CAMBODIA

Beyond Connections

Energy Access Diagnostic Report
Based on the Multi-Tier Framework

MTF Multi-Tier FRAMEWORK

ESMAP

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SUSTAINABLE ENERGY FOR ALL

CAMBODIA

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Energy Access Diagnostic Report Based on the Multi-Tier Framework

Rutu Dave, Sandra Keller, Bryan Bonsuk Koo, and Gina Fleurantin, Elisa Portale and Dana Rysankova

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CONTENTS

ACKNOWLEDGMENTS vii

ABBREVIATIONS ix

NUMERICAL HIGHLIGHTS x

Access to Electricity x

Access to Modern Energy Cooking Solutions x

Gender Analysis xi

POLICY HIGHLIGHTS xii

Access to Electricity xii

access to Modern Energy Cooking Solutions xiii

KEY FINDINGS AND POLICY IMPLICATIONS xiv

Access to Electricity xiv

Access to Modern Energy Cooking Solutions xix

Gender Gaps in Access xxiii

MEASURING ENERGY ACCESS IN CAMBODIA xxvi

The Multi-Tier Framework Global Survey 1

Access to electricity 2

Access to modern energy cooking solutions 5

Using the Multi-Tier Framework to drive policy and investment 9

Multi-Tier Framework survey implementation in Cambodia 9

ACCESS TO ELECTRICITY 12

Assessing access to electricity 13

Technologies 13

MTF Tiers 14

MTF Attributes 18

Use 22

Improving access to electricity 25

Providing electricity access to households without an electricity source 26

Improving electricity access for grid-connected households 29

Improving electricity access for households that use an off-grid solar device 32

ACCESS TO MODERN ENERGY COOKING SOLUTIONS 36

Assessing access to modern energy cooking solutions 37

Technologies 37

MTF Tiers 42

MTF Attributes 44

Improving access to modern energy cooking solutions 50

Increasing penetration of clean fuel stoves 51

Increasing the use of improved cookstoves as the primary cooking solution 52

GENDER ANALYSIS 54

Access to electricity 56

Access to modern energy cooking solutions 60

ANNEX 1 63

ANNEX 2 65

ANNEX 3 67

ANNEX 4 69

TABLES

Table 1 • Load levels, indicative electric appliances, and associated Capacity tiers 4

Table 2 • Stove emissions tier 8

Table 3 • Distribution of villages and households in Cambodia sampled for the Multi-Tier Framework survey 10

Table A1.1 • Multi-Tier Framework for measuring access to electricity* 63

Table A1.2 • Multi-Tier Framework for measuring access to modern energy cooking solutions 64

Table A4.1 • Number of electrified and non-electrified households interviewed by enumeration area 69

Table A4.2 • Number of enumeration areas selected per stratum, by electrification status 69

Table A4.3 • Sample framework 71

BOXES

Box 1 • Minimum requirements by tier of electricity access 3

Box 2 • Typology of off-grid solar devices and tier calculation 4

Box 3 • Typology of cookstoves in Cambodia 6

FIGURES

Figure 1 • Multi-Tier Framework attributes for access to electricity xiv

Figure 2 • Multi-Tier Framework tiers for access to electricity xv

Figure 3 • More than 87% of households are in Tier 1 or above for access to electricity xvi

Figure 4 • Multi-Tier Framework attributes for access to cooking xxi

Figure 5 • Multi-Tier Framework tier distribution for access to modern energy cooking solutions xxii

Figure 6 • Spatial distribution of the households in Cambodia sampled for the Multi-Tier Framework survey 11

Figure 7 • Nearly 98% of households have access to at least one source of electricity 13

Figure 8 • The government has rapidly increased grid electrification over the past decade 14

Figure 9 • Off-grid solar devices are critical in closing the gap in access to electricity among rural households 14

Figure 10 • The majority of households are in Tier 1 or above for access to electricity; most electrified households are in Tier 3 15

Figure 11 • Grid-connected households are typically in Tier 3 or above for access to electricity, while households that use off-grid solutions are typically in Tiers 0–2 15

Figure 12 • Only 12.4% of households in Tier 0 for access to electricity have no source of electricity 16

Figure 13 • Urban households are more likely than rural households to be in Tier 3 or above for access to electricity 16

Figure 14 • Higher income households are more likely to be in Tiers 3–5 for access to electricity 17

Figure 15 • Higher income households are more likely to be connected to the grid, while lower income households are more likely to use off-grid solutions 17

Figure 16 • Capacity is more of an issue in rural areas 18

Figure 17 • A quarter of households do not receive 24/7 electricity supply 19

Figure 18 • 87% of households receive 4 hours of electricity in the evening 19

Figure 19 • Rural grid-connected households face more power supply disruptions than urban households do 20

Figure 20 • Voltage issues affect one in three grid-connected households 20

Figure 21 • Affordability of electricity is more critical among rural households than among urban households 21

Figure 22 • Nearly 5% of households have an informal grid connection 21

Figure 23 • Very few households experience electricity safety issues 22

Figure 24 • Electricity consumption (kWh per month) 22

Figure 25 • Household spending on electricity (riels) 22

Figure 26 • Spending on electricity as a share of total household spending (%) 22

Figure 27 • More than 57% of rural households with grid access use only very low– or low-load appliances 23

Figure 28 • Use of high-load appliances is rare among rural grid-electrified households 23

Figure 29 • The percentage of households that have low-load appliances is higher among households that use an off-grid solar device than among grid-connected households 24

Figure 30 • Lighting, phone chargers, fans, and televisions are the most common appliances for both grid-electrified households and households that use an off-grid solar device 25

Figure 31 • Gap analysis shows what prevents Cambodian households from moving to higher tiers 26

Figure 32 • The main barrier to grid electricity access for urban household is ability to pay for connection fee, while distance from the grid infrastructure is the main barrier for rural households. 27

Figure 33 • Most households without access to the grid appear willing to pay for access to electricity at full price 27

Figure 34 • The main constraints to willingness to pay for a grid connection are household ability to pay for internal wiring and the connection cost 28

Figure 35 • Most households reported being unwilling to pay for a solar home system 28

Figure 36 • The largest shares of rural and urban grid-connected households are in Tier 3 29

Figure 37 • Affordability is an obstacle for nearly 7% of grid-connected households 30

Figure 39 • More than 67% of grid-connected households do not have any issue with the grid electricity supply 30

Figure 38 • Nearly 5% of grid-connected households have an informal connection 30

Figure 40 • More urban households than rural households use candles as their backup source of lighting 31

Figure 41 • Spending on backup sources of lighting accounts for a small percentage of household monthly spending 31

Figure 42 • Most households that use an off-grid solar device are in Tier 2 for access to electricity 32

Figure 43 • Off-grid solar energy for households is a recent phenomenon 32

Figure 44 • Most households that use a solar device purchased it 33

Figure 45• There is a direct correlation between household income and size of solar home system used 33

Figure 46 • Few households that use an off-grid solar device are limited by Capacity 34

Figure 47 • Insufficient Availability is a major hindrance to households in Tier 0 for access to electricity 34

Figure 48 • Most households that use a solar device are satisfied with the electricity service from it 34

Figure 49 • Most households that use a solar device did not have any problems with it 35

Figure 50 • A third of households use a clean fuel stove as their primary stove 37

Figure 51 • Clean fuel use is rising 38

Figure 52 • Roughly 77% of urban households use a clean fuel stove, while most rural households use a biomass stove as their primary stove 38

Figure 53 • A third of households use an improved cookstove as their primary stove 39

Figure 54 • More than 60% of households use only one type of stove 40

Figure 55 • Stove stacking is most common among users of clean fuel stoves 41

Figure 56 • Firewood is by far the most common cooking fuel 41

Figure 57 • Fuel stacking is common in both urban and rural areas 42

Figure 58 • More than 84% of households are in Tier 1 or above for access to modern energy cooking solutions 42

Figure 59 • Clean fuel stoves move households to higher tiers for access to modern energy cooking solutions 43

Figure 60 • More urban households than rural households are in Tiers 4 and 5 for access to modern energy cooking solutions 44

Figure 61 • More urban households than rural households are in Tier 4 or 5 for Cooking Exposure 44

Figure 62 • A third of households use clean fuel for their primary stove 45

Figure 63 • Over 40% of households use their primary stove mainly outside 45

Figure 64 • More rural households that use a biomass stove or liquefied petroleum gas or biogas stove cook outside 46

Figure 65 • More than 68% of households are in Tier 3 or above 46

Figure 66 • Nearly 40% of urban households are in Tier 4 or 5 for Convenience 47

Figure 67 • Safety is not a major hurdle 47

Figure 68 • Cooking fuel is always or mostly available for more than 90% of households 48

Figure 69 • More urban households are in a lower tier because of Affordability 48

Figure 70 • Close to 10% of households using clean fuel stoves as primary spend more than 5% of household budget on cooking fuel 49

Figure 71 • More rural households obtain cooking fuel by collecting 49

Figure 72 • Cooking Exposure and Convenience are major constraints to improving access to modern energy cooking solutions 50

Figure 73 • Households that use a clean fuel stove are significantly wealthier than households that use other stove types 51

Figure 74 • Less affluent households are more likely to obtain cooking fuel by collecting 51

Figure 75 • Traditional stove users consume more fuels than improved cookstove users do 52

Figure 76 • Using an improved cookstove can save time collecting fuel 52

Figure 77 • Many households are willing to pay upfront for an inexpensive improved cookstove 53

Figure 78 • Men head 65.1% of households 55

Figure 79 • About 47% of female-headed households and 37% of male-headed households are in the bottom two spending quintiles 56

Figure 80 • More female-headed households than male-headed households use off-grid solutions 56

Figure 81 • Male-headed households tend to be in higher tiers for access to electricity than female-headed households are 57

Figure 82 • Distance is the major barrier for connecting to the national grid 58

Figure 83 • Willingness to pay upfront for a grid connection varies little by gender 58

Figure 84 • Affordability of internal wiring constrains the willingness of female-headed households to pay for grid connection 59

Figure 85 • Female household heads showed a lower willingness to pay for an off-grid solar device 59

Figure 86 • Slightly more male-headed households than female-headed households own an improved cookstove 60

Figure 87 • Among rural households, a larger share of male-headed households than of female-headed households own an improved cookstove 60

Figure 88 • Clean fuel stoves and improved cookstoves considerably reduce the time for fuel collection and preparation 61

Figure 89 • Women spend much more time cooking than men do, whatever the primary stove 61

Figure 90 • Nearly all male-headed households were willing to pay at least a third of the full price of an improved cookstove 62

Figure 91 • Willingness to pay for a higher price aspirational cookstove showed narrower differences between male- and female-headed households 62

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ABBREVIATIONS

ESMAP	Energy Sector Management Assistance Program
ICS	improved cookstove
kW	kilowatt
kWh	kilowatt-hour
LPG	liquefied petroleum gas
MTF	Multi-Tier Framework
MW	megawatts
NKS	Neang Kangrey stove
NLS	New Lao stove
SHS	solar home system
SLS	solar lighting system
W	watt
WTP	willingness to pay

NUMERICAL HIGHLIGHTS

ACCESS TO ELECTRICITY

- 97.6% of Cambodian households have access to at least one source of electricity: 71.5% on the grid, and 26.1% off the grid, mostly solar home systems and rechargeable batteries.
- 88.2% of households have access to at least 4 hours of electricity supply a day (Tier 1–5 access). 65.6% have access to at least 8 hours of supply a day (Tier 3–5 access). But only 13% are in the top supply category, with access to 23 hours of supply a day with adequate Reliability, Quality, Affordability, and Health and Safety (Tier 5 only).
- 69.3% of grid-connected households face frequent unpredictable power shortages.
- 32.6% of grid-connected households experience appliance damage due to voltage fluctuation.
- 9.4% of grid-connected households cannot afford the electricity tariff.
- Only 2.8% of urban households have no access to grid electricity.
- 69.6% of urban non-electrified households cite high costs as the main reason for not having a grid connection, while 47.8% of rural households cite distance from the grid as the main reason.
- Urban grid-connected households consume 90 kWh a month more than rural households. Only 45.1% of rural households use medium-, high-, or very high–load appliances such as refrigerators, food processors, and water pumps.
- 99.7% of households that use a solar device live in rural areas. Most households that use an off-grid solar device (66.6%) are in Tier 2 for access to electricity.
- Households in the bottom spending quintile are 27.1% less likely to have grid electricity and 20.1% more likely to have off-grid electricity than households in the top quintile are: 55.6% and 36.8% of households in the bottom spending quintile have access to grid and to off-grid solutions, compared with 82.7% and 16.7% of households in the top quintile.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

- 32.9% of Cambodian households, including 77.1% of urban households, use a clean fuel stove as their primary stove. LPG stove is the most popular (prevalent) type of clean fuel stove.
- Two-thirds of households that use a clean fuel stove as their primary stove use it in combination with a biomass stove.

- Affordability is a key issue for households that use LPG: 10% of households that use a clean fuel stove as their primary stove allocate on average more than 5% of total spending on fuel, and these households are typically not in the lowest spending quintiles.
- Households in the top spending quintile are 2.7 times more likely to have a clean fuel stove as their primary stove than households in the bottom quintile are; 49.7% of households in the top spending quintile use clean fuel stoves, compared with 18.3% of households in the bottom quintile.
- 35.1% of households use an improved cookstove as their primary stove, 79.1% of them exclusively.
- 28.6% of households—most of them in rural areas—use a three-stone or traditional biomass stove.
- Households that switch from a traditional cookstove to an improved cookstove save 4.7 hours a week in fuel collection and 24.3 minutes a meal in fuel preparation.
- 79.6% of households are willing to pay about $5 or 20,000 riels for an improved cookstove, but only 36.6% are willing to pay $40 or 160,000 riels (even with a 24-month installment option) for an aspirational higher performance stove.
- Given the prevalence of clean fuel stoves in urban areas and traditional cooking practices in rural areas, the disparities in tier structure between urban and rural areas are large. 84.3% rural households are in Tiers 0 and 1, while 66.9% of urban households are in Tiers 3–5.

GENDER ANALYSIS

- Women head 34.9% of Cambodian households.
- 14% of female household heads have received a primary education, with only 1% having completed a bachelor's degree (or higher).
- 46.9% of female-headed households are in the two lowest household monthly spending quintiles, reflecting a gender gap in attained levels of education.
- 32.3% of female-headed households have off-grid access, compared with 29.3% of male-headed households, while 69.3% of male-headed households have grid access, compared with 65.4% of female-headed households.
- 62.7% of female-headed households stated that affordability of internal wiring constrains their willingness to pay for access to the grid, compared with 26.9% of male-headed households.
- 13% of female-headed households have less than 4 hours of supply a day, compared with 8% of male-headed households.
- 84% of female-headed households find the cost of connection and monthly fees to be the biggest hurdles to gaining grid access.

POLICY HIGHLIGHTS

ACCESS TO ELECTRICITY

- Universal access to electricity in Cambodia is achievable in the near term if grid and off-grid electrification—and supply and demand measures—are pursued in parallel.
- Most households are served by the grid. But the grid supply is not performing up to its potential. Targeted measures to reduce outages and provide stable voltage would eliminate key barriers for households in lower tiers, shifting the average tier for access to electricity from Tier 2.6 to Tier 3.6 by moving 42.7% of households in Tier 3 to Tier 4 and 6.2% of households in Tier 4 to Tier 5.
- In urban areas electrification is moving to the last mile phase. But further progress requires overcoming affordability constraints because the remaining non-electrified households are among the poorest, and many of them belong to vulnerable groups such as female-headed households.
- In rural areas off-grid solutions promise the fastest expansion path, but their performance and affordability need to improve.
- Most households without basic electricity access (Tier 0 households) already have an off-grid solution (solar device or rechargeable batteries). Upgrading performance of these devices would allow an additional 9.4% of households to enjoy the benefits of basic electricity access (Tier 1), increasing the percentage of households in Tiers 1–5 from 87.6% to 97%.
- To get more from solar home systems, introducing quality-verified solar kits, improving household understanding of the technology, enforcing quality standards, and increasing the capabilities of technicians (for example - through certification programs as recommended by RISE indicators) are recommended.[1]
- Because Affordability is the biggest barrier to access to electricity, options that spread payments for grid connections and solar home systems—such as pay-as-you-go arrangements—should be explored and promoted.
- Affordability support should target the poorest households (bottom quintile of the monthly spending distribution) and female-headed households.
- In rural areas, both grid supply and off-grid systems are underused because of low appliance ownership. Promoting energy-efficient appliances and affordable schemes for purchasing them would allow households to enjoy more benefits from their grid or off-grid electricity sources.

[1] RISE results for Cambodia can be viewed at: http://rise.worldbank.org/country/cambodia

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

- To promote health benefits, the already high LPG penetration should be increased further, especially in urban areas. Where LPG is unavailable, advanced biomass stoves (such as advanced gasifiers), which have already started penetrating the Cambodian market, should be promoted.
- To expand the use of clean fuels and technologies, Affordability needs to be tackled through innovations in business models for stoves and fuels (such as pay-as-you-go arrangements), as well as through targeted support for special groups, such as low-income and female-headed households.
- Awareness campaigns should promote the shift toward exclusive use of clean technologies and fuels, reducing fuel stacking (parallel use of several fuels; in Cambodia mostly LPG and biomass). These campaigns should be based on full understanding of the current barriers to the adoption of clean fuels and technologies, which are likely to include a combination of affordability, socioeconomic, and cultural aspects.
- Where biomass stoves are in use, awareness campaigns should also target ambient and behavior aspects—such as improving ventilation, separating cooking areas from sleeping areas, and minimizing time in the cooking area—to limit household member exposure to harmful pollutants.
- Constraints to LPG supply should be analyzed to determine why some households that use LPG spend as much as 5 hours a week preparing the fuel and stove for cooking.
- Where clean fuels and technologies cannot yet be delivered, access to more affordable improved cookstoves should be supported as the most feasible and immediate improvement for the 28.6% of households that use a three-stone or traditional stove, particularly those in rural areas. This transition can deliver important benefits to all household members through reduced spending and time spent collecting fuels and preparing meals.

