NEPAL

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

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MTF Multi-Tier FRAMEWORK

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ABBREVIATIONS

AEPC	Alternative Energy Promotion Centre
ESMAP	Energy Sector Management Assistance Program
GTF	Global Tracking Framework
ICS	improved cookstove
kW	kilowatt
kWh	kilowatt hour
LPG	liquefied petroleum gas
MTF	Multi-Tier Framework
MW	megawatts
NEA	Nepal Electricity Authority
NIBC	Nepal Interim Benchmark for Solid Biomass Cookstoves
NPR	Nepalese rupees
RETS	Renewable Energy Test Station
RISE	Regulatory Indicators for Sustainable Energy
SDG	Sustainable Development Goal
SEforAll	Sustainable Energy for All
SHS	solar home system
SLS	solar lighting system
W	watt
WTP	willingness to pay

** 1 U.S. dollar = 103.40 Nepalese rupees on July 1, 2017*

EXECUTIVE SUMMARY

The Multi-tier Framework (MTF) was developed to address the specifics of energy-access needs outlined in the Sustainable Development Goals (SDGs) of the United Nations and the Sustainable Energy for All (SEforAll) initiative launched by the Secretary-General of the United Nations. It examines a variety of energy-service issues and solutions that include but go beyond access alone. For example, MTF considers the viability of decentralized off-grid solutions (such as mini-grid and solar home systems) as well as on-grid solutions as sources of electricity.

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

As part of the stock-taking exercise on measuring access via the MTF, ESMAP has launched detailed data collection activities in 17 countries. One of those is Nepal, a country of 29 million people in South Asia committed to achieving the Sustainable Development Goal on Energy Access (SDG 7.1). With the Government of Nepal, the World Bank carried out a nationally representative household survey in 2017 to determine a baseline for Nepal's access to energy. The findings of this report are based on the data from that survey.

ACCESS TO ELECTRICITY

Nepal has made great strides toward achieving universal access to electricity: 71.7% of households have electricity from the national grid, and 23% are connected to off-grid sources. Among households using an off-grid solution, the mini-grid and solar lighting systems are the most common sources. Twelve percent of Nepalese households are connected to an isolated mini-grid: a pico-hydro, micro-hydro, or mini-hydro system. Households connected to a pico-hydro system as their main source of electricity make up 2% of the households in this study. About 5% of the households in Nepal have no access to electricity in any form and rely on dry-cell batteries or solid fuels for lighting.

The MTF analysis shows that Tier 3 households make up the largest share of households nationwide, at 31.7%. A significant share of households are in the higher tiers—17.9% in Tier 4 and 17.3% in Tier 5—while Tiers 1 and 2 have 23.2% of the households combined. In Nepal, 6.1% of households are in Tier 0, and most of them have no access to electricity.

The availability of electricity supply is a major concern for households connected to the national grid. While 47.4% of grid-connected households receive almost 24 hours of electricity supply, the situation for half the population is less optimistic. Over 41.7% of the households have fewer than 4 hours of electricity available between 6 p.m. and 10 p.m. On average, grid-connected households consume 46.63 kWh each month.[1] They invest in backup sources of lighting using rechargeable batteries and solar lighting systems.

[1] The consumption figure is an average of only 638 households out of the 4,047 who are connected to the grid and reported the monthly consumption from their electricity bill.

The Reliability and Quality of grid electricity also affect the level of service and access for households. Even though households report not having load shedding, the incidence of unscheduled and unpredictable outages is high. Issues of the Reliability of the electricity supply affect 70% of households. In addition, 17% of households report having serious voltage problems that damage appliances. To offset the voltage issues, households invest in stabilizers. These findings are reflected in households' perspectives of the main challenges with the grid electricity supply and their coping mechanisms.

Households connected to mini-grids have lower electricity access levels than others, making up 38.1% of the households in Tier 1, mainly due to Capacity constraints and limitations in Availability, Reliability, and Quality attributes of the electricity service. Households face constrains due to the Capacity of the mini-grid system when operators impose restrictions on the households' appliances and load. These households use low-load appliances limited to lighting, mobile phone charging, radios, and televisions. Unlike households that use the grid, most of those (91%) in mini-grid areas have sufficient electricity supply between 6 p.m. and 10 p.m., but they have limited supply throughout the 24-hour period. These households are generally less well-off and consume less electricity than grid-connected households.

Most of the households (89.6%) that use a solar device as their main source of electricity are in Tier 1, because they are limited by the capacity of their device. These households are unable to power appliances beyond basic lights, radios, and mobile phone chargers. Only 4% of the solar users own televisions even though there is a latent demand—households report that one of their main problems with solar devices is that they cannot power larger appliances. Households are also affected by availability of electricity supply through the day. Their devices provide limited supply, which is mainly used from 6 p.m. to 10 p.m.

For households with no access, adopting a solar device is a more affordable short-term solution than other options. Of all households in Nepal, 6.1% are in Tier 0, and 5.2% have no source of electricity. Out of those households with no access, 30% are not connected to the grid because of administrative barriers. The expense of connecting to the grid and the distance from a household to the grid are also reported obstacles that prevent households from gaining electricity access.

The Government of Nepal has recently outlined strategies for increasing generation capacity, improving the transmission and distribution of grid electricity and introducing high-capacity solar generation. The White Paper "Current Status and the Roadmap for the Future" provides a plan for the energy sector for the next 10 years. The proposed measures on planning and financing the various aspects of grid and off-grid electrification are important steps in the government's effort to close gaps in access. Households connected to the national grid and mini-grids will require more reliable electricity supply in the future, with fewer outages and voltage fluctuations. Better quality of service will be able to facilitate increased demand. Households currently using solar devices and other low-capacity sources of electricity will need to switch over to the grid or high-capacity off-grid solutions in the medium to long terms. For the last mile connections, households with no electricity can be offered low-cost renewable electricity with flexible payment options as an interim solution.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

In Nepal, a majority of the households use biomass stoves as their primary stove: 15.1% of all households cook on an open fire and 47.6% of all households cook on a traditional stove with an enclosed fire, while 8.9% of households use improved biomass stoves. Clean-fuel stoves are becoming more prevalent, with 26.3% of households using liquefied petroleum gas (LPG) stoves and 2% using biogas. Firewood is the most widely used source of cooking fuel—73.5% of the households depend on wood. Animal waste and crop residue or plant biomass are the other sources of biomass fuel for households. Across the country, 16.3% of households use two types of stoves for cooking while 1% of the households use 3 types of stoves; 7.3% of households use an LPG stove with their traditional stove.

In Nepal, a majority of the households are clustered along the lower end of the tiers, with 52.9% of them in Tier 0. About 15% of households are in Tier 1, while Tiers 2 and 3 have 14.8% of the households. Tiers 4 and 5 represent households that have attained access to modern energy cooking services, and they have 2.8% and 14.7%, respectively, of the total households in Nepal.

The main attributes that hinder households' level of access are the Cooking Exposure, the Convenience, and the Affordability of the cooking solution. A large share of households use traditional stoves and solid biomass and are mainly in Tiers 0 and 1 for Cooking Exposure. A large amount of time is spent collecting and preparing the fuel as well as preparing the stove for cooking, resulting in only 19.1% of the households across the country to reach Tier 5. Finally, about 14.3% of the households spend more than 5% of their household expenditure on cooking fuels annually, putting them in Affordability Tier 3.

To shift households up the tiered framework, a short- to medium-term solution is to switch households to improved cooking solutions. As biomass, in the form of fuelwood, animal waste, and crop residue, is dominant in the energy mix, improved biomass solutions can be a transitionary technology until clean fuels are more sustainably available with better supply chains. The Government of Nepal's Biomass Energy Strategy and other energy subsidy programs have facilitated policy making around the issue of clean cooking. However, there is still a long way to go to completely shift households away from polluting technology and fuels. A lack of awareness among households using traditional stoves and a constraint of financial resources are impediments that can be overcome through smart subsidies and flexible payment options. The stoves promoted should incorporate some of the desirable features for households: ease of use, speed of cooking, and cleanliness of the stove.

Getting households to switch to clean fuels such as electric stoves or biogas can be a long-term solution for Nepal. Given the high monetary and time cost on the import of LPG, the Government of Nepal is focusing on increasing access to biogas and electric cooking solutions for households who want to switch to clean options. Biogas has the potential to be adopted by a wide share of the population, given that it requires biomass waste. The government already has put policies in place to promote the use of biogas as well as increase the penetration of biogas through various financing incentives. The government and the Nepal Electricity Authority (NEA) have to work in parallel to provide reliable and high-quality service so that households can adopt and use electric cooking solutions without any hinderance.

Nepal requires a multi-pronged approach to address the modern energy cooking solution challenge. First, markets need to come together and target users through private sector involvement and such strategies as results-based financing. Second, for quality assurance and monitoring, the country needs to develop a decentralized testing and labelling regime. Third, local governments can play a crucial role in improving access to improved and clean cooking solutions. They need to be brought into the policy-making process, and local capacity needs to be built.

ACCESS BASED ON GENDER

Gender disparity is relatively low in energy access, despite the fact that female-headed households are not as economically well off as male-headed households. In Nepal, a large proportion of households have a male as the head (81.8%), as compared to households with a female head (18.2%). Female-headed households have a lower budget and the female head receives less education. More female-headed households belong to the bottom quintile of household expenditure (31.1%), compared to male-headed households (17.6%). Among the households in grid-electrified areas, female- and male-headed households have similar rates of connection, 95.1% and 91.7%, respectively. The take-up rates for mini-grid connection in areas with only mini-grid and for solar devices in areas with neither grid nor mini-grid are also similar between female- and male-headed households. Additionally, 43.6% of female-headed households use an electric, LPG, or biogas cookstove, compared to 36.1% of male-headed households.

Gender matters when it comes to how time is allocated among tasks, particularly time spent when households have different energy solutions. To understand the impact of improved energy solutions on women's empowerment, women's time-use data were compared across households with different energy solutions. Among the households in the bottom 20% of the overall household economic expenditure , women in households with a grid connection spend more time studying or helping with school work and on entertainment and socializing than do women in households that do not have grid connection. Women in households that use an electric, biogas, or LPG stove spend more time on entertainment and socializing than do women in households that do not use these stoves. Clean and improved solutions can play a role in bringing more gender parity and development for households. To gain a more comprehensive understanding of the drivers and barriers for energy access and the use of time, further analysis and complementary studies are required to establish causality. The current analysis provides an indication of the relationships and shows correlations but is not statistically significant.

MEASURING ENERGY ACCESS IN NEPAL

Without energy, promoting economic growth, overcoming poverty, and supporting human development are challenging, if not impossible. Energy access is thus a precondition to many development goals. Indeed, sustainable energy is the 7th of the 17 United Nations' Sustainable Development Goals—"to ensure access to affordable, reliable, sustainable, and modern energy for all" by 2030. The Government of Nepal has committed to maximizing energy access benefits for its people. The National Planning Commission's report *Sustainable Development Goals, Status and Roadmap: 2016–2030* proposes a target of 99% of households with access to electricity; a reduction to 30% (from the current 75%) of households who use firewood for cooking; a limit on the use of liquefied petroleum gas (LPG) to less than 40% of the households; the generation of 15,000 MW of installed capacity; and an increase in per capita electricity consumption to 1,500 kWh (GoN NPC 2017b). As part of this effort, the Government of Nepal has collaborated with the World Bank to put the Multi-Tier Framework (MTF) survey into practice and to obtain guidance on setting access targets, policies, and investment strategies.

COUNTRY CONTEXT

SOCIOECONOMIC AND POLITICAL STATUS

Nepal's economy has some development challenges to overcome despite its general trend of growth. With a population of 29 million, Nepal had a per capita gross national income of US$790 in 2017, the second lowest among the South Asian countries (WDI, "GDP per capita"). The proportion of the population living below the poverty line is on a decreasing trend: 25.2% in 2011, compared to 41.8% in 1996 and 30.9% in 2004. Much of the labor force works in sectors with low productivity. According to Nepal's Central Bureau of Statistics, in fiscal year 2016/17, the agricultural sector employed the largest share of workers (73.9%), whereas manufacturing employed 6.6%, the lowest share (ILO 2017). This contributes to exports having a low share of gross domestic product compared to surrounding countries such as Bangladesh, China, and India. The level of education is higher in the younger population. In 2017, the net primary school enrollment was 94.7% compared to 59.4% in 1983 (WDI, "School Enrollment").

In fiscal year 2017/18, the economic growth rate was 7.5%, the highest since 1994. Some factors that contributed to the rate were a favorable monsoon, better availability of electricity, increased investment as recovery from the 2015 earthquake took speed, and the low growth in the previous year. This high growth rate is a rebound from rates of 3.3% in fiscal year 2015/16 and 0.4% in fiscal year 2016/17, which were due to a complete disruption in cross-border trade with India. Looking ahead, the economic growth is expected to remain strong at about 5% over the next two fiscal years, with some downside risks that include the fluid political environment, a vulnerable financial sector, and underperformance of exports (World Bank 2018).

Following a decade of political unrest and an impasse in drafting the constitution, Nepal passed a new constitution in September 2015. The main issue of contention was the demarcation of provinces in the federal organization. After the constitution was passed, the Nepalese people voted into office members of parliament, 753 newly created local councils, and of seven new provincial assemblies.

SECTORAL CONTEXT: ELECTRICITY

Among the various types of energy resources, hydropower has the largest potential to provide energy for Nepal. Theoretically estimated hydropower potential is 84,000 MW, of which 43,000 MW is estimated to be economically viable (IHA 2019). It is also estimated that solar resources in Nepal can provide 2,100 MW to the electricity grid (UNDP 2018). The potential of fossil fuel resources is limited, and the petroleum products and LPGs used for transportation and cooking are all imported. Hydropower is the least-cost option for Nepal to meet domestic demand for electricity and has the potential to be exported to other South Asian countries.

The electricity supply and demand gap in FY2017 was about 360 MW when peak demand reached 1,444 MW (NEA 2017). In April 2013, the top leaders of the seven political parties signed a joint statement acknowledging the need to improve hydropower license management, support hydropower export, ensure environmental sustainability, share benefits with the local people, and not hinder hydropower project works. In FY2017, the Nepal Electricity Authority, the country's national utility, completed the construction of several transmission lines and substation projects. Additionally, Nepal increased imports of electricity from India and the amount of power purchased independent power producers to meet the growing demand.

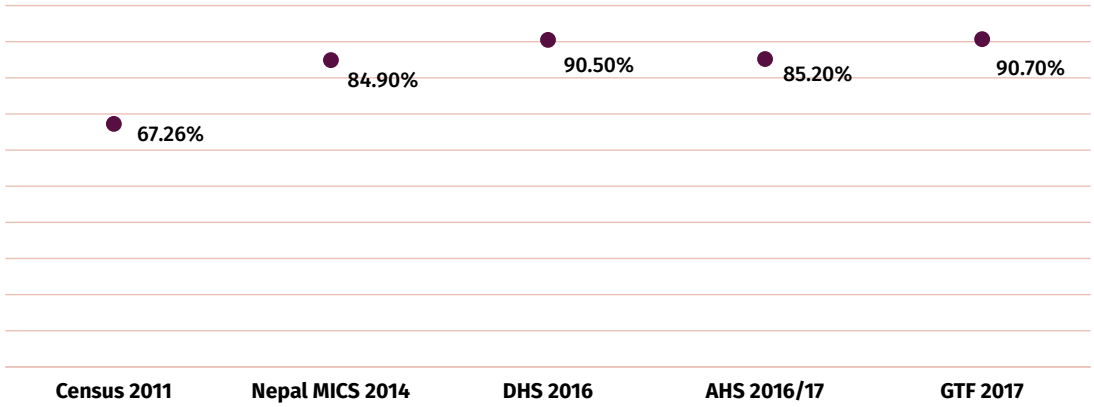
Another key feature of the electricity sector in Nepal is the role of mini- and micro-hydro grids, which are often more practical and economic for households in remote Hill and Mountain areas than the national grid. According to the MTF mini-grid operator survey, currently about 1,700 off-grid micro-hydropower plants have been installed throughout the country, with total installed capacity of approximately 30 MW. An International Finance Corporation (IFC) study suggested that 78MW of electricity can be generated from micro-hydropower projects smaller than 100kW and 369MW from mini-hydropower projects between 100kW and 1MW (IFC 2014). In 2016, the Government of Nepal introduced a revised Renewable Energy Subsidy Policy to attract the private sector, mobilize credit, and reduce investment risks to support the growth of the renewable energy market, which would facilitate development of mini- and micro-hydro grids.

Nepal's electrification rate has risen since 2011 when the Census of Nepal reported that 67.26% of the population used electricity for lighting (Figure 1). The Central Bureau of Statistics in its Annual Household Survey in 2016–17 reported that 85.2% of the households in Nepal use electricity as the main source of lighting. Urban areas have a larger share of households using electricity, 91.3% compared to rural households, where 80.4% use electricity as the main source of lighting. Solar is the second most common source of lighting, with 9.6% of households across Nepal using solar. It is more frequently used among rural households (13.1%) than urban households (5.2%) (GoN NPC 2017a).

The World Bank's Regulatory Indicators for Sustainable Energy (RISE) assess a country's progress on national policy and regulation on access to modern energy, energy efficiency, and renewable energy. The RISE indicators show that Nepal's policy framework for electricity access is only moderately developed, despite remarkable improvements from 2010 to 2017. Nationwide planning for electrification was absent, as was inclusive planning for electrification. The state of access in Nepal and the necessity to reach remote consumers, however, has spurred ad hoc policy making for mini-grids and stand-alone systems that have seen major improvements since 2010. These programs are mainly implemented by the Alternative Energy Promotion Centre under the Renewable Energy for Rural Livelihood program.

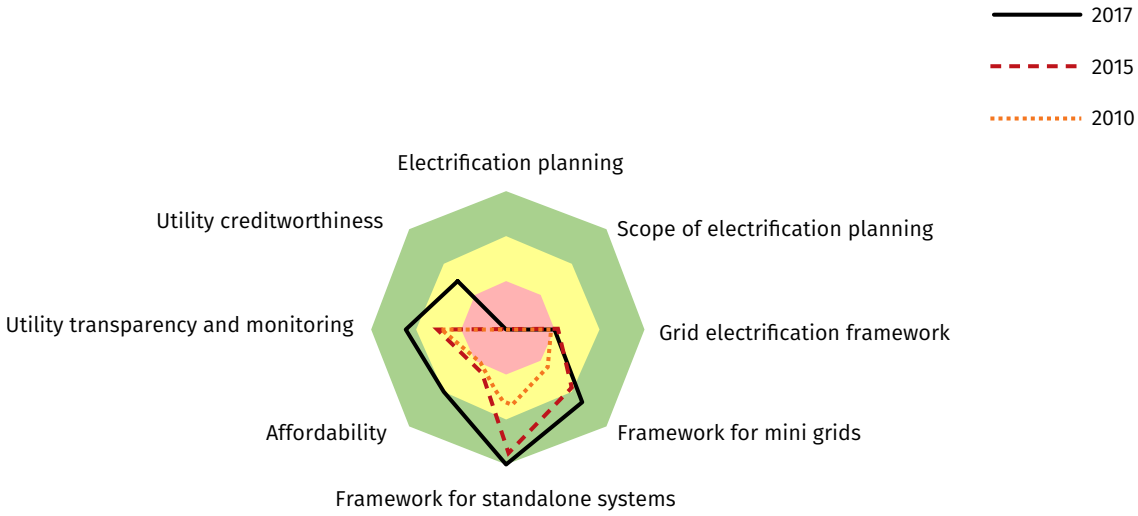
Policy improvements for mini-grids and stand-alone systems have sometimes come at the cost of grid electrification policies, however, for which policy development came to standstill during the same period. There is some funding support for grid electrification in rural areas, but it does not expand to funding support for consumer connections. This in turn may be affecting the affordability of consumer electricity connection and basic electricity supply, as well as utility finances. Due to these policy gaps, Nepal lags behind other access-deficit countries in South Asia in RISE on electricity access (Figure 2).

FIGURE 1 • **Electrification rate: households using electricity for lighting**



Note: MICS = Multiple Indicator Cluster Surveys; DHS = Demographic and Health Surveys; AHS = Annual Household Survey; GTF = Global Tracking Framework.

FIGURE 2 • **Regulatory Indicators for Sustainable Energy: progress by indicator on electricity access, 2010, 2015, and 2017**



Source: World Bank RISE 2018.

Since the RISE were published, Nepal has taken additional steps toward energy planning. In November 2017, the Government of Nepal and several development partners set up the National Renewable Energy Framework (NREF). The NREF is a mechanism under which the Alternative Energy Promotion Centre (AEPC) coordinates all the renewable energy activities with various stakeholders, such as tracking results from various initiatives, engaging stakeholders, and helping to mobilize finance. Renewable energy under this framework covers hydropower up to 10MW, solar energy, wind energy, and bio-energy systems for cooking, heating, and generating electricity.

In May 2018, the Ministry of Energy, Water Resources and Irrigation published a White Paper on the current status of the energy sector and a roadmap for the future. In addition to a plan for changes in generation and transmission, the White Paper also discusses the roadmap for distribution and consumer services to ensure electricity is accessible within five years. The plan is not limited to grid electrification but discusses steps for increasing electricity through renewable energy sources such as solar.

SECTOR CONTEXT: COOKING

Nepal is heavily reliant on solid biomass, primarily in the form of firewood, cow dung, and plant residue (such as leaves, straw, and thatch) to meet its cooking fuel needs. According to the Annual Household Survey in 2016–17, 52.4% of the households across Nepal used firewood as their main source of fuel (35.4% of households in the urban areas and 65.8% of households in the rural areas). Meanwhile, 8.5% of households in Nepal use cow dung as their primary fuel, while 2.7% of households use plant residue. A larger share of households in rural areas than in urban areas use cow dung and plant residue to meet their main fuel needs.

Clean fuels are also common in Nepal, with 33.1% of the households using LPG and 3.1% of the households using biogas. There is a larger share of households in urban areas (54.1%) than rural areas (16.5%) using LPG. The use of clean fuels for cooking comes with its own challenges. Nepal relies entirely on imports to supply LPG to its households. Thus, use of LPG stoves is limited by supply risks and broader macroeconomic concerns by the government about supporting increased LPG imports. The use of an electric stove as a clean alternative is determined by whether the household uses a grid-connected or off-grid solution. Further, households with electricity may still be constrained by supply or reliability issues. However, given the large hydro-potential, one could imagine that electric cooking could be a viable option for Nepal in the long term, if the potential hydropower is developed and electricity is both reliable and affordable. Potentially, electricity could even be a solution for mini-grid users, if properly designed, given that these are mostly hydro-powered mini-grids (which more effectively power cooking appliances than do solar mini-grids, which have to rely on battery power in the evening).

Biogas has an increasing share in the cooking-fuel mix. The Annual Household Survey 2016 reports that 3.1% of households across Nepal use biogas to meet their primary cooking-fuel needs. The Government of Nepal has a long history of promoting and supporting biogas programs, mainly through the Biogas Support Program, with the installation of domestic, community, and institutional biogas plants over the past three decades. The government has offered different levels of subsidies for setting up a domestic biogas plant, up to 50% of the total cost (not exceeding 10,000 Nepalese rupees) through its Rural Energy Policy. In tandem with the subsidies, awareness creation, capacity building, and diverse financing options were promoted by the government and its partner organizations. With active support from the government, biogas construction companies were established to take advantage of the business opportunity targeting rural households willing to adopt a biogas plant. Under the National Planning Commission, the Thirteenth Plan (2013–16) set a target of installing 80,000 biogas systems. Through AEPC, the government had met the initial target and installed over 20,500 biogas plants in fiscal year 2016/17.

In addition to developing and introducing more efficient and cleaner fuels, the government has also included improved biomass cookstoves that burn fuel more efficiently, such that less fuel is required and fewer fumes are emitted. These efforts started in the 1980s, primarily to address firewood shortages, and gained momentum in the early 2000s when the AEPC launched the National Improved Cookstove (ICS) Program to distribute information and raise awareness about ICS and train local artisans to install, repair, and maintain improved cookstoves that meet local demands. The program gradually expanded from its initial focus on the hill area to all ecological regions and promoted diverse technologies, including the mud ICS, metallic ICS, institutional ICS, and gasifiers.

Considering households' high reliance on biomass, the Government of Nepal targeted poverty reduction and environmental conservation together in rural areas through the Rural Energy Policy of 2006. The main objective of this policy was to mobilize financial resources at the local level to create public awareness, promote research, and disseminate ICSs, biogas plants, solar energy technologies, and production of processed fuels such as briquettes and biofuels. In May 2016, the Government of Nepal implemented the Renewable Energy Subsidy Policy with the objective of reducing the "dependence on traditional and imported energy by increasing access to renewable energy." This policy aims at improving the livelihoods of people and creating employment opportunities in the rural areas through reductions in the initial upfront costs of energy, improving service delivery and efficiency, supporting the growth of renewable energy markets by mobilizing commercial credit, and encouraging public-private sector participation. Following this policy, the government established the Biomass Energy Strategy 2017, which aims to modernize the use of biomass energy through research, creating public awareness, market development, technology transfer, capacity development, and efficient use of biomass energy. There are four key strategies outlined: increase the production of sustainable biomass energy by using agriculture and forest residue and organic wastes; increase the access to clean cooking technologies through modern biomass energy; increase the effectiveness and efficiency in the use and production of biomass energy; and partially substitute the use of diesel and petrol with biofuels (biodiesel and bioethanol).

Along with these policy measures, AEPC published an interim benchmark for solid biomass fuel stoves. This step was taken to support the development and dissemination of high-performing, good quality, improved biomass stoves by recognizing and certifying stoves that can then be eligible for government subsidy or included in the Clean Development Mechanism[2]. The 2016 report *Nepal Interim Benchmark for solid biomass Cookstoves* outlines the testing protocols, requirements, and standards for performance on efficiency, emissions, user safety, and durability. It was finalized after consultative meetings with national and international stakeholders. Nepal has two national laboratories that are equipped to test different stove types: the Renewable Energy Test Station (RETS) and Centre for Rural Technology, Nepal.

THE MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the MTF approach. The first phase is being carried out in 16 countries across Africa, Asia, and Latin America, including Nepal. The survey's objective is to provide comprehensive data on energy access, including access to electricity and cooking solutions. The survey also collects household-level data on socioeconomic indicators and demographics. The

[2] The *Clean Development Mechanism* allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

study is nationally representative and incorporates urban and rural households as well as households with and without a national grid connection.

The MTF approach goes beyond the traditional binary measurement of energy access and uses a comprehensive methodology to measure access. For example, access traditionally is reported as having or not having a connection to electricity, or using or not using clean fuels in cooking. The MTF approach captures the multidimensional nature of energy access. It examines the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[3]

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

MEASURING ACCESS TO ELECTRICITY

The measurement of access to electricity is based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety (see annex 1 for definitions and questions used to calculate the attributes). These attributes help determine the usefulness of electricity supply and influence the extent to which households can use electricity services.

Capacity: The capacity of the electricity supply (or "peak capacity") is the ability of the system to provide a certain amount of electricity to operate different appliances, ranging from a few watts for LED lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. (See table 1 for load levels for the peak capacity and associated appliances.).

Availability: Availability of supply refers to the amount of time during which electricity is available. It is measured through two indicators: the total number of hours per day (24-hour period) and the number of evening hours (the 4 hours after sunset) during which electricity is available.

Reliability: Reliability of electricity supply is a combination of the frequency and the duration of unexpected disruptions.

Quality: Quality of the electricity supply refers to the absence of severe voltage fluctuations that can damage a household's appliances.

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

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

[3] 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.

Health and Safety: The spectrum of electrical injuries is broad, ranging from minor burns to severe shocks and death. The Health and Safety attribute relates to high-risk, permanent injuries from the energy supply.

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

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

Source: Bhatia and Angelou 2015.

For each of these attributes, households are placed in a tier depending on the level of service as defined by the different thresholds. (Annex 2 shows the thresholds in the Multi-Tier Matrix for Measuring Access to Electricity). A household's aggregate tier or level of access is determined by the lowest tier value the household obtains among the attributes. At the national level, we can see the aggregate tiers for all households as a distribution, that is, we obtain a share of the total households that fall into each tier.

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

MEASURING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Despite well-documented benefits of access to clean cookstoves, almost 3 billion of the world's population still use polluting, inefficient cooking solutions that emit toxic smoke (Tracking SDG7 2018). The inefficient use of solid fuels has significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009; WB 2011b).[4] For

[4] Household air pollution has been associated with a wide range of adverse health impacts, such as increasing risk of acute lower respiratory infections among children under 5 years old and chronic obstructive pulmonary disease and lung cancer (in relation to coal use) among adults above age 30. An association between household air pollution and adverse pregnancy outcomes (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).

