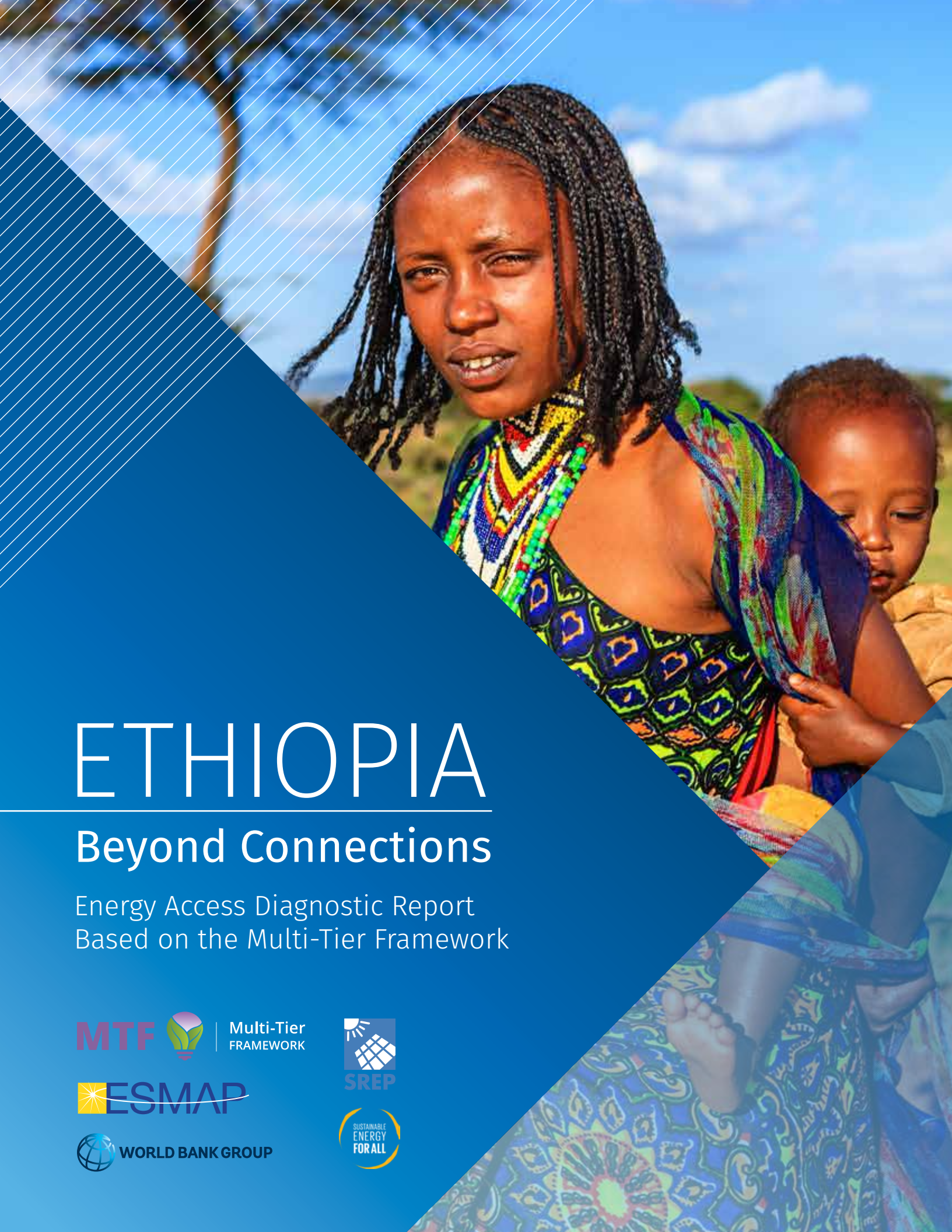

ETHIOPIA

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

MTF Multi-Tier FRAMEWORK

ESMAP

WORLD BANK GROUP

SREP

SUSTAINABLE ENERGY FOR ALL

ETHIOPIA

Beyond Connections

Energy Access Diagnostic Report Based on the Multi-Tier Framework

Written by Gouthami Padam, Dana Rysankova, Elisa Portale, Bryan Bonsuk Koo, Sandra Keller, Gina Fleurantin

MTF Multi-Tier FRAMEWORK

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SUSTAINABLE ENERGY FOR ALL

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ABBREVIATIONS

CSA	Central Statistics Agency of Ethiopia
ESMAP	Energy Sector Management Assistance Program
ICS	improved cookstove
kW	kilowatt
kWh	kilowatt-hour
LPG	liquefied petroleum gas
MTF	Multi-Tier Framework
SHS	solar home system
SLS	solar lighting system
SNNP	Southern Nations, Nationalities and Peoples
SREP	Scaling Up Renewable Energy Program in Low Income Countries
W	watt
WTP	willingness to pay

NUMERICAL HIGHLIGHTS

ACCESS TO ELECTRICITY

- 57% of households have access to at least one source of electricity: 33.1% of households have access through the grid, and 23.9% have access through off-grid solutions.
- Of these 57% of households, only 77.7%—or 44.3% of all Ethiopian households—have access to at least basic electricity supply. The remaining 55.7% have no access to any electricity source, rely on dry-cell batteries, or have a grid or off-grid electricity supply that does not provide basic energy service (ability to light the house and charge phones and available for at least 4 hours a day, including 1 hour in the evening).
- 38.1% of unelectrified households are within 7 kilometers of the national grid and report administrative barriers or delay or refusal in being connected as the main reason for not having a grid connection.
- Half of the electrified households receive service at least 8 hours a day. A fifth of households have electricity available 23 hours a day, 7 days a week.
- 5.2% of electrified households receive less than 4 hours of service per day.
- 57.6% of grid-connected households face 4–14 disruptions a week, and 2.8% of households face more than 14 disruptions a week.
- 15.8% of households face voltage issues—which can damage appliances and limit their use.
- Electricity is affordable for the majority of households: 99.5% of households spending is less than 5% of their total household expenditure for basic grid electricity service.
- On average, electrified households have been connected to the grid for 11 years and consume 120.7 kWh of electricity per month. Most households that use an off-grid solar device bought their first solar product within the last three years.
- Only 29.8% of grid-connected households have medium- or high-load appliances, such as a refrigerator or washing machine.
- 96.1% of households are willing to pay for a grid connection, and 79.8% of households are willing to pay for a solar home system capable of powering a television, either up-front or with a payment plan.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

- 63.3% of households use a three-stone stove as their primary cooking solution.
- Only 4.1% of households use a clean stove with electricity as a fuel. The penetration of electric stoves is higher in urban areas (15.3%) than in rural areas (0.6%).
- 51.5% of households use a three-stone stove exclusively, while only 2.4% use a clean fuel stove exclusively.
- Stove stacking (use of multiple stove types) occurs in 27.2% of households.
- Only 18.2% of households use a manufactured stove, despite high willingness to pay for such a stove: 62.2% of households are willing to pay full price upfront for an improved charcoal stove priced at 175 birr[1], and 28% of households are willing to pay full price with a 6- to 24-month payment plan.
- Penetration of manufactured biomass stoves and clean fuel stoves increases with household spending quintile: 6.1% of households in the top spending quintile use a manufactured biomass stove, compared with 1.3% of households in the bottom spending quintile, and 2.6% of households in the top spending quintile use a clean fuel stove, compared with 0.1% of households in the bottom spending quintile.
- 64.3% of households that use a biomass stove have poor ventilation—they cook indoors with no exhaust system and have two or fewer doors or windows in the cooking space.
- 53.3% of households—including 59.1% of rural households and 32% of urban households—spend more than 7 hours a week acquiring (through collection or purchase) fuel and more than 15 minutes preparing the stove for each meal.
- 28.4% of households use more than 5% of their monthly spending for fuel.

GENDER ANALYSIS

- 18.9% of households are headed by women.
- 47% of female-headed households are in the bottom two spending quintiles, compared with 38.4% of male-headed households.
- 39.6% of households in urban areas are headed by women, compared with 12% of households in rural areas.
- 58.8% of female-headed households are connected to the grid, compared with 27.1% of male-headed households. This is mostly due to a higher concentration of female-headed households in electrified urban areas. The gender gap disappears when female- and male-headed households are compared in urban and rural areas separately.

[1] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

- 37.1% of female-headed households use a solar home system or solar lighting system, compared with 46.5% of male-headed households.
- Among unconnected households, 37.5% of female-headed households are willing to pay full price upfront for a connection to the grid, compared with 60.1% of male-headed households.
- 28.4% of female-headed households are willing to pay full price upfront for an off-grid solar device that allows the household to use lighting service and watch television, compared with 47.5% of male-headed households.
- 33.9% of female-headed households and 14.6% of male-headed households use a manufactured biomass stove, while 8.3% of female-headed households and 3.2% of male-headed households use a clean fuel stove.
- 61.3% of female-headed households and 62.4% of male-headed households are willing to pay full price upfront for an improved biomass stove.

POLICY HIGHLIGHTS

ACCESS TO ELECTRICITY

- Ethiopia's greatest challenge is to enable at least basic electricity supply (Tier 1 and above) to the 55.7% of households that have no or insufficient access to electricity (Tier 0).
- Given that the majority of unelectrified households are located within 10 kilometers of the national grid on average, grid densification could connect many unelectrified households. Densification should address supply-side barriers (in particular, high administrative barriers to connect) and demand-side barriers (providing a mechanism for paying the connection fee over time).
- Given the low electricity consumption and uptake of appliances among rural households, off-grid solar solutions should be prioritized as an immediate solution for unelectrified rural households that are not covered by the densification program in the short term.
- The approach to expand off-grid solar solutions should prioritize larger Tier 1 and Tier 2 systems, given the high willingness to pay for such systems. To maximize uptake, business models that allow users to pay over time should be prioritized. Barriers to expanding larger systems and offering flexible payment options should be analyzed and addressed. RISE indicators for Ethiopia reflect historical policy support for off-grid solutions such as standalone solar home systems.[2]

[2] RISE results for Ethiopia can be viewed at http://rise.worldbank.org/country/ethiopia

- Measures should be taken to improve the Availability, Reliability, and Quality of supply for grid-connected households, so that these households can maximize the benefits of their grid connection. Providing electricity for longer hours, especially in the evening, is important to move grid-connected households in Tiers 1–3 to a higher tier (Tier 4 or 5). In addition, reducing interruptions and improving voltage are important to move households in Tiers 3 and above to a higher tier.
- Given the underutilization of the grid, programs to increase electricity use—in particular programs that focus on the productive uses of electricity and the promotion of energy-efficient appliances—should be explored.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

- Given the low penetration rate of clean fuel stoves (4.1%), the primary objective should be to increase the use of clean fuel stoves—and electric stoves in particular—so that households can enjoy the associated health benefits.
- A starting point is to investigate why only 4.1% of households use electricity as their primary cooking fuel despite the low cost of electricity. One possible reason is that the grid connection is not reliable. Other reasons could include upfront costs of electric stoves, availability of energy-efficient stoves, or cultural factors. Specific measures to increase the uptake of electric stoves—such as financial incentives, payment plans, and awareness campaigns—should be designed.
- Bringing clean fuel stoves to all households may be a long process. In the interim, manufactured biomass stoves are the most feasible solution for the 76.8% of households that use a three-stone or self-built stove. Transitioning to a manufactured biomass stove can deliver important benefits to all household members, and women in particular, through reduced spending on fuel and reduced time spent acquiring fuel and preparing the stove.
- Given the high willingness to pay for a manufactured biomass (improved) stove, the key factors that prevent faster adoption of manufactured biomass stoves should be analyzed and addressed on both the supply side (for example, availability of stoves in all areas of the country) and the demand side (further incentives to switch to manufactured biomass stoves).
- Allowing households to pay in installments would be an effective way to increase households' ability to pay for a manufactured biomass stove without upfront cost subsidies, which often suffer from lack of sustainability.
- The uptake of manufactured biomass stoves could be further increased by awareness campaigns. The campaigns should target ambient and behavior aspects—such as improved ventilation, separating cooking areas from sleeping areas, and minimizing time in the cooking area—among users of both traditional and manufactured biomass stove to limit household members' exposure to harmful pollutants.

GENDER ANALYSIS

- While there is not currently much of a gender gap in access to electricity, ability to pay for and willingness to pay for a grid connection, an off-grid solar solution, and an improved cookstove is lower among female-headed households. These barriers need to be addressed to prevent a gender gap in the future.
- The gender gap in willingness to pay for a grid connection, an off-grid solar solution, and an improved cookstove indicates that gender-targeted awareness efforts and financing mechanisms may be required to incentivize female-headed households to obtain electricity service and modern energy cooking solutions.
- Awareness campaigns should be carried out to incentivize both men and women to switch to stoves with lower emissions. These campaigns should target ambient and behavior aspects—such as improved ventilation, separating cooking areas from sleeping areas, and minimizing time in the cooking area—to limit household members' exposure to harmful pollutants.

KEY FINDINGS AND POLICY IMPLICATIONS

Technologies, attributes, tiers, and use—those are the key concepts that the Multi-Tier Framework (MTF) uses to assess the access of households in Ethiopia to various sources of electricity and improved cooking solutions. It thus goes well beyond traditional binary assessment of energy access—of having or not having a connection to electricity, or using or not using a modern energy cooking solution. The MTF achieves this by capturing the many dimensions of energy access and the wide range of technologies that households use for power and for cooking.

ACCESS TO ELECTRICITY

The MTF approach measures energy access provided by any technology or fuel based on seven attributes that capture key characteristics of the energy supply that affect the user experience (figure 1): Capacity, Availability,[3] Reliability, Quality, Affordability, Formality, and Health and Safety. Based on those attributes, it then defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement (figure 2). Higher tiers are defined by higher Capacity and longer Availability of supply—enabling the use of medium- and high-load appliances (such as refrigerators, washing machines, and air conditioning)—as well as by Affordability, Reliability, Quality, Formality, and Health and Safety.

[3] Previously referred to as "Duration" in the 2015 Beyond Connections report, this MTF attribute is now referred to as "Availability," examining access to electricity through levels of "Duration" (day and evening). For more information, please refer to table A1.1 in this report.

FIGURE 1 • **Multi-Tier Framework attributes for access to electricity**

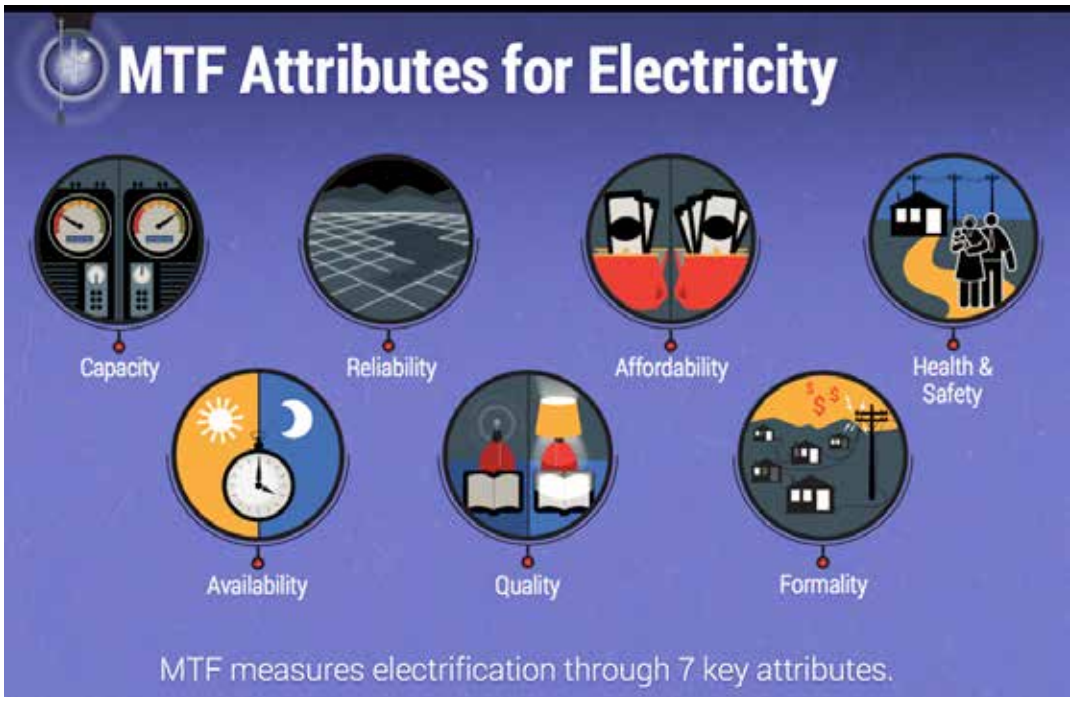
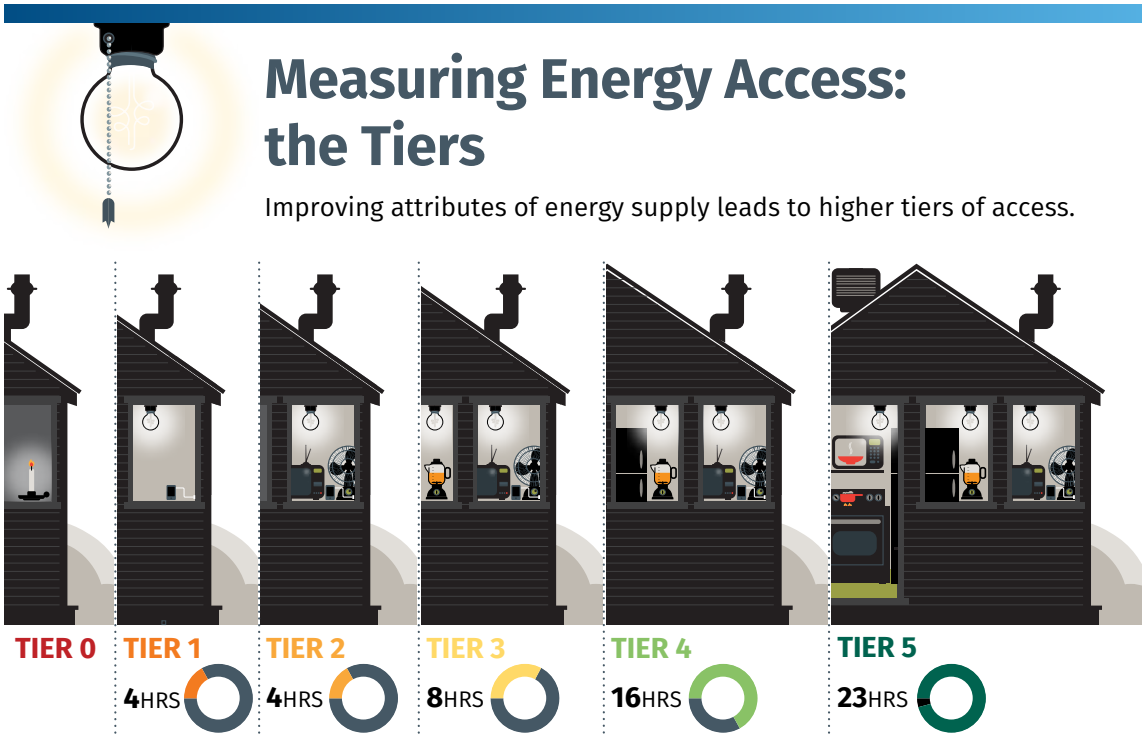


FIGURE 2 • **Multi-Tier Framework tiers for access to electricity**

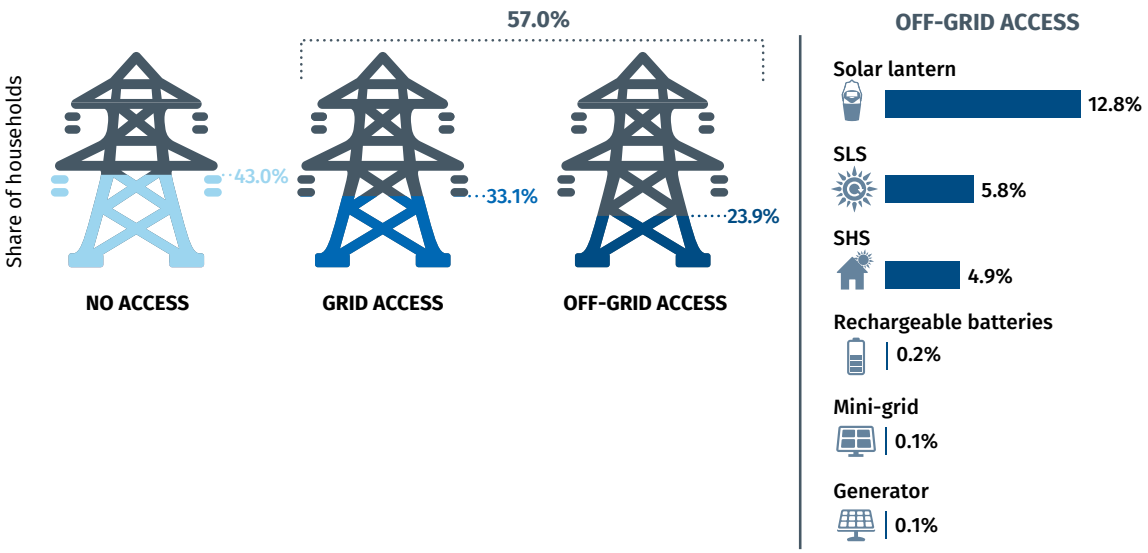


A grid is the most likely source for achieving a higher tier, though a diesel generator or a mini-grid may also do so. Technological advances in photovoltaic solar home systems (SHSs) and direct current–powered energy-efficient appliances also make higher access possible—to Tier 3 and even Tier 4—but such systems are rare in Ethiopia today.

Technologies. In Ethiopia 57% of households have access to at least one source electricity: 33.1% of households have access through the grid, and 23.9% have access through off-grid solutions (mostly solar lanterns) (figure 3). Off-grid solar solutions for households are a recent phenomenon in Ethiopia: 82% of households that use one as their primary source of electricity acquired it within the last three years.

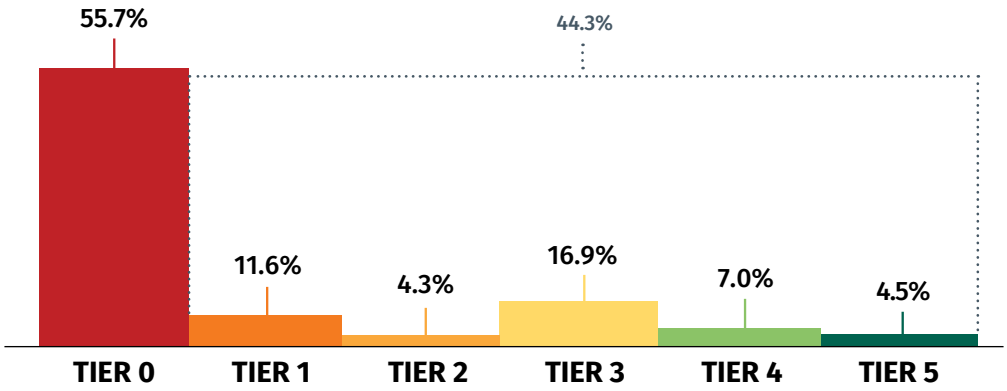
Off-grid solutions are more common in rural areas, where there is limited access to the grid: 31.6% of rural households use an off-grid solution as their primary source of electricity, and the majority of these households use a solar lantern.

FIGURE 3 • **Nearly 60% of households have access to at least one source of electricity**



MTF Tiers. Although 57% of electrified households have access to at least one source of electricity (either through on-grid or off-grid solutions), only 77.7% of those households—or 44.3% of all Ethiopian households—have access to at least basic electricity supply that qualifies them to be in Tier 1 (figure 4). The remaining 55.7% of households have no electricity source, rely on dry-cell batteries, or have a grid or off-grid electricity supply that does not provide the ability to light the house and charge phones and that is not available for at least 4 hours a day and 1 hour in the evening.

FIGURE 4 • **The majority of households do not have access to any source of electricity; most electrified households are in Tier 3**



Grid-connected households are in Tiers 2–5 for access to electricity, with the largest share in Tier 3, while most households that use an off-grid solution are in Tier 0 or 1. Of households in Tier 0, 33% do not have access to any source of electricity, and 44.2% use dry-cell batteries as their primary source of electricity.

There is a wide disparity in the share of households that are in Tier 3 or above for access to electricity between urban areas (82.9%) and rural areas (10.3%). The average tier is 3.2 for urban households, compared with 0.6 for rural households. This can be attributed largely to the fact that most rural households do not have access to any type of electricity.[4]

MTF Attributes. A key question that the MTF survey seeks to answer is what prevents 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 policymakers to pursue data-informed energy access policies and to design interventions that remove barriers to households moving to a higher tier. The value of access to electricity for households is defined by analyzing MTF attributes (as answered by questions embedded in the MTF survey):

- **Capacity:** *What appliances can I power?*
- **Availability:** *Is power available when I need it?*
- **Reliability:** *Is my service frequently interrupted?*
- **Quality:** *Will voltage fluctuations damage my appliances?*
- **Affordability:** *Can I afford to purchase the minimum amount of electricity?*
- **Formality:** *Is the service provided formally or by informal connections?*
- **Health and Safety:** *Is it safe to use my electricity service or do I risk injuries from using this service?*

[4] The MTF approach does not count dry-cell battery users as having access to electricity.

Because grid-connected households are considered to receive high-capacity electricity (over 2,000 W) or Tier 5 access, the proportion of households that receive Tier 5 access is the same as the proportion of households that are connected to the grid (33.1%). While 96.2% of urban households are in Tier 5 for Capacity, only 12.2% of rural households are, and 16.8% of rural households are in Tier 1, due mostly to the penetration of off-grid solutions.

Electricity is available at least 23 hours a day, 7 days a week, for 20.9% of households, but 5.2% of grid-connected households receive less than 4 hours of service per day. In rural areas limited Availability is more acute: only 9.6% rural households receive more than 23 hours of supply a day, while 60.1% receive less than 8 hours a day. And 54.7% of households nationwide receive electricity for 4 hours during the evening, when lighting is required the most.

In Ethiopia 57.6% of grid-connected households face 4–14 outages a week, and 2.8% of households face more than 14 outages a week. Reliability of supply is holding back these grid-connected households from moving to a higher tier for access to electricity.

In Ethiopia 15.8% of households experience voltage issues—such as low or fluctuating service—that limit their use of appliances. The prevalence of voltage issues is similar in rural and urban areas. Electric appliances generally require a certain voltage supply to operate properly, and low voltage supply tends to result from an overloaded electricity system or from long-distance low-tension cables connecting spread-out households to a singular grid. Voltage fluctuations and surges can damage electrical appliances and sometimes result in electrical fires.

Almost all households nationwide and in rural and urban areas pay less than 5% of their household spending for basic electricity service (at least 1 kWh a day and 365 kWh a year). Electricity tariffs in Ethiopia are low, so most grid-connected households can afford to pay for the minimum level of service to satisfy basic electricity needs.

Use. On average, electrified households have been connected to the grid for 11 years and consume 120.7 kWh of electricity per month;[5] urban households consume more than three times as much as rural households. Spending on electricity (60.10 birr or about $2.70[6] a month) accounts for 4.3% of average monthly household spending; this share is higher (5.2%) for rural households (24.10 birr or about $1.10 a month) and lower (1.9%) for urban households (73.90 or about $3.30 a month). Based on appliance ownership, grid-connected households do not take full advantage of the service performance of the electricity supply they receive. Most grid-connected households use low-load electric appliances corresponding to Tiers 1–3. This is true particularly in rural areas, where 74.6% of households in Tiers 2–5 own only Tier 1 appliances (lighting, phone charging, and radio; see table 1).

Among households that use an off-grid solar device, 98.1% have very low–load appliances, while 29.8% of grid-connected households have medium- or high-load appliances. Households that

[5] Consumption data are from household electricity bills.
[6] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

use an off-grid solar device use electricity mostly for phone charging (47.6%) and radio (11%), while grid-connected households use electricity to power larger appliances such as refrigerators, washing machines, televisions, and air coolers.

Improving access to electricity. Ethiopia's greatest challenge is to enable at least basic electricity service (Tier 1 or above) to the 55.7% of households in Tier 0 that have no or insufficient access to electricity.

Grid densification could connect a large number of currently unelectrified households, given that many of them are located within 7 kilometers of the national grid. The densification approach should address supply-side barriers (in particular, high administrative barriers to connect) and demand-side barriers (providing a mechanism to pay the connection fee over time or simplifying the complex application process).

Given the low electricity consumption and uptake of appliances among rural households, off-grid solar solutions should be prioritized as an immediate solution for unelectrified rural households that are not covered by the grid densification program in the short term. The approach to expand off-grid solar solutions should prioritize larger Tier 1 and Tier 2 systems, given the high willingness to pay (WTP) for such systems. To maximize uptake, business models that allow users to pay for the system over time should be prioritized. Barriers to expanding larger systems and offering flexible payment options should also be analyzed and addressed.

Providing electricity for longer hours is important to move grid-connected households in Tiers 1–3 to a higher tier (Evening Availability is a particularly large problem for households in Tiers 2 and 3), while reducing interruptions and improving voltage are important to move households in Tiers 3 and 4 to a higher tier. Affordability of grid electricity is not a major barrier in Ethiopia. Providing 3 hours of supply in the evening would help move 3.6% of households to Tier 3, and providing 4 hours of supply in the evening would move 13.2% of households to Tier 4 (provided the service is reliable and there are no voltage issues). Reducing supply interruptions to less than 3 a week and ensuring that the total duration is less than 2 hours would move 3.8 % of households to Tier 5.

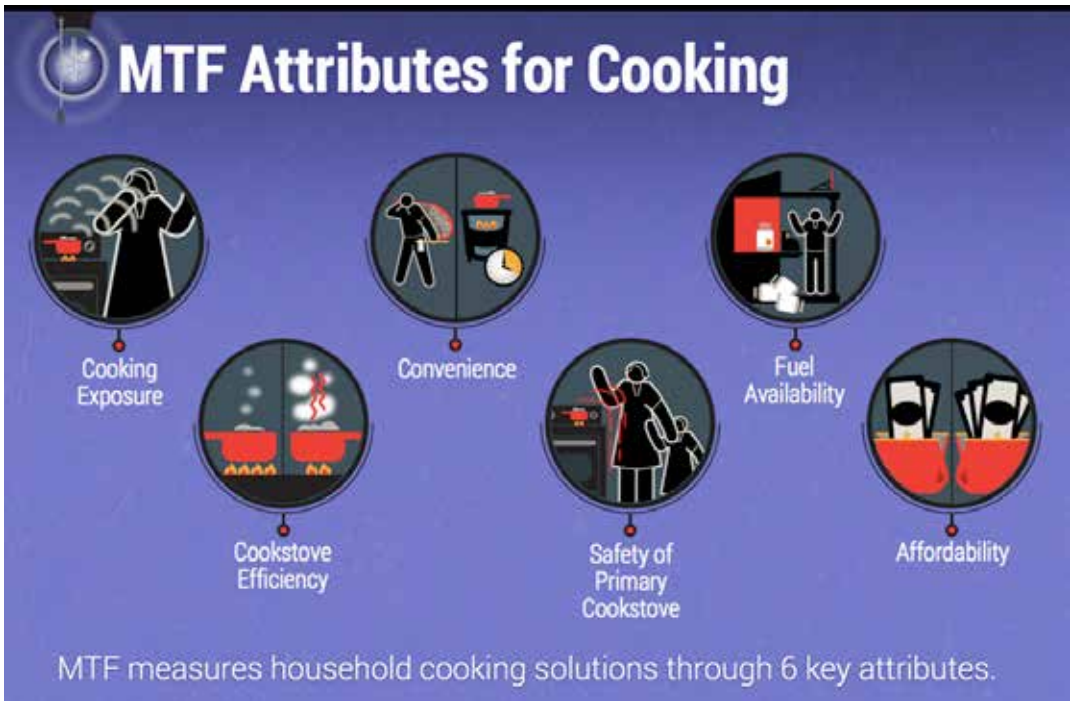
The vast majority of households are satisfied with their on-grid or off-grid electricity service (80.1% and 73%, respectively). Among households that use an off-grid solar solution, satisfaction increases with system size. Capacity and Availability are the main issues that the households cited with their off-grid solar devices and which could be resolved.

Considering the relative underutilization of the grid, programs to increase electricity use should be explored, in particular promotion of productive uses of electricity and energy-efficient appliances.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

The MTF approach measures access to modern energy cooking solutions based on six attributes (figure 5). Attributes directly related to the cooking solution (cookstove and fuel), such as Cooking Exposure, Cookstove Efficiency, and Safety of Primary Cookstove, are the main concern in the lower tiers. This report uses a simplified interim framework based on four stove categories: three-stone stove, self-built stove, manufactured biomass stove, and clean fuel stove.

FIGURE 5 • **Multi-Tier Framework attributes for access to modern energy cooking solutions**



MTF Attributes. A key question about cookstoves and their use is what constrains a household from moving to a higher tier. Equipped with the answers, policymakers can target energy and design interventions to remove barriers. Answering the question starts with the analysis of attributes that define the value of access to modern energy cooking solutions and fuels for the customer (as answered by the questions in MTF surveys). Each tier specifies the performance criteria for each attribute (see table A1.2). For stoves, the issues are:

- **Cooking Exposure:** *How is the user's respiratory health affected?* This is based on personal exposure to pollutants from cooking activities, which depends on stove emissions, ventilation structure (which includes cooking location and kitchen volume[7]), and contact time (time spent in the cooking environment).

[7] 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.

