SÃO TOMÉ AND PRÍNCIPE

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

ESMAP

WORLD BANK GROUP

MTF Multi-Tier FRAMEWORK

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ESMAP is a global knowledge and technical assistance program to support low- and middle-income countries to increase their knowledge as well as their institutional capacity to achieve environmentally sustainable energy solutions for both poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, the European Commission, Finland, France, Germany, Iceland, Italy, Japan, Lithuania, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and the Rockefeller Foundation, as well as the World Bank. Financial and technical support from ESMAP for the MTF survey is gratefully acknowledged.

This Energy Access Diagnostic Report details the results of the MTF survey in São Tomé and Príncipe and provides the status of both access to electricity and access to modern energy cooking solutions in the country. This initiative has relied on the critical support of multiple entities and individuals that the MTF team would like to acknowledge.

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ABBREVIATIONS

CFL	Compact Fluorescent Lamp
EMAE	Empresa de agua e electricidade – Water and Electricity National Utility Company
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICS	Improved cookstove
kW	Kilowatt
kWh	Kilowatt-hour
LED	Light-Emitting Diode
LPG	liquefied petroleum gas
MTF	Multi-tier Framework
MW	Megawatt
PV	Solar photovoltaic
R.A. Príncipe	Região Autónoma do Príncipe / Príncipe Autonomous Region
SHS	Solar Home System
SLS	Solar lighting system
SL	Solar Lantern
STN	Sao Tomé New Dobras (currency)*
STP	São Tomé & Príncipe
W	Watt
WHO	World Health Organization
WTP	Willingness to Pay

**At the time of the survey, the exchange rate was 1 USD = 20.567 STN*

EXECUTIVE SUMMARY

São Tomé and Príncipe (STP) is one of the smallest economies in Africa, a lower-middle-income, developing small-island state with a fragile economy that is highly vulnerable to exogenous shocks. Data show that poverty incidence is significant, with about one-third of the population living on less than US$1.90 per day and more than two-thirds of the population below the poverty line. The average person lives on less than US$3.20 per day.

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the Multi-Tier Framework (MTF) approach. The survey's objective is to provide more nuanced data on energy access, including access to electricity and cooking solutions. The MTF approach goes beyond the traditional binary measurement of energy access—for example, "having or not having" a connection to electricity, "using or not using" clean fuels in cooking—to capture the multidimensional nature of energy access and the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.[1]

ACCESS TO ELECTRICITY

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

- **Source of electricity:** The MTF survey data show that, as of 2018, 71% of STP households have access to electricity through either the national grid or off-grid sources, while the remaining 29% have no access to electricity. Virtually all households with access to a source of electricity are connected to the national grid (69.4%), and the remaining 1.6% primarily use off-grid solutions. A certain gap exists in access to electricity between urban and rural areas: three-quarters of urban households (76.2%) access electricity through the national grid, while 58.7% of rural households do.
- **MTF aggregate tier for access to electricity:** The MTF defines Tier 1 or above as having access to electricity based on Sustainable Development Goal (SDG) 7.1.1. Nationwide, 70.4% of STP households are in Tier 1 or above for electricity access. Specifically, 76.7% of urban households and 60.5% of rural households are in Tier 1 or above. Grid users are

[1] The MTF access rate includes access provided by off-grid technologies, which is often excluded by the binary rate, but excludes connections that do not meet its criteria for minimum level of service.
[2] For descriptions of the MTF and its attributes, see Annex 1.

mainly concentrated in Tiers 3 through 5, while the very few users of off-grid solutions are primarily in Tiers 0 through 2.

- **Households in Tier 0:** Nationwide, 29% of households are in Tier 0 for access to electricity, and the majority of them do not have any source of electricity. For households without any source of electricity, it will be critical to provide either a grid connection or an off-grid energy solution. A major barrier preventing households from gaining a grid connection is the up-front cost. More flexible payment plan options or access to financing, such as subsidies, could help in addressing the burden of paying high up-front costs, while other direct costs associated with gaining a connection, such as internal wiring, should be examined. Mini-grid development could be considered in areas not covered by the grid, where a sizeable electricity demand exists. Off-grid solar products could help households in other villages not yet reached by the grid infrastructure. The latter relies on actions to both develop the offer of solar products in STP as well as to address Affordability issues through payment plans. The penetration rate for off-grid solutions can also be improved through a consumer awareness program.

- **Grid-connected households:** Grid-connected households are mostly in higher tiers: 91.4% of grid-connected households are in Tier 3 or above, with 27.5% being in the highest tier, Tier 5. Challenges with Reliability, Availability and Quality are the main issues preventing grid-connected households from being in the highest tier.

ACCESS TO MODERN-ENERGY COOKING SOLUTIONS

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

- **Primary cookstove and fuel:** STP households reported usage of five types of cookstoves as their main cookstove: 53.5% of households use kerosene stoves; 31.8% use open fire/three-stone[4] stoves; 8.3% use improved cookstoves (ICS); 5.1% use a traditional stove; and the remaining 1.2% use liquefied petroleum gas (LPG). Urban and rural households rely on different cooking technologies, with a majority of urban households (65.1%) using kerosene stoves while 55.9% of rural households use open-fire stoves. LPG penetration is very limited and essentially an urban phenomenon (used by 1.7% of households in urban areas vs. 0.3% in rural areas). Additionally, a third of households practice stove stacking.

- **MTF aggregate tier for access to modern energy cooking solutions:** The majority of households are concentrated in Tiers 0, 1, and 2 (27.5%, 25.8% and 34.9%, respectively). Households in Tiers 0 and 1 mostly use biomass fuels, while most kerosene users reach

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

Tier 2 for access to cooking solutions. A higher portion of rural households (44.3%) is in Tier 0 compared to urban households (17%). Clean-fuel stove users tend to be in higher tiers for access to modern-energy cooking solutions.

- **The main constraint for the 53.3% of households in Tiers 0 and 1 is Cooking exposure caused by the usage of three-stone stoves as their primary stoves.** Since no efficient improved cookstoves currently exist in STP, a possible solution is to introduce adequate cookstoves both for wood and for charcoal fuel users based on the assessment of households' needs, preferences, and willingness to pay and to promote their use through awareness-raising campaigns.
- **Kerosene stove users that fall in higher tiers (Tiers 2, 3 and 4) also face challenges stemming mainly from Cooking exposure.** Given the substantial penetration of kerosene stoves that do not qualify as clean fuel stoves, particularly in urban areas where 41.1% use them as the sole stove, promoting LPG stoves for cooking would lift the majority of STP households to higher tiers. This requires action on both the offer and demand side, respectively to facilitate a stable and sustainable fuel supply and to tackle the Affordability of LPG as a main cooking fuel, which may be another obstacle.
- **For the significant share (19.6%) of households lacking both access to the grid and access to ICS for cooking with biomass, synergies can be found** by providing public support to distributors that can deliver both solar products and ICS to this segment, improving access to electricity as well as access to modern cooking solutions while reducing the cost of serving these households.

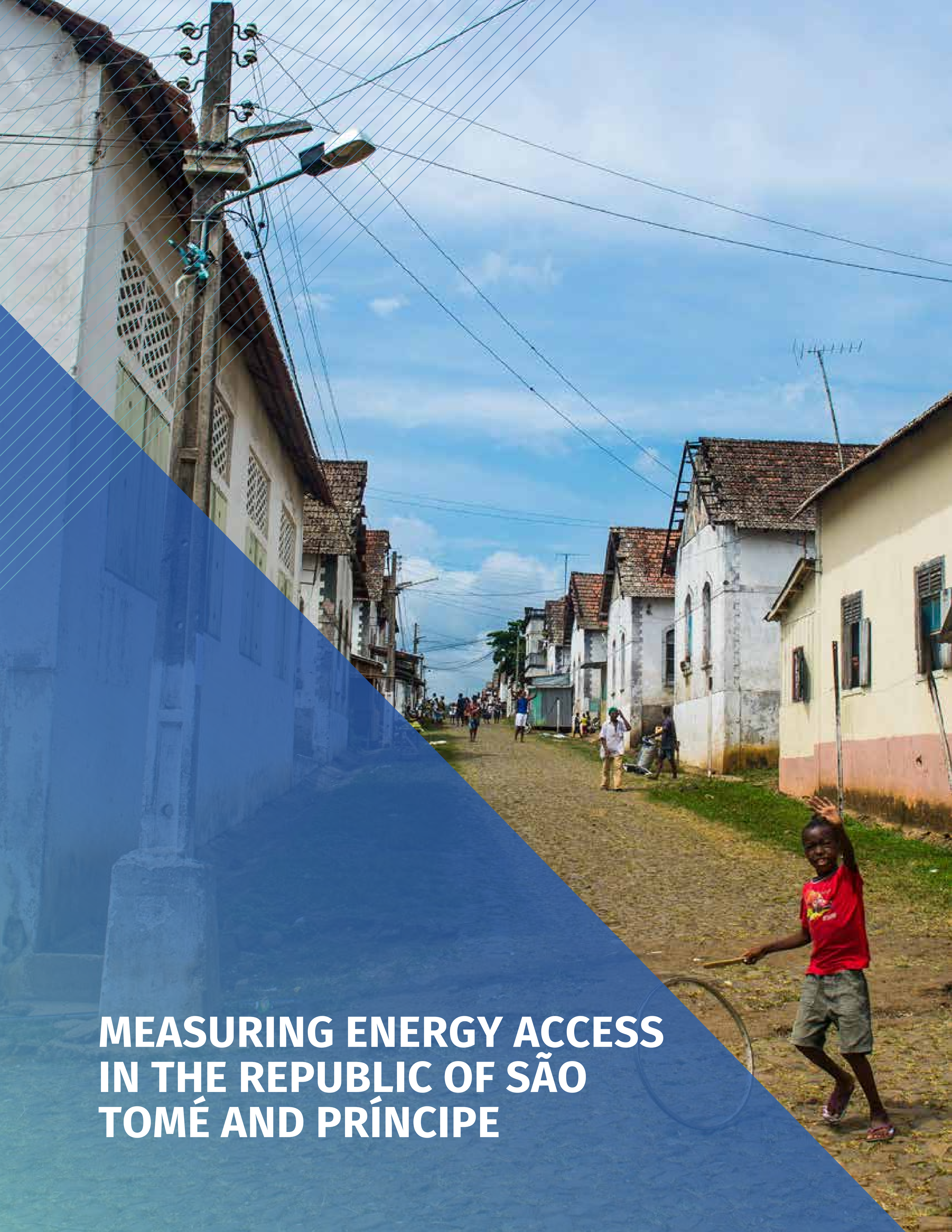
GENDER ANALYSIS

Nationwide, 62.1% of STP households are headed by men and 37.9% of households are headed by women. Female-headed households account for 39.5% of urban households and 35.4% of rural households.

Male household heads have higher levels of education than female household heads: more than a half of female household heads (54.5%) completed primary education only, 12.8% higher than the rate among male household heads. Female-headed households are poorer than male-headed households: 43.5% of female-headed households are in the bottom two income quintiles compared with 37.6% of male-headed households.

Male-headed households are slightly more likely than female-headed households to lack access to electricity (30.5% versus 26.6%) and less likely to have a grid connection (67.6% versus 72.3%). This translates into a better performance in terms of the tier ranking for female-headed households: 45.4% of them are in Tiers 4-5, compared with 37.3% of male-headed households. Nevertheless, female-headed households are less willing to pay for a grid connection. This response may be attributed to differences in the ability to pay due to differences in wealth. Beyond the fact that solar technologies are relatively new and not widespread in STP, the economic gap identified between gender groups could also explain the lower willingness to pay for a solar home system among female-headed households.

Male-headed households and female-headed households use similar cooking technologies. Male-headed households reach only marginally higher tiers in terms of access to modern energy cooking solutions: 48.1% of male-headed and 44.3% of female-headed households are in Tiers 2 and above. In STP, women ages 15 and older spend a considerably higher amount of time cooking or in the cooking area (more than 4 hours per day) than either men, girls, or boys. Women are thus much more likely to be affected by indoor air pollution. The amount of time spent in cooking and acquiring fuel is also disproportionately higher for women (ages 15 and older) than for others, and it decreases with the use of clean cooking solutions. Hence, cooking solutions may have a larger impact on women compared to the other three groups.



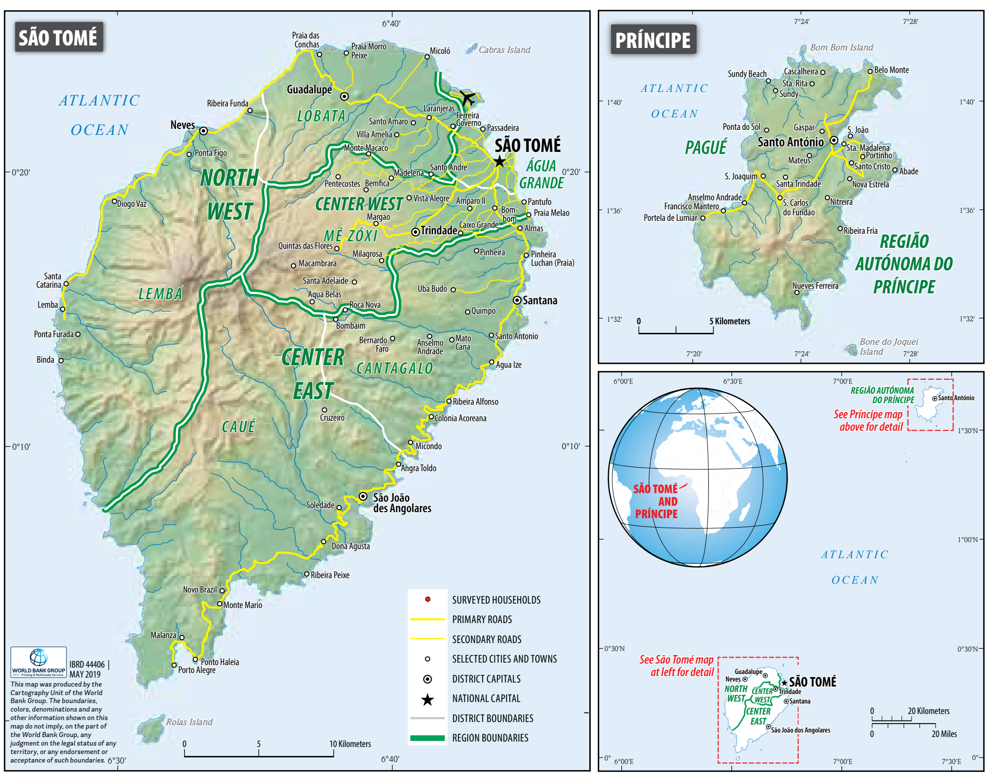
MEASURING ENERGY ACCESS IN THE REPUBLIC OF SÃO TOMÉ AND PRÍNCIPE

At the nexus of critical development challenges in the Republic of São Tomé and Príncipe (STP) lies access to energy. Energy deeply influences human development and is an engine for economic growth and social development.

The importance and wide-ranging impact of energy access is recognized by the United Nations under Sustainable Development Goal 7.1, which seeks universal access to affordable, reliable, and modern energy services. SDG7 is crucial to achieving many other Sustainable Development Goals as well – from poverty eradication via advancements in health, education, water supply, and industrialization to mitigating climate change.[5] The Government of STP has been committed to achieving Sustainable Development Goal 7 to benefit its people, and has thus collaborated with the World Bank to realize the Multi-Tier Framework (MTF) survey to obtain guidance on setting targets, policies, and investment strategies for enhancing energy access.

Also working toward this objective is the Sustainable Energy for All (SEforAll) initiative, launched by the Secretary General of the United Nations, which sets universal access to modern energy as one of its three energy-access goals to be met by 2030.

FIGURE 1 • **Map of São Tomé and Príncipe**



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5 https://unstats.un.org/sdgs/report/2016/goal-07/

COUNTRY CONTEXT

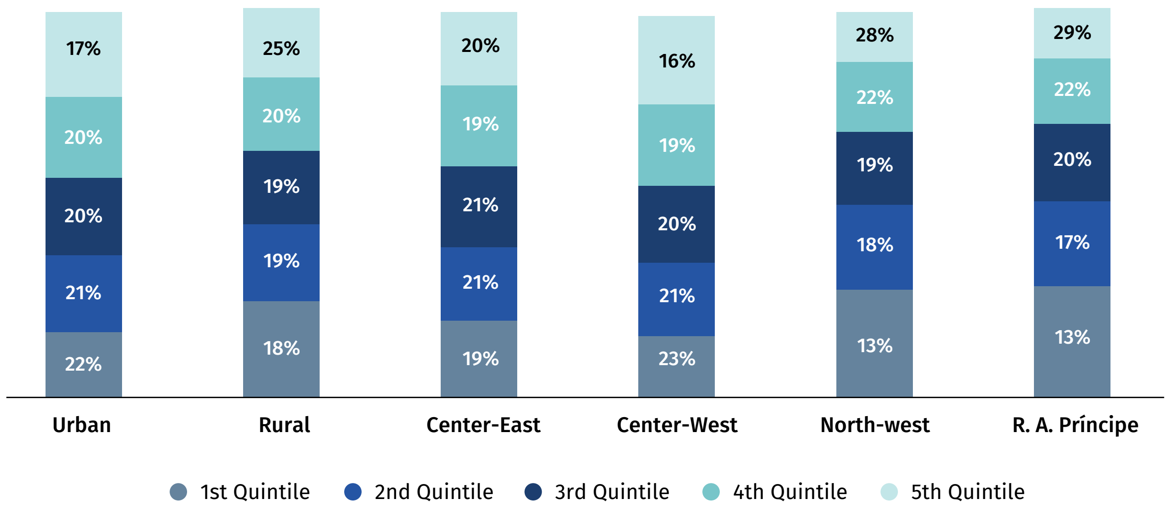
The Republic of São Tomé and Príncipe (STP) is an archipelago of just over 1,000 square kilometers in the Gulf of Guinea. It consists of two main islands—São Tomé and Príncipe—and several rocky islets. In the south and west of both islands, high volcanic mountains fall precipitously to the sea on one side and descend gradually to small plains in the northeast. The population of roughly 200,000 inhabitants is concentrated in the drier and flatter areas of both islands. Whereas a third of the inhabitants live in São Tomé city and its outskirts, where economic activity is concentrated, only about 5% live on the island of Príncipe. Two thirds of the population are considered urban (Clarence-Smith & Seibert, 2018).

STP is one of the smallest economies in Africa, a lower-middle-income, developing small-island state with a fragile economy, and it is therefore highly vulnerable to exogenous shocks. Data shows that poverty incidence is significant, with about one-third of the population living on less than US$1.90 per day and more than two-thirds of the population below the poverty line, on average living on less than US$3.20 per day (World Bank, 2016). The country faces the challenges typical of small island states: overcoming insularity and small market size as well as vulnerability to natural shocks and the effects of climate change. Moreover, the island has limited human capital and suffers from a scarce amount of tradable resources to generate sustainable and inclusive growth to reduce its poverty rate.

STP is nevertheless endowed with excellent conditions for tropical agriculture. Consequently, the economy remains dependent on plantation agriculture, especially cacao and coffee. Apart from these main national economic resources, the state budget relies heavily on foreign aid. The tourism sector has the potential to be a strong source of economic diversification for the country and has somewhat expanded with foreign investment in recent years.

STP is divided into four administrative regions, of which three are on São Tomé island (North-West, Center-East and Center-West, where the capital city is located,) and R.A. Príncipe, a separate island and region itself. The development of these four regions is uneven, since most wealth is concentrated in the Center-West region of São Tomé island while North-West and Príncipe regions lag behind (Figure 2). Rural households are also overrepresented in the bottom expenditure quintile.

FIGURE 2 • **Distribution of expenditure quintiles, by urban/rural and by region**[8]



Energy access has been growing steadily in STP. In 2014, 69% of the population gained access to electricity, and 19% of the population were reported to have gained access to clean fuels and technologies for cooking as well. However, recent data show a decline in both aspects of gained energy access, which has declined respectively to 65% and 17% in 2016, revealing the country's inability to expand electricity production as well as maintain the existing infrastructure (World Bank, 2018).

Electricity coverage in STP is more widespread among higher-income families than lower-income families. Structural financial and technical difficulties are affecting the energy sector, compounded by sector management problems that could expose the sustainability of power supply to great risks. Despite having one of the highest tariffs in the region, the national utility, EMAE (*Empresa de Agua e Electricidade,* or National Utility for Water and Electricity), is currently struggling with the challenge of recovering costs due to a generation mix that is overwhelmingly reliant on inefficient thermal capacity and expensive fuel imports. The Government of STP has set an objective of achieving 40% renewable energy penetration by 2020 to foster the development of renewable energy capacity, such as hydroelectricity and/or solar photovoltaic (PV) (Government of São Tomé & Príncipe, 2017). Despite the present deficit, current investments in this sector are focused on the delivery of additional thermal capacity. Moreover, the deficient maintenance of grid installations means that generation, transmission, and distribution segments are highly vulnerable to failure across the islands.

It is estimated that EMAE's system losses reached 40% in 2015, of which the vast majority are non-technical. Losses are mainly experienced by the commercial market, and consist primarily of informal connections, nonpayment by accounted-for customers, and errors in accounting and record-keeping (World Bank, 2016).

6 Note that SWIFT methodology was used for estimating household consumption expenditure in STP. Refer to Annex 4 for more details.

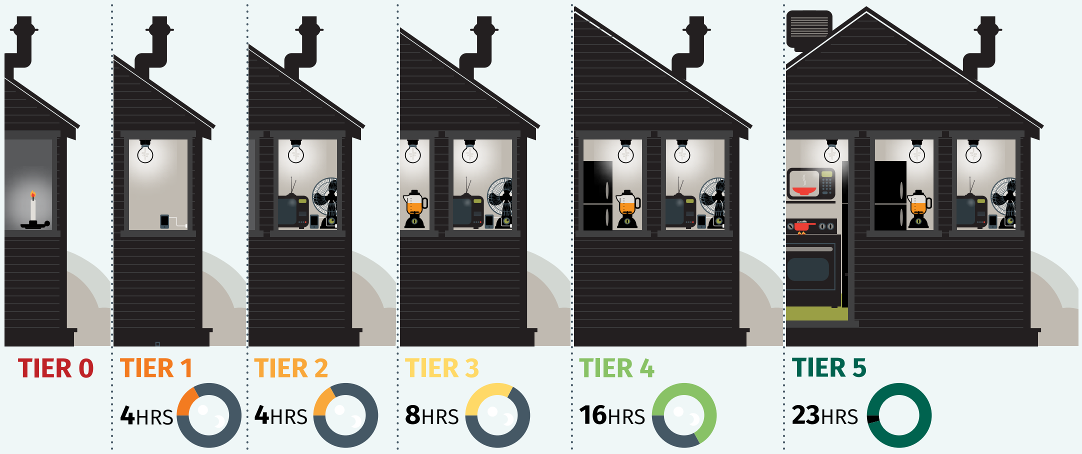
THE MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Multi-Tier Framework (MTF) Global Survey, whose objective is to provide more nuanced data on energy access, including access to electricity and cooking solutions. The first phase is being carried out in 16 countries across Africa (including Zambia), Asia, and Latin America. The MTF approach goes beyond the traditional binary measurement of energy access—for example, "having or not having" a connection to electricity, "using or not using" clean fuels in cooking—to capture the multidimensional nature of energy access and the vast range of technologies and sources that can provide energy access, while accounting for the wide differences in user experience.

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 these attributes, six tiers of access are defined, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement. Each attribute is assessed separately, and the overall tier for a household's access to electricity is the lowest tier attained across the attributes (Bhatia and Angelou, 2015).

Access to electricity. Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety (see Table A.1 in Annex 1). Tier 0 refers to households that receive electricity for less than four hours a day (or less than one hour per evening) or that have a primary energy source with a capacity of less than 3 watts. (See Box 1 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 2 for a typology of off-grid solar devices).

BOX 1 • MINIMUM REQUIREMENTS, BY TIER OF ELECTRICITY ACCESS



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

Tier 3	Tier 4	Tier 5
Electricity is available at least eight hours a day, including at least three 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 kilowatt-hours per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	Electricity is available at least 16 hours a day, including at least four hours per evening, and capacity is sufficient to power high-load appliances as needed during that time, such as a washing machine, iron, hairdryer, toaster, and microwave. There are no long or frequent unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	Electricity is available at least 23 hours a day, including four 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. The most likely source for meeting these requirements is the national grid, though a generator or mini-grid might suffice as well.

Source: Bhatia and Angelou 2015.

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

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

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

TABLE 1 • Appliances by load level and associated capacity tiers

Load level	Indicative electric appliances	Capacity tier typically needed to power the load
Very low load (3–49 W)	Task lighting, radio, lightbulb or incandescent lightbulb, fluorescent tube, compact fluorescent lamp, light-emitting diodes (LEDs), 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, DVD, printer, electronic tablet, satellite dish	TIER 2
Medium load (200–799 W)	Indoor air cooler, refrigerator, water pump, rice cooker, sewing machine, electric water cooler, freezer, electric hot water pot or kettle, blender, electric food processor	TIER 3
High load (800–1,999 W)	Washing machine, electric iron, microwave oven, electric toaster, dishwasher, electric hairdryer	TIER 4
Very high load (2,000 W or more)	Space heater, electric water heater, solar-based water heater, electric stove	TIER 5

Source: Bhatia and Angelou 2015

A key issue that the MTF survey explores is the nature of the barriers that prevent a household from moving to a higher tier for access to electricity. This is the value-added of the MTF survey. By capturing full-spectrum data, it empowers policy makers to pursue data-informed energy policies and to design interventions that remove barriers so households can graduate to higher tiers. The value of access to electricity for households is defined by analyzing the MTF attributes based on responses to questions in the MTF survey, as follows:

- **Capacity** *("What appliances can I power?")*: The Capacity of the electricity supply (or peak capacity) is the ability of the system to provide a certain amount of electricity to operate various appliances, ranging from a few watts for light-emitting diode (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. First, appliances are classified into tiers based on their power ratings (see Table 1). Then, each household's appliance tier is determined by the highest tier of all its appliances; that is, if a household owns multiple appliances, the highest-capacity appliance determines the household tier.[7] Capacity is measured in watts for grids, mini-grids, and fossil-fuel-based generators, and in watt-hours for rechargeable batteries, solar lanterns, solar lighting systems (SLS), and solar home systems (SHS). It may be difficult to determine the Capacity of the system by simple observation. An estimate of the available Capacity may be done based on the source of the supply (for example, grid power is considered > 2,000 watts) or the appliances used (Table 1).

- **Availability** *("Is power available when I need it?")*: The availability of supply refers to the amount of time during which electricity is available. It is measured through two indicators: the total number of hours per day (24-hour period) and the number of evening hours (the four hours after sunset) during which electricity is available.
- **Reliability** *("Is my service frequently interrupted?"):* The Reliability of electricity supply is a combination of the frequency and the duration of unexpected disruptions. In this report, the Reliability attribute is only measured for households connected to the grid.
- **Quality** *("Will voltage fluctuations damage my appliances?")*: The Quality of the electricity supply refers to the absence of severe voltage fluctuations that can damage a household's appliances. Electric appliances generally require a certain level of voltage to operate properly. Low or fluctuating voltage can damage appliances, and even result in electrical fires. A low or fluctuating voltage supply tends to result from an overloaded distribution system or from long-distance low-tension cables connecting spread-out households to a singular grid. The MTF survey does not measure voltage fluctuation directly but uses incidents of appliance damage as a proxy. In this report, the Quality attribute is measured for households connected to the grid or mini-grid.
- **Affordability** *("Can I afford to purchase the minimum amount of electricity?"):* The Affordability of the electricity service is determined by comparing the price of a standard electricity service package (one kilowatt-hour [kWh] of electricity per day or 365 kWh per year) with household expenditure. The price of the package is determined from the prevailing lifeline tariff. If the household spends more than 5% of household expenditure on electricity, then electricity service is considered unaffordable for that household.
- **Formality** *("Is grid electricity provided through a formal connection?"):* If households use the electricity service from the grid, but do not pay anyone for the consumption, their connection could be defined as an informal connection. The Formality of the grid connection is important, since it ensures that the electricity authority gets paid for the services it provides, besides providing for the safety of electric lines. A grid connection is considered formal when the bill is paid to the utility, a prepaid card seller, or an authorized representative. Informal connections pose a significant safety risk and affect the financial sustainability of the utility. Reporting on the Formality of a connection is challenging. Households may be sensitive about disclosing such information in a survey. The

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

MTF survey therefore infers information on Formality from indirect questions that respondents may be more willing to answer, such as what method a household uses to pay the electricity bill.

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

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

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Despite the well-documented benefits of access to clean cookstoves, around three billion of the world's population still use polluting and inefficient cooking solutions. The inefficient use of solid fuels has significant impacts on health, socioeconomic development, gender equality, education, and climate (Ekouevi and Tuntivate 2012; UNDP and WHO 2009; World Bank 2011).[8] 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).

The MTF measures access to modern energy cooking solutions based on six attributes: Cooking Exposure, cookstove Efficiency, Convenience, Affordability, Health and Safety of primary cookstove, and fuel Availability (see Annex 1).

- **Cooking Exposure** *("How is the user's respiratory health affected?")*: This attribute assesses personal exposure to pollutants from cooking activities, which depends on stove emissions and ventilation

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

structure (which includes cooking location and kitchen volume).[9] Thus, Cooking Exposure is a proxy indicator to measure the health impacts of the cooking activity on the primary cook. This attribute is a composite measurement of the emissions from the cooking solution, that is, a combination of the stove type and fuel, mitigated by the ventilation in the cooking area. Each of these components further has one or more subcomponents. The cooking exposure tier is assigned as a composite of emissions and ventilation tiers and is weighted by the amount of time spent on each stove, if a household relies on multiple stove types.

