PAPUA NEW GUINEA

Beyond Connections

Energy Access Diagnostic Report Based on the Multi-Tier Framework

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Energy Sector Management Assistance Program
THE WORLD BANK
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MTF
Multi-Tier FRAMEWORK

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Aditi Sadia Rahman and Bryan Bonsuk Koo

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

Internet: www.worldbank.org

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ESMAP is a partnership among the World Bank and over 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated with the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) (UN n.d.) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the World Bank Group Climate Change Action Plan (World Bank 2016) targets. Due to the COVID-19 pandemic, data were collected based on a phone-based survey conducted by the World Bank's Poverty Global Practice and World Bank Papua New Guinea Energy Team. The MTF team would like to thank the National Energy Authority of Papua New Guinea. In Addition, acknowledgment goes to the technical support provided throughout the entire survey process by the multi-stakeholder Technical Working Group.

This Energy Access Diagnostic Report represents the detailed findings of the MTF survey in Papua New Guinea. The survey analysis reports the current status of access to electricity and modern energy cooking solutions in Papua New Guinea, highlights the ongoing issues, and provide recommendations. The MTF team acknowledges the valuable support from various entities and individuals, recognizing the collaborative effort needed to address energy accessibility issues in the country. This study is part of a series of deliverables on sustainable energy commissioned by the World Bank under the Papua New Guinea and Pacific Energy and Extractives Programmatic Advisory Services and Analytics (P180641).

The lead authors for this report were Aditi Sadia Rahman (Data Analyst Consultant, IEEES) and Bryan Bonsuk Koo (Energy Specialist, IEESE). The field coordinator and data analyst for the energy survey were Aditi Sadia Rahman (Consultant, IEEES) and Gina Fleurantin (Consultant). Niki Angelou (Consultant, IEEES) reviewed the gender section of the report. Support and contributions from the World Bank Papua New Guinea Energy Team were also vital to realizing the MTF's Papua New Guinea survey materials. This team included Gerard Fae (Senior Infrastructure Specialist, IEAE1), Mits Motohashi (Senior Energy Specialist, IEAE1), and the MTF Task Team Leader, Bryan Bonsuk Koo. Additionally, the MTF Team would like to recognize Crispin Pemberton-Pigott (Consultant) for providing technical support in identifying cookstove performance; Aisha Noella Pinto (Energy Specialist), Shelton Sofeil Elisa Kanyan (Consultant, DECPM); Laurent Durix (Consultant); and Johana Christen Galan (Energy Specialist, IEEES) for providing valuable comments; Kristen Himelein (Senior Economist, Statistician, EEAPV) for providing guidance on the sampling strategy and methodology; Lachlan Bruce (Computer Assisted Telephone Interviewing[CATI] Programmer) for preparing the CATI program to collect survey data; and Darian Naidoo (Economist, Poverty and Equity), Jane Sprouster (Senior Operation Officer), and Myoe Myint (Senior Energy Specialist) for providing their valuable comments in the decision review.

ABBREVIATIONS AND ACRONYMS

DHS	Demographic and Health Survey
ESMAP	Energy Sector Management Assistance Program
GDP	gross domestic product
ISO	International Organization for Standardization
K	kina, currency of Papua New Guinea
kg	kilogram
kW	kilowatt
kWh	kilowatt-hour
LPG	liquid petroleum gas
MECs	modern energy cooking services
MTF	Multi-Tier Framework
NEA	National Energy Authority
NEROP	National Electrification Roll-Out Plan
PNG	Papua New Guinea
PPL	PNG Power Ltd.
RISE	Regulatory Indicators for Sustainable Energy
SHS	solar home system
SL	solar lantern
SLS	solar lighting system
SUSO	Survey Solutions software
W	watt
Wh	watt hour(s)
WTP	willingness to pay

Exchange rate: 1 Papua New Guinea kina (K 1.0) = 0.28459 US dollars (US$0.28459)

EXECUTIVE SUMMARY

With the collaboration of the National Energy Authority of Papua New Guinea, the World Bank team launched the first Global Energy Access Households Surveys in Papua New Guinea in 2021 to establish a baseline for tracking progress toward the Sustainable Development Goal 7 target 7.1: "Ensure access to affordable, reliable and sustainable modern energy for all" by 2030. The survey aimed to inform the government of access targets, policies, and investment strategies for energy access based on Multi-Tier Framework (MTF).

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

ACCESS TO ELECTRICITY

Access to electricity is evaluated based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety[1] (see annex 1). About 69 percent of the households in Papua New Guinea use electricity from off-grid or grid connections. Nationwide, 67.1 percent and 86.7 percent of rural and urban households, respectively, have access to any source of electricity. About one out of seven households (13.9 percent) have a grid electricity connection. Nationwide, off-grid energy solutions are the dominant source of electricity, with more than half (55.1 percent) of the households using off-grid solutions, particularly solar lantern (50.6 percent). One third of the households (31 percent) nationwide are unable to get any sources of electricity. More households in rural areas (32.9 percent) have no electricity than households in urban areas (13.1 percent).

Nationwide, 43 percent of households in Papua New Guinea have aggregated Tier 1 or higher access. About 57 percent of the households are in aggregated Tier 0. Among Tier 0 households, 31 percent do not have any source of electricity, and 26 percent households have some sources of electricity without meeting the minimum requirement of Tier 1. Among 26 percent of Tier 0 households, most of them (25.5 percent) use solar lanterns as the main source of electricity. Due to their capacity constraints, they are found in the aggregated Tier 0.

Among those who are using off-grid solar products, they tend to use cheaper "generic" products, which make up over 80 percent of off-grid solar products sold in Papua New Guinea (IFC 2019). Such prevalence of using cheap and often lower-quality products may negatively affect a consumer's satisfaction with off-grid solar products and perception of off-grid products overall. It is estimated that about 11 percent of households use a certified solar product in Papua New Guinea. If we limit the study field to certified solar products for the government to track the progress under the National Energy Access Project, about 25 percent of Papua New Guinea households use either the grid network (13.9 percentage) or certified off-grid solar product (11 percentage) as the main source of electricity.

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[1] However, due to time restrictions, survey questions regarding affordability and safety could not be included in this survey. Therefore, the aggregated tier does not include these two attributes in calculation.

Richer households are more likely to have access to electricity than poorer households. Among the grid-electrified households, most (77.5 percent) are in the top 20 percent expenditure quintile. Among the households who are unelectrified, more than 60 percent are in the bottom 40 percent expenditure quintile.

Households who do not have the grid connection are willing to pay upfront for grid connection regardless of their wealth quintile. About 81 percent, 76 percent, 88 percent, and 90 percent of the bottom 40 percent, 3rd quintile, 4th quintile, and top 20 percent expenditure quintile are willing to pay for the grid connection, respectively, if the grid network is available.

Households using off-grid energy solutions spend approximately US$4 per month for backup electricity service for lighting, including dry-cell battery, candle light, kerosene, and so on, which is almost two times more than the grid-connected households' cost for backup service. Dry-cell batteries are the most used backup source for lighting. On average, households without access to electricity spend K 307.2 (US$86.9) per year on such coping mechanisms for lighting.

Affordability is one of the major constraints for households to switch to higher capacity off-grid solar solutions. Grid availability in rural areas would be a constraint in electrifying unelectrified households even though households are willing to pay for the grid connection. Therefore, the role of off-grid solar products is critical to provide electricity services to households living in the areas where the grid infrastructure is not available.

Papua New Guinea is embracing pay-as-you-go (PAYGo) schemes for off-grid solar solutions (UNCDF 2020), which can address affordability issues. Papua New Guinea could benefit from least-cost electrification planning based on the geospatial data. This would enable the government to determine the optimal energy solutions to electrify households in a least-cost manner. Ensuring the timely and effective implementation of the National Electrification Rollout Plan (NEROP) is pivotal for advancing electrification across on-grid, mini-grid, and off-grid market developments (Motohashi 2022).

ACCESS TO MODERN ENERGY COOKING SERVICES

Cookstoves are assigned in five categories. More than 85 percent of households in Papua New Guinea use either a three-stone stove or a traditional stove. About half (54.7 percent) of the population use traditional stoves followed by the three-stone stoves (31.6 percent). Urban populations are more likely to use clean fuel stoves (34.8 percent) compared to rural population (10.3 percent). About three-fourths (73.5 percent) of urban households with clean fuel mostly use electric stoves. Among 10.3 percent of rural households with clean fuel stoves, liquid petroleum gas stoves (44.7 percent) and electric stoves (47.8 percent) are most popular. Firewood (84.7 percent) is the most dominant fuel in Papua New Guinea. About 87 percent and 64.1 percent of rural and urban households, respectively, use firewood as their main fuel for cooking.

The MTF survey identifies the variance in the cookstove use by geographical region and wealth distribution. The Southern region mostly uses traditional stoves (71.8 percent) and has the highest penetration of clean fuel stoves (21.4 percent). In the Highlands region, almost half (46.8 percent) of the population uses three-stone or open fire stoves, the highest compared to other regions. There is a significant difference between the top 20 percent expenditure quintile and the other quintile groups in use of clean cooking solutions. The population in the top 20 percent quintile mainly uses electricity (30.5 percent) as fuel for their clean stoves. Even though currently more of the top quintile households are using clean cooking solutions, it is quite expensive and a financial burden for them. Monthly expenditure on clean fuel compared to firewood is substantially high.[2] Affordability and accessibility of cooking fuel are critical factors affecting the adoption of clean fuel stoves.

In the MTF analysis, the Exposure Tier is calculated based on stove typology and the level of ventilation in the cooking space. Because of the lack of information on all other criteria for the Cooking Tier except Exposure Tier, the report presents the Cooking Tier information based on only the Exposure Tier. The analysis shows that two-thirds of households in Papua New Guinea are in Tier 0 due to the Exposure attribute. Since more than 85 percent of households use either three-stone or traditional stoves, more than 80 percent of households are found in Tiers 0–2, on which more than 66 percent of households are solely in Tier 0. In urban areas, more households use clean fuel stoves, and thus 34.8 percent of households are in Tiers 4–5, while in rural areas, only 10.3 percent of households are found in Tiers 4–5. The ventilation of the cooking area has a critical role in the calculation of the Exposure Tier. Enhancing ventilation in household cooking areas could potentially raise the tier level.

GENDER ANALYSIS

Nationwide, 27 percent of households are headed by women. Female-headed households are more likely to be in rural areas (28 percent) than urban areas (18 percent). Female heads of households are less likely to have attended school, to be employed, and when employed, to have a full-time job. They tend to be poorer than male-headed households: 50 percent of female-headed households are in the bottom 40 percent in income, compared to 40 percent of male-headed households.

Significantly, fewer female-headed households have access to electricity compared to male-headed households (74 percent versus 54 percent respectively), driven by their lower access to off-grid solutions (42 percent versus 62 percent, respectively). In urban areas, female-headed households are considerably more likely to access the grid (49 percent), compared to male-headed households (27 percent). Among households that are not connected to the grid, female-headed households report significantly higher willingness to pay for a grid connection compared to male-headed households (98 percent versus 78 percent, respectively). Despite large gaps in access to electricity by technology, the MTF tier distribution is very similar for both male and female-headed households. This is mainly explained by the fact that a high share of the off-grid solutions used by male-headed households fall in Tier 0. In urban areas, driven by higher grid penetration, female-headed households are more likely to reach Tier 2 and above (51 percent), compared to male-headed households (27 percent).

More female-headed households use clean fuel stoves than male-headed households (23 percent versus 11 percent, respectively). Fewer female-headed households use three-stone stove and traditional stoves than male-headed households across urban and rural areas. The gender gap widens significantly when looking at the share of households in Tier 0 for modern energy cooking services (MECS): 40 percent of female-headed households versus 71 percent of male-headed households. The difference is explained by the fact that male-headed than female-headed households cooking with traditional stoves are significantly more likely to fall in Tier 0 because of poorer ventilation levels.

[2] Nationwide average cost of fuel per month is K 2.5 for firewood, K 62.5 for electricity, K 35.9 for biogas, and K 34.4 for liquid petroleum gas/cooking gas. See figure 25.

MEASURING ENERGY ACCESS IN PAPUA NEW GUINEA

Photo: © Kalo Fainu/World Bank

Access to energy stands at the core of pivotal development challenges. Energy plays a profound role in shaping human development and serves as a driving force for both economic growth and social progress. The United Nations acknowledges the significance and far-reaching effects of energy access, as reflected in Sustainable Development Goal 7 (SDG7) target 7.1. This target aims for universal access to affordable, reliable, and modern energy services. SDG7 stands as a linchpin for accomplishing various other SDG targets, spanning from the eradication of poverty through advancements in health, education, water supply, and industrialization to the mitigation of climate change. The National Energy Authority of Papua New Guinea (PNG) collaborated with the World Bank Team to launch the first Global Energy Access Household Surveys in PNG in 2021 to establish a baseline for tracking progress toward the SDG 7.1 on access to affordable, reliable, and sustainable modern energy by 2030 (World Bank 2018b). The survey's objective is to use the Multi-Tier Framework (MTF) to obtain direction on setting access targets, policies, and investment strategies for energy access.

COUNTRY CONTEXT

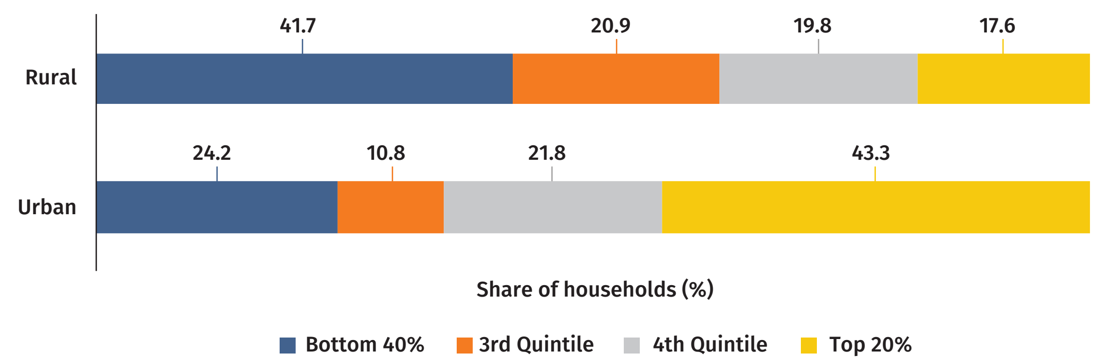
According to the United Nations (UN) World Population Prospects, the total population in PNG was estimated to be 10,142,619 as of 2022. The gross domestic product (GDP) annual growth rate in PNG at market prices based on constant local currency was 4.6 percent in 2022, and total unemployment rate (percent of total labor force) (modeled International Labour Organization estimate) was estimated to be 2.8 percent in 2022 according to the World Development Indicators database.[3] PNG has wide range of geographical features, including mountains, tropical forests, grasslands, rivers, deltas, islands, and atolls. PNG has a large variety of natural resources such as gold, copper, nickel, petroleum, and mineral deposits as well as renewable resources and agricultural products. In PNG the primary catalyst for economic growth has been the extractive industries. In 2015, natural resources were estimated to contribute to 47 percent of the GDP. Mining and petroleum alone now constitute 24 percent of the GDP, nearly matching the combined contribution of all other primary sectors. Despite their significant economic impact, these two sectors only employ around 7 percent of the total workforce. PNG ranks 32nd globally in terms of subsoil wealth per capita. With 848 languages, it is one of the most diverse nations in the world (Motohashi 2022). Economic development and improved access to public services are crucial for enhancing the well-being of the country's population. Addressing these issues requires coordinated efforts from both domestic and international stakeholders. The country's ranking on the UN's Human Development Index (UN HDI) is 0.558 in 2021, ranking 156 out of 191 countries. The gross national income purchasing power parity per capita was estimated at US$2,700 in 2022 (World Bank Open Data 2022). The urbanization rate in PNG was 13.6 percent in

[3] For the unemployment rate in PNG, see the World Development Indicators (WDI) database, "Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate)—Papua New Guinea," Washington, DC (accessed February 2, 2024), https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=PG. As a comparator, see the WDI world unemployment rate at "Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate)," https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS.

2022. PNG is positioned as one of the countries most prone to natural disasters and the repercussions of climate change. As per the 2019 INFORM Risk Index, PNG ranks 22nd out of 191 countries, underscoring its significant susceptibility.

The MTF survey estimates that, while rural areas have a significant proportion of households in the bottom 40 percent of expenditures and a smaller proportion in the top 20 percent, urban areas show the opposite trend, with a likely concentration of households in the top 20 percent and fewer in the bottom 40 percent (figure 1).

FIGURE 1 • **Distribution of expenditure quintile by area**



Source: Papua New Guinea Energy Survey 2021.

The government of Papua New Guinea has set an ambitious target of achieving 70 percent electrification for the population by 2030. With support from the World Bank the government prepared a detailed implementation strategy and investment plan in May 2022, the National Electrification Roll-Out Plan (NEROP), which recognizes electrification based on tier level. NEROP investments are strategically prioritized to achieve a balance between early successes and the development of necessary institutions, sequencing on-grid, mini-grid, and off-grid market developments (Motohashi 2022).

PNG Power Ltd. (PPL) serves as an integrated utility, overseeing the entire electricity process, from generation and transmission to distribution and retailing across PNG. Additionally, it caters to needs of individual electricity consumers. PPL, as a state-owned entity, has Kumul Consolidated Holdings Limited as a shareholder, managing shares as a trustee of the General Business Trust. The government of PNG, serving as the ultimate shareholder, appoints the board through the National Executive Council. PNG has three primary grids covering urban centers in Port Moresby (the capital), Ramu (the highlands), and the Gazelle Peninsula.

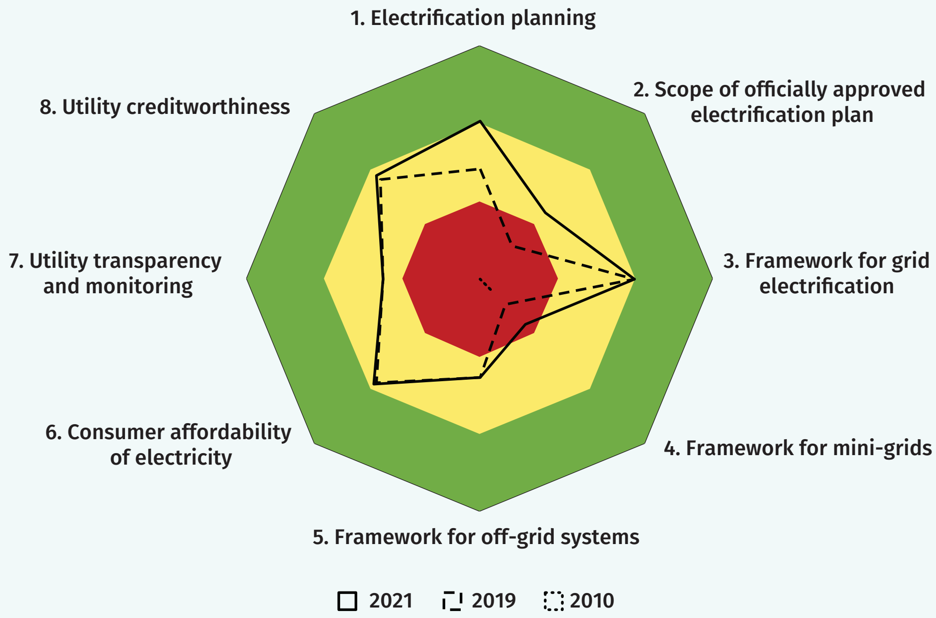
According to 2023 Tracking SDG7 report, 21 percent (in 2021) of the population in PNG currently enjoys reliable access to electricity (IEA et al. 2023), which is much lower than the Oceania region's access rate of 81 percent. The urban and rural electrification rate is 65 percent and 14 percent, respectively.

According to this MTF household survey, 84.7 percent of households rely on wood for their cooking. Relying excessively on wood can have adverse environmental impacts, contributing to deforestation. This can lead to habitat loss, biodiversity decline, and disruptions in ecosystems. It is crucial to explore sustainable alternatives to mitigate these environmental concerns. The survey also reveals that only 12.8 percent of households use clean fuel stoves, with a preference for electric or liquid petroleum gas (LPG) stoves. According to 2023 Tracking SDG7 report, nationwide only 10 percent (in 2021) of the population utilizes clean fuel stoves (IEA et al. 2023). Exploring the potential of gas, geothermal, hydro, and solar energy could offer alternative methods for electricity generation, fostering cleaner and more sustainable cooking solutions. Box 1 illustrates the electricity access indicators and regulatory indicators for sustainable energy in Papua New Guinea provided by RISE, ESMAP.

BOX 1 • SUMMARY OF ELECTRICITY ACCESS INDICATORS AND REGULATORY INDICATORS FOR SUSTAINABLE ENERGY IN PAPUA NEW GUINEA

According to the World Bank's Regulatory Indicators For Sustainable Energy (RISE), eight indicators measure the level and ambition of electricity access policy frameworks. Electrification policies and regulations in PNG have improved since 2010, most recently in the off-grid space, with the inclusion of good practice mini-grid regulations in the National Electricity Roll-out Plan (NEROP). There is still room for improvement in the policy environment to keep pace with the performance at the global and regional levels. Since 2010, the most noteworthy progress was observed in policy and regulatory measures to support stand-alone systems development and mini-grids. The grid electrification framework has remained at an intermediate level. The increasing policy support for non-grid services proves a growing understanding of their potential to accelerate electricity access, particularly when it comes to geospatial planning. However, the scope of electrification plans in the country needs to be more inclusive of geographically remote and off-grid areas in regulatory frameworks in order to advance the expansion of electricity access. The lackluster investor perception of utility creditworthiness is a barrier to electrification, as there are no mechanisms to guarantee offtaker risk for new energy projects. Consumer affordability of electricity has remained constant since 2019 at an intermediate level of performance in implementing strategies for the poorest populations without access. See figure B1.1.

FIGURE B1.1 • Eight regulatory indicators for electrification



Source: ESMAP RISE database, 2020.

BOX 2 • SUMMARY OF CLEAN COOKING INDICATORS AND REGULATORY INDICATORS FOR SUSTAINABLE ENERGY IN PAPUA NEW GUINEA

PNG is yet to initiate a measurable action toward providing access to clean cooking solutions. As per the Regulatory Indicators For Sustainable Energy (RISE) 2020 report, the country does not yet have a strong priority toward clean cooking plans, nor institutional set up, to advance the clean cooking agenda. From 2010 until 2019, the country did not make significant progress in any of the clean cooking sub-indicators and hence the score remains zero. The country first needs to have clearly articulated policy goals and policy instruments in order to allow development of a dedicated institutional vehicle to drive forward the clean cooking initiatives with clearly defined physical targets. The country should focus on first prioritizing a feasible tracking mechanism to determine the rate of access to clean cooking solutions in different geographic areas of the island. Once tracking is established on a regular basis, a national plan and regulatory framework can be developed. The planning should focus on creating a market for clean cooking fuel and cookstove suppliers and overcoming barriers for last-mile distribution to consumers. The market for suppliers can be enhanced with standards and labeling to incentivize higher quality of efficiency and safety of stoves and fuels. At a later stage, as plan aspects are implemented, the market can grow with result-based incentive structures for suppliers.

Source: ESMAP RISE database, 2020.

GLOBAL SURVEY ON ENERGY ACCESS USING THE MULTI-TIER FRAMEWORK

The World Bank, with the support from the Energy Sector Management Assistance Program (ESMAP), launched in 2016 the Global Survey on Energy Access, using the MTF. The survey's objective is to provide nuanced data on energy access, including access to electricity and MECS. The first phase (2016–19) was carried out in 16 countries across Africa, Asia, and Latin America. The second phase started in 2020 with additional countries.