- **Cookstove Efficiency:**[8] *How much fuel will a person need to use?*
- **Convenience:** *How long does it take to gather and prepare the fuel and stove before a person can cook?*
- **Safety of Primary Cookstove:** *Is it safe to use the stove, or does a person expose himself or herself to possible accidents?* This can be based on laboratory testing and the absence of serious accidents in the household.
- **Affordability:** *Can a person afford to pay for both the stove and the fuel?*
- **Fuel Availability:** *Is the fuel available when a person needs it?*

In Ethiopia 63.6% of households, including 77.5% of rural households and 18.8% of urban households, use a three-stone stove, which emits a high rate of pollutants, such as particulate matter below 2.5 microns in diameter and carbon dioxide. Those households are in Tier 0 for stove emissions. In contrast, 32.2% households use either a self-built stove or a manufactured biomass stove, both of which emit a lower rate of pollutants. Those households are in Tiers 1–3 for stove emissions. Lack of detailed information on specific stove type and stove emissions prevents more precise tier classification. The penetration rate of clean fuel stoves, mostly electric stoves, is still low, at 4.1%. Households that use a clean fuel stove—including 0.6% of rural households and 15.3% of urban households—are in Tier 5 for stove emissions.

A household can move to a higher tier for Cooking Exposure if it has good ventilation, which depends on the cooking location and the presence of an exhaust system (such as a hood or chimney). The cooking location for the primary stove is outdoors for 13.9% of households that use a manufactured biomass stove, including 12.3% of rural households and 19.9% of urban households. Of households that cook indoors and whose primary stove is a biomass stove, 64.3% have poor ventilation (no exhaust system and two or fewer doors or windows in the cooking space). More urban households (70.8%) than rural households (62.6%) have poor ventilation.

Nationwide, 56.3% of households are in Tier 0 for Cooking Exposure, mainly because they use a three-stone stove as their primary cooking solution and do not have good ventilation. Although 63.3% of households use a three-stone stove, some of these households are in Tier 1 if they have good ventilation, while 39.5% of households are in Tiers 1–3 because they use a self-built stove or manufactured biomass stove. Lack of detailed information on stove emissions prevents more precise tier classification. Only 4.2% of households use a clean fuel stove (mostly with electricity) and are in Tier 5.

Nationwide, 53.3% of households are in Tier 1 for Convenience because they spend more than 7 hours a week acquiring (through collection or purchase) fuel and more than 15 minutes preparing the stove for each meal. More rural households (59.1%) than urban households (32%) are in Tier 1. And 48% of rural households spend more than 7 hours a week acquiring fuel, compared

[8] Cookstove Efficiency was not calculated in Ethiopia because of a lack of detailed data.

with 9% of urban households. In contrast, 4.9% of households nationwide are in Tier 4 or 5 for Convenience as they use a clean fuel stove and do not spend much time on fuel acquisition and preparation or stove preparation. Because more urban households than rural households use a clean fuel stove, 16.9% of urban households and 1.6% of rural households are in Tier 4 or 5.

Affordability of fuel prevents 28.4% of households from reaching a higher tier for access to modern energy cooking solutions because primary cooking fuel accounts for more than 5% of their monthly spending. Of those households, 66.2% use firewood as their primary cooking fuel, and 30.9% use charcoal. Because more urban households than rural households purchase firewood for cooking, 43.6% of urban households use more than 5% of their monthly spending for fuel, compared with 23.7% of rural households.

Safety of Primary Cookstoves and Fuel Availability are not major constraints for households.

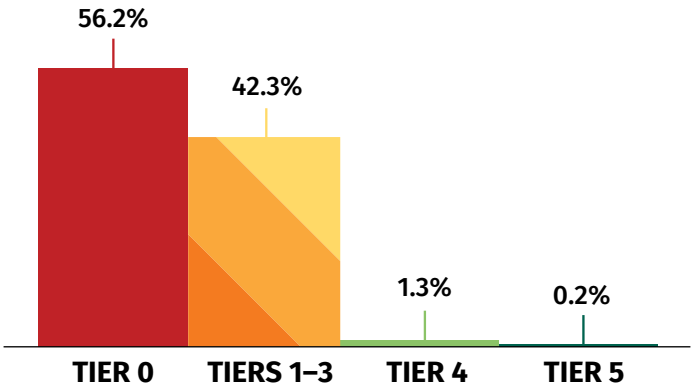
Technologies. In Ethiopia 63.3% of households use a three-stone stove as their primary stove, 13.6% use a self-built stove, 18.2% use a manufactured biomass stove, and 4% use a clean fuel stove with electricity. Cooking with clean fuels such as biogas and liquefied petroleum gas (LPG) is rare. Less than 1% of households use LPG as their primary cooking solution, while 96% of households use biomass fuels. Urban and rural households use different cooking technologies: 54.3% of urban households use a manufactured biomass stove, and 15.3% use a clean fuel stove, while 77% of rural households use a three-stone stove. And 85.4% of rural households use firewood as their primary fuel, while 60.3% of urban households use charcoal.

MTF Tiers. Nationwide, 56.2% of households are in Tier 0 for access to modern energy cooking solutions because they use a three-stone stove as their primary cooking solution and have poor ventilation, and 42.3% of households are in Tiers 1–3 because they use a self-built or manufactured biomass stove (figure 6). Self-built and manufactured biomass stoves meet the requirement for at least Tier 1, but because of a lack of information on the emissions of these types of stoves, the exact tier status for these stoves could not be determined. So most of these households are assigned to Tiers 1–3. Only 1.5% of households are in Tier 4 or 5.

Only 2.4% of households use a clean fuel stove exclusively, while 2.7% of households use a clean fuel stove in combination with a manufactured biomass stove. Households that use a clean fuel stove in combination with a manufactured biomass stove are held back in a lower tier because of the Convenience or Affordability attributes.

In rural areas 69.1% of households are in Tier 0 because they use a three-stone stove as their primary cooking solution, while in urban areas 80.4% of households are in Tiers 1–3 because they use a self-built or manufactured stove. Although 15.3% of urban households use a clean fuel stove as their primary stove, only 5.1% of them are in Tier 4 or 5 for access to modern energy cooking solutions. Convenience, Safety of Primary Cookstove, Affordability, and Fuel Availability keep some households in a lower tier.

FIGURE 6 • **More than half of households are in Tier 0 for access to modern energy cooking solutions**



Improving access to modern energy cooking solutions. The ultimate objective of improving access to modern energy cooking solutions in Ethiopia should be to provide all households with access to cooking solutions that are clean, convenient, efficient, affordable, safe, and available (that is, to move all households to Tier 4 or 5 for access to modern energy cooking solutions). Given the low penetration rate of clean fuel stoves (4.1%), the primary objective should be to increase the use of clean fuel stoves—and electric stoves in particular—so that households can enjoy the associated health benefits.

It is worth investigating why only 4.1% of households use electricity as their primary cooking fuel despite the low cost of electricity. One possible reason is that the grid connection is not reliable, especially given that only 4.5% of households nationwide, 11.3% of urban households, and 2.2% of rural households are in Tier 5 for access to electricity. Upfront costs of electric stoves, availability of energy-efficient stoves, or cultural factors could also be reasons. Specific measures to increase the uptake of clean fuel stoves—such as financial incentives, payment plans, and awareness campaigns—should be designed.

Bringing clean fuel stoves to all households may be a long process. In the interim, manufactured biomass stoves are the most feasible solution for the 76.8% of households that use a three-stone or self-built stove. Transitioning to a manufactured biomass stove can deliver important benefits—namely less time collecting firewood (because manufactured biomass stoves use considerably less fuel than three-stone and self-built stoves)—with women in particular benefiting.

Increased adoption of manufactured biomass cookstoves would move the 56.2% of households currently in Tier 0 for access to modern energy cooking solutions to Tier 1 or above. This is likely a feasible goal, given the high WTP for an improved cookstove in Ethiopia. Currently 62.2% of households are willing to pay full price upfront for such a stove, and 28% of households are willing to pay full price with a 6- to 24-month payment plan. The key factors that prevent faster adoption of manufactured biomass stoves should be analyzed, and the constraints should be addressed on both the supply side (for example, availability of stoves in all areas

of the country) and the demand side (further incentives to switch to manufactured biomass stoves).

GENDER ANALYSIS

Nationwide, 18.9% of households are headed by women. Female-headed households are more likely than male-headed households to live in urban areas: 39.6% of urban households are headed by women, compared with 12% of rural households.

Access to electricity. There is not much of a gender gap in access to electricity. Nationwide, more female-headed households (58.8%) than male-headed households (27.1%) have access to the grid, fewer female-headed households (36.4%) than male-headed households (60.2%) are in Tier 0, and more female-headed households (51.7%) than male-headed households (22.8%) are in Tiers 3–5. But when comparing tier distribution within urban and rural areas, the difference in access rates between female- and male-headed households is much smaller: in urban areas 96.7% of both female- and male-headed households have access to the grid electricity, and 3.1% of both female- and male-headed households have no access to any source of electricity. In rural areas 23.8% of female-headed households and 15% of male-headed households have access to the grid, and 43.7% of female-headed households and 42.9% of male-headed households do not have access to any source of electricity.

Among households, more female-headed (25.3%) than male-headed households (18.8%) are in the bottom spending quintile. The gap is consistent in both urban and rural areas and suggests that a larger share of female-headed households than of male-headed households have less ability to pay for access to electricity (either through the grid or through off-grid solutions).

Fewer female-headed households than male-headed households are willing to pay for a grid connection or a Tier 2 off-grid solar device: 15.5% of female-headed households are not willing to pay upfront or through a payment plan for a grid connection, compared with 2.6% of male-headed households, and 30.5% of female-headed households are not willing to pay upfront or through a payment plan for a Tier 2 off-grid solar product, compared with 18.6% of male-headed households.[9]

Although there is no substantial gender gap in access to electricity, financial support to help female-headed households in the bottom two spending quintiles obtain to access to electricity are needed to prevent the gap between female- and male-headed households from growing.

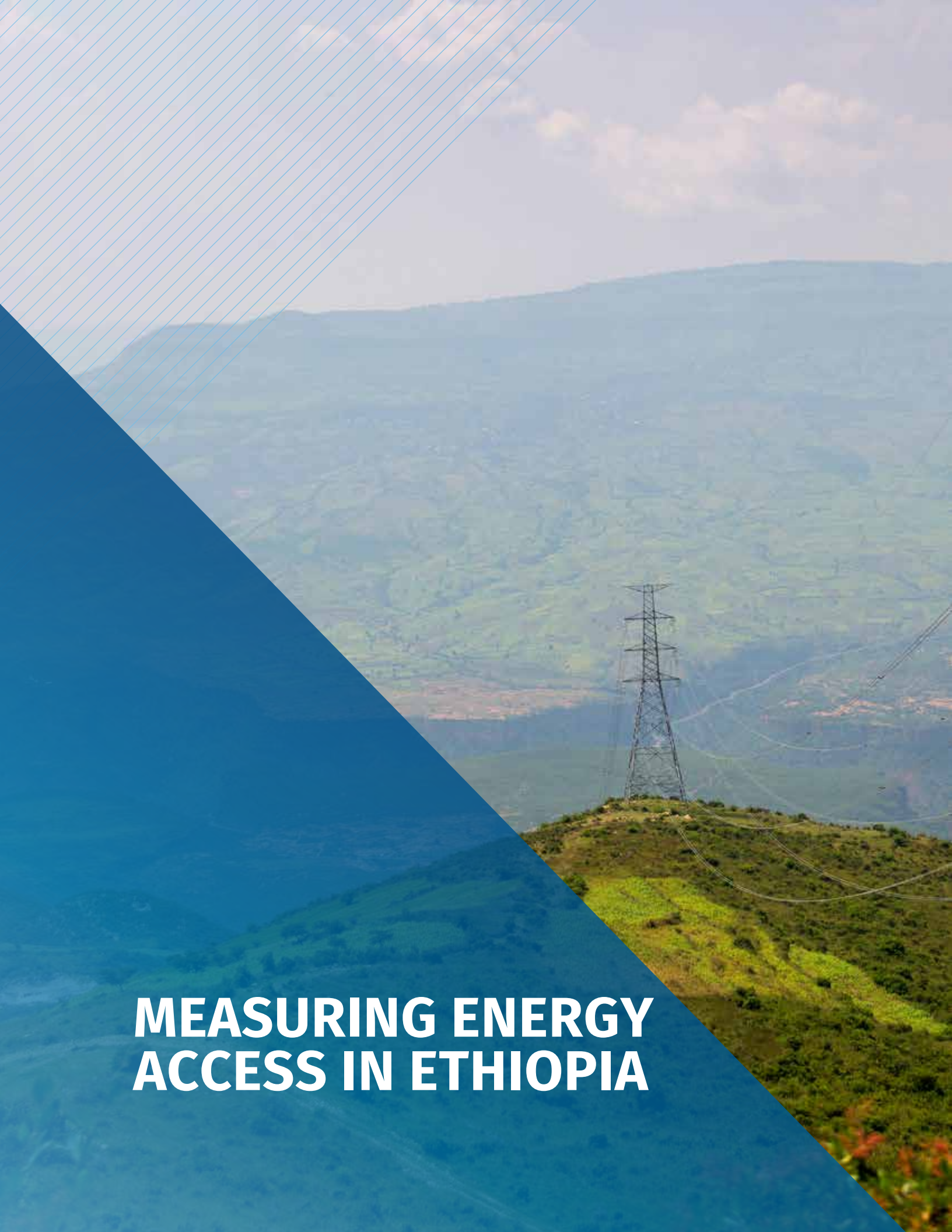
Access to modern energy cooking solutions. More female-headed households than male-headed households use a manufactured biomass or clean fuel stove: 33.9% of female-headed

[9] Gender of the household was not considered as a separate stratum during the sampling for the MTF survey, so the results may not be totally representative of the country's actual gender distribution.

households and 14.6% of male-headed households use a manufactured biomass stove, while 8.3% of female-headed households and 3.2% of male-headed households use a clean fuel stove. There is no significant difference in stove type use between male- and female-headed households in either urban or rural areas.

Ability to pay is an issue among female-headed households: 61.3% of female-headed households and 62.4% of male-headed households are willing to pay full price (175 birr or about $7.70) upfront for a manufactured biomass stove, but more female-headed households (16.4%) than male-headed households (8.6%) are not willing to pay even with a payment plan. Of the female-headed households that are not willing to pay under any given terms, around 60% indicated that they cannot afford the payment even with a payment plan. Gender-targeted financial mechanisms are needed to increase adoption of manufactured biomass stoves and to move households to a higher tier for access to modern energy cooking solutions.

Female household members in all age groups spend significantly more time cooking than their male counterparts do, regardless of primary stove type. And women spend more time acquiring fuel (through collection or purchase) and preparing the stove than their male counterparts do. Switching to stoves with lower emissions and improving ventilation structures, especially in households that use a manufactured biomass stove, will benefit women by reducing time spent collecting fuel and preparing the stove and reducing overall exposure to harmful indoor air pollution.



MEASURING ENERGY ACCESS IN ETHIOPIA

Without energy, promoting economic growth, overcoming poverty, and supporting human development are challenging, if not impossible. Energy access is thus a precondition to many development goals. Indeed, sustainable energy is the 7th of the 17 UN Sustainable Development Goals—to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. The Ethiopian government, steadfastly committed to maximizing energy access benefits for its people, has thus collaborated with the World Bank to put the Multi-Tier Framework (MTF) survey into practice and to obtain guidance on setting access targets, policies, and investment strategies for energy access.

Located in the Horn of Africa, Ethiopia is the second most populous country in Sub-Saharan Africa.[10] It occupies a territory of 1.1 million square kilometers and is home to over 100 million people.[11] Its largest city, Addis Ababa, boasts a population of 3.4 million people.[12] Over 80% of Ethiopia's population lives in rural areas, with agriculture functioning as the backbone of the country's economy.

Over the past decade Ethiopia has become one of the world's fastest growing economies, with growth averaging 10.9%, higher than the region's average of 5%.[13] Ethiopia's extreme poverty rate fell from 55% in 2000 to 31% in 2011.[14] These are notable advancements given that throughout the 1970s and 1980s, Ethiopia experienced a number of civil wars and a cycle of droughts that greatly affected the country's GDP.

The Ethiopian government has set the goal to achieve universal access to electricity by 2025 through grid and off-grid technologies, including mini-grids and off-grid solar solutions. This goal was set through the National Electrification Program—Implementation Roadmap, which was formally launched in November 2017. One of the main operational targets of the roadmap is to scale up energy access in Ethiopia to reach 65% through grid connection and 35% through off-grid solutions.

[10] http://www.worldbank.org/en/country/ethiopia/overview
[11] http://data.worldbank.org/country/ethiopia
[12] 2007 Population and Housing Census of Ethiopia, Central Statistical Authority, April 2012
[13] World Bank. 2016. 5th Ethiopia economic update : why so idle? - wages and employment in a crowded labor market
[14] "World Bank Group. 2015. Ethiopia Poverty Assessment 2014.

The government has also made access to modern energy cooking solutions a priority. Traditional biomass accounts for more than 90% of total primary energy in Ethiopian households, which is affecting the country's physical landscape and contributing to indoor air pollution, with resultant negative health effects to household members. The National Improved Cook Stove Program aims to reduce the population's dependence on biomass fuels (firewood and charcoal) by promoting cleaner cooking technologies.[15]

THE MULTI-TIER FRAMEWORK GLOBAL SURVEY

The World Bank, with support from the Energy Sector Management Assistance Program (ESMAP), has launched the Global Survey on Energy Access, using the MTF approach. The first phase is being carried out in 17 countries across Africa, Asia, and Latin America, including Ethiopia. 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.[16]

The MTF approach measures energy access provided by any technology or fuel based on a set of attributes that capture key characteristics of the energy supply that affect the user experience. Based on those attributes, it then defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access) along a continuum of improvement. Each attribute is assessed separately, and the overall tier for a household's access to electricity is the lowest applicable tier attained among the attributes.[17]

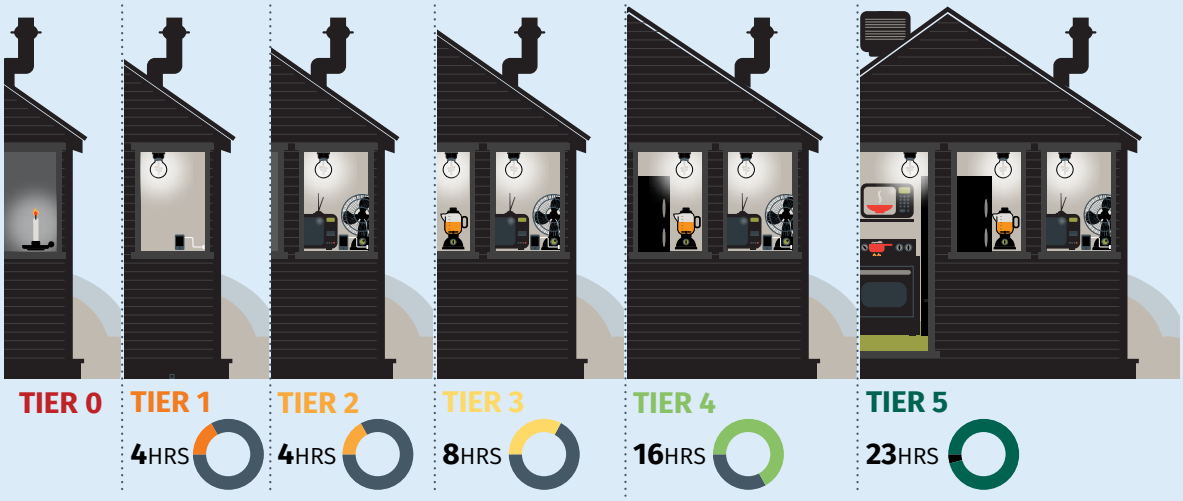
ACCESS TO ELECTRICITY

Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety (see table A1.1). Tier 0 refers to households that receive electricity for less than 4 hours per day (or less than 1 hour per evening) or that have a primary energy source with capacity of less than 3 W (see box 1 for 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; see box 2 for a typology of off-grid solar devices), for a few hours a day, enabling electric lighting and phone charging.

Higher tiers are defined by higher Capacity and longer Availability of supply—enabling the use of medium- and high-load appliances (such as a refrigerator, washing machine, or air conditioner)—as well as by Affordability (applicable for Tiers 3–5) and Reliability, Quality, Formality, and Health and

[15] National Electrification Program-Implementation Roadmap and Financing Prospectus 2017.
[16] 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.
[17] Bhatis and Angelous 2015.

BOX 1 • MINIMUM REQUIREMENTS BY TIER OF ELECTRICITY ACCESS



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

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

Source: Bhatia and Angelou 2015.

Safety (applicable for Tiers 4 and 5) (see table 1 for load levels, indicative electric appliances, and associated Capacity tiers). A grid is the most likely source for achieving a higher tier, though a diesel generator or a large mini-grid may also do so. Technological advances in photovoltaic SHSs and direct current–powered energy-efficient appliances also make higher access possible—to Tier 3 and even Tier 4—but such systems are rare in Ethiopia today.

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

Three types of solar devices are classified by the number of light bulbs and the type of appliance or service that a household can use.

Solar lantern. Powers a single light bulb and allows only part of the household to be classified in Tier 1. 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. Because the survey could not gather precise information on these service outputs, this report uses a simplified methodology. For a household that owns one solar lantern without phone charging capability, it is assumed that 20% of the household members are in Tier 1; for a household that owns one solar lantern with phone charging capability, it is assumed that 60% of the household members are in Tier 1.

Solar lighting system (SLS). Powers two or more light bulbs and allows part or all of the household to be classified in Tier 1. For a household that uses an SLS without phone charging capability, it is assumed that 70% of the household members are in Tier 1; for a household that uses an SLS with phone charging capability, it is assumed that all the household members are in Tier 1.

Solar home system (SHS). Powers two or more light bulbs and appliances such as a television, iron, microwave, or refrigerator. See table 1 for the load level associated with each tier.

This is a simplified methodology used to approximate off-grid access based on survey results (since survey data lack details on system sizes and performance). To review a more detailed methodology where system size and performance are explained, please consult the World Bank's Beyond Connections report. A more thorough analysis of survey data will be carried out in the MTF Global report.

Source: Bhatia and Angelou 2015.

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

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

Source: Bhatia and Angelou 2015.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Access to modern energy cooking solutions is measured based on six attributes: Cooking Exposure, Cookstove Efficiency, Convenience, Safety of Primary Cookstove, Affordability, and Fuel Availability (see table A1.2).[18] Cooking Exposure assesses personal exposure to pollutants from cooking activities, which depends on stove emissions, ventilation structure (which includes cooking location and kitchen volume[19]), and contact time (time spent in the cooking environment). Cookstove Efficiency assesses the performance of the stove in regard to its thermal efficiency. Convenience measures the time spent acquiring (through collection or purchase) fuel and preparing fuel and the stove for cooking. Safety of Primary Cookstove assesses the safety in using the most used cookstove within the household. Affordability assesses a household's ability to pay for both the cookstove and fuel. Fuel Availability assesses the availability of fuel when needed for cooking purposes.

Attributes directly related to the cooking solution (cookstove and fuel; see box 3 for a typology of cookstoves), such as Cooking Exposure, Cookstove Efficiency, and Safety of Primary Cookstove, are the main concern in the lower tiers. This report uses a simplified interim framework based on four stove categories: three-stone stove, self-built stove, manufactured biomass stove, and clean fuel stove. Most households that use a three-stone stove without good ventilation are in Tier 0 (no access) for modern cooking energy solutions, while households that use a three-stone stove with good ventilation can move up to Tier 1. Households with a self-built or manufactured biomass stove are in Tiers 1–3, and households with a clean fuel stove are in Tier 5.[20] Cookstove Efficiency was not analyzed for Ethiopia. Convenience, measured as time spent acquiring (through collection or purchase) and preparing fuel, is applicable in Tiers 2–5. Additional attributes—such as Affordability and Fuel Availability—are applicable in higher tiers.

[18] The Tier threshold values for the MTF Attributes on Cookstove Exposure, Efficiency and Health and Safety are being finalized based on an international consensus that needs to be reached. In the meantime, the analysis presented here is based on a simplified framework and the available data

[19] In this report ventilation is determined by the location of the cookstove (indoor or outdoor) and, if the cookstove is located indoors, the number of openings and exhaust structures (such as a chimney or hood) in the cooking location.

[20] These categories are approximate. The actual tier allocation needs to be done through appropriate stove tests, reflecting local cooking practices and conditions.

BOX 3 • TYPOLOGY OF COOKSTOVES IN ETHIOPIA

Cookstoves in Ethiopia were classified into four categories:

Three-stone stove. A pot balanced on three stones over an open fire. Fuel use and emissions are high, and thermal efficiency and safety are low. Three-stone stoves usually use fuelwood, but other solid fuels may also be used.

Other self-built stove. Locally produced using mud, metal, or other low-cost materials and following cultural practices. Other self-built stoves use biomass fuels. Although three-stone stoves are self-built stoves, they are not included in this category; throughout the report "self-built stove" refers to other self-built stoves.

Manufactured biomass stove. Biomass cookstoves that are manufactured by a private company, nongovernmental organization, or community rather than by an individual households. Manufactured biomass stoves are designed to improve efficiency, cleanliness, and safety compared with three-stone and other self-built stoves.

Clean fuel stove. Uses fuels with very low levels of polluting emissions, such as biogas, liquefied petroleum gas (LPG)/cooking gas, electricity, ethanol, natural gas, and solar. Such fuels often provide high technical performance in emissions and efficiency that is largely "stove independent." In Ethiopia the most prevalent type of clean fuel stove is an electric stove.

Ethiopian households commonly use injera baking stoves in addition to regular stoves for cooking. But information on injera baking stoves was not collected in the MTF survey, so the analysis focuses only on regular cooking stoves.

A key question about cookstoves and their use is what constrains a household from moving to a higher tier. Equipped with the answers, policymakers can target energy and design interventions to remove barriers. Answering the question starts with the analysis of attributes that define the value of access to modern energy cooking solutions and fuels for the customer (as answered by the questions in MTF surveys). Each tier specifies the performance criteria for each attribute (see table 2). For stoves, the issues are:

- **Cooking Exposure:** *How is the user's respiratory health affected?* This is based on personal exposure to pollutants from cooking activities, which depends on stove emissions, ventilation structure (which includes cooking location and kitchen volume as described earlier), and contact time (time spent in the cooking environment).
- **Cookstove Efficiency.** *How much fuel will a person need to use?*
- **Convenience.** *How long does it take to gather and prepare the fuel and stove before a person can cook?*
- **Safety of Primary Cookstove.** *Is it safe to use the stove, or does a person expose himself or herself to possible accidents?* This can be based on laboratory testing and the absence of serious accidents in the household.
- **Affordability.** *Can a person afford to pay for both the stove and the fuel?*
- **Fuel Availability.** *Is the fuel available when a person needs it?*

Health impacts from household air pollution caused by traditional cooking activities have been a key driver in promoting clean and efficient cooking. According to the World Health Organization guidelines for indoor air quality,[21] average annual PM2.5 concentration should be less than 10 μg/m^3, and 24 hour

[21] World Health Organization, 2014, *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion*, Geneva (http://apps.who.int/iris/bitstream/10665/141496/1/9789241548885_eng.pdf?ua=1).

exposure to carbon dioxide concentration should be less than 7 µg/m^3. The World Health Organization guidelines and interim targets have been a reference for the MTF.

Direct exposure measurement on the body of the cook would be the most accurate methodology. However, this process is not practical to implement through a large-scale household survey. One alternative is to calculate exposure based on simulation through mathematical models that consider key factors contributing to indoor air quality, such as indoor fuel combustion, ambient air pollution in the area, and kitchen volume and air exchange. Indoor emissions depend on the characteristics of each cooking solution (to account for stacking), along with its use, duration, and pattern. Emissions also depend on fuel quality, device maintenance, and user adherence to specifications. This approach is under development; its validity has not been verified by comparing the wide range of simulated data and direct measured exposure data.

Another alternative is to use proxy indicators that do not provide measured or estimated exposure data but classify different real-life situations in the sense of "contributing more or less to exposure." By including a broad variety of factors, the overall assessment still presents a comprehensive picture of exposure. The validity of this approach has not been verified by comparing the proxy indicators with direct measured exposure data and how they aligned with the World Health Organization guidelines.

The analysis for Ethiopia uses this proxy indicators approach, learning from Energising Development's (EnDev) experience developing the Energy Cooking System and awaiting a final consensus among international partners on the tiers and thresholds. This interim approach considers the household's or user's perspective of accessing energy services and the exposure of family members, particularly the primary cook, to indoor air pollution.

To estimate Cooking Exposure, the first step is to determine the tier for emissions for a household based on its primary stoves. Each stove that the household uses is classified based on a combination of the primary stove design and the primary fuel used with that stove. This classification is adapted from EnDev's Cooking Energy System (table 2). However, in this report, stove stacking was not considered in the calculation of the tier for Cooking Exposure and for Efficiency.

The second step is to determine the ventilation for the cooking area, categorized by the location of the cooking activity. A household that prepares its meals indoors in an area with fewer than two openings (windows and doors) to the outside is classified as having poor ventilation. A household that prepares its meals indoors in an area with more than two openings or a chimney or hood is classified as having average ventilation. And a household that cooks its meals outdoors or in a veranda is classified as having good ventilation. Ventilation mitigates the indoor air pollution that a household is exposed to by diluting the concentration of emissions from polluting fuels and expelling the pollutants from the cooking area.

Households in Tier 0 for stove emissions remain in Tier 0 for Cooking Exposure if they have poor or average ventilation but move to Tier 1 if they have good ventilation. Households that use a self-built or manufactured biomass stove are in Tier 1, 2, or 3, regardless of ventilation structure; the exact tier cannot be specified because the stove emissions level for each stove type in Ethiopia is not available. Households in Tier 4 for emissions remain in Tier 4 for Cooking Exposure if they have poor or average

ventilation and move to Tier 5 if they have good ventilation. Households in Tier 5 for emissions remain in Tier 5 regardless of ventilation.

TABLE 2 • **Stove emissions tier**

Type of fuel	Description of level	Tier
Firewood, dung, twigs, and leaves	Three-stone, tripod, flat mud ring	0
	Conventional ICS	1
	ICS with chimney, rocket stove with conventional material for insulation	2
	Rocket stove with high insulation, rocket stove with chimney (not well sealed)	3
	Rocket stove with chimney (well sealed), rocket stove gasifier, batch feed gasifier	4
Charcoal	Traditional charcoal stoves	0
	Old generation ICS	1
	Conventional ICS	2
	Advanced insulation charcoal stoves	3
	Advanced secondary air charcoal stoves	4
Rice husks, pellets, and briquettes	Natural draft gasifier (only pellets and briquettes)	3
	Forced air	4
LPG and biogas; electricity		5

Note: Because of lack of information on each stove type in Ethiopia, a simplified cookstove typology was used for the data analysis. Cookstoves are categorized as three-stone, self-built, manufactured biomass, or clean fuel stoves.

USING THE MULTI-TIER FRAMEWORK TO DRIVE POLICY AND INVESTMENT

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

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

MTF data also 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 insight into the deficiencies that restrict households in lower tiers and the key barriers—such as lack of generation capacity, high energy cost, or a poor transmission and distribution network. Access interventions can thus be targeted to maximize household access. MTF data provide guidance about what technologies are most suited to satisfy demand of non-electrified

households (for example, grid or off-grid). And MTF data on demand—such as energy spending, WTP, energy use, and appliances—inform the design and targeting of their programs, projects, and investments for energy access.

The MTF surveys provide three types of disaggregation: urban-rural, by quintile, and by gender of household head. For gender-disaggregated data, non-energy information is also collected. Such non-energy-related information includes household total monthly spending, educational attainment, and other socioeconomic data. Such data 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 ETHIOPIA

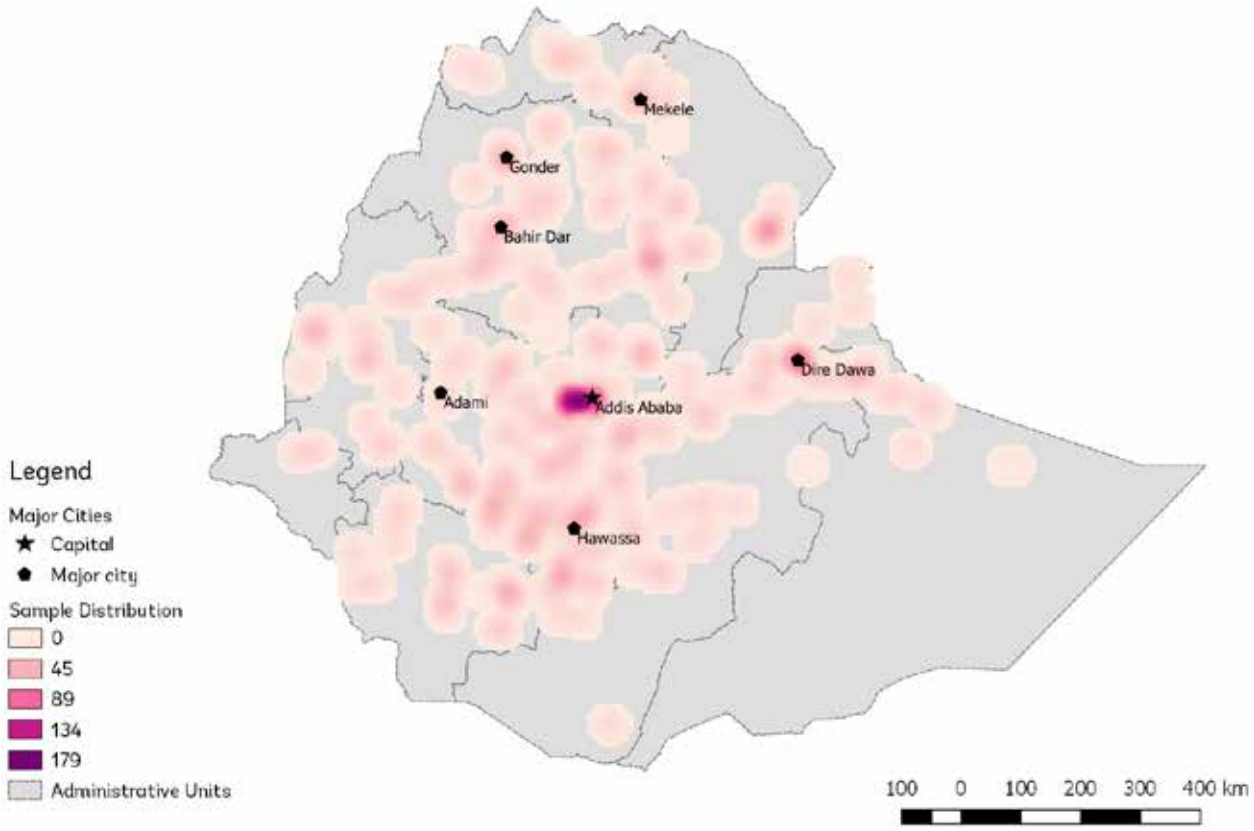
Data collection exercise for the MTF survey in Ethiopia was carried out between January–April 2017 and was undertaken by BDS Center for Development Research. The MTF survey sampled 4,317 households across the country's 11 regions (table 3 and figure 7). The data are representative at the national, urban and rural, and province levels. The household sample selection was based on a two-stage stratification strategy, with equal allocation between urban and rural areas and equal allocation between electrified and non-electrified households for the tier analysis. The purpose of implementing the two-level stratification was mostly to obtain consistent and uniform levels of significance during the data analysis. The sample also included an oversample of 708 households in selected urban areas in Addis Ababa to identify issues related to energy access specific to urban dwellers. See annex 3 for more on the sampling strategy.