- **Cookstove Efficiency** *("How much fuel will a person need to use?")*: This attribute is a combination of combustion efficiency and heat-transfer efficiency. Laboratory testing of the efficiency of various types of cookstoves informs the breakdown of efficiency levels by cookstove and fuel combinations, which can be observed in the field with relative ease.[10]

- **Convenience** *("How long does it take to gather and prepare the fuel and stove before a person can cook?")*: This attribute is measured by the amount of time a household spends collecting or purchasing fuel and preparing the fuel and their stove for cooking. Convenience is measured through two indicators. First, the amount of time household members spend collecting or purchasing cooking fuel and preparing the fuel (in minutes per week) and the amount of time needed to prepare the cookstove for cooking (in minutes per meal).

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

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

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

A methodology similar to the electricity framework is applied to obtain the aggregate tier for modern cooking solutions. The lowest tier among the attributes is taken as the final tier for the household (for more information on the threshold and tier calculation, see Annex 1.)

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

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

BOX 3 • TYPOLOGY OF COOKSTOVES IN SÃO TOMÉ AND PRÍNCIPE

In consultation with sectoral experts, STP cookstoves are classified into four categories. See Annex 3 for detailed information.

- **Three-stone stove** consists of a pot balanced on three stones over an open fire. 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. In São Tomé, another form of traditional stove, consisting of a simple metal grid placed over an open fire, is also classified under this category.
- **Traditional stove** typically uses conventional material to insulate the fire, and the pot rests above the flames. It is also produced locally using available, low-cost materials and fuels, reflecting cultural practices.
- **Improved cookstove** (ICS) insulates the fire more effectively, and the fuel rests on a shelf so that it reaches higher temperatures. In STP, only basic charcoal ICS can be found.
- **Kerosene stove**, whose use is widespread in STP, tends to have higher performance than a traditional stove but lower than a clean fuel stove.
- **Clean fuel stove** uses clean and efficient fuels, such as liquefied petroleum gas (LPG), electricity, or biogas. Only LPG stoves can be found in STP.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

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

Insights derived from the MTF data enable governments to set country-specific access targets. The data can be used in settings targeted 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) with the provision of new connections. They also help governments determine the minimum tier the new connections should target.

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

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

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN SÃO TOMÉ AND PRÍNCIPE.

MTF data collection in STP started in mid-March 2018 and was completed in the second week of May 2018. The household survey sample selection was based on a stratified household sampling by urban/rural strata and connected/not connected to the national electric grid, aimed at achieving nationally and regionally representative samples. The selection of households was done through a systematic method. Households were ordered by urban/rural, grid-connected/non-grid-connected and for their geographic coordinates (from North to South). The sampling frame used for this stratified random sampling was the national listing of permanent residences, obtained from the national listing of all buildings in the country conducted prior to data collection. This listing was based on the existing information from the National Institute of Statistics (INE-STP) Geographic Operational Base (BOG), which was built during last census.[11]

The design for sampling permanently occupied households was based on a stratified random sampling, composed of 16 strata:

- 4 national regions: North-West, Centre-West, Centre-East, and Regiao Autonoma do Príncipe
- 2 environments: Urban/rural
- 2 grid connection statuses: connected/not connected to the national grid.

With the objective of maintaining a 1:1 ratio of electrified to non-electrified households for the tier analysis and equal allocation between urban and rural areas, this would have resulted in 150 households per strata, adjusted to real conditions in the region, to get the final sample distribution showed in Table 2 and Figure 3.

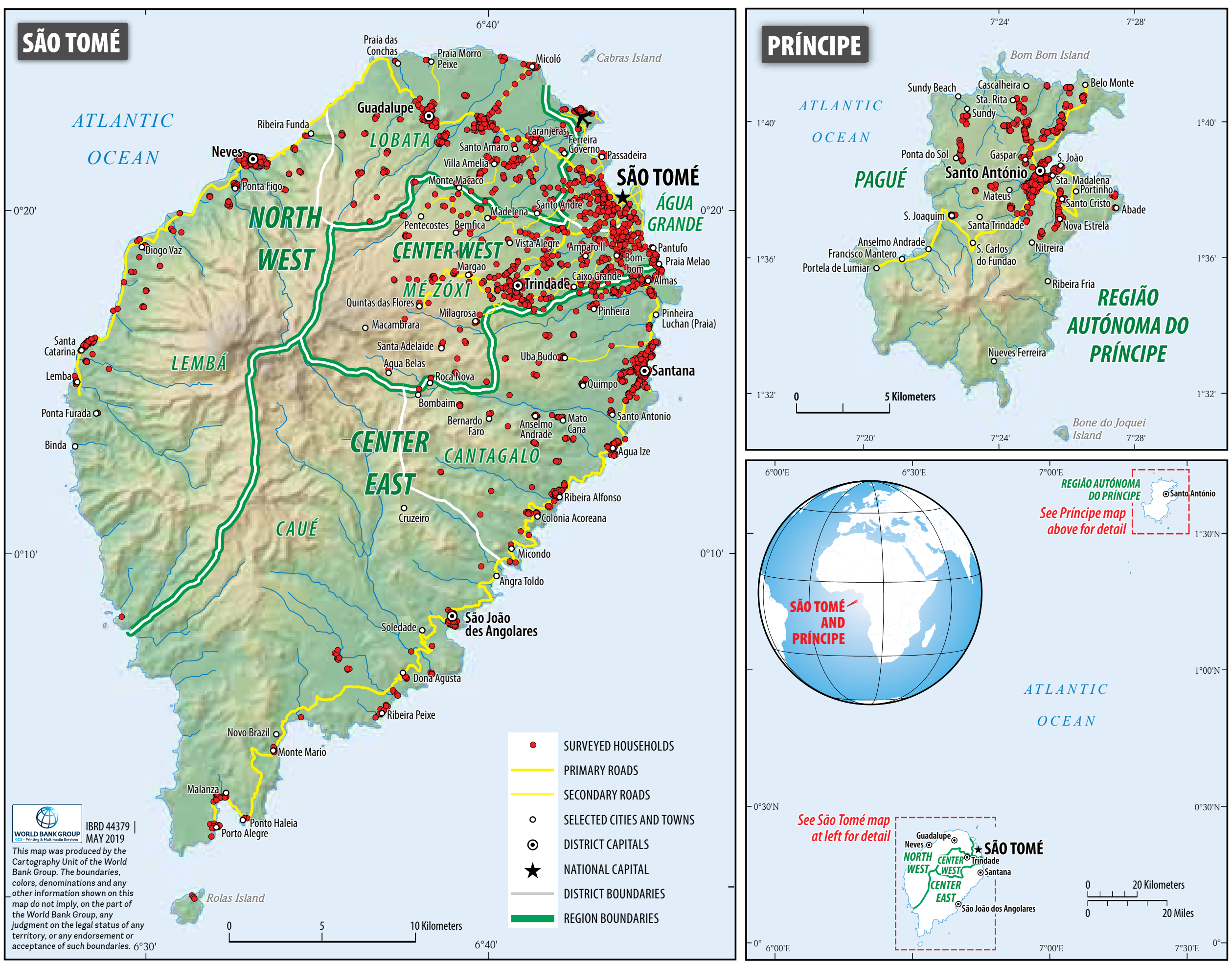
[11] The last census in STP, IV General Census of Population and Housing of 2012 (RGPH-2012), was carried out in 2012.

TABLE 2 • Distribution of enumeration areas and sampled households in São Tomé and Príncipe

Region	Urban				Rural				Total	
	Electrified		Non-electrified		Electrified		Non-electrified			
	Pop	Sample	Pop	Sample	Pop	Sample	Pop	Sample	Pop	Sample
North-West	1,876	150	890	178	1,852	150	1,657	150	6,275	628
Centre-West	13,094	150	1,973	192	4,003	150	1,506	150	20,576	642
Centre-East	1,588	150	607	165	804	150	1,529	150	4,528	615
Regiao Autonoma do Príncipe	776	150	65	65	1,182	150	428	150	2,451	515

Source: MTF survey, 2018

FIGURE 3 • Sample distribution for Multi-Tier Framework Survey



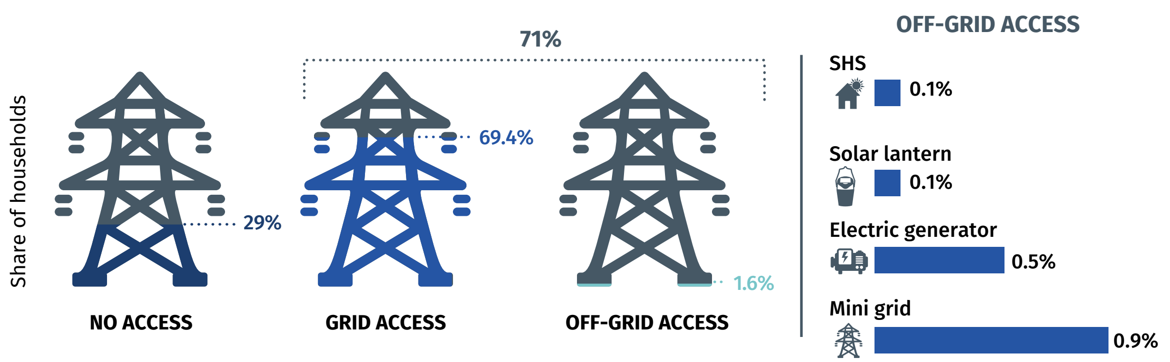
ACCESS TO ELECTRICITY

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

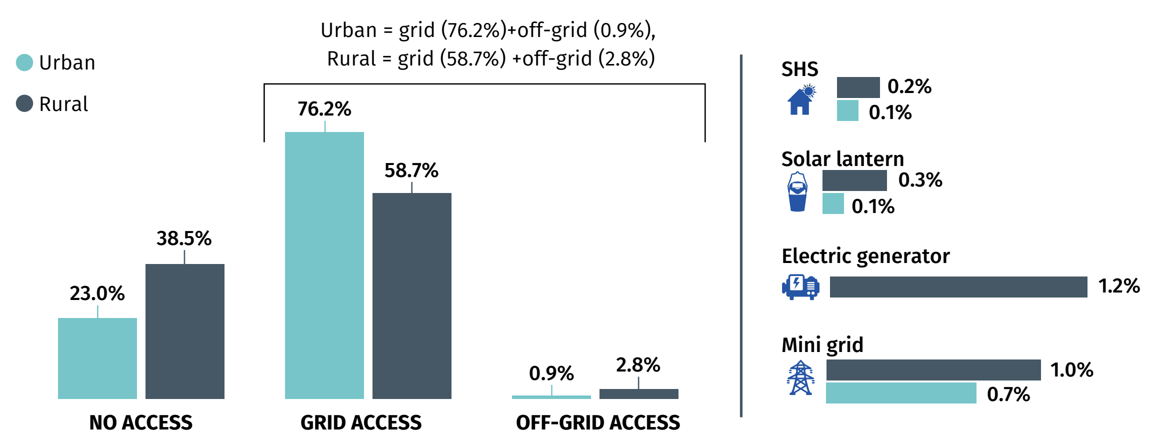
In São Tomé & Príncipe, 71% of households have access to at least one source of electricity; 69.4% have access through the national grid, while only 1.6% use off-grid solutions, including 0.9% who rely on a mini-grid and 0.2% using off-grid solar solutions (Figure 4).

FIGURE 4 • **Access to electricity by technology (nationwide)**



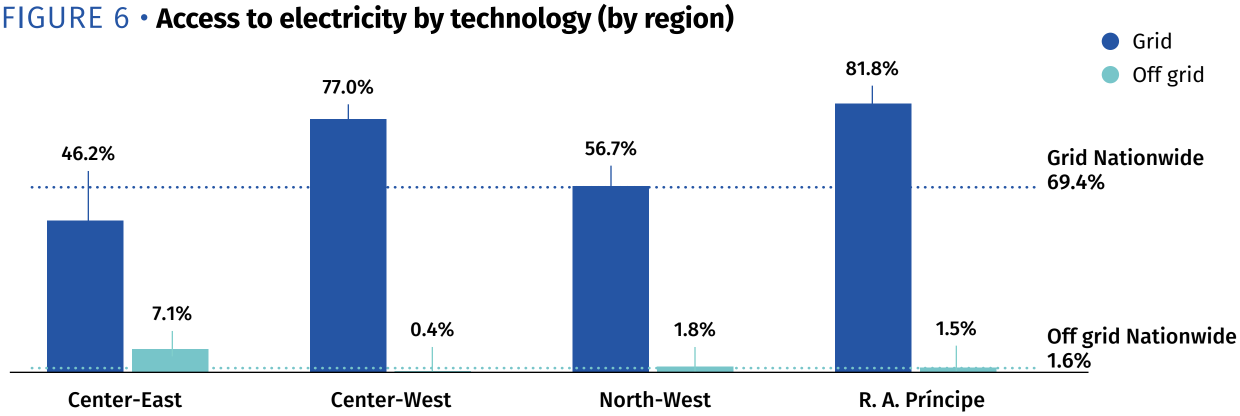
Off-grid solutions are more commonly used among rural households (Figure 5). Despite the wide discrepancy in electricity access between urban and rural households in STP, only 2.8% of rural households rely on off-grid solutions as their primary source of electricity, versus less than 1% of urban households. Generators and mini-grids are the most common solutions found in rural areas; they serve 1.2% of urban and 1% of rural households.

FIGURE 5 • **Access to electricity by technology (urban/rural)**



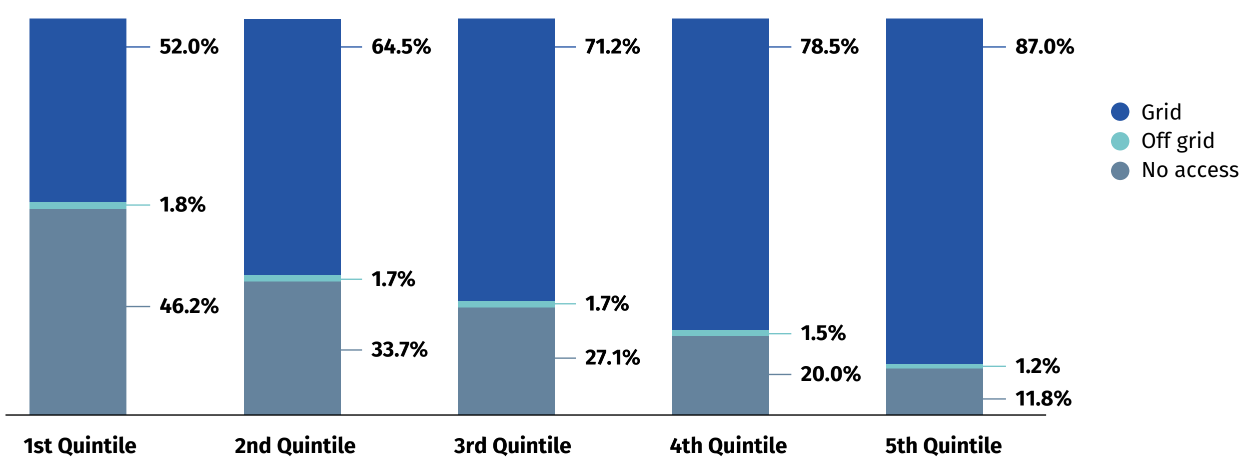
The region with the highest grid electrification rate is R.A. Príncipe (81.8%), followed by the Center-West (77%) region. The grid access rates in the North-West and Center-East regions are below the national average. However, more than 50% of households in all regions of STP have electricity, except in the Center-East, but this region has the highest rate of access to off-grid energy solutions (7%). High grid access is not surprising in the Center-West region, which is the most developed region of the São Tomé island, hosting the capital city and the largest share of the country's population. The remote island of Príncipe, however, is also particularly well endowed (Figure 6). On the other hand, infrastructure is not well developed to reach the Center-East and North-west regions, where the population tends to be more scattered.

FIGURE 6 • **Access to electricity by technology (by region)**



Households in the bottom expenditure quintile are five times more likely to lack access to electricity than those in the top quintile: only 11.8% of the latter lack access, versus over half of households in the poorest quintile (Figure 7). Conversely, grid penetration increases with rising expenditure quintile: it starts with 46.2% of the households in the bottom quintile and reaches 87% of households in the top quintile, a rate almost double the bottom-quintile rate. Off-grid solutions are equally used across households in all quintiles.

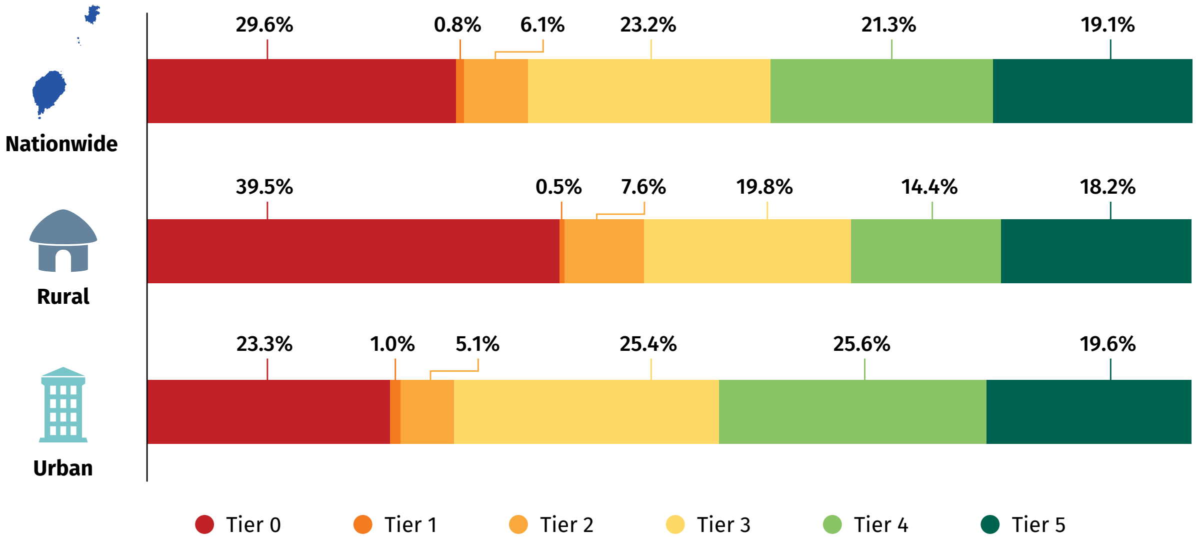
FIGURE 7 • **Access to electricity by technology, by expenditure quintile (nationwide)**



MTF TIERS[12]

Nationwide, 70.4% of households fall into Tier 1 or above (Figure 8). Because of the high penetration of the grid, the large majority of electrified households surveyed in the STP fall in Tier 3 or above, even more so in urban areas (70.6%) than in rural areas (52.4%). Electricity access is more of a rural challenge: 40% of rural households are in Tier 0, compared with 23% of their urban counterparts. Among households in Tier 0, almost all lack access to any source of electricity. Only 0.3% of Tier 0 urban households and 1% of Tier 0 rural households have access to electricity, but their supply does not satisfy Tier 1 requirements. Nationwide, almost one-fifth of households are in Tier 5.

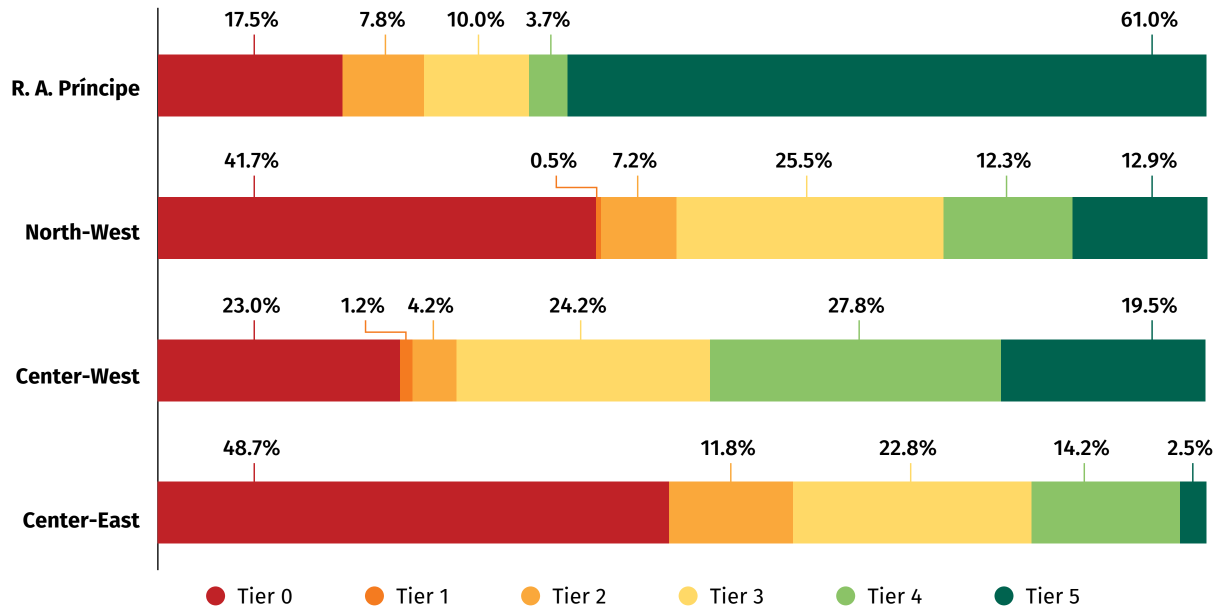
FIGURE 8 • **MTF Tier distribution (nationwide, urban/rural)**



The MTF tier distribution shows disparities across regions (Figure 9). Interestingly, the two most electrified regions (Center-West and R.A. Príncipe) have very different tier results. In R.A. Príncipe, 61% of households reach Tier 5 access, versus only 19.5% in Center-West. A higher (and disproportionate) percentage of households are in Tier 0 across the Center-East and North-West regions of STP, driven by lower electrification rates.

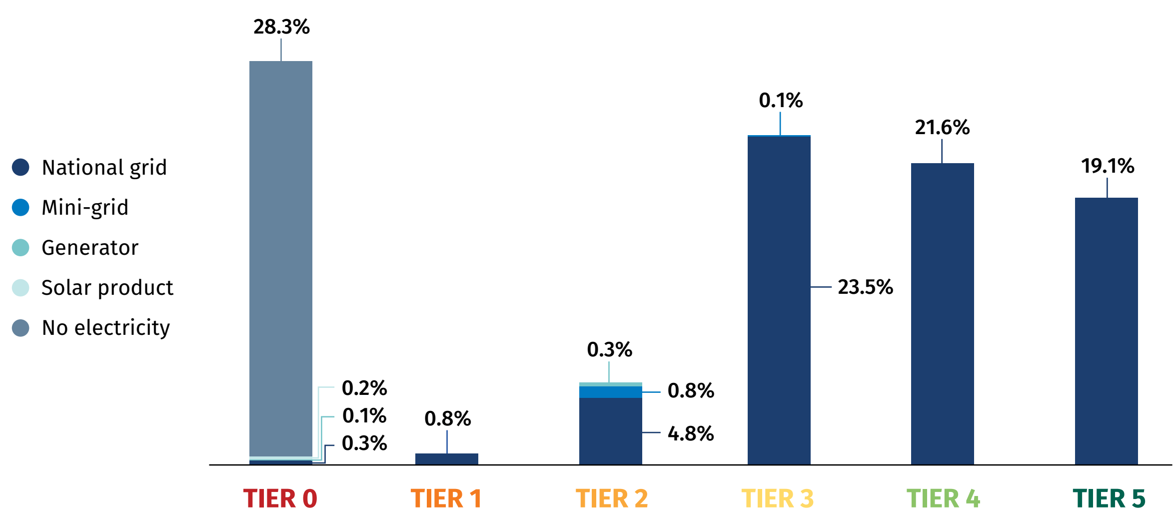
[12] For more details about the MTF attributes and formulation, please see Annex 1.

FIGURE 9 • **MTF Tier distribution (by region)**



Electricity sources used in São Tomé and Príncipe mostly fall into Tiers 3 through 5 (Figure 10). Off-grid solutions in the country are very limited and are categorized in Tiers 0-2. Tier 3 to Tier 5 levels are driven by grid usage and account for two-thirds of STP households. Moreover, off-grid solutions are only slightly more of a rural phenomenon, where mini-grids and generators marginally help to fill the energy access gap, while solar products have yet to reach the commercial market.

FIGURE 10 • **MTF tier distribution by technology (nationwide)**

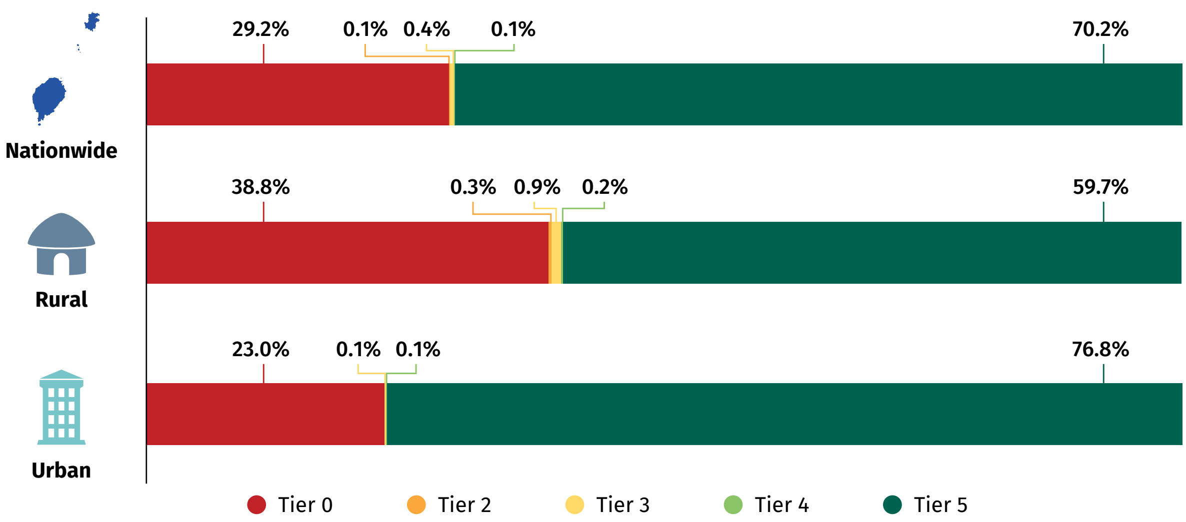


MTF ATTRIBUTES

Capacity

The *Capacity* of the electricity supply is the ability of the system to provide a certain amount of electricity to operate various appliances. By definition, the Capacity of the grid is over 2 kilowatts, thus all grid-connected households have Tier 5 Capacity (Figure 11). Mini-grid households (representing 0.9%) mainly reach Tier 5 Capacity as well. Thus, the proportion of households that receive high-capacity electricity is almost equal to the proportion of households that are connected to either the grid or mini-grids (70.2%).

FIGURE 11 • **Distribution of households by Capacity (nationwide, urban/rural)**



Availability

The Availability of supply refers to the amount of time during which electricity is available during a 24-hour day and during the evening (from 6 pm to 10 pm). Among electrified households, three in four have more than 23 hours of electricity per day, and over 83% have four hours of electricity in the evening (Figures 12 and 13). Among the remaining households, most receive between 16 and 23 hours of supply per day. About 8% of households in STP receive less than eight hours of electricity per day. The share is slightly higher in rural areas.