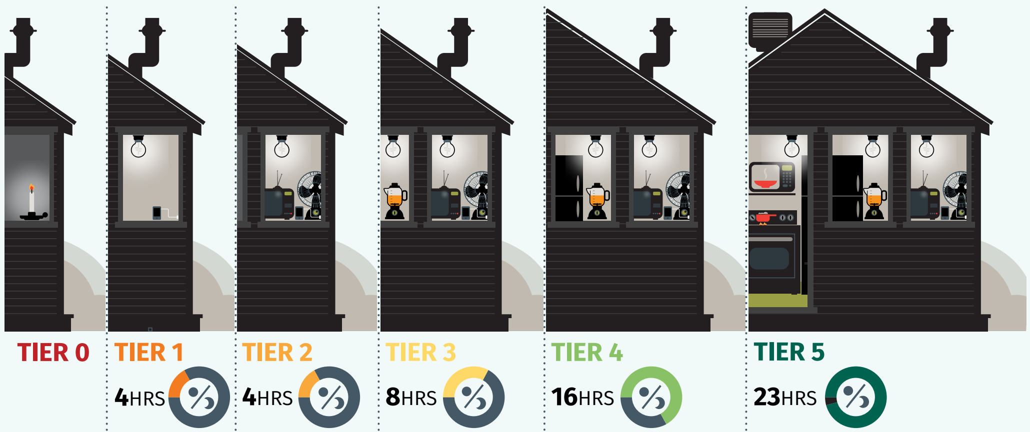
The MTF goes beyond the traditional binary measurement of energy access—namely, having access or not to electricity, and having access or not to clean cooking fuels and technologies—to capture the multi-dimensional nature of energy access at the end user level and the vast range of technologies that can provide energy access, while accounting for the wide differences in user experience.

The MTF defines energy access as the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, formal, convenient, healthy, and safe for all required energy applications across households, enterprises, and community institutions. Based on this definition, the MTF measures energy access provided by any technology or fuel, based on a set of attributes that capture key characteristics of the energy supply that affect the user experience. Based on those attributes, it defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access), along a continuum of improvement. Each attribute is assessed separately, and the overall tier of access to electricity or MECS for each user (household, enterprise, education facility, or health facility) is the lowest tier attained across the attributes (Bhatia and Angelou 2015).

ACCESS TO ELECTRICITY

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

BOX 3 • MINIMUM ELECTRICITY REQUIREMENTS, BY TIER OF ELECTRICITY ACCESS



Tier 0	Tier 1	Tier 2
Electricity is not available or is available less than 4 hours a day (or less than 1 hour per evening), or has a capacity of <3 W (or <12 Wh). Households cope by using candles, kerosene lamps, or battery-powered devices, such as flashlights and radios.	Electricity is available at least 4 hours a day, including at least 1 hour per evening, and the capacity is sufficient to power task lighting and phone charging or a radio. All electricity sources may meet these requirements—from certain solar lighting systems to the national grid.	Electricity is available at least 4 hours a day, including at least 2 hours per evening, and capacity is sufficient to power low-load appliances as needed during that time, such as multiple lights, a television, or a fan (see table 1). Sources that may meet these requirements include a rechargeable battery, solar home system (SHS), generator, mini-grid, and the national grid.
Tier 3	**Tier 4**	**Tier 5**
Electricity is available at least 8 hours a day, including at least 3 hours per evening, and capacity is sufficient to power medium-load appliances as needed during that time, such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1). In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that may meet these requirements include an SHS, generator, mini-grid, and the national grid.	Electricity is available at least 16 hours a day, including at least 4 hours per evening, and capacity is sufficient to power high-load appliances as needed during that time, such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1). There are not long or frequent unscheduled interruptions, there are no voltage issues, and the electricity source is formal and safe. Sources that may meet these requirements include a generator, mini-grid, and the national grid.	Electricity is available at least 23 hours a day, including 4 hours per evening, and capacity is sufficient to power very-high-load appliances as needed during that time, such as air conditioners, space heaters, vacuum cleaners, and electric stoves (see table 1). The most likely source for meeting these requirements is the national grid, although a generator or mini-grid might suffice as well.

Source: Bhatia and Angelou 2015.

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

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

Source: Bhatia and Angelou 2015.

BOX 4 • TYPOLOGY OF OFF-GRID SOLAR DEVICES AND TIER CALCULATION

Solar devices are classified into three types based on the number of light bulbs and the type of appliances or electricity services they can provide. This typology is used to assess the Capacity Tier of the solar solution.

- **Solar lanterns** power only one light bulb, and may or not include a power outlet (to charge a phone or power a radio). The Capacity Tier of a solar lantern may be Tier 0 or Tier 1, depending on their score. The score will depend on the possibility to charge a mobile phone or power a radio and the level of the lighting service calculated based on the ratio between the number of people served with adequate lighting and the household size (annex 1).

- **Solar lighting systems (SLSs)** power two or more light bulbs, and may or not include a power outlet (to charge a phone or power a radio). The Capacity Tier of an SLS may be Tier 0 or Tier 1, depending on their score. The score will depend on the possibility to charge a mobile phone or power a radio and the level of the lighting service calculated based on the ratio between the number of people served with adequate lighting and the household size (annex 1).

- **Solar home systems (SHSs)** power two or more light bulbs and can power at least low-load appliances (such as a television, fan, computer, or VCD/DVD player). The Capacity Tier of a SHS is Tier 2 by default, unless the household owns appliances that reach Appliance Tier above Tier 2, in which case the Capacity Tier will correspond to the highest Appliance Tier reached by the appliances (in working condition) owned by the household. (See table 1 for appliances by load level and associated Capacity Tier).

The MTF aims to provide insight into the types of policy reforms and project interventions that would drive higher levels of access to energy as well as facilitate monitoring and evaluation. The richness of MTF data can provide valuable market intelligence for the private sector to identify the market potential. In several countries, results from the MTF survey are helping to deepen sector dialogue and inform policies and investments to meet ambitious access targets. As such, MTF data analysis offers useful input for policy formulation, investment strategies, project design, utility performance accountability, and evaluations of project impact. The MTF is also a useful tool for setting SDG 7.1 targets and tracking progress toward achieving them.

ACCESS TO MODERN ENERGY COOKING SERVICES (MECS)

Progress on Sustainable Development Goal 7.1, access to clean cooking fuels and technologies, has been slow, with around 2.8 billion of the world's population still using polluting and inefficient cooking solutions (IEA et al. 2020). 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).[4] The consequences of inefficient energy use for cooking extend beyond direct health impacts. Such use also affects socioeconomic development; for example, fuel collection and cooking tasks are often carried out by women and girls. Collection time depends on the local availability of fuel and may reach up to several hours a day (ESMAP 2004; Gwavuya et al. 2012; Parikh 2011; Wang et al. 2013). The time spent on fuel collection and preparation often translates into lost opportunities for gaining education and increasing income (Blackden and Wodon 2006; Clancy, Skutsch, and Bachelor 2003). In addition, the associated drudgery increases the risk of injury and attack (Rehfuess, Mehta, and Prüss-Üstün 2006).

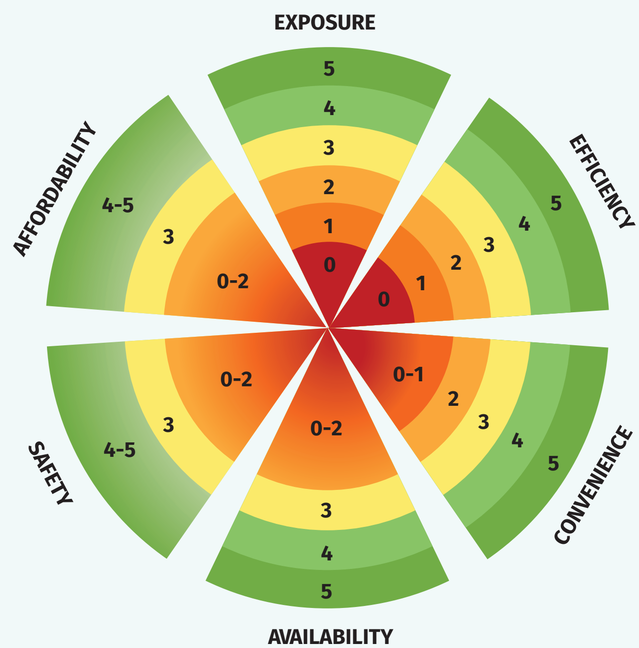
MECS are defined by six technical and contextual attributes that consider users' cooking experience, environment, and the market and energy ecosystems in which they live: exposure, efficiency, convenience, safety, affordability, and fuel availability. See box 5 for a full description:

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

BOX 5 • SIX ATTRIBUTES DEFINE ACCESS TO MODERN ENERGY COOKING SERVICES

1. *Exposure.* Personal exposure to pol¬lutants, which depends on both stove emissions and ventilation (higher tiers indicate lower exposure)
2. *Efficiency.* Combination of combus¬tion and heat-transfer efficiency
3. *Convenience.* Time spent collecting or purchasing fuel and preparing the stove
4. *Safety.* Severity of injuries caused by the stove over the past year
5. *Affordability.* Share of household budget spent on fuel (higher tiers indi¬cate lower share of spending)
6. *Fuel availability.* Readiness of the fuel when needed by the user

FIGURE B5.1 • **MTF Attributes showing tiered progress toward access to modern energy cooking services**



Source: ESMAP 2020.

Note: "Modern energy cooking services (MECS)" refer to a household context that has met the standards of Tier 4 or higher across all six measurement attributes of the Multi-Tier Framework MTF).

Beyond the stove and fuel technologies, many contextual factors contribute to the household cooking experience, including human behavior (for example, who cooks, what is cooked, how, for how long, and how often); housing conditions (for example, kitchen location, arrangement and size of rooms, construction materials, and quality of ventilation); and other types of energy demand that may equally contribute to Household Air Pollution (for example, lighting, space heating, and water heating). Other dimensions of household choice, adoption, and adherence—including economic conditions (for example, income/affordability and proximity to fuel markets)—must also be captured.

"Improved cooking services" refers to a household context that has met at least the Tier 2 standards of the MTF across all six measurement attributes but not all for Tier 4 or higher. Household contexts with a status of MTF Tier 2 or Tier 3 are considered in transition.

These six attributes are integrated into the MTF to capture detailed, indicator-level data for tracking stepwise progress across tiers of access. Each attribute is scored across six tiers (Tiers 0–5), and these tiers are measured using one or more indicators, each spanning a lower and upper threshold (see annex 2 for detailed metrics).

Understanding the stove type used in households in crucial, as it serves as a one of the key characteristics for assessing attribute threshold. The types of the stoves used in Papua New Guinea are presented in box 6.

BOX 6 • TYPOLOGY OF COOKSTOVES IN PAPUA NEW GUINEA

The cookstoves in Papua New Guinea have been classified into following categories:

Three-stone stoves: these consist of a pot balanced on three stones. The pot sits on the flames and the fuel rests on the ground. In general, this stove uses firewood and has a low combustion temperature; its fire is exposed to cold wind causing the heat to be lost to the ambient air.

Traditional stoves (biomass, artisan, or self-built stoves): Traditional stoves typically use conventional material to insulate the fire, and the pot rests above the flames. They are produced locally using available, low-cost materials and fuels, reflecting cultural practices.

Improved cookstoves (biomass manufactured stoves): The conventional improved cookstove is a wood, charcoal, or pellet stove with an insulated combustion chamber. The pot rests above the fuel.

Liquid fuel or kerosene stoves: These use kerosene or other liquid fuel.

Clean fuel: clean fuel stoves use clean and efficient fuels, such as liquefied petroleum gas (LPG), electricity, or biogas.

BOX 7 • MINIMUM REQUIREMENTS, BY TIER, OF ACCESS TO MECS

Tier 0	Tier 1	Tier 2
The main cookstove is a stove with Tier 0 emissions (such as a three-stone stove) used in a cooking area with bad or medium ventilation, OR a stove with Tier 1 emissions (such as a traditional stove or an improved cookstove without exhaust system) used in a cooking area with bad ventilation.	The main cookstove is a stove with Tier 0 emissions (such as a three-stone stove) used in a cooking area with good ventilation, OR a stove with Tier 1 emissions (such as a traditional stove or an improved cookstove without exhaust system) used in a cooking area with medium ventilation, OR a stove with Tier 2 emissions (such as an improved cookstove with exhaust system) used in a cooking area with bad ventilation.	The main cookstove is a stove with Tier 1 emissions used in a cooking area with good ventilation, OR a stove with Tier 2 emissions used in a cooking area with medium ventilation, OR a stove with Tier 3 emissions used in a cooking area with bad ventilation.

Tier 3	Tier 4	Tier 5
The main cookstove is a stove with Tier 2 emissions used in a cooking area with good ventilation, OR a stove with Tier 3 emissions used in a cooking area with medium ventilation. The main cooking fuel is available over 80% of the time. The main cooking solution has caused only minor accidents if any. In addition, acquisition and preparation time of the main fuel is less than 3 hours per week and preparation time of the main stive is less than 10 minutes per meal.	The main cookstove is a stove with Tier 3 emissions used in a cooking area with good ventilation, OR a stove with Tier 4 emissions used in a cooking area with bad or medium ventilation. The main cooking fuel is mostly available (over 90% of the time), and the cost of cooking fuels is under 5% of total household expenditure. The main cooking solution has not caused any accidents. In addition, acquisition and preparation time of the main fuel is less than 90 minutes per week and preparation time of the main stove is less than 5 minutes per meal.	The main cookstove is a stove with Tier 4 emissions used in a cooking area with good ventilation, OR a stove with Tier 5 emissions (such as a clean fuel stove). The main cooking fuel is always available, and the cost of cooking fuels is under 5% of total household expenditure. The main cooking solution has not caused any accidents. In addition, acquisition and preparation time of the main fuel is less than 30 minutes per week and preparation time of the main stove is less than 2 minutes per meal.

Source: World Bank.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

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

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

MTF data can inform the design interventions meant to expand access, in addition to prioritizing them so that they may have the maximum impact on tier access for a given budget. The data can be disaggregated by attribute and technology, providing insights into the variables that keep 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 also provide guidance on the technologies that are most suited to satisfy the demand of non-electrified households (for example, grid or off-grid). MTF demand-side data, such as energy spending, WTP, energy use, and appliances, can also be used to inform the design and targeting of government programs, projects, and investments for energy access.

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

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN PAPUA NEW GUINEA

The MTF survey in PNG was conducted as a continuum of World Bank's Poverty Global Practice's (GP's) survey, which was planned for four subsequent rounds and was meant to measure the socioeconomic impacts of COVID-19 in the country. In the third round of this survey, the MTF team captured the energy access status in PNG by incorporating questions of the MTF in the Poverty GP's survey questionnaire.

SURVEY INSTRUMENT AND IMPLEMENTATION

Due to time restrictions, the phone survey questionnaire included selected questions aiming to assess the MTF attributes. The survey was conducted May 7–17, 2021, by the consulting firm Digicel (Port Moresby call center) with the collaboration of the Poverty GP. The length of the survey was limited to 14–18 minutes, and the survey instrument consisted of the following modules: interview information, basic information, household electricity, household cooking, WTP for grid connection fee, WTP off-grid solutions, energy expenditure, assets, impact on energy sector of COVID-19 pandemic, and behavior vis-à-vis COVID-19 vaccination.

Digicel conducted the field work with 18 interviewers who were trained under the supervision of four senior project leaders and the World Bank team. The sampling list was based on the World Bank's Poverty GP's second round survey's call list. To address attrition, replication was made with respondents in the same location and was targeted as much as possible toward lower deciles of the wealth distribution (Hemelein et al.). The analysis used quintiles to divide the population based on households' expenditure. Due to small sample sizes and potential bias in the bottom quintile, the lowest two quintiles were aggregated into the bottom 40 percent and analyzed against the 3rd quintile, 4th quintile, and top 20 percent quintile.

WEALTH INDEX

It is important to note that mobile phone surveys tend to be biased toward wealthier population groups, who are able to use (charged) mobile phones at the time of the survey and live in areas with mobile phone coverage. Therefore, there is a likelihood that households from the lowest expenditure quintiles are under-represented, affecting the accuracy of results. To avoid this bias, a wealth index was calculated to mitigate the potential bias as much as possible.

The MTF survey in 2021 re-created the wealth index which allows comparison between the MTF survey and the Demographic and Health Survey (DHS) from 2016 to 2018. The 2016–18 DHS dataset in PNG (DHS 2019) used a wealth index based on household assets and housing characteristics. If households have steadily acquired more assets, they will appear higher in the wealth distribution in this MTF survey than they would in the DHS. According to the Papua New Guinea High Frequency Survey on COVID-19: Results from Round 1 (World Bank 2020), the DHS wealth index (DHS n.d.) is calculated using principal components analysis.[5] Not all variables of the full DHS wealth index were considered in the mobile phone survey due to the limited survey length. In the recalculation of the wealth index of the phone survey there is more than 98 percent correlation between the recalculated and original measurements. To get the identical measurement, the pooled data was used with a single set of codes. To infer at the population level instead of mobile phone holders, it was essential to re-weight the survey data.

To address the potential upward bias, several methodologies were use, such as correlation, logit model, and raking, among others. The detailed methodology of wealth index can be found in Kastelic et al. (n.d). And the general sample design can be found in Papua New Guinea High Frequency Phone Survey on COVID-19 (Kastelic et al. n.d.), which presents the results from round 2. In the round 2 survey, to address a skew to higher deciles of wealth distribution in round 1, a different stratification mechanism was applied based on the subscribers' characteristics. For example, if households did not send text messages, they were assumed to be less literate. If they received only incoming calls, or credit transferred from other subscribers, the household was assumed to be poorer. The round 3 survey used a similar methodology in wealth index calculation. For the quality check of the cleaned final survey data the margin of error[6] of the grid access rate is calculated, which is about 2.6 percent.

SAMPLING

The total sample was 2,500 households. The Survey Solutions (SUSO) computer software package was used for data collection and management. Based on test questionnaire's results, a lead list of 20,000 random digital dialing numbers (households) were generated for call center enumerators to perform a survey. The total number of interviews recorded on the SUSO application was 4,227, from which 1,560 were rejected due participation refusal, disengagement, or an inability to reach respondents over the phone (calls directly led to voicemails). Accordingly, 2,667 successfully completed surveys were conducted. Sampling weights were used to mitigate the impact of selection bias. The weights were based on information from the 2016–18 PNG DHS and included adjustments for household location, size, and wealth and the respondent's sex and education level. After cleaning and incorporating the wealth index, the sample size was reduced to 2,635.

Interviews were conducted in a total of 87 districts. The targeted sample sizes by district are provided in annex 3, table A3.1. The survey was reweighted based on the 2016–18 DHS nationally representative

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[5] Principal component analysis, or PCA, is a dimensionality reduction method that is often used to reduce the dimensionality of large data sets, by transforming a large set of variables into a smaller one that still contains most of the information in the large set.

[6] Margin of error: To put it simply, the margin of error means the degree of uncertainty that survey results might have. The larger the margin of error is, the more likely it is for results to be further away from the "true figures" for the whole population.

dataset (World Bank 2020). PNG is divided into four regions, which are its broadest administrative divisions. Table 2 shows the achieved unweighted sample size of completed responses by region. Table 3 shows the administrative regions based on 22 provinces, and map 1 aids in understanding the geographic distribution.

TABLE 2 • Implemented sampling frame as per region (unweighted)

Regions in PNG	Urban	Rural	Nationwide
Highlands region	388	617	1,005
Islands region	210	274	484
Momase region	276	452	728
Southern region	273	145	418
Total	**1,147**	**1,488**	**2,635**

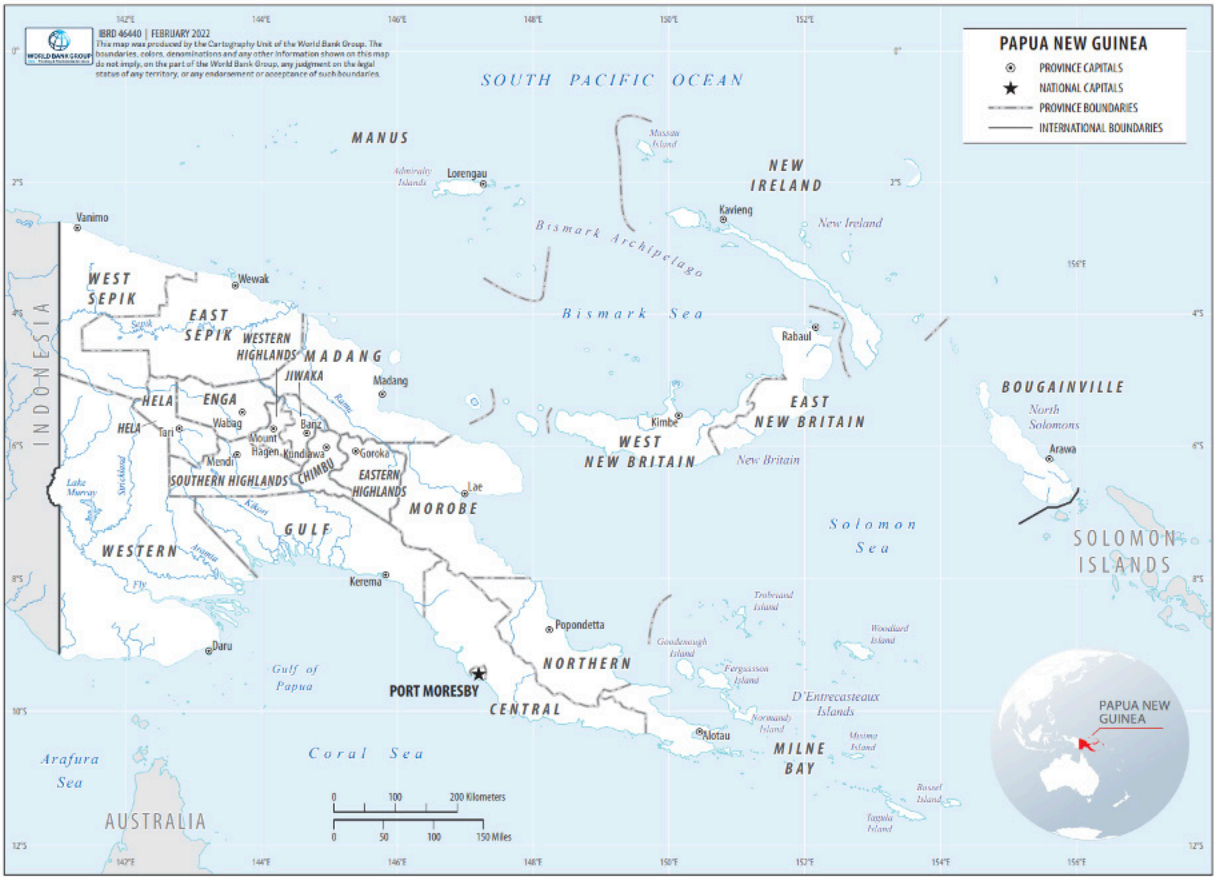
Source: Papua New Guinea Energy Survey 2021.

TABLE 3 • Sample distribution of four administrative regions based on 22 provinces in Papua New Guinea

Region	Province	Frequencies
Highlands region	Chimbu Province	131
	Eastern Highlands Province	217
	Enga Province	159
	Southern Highlands Province	163
	Western Highlands Province	104
	Hela Province	110
	Jiwaka Province	121
Islands region	East New Britain Province	126
	Manus Province	35
	New Ireland Province	79
	West New Britain Province	100
	Autonomous Region of Bougainville (Bougainville Region)	144
Momase region	East Sepik Province	144
	Madang Province	222
	Morobe Province	247
	Sandaun (West Sepik) Province	115
Southern region	Central Province	70
	Gulf Province	42
	Milne Bay Province	64
	Oro (Northern) Province	22
	Western (Fly) Province	66
	National Capital District	154
Total		**2,635**

Source: Papua New Guinea Energy Survey 2021.

MAP 1 • **Papua New Guinea**



Source: World Bank.