BOX 1 • MINIMUM REQUIREMENTS OF ELECTRICITY ACCESS BY TIER

Tier 0	Tier 1	Tier 2
Electricity is not available or is available for fewer than four hours per day (or less than one hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least four hours of electricity per day is available (including at least one hour per evening), and capacity is sufficient to power task lighting and phone charging or radio playing. Sources that can be used to meet these requirements include a solar lighting system, a solar home system (SHS), a mini-grid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and 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 that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, and the national grid.

Tier 3	Tier 4	Tier 5
At least eight hours of electricity per day is 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 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity per day is available (including four hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high–load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker—as needed during that time. The most likely source for meeting these requirements is the national grid, although in theory a generator or mini-grid could as well.

Source: Bhatia and Angelou 2015.

example, fuel collection and cooking tasks are often undertaken by the women and girls in a household and affects the time spent for education or income-generating activities. Collection time depends on the local availability of fuel and may reach up to several hours per day (ESMAP 2004; Gwavuya et al. 2012; Parikh 2011; Wang et al. 2013). 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 for injury and attack (Rehfuess et al. 2006).

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

Cooking Exposure: Cooking Exposure assesses personal exposure to pollutants from cooking activities, which depends on a stove's emissions and ventilation structure (which includes cooking location and kitchen volume).[5] It is a composite measurement of the emissions from the cooking activity—the combination of the stove type and fuel, mitigated by the ventilation in the cooking area. If a household uses multiple stoves, the Cooking Exposure attribute is measured as a weighted average of the time each stove is used.

Cookstove Efficiency: Cookstove Efficiency 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.[6]

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

Affordability: Affordability assesses a household's ability to pay for the fuel measured by the levelized cost of fuel over a year. A cooking solution is considered affordable if a household spends less than 5% of the household expenditure on cooking fuel.

Health and Safety: The degree of safety risk can vary by the type of cookstove and fuel used. Risks may include exposure to hot surfaces, fire, or potential for fuel splatter. Reported incidences of past injury and/or fire are used to measure safety.

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

Changes in calculating the attributes on Cooking Exposure and Cooking Efficiency

This report applies an updated framework (from Bhatia and Angelou, 2015) of the attributes to the household data on cooking behavior, in particular, the attribute on Indoor Air Quality is now measured through Cooking Exposure. The negative health impacts of household air pollution caused by traditional cooking activities are a key driver in promoting clean and efficient cooking. According to the World Health Organization guidelines for indoor air quality (WHO 2014), average annual $PM_{2.5}$ concentration[7] should be less than 10 $\mu g/m^3$, and 24-hour exposure to carbon monoxide concentration should be less than 7 $\mu g/m^3$. The World Health Organization guidelines and interim targets have been a reference for the MTF.

[5] In this report *ventilation* is defined as using a chimney, hood, or other exhaust system while using a stove or having doors or windows in the cooking area. We do not include the data on volume of the cooking area as there are a large share of missing values.

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

[7] Fine particulate matter with aerodynamic diameters of 2.5 μm or 2.5 micrometers

Direct exposure measurement on the body of the cook would be the most accurate methodology. However, this process is very costly and not practical to implement through a large-scale household survey. One alternative is to calculate exposure based on simulation through mathematical models that consider key factors contributing to indoor air quality, such as indoor fuel combustion, ambient air pollution in the area, and kitchen volume and air exchange. Indoor emissions depend on the characteristics of each cooking solution (to account for stacking), along with its use, duration, and pattern. Emissions also depend on fuel quality, device maintenance, and user adherence to specifications.[8] Another alternative is to use proxy indicators that do not provide measured or estimated exposure data but classify different real-life situations in the sense of "contributing more or less to exposure." By including a broad variety of factors, the overall assessment still presents a comprehensive picture of exposure.

Much like Cooking Exposure attribute, Cookstove Efficiency can be quite complicated to measure directly. The thresholds for the efficiency tiers are set using the technical report *Clean Cookstoves and Clean Cooking Solutions—Harmonized Laboratory Test Protocols*, part 3, "Voluntary Performance Targets for Cookstoves Based on Laboratory Testing," published by the International Organization for Standardization. The efficiency tiers are as follows:

Tier 0: Stoves with less than 10% thermal efficiency
Tier 1: Stoves with 10%–20% thermal efficiency
Tier 2: Stoves with 20%–30% thermal efficiency
Tier 3: Stoves with 30%–40% thermal efficiency
Tier 4: Stoves with 40%–50% thermal efficiency
Tier 5: Stoves with 50% or higher thermal efficiency

In Nepal, the government's Alternative Energy Promotion Centre published the 2016 NIBC report that outlines the standards and protocols for testing stoves and recognizing and certifying the stoves that meet the standards. The stoves are tested for emissions levels of $PM_{2.5}$ and carbon monoxide as well as thermal efficiency. There are two established national laboratories in Nepal that undertake stove testing: the Centre for Rural Technology, Nepal and RETS (RETS 2018). The survey did not measure stove efficiency directly. Households that were interviewed in the survey were able to provide information that could help identify all the models and makes of the improved biomass stoves in use. Of the stoves identified through the survey, not all had testing data available with which to assess their efficiency level. To consistently apply the Efficiency attribute across the sample, it would require information on the efficiency level of each stove a household uses, particularly for the solid biomass improved cookstoves. Without this detailed data, this report presents a version of the MTF that does not include the Efficiency attribute but calculates the aggregate tier for access to modern energy cooking services with the other five attributes.

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

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

BOX 2 • TYPOLOGY OF COOKSTOVES IN NEPAL

Cookstoves in Nepal were classified into four broad categories based on consultation with development partners and government officials during the MTF survey workshop in Kathmandu. For analysis, the clean stove types were further divided into biogas, LPG, electric, and solar cookstoves.

TRADITIONAL STOVE (OPEN FIRE)

A pot balanced on three stones over an open fire—it is the most traditional method of cooking in Nepal.

Features

- Open fire
- Fuel placed on the ground

TRADITIONAL STOVE (ENCLOSED FIRE)

These are locally produced using available and low-cost materials and fuels, reflecting cultural practices.

Features

- Enclosed combustion chamber
- Pot placed above fire
- Fuel rests on ground

IMPROVED BIOMASS STOVE

The improved biomass stove uses newer stove technology compared to traditional stoves to improve efficiency, cleanliness, and safety. They may be built with local materials or be factory manufactured. In addition, improved biomass stoves may have some exhaust system.

There are four main types of improved stoves identified in this study: (i) improved stove, no exhaust; (ii) improved stove, with exhaust; (iii) improved stove, factory manufactured; and (iv) improved stove, factory manufactured with exhaust.

BOX 2 • TYPOLOGY OF COOKSTOVES IN NEPAL

Improved stove, no exhaust

Features
- Insulation of combustion chamber (enclosed combustion chamber)
- High internal chimney
- Fuel is resting on ground or shelf

Improved stove, with exhaust

Features
- Has exhaust system
- Enclosed combustion chamber
- Pot placed above fire
- Fuel rests on ground

Improved stove, factory manufactured

Features
- Rocket stove with very effective insulation material

Improved stove, factory manufactured with exhaust

Features
- Serves dual purpose of cooking and space heating

CLEAN-FUEL STOVE

This type of stove uses clean and efficient fuels such as LPG, electricity, or biogas. Biogas stoves burn biogas that is produced in local biogas digesters.

Biogas stove

Features
- The digester converts organic wastes and dung into combustible methane gas called biogas, which is piped from the digester to the cookstove.

BOX 2 • TYPOLOGY OF COOKSTOVES IN NEPAL

LIQUIFIED PETROLEUM GAS STOVE

LPG stoves exclusively burn LPG, which is a gaseous fuel obtained during petroleum refining and consists mainly of butane or propane.

Features

- For distribution to the end-user, LPG is bottled in individual gas cylinders of various sizes (between 3 kg and 50 kg or larger).

ELECTRIC STOVE

Electric stoves convert electrical energy into heat for cooking.

Features

- Electric stoves can be either an induction type stove or an electric coil stove

SOLAR COOKSTOVE

Solar cookstoves, often called solar cookers, can be used in areas where solar energy is abundant for most of the year, typically between 30 degrees north and south of the equator.

Features

- There are several types of solar cookers: panel cookers with a clamshell shape, box cookers that fully enclose the pot, parabolic cookers that resemble a satellite dish, and vacuum tube cookers that work like greenhouses.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

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

MTF data enable governments to set country-appropriate access targets for maximizing energy access. The data can be used in setting targets for universal access based on the country's conditions, budget, and target date for achieving such access. They can also help governments balance improving energy access to existing users (raising electrified households to higher tiers) and providing new connections (and determining what minimum tier the new connections should target).

Governments and policy makers can benefit from MTF findings in a number of ways. First, using MTF findings, countries can track progress toward achieving their SDG7 goals and set targets for universal access based on existing status, budget, and other constraints. MTF analysis can also identify the barriers to achieving energy access goals, and the government and policy makers can revise their strategies accordingly. For example, given existing budgets, governments can balance improving energy access for existing users (for example, reducing load shedding) and providing new connections. Moreover, since MTF analysis disaggregates findings by rural and urban areas, income quantile, and gender of household heads, governments can take these into account while prioritizing their energy access goals.

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

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

Finally, the MTF findings on WTP may provide inputs on how to price different access products (for example, connection fee for grid access, price of solar home systems, or improved cookstoves). Given the available resources, the government can subsidize or set up a financing mechanism for these components to ensure maximum access to energy.

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

and appliances—inform the design and targeting of their programs, projects, and investments for energy access.

The MTF surveys provide three types of disaggregation: urban-rural, economic quintile, and gender of household head. Nepal's geography is unique, as the country has a distinct Mountain area, which is sparsely populated, a fairly populated Hill region, and densely populated plains called the Terai. In Nepal, data is also disaggregated based on the ecological regions: Mountains, Hills, and Terai. For gender-disaggregated data, non-energy information is also collected, such as mobility, access to finance, and time use. Indicators such as primary energy source, tier of access, energy-related spending, WTP, and user preferences are disaggregated by male-headed and female-headed households. Such data add value to energy access planning, implementation, and financing. The MTF survey provides additional gender-related information, including gender roles in determining energy-related spending and gender-differentiated impacts on health and time use.

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN NEPAL

Through consultations with energy and survey experts and statisticians, and proper coordination with the local authorities—the Central Bureau of Statistics; Ministry of Energy, Water Resources and Irrigation; and Alternative Energy Promotion Center—the MTF team has devised survey tools (such as questionnaires, sampling technique, and CAPI-based programs)[9] to collect nationally representative data on access to electricity and cooking solutions. The World Bank, through a competitive bidding process, hired the Nepal-based survey firm Solutions Consultants Pvt. Ltd. to undertake the fieldwork and data collection across Nepal. The MTF household survey data collection began in July 2017 and was completed in December 2017.

Nepal is currently divided administratively into seven provinces and geographically into three ecological regions, comprising 14 zones. At the time of the 2011 census, when earlier administrative divisions were in place, Nepal was divided into 75 districts, and further into 3,157 smaller Village Development Committees (VDCs, designated as rural areas) and 217 municipalities (designated as urban areas). These VDCs and municipalities were again divided into wards (36,020 in all), which are the smallest administrative units. However, during the time of this survey, changes in the administrative divisions of Nepal replaced the earlier 14 zones and 75 districts with 7 provinces, and the VDCs and municipalities with 744 local units. As per the current restructuring, the local units have been divided into 4 metropolitan cities, 13 sub-metropolitan areas, 246 municipal councils, 481 village councils, and 6,679 wards. This change in the administrative structure involved the merging of various wards, which increased the size of many of them. Similarly, 45% of the earlier rural wards have now been categorized as urban.

The sample frame of this study is the 2011 census conducted by the Central Bureau of Statistics. The sample frame was updated to reflect the recent administrative and geographical changes. The new changes took into consideration the seven provinces of Nepal (Province 1, Province 2, Province 3, Gandaki Province, Province 5, Karnali Province, and Province 7) and the new classification of urban and rural locations, officially now known as Nagarpalika and Gaonpalika.

[9] CAPI stands for computer-assisted personal interviewing. Where stand-alone, full-spectrum surveys cannot be implemented, the ESMAP offers governments the option of incorporating a set of MTF-related core energy questions into their existing national surveys.

The MTF global survey has a benchmark of 3,500 households for a national-level survey, with a 50:50 distribution of urban and rural areas and 50:50 distribution of grid and non-grid households, if possible.[10] Based on the needs of project teams within the World Bank, some additional areas were selected for oversampling to better understand the use of various cooking solutions. However, the oversample did not specifically target areas with existing programs on clean or improved stove distribution; instead larger administrative regions were selected to be included. With oversampling, the Nepal MTF survey covered a total of 6,000 households. The allocation aimed at generating a sample large enough to produce estimates by province, ecological region, rural and urban areas, and grid connection status. For rural and urban areas, the sample was drawn from all seven provinces and the three geographic areas (Mountain, Hill and Terai). The Hill region was further divided into two groups—Kathmandu region and the rest of the Hill area—to highlight the findings from the national capital area.

The household survey sample selection, based on two-stage stratification, aimed at being representative of the country at large. At the first stage, the enumeration areas—wards—were selected randomly from each of the newly formed provinces to be representative of urban and rural areas and the distinct ecological regions in Nepal (the Mountains, Hills, and Terai).[11] The number of wards selected from each province was roughly in proportion to the province size (that is, the number of wards in a province). All in all, 400 wards were selected nationwide.[12] The field teams visited each selected ward, and the enumerators compiled a list of the households in the ward to obtain an updated version of the total number of households in each ward and their grid-electrification status. In the second stage, 15 households were selected for interview from the list for each ward. The criterion for selection of households was that a ratio of 50:50 grid-connected and non-grid households needed to be maintained, following the standard sampling methodology for the national household surveys of the MTF for Energy Access.[13]

At the time of the sample selection, the grid connection (electrification) status of wards was not available. The distribution was estimated based on the results from recent surveys, such as the 2013/14 Nepal household survey, which shows the share of households with electricity as their main source of light to be 72.9% in rural areas and 97.2% in urban areas. Because of the overwhelmingly large share of the grid households, both in urban and rural areas, it was not possible to maintain the planned 50:50 distribution of grid-connected and non-grid households in the sample. Accordingly, it was decided that the allocation of grid and non-grid households would be 10 and 5, respectively, in rural enumeration areas, and 13 and 2, respectively, in urban enumeration areas. Overall, 4,660 grid-connected and 1,340 non-grid households were sampled for the survey.[14] Table 2 shows the distribution of sampled households.

[10] Details of sample-size calculation are beyond the scope of this report but will be made available on the MTF website.

[11] The results presented in this report will provide a breakdown of the analysis at the urban and rural level and the ecological region level, with Kathmandu as a separate stratum. The results are also available at the province level and can be provided on request.

[12] Please note that only wards with roughly 250–300 households were considered. If any sampled wards (mostly urban) were found much larger, they were segmented (divided into equal-sized smaller groups), and one segment was selected as the enumeration area.

[13] The sampling methodology and the stratification did not consider during the household selection process the share of households owning or using an improved cook stove in each ward. This decision was made during the design phase of MTF implementation because data or statistics on grid connection rate at the national or sub-national level are more commonly available for most countries. Moreover, sampling based on grid connectivity is easier to implement than sampling based on the ownership of ICS, as there is a lack of consensus on the specification of ICS, not just across the countries but also within the countries in many cases. In most developing countries, ICS is disseminated by multiple vendors and agencies, and they vary in specification. Notwithstanding its dependence on grid connectivity, the sampling methodology has so far generated fairly representative statistics on cooking solutions in all countries.

[14] The sampling strategy did not use "districts" as a stratum for sampling. However, for an easy understanding of the geographic locations of where the survey was conducted for those familiar with Nepal, please note that this survey covers 71 districts. The list of districts is as follows: Taplejung, Panchthar , Ilam, Jhapa, Morang, Sunsari, Dhankuta, Tehrathum, Sankhuwasabha, Bhojpur, Solukhumbu Okhaldhunga, Khotang, Udayapur, Saptari, Siraha, Dhanusha, Mahottari, Sarlahi, Sindhuli, Ramechhap, Dolakha, Sindhupalchok , Kavrepalanchok, Lalitpur, Bhaktapur, Kathmandu, Nuwakot, Dhading, Makwanpur, Rautahat, Bara, Parsa, Chitwan, Gorkha, Lamjung, Tanahun, Syangja, Kaski, Myagdi, Parbat, Baglung, Gulmi, Palpa, Nawalparasi, Rupandehi, Kapilbastu, Arghakhachi, Pyuthan, Rolpa, Rukum, Salyan, Dang, Banke, Surkhet, Dailekh, Jajarkot, Dolpa , Jumla, Kalikot, Mugu, Humla , Bajura, Bajhang, Achham,Doti, Kailali, Kanchanpur, Dadeldhura, Baitadi, and Darchula.

TABLE 2 • **Nepal MTF sample: Distribution of grid and non-grid households**

	Allocation	Total number of households	Grid number of households	Non-grid number of households	Non-grid as % of total
Rural	10 grid, 5 non-grid	2,700	1,800	900	33
Urban	13 grid, 2 non-grid	3,300	2,860	440	13
Total		6,000	4,660	1,340	22

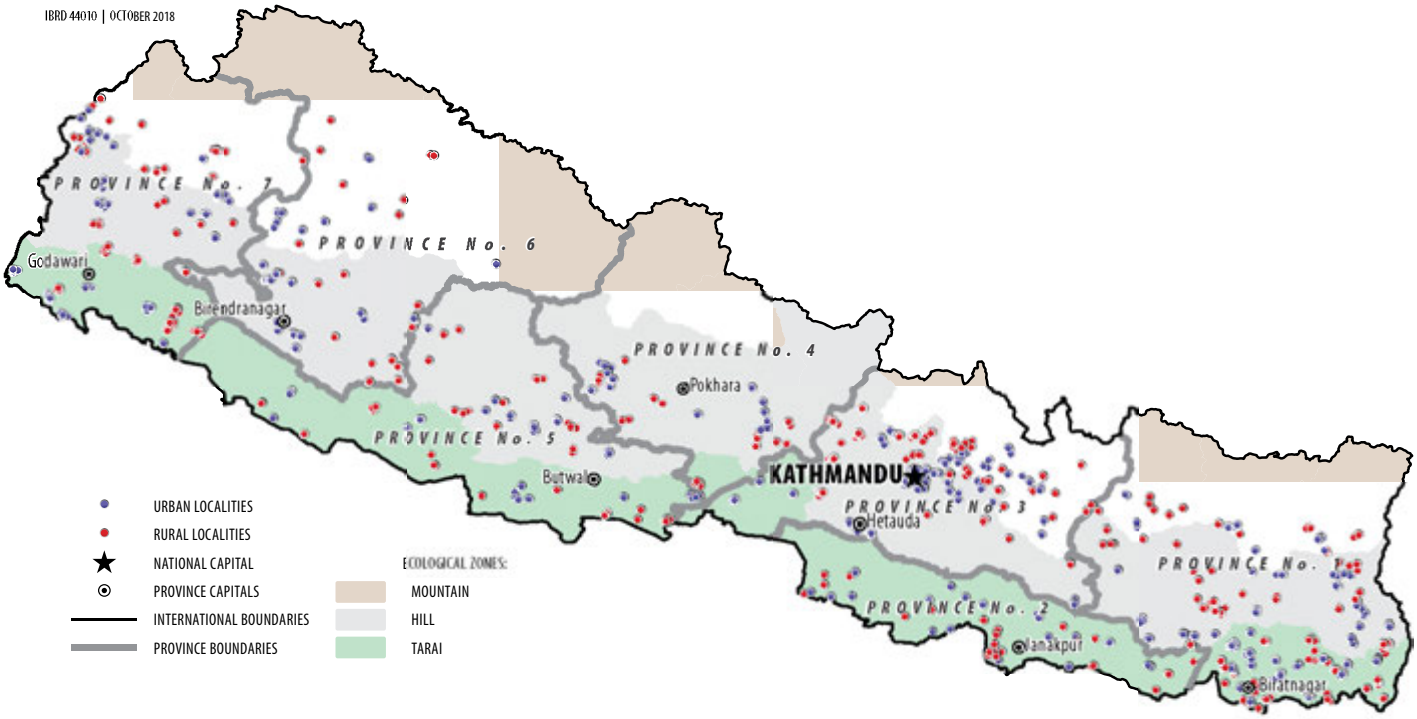
Since the distribution of grid and non-grid households in the sample differs from that in the population, any findings based directly on the data are expected to be biased. To adjust for the biases, sampling weight was used in the analysis of the data so that the findings are representative of the rural and urban areas and at the national level.[15] Details of sampling design are beyond the scope of this report; suffice it to say that calculation of sample weight requires census data with rural-urban disaggregation. As mentioned, the sample frame was the 2011 census from the Central Bureau of Statistics with projections to obtain the 2017 figures. Table 3 has the complete sample distribution of the 400 wards and 6,000 households across provinces, ecological regions, and urban-rural disaggregation. Below is a map of the GPS locations of urban and rural households across the country.

TABLE 3 • **Sample distribution in Nepal for the Multi-Tier Framework survey**

Province	Ecological region	Total wards (enumeration areas)	Total sample	Urban households	Rural households	Total households
1	Mountain	16	240	120	120	240
3	Mountain	22	330	165	165	330
6	Mountain	40	600	135	105	240
7	Mountain			165	195	360
1	Hill	39	585	285	300	585
3	Hill (excluding Kathmandu)	40	600	300	300	600
3	Hill (Kathmandu)	40	600	600	–	600
4	Hill	40	600	165	135	300
5	Hill			135	165	300
6	Hill	40	600	225	165	390
7	Hill			75	135	210
1	Terai	40	600	300	300	600
2	Terai	44	660	285	330	615
3	Terai			45	–	45
4	Terai	39	585	45	30	75
5	Terai			135	165	300
7	Terai			105	105	210
Total		**400**	**6,000**	**3,285**	**2,715**	**6,000**

[15] Sampling weight is an adjustment factor applied to each observation of the data during analysis to adjust for differential selection probability of sample units and make the findings representative of the underlying population.

SPATIAL DISTRIBUTION OF THE HOUSEHOLDS IN NEPAL SAMPLED FOR THE MULTI-TIER FRAMEWORK SURVEY



ACCESS TO ELECTRICITY

Along with determining electricity access, it is important to closely examine the level of services derived from the source, to assess how good a foundation it provides for households to overcome poverty and to improve women's and children's health and education. Particularly in Nepal, it is worthwhile to see whether the electricity received by households powers most appliances, provides electricity at any time of the day or night, is uninterrupted, does not damage appliances, is affordable, has a formal source, and does not endanger the health and safety of its users.

This section first compares how findings differ between a binary approach and the Multi-Tier Framework (MTF) approach, and then presents analysis on seven attributes—Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety—of household electricity in Nepal. The primary motivation behind the MTF approach is to delineate the difference between the traditional binary one of defining access and the multifaceted one of breaking down access into a range of services (attributes). Such distinctions help identify how access varies within households that have connectivity. The MTF results on electricity access show that many households with on- or off-grid electricity do not have Tier 5 level of access, with a majority in Tiers 1–4. Specifically, grid users face problems of short electricity availability in evenings, frequent outages, and unstable quality, and mini-grid users are found to use low-power appliances and have short duration during the day.

ASSESSING ACCESS TO ELECTRICITY BY TECHNOLOGY

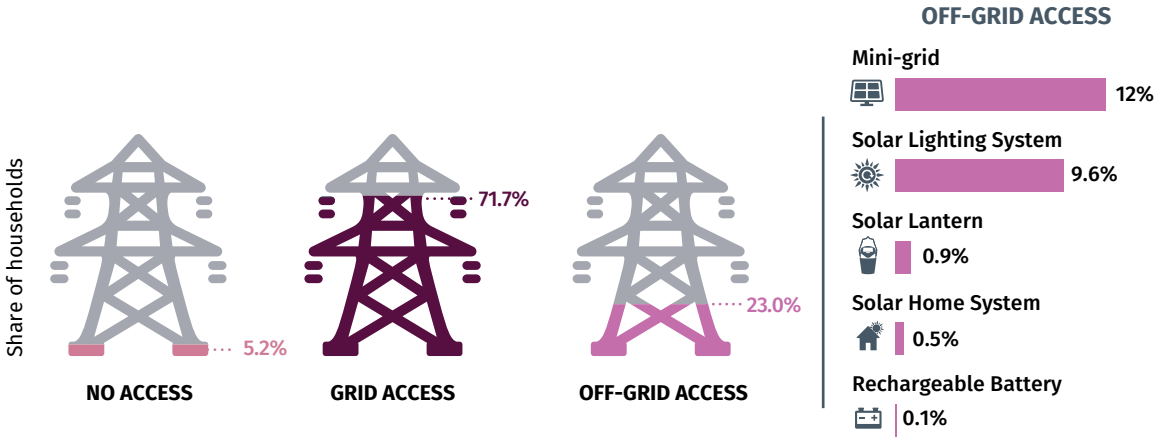
There are several sources of electricity that households use from the national grid (provided by the Nepal Electricity Authority, or NEA) to off-grid solutions such as mini- and micro-hydropower, solar devices and rechargeable batteries. In Nepal, 71.7% of the households are connected to the national grid while 23% of households are using an off-grid source to meet their energy needs (Figure 3).[16] About 5.2% of the households across the country have access to neither a grid connection nor any off-grid solutions.

There is variation across households on the different types of technologies and connections used. While a majority of households are connected to the national grid, not every household has an independent electricity connection. This study finds that 94.4% of the households connected to the grid have an electric meter or sub-meter, and from these households 11.7% share their meter or sub-meter with another household. On average, there are two households that share a connection, that is, share a meter or sub-meter. Among households connected to an off-grid solution, the mini-grid and solar lighting system are the most common source of electricity. Twelve percent of the Nepalese households are connected to an isolated mini-grid, that is, a pico-hydro, micro-hydro, or mini-hydro system. Households connected to a pico-hydro grid as their main source of electricity compose 2% of the households. The use of solar energy is common among households not connected to the national grid. There are three distinct solar devices identified through this survey: a solar lantern, solar lighting system, and a solar home

[16] The 95% confidence interval for households with some source of electricity (grid or off grid) is (93.955, 95.618).

system (SHS). A solar lantern is a device with only one light bulb, with or without a mobile charger. A solar lighting system has multiple light bulbs and can come with a mobile charger or radio or both. An SHS has two or more light bulbs and can power more appliances in addition to a mobile phone and a radio, such as a fan or television. In Nepal, 9.6% of households mainly use solar energy from a solar lighting system.

FIGURE 3 • **Share of households with access to different technologies (nationwide)**



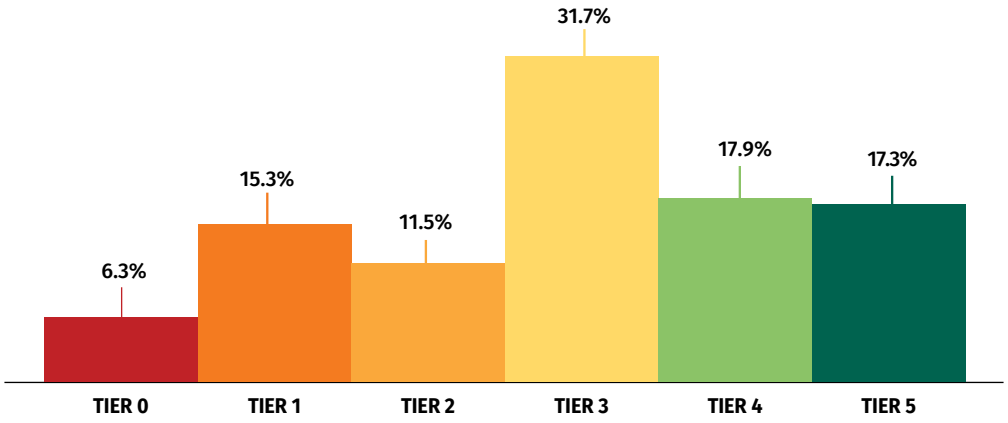
Note: The sample size is 6,000.