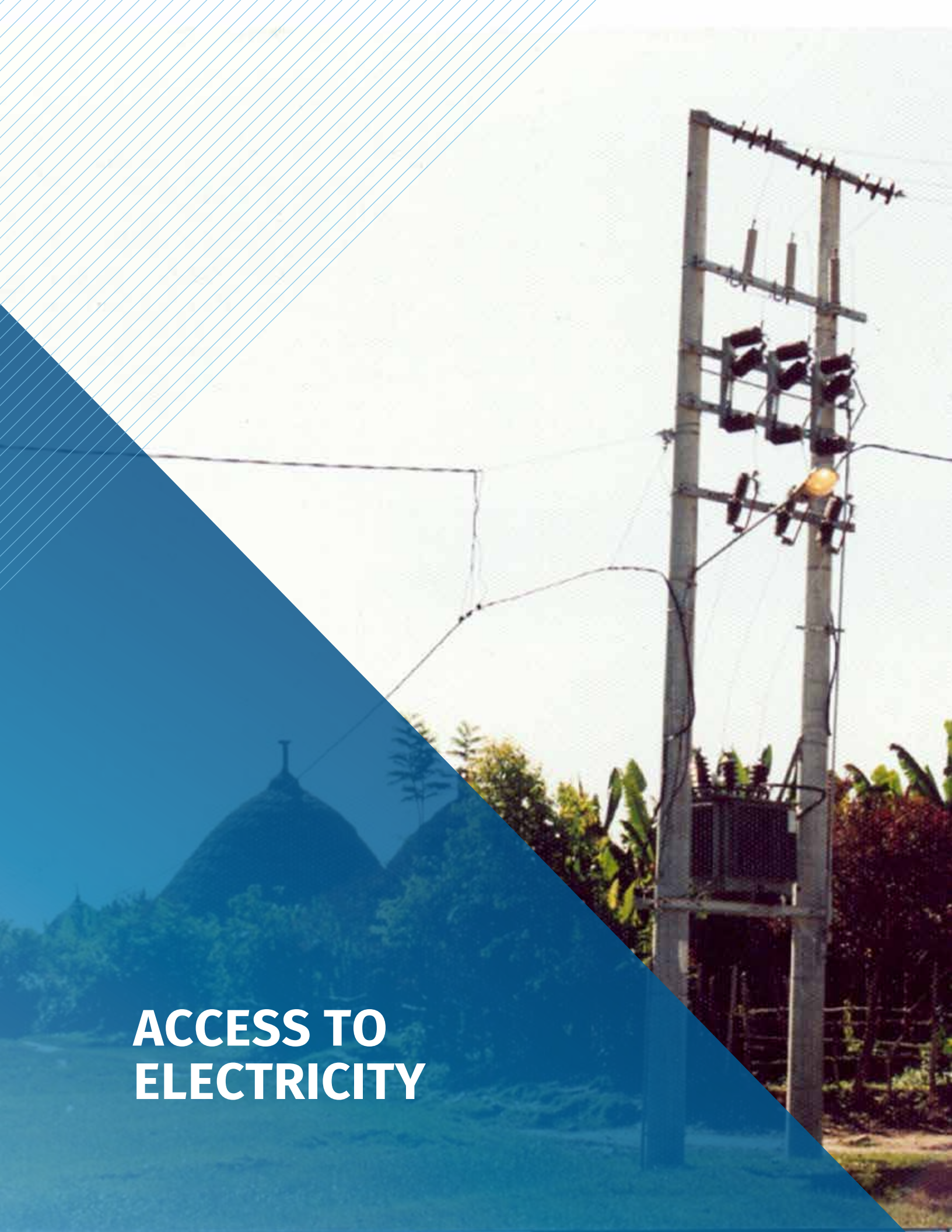
TABLE 3 • **Distribution of regions, woredas, and households sampled for the Multi-Tier Framework survey**

Region	Number of woredas	Number of enumeration areas			Number of households
		Rural	Urban	Total	
Tigray	14	7	10	17	204
Afar	9	9	7	16	192
Amhara	40	32	27	59	708
Oromiya	64	54	37	91	1,089
Somali	8	9	6	15	180
Benishangul	6	6	5	11	132
Southern Nations, Nationalities and Peoples (SNNP) Region	32	29	23	52	624
Gambela	5	2	3	5	60
Harari	1	1	3	4	48
Addis Ababa	10	0	59	59	984
Dire Dawa	1	2	6	8	96
Total	**190**	**151**	**186**	**337**	**4,317**

Note: The MTF survey used the sampling frame of the 2012 Ethiopia Population and Housing Census.

FIGURE 7 • **Spatial distribution of the households in Ethiopia sampled for the Multi-Tier Framework survey**





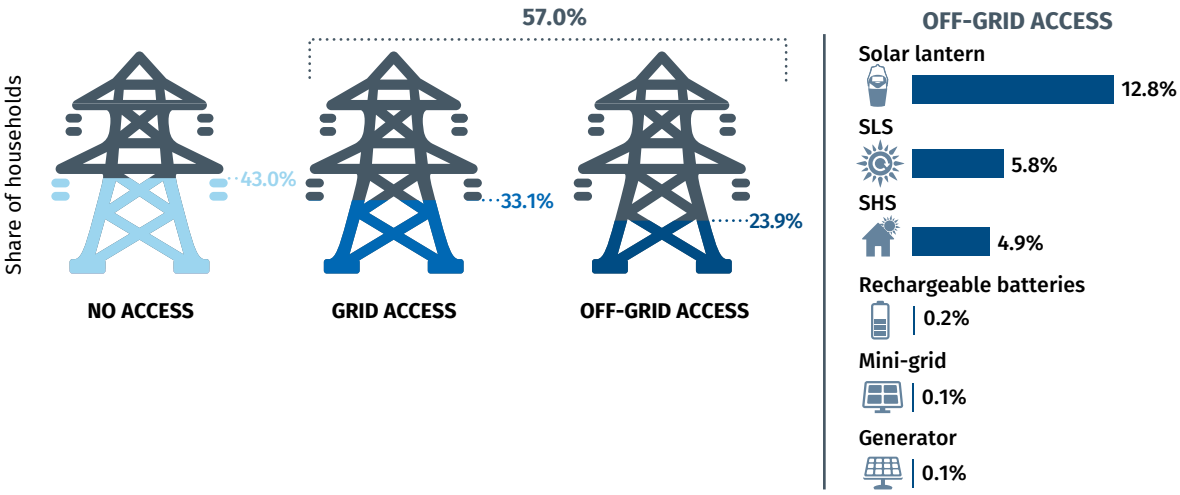
ACCESS TO ELECTRICITY

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

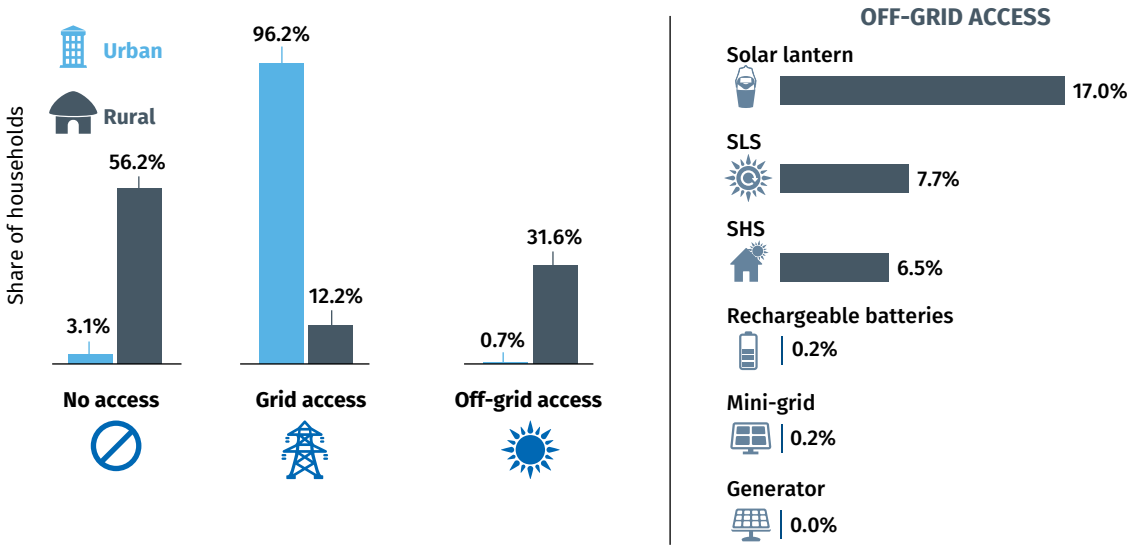
In Ethiopia 57% of households have access to at least one source of electricity: 33.1% of households have access through the grid, and 23.9% have access through off-grid solutions (mostly off-grid solar solutions) (figure 8). Off-grid solar solutions for households are a recent phenomenon in Ethiopia: 82% of households that use an off-grid solar solution as their primary source of electricity acquired their first solar device within the last three years. Other off-grid technologies, such as a mini-grid or pico-hydro, are rarely used as a primary source of electricity in Ethiopia, so this report does not include a detailed analysis of these solutions.

FIGURE 8 • **More than 43% of households do not have access to any source of electricity**



Off-grid solutions are more common in rural areas, where access to the grid is limited: 31.6% of rural households use an off-grid solution (17% use a solar lantern, 7.7% use a solar lighting system [SLS], and 6.5% use a solar home system [SHS]) as their primary source of electricity (figure 9).

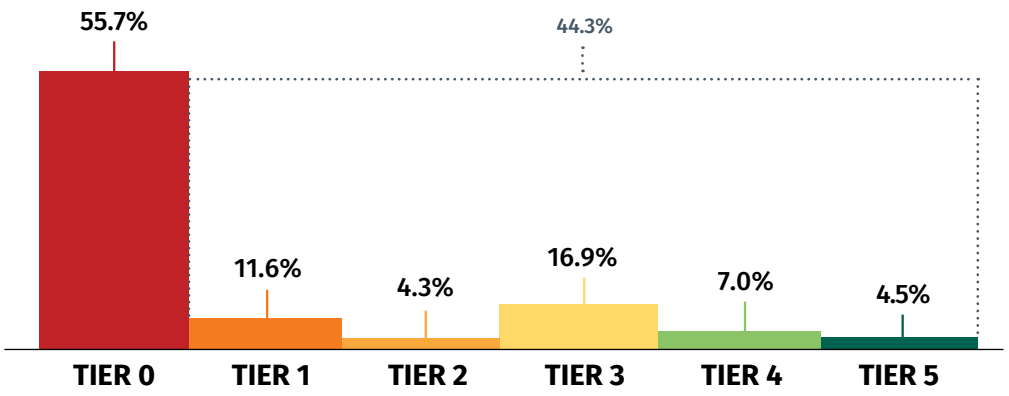
FIGURE 9 • **Off-grid solutions, particularly solar lanterns, are more common in rural areas**



MTF TIERS

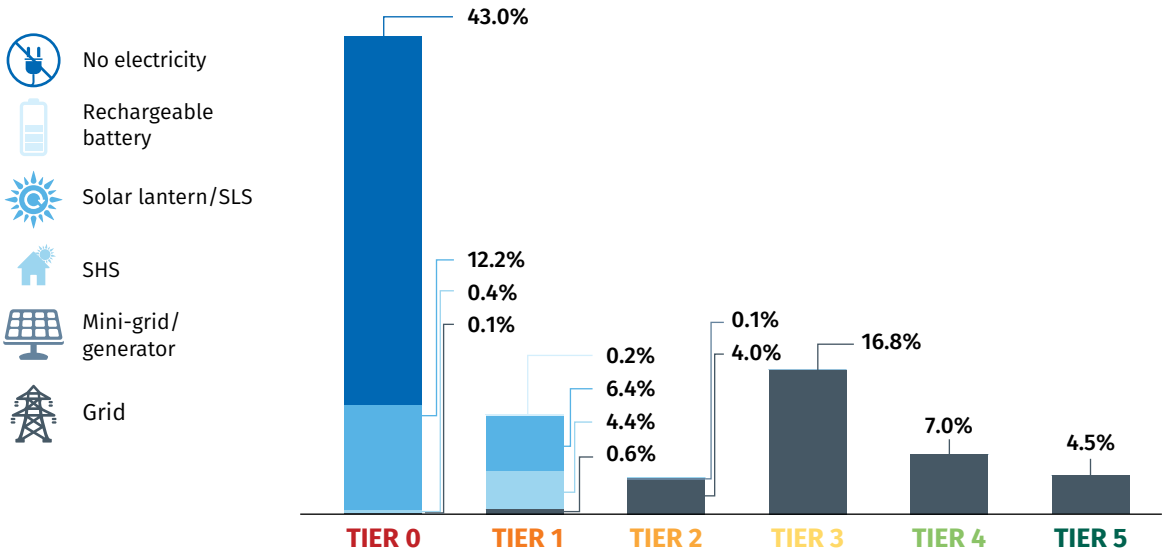
Although 57% of households have access to at least one source of electricity, not all of them meet the criteria to be in Tier 1. Only 44.3% are in Tier 1 or above for access to electricity (figure 10). That means that 12.7% of households with access to on- or off-grid electricity do not meet the criteria to be in Tier 1, usually because of Capacity or Availability. Among these 12.7% of households, those with off-grid solutions do not receive sufficient Capacity, which means that they do not have enough electricity to provide lighting for all household members or to power additional devices such as a radio or phone charger. Some of the grid connected households may be in Tier 0 because they have supply for less than 4 hours a day or less than 1 hour per evening.

FIGURE 10 • **The majority of households are in Tier 0 for access to electricity based on the Multi-Tier Framework approach; most electrified households are in Tier 3**



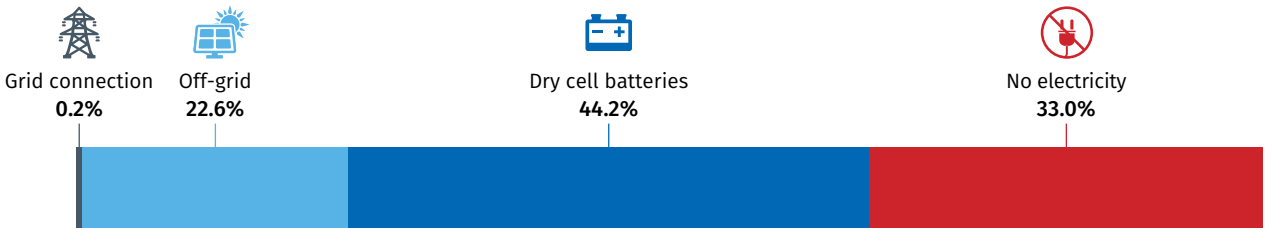
Grid-connected households are in Tiers 2–5 for access to electricity, with the largest share in Tier 3, while most households that use off-grid solutions are in Tiers 0 and 1 (figure 11). Most households in Tier 0 that have access to electricity use a solar lantern that does not provide the minimum level of service needed for the household to reach Tier 1. A small fraction of households that use an SHS are also in Tier 0 because they receive less than 4 hours of supply a day. About 11% of households with an off-grid solar solution as their primary source of electricity were considered to have access to electricity under the MTF approach. Considering that off-grid solar solutions are a recent phenomenon in Ethiopia, their fast expansion is proving a promising avenue for moving households in Tier 0 to Tier 1.

FIGURE 11 • **Grid-connected households are in Tiers 2–5 for access to electricity, with the largest share in Tier 3**



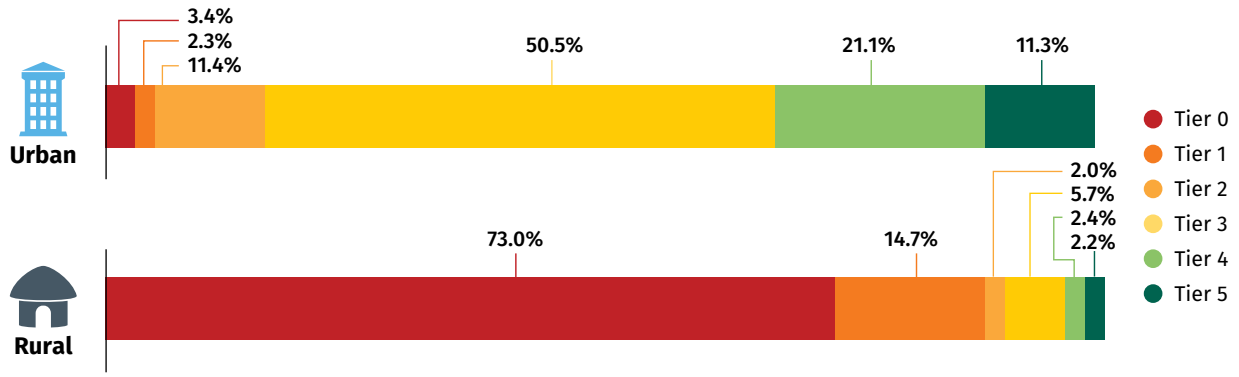
Most households in Tier 0 do not have access to any source of electricity. Of households in Tier 0, 0.2% are connected to the grid, 33% do not have access to any source of electricity, 22.6% use an off-grid solar solution, and 44.2% use dry-cell batteries as their primary source of electricity (because dry-cell batteries are not considered a reliable source of electricity, households that use them are categorized as Tier 0) (figure 12). Grid-connected households in Tier 0 have electricity for less than 4 hours a day or 1 hour a night, while off-grid households in Tier 0 have low Capacity and Availability of electricity supply.

FIGURE 12 • **Of households in Tier 0 for access to electricity, 33% do not have access to any source of electricity, and more than 44% use dry-cell batteries as their primary source of electricity**



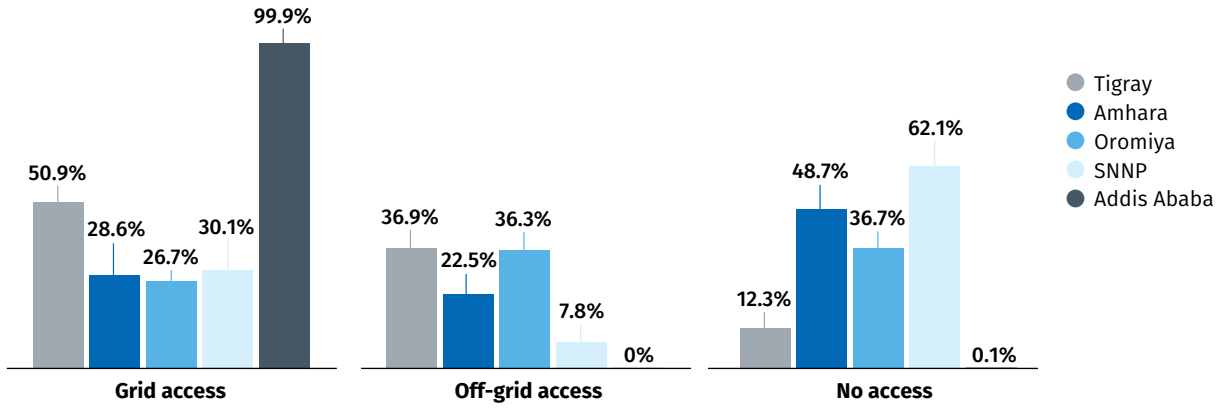
There is a wide disparity in the share of households that are in Tier 3 or above for access to electricity between urban areas (82.9%) and rural areas (10.3%) (figure 13). The average tier is 3.2 for urban households, compared with 0.6 for rural households. Among electrified households (those in Tier 1 and above), 50.5% of urban households are in Tier 3, while 14.7% of rural households are Tier 1. This is attributed mostly to the fact that connectivity to the national grid is low in rural areas, so these households depend on low-capacity off-grid solutions to meet their electricity needs.

FIGURE 13 • **Electricity access in Ethiopia is primarily a rural challenge**



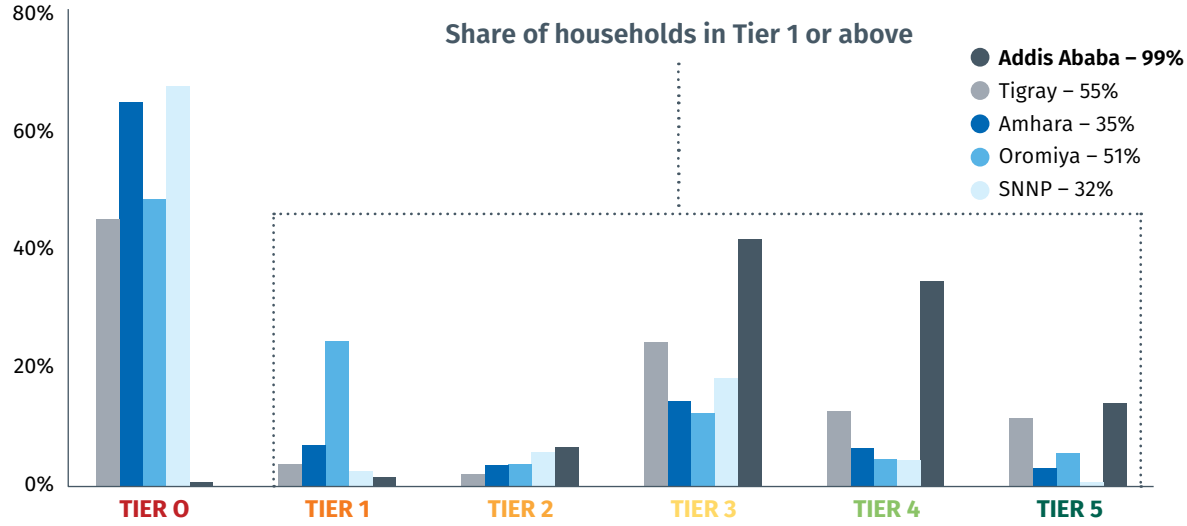
Almost all households in Addis Ababa (99.9%) are connected to the grid, while penetration of off-grid solutions is sizable in Tigray (36.9%, with 16.6% of households using a solar lantern, and 20.2% using an SLS), Oromiya (36.3%, with 6% of households using a solar lantern 17.6% using an SLS, and 12.6% using an SHS), and Amhara (22.5%, with 8.7% of households using a solar lantern, 12.5% using an SLS, and 1.2% using an SHS) (figure 14).

FIGURE 14 • **Access to various sources of electricity varies widely between the capital region and the rest of the country**



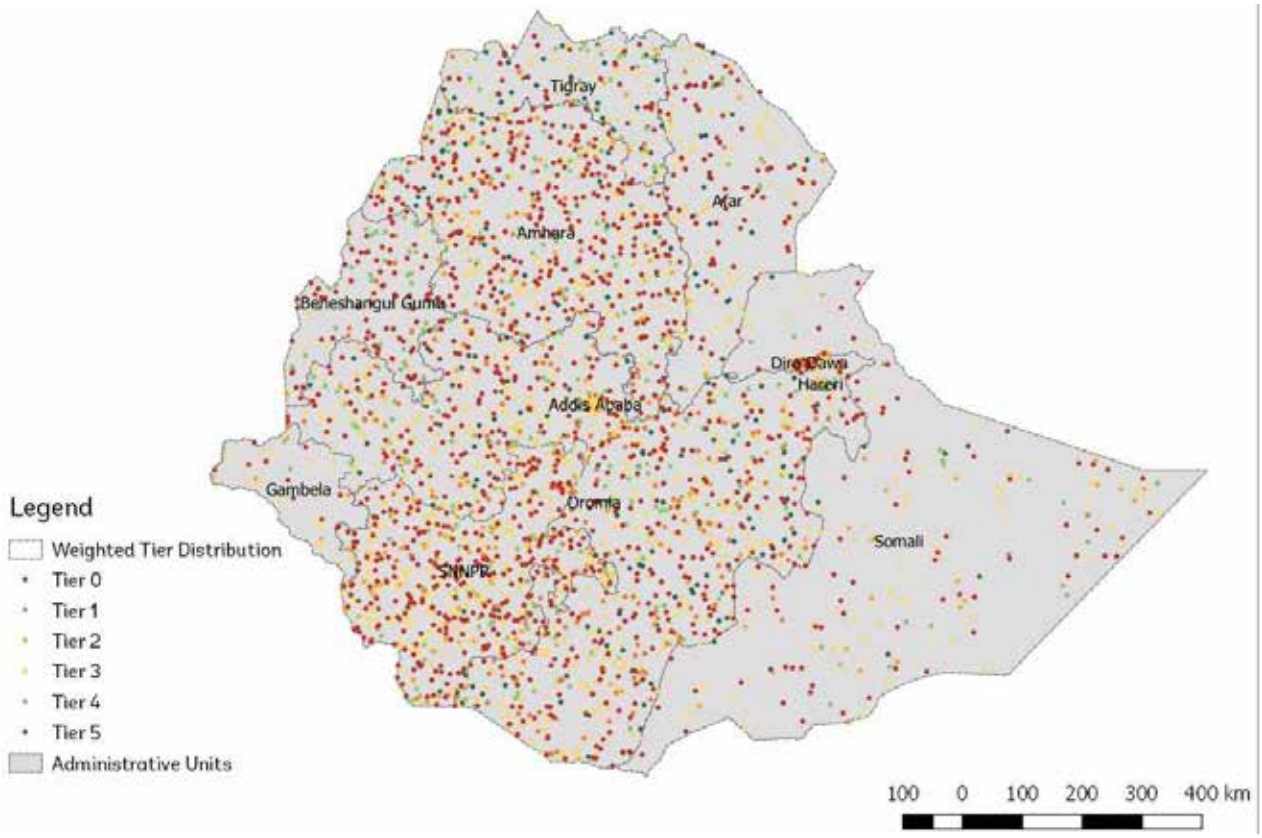
In Addis Ababa 91.1% of households are in Tiers 3–5 (figure 15). But access varies in other regions: 65.4% of households in Amhara and 68.2% of households in the Southern Nations, Nationalities and Peoples (SNNP) Region are in Tier 0. In Oromiya 24.7% of households are in Tier 1, which could be attributed to the increased penetration of off-grid solutions (mostly SLSs and SHSs) in the region.

FIGURE 15 • **In Addis Ababa 91.1% of households are in Tiers 3–5 for access to electricity**



The vast majority of households are in Tiers 0–3. Only 11.5% of households are in Tier 4 or 5. This concentration is apparent in the spatial distribution of the MTF results (figure 16) and supports the recommendation to include measures that move households in Tier 0 to Tier 1 or above as well as measures that move households in Tiers 1–3 to a higher tier in any plans for achieving universal access.

FIGURE 16 • **Spatial distribution of households by Multi-Tier Framework tier**

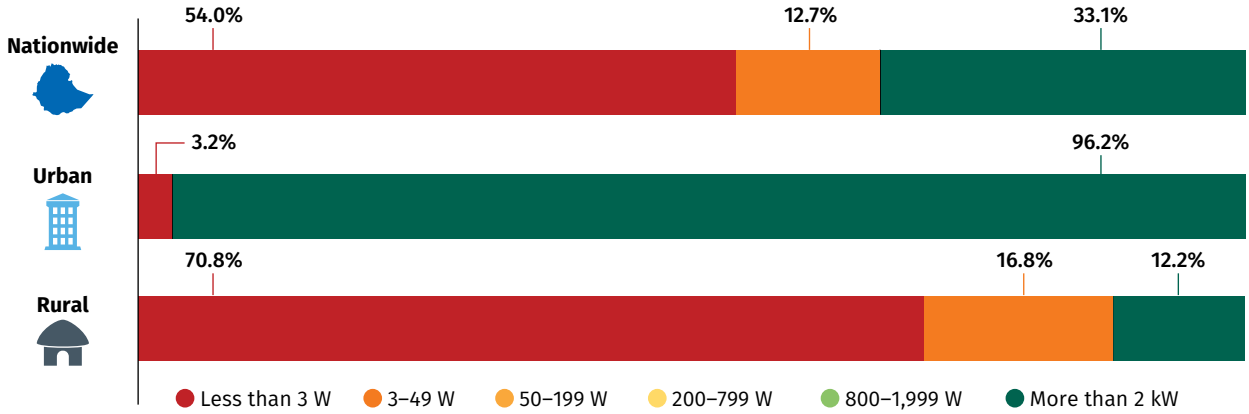


MTF ATTRIBUTES

Capacity

Because grid-connected households are considered to have high-capacity electricity (over 2,000 W) or Tier 5 access, the proportion of households that receive Tier 5 access is the same as the proportion of households that are connected to the grid (33.1%). While 96.2% of urban households are in Tier 5 for Capacity, only 12.2% of rural households are; 70.8% of rural households are in Tier 0 (less than 3 W), and 16.8% are in Tier 1 (3 W-49 W), due mostly to the penetration of off-grid solutions (figure 17).

FIGURE 17 • **Capacity is more of an issue in rural areas**



Availability

The Availability of electricity supply prevents some grid-connected households from moving to a higher tier. Electricity is available at least 23 hours a day, 7 days a week, for 20.9% of households, but 5.2% of households receive less than 4 hours of service per day (figure 18). In rural areas limited Availability is more acute: only 9.6% rural households receive more than 22 hours of supply a day, and 60.1% receive less than 8 hours a day. And 54.7% of households nationwide receive electricity for 4 hours during the evening, when lighting is required the most (figure 19).

FIGURE 18 • **Only about 20% of households receive more than 22 hours of electricity supply a day**

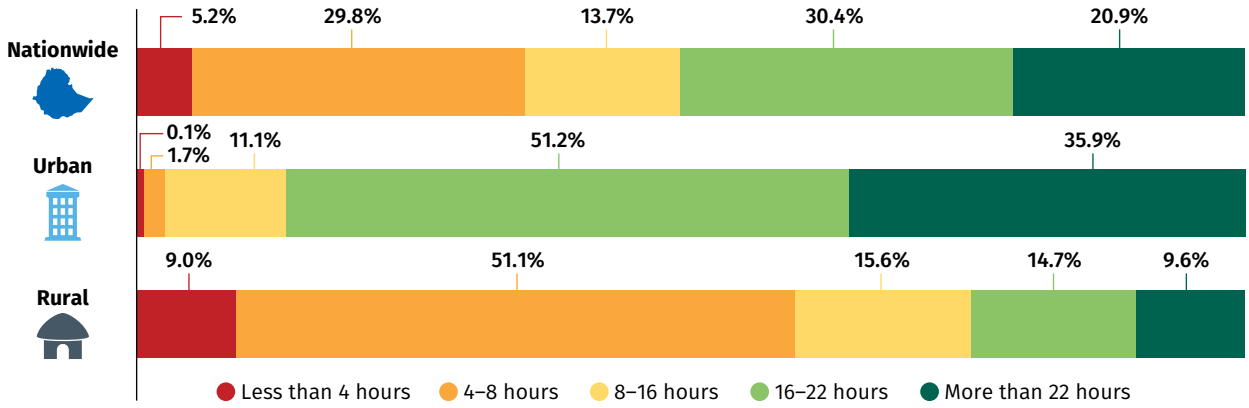
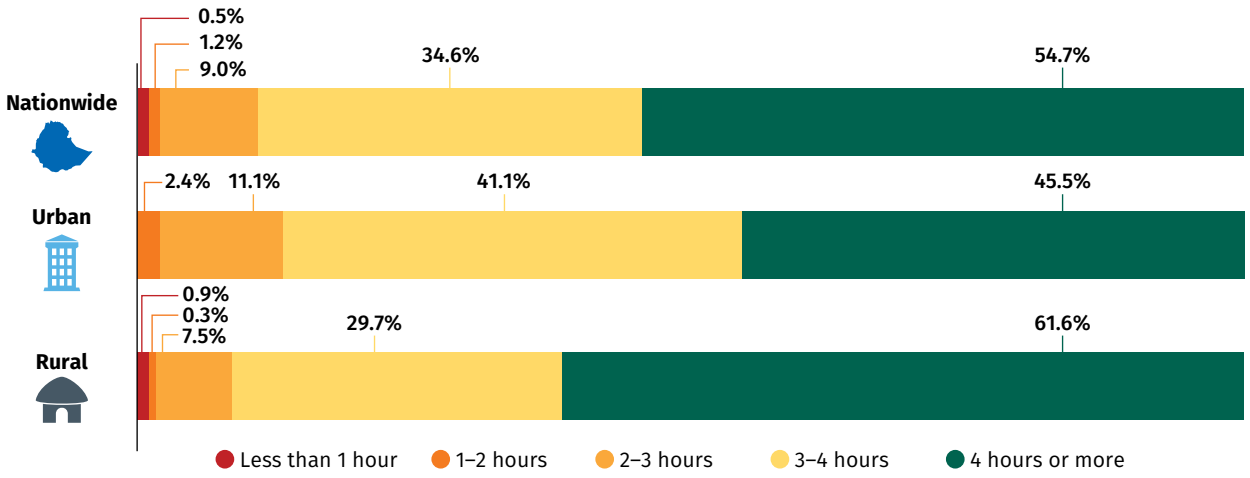


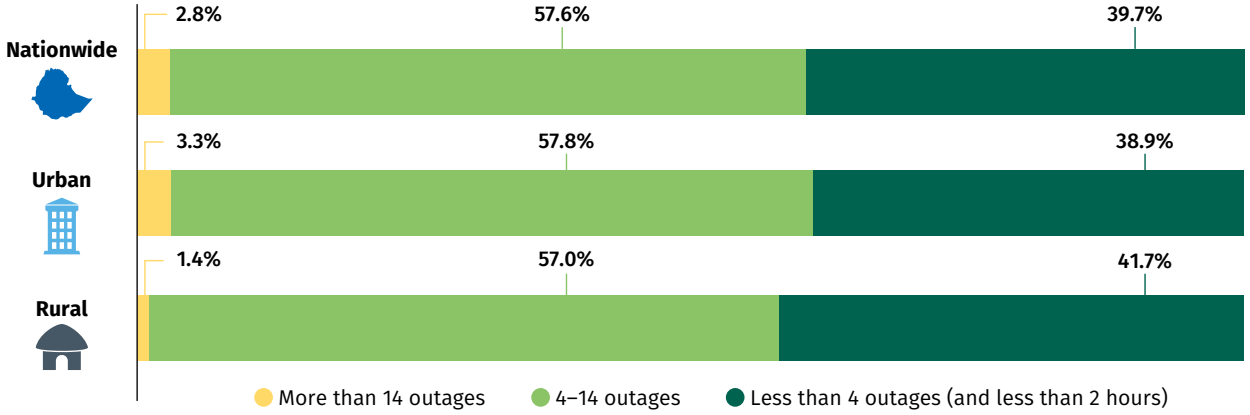
FIGURE 19 • **Nearly 55% of households receive 4 hours of electricity in the evening**



Reliability

In Ethiopia 57.6% of grid-connected households face 4–14 outages a week, and 2.8% of households face more than 14 outages a week (figure 20). Reliability of supply is holding back these grid-connected households from moving to a higher tier for access to electricity.