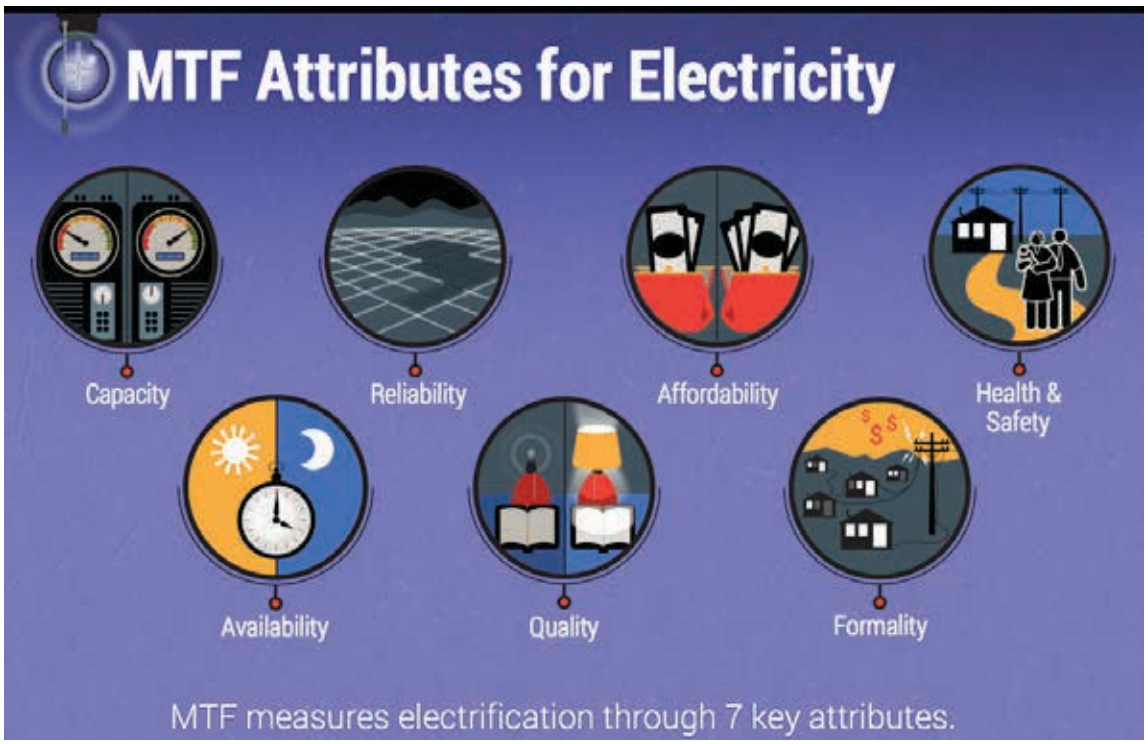
KEY FINDINGS AND POLICY IMPLICATIONS

Technologies, attributes, tiers, and use—those are the key concepts that the Multi-Tier Framework (MTF) uses to assess the access of households in Cambodia 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

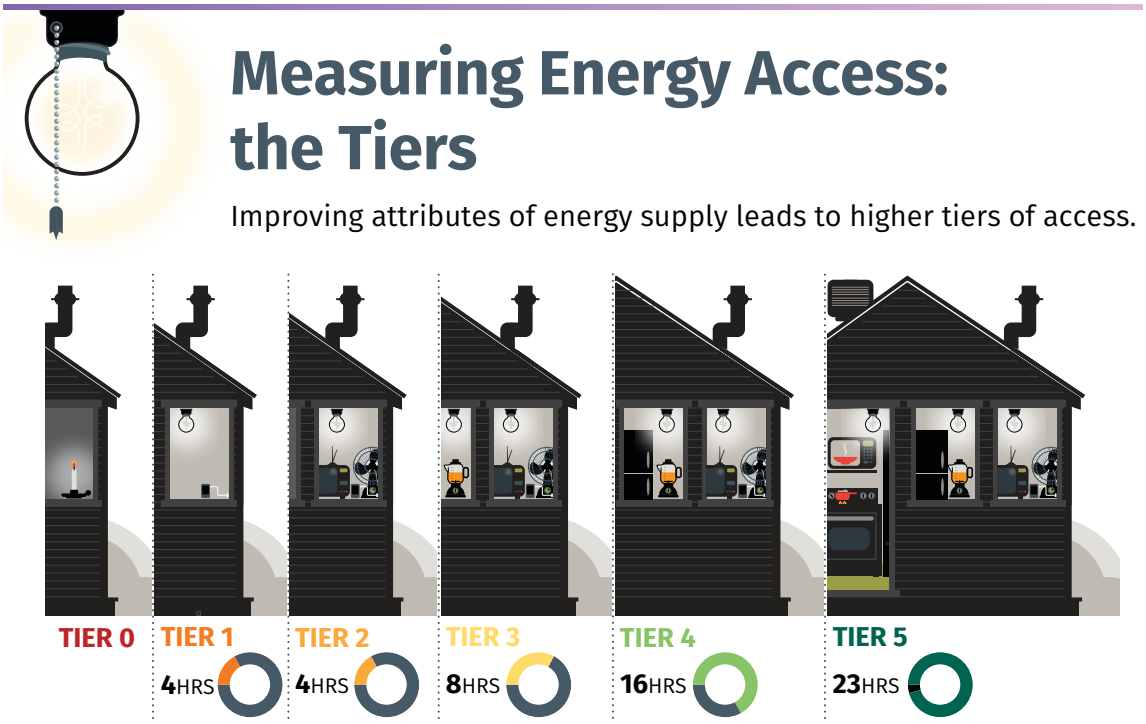
The MTF approach measures energy access provided by any technology or fuel based on seven attributes that capture key characteristics of the energy supply that affect the user experience (figure 1): Capacity, Availability,[2] Reliability, Quality, Affordability, Formality, and Health and Safety. Based 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.

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



[2] 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 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 large 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 quite rare in Cambodia today.

The MTF approach yields a higher electrification rate than the traditional binary approach because the MTF approach captures electricity access provided by all technologies, including off-grid solar devices, whose use has recently expanded. Off-grid solutions allow 11.3% of households to be in Tiers 1 and 2. Consequently, the MTF approach estimates that 87.6% of households in Cambodia are in Tier 1 or above.

Technologies. Among households interviewed in Cambodia, 97.6% have access to at least one source of electricity — 71.5% of households have access through the grid, and 26.1% have access through off-grid solutions—including the 13.2% of households that have access through an SHS, which can power a television or fan. Fewer than 1% of households use a solar lantern or solar lighting system (SLS), which can typically provide only lighting and phone charging. And 11.5% of households use rechargeable batteries.

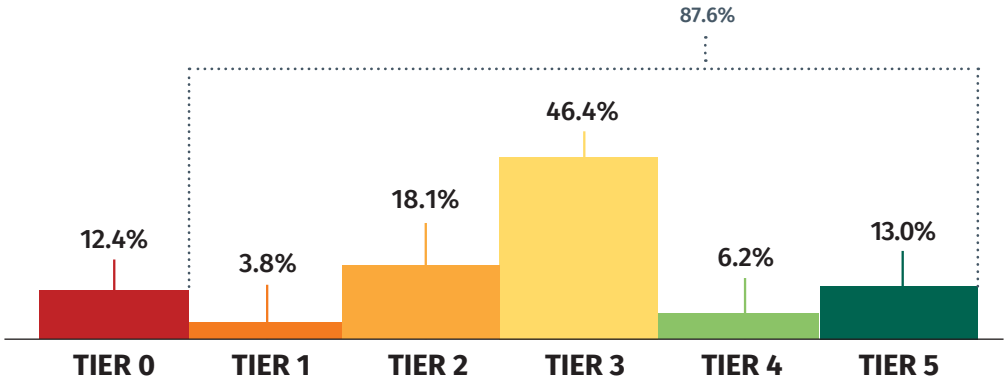
Off-grid solutions play a critical role in providing electricity to those without access to grid electricity, but such off-grid solutions are more common in rural households, where the gap in access to grid electricity remains wide: 30.4% of rural and 2.4% of urban households use off-grid solutions such as off-grid solar solutions and rechargeable batteries. More than 30% of rural households use off-grid solutions as their primary source of electricity: 15.5% of

rural households use either an SHS or a solar lantern or SLS, while 13.2% use rechargeable batteries.

MTF Tiers. Not all households that have access to electricity are in Tier 1 or above; some are in Tier 0 because of Capacity or Availability constraints. In Cambodia, 87.6% of households are in Tier 1 or above for access to electricity, and most electrified households are in Tier 3 (figure 3). So most electrified households have at least 8 hours of supply a day, including at least 3 hours in the evening, with enough capacity to power a medium-load appliance, such as a refrigerator, food processor, or water pump (see table 1 for the load levels associated with various appliances). The vast majority (99.6%) of households in Tiers 3–5 are powered by the grid.

In general, grid-connected households are in a high tier, mostly Tier 3, for access to electricity, but access is uneven between urban and rural areas. The highest concentration of grid-connected households is in urban areas: 97.2% urban households have access to the grid, with an average tier of 3.6, compared with 2.5 in rural areas, where 66.9% of households have access to the grid. The vast majority of households in Tier 0 are in rural areas. And 0.8% of urban households are in Tier 0, compared with 14.5% of rural households.

FIGURE 3 • **More than 87% of households are in Tier 1 or above for access to electricity**



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?*

Because grid-connected households are considered to have high-capacity electricity (over 2 kW), the proportion of households in Cambodia that receive high-capacity electricity is the same as the proportion of households that are connected to the grid (71.5%). While 97.2% of urban households receive high-capacity electricity, the situation is more nuanced in rural areas, where penetration of off-grid solutions that provide limited capacity is higher.

Poor Reliability prevents 39.3% of households in Tiers 3 and 4 from reaching Tier 5, and poor Quality prevents 9.5% of households in Tiers 3 from reaching Tier 5. In urban areas 55.2% of households could maximize the benefit of electricity by having more reliable and better quality of electricity.

Nationwide, 69.3% of households face frequent, unpredictable power outages. Most households experience more than four electricity disruptions a week. Reliability is more of an issue in rural areas, possibly because of bottlenecks in the transmission and distribution networks that serve those areas.

In Cambodia 32.6% of households experience voltage issues such as low or fluctuating service. 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.

Lack of affordability prevents 6.7% of grid-connected households in Tier 2 from reaching a higher tier because the cost to consume 1 kWh of electricity a day is more than 5% of their monthly spending. Affordability is a larger issue for rural households, lower income households, and female-headed households. Affordability is further aggravated by low Availability and poor Reliability, which result in urban grid-connected households allocating an additional 0.3% of their monthly spending to backup sources of lighting (such as candles, fuels, and batteries) and rural grid-connected households allocating an additional 0.8%.

Use. Average monthly household electricity consumption in Cambodia is 55.2 kWh, and urban households consume 89.9 kWh a month more than rural households do (127.8 kWh compared with 37.9 kWh). Spending on electricity accounts for 3% of average monthly household spending; that share is substantially higher (5.3%) for urban households (111,800 riels, or $29, a month) and slightly lower (2.5%) for rural households (30,100 riels, or $8, a month). Households have been electrified for 5.6 years on average, so receiving electricity is a new phenomenon for many households.

Among households with grid access (typically those in Tier 3 or above), 2.4% own only very low–load appliances, and 50.3% own only low-load appliances. In rural areas 54.8% of grid-connected households own only low-load appliances, such as a television, fan, or computer (see table 1 for the load levels associated with various appliances).

High- and very high–load appliances, such as washing machines (3.8%) and microwaves (0.7%), are rare in rural households. This could be due to the price of electricity or appliances being inaccessible to many households. Because many households have been electrified for less than 5 years, it is possible that consumption and appliance ownership will grow.

Increasing access to higher tiers. Expanding energy-efficient technology can reduce the burden of electricity spending for all electrified households in Cambodia. Having more-efficient appliances would allow electrified households to enjoy the same benefit with lower electricity consumption and expenditure. Improving the Reliability and Quality of the electricity supply would also improve Affordability for all households by allowing them to reduce their spending on backup sources of electricity. Those savings could go toward consumption of more-efficient electricity services rather than less-efficient and polluting alternatives such as kerosene and candles.

Different solutions are required for rural and urban households. The 97.2% of grid-connected urban households would benefit most from improved Quality (reducing voltage fluctuation), Reliability (reducing the number and length of outages), and evening Availability. These three improvements would move the vast majority of households in Tier 3 to a higher tier. For households in lower tiers, improvement in Affordability (of both connections and tariffs) is most important—and could also help connect the 0.4% of households in Tier 0 to achieve 100% electrification in urban areas.

Areas for improvement are more diverse for rural households, which include non-electrified, grid-connected, and off-grid households, each with different needs. Moving the 12.4% of households that are in Tier 0 to a higher tier would require connecting non-electrified households to the grid or providing them with higher tier off-grid solutions. For grid-connected rural households, the issues are similar to those of urban households, but more pronounced. Improving Reliability, Quality, and evening Availability would move most grid-connected households in Tier 3 to Tier 4 or 5.

Most households that are in Tier 0 because their primary source of electricity is rechargeable batteries (which provide insufficient Capacity and/or Availability of service) are in rural villages, where the grid is inaccessible. Solar devices could help move these households to a higher tier.

Analyzing the performance of existing off-grid systems could identify issues that would improve daily Availability, the main issue for off-grid households in Tier 0. Anecdotal evidence points to battery problems, which is also reflected in the 10% of households that use an off-grid solar device that report battery maintenance issues (in particular, battery

replacement). Resolving battery quality and maintenance could help a sizable portion of off-grid households move to a higher tier. This could be done by promoting quality-verified solar kits, enforcing quality standards and warranties, educating users, and building better capacity in off-grid service providers and technicians.

The MTF survey includes a Willingness to Pay (WTP) module that is used to assess a household's WTP for a grid connection or a off-grid solar device. Incremental payment options provide further insight into the appeal of investment in a service or device.

Affordability of larger SHSs is still an issue, as reflected in the WTP results. Innovative financing mechanisms that increase ability to pay—such as pay-as-you-go approaches, which have been limited so far—should be explored.

The causes of low consumption and appliance ownership among households that have a grid connection and households that use an off-grid solar device also need to be analyzed. The causes may include lack of productive uses, unavailable or unaffordable appliances, being unaccustomed to electricity use (most grid and off-grid users acquired electricity within the last 5 years), and unreliable or low-quality service from a solar device. And additional measures should be taken to increase the use of electricity service and the adoption of energy-efficient appliances by all electrified users.

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

The MTF approach measures access to modern energy cooking solutions based on six attributes (figure 4). Attributes directly related to the cooking solution (cookstove and fuel), such as Cooking Exposure, Cookstove Efficiency, and Safety of Primary Cookstove, are the main concerns in the lower tiers. This report uses a simplified interim framework based on five stove categories: three-stone fire, traditional cookstove, improved biomass cookstove, advanced biomass stove, and clean fuel cookstove.

MTF Attributes. In Cambodia 52.1% of households that are in Tier 1 are not in a higher tier because of the Cooking Exposure attribute, the remaining 46.9% are not in a higher tier because of the Convenience attribute (they spend more than 7 hours a week acquiring, through collection or purchase, fuel and more than 15 minutes preparing stoves for each meal). 1% of Tier 1 households are held back in Tier 1 due to Efficiency.

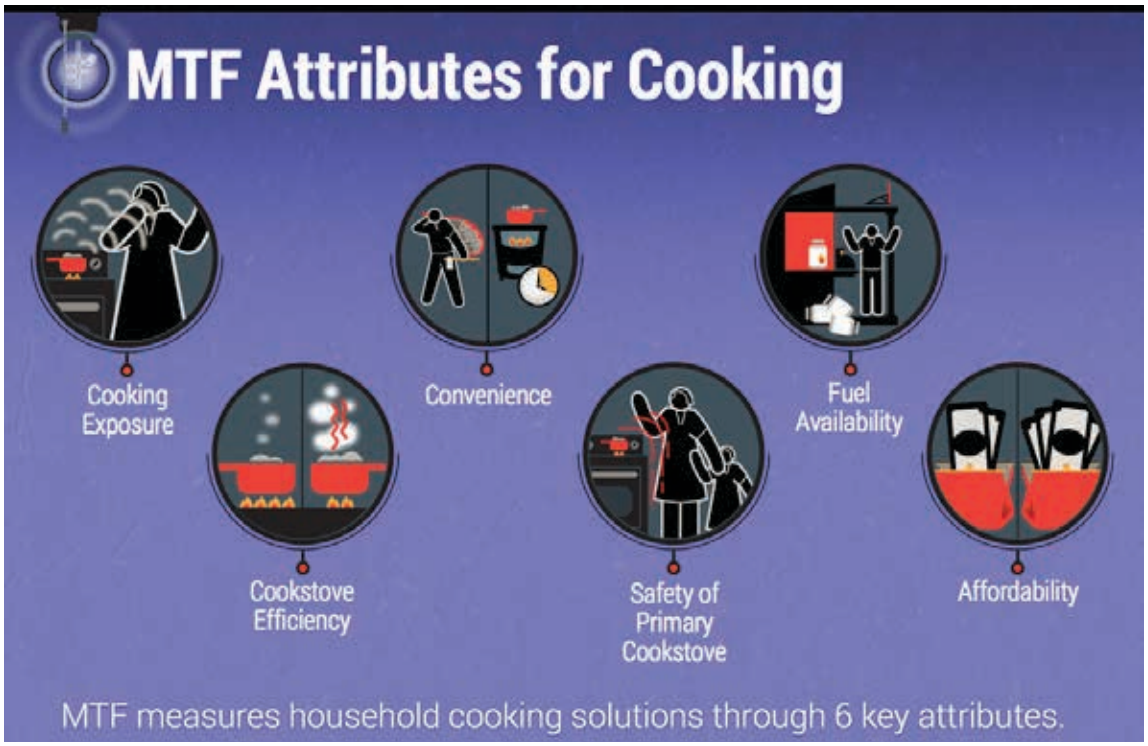
Given the important health benefits of using clean fuels for cooking, the government should explore how to increase the use of clean fuel stoves (mainly LPG stoves). The percentage of households using a clean fuel stove as their primary stove rose from 9% in 2007 to 24.8% in 2014 to 32.9% in 2017—driven by more affluent urban areas, where 77.1% of households use a clean fuel stove as their primary stove. It would be valuable to analyze what has contributed to the expanded use and availability of clean fuel stoves and incorporate those elements into future policy and project design.

A key question about cookstoves and their use is what constrains a household from moving up to the next 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[3]), and contact time (time spent in the cooking environment). Kitchen volume and contact time were not analyzed for Cambodia.
- **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?*

[3] 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.