In urban areas, about 90% of the hosueholds are connected to the national grid while 6% are connected to off-grid sources and 4% have no electricity. The share of households using the national grid in rural areas is lower than in the urban areas; about 67% of rural households use the grid as their main sources of electricity. There are 27% of households that have off-grid electricity access, and 5.6% of households with no electricity access. As Nepal's population is spread across three distinct ecological regions, the remote Mountains, the Hills, and the densely-populated Terai, the analysis looks at this distribution of households, incuding Kathmandu as an additional stratum . In Kathmandu, 100% of the households are connected to the grid. In the Terai, 90.1% of the households are connected to the national grid, while in the Hill and Mountain areas, the share of households connected to the national grid is smaller (55.5% and 36.1%, respectively). However, in these areas households have access to electricity from a mini-grid system (21.5% in the Hill areas and 40.1% in the Mountains). In the Hill and Mountain areas, there is a larger share of households that use solar energy, mainly from solar lighting systems (18.1% of households in the Hills and 17.6% in the Mountains) compared to households in the Terai. Despite high grid-electrification rate in the Terai, 7.8% of households in the Terai areas have no access to electricity, compared to only 2.7% of households in the Hills and 3.6% of households in the Mountains without any source of energy.

MULTI-TIER FRAMEWORK TIERS

Nepal has been successful in getting households access to electricity: moving them from Tier 0 to a higher tier. The challenge going forward will be for households to continue rising from the lower tiers to higher tiers. In Nepal, 93.7% of the households have access at Tier 1 and higher. However, the largest share of households, 31.7%, are concentrated in Tier 3, while 17.9% of the households are in Tier 4 and 17.3% in Tier 5. Tiers 1 and 2 have a total of 26.8% of the households, and only 6.3% of households are in Tier 0 (Figure 4).

FIGURE 4 • **The MTF aggregate tier distribution (nationwide)**

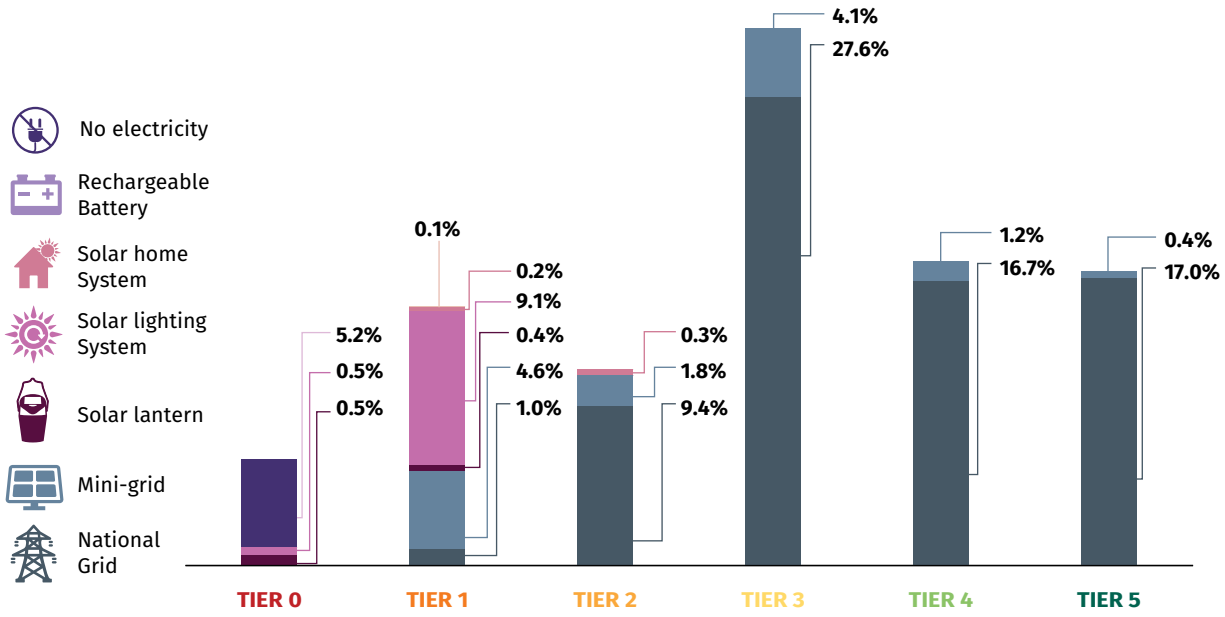


Urban areas have the larger share of households in Tiers 4 and 5—46.4% of households, compared to 32.2% of households in rural areas. Almost 90% of the households in urban areas are connected to the national grid, whereas in rural areas about 67% of the households have grid access. At the low end, 6.8% of rural households are in Tier 0 while 4.3% of urban households are in Tier 0. Across the ecological regions, the Terai areas have the lowest share of households in Tier 5 and the highest percentage in Tier 0 compared to the Mountain and Hill areas. Households in the Terai are predominantly in Tier 3, while households in the Mountain and Hill areas are mostly in Tier 1. Even though 90.1% of the households in the Terai area have grid electricity, only 9.5% of the households are in Tier 5, compared to 24.2% in the Hill region and 18.7% in the Mountain areas. In addition, 8.1% of the households in the Terai are in Tier 0, while the Hill area has 4.5% of households and the Mountain areas has 5.5% of households in Tier 0. Located in the largest urban center, households in the Kathmandu area are all connected to the grid and are mainly in Tier 5. Annex 6 has the distribution of households across the different strata and tiers.

To understand what types of households are in the different tiers, we compare the households across the MTF distribution by the households' main source of electricity (Figure 5). Despite having 71.7% of households connected to the national grid, only 17% of the households attain the highest levels of access, Tier 5. Most of the grid-connected households are in Tiers 3 and 4, implying that there are issues with the service households receive from the national grid. The unavailability of electricity supply (Availability attribute), unexpected outages (Reliability attribute), and the poor quality of the voltage (Quality attribute) are the primary reasons a large proportion of the grid-connected households do not have Tier 5 level of access.

Households connected to mini-grids are mostly in Tier 3 (6.4% of the households), but a small share reaches higher tiers, all the way to Tier 5. The availability of electricity supply through the day and night is the main obstacle affecting the households' aggregate tier level. For solar users, particularly for households using only a solar lantern, the capacity of the device limits them to lower tiers, with 9.1% of households in Tier 1. Availability of electricity supply is low for solar users and keeps them in lower tiers.

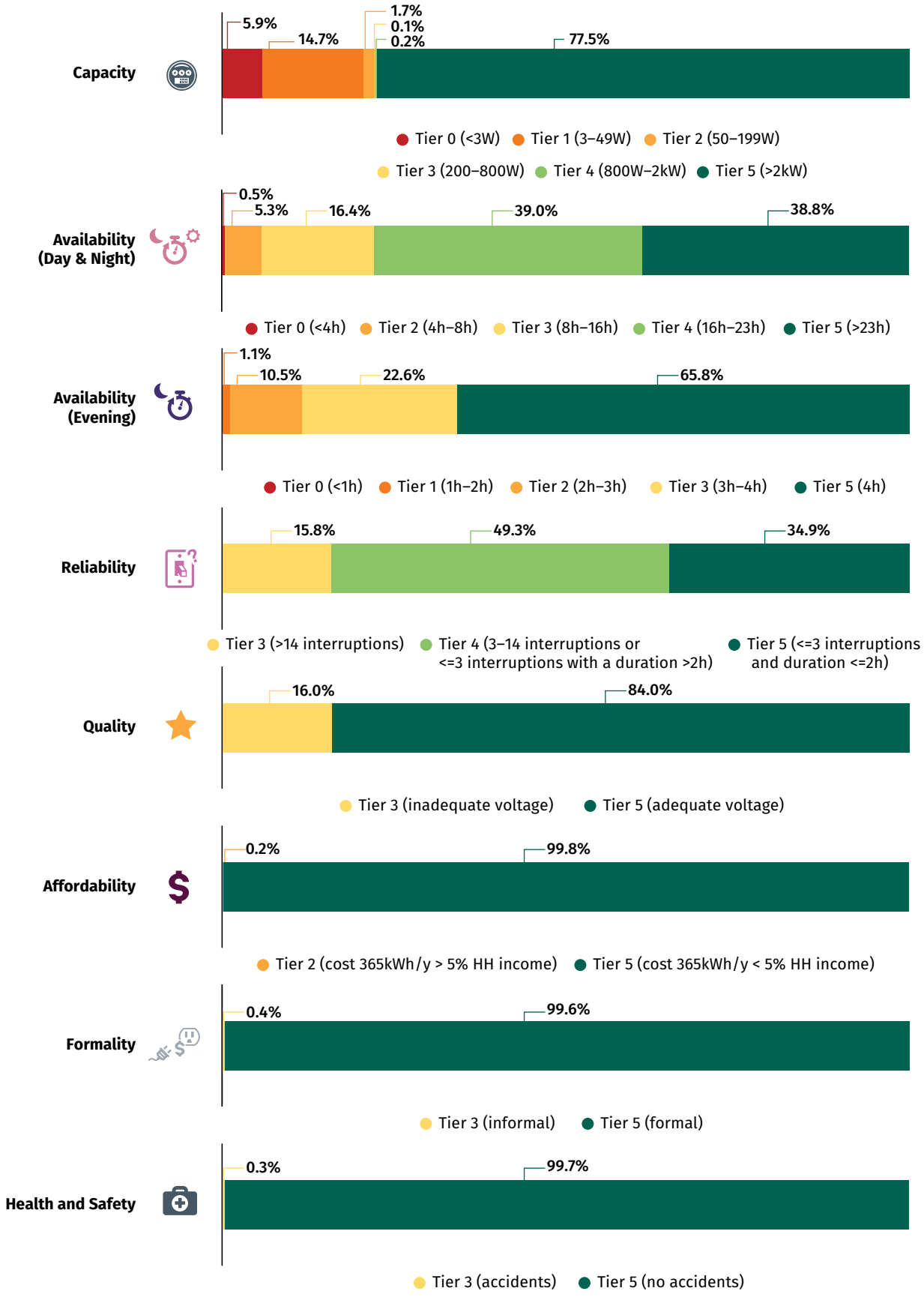
FIGURE 5 • **MTF aggregate tier distribution by technology**



MULTI-TIER FRAMEWORK ATTRIBUTES

A household's aggregate tier allocation is based on its performance across the seven attributes measuring access, and the lowest tier level among the attributes is considered its final aggregate tier. In Nepal, the major constraints that households face are in the Capacity, Availability, Reliability, and Quality attributes. Nearly all households are in Tier 5 for attributes on Affordability, Formality, and Safety. Figure 6 provides an overview of how households across the country perform on each of these attributes. To better understand the household's experience with access, in the following sections each attribute is discussed in detail in the context of a household's main source of electricity.

FIGURE 6 • **MTF attributes (nationwide)**



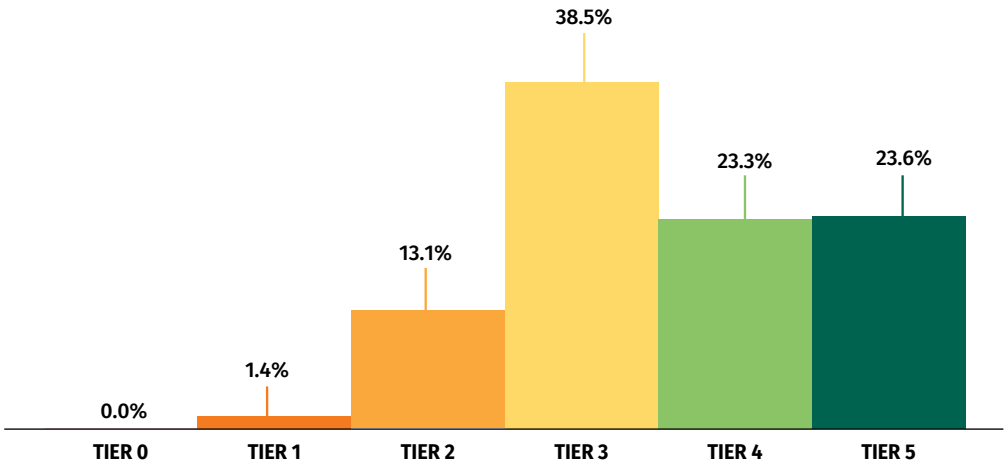
IMPROVING ACCESS TO ELECTRICITY

Strategies for elevating households from the lowest tier will depend on why households are in a lower tier. Examples of such strategies are deciding whether to connect households with no electricity source to the national grid or to an off-grid solution, or addressing weaknesses in Capacity and Availability attributes for households that already have electricity. This section investigates why households are in a specific tier and which aspects of the electricity service need to be addressed for them to gain better access. We examine the households based on their main source of electricity. The first section addresses households using the national grid as their main source of electricity. The second section focuses on households connected to mini-grids (mini-, micro- and pico-hydro grids), and the third looks at households using solar as their main source of electricity. The fourth and final section focuses on households without any electricity source.

ELECTRICITY ACCESS FOR THE GRID-CONNECTED HOUSEHOLDS

In Nepal, 71.7% of the households have a connection to the national grid. However, the households experience varying levels of access. The Capacity attribute is a non-issue. Households are assigned Tier 5 for the Capacity attribute as it is assumed that the electricity from the grid has a load capacity above the minimum of 2 kW as defined in the framework. For the past decade, Nepal has grappled with a severe power crisis, with an increasing gap between the peak demand and installed generation capacity. While the NEA has taken steps to improve the level of services for households, there are lingering issues. All the households connected to the national grid have at least the minimum electricity services available, that is, are above Tier 1 (Figure 7). There is still a large share of households in Tiers 1, 2, and 3. In this section, we look more closely at grid-connected households in the lower tiers and how they can be moved to a higher tier of access.[17] Of the seven attributes of the MTF, Availability, Reliability, and Quality are crucial in determining the access level for the grid-connected households. We focus on these attributes in more detail to understand the households' current patterns of behavior.

FIGURE 7 • **MTF tier distribution for grid-connected households (nationwide)**



[17] The analysis provided is only for the section of grid connected households, that is, 71.7% of the sample, or N = 4,047.

Availability

Households connected to the national grid do not always receive sufficient electricity supply, especially during the evening time, when it is most needed. There are two bases for estimates that are used for measuring the Availability attribute—the duration of electricity supply for a household during a 24-hour period and duration in the most vital hours, between 6 pm and 10 pm. While 47.4% of households receive almost 24 hours of electricity supply, the situation for half the population is less optimistic (Figure 8). Almost 5% of households receive 8 to 16 hours of electricity a day, and the remaining 47.7% of households have 16 to 23 hours of electricity available to them. The situation is more dire during the hours of 6 pm to 10 pm, when 1.4% of the households receive between 1 to 2 hours of electricity supply, bringing them to Tier 1 (Figure 9). About 13% of households receive 2 to 3 hours (Tier 2), and 27.2% of household receive more than 3 but fewer than 4 hours (Tier 3) of electricity in the evening time. The analysis also finds that the availability of electricity in rural areas is worse than that in urban areas.

Until 2016, households were experiencing long hours of load shedding daily (nearly 12–14 hours). However, with the completion of different transmission and distribution projects and imports of electricity from India, the National Electricity Authority (NEA) has been able to meet some of the demand. In April 2017, NEA announced that it was eliminating load shedding in Nepal for domestic consumers. Our survey found that 92.3% of the households reported that they don't recevie a load shedding schedule. Given that load shedding is not a reported issue, the constrains of electricity supply for households still needs to be addressed. The provision of better electricity supply at least during peak hours, at a minimum of three hours in the evenings, can shift about 14% of households in the low tiers to Tier 3.

FIGURE 8 • **Availability (day and night) tier distribution for the grid-connected households**

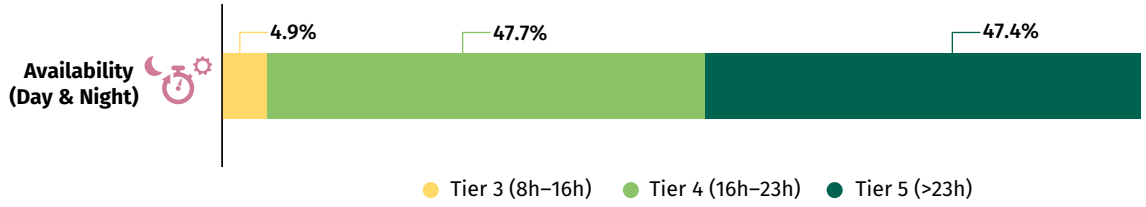
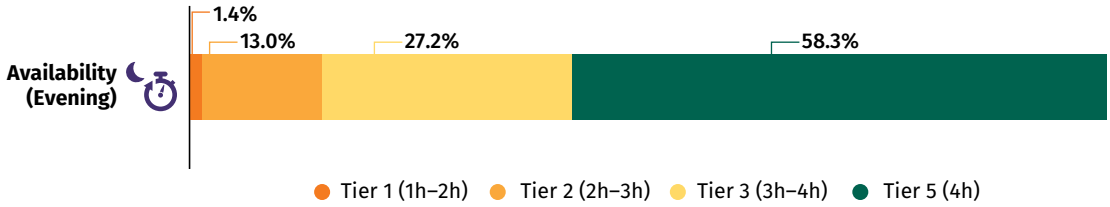


FIGURE 9 • **Availability (evening) tier distribution for grid-connected households**

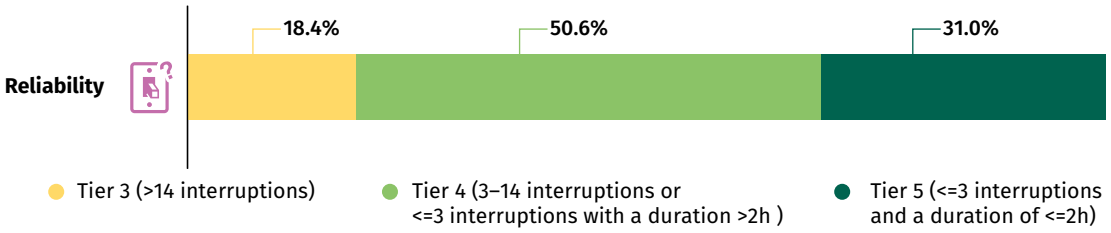


Reliability

Electricity interruptions can either be planned, such as in the case of load shedding from the grid, or unplanned and unpredictable. The NEA stated that any outages households experience would be a result of technical problems with the grid (Himalayan Times 2017). Reliability of the grid electricity supply or the absence of unpredictable disruptions in electricity supply play a vital role in ensuring adequate electricity services to households.

The high frequency of such unplanned outages in electricity supply pose an inconvenience for grid users: 18.4% of households report experiencing more than 14 disruptions per week and 50.6% of households either experience between 3 to 14 disruptions or experience 3 or less disruptions that last longer than 2 hours in total (Figure 10). The grid-connected household experiences about 8.4 outages per week that lasts a total of 8.2 hours on average. The NEA is currently upgrading the distribution system through improving the capacity of transformers and feeders.

FIGURE 10 • **Reliability tier distribution for grid-connected households**



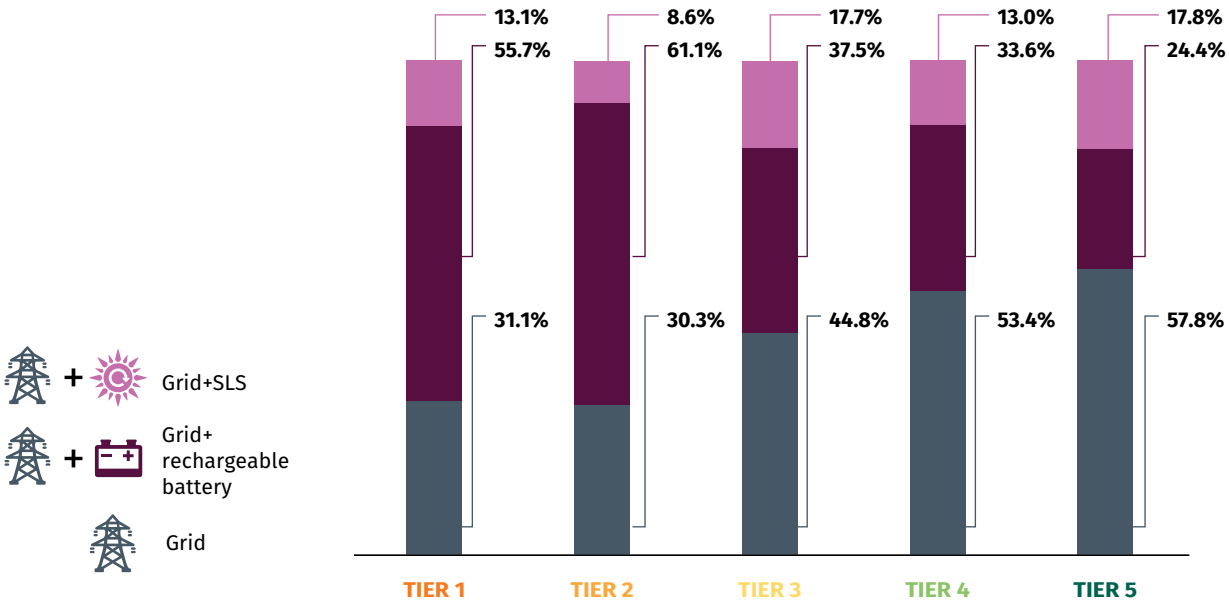
Backup sources

With the unreliable and poor supply of electricity from the national grid, backup sources of electricity are prevalent, particularly for lighting. While 92.3% of the households have a backup source of lighting, 38.7% do not back up using electricity, but use candles, kerosene lamps, or dry cell batteries, and 7.7% of households do not have a backup source at all for lighting. Examples of backup sources of electricity for lighting are a rechargeable battery (35.8% of grid-connected households) and solar lighting system (used by 15% of grid-connected households). A small share of households (10.5%), use a rechargeable battery as a backup source for powering their appliances.

A trend observed in Nepal is that households with worse grid electricity supply and a subsequently lower aggregate tier are more likely to use a rechargeable battery as a backup source (Figure 11). There are 61.1% of the households in Tier 2 and 37.5% of households in Tier 3 that back up their grid electricity with a rechargeable battery. However, households in all tiers, even Tier 5, use a solar lighting system as backup lighting, demonstrating the perceptions on the reliability of grid electricity.

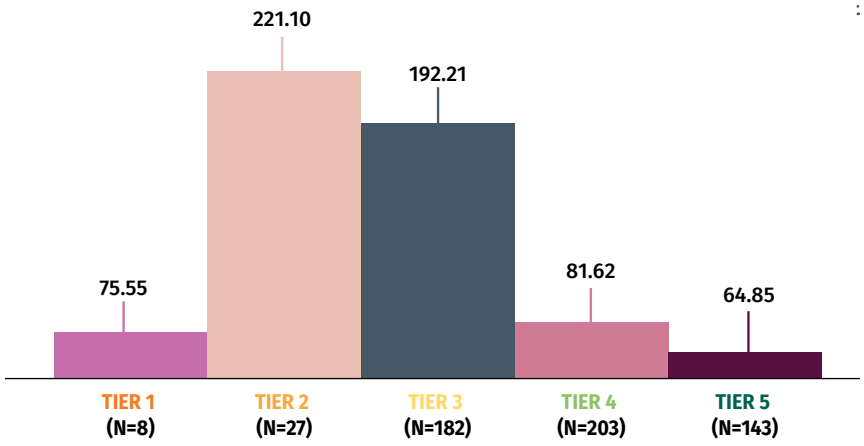
Unreliable supply adds to the financial burden of a household. On average, households connected to the grid spend about 254.3 Nepalese rupees (US$2.46) every month on their energy bill. For those using backup sources, the average monthly expenditure is 222.38 Nepalese rupees (US$2.15) for Tier 2 households and 204.11 Nepalese rupees (US$1.97) for Tier 3 households. Figure 12 shows the average monthly expenditure on backup sources declining for households in higher tiers. With insufficient electricity supply and unpredictable outages, households tend to spend a substantial amount of money to offset these negative experiences from the grid.

FIGURE 11 • **Aggregate tier distribution by backup source**



Note: SLS = solar lighting system.

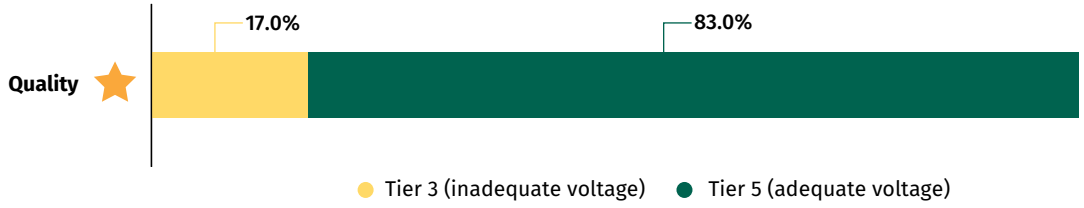
FIGURE 12 • **Average monthly expenditure on backup sources by aggregate tier (Nepalese rupees)**



Quality

The third attribute impacting the level of access for grid users is the Quality of the electricity supply. Severe voltage fluctuation prevents 17% of the grid-connected households from moving to higher tiers and brings them down to Tier 3 (Figure 13). In order to deal with the problem of voltage fluctuations, 15.1% of households use a stabilizer, which is an additional investment choice that households make to cope with the poor electricity services from the national grid.

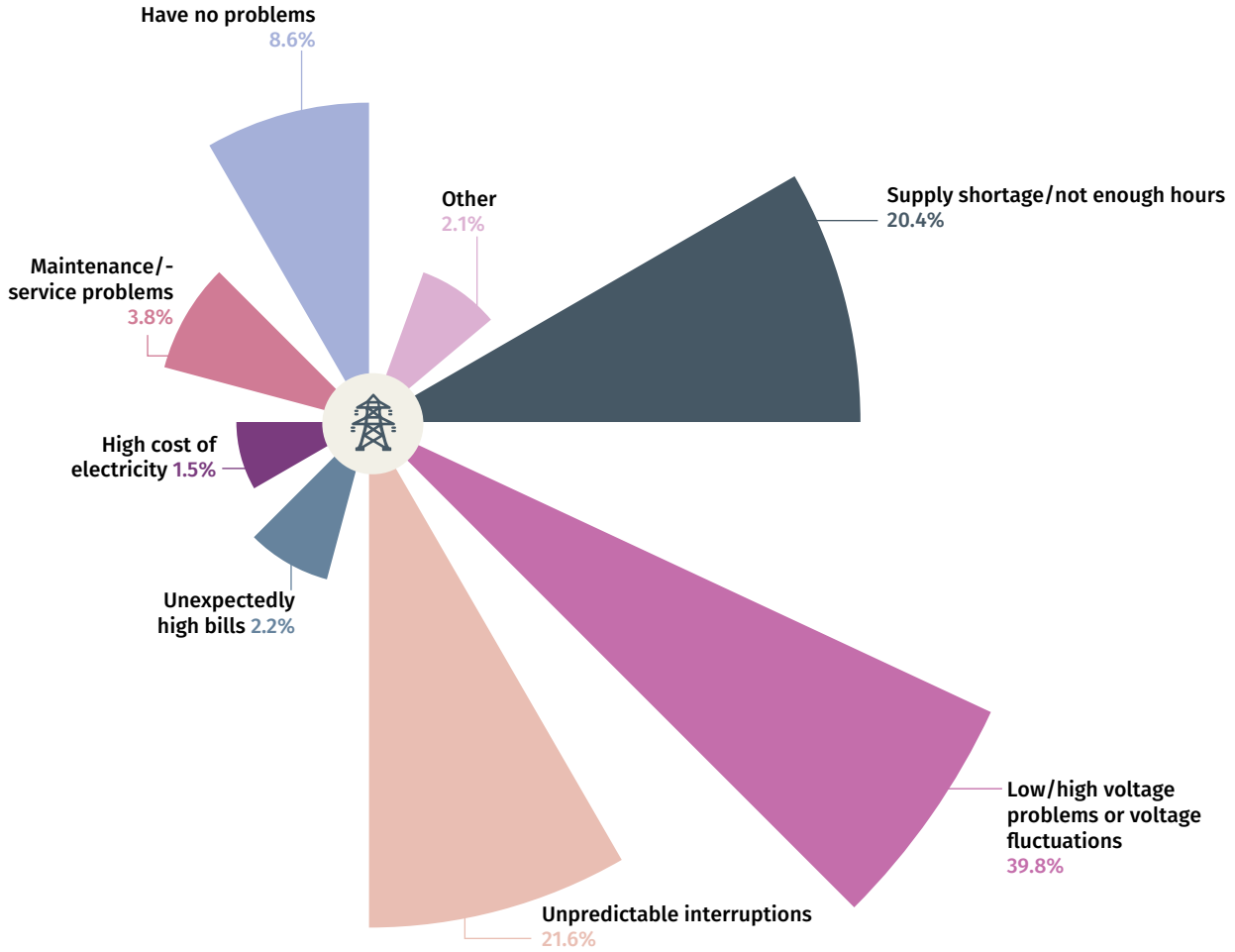
FIGURE 13 • **Quality tier distribution for grid-connected households (nationwide)**



Household perception about grid service

The results on these three attributes, Availability, Reliability, and Quality, are reflected in the perceptions of the major issues that households experience with the grid. When asked about the most serious problem with the grid, 39.8% of households reported problems with the voltage, 21.6% of households cited unpredictable interruptions, and 20.4% of households said that supply shortages affected them most severely (figure 14).