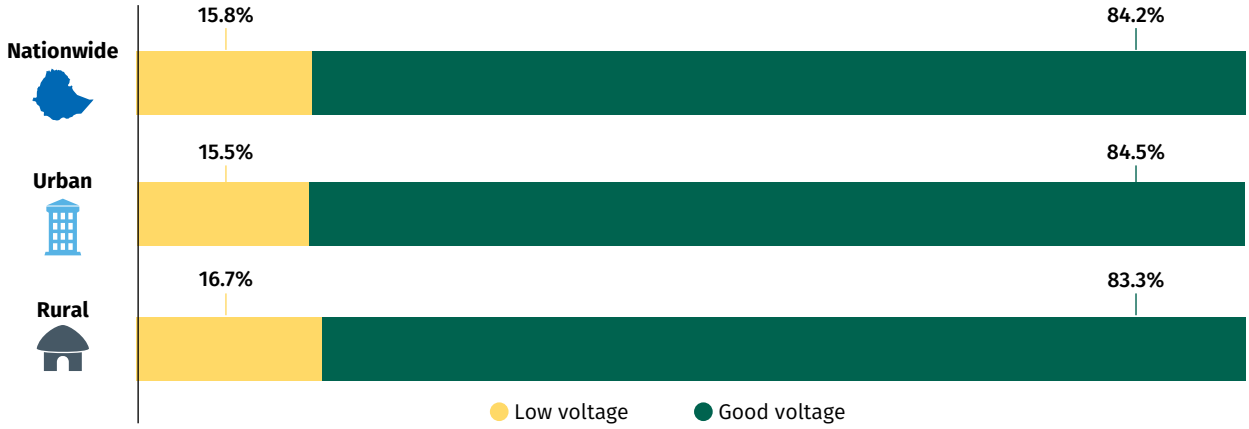
FIGURE 20 • **Nearly 58% of households face 4–14 outages a week**



Quality

In Ethiopia 15.8% of households face voltage issues that lead to appliance damage (figure 21). Voltage issues are found to be similar in rural and urban areas. Electric appliances generally require a certain voltage supply to operate properly, and low voltage supply tends to result from an overloaded electricity system or from long-distance low-tension cables connecting spread- out households to a singular grid. Voltage fluctuations and surges can damage electrical appliances and sometimes result in electrical fires.

FIGURE 21 • **More than 15% of households experience voltage issues**



Affordability

Almost all grid-connected households nationwide and in rural and urban areas pay less than 5% of their household spending for basic electricity service (at least 1 kWh a day and 365 kWh a year) (figure 22). Electricity tariffs in Ethiopia are low,[22] so most grid-connected households can afford to pay for the minimum level of service to satisfy basic electricity needs.[23]

FIGURE 22 • **Affordability of electricity supply is not an issue**

Formality

Only 6% of grid-connected households have an informal grid connection, which may pose a safety risk (because informal electricity supply is unlikely to be regulated) and has a risk of disconnection (figure 23). Reporting on Formality is challenging because households may be sensitive about disclosing such information in a survey. The Multi-Tier Framework (MTF) survey infers information on Formality

[22] The average tariff, last revised in 2006, is $0.03 per kWh, below the full cost of service, which is estimated at $0.06–$0.07 per kWh.
[23] Bhatia and Angelou 2015.

from indirect questions that respondents may be more willing to answer (such as what method a household member uses to pay the electricity bill), so the actual percentage of households with an informal connection may differ from the data reported here.

FIGURE 23 • **About 6% of households have an informal grid connection**

Health and Safety

Only 0.5% of households reported a serious injury such as a permanent limb damage or death caused by electrocution over the past year (figure 24). Electricity supply from the grid is thus generally reported to be safe.

FIGURE 24 • **Electricity supply from the grid is generally safe**

USE

On average, electrified households have been connected to the grid for 11 years and consume 120.7 kWh of electricity per month.[24] Urban households consume more than three times as much as rural households (figure 25). Spending on electricity (60.10 birr or about $2.70[25] a month) accounts for 4.3% of average monthly household spending; this share is higher (5.2%) for rural households (24.10 birr or about $1.10 a month) and lower (1.9%) for urban households (73.90 birr or about $3.30 a month) (figures 26 and 27).

FIGURE 25 • **Electricity consumption (kWh per month)**

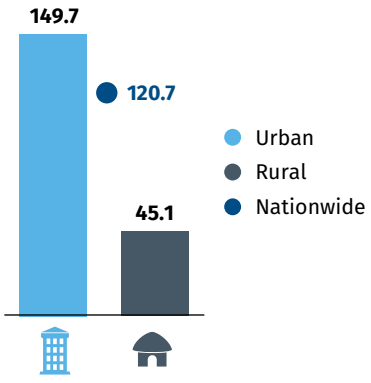


FIGURE 26 • **Household spending on electricity (birr)**

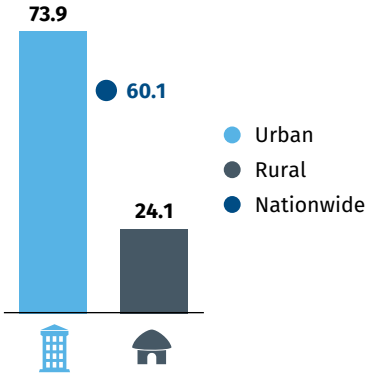
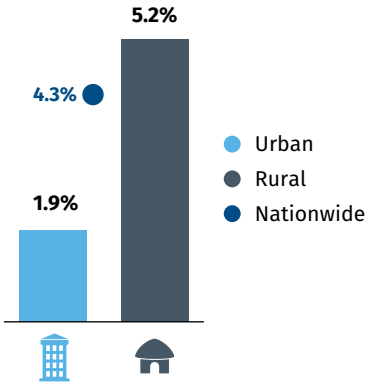


FIGURE 27 • **Spending on electricity as a share of total household spending**



Based on appliance ownership, grid-connected households do not take full advantage of the service performance of the electricity supply they receive. Most grid-connected households use low-load electric appliances corresponding to Tiers 1–3 (figure 28). This is true particularly in rural areas, where 74.6% of households in Tiers 2–5 own only very low–load appliances (lighting, phone charger, or radio, which correspond to Tier 1 capacity; see table 1).

[24] Consumption data are from household electricity bills.
[25] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

FIGURE 28 • Three-quarters of rural grid-connected households in Tiers 2–5 own only Tier 1 appliances

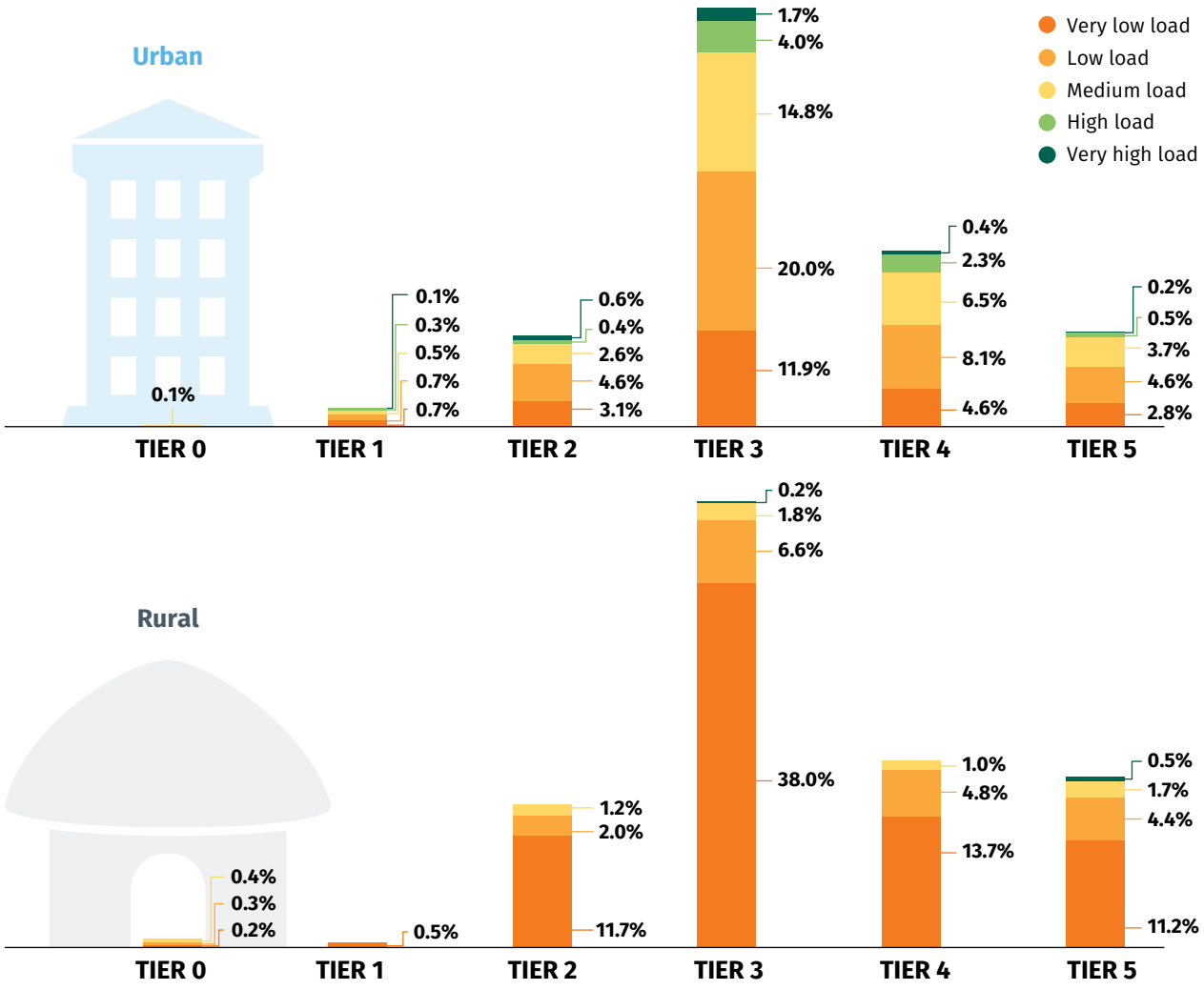


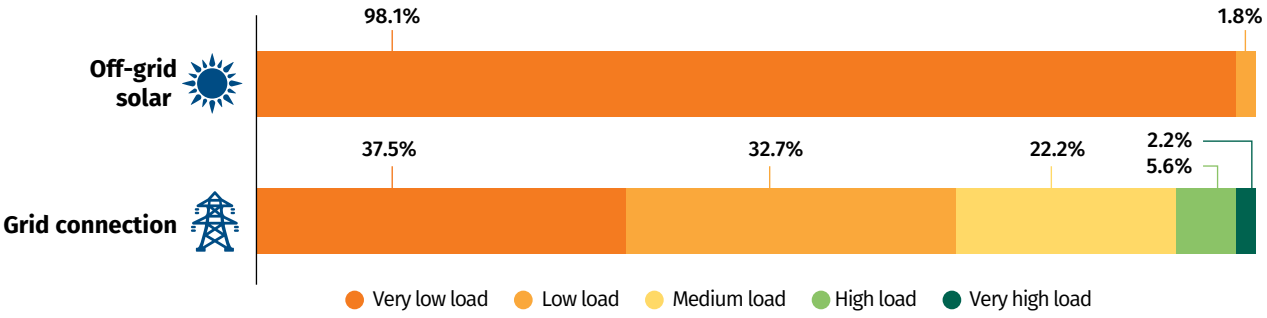
TABLE 4 • Load levels, indicative electric appliances, and associated Capacity tiers

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

Source: Bhatia and Angelou 2015.

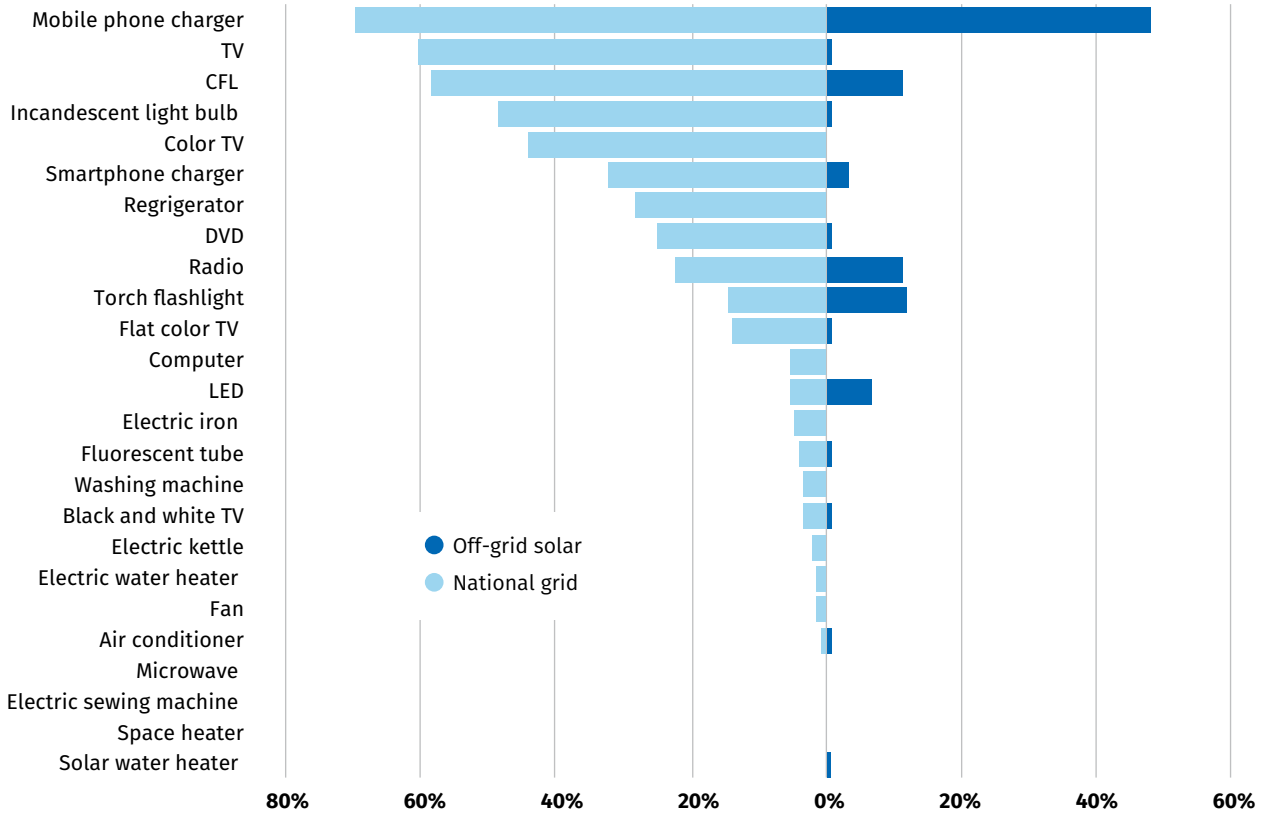
Among households that use an off-grid solar device, 98.1% have very low–load appliances, such as task lighting, phone charging, and radio, while 29.8% of grid-connected households have medium- or high-load appliances such as a refrigerator or iron (figure 29).

FIGURE 29 • **Most households that use an off-grid solar device have only very low–load appliances**



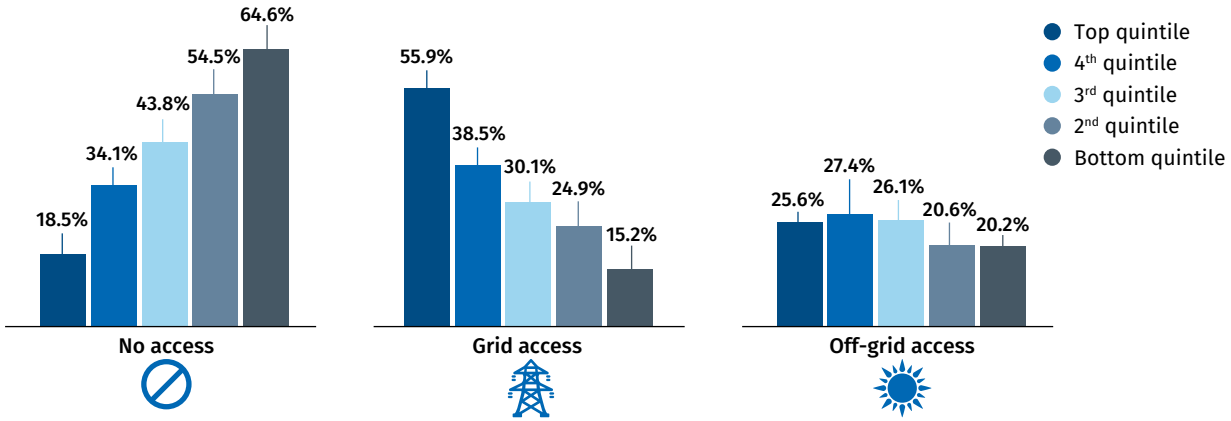
Households that use an off-grid solar device use electricity mostly for phone charging (47.6%) and radio (11%), in addition to lighting (figure 30). Grid-connected households, particularly those in urban areas, use more diverse appliances, including medium- to very high–load appliances such as televisions, refrigerators, air coolers, and washing machines, though use of such high-load appliances remains limited.

FIGURE 30 • **Most households that use an off-grid solar device have only very low–load appliances**



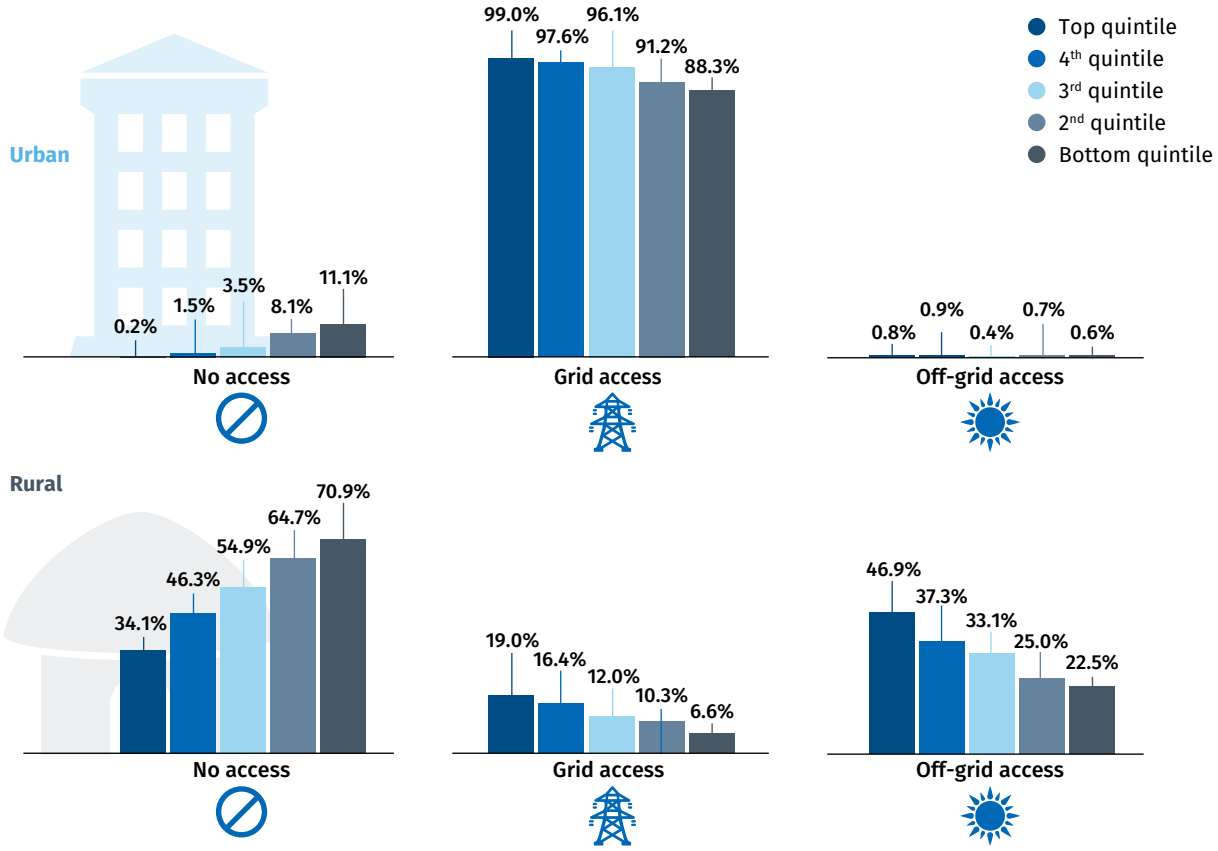
The grid is the leading technology for wealthier households: 55.9% of households in the top spending quintile are connected to the grid. Off-grid penetration is similar across all spending quintiles (figure 31).

FIGURE 31 • **Grid penetration goes up with income**



Most off-grid penetration is being led by rural households: 46.9% of rural households in the top spending quintile use off-grid solutions, compared with 22.5% of rural households in the bottom quintile (figure 32).

FIGURE 32 • **Most off-grid penetration is being led by rural households**



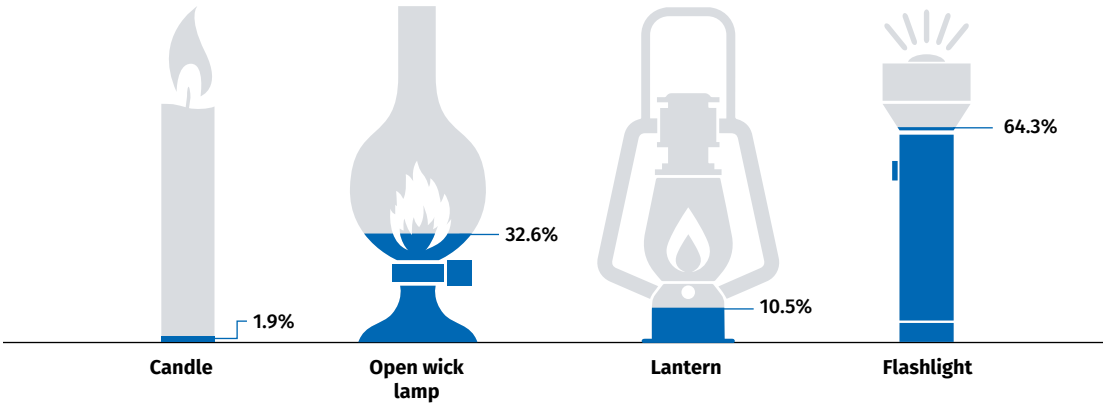
IMPROVING ACCESS TO ELECTRICITY

MTF data analysis can be used to formulate recommendations for providing and improving access to electricity. The MTF gap analysis provides policymakers with insights on the types of interventions that will move households to a higher tier. Linking this information to other relevant findings from the MTF survey—willingness to pay (WTP), use of electricity, expenditure analysis, and user perceptions—yields more specific information on how to provide and improve access to electricity.

PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

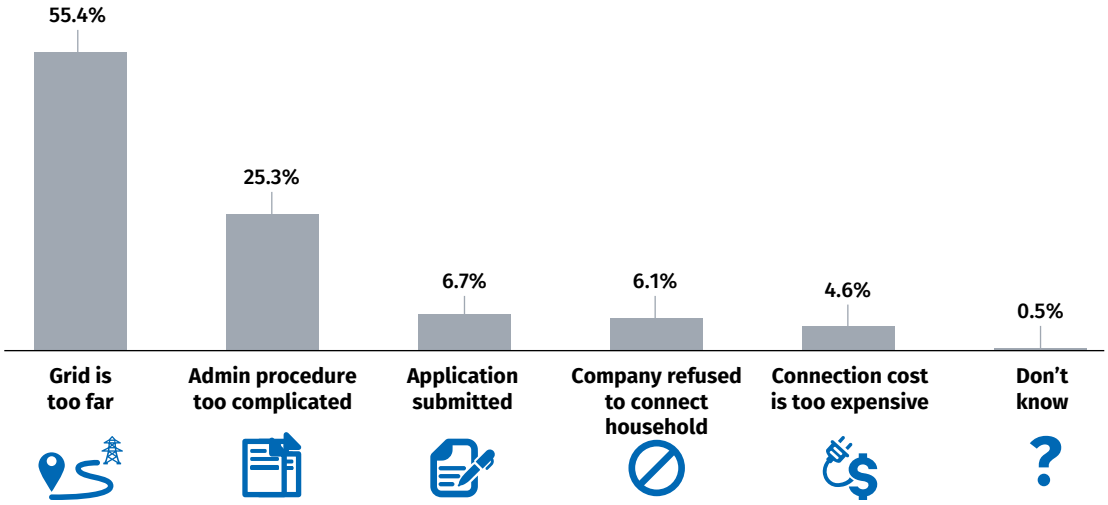
Households with no access to electricity use coping solutions for lighting and basic electricity services that are harmful to health and the environment. The 55.7% of households that have no access to any source of electricity (Tier 0) use mostly flashlights (64.3%), open-wick lamps (32.6%), and lanterns (10.5%) to meet their lighting needs (figure 33).

FIGURE 33 • **The nearly 56% of households that have no access to any source of electricity use mostly flashlights and open-wick lamps**



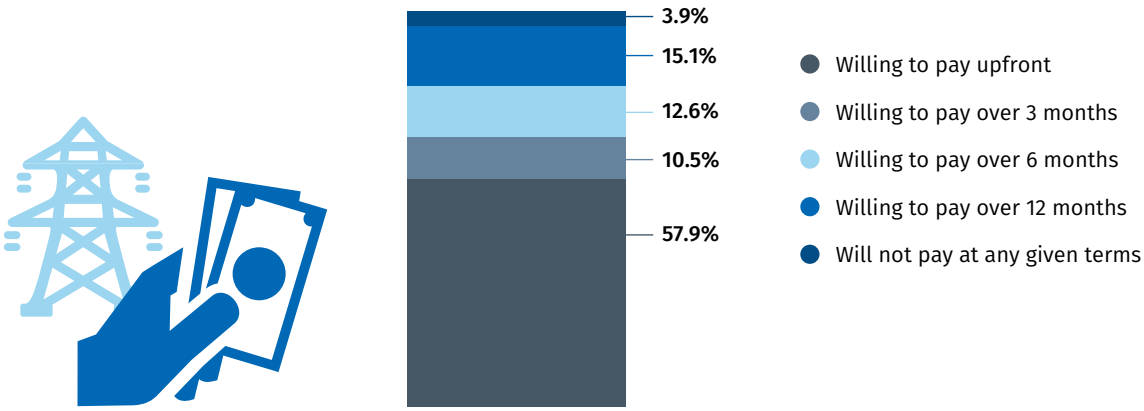
Distance to the national grid is a barrier for 55.4% of households without grid access (figure 34). This is because most of these households are in rural areas, where grid penetration is very low. Off-grid solutions that provide Tier 1 or above access would be an immediate solution to provide access to electricity for these households. Complicated administrative procedures are an obstacle for 25.3% of unconnected households, 6.7% of households are still waiting to get connected after putting in an application, and 6.1% of households were refused a connection. A majority of the 38.1% of households that report some form of administrative obstacle live within 7 kilometers of the national grid. These households appear to be interested in being connected and could be a good target for grid densification. Reducing administrative barriers to connection could also induce grid densification.

FIGURE 34 • **The two main reasons that households are not connected to the grid are distance from the grid and complicated administrative procedures**



The majority of unconnected households (57.9%) are willing to pay full price (1,900 birr or about $83.80[26]) upfront for a grid connection, and 38.2% are willing to pay with a 3- to 12-month payment plan (figure 35). Only 3.9% of households were unwilling to pay for the connection fee at the given terms—66% of those households think that the connection fee is too expensive even with the flexible payment options, and 15% do not want to pay for the connection fee because they rent their house.

FIGURE 35 • **More than 96% of households are willing to pay for a grid connection**

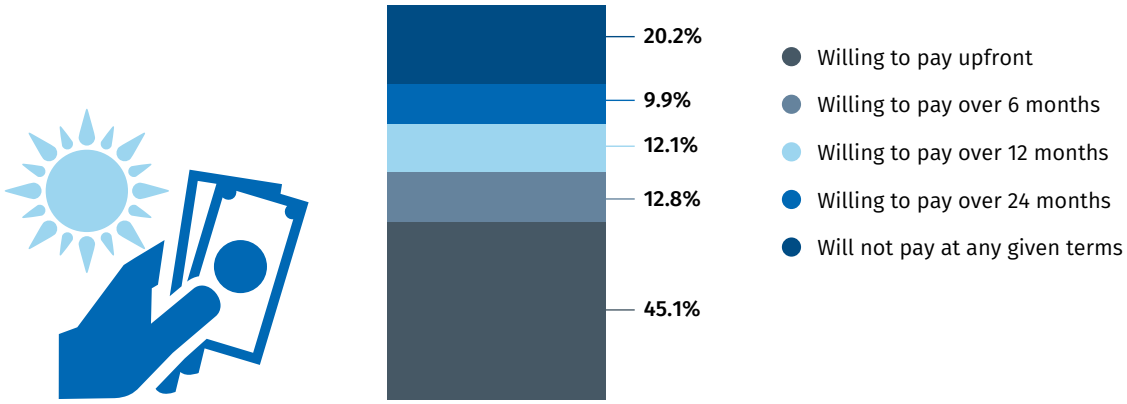


Households without access to the grid are likely to connect if the grid becomes available. Some of these households may be in remote areas where grid extension is not the least cost solution or where it may take years for the grid to reach. Thus, off-grid solutions, such as mini-grids and off-grid solar devices, are likely to be feasible intermediate options for these households. WTP for a Tier 2 solar device is also very high, and adoption of SHSs could increase further when a financing option is offered. When households are asked whether they are willing to pay for a Tier 2 solar product (with capacity to

[26] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

power more than two light bulbs and appliances such as a fan or television) for the full price of 13,200 birr (or about $582.50[27]), 45.1% are willing to pay upfront, and 34.8% are willing to pay with a 6- to 24-month payment plan (figure 36). The remaining 20.2% are not willing to pay for a device with the given options—68% of these households find it very expensive to buy the device even with a payment plan, and 26% are not convinced that the electricity service from this device would be reliable. Even with such a high WTP upfront or in installments for a larger capacity SHS, the penetration of such products is still very low, and most off-grid solar products that households own have only Tier 1 capacity. One barrier could be lack of financing mechanisms, providing a payment plan (such as pay-as-you-go systems in Kenya) could rapidly expand higher capacity solar products, thereby increasing access to electricity. Other reasons for low availability of such products in the market that need to be explored further could include administrative barriers to market entry for off-grid solar providers.

FIGURE 36 • **Nearly 80% of households are willing pay for a Tier 2 solar product**



Households with no access to any source of electricity can reach Tier 1 or above by using a combination of grid or off-grid electrification. The optimal energy solution, either an on- or off-grid approach, should consider such factors as the availability of grid infrastructure, electricity demand, household's ability to pay, and household willingness to adopt certain technology. Grid connections are likely to be the most effective solution in urban areas, where grid infrastructure is already present, as well as in rural areas where grid infrastructure has already been expanded. Because urban households tend to have higher consumption levels and use higher load appliances, the electricity supply from the grid would be more feasible and suitable, and grid densification should be a priority in these areas. Administrative procedures, in particular, should be smoothed to incentivize more households that are located close to the grid to connect.