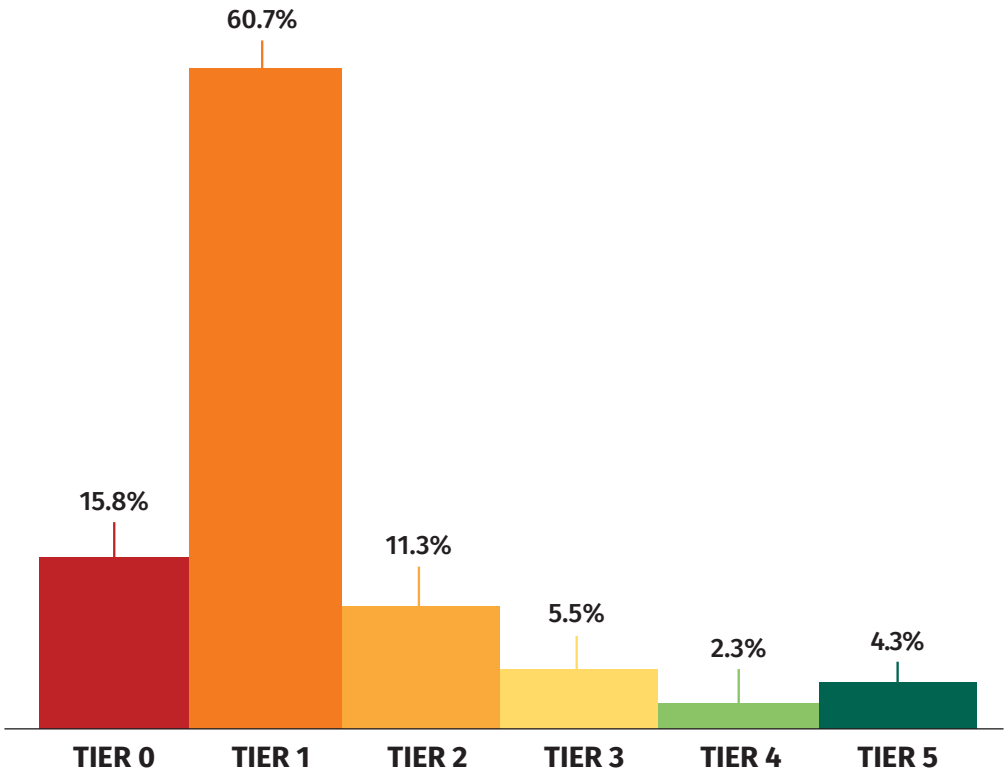
FIGURE 4 • **Multi-Tier Framework attributes for access to cooking**



Technologies. Of the households interviewed in Cambodia, 66.7% use a biomass stove as their primary stove, with 62% using firewood as their primary fuel source and 5% using charcoal. In urban areas clean fuel stoves—mainly LPG—are the most common (77.1%). In rural areas, where firewood is more common, 24.8% of households use a clean fuel stove. Nationwide, 35.1% of households use an improved cookstove (ICS) as their primary stove, which is also the most common solution among rural households (38.7%).

MTF Tiers. Most households in Cambodia are in Tier 1. The percentage of households in Tier 4 or 5 is 6.5%—despite a third of households using a clean fuel stove as their primary stove. The discrepancy is due mainly to these households complementing their clean fuel stove with a biomass stove, which dilutes the benefits of a clean fuel stove. Many households that use a clean fuel stove are in a lower tier because of the Convenience attribute: they spend considerable time acquiring (through collection or purchase) and preparing fuel for their biomass stove or spend time to acquire LPG fuel, perhaps due to living in areas with limited LPG supply. Most households in Tiers 4 and 5 use a clean fuel stove exclusively or more frequently than they use a biomass stove. Affordability also keeps some households that use a clean fuel stove in Tier 3.

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



In urban areas 30.2% of households are in Tier 4 or 5, compared with 2.4% of households in rural areas, due mostly to much lower penetration of clean fuel stoves, which are also rarely used exclusively in rural areas. Conversely, 84.3% of rural households are in Tier 0 or 1, compared with 33.1% of urban households.

Use. Another challenge is how to reduce the burden of high fuel costs to promote the use of clean fuel stoves. Households that use a clean fuel stove are on average in a higher income bracket than households that use a biomass stove. Households with a clean fuel stove allocate around 2.6% of their monthly household budget to fuel, compared with less than 1% for households that use a biomass stove.

Improved biomass stoves (ICS) place households in a lower tier for access to modern energy cooking solutions than clean fuel stoves do but are more common and are often used exclusively. Nationwide, 35.1% of households use an improved stove as their primary stove, and 74.7% of them use it exclusively, while 19% use it in a combination with a clean fuel stove. ICSs use considerably less fuel than traditional stoves do, so household members spend less time collecting firewood.

Increasing access to modern energy cooking solutions. Promoting the use of ICSs is a promising solution for a large percentage of households in Cambodia that are in Tiers 0 and

1 (which use three-stone or traditional stoves), especially given that 79.6% of households are willing to pay full price (20,000 riels, or about $5) for an ICS. Budgets of households that use a three-stone stove or a traditional stove as their primary stove are not different from those of households that use an ICS. So expanding the use of ICSs in rural areas would be more feasible and effective than promoting clean fuel stoves, although, obviously, without producing the same benefits as clean fuel stoves.

Advanced biomass stoves—which tend to contribute less to indoor air pollution and thus can have positive health benefits—should also be promoted. But the WTP for such stoves is lower because of their high price and the reluctance to accept an unknown technology. Explaining the health benefits of advanced biomass stoves (better indoor air quality) and increasing their affordability (offering a payment plan), and perhaps a targeted subsidy, could expand their penetration. Awareness campaigns should also encourage households to improve ventilation, minimizing the exposure to indoor air pollution.

GENDER GAPS IN ACCESS

Electricity. Female-headed households in Cambodia have lower access to electricity for all technologies except for some off-grid solutions. In rural areas electricity access rates through SHSs and rechargeable batteries are higher for female-headed households than for male-headed households. Female household heads without access to the grid use an off-grid solar device to compensate.

Because more male-headed households are connected to the grid, male-headed households also tend to be in higher tiers for access to electricity than female-headed households are. Female-headed households tend to be in a lower tier for Capacity (because they are less likely than male-headed households to have a grid connection and more likely to have an SHS). Nearly 13% of female-headed households have less than 4 hours of electricity supply a day, compared with 8% of male-headed households. Affordability compounds the difficulties that female-headed households face.

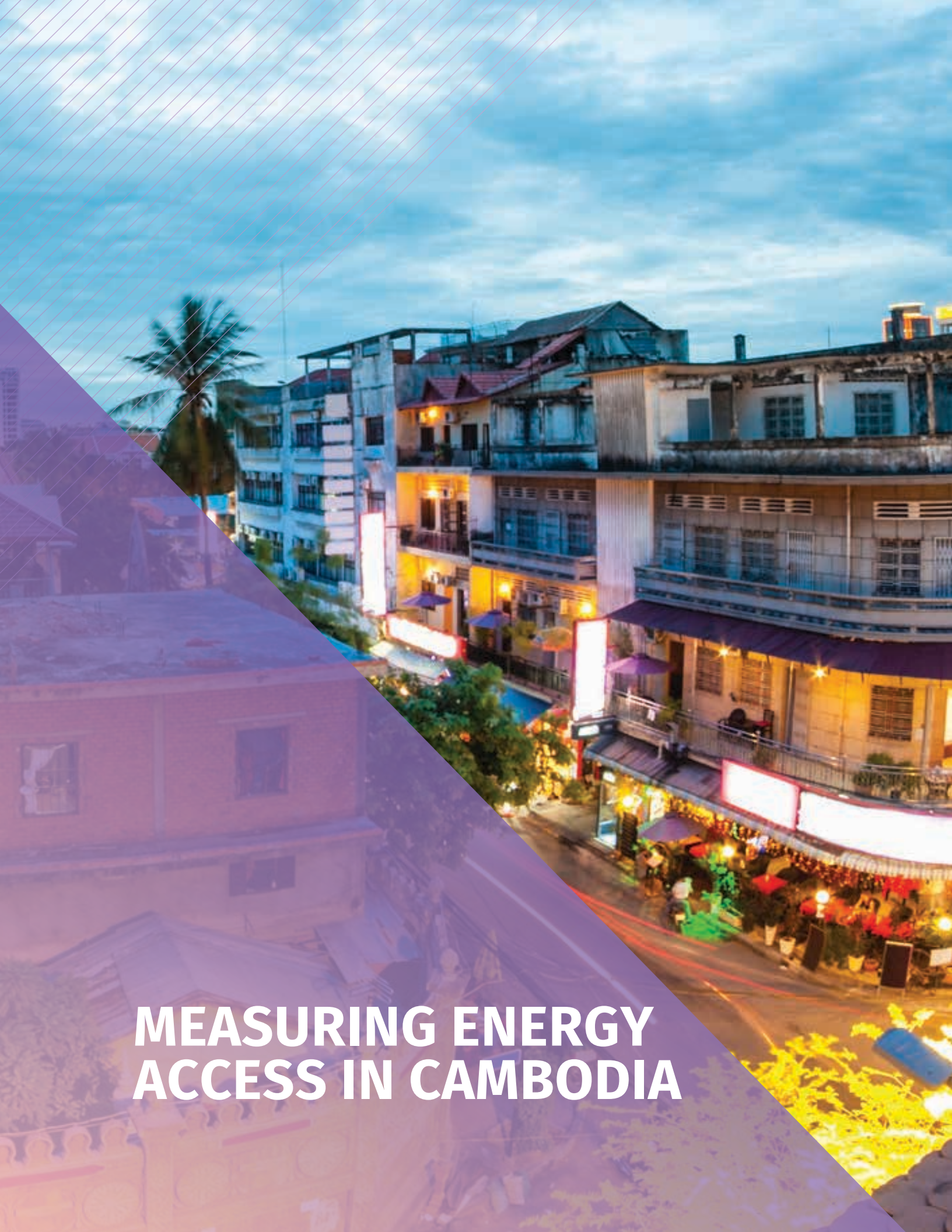
Nationally, the widest gender gap in access to electricity (almost 5 percentage points) is among households in Tier 0. The gap is wider in rural areas than in urban areas because most urban households—both male- and female-headed—are connected to the grid: 91.8% of female-headed households and 93.9% of male-headed households are in Tier 3 or above.

Overall, the cost of internal wiring and connection and the monthly fee are the biggest hurdles for female-headed households. For 84% of female-headed households and 81.1% of male-headed households Affordability is the primary reason for not being connected to the grid. Among female heads of household, 62.7% cited the cost of internal wiring as the biggest constraint, compared with 26.9% of male heads of household. Although female-headed households show greater interest in purchasing a pricier solar device than male household heads do, the cost to acquire the device is a barrier.

Access to modern energy cooking solutions. There is a significant gender gap in access to improved and clean fuel cookstoves in Cambodia: 63.5% of female-headed households use an improved biomass or a clean fuel cookstove compared with 70.2% of male-headed households. This suggests that female-headed households should be prioritized in strategies to increase access to improved and clean fuel stoves. Both male and female household heads have some hesitation in investing in an advanced ICS, a Prime stove (a gasifier stove), compared with investing in a popular ICS, the Neang Kangrey stove, as a primary stove, regardless of payment terms (see box 3 for a typology of stoves). To expand access to modern energy cooking solutions, more households—both female and male headed—need to be convinced of the importance of using these types of stoves and to be provided support to afford them (such as subsidies or a longer repayment plan).

Women are the main cook in households and are thus the most affected by changes in cooking practices. The switch to clean fuel stoves has reduced the time spent collecting fuelwood and cooking, the benefits of which accrue to both men and women. But female household members spend more time cooking than male household members do, so women benefit the most from switching to an ICS or clean fuel stove, both of which have fewer emissions than three-stone or traditional stoves do.

Energy access programs should pay more attention to gender issues—in particular the special needs and circumstances of female-headed households, including affordability in accessing grid and off-grid technologies and the administrative barriers that female-headed households encounter when trying to establish a connection. Programs should also accelerate and increase access to improved biomass and clean fuel stoves, which provide health and time-saving benefits to all household heads—with female household heads and primary cookstove operators most affected. Investing in these efforts can increase female household heads' participation in economic, leisure, and learning activities.



MEASURING ENERGY ACCESS IN CAMBODIA

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 Cambodian 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.

Cambodia is one of Asia's fastest growing economies. With a population of 15.8 million, the country spans 176,520 square kilometers, bordering Thailand and Vietnam.[4] After 20 years of steady economic growth, Cambodia secured lower-middle-income status in 2015. Its growth has averaged 7.6% a year over the last decade—higher than the regional average of 5.1%. Some 79% of Cambodia's people live in rural areas,[5] and the country's leading economic sector has historically been agriculture. But the garment, textiles, and tourism sectors have expanded, bringing increased foreign investment and international trade. Cambodia ranked 135th out of 190 countries in the 2017 World Bank *Doing Business* report.[6] It achieved Millennium Development Goal 1 in 2009 after halving its poverty rate. But 4.5 million people are still near-poor, and the country ranked 143th on the United Nations Development Programme's 2016 Human Development Index.[7]

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 Cambodia. The survey's objective is to provide more nuanced data on energy access, including access to

[4] World Bank World Development Indicators database (https://data.worldbank.org/indicator/SP.POP.TOTL; https://data.worldbank.org/indicator/AG.LND.TOTL.K2).
[5] World Bank World Development Indicators database (https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS).
[6] World Bank Doing Business website (http://www.doingbusiness.org/data/exploreeconomies/cambodia).
[7] United Nations Development Programme, Human Development Report Office website (http://hdr.undp.org/en/countries/profiles/KHM).

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.[8]

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.[9]

ACCESS TO ELECTRICITY

Access to electricity is measured based on seven attributes: Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety. 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 refrigerators, washing machines, and air conditioning)—as well as by Affordability (applicable for Tiers 3–5) and Reliability, Quality, Formality, and Health and 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 quite rare in Cambodia today.

[8] 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.
[9] 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 a 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, nd 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 diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high–load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source would be mini-grids and the national grid.

Source: Bhatia and Angelou 2015.

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 FOR CAPACITY.

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 a SLS without phone charging capability, it is assumed that 70% of the household members are in Tier 1; for a household that uses a 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 televisions, irons, microwaves, or refrigerators. See table 1 for the load level associated with each tier. For a household that uses a SHS, it is assumed that all the household members are at least in Tier 2 for Capacity.

Please note that this is a simplified methodology used to approximate off-grid access based on survey results (since survey data lack details on system sizes and their performance). To review a more detailed methodology where system size and their 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 A1.1). Cooking Exposure assesses personal exposure to pollutants from cooking activities, which depends on stove emissions, ventilation structure (which includes cooking location and kitchen volume[10]), and contact time (time spent in the cooking environment). Kitchen volume and contact time were not analyzed for Cambodia. 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. However, due to data limitations, this report only considers a household's ability to pay for cooking fuel.

Attributes directly related to the cooking solution (cookstove and fuel) (see box 3 for a typology of cookstoves), such as Cooking Exposure (based on emissions), Cookstove Efficiency, and Safety of Primary Cookstove, are the main concerns in the lower tiers. Households with a three-stone stove or traditional biomass stove are in Tier 0 (no access), households with an improved biomass stove are in Tier 2, households with an advanced biomass stove are in Tier 3 or 4, households with a cookstove fueled with biogas, lliquefied petroleum gas (LPG), or natural gas are in Tier 4, and households with an electric stove are in Tier 5.[11] 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. This report uses a simplified interim framework based on five stove categories: three-stone fire, traditional cookstove, improved biomass cookstove, advanced biomass stove,[12] and clean fuel cookstove.

[10] 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.
[11] These categories are approximate. The actual tier allocation needs to be done through appropriate stove tests, reflecting local cooking practices and conditions.
[12] MTF data included one household using a Mimi Moto as its primary stove.

BOX 3 • TYPOLOGY OF COOKSTOVES IN CAMBODIA

Cookstoves in Cambodia were classified into five categories based on existing literature[12] and consultation with development partners and government officials during the MTF survey kickoff workshop in Phnom Penh. See annex 2 for detailed information.

Three-stone stove. A pot balanced on three stones over an open fire. It is the most traditional method of cooking in Cambodia.

Traditional biomass stove. Locally produced using available and low-cost materials and fuels, reflecting cultural practices. In Cambodia four types of stoves were identified as traditional: Mong/siam, Traditional Kampong Chhnang, Traditional Lao, and cement (also known as "the traditional stove").

Improved biomass stove. Uses newer stove technology to improve efficiency, cleanliness, and safety. In Cambodia two types of stoves were identified as improved biomass: Neang Kangrey stove (NKS) and New Lao stove (NLS).

Advanced biomass stove. Uses a fan to force emissions back into the flame for more complete burning. Because only one household in the survey used an advanced biomass stove (a Mimi Moto), this category was merged with the improved biomass stove category for the analysis.

Clean fuel stove. Uses clean and efficient fuels such as LPG, electricity, or biogas.

A key question about cookstoves and their use is what constrains a household from moving up to the next 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[14]), and contact time (time spent in the cooking environment). Kitchen volume and contact time were not analyzed for Cambodia.
- **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?*

[13] During the MTF survey preparation phase, the team referred to "Efficient Cookstoves to Mitigate Global Warming and Contribute to Poverty Alleviation in Cambodia" (a Project Design Document for the Cambodia Fuelwood Saving Project, published in 2007) and "Dissemination of Domestic Efficient Cookstoves in Cambodia" (published in 2009). The team also organized two workshops in Cambodia to have feedback from the government and development partners: the kickoff workshop was held March 23, 2017, and the dissemination workshop was held November 29, 2017. During this process, the cookstove stove typology for the data collection and analysis was finalized.

[14] 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.

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,[15] average annual PM2.5 concentration should be less than 10 μg/m^3, and 24-hour 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 very costly and not practical to implement through a large-scale household survey. One alternative is to calculate exposure based on simulation through mathematical models that consider key factors contributing to indoor air quality, such as indoor fuel combustion, ambient air pollution in the area, and kitchen volume and air exchange. Indoor emissions depend on the characteristics of each cooking solution (to account for stacking), along with its use, duration, and pattern. Emissions also depend on fuel quality, device maintenance, and user adherence to specifications. 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 Cambodia 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. Based on the MTF data in Cambodia, the tier for Cooking Exposure is a composite of the tier for emissions from the cooking activity and the tier for ventilation in the cooking area.

To estimate Cooking Exposure, the first step is to determine the tier for emissions for a household based on its primary and secondary stoves. Each stove that the household uses is classified based on a combination of the stove design and the primary fuel used with that stove. This classification is adapted from EnDev's Cooking Energy System (table 2). For households that use only one stove, the tier for emissions for that stove is used. For households that use more than one stove (or stack their stoves), the emissions of each stove are weighted by the proportion of time spent cooking with it.

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 two or more openings is classified as having average ventilation. And a household that cooks its meals outdoors is classified as having good ventilation. Ventilation

[15] 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).

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 emissions remain at Tier 0 for Cooking Exposure if they have poor or average ventilation but move to Tier 1 if they have good ventilation. Households in Tiers 1–3 for emissions (using traditional and improved cookstoves [ICSs]) move down one tier for Cooking Exposure if they have bad ventilation, remain in the same tier if they have average ventilation, and move up one tier if they have good ventilation. 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

Efficiency is calculated by using draft of International Organization for Standardization thermal efficiency standards. Stoves with less than 10% thermal efficiency are in Tier 0, those with 10%–20% thermal efficiency are in Tier 1, those with 20%–30% thermal efficiency are in Tier 2, those with 30%–40% thermal efficiency are in Tier 3, those with 40%–50% thermal efficiency, and those with 50% or higher thermal efficiency are in Tier 5. Since a high percentage of households use multiple cooking solutions, it is also critical to incorporate the frequency of use for each stove to assess efficiency.

