were used to identify the selected EAs and establish their boundaries. The firm obtained the block maps from the NPopC, and updated the maps using transect walk of each EA.

At the second stage of sampling, all the households in the area were listed. This listing identified institutional and residential buildings. The head of the household or his/her spouse was the point of contact with the listing team at this point. All the relevant household information was collected including name of head of household, household size, and grid connection status (electrified and non-electrified). Next, the supervisor sent the household information collected to the administrative office where a fixed number of households was selected from all households within each EA. Systematic sampling was used, making use of a random start between 1 and the sampling interval (SI) (determined by sampling frame divided by sample size). Where empty households were encountered at the time of the listing, the team was instructed to ask about the household from neighbours.

Thereafter, the list of selected households was given to the field team who went to the households to administer the survey questionnaire. This approach was adopted to reduce non-sampling error and ensure the sampling selection was free from any biasness. The main interview was conducted with the head of household or their spouse. The interviewer took the GPS reading of the location both prior to and at the end of the interview for increased accuracy.

SYSTEMATIC SELECTION OF HOUSEHOLD

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:

1. newborn children who were members of the household, even if they were less than six (6) months of age;
2. 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
3. students who had attended school during the school year were considered as members of the household in which they lived during the school year.

The selection of households from the sample frame was done in the following manner: The compiled household list was stratified by connection status and thereafter the selection of both categories of households was drawn.

Assuming N1 (electrified households) = 160 and N2 (non-electrified households) = 40, then the sampling gap for electrified and non-electrified households was 23 and 6 respectively as shown below:

Electrified households (N1 = 160, n = 7)

$$\text{sampling interval} = \frac{160}{7} = 22.86\ \textit{approximately}\ 23$$

The firm then randomly selected a number from 1 to 23 as the starting point (random start) and every 23rd household on the list was chosen as an eligible household for the survey.

Non-electrified households (N2 = 40, n = 7)

$$\text{sampling interval} = \frac{40}{7} = 5.72\ \textit{approximately}\ 6$$

The firm then randomly selected a number from 1 to 6 as the starting point (random start) and every 6th household on the list was chosen as an eligible participant for the survey.

WEIGHTING

To ensure that the household sample is representative of the target population weights were calculated. The process involves the steps described below. In terms of terminology, for this study PSU is equivalent to EA. The use of PSU below is therefore interchangeable with EA.

Design weights calculation

The design weights will adjust for the differential sampling probabilities, reflecting the clustered sample:

P_{1hi} : probability of selecting the ith PSU/cluster in stratum h in stage 1

P_{2hi} : probability of selecting the household within the i^{th} PSU/cluster in stage 2

Assuming that n_h is the number of PSUs selected in stratum h; M_{hi} is the measure of size of the PSU used in the first stage's selection, that means it is the number of households residing in the PSU according to the sampling frame (or census); $\sum M_{hi}$ is the total measure of size in the stratum h. The probability P_{1hi} of selecting the i^{th} PSU in the sample is thus:

$$P_{1hi} = \frac{n_h\ M_{hi}}{\sum M_{hi}}$$

$$P_{1hi} = \frac{\text{\# PSUs selected in stratum h * \# HHs in the PSU}_i \text{ in stratum h (from census)}}{\text{total \# HHs in stratum h}}$$

Assuming that is the number of households selected in the EA i in stratum h, and is the number of households listed in the household listing operation in EA i in stratum h. The second stage selection probability P2hi for each household in the EA is thus:

$$P_{2hi} = \frac{t_{hi}}{L_{hi}}$$

$$P_{2hi} = \frac{\text{\# HHs selected in the PSU}_i \text{ in stratum h}}{\text{\# HHs listed in the PSU}_i \text{ in stratum h}}$$

Consequently, the overall selection probability of each household in PSU i of stratum h is the product of the selection probabilities of the two stages:

$$P_{hi} = P_{1hi} \times P_{2hi}$$

Finally, the firm calculated the design weight for each household in PSU i of stratum h as the inverse of its overall selection probability:

$$d_{hi} = 1/P_{hi}$$

Correction for non-response

To adjust for non-response among certain groups of the population, for example the very wealthiest or poorest, non-response weights were created.

In general, correcting for unit non-response is required to calculate a response rate for each homogeneous response group; subsequently, the design weight must be divided by the response rate for each response group.

The firm first calculated the sampling weight by calculating the various response rates for unit non-response. For this study only PSU and household levels response rates were considered.

PSU/Cluster level response rate:

Assuming that n_h is the number of PSUs selected in stratum *h* and n^*_h is the number of PSUs interviewed. The PSU level response rate in stratum h is:

$$R_{ch} = n_h^* / n_h$$

Household level response rate:

Assuming that m_{hi} is the number of households found in PSU *i* of stratum *h* and m^*_{hi} is the number of households interviewed in the PSU. The household response rate in stratum h is:

$$R_{hh} = \sum d_{hi} m_{hi}^* / \sum d_{hi} m_{hi}$$

where d_{hi} is the design weight of PSU i in stratum h. The summation is over all PSUs in the stratum h.

The household sampling weight of PSU i in stratum h is obtained by dividing the household design weight (previously calculated) by the product of the response rate at PSU and at household levels, for each of the sampling stratum:

$$D_{hi} = d_{hi} / (R_{ch} \times R_{hh})$$

The household sampling weight above was then used to calculate any indicators at the household level. Given that a sampling weight is an inflation factor, the weighted sum of households interviewed is calculated as:

$$T = \sum\sum D_{hi} m^{*}_{hi}$$

This is an unbiased estimate of the whole number of residential households of the country. The summation is over all PSUs and strata in the full sample.