Off-grid solutions are likely to be the least cost intermediate solution for households in rural areas where grid electricity will not be available soon. Since many rural households are far from the grid, have lower electricity consumption, and use electricity primarily for lighting and phone charging (or at best for powering radio), their current electricity demand can be easily met by off-grid Tier 1 and 2

[27] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

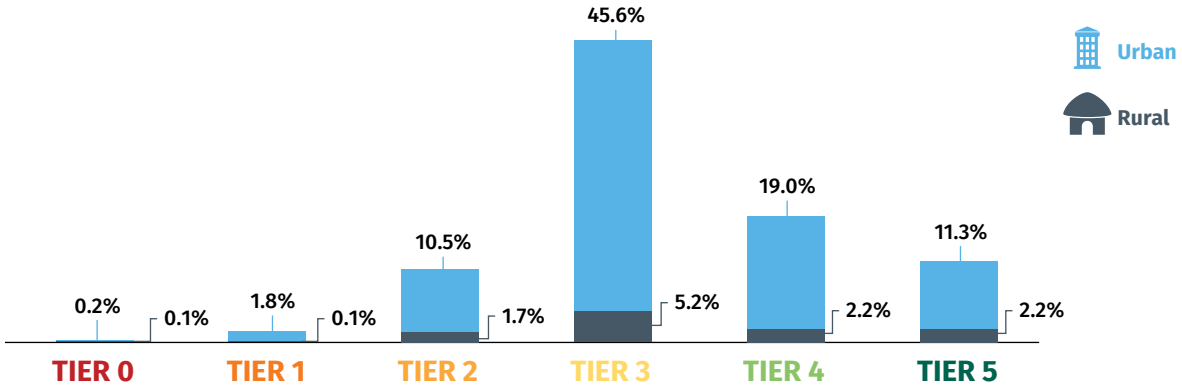
solutions. Given the high WTP for an SHS, these households could be provided with targeted financing mechanisms to pay for these products over time, such as pay as you go or microfinance.

Geospatial electrification planning tools could provide further guidance about the least cost path toward universal access to electricity, combining grid, mini-grid, and off-grid technologies.

IMPROVING ELECTRICITY ACCESS FOR GRID-CONNECTED HOUSEHOLDS

In Ethiopia 33.1% of households use the national grid as their main source of electricity, and these households have had a grid connection for an average of 11 years. Among households that use electricity from the national grid, 85.6% are in Tier 3 or above for access to electricity (figure 37). Penetration of the national grid in rural areas is still limited, but most grid-connected rural households are in Tier 3 or above, implying that the service from the grid is comparable to that in urban areas.

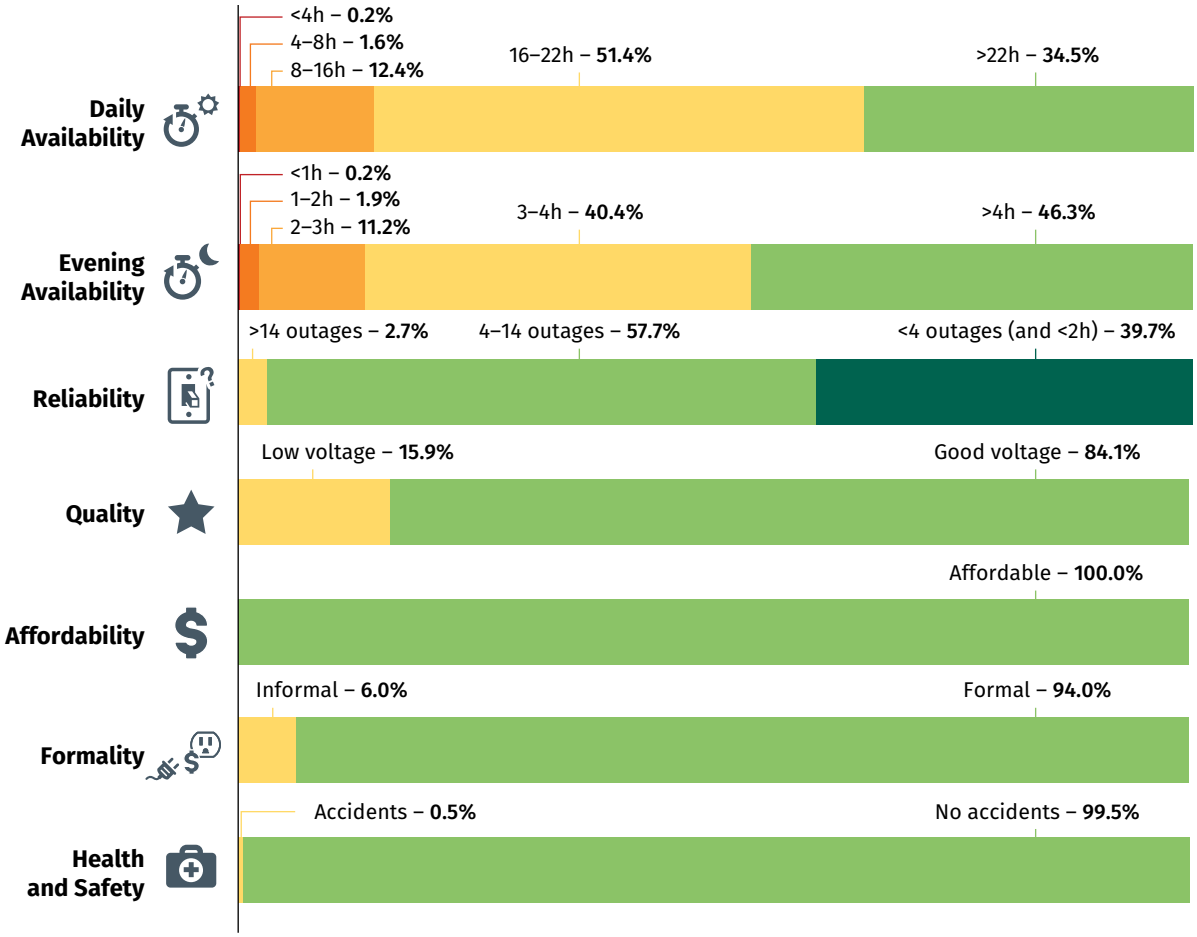
FIGURE 37 • **More than 85% of grid-connected households are in Tier 3 or above for access to electricity**



Room for improvement, however, exists to move grid-connected households to Tier 5, which is the tier that the grid service should aspire to provide. Lower tiers do not allow households to fully exploit all the advantages that a grid connection can provide.

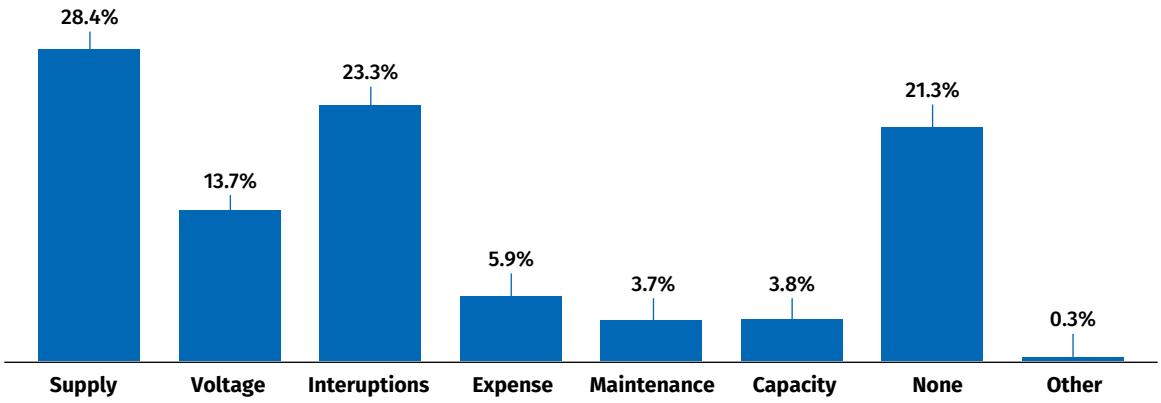
Availability and Quality are the key MTF attributes preventing grid-connected households from moving to a higher tier (figure 38). Evening Availability keeps 1.9% of grid-connected households in Tier 1 and 11.2% of households in Tier 2 from moving to a higher tier. Availability of supply (both daily and evening) and Quality are the main attributes keeping households in Tier 3 from moving to a higher tier.

FIGURE 38 • **Availability and Quality are the key Multi-Tier Framework attributes preventing grid-connected households from moving to a higher tier**



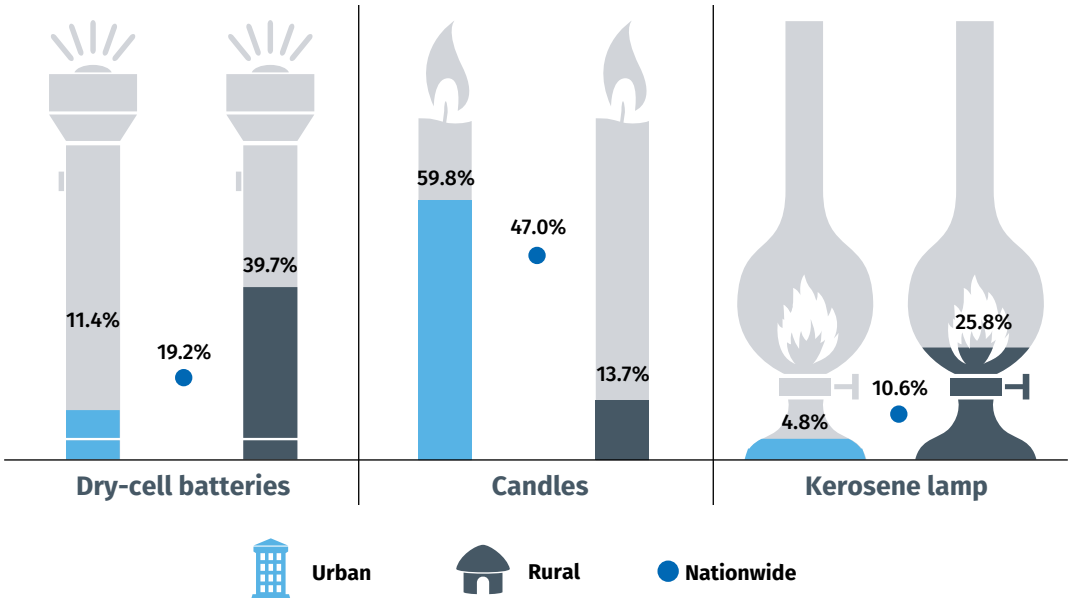
Ethiopia needs to increase its daily hours of supply (both daytime and evening) to move grid-connected households to a higher tier. But this alone will not move households to Tier 5 unless improvements in Quality and Reliability are also made. These issues are reflected in households' main concerns with the grid service: 28.4% of households consider availability of supply as a key issue, and 23.3% consider unpredictable interruptions a major concern (figure 39).

FIGURE 39 • **Availability of supply and unpredictable interruptions are households' main issues with grid electricity supply**



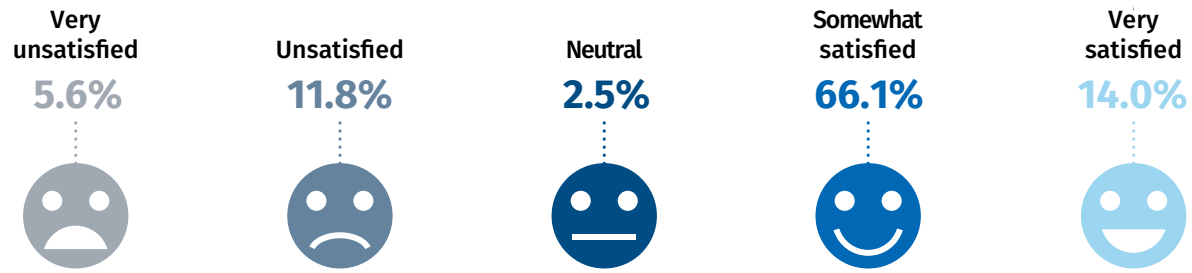
To cope with insufficient hours of service and power outages, households' main backup solutions for lighting are candles (47%) and torches/flashlights (19.2%) (figure 40). Urban households rely heavily on candles as a back-up solution, while rural households rely more on dry-cell batteries and kerosene lamps. And 7.7% of grid-connected households also use some solar product mainly as a backup solution.

FIGURE 40 • **Households' main backup solutions for lighting are candles and torches/flashlights**



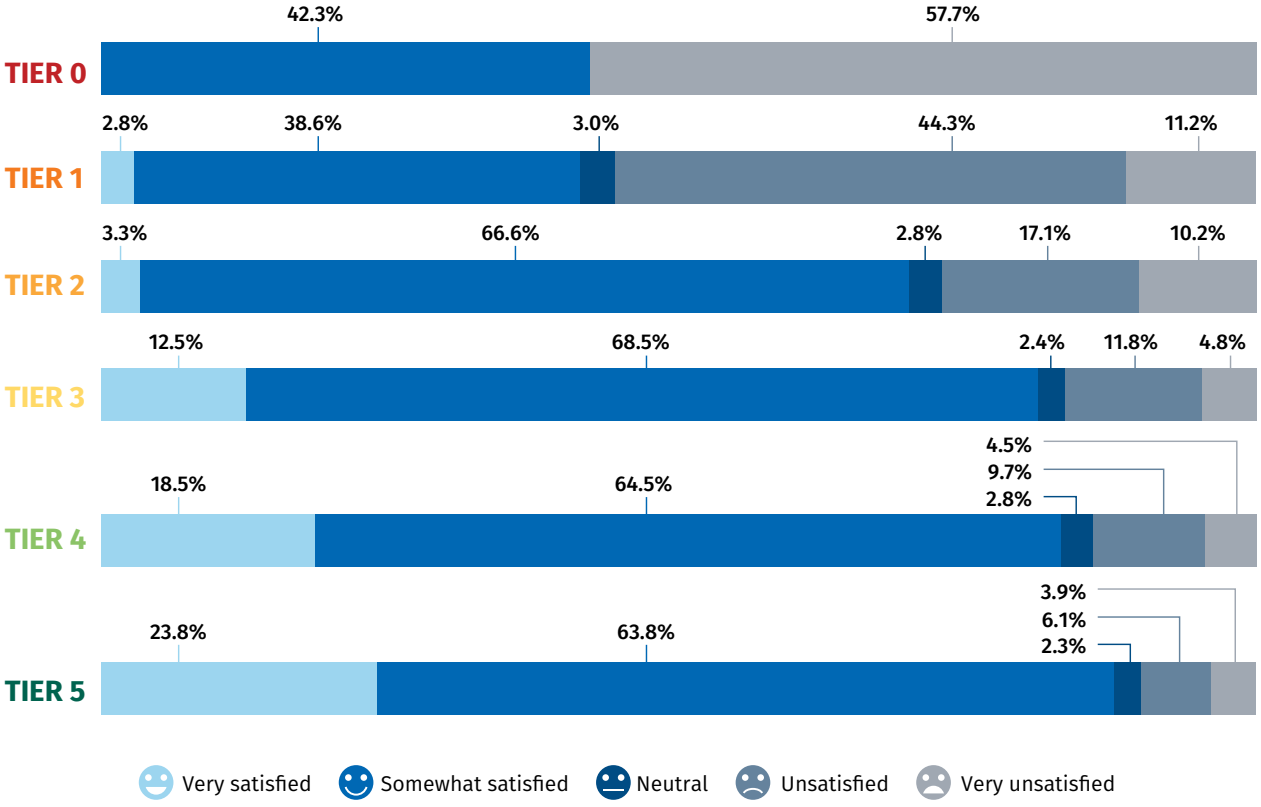
Despite concerns about availability of supply (daily and evening) and frequent disruptions, 80.1% of grid-connected households are very or somewhat satisfied with their grid electricity supply (figure 41). Only 17.4% of grid-connected households are not satisfied

FIGURE 41 • **Most households are satisfied with their grid electricity supply**



As expected, satisfaction rises as grid-connected households move to a higher tier. Only 10.1% of households in Tier 5 are not satisfied with their service, compared with 57.7% of household in Tier 0 (figure 42)

FIGURE 42 • **Satisfaction rises as households move to higher tiers**

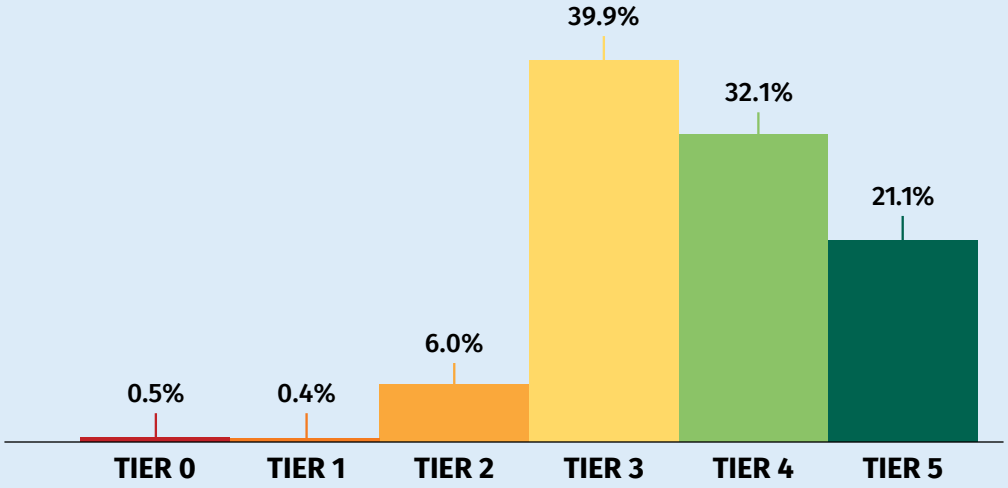


BOX 4 • FINDINGS FOR OVERSAMPLE OF URBAN HOUSEHOLDS IN ADDIS ABABA

To assess the specific challenges that households in urban areas face, the MTF survey oversampled 708 households in Addis Ababa. Since Addis Ababa's population is almost universally electrified, all households, irrespective of their income group, have access to the national grid. The analysis looks into more detail on the quality and level of service from the grid in these areas.

In Addis Ababa 93.1% of households are in Tiers 3–5, and 53.2% are in Tier 4 or 5 (see figure). This suggests that service from the national grid is relatively good.

Distribution for grid-connected households in Addis Ababa



Households in Addis Ababa are wealthier than those in other regions. Average annual income of households in Addis Ababa is 42,149 birr, compared with 39,494 for households in the rest of urban Ethiopia. This is expected because Addis Ababa is the largest city in Ethiopia and has more employment options. Differences in household wealth are also reflected in the type of appliances that households own and in overall consumption of electricity: average monthly consumption is 193 kWh in Addis Ababa and 150 kWh in other urban areas.

Availability and Quality are the key attributes preventing grid-connected households in Addis Ababa from moving to a higher tier. Daily Availability keeps around 6% of households in Tier 1 from moving to a higher tier, and Evening Availability keeps over 2% of households in Tier 1 and 30% of households in Tier 3 from moving to a higher tier. Quality keeps 16% of households in Tier 3 from moving to a higher tier. Other MTF attributes such as Affordability, Formality, and Health and Safety are not major constraints.

Overall, the findings for the oversampled households in Addis Ababa were closely in line with the findings for grid-connected households nationwide. As with grid-connected households nationwide, moving households in Addis Ababa to a higher tier would entail increasing Daily and Evening Availability and improving Quality.

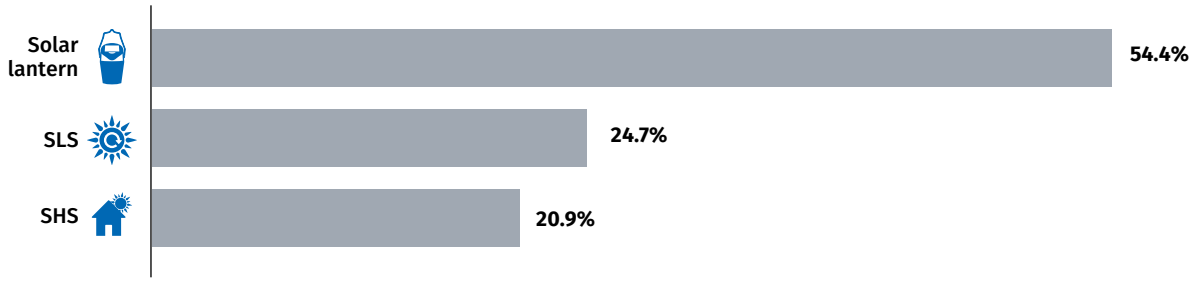
IMPROVING ELECTRICITY ACCESS FOR HOUSEHOLDS THAT USE AN OFF-GRID SOLAR DEVICE

Households that use an off-grid solar solution are only in Tiers 0 and 1 but could reach a higher tier over time due to the decrease in solar panel prices, technological advancements, and the increase in electricity demand from households that use off-grid solar solutions. Of the 23.9% of households that use an off-grid solar solution as their primary source of electricity, 53.6% are in Tier 0 (figure 43).[28] This is due to the low Capacity (insufficient light and inability to charge phones) and Availability (less than 4 hours of supply a day) of solar devices. The remaining households that use an off-grid solar solution as their primary energy source are in Tier 1 and have the ability to charge a phone and receive more than 4 hours of supply a day and 1 hour of supply in the evening. It is rare to find households using an SHS that can power higher load appliances such as a television, fan, or refrigerator. However, 80% of households have also expressed WTP (either upfront or in installments) for a higher capacity solar product, so once such products become available in the market, a larger proportion of households may switch to such systems.

FIGURE 43 • **More than 52% of rural households that use an off-grid solar device are in Tier 0**

Single-light solar lanterns, used by 54.4% of households that use an off-grid solar solution, are the most common solar device, followed by SLSs (24.7%, with similar penetration in urban and rural areas) and SHSs (20.9%) (figure 44). Most households with an SHS are still constrained by the capacity of the system and are able to power only very low–load appliances such as lighting and a radio. Thus, a majority of them do not qualify for Tier 2 access.

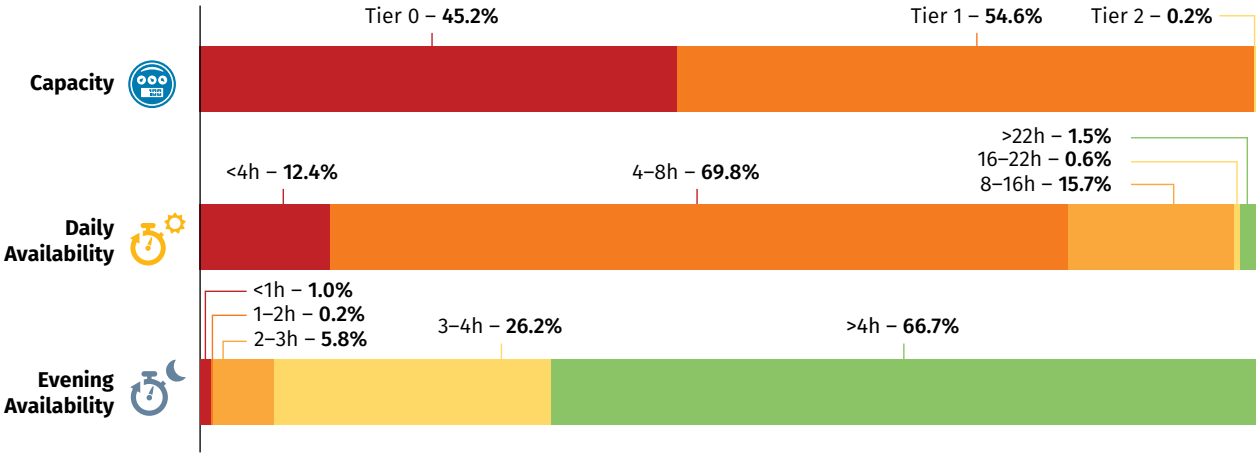
FIGURE 44 • **Single-light solar lanterns are the most common solar device**



[28] Households that use a solar lantern receive partial credit of Tier 1 under the MTF, but households with less than 0.5 are classified as Tier 0 to present the aggregated tier distribution (see box 2).

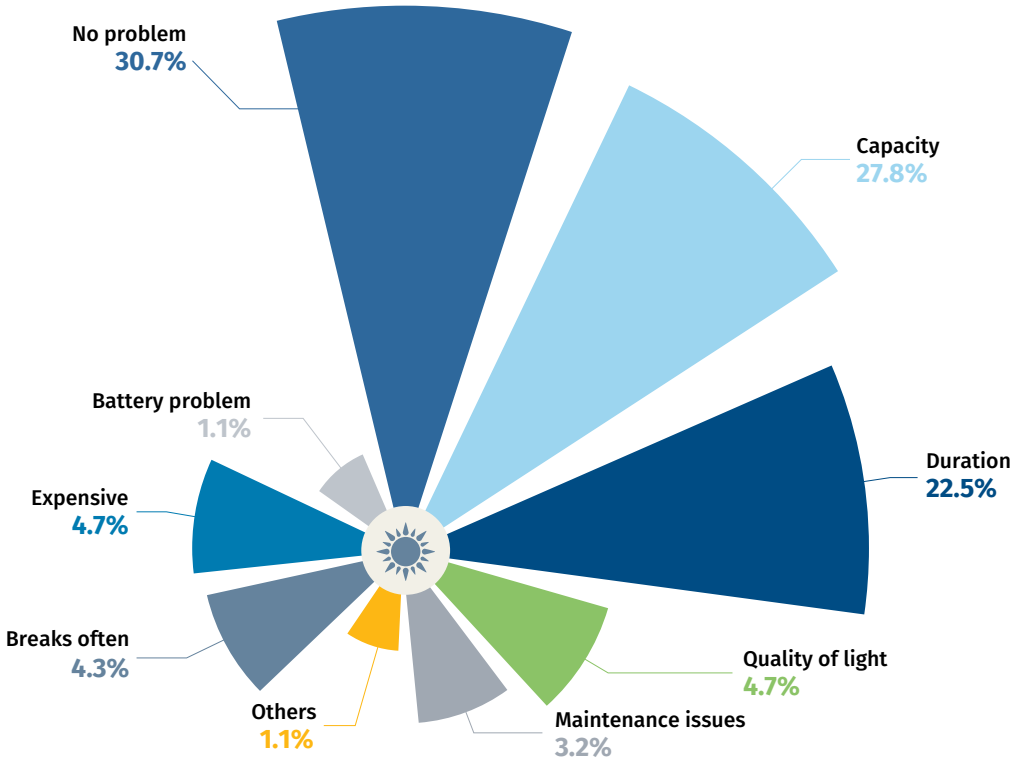
Capacity is the main constraint to households that use an off-grid solar solution: 54.6% of households use very low–load appliances (Tier 1 level) with their solar device (figure 45). Off-grid solar devices are used mostly for evening lighting purposes: 69.8% of households receive 4–8 hours of supply a day (placing them in Tier 2 for Daily Availability), while 66.7% of households receive at least 4 hours of supply in the evening (placing them in Tier 5 for Evening Availability).

FIGURE 45 • **Capacity is the main factor constraining households that use an off-grid solar solution**



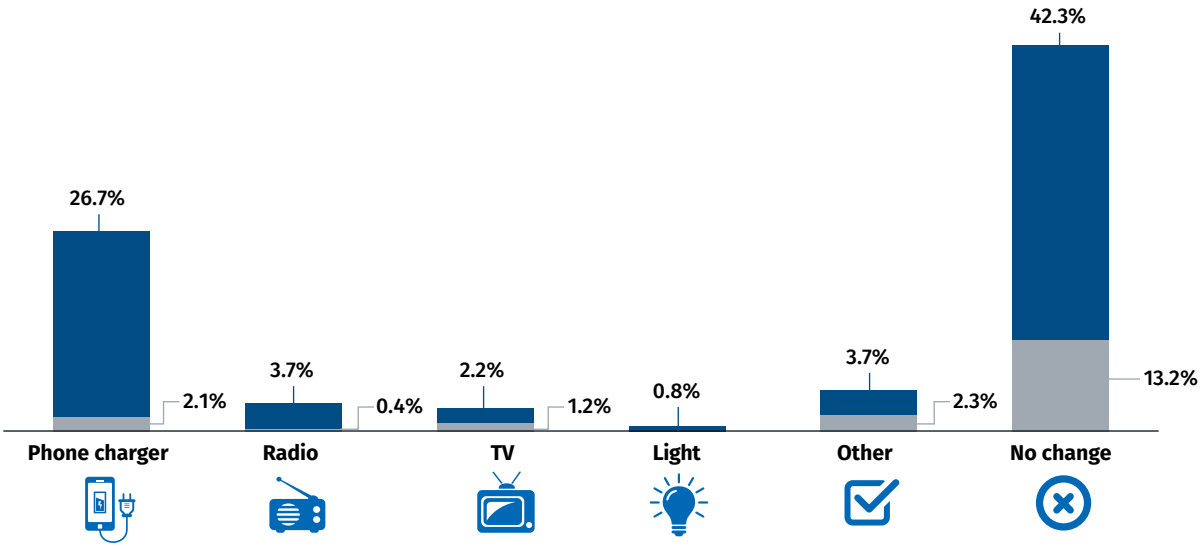
Capacity and Availability were the main issues that households cited with their off-grid solar device (figure 45). Other issues such as the expense and quality of light appear are minor.

FIGURE 46 • **Capacity and Availability were the main issues that households cited with their off-grid solar device**



To reach a higher tier for access to electricity, households that use an off-grid solar solution will need to upgrade to a larger system. More than half (55.5%) of households do not report any change in the appliances that they use from the first solar device that they owned. This may be due to the fact that off-grid solar devices are relatively new in Ethiopia and that larger systems are not yet common on the market. The appliance with the biggest change was phone charger: 28.8% of households upgraded from a single light solar option to one that provides basic phone charging (figure 47).

FIGURE 47 • **More than half of households do not report any change in the appliances that they use from the first solar device that they owned**



While higher capacity off-grid solar systems (ones that can power medium- to very high–load appliances such as refrigerators) are rare, the advancement in off-grid solar technologies has increased the probability that Tier 3 or higher systems will become available. The key is to ensure that higher tier off-grid systems are made available in the market and to ensure that households can afford them.

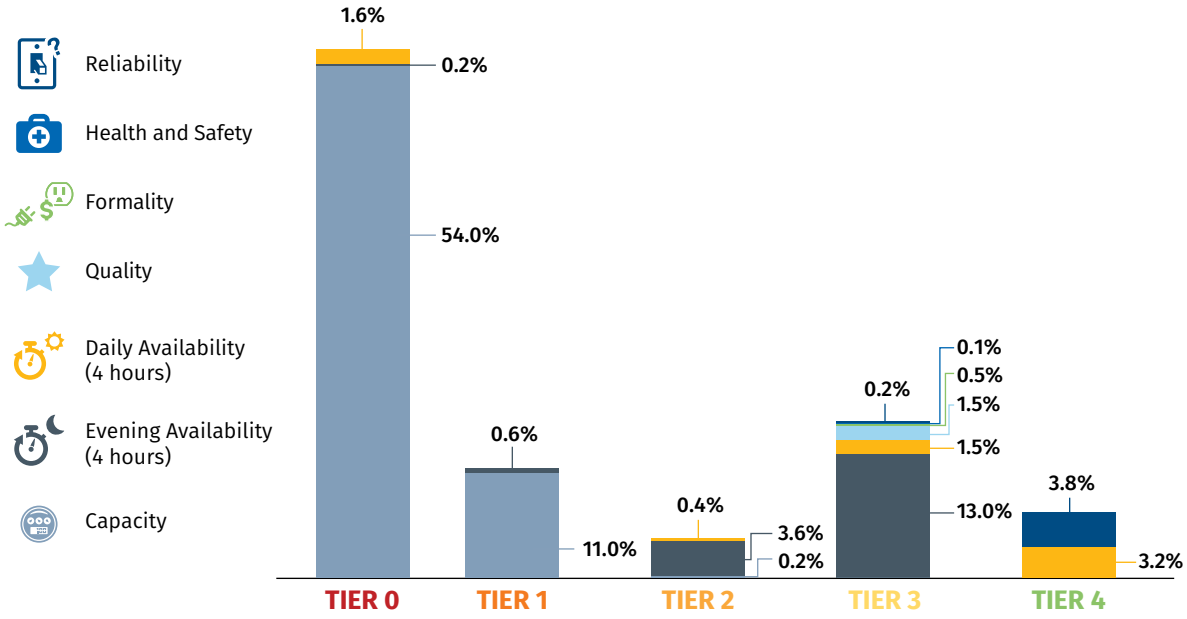
GAP ANALYSIS AND POLICY RECOMMENDATIONS

Ethiopia's greatest challenge is to move households in Tier 0 to Tier 1 or above for access to electricity. Only 1.6% of households are in Tier 0 because of limited Daily Availability, while 54% of households are in Tier 0 because of Capacity (figure 48). These households do not have any source of electricity (18.4%), use dry-cell batteries (24.6%), or rely on small solar lanterns that do not qualify for Tier 1 access (12.6%). It is thus necessary to provide households in Tier 0 with access to electricity through the national grid, mini-grids, or standalone off-grid solutions with high capacity.

Providing electricity for longer hours is important to move grid-connected households in Tiers 1–3 to a higher tier (Evening Availability is a particularly large problem for households in Tiers 2 and 3), while reducing interruptions and improving voltage are important to move households in Tiers 3 and 4 to

a higher tier. Affordability of grid electricity is not a major barrier in Ethiopia. Providing 3 hours of supply in the evening would help move 3.6% of households to Tier 3, and providing 4 hours of supply in the evening would move 13.2% of households to Tier 4 (provided the service is reliable and there are no voltage issues). Reducing supply interruptions to less than 3 a week and ensuring that the total duration of the interruptions is less than 2 hours would move 3.8% of households to Tier 5.

FIGURE 48 • **Capacity prevents most households from moving to a higher tier**



Wherever the grid is available, densification of the grid should be a priority to provide electricity to households without access to any source of electricity. Ability to pay for a connection is not a major constraint, particularly if the connection fee can be spread over time (96% of households stated that they would be willing to pay for an electricity connection), but administrative procedures are a significant barrier. For 38.1% of households that live within 7 kilometers of the national grid complicated administrative procedures are the main barrier to a grid connection. These barriers need to be addressed to facilitate a higher connectivity rate.