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. Indicators such as primary energy source, tier of access, energy-related spending, WTP, and user preferences are disaggregated by male-headed and female-headed households. Such data add value to energy access planning, implementation, and financing. The MTF survey provides additional gender-related information, including on gender roles in determining energy-related spending and gender-differentiated impacts on health and time use.

MULTI-TIER FRAMEWORK SURVEY IMPLEMENTATION IN CAMBODIA

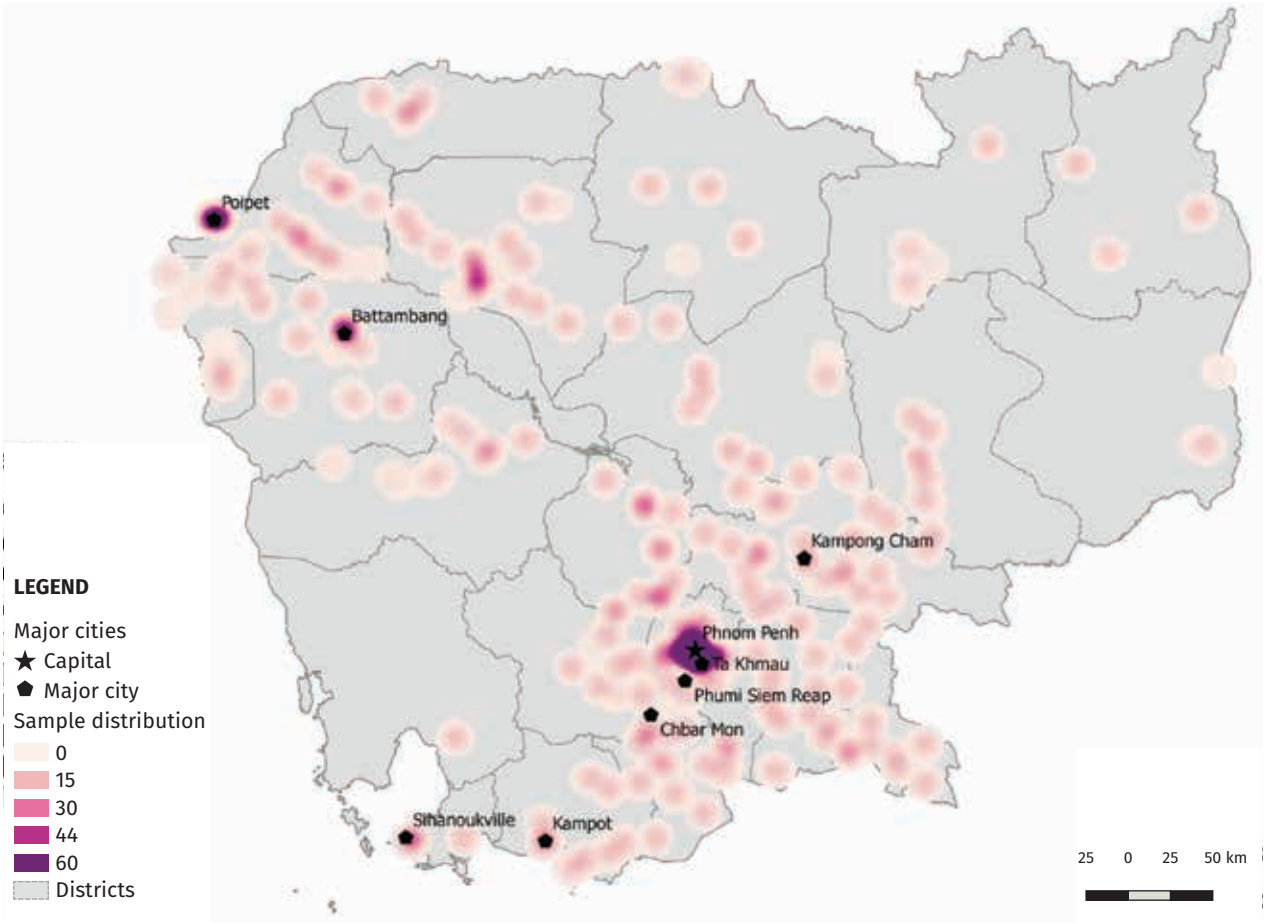
MTF data collection in Cambodia occurred mostly in June–July 2017 and was completed on August 2, 2017. The household survey sample selection was based on two-stage stratification, aimed at being representative of the country at large. The National Institute of Statistics provided advice on sampling strategy, and the Electricity Authority of Cambodia supported the MTF team in identifying the electrification status of enumeration areas. A total of 3,300 households were surveyed, following the stratification criteria: 50:50 ratio of electrified and non-electrified households for the tier analysis

and equal allocation between urban and rural areas (table 3 and figure 6). The results of the MTF survey data collection and analysis were presented to the Ministry of Mines and Energy, the Ministry of Economy and Finance, the Electricity Authority of Cambodia, and the National Institute of Statistics, as well as to development partners.

TABLE 3 • **Distribution of villages and households in Cambodia sampled for the Multi-Tier Framework survey**

	Urban				Rural				Total	
	Electrified		Non-electrified		Electrified		Non-electrified			
Provinces	Villages	HHs	Villages	HHs	Villages	HHs	Villages	HHs	Villages	HHs
Banteay Meanchey	7	82	6	72	2	29	5	64	20	247
Battambang	2	24	4	48	2	25	8	95	16	192
Kampong Cham	0	0	2	20	3	36	7	90	12	146
Kampong Chhnang	1	11	2	23	3	44	3	36	9	114
Kampong Speu	0	0	2	24	3	38	5	62	10	124
Kampong Thom	0	0	1	10	4	47	4	53	9	110
Kampot	0	0	2	24	0	0	6	72	8	96
Kandal	1	11	3	37	1	14	9	108	14	170
Kep	0	0	1	12	0	0	1	12	2	24
Koh Kong	0	0	1	12	0	0	0	0	1	12
Kracheh	0	0	1	12	3	36	2	24	6	72
Mondul Kiri	0	0	0	0	1	12	0	0	1	12
Otdar Meanchey	1	12	1	13	1	12	1	12	4	49
Pailin	0	0	1	11	0	0	1	12	2	23
Phnom Penh	37	443	39	477	1	12	1	12	78	944
Preah Sihanouk	0	0	2	35	0	0	1	12	3	47
Preah Vihear	0	0	1	12	2	24	1	12	4	48
Prey Veng	0	0	1	9	5	59	7	90	13	158
Pursat	0	0	1	12	1	12	4	48	6	72
Ratanak Kiri	0	0	0	0	2	24	1	12	3	36
Siem Reap	2	25	6	72	4	48	4	47	16	192
Stung Treng	0	0	0	11	1	12	1	12	2	35
Svay Rieng	0	0	0	0	6	72	2	24	8	96
Takeo	0	0	1	12	1	10	7	88	9	110
Tboung Khmum	1	12	1	23	2	24	6	71	10	130
Total	**52**	**620**	**79**	**981**	**45**	**590**	**87**	**1,068**	**266**	**3,259**

FIGURE 6 • **Spatial distribution of the households in Cambodia sampled for the Multi-Tier Framework survey**



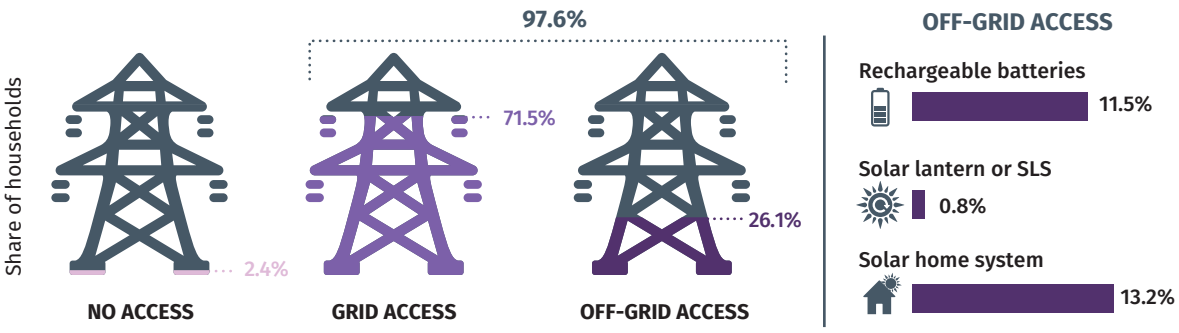
ACCESS TO ELECTRICITY

ASSESSING ACCESS TO ELECTRICITY

TECHNOLOGIES

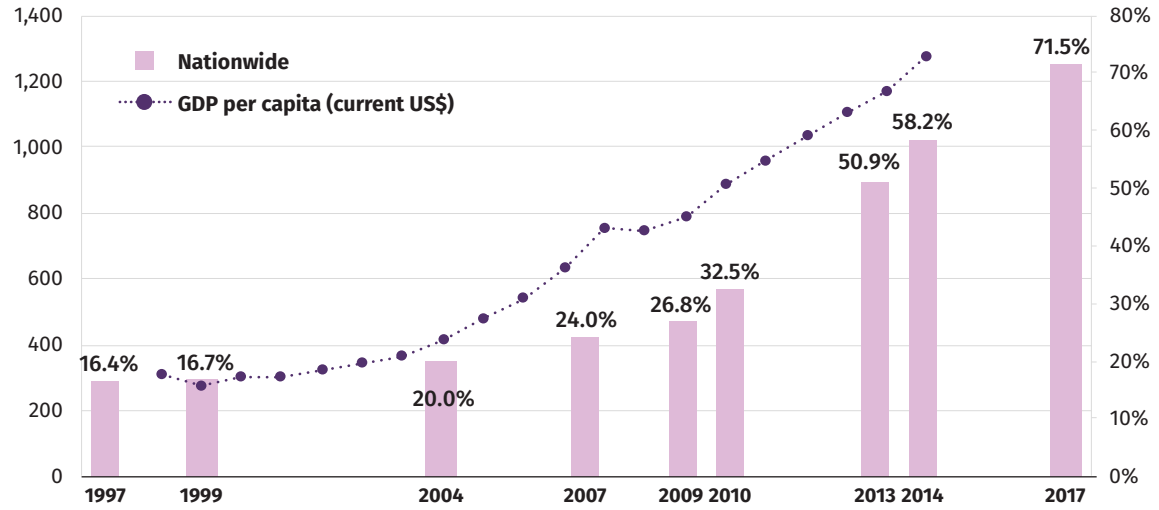
In Cambodia 97.6% of households have access to at least one source of electricity: 71.5% of households have access through the grid, and 26.1% have access through off-grid solutions—including the 13.2% of households that have access through a solar home system (SHS), which can power a television or fan (figure 7). Only 0.8% of households use a solar lantern or solar lighting system (SLS), which can typically provide only lighting and phone charging. And 11.5% of households use rechargeable batteries.

FIGURE 7 • **Nearly 98% of households have access to at least one source of electricity**



The electric grid has expanded rapidly, with the electrification rate greatly increasing, from 16.4% in 1997 to 32.5% in 2010 and to 58.2% in 2014 (figure 8).

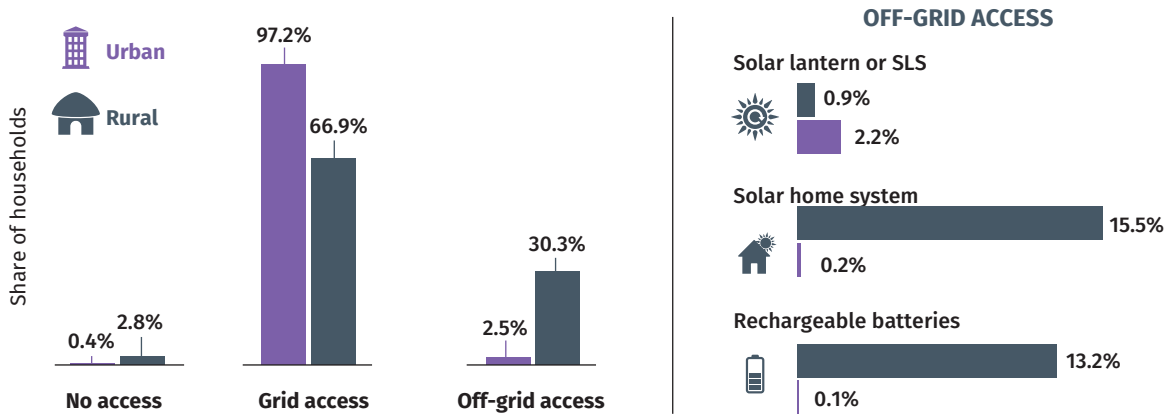
FIGURE 8 • **The government has rapidly increased grid electrification over the past decade**



Source: Grid electrification rates: 1997–2014, Cambodia Socio-Economic Survey; 2017, Multi-Tier Framework survey. GDP per capita: World Bank World Development Indicators database.

Both urban and rural households use off-grid solar devices and rechargeable batteries, but such off-grid solutions are more common in rural households, where the gap in access to electricity remains wide. Some 30.3% of rural households use off-grid solutions as their primary source of electricity: 16.4% use either a SHS or a solar lantern or SLS, while 13.2% use rechargeable batteries (figure 9)

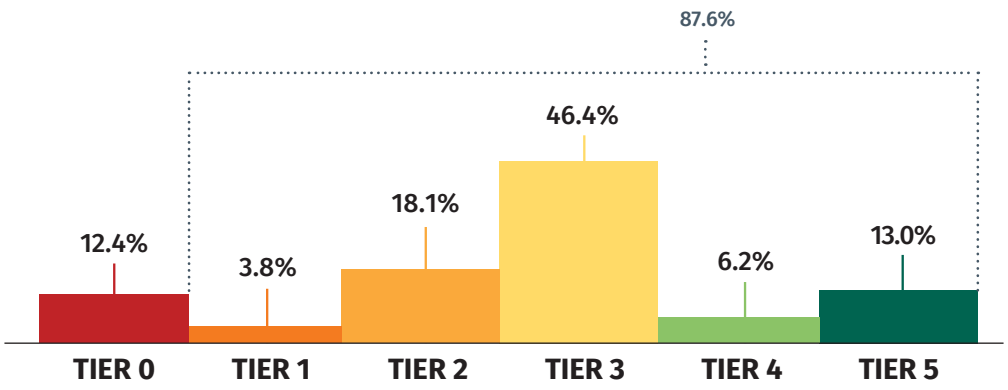
FIGURE 9 • **Off-grid solar devices are critical in closing the gap in access to electricity among rural households**



MTF TIERS

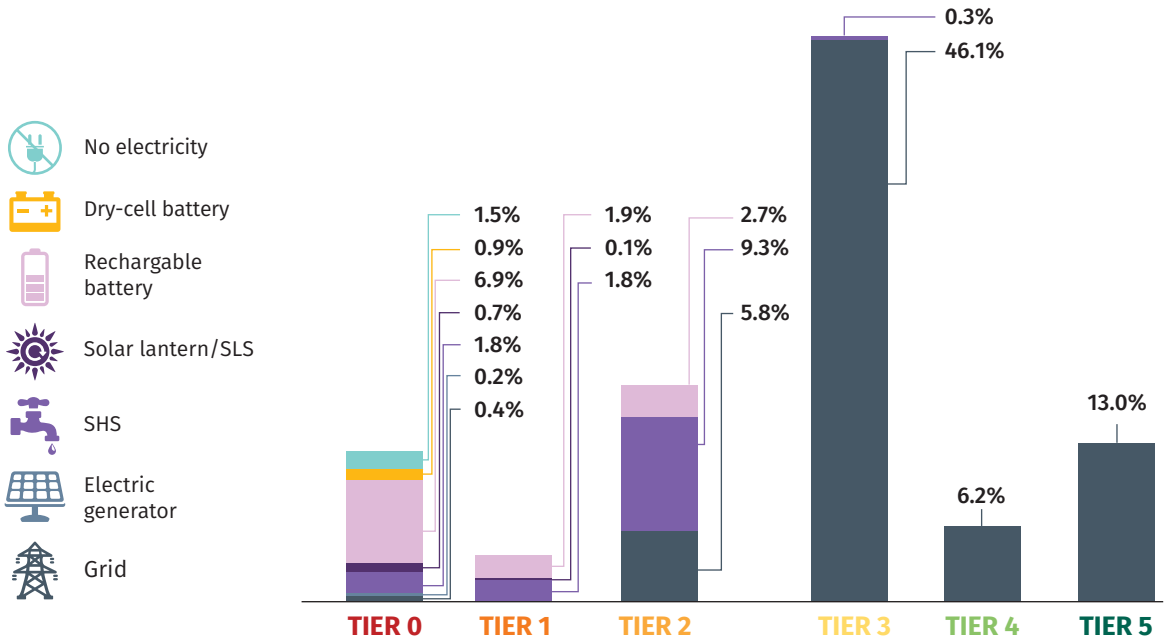
Nationwide, 87.6% of households are in Tier 1 or above for access to electricity, and most electrified households (those in Tier 1 or higher) are in Tier 3 (figure 10). And 99.5% of households in Tiers 3–5 have access to the grid. So most electrified households have at least 8 hours of supply a day, including at least 3 hours in the evening, with enough capacity to power medium-load appliances, such as a refrigerator, food processor, or water pump (see table 1 for the load levels associated with various appliances).

FIGURE 10 • **The majority of households are in Tier 1 or above for access to electricity; most electrified households are in Tier 3**



Almost all households in Tier 3 and above for access to electricity are connected to the grid (figure 11). Among households that are not, off-grid solar devices are critical in providing electricity. Most households that use an off-grid solar device are in Tier 2, but some are in Tiers 0 and 1.