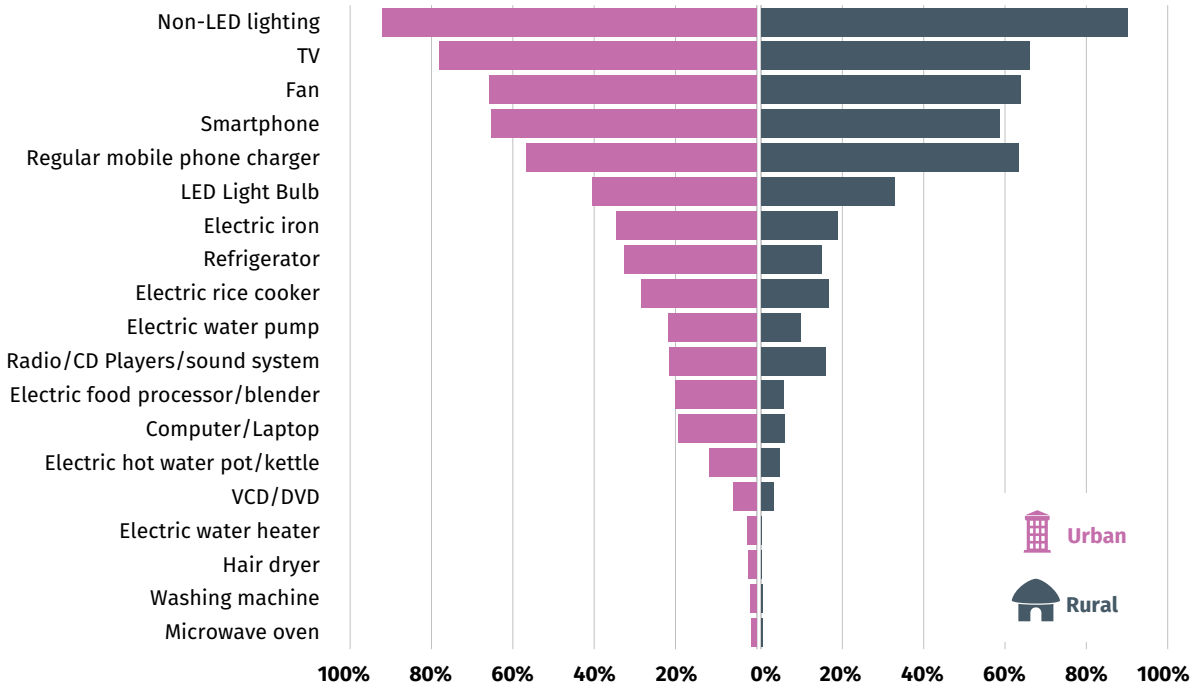
FIGURE 14 • **Most serious problem with the grid**



Electricity consumption

The discussion on grid-connected households would not be complete without examining the patterns of consumption. Grid users in Nepal mostly invest in low-load appliances equivalent to Capacity Tiers 1 and 2. Besides lightbulbs and mobile phone chargers, which are Tier 1 appliances, fans and televisions (Tier 2 appliances) are the most commonly used appliances (Figure 15). However, less than 20% of the households own a refrigerator (a medium-load or Tier 3 appliance) and just a fraction has high-powered appliances such as air conditioners or space heaters. Urban households use more appliances, particularly low- to medium-load appliances. The use of low-load appliances reflects in the national average of electricity consumption of grid-connected households, which is 46.63 kWh.[18] When asked what appliances they would like to purchase that they do not already have, refrigerators and televisions were the most common appliances mentioned. Households had not purchased these appliances already, as they were seen to be too expensive.

FIGURE 15 • **Appliances owned by grid-connected households**



IMPROVING ELECTRICITY ACCESS FOR HOUSEHOLDS THAT USE AN OFF-GRID SOURCE

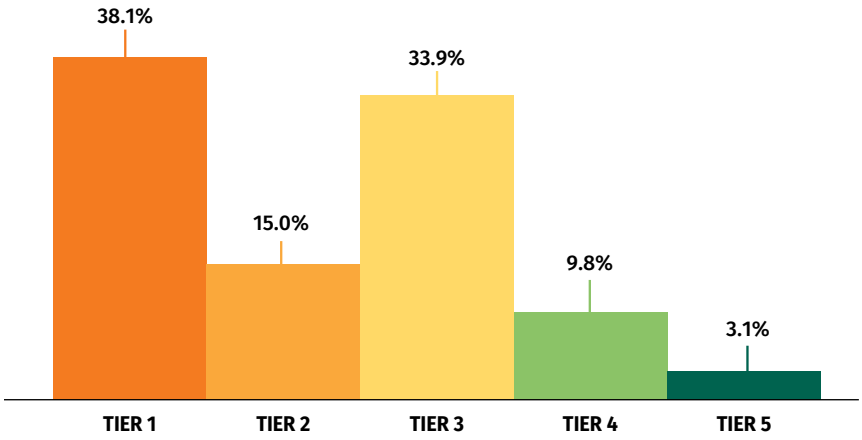
There is a high prevalence of off-grid sources of electricity available and being used by households in Nepal. Electricity from micro-hydro, mini-hydro, and pico-hydro plants and solar devices account for 23% of the nation's main electricity source. It is important to reflect on the overall patterns of access and consumption for these households to help move them up the tiers. The findings show that like grid-connected households, households using mini-grid sources and solar devices have similar issues of short duration of electricity during the day and limited use of high-power appliances, which place them in lower Capacity and Availability Tiers.

[18] The consumption figure is an average of only 638 households out of the 4,047 who are connected to the grid and reported their monthly consumption from their electricity bill.

Households connected to the mini-grid

Households connected to a mini-grid demonstrate similar patterns to grid-connected households on the access of electricity. [19] That is, these households face challenges with the supply of electricity (Availability), the Reliability and Quality of electricity, in addition to facing capacity issues. Nationwide, a larger share of households are in lower tiers: 38.1% of households using the mini-grid sources are in Tier 1, 15% in Tier 2, and 33.9% in Tier 3 (Figure 16). Only 12.9% of the households attain Tiers 4 and 5 levels of electricity access.

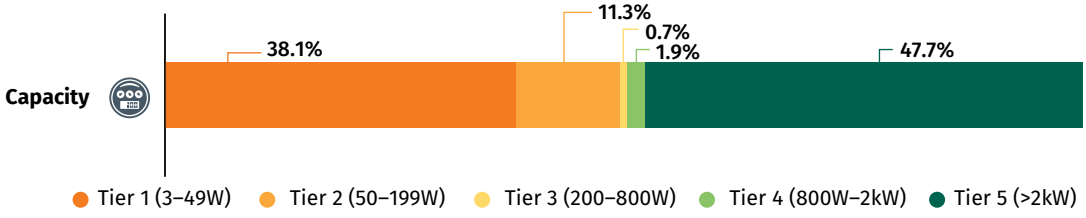
FIGURE 16 • **Aggregate tier distribution of mini-grid households**



Capacity

In Nepal, most of the mini-grids funded by Alternative Energy Promotion Centre have a capacity that is higher than 2 kW required for a household to be in Tier 5 on the Capacity attribute. However, in some locations, demand and the limited services offered by the mini-grid operators may impose limits on the household's appliance usage. If a household reports that there are limits on the load or the types of appliances they can use, we then assign the Capacity Tier based on the appliance tier of the households. For this reason, about half the households are in the lower tiers,:38.1% of households are in Tier 1 and 11.4% are in Tier 2 for Capacity (Figure 17). On the hand, 47.7% of the households are in Tier 5, as there are no restrictions on their capacity usage.

FIGURE 17 • **Capacity tier distribution of mini-grid households**



[19] The analysis provided is only for the section of mini-grid connected households: 12% of the sample or N = 815.

Availability

The aggregate tier is influenced by the number of hours of electricity supply available within a 24-hour period. The unavailability of electricity during the entire day (24 hours) keeps mini-grid households in a lower tier: 68.2% of households have fewer than 16 hours of electricity and 4.2% of the households have fewer than 8 hours available (Figure 18). Unlike the households connected to the national grid, the mini-grid users have sufficient electricity supply in the peak evening hours. During the hours between 6 p.m. and 10 p.m., only 8.1% of households report 3–4 hours of electricity available, while 91.3% report having 4 hours available during that period (Figure 19).

FIGURE 18 • **Availability (day and night) tier distribution for mini-grid households**

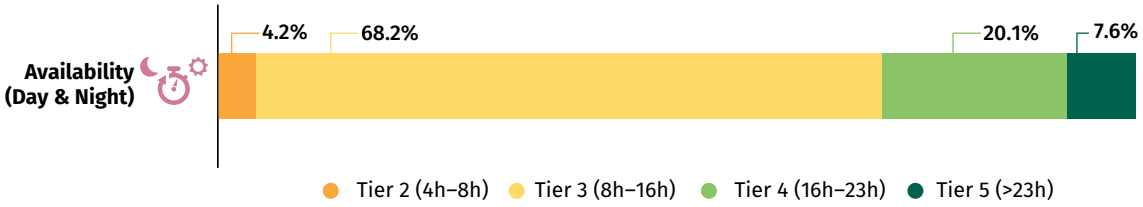
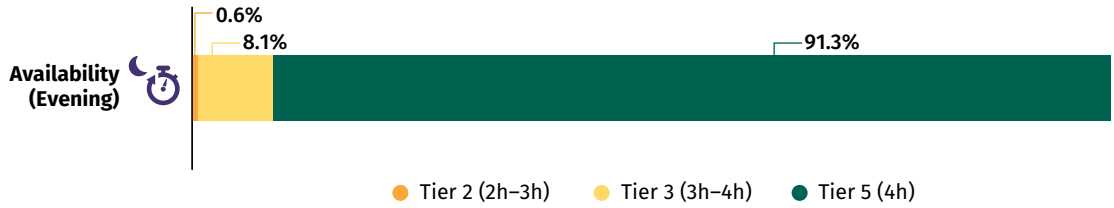


FIGURE 19 • **Availability (evening) tier distribution for mini-grid households**



Reliability and quality

The Reliability and Quality attributes of the electricity supply are additional barriers for households connected to the mini-grid. While a majority of households do not report severe interruptions, 41.2% of these households have three or more outages lasting more than 2 hours in a week (Figure 20). On average, households report experiencing two outages each week, lasting a total of 5.5 hours. Mini-grid users also experience problems in the Quality of electricity supply, that is, severe voltage fluctuations that damage their appliances. About 10% of the households connected to the mini-grid are in Tier 3 for the Quality attribute (Figure 21). Households are coping with these voltage issues by investing in a stabilizer—about 4.7% of households connected to a mini-grid use a stabilizer.

FIGURE 20 • **Reliability tier distribution for mini-grid households**

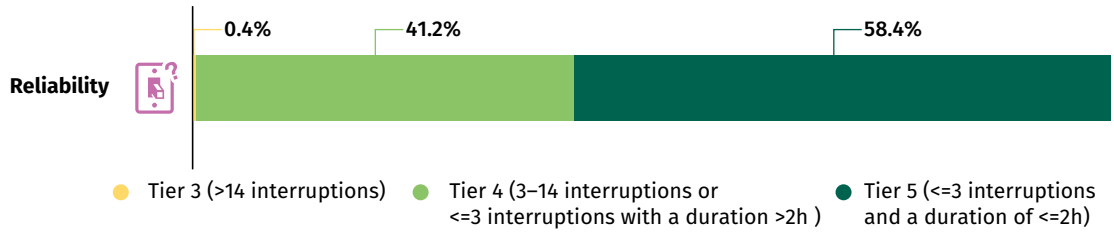
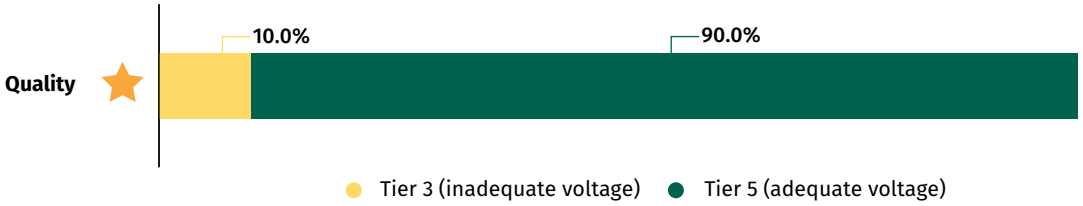


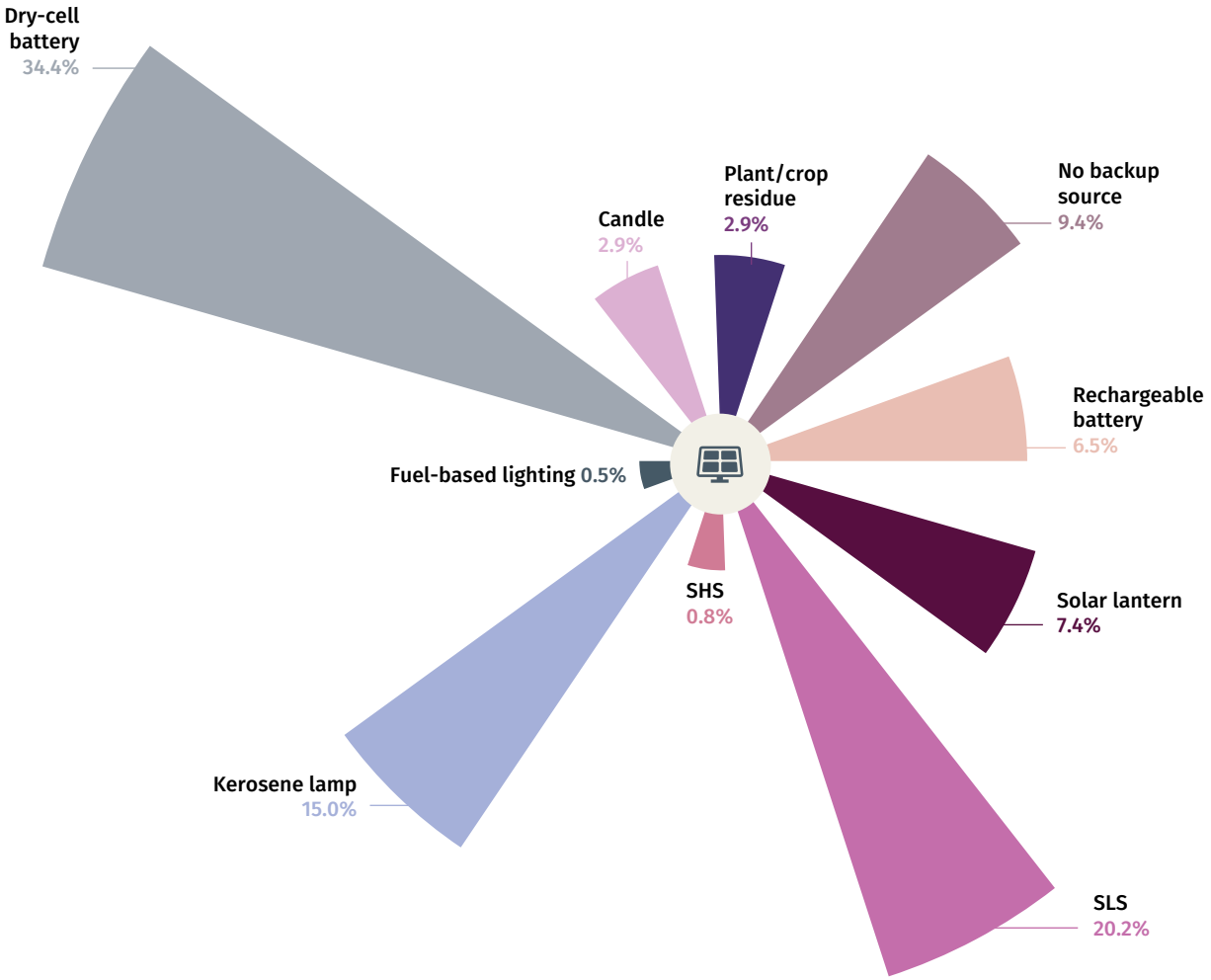
FIGURE 21 • **Quality tier distribution for mini-grid households**



Backup sources

To overcome shortages and the unreliable supply, 90.6% of mini-grid-connected households use backup electricity for lighting. Households primarily use dry cell batteries (34.4%) and solar lighting systems (20.2%) (Figure 22). Households are also spending 143 Nepalese rupees per month on average on their backup sources.

FIGURE 22 • **Backup sources for lighting (mini-grid households)**



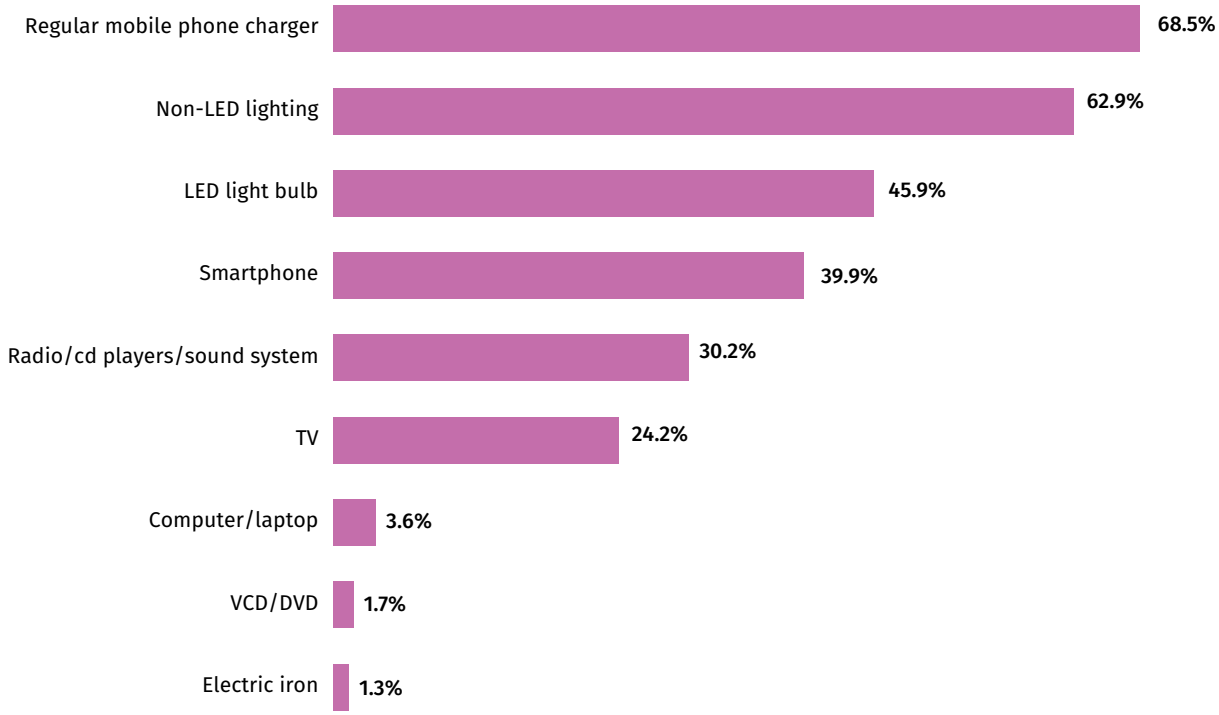
Electricity consumption

While mini-grids allow households to power high-load appliances, most of those used are low-load appliances. Along with lightbulbs, mobile phone chargers, radios or sound systems, and televisions are the most common appliances used (Figure 23). These are low-load appliances, corresponding to Tier 1 and 2 for the Appliance tier. As a result, mini-grid households consume less electricity compared to grid users. On average, mini-grid households consume 14.84 kWh each month and spend about 102.67 Nepalese rupees (US$0.99) on their monthly electricity bill.[20]

Even though the electricity consumption among the mini-grid-connected households is low, these households are likely to increase their electricity consumption conditional upon the affordability of obtaining additional appliances as well as the capacity of power system. When asked about the types of appliances they would like to have that they do not already own, a television was the most desired choice, followed by power tools, smart phones, and radios. Households reported that the appliances were either too expensive (64.4% of households) or required too much power (27.1% of households), which was why they did not currently own them.[21] Considering this last fact, two different factors constrain a mini-grid household using an appliance that they desire: the capacity of electricity supplied by the mini-grid and the household's financial ability to purchase an appliance.

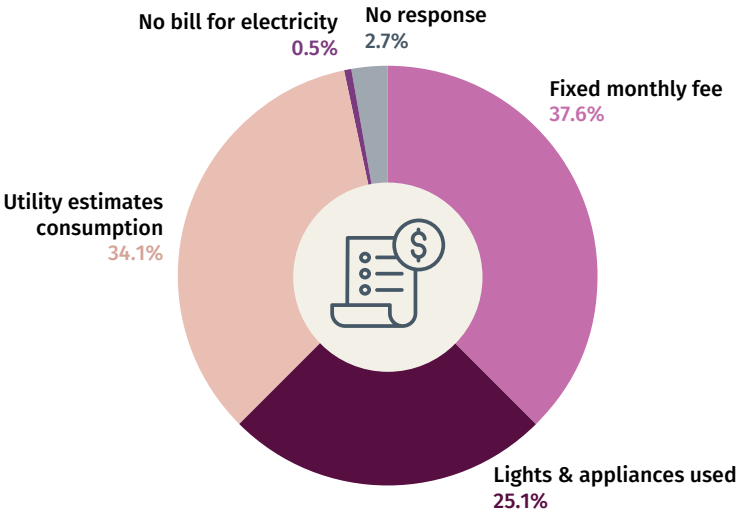
The lack of a consumption-based price system may prevent mini-grid operators from increasing capacity and availability. The fact that 37.9% of the households pay a fixed monthly fee for their electricity means the mini-grid operators do not have an incentive to increase capacity or availability for households willing to purchase appliances and increase power consumption (Figure 24). These households are likely to be limited in the amount of electricity supplied.

FIGURE 23 • **Use of appliances by mini-grid households**



[20] The sample size is 50 for electricity consumption and 801 for monthly electricity bill .
[21] About 52.7% said the mini-grid operator imposes a limit on the capacity of appliances they can use.

FIGURE 24 • **Type of payment mechanism for a household**



Households with solar devices

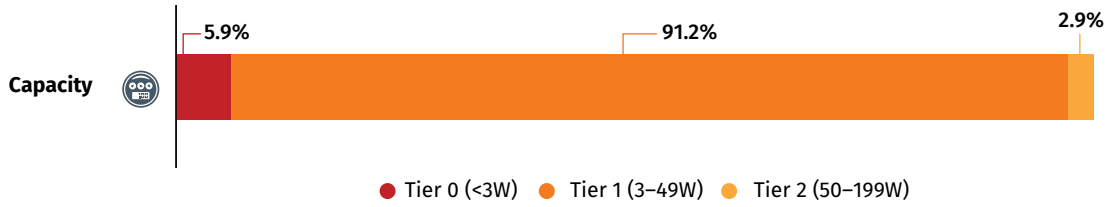
The most common solar device in Nepal is the solar lighting system, which usually powers a few light bulbs, mobile phone charger, and radio. Most of the households (87.7%) that use a solar device as their main source of electricity are in Tier 1.[22] Only 2.9% of solar users reach Tier 2, while 9.4% of households are in Tier 0.

Capacity

Capacity is the major factor among the attributes that constrains solar users (Figure 25). Households with a solar device mainly use it to power very low-load appliances, such as mobile charger or radio, along with the lighting. For households using an SHS, Capacity attribute is calculated from the reported peak capacity rating of the solar panels or the appliance load tier. The number of devices a household owns, the appliances available with that device, and the number of household members sharing a device are used to calculate the capacity of solar lighting systems and solar lanterns. The Capacity attribute accounts for whether the device has a mobile phone charger or not. If the device is used only for lighting (without mobile phone charging) then capacity is not considered sufficient for an entire household. In addition, the light from the single lightbulb of a solar lantern or couple of bulbs (in the case of a lighting system) will have to be shared by multiple household members. So, the Capacity Tier for these households can be in Tier 1 or 0 depending on the household size and the number of devices being used. Capacity Tiers and, subsequently, the aggregate tier of most households with a stand-alone solar device is Tier 1.

[22] The analysis provided is only for the section of solar users i.e. 10.2% of the sample or N = 793.

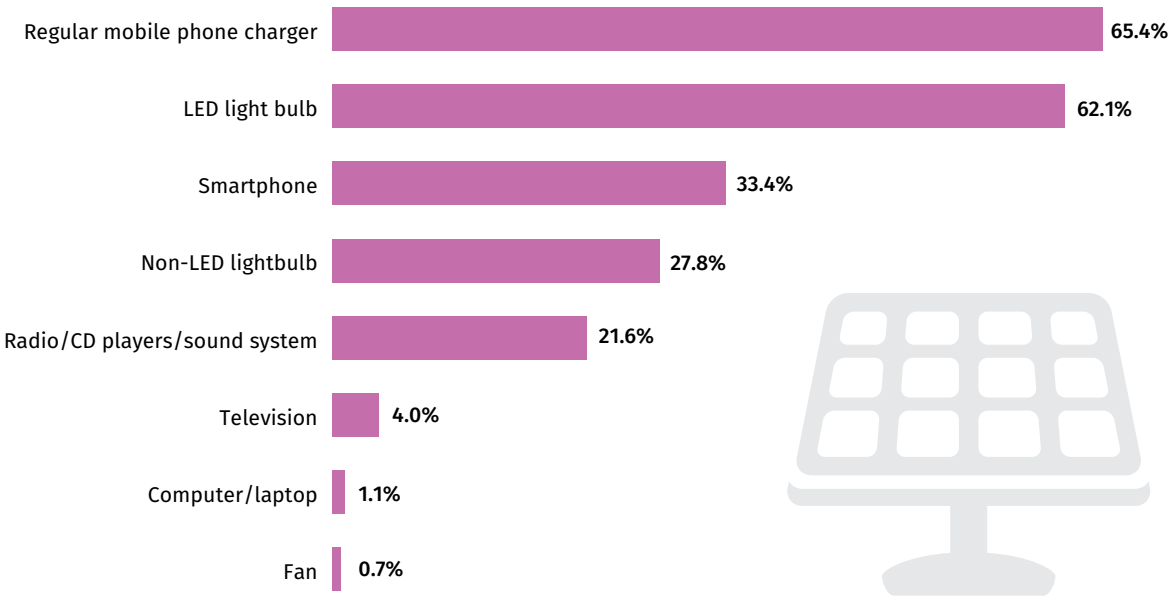
FIGURE 25 • **Capacity Tier distribution for solar users**



Appliance ownership

Solar users are less likely to own Tier 2 or low-load appliances such as a television compared to households with grid or mini-grid connection who can use higher-load appliances. While almost a quarter of the households with a mini-grid own a television, only 4% of solar users have a television (Figure 26). The low prevalence of television ownership, however, does not necessarily mean these households have low demand for electricity. About one-third (30.3%) of the households using solar solutions would like to own a television, and about three-quarters (74.2%) expressed that their current solar does not have enough capacity to power a television. This is a contrast to the smaller 29.7% of mini-grid households that aspired to have a television but could not, because it would require too much energy.

FIGURE 26 • Appliances owned by stand-alone solar device users

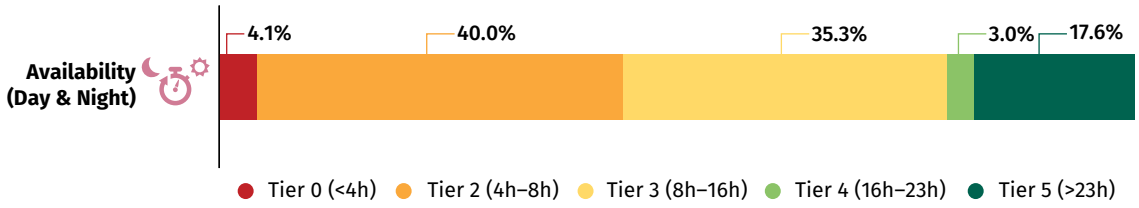


Availability

Solar users mainly consume electricity during the evening time. For these households, evening duration is not an issue, but the electricity supply during the 24 hours of the day is insufficient (Figure 27). Most solar users have the full 4 hours of electricity in the evening (86.4%). However, 44.1% of them have fewer than 8 hours of electricity out of 24 hours (Figure 28). Only 17.6% of solar users have electricity all day.