FIGURE 12 • **Distribution of households based on Daily Availability (24-hour day) (nationwide, urban/rural)**

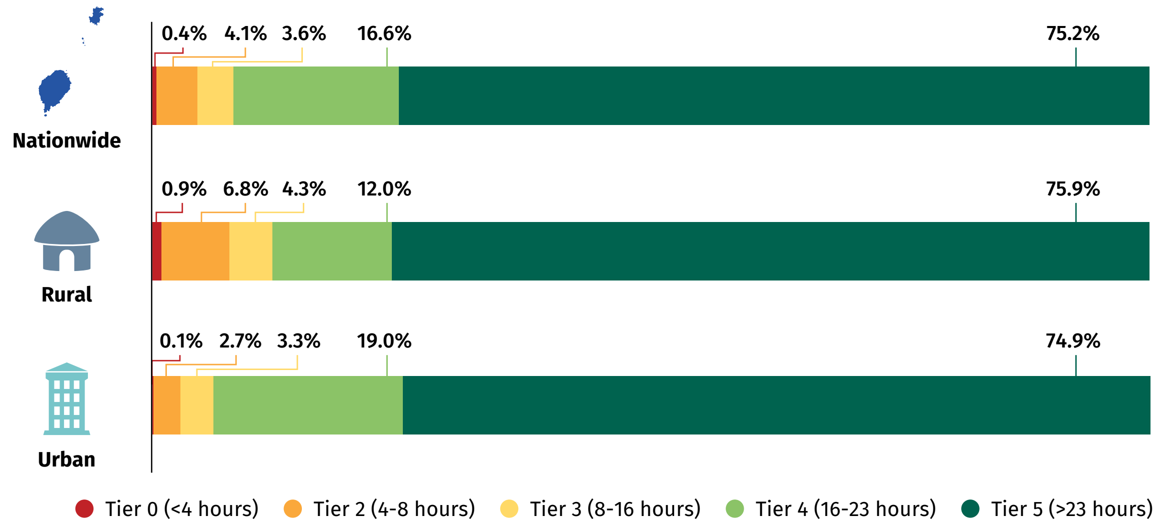
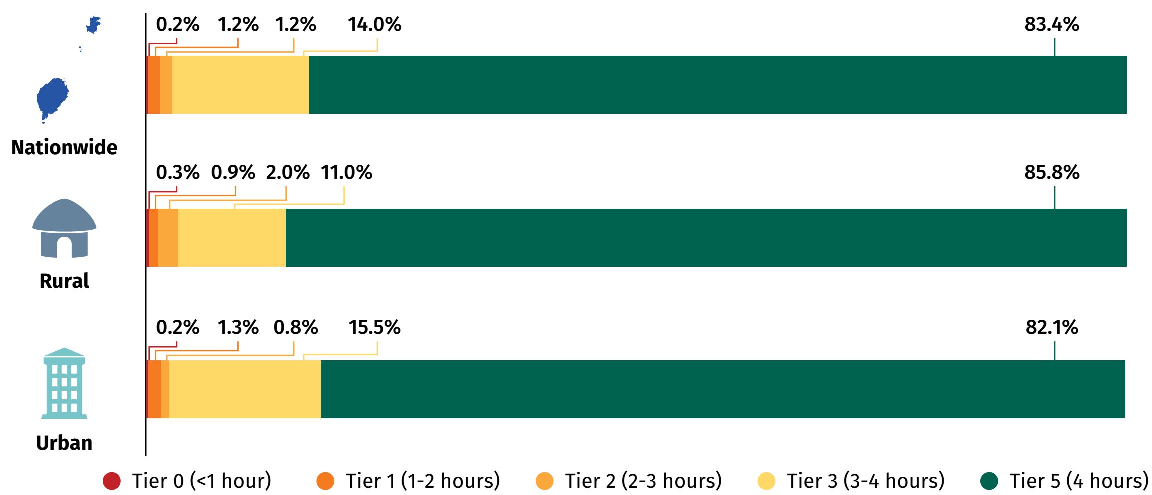


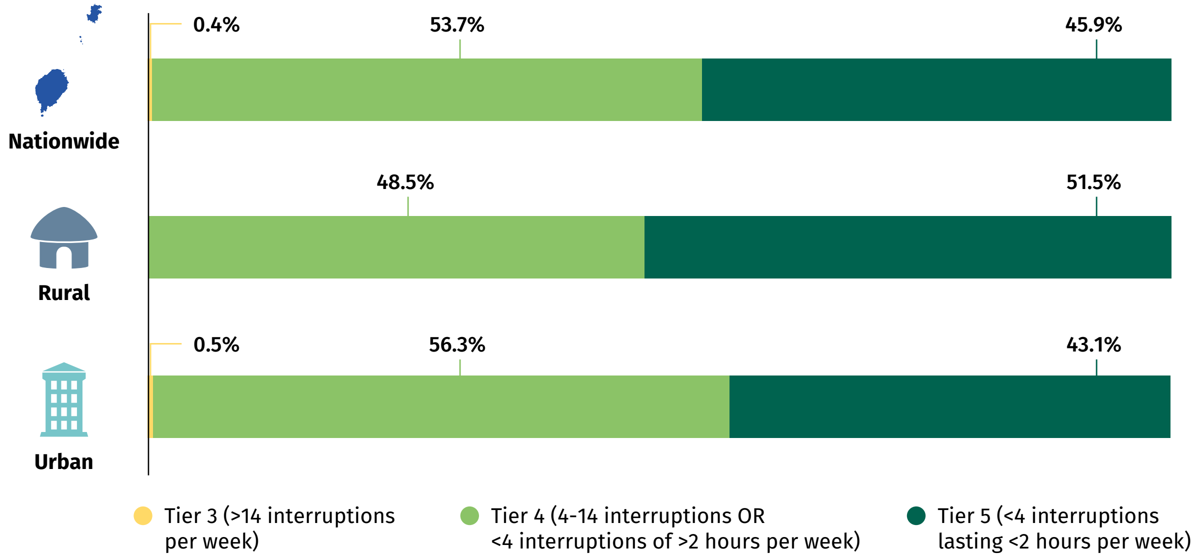
FIGURE 13 • **Distribution of households based on Evening Availability (4-hour period) (nationwide, urban/rural)**



Reliability

The *Reliability* of electricity supply captures the frequency and duration of unscheduled outages, and only applies to grid-connected households. Over half of the grid-connected households in STP experience more than three outages per week or outages lasting over two hours per week (Figure 14). The issue of unreliable electricity supply tends to be more serious in urban areas.

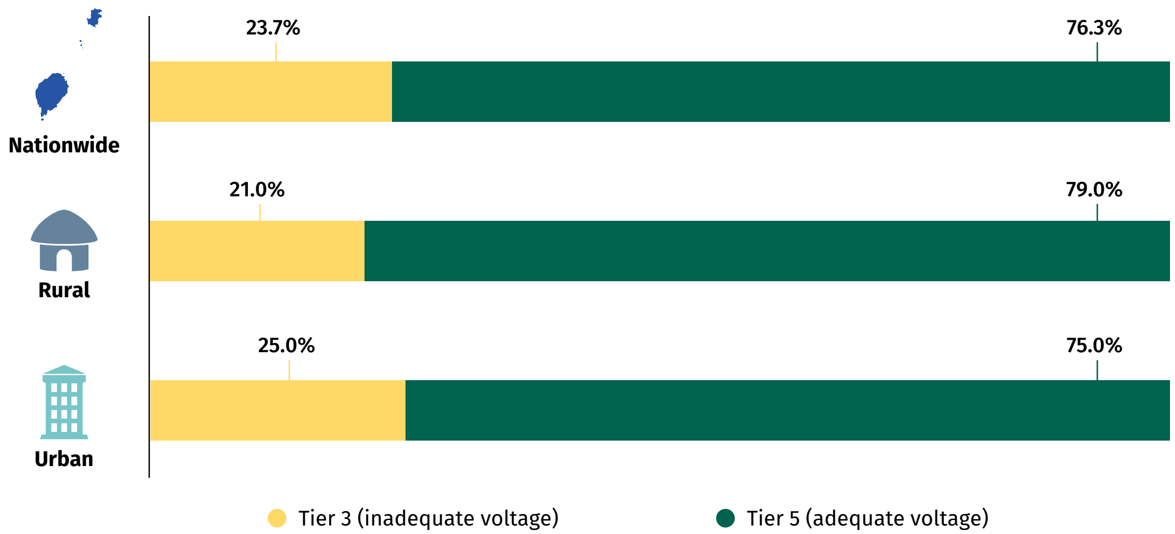
FIGURE 14 • **Distribution of households based on Reliability (nationwide, urban/rural)**



Quality

The Quality of the electricity supply refers to whether voltage is high, low, or fluctuating. This attribute is only measured for households connected to the grid or a mini-grid. In STP, almost a quarter (23.7%) of households face voltage issues resulting in appliance damage (Figure 15). As with the Reliability attribute, the Quality issue tends to be more significant in urban areas.

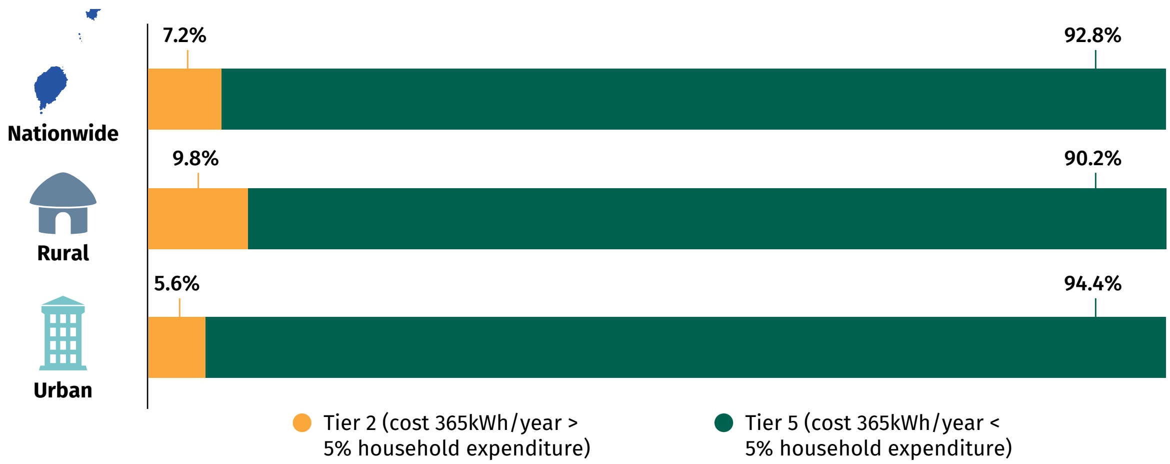
FIGURE 15 • **Distribution of households based on Quality (nationwide, urban/rural)**



Affordability

The *Affordability* of the electricity service is determined by whether the cost of a standard consumption package of 365 kilowatt-hours a year is less or more than 5% of a household's expenditure. About 7.2% of households in STP cannot afford to pay for basic electricity services corresponding to 365 kWh per year (Figure 16). The current cost of 30kWh per month corresponds to STN 68.5 (US$3.33). Urban households are slightly more likely to afford such a cost than rural households.

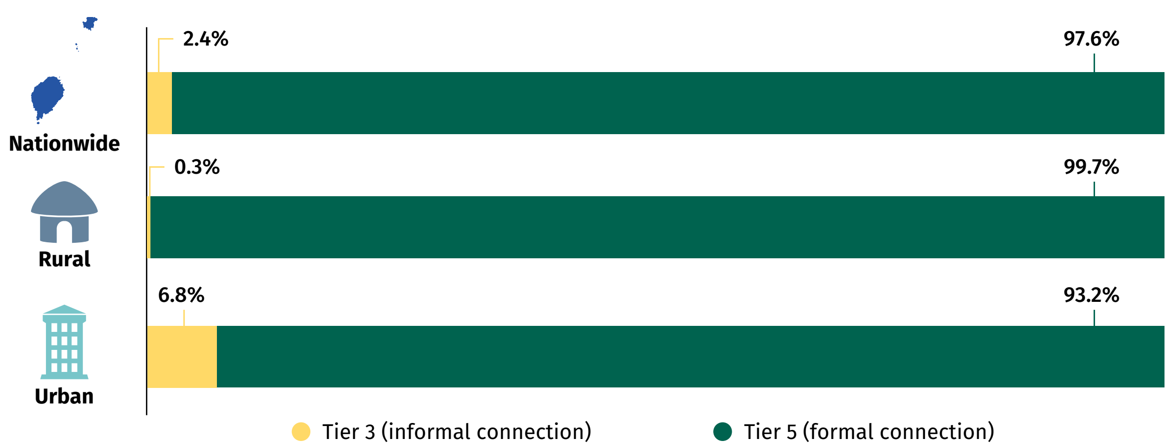
FIGURE 16 • **Distribution of households based on Affordability (nationwide, urban/rural)**



Formality

Formality is a measure of whether a household's connection to the grid has been provided or sanctioned by a governing authority. This attribute is only measured for households connected to the grid or a mini-grid. In STP, it is estimated that 2.4% of the grid-connected households have an informal grid connection (Figure 17). Formality issues seem to occur only in urban areas. Reporting on Formality is also a challenge, since household respondents may be sensitive to disclosing information on the nature of their grid connection in a documented survey. As a result, the MTF survey infers Formality of a household's connection from indirect questions that respondents may be more willing to answer (such as to whom a household member pays the electricity bill).

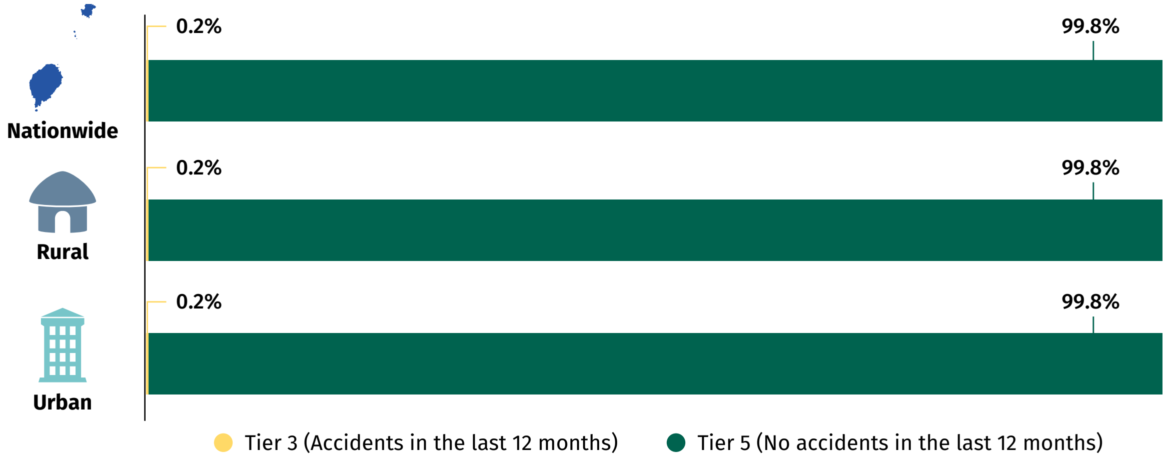
FIGURE 17 • **Distribution of households based on Formality (nationwide, urban/rural)**



Health and Safety

Health and Safety refers to past accidents related to electricity, such as faulty internal wiring or incorrect use of appliances, over the last 12 months. In STP, electricity supply from the grid is generally safe, and only 0.2% of households reported permanent limb damage or death due to electrocution (Figure 18). However, it is important to ensure that all household members are aware of basic safety measures; moreover, it must also be encouraged that all household wiring be installed according to national standards to prevent accidents.

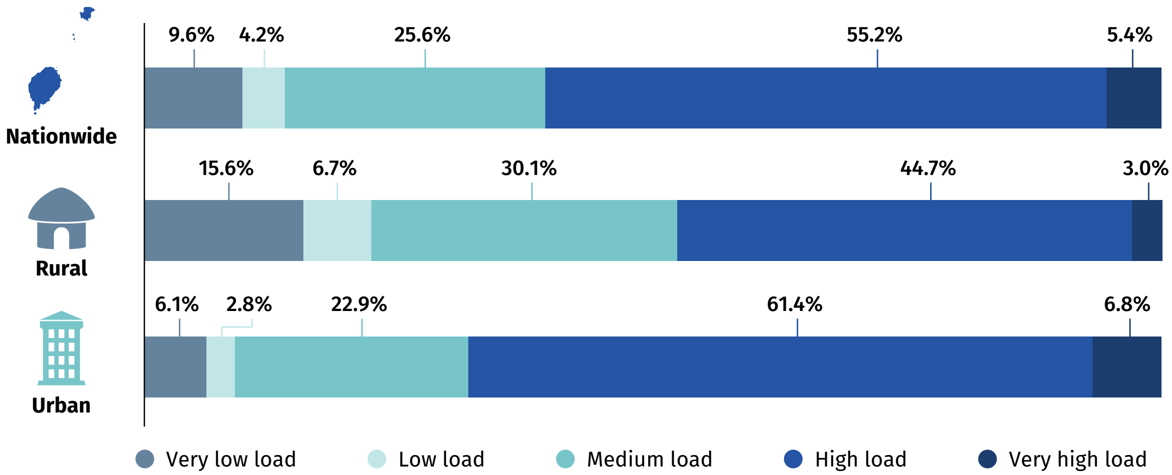
FIGURE 18 • **Distribution of households based on Health and Safety (nationwide, urban/rural)**



Use

The penetration of high-load appliances[13] is quite high in both urban and rural areas, due to the high share of grid electrified households in STP (Figure 19). Almost 7 in 10 urban households and close to 5 in 10 rural households own a high or very high load appliance. Household ownership of very low or low load appliances is limited in urban areas (fewer than 1 in 10 households) and quite low in rural areas as well (about 2 in 10 households).

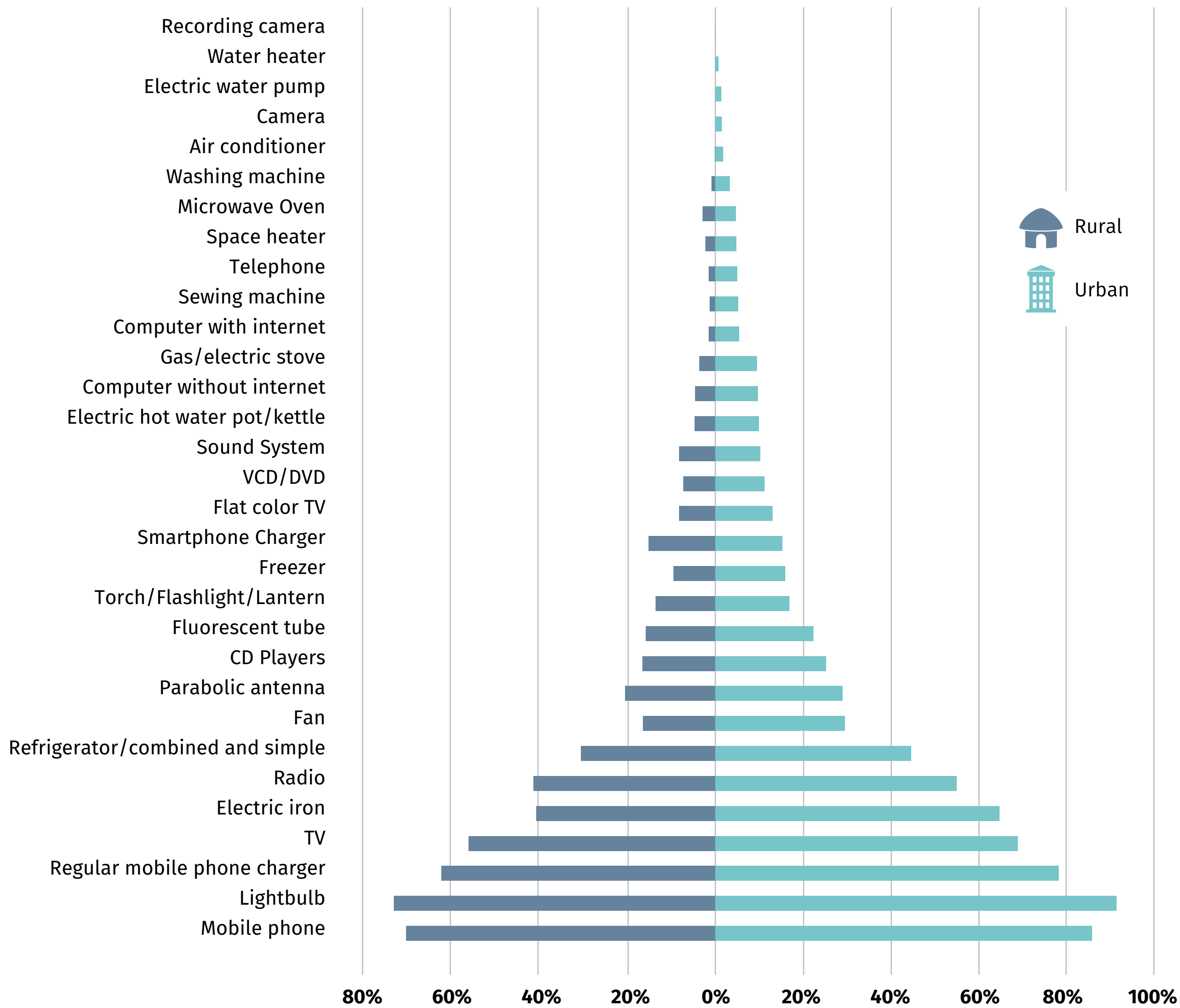
FIGURE 19 • **Household ownership of appliances by load level (nationwide, urban/rural)**



[13] For more information on appliances by load level see Table 1.

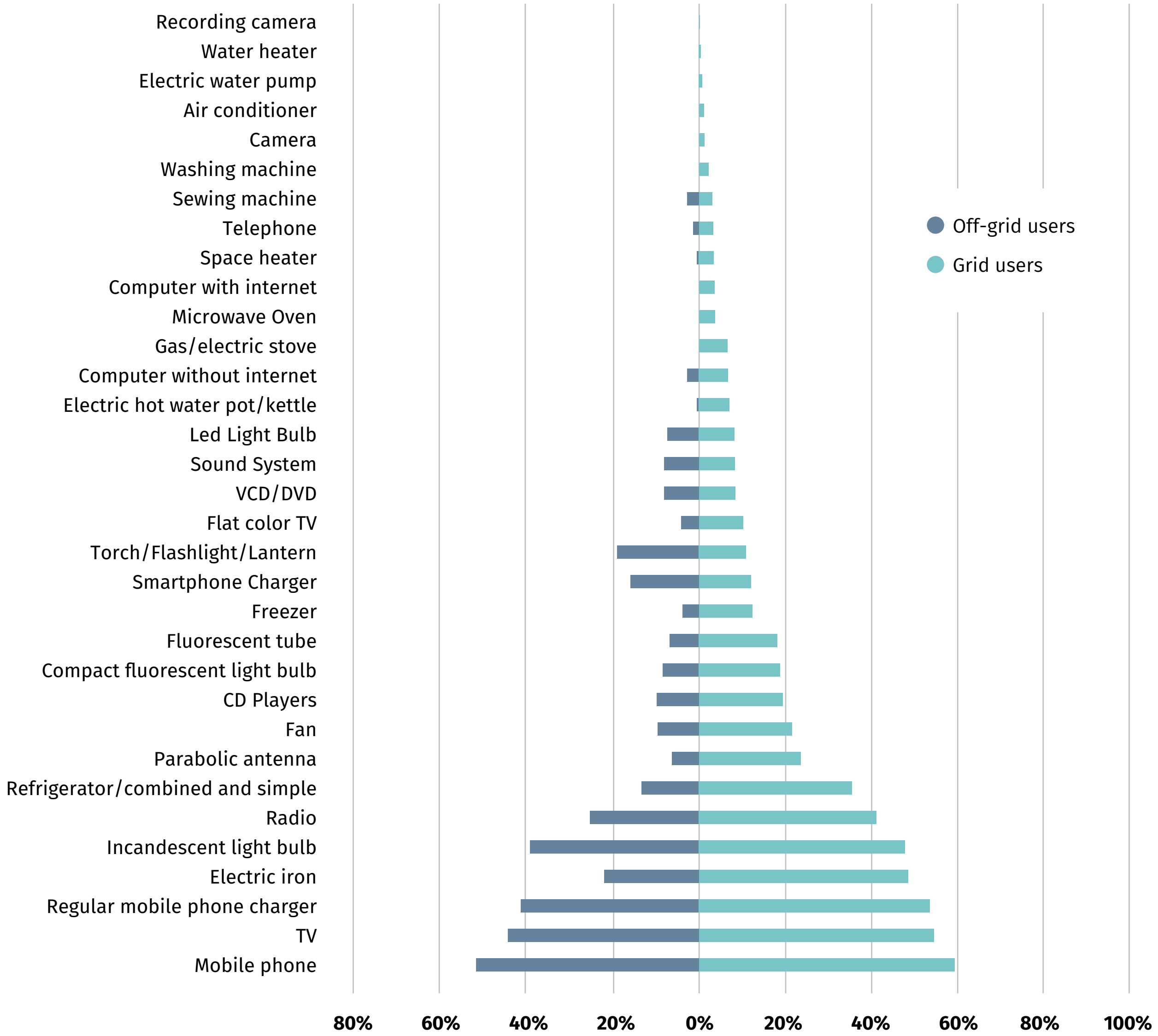
The five most common appliances owned by urban households are light bulbs, regular mobile phone chargers, televisions, electric irons, and radios (Figure 20). In rural areas, the most common appliances owned by households are similar, with the difference that radios are more widespread than electric irons. The share of households using electric irons, a high energy consuming appliance, is higher among urban households but still significant for both groups (64.9% for urban households and 40.9% for rural households), suggesting a cultural specificity in STP.

FIGURE 20 • **Household ownership of appliances by type (urban/rural)**



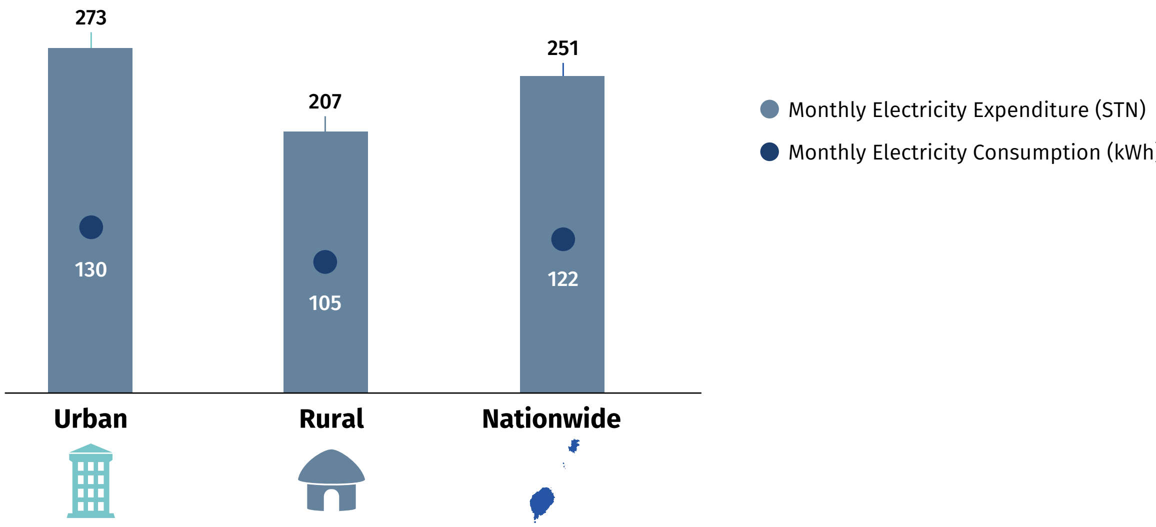
Appliance ownership is quite different when comparing grid-connected and off-grid households (Figure 21). A higher share of grid-connected households than off-grid households use electrical appliances, and they use a greater variety of them, from low-load to high-load. Off-grid users mostly own low-load appliances, with the exception of electric irons (owned by a third of off-grid users).

FIGURE 21 • **Household ownership of appliances by type (grid/off-grid)**



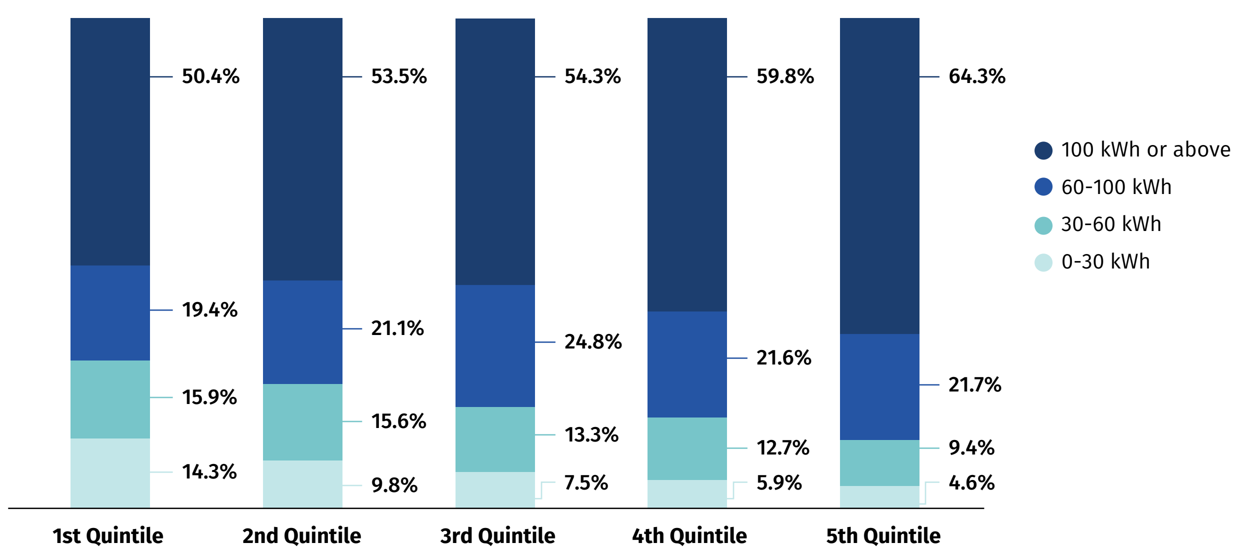
Grid-connected households in STP consume on average 122 kWh per month (Figure 22). Urban households consume 25% more than rural households. Grid-electrified households spend on average STN 251 per month for electricity, representing on average 7.3% of household expenditures. Monthly electricity expenditure is slightly higher, at STN 273, for urban households (6.8% of urban household expenditures) and for rural households it is lower, at STN 207, yet it represents a higher share of rural households' monthly expenditure (8.3%).

FIGURE 22 • **Monthly household expenditure and consumption of electricity (nationwide, urban/rural)**



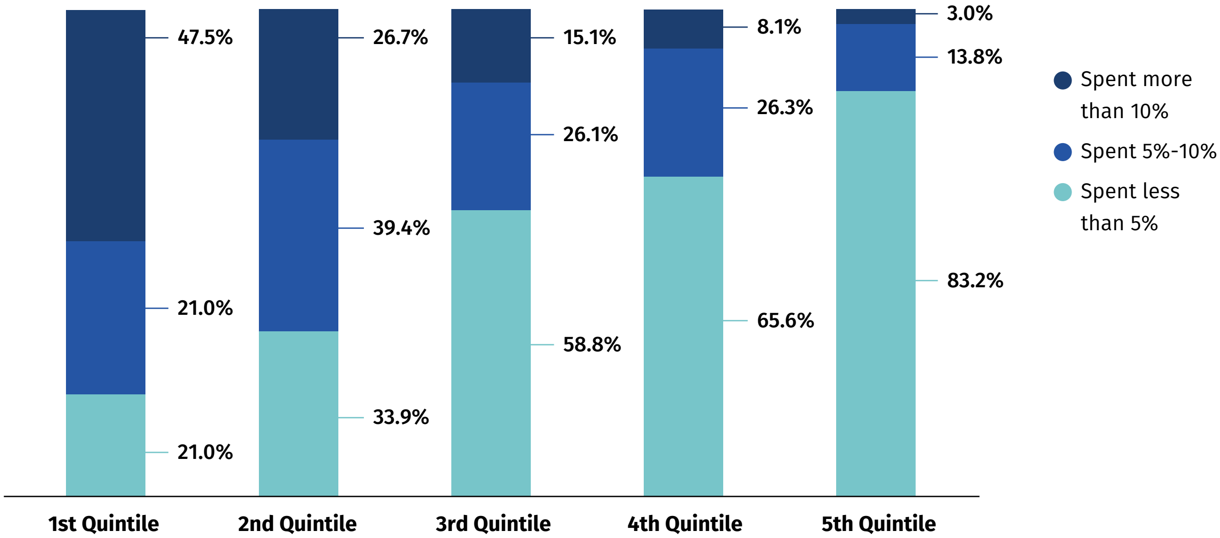
Grid-electrified households across all expenditure quintiles tend to consume relatively high levels of electricity (Figure 23). Nonetheless, electricity consumption rises steadily as expenditure quintiles increase: 50% of the bottom quintile consume less than 100 kWh per month, versus 36% of the top spending quintile.