ACCESS TO ELECTRICITY

Photo: ©Kalo Fainu/World Bank

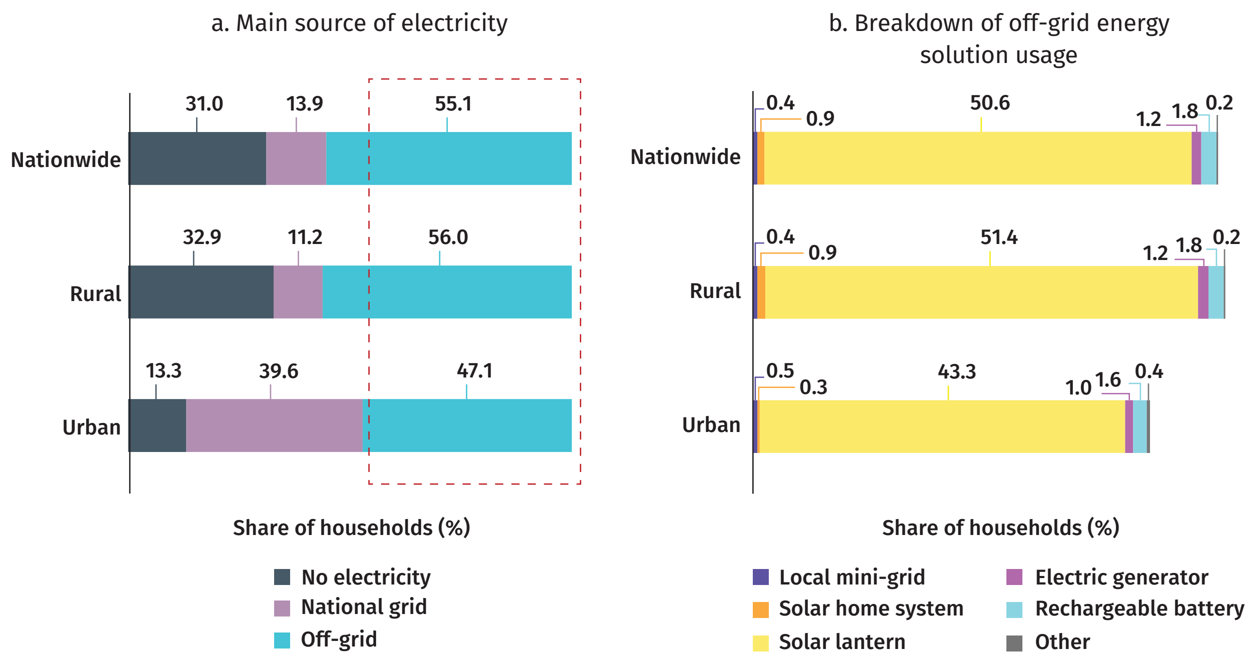
ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

Overall, about 69 percent of the households enjoy electricity from off-grid or grid connections in Papua New Guinea (PNG). This breaks down to about 67 percent and 87 percent, respectively, of rural and urban households having access from either the national grid or off-grid energy solutions. However, a relatively small share of households nationwide has electricity from the grid network (13.9 percent). There is a stark difference in the grid connection rate between urban and rural areas: 40 percent (39.6 percent) of urban households and about 11 percent (11.2 percent) of rural households have a grid connection.

Nationwide, off-grid energy solutions are the dominant source of electricity, with more than one-half (55.1 percent) of households having electricity from off-grid solutions, particularly from off-grid solar lanterns (50.6 percent). The solar solutions include both quality verified and non-quality verified products. Lanterns are more commonly used in rural areas (51.4 percent) than urban areas (43.3 percent). Almost one-third of the households (31 percent) are unable to get any source of electricity. About one-third (32.9 percent) of rural households live without electricity, which is more than double compared to urban areas (13.3 percent) (figure 2).

FIGURE 2 • **Access rate of the main source of electricity**

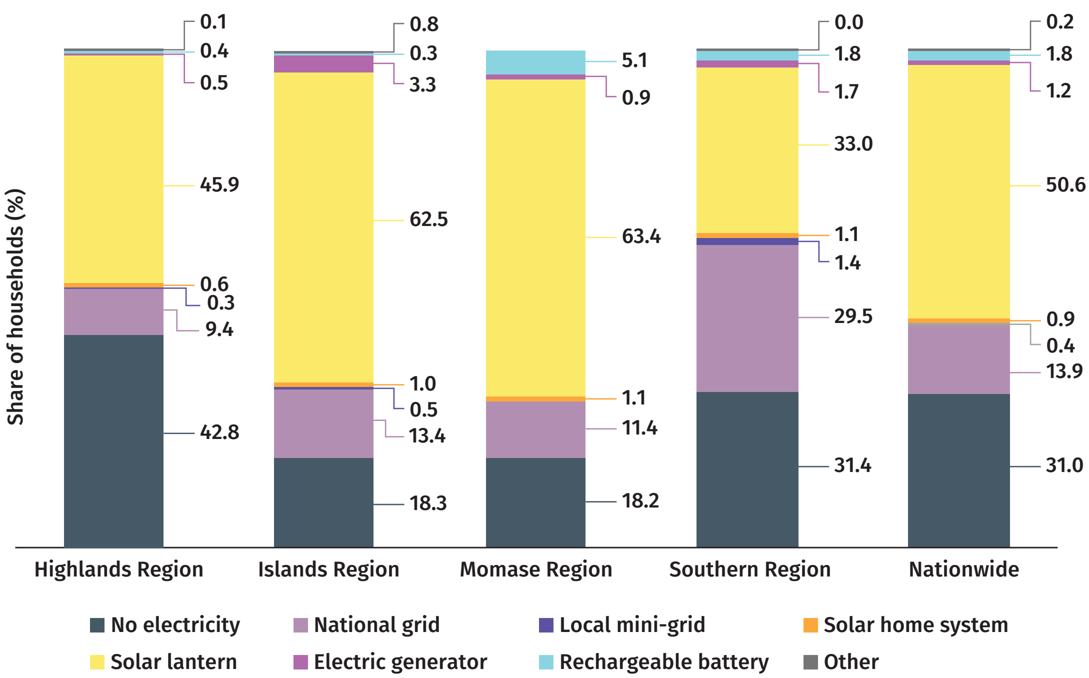


Source: Papua New Guinea Energy Survey 2021.

Among those who are using the off-grid solar products, cheaper "generic" products comprise over 80 percent of off-grid solar products sold in PNG (IFC, 2020). Such prevalence of using cheap and often lower-quality products may affect negatively consumer's satisfaction with off-grid solar products. It is estimated that about 11 percent of households use a certified solar products in PNG. Thus, if we limit it to certified solar products for the government to track the progress under the National Energy Access Project, about 25 percentage of PNG households use either the grid network (13.9 percentage) or certified off-grid solar product (11 percentage) as the main source of electricity.

The Southern region has the highest grid access rates, but a substantial share of the population does not have access to electricity. Furthermore, this region is lowest in the off-grid penetration rate. In the Highland region, more than 40 percent of households do not have access to any source of electricity and have the lowest grid access rate. In the Islands and Momase regions, the number of households from rural areas is higher than in urban. In Islands region (63.5 percent) and Momase region (64.5 percent) off-grid solar solutions are popular compared to the other two regions. However, the grid access rates in Islands and Momase regions are low, 13.4 percent and 11.4 percent, respectively. In these two regions, less than one-fifth of the population has access to electricity, a figure lower than the other two regions, primarily due to the implementation of off-grid solutions (figure 3).

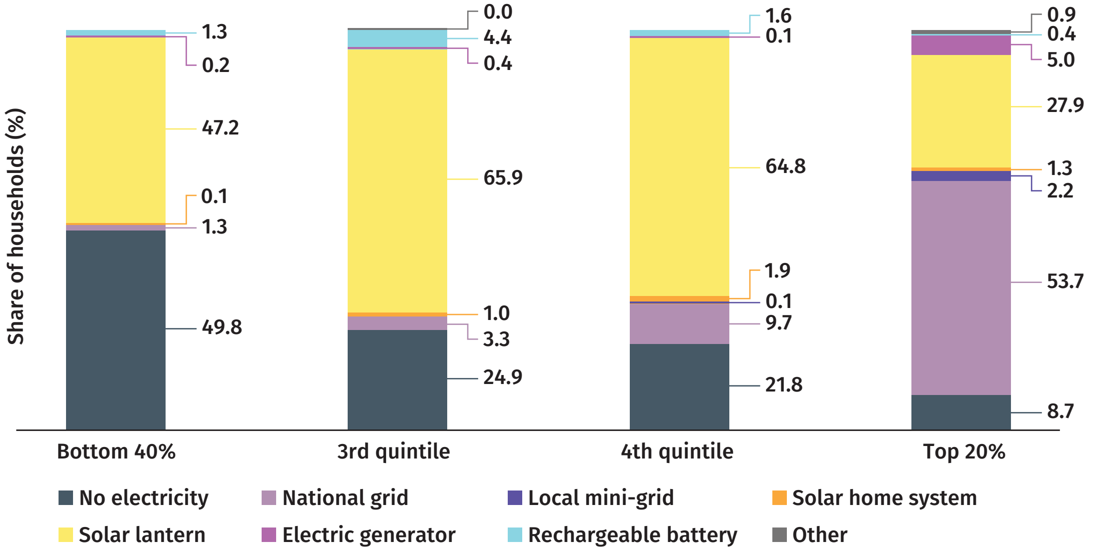
FIGURE 3 • **Distribution of households based on main sources by Regions**



Source: Papua New Guinea Energy Survey 2021.

The MTF survey results show that poorer populations are less likely to have access to electricity. Less than 10 percent of the top quintile group have no access to electricity while about half of the bottom 40 percent of households have no electricity. The top quintile and the bottom 40 percent households are less likely to use off-grid energy solutions, particularly solar lanterns, compared to the rest of quintile groups (65.9 percent of the third quintile and 64.8 percent of the fourth quintile). Since more than half of the top quintile households are connected to the national grid, they may not need to use off-grid solar solutions to the extent that other quintile groups do. Even though the share of the bottom 40 percent households using off-grid energy solutions is less than the third and fourth quintile groups, the share of the bottom 40 percent households using off-grid energy solutions is still substantial (47.2 percent) (figure 4).

FIGURE 4 • **Share of households of main source of electricity by expenditure quintiles**

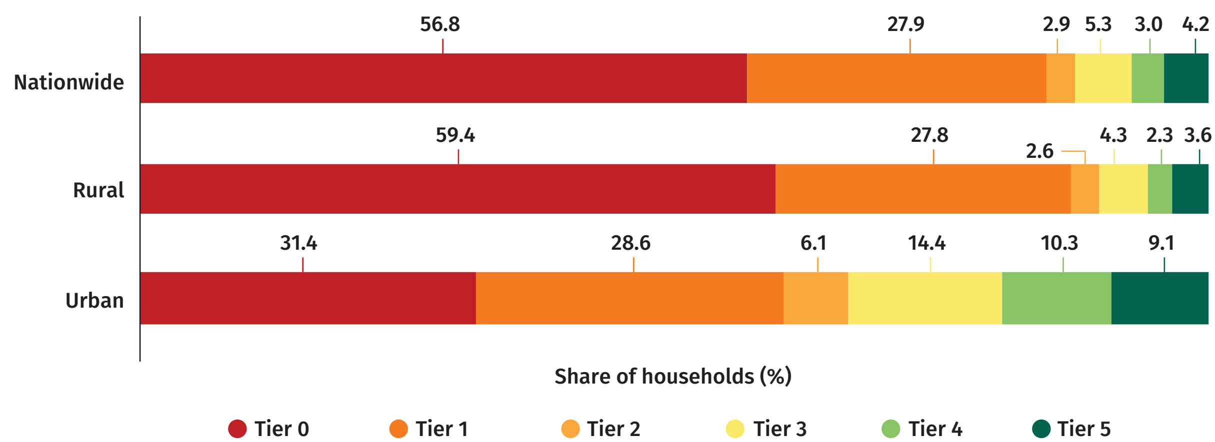


Source: Papua New Guinea Energy Survey 2021.

MTF TIERS

More than half of households in PNG are in Tier 0 (57 percent): 31 percent of Tier 0 households do not have any source of electricity and 26 percent of Tier 0 households use electricity which does not meet the minimum requirement of Tier 1 (figure 2). Similarly, in rural and urban areas, respectively, about 26.5 percent and 18.1 percent of households have some access to electricity but need support to achieve a minimum tier level (figure 5). The calculation of the aggregated MTF tier does not incorporate considerations of Affordability and Safety Tiers, due to insufficient information. Additional surveys can shed light on these key features. More details of the methodology of tier attribute calculations and the feature of all the attributes can be found the annex 1, table A1.1, and in the "Access to Electricity" section of this report.

FIGURE 5 • **Distribution of households based on aggregated MTF tier**



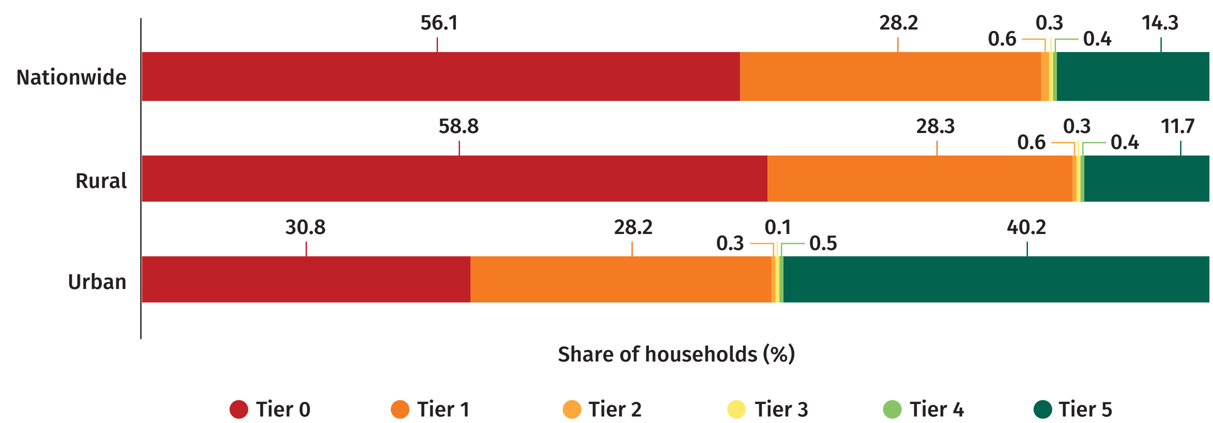
Source: Papua New Guinea Energy Survey 2021.

MTF ATTRIBUTES

Capacity

The Capacity Tier ranges from least to highest based on the ability to operate appliances in W or kW. Nationwide, with the existing sources of electricity, about four-fifths (Tier 0–1) of the population are unable to operate more than 49 W of appliances, indicating either they do not have electricity or use dry-cell batteries or can charge mobile phone or listen to radio, and so forth. Only about one-seventh of the population can enjoy the benefit of the appliances with highest (more than 2 kW) capacity, such as a refrigerator, air-conditioner, and so forth. Rural households use energy sources with less capacity than do urban households (figure 6).

FIGURE 6 • **Distribution of households based on Capacity Tier**

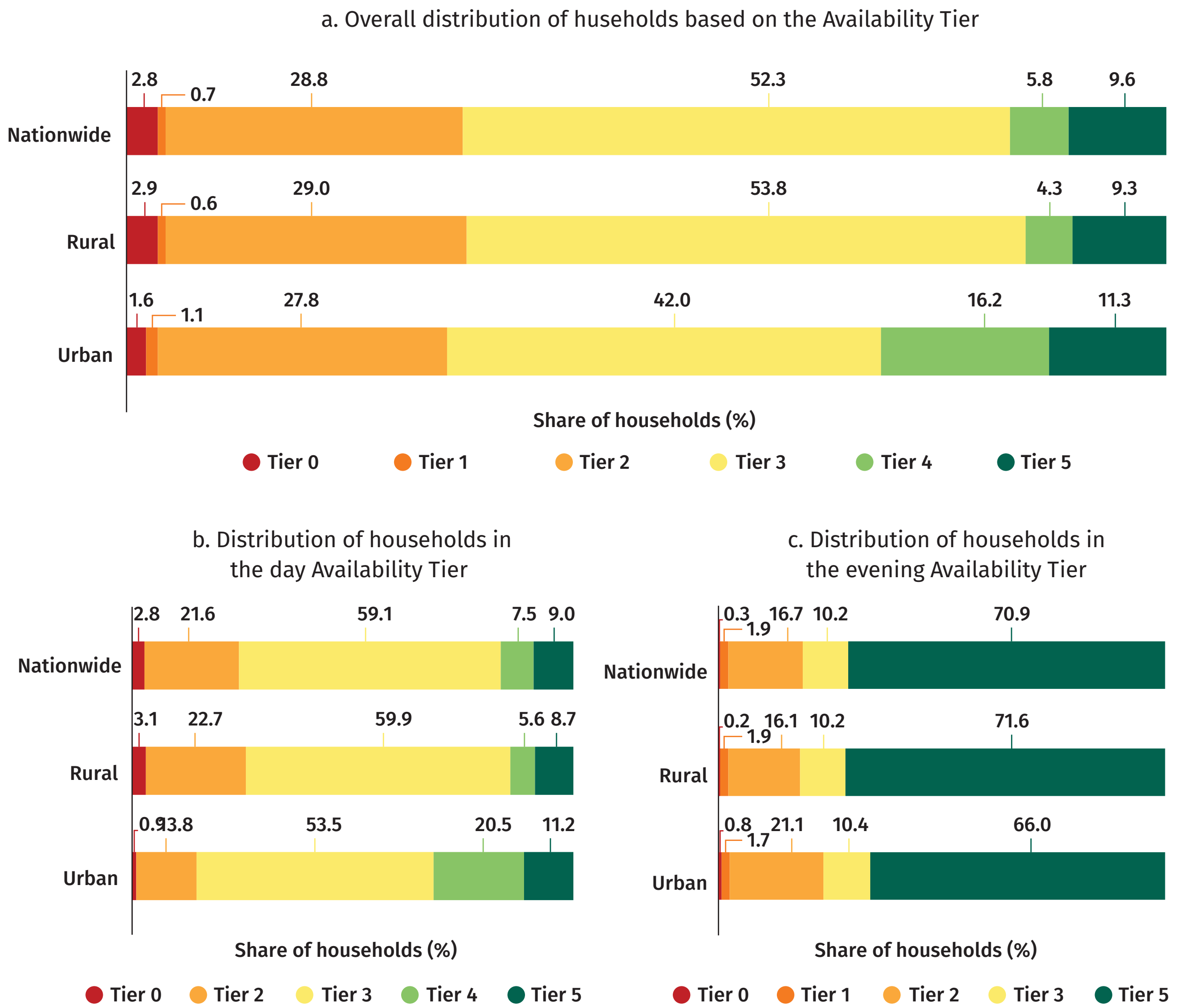


Source: Papua New Guinea Energy Survey 2021.

Availability

Nationwide among electrified households, more than half have electricity availability for a minimum of 8 hours in a 24-hour period or a minimum of 3 hours at night (Tier 3). About five out of seven (70.9 percent) households are in Tier 5 for the evening Availability Tier, indicating 4 hours of availability between 6:00 pm and 10:00 pm. Nationwide, only about one out of ten of the households (9.6 percent) have 24 hours of electricity availability (figure 7).

FIGURE 7 • Distribution of households based on the Availability Tier

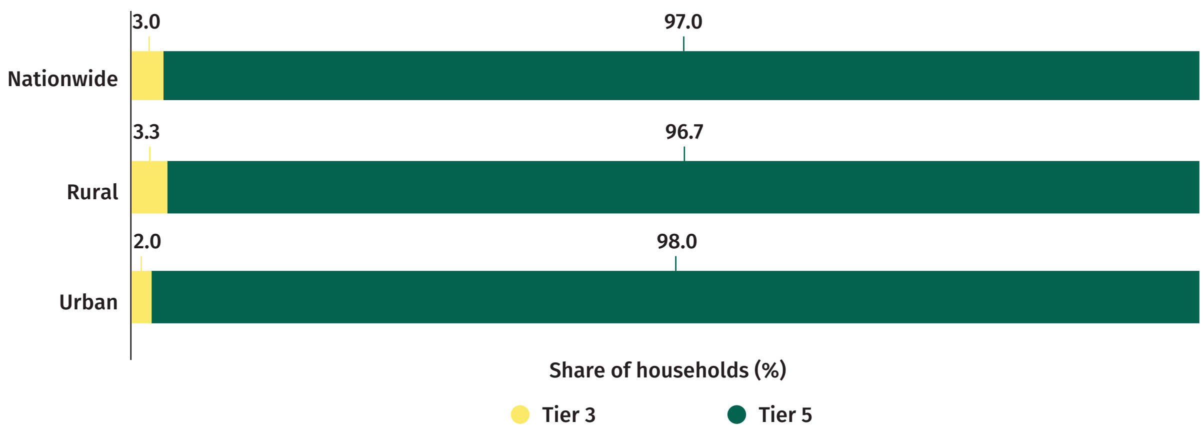


Source: Papua New Guinea Energy Survey 2021.

Formality

Formality refers to whether a household has a legal connection to the grid or a mini-grid. The households that pay bills to energy companies, landlords, utility offices, and so forth for their energy services are considered to be legally connected.[7] Informality is not an issue in PNG. Nationwide only 3 percent of households are connected informally (figure 8).

FIGURE 8 • **Distribution of households based on the Formality Tier**

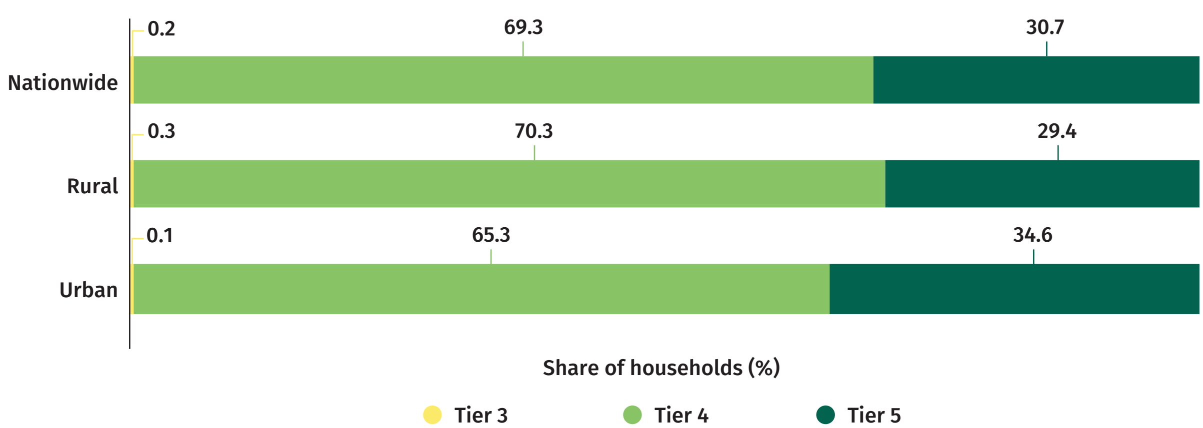


Source: Papua New Guinea Energy Survey 2021.

Reliability

The reliability of electricity supply is determined using duration and frequency of energy supply interruption per week for those using mini-grid or grid sources. Nationwide, only less than one-third of the households are in the highest Reliability Tier, which refers to at most three interruptions with at most two hours of duration per week. The rest of the households (69.2 percent) observe more, longer and frequent interruptions of power supplies (figure 9).

FIGURE 9 • **Reliability Tier among households**



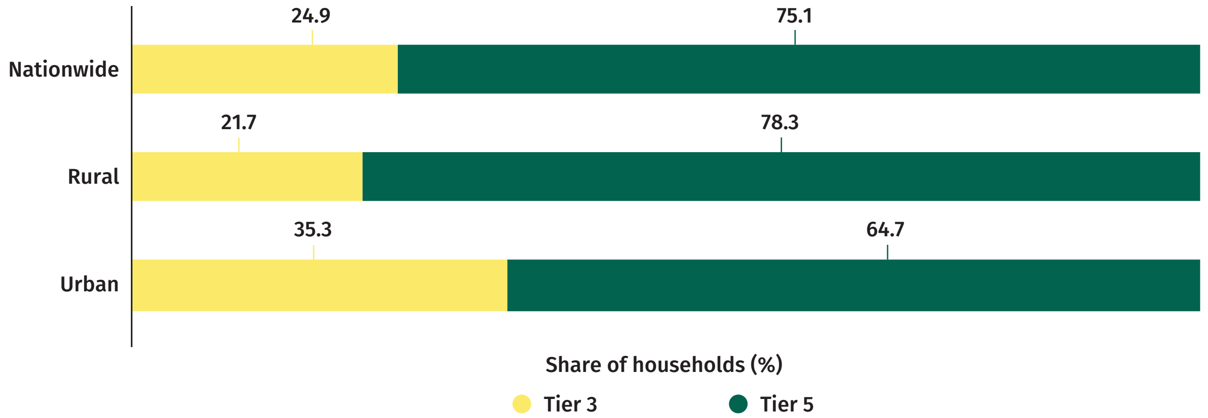
Source: Papua New Guinea Energy Survey 2021.