FIGURE 27 • **Availability (evening) tier distribution for solar households**

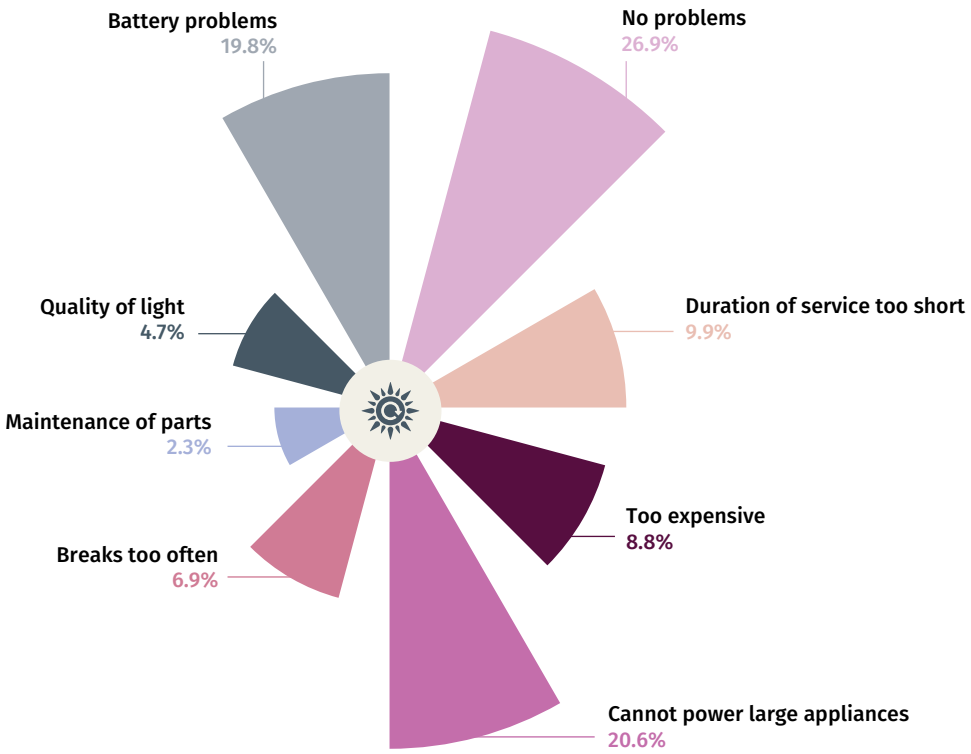
FIGURE 28 • **Availability (day and night) tier distribution for solar households**



Problems with the solar device

It is important to understand what problems households experience when using solar devices (Figure 29), as this is the key source of electricity for households without access to a mini-grid or the national grid. The three main problems reported by households were that they cannot power large appliances (20.6%), there are problems with the battery (19.8%), and the duration of service is too short (9.9%). These results are consistent with the low Capacity and Availability attribute tiers.

FIGURE 29 • **Most serious problem using a solar device**



PROVIDING ELECTRICITY TO HOUSEHOLDS WITHOUT ACCESS

Nepal has 6.1% of households in Tier 0 and 5.2% of households without any source of electricity. This section will discuss households that do not have any source of electricity available. The expense of connecting to the grid (36.4%), the distance of the grid line from the household (26.1%), and administrative issues (30.8%) are the main reasons households are not yet connected to the grid (Figure 30). About 30% of the households are not connected to the grid due to some administrative barriers—14.1% find the administrative process too complicated, while 15.4% are waiting for their application to be approved and 1.3% had their application refused. When considering how to move households out of Tier 0, the households facing administrative issues would be the easiest to focus on, as they are the most willing to be connected to the national grid if the utility is willing to facilitate the process.

Additionally, the costs involved in setting up a grid connection are substantial (Figure 31). The expenses for a household can climb up to more than 8000 Nepalese rupees (US$77.58) on average. The costs are not only for the connection fee but for internal wiring, electricity poles, and external wiring, all of which the household pays for.

FIGURE 30 • **Reason household is not connected to the grid**

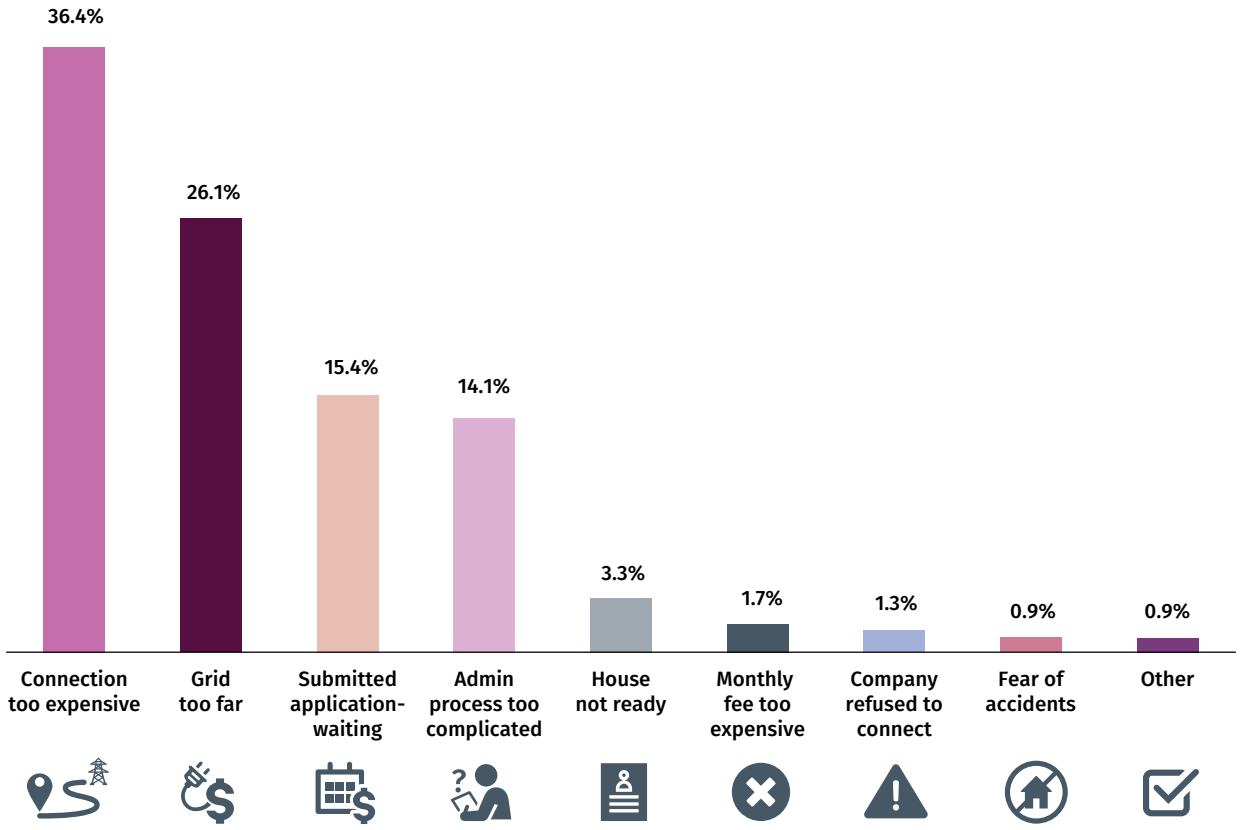


FIGURE 31 • **Investment costs for a grid connection (Nepalese rupees)**

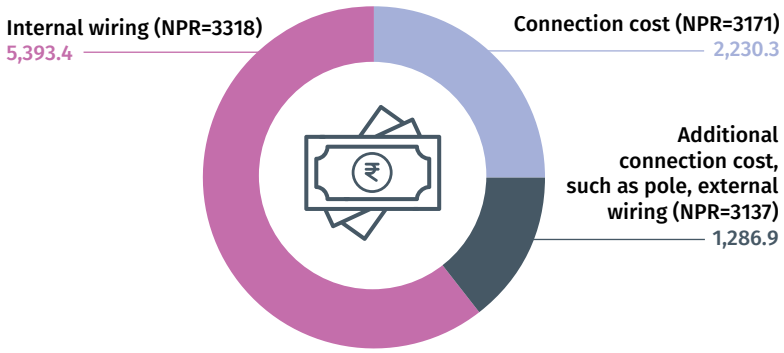
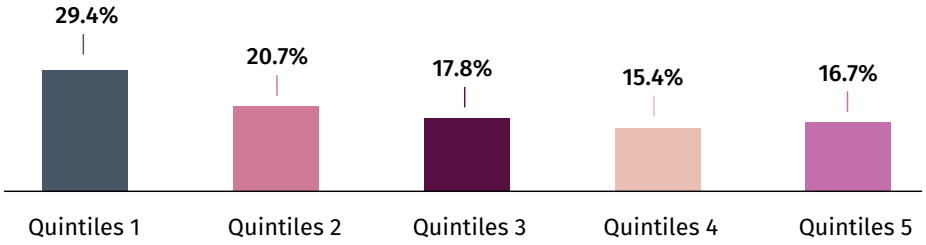


FIGURE 32 • **Expenditure quintiles of households with no electricity access**



About 68% of the households are in the bottom three expenditure quintiles (Figure 32), indicating that these are poorer households. The reasons vary as to why some households in the higher expenditure quintiles have not got a grid connection. However, the reason that financially better-off households with no electricity did not purchase a solar device may be clearer. In figure 33, households using dry-cell batteries or no electricity are on average closer to the national grid than mini-grid and solar users. One possibility is that households close to the grid are not purchasing solar devices because they have reason to believe they will have grid connection in the near future. This is further supported by the survey responses: 51.9% of households with no electricity stated that they expect to get grid connection within the next two years (Figure 34).

FIGURE 33 • **Distance to nearest grid by main source of electricity (meters)**

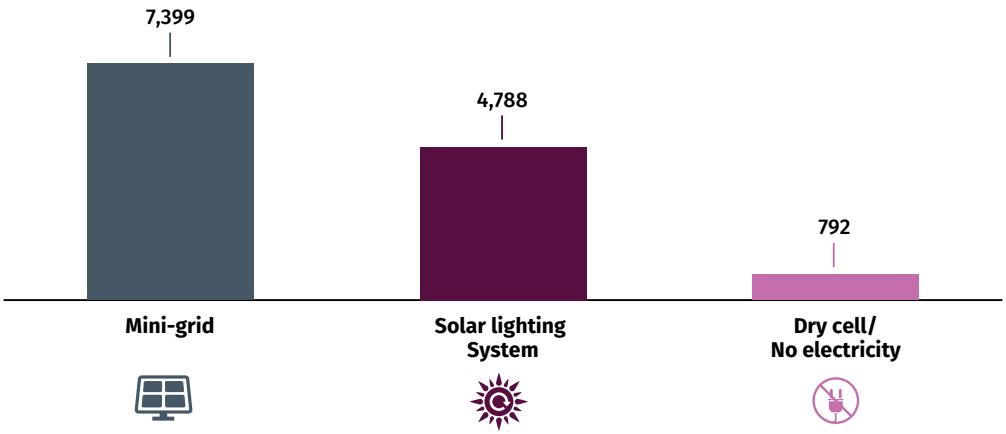
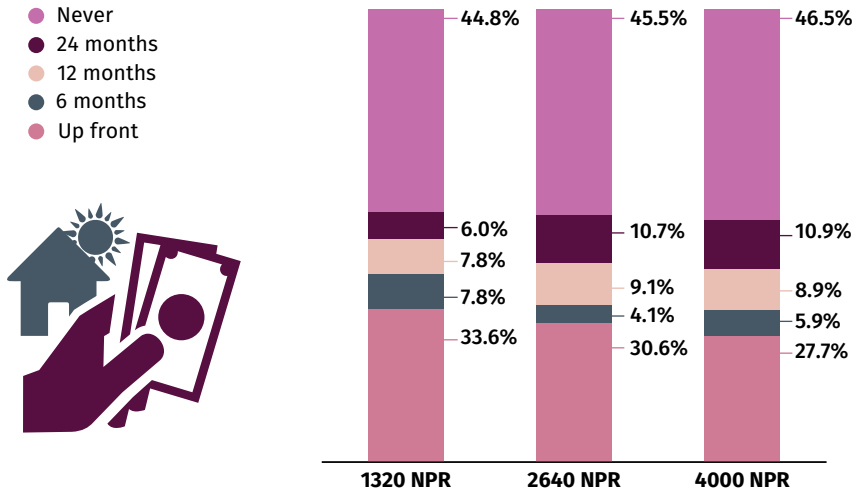


FIGURE 34 • **When household expects to get grid connection**

Households that do not expect to be connected to the grid in the near future would benefit from installing a solar device. Households with no electricity were asked whether they would be willing to pay for an SHS costing 4,000 Nepalese rupees (US$38.79). Given flexible payment options, 53.5% of the households were willing to pay for the solar device (Figure 35). The willingness to pay did not increase substantially for lower price points (2,640 and 1,320 Nepalese rupees, equivalent to US$25.6 and US$12.8, respectively). Households that indicated that they would never pay for the solar device were asked why. Reasons given were that they cannot afford the payments (79.8%), they prefer the national grid (9.5%), or that maintenance service is not available (8%). Considering these results, flexible payment options can be integrated into existing government programs and improved maintenance services could induce these households to adopt a solar home system as an interim solution.

FIGURE 35 • **Willingness to pay for a solar home system**



POLICY IMPLICATIONS

Nepal has undergone a rapid increase in its electrification rate over the past decade. The Government of Nepal committed to ensuring universal access to electricity by 2030 (99% of households using electricity) as part of its targets for Sustainable Development Goal 7 (SDG7). It plans to increase its installed capacity to 15,000MW and the overall per capita electricity consumption to 1,500 kWh. Nepal has 71.7% of households connected to the national grid, with 23% connected to off-grid sources, particularly to micro- and mini-hydro grids and solar lighting systems. Despite Nepal's high grid-electrification rate, the MTF analysis shows that only 17% of households across Nepal are in Tier 5 for electricity access. The results from the MTF Framework survey will allow the government to take stock of its current achievements and provide a detailed analysis on the needs and gaps facing households when it comes to better access.

With a majority of the households already connected to the national grid, Nepal is well positioned to move closer to the target of universal access. However, these grid-connected households experience three major issues that affect their level of energy access. The first issue is electricity supply shortages, particularly in between 6 p.m. and 10 p.m., a peak time for electricity usage. In 2018, the NEA was able to minimize load shedding for most of the country by effectively managing the load. Given the seasonality of electricity availability, the NEA will have to maintain this balance of demand and supply throughout the year. With the completion of a couple of transmission lines and the importing of electricity from India, the NEA further managed some of the unmet demand. To plan for reaching the ambitious targets for SDG7, the Ministry of Energy, Water Resources and Irrigation laid out a strategy in its White Paper, "Current Status and the Roadmap for the Future." There are planned investments to increase the installed generation capacity to 10,000MW for domestic consumption in the next 10 years. To ensure the distributional equity of grid electricity, the government is working on greater coordination between the central, provincial and local governments. Along with generation, there are concurrent proposals on constructing transmission and distribution lines across the country. The government needs to steadily continue toward these goals in order for households' electricity demand to be met.

The second issue households face is the high frequency of interruptions or outages in electricity supply. Households face 3 to 14 interruptions each week and outages that have a total duration of more than 2 hours per week. Third, households report that they experience problems with the voltage of the electricity supply to the extent that their appliances get damaged. Households are compelled to make additional investments in stabilizers to offset the issues they face with low voltages. Improvement in power supply shortages during peak hours could resolve availability problems and potentially decrease outages. Grid users below Tier 3 spend more than 200 Nepalese rupees (US$1.93) per month on backup sources; this amount could be saved and spent on grid-electricity of a higher tier once the supply issue is resolved. Addressing the quality of the electricity supply is another area that can improve levels of access and free up some of the household expenditure that is diverted into temporary solutions like stabilizers. The government's plan to strengthen and modernize the existing distributional network (for example, by laying underground cables in the major cities) can help address the problems of reliability and quality of electricity services. A consistent demonstration of these improvements will build trust among the households that they can depend on the services from the grid, which hopefully will increase the access to and demand for electricity.

Renewable energy contributed to 3.5% of Nepal's total energy generation. The off-grid sources of electricity have been targeted to households that are located in remote parts of the country where the national grid has not yet been extended. In particular, households connected to a micro-, mini-, or pico-hydro system are usually in rural areas in the Hill and Mountain regions. Households using mini-grids have limited availability of electricity supply during the day. They also face challenges

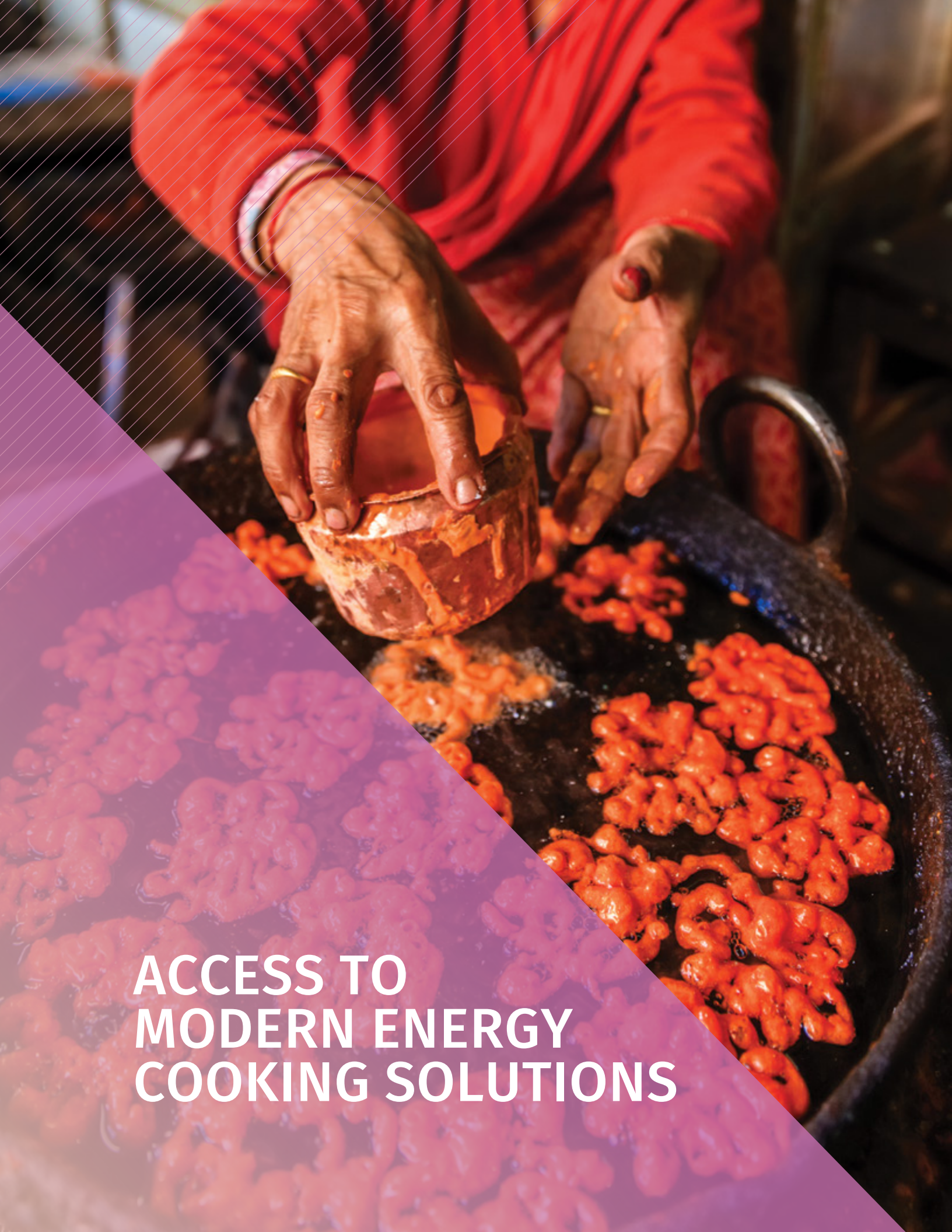
with electricity outages and quality of supply. To move households up the tiers for gaining better access, the hours of electricity supplied to households need to be increased. However, it is important to understand the patterns of consumption. The households using mini-grids appear to be a mixed group of households. One group uses electricity to power lighting and mobile chargers and does not plan to use more power. Another group of households owns a television or would buy one if electricity supply would power it. To address this issue, mini-grid operators that currently charge a fixed monthly fee can switch to a consumption-based billing system. By doing so, they can generate additional revenue and consequently increase generation capacity or extend operation hours to better meet the demand of the users.

Solar users face similar issues as the mini-grid users in using electricity, but the limitation in capacity is more pronounced for solar users. There is a high demand for increased capacity that would allow solar households to own and use a television. Because these households are located far from both the grid and mini-grids, a feasible solution could be to acquire a higher capacity solar device. The introduction and promotion of business models such as “pay as you go” can allow solar devices to be upgraded.

Another approach is to shift households to higher capacity solar-generated electricity on a larger scale. The government is proposing to establish a fund for local bodies to install solar power plants (100–500 kw capacity) through a cost-sharing mechanism. The solar plants would not only have the capacity to generate for local consumption but also sell electricity back to the grid. Along with this program, the government will prepare a set of procedures, regulations, and guidelines for the different levels of government and for collaborating with customers and the private sector.

There are about 5.2% of households with no source of electricity, whose major constraints are the distance from the grid and the costs associated with getting electricity supply. There are households that reside in close proximity to the national grid facing two main barriers to connecting: administrative obstacles and affordability. Administrative issues for households are an obstacle easy to solve by working along with the NEA. Issues related to affordability for last mile connections can be addressed through targeted subsidized access for the households likely to be poorer. The government is planning to launch a targeted program for certain disadvantaged groups in the population to provide renewable energy. For the households that reside too far away from the grid and will not be able to get a grid connection in the near future, low-cost interim solutions such as a solar lighting system should be considered to move them out of Tier 0. This would allow them to have access to some form of electricity connection that can provide basic amenities like lighting and phone charging during the peak hours of the evening.

The Government of Nepal through the Central Bureau of Statistics already tracks household-level data through the annual household surveys and the census. For access to electricity, the surveys track the binary measure on the share of households with lighting. Going forward, integrating more comprehensive survey instruments and questions can provide provincial and local governments with a detailed status of the electricity access of their population and facilitate more targeted policy measures and strategies to meet the SDGs on electricity access. Furthermore, future analysis can delve into the main determinants for households to adopt grid electricity, the impacts of electrification on education and health outcomes, and the way more reliable electricity service affects the consumption and demand of households.



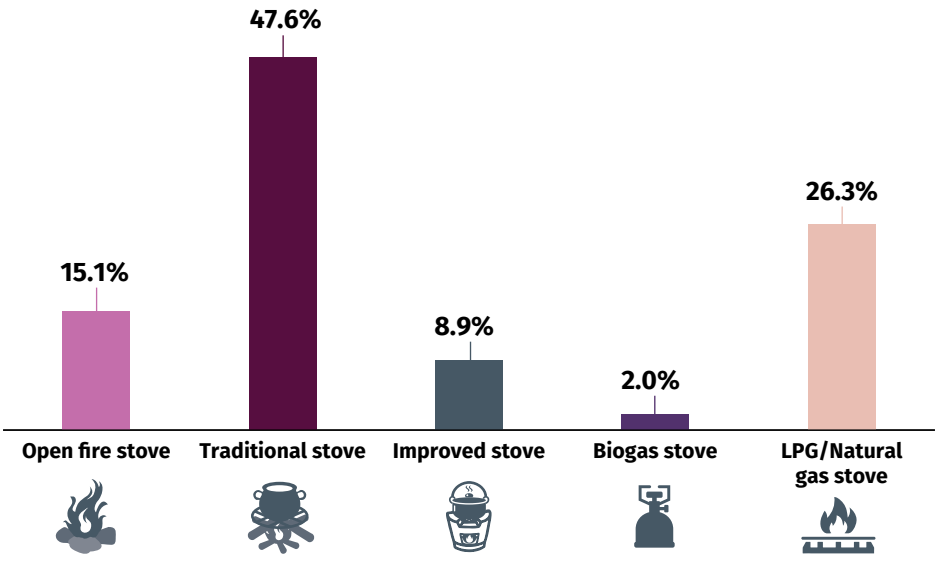
ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Measuring access to modern energy cooking solutions in Nepal is crucial, as the country has historically relied heavily on solid biomass, and making concerted efforts to change this trend is key to numerous potential positive outcomes. This chapter examines the cooking behavior of households, then assesses the level of access using the Multi-Tier Framework (MTF), and finally determines ways to move forward to increase access.

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS BY FUEL AND TECHNOLOGY

For the purposes of this report, the various types of cookstove used in Nepal were classified into seven stove categories: (i) open fire biomass, (ii) traditional biomass, (iii) improved biomass, (iv) biogas, (v) solar, (vi) liquefied petroleum gas (LPG), and (vii) electric cookstoves. In Nepal, 71.6% of the households use biomass stoves as their primary cookstove. An open fire stove is the primary stove for 15.1% of households and the traditional stove for 47.6%, making it the most common type of stove used as the primary stove (Figure 36). There are a variety of biomass stoves designed to improve efficiency and emissions (box 2), and 8.9% of the households use an improved biomass stove as their primary stove. Biogas, LPG, electric, and solar cookstoves are the types of clean-fuel stoves used in Nepal. Of the clean cooking solutions, 26.3% of the households use the LPG stove, making it the most common primary stove. Biogas stoves are used by 2% of the population, and a very small portion of the population uses electric and solar cookers.

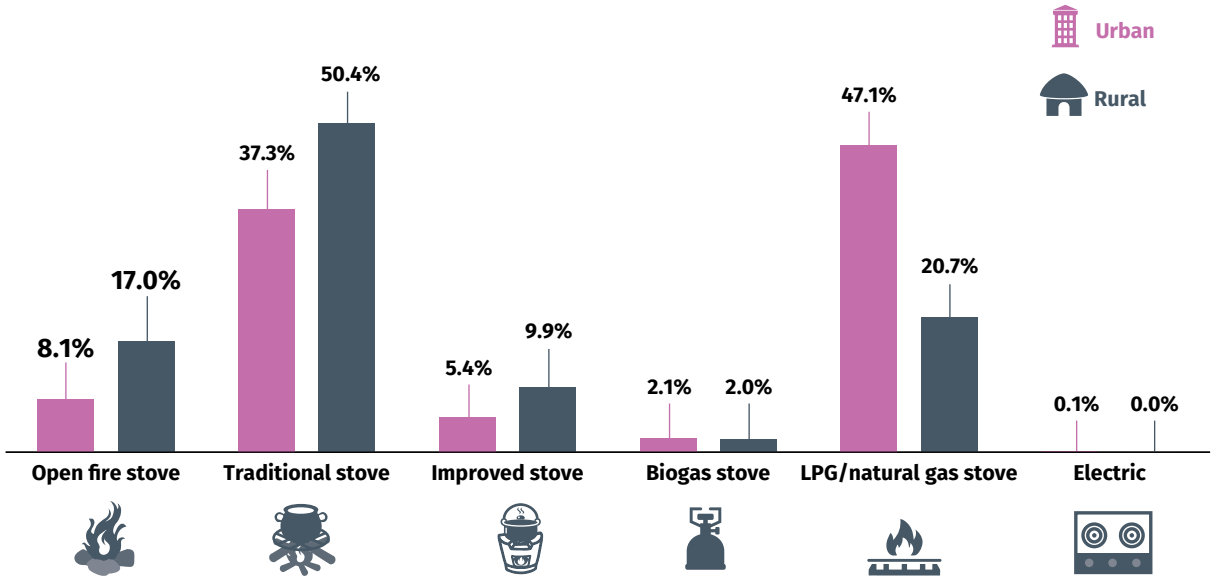
FIGURE 36 • **Distribution of primary stoves (nationwide)**



Note: The sample size is 6,000 households, or N = 6,000.

There are different patterns of use based on locality of the household, such as whether households reside in urban or rural areas (Figure 37). In urban areas, about half of the households use a clean-fuel stove as their primary stove. Over 47.1% of the households use an LPG stove as their primary stove, 2% use a biogas stove, and a very small portion use an electric stove (0.1% of urban households). The other half of the urban households use a biomass stove; the most common is the traditional stove (37.3% of households). An open fire stove is being used as a primary stove by 8.1% of the urban households, while 5.4% households use improved stoves. In the rural areas, clean-fuel stoves account for 22.8% of the primary stoves. LPG stoves are the most common type of clean-fuel stove in rural areas, but they account for a much smaller share, 20.7% of households, compared to urban areas. Biogas stoves are the primary stoves for 2.1% of the rural households. Biomass stove users are the overwhelming majority in rural areas. Of these households, 67.4% use an open fire or traditional stove. An improved cookstove is used by 9.9% of the rural households.