Off-grid solutions should be promoted in remote rural areas and as an intermediate solution in areas where grid connectivity is the least cost solution but where grid access may take several years to achieve. Because this mostly affects rural households and because grid-connected rural households mostly own only Tier 1 and Tier 2 appliances, solar solutions that qualify for Tiers 1 and 2 should be able to accommodate current household demand.

The rapid expansion of smaller solar devices such as solar lanterns in rural areas (close to 11% of rural households are in Tier 1 thanks to solar technology) demonstrates the potential for this technology to close the access gap, especially since Tier 1 solar solutions are uniformly spread across all income quintiles, including the poor. But many of the solar products available are below Tier 1:

12% of households are in Tier 0 despite using a solar device or devices. There is high WTP for larger systems but low penetration of Tier 2 solar products. It would be worth analyzing the factors that have enabled other countries in East Africa to increase the uptake of such products in the market (such as the pay-as-you-go systems spreading rapidly across the region) and the barriers to similar expansion in Ethiopia. These barriers should be examined and addressed to ensure that more households adopt larger and higher capacity solar products.

The vast majority of households are satisfied with their on-grid (80%) or off-grid electricity service (73%). Among households that use an off-grid solar solution, satisfaction increases with system size, and the main issues relate to Capacity and Availability, which could be resolved with off-grid solar systems that have a higher Capacity, including batteries.

Considering the relative underutilization of the grid, programs to increase electricity use should be explored, in particular promotion of productive uses of electricity and energy-efficient appliances.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

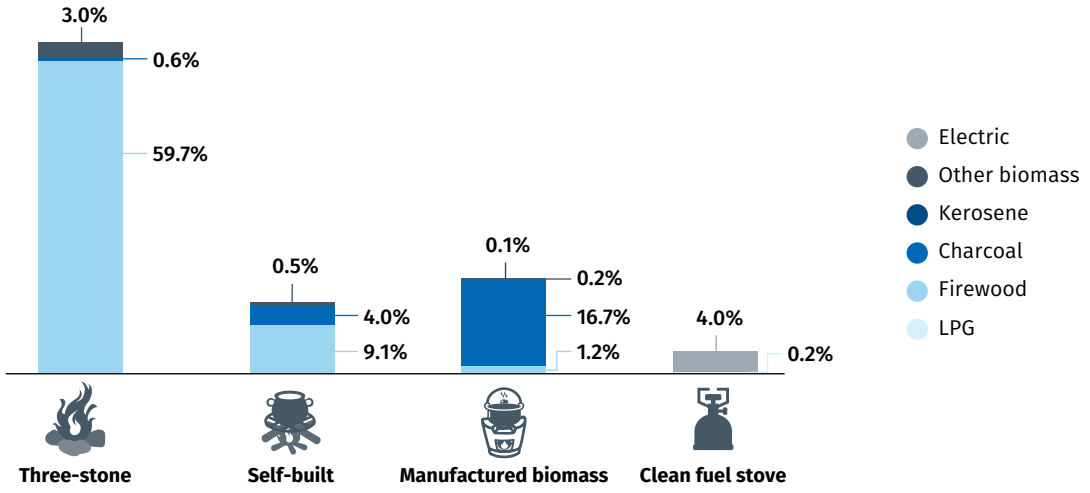
TECHNOLOGIES

In Ethiopia 63.3% of households use a three-stone stove as their primary stove, 13.6% use a self-built stove as their primary cooking solution, 18.2% use a manufactured biomass stove, and 4.1% use a clean fuel stove with electricity (figure 49). Cooking with clean fuels such as biogas and liquefied petroleum gas (LPG) is rare. Less than 1% of households use LPG as their primary cooking solution, while 96% of households use biomass fuels.

A three-stone stove is a pot balanced on three stones over an open fire. A self-built stove is typically an enclosed stove made using stone, mud, and flat clay that can be slightly more efficient than a three-stone stove. A manufactured biomass stove is typically produced in a factory or by an artisan and usually made of metal and can be considered an improved cookstove (ICS). Clean fuel stoves are manufactured stoves that use clean fuels such as electricity or LPG exclusively.

Ethiopian households commonly use Injera baking stoves in addition to regular stoves for cooking. Injera stoves consume a significant amount of cooking energy per household. In addition, households also use stoves for coffee making. However, during the data collection, information on the Injera baking stoves or coffee stoves was not collected, so the analysis here focuses on regular cooking stoves, comparable to the scope of similar surveys carried out in other countries. As a result, the analysis may omit some aspects of the household cooking scenario such as additional exposure from baking and coffee stoves, additional use of biomass fuel, and total spending on the cooking solution.

FIGURE 49 • **Cooking with modern energy cooking solutions and clean fuels is rare**

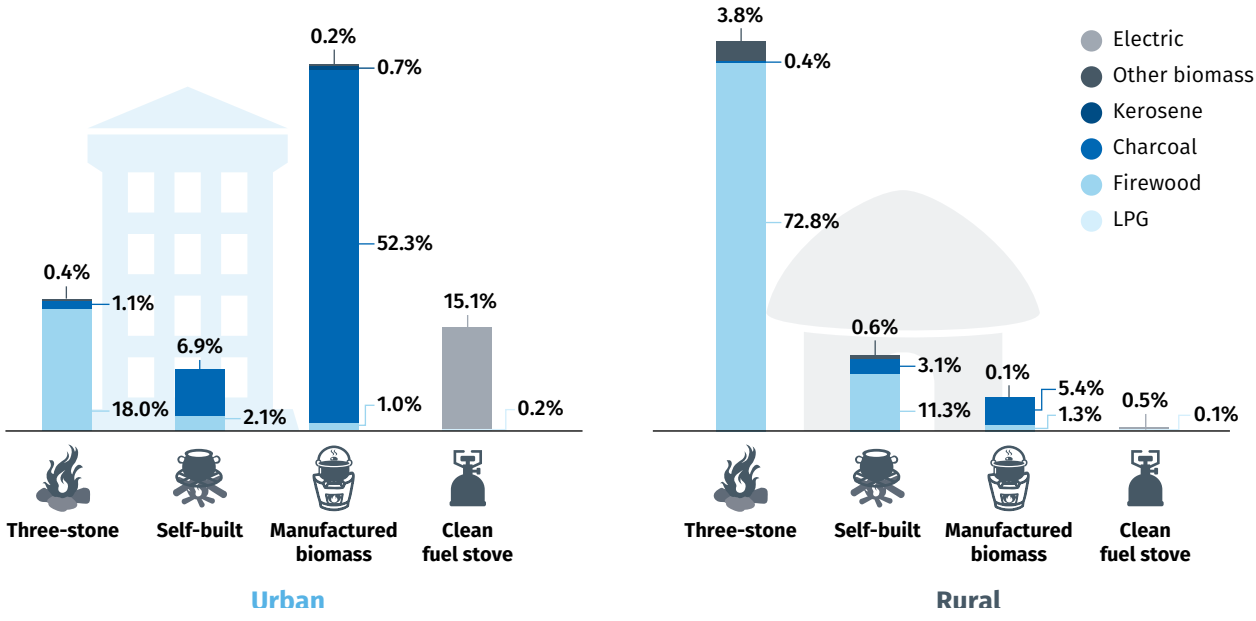


Note: Other biomass includes animal waste (such as dung), plant biomass/crop residue, sawdust, and processed biomass (briquette).

Urban and rural households use different cooking technologies: 54.3% of urban households use a manufactured stove and 15.3% use a clean fuel stove, while 77% of rural households use a three-stone stove (figure 50). And 85.4% of rural households use firewood as their primary fuel, while 60.3% of urban households use charcoal.

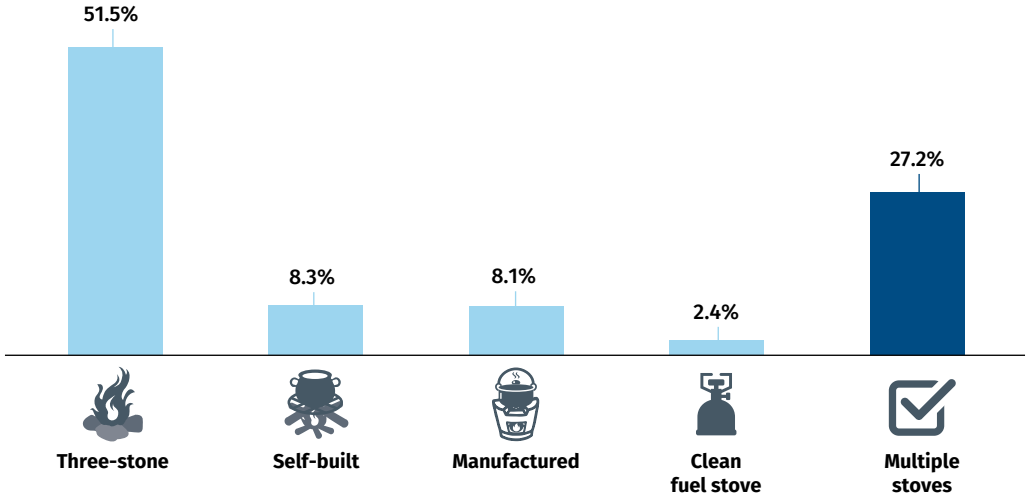
The penetration rate of clean fuel stoves is still low, at 4.1%. Given the health benefits of using clean fuels for cooking and the relatively low electricity tariff, it would be worth investigating how the penetration of clean fuel stoves, mainly electric stoves, can be further increased among grid-connected households.

FIGURE 50 • **Urban and rural households use different cooking technologies and fuels**



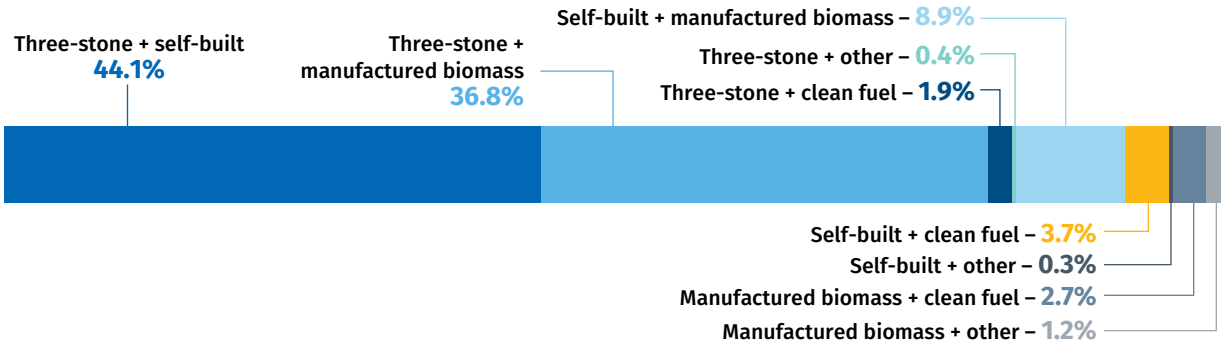
Stove stacking (using multiple cookstoves) occurs in 27.2% of households (figure 51).[29] By contrast, 51.5% of households use a three-stone stove exclusively, 8.1% use a manufactured biomass stove exclusively, and only 2.4% use a clean fuel stove exclusively.

FIGURE 51 • **Nearly three-quarters of households use only one type of stove**



Of households that use multiple stoves, 44.1% use a three-stone stove and a self-built stove, 36.8% use a three-stone stove and a manufactured biomass stove, and 8.3% use a clean fuel stove in combination with another type of stove (figure 52).

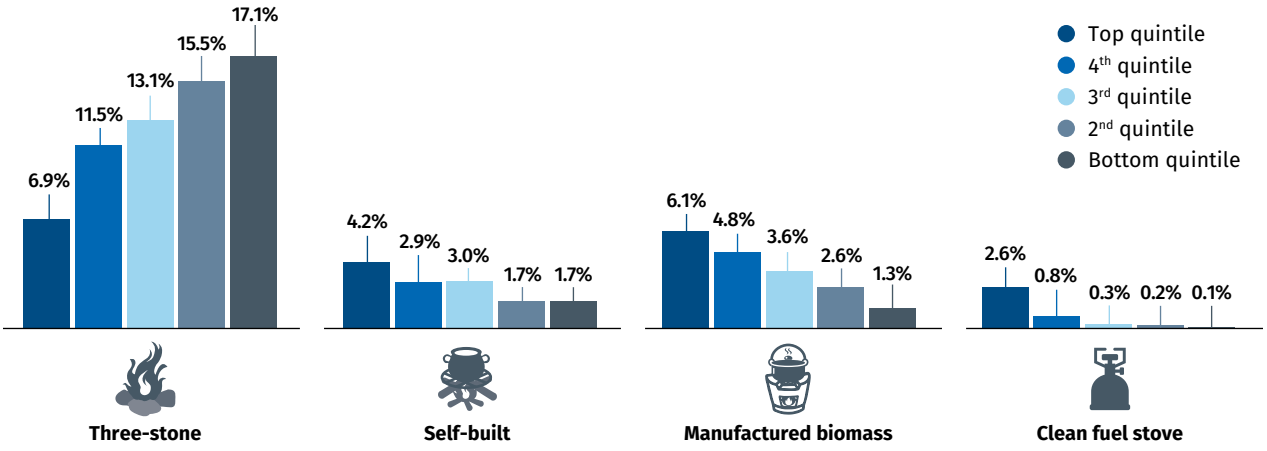
FIGURE 52 • **Most households that use multiple stoves use a three-stone stove in combination with another type of stove**



Penetration of manufactured biomass stoves and clean fuel stoves increases with household spending quintile: 6.1% of households in the top spending quintile use a manufactured biomass stove, compared with 1.3% of households in the bottom spending quintile, and 2.6% of households in the top spending quintile use a clean fuel stove, compared with 0.1% of households in the bottom spending quintile (figure 53).

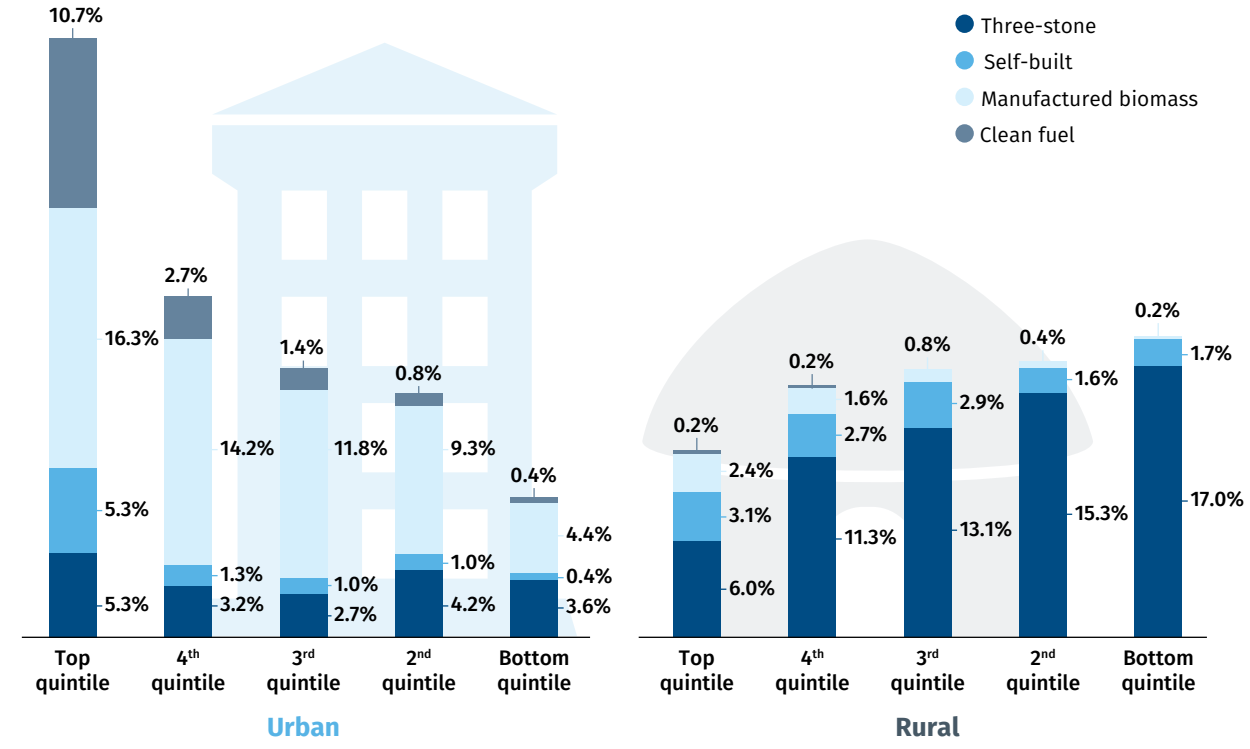
[29] This refers to the main cookstove and not to stoves used exclusively for baking or making coffee.

FIGURE 53 • **Penetration of manufactured biomass stoves and clean fuel stoves increases with household spending quintile.**



In urban areas 10.7% of households in the top spending quintile use a clean fuel stove as their primary stove, compared with 2.7% of households in the 4th spending quintile and 0.4% of households in the bottom spending quintile (figure 54). This suggests that the upfront cost of purchasing an electric stove could be a burden for most households. Further investigation is required to clarify the barriers of electric stove adoption. Most rural households use a three-stone stove as their primary stove, and very few rural households use a clean fuel stove, regardless of spending quintile.

FIGURE 54 • **Most rural households use a three-stone stove as their primary stove, regardless of spending quintile**

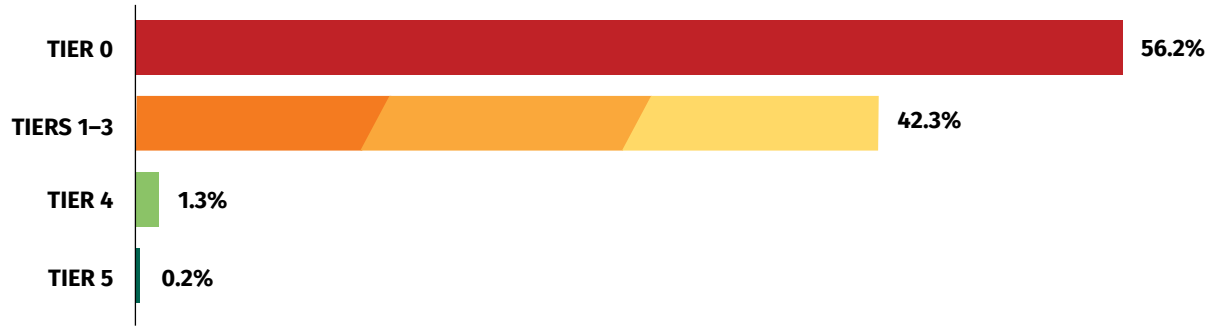


MTF TIERS

This report presents a preliminary estimated tier structure based on an interim MTF cooking framework. The analysis takes into account the information available on stove classification and the defined attributes that can be measured (box 5). For details on this simplified methodology, see the section on measuring energy access in Ethiopia and the detailed attribute analysis below.

Nationwide, 56.2% of households are in Tier 0 for access to modern energy cooking solutions because they use a three-stone stove as their primary cooking solution and have poor ventilation, and 42.3% of households are in Tiers 1–3 because they use a self-built or manufactured biomass stove (figure 55). Self-built and manufactured biomass stoves meet the requirement for Tier 1, but because of a lack of information on the emissions of these types of stoves, the exact tier status for these stoves could not be determined. So most households that use a self-built or manufactured biomass stove are assigned to Tiers 1–3. Only 1.5% of households are in Tier 4 or 5.

FIGURE 55 • **More than half of households are in Tier 0 for access to modern energy cooking solutions**



BOX 5 • MINIMUM REQUIREMENTS BY TIER OF COOKING SOLUTIONS

Tier 0: Households use a three-stone stove as their primary stove and do not have good ventilation.

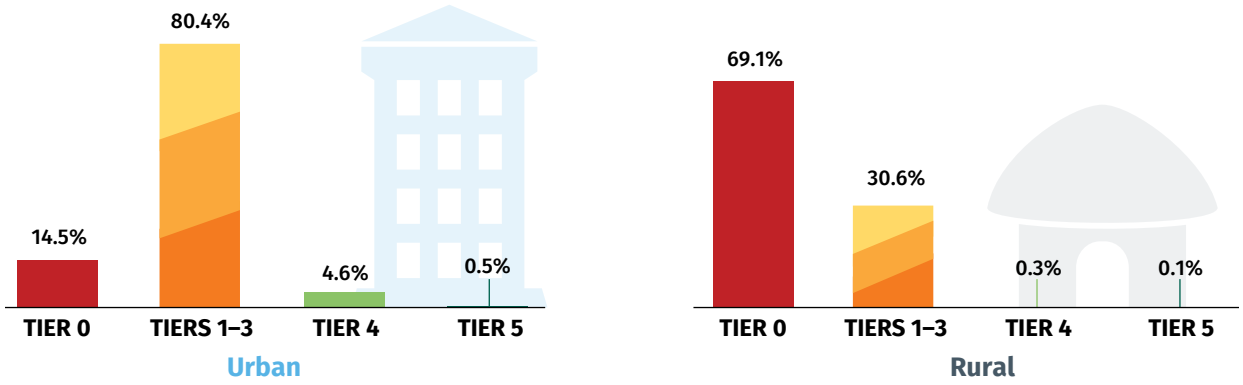
Tiers 1–3: Households use a self-built or manufactured biomass stove. They have been broadly classified in this category because no data are available on the emissions and efficiency of self-built and manufactured biomass stoves. This category also includes households that use a clean fuel stove as their primary stove and spend more than 1.5 hours a week acquiring and preparing cooking fuel or more than 5 minutes per meal preparing the stove, allocate more than 5% of their spending to cooking fuel, or have experienced a serious accident over the past year because of their cooking solution.

Tier 4: Households cook primarily with a clean fuel stove, spend 0.5–1.5 hours a week acquiring and preparing cooking fuels and 2–5 minutes per meal preparing the stove, did not experience a serious accident over the past year because of their cooking solution, and find their primary cooking fuel to be mostly available for at least 80% of the year.

Tier 5: Households use a clean fuel stove as their primary stove, spend less than 0.5 hour a week acquiring and preparing cooking fuels and less than 2 minutes per meal preparing the stove, did not experience a serious accident over the past year because of their cooking solution, and find that electricity for cooking is always available throughout the year.

In rural areas 69.1% of households are in Tier 0 because they use a three-stone stove as their primary cooking solution, while in urban areas 80.4% of households are in Tiers 1–3 because they use a self-built or manufactured biomass stove (figure 56). Although 15.3% of urban households use a clean fuel stove as their primary stove, only 5.1% of them are in Tier 4 or 5 for access to modern energy cooking solutions. Convenience, Safety of Primary Cookstove, Affordability, and Fuel Availability keep some households in a lower tier.

FIGURE 56 • **Most urban households are in Tier 3, while most rural households are in Tier 0**



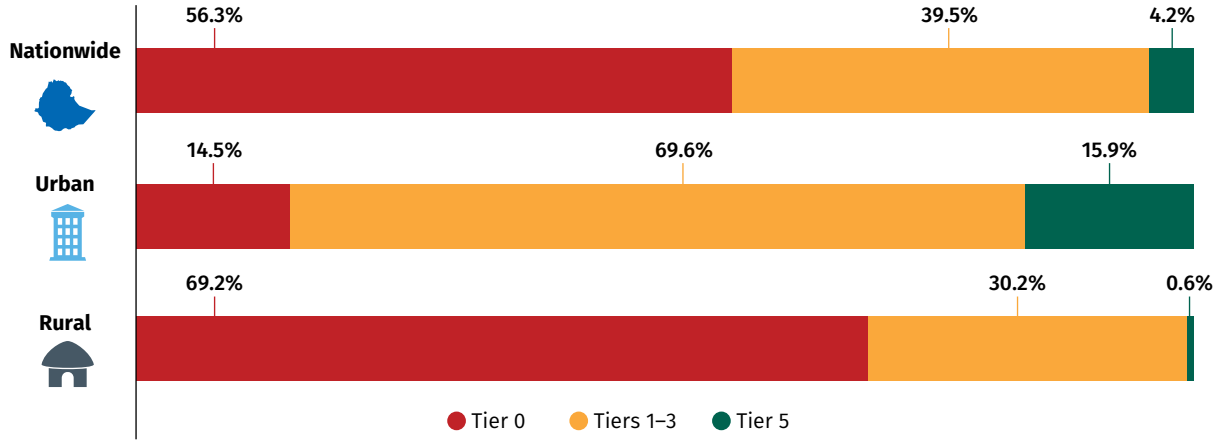
MTF ATTRIBUTES

Cooking Exposure

The tier for cooking exposure is a composite of the tier for emissions from the cooking activity (determined by the type of cookstove) and the level of ventilation in the cooking area, which can mitigate pollutants from cooking. Good ventilation can help move households to a higher tier for Cooking Exposure, irrespective of the stove exposure.

Nationwide, 56.3% of households are in Tier 0 for Cooking Exposure, mainly because they use a three-stone stove as their primary cooking solution and do not have good ventilation (figure 57). Although 63.3% of households use a three-stone stove, some of these households are in Tier 1 based on ventilation, while 39.5% of households are in Tiers 1–3 because they use a self-built or manufactured biomass stove. As discussed above, lack of detailed information on stove emissions prevents more precise tier classification. Only 4.2% of households use a clean fuel stove (mostly with electricity) and are in Tier 5.

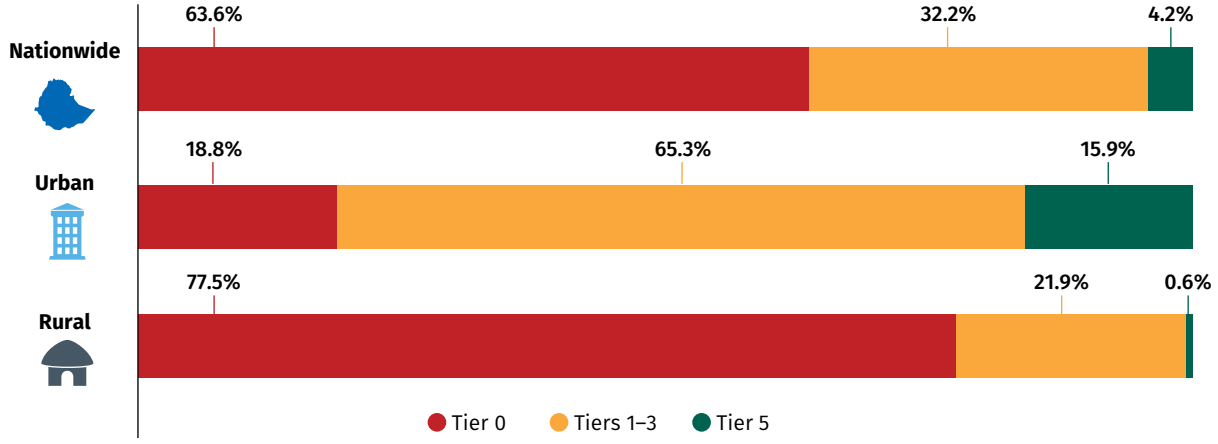
FIGURE 57 • **More than 56% of households are in Tier 0 for Cooking Exposure**



Stove emissions

Nationwide, 63.6% of households are in Tier 0 for stove emissions, with a wide gap between rural (77.5%) and urban (18.8%) households (figure 58), mostly because of the use of three-stone stoves. In urban areas 65.3% of households are in Tiers 1–3, mostly because they use a self-built or manufactured biomass stove, compared with 21.9% of households in rural areas. More precise tier classification among these households is not possible because of a lack of information on the emissions of these types of stoves. Only 0.6% of rural households are in Tier 5, compared with 15.9% of urban households.

FIGURE 58 • **There is a wide gap between the percentage of urban and rural households in Tier 0 for stove emissions**

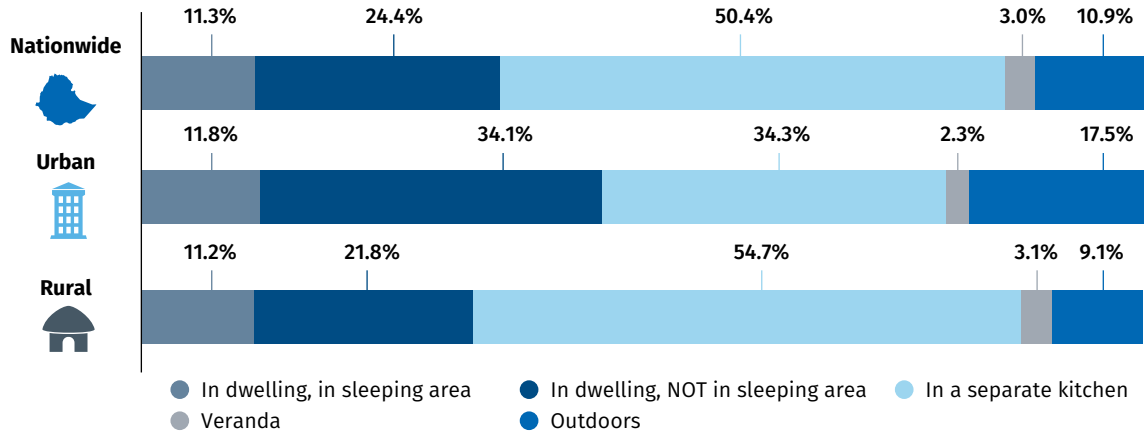


Ventilation structure

Ventilation structure takes into account the location of the cookstove (indoors or outdoors) and, if indoors, the number of doors and windows in the cooking space. This is relevant mostly for households that use a biomass stove.

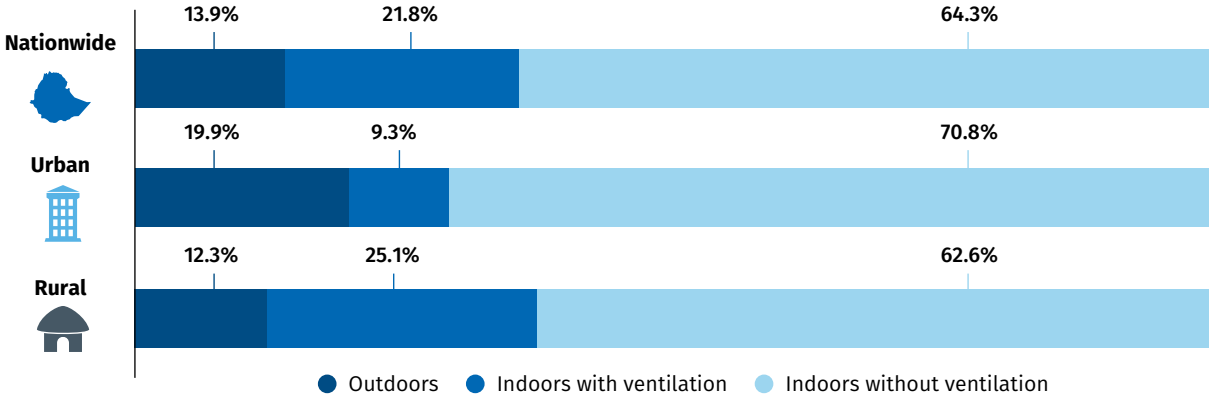
The cooking location for the primary stove is outdoors for 10.9% of households that use a biomass stove, including 9.1% of rural households and 17.5% of urban households (figure 59).

FIGURE 59 • **More than 86% of households cook indoors**



Of the households that cook indoors and whose primary stove is a biomass stove, 64.3% have poor ventilation (no exhaust system and two or fewer doors or windows in the cooking space) (figure 60). More urban households (70.8%) than rural households (62.6%) have poor ventilation.

FIGURE 60 • **A majority of households have poor ventilation**

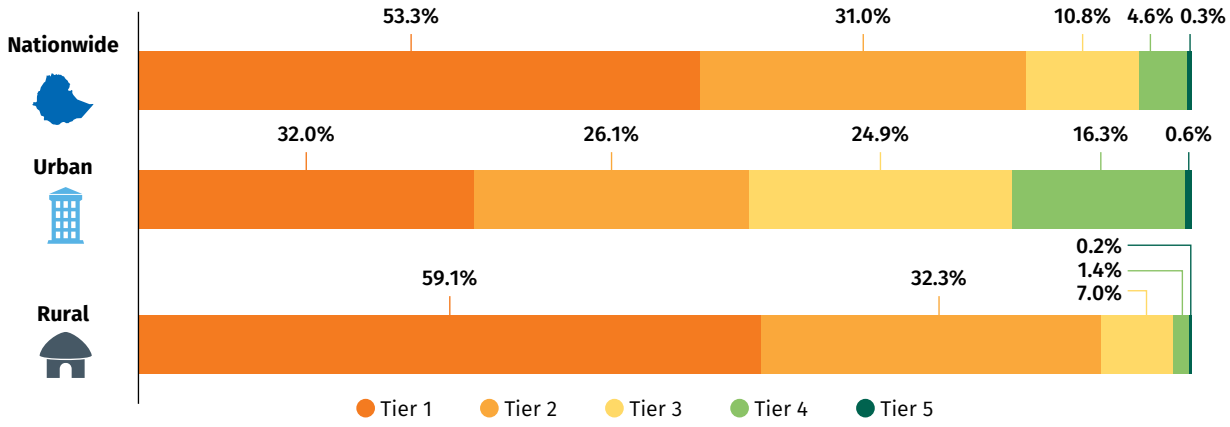


Convenience

Nationwide, 53.3% of households are in Tier 1 for Convenience because they spend more than 7 hours a week acquiring (through collection or purchase) fuel and more than 15 minutes preparing the stove for each meal (figure 61). More rural households (59.1%) than urban households (32%) are in Tier 1 because rural households are more likely to collect fuel than urban households are: 48% of rural households spend more than 7 hours a week acquiring fuel, compared with 9% of urban households. In contrast, 4.9% of households nationwide are in Tier 4 or 5. Households that use a clean fuel stove, particularly those that use an electric stove, do not spend much time on fuel acquisition and preparation

or stove preparation, so all those households are in the highest tier for Convenience. Because more urban households than rural households use a clean fuel stove, 16.9% of urban households and 1.6% of rural households are in Tier 4 or 5.