[7] The Formality attribute is generated based on the indirect question of whom in a household member pays the electricity bill, as the respondents may be uncomfortable disclosing the type of their grid or mini-grid connection in a recorded survey. A connection is considered informal if no one receives payment for electricity services.

Quality

The quality of electricity supply refers to the absence of voltage fluctuation. Voltage fluctuations may damage electric appliances. About 75 percent of households are not affected by voltage fluctuation, which is higher in rural areas (78.3 percent) compared to the urban areas (64.7 percent) (figure 10).

FIGURE 10 • **Quality Tier among households**



Source: Papua New Guinea Energy Survey 2021.

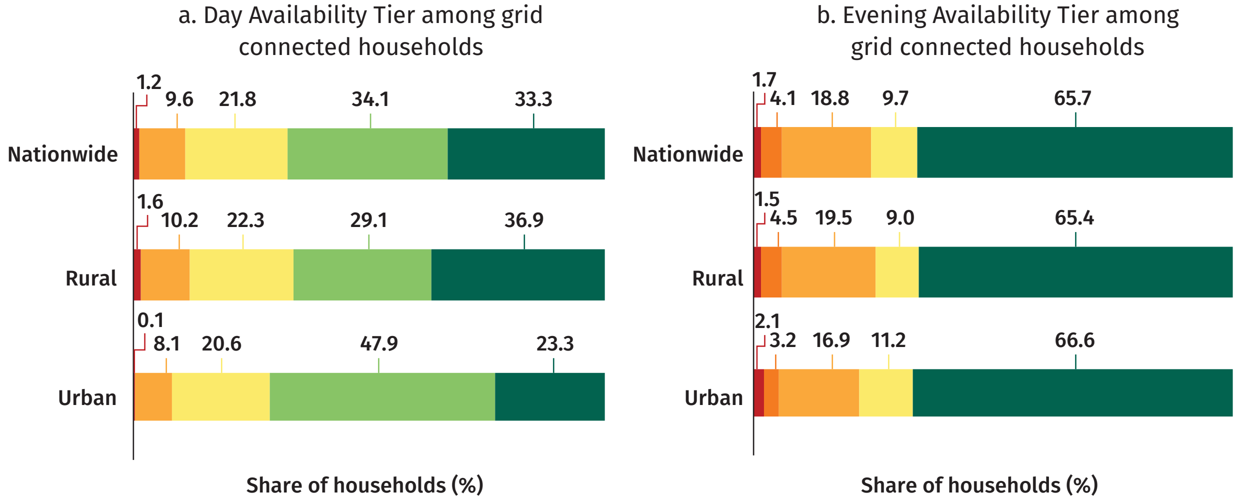
IMPROVING ELECTRICITY ACCESS AMONG HOUSEHOLDS

The fundamental objective of improving electricity access among households is to increase access rates and acquire higher tier levels. About 69 percent of households are connected to some source of electricity. Among them, 13.9 percent represent grid-connected households and the rest use off-grid energy solutions. Among the off-grid solutions, about 50.6 percent of households are using solar lanterns (figure 2). With 4.2 percent of households in Tier 5, there is room for improvement for the remaining 95.8 percent of households (figure 5).

IMPROVE THE QUALITY OF ELECTRICITY SUPPLY FROM THE GRID NETWORK (GRID-CONNECTED)

The data underscore that a substantial portion of grid-connected households in PNG cannot achieve the highest tier due to availability (figure 11). Addressing these availability issues is critical for enhancing the overall quality of electricity supply and ensuring that more households can benefit from higher-tier energy access.

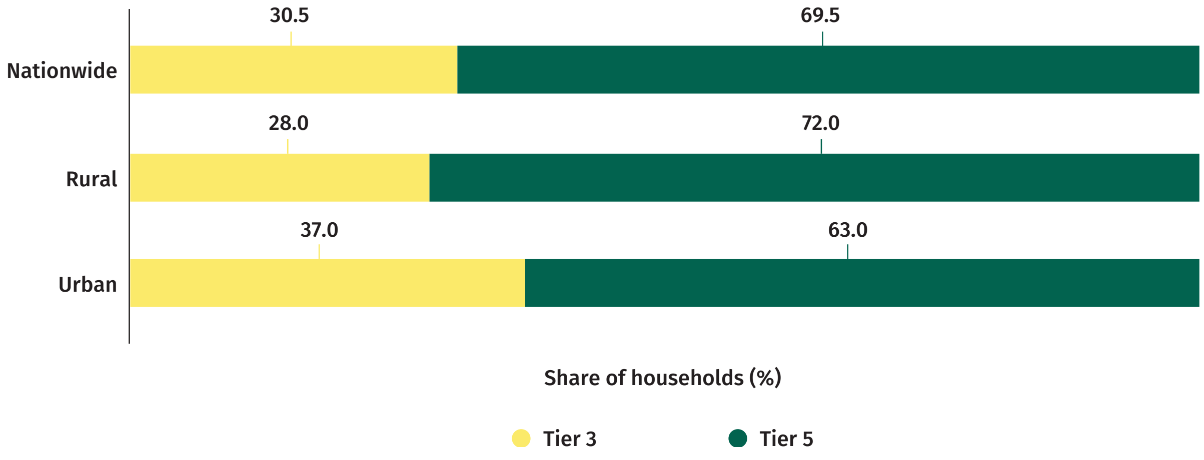
FIGURE 11 • **Distribution of the Availability Tier among grid connected households**



Source: Papua New Guinea Energy Survey 2021.

Investing in technologies and systems to regulate voltage fluctuations is crucial, too, especially in urban areas, where approximately 37 percent of grid-connected households experience these issues (figure 12). Ensuring a stable and consistent electricity supply would enable a significant improvement in the quality of electric services. Adequate planning and coordination can reduce damage to appliances and enhance the overall reliability of the grid for affected households.

FIGURE 12 • **Distribution of the Quality Tier among grid-connected households**

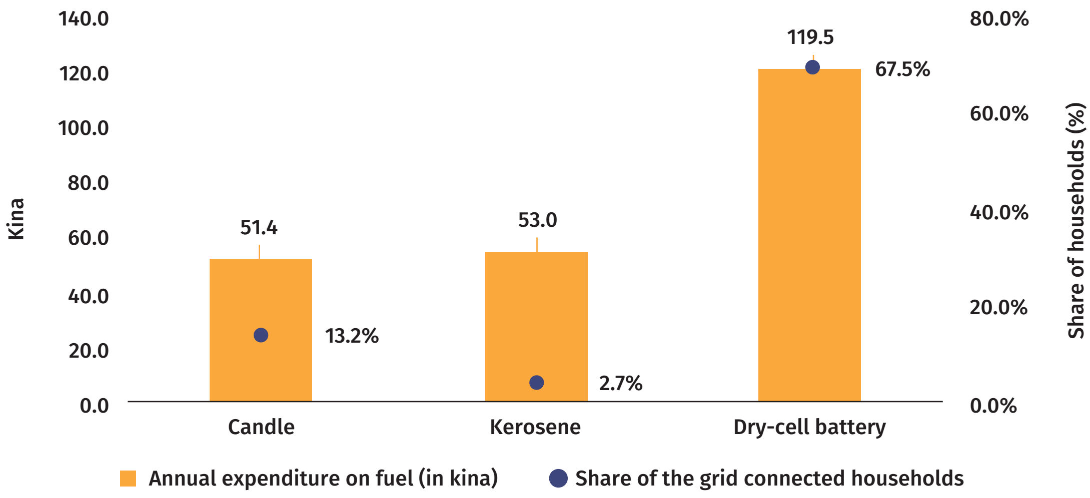


Source: Papua New Guinea Energy Survey 2021.

Due to the lack of reliable and good quality electricity supply from the grid network, households with the grid connection need to allocate a substantial share of their budget for the backup solutions. The grid-connected households mostly use dry-cell batteries (67.5 percent) as their backup source. In addition, candle (13.2 percent) and kerosene (2.7 percent) also support households for lighting throughout the year. On average, the grid connected households spent K 88.9 (US$25.3)[8] yearly on these various backup sources (figure 13). As the quality of electricity supply from the grid network improves, households could reduce their financial burden of the backup sources.

[8] Using K I.00 = US$0.29.

FIGURE 13 • **Use of backup solutions by the grid connected households**



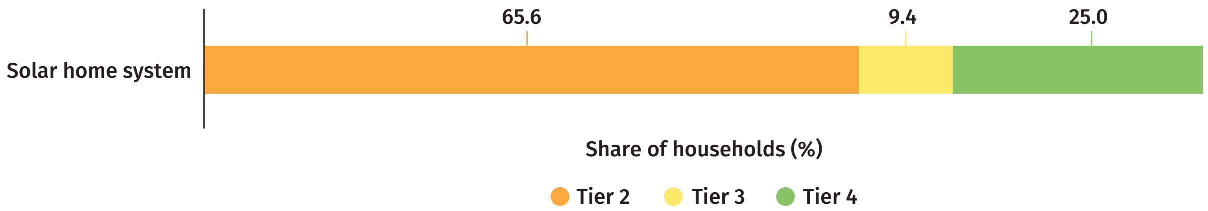
Source: Papua New Guinea Energy Survey 2021.

OFF-GRID SOLAR CUSTOMER: CAPACITY, AVAILABILITY, QUALITY STANDARDS

Given the geographical characteristics and challenges of rural electrification, the role of off-grid solar solutions in electrification will get bigger and bigger in PNG. A significant share of households in PNG currently use off-grid solar solutions as a main source which reveals the importance of off-grid solar solutions in PNG. However, households in PNG mainly use off-grid solar solutions largely for lighting purpose (solar lantern). Among Tier 0 households are unelectrified households and the rest are mostly households using solar lanterns (figure 5). Very few households who have a solar home system (0.9 percent) are in Tier 2–3 level access. Therefore, if the government could provide incentives which could enable households to transition from solar lanterns to solar home systems, it could conceivably convert all these households from Tier 0–1 level to Tier 1+ level access. Therefore, introducing an incentive structure and allowing people to procure solar home systems could be a faster approach than introducing a new infrastructure through which the government can achieve a higher level of access at a faster pace.

Certainly, solar lanterns have capacity limitations, hindering their ability to power appliances with higher capacity. Off-grid energy solutions like solar home systems (Tier 2+) and mini-grids (Tier 5) can provide more comprehensive energy services (figure 14).

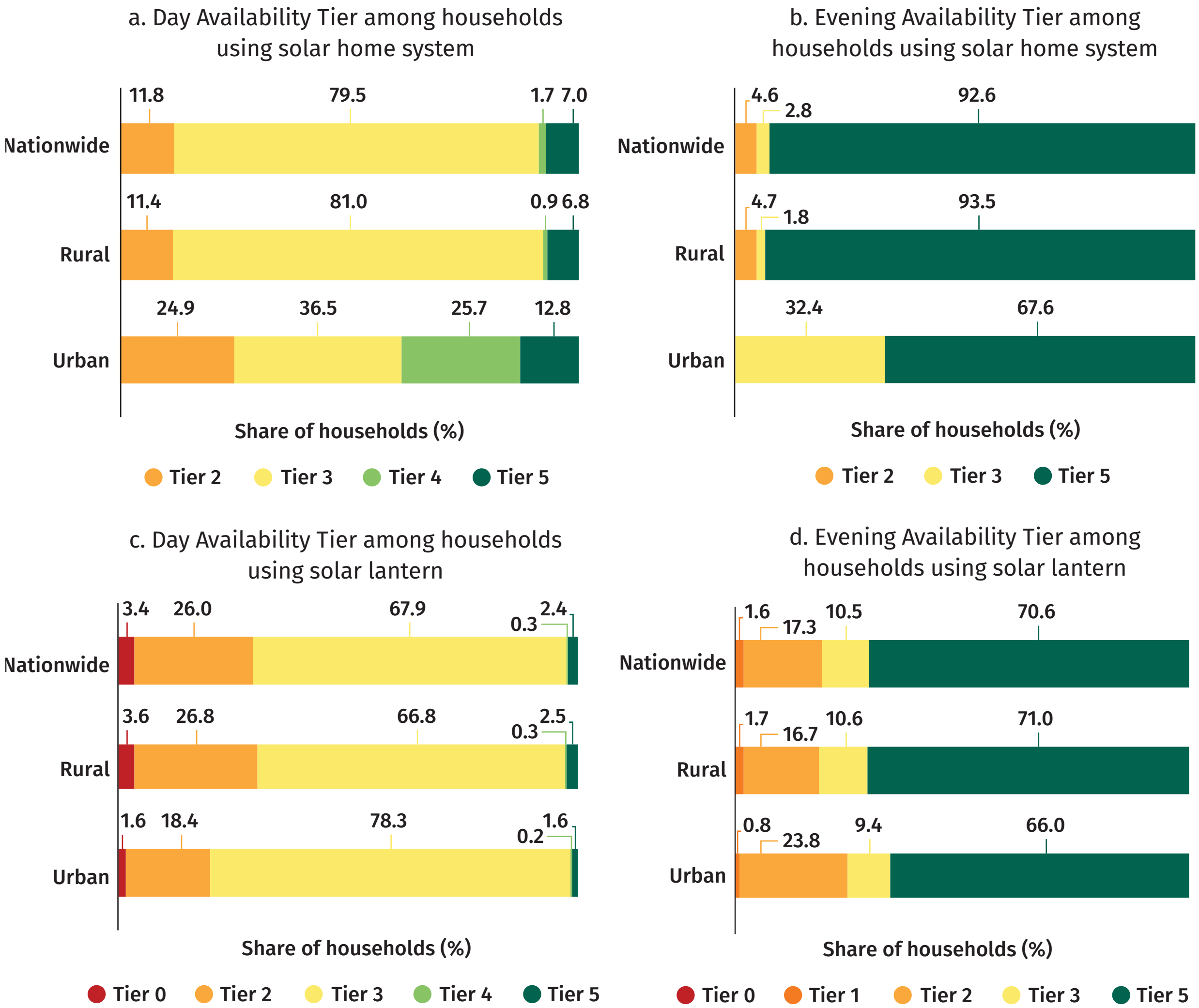
FIGURE 14 • **Distribution of the Capacity Tier for solar home systems**



Source: Papua New Guinea Energy Survey 2021.

Acknowledging the availability challenges in off-grid solutions, it is noteworthy that solar home systems stand out with a higher tier for Availability attributes among solar solutions. Addressing and improving the availability issues in off-grid solutions can contribute to enhancing their overall tier level and making them more effective in providing consistent energy services (figure 15). It is also important to understand why some off-grid solar product customers cannot use their solar products as they expected. From the policy perspective, it is important to adopt a quality standard and enhance public awareness to understand why it is more economical and efficient to buy a certified solar product.

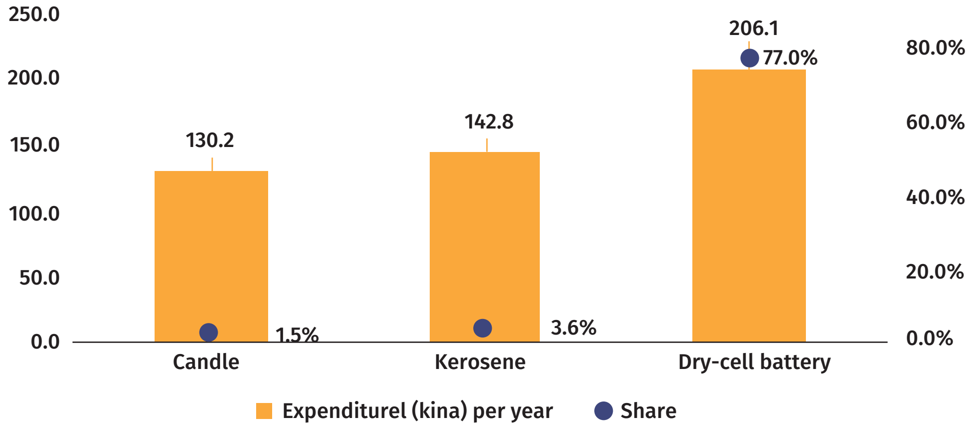
FIGURE 15 • **Distribution of the Availability Tier among off-grid solar solutions**



Source: Papua New Guinea Energy Survey 2021.

Even if households own off-grid solar solutions, as mentioned, mainly due to the availability issue, off-grid solar product customers still need to allocate their budget to purchase backup sources, mainly for lighting. On average, households using off-grid energy solutions spent K 166.6 per year (US$47.1) on backup sources on lighting, which is approximately US$4 per month, almost twice the grid-connected households (K 88.9, US$25.3 per year). Households using off-grid energy solutions also rely more on dry-cell batteries than the households with the national grid (figure 16).

FIGURE 16 • **Use of backup solutions by the off-grid connected households**

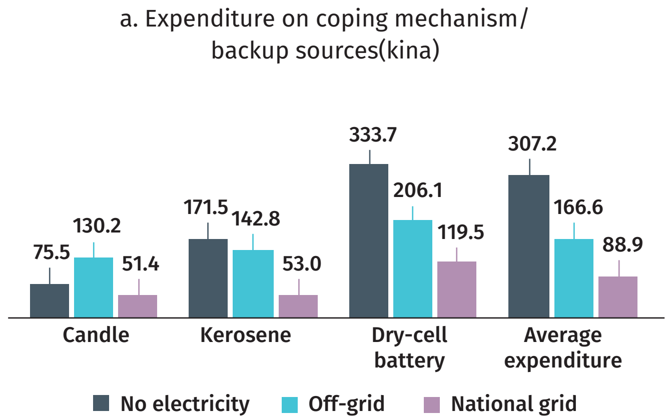


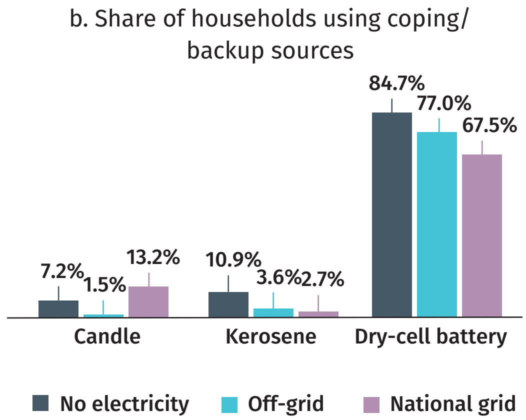
Source: Papua New Guinea Energy Survey 2021.

UNELECTRIFIED HOUSEHOLDS

The fact that 31 percent (figure 2) of unelectrified households are predominantly located in rural areas highlights the challenge of limited electricity access to rural households. Addressing electrification gaps in rural areas is critical to achieve nationwide energy access and promote more inclusive development. Leveraging the least-cost power development plan based on geographical structure, untapped energy sources,[9] and grid infrastructure availability is a strategic approach for identifying electricity solutions and implementing investment projects competitively in PNG. This method can optimize resource utilization, enhance cost-effectiveness, and ensure a more sustainable and efficient development of the power sector. Even though households do not use electricity, it doesn't necessarily mean that these households without any source of electricity do not have any demand for electricity. Households without any source of electricity spend a substantial amount of their budget for lighting. Unelectrified households are more likely to spend money on energy sources for lighting. About 11 percent and 85 percent of unelectrified households use kerosene and dry-cell batteries, respectively, as the main source of lighting. On average, households without access to electricity spent K 307.2 (US$86.9) per year (figure 17). As shown in (figure 4), unelectrified households are more likely to be poorer than those with either national or off-grid energy solutions. Thus, additional spending on coping mechanisms such as candle, kerosene, and dry-cell battery can be a substantial financial burden.

FIGURE 17 • **Expenditure and share of the backup sources**



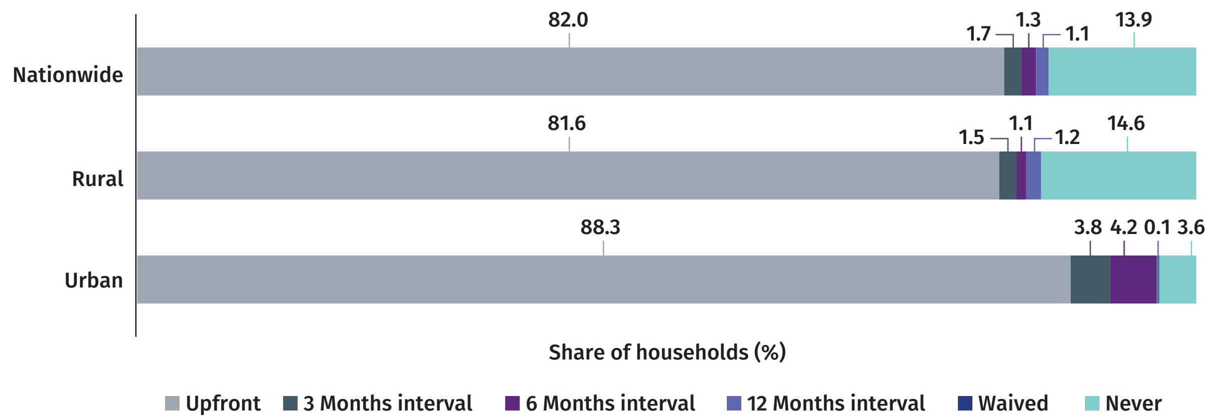


Source: Papua New Guinea Energy Survey 2021.

[9] Untapped natural sources refer to hydroelectricity, wind power, geothermal energy, and solar energy.

Most of the unelectrified households (82 percent) are willing to pay for the grid connection fee upfront (K 48, or approximately US$13–14). Grid availability in rural areas would be a constraint in electrifying unelectrified households, even though households are willing to pay for the grid connection (figure 18).

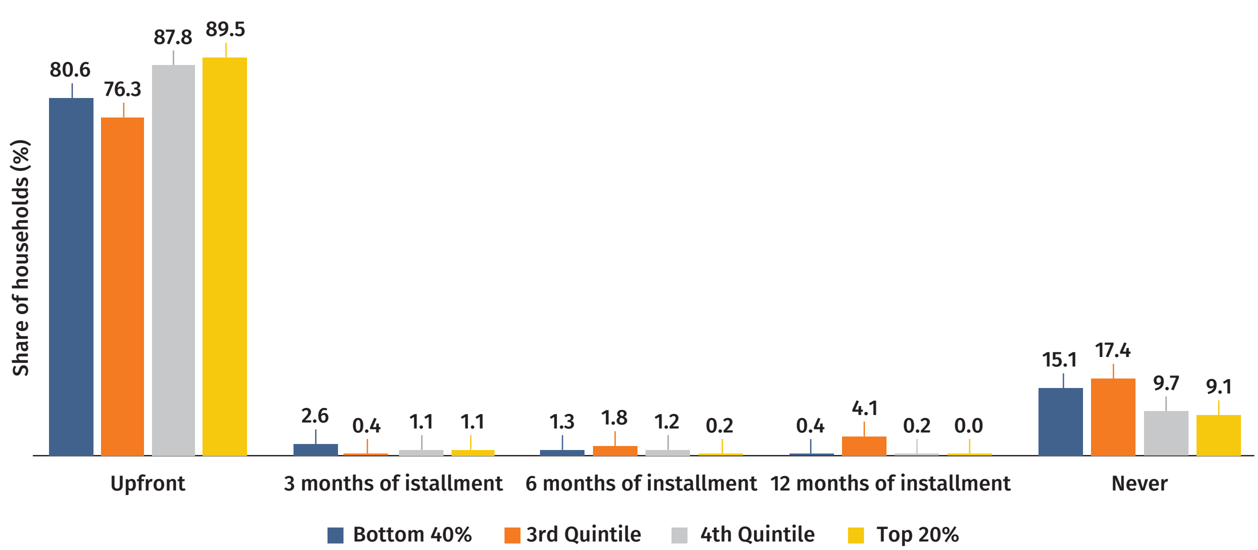
FIGURE 18 • **Willingness to pay for the grid connection**



Source: Papua New Guinea Energy Survey 2021.