FIGURE 23 • **Monthly grid electricity consumption by expenditure quintile (nationwide)**



Spending on electricity is, however, disproportionately burdensome for lower spending quintiles (Figure 24). Only 21% of households in the bottom quintile spend less than 5% of their household budget on electricity, while close to half of them spend over 10%. Conversely, 83% of households in the top quintile spend less than 5% of their household budget on electricity.

FIGURE 24 • **Share of household budget spent on electricity by expenditure quintile (nationwide)**



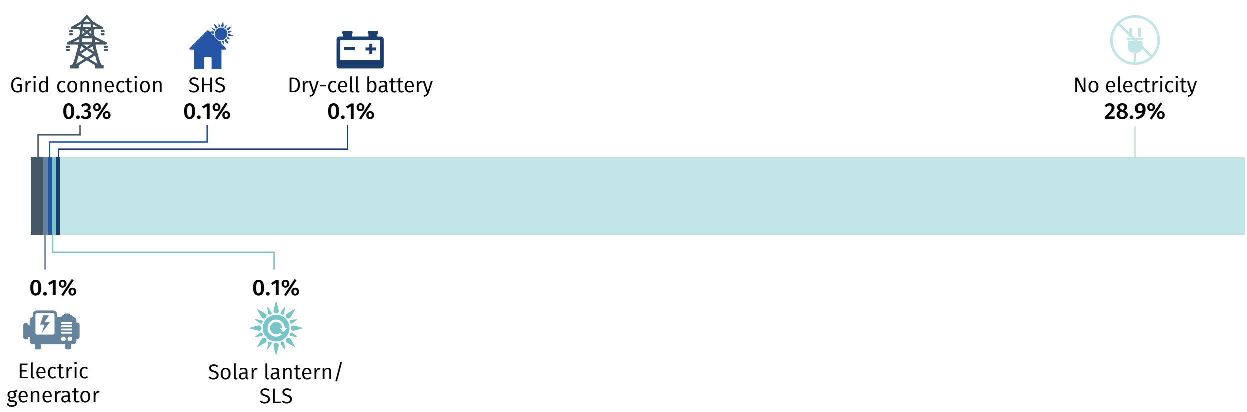
IMPROVING ACCESS TO ELECTRICITY

PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

In STP, 29.6% of households are in Tier 0 for electricity access, with a larger share located in rural areas that are less covered by the national grid network and sometimes difficult to reach. Virtually all households in Tier 0 have no electricity source (Figure 25).

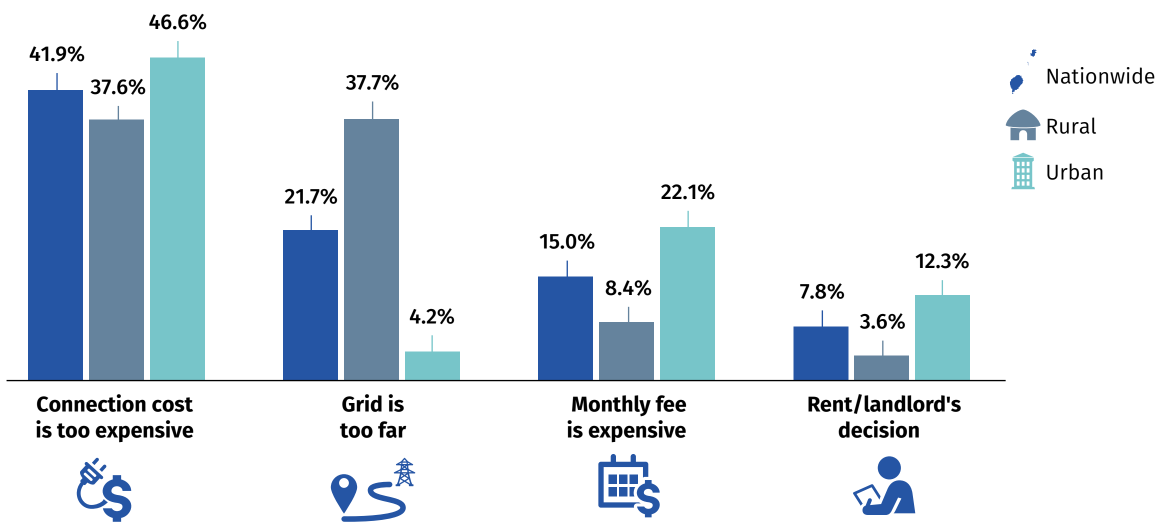
Strategies for shifting households to higher tiers will be determined by what is keeping certain households in that tier, for example providing on or off-grid solutions to those without electricity or improving the availability of electricity supply for those using electricity service.

FIGURE 25 • **MTF Tier 0 disaggregation by source of electricity**



The most common barrier preventing households from gaining access to the grid are the following: high upfront cost of acquiring service (41.9%), distance of affected households from grid infrastructure (21.7%), and cost of using the available electricity service (15%) (Figure 26). The situation is quite diverse whether urban or rural settings are considered. For urban households, grid access is not a key challenge; however, the cost of connection and monthly fees are. The distance to the grid is an equally important issue in rural areas.

FIGURE 26 • **Barriers cited for not gaining access to grid electricity (nationwide, urban/rural)**

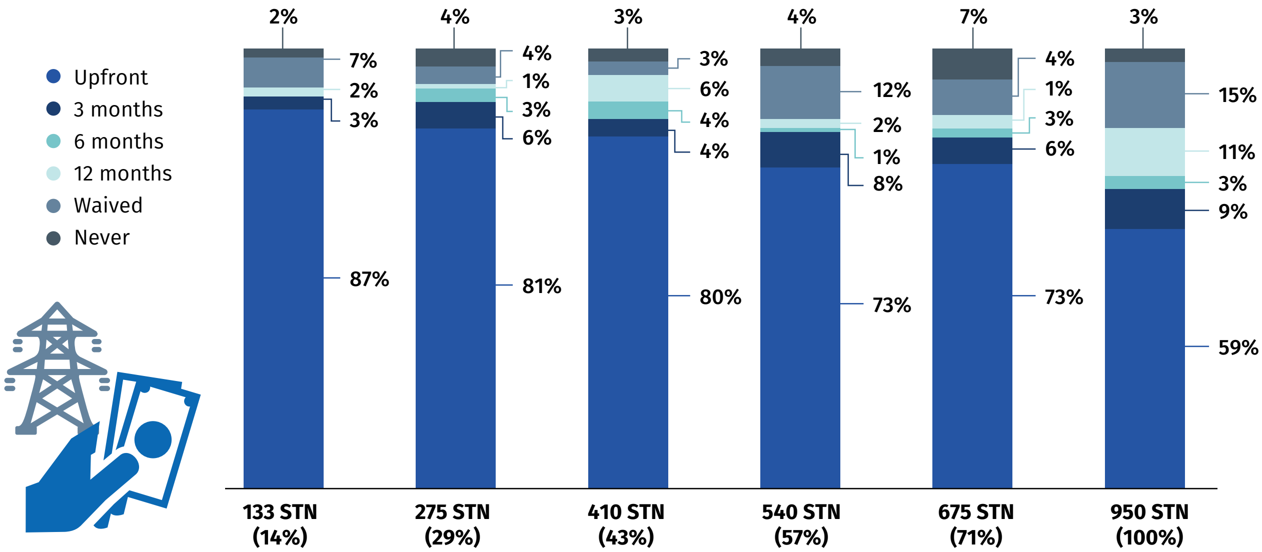


To effectively address the financial burden of gaining a grid connection, that is, covering the high upfront connection cost (950 STN),[14] the option of a flexible payment plan should be offered, such as a plan providing payments in installments. When unconnected households nationwide were asked if they were willing to pay for access to the national grid, a large percentage reacted positively, even when presented with the full upfront connection cost (59% were willing to pay 950 STN; see Figure 27). Results show that the percentage of households willing to pay for a connection to the grid increases if the connection fee could be paid in installments: 82% of unconnected households were willing to pay for the full connection cost provided that it could be done in installments. Offering potential recipients with this payment flexibility could increase the uptake rate of the national grid.

Along with offering this last option, well-targeted subsidies could also further boost opportunities to gain access to the grid. The willingness to pay for a grid connection with such a subsidy response in STP is very high: over 80% of households responded that they would be willing to pay the upfront cost when they were offered a rate that was 43% of the market price (410 STN), and up to 87% were willing to pay if the cost were brought down to 14% of the market price (133 STN).

[14] This represents 20% of the monthly average expenditure of a household in STP.

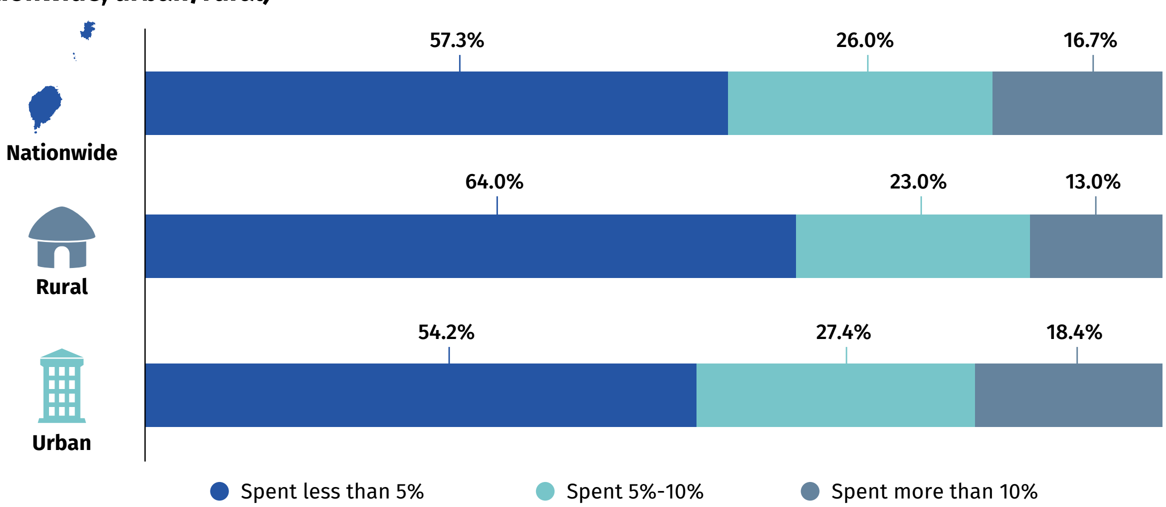
FIGURE 27 • **Willingness to pay for the grid connection fee**



Given these findings, addressing the high upfront connection fee will undoubtedly increase the uptake rate of the national grid. However, addressing this approach won't necessarily guarantee that remaining unconnected households will be connected to the grid: 4% of unconnected households, mostly in low-income quintiles, reported in the survey that they did not want the grid connection even if the connection fee were waived, mainly because of the financial barrier of wiring costs.

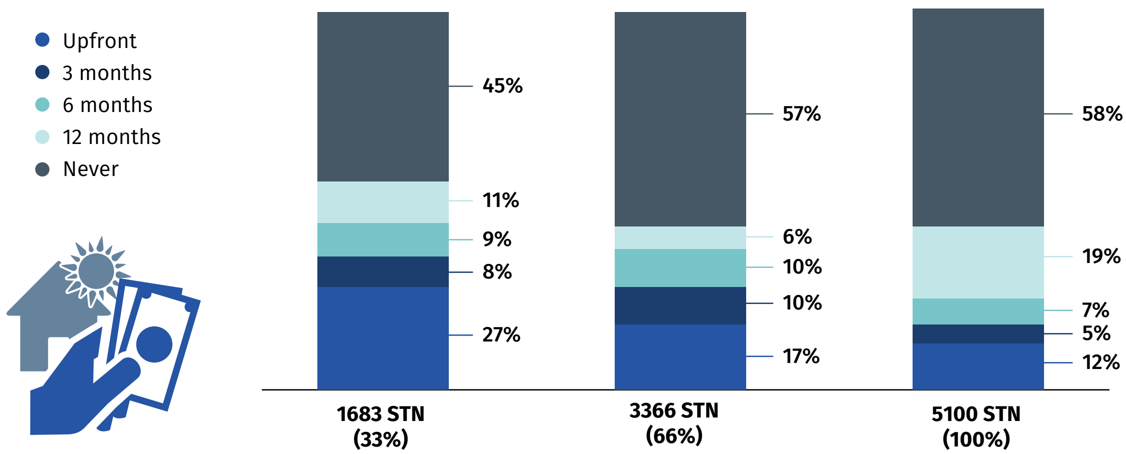
Thus, these findings point to a need for designing and implementing more comprehensive policies for the grid densification. This will require financing options that will help households not only to afford the official connection fee but also to pay any cost associated with the grid connection. This is especially valid for rural households, whose spending on electricity is more of a financial burden (Figure 28).

FIGURE 28 • **Distribution of households by share of budget spent on electricity on budget (nationwide, urban/rural)**



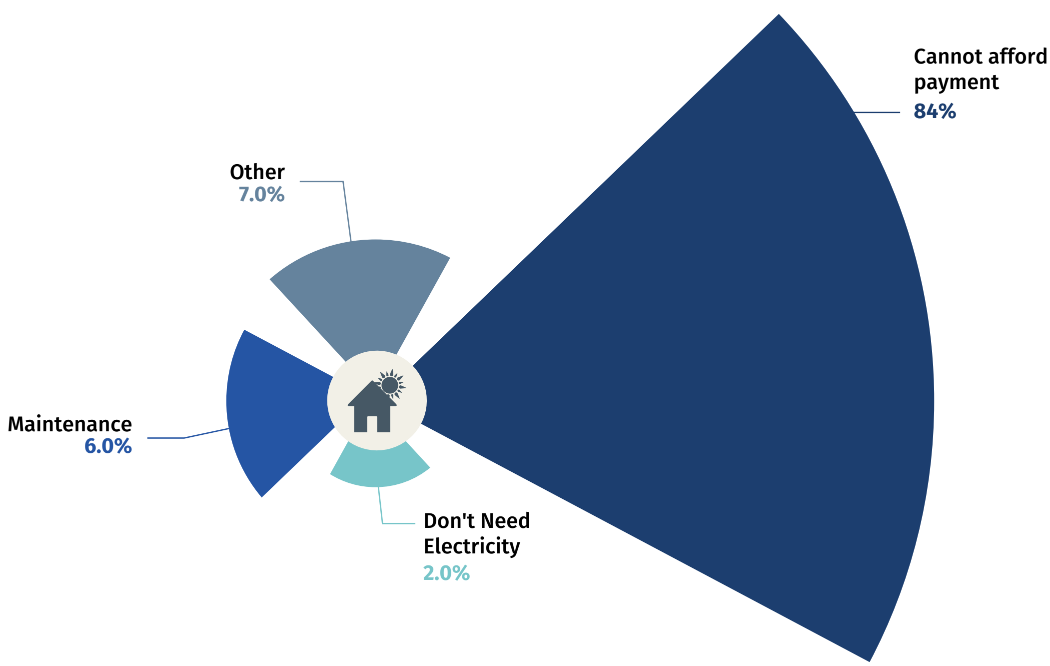
Willingness to pay for a solar home system (SHS)[15] is much lower than the willingness to pay for a connection to the grid, but it increases as the price drops (Figure 29). Although only 12% of households are willing to pay for a high-capacity SHS at the full price of STN 5,100 (USD $248), the share more than doubles to 27% if the price drops to STN 1,683 (corresponding to one-third of the initial price). Depending on the price, 26 to 31% of households were interested in flexible payment options (installments over 6, 12, and 24 months).

FIGURE 29 • **Willingness to pay for a high capacity solar home system (SHS)**



The large majority of households (84%) are not willing to pay for a solar device under any price or payment plan, due to Affordability issues (Figure 30). Only 6% of households considered maintenance to be a barrier. Thus, Affordability issues should be addressed when promoting access to off-grid solar.

FIGURE 30 • **Reasons cited by households for not being willing to pay for a SHS**

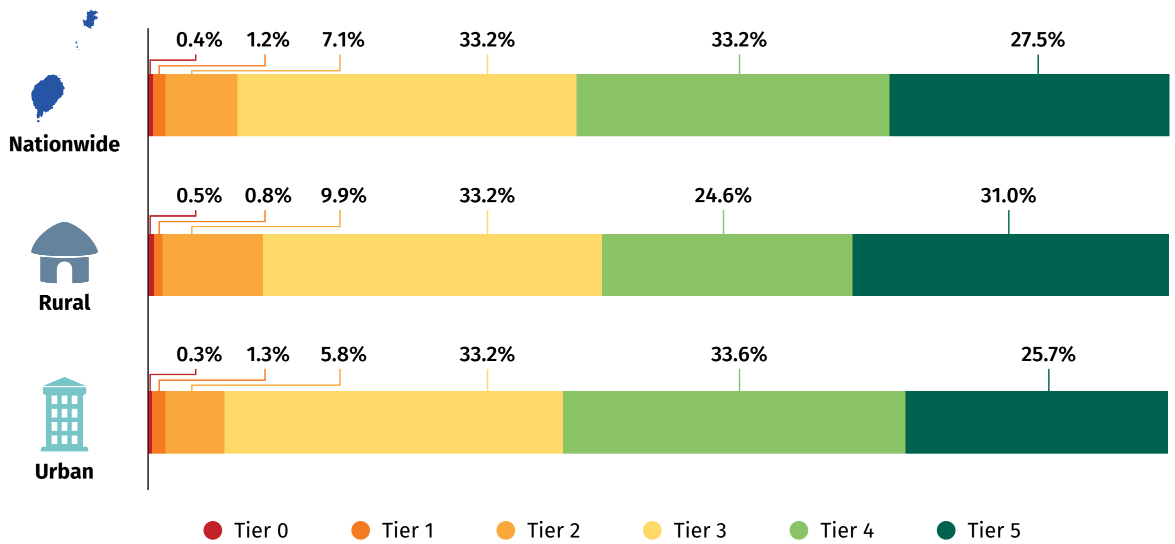


[15] A high-capacity SHS refers to a system that can power at least two lights, a mobile phone charger, and a television or a fan.

IMPROVING ELECTRICITY ACCESS AMONG GRID-CONNECTED HOUSEHOLDS

In STP, the national grid provides a fair quality of service to the customers (Figure 31). Nationwide, 91.4% of grid-connected households are in Tier 3 or above, while a quarter reaches Tier 5 access. Grid users are relatively equally distributed between Tiers 3, 4, and 5 (with shares varying from 27.5% to 33.2%). The remaining 8.6% of grid users suffer from poor performance of the grid supply, but mainly fall in Tier 2. On average, rural households have been grid-electrified for 7.6 years compared, with 10.5 years for urban households. The Center-West region has historically been the region where households have been electrified for the longest time.

FIGURE 31 • **MTF tier distribution of grid-connected households (nationwide, urban/rural)**



Slightly less than three-quarters of grid-connected households are not in the highest tier (Tier 5) and could move up to higher tiers. More specifically, improved Availability, Reliability, Quality, and Affordability of electricity supply could eventually shift grid users to the highest tier (Figure 31).[16] Policies can be tailored to address regional disparities existing in STP in terms of energy access performance. In addition to being the least electrified region in the country, the Center-East region is lagging behind on almost all electricity attributes, suggesting underinvestment in both the grid's infrastructure and its maintenance.

Limited Availability of electricity supply is an issue for about a quarter of grid-connected households in STP (Figure 32). Most of these households receive between 16 and 23 hours of electricity per day. Only 6% of grid-connected households receive less than 16 hours of electricity per day. Evening Availability is an issue for 16.5% of grid-connected households (Figure 33).

[16] Note that Tier 5 level does not entail any constraint.

FIGURE 32 • **Distribution of grid-connected households based on Daily Availability (over 24 hours) (nationwide, urban/rural)**

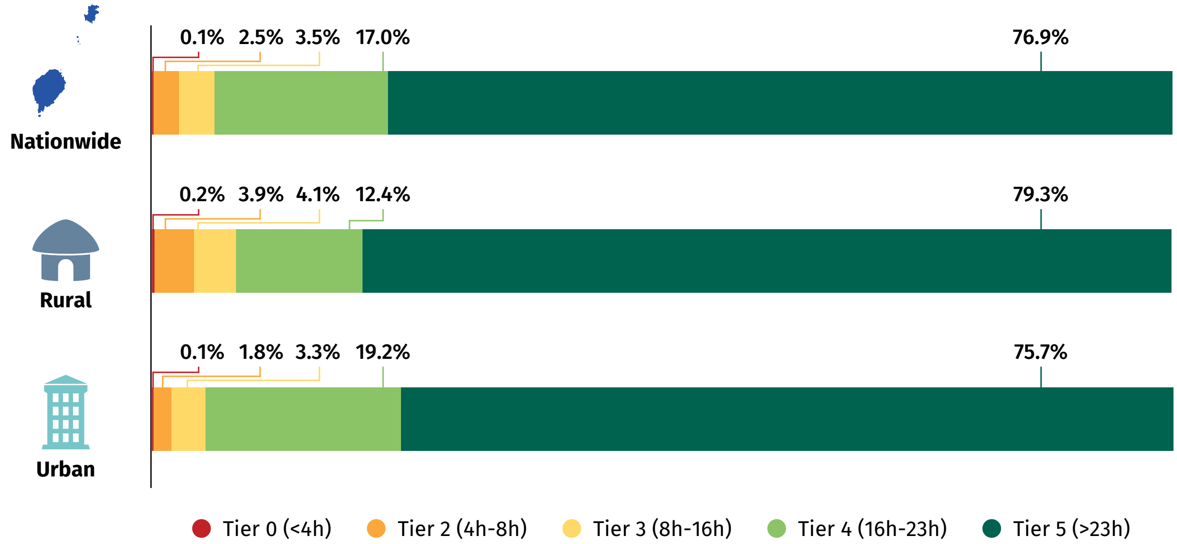
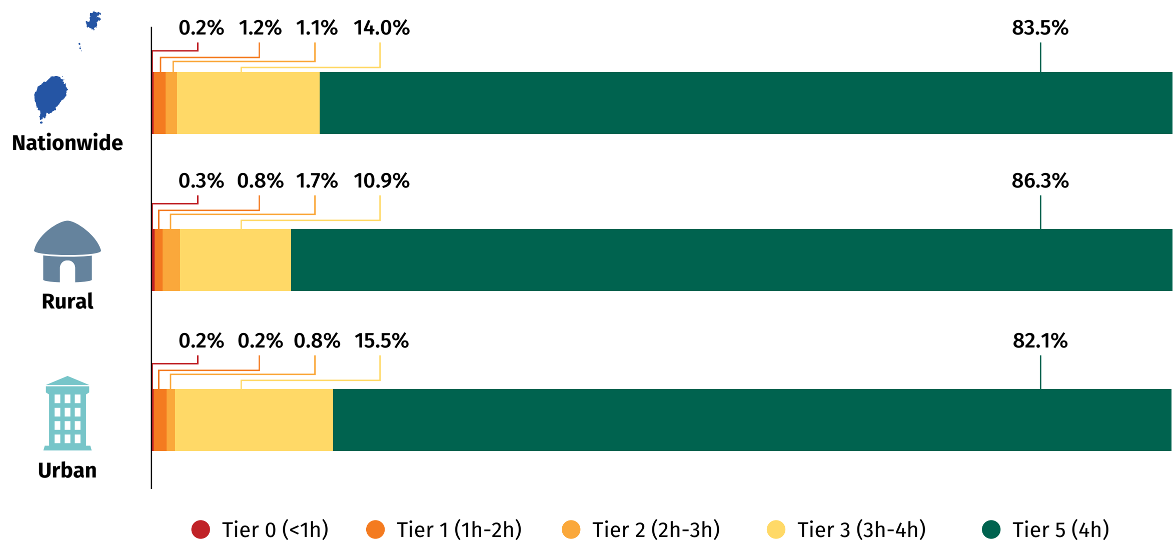


FIGURE 33 • **Distribution of grid-connected households based on Evening Availability (over 4 hours) (nationwide, urban/rural)**



The Center-East region has by far the worst performance across the country for both daily and evening availability of electricity supply. Only half of grid-connected households in the Center-East region enjoy more than 23 hours of electricity supply a day, compared to three-quarters of the households nationally and almost all of the grid users in Príncipe (96.7%).

More than half of the grid-connected households experience more than three outages a week or more than two hours of interruptions (Figure 34). The situation is slightly better in rural areas. Nearly a quarter of grid-connected households (23.7%) experience voltage issues resulting in appliance damage (Figure 35). Urban households tend to be a little more affected.

FIGURE 34 • **Distribution of grid-connected households based on Reliability (nationwide, urban/rural)**

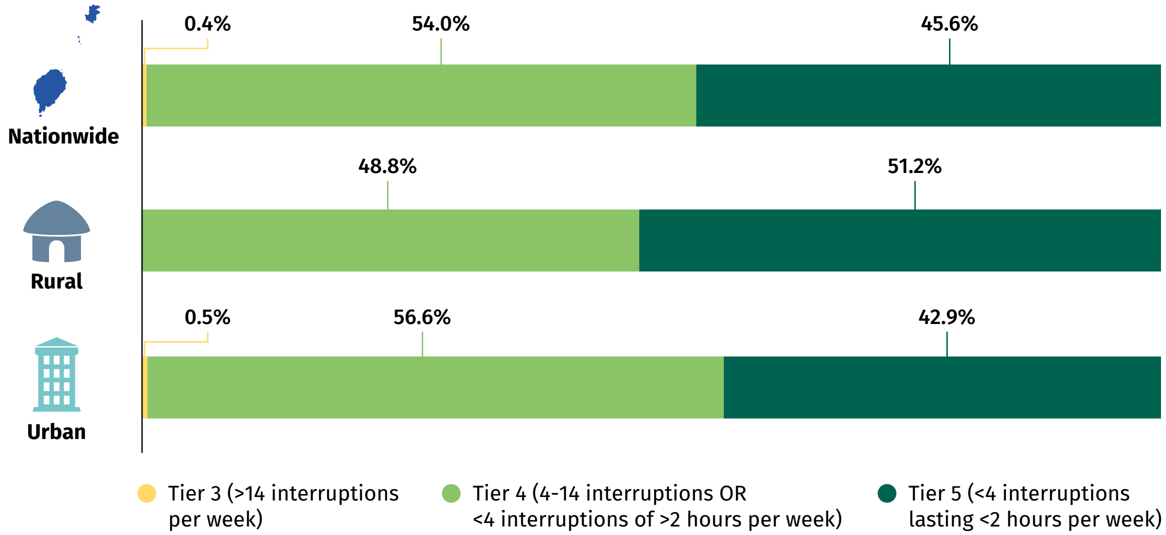
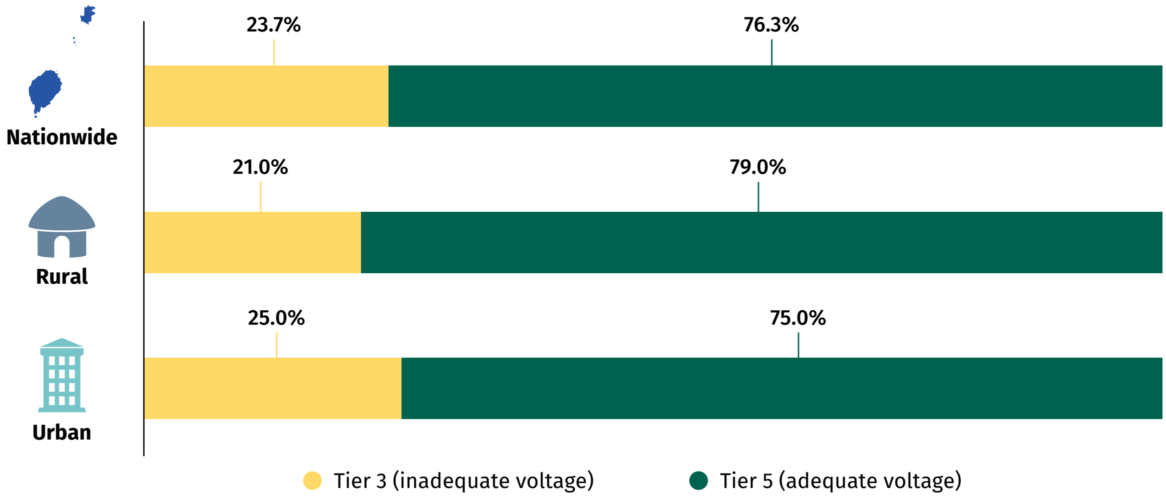


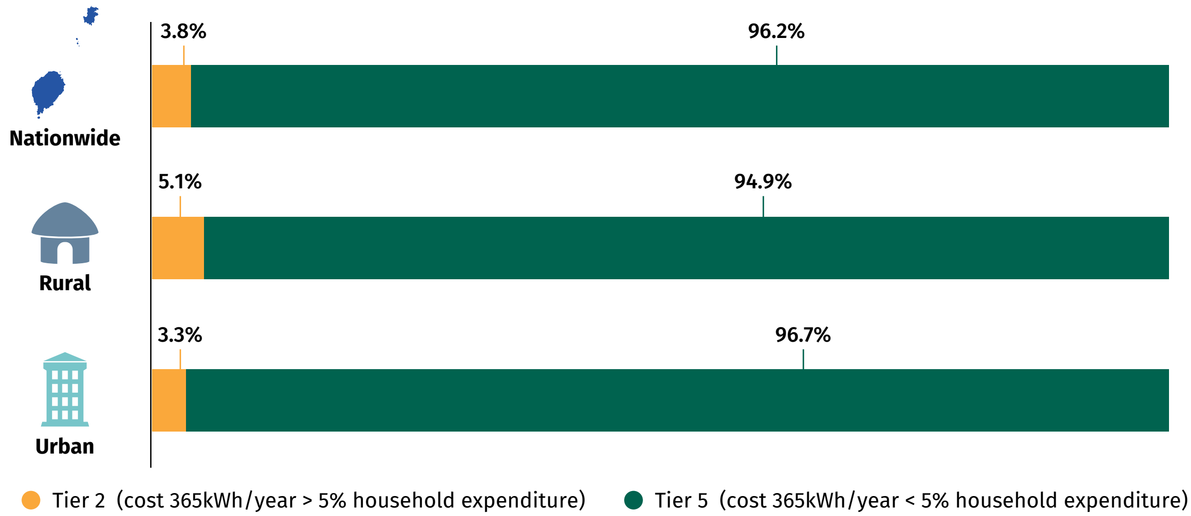
FIGURE 35 • **Distribution of grid-connected households based on Quality (nationwide, urban/rural)**



Similarly, grid-connected households in Center-East experience higher frequency and possibly greater duration of supply outages than in any other part of the country, since the vast majority of households (83.2%) face up to 14 disruptions per week and interruptions longer than two hours. Reliability appears to be an issue for households in the North-West and Center-West regions too. Grid users in Center-East experience the worst quality of service, in as much as a third of the households in this group have experienced damage to appliances due to voltage fluctuations.