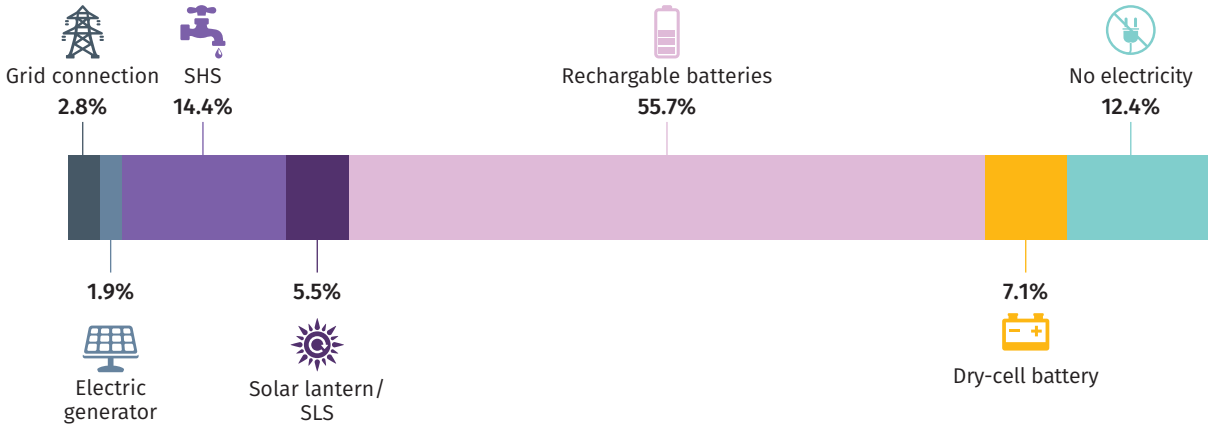
FIGURE 11 • **Grid-connected households are typically in Tier 3 or above for access to electricity, while households that use off-grid solutions are typically in Tiers 0–2**



In Cambodia 12.4% of households are in Tier 0 for access to electricity, and only 12.4% of households in Tier 0 have no access to electricity. Of the households in Tier 0, 55.7% use rechargeable batteries as their primary source of electricity, 19.9% use an off-grid solar device, and 2.8% are connected to the grid (figure 12). Grid-electrified households that are in Tier 0 have electricity for less than 4 hours a day or 1 hour a night, while off-grid households that are in Tier 0 have low Capacity and Availability

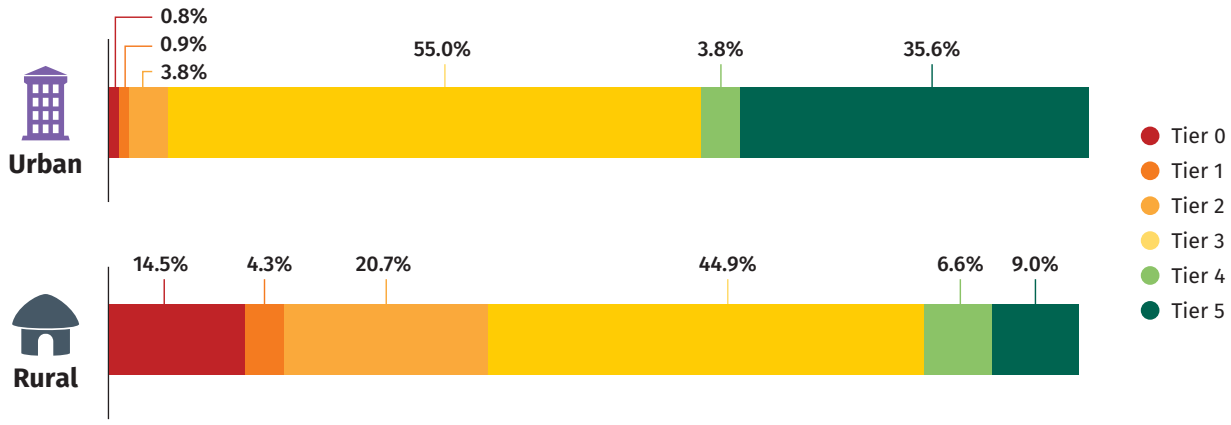
of electricity supply. About a third of households in Tier 0 do not have access to electricity use dry-cell batteries as their alternative source of electricity.[16]

FIGURE 12 • **Only 12.4% of households in Tier 0 for access to electricity have no source of electricity**



Electricity access is mostly a rural challenge: 97.2% of urban households are connected to the grid, compared with 66.9% of rural households. As a result, rural households are concentrated in Tiers 0–2: 0.8% of urban households are in Tier 0, compared with 14.5% of rural households, and 4.7% of urban households are in Tiers 1 and 2, compared with 25% of rural households (figure 13). The disparity between urban and rural households is also reflected in the average tier: 3.6 for urban households, compared with 2.5 for rural households.

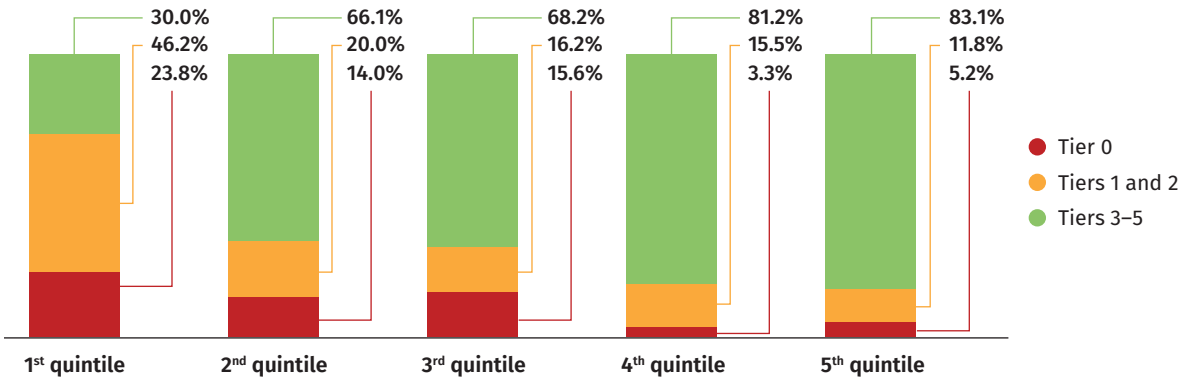
FIGURE 13 • **Urban households are more likely than rural households to be in Tier 3 or above for access to electricity**



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

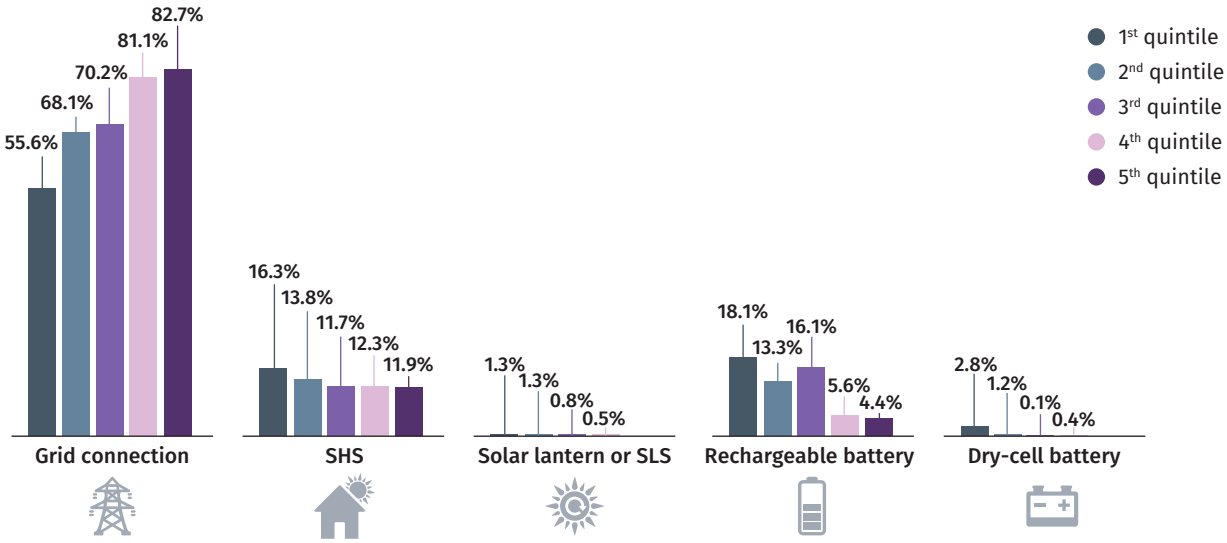
Access to electricity is skewed toward higher income households: 83.1% of households in the top spending quintile are in Tiers 3–5, compared with 16.1% of households in the bottom spending quintile (figure 14). Conversely, 5.2% of households in the top spending quintile are in Tier 0, compared with 23.8% of households in the bottom spending quintile.

FIGURE 14 • **Higher income households are more likely to be in Tiers 3–5 for access to electricity**



Among households in the top spending quintile, 82.7% are connected to the grid, compared with 55.6% of households in the bottom spending quintile (figure 15). The proportion of households that use a SHS is higher among households in the bottom two spending quintiles than among households in the other spending quintiles, suggesting that lower income households benefit more from off-grid solutions, mainly SHSs and rechargeable batteries, perhaps as a coping solution for unavailable or unaffordable grid electricity.

FIGURE 15 • **Higher income households are more likely to be connected to the grid, while lower income households are more likely to use off-grid solutions**

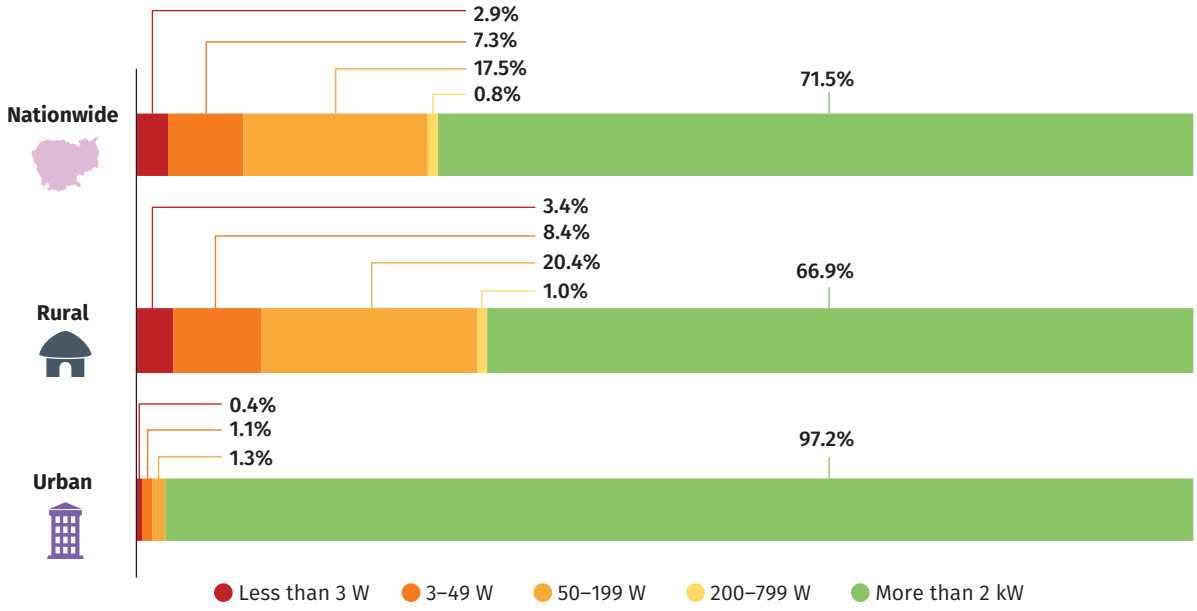


MTF ATTRIBUTES

Capacity

Because grid-connected households are considered to have high-capacity electricity (over 2 kW), the proportion of households that receive high-capacity electricity is the same as the proportion of households that are connected to the grid (71.5%). While 97.2% of urban households receive high-capacity electricity, 66.9% of rural households do, because penetration of off-grid solutions that provide limited capacity is higher in rural areas (figure 16).

FIGURE 16 • **Capacity is more of an issue in rural areas**



Availability

The Availability of electricity supply is limited for about a quarter of households. Electricity is available at least 23 hours a day, 7 days a week, for 74.2% of households, but 9.9% of grid-connected households receive less than 4 hours of service per day (figure 17). In rural areas limited Availability is more acute: 28.2% of rural households receive less than 16 hours a day of electricity, compared with 6% of urban households. And 87% of households nationwide receive adequate evening supply (figure 18).

FIGURE 17 • **A quarter of households do not receive 24/7 electricity supply**

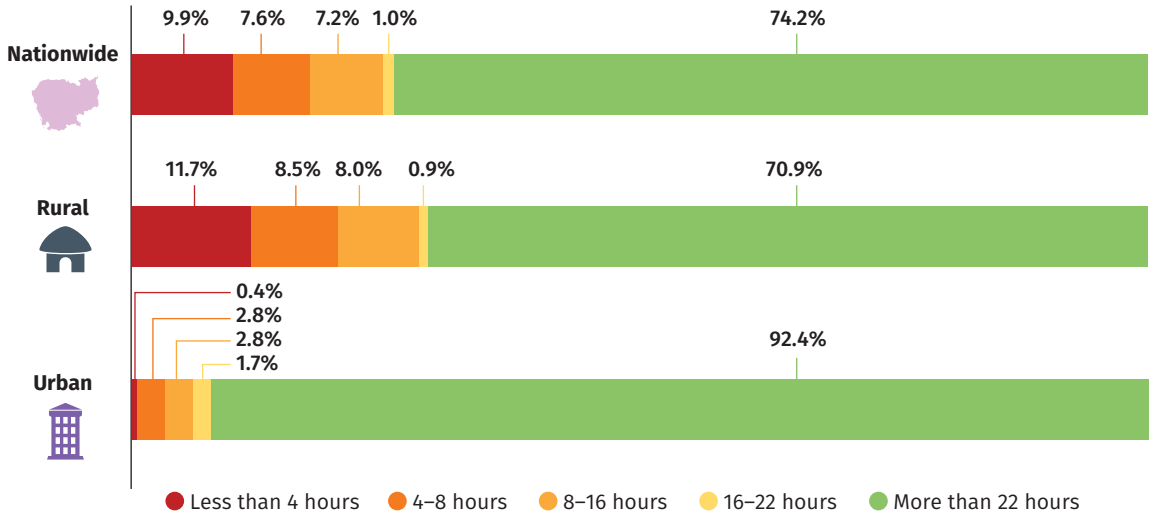
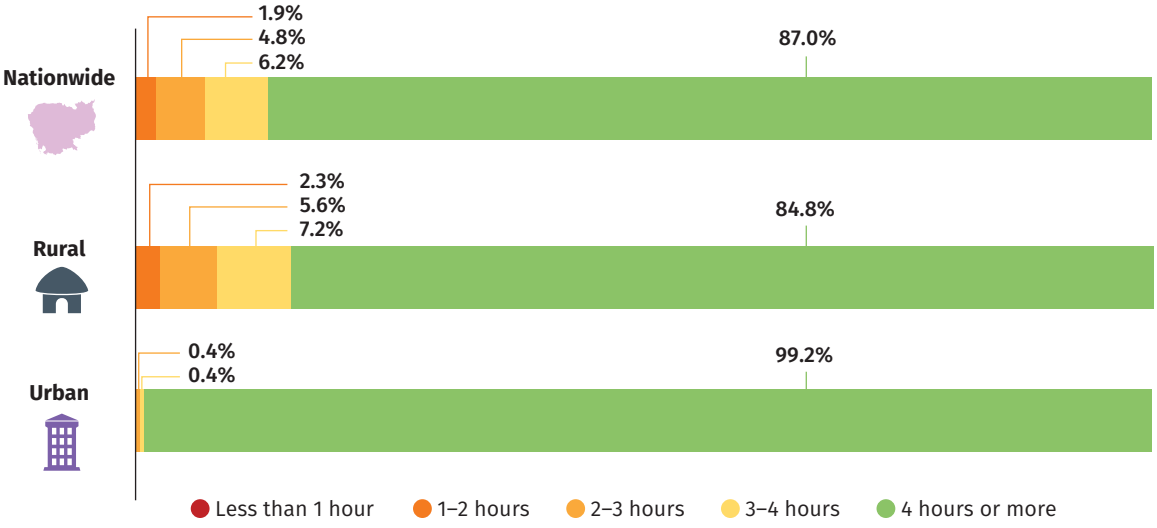


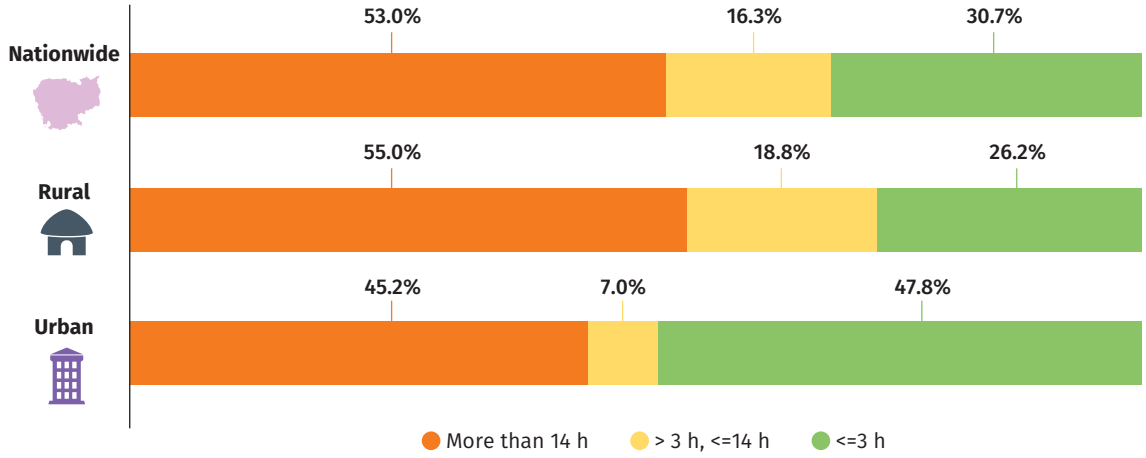
FIGURE 18 • **87% of households receive 4 hours of electricity in the evening**



Reliability

In Cambodia 69.3% of grid-connected households face frequent, unpredictable power outages. Most households experience more than four electricity disruptions a week (figure 19). Reliability is more of an issue in rural areas, possibly because of bottlenecks in the transmission and distribution networks that serve those areas.