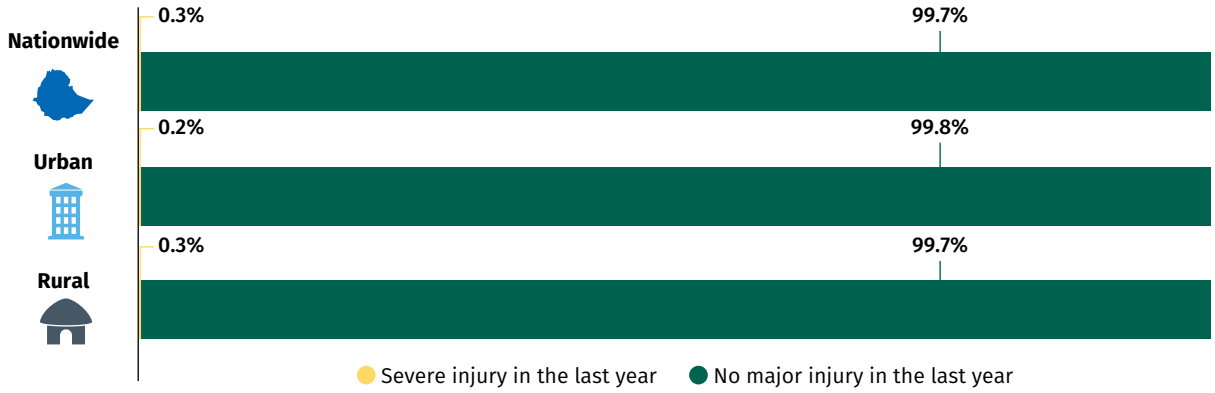
FIGURE 61 • **Over half of households are in Tier 1 for Convenience**



Safety of Primary Cookstove

Less than 0.5% of households reported the death or serious injury of a household member—including permanent health damage; burns, fire, or poisoning; severe cough or respiratory problem; or other major injury associated with use of a cookstove in the last year (figure 62).

FIGURE 62 • **Almost no injuries associated with cookstoves were reported in the last year**

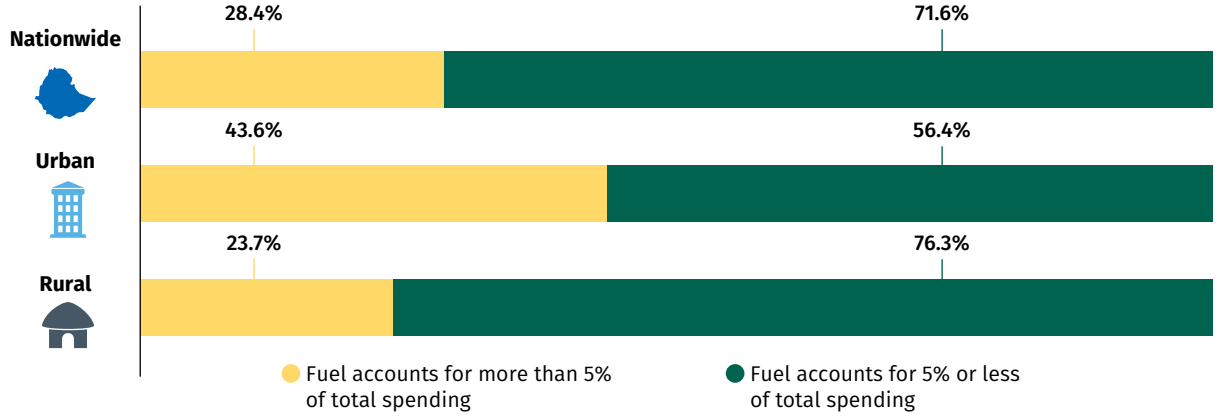


Affordability

Affordability prevents 28.4% of households from reaching a higher tier for access to modern energy cooking solutions because primary cooking fuel accounts for more than 5% of their monthly spending (figure 63). Of those households, 66.2% use firewood as their primary cooking fuel, and 30.9% use charcoal. Because more urban households than rural households purchase firewood for cooking, 43.6%

of urban households use more than 5% of their monthly spending for fuel, compared with 23.7% of rural households. The percentage of households being prevented from reaching a higher tier because of Affordability may be overestimated because the data on spending on primary cooking fuel may include spending on injera baking stoves, especially if the same fuel is used for the cooking stove and the baking stove.

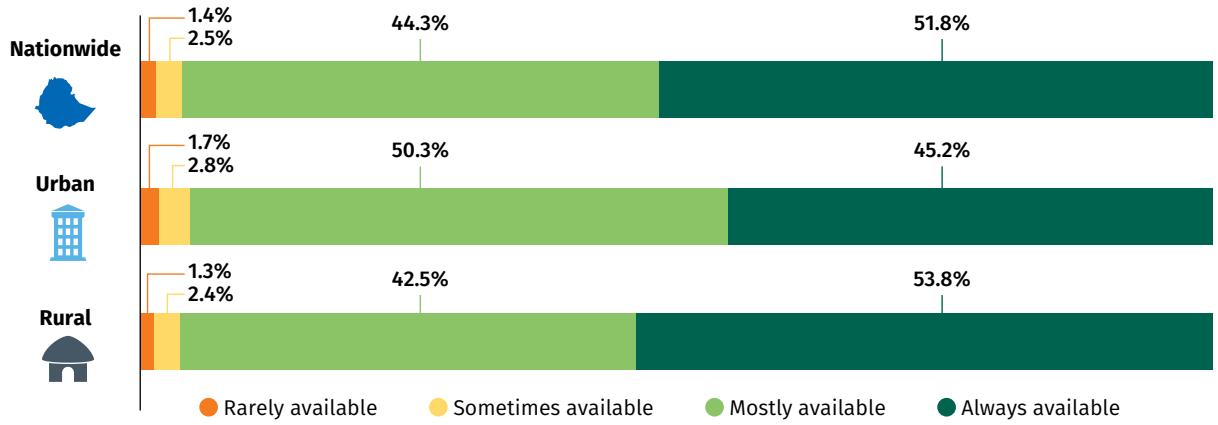
FIGURE 63 • **Affordability of fuel prevents more than 28% of households from reaching a higher tier for access to modern energy cooking solutions**



Fuel Availability

Fuel Availability is not a major constraint for most households: 96.1% reported that fuel is always or mostly available throughout the year (figure 64).

FIGURE 64 • **Fuel Availability is not a major constraint for most households**



IMPROVING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

INCREASING THE PENETRATION OF ELECTRIC STOVES

The ultimate objective of improving access to modern energy cooking solutions in Ethiopia should be to provide all households with access to cooking solutions that are clean, convenient, efficient, affordable, safe, and available (that is, to move all households to Tier 4 or 5 for access to modern energy cooking solutions). Given the low penetration rate of clean fuel stoves (4.1%), the primary objective should be to increase the use of clean fuel stoves—and electric stoves in particular—so that households can enjoy the associated health benefits.

Several factors could facilitate adoption of electric stoves. First, given government efforts, a larger share of the population is likely to have access to electricity in the near future. Second, the low electricity tariff should incentivize adoption of electric stoves, particularly for households that purchase fuel, given the relatively high costs of charcoal and firewood in Ethiopia.

Even though 96% of households use biomass as their primary fuel, Affordability of fuel is a constraint for a large share of households. In urban areas 43.6% of households use more than 5% of their monthly spending for fuel because they purchase firewood and charcoal. Since grid penetration is high (96.2%) in urban areas and the cost of electricity is low,[30] electric stoves should be promoted, particularly in urban and peri-urban areas, where grid penetration is higher.

A starting point is to investigate why only 4.1% of households use electricity as their primary cooking fuel despite the low cost of electricity. One possible reason is that the grid connection is not reliable, especially given that only 4.5% of households nationwide, 11.3% of urban households, and 2.2% of rural households are in Tier 5 for access to electricity. Upfront costs of electric stoves, availability of energy-efficient stoves, or cultural factors could also be reasons. Specific measures to increase the uptake of electric stoves—such as financial incentives, payment plans, and awareness campaigns—should be designed.

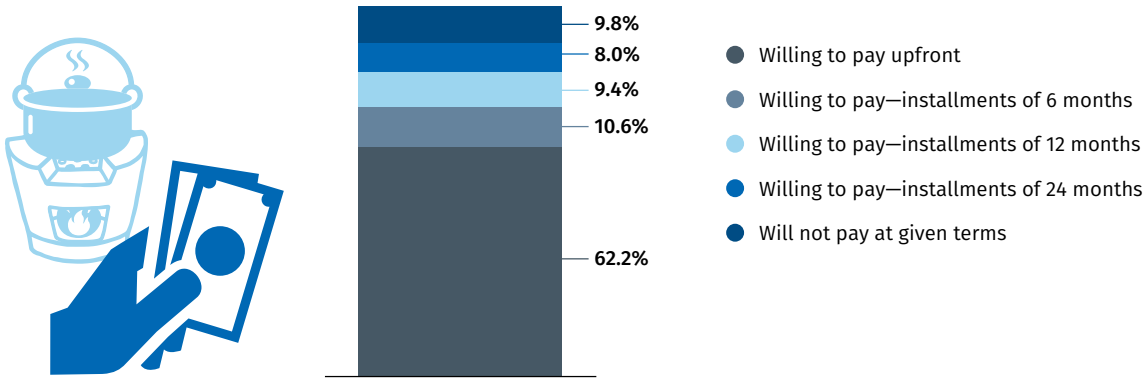
SUPPORTING ADOPTION OF IMPROVED COOKSTOVES AS AN INTERIM MEASURE

Bringing clean fuel stoves to all households may be a long process. In the interim, manufactured biomass stoves are the most feasible solution for the 76.8% of households that use a three-stone or self-built stove. Transitioning to a manufactured biomass stove can deliver important benefits—namely less time collecting firewood (because manufactured biomass stoves use considerably less fuel than three-stone and self-built stoves). This freed time benefits women in particular because they carry the largest burden of firewood collection (see section on gender analysis).

[30] The average tariff, last revised in 2006, is $0.03 per kWh, below the full cost of service, which is estimated at $0.06–$0.07 per kWh.

Increased adoption of manufactured biomass stoves would move the 56.2% of households currently in Tier 0 for access to modern energy cooking solutions to Tier 1 or above. This is likely a feasible goal, given the high willingness to pay (WTP) for one such manufactured biomass stove in Ethiopia. Currently 62.2% of households are willing to pay full price upfront for a Laketch stove (an improved charcoal stove priced at 175 birr or about $7.70[31]), and 28% of households are willing to pay full price with a 6- to 24-month payment plan (figure 65). Only 9.8% are not willing to purchase at the given terms because they thought the stove was too expensive, even with the payment options (55%) or they felt that they did not need a manufactured biomass stove (39%). Allowing households to pay in installments would be an effective way to increase households' ability to pay for a manufactured biomass stove without upfront cost subsidies, which often suffer from lack of sustainability. Given the high WTP, the key factors that prevent faster adoption of manufactured biomass stoves should be analyzed and addressed on both the supply side (for example, availability of stoves in all areas of the country) and the demand side (further incentives to switch to manufactured biomass stoves).

FIGURE 65 • **More than 90% of households are willing to pay full price upfront or with a payment plan for an improved charcoal stove**



Uptake of manufactured biomass stoves could be further increased by awareness campaigns. The 63.3% of households that use a three-stone stove as their primary cooking solution could be educated on the benefits of using a manufactured biomass stove. The campaigns should target ambient and behavior aspects—such as improved ventilation, separating cooking areas from sleeping areas, and minimizing time in the cooking area—among users of both traditional and manufactured biomass stoves to limit household members' exposure to harmful pollutants.

Given that Injera baking stoves consume a significant amount of cooking energy in Ethiopia and are not covered in this analysis, to achieve full impact of switching to a modern energy cooking solution, this cooking segment also should be analyzed and addressed.

[31] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

GENDER ANALYSIS

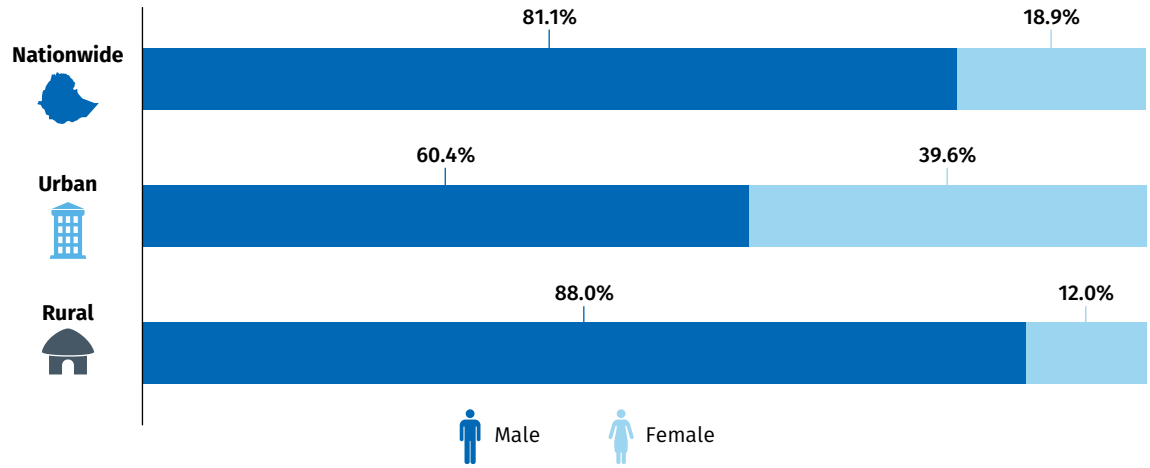
ASSESSING GENDER ANALYSIS

Nationwide, 18.9% of households are headed by women (figure 66). Female-headed households are more likely than male-headed households to live in urban areas: 39.6% of urban households are headed by women, compared with 12% of rural households.[32]

The average household size for female-headed households is 3.4, compared with 5.1 for male-headed households. The employment rate is lower for female household heads (73%) than for male household heads (95%). The average age of female household heads is 45, compared with 43 for male household heads.

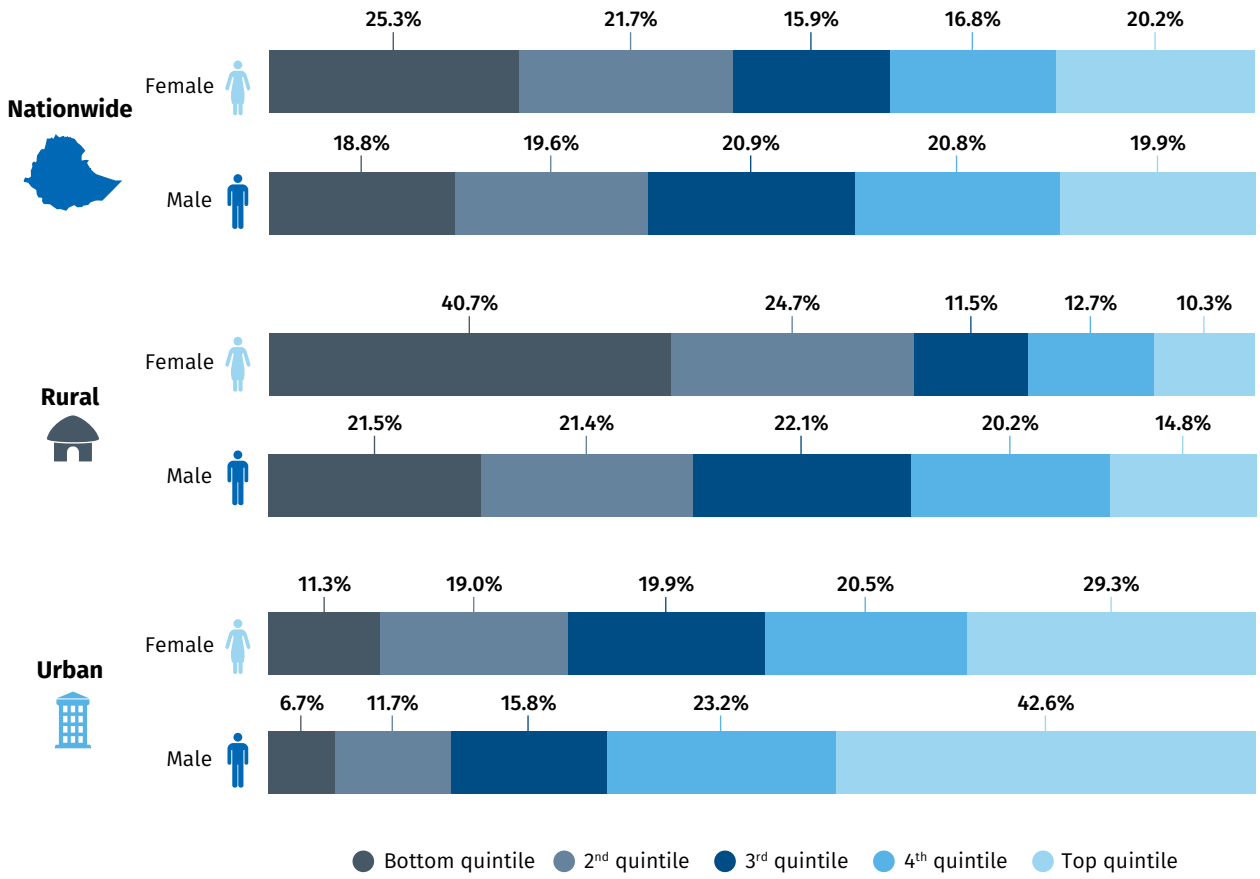
Nationwide, average monthly spending is 29,211 birr (or about $1,289[33]) for female-headed households and 29,862 birr (or about $1,317) for male-headed households. The percentage of households in each spending quintile is similar, though more female-headed households (47%) than male-headed households (38.4%) are in the bottom two quintiles (figure 67). The gap is similar in both rural and urban areas: 65.4% of female-headed households and 42.9% of male-headed households in rural areas are in the bottom two quintiles, compared with 30.3% of female-headed households and 18.4% of male-headed households in urban areas. This implies that in both rural and urban areas female-headed households are worse-off than male-headed households.

FIGURE 66 • **Men head 81% of households**



[32] Gender of the household head was not considered as a separate stratum during the sampling for the MTF survey, so the results may not be totally representative of the country's actual gender distribution.
[33] 1 U.S. dollar = 22.6615 Ethiopian birr (average exchange rate in April 2017).

FIGURE 67 • **More female-headed households than male-headed households are in the bottom two spending quintiles**

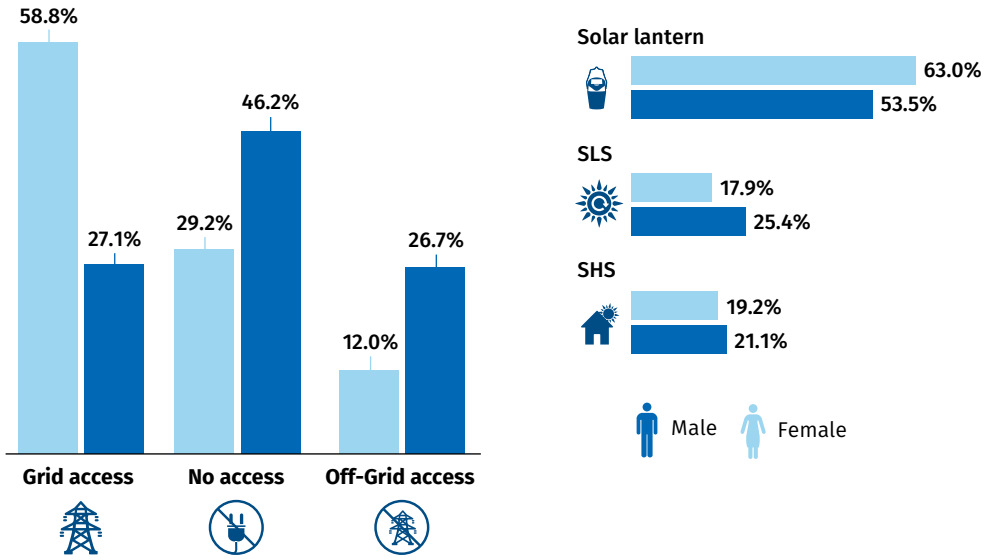


ACCESS TO ELECTRICITY

Nationwide, female-headed households have higher access to electricity: 58.8% of female-headed households are connected to the grid, compared with 27.1% of male-headed households (figure 68). However, this is driven by the fact that female-headed households are disproportionately located in urban areas, where the electrification rate is high. Only 12% of rural households were headed by women, compared with 39.6% of urban households.

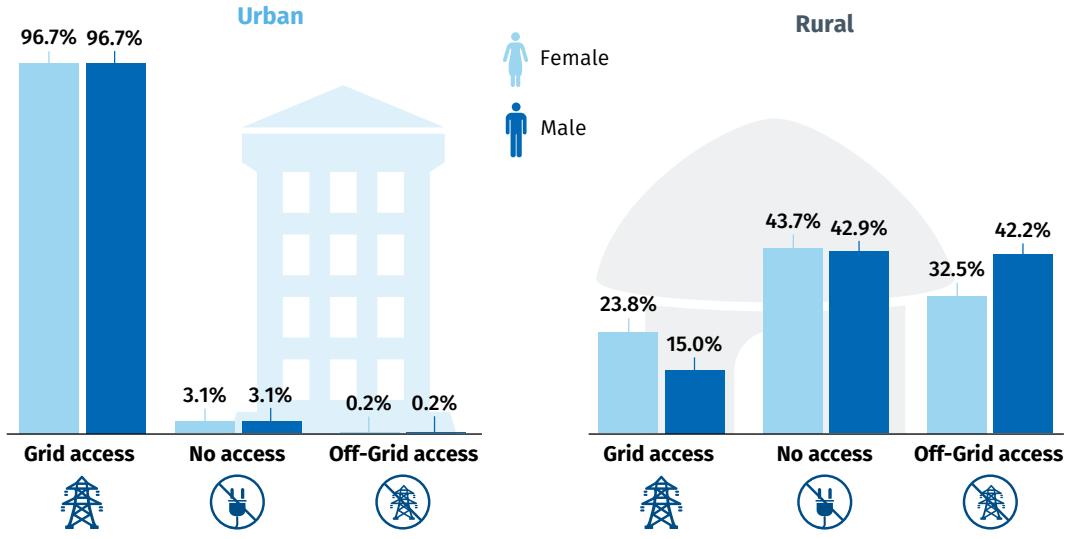
Since 58.8% of female-headed households have access to the grid, penetration of off-grid solar solutions is lower among female-headed households than among male-headed households. However, among households that use an off-grid solar solution as their primary source of electricity, 37.1% of female-headed households use a solar home system (SHS) or solar lighting system (SLS), compared with 46.5% of male-headed households. This means that male-headed households are more likely than female-headed households to have a larger capacity system.

FIGURE 68 • **Female-headed households have higher access to electricity**



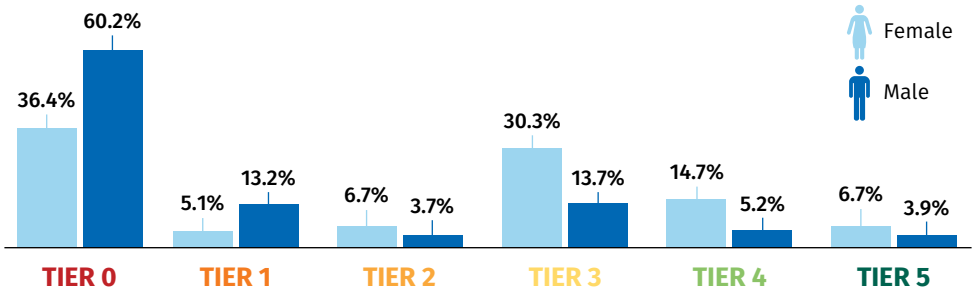
When access to electricity is compared within urban and rural areas, the gender gap diminishes. In urban areas access to the grid is similar among female- and male-headed households (96.7% for both) (figure 69). In rural areas access to the grid is higher among female-headed households (23.8%) than among male-headed households (15%), but penetration of off-grid solutions is slightly higher among male-headed households (42.2%) than among female-headed households (32.5%).

FIGURE 69 • **In urban areas access to the grid is similar among female-headed and male-headed households**



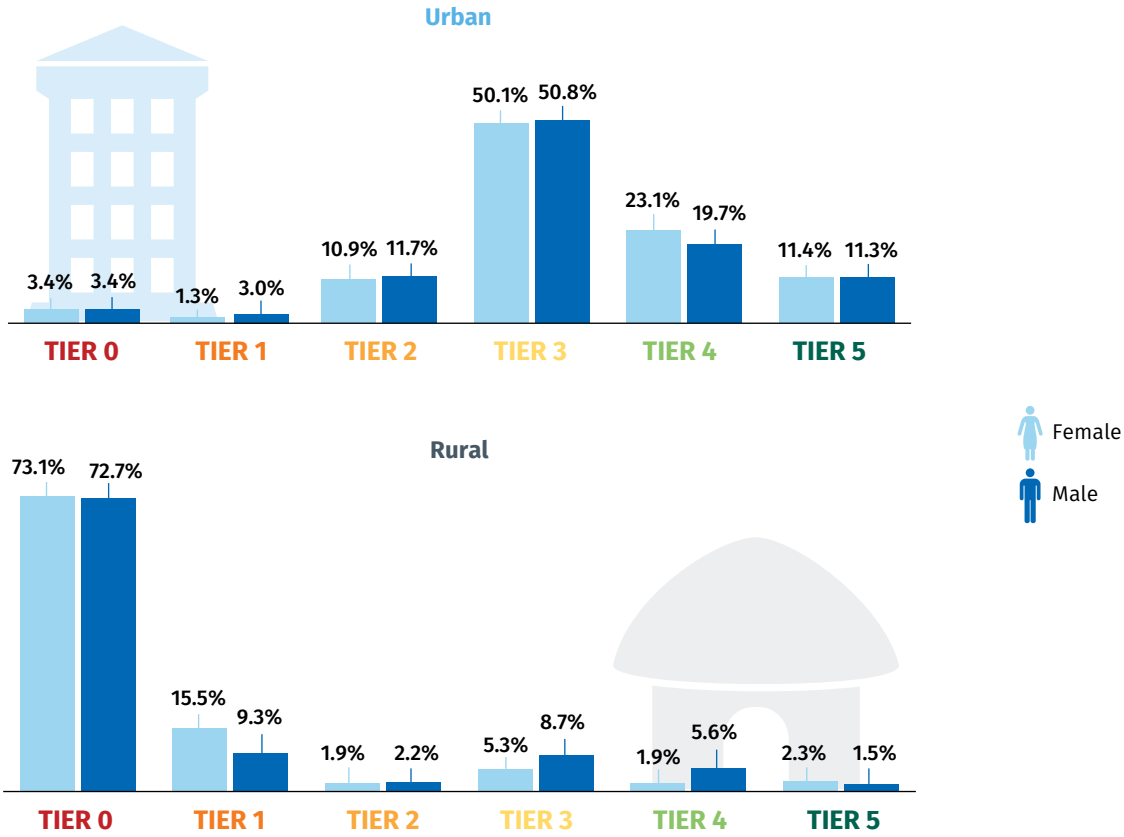
Fewer female-headed households (36.4%) than male-headed households (60.2%) are in Tier 0 for access to electricity (figure 70). Because a larger share of female-headed households are connected to the grid, 51.7% of female-headed households are in Tiers 3–5, compared with 22.8% of male-headed households.

FIGURE 70 • **More female-headed households than male-headed households are in Tiers 3–5**



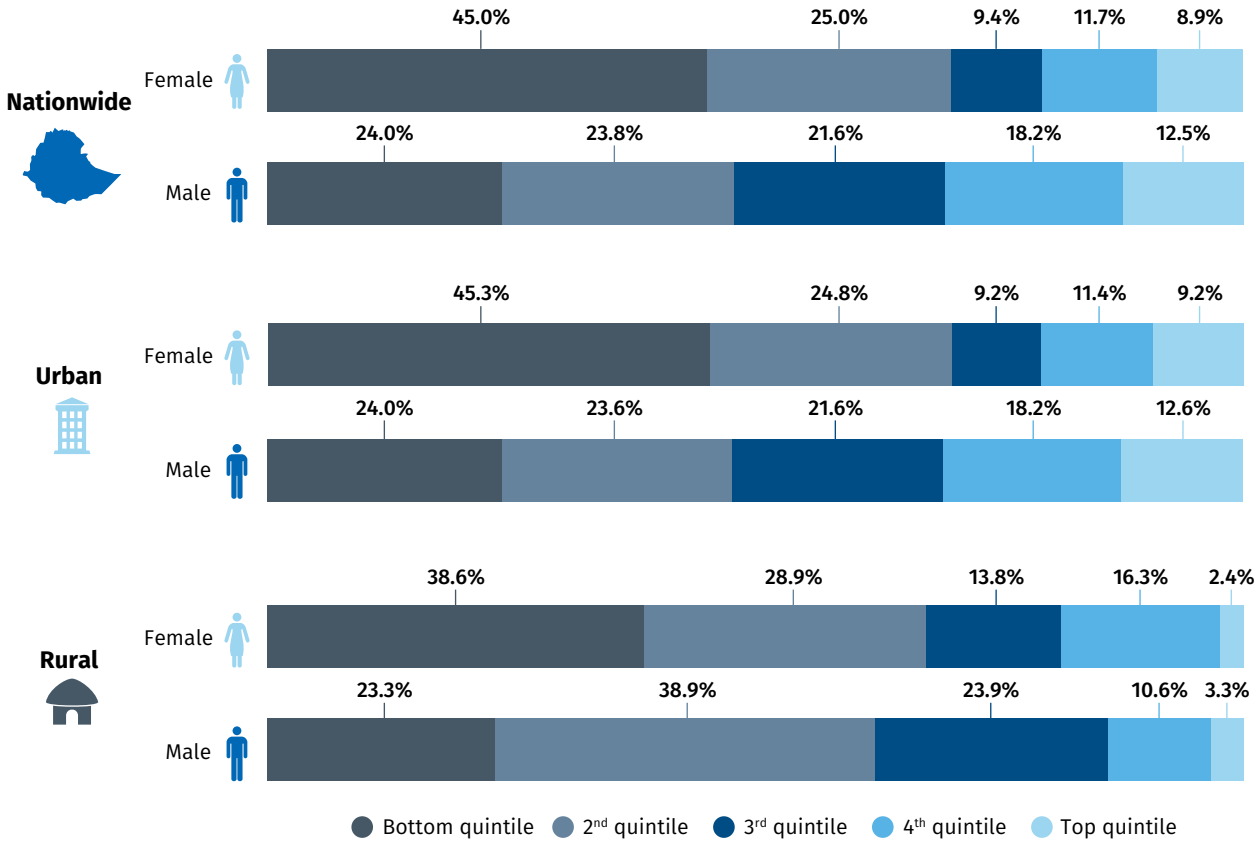
When comparing tier distribution within urban and rural areas, the difference in access rates between female- and male-headed households is much smaller. Most urban households are connected to the grid and the percentage of female- and male-headed households in each tier is similar: 84.5% of female-headed households and 81.9% of male-headed households are in Tiers 3–5 (figure 71). In rural areas the access rate is slightly lower among female-headed households, which indicates that the access rate depends mostly on household location rather than gender of the household head.

FIGURE 71 • **The tier distribution among female- and male-headed households is similar across rural and urban areas**



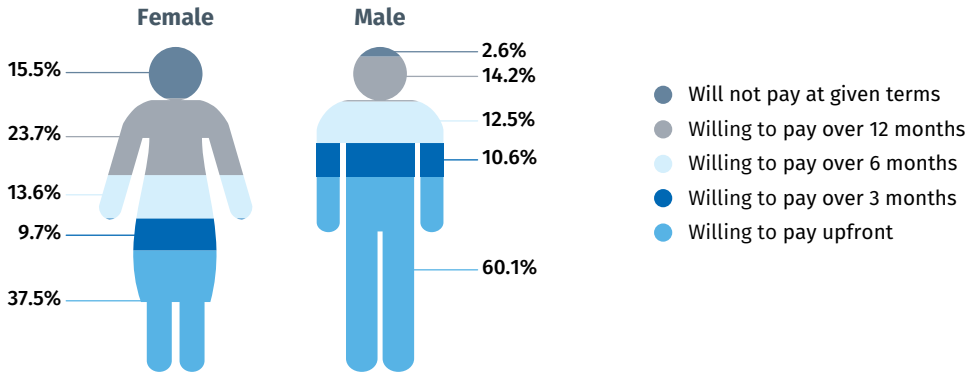
Thus, there does not appear to be a gender gap in access to electricity. But unelectrified female-headed households may face greater barriers to connecting to electricity. Among unconnected households, a larger proportion of female-headed households (45%) than of male-headed households (24%) are in the bottom spending quintile nationwide and in rural and urban areas (figure 72).

FIGURE 72 • **Among unelectrified households, more female-headed households than male-headed households are in the bottom spending quintile**



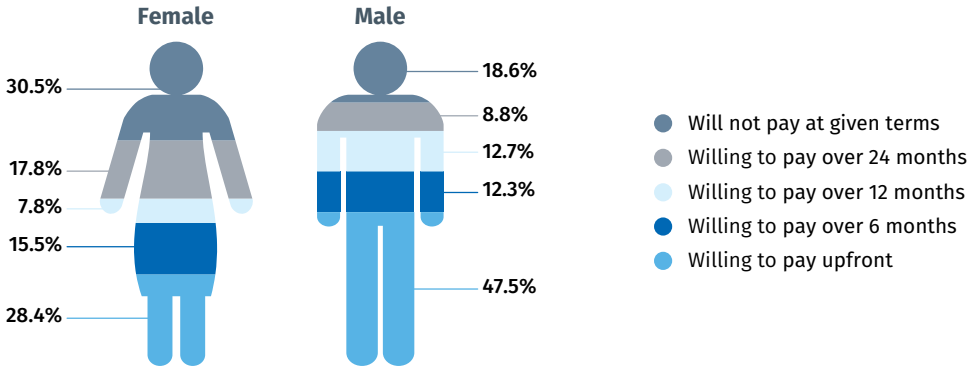
Female-headed households are more concerned about being able to pay for a connection to the grid. Among unconnected households, 37.5% of female-headed households are willing to pay full price (1,900 birr or about $83.80) upfront for a connection to the grid, compared with 60.1% of male-headed households (figure 73). But 15.5% of female-headed households are not willing to pay for a connection to the grid even with a 3- to 12-month payment plan, compared with only 2.6% of male-headed households. Allowing payment over 12 months is thus a very effective measure to increase female-headed households' ability to pay.