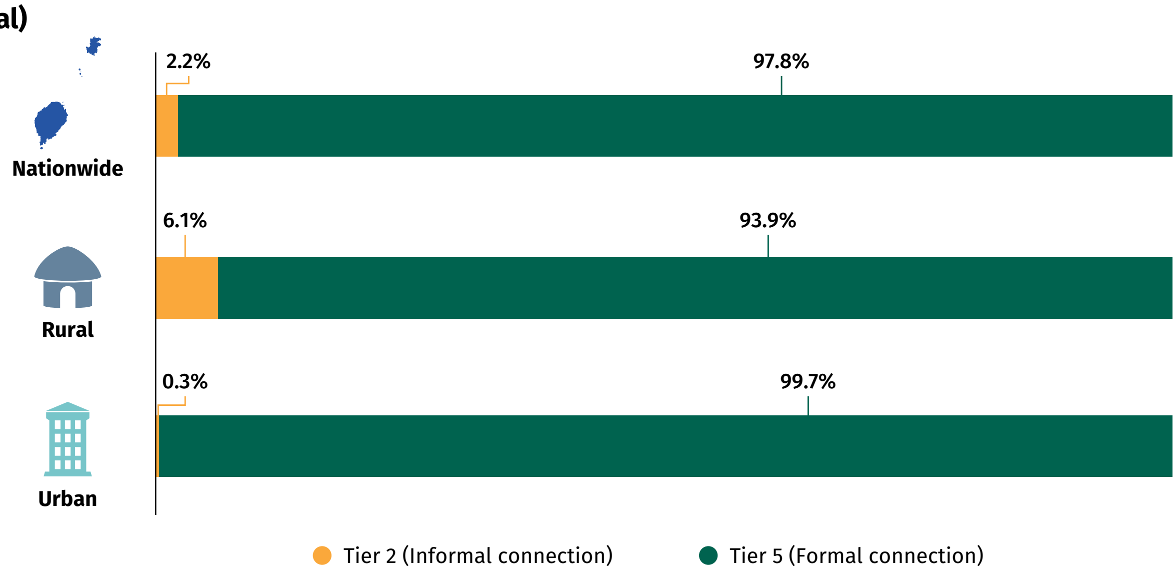
Affordability is only an issue for about 3.8% of grid-connected households in STP (Figure 36). The problem is slightly more common in rural areas. Based on regional disaggregated analysis, Affordability constraints are more common in the Príncipe and North-West regions, which are also the regions with the larger share of households in the bottom spending quintiles.

FIGURE 36 • **Distribution of grid-connected households based on Affordability (nationwide, urban/rural)**



Informality appears to be very low in STP, as only 2.2% of grid-connected households reported not paying their bill to anyone (Figure 37). In rural areas, the share rises to 6.1%, while in urban areas it is almost nonexistent. Formality of grid connection is almost exclusively an issue in the North-West region: more than 11% of households in that region have an informal connection.

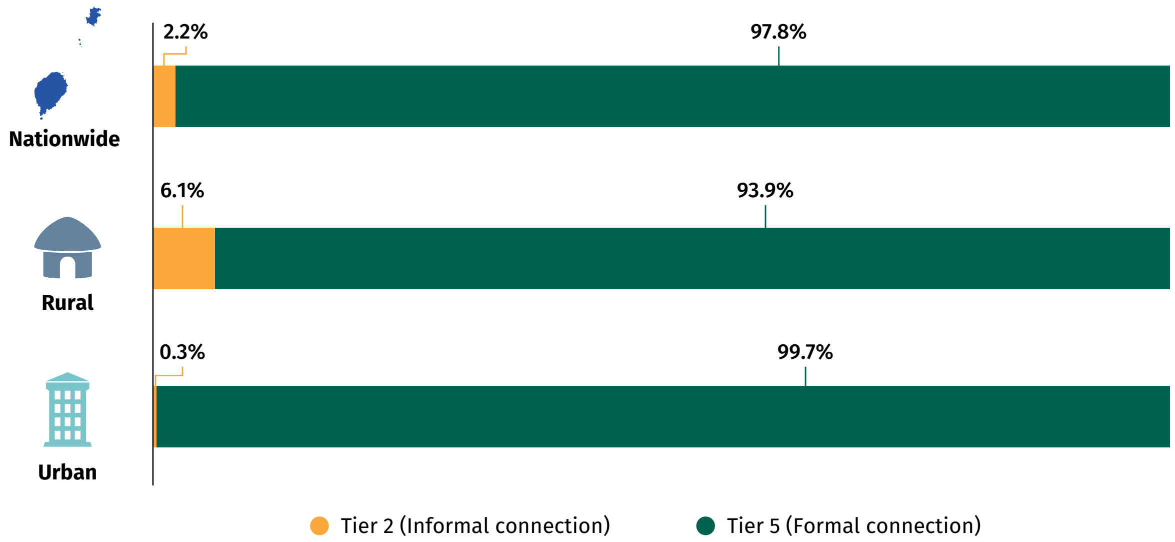
FIGURE 37 • **Distribution of grid-connected households based on Formality (nationwide, urban/rural)**



About 33.8% of grid-connected households reported that unpredictable interruptions of electricity represent the main issue in their supply, followed by 17.7% and 15.5% (respectively) stating that unexpectedly high bills and the high cost of electricity are the main issues. The most common issues for the grid-connected households were related to Reliability, Affordability, Quality, and Availability constraints with the grid (Figure 38). However, 37.1% of grid-connected households reported having

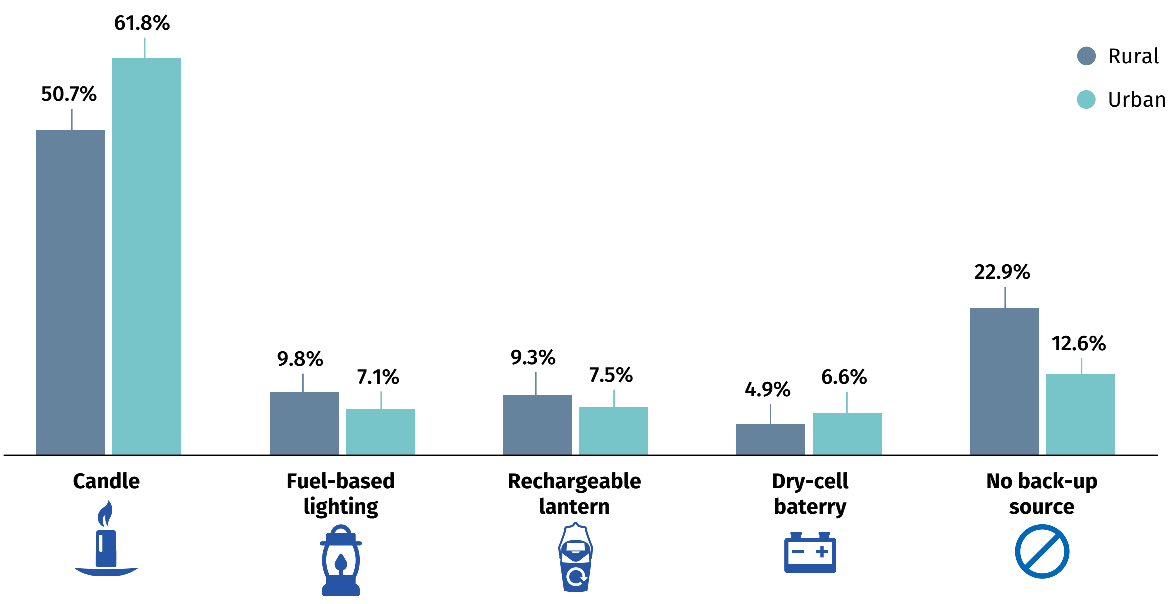
no issue with their grid connection. These findings are based on consumer perception of key issues and are therefore more subjective than those analyzed under MTF attributes; households are only partly satisfied with the grid service.

FIGURE 38 • **Main issues related to grid electricity supply (nationwide)**



To cope with power outages, candles are by far the most common coping solution in STP. About 50.7% of rural households and 61.8% of urban households use candles as their backup source of lighting (Figure 39). Among grid-connected households, 16% do not have any backup source of lighting; and more urban households (87.4%) than rural households (77.1%) use a backup source.

FIGURE 39 • **Share of the grid-connected households using backup source for lighting**



POLICY RECOMMENDATIONS

More than two-thirds (69.4%) of STP households are connected to the national grid. Among them, more than a quarter (27.5%) are in Tier 5. Improvement in Reliability (reducing the number and duration of outages), as well as in its Availability (increasing the amount of time during which electricity service is available) and Quality (reducing voltage fluctuation), could shift nearly two-thirds (63.9%) of the grid-connected households to higher Tiers (4-5).

Only 1.6% of households use off-grid solutions, including 0.9% who rely on a mini-grid, while solar products are almost nonexistent. Government policies are needed to facilitate the bulk import into the country of solar products and their distribution, installation, and maintenance.

About 30% of households (29.6%) are in Tier 0 for electricity access. Virtually all households in Tier 0 have no access to any electricity source. Moving them to higher tiers would require the provision of either grid or off-grid access. The following are policy recommendations for providing electricity to those who currently do not have any:

- Optimal energy solutions with the least cost need to be formulated, considering the population density, the distance to the national grid network, potential electricity demand from various type of customers, and socio-economic environment. With the advancement in the Geographic Information System technology, the optimal energy solutions are often devised using the geospatial planning methodology.
- Densify the grid, especially by offering payment periods for the connection cost and more financing options, which would effectively address the financial barrier of the connection fee that households face. Beyond grid densification, expansion of the grid infrastructure can provide electricity to those without electricity as long as this is the lowest-cost approach.
- For settlements located far from the grid infrastructure with sizeable electricity demand from households as well as productive uses, mini-grid development should be considered.
- Off-grid solar products may often be a more feasible solution for households living in areas where the grid infrastructure is not available. The market for solar products is not yet developed in STP. Very few products are distributed, and few households use them. Consumer awareness programs could raise awareness among potential customers and build the demand. It could also raise their willingness to pay for solar products, along with providing subsidies and leasing opportunities to increase the adoption of solar devices.

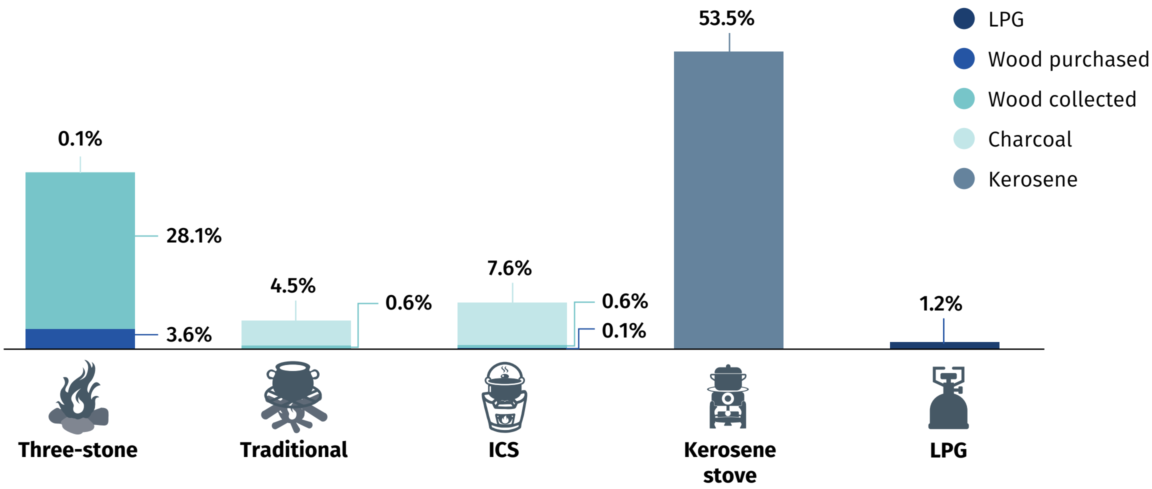
ACCESS TO MODERN ENERGY COOKING SOLUTIONS

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

TECHNOLOGIES

In STP, over 53% of households primarily cook with kerosene and 43.5% with biomass (Figure 40). About 32% of STP households use a three-stone stove as their primary cooking solution burning firewood. Improved cookstoves are used by 8.3% of households, almost entirely with charcoal (7.6%), and clean fuel stoves (LPG stoves) are the primary cooking solution of 1.2% of households.

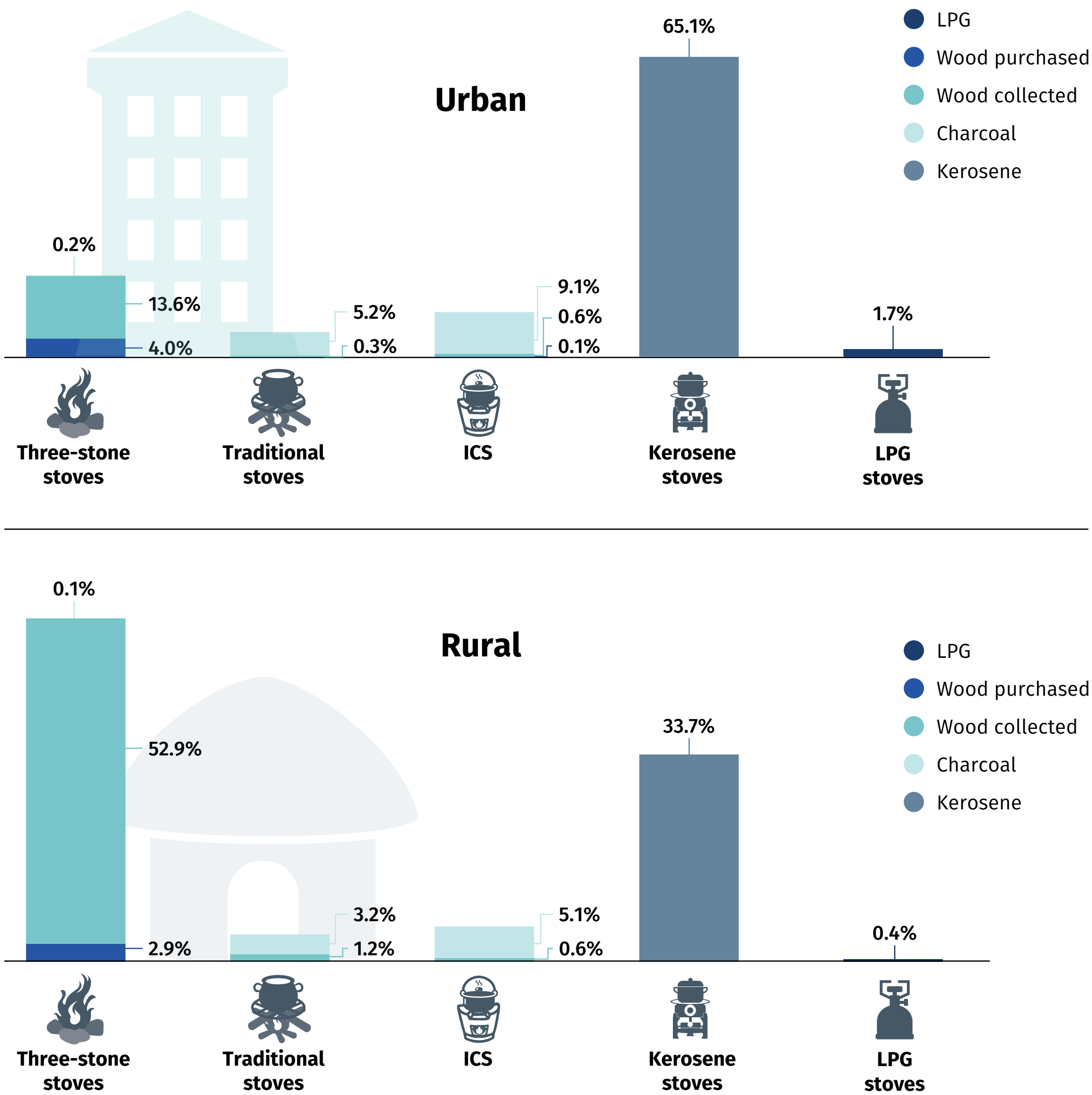
FIGURE 40 • **Distribution of cookstove types and fuel used (nationwide)**



Urban and rural households have different cooking patterns. Urban households cook predominantly with kerosene (65.1%), followed by firewood (18.7%) (Figure 41). In urban areas, nearly two in three households use kerosene-based stoves as their primary cooking solution, followed by three-stone stoves (17.8%) and improved cookstoves (9.%). In rural areas, most households cook with firewood (57.5%), while a third of them rely mainly on kerosene (33.7%). Most rural households use almost exclusively three-stone stoves to cook with biomass (55.9%), followed by a third of rural households that use kerosene stoves. Interestingly, wood is mainly collected (not purchased), a strong pattern even among urban users. Charcoal use is more widespread in urban than rural settings but remains a marginal fuel, far behind kerosene and fuelwood. The use of clean fuel stoves (using LPG) is negligible and concentrated in urban areas.

Kerosene is the main fuel for two-thirds of the households in Center-West region, while collected wood used on three-stone stoves is the dominant cooking solution in the Center-East and North-West regions, which show similar fuel usage habits. Charcoal use only stands out in the Príncipe region, where nearly half of the households use it as their main cooking fuel either on traditional stoves or ICS. LPG is very marginally used in the Center-West and Príncipe regions.

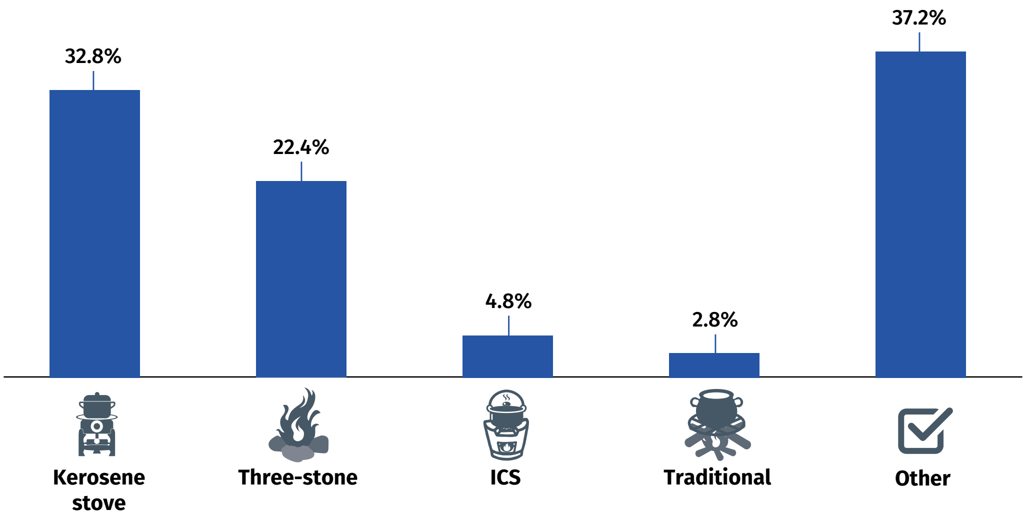
FIGURE 41 • **Distribution of cookstoves and fuel used (urban/rural)**



Stove stacking[17] occurs in more than one in three households (Figure 42). Stacking is equally common in urban and rural areas. About 28.7% of households use two cookstoves, and 6.8% of households use three or more stoves. LPG stoves are not used as exclusive cooking solutions.

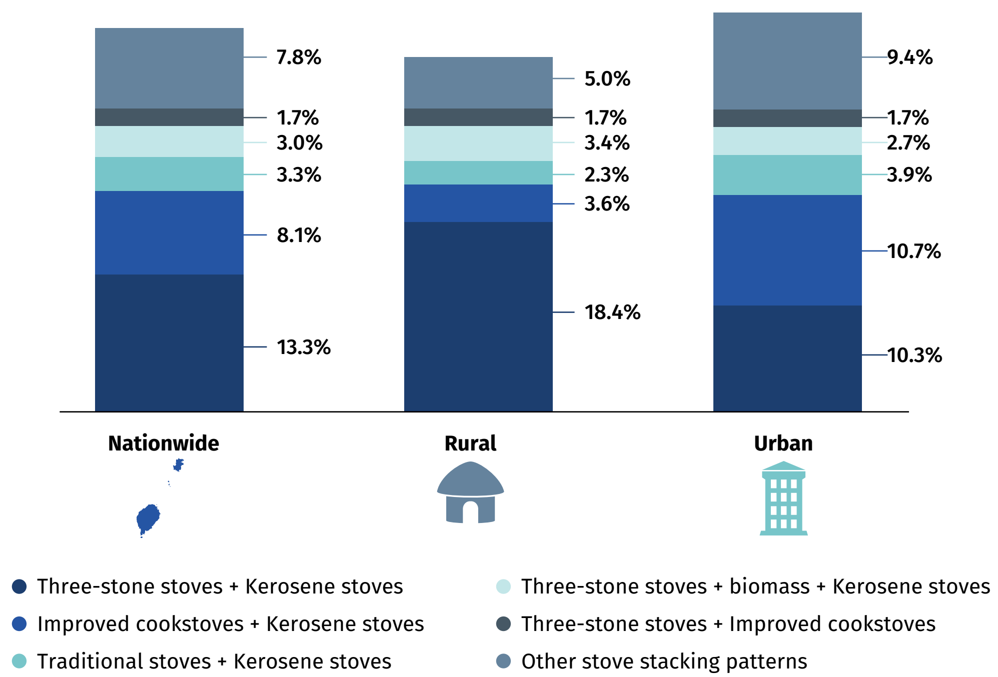
[17] Stove stacking refers to the parallel use of multiple cooking solutions in the same household. It reflects either households' aspiration to use higher performing solutions or the need for backup solutions, which are often used in addition to (rather than instead of) the primary cooking solution.

FIGURE 42 • Exclusive use of cookstoves versus stacking



The most frequent stove stacking combination refers to households that primarily cook with a three-stone stove and a kerosene stove (13.3%), followed by households cooking with an improved cookstove while using in parallel a kerosene stove (8.1%) (Figure 43). The major combination in cooking solutions for rural households is the use of a three-stone stove, primarily associated with the use of a kerosene stove (18.4%). In urban areas, however, the combination of an improved cookstove and a kerosene stove (10.7%) is as prevalent as the combination of a three-stone stove and a kerosene stove (10.2%).

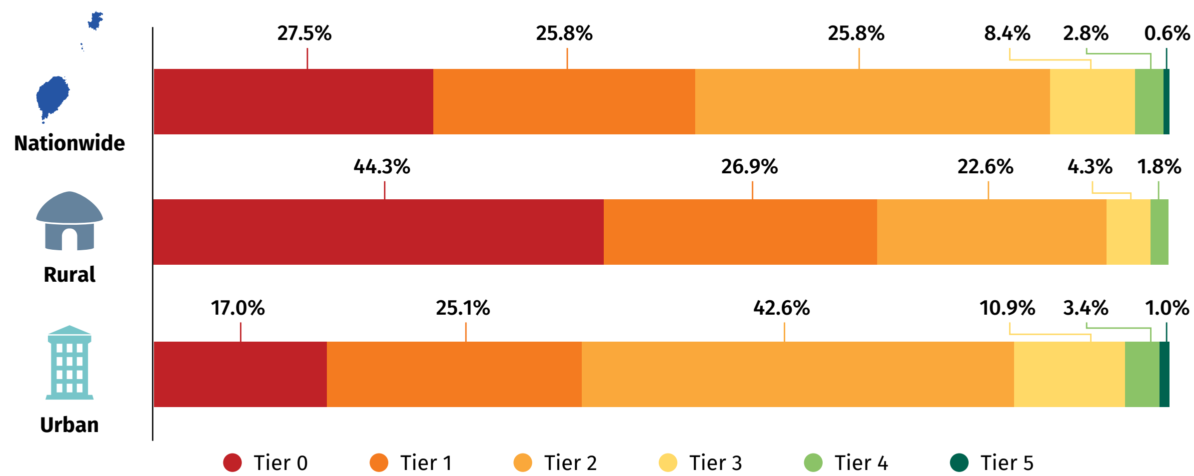
FIGURE 43 • Stove stacking patterns (nationwide, urban, rural)



MTF TIERS

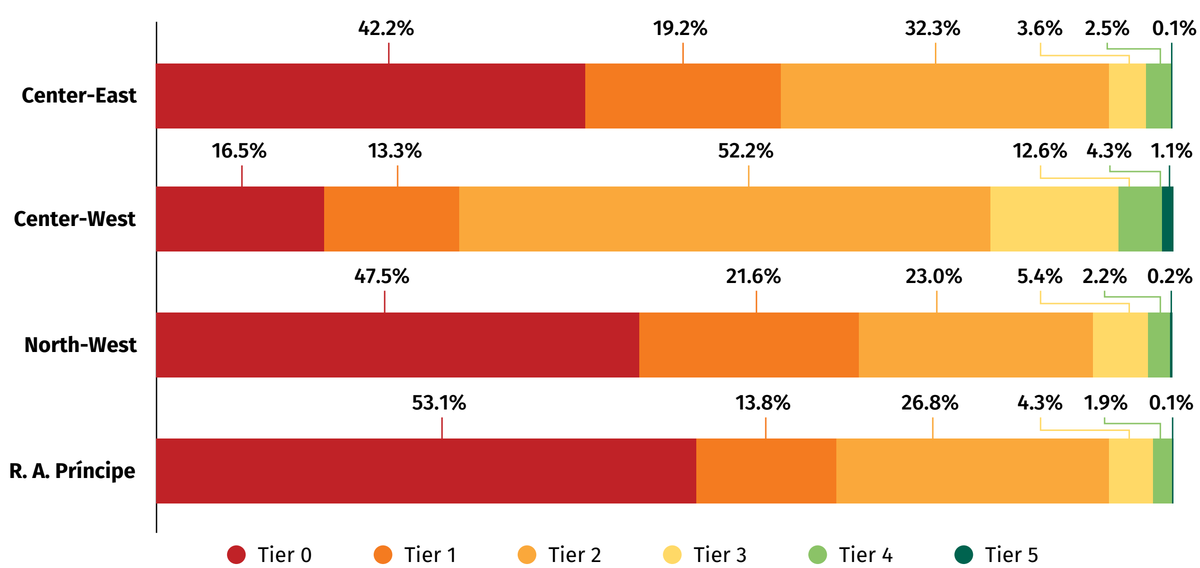
About 88% of STP households are in Tiers 0-2 for access to modern cooking solutions. Only 0.6% of households are in Tier 5 among the 11.8% that are in Tier 3 or above (Figure 44). A significant gap between urban and rural households has been identified in the MTF cooking tier distribution: only 17% of urban households are in Tier 0, compared with 44.3 % of rural households. In fact, the majority of rural households are within Tiers 0-1 (71.2%), while 57.9% of urban households are in Tier 2 or above.

FIGURE 44 • **MTF tier distribution (nationwide, urban/rural)**



Disparities can be observed across STP's regions (Figure 45). The Center-West region shows better access levels compared to the rest of the country, as 59% of households are within Tiers 2-5. Tier 5 households are all located in that region. In all three other regions, around 70% of households are within Tiers 0-1 for access to cooking solutions.