Households across all expenditure quintiles express their high willingness to pay for a grid connection upfront (figure 19). This shows that households have interest in having electric services regardless of their wealth status. However, currently, most unelectrified population do not have access to the grid network, so the availability of grid infrastructure is another hurdle that the government could tackle. In this survey, to be comparable across all samples, the connection price was set assuming that households are living under the grid and they need to pay the minimum of the connection cost.

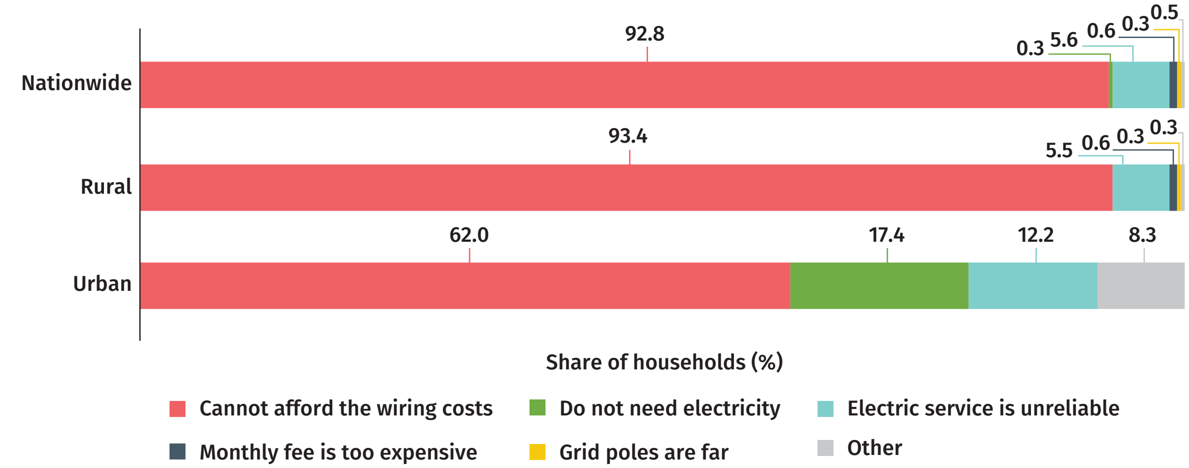
FIGURE 19 • **Distribution of households based on the installment fees for willingness to pay for grid connection by expenditure quintile**



Source: Papua New Guinea Energy Survey 2021.

Nationwide, about 13.9 percent households reported that they will never be willing to pay for the grid even if they are offered flexible payment schemes for grid connection (figure 18). The high internal wiring cost is the main underlying factor in this regard. So, for those who cannot afford the internal wiring, the provision of ready boards[10] could increase the affordability of households toward grid connection (figure 20).

FIGURE 20 • **Distribution of households based on never willing to pay for grid connection**



Source: Papua New Guinea Energy Survey 2021.

The data highlights significant annual expenditures on backup sources for lighting. Wiring costs or grid infrastructure unavailability are identified as main obstacles for grid connection among unelectrified households. Clarifying whether respondents refer to internal wiring or connection from the electric pole is crucial. Subsidies on wiring or ready boards and connection fees can promote grid connections, reduce annual backup source expenses, and encourage the use of appliances with higher-tier energy access, contributing to improved overall service and affordability.

Willingness to Pay for Off-Grid Solar Device

High capacity (more than 50 W) solar home systems (SHSs) would require more flexible payment arrangements. Although solar lanterns (SLs) can operate only appliances of lower capacity, due to their lower cost compared to solar home systems (SHSs), unelectrified households prefer lower tier off-grid solar products (for example, SLs) than higher capacity SHSs. With more flexible payments, more households would be willing to pay for the higher capacity SHSs. Figure 21 demonstrates willingness toward different payment schemes for different price points (33 percent, 66 percent, 100 percent) of two solar devices (Sunking Pro 200 and Sunking Home 400). Payment flexibility will be more important for higher capacity of off-grid solar products. Implementing a knowledge-based program to explain the quality and benefits of solar solutions is a strategic approach. This initiative can guide households in making informed decisions, ensuring they acquire better and more suitable solar solutions. Increasing awareness about the advantages of various solar options fosters a more informed consumer base, contributing to the adoption of higher-quality and more efficient solar energy solutions.

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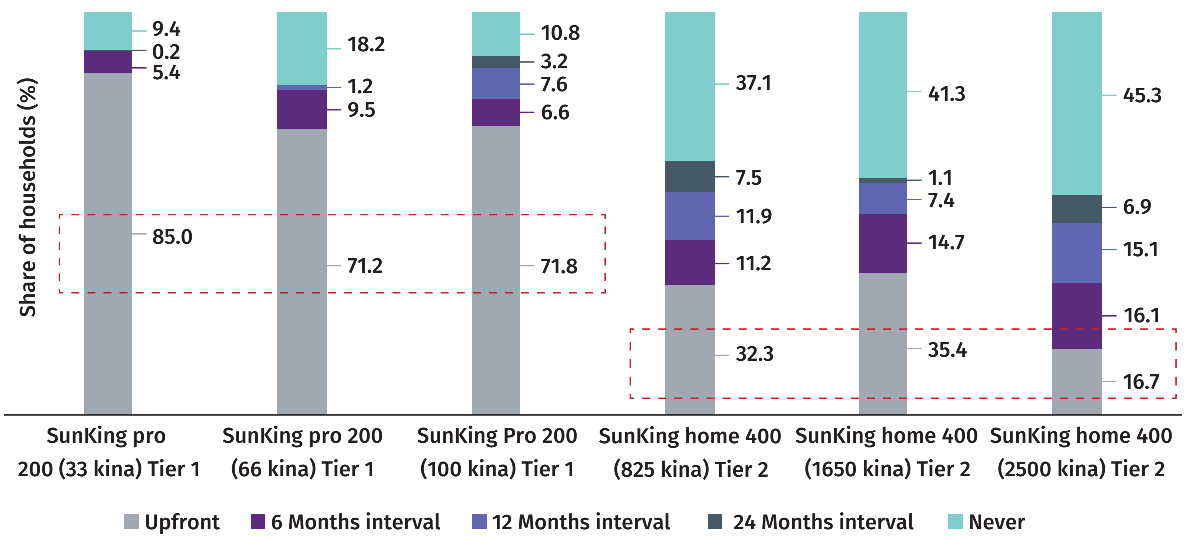
[10] A ready board is a small gadget used to distribute power in a small building of two rooms or less. Since no wiring is needed, extension cables are used to supply power from the gadget to places where power is needed.

FIGURE 21 • **Willingness to pay for two specified solar devices**



Source: Papua New Guinea Energy Survey 2021.

POLICY RECOMMENDATIONS

Access to grid electricity is low in PNG. Off-grid solar solutions are the pre-dominant energy source for poorer households. Given the geographical challenges, the role of off-grid solar solutions will play a more critical role in providing electricity in PNG. The importance of addressing economic barriers to ensure widespread and equitable access to energy should be highlighted.

Policy recommendations to accelerate electricity access to households are as follows:

- Strategic steps require mitigating such challenges such as inadequate planning, coordination, and reliance on ad-hoc investment decisions. It is important to understand the benefit of adopting long-term, least-cost plans for sustainable progress in energy access. Coordinated efforts can help avoid high costs and ensure efficient, well-planned investments in the energy sector.

- Based on the geographical structure, untapped energy sources,[11] and grid infrastructure availability, the least-cost power development plan of PNG should be used to identify electricity solutions and implement investment projects competitively.

- Grid availability in rural areas is an obstruction to electrification even though households are willing to pay the grid connection fee. For densification of grid connection in grid-connected area, offering subsidies, payment plans, and financing opportunities for connection fees and internal house wiring could successfully address the barriers of connection, lessen financial burdens, promote affordability, and increase flexibility in appliance use, potentially improving access to grid connection.

- Improving and facilitating administrative procedures within the power utility can play a pivotal role in increasing grid connectivity. Streamlining processes, reducing bureaucratic hurdles, and improving overall efficiency can positively impact the ease with which households and businesses connect to

[11] Hydro electricity, wind power, geothermal energy, and solar energy.

the grid. This administrative improvement would contribute to a more accessible and responsive energy infrastructure. Grid expansion is recommended to electrify households for whom this is the least costly and fastest approach.

- The challenges related to weak institutional capability in the energy sector in PNG highlight the need for ongoing capacity building. While PNG Power Ltd. (PPL) and the newly established National Energy Authority (NEA) play distinct roles, their effectiveness depends on strengthening institutional capacity. Progress, such as the drafting of legislation by NEA (for example, the Off-grid Small Power Producers Regulation), indicates positive steps, but continuous efforts are essential to enhance capabilities for effective energy access expansion.

- PPL should take necessary administrative steps to improve availability and reduce voltage fluctuation issues among grid-connected households to provide reliable and stable electricity services. Administrative steps such as infrastructure maintenance, voltage regulation, monitoring systems, and customer communication can provide ultimately a higher-quality services to grid-connected households and reduce substantially the expenditure on backup sources for lighting.

- Support timely and effective implementation of National Electrification Roll-Out Plan (NEROP), which emphasizes sequencing of on-grid, mini-grid, and off-grid market development investments, considering, lower-cost electrification opportunities, improving service quality, institutional development, and private sector participation (Motohashi 2022).

- More areas as well as households can be electrified with off-grid solar where grid infrastructure is not available yet. Introducing government subsidies and providing access to finance for solar companies either through working capital loans[12] or by providing microfinance[13] to households, in addition to use of pay-as-you-go payment mechanisms[14] and result-based financing can help promote off-grid solar broadly. Enforcement of quality standard frameworks will allow superior quality products to be available in the market. It will also protect consumers from buying inferior products. Awareness campaigns and training programs can inform people of the benefits of solar products and help them understand the differences between good-quality and poor-quality products.

- It is also important to stimulate electricity demand to allow households to benefit from the use of modern appliances and identify income opportunities from use of electricity. Promoting private sector participation in off-grid electrification in PNG is crucial. By tackling the barriers, PNG can attract private sector participation, fostering the development of sustainable and diverse off-grid electrification solutions. Providing clear and supportive regulations, addressing the challenges of foreign currency availability; exploring ways to mitigate high transport costs to underserved locations; implementing strategies to enhance affordability; developing measurements to address issues related to system protection, maintenance, and vandalism; and creating a secure environment can accelerate private sector investments.

- The World Bank, MTF team can collaborate with the National Statistical Office to enhance their capacity in grasping the significance of energy indicators and ensuring sustainable data collection for future tracking or monitoring purposes.

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[12] A working capital loan is specifically designed to support a company's day-to-day operations by providing funds to cover short-term operational needs.

[13] There are two principal microfinance providers: PNG Microfinance Limited and Nationwide Microbank. They have expanded their rural outreach and have a total of 21 branches

[14] Collaboration between IFC and Origin Energy PNG Ltd. to implement a pay-as-you-go business model for solar systems is a positive step. This approach enables customers to access essential services such as lights, cell phone chargers, and radios powered by rooftop panels on a monthly payment basis, enhancing affordability and expanding energy access in PNG.

ACCESS TO MODERN ENERGY COOKING SERVICES

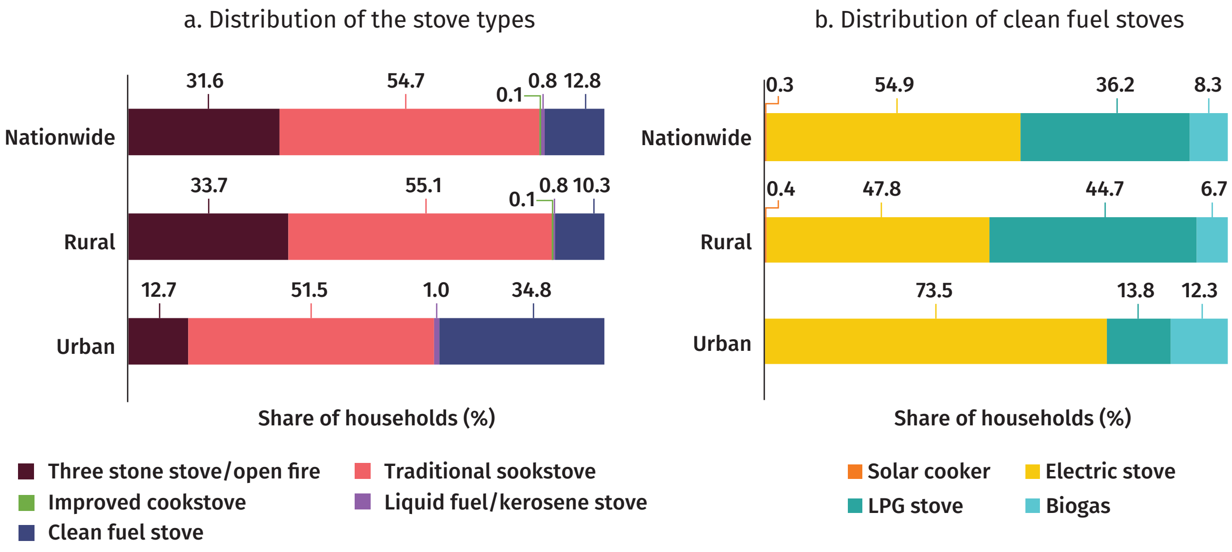
Photo: ©Shutterstock

ASSESSING ACCESS TO MODERN ENERGY COOKING SERVICES

TECHNOLOGIES

Throughout PNG, traditional cookstoves are the most popular cookstove (54.7 percent). Second in position is three-stone stoves (31.6 percent). Use of clean fuel stoves are about more than one-third fewer in rural areas (10.3 percent) compared to urban (34.8 percent). Electric stoves are the most popular cookstoves among all clean fuel stoves nationwide. Use of electric stoves can be increased along with the increment in grid electrification rate. Among clean fuel stoves nationwide, cooking gas/liquid petroleum gas (LPG) stoves (36.2 percent) followed by biogas stoves (8.3 percent) are also quite familiar (figure 22). The survey did not identify use of improved cookstoves among the households interviewed.

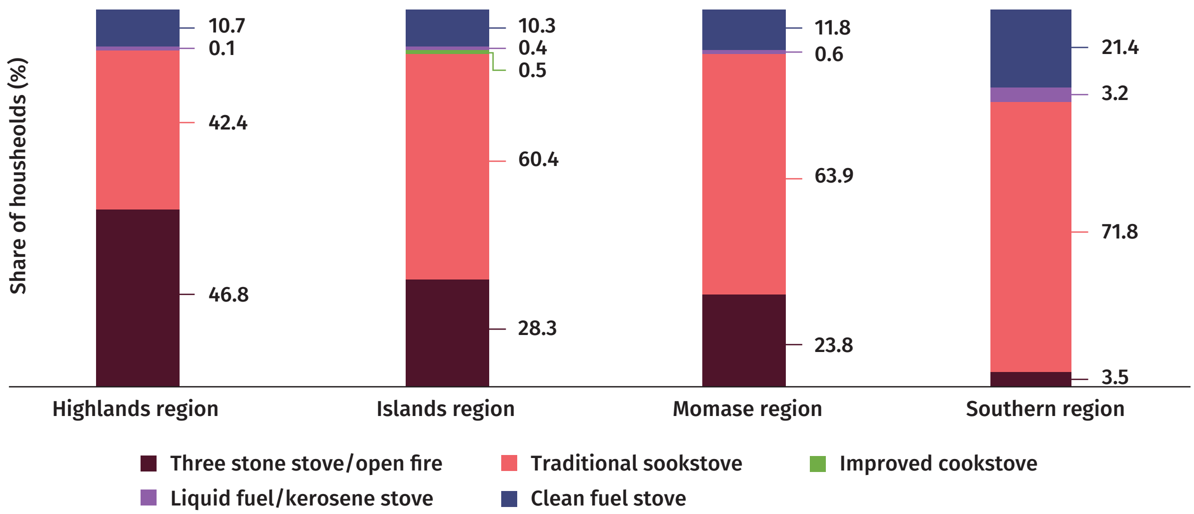
FIGURE 22 • **Distributions of the main cookstove typology**



Source: Papua New Guinea Energy Survey 2021.

Among regions, the penetration of clean fuel stoves in the Southern region (21.4 percent) is the highest. The Southern region mostly uses traditional stoves (71.8 percent), however. Thus, three-stone stoves are least penetrated in this region. In the Highlands region, almost one-half (46.8 percent) of the population uses three-stone or open fire stoves, which is highest compared among the regions (figure 23).

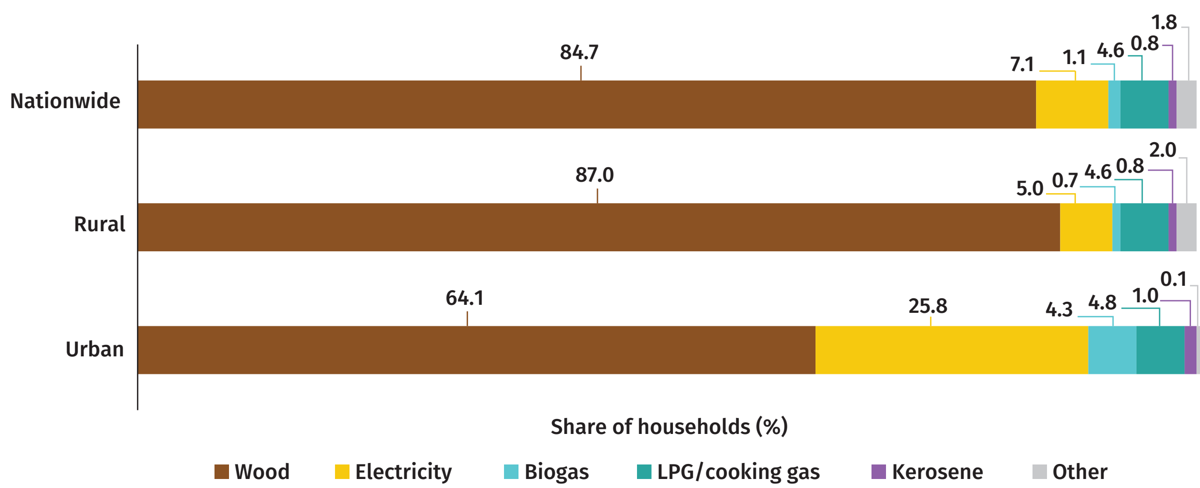
FIGURE 23 • **Distributions of stove types by region**



Source: Papua New Guinea Energy Survey 2021.

Nationwide, firewood (84.7 percent) is the most prevalent fuel in PNG, followed by electricity (7.1 percent); 87 percent and 64.1 percent of rural and urban households, respectively, use firewood as their main fuel for cooking. The use of electricity as fuel is higher in urban (25.8 percent) compared to rural (5.0 percent) environments (figure 24).

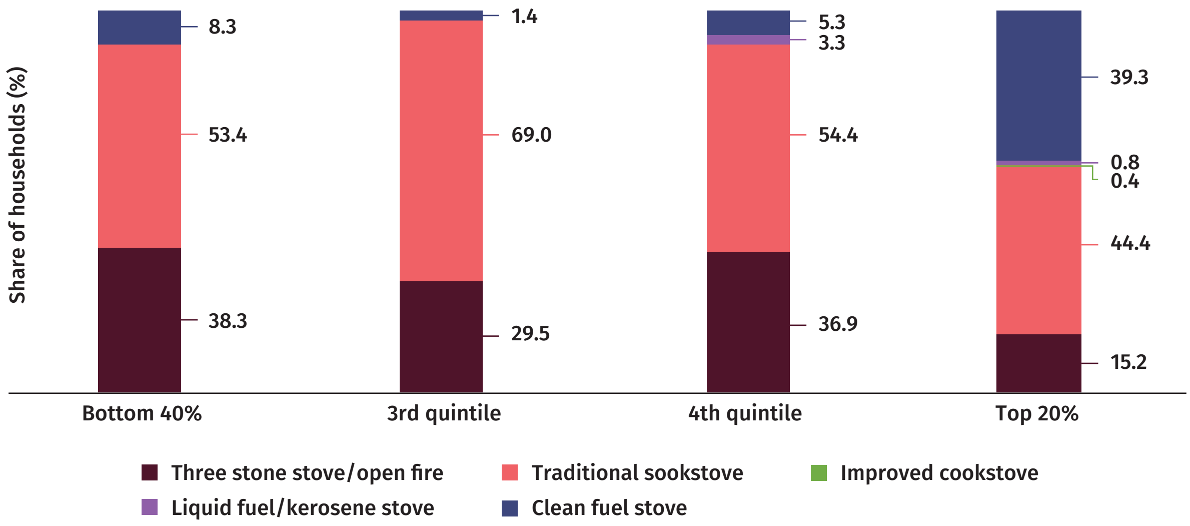
FIGURE 24 • **Distribution of households based on fuel used**



Source: Papua New Guinea Energy Survey 2021.

There is a significant difference between the top quintile and the rest of the quintile groups in use of clean cooking solutions. The households from the rest of expenditure quintiles use traditional or three-stone stoves. Wood is the most dominant fuel for all expenditure quintiles as the consequence of high use of traditional and three-stone cookstoves (figure 25).

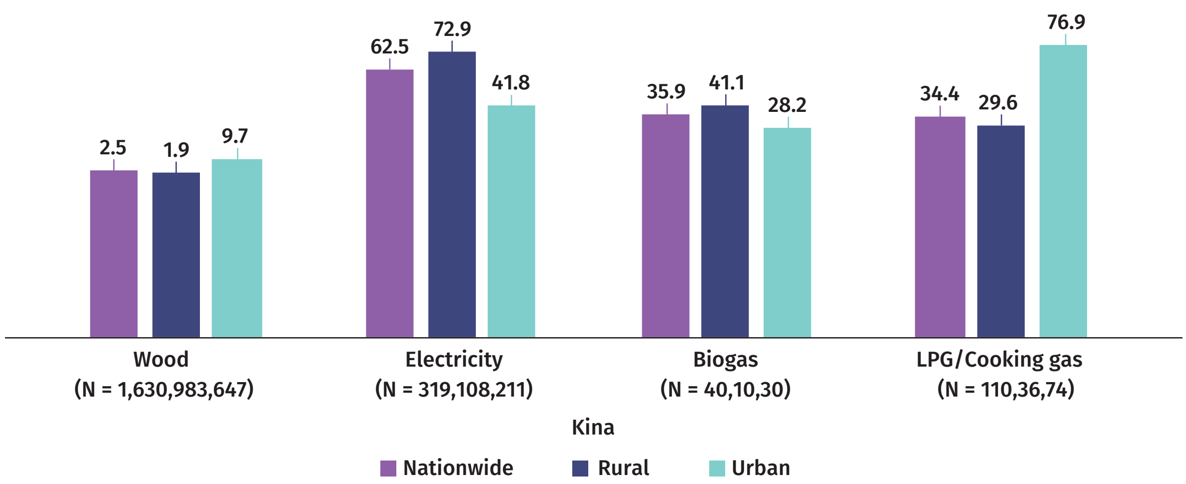
FIGURE 25 • **Distributions of stoves types by expenditure quintiles**



Source: Papua New Guinea Energy Survey 2021.

Households utilizing clean fuel for cooking incur higher expenses compared to those using firewood. The affordability and accessibility of cooking fuel emerge as critical factors influencing the adoption of clean fuel stoves. Wood is relatively less expensive in rural households, primarily because residents can collect wood instead of purchasing it (figure 26).

FIGURE 26 • **Average monthly expenditure on cooking fuel (in kina)**



Source: Papua New Guinea Energy Survey 2021.