FIGURE 37 • **Distribution of primary stoves (urban-rural)**



Stove stacking

While most of the households in Nepal use only one type of stove, there are some households that use two or more different types at the same time. This practice is referred to as *stove stacking*. In Nepal, 16.4% of households use two types of stoves for cooking, while 0.7% of the households use three types of stoves (Figure 38). Most households that stack use an LPG stove along with a biomass stove. The two most common forms of stacking are to use an LPG stove with a traditional stove (7.2% of households) or with an open fire stove (2.7% of households) (Figure 39). It is not uncommon for households to use two different types of biomass stoves; 1% of households use a traditional stove with an open fire stove and another 1% use an improved stove with an open fire stove. More households using LPG stoves with a biomass stove consider the biomass stove as the primary stove and use the biomass stove for longer periods of time compared to the LPG stove. Stove stacking reflects a household's aspiration to use higher performing solutions, often used in addition to (rather than instead of) existing cooking solutions.

FIGURE 38 • **Stove stacking (nationwide)**

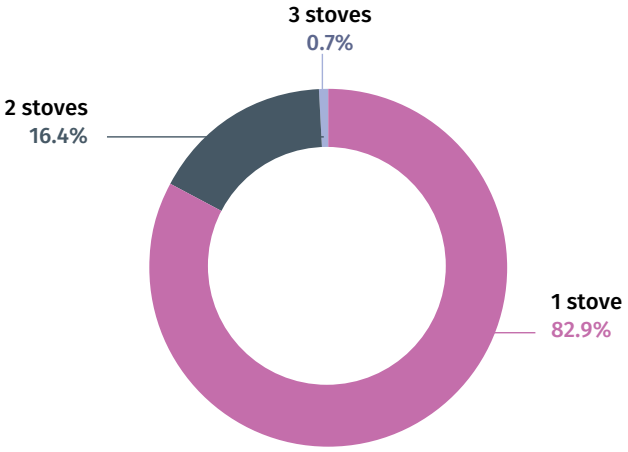


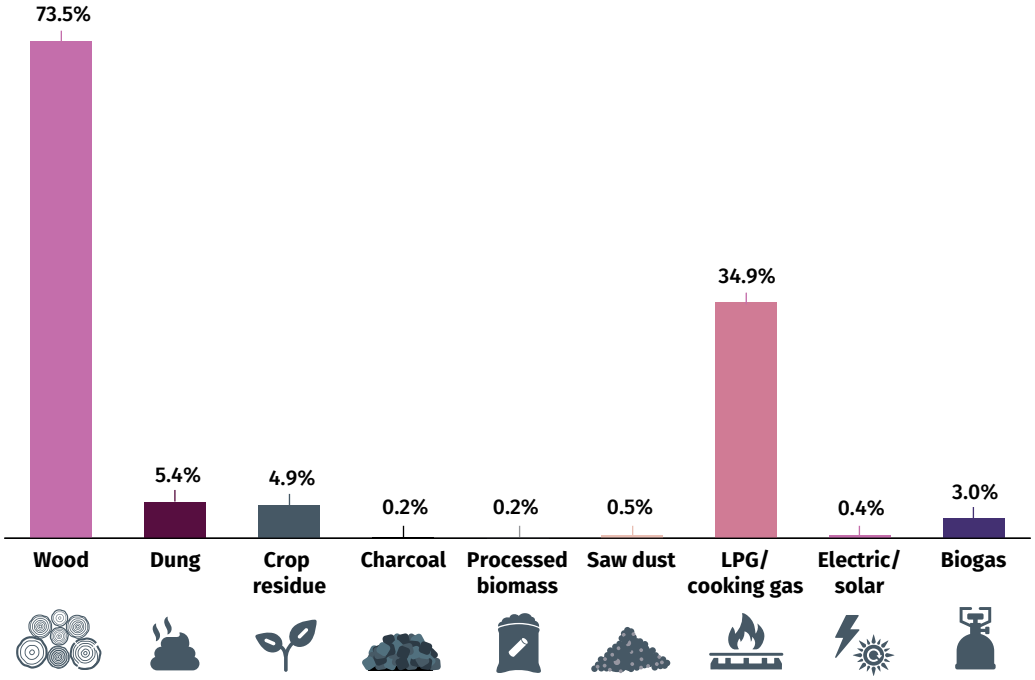
FIGURE 39 • **Combinations of stoves stacked (nationwide)**

7.2% Traditional + LPG	**2.7%** Open fire + LPG	**1.9%** Other	**1.2%** Improved + LPG
1.1% Open fire + Biogas	**1.1%** Traditional + Improved	**1.0%** Open fire + Traditional	**1.0%** Open fire + Improved stove

Fuel use

In Nepal, households are still heavily reliant on biomass to meet their cooking needs. The share of the total households using a fuel indicates the nationwide dependency on different fuel types. Firewood is the most widely used source of cooking fuel: 73.5% of the households across the country depend on wood (Figure 40). In rural areas, the percentage of households using wood is 78.5%, and in urban areas it is 54.8%. Animal waste (used by 5.4% of households) and crop residue or plant biomass (used by 4.9% of households) are the other sources of biomass fuel for households. Clean fuels are quite prevalent in Nepalese households: 34.9% of the households in Nepal use LPG and 3% of the households use biogas. These figures take into account households that use more than one stove type, that is, the households using LPG either for their primary stove or secondary stove. Looking at the breakdown of the proportion of LPG use by locality, 29.1% of households in rural areas use LPG compared to 56.5% of households in urban areas.

FIGURE 40 • **Fuel penetration rate: share of households using a type of fuel (nationwide)**



Fuel stacking

Fuel stacking refers to the practice where a household uses more than one type of fuel to meet their cooking needs. In Nepal, the pattern of fuel use closely follows the different types and number of stoves a household uses (Figure 41). About 80.7% of the households use one fuel to meet their cooking energy needs, with 55.3% of the total households using wood exclusively and 22.5% using LPG exclusively. About 15.6% of the households use two fuels, and 3.7% use three or more fuels. The most common form of fuel stacking is having wood and LPG as cooking fuels, practiced by 7.9% of households. Other households stack different types of solid biomass, such as wood, animal dung, and crop residue. About 4% of the households use wood and animal waste together (Figure 42). While clean fuels such as LPG and biogas are part of the energy mix for households that stack fuels, there is a strong dependence on solid biomass.

FIGURE 41 • **Fuel stacking (nationwide)**

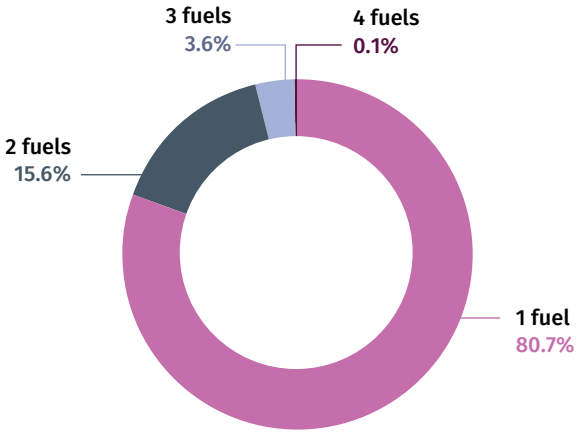


FIGURE 42 • **Combinations of fuels stacked (nationwide)**

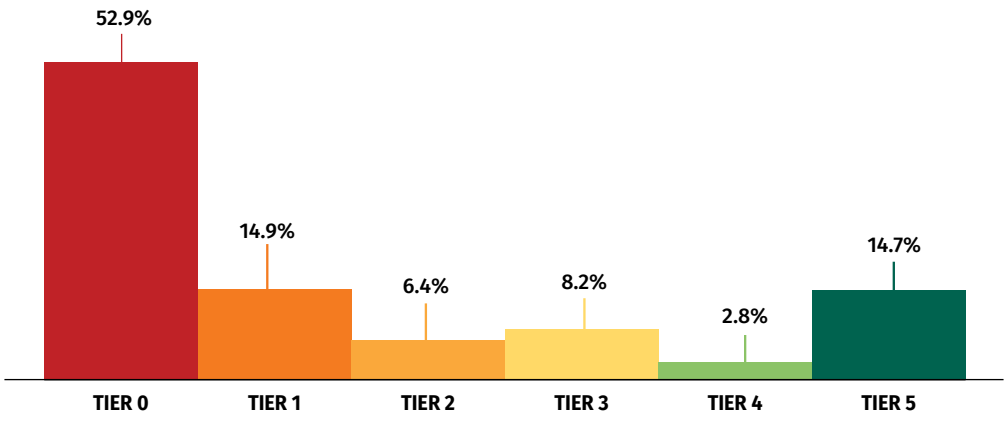
7.9%	0.4%	4.1%	0.8%	1.6%
LPG+wood	LPG+electric	Wood+dung	Wood+crop residue	Wood+biogas

0.4%	2.3%	0.4%	1.4%
LPG+wood+dung	LPG+wood+crop residue	LPG+wood+saw dust	All other

DISTRIBUTION OF TIERS FOR MODERN ENERGY COOKING SOLUTIONS

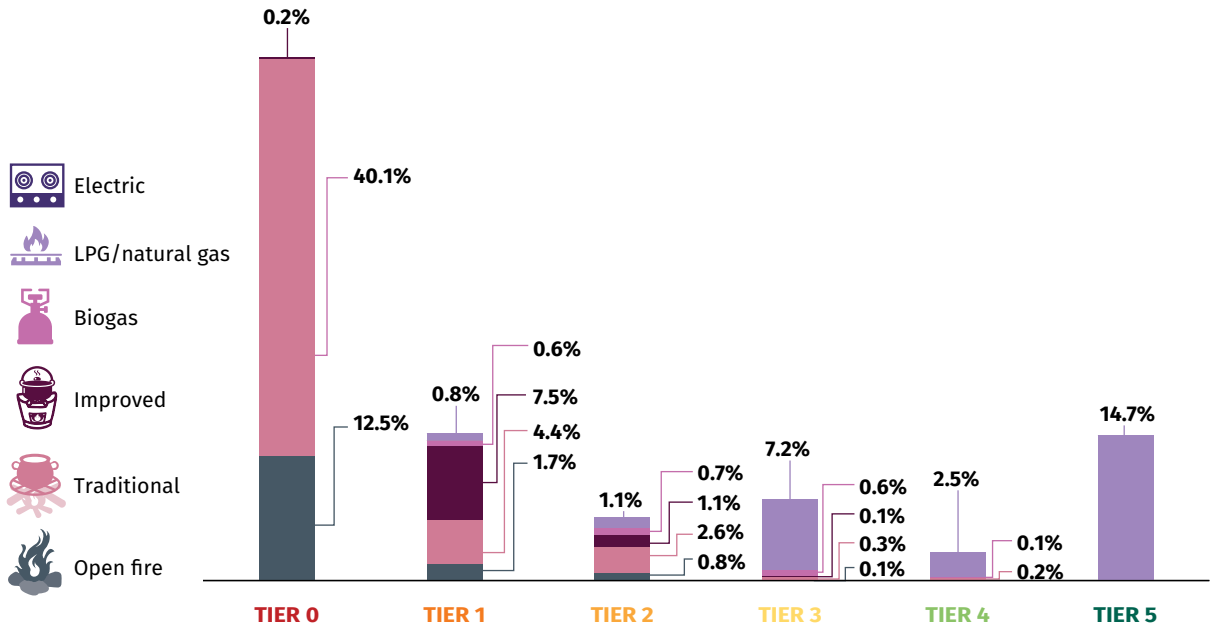
In Nepal, the MTF measures a household's access to modern energy cooking services using five attributes: Cooking Exposure, Convenience, Safety of the primary cookstove, Affordability, and Availability of primary fuel. The final aggregate tier for a household is based on the lowest tier that the household attains among all the attributes. A majority of the households are clustered along the lower end of the tiers—52.9% of the households are in Tier 0 (Figure 43), about 14.9% of households are in Tier 1, while Tiers 2 and 3 have 6.4% and 8.2% of the households, respectively. Tiers 4 and 5 represent households that have attained access to modern energy cooking services and each have 2.8% and 14.7% of the total households in Nepal.

FIGURE 43 • **MTF cooking tier distribution (nationwide)**



The combination of stove and fuel plays an important role in determining the aggregate tier level for a household. In figure 44, households with solid biomass stoves are held in lower tiers while clean-fuel stoves are in higher tiers. The high proportion of households using traditional biomass stoves (more than 50%) keeps households concentrated in the bottom three tiers (Tiers 0 to 2) mostly because of the Cooking Exposure attribute. Households who primarily use LPG are spread across Tiers 3 to 5. Some of the households that use an LPG stove as their primary stove are pulled down to lower tiers, some even to Tiers 1 or 2, because they use a secondary stove that has a low tier. Households that use an LPG stove exclusively may also be in Tiers 3 or 4 because the fuel is unaffordable (Affordability attribute) or it takes a long time to purchase the LPG (Convenience attribute).

FIGURE 44 • **MTF tier distribution by primary stove type (nationwide)**



To understand which households are in lower tiers, it is important to investigate how households fare on the different attributes and what attribute presents an obstacle for households to move up the tiers. The next section looks at how households are placed in the different tiers for each of the attributes pertaining to modern energy cooking services. The subsequent section delves into options for improving access through the results of a willingness to pay assessment.

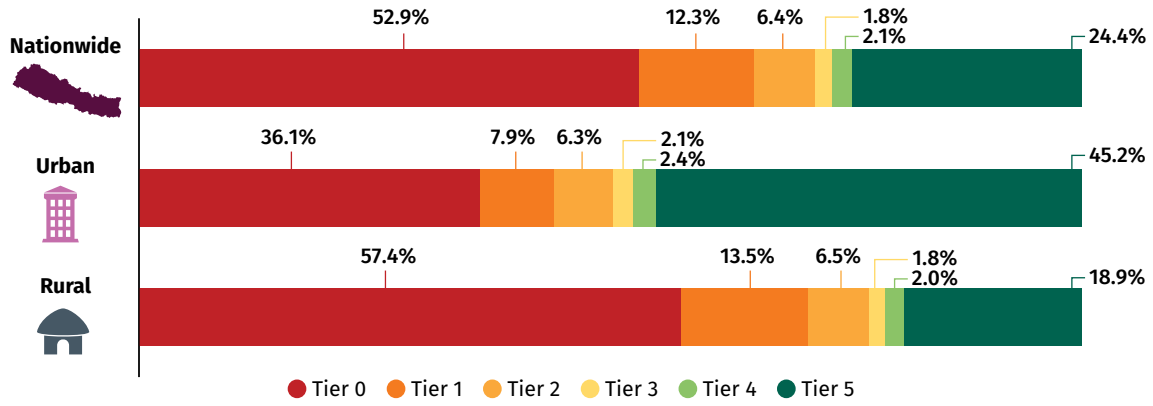
MULTI-TIER FRAMEWORK ATTRIBUTES

Cooking exposure

The Cooking Exposure attribute is a proxy indicator to measure the health impacts of cooking activity on the primary cook. It is calculated by, first, determining the level of emissions based on a combination of fuels and stove technologies reported in the data. Then the Ventilation factor is measured based on the structure of the household's cooking space. The ventilation factor plays a role in mitigating pollutants from cooking. The final Cooking Exposure Tier is assigned as a composite of the Emission and Ventilation levels (annex 3) and is weighted by the amount of time spent on each stove, if a household uses more than one stove type.

In Nepal, 24.4% of households are in Tier 5, as they exclusively use clean-fuel stoves for their cooking needs (Figure 45). In urban areas, the share of households in Tier 5 is 45.2%, while in rural areas only 18.9% of the households are in Tier 5. In comparison, the share of rural households in Tier 3 and 4 are low and do not differ much across locality. On the other side of the tier scale, more than half of Nepalese households are in Tier 0 and 1 for Cooking Exposure, due to the use of traditional (open and enclosed fires) stoves with poor ventilation.

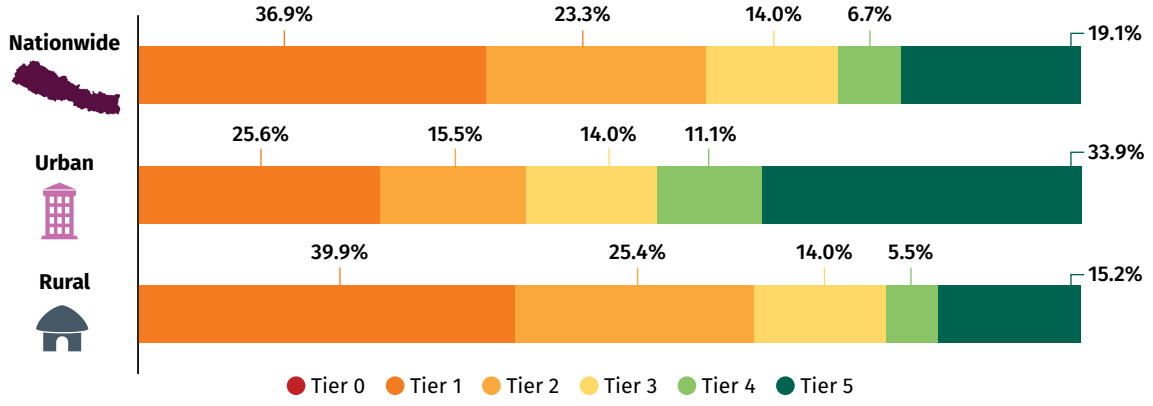
FIGURE 45 • **Cooking exposure tier distribution (nationwide)**



Convenience

The attribute on Convenience is composed of the amount of time a household spends acquiring and preparing the fuel each week and the amount of time a household spends preparing a stove before each meal. Across the country, a majority of the households are in Tiers 1 and 2 for Convenience. This pattern is true for both rural and urban areas, although urban areas have a greater share of households in Tier 5 (Figure 46). Urban areas have 25.6% of households in Tier 1, compared with 39.9% of rural households, while 33.9% of urban households are in Tier 5, compared with 15.2% of rural households. The results reflect the large percentage of urban households that use a clean-fuel stove as their primary stove (which requires much less time to acquire and prepare fuels for use and to prepare the stove for cooking). Also, urban households are more likely to purchase fuel, while rural households are more likely to gather firewood, which is time consuming.

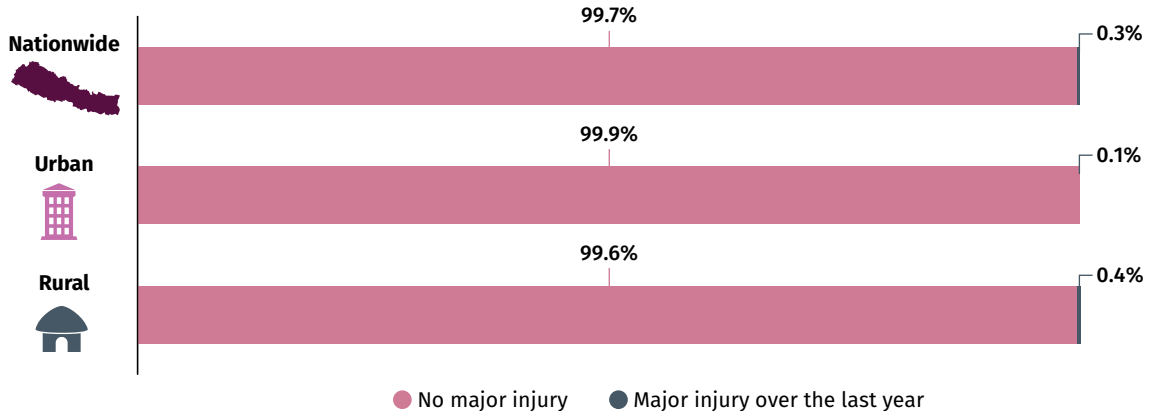
FIGURE 46 • **Convenience tier distribution (nationwide)**



Safety of primary cookstove

Most households did not recall a major injury that required medical attention while using the stove over the past year. Only 0.3% of households reported a death or a serious injury of a household member, including permanent health damage, burns, or fire, within the past year related to cooking and cookstoves (Figure 47).

FIGURE 47 • **Safety tier distribution for cooking (nationwide)**



Fuel availability

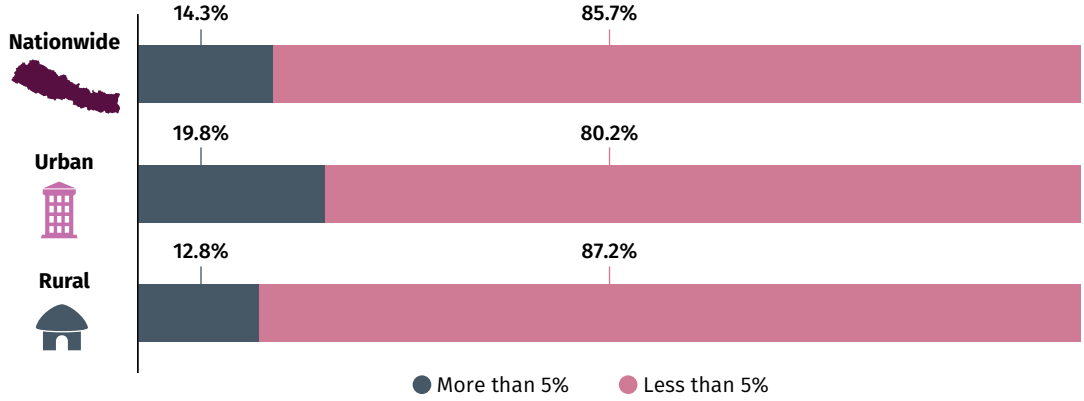
Fuel Availability affects about 9.8% of households across Nepal, that is, these households reported that their primary fuel was available for 80% or less of the year. There was no significant difference between rural and urban households with respect to Fuel Availability: 90.8% of urban households and 90% of rural households responded that their primary fuel was always or mostly available (Figure 48). It appears that households facing Fuel Availability issues are more likely to use multiple fuels. Among households with Tier 5 level of Availability, 18.7% use multiple fuels to meet their cooking needs, compared to the larger 26.8% of households in Tier 4.

FIGURE 48 • **Primary cooking-fuel Availability tier distribution (urban-rural)**

Affordability

Unaffordability prevents households from reaching a higher tier for access to modern energy cooking solutions. The Affordability attribute is formulated by comparing the share of the annual expenditure on cooking fuel to the total annual household expenditure. For 14.3% of households, cooking fuels account for more than 5% of monthly spending (Figure 49). Affordability is more burdensome to urban households (19.8%) than rural households (12.8%).

FIGURE 49 • **Affordibility of cooking solution tier distribution**

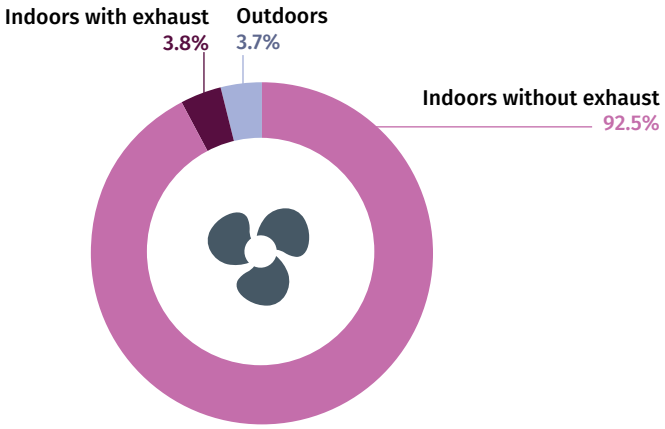


IMPROVING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

In order to improve access for households, this section takes a closer look at the attributes that constrain households to lower tiers: Cooking Exposure, Convenience, and Affordability.

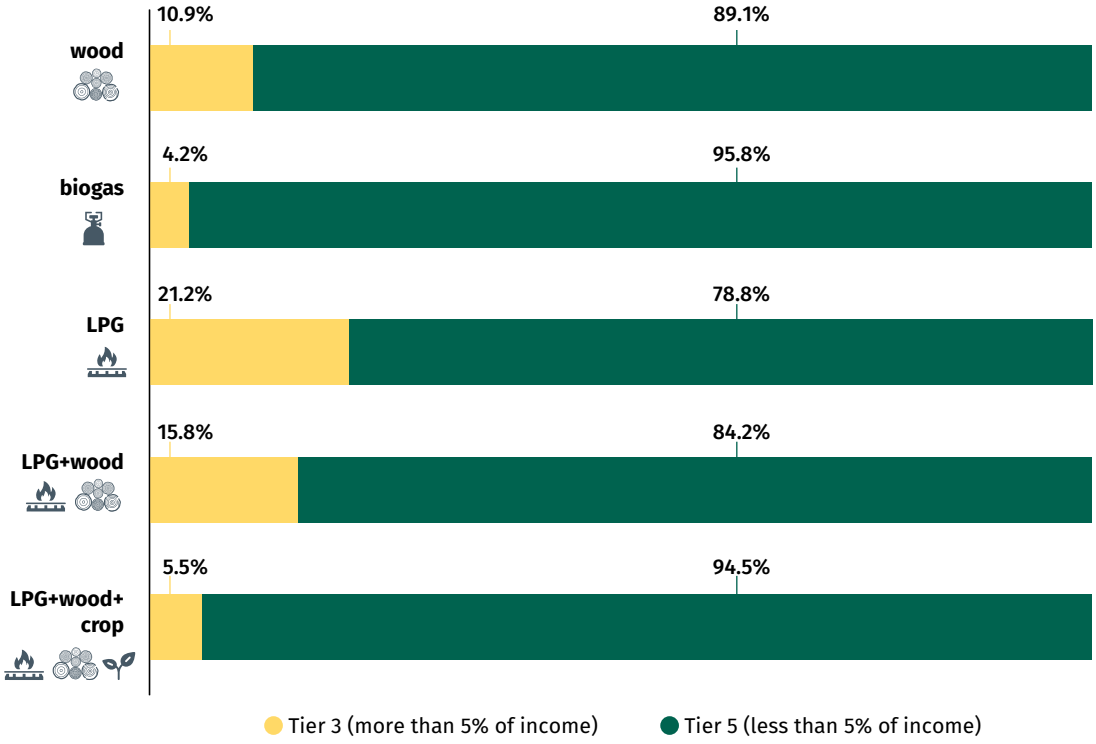
The Cooking Exposure attribute presents a major obstacle for most Nepalese households; their current status prevents them from attaining a higher tier. The stove design determines the Cooking Exposure attribute (the Emissions factor) along with the Ventilation level. It is extremely common for households to cook indoors without any exhaust system (Figure 50). Households using traditional stoves, with either open fire or enclosed fire, are placed in lower tiers based on their stove design. In addition, 92.5% of the households that use a biomass stove use it indoors without an exhaust system, which increases the exposure. A mere 3.7% have a chimney either in the kitchen or on the stove, and 3.8% of biomass users cook with stoves outdoors. Having better ventilation can decrease their exposure; shifting households to improved or cleaner solutions will help to move them to a high level of access.

FIGURE 50 • **Ventilation structure and cooking location**



The Convenience attribute is another factor that holds households back in lower tiers. The convenience of a cooking solution is related to the hours spent every week acquiring the fuel and the minutes spent in preparing the stove for cooking. Even if the Cooking Exposure attribute is not an obstacle, households can be held in a lower tier if they are spending between three and seven hours in a week collecting or acquiring fuel or between 10 and 15 minutes preparing the stove before they cook a meal. Households using fuelwood and animal waste spend a substantial amount of time in collecting and preparing their fuel for the final use.

FIGURE 51 • **Affordability attribute by fuel source (with fuel stacking)**



In Nepal, affordability is an issue affecting households using LPG as well as wood for their cooking needs. The combinations of different fuels can lead to higher costs for households, thus making certain cooking solutions unaffordable. Figure 51 shows the Affordability Tier comparing the households with different combinations of fuels, focusing on households that have a problem with affordability. In general, more households are in Tier 3 when they stack their fuels:15.8% of households using a combination of LPG and wood are in Tier 3. It is possible that fuel stacking is practiced by poorer households because unaffordability causes them to switch between different fuel types. However, affordability is not only an issue of fuel stacking, as there are costs associated with the use of clean fuels like LPG. We see that 21.2% of households are spending more than 5% of their expenditures on using LPG exclusively.