FIGURE 45 • **MTF tier distribution (by region)**

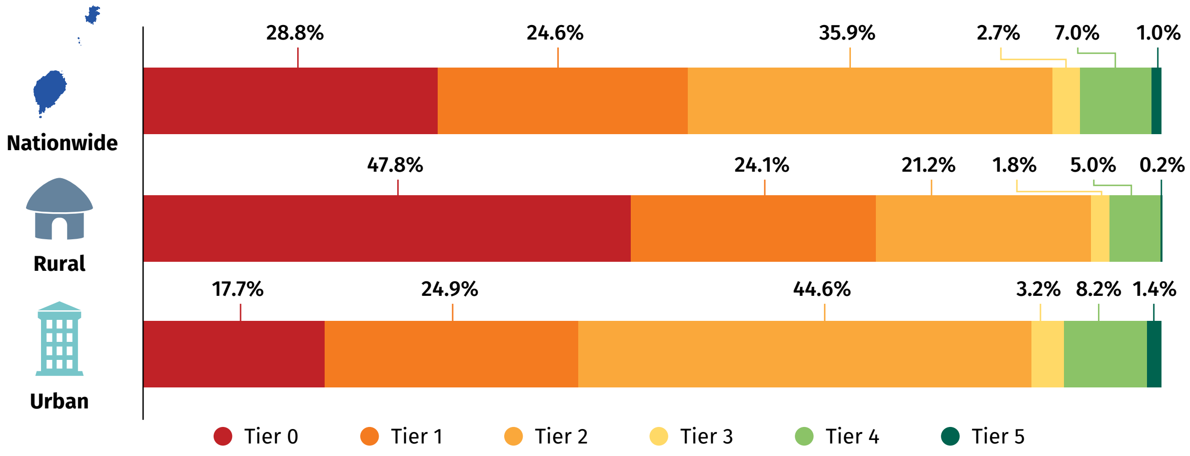


MTF ATTRIBUTES

Cooking Exposure

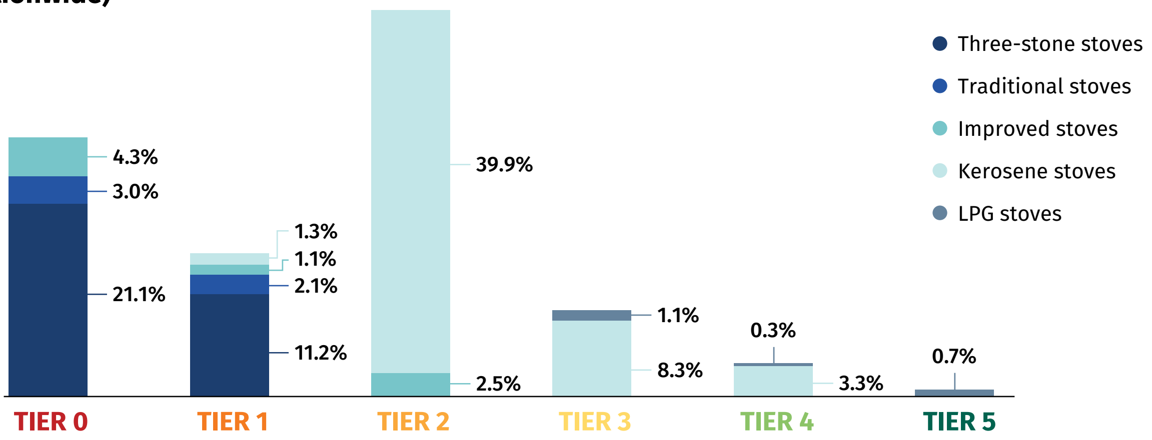
For the *Cooking Exposure* attribute, which represents an estimate of personal exposure during cooking activities based on emissions from cooking and ventilation, over half of STP households are in Tiers 0 and 1 (Figure 46). The tier associated with Cooking Exposure is negatively affected by the fact that 70.9 % of households use kerosene or biomass stoves without sufficient ventilation. Twice as many urban households are in Tiers 2–5 (57.4 %) relative to rural households (28.2 %).

FIGURE 46 • **Tier distribution of the Cooking Exposure attribute (nationwide, urban/rural)**



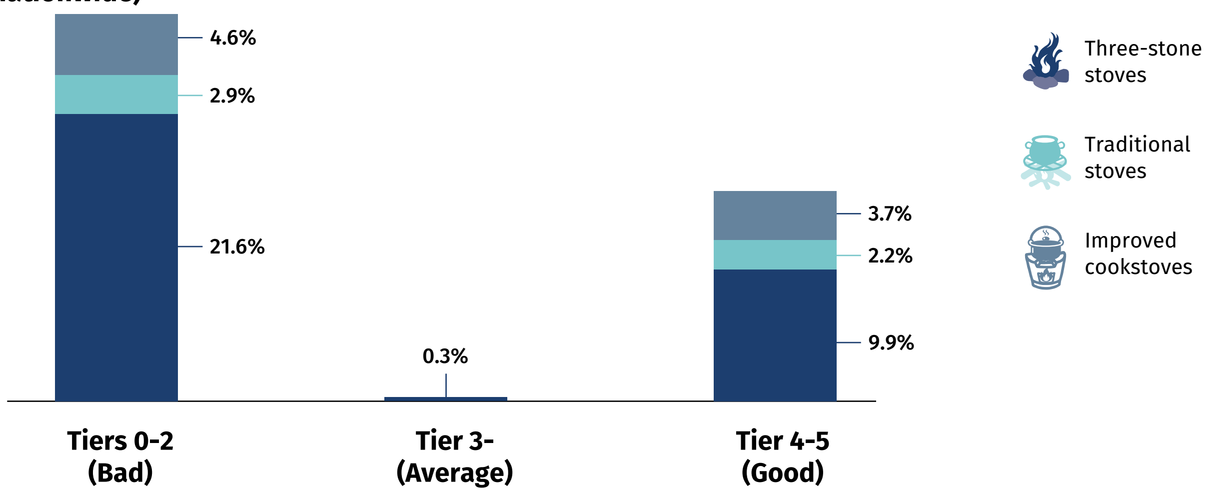
Households using three-stone or open fire stoves as their primary stoves account for the largest share of Tier 0 for the Cooking Exposure attribute. A portion of primary stoves (11%) that are open fire stoves reach Tier 1, which derives from their better ventilation. Households using an improved cookstove are unevenly classified between Tier 0 and Tier 2 for Cooking Exposure. Few biomass stoves, however, achieve Tier 2 or 3 in exposure because of the absence of advanced biomass stoves, such as gasifier stoves, which could reduce pollutants significantly (Figure 47).

FIGURE 47 • **Distribution of households based on Cooking Exposure by primary cookstove (nationwide)**



The Ventilation tier for biomass fuel stoves mostly ranges from Tier 0 to Tier 2 and to a less extent from Tier 4 to Tier 5. The bad ventilation tiers result from the fact that many households cook in small indoor spaces with no or few openings. The absence of Tier 3 in ventilation structure indicates that households do not use chimneys in kitchens (Figure 48). However, a share of households cooking outdoors is able to reach a good ventilation status.

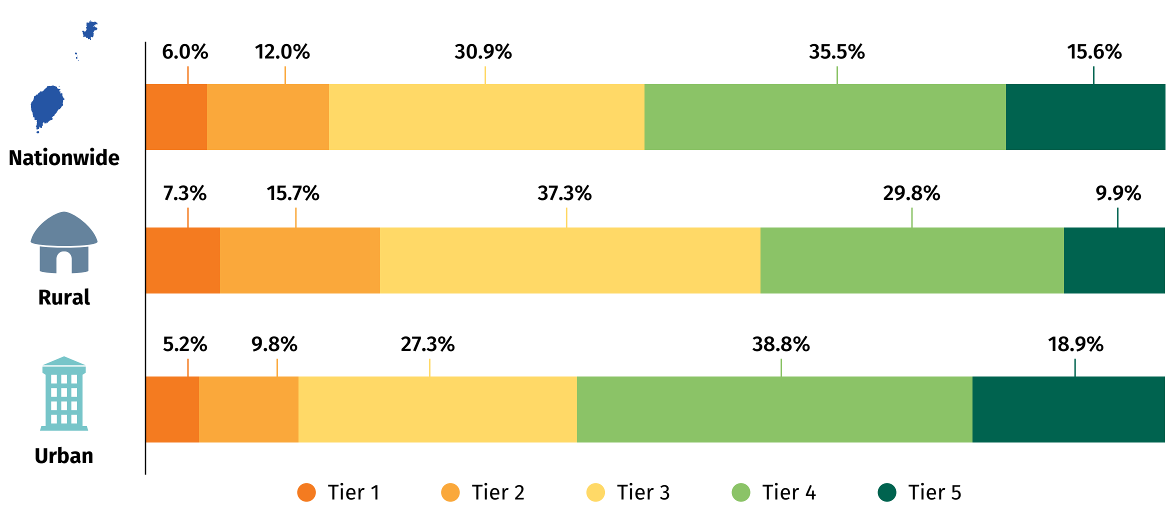
FIGURE 48 • **Distribution of households based on Ventilation, by primary biomass cookstove (nationwide)**



Convenience

Convenience is determined by the time spent collecting and preparing fuel per week and preparing the stove for cooking. In STP, 18% of households spend more than three hours a week in fuel collection or at least 10 minutes per meal in stove preparation (Figure 49). Biomass users are overrepresented in the low Convenience tiers, while the majority of kerosene and LPG users reach Tier 4 or 5 for Convenience.

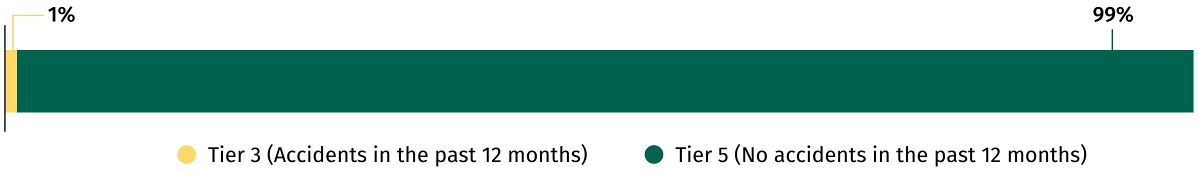
FIGURE 49 • **Distribution of households based on Convenience (nationwide, urban/rural)**



Safety of Primary Cookstove

The degree of risk of injury varies by type of cookstove and the fuel used. Risks may include exposure to hot surfaces or fire or the potential for fuel splatter. In defining this attribute, the reported incidence of past injury or fire is used to measure safety. Over the year prior to the survey, if household members did not experience any accidents that required professional medical attention, then the cooking device was considered safe. This was the case for 99% of households, which did not experience such accidents (Figure 50). Of the 1% of households reporting having had such accidents during the previous 12 months, more than two-thirds (68.5%) were using open fire stoves.

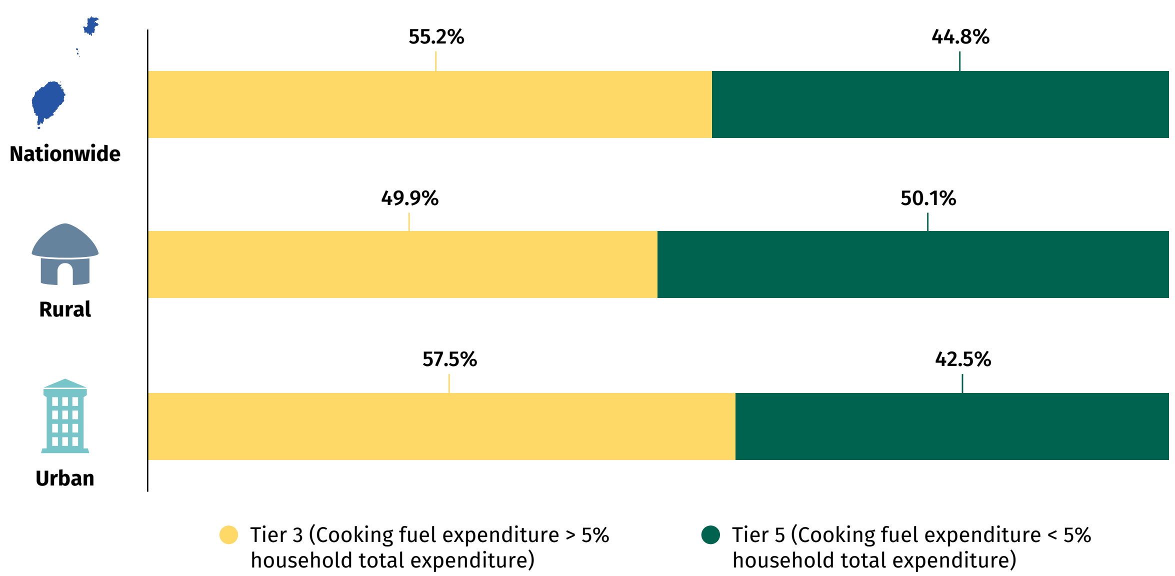
FIGURE 50 • **Distribution of households based on Safety of primary cookstove**



Affordability

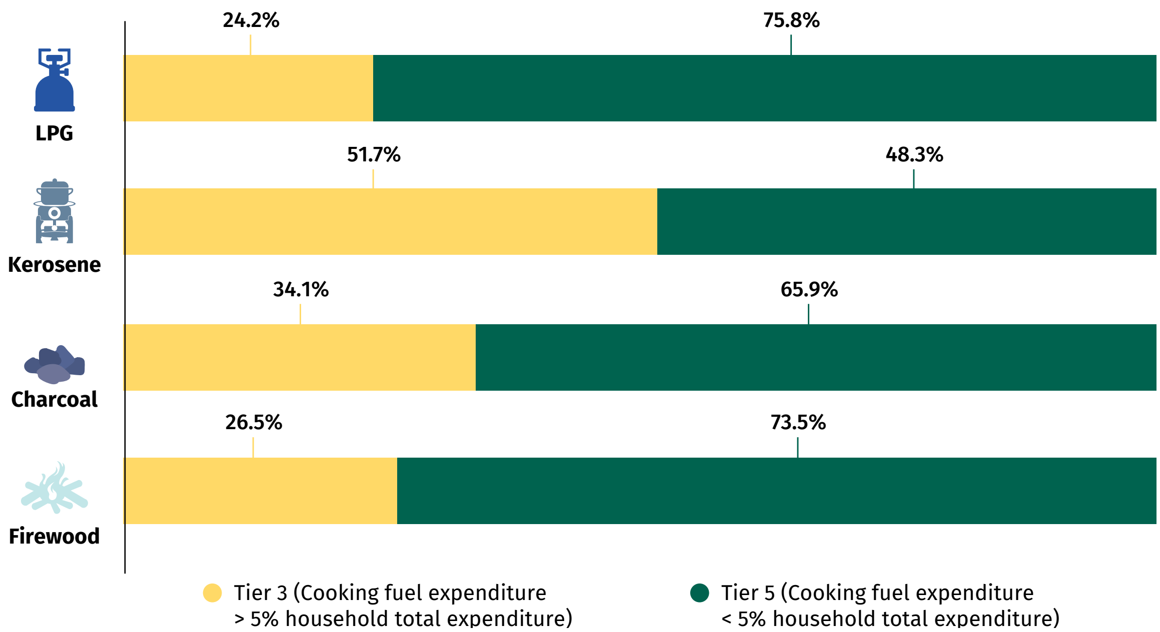
The *Affordability* attribute is calculated using two factors, total monthly household expenditure and household expenditure on cooking fuel. If a household's expenditure on cooking fuel does not exceed 5% of household monthly expenditure, the fuel is considered affordable. According to this criterion, more than half of households in STP do not view their current cooking solution as affordable (Figure 51). A notable difference in Affordability was identified between rural and urban households: Affordability is a more pronounced problem for the latter. This can partly be explained by the fact that over half of rural households collect wood for free, against only 14% of urban households.

FIGURE 51 • **Distribution of households based on Affordability (nationwide, urban/rural)**



Households using firewood as the primary cooking fuel as well as those using LPG are the least likely to experience Affordability issues (Figure 52). This is mainly due to the fact that most firewood users get their fuel for free and that LPG users tend to be overrepresented in the top quintiles. Kerosene users are the most likely to show Affordability issues. More than half of them spend over 5% of their household expenditures on kerosene for cooking.

FIGURE 52 • **Distribution of households based on Affordability, by fuel type (nationwide)**



IMPROVING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

The ultimate objective of improving access to modern energy cooking solutions should be to facilitate access among all households to cooking solutions that are clean, convenient, efficient, affordable, safe, and available. In STP, an increase in the rate of adoption of clean fuel stoves, especially for kerosene stove users, could boost households to higher tiers. In addition, the introduction and promotion of improved cookstoves could help shift households, particularly Tier 0-1 households, to higher tiers.

INCREASE PENETRATION OF CLEAN FUEL STOVES

The use of clean fuel stoves is in its infancy in STP, where 1.2% of households use LPG stoves as their main cooking solution, mostly in urban settings. Given the substantial penetration of kerosene stoves, particularly in urban areas where 41.1% use it as their sole stove, promoting a switch to clean stoves, namely LPG stoves for cooking, would lift the majority of STP households to higher tiers. Indeed, although it is deemed cleaner than solid fuels, kerosene cannot be considered a clean fuel according to WHO guidelines (Box 4).

BOX 4 • KEROSENE IS CLASSIFIED AS A POLLUTING FUEL BY WHO

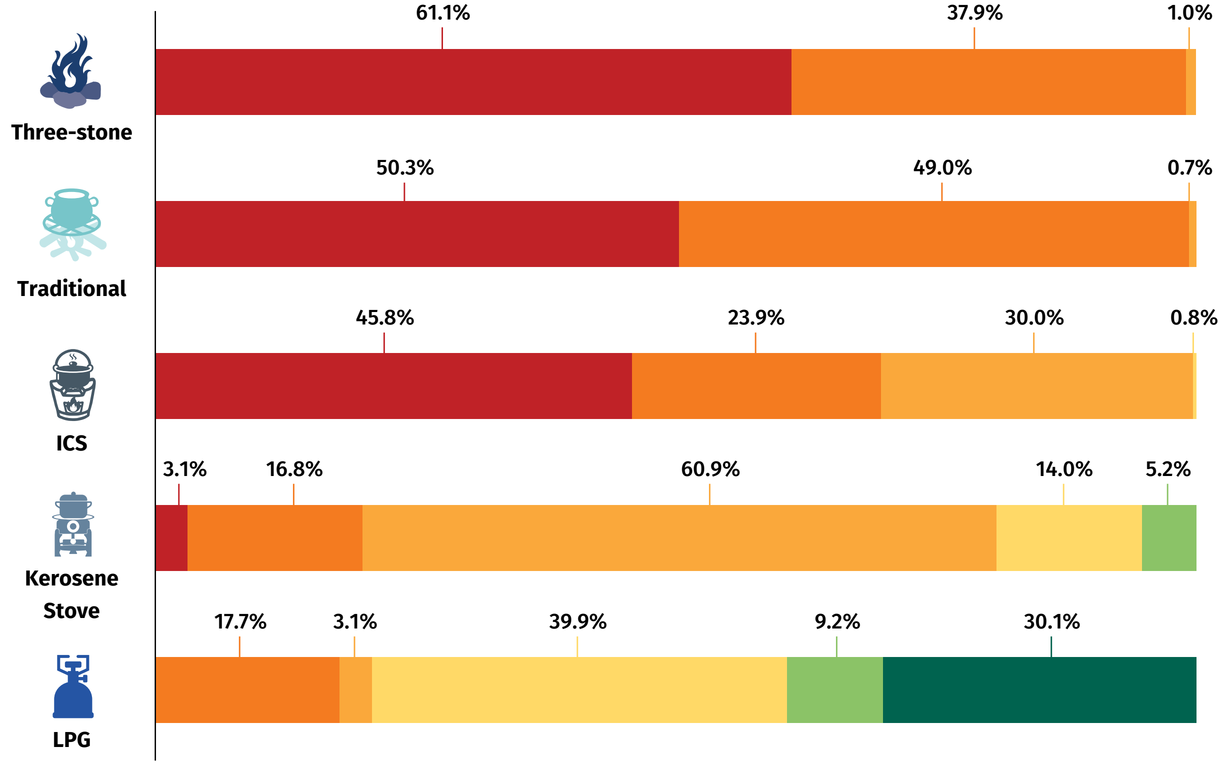
Kerosene used to be grouped together with LPG, biogas, and electricity as a "modern" fuel. Despite its continued widespread use, kerosene can no longer be considered a "clean" fuel. The fourth recommendation of the WHO IAQ guidelines for household fuel combustion discourages the use of kerosene for any household purpose. Studies that have measured emission rates and pollutant concentrations in households using kerosene find pollution levels that are consistent with substantially increased risks of adverse health outcomes. One recent study conducted in the city of Bhaktapur, Nepal, found that children in households where kerosene was used for cooking had a significantly higher risk of acute lower respiratory infection (ALRI) than those living in homes where electricity is used (Bates et al., 2013).

Kerosene use can also lead to poisoning, injuries, and house fires. Millions of people suffer burns from using kerosene lamps every year. Unintended ingestion of kerosene is one of the most common causes of child poisoning worldwide, particularly in LMICs. These risks are well-documented and yet are also likely to be underestimated, as many injuries go unreported (Mills, 2016). Kerosene use poses dangers far beyond the boundaries of the home or village. Particulate matter emitted by burning kerosene is almost pure black carbon, a form of fine particulate pollution that is the second biggest contributor to global warming after carbon dioxide.

Source: WHO 2016.

The majority of kerosene stoves users are in Tier 2, mostly due to their performance on the Exposure attribute, whereas most LPG stoves users in STP enjoy access at Tiers 3-5 (Figure 53).

FIGURE 53 • Tier distribution by stove type

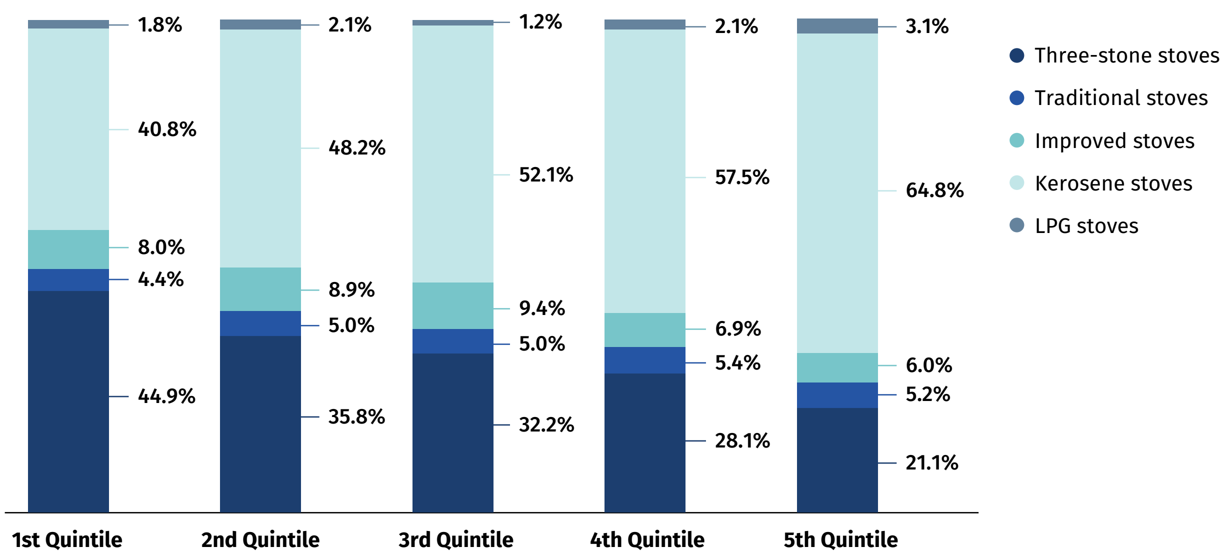


The promotion of LPG would require coordinated government support to facilitate a stable and sustainable fuel supply. If propane and butane gas cookstoves are generally available in the country, cylinders have faced stock breaks in the past (CESO 2018), and since a limited share of STP households currently use LPG as their main fuel, a vast increase in gas imports would be needed. The use of cooking gas, concentrated in the Center-West and Príncipe regions, suggests that the infrastructure may not be readily available for households to acquire and replace their cylinders in other regions of São Tomé island.

Affordability of LPG may also be an issue, particularly for households in the lower quintiles. At the time of the survey, the cost of acquisition of a first LPG cylinder of 6 kilograms was STN 1,000 (USD 49), while a kerosene stove was four times less expensive, at STN 250 (USD 12).

The share of kerosene stove users, although increasing as household expenditure rises, is very significant across all expenditure quintiles (Figure 54). This means that other characteristics of such fuel must be attractive to the population. Efforts to promote LPG cookstoves would need to ensure that any potential Availability, Affordability, Convenience, and Safety issues are being adequately addressed, to convince kerosene users to switch to LPG. Availability of affordable LPG stoves and awareness campaigns on the benefits of clean fuels will help increase adoption of LPG stoves.

FIGURE 54 • **Main stove used by expenditure quintiles**



INTRODUCE AND PROMOTE THE USE OF IMPROVED COOKSTOVES AS THE PRIMARY COOKING SOLUTION

Introducing and promoting the use of improved cookstoves is the most feasible and immediate solution for households that use three-stone or traditional stoves, particularly rural households and those located in the North-West and Center-East regions, among which switching to clean fuel stoves (LPG) is not feasible because fuel is not available or affordable. Among rural households, 60.3% use three-stone stoves (55.9 %) or traditional stoves (4.4%) as their main stove. Virtually all of these rely on wood for cooking and are in Tier 0 or 1, mainly because of the cooking exposure and convenience attributes.

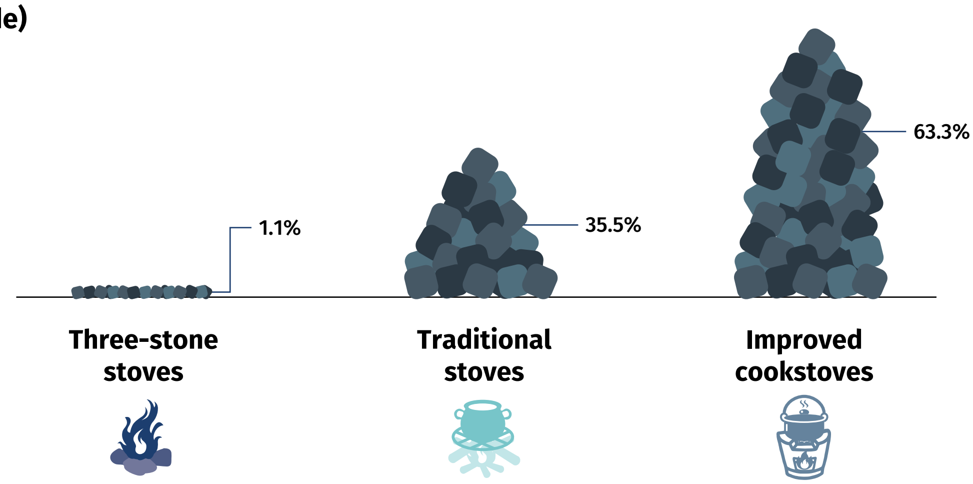
In STP, the only type of improved cookstoves to be found are very basic charcoal improved cookstoves. Yet the largest biomass energy source used for cooking in the country is firewood (used as the main fuel source by 33.9% of households), and no improved cookstoves burning firewood exist. Charcoal use is only significant in Príncipe region.

The potential benefit of switching to an improved cookstove is not as significant as in the case of clean fuels, but it is still substantial, particularly because of greater energy efficiency and the reduction in expenditures on fuel and in the time spent obtaining fuel. Households that switch from three-stone stoves or traditional stoves to an improved cookstove will save on the time spent collecting fuel. Households cooking with three-stone stoves or traditional stoves currently spend an average 5.4 hours and 3.6 hours a week, respectively, on obtaining cooking fuel. Users of improved cookstoves burning charcoal spend on average 2.1 hours per week.

In order to propose improved woodstoves that could be adopted and bring added value to households in STP, the needs and preferences of these households would need to be thoroughly assessed in the first place. This would entail conducting a detailed analysis of current fuel use, stove use and cooking practices of wood fuel users and assessing their willingness to pay for improved cooking devices. This is especially true for the important share of households that freely collect wood for cooking on three-stove stoves at no cost (27.8%). Key drivers of adoption of improved cookstoves need to be determined in order to promote a range of adequate and sustainable improved cookstoves in the country, be they locally manufactured or (most likely) imported in the case of STP. Raising public awareness regarding the positive health, social, and environmental impacts of switching to improved cookstoves is key to ultimately foster adoption.

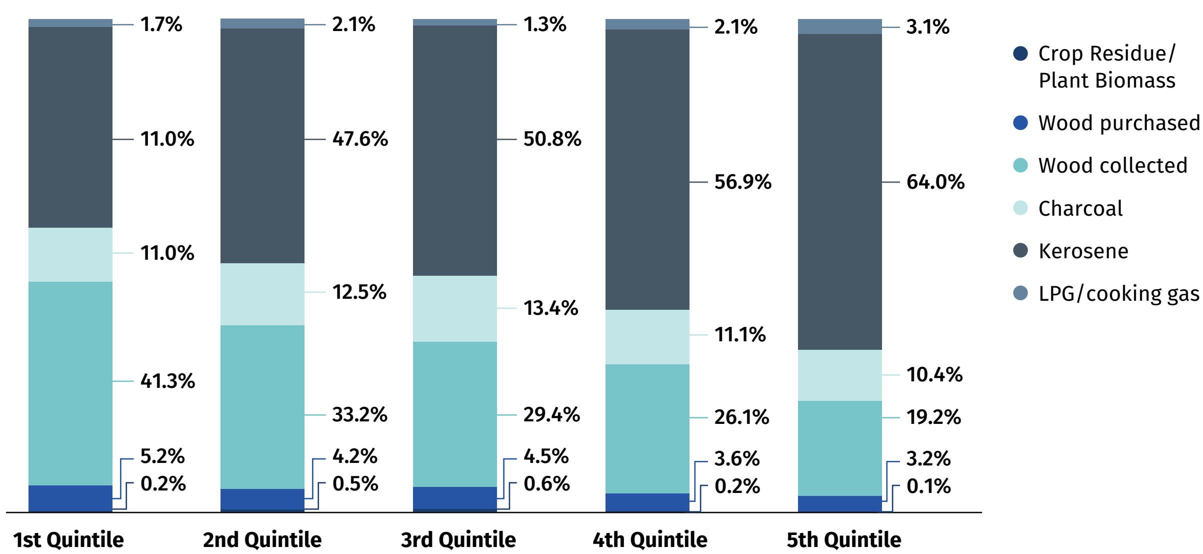
Basic improved charcoal stoves found in STP have not been tested by any recognized laboratory for emissions or efficiency; however, based on design features these have been assigned Tier level 1 for emissions. Although performing only marginally better than traditional charcoal stoves (Tier 0 for emissions), they are used by 63.3% of charcoal users as primary fuel (Figure 55). Charcoal fuel users in STP, mainly located in Príncipe region, would thus benefit from switching to high performance charcoal stoves to reach higher access tiers. In the absence of such products on STP markets, it was not possible to test households' willingness to pay for such low-emission, cleaner, and more efficient devices. There is, however, a willingness to pay for better performing stoves in STP, as 63.3% of households using charcoal as primary fuel have already adopted these basic improved cookstoves over the less expensive, traditional ones.