FIGURE 73 • **Male-headed households are more willing to pay for a connection to the grid than female-headed households are**



Female-headed households (28.4%) are also less willing to pay full price (13,200 birr or about $582.50) upfront for a Tier 2 off-grid solar device than male-headed households (47.5%) are (figure 74). But more female-headed households (41.1%) than male-headed households (33.8%) are willing to pay with a 6- to 24-month payment plan. A larger share of female-headed households (30.5%) than of male-headed households (18.6%) are not willing to pay under the given terms.

FIGURE 74 • **Female-headed households are less willing to pay for a Tier 2 off-grid solar device than male-headed households are**



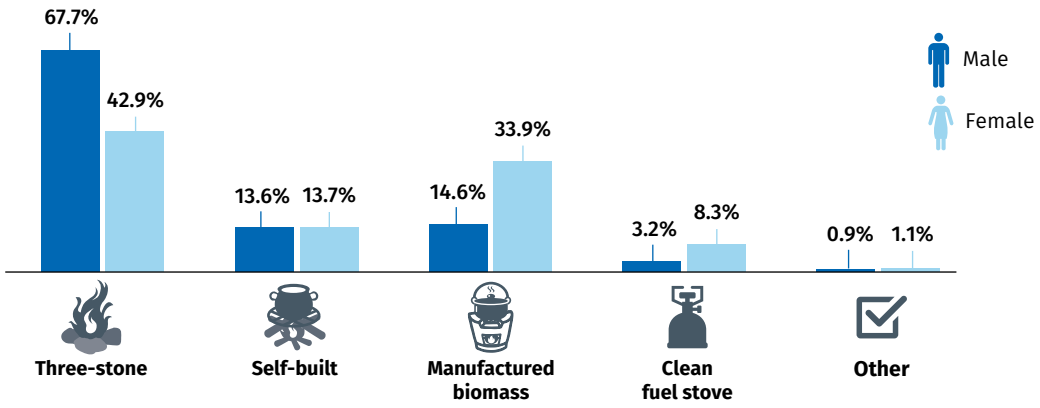
The gender gap in willingness to pay (WTP) for both a grid connection and a Tier 2 solar device indicates that gender-targeted awareness efforts and financing mechanisms may be required to incentivize female-headed households to obtain a grid connection or move to a higher tier solar device.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

More female-headed households than male-headed households use a manufactured biomass or clean fuel stove: 33.9% of female-headed households and 14.6% of male-headed households use a manufactured biomass stove, while 8.3% of female-headed households and 3.2% of male-headed households use a clean fuel stove (figure 75). The larger share of manufactured biomass and clean

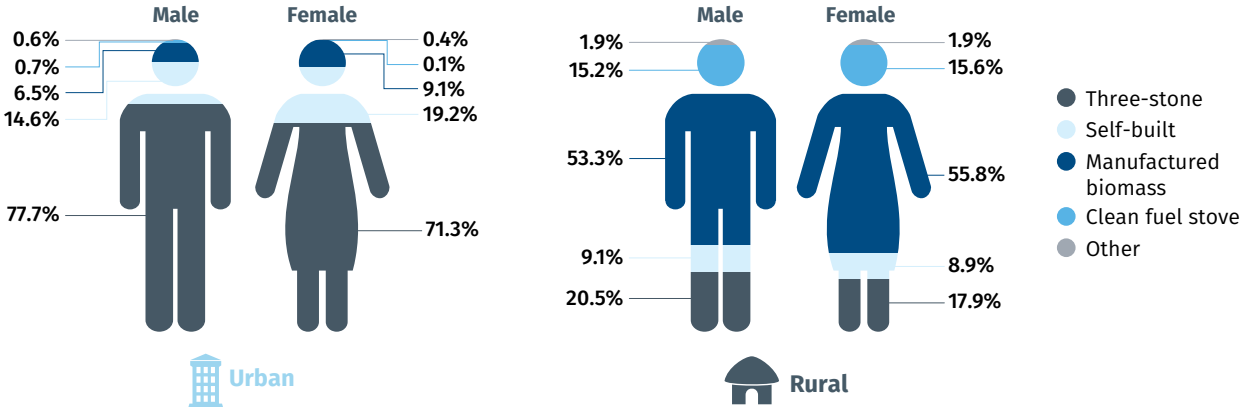
fuel stoves among female-headed households could be explained by the fact that a majority of female-headed households live in urban areas, where use of three-stone stoves is lower than use of manufactured biomass and clean fuel stoves.

FIGURE 75 • **More female-headed households than male-headed households use a manufactured biomass or clean fuel stove**



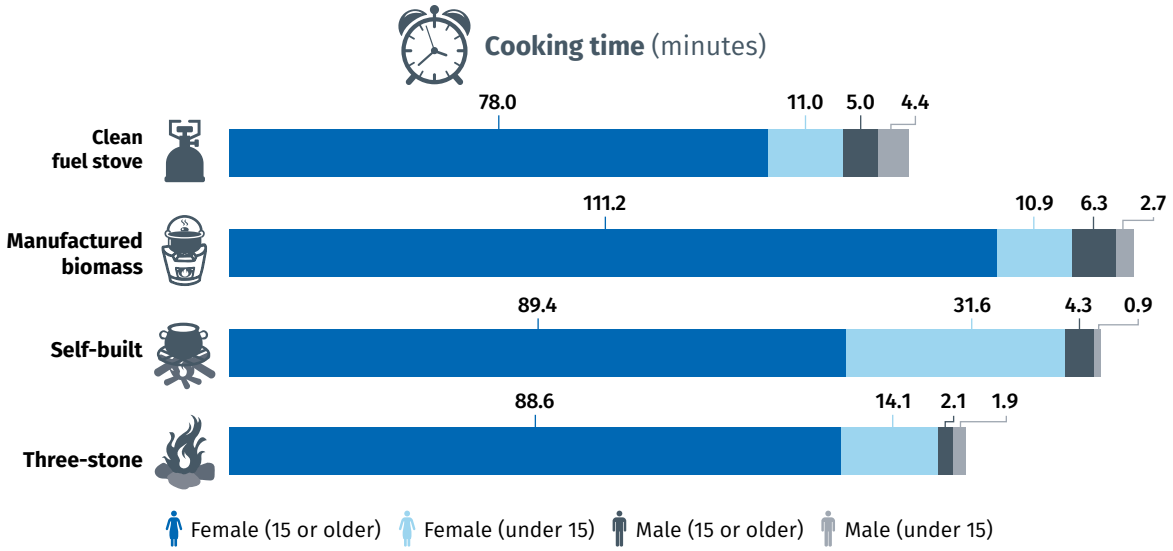
When comparing access to modern energy cooking solutions within urban and rural areas, the difference in access rates between female- and male-headed households is much smaller. The percentage of female-headed households that use a manufactured biomass stove is only slightly higher than the percentage of male-headed households that do (figure 76). Further investigation is recommended to assess the impact of gender on the adoption of manufactured biomass stoves, controlling for locality and wealth.

FIGURE 76 • **There is little difference in stove type use between female- and male-headed households in either urban or rural areas**



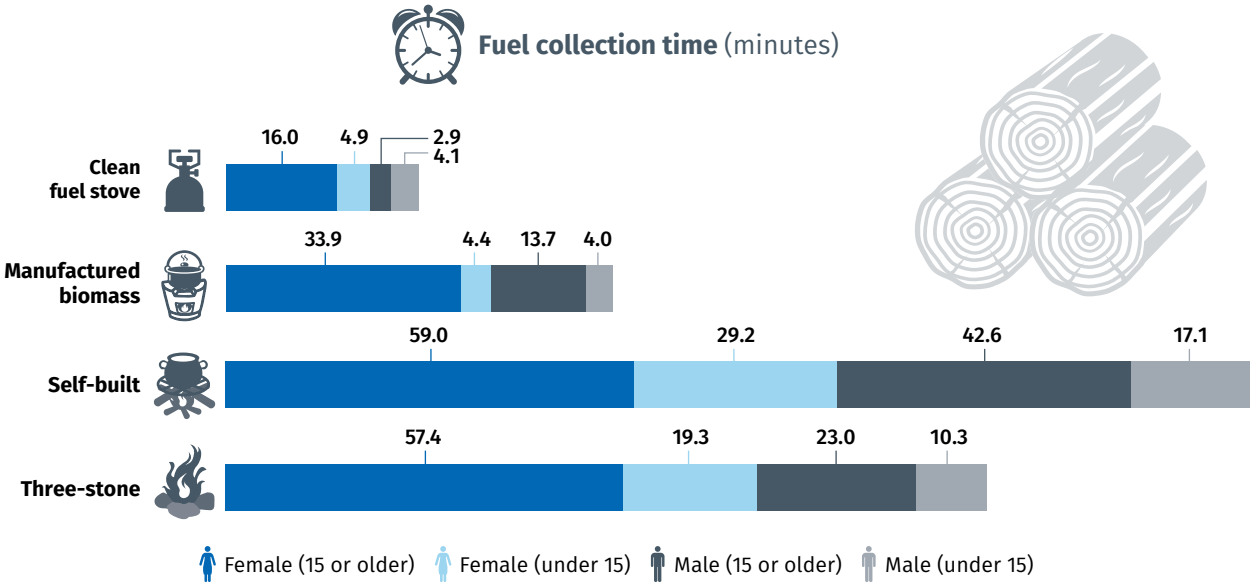
Female household members in all age groups spend significantly more time cooking than their male counterparts do, regardless of primary stove type (figure 77).

FIGURE 77 • **Female household members in all age groups spend significantly more time cooking than their male counterparts do, regardless of primary stove type**



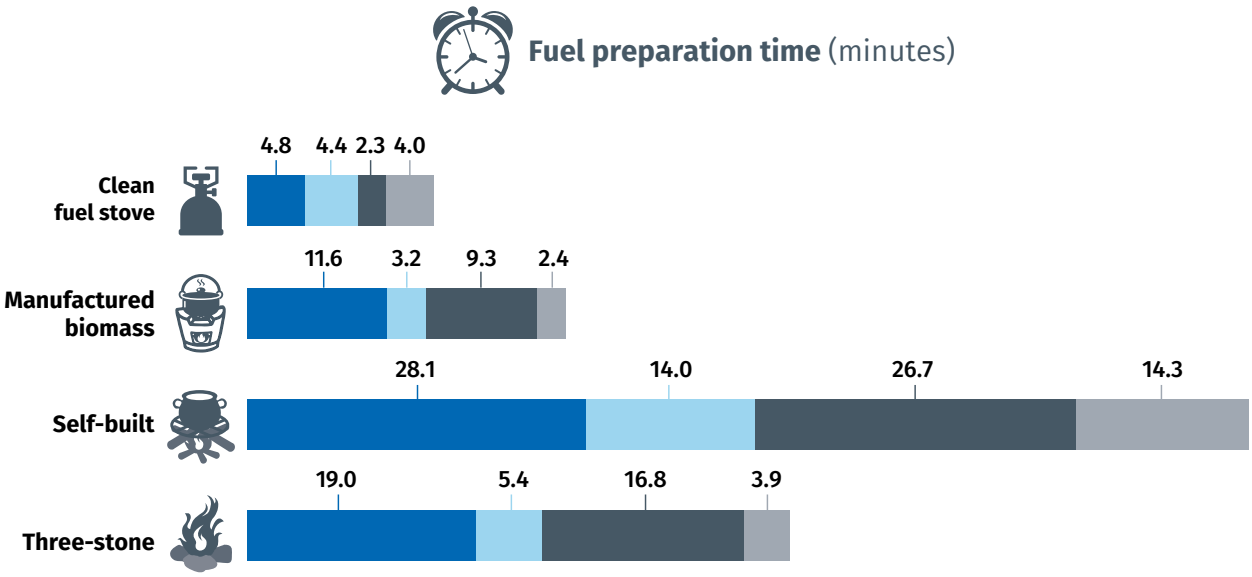
Women also spend more time acquiring (through collection or purchase) fuel. Women in households that use a manufactured biomass stove spend an average of 33.9 minutes a day collecting fuel, compared with 16 minutes for women in households that use a clean fuel stove, 59 minutes for women in households that use a self-built stove, and 57.4 minutes for women in households that use a three-stone stove (figure 78). Switching to stoves with lower emissions and improving ventilation structures, especially in households that use a manufactured biomass stove, will benefit women.

FIGURE 78 • **Women spend more time acquiring fuel than their male counterparts do**



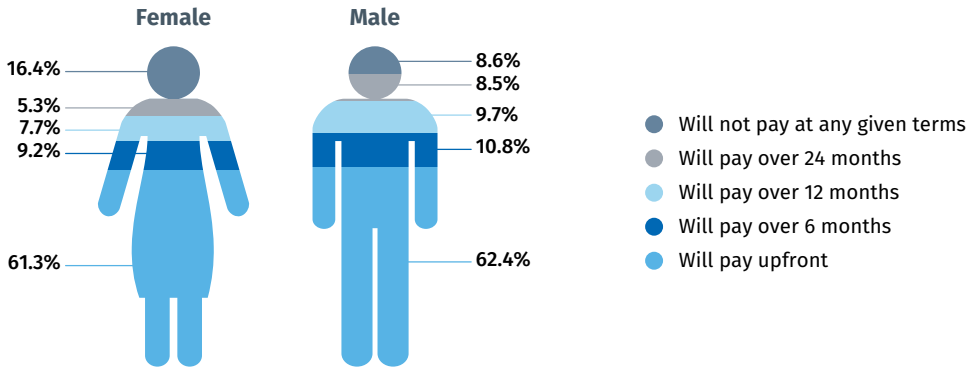
Fuel preparation time is somewhat similar for women and men, though total time spent preparing fuel is significantly less for clean fuel stoves. Women spend an average of 4.8 minutes a day preparing fuel for a clean fuel stove, compared with 28.1 minutes for a self-built stove (figure 79).

FIGURE 79 • **Fuel preparation time is somewhat similar for women and men**



About 62% of both female- and male-headed households are willing to pay full price (175 birr or about $7.70) upfront for an improved biomass stove, but more female-headed households (16.4%) than male-headed households (8.6%) are not willing to pay even with a payment plan (figure 80). Of the female-headed households that are not willing to pay under any given terms, around 60% indicated that they cannot afford the payment even with a payment plan.

FIGURE 80 • **About 62% of both female- and male-headed households are willing to pay full price for an improved biomass stove**



CONCLUSIONS AND RECOMMENDATIONS

There is not much of a gender gap in access to electricity. But ability to pay is a bigger issue for female-headed households: only 37.5% of female-headed households are willing to pay upfront for a grid connection, compared with 60.1% of male-headed households. Similarly, female-headed households are less willing to pay for a Tier 2 solar product than male-headed households are: only 28.4% of female-headed households are willing to pay full price upfront, compared with 47.5% of male-headed households, while a larger share of female-headed households (30.5%) than of male-headed households (18.6%) are not willing to pay for a solar device even with a payment plan. The gender gap in WTP for both a grid connection and a Tier 2 solar device indicates that gender-targeted awareness efforts and financing mechanisms may be required to incentivize female-headed households to obtain a grid connection or move to a higher tier solar device.

Affordability is a barrier for female-headed households when it comes to modern energy cooking solutions as well. Although 62% of both female- and male-headed households are willing to pay full price (175 birr or about $7.70) upfront for an improved manufactured biomass stove, more female-headed households (16.4%) than male-headed households (8.6%) are not willing to pay even with a payment plan. Of the female-headed households that are not willing to pay under any given terms, around 60% indicated that they cannot afford the payment even with a payment plan. Gender-targeted financial mechanisms are needed to increase adoption of manufactured biomass stoves and to move households to a higher tier for access to modern energy cooking solutions.

Women suffer more from indoor-air related health impacts as well as from drudgery related to fuel collection. Switching to stoves with lower emissions and improving ventilation structures, especially in households that use a manufactured biomass stove, will benefit women by reducing time spent collecting fuel and preparing the stove and by reducing exposure to harmful indoor air pollution. Households should be incentivized to switch to such stoves. Electric stoves should also be promoted, especially in grid-connected urban and peri-urban areas, where there is a sizable proportion of female-headed households.

Because biomass stoves are so prevalent, awareness campaigns should target ambient and behavior aspects—such as improved ventilation, separating cooking areas from sleeping areas, and minimizing time in the cooking area—to minimize household members' exposure to harmful pollutants. These campaigns should target 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 (W or daily Wh)	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability[a]	Daily Availability	Less than 4 hours	At least 4 hours		At least 8 hours	At least 16 hours	At least 23 hours
	Evening Availability	Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours"	(> 3 to 14 disruptions / week) or ≤ 3 disruptions / week with > 2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorized representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

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

Source: Bhatia and Angelou 2015.

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 [a]	Emission: Fuel	Firewood, dung, twigs, leaves, rice husks, processed biomass pellets or briquette, charcoal, kerosene				Biogas, ethanol, high quality processed biomass pellets or briquettes	Electricity, solar, LPG
	Emission: Stove Design	Three-stone fire, tripod, flat mud ring, traditional charcoal stove	Conventional or old generation ICS	ICS+ chimney, rocket stove or ICS + insulation	Rocket stove with high insulation or with chimney, advanced insulation charcoal stoves	Rocket stove with chimney (well sealed), Rocket Stove gasifier, Advanced secondary air charcoal stove, forced air	
	Ventilation: Volume of Kitchen [b]	Less than 5 m^3	More than 5 m^3	More than 10 m^3	More than 20 m^3	More than 40 m^3	Open air
	Ventilation: Structure	No opening except for the door	1 window	More than 1 window	Significant openings (large openings below or above height of the door)	Veranda or a hood is used to extract the smoke	Open air
	Ventilation Level	Bad			Average	Good	
	Contact Time [c]	More than 7.5 hours	Less than 7.5 hours	Less than 6 hours	Less than 4.5 hours	Less than 3 hours	Less than 1.5 hours
		Bad			Average	Good	
Cookstove Efficiency	ISO's Voluntary Performance Targets (TBC)	Less than 10%	More than 10%	More than 20%	More than 30%	More than 40%	More than 50%
Convenience	Fuel acquisition (through collection or purchase) and preparation time (hours per week)	More than 7 hours		Less than 7 hours	Less than 3 hours	Less than 1.5 hours	Less than 0.5 hour
	Stove preparation time (minutes per meal)	More than 15 minutes		Less than 15 minutes	Less than 10 minutes	Less than 5 minutes	Less than 2 minutes
Safety of Primary Cookstove		*Serious accidents over the past 12 months*				No serious accidents over the past year	
Affordability [d]		Levelized cost of cooking solution (fuel) more than 5% of household income				Levelized cost of cooking solution (fuel) less than 5% of household income	
Fuel Availability		*Primary fuel available less than 80% of the year*				Primary fuel is readily available 80% of the year.	Primary fuel is readily available throughout the year

a. Determined by combination of fuel and stove design, ventilation of cooking space, and contact time

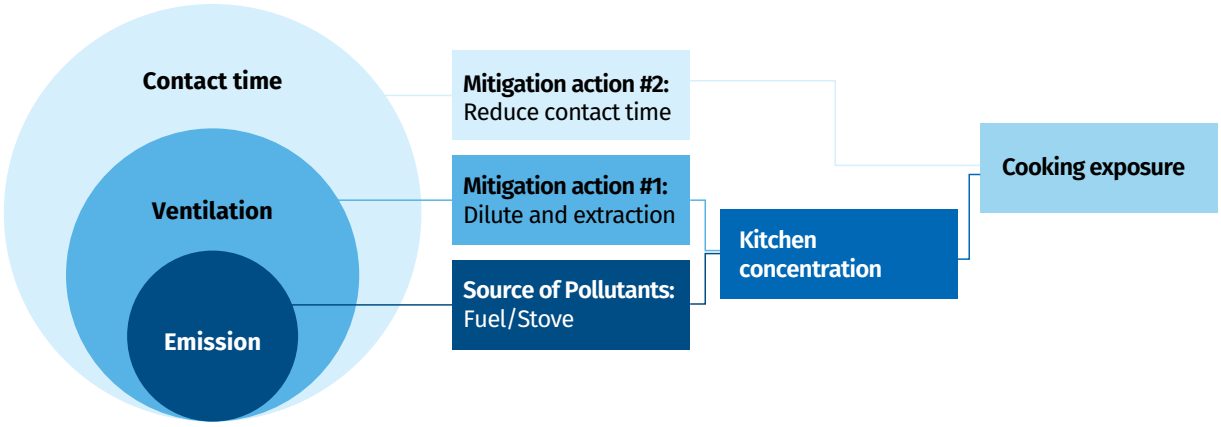
b. Not used in the analysis of Cooking Exposure in Ethiopia.

c. Not used to calculate an individual stove's tier for Cooking Exposure but used to weight each stove's tier for Cooking Exposure in the calculation of a household's tier for Cooking Exposure.

d. In this report, cookstove cost was not considered when calculating the Affordability tier due to data limitations which hindered making this calculation.

* Color signifies tier categorization.

ANNEX 2:
Cooking Exposure Attribute



Cooking exposure is mainly a factor of the emissions from the cooking activity which consist in fuel and stove characteristics through the fuel quality and the stove design type. Emissions can be mitigated by the ventilation factor, consisting in a combination of the kitchen volume and the ventilation structure. Finally, contact time further influences the level of exposure to cooking activities one faces.

Due to limited data available in Ethiopia, the Cooking Exposure tier is calculated using the level of emission from the combination of stove type and the ventilation level.

Emission has been currently only calculated based on the primary cookstove used by the household. Households using a three-stone stove are in Tier 0 for Exposure; ones using self-built and manufactured biomass stoves are in Tiers 1-3; and those that use clean stoves (electric/LPG) are in Tier 5.

Ventilation for the cooking area is categorized by the location of the cooking activity. A household that prepares its meals indoors in an area with fewer than two openings (windows and doors) to the outside is classified as having poor ventilation. A household that prepares its meals indoors in an area with more than two openings or a chimney or hood is classified as having average ventilation. And a household that cooks its meals outdoors or in a veranda is classified as having good ventilation. Ventilation mitigates the indoor air pollution that a household is exposed to by diluting the concentration of emissions from polluting fuels and expelling the pollutants from the cooking area.

VENTILATION STRUCTURE

Overall	Level	Kitchen Volume (m^3)	Description of the structure of the cooking space
High	5	Open air	Open air
	4	>40	Veranda or a hood is used to extract the smoke
Average	3	>20	Significant openings (large openings below or above height of the door)
Low	2	>10	> 1 window
	1	>5	One window
	0	≤ 5	No opening except for the door

CALCULATION OF THE TIERS OF COOKING EXPOSURE

- **For emissions Tier 5,** Cooking Exposure tier is 5.
- **For emissions Tier 4,**
  - If ventilation tier is good, regardless contact time, Cooking Exposure tier is 5.
  - For other cases, Cooking Exposure tier is 4.
- **For emissions Tier 3,**
  - If ventilation tier is good and contact time is short, Cooking Exposure tier is 4.
  - If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 3.
  - If ventilation tier is average, regardless contact time, Cooking Exposure tier is 3.
  - If ventilation tier is poor and contact time is short, Cooking Exposure tier is 3.
  - If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 2.
- **For emissions Tier 2,**
  - If ventilation tier is good and contact time is short, Cooking Exposure tier is 3.
  - If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 2.
  - If ventilation tier is average, regardless contact time, Cooking Exposure tier is 2.
  - If ventilation tier is poor and contact time is short, Cooking Exposure tier is 2.
  - If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 1.
- **For emissions Tier 1,**
  - If ventilation tier is good and contact time is short, Cooking Exposure tier is 2.
  - If ventilation tier is good and contact time is medium or long, Cooking Exposure tier is 1.
  - If ventilation tier is average, regardless contact time, Cooking Exposure tier is 1.
  - If ventilation tier is poor and contact time is short, Cooking Exposure tier is 1.
  - If ventilation tier is poor and contact time is medium or long, Cooking Exposure tier is 0.
- **For emissions Tier 0,**
  - If ventilation tier is good, regardless contact time, Cooking Exposure tier is 1.
  - If ventilation tier is average or poor, regardless contact time, Cooking Exposure tier is 0.

ANNEX 3:
Sampling strategy

Ethiopia is a large country with a land area of over 1.1 million square kilometers. It has nine regions and two city administrations. At the time of the 2007 census, the regions and the city administrations were further subdivided into 73 zones, 731 woredas, 10 subcities in Addis Ababa, and 14,850 rural and 1,478 urban kebeles (table A3.1).

The kebeles (the lowest administrative units in the country) were subdivided by the Central Statistics Agency of Ethiopia (CSA) into census enumeration areas (assignment areas for a team of enumerators to work in during the census). Ethiopia has conducted only three national population and housing census: in 1984, 1994, and 2007. The 2007 national population and housing census is the sample frame used for this study. It consists of 86,825 enumeration areas (19,636 urban and 69,462 rural). Most enumeration areas consist of 150–200 households, depending on terrain and density, with some in sparsely populated places having fewer than 150 households and some in densely populated areas having more than 200.

The sample design for this survey is based on the household population size as generated during the 2007 census conducted by the CSA. The entire population residing in noninstitutional dwelling units was considered based on urban/rural and electrified/non-electrified stratifications.

TABLE A3.1 • **Distribution of enumeration areas by region**

Region	Zones	Woredas	Kebeles		Enumeration areas	
			Urban	Rural	Urban	Rural
Tigray	6	47	92	611	1,507	4,112
Afar	5	30	49	338	251	812
Amhara	11	139	348	3,074	3,335	17,899
Oromiya	20	278	546	6,484	4,972	25,613
Somali	9	54			608	5,211
Benishangul Gumuz	3	20	29	417	174	785
Southern Nations, Nationalities and Peoples Region	14	145	270	3,666	2,086	14,412
Gambella	3	12	17	211	133	327
Harari	1	1	19	17	169	98
Addis Ababa	10		99		3,779	
Dire Dawa	1	1	9	32	317	128
Special enumeration areas		4			32	65
Total	**83**	**731**	**1,478**	**14,850**	**17,363**	**69,462**

Source: CSA 2007 population and housing report.

SAMPLING PROCEDURE

The sample for the survey is a stratified sample with enumeration areas selected independently within a region in a two-stage sampling frame. The first stage involved the stratification of all the enumeration areas in each region into urban and rural categories. At the second stage, within the rural or urban stratification, the samples (enumeration areas) were further stratified into electrified and non-electrified enumeration areas.

The number of households in each enumeration area was used as a measure of size for the sample. The cumulative measure of size of the enumeration areas in each stratum (for example, rural-electrified) per region was obtained by successive addition of the estimated number of households of the enumeration areas in the stratum. The required number of enumeration areas within each stratum was selected adopting the probability proportional to size approach based on household population size.

PROBABILITY PROPORTIONAL TO SIZE STEPS

Step 1. The enumeration areas were numbered within each stratum serially from 1 to *N*.

Step 2. The total number of households in each stratum was determined by applying the cumulative measure of size approach (table A3.2).

Step 3. The sampling interval (*SI*) was determined by dividing the total number of households by the required number of enumeration areas per stratum (*TP*/*n*),

Step 4. The random start (*RS*) was determined by randomly selecting a number between 1 and *SI*.

Step 5. The *SI* was then added to the random start (RS_{n-1}) times and n successive random numbers were generated using this formula: *RS*, *RS* + *SI*, *RS* + 2 * *SI*, *RS* + 3 * *SI*..... *RS* + (*n* − 1).

The enumeration areas that correspond to any of the *n* random numbers generated as above were selected to be used in the survey cluster. The procedure ensures equal chance of including any of the enumeration areas in the sample. This can be further illustrated in the table below:

Serial number	Ordered enumeration areas	Number of households	Cumulative measure of size
1.	EA1	S1	SI
2.	EA2	S2	SI + S2
3.	EA3	S3	SI + S2 + S3
4.	EA4	S4	SI + S2 + S3 + S4
..	..	..	..
..	..	..	..
..	..	..	..
N	EA_N	S*N*	S1+S2+S3+S4.....S*N*
Total		**TP**	

Note: *N* = number of enumeration areas in each state.
EAi = i = 1 to N
TP = S1+S2+S3+S4..... + S*n*

WEIGHTING

The sample has the 2007 census frame as its base. The advantage here is that the whole landmass has been carved into small compact enumeration areas without omission, duplication, or overlap. As such, all enumeration areas have equal chance of being included in the sample as soon as they fall within the stratification categories. However, enumeration areas have unequal populations, and this will affect the weight attached to each one, as this will be a representative of the value of the selected enumeration area.

The weighting was calculated using a similar approach to that used in Ethiopia:

- Number of households: the number of households per enumeration area.
- Total enumeration areas in the stratum: the total number of enumeration areas in each stratum.
- Total households in the stratum: the total number of households in each stratum.
- PSU: total number of enumeration areas to be selected from each stratum.
- SSU: total number of households to be selected per enumeration area.
- Sampling interval = $\frac{Stratum\ Cummulative\ HHs\ 2007}{PSU}$
- 1st probability = $\frac{No\ of\ HHs*PSU}{Stratum\ Cummulative\ HHs\ 2007}$
- 2nd probability = $\frac{SSU}{No\ of\ HHs}$
- 1st weighting: 1 / (1st probability) * 1 / (2nd probability) = $\frac{Stratum\ Cummulative\ HHs\ 2007}{No\ of\ HHs*PSU} * \frac{SSU}{No\ of\ HHs}$

SAMPLED ENUMERATION AREAS AND HOUSEHOLDS

Based on the above sampling strategy, the MTF survey in Ethiopia sampled nationally representative households. Table A3.3 presents the sample by region and rural/urban classification. The sample is a two-stage probability sample. During the first stage of sampling a total of 337 enumeration areas were selected based on probability proportional to size of the total enumeration areas in each stratum (urban and rural) of each region. The first stage of sampling entailed selecting primary sampling units, or CSA enumeration areas. For the rural sample, 151 enumeration areas were selected from all regions in the country. A total of 186 enumeration areas were selected for urban areas in the country. The urban sample is higher than the rural enumeration areas samples because there was an oversampling of urban enumeration areas in Addis Ababa. This oversample for urban poor areas was undertaken to check for specific issues on energy access that would affect urban areas and to conduct a detailed analysis for Addis Ababa. To ensure sufficient sample size in all regions of the country, regions with small population size were also oversampled (Benshangul Gumuz, Dire Dawa, Gambella, and Harari regions). Therefore, estimates can be produced for all regions as well as urban and rural estimates

at the national level. The addition of urban enumeration areas increased the sample size from 333 to 433 enumeration areas and from 3,969 to 5,469 households.

The second stage of sampling involved the selection of households from each enumeration area. For all enumeration areas except the oversampled Addis Ababa enumeration area, 12 households were sampled from each list: 9 grid-connected households and 3 unconnected households from grid-connected enumeration areas and 9 unconnected households and 3 grid-connected households from unconnected enumeration areas. In some grid-connected enumeration areas there were zero, one, or two unconnected households, in which case less than three unconnected households were surveyed, and more grid-connected households were interviewed instead so that the total number of households per enumeration area remained the same. The same was true for unconnected enumeration areas. In some enumeration areas it was hard to find three grid-connected households, so zero, one, or two grid-connected households were interviewed, and more unconnected households were interviewed as well, so that the total number of households per enumeration area remained the same. In 24 oversampled enumeration areas in Addis Ababa 20 households per enumeration area were surveyed.

TABLE A3.3 • **Distribution of regions, woredas, and households sampled for the Multi-Tier Framework survey**

Serial number	Region	Number of woredas	Number of enumeration areas			Number of households
			Rural	Urban	Total	
1	Tigray	14	7	10	17	204
2	Afar	9	9	7	16	192
3	Amhara	40	32	27	59	708
4	Oromiya	64	54	37	91	1,089
5	Somali	8	9	6	15	180
6	Benishangul	6	6	5	11	132
7	Southern Nations, Nationalities and Peoples (SNNP) Region	32	29	23	52	624
8	Gambela	5	2	3	5	60
9	Harari	1	1	3	4	48
10	Addis Ababa	10	0	59	59	984
11	Dire Dawa	1	2	6	8	96
Total	**190**	**151**	**186**	**337**	**4,317**	

REFERENCES

Bhatia, Mikul; Angelou, Nicolina. 2014. Capturing the Multi-Dimensionality of Energy Access. Live Wire, 2014/16. World Bank, Washington, DC. © World Bank. https://www.openknowledge.worldbank.org/handle/10986/18677 License: CC BY 3.0 IGO.

Bhatia, Mikul; Angelou, Niki. 2015. Beyond Connections: Energy Access Redefined. ESMAP Technical Report;008/15. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/24368 License: CC BY 3.0 IGO."

IEA (International Energy Agency) and the World Bank. 2017. *Sustainable Energy for All 2017: Global Tracking Framework Report. Progress Towards Sustainable Energy*. Washington, DC: World Bank. http://gtf.esmap.org/data/files/download-documents/eegp17-01_gtf_full_report_final_for_web_posting_0402.pdf

World Bank. 2016. *5th Ethiopia economic update: why so idle? - wages and employment in a crowded labor market : draft for public launch (English)*. Washington, D.C. : World Bank Group.

World Bank. 2014. Hill, Ruth; Tsehaye, Eyasu. 2014. *Ethiopia - Poverty assessment (English).* Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/131011468247457565/Ethiopia-Poverty-assessment

World Health Organization, 2014, *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion*, Geneva

World Bank. 2017. Living Standards

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