INCREASING THE USE OF CLEAN FUEL AND IMPROVED COOKSTOVES AS THE PRIMARY COOKING SOLUTION

The majority of households in Nepal use traditional stoves exclusively or in combination with another stove type. To move households from lower tiers to higher tiers of access, the first issue to tackle is the Cooking Exposure attribute and switching households over to less polluting stoves and fuels. If affordability and supply of LPG and other clean fuels are limited in the short term, shifting households to improved stoves may be more feasible. Under the Government of Nepal's National Improved Cookstove (ICS) Program, improved biomass cookstoves, new business models, and investment opportunities were promoted across the country. To further enhance this understanding of consumer preferences and demand, the MTF survey asked households that were still cooking with traditional stoves, their willingness to pay to use an improved cookstove. For households to improve their levels of access, their willingness to pay for an improved cooking solution can give an indication of possible price points and solutions. For this assessment, households using a traditional stove were theoretically offered one of two types of improved stove and randomly assigned a price point. The stoves offered were the three-pothole metal ICS (hereafter metal ICS) and the Mimi Moto stove. The metal ICS ranks in Tier 4 for emissions and Tier 2 for efficiency (as tested by the Renewable Energy Test Station Nepal). The Mimi Moto stove is a forced-air gasifier stove that ranks as Tier 4 on Emissions and Efficiency (as tested by Colorado State University). There were three different price points used for each stove: full price, 60%, and 30%. Households were shown a photograph and given a description of the features of the stove (box 3). Enumerators then asked if they would be willing to pay a full or reduced price for a metal ICS (full price was 5,000 Nepalese rupees or US$49.4) or a Mimi Moto stove (full price was 7,000 Nepalese rupees or US$69.2). If a household refused the offer at the upfront cost, they were then asked if they would pay the cost over a period of 3 months, 6 months, or 12 months.

BOX 3 • STOVES USED IN THE WILLINGNESS-TO-PAY ASSESSMENT

The household survey included a module that asked households using traditional stoves what they would be willing to pay for an improved cookstove. The households were assigned one of two types of ICS for this assessment: either a three-pot-hole metal ICS or a Mimi Moto stove. The households were also presented with a randomized price of either 30%, 60%, or full price. The main features and options for installment payments were presented to the households.

Three-pot-hole metal ICS

The three-pot-hole model with ash tray (but without water tank) stove provides households with cooking as well as space-heating options. As it has a chimney to take smoke out of the kitchen, it can greatly reduce indoor air pollution (IAP). If properly used, the stove also helps to reduce the amount of firewood used in the stove by about 50%. It is made of metal and is durable. The ash tray helps in easy removal of ash. Also, proper use of the cookstove will surely reduce cooking time per meal. The stove can also help raise room temperatures to a comfortable level.

Mimi Moto stove

The Mimi Moto stove has a single-pot-hole/burner. It can reduce IAP in the kitchen, as it emits fewer pollutants compared to the traditional cooking stove. If properly used, the stove also helps to reduce the amount of firewood used by about 50%. This stove performs best with processed fuel or pellets. Also, proper use of the cookstove will reduce the cooking time per meal. It is easier to start a fire (because of a small combustion chamber) with this stove, and the stove is suitable for light and moderate cooking needs. This stove can be easily carried from one place to another, as it is portable. The stove supplier may provide consumers with after-sales service.

Reduction in the upfront cost (for example, via subsidy) and payment flexility (for example, through installments) could help expand the use of ICSs in Nepal. For households offered a metal improved cookstove, with the highest subsidy level (60% of full price of 1,500 Nepalese rupees or US$14.54), 46.1% of the households accepted the offer upfront, while 36.2% would not accept the offer under any installment payment flexibility. At 30% subsidy, the share of households willing to pay upfront was 25.4%, while 52.4% of households refused the offer. At full price (5,000 Nepalese rupees or US$48.48), only 13.7% of the households were willing to pay for a stove upfront, and 64.6% of the households would not be willing to accept any offer (Figure 52).

FIGURE 52 • **Willingness to pay for a metal improved cookstove with a chimney**

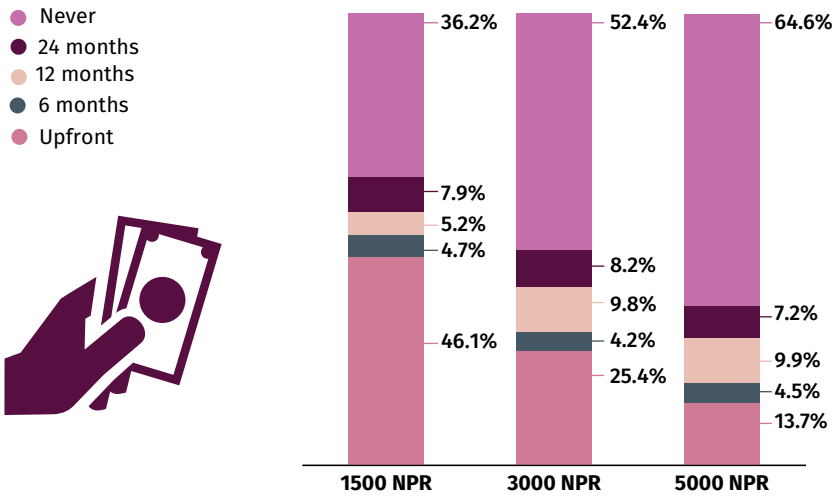
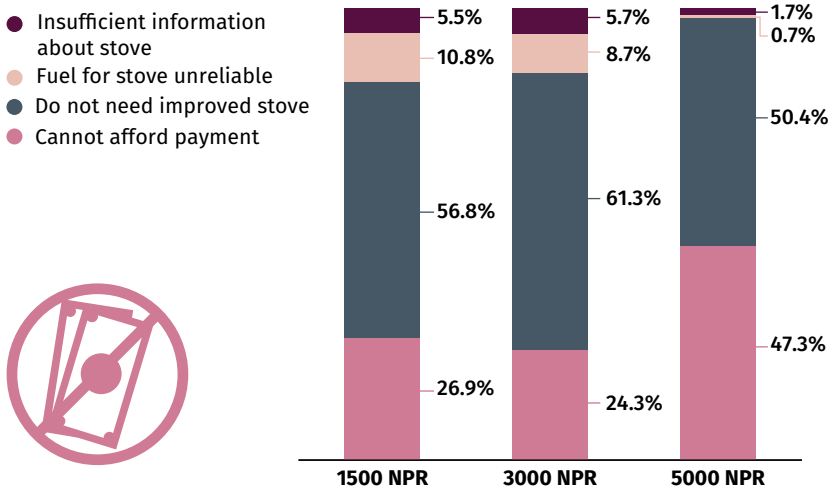


FIGURE 53 • **Reasons for not accepting the offer (metal ICS)**



For the households who were not willing to pay for a metal ICS even with time flexibility, the survey asked why they would not pay for the stove (Figure 53). With the highest subsidy level, 56.8% of households responded that they did not need an improved stove for their cooking and 26.9% said that they could not afford the payment. A much smaller fraction of households said they would not be willing to pay for the stove because they had insufficient information about the stove or because the fuel used in the stove was unreliable. For the other price levels, households rejected the offer because of the cost of the stove or because they did not require an improved stove. Thus, it is important to address affordability and consumer awareness of improved solutions.

For the Mimi Moto, a majority of the households were not willing to pay for the stove at any of the price levels, even with installments or time flexibility for the payment (Figure 54). At 60% subsidy (2100 Nepalese rupees or US$20.36), 20% of the households were willing to pay upfront and 56% were not willing to pay for the stove. The share of households not willing to pay for a Mimi Moto goes up to 65.2% of households with a subsidy of 30% (4,200 Nepalese rupees or US$40.72) and 75.1% at full price (7,000 Nepalese rupees or US$67.88). The share of households willing to pay upfront for a Mimi Moto stove with 30% subsidy and at full price correspondingly decreases.

The cost of the stove and the lack of perceived need for an improved stove were the main reasons households were not willing to pay for the Mimi Moto stove at any price level (Figure 55). Those two reasons accounted for the majority perception of the households who were not willing to pay for a Mimi Moto.

FIGURE 54 • **Willingness to pay for a Mimi Moto stove**

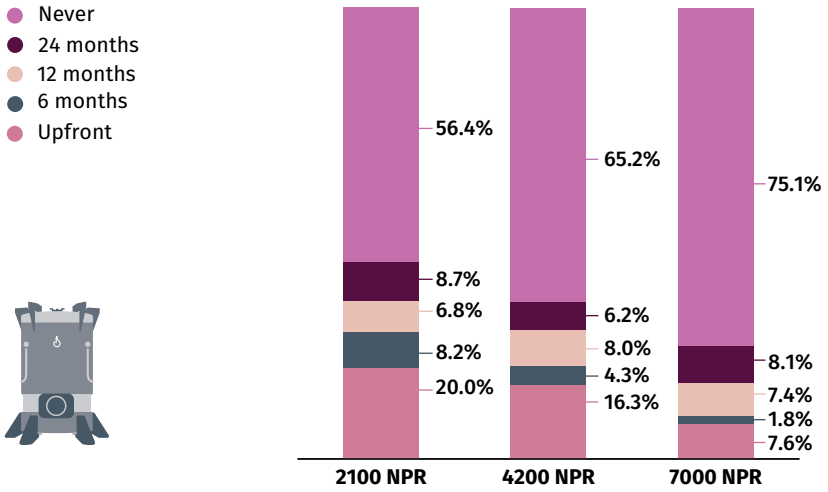
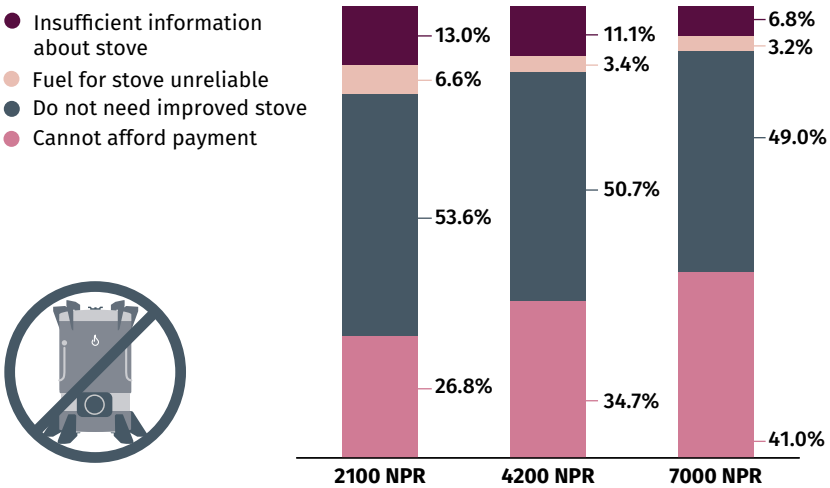
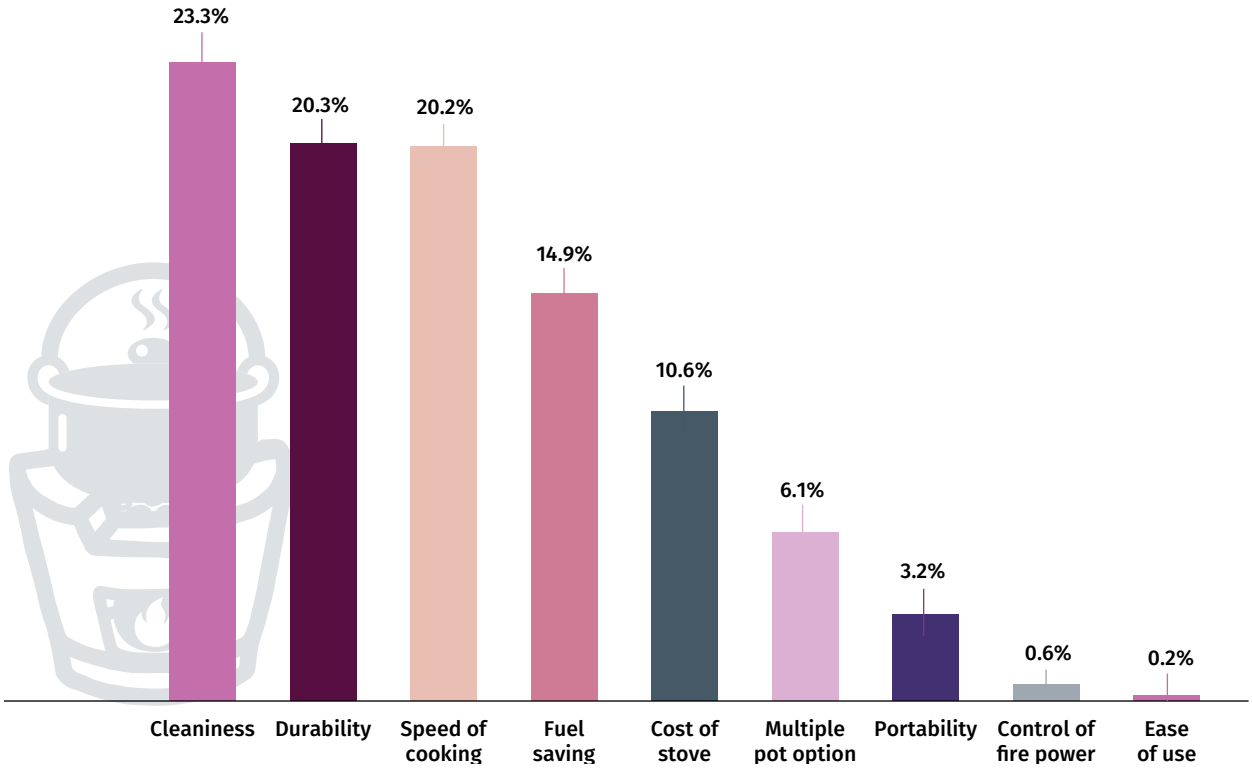


FIGURE 55 • **Reasons for not accepting the offer (Mimi Moto stove)**



The households that were not willing to pay for either stove under any price condition were also asked about the most desirable features they sought in a cookstove (Figure 56). Cleanliness and durability of the stove are the most important features that 23% of the households listed. About 20% of the households stated that they would like a stove that affects the speed of cooking, while 15% said that the stove should save on fuel. A smaller share, 11% of households, mentioned that the cost of the stove was important, and 6% said having multiple pot options was a key feature. When working to design and promote improved or clean cookstoves in Nepal, these preferences need to be accounted for in order to have households fully adopt the stoves.

FIGURE 56 • **Desired features of the cookstove**



While a majority of the households in Nepal rely on traditional stoves and solid biomass to meet their cooking needs, there is a significant share of households using clean-fuel stoves across the country, particularly LPG stoves. Not only are there households already using LPG stoves exclusively but also households in both urban and rural areas using LPG along with a traditional stove (usually with solid biomass). For these households, the Affordability and Convenience attributes need to be addressed. On average, households spend an annualized monthly cost of 1087 Nepalese Rupees (US $10.54) on LPG. Since these households currently show a preference for clean fuel, the question is how to get households to completely switch over to gain the full health benefits of using clean fuel. One of the main obstacles for LPG stove users is the Affordability attribute. For poorer households, these high costs can pose a barrier to switching over. The second issue is the convenience of acquiring the fuel, particularly for households in rural, remote areas. Nepal is highly reliant on imports of LPG from India to meet domestic demand. To meet the growing demand and reduce transportation costs, Nepal Oil Corporation reports that a 37km pipeline has started being constructed between India and Nepal (between Motihari and Amlekhgunj). In the medium term, access can be expanded to reach more urban households who already constitute a large share of the LPG users. For the expansion of other clean-fuel stoves such as an electric or induction stove, the problems of the Availability, Reliability, and Quality attributes that affect electricity access in general, need to be addressed for it to become a viable solution.

POLICY IMPLICATIONS

Compared to a Nepalese household's access to electricity, Nepal has a long way to go to address access to modern energy cooking solutions. The MTF survey finds that traditional cooking technology is still a predominant part of a Nepalese household's kitchen. Households rely on both traditional open fire stoves (15.1% of households) and traditional enclosed fire stoves (47.6% of households). Given that households depend on traditional stoves, solid biomass is the most important source of cooking fuel and includes firewood, animal dung, and crop or plant residue. Close to three-quarters of households (73.5%) use firewood to meet their cooking requirements. The heavy use of biomass as cooking fuel brings substantial exposure to fumes while cooking, keeping many households in lower tiers. Besides the combination of stove and fuel, households across Nepal are in lower tiers because of their status in the Convenience and Affordability attributes.

For households to move to Tiers 4 and 5 from the lower tiers, switching over to clean fuels such as electricity can be a medium- to long-term solution, provided clean energy forms are available at a reasonable price and quality. As most of the LPG used in Nepal is imported, its use entails high transportation costs, in terms of both money and time. Electricity supply is still unreliable, with unscheduled outages being common across the country and voltage problems damaging appliances. However, with urban areas experiencing some of the benefits from better supplies of both LPG (with a higher consumer base) and electricity (fewer disruptions in supply), the expansion of clean-fuel stoves is more feasible. For households already using clean fuels, particularly LPG, a small share is still in Tiers 2 and 3 because of the Convenience and Affordability attributes. In its White Paper "Current Status and Roadmap for the Future," the government proposes to implement a program of "an electric stove at every home." The Government of Nepal's strategy for improving access to cleaner fuels is first to encourage electric cooking and to reduce the reliance on imported LPG, thereby reducing the trade deficit as well.

Biogas is another clean cooking fuel with potential to be adopted by a wider portion of the population. Active government support has resulted in the establishment of biogas construction companies that have the capacity to build biogas plants for rural households with access to animal waste. These companies have the incentive to increase awareness of the benefits and convenience of cooking with biogas. Thus, there is potential that biogas penetration will continue in the future. The Biomass Energy Strategy of the government outlines several steps to support the expansion and coverage of biogas for households using biomass. The strategy is to provide financial and technical assistance for research on biomass technologies, to include private sector participation in production and marketing of biogas stoves and digesters.

LPG and electricity may not be available or affordable to many households, and biogas may not be a feasible strategy in some areas of the country; thus it is equally important to make improved biomass stoves used with fuels such as firewood and animal waste a viable option for these households. Improved stoves offer efficient burning of fuels and better exhaust and can bring households relying on biomass to higher tiers. Although the government-supported programs (such as the Rural Energy Policy 2006, National Energy Strategy, and Renewable Energy Subsidy Policy 2016) assisted in the awareness building and penetration of improved cookstoves to an extent, our results show that there are still more households that use a traditional stove, mainly because they find improved cookstoves unaffordable or unnecessary. To lower the cost barrier, additional payment options could be offered as households demonstrate a higher willingness to pay for an improved cookstove when offered

reduced upfront costs and payment flexibility. This points to the need of awareness programs and behavioral reinforcement for complete adoption of cleaner cookstoves and incentives such as smart subsidies and financing for users. Awareness should continue to be raised among households and communities that do not currently perceive the need for improved stoves. Efforts should be made to provide information on the benefits of clean cooking as well as on the as stove options available. Based on responses to the present survey, the ease of use, speed of cooking, and cleanliness of the stove are features households that cook with traditional stoves rank as important. Thus, an emphasis on these features can be considered to create more demand for the improved cookstoves.

Simultaneously, Nepal needs to bring markets closer to the target users through the private sector with the support of result-based incentives. There should be a variety of affordable choices and assurances of reliable supply. The government is already moving in this direction with the Biomass Energy Strategy emphasizing investing in research and development and market mechanisms and promoting private sector participation. For quality assurance and monitoring of the access to clean cooking in qualitative terms, the country needs to have a decentralized testing and labeling regime for stoves being sold in the market. Further, local governments have a very crucial role to play in improving access to clean cooking solutions, and their capacity needs to be strengthened in this regard. As the ultimate goal is to make lives of people (mainly rural women and poor) better by safeguarding health, conserving the environment, and reducing drudgery, the focus should be on indoor air quality and kitchen management: less travel distance around kitchen, comfortable sitting, and proper ventilation, for example. Clean cookstoves, clean fuel, and proper kitchen management all need due consideration when designing and implementing clean-cooking programs. With a multi-pronged approach, Nepal can address the different cooking and energy needs and gaps facing households.

ACCESS BASED ON GENDER

The level of access to better electricity and modern clean cooking solutions can be looked at from a gender perspective, as males and females may make different choices regarding means of electricity and cooking. These potentially divergent choices could be due to distinct preferences or different levels of awareness between men and women. Additionally, men and women might face different barriers or constraints to access. To examine this effect, the report presents the household's choice of electricity source and type of cookstove depending on the sex of the household head. Furthermore, given the evidence that women carry the burden of unsafe energy solutions and the access-to-electricity gap, women would benefit more from using cleaner and more convenient energy solutions, especially in terms of time use. For example, women are primarily responsible for purchasing, collecting, and preparing the fuel for cooking activities, as well as preparing the cookstove. Thus, this section examines the differences in how women use time depending on the type of energy solution used in the household. The results presented are important indications of the patterns found in Nepal but do not imply causality.

OVERVIEW OF FEMALE- AND MALE-HEADED HOUSEHOLDS

In Nepal, a large proportion of households have a male as the head (81.8%) compared to households with a female head (18.2%). These figures, added to the fact that 40.8% of the female household heads do not have a spouse—they never married or are divorced, separated, or widowed—reflect that when there is a husband and wife in a household, males are likely to be the head of household. Female-headed households have a lower budget and have received less education than their counterparts. More of female-headed households belong to the bottom quintile of household expenditure (31.1%) compared to male-headed households (17.6%) (Figure 57). A majority of female household heads had no education (66.8%) compared to a lower proportion for male household heads (36.7%) (Figure 58). Almost 80% of male-headed households live in rural areas, while about 75% of female-headed households live in rural areas.

FIGURE 57 • **Distribution of expenditure quintiles by gender of household head**

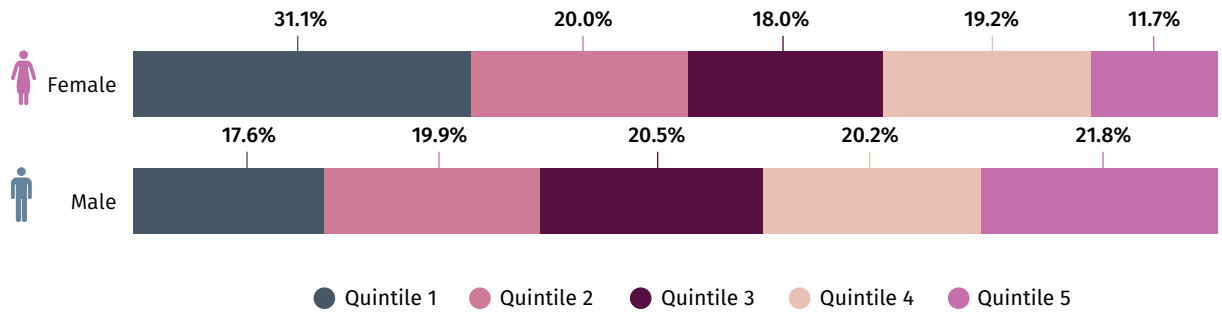
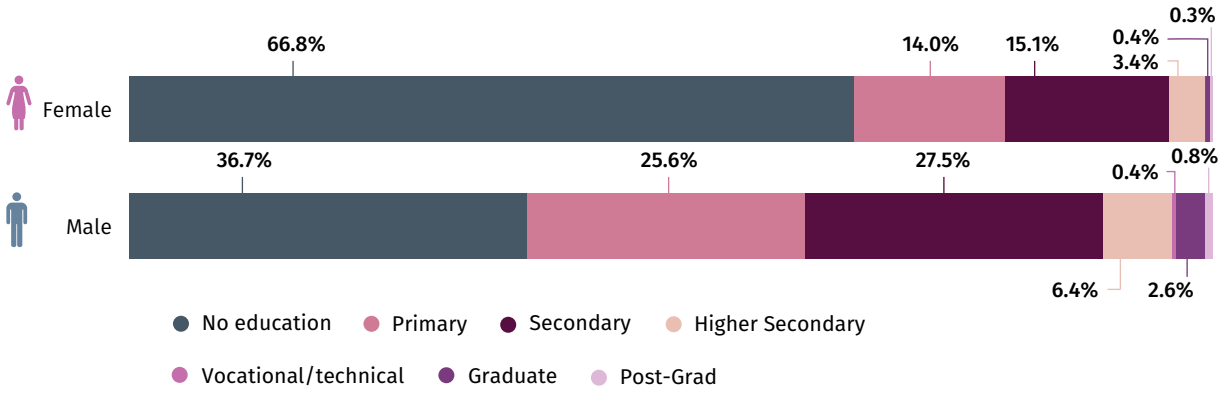


FIGURE 58 • **Education of household head by gender**



CHOICES ON ENERGY SOLUTIONS BY FEMALE- AND MALE-HEADED HOUSEHOLDS

In addition to difference in financial aspects and education, male and female individuals likely have other differences, such as preferences and information on energy solutions. Men and women might face different obstacles to gaining access that impact their decisions and choices. Because access to better electricity service or modern cooking solutions bring various benefits to the household, it is important to explore whether male and female household heads make different decisions in selecting the type of energy solution.

In Nepal, 22.8% of the female-headed households are in Tier 5 and 16.1% of male-headed households in the same tier (Figure 59). Among the households in grid-electrified areas, female- and male-headed households have similar rate of connection, 95.1% and 91.7%, respectively (Figure 60). The take-up rates of mini-grid in areas with only mini-grid connection and take-up rates of solar devices in areas with neither grid nor mini-grid are also similar between female- and male-headed households.

FIGURE 59 • **Distribution of MTF electricity tiers by gender of household head**

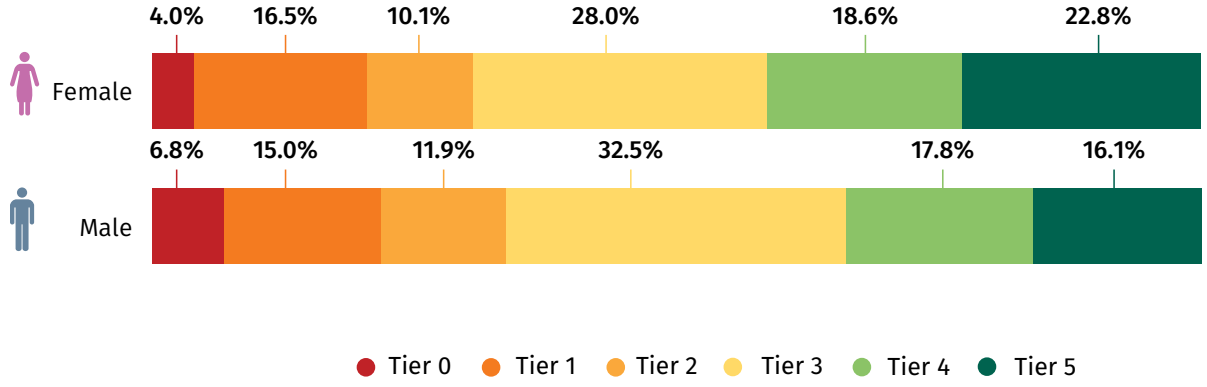
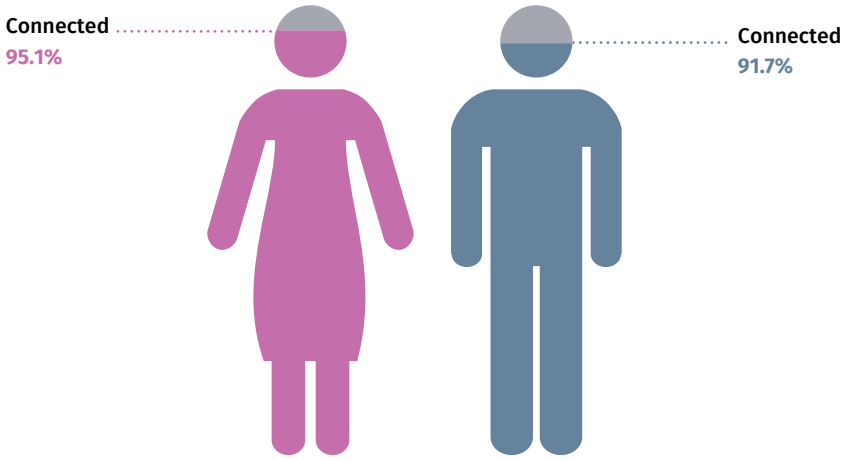
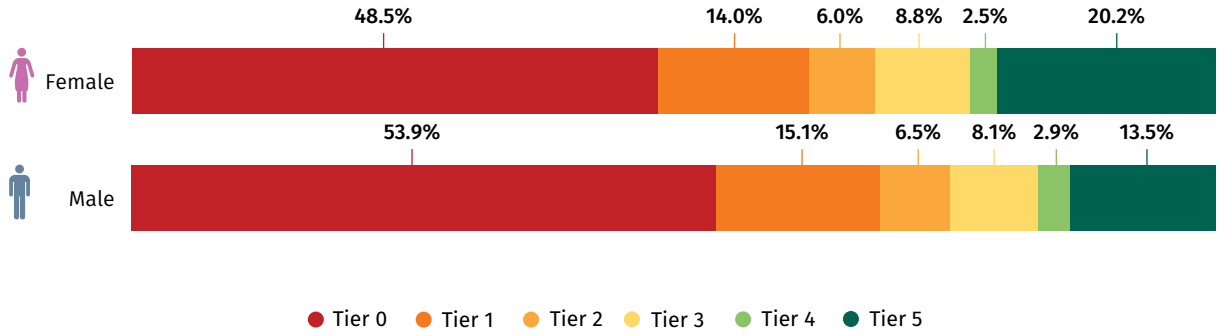


FIGURE 60 • **Grid take-up rate by gender of household head**



Female- and male-headed households have similar levels of access to modern energy cooking services. There are about 20.2% of female-headed households in Tier 5 compared to 13.5% of male-headed households. In addition, the proportion of households in Tier 0 is equally high for male- and female-headed households (Figure 61).