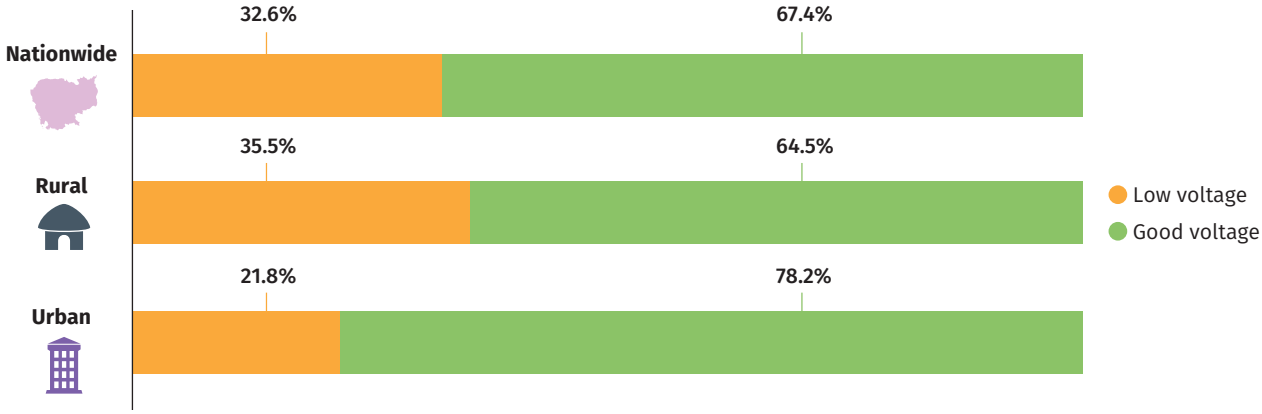
FIGURE 19 • **Rural grid-connected households face more power supply disruptions than urban households do**



Quality

In Cambodia 32.6% of grid-connected households face voltage issues—such as low or fluctuating service—resulting in appliance damage (figure 20). 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 20 • **Voltage issues affect one in three grid-connected households**

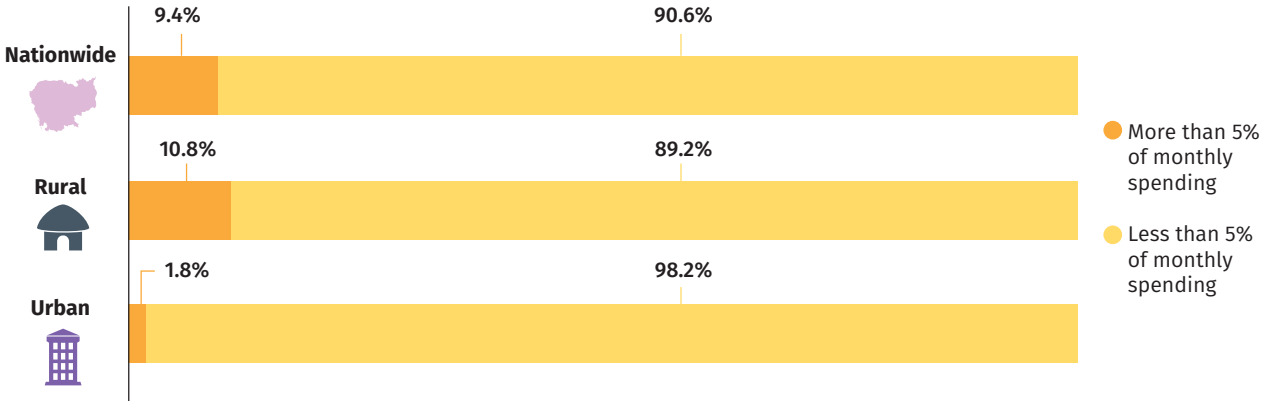


Affordability

In Cambodia 9.4% of households are in Tiers 0–2 because they cannot afford electricity (figure 21). For 10.8% of rural households and 1.8% of urban households, more than 5% of their household spending goes to basic electricity service (at least 1 kWh a day and 365 kWh a year). Affordability also manifests itself as a constraint in electricity consumption. Rural households' electricity consumption

is 30% of urban households' (see figure 24 on next page). The electricity tariff rate in Cambodia varies among electricity enterprises and between urban and rural areas: the electricity tariff is more expensive for rural households than for urban households. To improve affordability, the Electricity Authority of Cambodia has implemented a strategic plan to reduce tariffs for consumers by subsidizing licensees through the Rural Electrification Fund. The Cambodian government has also introduced a social tariff for poor customers: the tariff for the first 10 kWh each month has been reduced to 480 riels per kWh.

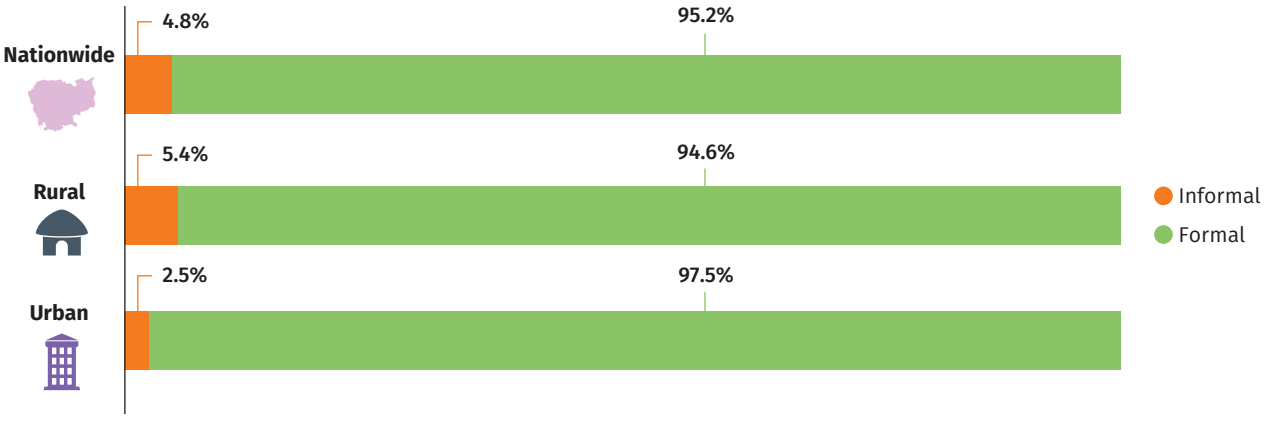
FIGURE 21 • **Affordability of electricity is more critical among rural households than among urban households**



Formality

Only 4.8% 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 22). 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 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 22 • **Nearly 5% of households have an informal grid connection**



Health and Safety

Although only 0.3% of households reported permanent limb damage or death caused by electrocution (figure 23), it is important to ensure that all households are aware of basic safety measures and that wiring is installed according to national standards to prevent accidents when operating electricity under both normal and fault conditions.

FIGURE 23 • **Very few households experience electricity safety issues**

USE

Average monthly household consumption is 55 kWh, and urban households consume 90 kWh a month more than rural households do (figure 24). Spending on electricity accounts for 3% of average monthly household spending; that share is slightly higher (5.3%) for urban households (111,800 riels, or $28, a month) and slightly lower (2.5%) for rural households (30,100 riels, or $8, a month) (figures 25 and 26). Households have been electrified for 5.6 years on average, meaning that receiving electricity is a new phenomenon for many households.

FIGURE 24 • **Electricity consumption (kWh per month)**

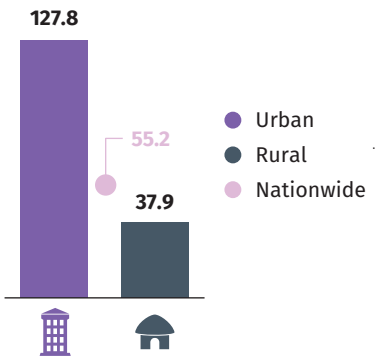


FIGURE 25 • **Household spending on electricity (riels)**

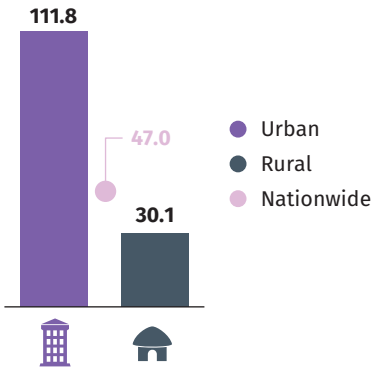
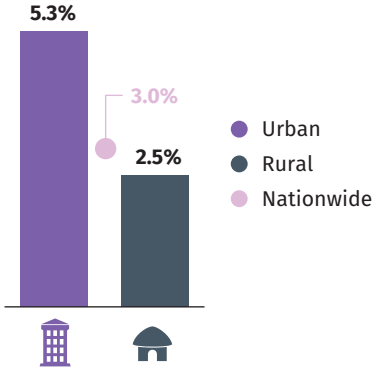


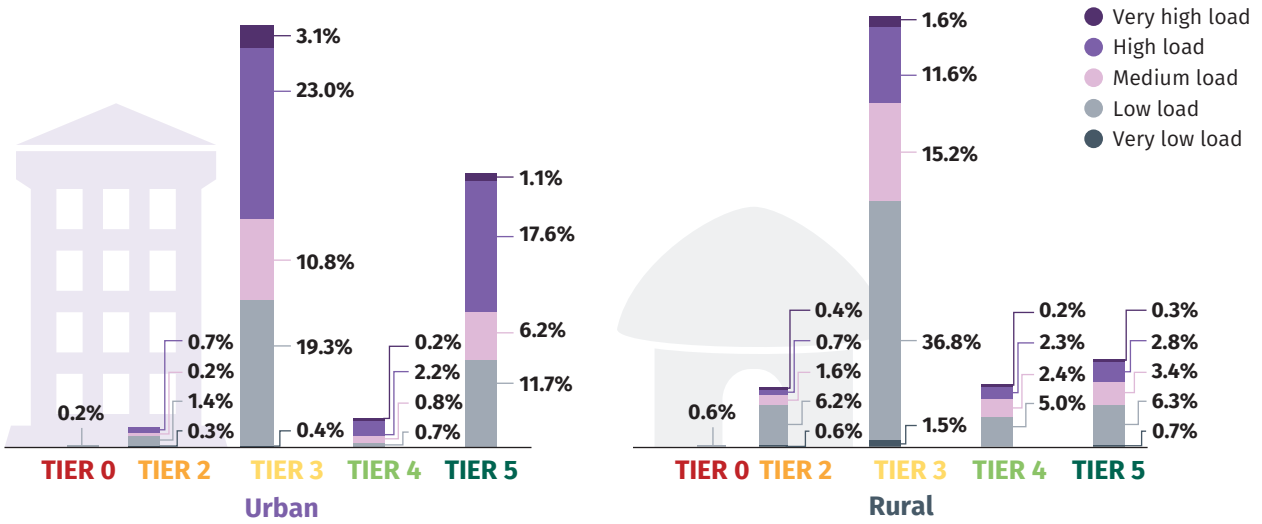
FIGURE 26 • **Spending on electricity as a share of total household spending (%)**



Note: The average exchange rate between August 1, 2017, and November 1, 2017 was 1 U.S. dollar = 3,984.6 riels.

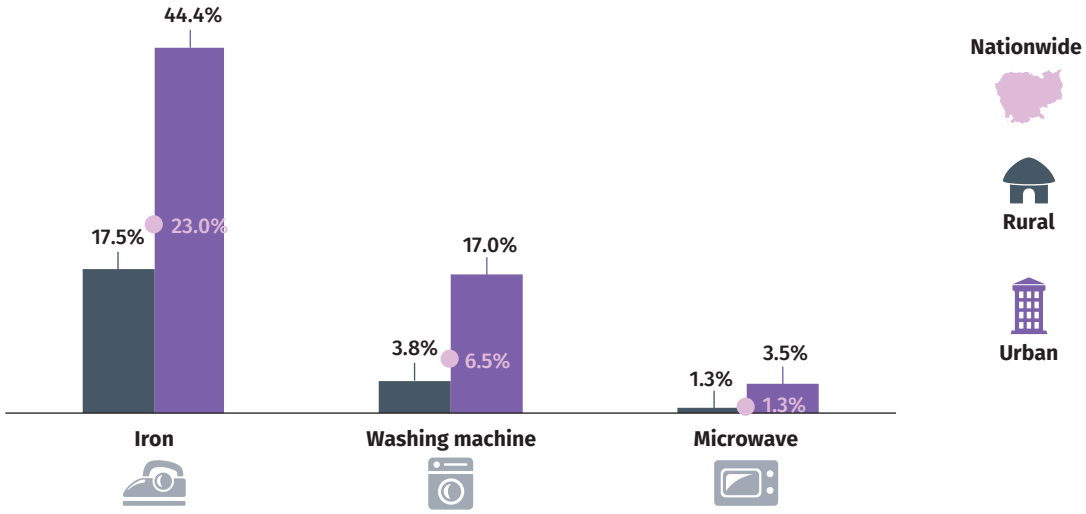
In Cambodia 53.3% of households with grid access (typically those in Tier 3 or above), own very low– or low-load appliances—particularly in rural areas, where 2.8% and 54.9% of grid-connected households use only very low– or low-load appliances (such as a television, fan, or computer), respectively (figure 27). Of urban grid-connected households, 0.7% and 33.3% of them use only very low– or low-load appliances, respectively.

FIGURE 27 • **More than 57% of rural households with grid access use only very low– or low-load appliances**



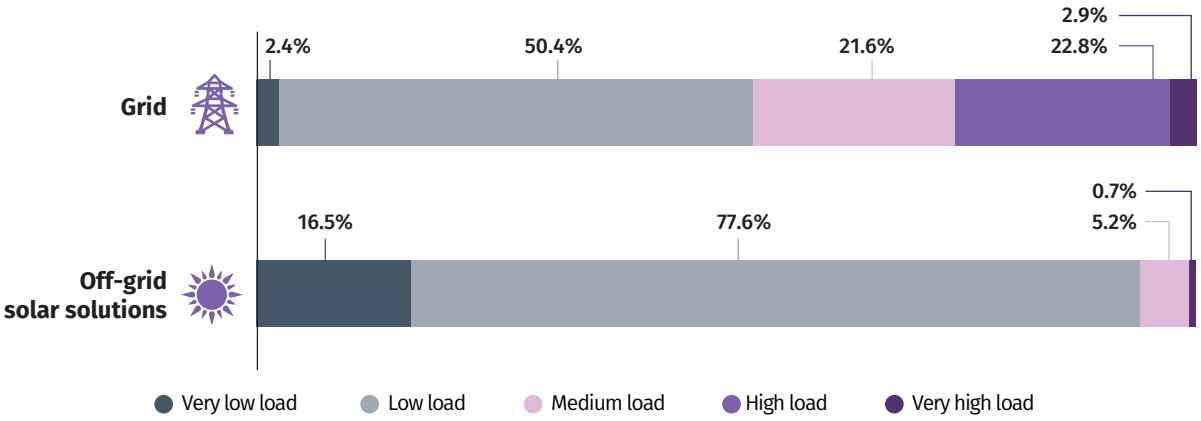
Just 2.8% of rural households use grid electricity only for lighting and phone charging. High- and very high–load appliances, such as washing machines (3.8%) and microwaves (1.7%), are rare in rural households (figure 28). This could be due to the price of electricity or appliances being inaccessible to many households. Because many households have been electrified for fewer than 5 years, it is possible that consumption and appliance ownership will grow.

FIGURE 28 • **Use of high-load appliances is rare among rural grid-electrified households**



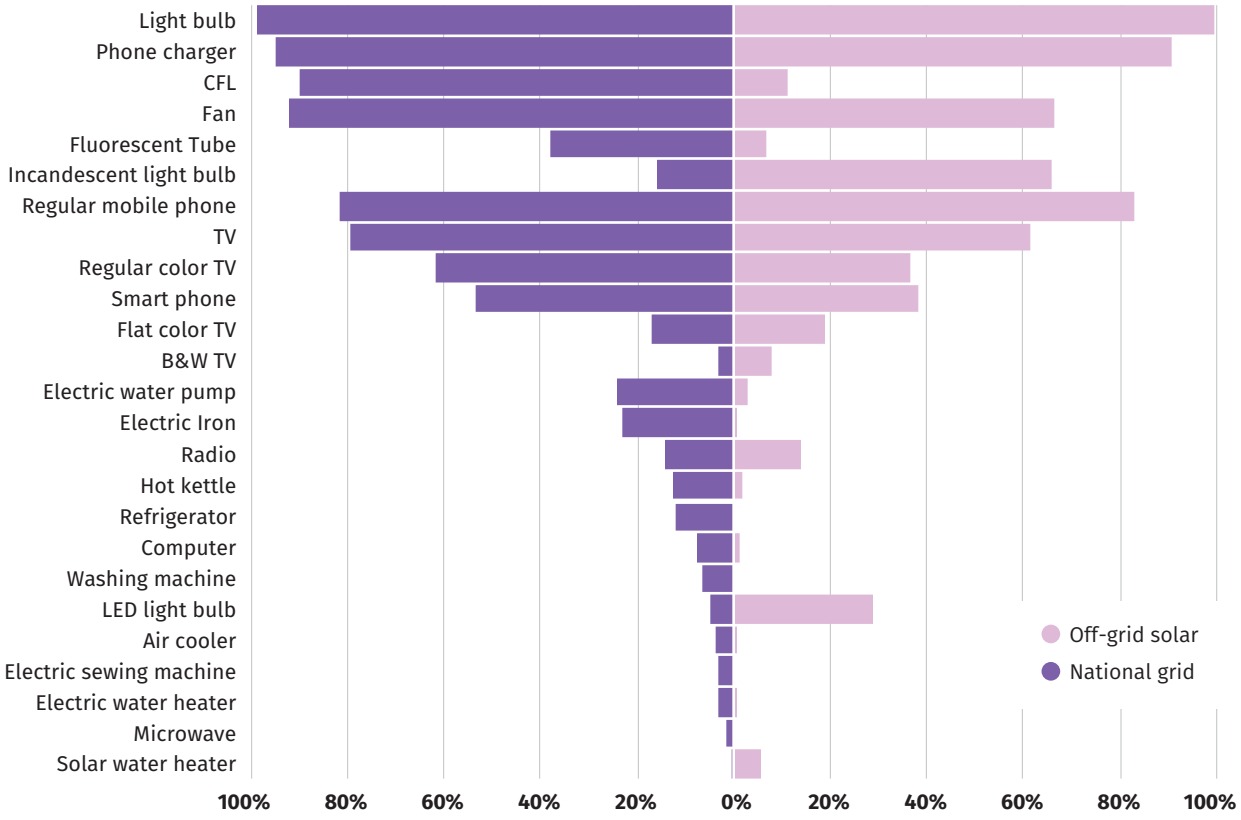
Among households that use an off-grid solar device, 5.2% have medium-load appliances (figure 29), such as an electric water pump (used by 2.8% of those households), hot kettle (used by 1.8%), and air cooler (used by 0.5%) (figure 30).

FIGURE 29 • **The percentage of households that have low-load appliances is higher among households that use an off-grid solar device than among grid-connected households**



Households with an off-grid solar device use electricity mostly for lighting (99.4%), phone charging (90.9%), playing DVDs (83.2%), watching television (61.5%), and using a fan (66.2%) (figure 30). Households with off-grid solar devices use incandescent light bulbs, LED light bulbs, flat screens, and color TVs with higher frequency than grid-connected households do. This suggests a divide among off-grid system users: those that bundle their system with energy-efficient appliances and those that are using older systems such as incandescent light bulbs and therefore not leveraging their full system's potential.