State-level population weights

The sample was drawn based on available population estimates from the NPopC. During the study, updated official household population projections for 2016 were released. While these population projects were largely in line with the data used for sampling, a state level weight was created to reflect the latest population data.

The state level weights were calculated as follows:

State_wt=1/(% HHs in state based on sample / % HHs in state based on 2016 projections)

FIELDWORK

Team Formation

Teams were selected based on previous experience and involvement in similar household survey of this nature. Educational qualification was also considered as a requirement for selection of field staffs, a minimum qualification of ordinary national diploma was used as a benchmark. Females were given preference than their male counterpart because the culture in the north does not allow males into the households, except with the permission of the head of household.

The team composition during the household listing was three field staff per team (a Mapper, Lister and team leader) while during the main household survey, the team composition was five (4 enumerators and 1 team leader). In addition, the firm assigned one supervisor to each of the sample locations to monitor the fieldwork and approve/reject interviews on the data collection platform (Survey Solution). In total, the MTF base line survey employed 115 field workers (90 enumerators, 18 team leaders and 7 Supervisors).

Field Guidelines

Substitution, Call Backs, Refusals: The selected household were only allowed to be substituted after the interviewer made three additional unsuccessful visits over a 2-day period and at different times of the day. After these visits, the supervisor gave the interviewer replacement households at the same point as the initial selection.

Scheduling interviews/Increasing strike rate: To increase the strike rate, we planned the interviews around the time that most members of the community were available once the EAs had been identified. Interviews were staggered over different days of the week and onto weekends for interviews in urban areas.

Call Log: All records of successful calls, unsuccessful calls (due to different reasons such as closed doors, refusals etc.) substitution, call backs were kept by the team.

ANNEX 3.
Cookstove Typology

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


Self-built/Traditional stove: The pot sits mostly on the fuel. It has a low combustion temperature due to poor insulation and is affected by significant cold excess primary air because of too many openings.


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


Kerosene stove: A single burner stove that uses kerosene as the main source of fuel.

LPG stove: A single burner stove that uses liquefied petroleum gas for fuel.	
Electric stove: A stove that uses electricity for fuel.	

REFERENCES

Bhatia, Mikul; Angelou, Niki. 2015. *Beyond Connections: Energy Access Redefined*. ESMAP Technical Report 008/15. Energy Sector Management Assistance Program. Washington, DC: World Bank Group. https://openknowledge.worldbank.org/handle/10986/24368.

Blackden, M., and Q. Wodon, ed. 2006. "Gender, Time Use, and Poverty in Sub-Saharan Africa." World Bank Working Paper 73, World Bank, Washington, DC.

Clancy, J. S., M. Skutch, and S. Batchelor. 2003. *The Gender–Energy–Poverty Nexus: Finding the Energy to Address Gender Concerns in Development.* DFID Project CNTR998521. London, U.K.: Department for International Development.

Dherani, M., D. Pope, M. Mascarenhas, K. R. Smith, M. Weber, and N. Bruce. 2008. "Indoor Air Pollution from Unprocessed Solid Fuel Use and Pneumonia Risk in Children Aged Under Five Years: A Systematic Review and Meta-Analysis." *Bulletin of the World Health Organization* 86 (5): 390–98.

EIA, 2016, Country Analysis Brief: Nigeria. Online: https://www.eia.gov/international/analysis/country/NGA

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

ESMAP (Energy Sector Management Assistance Program). 2004

Grosh, Margaret E., and Juan Muñoz. 1996. "A Manual for Planning and Implementing the Living Standards Measurement Study Survey." Living Standards Measurement Study Working Paper 26, World Bank, Washington, DC.

Gwavuya, S. G., S. Abele, I. Barfuss, M. Zeller, and J. Muller. 2012. "Household Energy Economics in Rural Ethiopia: A Cost-Benefit Analysis of Biogas Energy." *Renewable Energy* 48: 202–09.

IEA (International Energy Agency), IRENA (International Renewable Energy Agency), UNSD (United Nations Statistics Division), World Bank, and WHO (World Health Organization). 2018. *Tracking SDG7: The Energy Progress Report 2018*. Washington, DC: World Bank.

Parikh, J. 2011. "Hardships and Health Impacts on Women Due to Traditional Cooking Fuels: A Case Study of Himachal Pradesh, India." *Energy Policy* 39 (12): 7587–94.

Puzzolo, E., H. Zerriffi, E. Carter, H. Clemens, H. Stokes, P. Jagger, J. Rosenthal, and H. Petach. 2019. "Supply Considerations for Scaling Up Clean Cooking Fuels for Household Energy in Low- and Middle-Income Countries." *GeoHealth* 3 (12): 370–390. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7038875/.

Rehfuess, E. A., S. Mehta, and A. Prüss-Üstün. 2006. "Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals." *Environmental Health Perspectives* 114 (3): 373–78.

Smith, K. R., S. Mehta, and M. Maeusezahl-Feuz. 2004. "Indoor Air Pollution from Household Use of Solid Fuels." In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*, edited by M. Ezzati, A. D. Lopez, A. Rodgers, and C. J. L. Murray, 1435–93. Geneva: World Health Organization.

UNDP (United Nations Development Programme). 2018. *Human Development Report*. NY: UNDP. http://hdr.undp.org/en/countries/profiles/NGA.

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

Wang, X., J. Franco, O. R. Masera, K. Troncoso, and M. X. Rivera. 2013. *What Have We Learned about Household Biomass Cooking in Central America?* ESMAP Report 76222. Washington, DC: World Bank ESMAP.

World Bank. 2018. World Development Indicators, database. Washington, DC: World Bank. https://data.worldbank.org/indicator/

———. 2019. The World Bank in Nigeria: Overview. https://www.worldbank.org/en/country/nigeria/overview.

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