FIGURE 61 • **Distribution of MTF cooking tiers by gender of household head**



Across Nepal, 43.6% of female-headed households use an electric, liquified petroleum gas (LPG), or biogas cookstove compared to a slightly lower 36.1% of male-headed households (Figure 62). In addition, when asked about their willingness to pay for a metal improved cookstove (ICS) and Mimi Moto stove for different price points, households with a female head and households with a male head expressed similar willingness to pay (Figure 63 and figure 64).

FIGURE 62 • Clean stove use by gender of household head

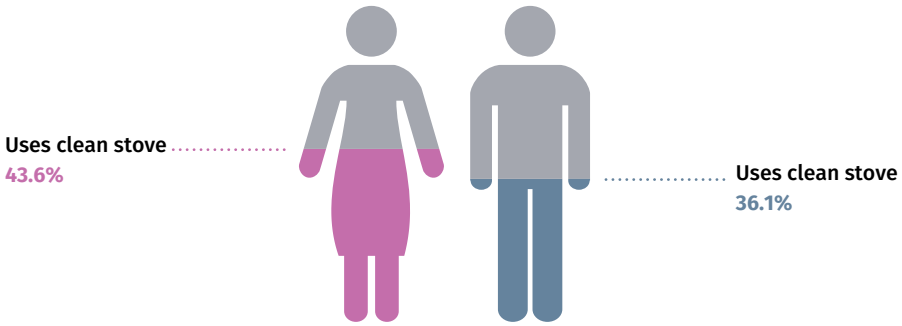


FIGURE 63 • Willingness to pay for a metal improved cookstove with a chimney

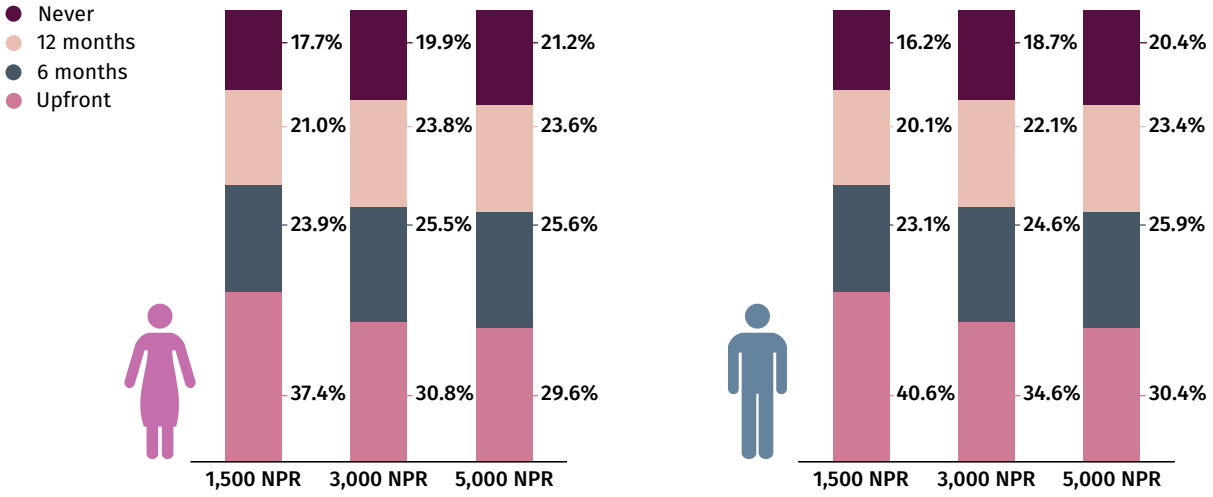
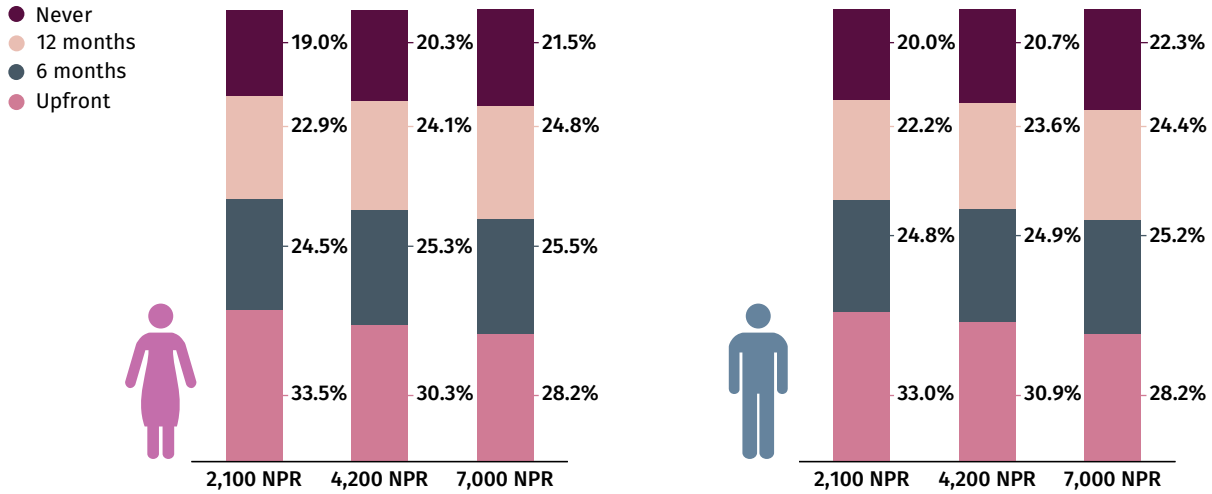


FIGURE 64 • Willingness to pay for Mimi Moto stove



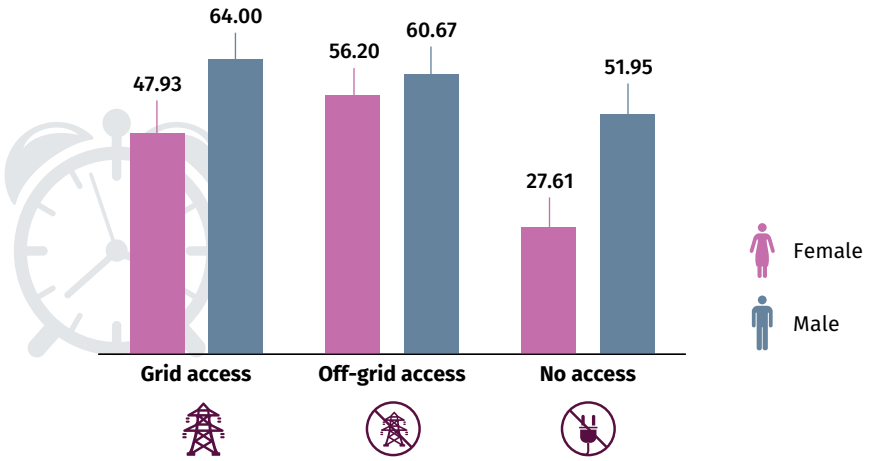
TIME USE OF WOMEN IN RELATION TO HOUSEHOLD'S ENERGY SOLUTION

To shed light on the impact of improved energy solutions on women's empowerment, data on women's use of time was compared across households with different energy solutions. Using modern energy solutions will free up more time, allowing women to engage in more productive activities that increase their human capital. Specifically, the report compares different results in time spent studying or helping with schoolwork and time spent on entertainment or socializing. As women from poorer households are in the most need of resources such as time and human capital, the analysis concentrates on women in households whose expenditure belongs to the lowest 20%.[23]

HOUSEHOLD ELECTRICITY SOLUTION AND WOMEN'S USE OF TIME

Women over 15 years of age in grid-connected households spend an average of 56.2 minutes per week studying or helping with schoolwork, while women in a household with no electricity spend 27.61 minutes per week in this activity (Figure 65). This difference in time use between grid-connected households and no-access households is less pronounced for men.

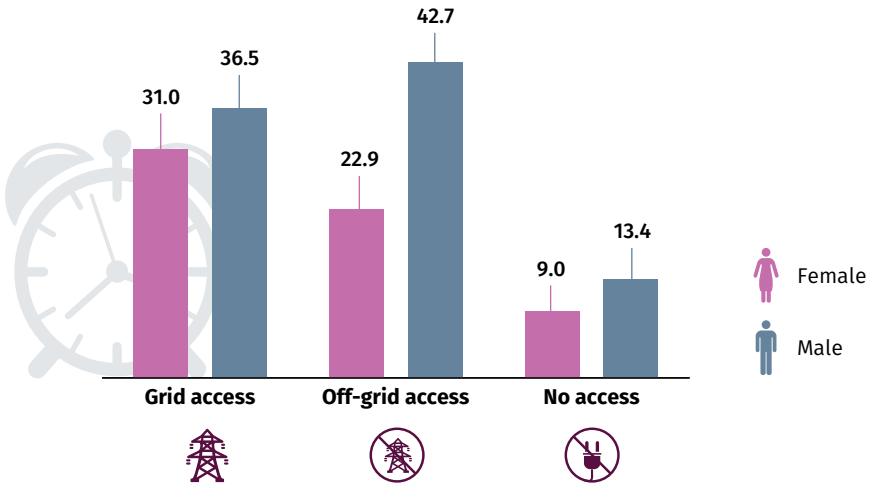
FIGURE 65 • **Average minutes per week spent by women and men studying or helping schoolwork by level of grid access (households in bottom quintile)**



When households do not have access or have limited access to the grid, there is a disproportionate burden that falls on the women in the household. Women from households with grid connection spend 31.02 minutes per day on entertainment or socializing, while women from households with no access to electricity spend 8.99 minutes in this activity (Figure 66). This result holds similarly for men and women.

[23] The analysis corresponds to 1,188 of the total sample.

FIGURE 66 • **Average minutes per day spent by women and men on entertainment or socializing by main source of electricity (households in bottom quintile)**



HOUSEHOLD COOKING SOLUTION AND WOMEN'S USE OF TIME

For households whose expenditure is in the lowest 20% of all Nepalese households, women over 15 years spend an average 109.54 minutes per day cooking (Figure 67). This is substantially larger than men over 15 and girls and boys under 15. Furthermore, in the same group of households, women over 15 spend an average of 2.28 hours per week collecting and preparing fuel (Figure 68). Men also spend a significant amount of time in the same activity (1.96 hours per week). On average, for all spending groups, women in a household using a traditional (open or enclosed fire) stove spend more than 115 minutes per day cooking, while women in households using an LPG stove spend 30 fewer minutes on cooking (Figure 69). This improvement is disproportionately large for women, as the time saved by men from making the same switch would be 4 to 8 minutes (Figure 69). These findings suggest how much of women's time can be saved by using a convenient cookstove.

FIGURE 67 • **Average time spent cooking by age and gender group (minutes per day, households in bottom quintile)**

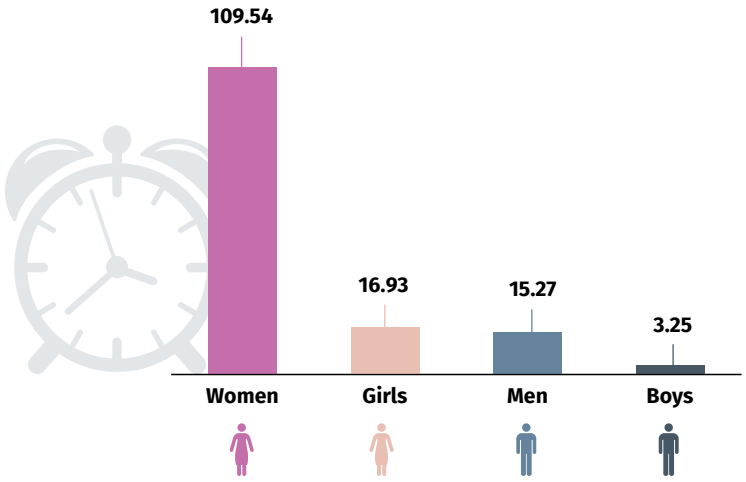


FIGURE 68 • **Average time spent on collecting and preparing fuel by age and gender group (hours per week, households in bottom quintile)**

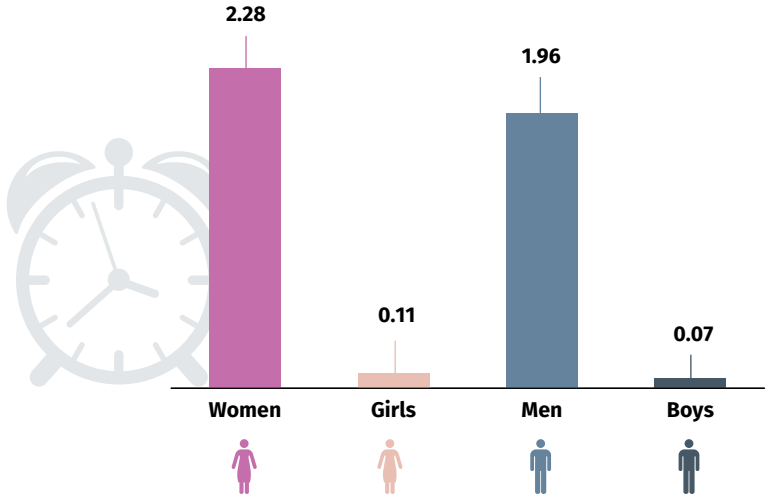
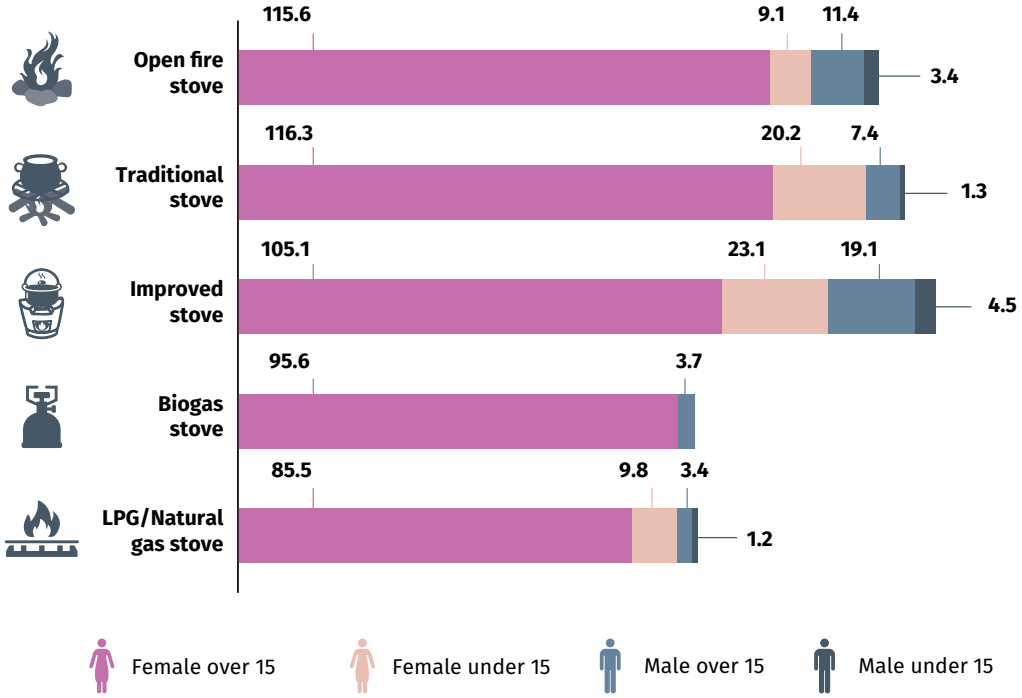
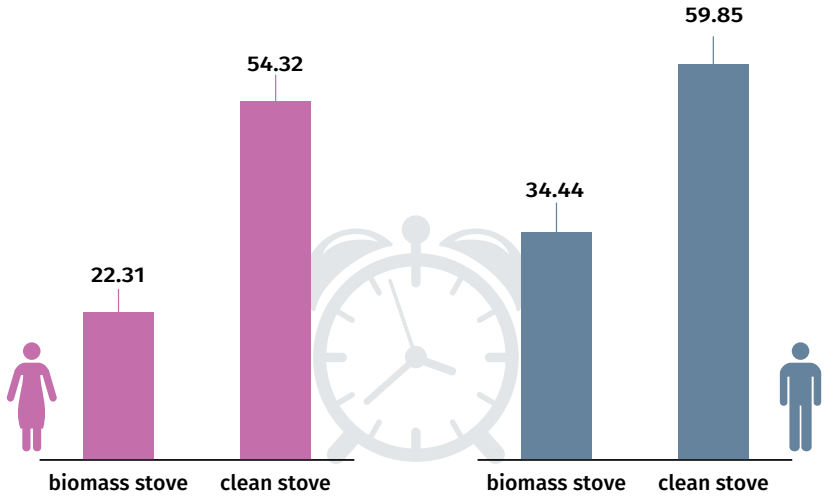


FIGURE 69 • **Average time spent cooking by age and gender group by cookstove type (households in all spending groups)**



Women from households that use a clean cookstove (electric, LPG, or biogas) as their primary stove spend 54.32 minutes per day on entertainment or socializing, while women from households that use a biomass stove as their primary stove spend approximately half the amount of time in the same activity (Figure 70). A similar pattern holds for men; those from households using a clean stove as their primary stove spend more time on entertainment or socializing.

FIGURE 70 • **Average minutes per day spent by women and men on entertainment or socializing by aggregate cooking tier (households in bottom quintile)**



GENDER-BASED IMPLICATIONS

The gender analysis of the MTF data finds that despite the disadvantage of financial means and education levels, there are similarities in the choices of energy solutions between male- and female-headed households. When a household is located in a grid-electrified area, a similar proportion of female-headed households choose to be connected to the grid as that of male-headed households. This result is true for the likelihood of adopting and using a clean-fuel cookstove. Moreover, it is found that for households in the lowest 20% in income level, women in households with grid connection have more time to spend studying or helping with schoolwork and on entertainment or socializing than those in households with no electricity. Furthermore, women in households with a clean cookstove spend a substantially larger amount of time on entertainment and socializing than those in households without a clean cookstove.

It should be noted that the comparison of energy solutions between female- and male-headed households and time use between households with different energy presented in this report is not an indication of causality but merely shows correlation. As there are likely many factors that vary with gender or decisions on energy solutions, a more careful approach addressing these co-varying relations is required to suggest a causal relationship. Such an analysis is beyond the scope of this report. Instead, descriptive statistics of sub-populations that show meaningful correlations between gender and energy solutions are presented. These descriptive statistics suggest that further analysis controlling for potentially co-varying factors, such as income, education, age, and employment status, may lead to statistically meaningful conclusions on the relation between the use of modern energy and women's time use. Complementary studies on these issues can provide further insight and draw better conclusions on the ways to improve electricity and modern energy solutions for households.

ANNEX 1:
Multi-Tier Framework Matrix and Theoretical Background

Attribute	Definition	Question from the survey
Capacity	The Capacity of the electricity supply (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate different appliances, ranging from a few watts for LED lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. Thus, it establishes what types of appliances may be used with the given supply. Capacity is measured in watts for grids, mini-grids, and fossil-fuel-based generators, and in watt-hours for rechargeable batteries, solar lanterns, and solar home systems.	What source of electricity is used most of the time in this household? What appliances are powered using this household's solar device or system? How many lightbulbs can be powered using this household's solar device or system?
Availability (duration)	Availability of supply refers to the amount of time during which electricity is available. It is measured through two indicators: (i) the total number of hours per day (24-hour period), and (ii) the number of evening hours (the 4 hours after sunset) during which electricity is available.	In the last 7 days, how many hours of electricity were available **each day** on average from [NAME MAIN electricity system]? *(Maximum 24 hours)* In the last 7 days, how many hours of electricity were available **each evening** on average**, from 6:00 pm to 10:00 pm from** [NAME MAIN electricity system]? *(Maximum 4 hours)*
Reliability (unscheduled outages)	The Reliability of electricity supply is a combination of two factors: (i) frequency and (ii) duration of disruption. When electricity supply goes off unexpectedly, it means that the grid is unreliable and needs backup generators as a coping mechanism.	In the last 7 days, how **many times** were there unscheduled outages or blackouts from [NAME MAIN electricity system]? What is the total duration of all the unscheduled outages or blackouts in the last 7 days?
Quality (voltage)	The Quality of the electricity supply is defined in terms of voltage. Most electricity applications cannot be operated properly below a minimum level of supply voltage.	In the last 12 months, did any of this household's appliances get damaged because the voltage was going up and down in the [NAME MAIN electricity system]?
Affordability	If households spend less than 5% of their monthly expenditure (or consumption) to consume 30 kWh of electricity per month, it could be defined as being affordable.	Expenditure/consumption aggregation Monthly expenditure to consume 30 kWh per month
Formality	If households use electricity service from grid but do not pay to anyone, their connection could be defined as informal connection.	Who does this household currently pay for [NAME MAIN electricity system]?
Health and Safety	This is an attribute of energy supply that relates to the risk of injury from the energy supply. The spectrum of electrical injuries is broad, ranging from minor burns to severe shocks and death.	In the last 12 months, did anyone using [NAME MAIN electricity system from HE1] die or have permanent limb (bodily injury) damage?

ANNEX 2:
Multi-Tier Framework for measuring access to electricity

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

Source: Bhatia and Angelou 2015
Note: Colors signify tier categorization

ANNEX 3:
Definitions and Questions used to calculate the Modern Energy Cooking Services Attributes

Attribute	Definition	Question from the short module
Cooking Exposure	The Cooking Exposure attribute is a composite measurement of the Emissions from the cooking activity, that is, the combination of the stove type and fuel, and mitigated by the Ventilation in the cooking area. If a household uses multiple stoves, the Cooking Exposure attribute is measured as a weighted average of the time each stove is used.	
Emissions: Stove		What does this household use for cooking **most of the time,** including cooking food, making tea/coffee, and boiling drinking water? What is the brand of the cookstove or device?
Emissions: Fuel		What type of fuel or energy source does this household use **most of the time** in this cookstove or device for cooking food, making tea/coffee, and boiling drinking water?
Ventilation		Is the cooking usually done in the house, in a separate building, or outdoors? Does the cookstove have a chimney or hood?
Contact time		**Yesterday**, how much time was this cookstove used for cooking food, making tea/coffee, and boiling drinking water?
Stove stacking		
Convenience	Convenience is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and their stove for cooking.	On a single trip, how long does it take for this person to go to collect the fuel, get the fuel, and come back? **In the past month (the last 30 days)**, how many times has this person collected this fuel for household cooking? **Yesterday,** how much time total was spent preparing the [COOKSTOVE] and fuel for cooking, including setting up the fuel and lighting/turning on the cookstove but not including gathering fuel or cooking time?
Affordability	Affordability is measured using the levelized cost of the fuel. A cooking solution is considered affordable if a household spends less than 5% of the household expenditure on their cooking fuel.	How much (in local currency) did this household pay for this fuel or energy source **last month** for cooking (the last 30 days)?
Fuel Availability	Fuel Availability measures the availability of the primary fuel over the past 12 months.	In the **past 12 months**, how often was this fuel or energy source **unavailable** in the quantity you desired?
Health and Safety	The Safety of the primary stove accounts for any serious injuries from the stove over the last 12 months.	In the past 12 months, did any harm or injury happen from using this cookstove, device, or fuel?

ANNEX 4:
Multi-Tier Framework for measuring access to modern energy cooking solutions

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

Source: Bhatia and Angelou 2015; ISO 2018

Note: Colors signify tier categorization

ANNEX 5:
Aligning Typology for biomass stoves with the Cooking Energy System

Typology for biomass stoves (including dung, leaves, twigs, and firewood)

	Stove type		
Level	**Endev's Cooking Energy System**	**Nepal MTF**	**Design features**
0	Three-stone fire; tripod; flat mud ring	Traditional stove (open fire)	• Pot sits in the flames • Low time to combust fuel gas as pot is sitting in the flames • Fuel resting on the ground being cooled and has less access to oxygen
1	Conventional improved cookstove (ICS)	Traditional stove (enclosed fire)	• Higher combustion temperature due to enclosed combustion chamber and sometimes insulation • Position of pot raised above the fire allowing more time for combustion • Fuel still resting on the ground being cooled and has less access to oxygen (no improvement over level 0)
2	ICS with chimney Rocket stove with conventional materials for insulation	Improved stove (exhaust) Improved stove (no exhaust)	• Insulation of the combustion chamber keeping fire hot • High internal chimney (combustion chamber) promoting the mixing of combustion gases with hot oxygen • Fuel resting on shelf (or hanging in air), promoting higher fuel temperature and more mixing for combustion gas with oxygen • For ICS with chimney—the chimney taking most of the emissions outside the kitchen
3	Rocket stove with high insulation Rocket stove with chimney	Improved stove (factory manufactured)	• High internal chimney (combustion chamber) promoting the mixing of combustion gases with hot oxygen • Fuel resting on shelf (or hanging in air), promoting higher fuel temperature and more mixing for combustion gas with oxygen • Temperatures higher due to application of very effective insulation materials • Chimney taking some emissions out, but significant emissions still entering the kitchen
4	Rocket stove with chimney (well-sealed) Rocket stove gasifier Batch feed gasifier	Improved stove (factory manufactured with chimney)	• Chimney taking out most of the emissions • Staged combustion with secondary air • Staged combustion with hot secondary combustion of gases • Fuel resting on shelf (or hanging in air), promoting higher fuel temperature and more mixing for combustion gas with oxygen • Temperatures higher due to application of very effective insulation materials Note: Emissions testing data needs to be available for the stove type to be classified into Tier 4.

ANNEX 6:
Aggregate Tier Distribution Table: Locality, province, and ecological region

Aggregate tier distribution for electricity access						
	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Urban	4.3%	5.3%	6.8%	37.1%	23.5%	22.9%
Rural	6.8%	17.9%	12.8%	30.2%	16.4%	15.9%
Province 1	2.9%	19.4%	11.6%	35.4%	19.4%	11.4%
Province 2	16.6%	2.2%	33.9%	39.0%	7.2%	1.1%
Province 3	2.5%	11.7%	3.4%	40.3%	17.8%	24.3%
Province 4	0.7%	3.2%	3.7%	24.5%	10.5%	57.4%
Province 5	4.0%	13.0%	6.8%	26.3%	30.3%	19.7%
Province 6	11.1%	61.0%	7.5%	13.8%	4.5%	2.1%
Province 7	7.5%	28.8%	2.1%	24.4%	30.5%	6.7%
Mountain	5.5%	29.2%	5.5%	24.1%	17.0%	18.7%
Hill	4.5%	26.9%	5.4%	25.3%	13.7%	24.2%
Terai	8.1%	3.7%	18.1%	38.9%	21.7%	9.5%
Hill (Kathmandu)	0.0%	0.2%	1.2%	14.2%	16.5%	68.0%

Aggregate tier distribution for access to modern energy cooking services						
	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Urban	36.1%	11.0%	6.6%	13.7%	6.5%	26.2%
Rural	57.4%	16.0%	6.4%	6.7%	1.9%	11.6%
Province 1	52.6%	16.3%	3.8%	3.9%	3.2%	20%
Province 2	68.8%	4.1%	3%	9.8%	2.8%	11.6%
Province 3	45.4%	16.1%	6.9%	7.9%	4.4%	19.3%
Province 4	31.3%	23.3%	14%	7.5%	3.6%	20.6%
Province 5	46.5%	13.2%	6.9%	16.6%	1.9%	14.9%
Province 6	61%	34%	0.6%	2.6%	1.1%	1%
Province 7	68.4%	12.5%	11.8%	3.2%	2%	2.5%
Mountain	69.6%	24.8%	2.2%	1.4%	0.5%	1.5%
Hill	50.2%	22.1%	7%	6.0%	3.0%	11.4%
Terai	52.9%	6.9%	6.3%	11.2%	3.0%	19.6%

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