FIGURE 30 • **Lighting, phone chargers, fans, and televisions are the most common appliances for both grid-electrified households and households that use an off-grid solar device**



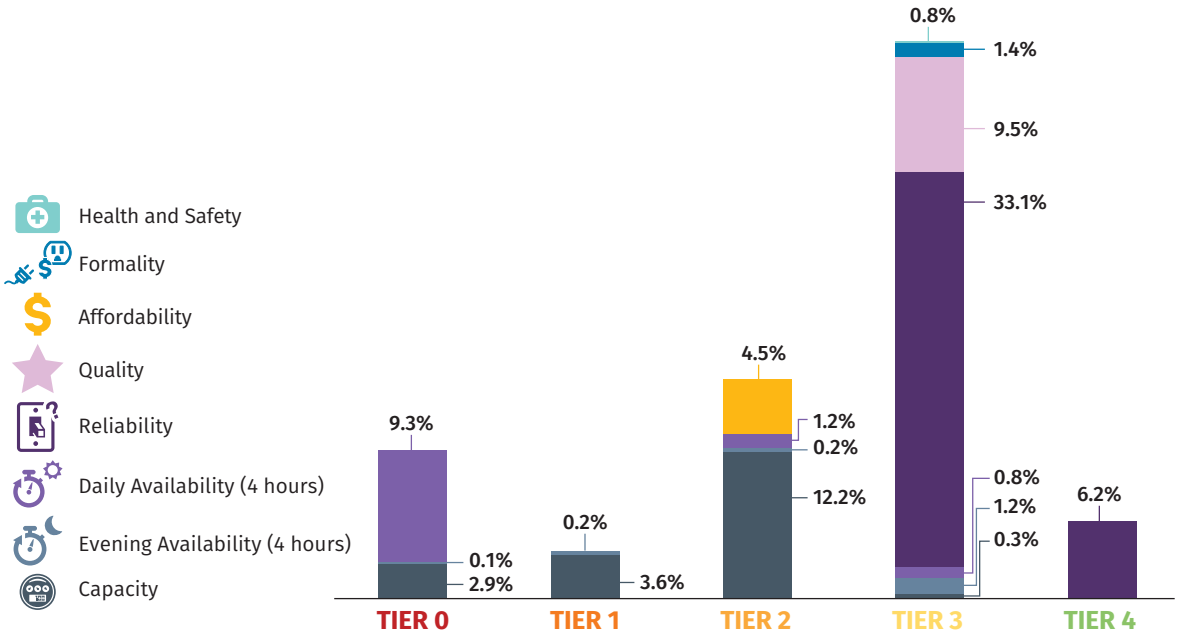
Note: The percentage for light bulb refers to households that own a compact fluorescent light bulb, a fluorescent tube, an incandescent light bulb, or an LED light bulb. The percentage for television refers to households that own a regular color television, a flat color television, or black and white television.

IMPROVING ACCESS TO ELECTRICITY

Only 12.4% of households are in Tier 0 for access to electricity, but nearly all of them are in rural areas. And 12.4% of households in Tier 0 have no source of electricity, 7.1% use only dry-cell batteries,[17] 55.7% use rechargeable batteries, and 19.9% use a solar device (see figure 12). Some households that use a solar device or rechargeable batteries are classified in Tier 0 because their electricity supply does not meet the Capacity and Availability criteria for Tier 1 (figure 31). Strategies for elevating households from Tier 0 will depend on why households are in that tier—for example, connecting households with no electricity source to the grid or to off-grid solutions and addressing weaknesses in Capacity and Availability attributes for users that already use an off-grid device.

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

FIGURE 31 • **Gap analysis shows what prevents Cambodian households from moving to higher tiers**

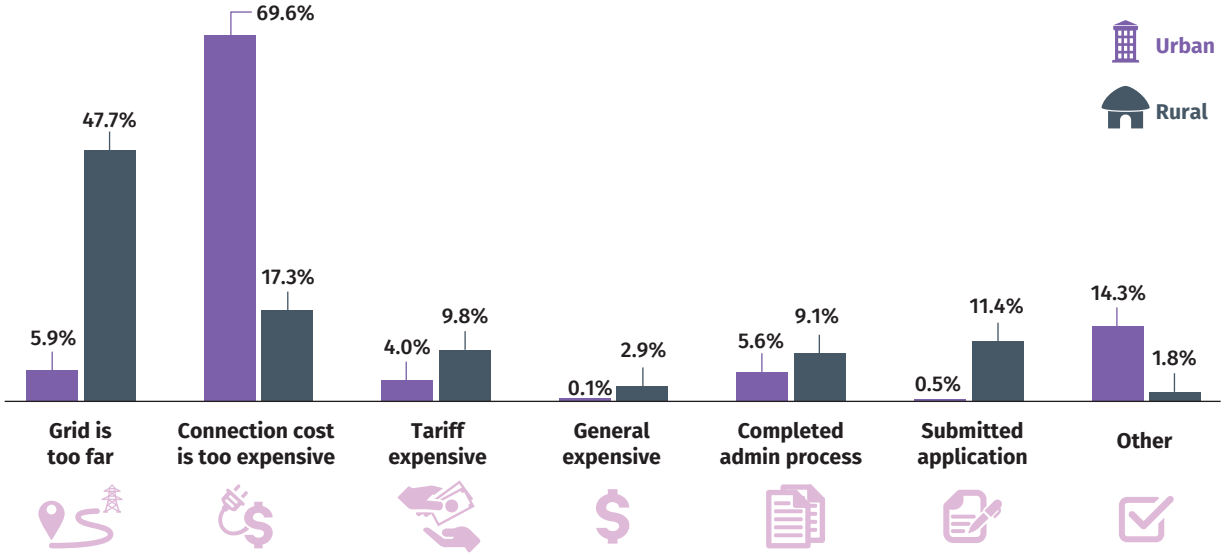


PROVIDING ELECTRICITY ACCESS TO HOUSEHOLDS WITHOUT AN ELECTRICITY SOURCE

The 12.4% of households in Tier 0 without an electricity source and the 7.1% that use only dry-cell batteries will need to be connected to the grid or to off-grid solutions to move to a higher tier. Doing so will require addressing the barriers that prevent these households from gaining connectivity. The main barrier for non-electrified urban households is the high upfront cost of acquiring service, and the main barrier for non-electrified rural households is distance from grid infrastructure (figure 32).

Although urban households are more affluent than rural households (average monthly spending is around 2.4 million riels for urban households and around 1.3 million riels for rural households), unconnected urban households are likely either among the poorest urban households or a member of a vulnerable group (such as a female-headed household) that requires additional support to connect. Indeed, the average monthly spending for non-electrified urban and rural households is similar, at around 1.2 million riels.

FIGURE 32 • **The main barrier to grid electricity access for urban household is ability to pay for connection fee, while distance from the grid infrastructure is the main barrier for rural households.**



Most households without access to the grid appear willing to pay for access to electricity at full price (figure 33). The percentage of unconnected households that reported being willing to pay the maximum amount (122,000 riels, $30) upfront for a grid connection was 89%; the percentage of households that reported that they would never pay for grid access was 2.3%–8% at all price points except 86,600 riels ($21). The main constraints to willingness to pay (WTP) for a grid connection are the ability to pay for internal wiring (48.6%) and the connection fee (25.3%;) (figure 34).

FIGURE 33 • **Most households without access to the grid appear willing to pay for access to electricity at full price**

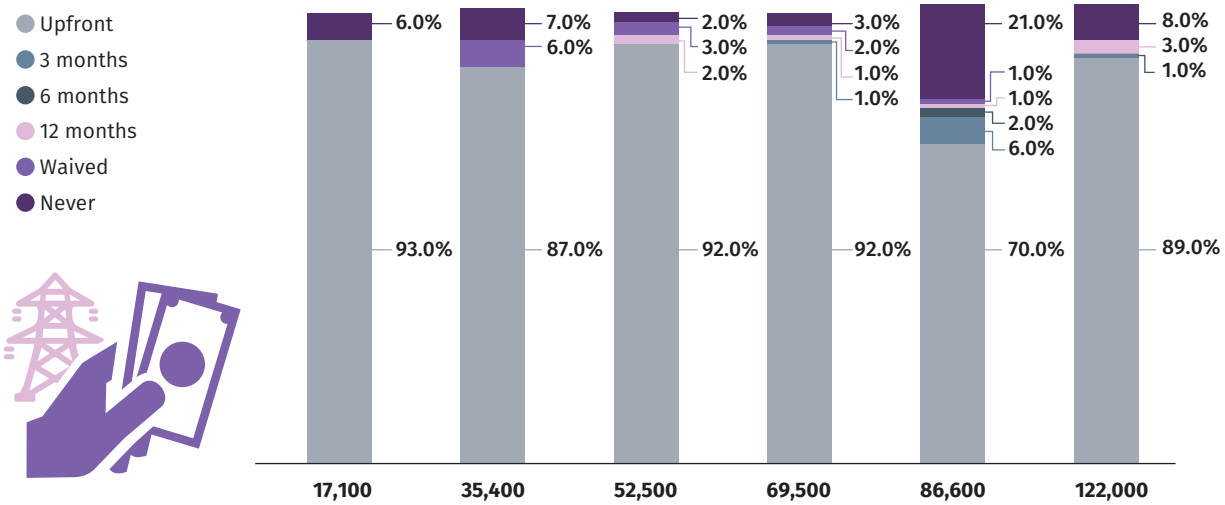
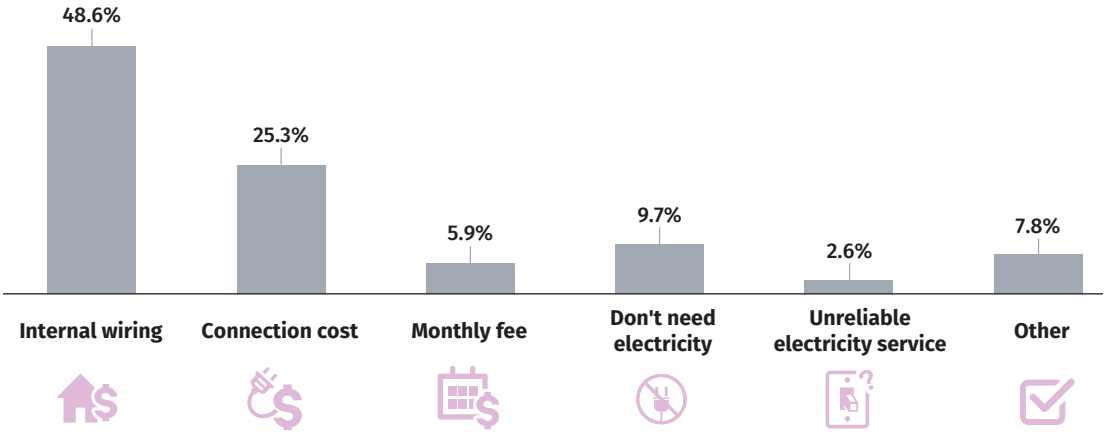


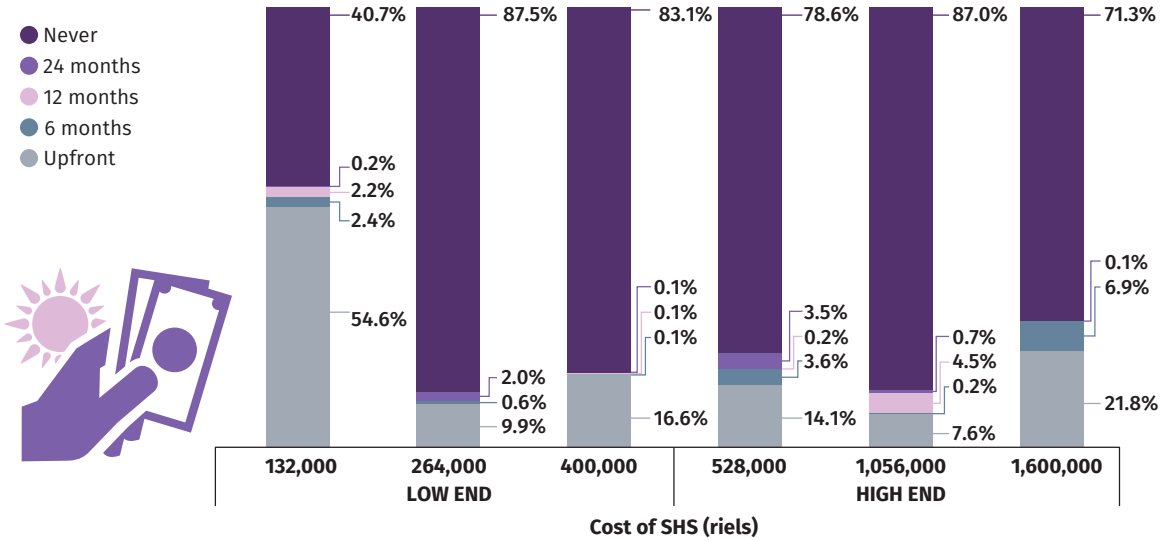
FIGURE 34 • **The main constraints to willingness to pay for a grid connection are household ability to pay for internal wiring and the connection cost**



These results show that distance from grid infrastructure is the main barrier for households with no electricity to access services. The vast majority of non-electrified households are likely to connect if the grid becomes available in their area. Some of these households may be in remote areas for which grid extension is not economically viable, particularly considering rural households' low average consumption; off-grid solutions, such as mini-grids and off-grid solar systems, are likely to be adequate for these households.

Despite the high penetration of SHSs, the WTP for an SHS is much lower than the WTP for a connection to the grid. The only price point at which a majority of households reported being willing to purchase a system was the lowest (132,000 riels, which is similar to the grid connection fee) (figure 35). At higher price points 71.3% of households reported that they would never purchase a system. Offering a payment period did not significantly change the responses. This may be due to the fact that most SHSs are component-based systems, for which households typically buy components gradually. Credit or pay-as-you-go payments for SHSs account for a minority of sales in Cambodia (14.4%).

FIGURE 35 • **Most households reported being unwilling to pay for a solar home system**

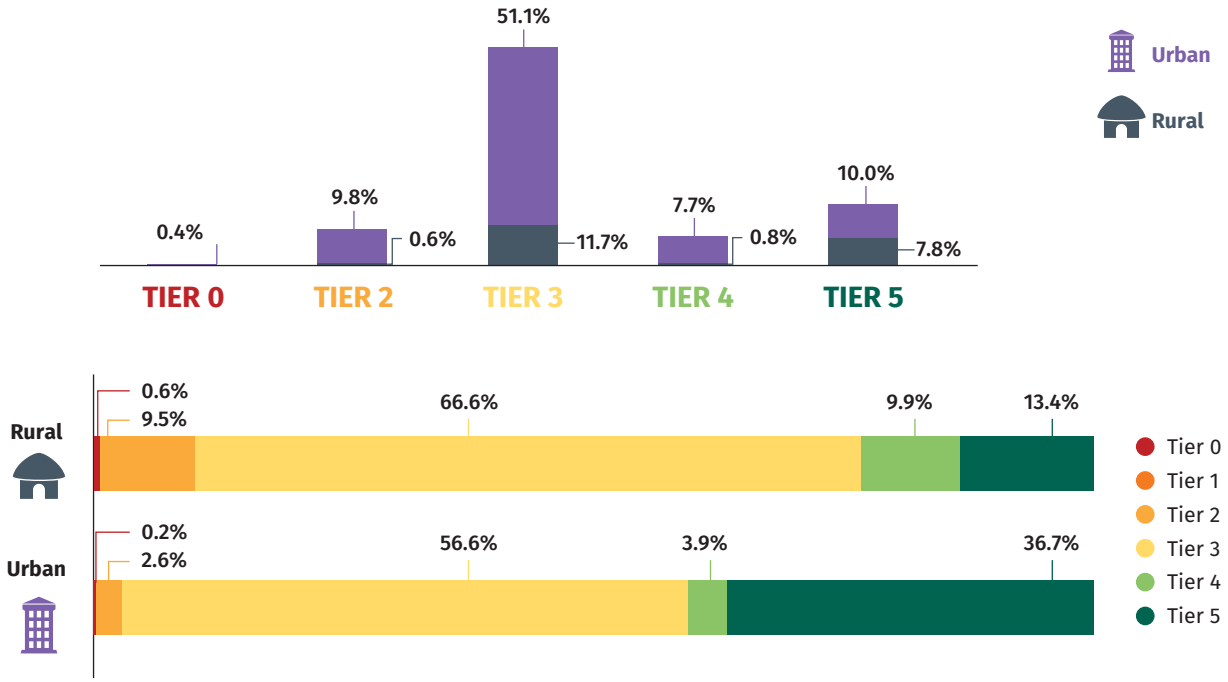


IMPROVING ELECTRICITY ACCESS FOR GRID-CONNECTED HOUSEHOLDS

The grid provides access to electricity mostly for households in Tiers 2–5. Nationwide, grid-connected households have been connected for an average of 5.6 years, with urban households connected for 10.3 years on average and rural households connected for 4.5 years on average. This suggests that electrification expansion in rural areas is a recent development.

Nationwide, 89.1% of grid-connected households are in Tier 3 or above for access to electricity. Most of the remaining 10.9% of households are in Tier 2, with 0.4% in Tier 0 (figure 36). The largest shares of rural and urban households are in Tier 3 (66.6% of rural grid-connected households and 56.6% of urban grid-connected households). More rural households than urban households are also in Tier 2 (9.5% versus 2.6%) and Tier 4 (9.9% versus 3.9%).

FIGURE 36 • **The largest shares of rural and urban grid-connected households are in Tier 3**



Reliability and Quality are the main constraints holding back grid-connected households in Tiers 3 and 4 from reaching Tier 5: 53% of grid-connected households have experienced more than 14 outages a week, placing them in Tier 3 for Reliability (see figure 19). Only 30.7% of households have experienced fewer than 3 outages a week and total Availability of less than 2 hours, placing them in Tier 5. And 32.6% of grid-connected households had an appliance damaged due to voltage fluctuation, placing them in Tier 3 (see figure 20).

Rural grid-connected households experience more severe issues with Reliability and Quality than urban grid-connected households do: 47.8% of urban grid-connected households are in Tier 5 for Reliability, compared with 26.2% of rural households, and 21.8% of urban households are in Tier 3 because of Quality, compared with 35.5% of rural households.

In Cambodia 6.7% of grid-connected households, including 8% of rural households, spend more than 5% of their monthly budget to consume 1 kWh a day (or 365 kWh a year), placing them in Tier 2 for Affordability (figure 37). And 4.8% of grid-connected households have an informal connection to the grid, placing them in Tier 3 for Formality, a situation that is slightly more common among rural households (figure 38).