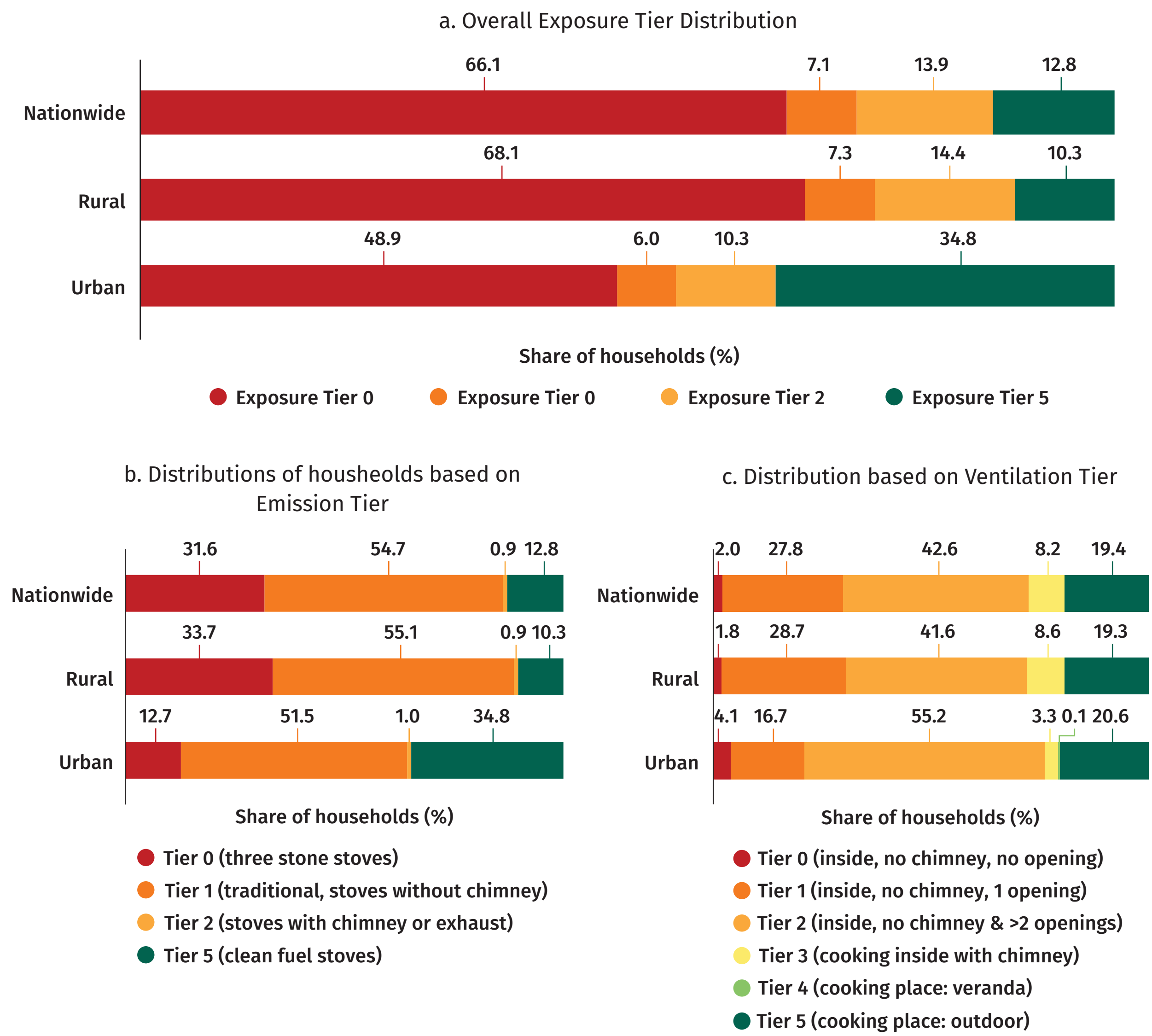
MTF ATTRIBUTES

The detailed explanations of the cooking tier methodology are in section "Access to Modern Energy Cooking Services" and annex 2. The ultimate objective is to introduce clean and sustainable cooking services. The MTF Tier attributes in cooking services can identify the attributes to focus on. Since the survey is based on a phone survey due to time constraints, and therefor based on limited availability of information, only the Exposure attribute was captured for analysis; Efficiency, Convenience, Safety, Affordability, and Availability attributes were not captured.

Exposure Tier

The Cooking Exposure attribute pertains to an individual's direct exposure to pollutants generated during cooking activities. It serves as a surrogate measure for assessing the health consequences of cooking on the primary cook within a household. This attribute is gauged through two key indicators: emissions from the primary cookstove and the ventilation status of the primary cooking area. The Exposure Tier (annex 2) is calculated based on the cookstove type (Emission Tier) and the good, average, or bad ventilation structure (Ventilation Tier) of the cooking area. Nationwide, most households (66.1 percent) are in Tier 0, and higher in rural (68.1 percent) areas than urban (48.9 percent), which reflects mostly that the population is using traditional stoves or three-stone stoves in a closed cooking area without ventilation. Since the urban population uses more clean fuel than the rural, the portion of the population in the highest Exposure Tier (Tier 5) is higher in urban areas (34.8 percent) (figure 27).

FIGURE 27 • **Distribution of Exposure Tier: Emission and Ventilation Tier**



Source • Papua New Guinea Energy Survey 2021.

Certainly, improving ventilation in cooking areas is a crucial aspect of creating a safer and healthier environment, especially in households with less efficient cooking stoves. Adequate ventilation helps to decrease exposure to indoor air pollutants produced during cooking. If enhancing ventilation is cost-effective and can effectively raise the Exposure Tier, it can be a practical and impactful solution. However, transitioning from traditional or three-stone stoves to clean cooking stoves is a crucial step in promoting both environmental sustainability and public health. Clean cooking stoves are designed to be more efficient, reduce indoor air pollution, and decrease the reliance on traditional biomass fuels, such as wood or charcoal.

POLICY RECOMMENDATIONS

Addressing the widespread use of traditional stoves in PNG is crucial for health and environmental reasons. Promoting the adoption of cleaner cooking services can bring about significant benefits. The survey identified that, among clean cooking stoves, electric stoves are most popular. Innovative business models and targeted incentives, supported by the government, could make the cleaner cooking solutions (electric, solar, LPG) more affordable. This approach not only improves health outcomes but also contributes to sustainable and environmentally friendly practices in cooking.

Interventions to switch from three-stone stoves or traditional stoves to improved cookstoves and clean fuel stoves include the following.

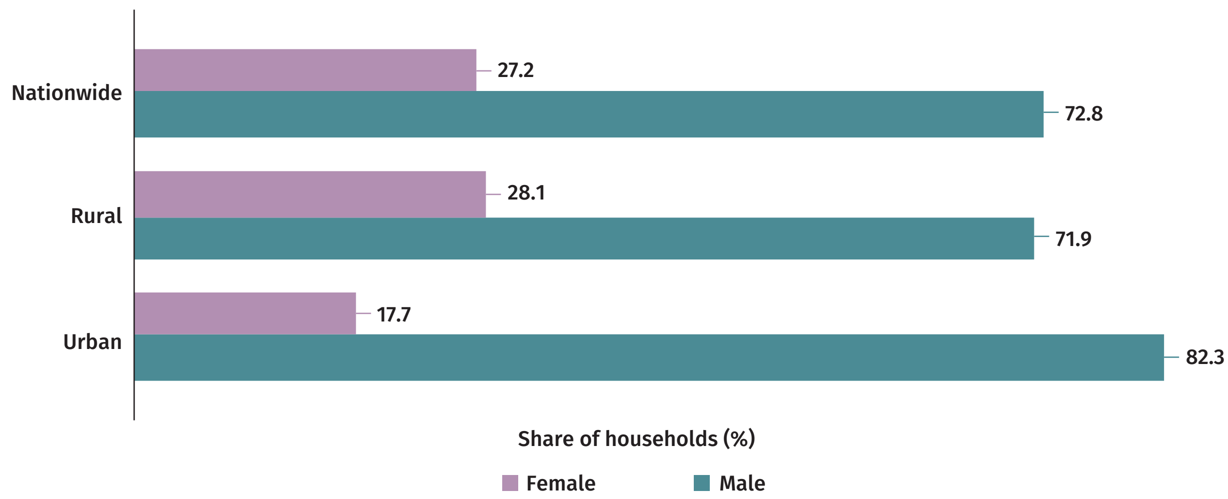
- Enhance public awareness campaigns to spread knowledge on the greater health benefits of using improved cookstoves and clean fuel stoves and to increase demand and uptake.
- Increase the accessibility of the grid connectivity as the primary task to increase access to the electric stove.
- Promote advanced biomass stoves, for example, gasifier biomass stoves that can reduce pollutant emissions significantly.
- Offer installment payments to mitigate affordability challenges of households to switch to electric stoves and LPG stoves.
- Take initiatives to promote and introduce Energy efficient stoves.
- Embrace the pay-as-you-go (PAYGo) schemes for off-grid solar solutions (Burger 2021; UNCDF 2020). Similar PAYGo schemes can also benefit the cooking sector to promote new technologies to similar clients.
- Offer results-based financing or some other kind of targeted subsidy to reduce the current market price of the cooking services and make them affordable to the people.
- Collaborate with non-governmental organizations and community-based organizations to implement clean cooking stove initiatives. These organizations often have valuable experience in community engagement and development.

GENDER ANALYSIS

Photo: ©Kalo Fainu/World Bank

In PNG, 27 percent of households are headed by women. The share of female-headed households is lower in urban areas (18 percent) compared to rural areas (28 percent). The survey sample size includes 424 female-headed households and 1,132 male-headed households (figure 28).

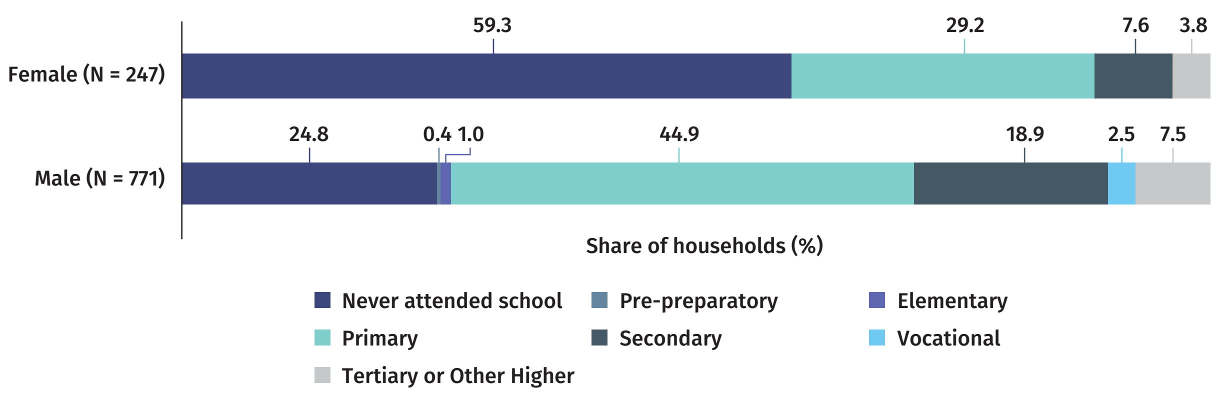
FIGURE 28 • **Distribution of households by sex of the household head (nationwide, urban, rural)**



Source: Papua New Guinea Energy Survey 2021.

About 59 percent of female heads never attended school, compared to 25 percent of male heads. Among heads that have attended school, male heads are more likely to have attended secondary school or beyond (11percent of female heads versus 29 percent of male heads) (figure 29).

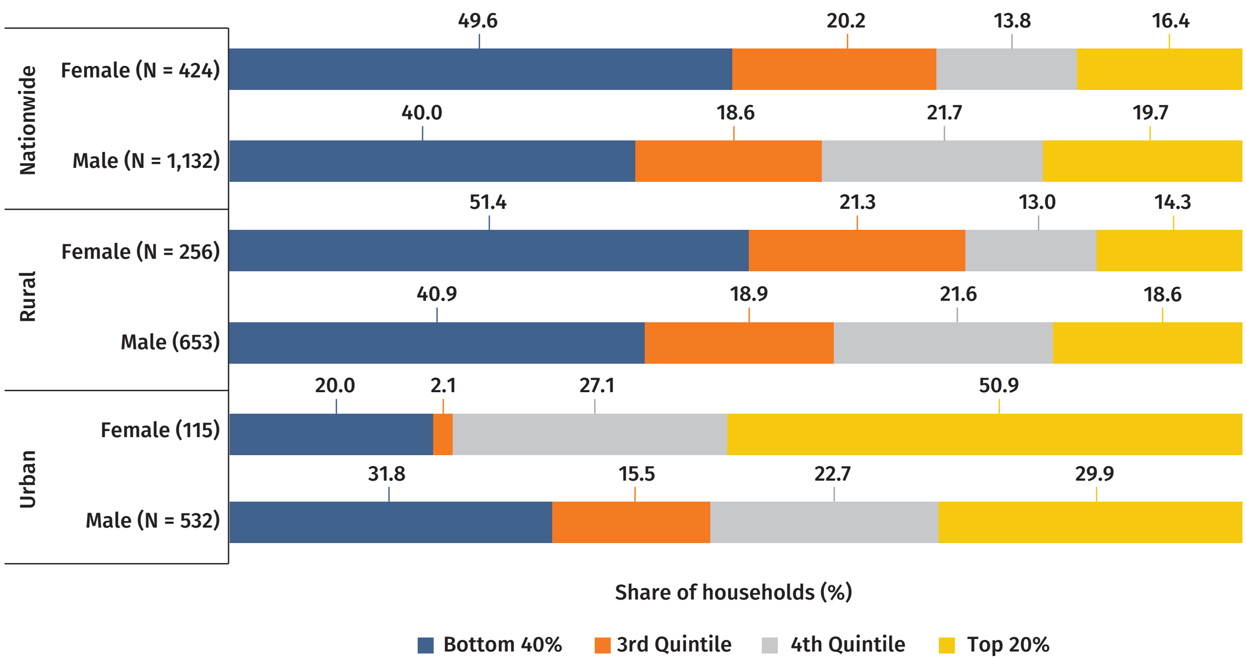
FIGURE 29 • **Distribution of male and female heads by education level (nationwide)**



Source: Papua New Guinea Energy Survey 2021.

Female-headed households tend to be poorer than male-headed households. Nationwide, 50 percent female-headed households are in the bottom 40 percent, versus 40 percent of male-headed households. Female-headed households are also underrepresented in the top quintile (16 percent versus 20 percent). Interestingly, in urban areas, female-headed households are overrepresented in the top quintile (51 percent versus 30 percent for male-headed households) (figure 30).

FIGURE 30 • **Distribution of male and female-headed households by expenditure quintile (nationwide, urban, rural)**

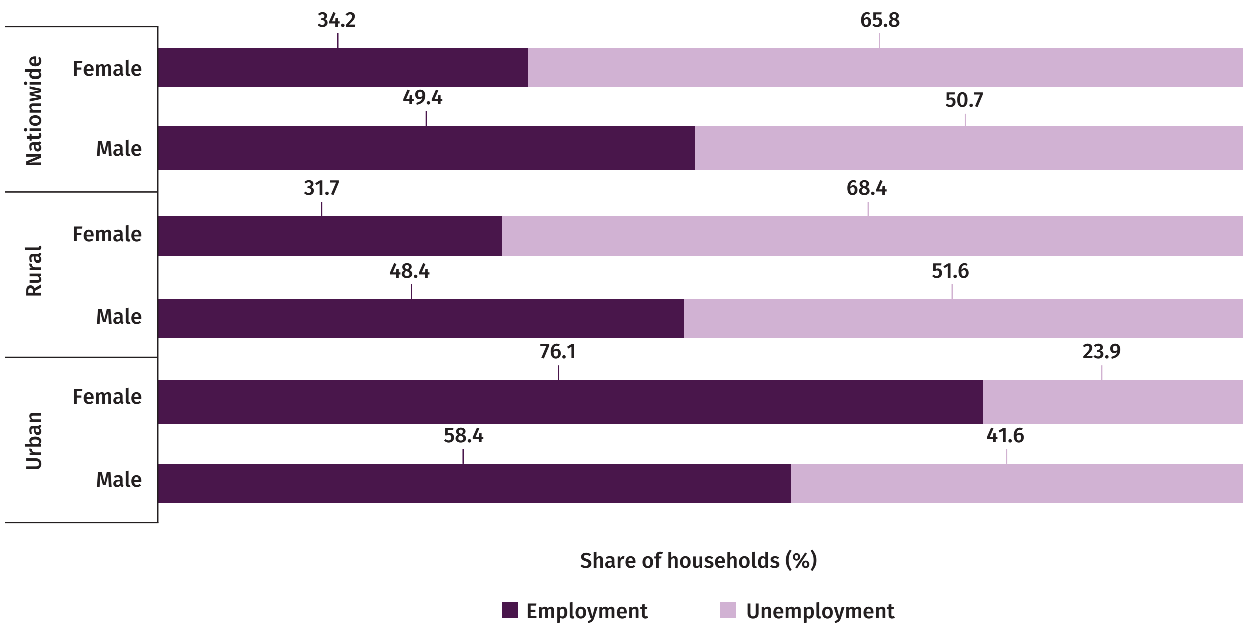


Source: Papua New Guinea Energy Survey 2021.

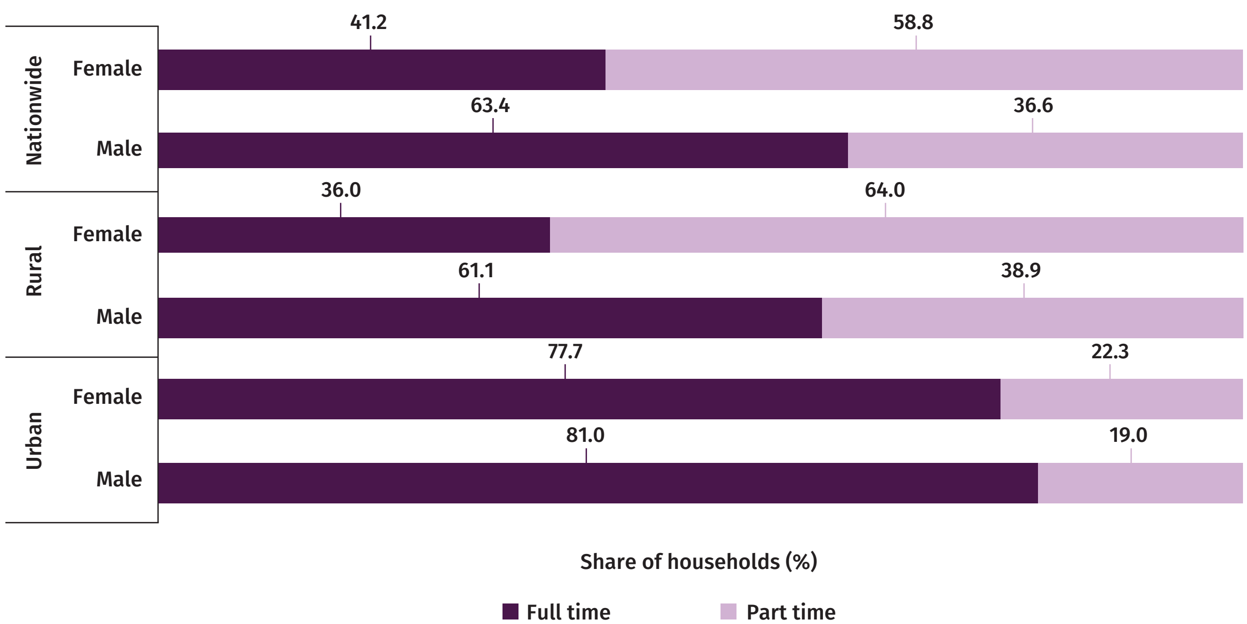
Nationwide, employment rates are lower among female heads (34 percent) compared to male heads (49 percent). In rural areas, female heads are less likely to be employed compared to male heads (32 percent versus 48 percent, respectively), whereas in urban areas female heads are more likely to be employed compared to male heads (76 percent versus 58 percent, respectively). However, female heads are less likely to be engaged in full-time jobs compared to male heads in both urban and rural areas (figure 31).

FIGURE 31 • **Share of employment status by gender of the household head (nationwide, urban, rural)**

a. Share of households with emploments/unemployment by gender



b. Share of households with full-time/part-time emploments by gender

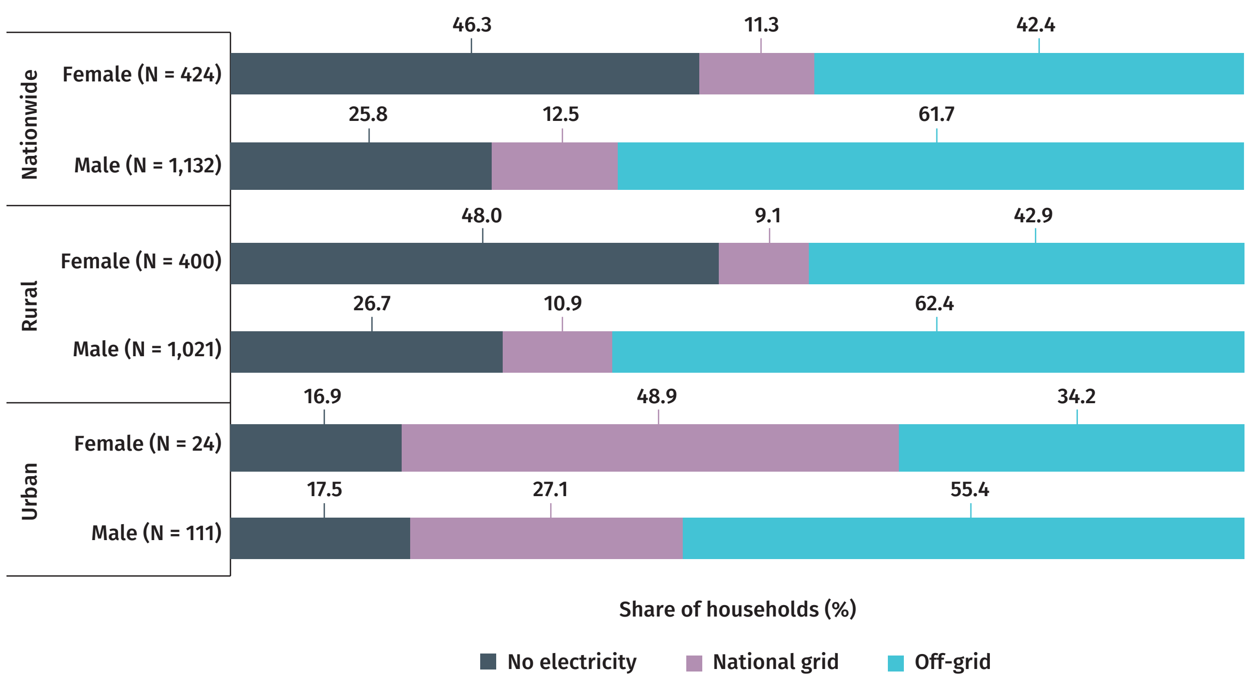


Source: Papua New Guinea Energy Survey 2021.

ACCESS TO ELECTRICITY

Nationwide, male-headed households are much more likely (74 percent) to have access to electricity, compared to female-headed households (54 percent), driven by access to off-grid solutions. In urban areas, about half of the female-headed households have access to the grid, versus 27 percent of male-headed households. It should, however, be noted that the small sample size of urban female-headed households (24) may compromise the reliability of results. In rural areas, the gender gap in grid access is much smaller (under 2 percentage points) and in favor of male-headed households. Access to off-grid solutions is considerably higher for male-headed households, across both urban and rural areas (figure 32). Due to the small sample sizes the confidence interval for the proportions of figure 32 is provided in annex 3, table A3.2.