FIGURE 55 • **Distribution of households using charcoal as the primary fuel by cookstove type (nationwide)**



The average monthly expenditure is lower among households that use biomass as their main cooking fuel than households using kerosene or to a lesser extent LPG. Purchasing an improved cookstove at the full up-front cost may thus be financially burdensome for the former (Figure 56).

FIGURE 56 • **Main fuel distribution by expenditure quintile**



POLICY RECOMMENDATIONS

More than half of households (53.5%) primarily use kerosene stoves for cooking, a figure that is higher in urban areas. The majority of kerosene stove users are in Tier, mostly due to the Cooking Exposure attribute (kerosene does not qualify as a clean fuel). In order to shift these households to higher tiers, switching to LPG stoves would be critical:

- **Increase penetration of clean fuel stoves** (LPG stoves): The use of LPG stoves can substantially reduce the emission of indoor air pollutants and shift households to higher tiers of access (most LPG stove users in STP enjoy access at Tiers 3-5). Wider adoption of these stoves should therefore be considered, especially in urban areas. The potential for increasing the adoption of LPG stoves should be analyzed with an emphasis on Fuel Availability and Affordability. Based on the results of the analysis, a comprehensive and systematic plan and strategy should be devised that cover both the supply side and the demand side, including awareness raising campaigns.

More than a third (36.7%) of households primarily use open fire or traditional biomass stoves. The majority of these households relying on wood for cooking and to a lesser extent on charcoal are in Tier 0 or 1, mainly because of the Cooking Exposure and Convenience attributes. In order to shift these households to higher tiers, switching to improved biomass stoves would be critical among households that cannot afford clean fuels or do not have clean fuel options available.

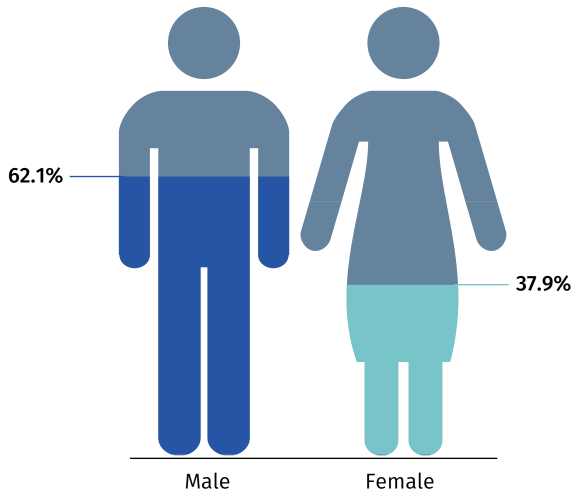
- **Promote improved biomass stoves**: No improved woodstoves exist in the country and only low-performance charcoal improved cookstoves exist. A thorough analysis of the demand side to assess the needs, preferences, and willingness to pay for improved cookstoves needs to be conducted, as well as a campaign to raise public awareness before introducing a range of adequate and sustainable biomass improved cookstoves in the country. That might possibly be coupled with measures offering a payment period or reducing the up-front cost of improved biomass stoves. Users of biomass fuels are indeed poorer than non-solid fuel users in the country.

About a fifth of households in STP (19.6%) lack both access to the grid and access to improved cookstoves for cooking with biomass as a primary fuel. Synergies can be found in providing public support to distributors that could deliver both solar products and improved cookstoves to this segment, improving access to electricity as well as access to modern cooking solutions while reducing the cost of serving these households.

GENDER ANALYSIS

In STP, 37.9% of households are headed by women (Figure 57). The share of female-headed households is higher in urban areas (39.5%) than in rural areas (35.4%). Female household heads are on average five years older than male heads (47.8 versus 42.5 years). The average household size in STP is similar for female- and male-headed households, with four members. The size of urban households is slightly higher for both gender groups.

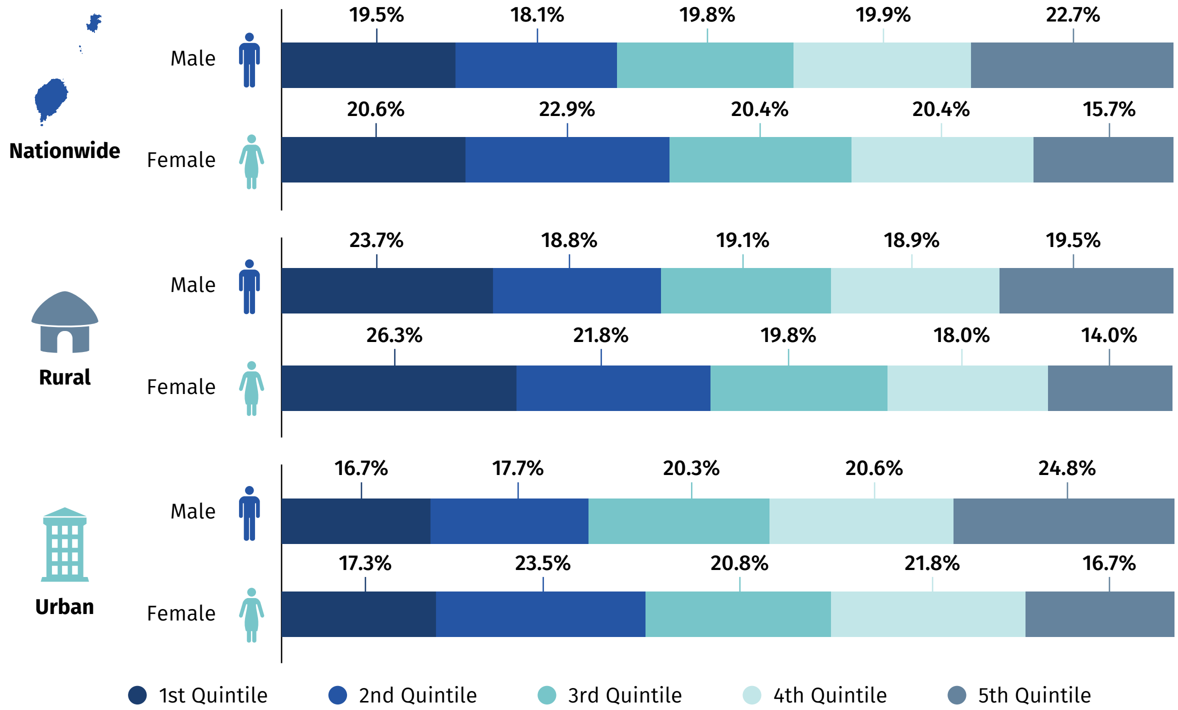
FIGURE 57 • **Distribution of households by gender of household head, nationwide**



On average, male heads of household have higher educational attainment than female heads. More than half of female household heads (54.5%) completed only primary education; this is 12.8 percentage points higher than for male household heads. A larger share of male household heads completed either secondary (47.8%) or university education (5.9%) than their female counterparts.

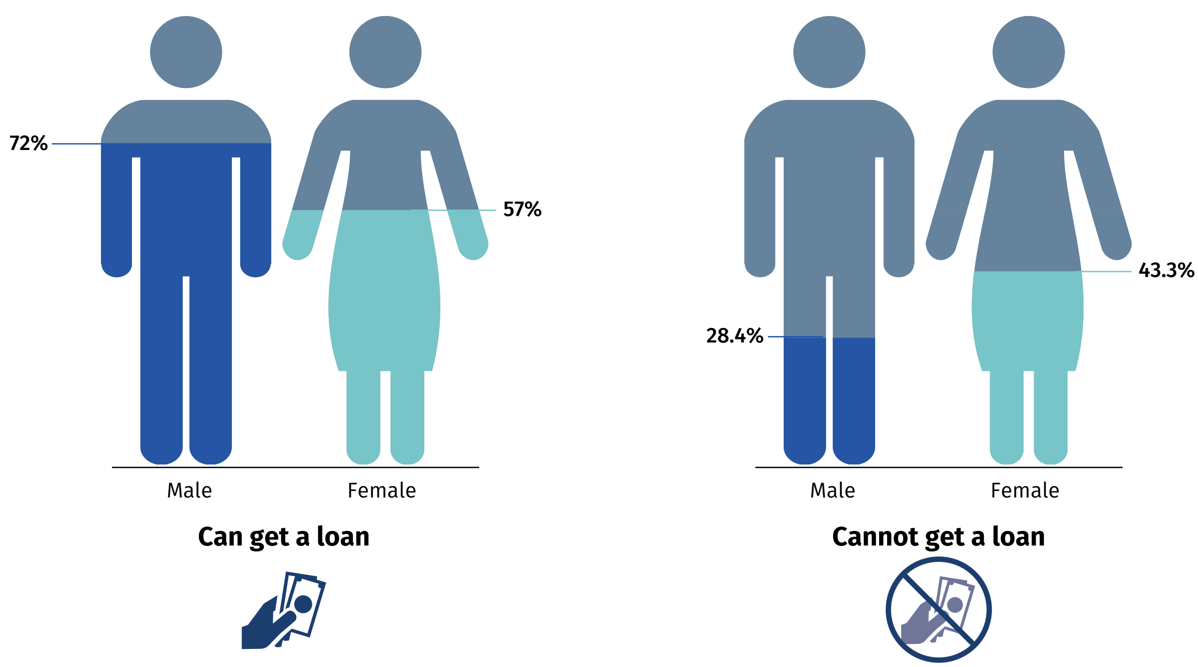
Female-headed households are overrepresented in the bottom expenditure quintiles in STP (Figure 58), with 43.5% of female-headed households in the bottom 40% compared with 37.6% of male-headed households. The average monthly household expenditure is 16% lower for female-headed households than male-headed households (STN 5,028 or USD 244 versus STN 4,214 or USD 205).

FIGURE 58 • Distribution of male- and female- household expenditure quintiles (nationwide, urban/rural)



A gender gap exists regarding access to finance. Only 57% of female-headed household have access to a loan or credit while 72% of male-headed households do (Figure 59).

FIGURE 59 • Access to finance by gender of household head (nationwide)



ACCESS TO ELECTRICITY

In STP, male-headed households are slightly more likely to lack access to electricity (30.5% versus 26.6%) and less likely to have a grid connection (67.6% versus 72.3%) (Figure 60). This is largely because two-thirds of female heads live in the Center-West region, where grid coverage is high. This translates into better performance in terms of tier ranking for female-headed households, with 45.4% in Tiers 4-5 compared to 37.3% of male-headed households (Figure 61). This gap favoring toward female-headed households is more acute in urban contexts, where the percentages belonging to the top two tiers are, respectively, 52% and 40.8%. More than two-fifth (41.3%) of male-headed households in rural areas are in Tier 0, compared with 36.3% of female-headed households.

FIGURE 60 • **Access to electricity, by technology, by gender of the household head (nationwide, urban/rural)**

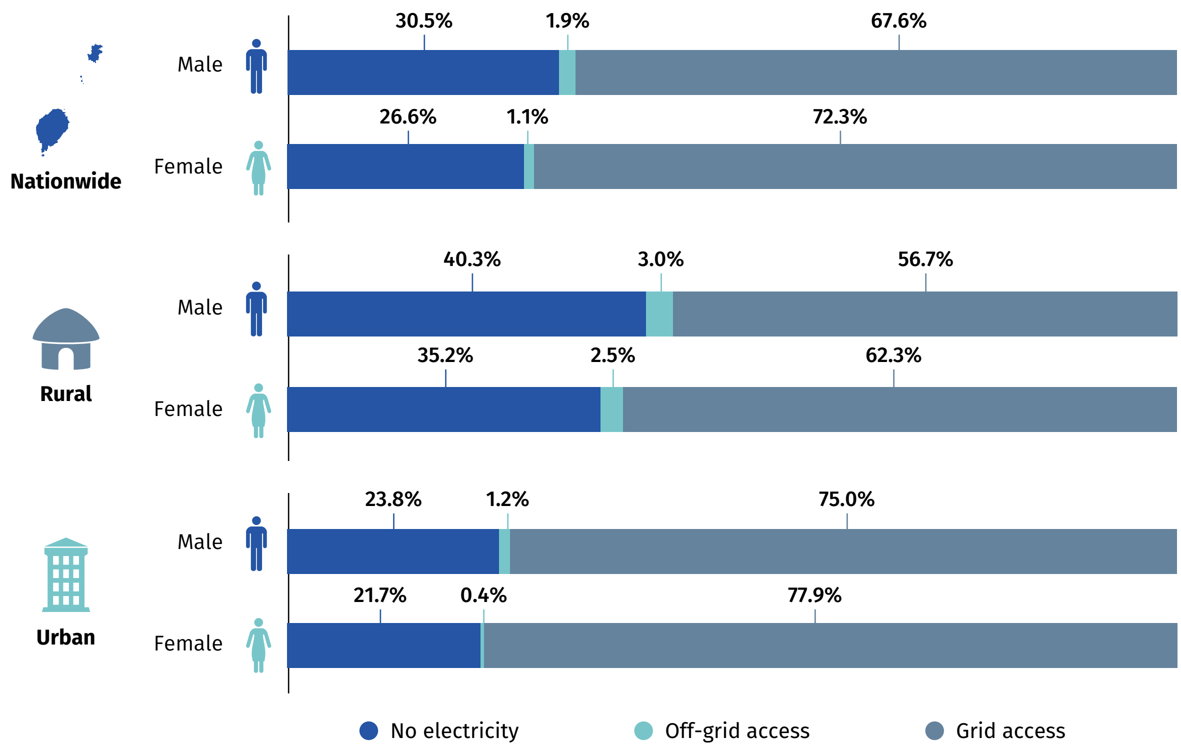
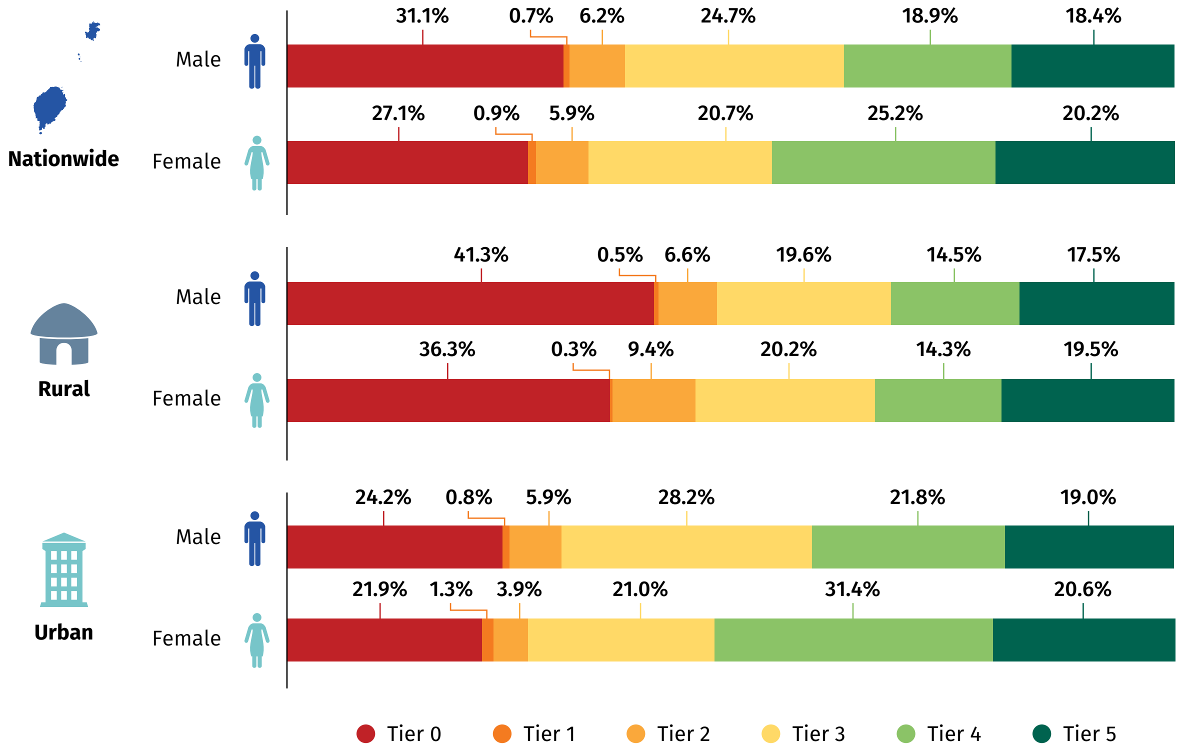
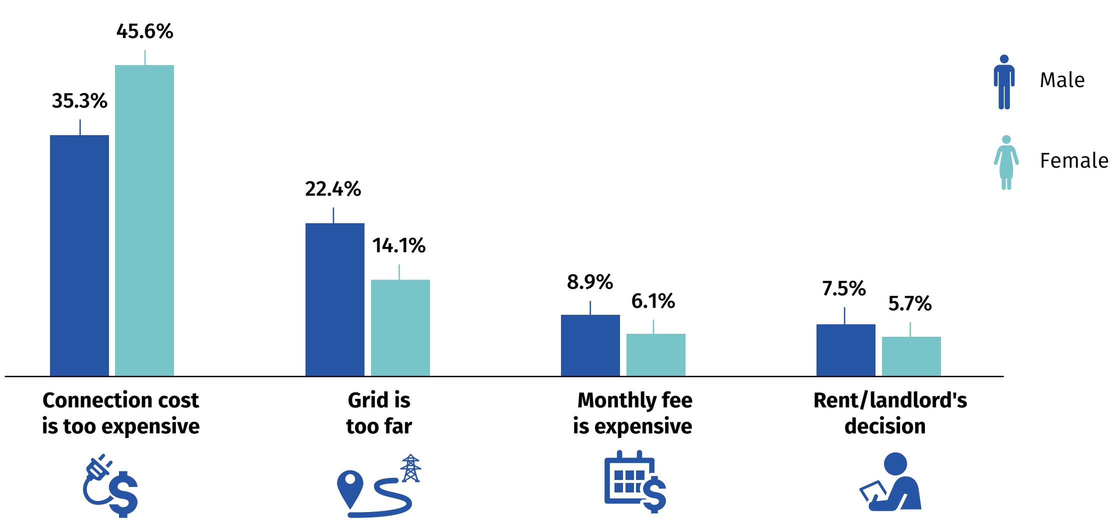


FIGURE 61 • **MTF electricity tier distribution, by gender of the household head (nationwide, urban/ rural)**



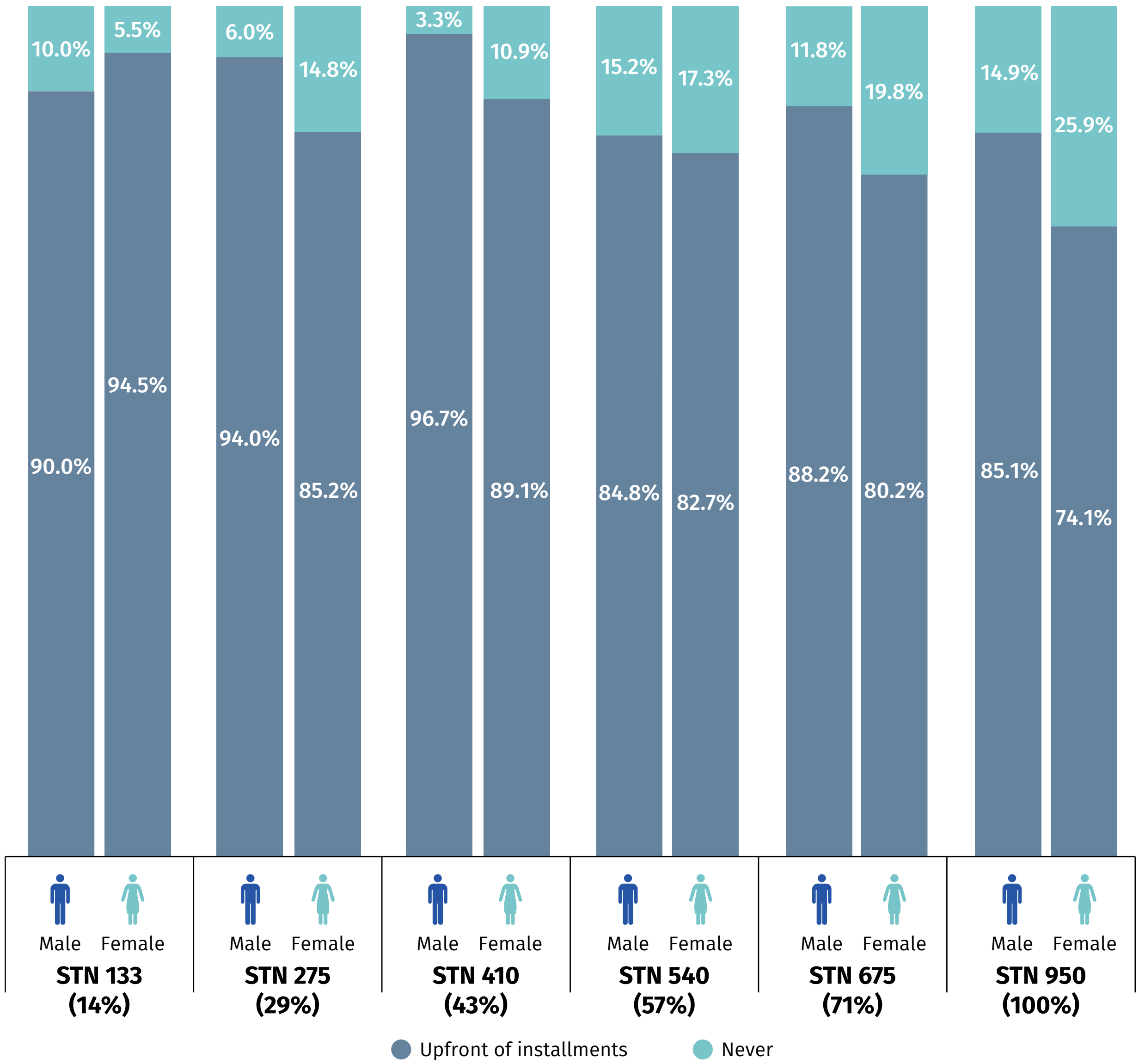
Both male-headed households and female-headed households identified the high cost of grid connection as the main reason they were not connected to the grid (Figure 62). Compared to male-headed households (35.3%), a larger portion of female-headed households (45.6%) reported that high connection cost was a major barrier. The availability of the grid is the second major constraint for both gender groups.

FIGURE 62 • **Barriers to gaining access to the electricity grid, by gender of household head (nationwide)**



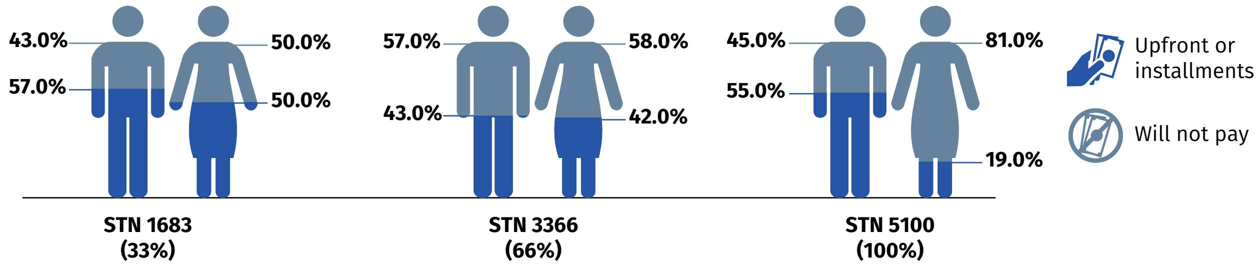
Female-headed households are generally less willing to pay for a grid connection, compared to male-headed households, particularly when the cost of connection is high (Figure 63). About 26% of female-headed households are not willing to pay for a connection fee of STN 950, versus 15% of male-headed households. The gender gap tends to be larger at the higher connection costs. If such cost were reduced to STN 133, the willingness to pay would be higher among female-headed households than among male-headed households.

FIGURE 63 • **Willingness to pay for a grid connection, by gender of the household head (nationwide)**



Female heads of household appeared to be less willing to pay for a SHS (Figure 64). Only 19% of female heads are willing to pay for an SHS at the full price of STN 5,100 (USD 248), against 55% of male heads. The gender gap is smaller at lower prices. Beyond the fact that solar technologies are relatively new and not widespread in STP, the economic gap identified between gender groups could also explain the lower willingness to pay for a SHS among female-headed households.

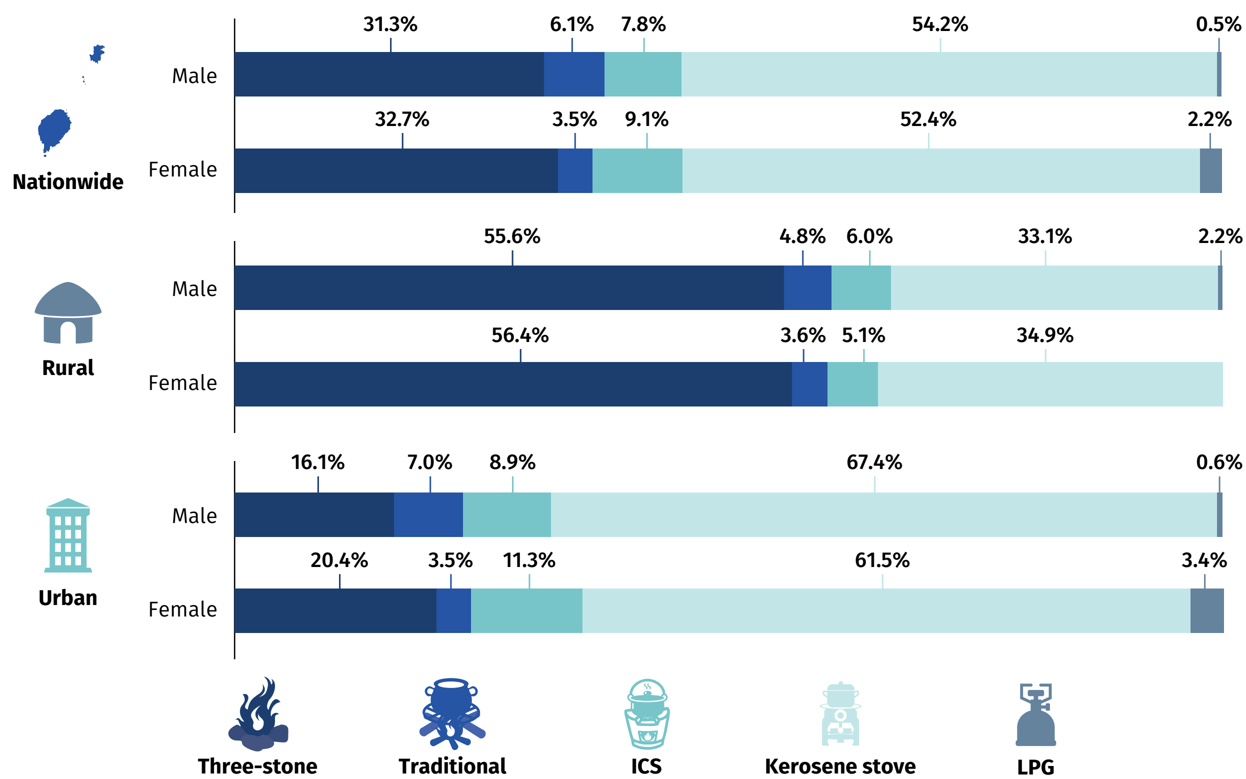
FIGURE 64 • **Willingness to pay for a SHS, by gender of household head (nationwide)**



ACCESS TO MODERN ENERGY COOKING SOLUTIONS

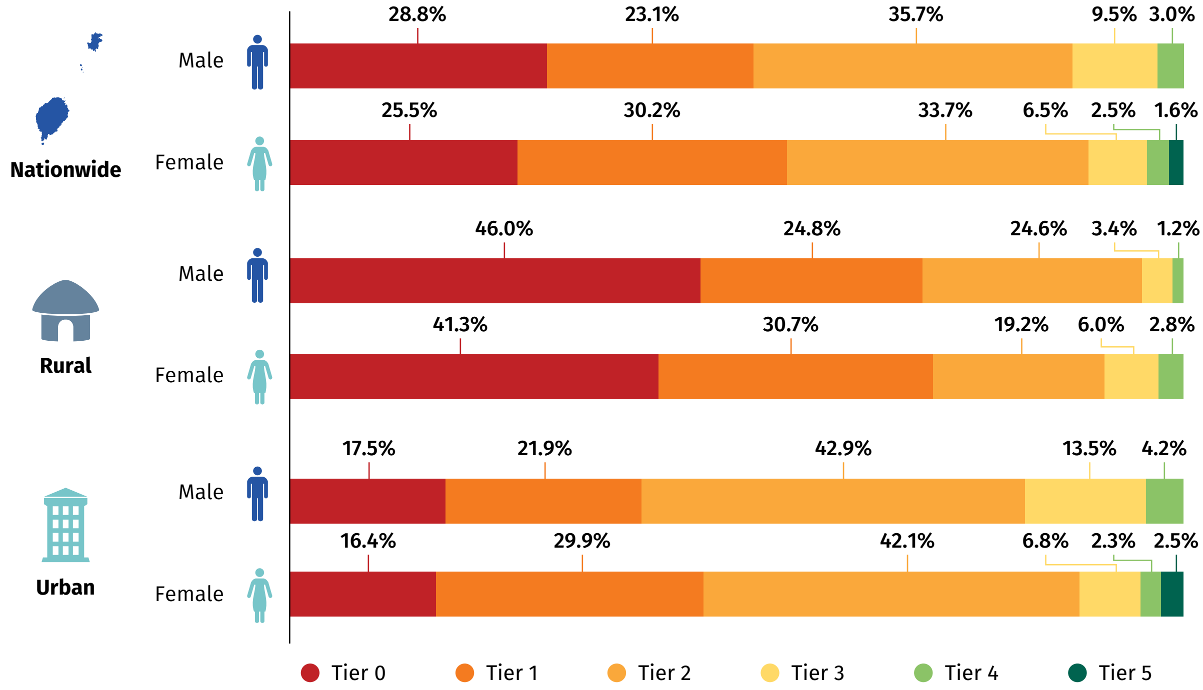
The differences in cookstove types used by female- and male-headed households are fairly small (Figure 65). However, female-headed households are more likely to cook with three-stone stoves, as well as with LPG stoves and improved stoves, especially in urban areas. Male-headed households are more likely to cook with traditional stoves and kerosene stoves, especially in urban areas.