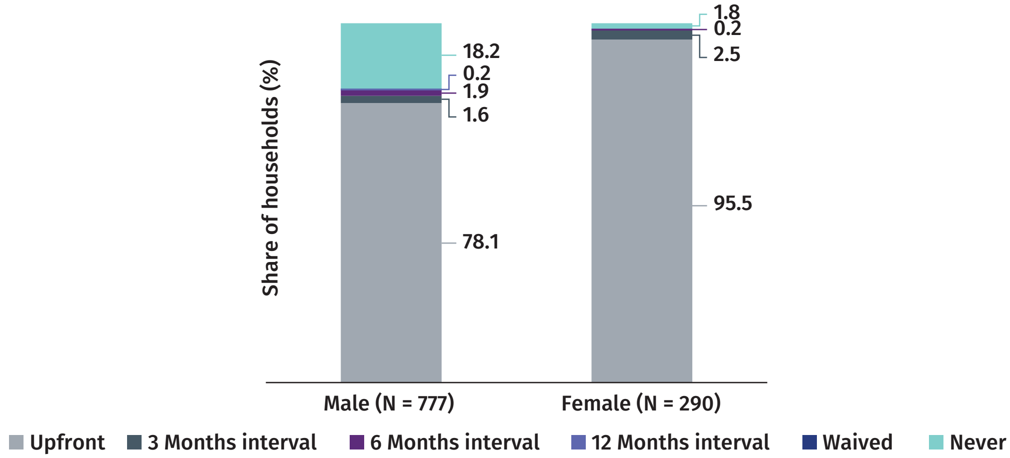
FIGURE 32 • **Access to electricity by technology and sex of the household head**



Source: Papua New Guinea Energy Survey 2021.

Among households that are not connected to the grid, female-headed households report significantly higher willingness to pay for a grid connection with upfront payment, compared to male-headed households. Over 18 percent of male-headed households are unwilling to pay for a grid connection even if the fee was waived, against only 2 percent of female-headed households (figure 33).

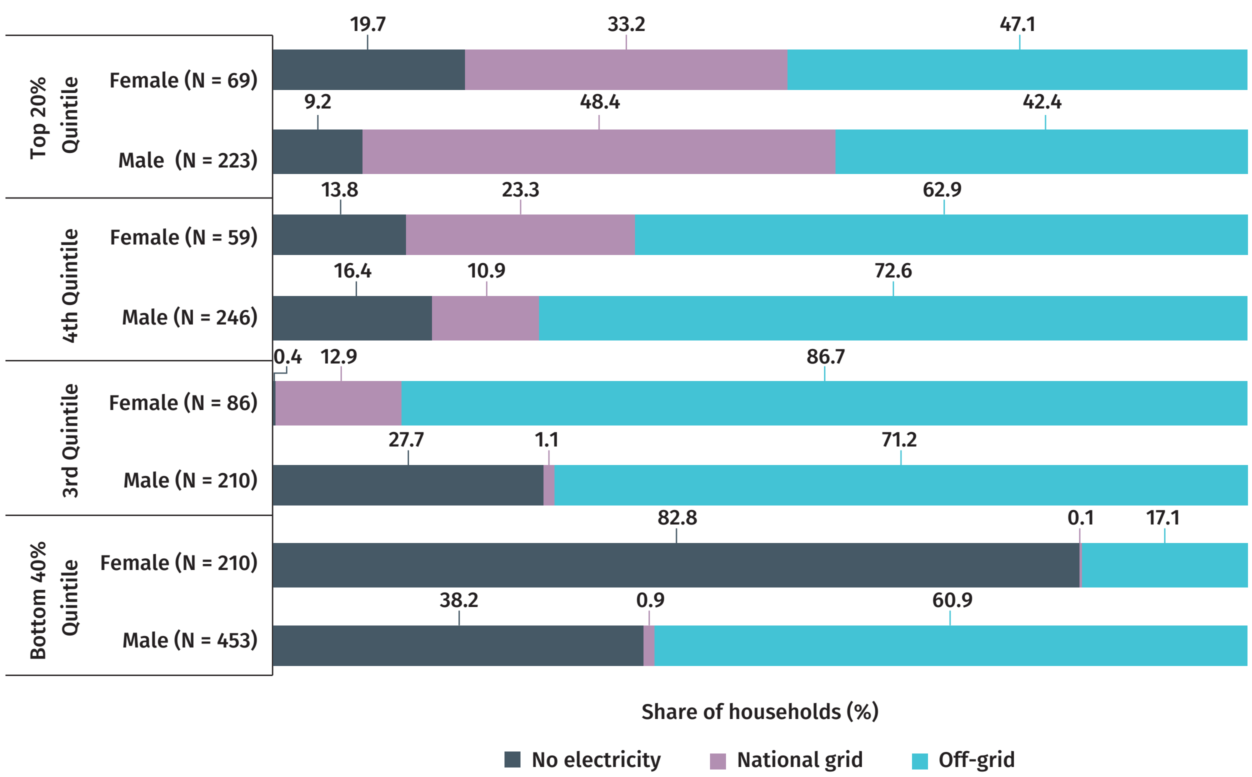
FIGURE 33 • **Willingness to pay for grid connection by sex of the household head (nationwide)**



Source: Papua New Guinea Energy Survey 2021.

When we look at access rates in each expenditure quintile, the largest gender gap is seen in the bottom 40 percent, where 83 percent of female-headed households lack access to electricity, against 38 percent of male-headed households. In the top quintile, the gender gap is smaller, with 20 percent of female-headed households lacking access compared to 9 percent of male-headed households (figure 34). Due to the small sample sizes, the confidence interval for the proportions of figure 35 is provided in annex 3, table A3.3.

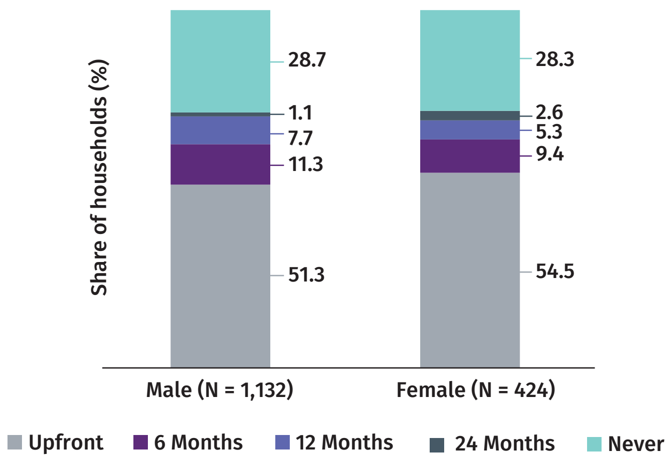
FIGURE 34 • **Access to electricity by technology, expenditure quintile, and sex of the household head (nationwide)**



Source: Papua New Guinea Energy Survey 2021.

Willingness to pay for a solar device is fairly similar across male- and female-headed households. Female-headed households have a slight preference for upfront payment compared to male-headed households, which are more likely to opt for payment over time (figure 35).

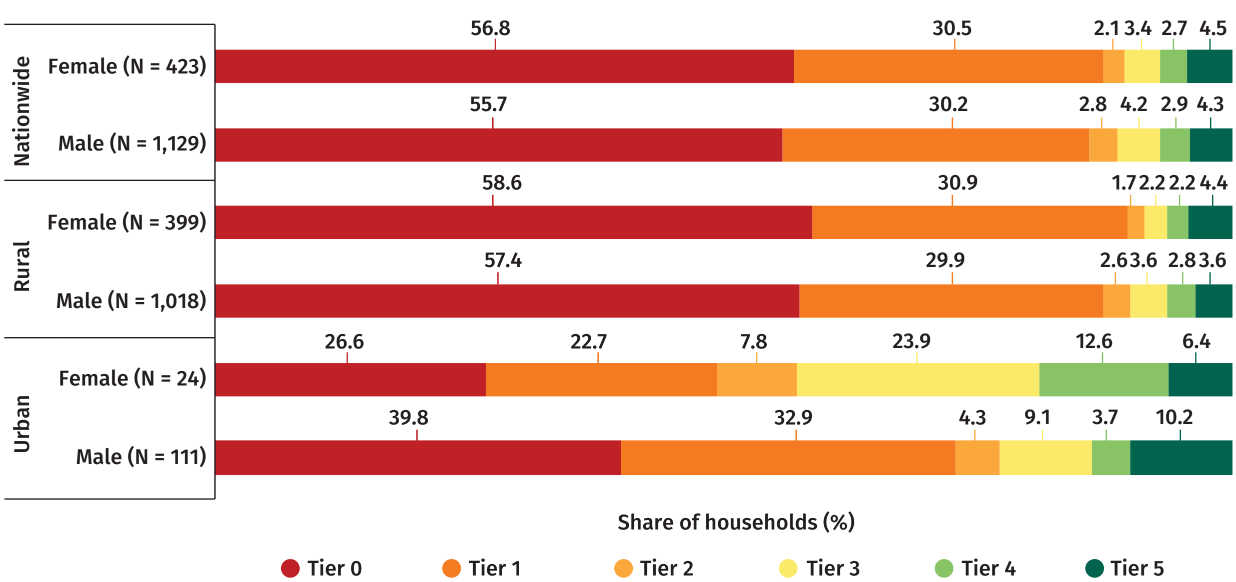
FIGURE 35 • **Willingness to pay for solar device by sex of the household head (nationwide)**



Source: Papua New Guinea Energy Survey 2021.

Nationwide, the MTF Tier distribution is very similar for both male- and female-headed households, despite a largely different distribution by technology. This is mainly explained by the fact that a high share of the off-grid solutions used by male-headed households fall in Tier 0. This explanation holds for rural areas. In urban areas, female-headed households are less likely to be in Tier 0 compared to male-headed households, because their access is mainly driven by the grid, whereas male-headed households are more likely to access off-grid solutions (figure 32) and thus more likely to fall into Tier 0. For this same reason, female-headed households are more likely to reach Tier 2 and higher compared to male-headed households (figure 36). The confidence interval for the sample size of figure 36 has been provided in annex 3, table A3.4.

FIGURE 36 • **MTF Tier distribution by sex of the household head (nationwide, urban, rural)**

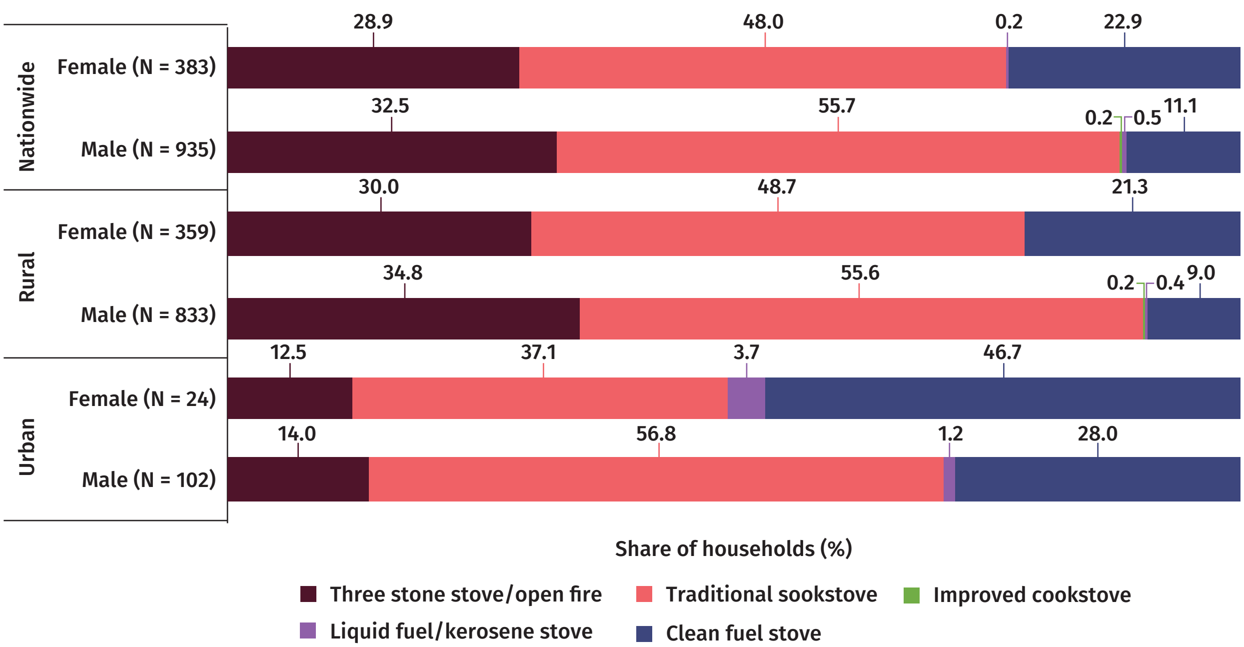


Source: Papua New Guinea Energy Survey 2021.

ACCESS TO MODERN ENERGY COOKING SERVICES (MECS)

Female-headed households are twice as likely to use clean fuel stoves than male-headed households, across both urban and rural areas. The gap is wider in urban areas. As a result, the female-headed households are less likely to use three-stone stove and traditional stoves compared to male-headed households, across urban and rural areas (figure 37). The confidence interval for the proportions are provided in annex 3, table A3.5.

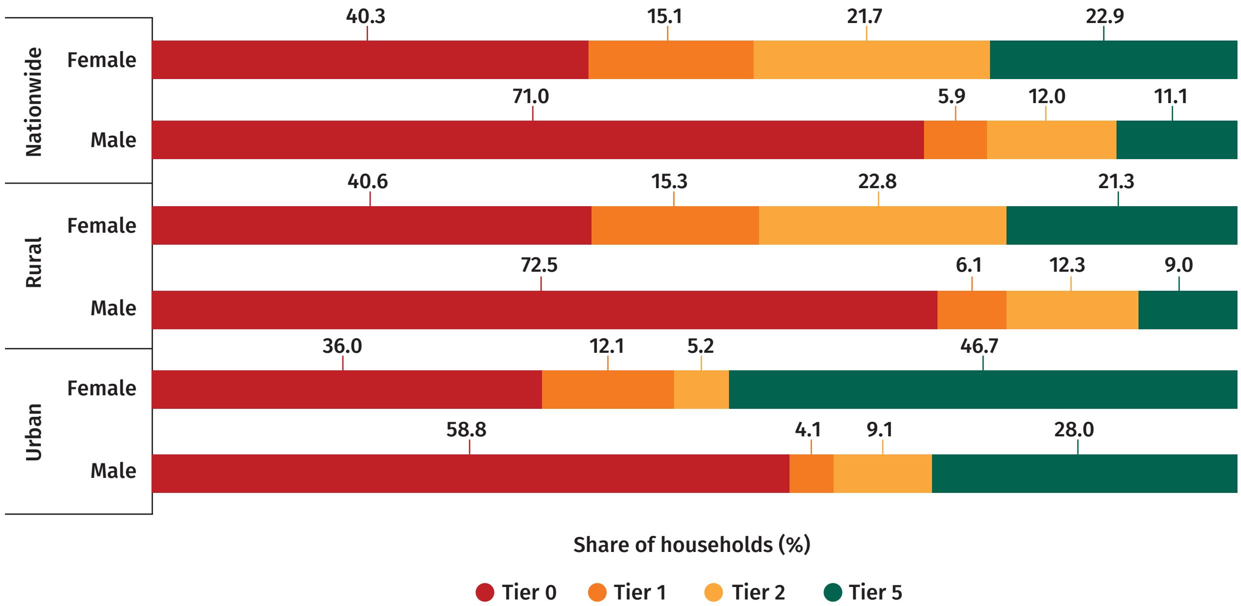
FIGURE 37 • **Access to modern energy cooking services, by type of primary cookstove and sex of the household head (nationwide, urban, rural)**



Source: Papua New Guinea Energy Survey 2021.

The MTF Tier distribution for MECS shows wider gender gaps compared to gaps reported in access by primary cookstove type. The difference is explained by the fact that male-headed households cooking with traditional stoves are significantly more likely to fall in Tier 0 than female-headed households cooking with traditional stoves, because of poorer ventilation levels for the male heads. Female-headed households are more likely to cook in the open air (45 percent versus 21 percent of male-headed households). Also, among households cooking indoors, female-headed households are more likely to use a chimney (20 percent versus 5 percent of male-headed households) (figure 38).

FIGURE 38 • **Cooking Exposure Tier distribution by sex of the household head (nationwide, urban, rural)**



Source: Papua New Guinea Energy Survey 2021.

POLICY RECOMMENDATION

Female-headed households appear to be more financially and socially vulnerable than male-headed households, as they tend to be poorer, particularly in rural areas, less educated, less likely to be employed, and when employed they are less likely to have a full-time job.

Female-headed households are significantly less likely to have access to electricity compared to male-headed households, driven by their lower access to off-grid solutions. Several pro-poor targeting actions, whereby female-headed households may be automatically eligible, may be considered, such as financial support for the purchase of off-grid solutions, including microfinance schemes, pay-as-you-go mechanisms, and result-based financing. Male-headed households are significantly less likely to access the grid in urban areas compared to female-headed households. However, the small female-headed household sample size may be distorting results. All households in the lower quintiles appear to be significantly constrained in accessing the grid. Several pro-poor targeting actions may be considered, such as subsidized connection costs.

Female-headed households are more likely to use clean fuel stoves than male-headed households, across both urban and rural areas. Local context and social norms should be considered when designing MECS, leveraging from information on culinary traditions, fuel preference, acquisition methods, and consumption levels. Affordability constraints affecting poor households may be addressed through targeted financing mechanisms. Education campaigns are also recommended to raise awareness of the benefits of MECS, targeting both men and women. Women (across both male- and female-headed households) are more likely to be affected by indoor air pollution than men, as they are very often the main cook. Men are more likely to be the decision-makers, in male-headed households in particular, and the purchase of a cookstove often depends on their spending preferences.

ANNEX 1: MULTI-TIER FRAMEWORKS: ELECTRIC ENERGY SERVICES

The MTF measures electricity access provided by any technology (grid or off-grid) used as a main source of electricity, through seven attributes that capture key characteristics of the energy supply that affect the user experience. Households without any source of electricity (including those using dry-cell batteries as their main source) are designated as having no access to electricity.

The seven attributes are Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety. Based on the combination of the attributes, the MTF defines six tiers of access with minimum requirements, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement (table A1.1). Each attribute is assessed separately, and the overall tier of electricity access for each user (household, enterprise, education facility, or health facility) is calculated by applying the lowest tier obtained in any of the attributes.

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

ATTRIBUTES	INDICATOR	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Capacity	Peak power capacity ratings (in W or daily Wh)	<3 W	Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
		<12 Wh	Min 12 Wh	Min 200 Wh	Min 1 kWh	Min 3.4 kWh	Min 8.2 kWh
Availability	Hours per day (24)	<4 hrs	Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening (6–10pm)	<1 hr	Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
Reliability	Number and duration of disruptions per week					Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
Quality	Voltage problems damage appliances	No				Yes	
Affordability	Cost of standard consumption package as a share of total HH expenditure	≥ 5%			< 5%		
Formality	HH pays for electricity	No				Yes	
Health and Safety	Past accidents	Yes				No	

Source: World Bank.

Note: HH = household; hrs = hours; min = minimum.

ATTRIBUTES

CAPACITY (WHAT APPLIANCES CAN BE POWERED?)

The Capacity attribute of the main electricity source (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate various appliances, ranging from a few W for light-emitting diode (LED) lights and mobile phone chargers to several thousand W for space heaters or air conditioners. Capacity is measured in W for the grid, mini-grids, and generators and in Wh for rechargeable batteries, solar lanterns (SLs), solar lighting systems (SLSs), and solar home system (SHSs). It is often difficult to determine the capacity of the system by simple observation. Thus, capacity is approximated based either on the electricity source or on the appliances owned by the surveyed entity (for example, a household). Appliances are classified into tiers based on their power ratings (see table 1, page 6). The Appliance Tier of a surveyed entity corresponds to the highest tier of all the appliances it owns. For example, if a household owns several appliances, the highest-load appliance determines the Appliance Tier for the household and thus the Capacity Tier. If a household does not own any appliance (in working condition)—including lighting—the Capacity Tier is 0. Households without any access to electricity (and households using dry-cell batteries as the main electricity source) fall by default in Capacity Tier 0. All households are included for the calculation of this attribute. The Capacity Tier ratings are distinguished by the following:

Grid-connected entity: Capacity is by default Tier 5.

Mini-grid: Capacity is Tier 5, unless the entity surveyed (for example, household) experiences a load limit or cannot power all its appliances, in which case the Capacity Tier corresponds to the highest Appliance Tier reached by the appliances (in working condition) owned by the entity.

Generator and rechargeable battery: Capacity corresponds to the highest Appliance Tier reached by the appliances (in working condition) owned by the household.

Solar home system: Capacity is by default Tier 2, unless the household owns appliances that reach Appliance Tier above Tier 2, in which case the Capacity Tier will correspond to the highest Appliance Tier reached by the appliances (in working condition) owned by the household.

Solar lantern and solar lighting system: Capacity Tier is Tier 0 or Tier 1, depending on a score calculated based on the number and type of solar devices used, the number of household members, and the possibility of charging a mobile phone or powering a radio (box A1.1).

BOX A1.1 • CALCULATING THE CAPACITY TIER FOR SOLAR LANTERNS (SL) AND SOLAR LIGHTING SYSTEMS (SLS)

SLs and SLSs will fall in either Tier 0 or 1 depending on their score. The score will depend on (1) the possibility to charge a mobile phone or power a radio (weight of 0.3) and (2) the level of the lighting service calculated based on the ratio between the number of people served with adequate lighting and the household size (weight of 0.7). The highest total score is capped at 1. For simplification, it is estimated that an SL can serve one person with adequate lighting and an SLS can serve two people with adequate lighting. The average (mean) score is then calculated, including all scores above 0 and below 1. The mean score will determine the benchmark below which a household is placed in Tier 0 and above which a household is placed in Tier 1. Since all solar devices used in the household are taken into account (not only the main solar device), the lighting score for each household will be calculated based on the number and type of solar devices. If any of the devices used has the possibility to charge a phone or power a radio, then the charging part of the score is 0.3 (if not, it is 0). Some indicative examples are provided in table A1.2 for clarification purposes.

TABLE A1.2 • Examples of calculation of the solar lantern (SL) and solar lighting system (SLS) score

HH	# of SL	# of SLS	Phone charging/ radio from any of the devices?	Score for phone charging /radio	# of people served with adequate lighting	HH size	Lighting score	Total score	Is score included in the mean?	Mean score	Tier
A	1		No	0	1	5	0.20	0.20	Yes	0.66	Tier 0
B		1	Yes	0.3	2	3	0.67	0.97	Yes	0.66	Tier 1
C	2		Yes	0.3	1+1	4	0.50	0.80	Yes	0.66	Tier 1
D		2	No	0	2+2	6	0.67	0.67	Yes	0.66	Tier 1
E	1	1	Yes	0.3	1+2	2	1.50	1.80	No	0.66	Tier 1
F	1		Yes	0.3	1	1	1.0	1.30	No	0.66	Tier 1
G		1	Yes	0.3	2	6	0.33	0.63	Yes	0.66	Tier 0
H	2		Yes	0.3	1+1	8	0.25	0.55	Yes	0.66	Tier 0
I		2	No	0	2+2	5	0.80	0.80	Yes	0.66	Tier 1
J	1	1	Yes	0.3	1+2	9	0.33	0.63	Yes	0.66	Tier 0

Source: World Bank.

Note: HH = household.

The questions related to the Capacity attribute are:

- What is the household's main source of electricity?
- For mini-grid as a main source: Are you able to power all your appliances with the mini-grid? Is there a load limit?
- For a generator, SHS, or rechargeable battery as a main source: How many[TYPE OF APPLIANCE] in working condition does your household own?
- For SL or SLS as main source: How many light bulbs do[ALL SOLAR DEVICES] have? Can you charge a phone with[ALL SOLAR DEVICES]? Can you power a radio with[ALL SOLAR DEVICES]?
- What is the number of household members?

AVAILABILITY ("IS POWER AVAILABLE WHEN NEEDED?")

The availability of the main electricity source refers to the number of hours during which electricity is available. It is measured through two indicators: daily availability, measured by the total number of hours per day (24-hour period), and the evening availability, measured by the number of evening hours (the 4 hours after sunset) during which electricity is available. Availability is measured only for households with access to electricity. Initially, the Availability attribute was named Duration attribute. Only households with access to electricity are included for the calculation of this attribute.

The questions related to this attribute are:

- How many hours of electricity (max 24 hours) are available each day and night from[MAIN SOURCE]?
- How many hours of electricity are available during the evening (between 6pm and 10pm) from[MAIN SOURCE]?

RELIABILITY ("IS SERVICE FREQUENTLY INTERRUPTED?")

The Reliability attribute of the main electricity source is measured through the combination of the frequency and duration of unscheduled outages or blackouts. Reliability is measured only for households with access to the grid and a mini-grid.

The questions related to this attribute are:

- How many unscheduled outages/blackouts occur in a typical week?
- What is the total duration (hours and minutes) of all the unscheduled outages/blackouts in a typical week?

QUALITY ("WILL VOLTAGE FLUCTUATIONS DAMAGE MY APPLIANCES?")

The Quality attribute of the main electricity source is defined by voltage adequacy. Electric appliances generally require a certain level of voltage to operate properly. Inadequate or fluctuating voltage can damage appliances and even result in electrical fires. A low or fluctuating voltage supply tends to result from an overloaded distribution system or from long-distance, low-tension cables connecting dispersed households to a single grid. The MTF survey does not measure voltage adequacy directly but uses incidents of appliance damage as a proxy. Quality is measured only for households with access to the grid or a mini-grid.

The question related to this attribute is:

- In the past 12 months, did any of your appliances get damaged because the voltage from[MAIN SOURCE] was going up and down?

AFFORDABILITY ("CAN A HOUSEHOLD AFFORD TO PURCHASE THE MINIMUM AMOUNT OF ELECTRICITY?")

The Affordability attribute of the main electricity source is determined by comparing the yearly cost of a standard electricity service package (30 kWh per month for one year) with total household expenditure. Total household expenditure corresponds to the aggregated and annualized amount of money that a household spends on goods and services, including the value of consumption of 13 categories of food items during the past week, of 8 categories of goods and services during the past month—such as medical expenses, house rent, and utility bills—and 13 categories of good and services purchased during the past year, such as education expenses, clothing, electronics, and vehicles. Electricity cost is calculated based on the corresponding grid tariff in the country. If the household spends more than 5 percent of household expenditure on electricity, then the electricity service is considered unaffordable for that household. Affordability is measured only for households with access to grid (and mini-grid for certain countries).

FORMALITY

The Formality attribute of the connection to the main electricity source is determined based on whether the household pays for the electricity used (supplied by the grid or a mini-grid). Reporting on the formality of a connection is challenging. Households may be sensitive about disclosing such information in a survey. The MTF survey therefore asks the household who is the recipient of the payment of the electricity bill. The connection is considered informal if the recipient of the payment is no one. Formality is measured only for households with access to the grid (and mini-grid for certain countries). Initially, the Formality attribute was named Legality attribute.

The question related to this attribute is:

- Who receives the payment for your electricity service?

HEALTH AND SAFETY

The Health and Safety attribute of the main electricity source is determined based on whether household members have experienced any permanent injury or death in the past 12 months because of the main electricity source (such as burns or electrocution). Such accidents can occur due to faulty wiring, incorrect use of or faulty appliances, or negligence. Health and safety is measured only for households with access to the grid (and a mini-grid for certain countries).

The question related to this attribute is:

- In the past 12 months, did any household members die or have permanent injury because of[MAIN SOURCE]?

ANNEX 2: MULTI-TIER FRAMEWORK FOR ACCESS TO MODERN ENERGY COOKING SERVICES (MECS)

The MTF measures access to modern energy cooking services (MECS), provided by any cookstove and fuel, using six attributes that capture key characteristics of the cooking services that affect the user experience: Cooking Exposure, Cookstove Efficiency, Convenience, Safety, Affordability, and Fuel Availability. Based on the combination of the attributes, the MTF defines six tiers of access with minimum requirements, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement (see table A2.1). Each attribute is assessed separately, and the overall tier of access to MECS for each user (household, enterprise, education facility, or health facility) is calculated by applying the lowest tier obtained in any of the attributes.

TABLE A2.1 • **The Multi-Tier Framework for Measuring Modern Energy Cooking Services (MECS)**

Attributes	Indicator	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Exposure	ISO's voluntary performance targets on emissions-default ventilation						
	$PM_{2.5}$ (mg/MJd) and	> 1030	≤ 1030	≤ 481	≤ 218	≤ 62	≤ 5
	CO (g/MJd)	> 18.3	≤ 18.3	≤ 11.5	≤ 7.2	≤ 4.4	≤ 3.0
	High ventilation $PM_{2.5}$ (mg/MJd) and 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) and 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/week)[a]	< 7		< 7	< 3	< 1.5	< 0.5
	Stove preparation time (minutes/meal)[b]	≥ 10			<10	< 5	< 2
Safety	Severity of accidents caused by the stove over the past year[c]	Fatal	Serious		Minor	None	
Affordability	Fuel cost as a share of household expenditure[d]	< 10%			< 10%	< 5%	
Availability	Availability[e] of primary fuel when needed (% of the year)f	< 80%			> 80%	> 90%	100%

Source: World Bank.

Note: CO =carbon monoxide ; g = gram; mg =milligrams ; MJd = megajoule ; PM2.5 = fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.;[15] ISO = International Organization for Standardization. The old framework was applied in the MTF Country Diagnostic Report for Bangladesh, Cambodia, Ethiopia, Honduras, Kenya, Liberia, Myanmar, Nepal, Niger, Nigeria, Rwanda, São Tomé and Príncipe, and Zambia. The MTF website data follow the new framework for all countries.

a. In the old framework, the thresholds were: ≥ 7 (Tier 1); < 7 (Tier 2); < 3 (Tier 3); < 1.5 (Tier 4); < 0.5 (Tier 5).
b. In the old framework, the thresholds were: ≥ 15 (Tier 1); < 15 (Tier 2); < 10 (Tier 3); < 5 (Tier 4); < 2 (Tier 5).
c. In the old framework, the thresholds were: Serious (Tier 3); No serious (Tier 5).
d. In the old framework, the thresholds were: ≥ 5% (Tier 3); < 5% (Tier 5).
e. In the MTF survey questionnaire, the options offered to respondents are: Rarely available (Tier 2); Sometimes available (Tier 3); Mostly available (Tier 4); Always available (Tier 5).
f. In the old framework, the thresholds were: < 80% (Tier 3); > 80% (Tier 4); 100% (Tier 5).

[15] Carbon Monoxide (CO) is measured in grams per megajoule delivered to the pot (g/MJd) and PM2.5 is milligrams per megajoule delivered to pot (mg/MJd). PM2.5 describes fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

ATTRIBUTES

COOKING EXPOSURE

The Cooking Exposure attribute refers to the personal exposure to pollutants from cooking activities, which depends on stove emissions, ventilation structure (which includes cooking space location and kitchen volume), and contact time (time spent in the cooking environment).[16] It is a proxy indicator to measure the health impacts of cooking activities on the household's main cook. In the MTF, cooking exposure is determined by two indicators: (1) emissions of the main cookstove and (2) ventilation of the main cooking area.

Cookstove Emissions Tiers are defined based on the ISO methodology. In case of missing data, approximate tiers are established (see table A2.2).[17] Ventilation Tiers are defined based on the location of the main cooking area and the number of openings to the outside (see table A2.3). Cooking Exposure Tiers are derived from the combination of Cookstove Emissions Tiers and Ventilation Tiers (see table A2.4).

The questions related to this attribute are:

Cooking emissions

- In the past 12 months, which cookstove(s) did your household use for preparing meals (including cooking, boiling water, baking or other purposes)?
- Is this[COOKSTOVE] your main cookstove for cooking meals?
- What exhaust system, in working condition, do you use with[MAIN COOKSTOVE]?

Ventilation of cooking space

- In the past 12 months, where did you normally cook with[MAIN COOKSTOVE]?
- What exhaust system, in working condition, do you use with[MAIN COOKSTOVE]?
- How many doors and windows (opening to the outside) does the cooking space have?

[16] Due to data quality issues, kitchen volume and contact time are not used for calculating the Cooking Exposure attribute in MTF survey data.
[17] Cookstove emissions are estimated for the main cookstove used in the household for preparing meals (including cooking, boiling water, baking, or other purposes).

TABLE A2.2 • **Cookstove Emissions Tiers**

EMISSIONS TIER	COOKSTOVE TYPE
Tier 0	Three-stone stove
Tier 1	Traditional stove[a] or improved cookstove[b] without embedded exhaust system[c]
Tier 2	Improved cookstove with embedded exhaust system
Tier 3	Kerosene stove or biomass rocket stove with high insulation
Tier 4	Clean fuel stove (biogas) or processed biomass gasifier stove
Tier 5	Clean fuel stove (electricity, ethanol, liquefied petroleum gas, piped natural gas, or solar)

Source: World Bank.

a. Traditional stoves refer to fixed/self-made stoves, traditional metal stoves, and self-built/traditional stoves.
b. Improved Cookstoves include rocket stoves (chimney, fan, and grate), ceramic stoves, ceramic stoves in metal buckets, and locally manufactured kerosene stoves.
c. A chimney, fan, or grate attached to the cookstove (as observed on product flyer).

TABLE A2.3 • **Ventilation Tiers**

VENTILATION TIER	COOKING AREA
Tier 0 (Bad)	Cooking inside without external exhaust system[a] and no opening[b]
Tier 1 (Bad)	Cooking inside without external exhaust system, with 1 opening
Tier 2 (Bad)	Cooking inside without external exhaust system, with 2 or more openings
Tier 3 (Medium)	Cooking inside with external exhaust system (regardless of number of openings)
Tier 4 (Good)	Cooking on a veranda
Tier 5 (Good)	Cooking in the open air

Source: World Bank.

a. The exhaust system refers to a fan attached to the fireplace, a chimney, or a hood, and the information is provided by the respondent.
b. An opening refers to a door or a window to the outside.

TABLE A2.4 • **Cooking Exposure Tiers**

COOKING EXPOSURE TIER	EMISSIONS TIER AND VENTILATION LEVEL
Tier 0	Emission Tier 0 with bad or medium ventilation Emission Tier 1 with bad ventilation
Tier 1	Emission Tier 0 with good ventilation Emission Tier 1 with medium ventilation Emission Tier 2 with bad ventilation
Tier 2	Emission Tier 1 with good ventilation Emission Tier 2 with medium ventilation Emission Tier 3 with bad ventilation
Tier 3	Emission Tier 2 with good ventilation Emission Tier 3 with medium ventilation
Tier 4	Emission Tier 3 with good ventilation Emission Tier 4 with medium or bad ventilation
Tier 5	Emission Tier 4 with good ventilation Emission Tier 5 regardless of ventilation level

Source: World Bank.

COOKSTOVE EFFICIENCY

The Cookstove Efficiency attribute is determined based on a combination of combustion efficiency and heat-transfer efficiency. Cookstove efficiency is assessed based on laboratory measurement under standard conditions or field testing under actual conditions. In cases where the cookstove also serves for space heating, the efficiency parameter is ignored (because heat-transfer efficiency becomes irrelevant). Due to lack of data, Cookstove efficiency could not be assessed in MTF surveys.

CONVENIENCE

The Convenience attribute refers to the amount of time household members spend collecting or purchasing fuel and preparing the fuel and stove for cooking. Thus, the Convenience attribute combines two indicators: (1) fuel acquisition and preparation time (hours per week) and (2) stove preparation time (minutes per meal). The lowest tier of each of the two indicators determines the overall Convenience Tier. The tier thresholds for this indicator have been updated.

The questions related to this attribute are:

Fuel acquisition and preparation time (hours per week)

- In a typical day, how many minutes in total do[ALL HOUSEHOLD MEMBERS] spend gathering, collecting, or purchasing fuels for the household and home-based income-generating activities, including travel time?
- In a typical day, how many minutes in total do[ALL HOUSEHOLD MEMBERS] spend on fuel preparation (that is, combined time of chopping wood, igniting wood for starter, turning on the stove)?

Stove preparation time (minutes per meal)

- How much time do household members spend preparing the[MAIN COOKSTOVE AND MOST-USED FUEL] for each meal on average (including setting up the fuel and turning on the stove but excluding gathering fuel and cooking time)?

AFFORDABILITY

The Affordability attribute refers to the household's ability to pay for cooking fuels. It is measured based on the annual cost of all fuels used for cooking as a share of total annual household expenditure. Total household expenditure corresponds to the aggregated and annualized amount of money that a household spends on goods and services, including the value of consumption of 13 categories of food items during the past week, of 8 categories of goods and services during the past month—such as medical expenses, house rent, and utility bills—and 13 categories of good and services during the past year, such as education expenses, clothing, electronics, and vehicles. The tier thresholds for this indicator have been updated.

The questions related to this attribute are:

- What unit do you purchase/collect[ALL COOKING FUELS] in (for example, kg, liter, etc.)?
- How often do you or a household member purchase/collect[ALL COOKING FUELS]?

- How much[ALL COOKING FUELS] do you buy or collect each time?
- How much[LOCAL CURRENCY] on average do you pay for the amount of[UNIT] that you purchase each time?

FUEL AVAILABILITY

The Fuel Availability attribute refers to the availability of the most-used fuel in the main cookstove used for cooking meals. Fuel shortages can force a household to switch to inferior fuel types. The tier thresholds for this indicator have been updated.

The question related to this attribute is:

- In the past 12 months, how many times was the[MOST-USED FUEL FOR MAIN COOKSTOVE] available?

SAFETY

The Safety attribute of the main cookstove is determined based on the severity of reported accidents in the past 12 months caused by the main cookstove used for cooking meals. The tier thresholds for this indicator have been updated.

The question related to this attribute is:

- In the past 12 months, what kind of illness/injury has your household been exposed to as a result of[MAIN COOKSTOVE]?

ANNEX 3: SAMPLING DISTRIBUTION AND CONFIDENCE INTERVAL

TABLE A3.1 • **Sample distribution by district**

District	Submit	District	Submit	District	Submit
NCD	154	Maprik	24	Angoram	7
Lae	105	North Fly	24	Kiriwina-Goodenough	7
Talasea	86	Obura-Wonenara	24	Pomio	6
Madang	82	Okapa	24	Kagua-Erave	6
Anglimp-South Waghi	71	Yangoru-Saussia	24	Tewae-Siassi	5
Goroka	61	Abau	23	Goilala	4
Mendi-Munihu	60	Ambunti-Dreikikir	22	Telefomin	4
Mount Hagen	60	Bulolo	22	Chimbu	3
Lagaip-Pogera	59	South Fly	22		
Vanimo-Green River	59	Unggai-Bena	22		
North Bougainville	55	Middle Fly	20		
Tari-Pori	55	Nawaeb	20		
Central Bougainville	54	Nuku	20		
Wewak	52	Rigo	20		
Kokopo	50	Daulo	19		
Ialibu-Pangia	49	Imbonggu	19		
Wabag	45	Koroba-Kopiago	19		
Kainantu	44	Middle Ramu	19		
Kavieng	44	Markham	18		
North Waghi	44	Dei	17		
Wapenamanda	39	Finschhafen	17		
Komo-Magarima	38	Kabwum	17		
Gazzelle	36	Menyamya	16		
Kundiawa-Gembogl	36	Tambul-Nebilyer	16		
Manus	35	Wosera-Gawi	16		
Namatanai	35	Esa'ala	15		
Rabaul	35	Gumine	15		
South Bougainville	35	Henganofi	15		
Rai Coast	34	Mul Baiyer	15		
Aitape-Lumi	33	Kandrian-Gloucester	14		
Nipa-Kutubu	33	Chuave	13		
Alotau	31	Sohe	13		
Usino-Bundi	31	Karimui-Nomane	12		
Kerema	30	Kikori	12		
Kerowagi	29	Samarai-Murua	11		
Sumkar	29	Jimi	10		
Huon	28	Kandep	10		
Bogia	27	Ijivitari	9		
Sina sina-Yonggomugl	26	Kompiam-Ambum	9		
Kairuku-Hiri	25	Lufa	9		

Source: Digicel, Trend Media Pacific, and World Bank 2021.

TABLE A3.2 • Confidence interval table of the proportion of the access to electricity by sex of the household head and area

AREA	MAIN SOURCE	VARIABLE	OBSERVATION	PROPORTION	STANDARD ERROR	95% CONFIDENCE INTERVAL
Rural	No electricity	Male head (N = 1021)	273	0.2673849	0.0138514	[.2404498, .2956682]
		Female head (N = 400)	192	0.48	0.02498	[.4300959, .5302021]
	Grid	Male head (N = 1021)	111	0.1087169	0.0097419	[.0902831, .1294403]
		Female head (N = 400)	36	0.09	0.0143091	[.0638315, .1224199]
	Off-grid	Male head (N = 1021)	637	0.6238981	0.0151599	[.5933726, .6537071]
		Female head (N = 400)	171	0.4275	0.0247358	[.3784628, .4776178]
Urban	No electricity	Male head (N = 111)	19	0.1711712	0.0357508	[.1063175, .254328]
		Female Head (N = 24)	4	0.1666667	0.0760726	[.0473536, .3738417
	Grid	Male head (N = 111)	30	0.2702703	0.042152	[.1903574, .3628316]
		Female head (N = 24)	12	0.5	0.1020621	[.2912418, .7087582]
	Off-grid	Male head (N = 111)	62	0.5585586	0.0471313	[.4611856, .6527286]
		Female head (N = 24)	8	0.3333333	0.096225	[.1563023, .5532196]

Source: World Bank.

TABLE A3.3 • **Confidence interval table of the proportion of the access to electricity by expenditure quintile and sex of the household head**

EXPENDITURE QUINTILE	GENDER OF THE HEAD	ACCESS TYPE	OBS	PROPORTION	STANDARD ERROR	[95% CONFIDENCE INTERVAL]
Bottom 40%	Male (N = 453)	No electricity	173	0.381899	0.0228273	[.336953 .4283968]
		Grid	4	0.00883	0.0043955	[.002411 .022453]
		Off-grid	276	0.609272	0.0229242	[.5626426 .6544639]
	Female (N = 210)	No electricity	174	0.828571	0.0260074	[.7706565 .8769513]
		Grid	0	0.004762	0.0047506	[.0001206 .0262446]
		Off-grid	36	0.171429	0.0260074	[.1230487 .2293435]
3rd quintile	Male (N = 210)	No electricity	58	0.276191	0.0308537	[.2168905 .3419295]
		Grid	2	0.009524	0.0067022	[.0011555 .033978]
		Off-grid	150	0.714286	0.031174	[.6480653 .7743441]
	Female (N = 86)	No electricity	1	0.011628	0.0115601	[.0002943 .0630905]
		Grid	11	0.127907	0.0360147	[.0656158 .2173461]
		Off-grid	74	0.860465	0.0373645	[.7689428 .9257689]
4th quintile	Male (N = 246)	No electricity	41	0.166667	0.0237611	[.1223364 .2192333]
		Grid	27	0.109756	0.0199297	[.0735873 .155662]
		Off-grid	178	0.723577	0.0285142	[.6631808 .7784969]
	Female (N = 59)	No electricity	8	0.135593	0.044571	[.0604035 .249804]
		Grid	14	0.237288	0.055385	[.1362257 .3659499]
		Off-grid	37	0.627119	0.0629556	[.4914548 .7495604]
Top 20%	Male (N = 223)	No electricity	21	0.09417	0.0195582	[.0592417 .1403448]
		Grid	108	0.484305	0.033466	[.4170655 .5519671]
		Off-grid	95	0.426009	0.0331138	[.3602376 .4937742]
	Female (N = 69)	No electricity	13	0.188406	0.0470752	[.1043122 .3006042]
		Grid	23	0.333333	0.0567504	[.2243675 .4571184]
		Off-grid	33	0.478261	0.060136	[.3564518 .601995]

Source: World Bank.

TABLE A3.4 • Confidence interval table of the proportion of the aggregated tier of the main electric sources by sex of the household head and area

AREA	GENDER OF THE HEAD	AGGREGATED TIER	VARIABLE	OBSERVATION	PROPORTION	STANDARD ERROR	CONFIDENCE INTERVAL
Rural	Male head = 1018, female head = 399	Tier 0	Male head	585	0.574656	0.015495	[.5436154 .6052641]
			Female head	234	0.586466	0.024654	[.5363985 .6352415]
		Tier 1	Male head	304	0.298625	0.014344	[.2706364 .3277828]
			Female head	123	0.308271	0.023118	[.2632767 .3561362]
		Tier 2	Male head	26	0.02554	0.004945	[.0167501 .0371996]
			Female head	7	0.017544	0.006573	[.0070819 .0358116]
		Tier 3	Male head	37	0.036346	0.005866	[.0257174 .049752]
			Female head	9	0.022556	0.007434	[.0103649 .0423859]
		Tier 4	Male head	29	0.028487	0.005214	[.0191596 .0406576]
			Female head	9	0.022556	0.007434	[.0103649 .0423859]
		Tier 5	Male head	37	0.036346	0.005866	[.0257174 .049752]
			Female head	17	0.042607	0.010111	[.0250126 .0673423]
Urban	Male head = 111, female head = 24	Tier 0	Male head	44	0.396396	0.046428	[.3048083 .493656]
			Female head	6	0.25	0.088388	.0977304 .4671128
		Tier 1	Male head	37	0.333333	0.044744	[.246707 .429103]
			Female head	5	0.208333	0.082898	[.0713186 .421512]
		Tier 2	Male head	5	0.045045	0.019686	[.0147856 .1019933]
			Female head	2	0.083333	0.056417	[.0102563 .2699728]
		Tier 3	Male head	10	0.09009	0.027175	[.044051 .1594424]
			Female head	6	0.25	0.088388	[.0977304 .4671128]
		Tier 4	Male head	4	0.036036	0.01769	[.0099044 .0896999]
			Female head	3	0.125	0.067508	[.0265593 .3236114]
		Tier 5	Male head	11	0.099099	0.02836	[.0505164 .1703997]
			Female head	2	0.083333	0.056417	[.0102563 .2699728]

Source: World Bank.

TABLE A3.5 • Confidence interval table of the proportion of the cooking stoves by sex of the household head and area

AREA	GENDER OF THE HEAD	VARIABLES	OBSERVATION	PROPORTION	STANDARD ERROR	CONFIDENCE INTERVAL
Rural	Male head (N = 833)	Three-stone stoves	290	0.348139	0.016506	[.3157747 .381583]
		Traditional cookstove	463	0.555822	0.017216	[.5213326 .5899158]
		Improved cookstove	2	0.002401	0.001696	[.0002909 .0086459]
		Liquid fuel/kerosene stove	3	0.003601	0.002076	[.0007433 .0104886]
		Clean fuel stove	75	0.090036	0.009917	[.0714765 .1115538]
	Female head (N = 359)	Three-stone stove	108	0.300836	0.024205	[.2538169 .3511753]
		Traditional cookstove	175	0.487465	0.026381	[.4346565 .5404823]
		Improved cookstove	0	0	0	[0 .0102228*]
		Liquid fuel/kerosene stove	0	0	0	[0 .0102228*]
		Clean fuel stove	77	0.214485	0.021664	[.1731398 .2606103]
Urban	Male head (N = 102)	Three-stone stove	14	0.137255	0.034073	[.0771181 .2195565]
		Traditional cookstove	58	0.568628	0.049039	[.4668231 .6663411]
		Improved cookstove	0	0	0	[0 .0355193*]
		Liquid fuel/Kerosene stove	1	0.009804	0.009756	[.0002482 .0534154]
		Clean fuel stove	29	0.284314	0.044664	[.1993797 .3821774]
	Female head (N = 24)	Three-stone stove	3	0.125	0.067508	[.0265593 .3236114]
		Traditional cookstove	9	0.375	0.098821	[.1879929 .5940636]
		Improved cookstove	0	0	0	[0 .1424736*]
		Liquid fuel/Kerosene stove	1	0.041667	0.040789	[.0010544 .2112017]
		Clean fuel stove	11	0.458333	0.101707	[.2555302 .6717919]

Source: World Bank.

ANNEX 4: PICTURES OF SOLAR DEVICES

a. Solar lantern

Pico Plus

Pro 300

Boom

GLP Pro 200: light up your home with bright tube lights and phone charging

b. Solar home system

HOME 400 with 32" TV/ online name: Sun King Home 400

Home 400 with 32” TV can entertain your family, and light up your home with bright tube lights and phone charging: And with solar, never pay a cent for electricity again. Fill your home with life and light.

Source: World Bank ESMAP.

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