FIGURE 65 • **Access to cooking solutions by technology, by gender of household head (nationwide, urban/rural)**



In terms of MTF tiers of access, male-headed households are slightly more likely to fall in Tier 0 (28.8%) than female-headed households (25.5%) (Figure 66), but they are also more likely to be in Tier 3 and above (12.5% versus 10.6%). Male-headed households show better results in terms of access tiers, especially in urban areas. Only female-headed households reach Tier 5 access, as they are the main users of LPG stoves.

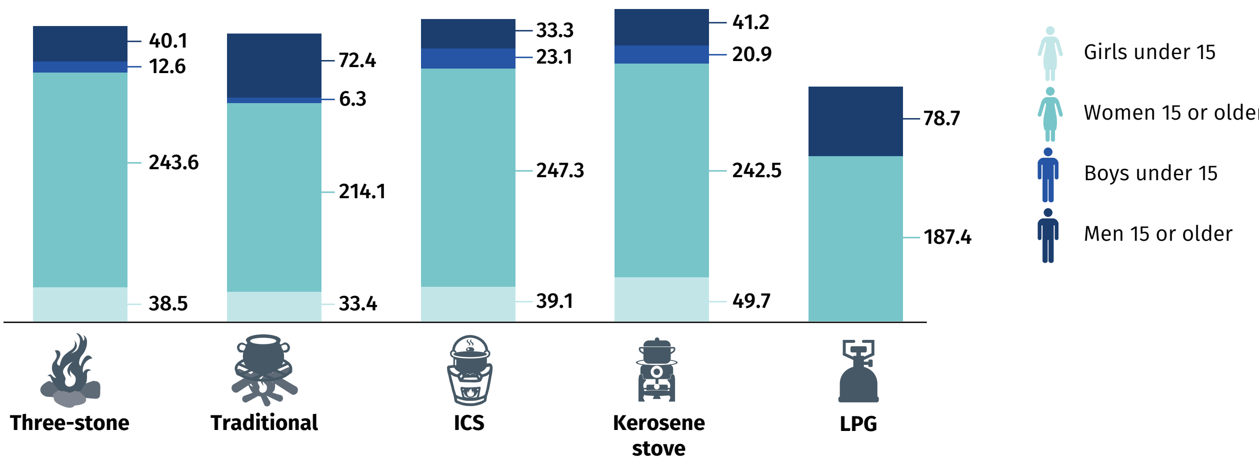
FIGURE 66 • **MTF cooking tier distribution, by gender of the household head (nationwide, urban/rural)**



Female household members, particularly over age 15, spend disproportionately more time in the cooking space relative to their male counterparts (Figure 67). Regardless of the type of primary stove used, the average adult woman spends more than 240 minutes per day in the cooking space[18], compared with around 40 minutes for the average adult man. Men spend the most time in the cooking space for this type of stove, although cooking time with LPG tends to be shorter than with more traditional fuels. Women over age 15 are thus more highly affected by indoor air pollution. Female household members would benefit most from reaching a higher tier for the Cooking Exposure attribute.

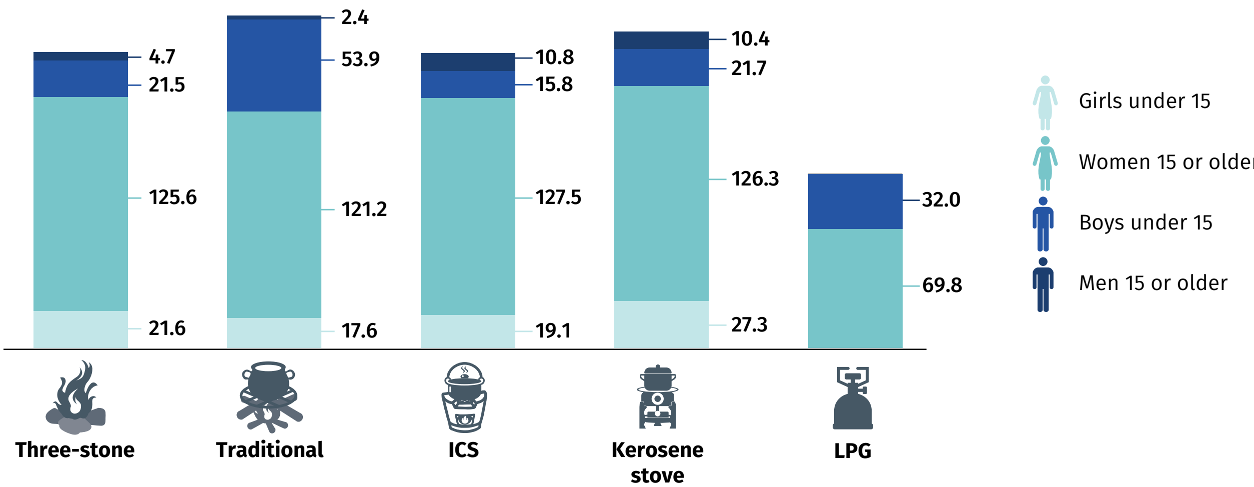
[18] Time spent in the cooking space refers to time spent cooking or undertaking other tasks in that area.

FIGURE 67 • **Time spent in the cooking space (minutes) per day, by gender and age and by primary cookstove type (nationwide)**



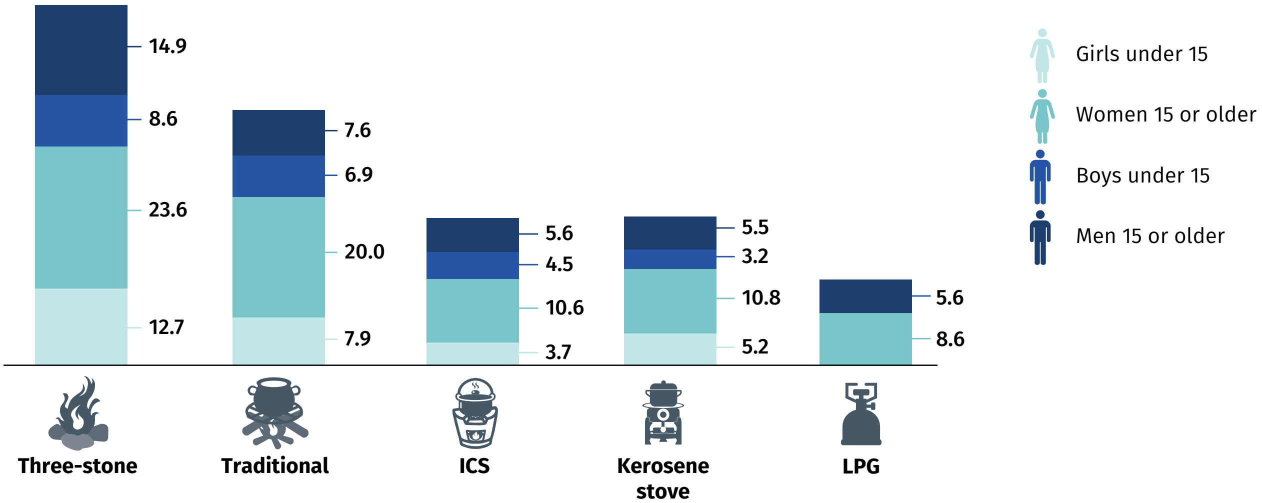
Women ages 15 and above are the primary cooks regardless of cookstove type, since they spend more time than men, girls, and boys on cooking (Figure 68). Improved stoves or kerosene stoves do not seem to reduce the amount of time women spend on cooking (over 120 minutes per day), compared to three-stone stoves and traditional stoves. Only LPG stoves seem to reduce cooking time for women to about 70 minutes per day.

FIGURE 68 • **Time spent on cooking (minutes per day), by gender and age and by primary stove type (nationwide)**



The use of modern cookstoves helps women save time on fuel preparation. Depending on their cookstove type, women in households using biomass spend 10.6 to 23.6 minutes per day preparing fuel for cooking, whereas women with clean fuel stoves spend 8.6 minutes daily (Figure 69).

FIGURE 69 • **Time spent preparing fuel for cooking (minutes per day), by gender and age by primary cookstove type (nationwide)**



POLICY RECOMMENDATIONS

Female-headed households appear to be more financially and socially vulnerable than male-headed households as they tend to be poorer and less educated. Male-headed households are slightly more likely to lack access to electricity and less likely to have a grid connection, largely because two-thirds of female heads live in the Center-West region, where grid coverage is high. Female-headed households are more likely to be unable to pay for a grid connection or an SHS. Therefore:

- Further research should be carried out to identify their needs and priorities and possible ways to overcome barriers to energy access. Several pro-poor targeting actions, whereby female-headed households may be automatically eligible, may be considered, including interest-free credit for the purchase of energy equipment, credit schemes allowing payment of connection fees in affordable installments, subsidized connection costs, and lifeline tariffs.

There is little difference in access to modern cooking solutions between male- and female-headed households at the country level. However, women and girls in STP (particularly those over 15) spend much more time in the cooking area compared with men and boys, as well as more time acquiring and preparing fuels for cooking. They are thus much more likely to be affected by indoor air pollution and more likely to benefit from cleaner cooking solutions for their health as well as to free up time for other activities such as income-generating ones. Therefore:

- Affordability constraints should be addressed for poor households and female-headed households, for example through targeted financing mechanisms. Education campaigns are also recommended to raise awareness of the benefits of clean and efficient cooking solutions targeting both men and women.

ANNEX 1:
Multi-Tier Frameworks

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

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3[b]	TIER 4	TIER 5
Capacity (Power capacity ratings)		<3W	3W-49W	50W-199W	200W-799W	800W-1999W	≥2kW
Availability	**Day**	<4hrs	4-8 hrs	4-8 hrs	8-16 hrs	16-22 hrs	≥23 hrs
	Evening	<1 hr	1-2 hrs	2-3 hrs	3-4 hrs	4 hrs	4 hrs
Reliability	(Frequency of disruptions per week)	> 14	> 14	> 14	> 14	4-14	≤3
	(Duration of disruptions per week)					≥ 2 hrs (if frequency ≤ 3)	<2 hrs
Quality (Voltage problems affect the use of desired appliances)		Yes	Yes	Yes	Yes	No	No
Affordability (Cost of a standard consumption package of 365 kWh/year)		≥ 5% of household expenditure (income)	≥ 5% of household expenditure (income)	≥ 5% of household expenditure (income)	< 5% of household expenditure (income)	< 5% of household expenditure (income)	< 5% of household expenditure (income)
Formality (Bill is paid to the utility, pre-paid card seller, or authorized representative)		No	No	No	No	Yes	Yes
Health and Safety (Having past accidents and perception of high risk in the future)		Yes	Yes	Yes	Yes	No	No

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

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

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

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

ANNEX 2:
Sampling Strategy

LISTING OPERATION

In the absence of reliable updated census information in STP, a nation-wide listing of all the buildings – households, formal and informal businesses/units, as well as public and social infrastructures – was conducted as a basis for sample selection.

In total, 33 830 Permanently Occupied Households have been listed. 12 961 in the rural area and 20 869 in urban environment. Around 74% (25 175) have access to electricity.

TABLE A2.1 • **Number of perrmenance occupied households, per district, environment (rural/urban) and connection to the grid**

District	Rural			Urban			Total		
	Connected to the Grid			Connected to the Grid			Connected to the Grid		
	Yes	No	Total	Yes	No	Total	Yes	No	Total
Lobota	1,440	942	2,382	916	319	1,235	2,356	1,261	3,617
Lembá	412	715	1,127	960	571	1,531	1,372	1,286	2,658
Mé-Zochi	4,003	1,506	5,509	2,454	618	3,072	6,457	2,124	8,581
Aqua Grande	0	0	0	10,640	1,355	11,995	10,640	1,355	11,995
Cantagalo	741	1,054	1,795	1,176	442	1,618	1,917	1,496	3,413
Caué	63	475	538	412	165	577	475	640	1,115
R. A. Principe	1,182	428	1,610	776	65	841	1,958	493	2,451
Total	7,841	5,120	12,961	17,334	3,535	20,869	25,175	8,655	33,830

SAMPLING STRATEGY

Considering the need of assuring a nationwide coverage, a Stratified Households Sampling by urban/rural strata and connected/not connected to national electric grid is applied.

In this case, the calculation of the sample size is done considering the following formula:

$$n = \frac{z^2\, r\, (1\text{-}r)\, f\, k}{e^2}$$

Where:
n = Sample size in terms of number of households to be selected;

f = Sample design effect, 1 Considering a stratified random sampling, the variance of an estimate is inferior to the variance of an estimate of a simple random sampling;

z = z-statistics corresponding to the level of confidence desired (the commonly used level of confidence is 95%, for which z is 1.96);

r = Estimate of the indicator of interest to be measured by the survey, 0,5;

k = Factor accounting for non-response (for most developing countries, the non-response rate is typically 10% or less, so a value of 1.1 [= 1 + 10%] for k would be conservative); and

e = Margin of error, 0,42.

Sample size calculation can be determined by each strata (Urban / Rural) as 600 which results in a national household sample size of 1,200.

The high non-response rate accounted for in previous surveys in STP has been taken into account when calculating an optimal sample size. According to the Instituto Nacional de Estatística de São Tomé e Príncipe (INE-STP), the recent Household Budget Survey (IOF) has registered a national non-response rate of 24.2%. A sample size of 2,400 households has been agreed between WB/ESMAP Team and the consulting firm implementing the survey. The overall sampling error is expected to be approximately 2.5%.

SAMPLE SELECTION

The selection of the permanently occupied households has been carried out based on the following variables of the 'Listing Form':

- District
- Enumeration Area code
- Building code
- Household code
- Access to the national electricity grid (connected / not connected)
- Geographic coordinates of the building (latitude, longitude)
- Urban / rural classification

The selection of households has been done by a systematic process with a random start.

Sampling design considers a stratified random sampling composed of 16 strata:

- (4) National regions: North-West, Center West, Center-East and Príncipe
- (2) Environments: Urban/Rural
- (2) Grid connection status: Connected / Not connected to the national grid

This would result in 150 households per strata. However, it was not possible to assure such dimension for the urban-not connected to the grid criteria in Príncipe region where only 65 households of this strata were listed. To compensate, 85 households were added to the urban-not connected to the grid strata within the other three regions.

The selection of the household sample units follows the distribution below:

TABLE A2.2 • **Household sample units' selection criteria**

	Total					
	Connected to the Grid					
	Yes		**No**		**Total**	
	Pop.	**Sample**	**Pop.**	**Sample**	**Pop.**	**Sample**
North-West	3,728	300	2,547	328	6,275	628
Center-West	17,097	300	3,479	342	20,576	642
Center-East	2,392	300	2,136	315	4,528	615
R. A. Príncipe	1,958	300	493	215	2,451	515
Total	25,175	1,200	8,655	1,200	33,830	2,400

	Rural					
	Connected to the Grid					
	Yes		**No**		**Total**	
	Pop.	**Sample**	**Pop.**	**Sample**	**Pop.**	**Sample**
North-West	1,852	150	1,657	150	3,509	300
Center-West	4,003	150	1,506	150	5,509	300
Center-East	804	150	1,529	150	2,333	300
R. A. Príncipe	1,182	150	428	150	1,610	300
Total	7,841	600	5,120	600	12,961	1,200

	Urban					
	Connected to the Grid					
	Yes		**No**		**Total**	
	Pop.	**Sample**	**Pop.**	**Sample**	**Pop.**	**Sample**
North-West	1,876	150	890	178	2,766	328
Center-West	13,094	150	1,973	192	15,067	342
Center-East	1,588	150	607	165	2,195	315
R. A. Príncipe	776	150	65	65	841	215
Total	17,334	600	3,535	600	20,869	1,200

Household selection also took into account the representativeness of the informal economic activities.

Therefore, 300 households with at least one resident with an informal activity were selected within the 2,400.

ANNEX 3:
Cookstove Typology

Typology	Picture	
Three-stone stove • Open fire • Fuel rests on the ground		
Traditional biomass stove • Enclosed combustion chamber • Pot placed above the fire		
Improved biomass stove • The combustion chamber is well insulated • Fuel rests on a shelf		
Kerosene stoves		
Clean fuel stove • LPG stoves		

ANNEX 4:
SWIFT methodology for estimating household consumption expenditure

In STP, household expenditure was estimated using a specific tool called Survey of Well-being via Instant, Frequent Tracking (SWIFT).

SWIFT is a rapid poverty assessment tool. Developed in-house at the Poverty and Equity Global Practice of the World Bank. It can produce accurate poverty data through household expenditure and poverty data in a very timely, cost-effective and user-friendly manner. It has also been used to improve availability and frequency of official poverty statistics.

Compared with a typical household consumption data collection, SWIFT is much faster and more cost-effective for producing consumption or income data and poverty statistics. This is because instead of collecting primary household consumption or income data, SWIFT collects only 10 to 30 questions on poverty-correlated variables, then projects household income or expenditure from them using a custom-built model, and estimates poverty and inequality statistics from the projected income or expenditure data. The poverty correlates typically include variables such as household size, household head's educational attainment, household head's employment status, ownership of consumer durables and housing conditions. To collect responses to the select questions from a household, we usually need only 7 to 10 minutes. This is much faster than a typical household consumption or income data collection, which takes at least one hour. Furthermore, the SWIFT approach is very quick to estimate poverty and inequality statistics from data collected – in 1 minute or less. This is in contrast with traditional methods that often require over one year to process consumption data collected by an official household survey and estimate poverty and inequality statistics.

BASICS AND ASSUMPTIONS

SWIFT collects only 10 to 30 questions on poverty correlates, projects household income or expenditure from them using a model, and estimates poverty and inequality statistics from the projected income or expenditure data. The poverty correlates usually include household size, household head's educational attainment, household head's employment status, ownership of consumer durables, housing conditions, etc. To do this accurately, model development is critical.

The model is developed assuming the relationship between household income or expenditure and poverty correlates is linear and that there is an error in projection.[19] Equation (a.1) shows this relationship:

[19] This does not mean SWIFT does not use a non-linear model, but it means that SWIFT's formula is linear in variables created in the dataset. Since some variables can be squares of other variables, SWIFT's formula can be non-linear. One of typical examples is that SWIFT uses household size and household size squared in a formula.

$$ln\ y_h = x_h'\beta + u_h \quad \text{(a.1)}$$

where $ln\ y_h$ refers to a natural logarithm of household income or expenditure of household h, x_h is a $(k\times 1)$ vector of poverty correlates of household h, β is a $(k\times 1)$ vector of coefficients of poverty correlates, k is a number of variables, and u_h is a projection error. In principle, SWIFT estimates the linear formula by regressing the natural logarithm of household income or expenditure on a set of poverty correlates in a household survey data that include both household income/expenditure and poverty correlates. The regression model becomes a formula, with which household expenditure or income will be projected into a dataset that has only poverty correlates. The latter dataset will be collected by a SWIFT survey. A SWIFT survey collects the poverty correlates. To improve accuracy of projections, SWIFT adopts approaches used in machine learning, poverty mapping, and multiple imputation. More details are available in annex of the guidelines for SWIFT (Yoshida, et al., 2015).[20]

The SWIFT modeling process includes multiple steps to improve the ability of the formula to project household income or expenditures by adjusting the coefficients (β) and estimating the distributions of both the coefficients and the projection errors. No formula is perfect; so inclusion of the projection error is essential. Indeed, estimating the distribution of the projection error is key for estimating poverty rates and their standard errors.

CROSS VALIDATION

Since consumption patterns can differ significantly across areas and population groups, the SWIFT team makes efforts to create a model that is specific to the areas and population groups of interest. Such an adjustment is good to create the model tailored to the needs, but can cause potentially large bias in poverty estimates because the sample used for creating a model declines by focusing on the specific group of population. “Over-fitting” is one of such problems. The over-fitting problem means that while a model can perform well within the sample developed for the model, it can perform badly outside the dataset. In a sense, the model over-fits the dataset used to develop it. To detect the problem the SWIFT team conducts a cross-validation analysis. The cross-validation approach separates data used for developing the model from those used for evaluating the model fitness.

More specifically, a household survey dataset is split randomly into 10 subsamples. Each of these subsamples is called a “fold.” A consumption model is estimated from nine folds by running a stepwise Ordinary Least Square (OLS) regression.[21] The stepwise OLS regression means that a statistical package searches for an OLS regression model where all variables are statistically significant, at a given p-value level. We use STATA and its stepwise selection model. The nine folds used for developing a model are known as “Training Data”.

After a model is selected, household expenditure or income data is projected using the model in the remaining fold, and a poverty rate and mean squared errors (MSEs) are estimated with the projected

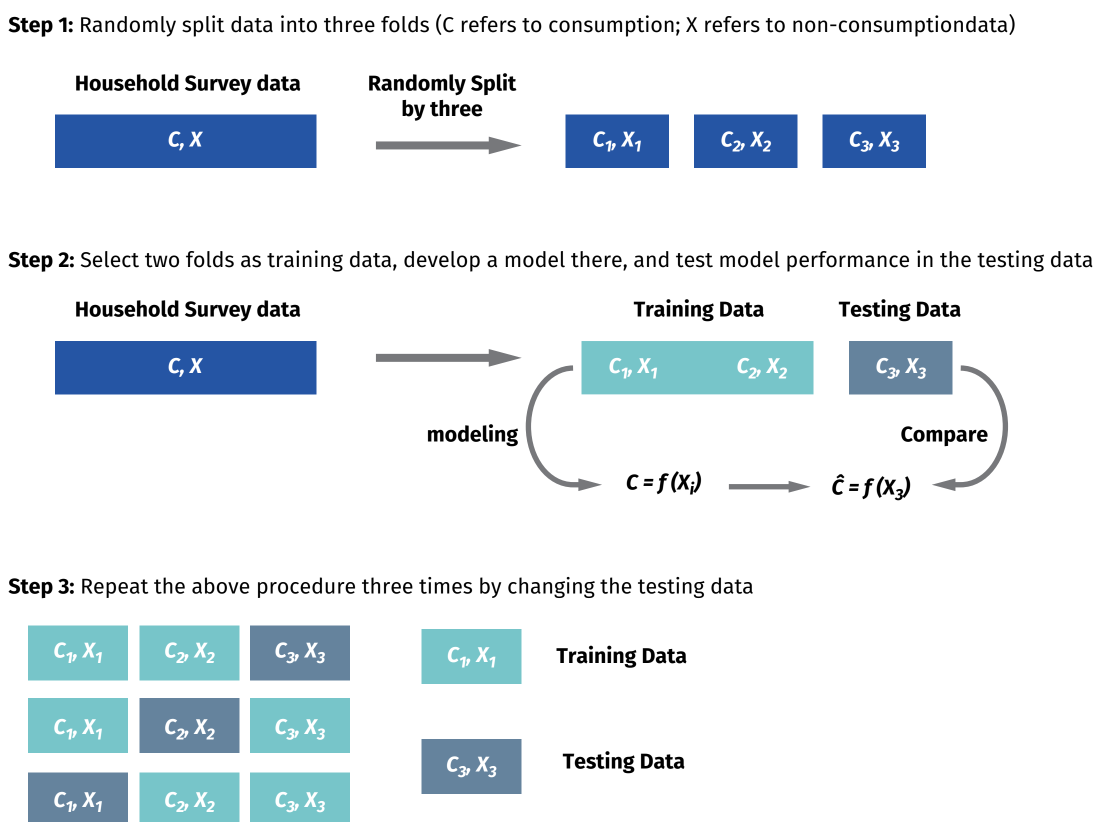
[20] Yoshida et al. (2015), SWIFT Data Collection Guidelines version 2 (Washington, DC: The World Bank).
[21] Or weighted least squares.

data. At the cross-validation stage, we project household expenditure or income data assuming the error term and regression coefficients follow normal distributions.

More specifically, suppose $\hat{\beta}^{2}$ is a vector of estimated coefficients and $\hat{\sigma}^2$ is an OLS estimator of error variance. We first draw a random value χ from a chi distribution with a degree of freedom, $(N\text{-}k)$, where N refers to the total sample size and k refers to the number of variables selected by the stepwise regression procedure, and calculate $\tilde{\sigma} = \hat{\sigma}\,(N\text{-}k)/\chi$. We then draw $\tilde{\beta}$ from a normal distribution of $(\hat{\beta}, \tilde{\sigma}(X'X)^{-1})$ where X is a $(N\times k)$ matrix of $(x_1, \dots, x_h, \dots, x_N)'$. Finally, we draw a simulated household expenditure or income for household h, $\widetilde{(ln\, y_h)}$, from a normal distribution of $(X\hat{\beta}, \tilde{\sigma} I_{N*N})$ where I_{N*N} refers to an $(N\times N)$ identity matrix. This simulation process is repeated for all households, typically twenty times.[22] A poverty headcount rate is calculated by comparing the simulated household expenditure or income with a poverty line for each of the twenty simulation rounds. The average poverty rate of the simulations is used as a poverty estimate. MSE is calculated in testing data by taking the average of the sum of squared differences between y_h and $\hat{y}_h = x'_h * \tilde{\beta}$.

This analysis is repeated 10 times, each of which uses a different fold as testing data to test the performance in terms of mean squared errors and the absolute value of the difference between the projected and actual poverty rates. This test detects the over-fitting problem because all testing statistics are calculated from out-of-sample. Figure 1 shows an illustration of a three-fold cross validation exercise.

FIGURE A4.1 • **Illustration of Three-fold Cross-validation**



[22] This process can be done using STATA's command "mi impute regress", or STATA Corp LP (2013).

This cross-validation exercise is conducted to determine the optimal threshold of the p-value for the stepwise regressions. For a specific p-value, the cross-validation exercise is done and produces the two testing statistics. The exercise is repeated for different levels of p-value, usually between 0.1% and 10%. The optimal p-value is the value where the absolute value of the difference between the actual and the projected poverty rates is minimized. The mean squared error is also examined to check whether the over-fitting problem occurs. If the mean squared error is minimized at a level of p that is smaller than the value where the absolute difference between the actual and the projected poverty rates is minimized, then the former value is chosen as the optimal number.

FINALIZING THE MODEL

After the optimal p-value is selected, a stepwise OLS regression procedure is carried out with a full sample of data to estimate a model. To ensure that the coefficients are stable, an OLS regression with the set of variables is carried out for all ten testing datasets to see whether the coefficients of the select variables do not change signs or are dropped due to collinearity. If some variables are dropped due to collinearity or some signs of the coefficients change, then these variables will be dropped from the final model. After dropping these variables, an OLS regression is carried out to estimate the coefficients and variance of the coefficients and error terms. In addition to the statistical tests, it is recommended to check whether the signs and values of all estimated coefficients make sense to those who know a country very well. If a sign of a variable is the opposite of an expert's intuition, this can be an indicator of multicollinearity and can be very unstable; therefore, it is strongly recommended to reconsider inclusion of such variables.

SIMULATION AND ESTIMATION OF POVERTY RATES

The final model is used to project household expenditure or income for all households 20 times following the procedure presented above. Poverty rates are estimated for each round of simulation and the average is taken as the estimate of the poverty rate. The variance of the poverty estimate is calculated using the following formula (Rubin, 1987 and Schafer, 1999):

$$V(H^*) = \left(1+\frac{1}{m}\right)\left[\left(\frac{1}{m-1}\right)\left(\sum_{l=1}^{m}(H^l - H^*)^2\right)\right] + \left[\frac{1}{m}\sum_{l=1}^{m} V(H^l)\right] \quad \text{(a.2)}$$

where m refers to the number of simulations, H^l refers to the poverty estimate in round l of the simulation, H^* refers to a mean of $\{H^l\}$ and the final estimate of the poverty headcount rate, and $V(H^l)$ is an estimate of the variance of the poverty estimate in round l of simulation. The first bracket presents the between simulation variance, while the second squared bracket presents the within simulation variance. Consequently, the variance of the final poverty estimate is a weighted average of the within and between simulation variances.

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