FIGURE 37 • **Affordability is an obstacle for nearly 7% of grid-connected households**

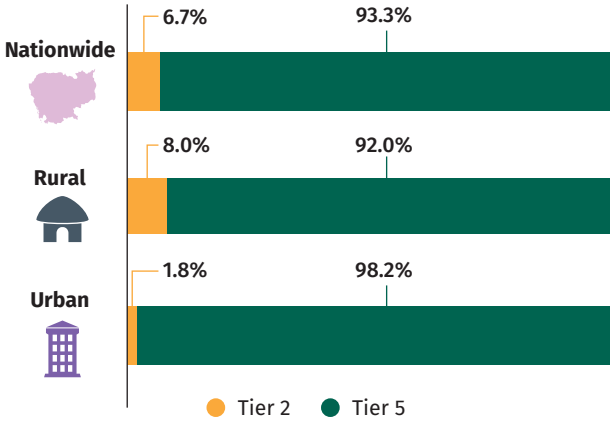
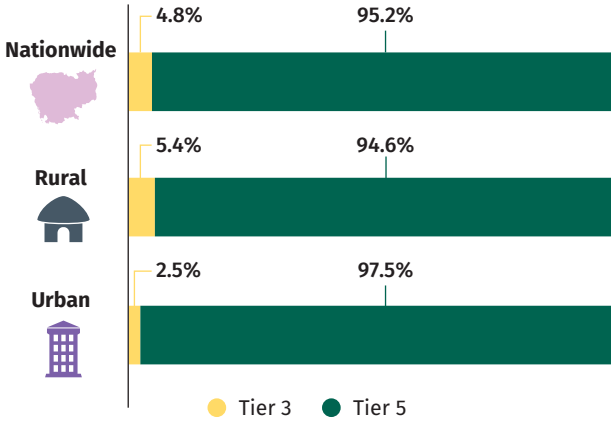
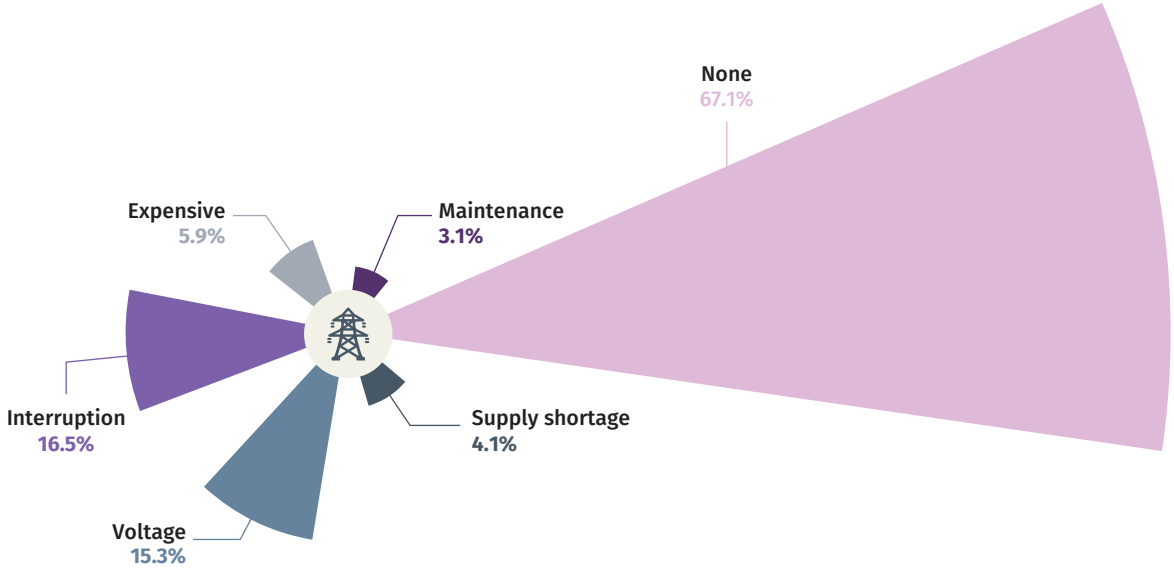


FIGURE 38 • **Nearly 5% of grid-connected households have an informal connection**



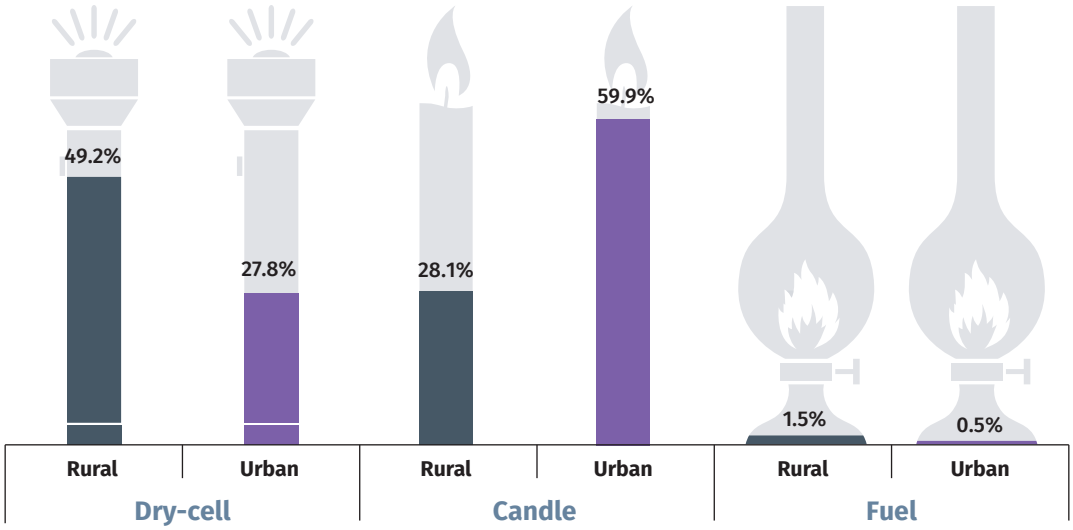
The most common issues that grid-connected households reported as their key concerns about the service were fluctuation, interruption, and affordability (figure 39). However, 67.1% of grid-connected households reported no issues with the grid. These findings are based on consumer perception of key issues and are therefore more subjective than those analyzed in MTF attributes, but overall they suggest that households are mostly satisfied with their grid supply.

FIGURE 39 • **More than 67% of grid-connected households do not have any issue with the grid electricity supply**



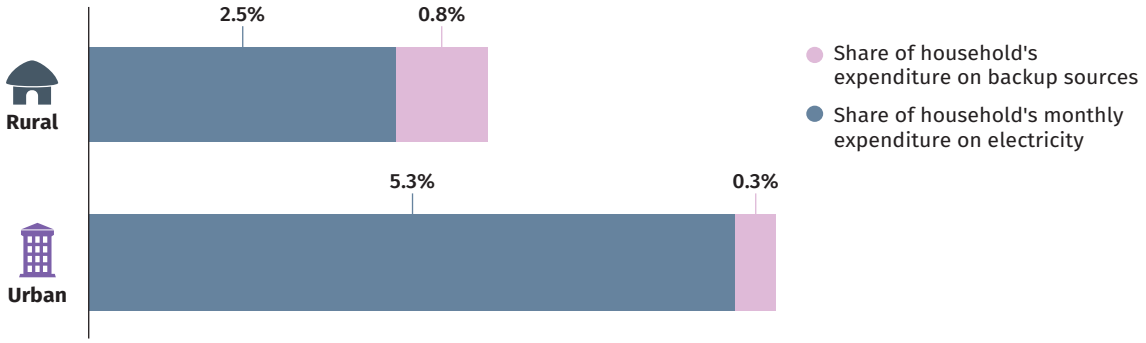
To cope with power outages, 49.2% of rural households and 27.8% of urban households use flashlights powered by dry-cell batteries as their backup source of lighting, and 28.1% of rural households and 59.9% of urban households use candles (figure 40). Roughly 11% of grid-connected households do not have any backup source of lighting, and more rural households (12%) than urban households (7%) use a backup source of lighting.

FIGURE 40 • **More urban households than rural households use candles as their backup source of lighting**



Spending on a backup source of lighting accounts for only 0.7% of household monthly spending. But even a negligible increase in that share would impose a large burden on a household's budget because households already spend substantially on electricity—particularly rural households, for which 0.8% of monthly spending goes to backup sources, compared with 0.3% for urban households (figure 41). Improving the Quality and Reliability of the electricity supply could help reduce the burden of energy spending, increase affordability, and shift spending on backup sources toward higher consumption of electricity.

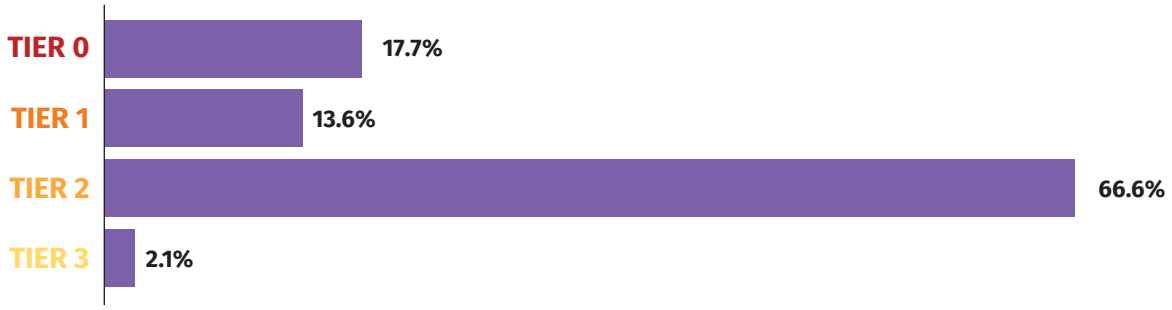
FIGURE 41 • **Spending on backup sources of lighting accounts for a small percentage of household monthly spending**



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

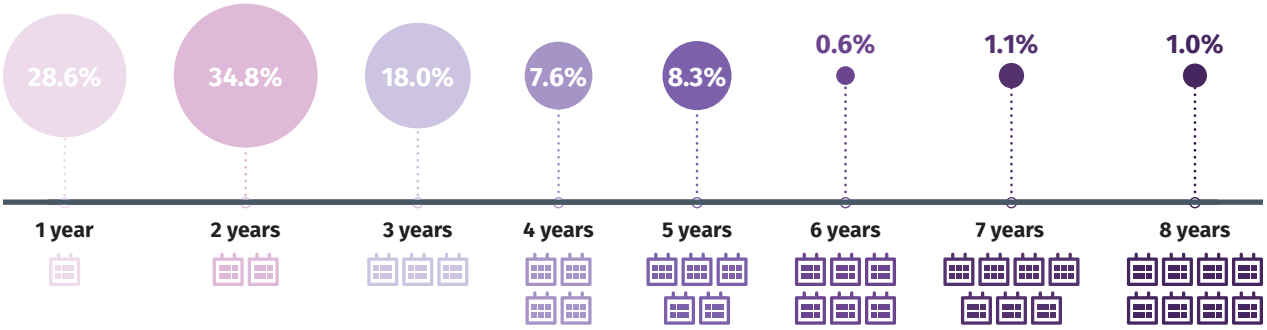
Where grid electricity is unavailable, off-grid solar devices are filling the electrification gap. Approximately 14% of households—nearly half of non-grid-connected households—use an off-grid solar device as their primary source of electricity. Roughly 99% of households that use a solar device are in rural areas. About 80% of households that use an SHS reside in a village with no access to electricity. About 60% of households in those villages use a solar device as their primary source of electricity, while 66.6% of households that use an off-grid solar device are in Tier 2 for access to electricity (figure 42).

FIGURE 42 • **Most households that use an off-grid solar device are in Tier 2 for access to electricity**



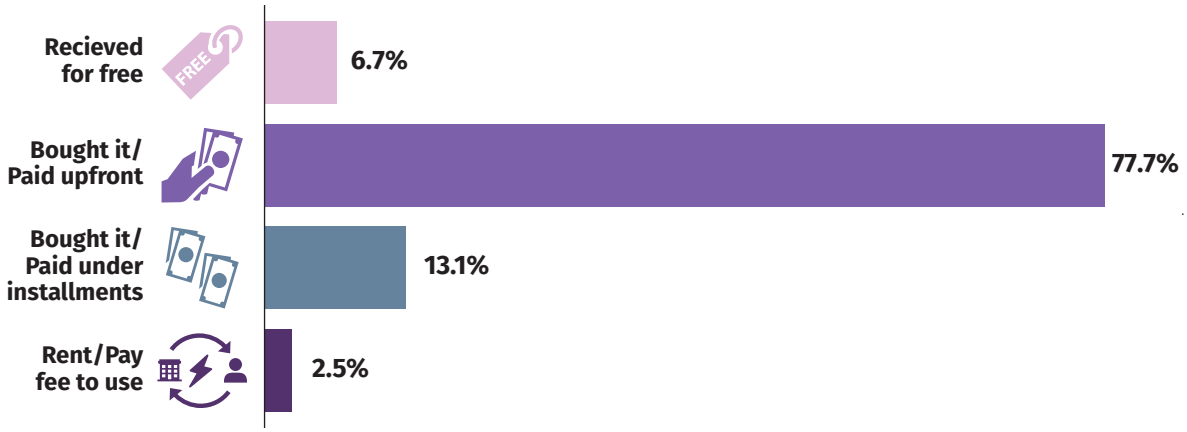
In Cambodia 97.3% of households obtained their first off-grid solar device within the last 5 years, and 63.4% did so within the last 2 years (figure 43).

FIGURE 43 • **Off-grid solar energy for households is a recent phenomenon**



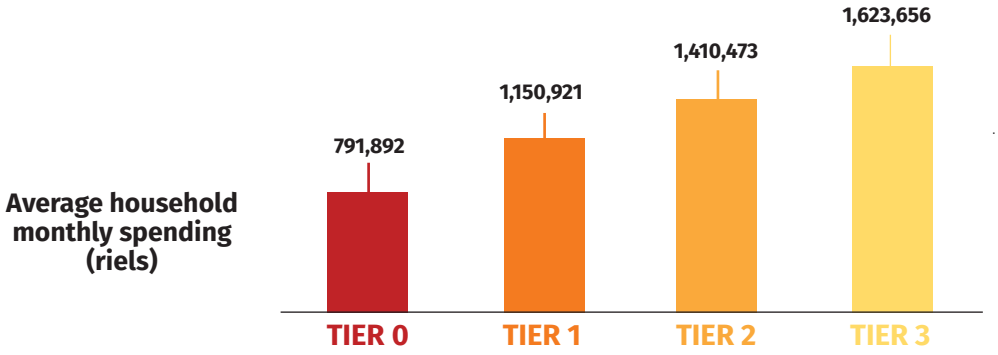
Among households that use a solar device, 90.8% purchased it (figure 44). The majority of households who purchased a solar device (77.7%) paid the full price upfront, and 13.1% paid in installments (the most common repayment period is within 12 months). Only 2.5% of households pay a fee or rent their solar device, and 6.7% of households received their device for free.

FIGURE 44 • **Most households that use a solar device purchased it**



While SHSs benefit all household quintiles, smaller SHSs are more likely to serve poorer households, while larger systems are more likely to serve richer households. Average monthly spending is 791,892 riels (approximately $198) for a household in Tier 0 for Capacity and 1,623,656 riels ($407) for a household in Tier 3 (figure 45).

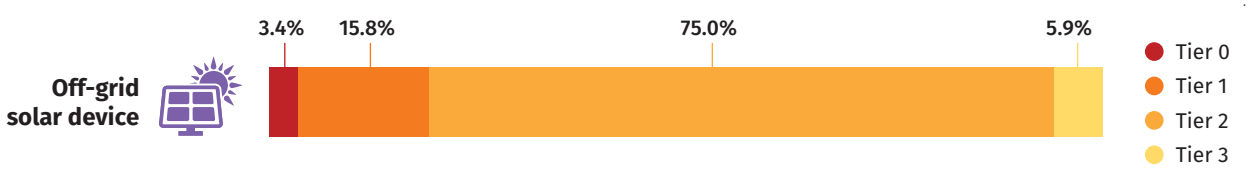
FIGURE 45• **There is a direct correlation between household income and size of solar home system used**



Rechargeable batteries are the second most common off-grid solution for rural households (39.8%), after a solar device (46.9%). About 60% of households that use rechargeable batteries are in Tier 0 because they have access to electricity for less than 4 hours a day and 1 hour an evening, mainly for lighting (96% of households using rechargeable batteries as their main source of electricity).

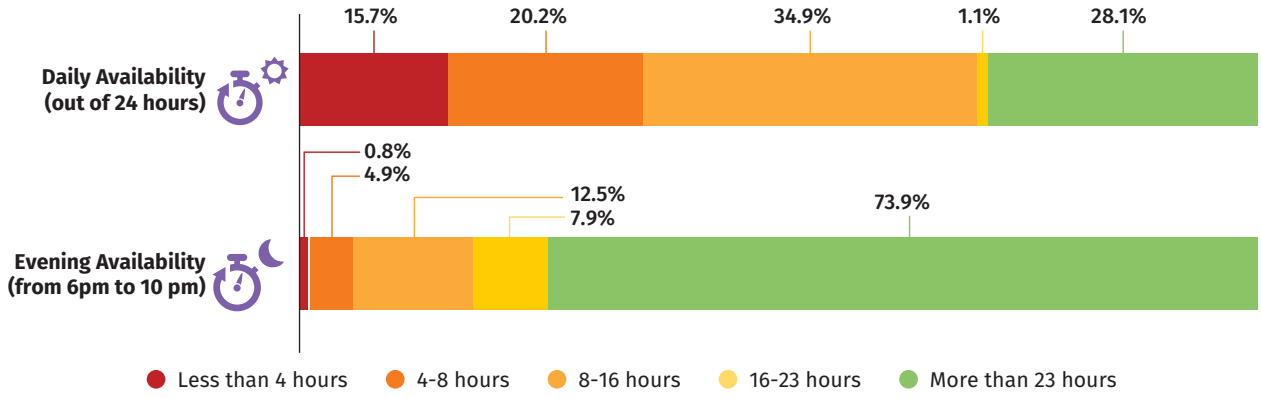
For the Capacity attribute, among households that use an off-grid solar device, 3.4% are in Tier 0; 75% are in Tier 2, meaning that they can power a low-load appliance such as a television; and 5.9% are in Tier 3, meaning that they can power a medium-load appliance, such as a refrigerator (figure 46) (see table 1 for the load levels associated with various appliances).

FIGURE 46 • **Few households that use an off-grid solar device are limited by Capacity**



Among households that use an off-grid solar device, 17.7% are in Tier 0 for access to electricity, and 80% of them are there because the device provides insufficient daily Availability. Furthermore, 15.7% of households have less than 4 hours of electricity per day, and 0.8% of households have less than 1 hour of electricity per evening (figure 47), the minimum requirements for Tier 1 for Availability. This suggests that to move households to Tier 1 and above, systems need to be improved so that they can deliver electricity for longer periods of time.

FIGURE 47 • **Insufficient Availability is a major hindrance to households in Tier 0 for access to electricity**



Among households that use a solar device, 51% are very or somewhat satisfied with it, while only 10% are unsatisfied or very unsatisfied (figure 48). Among households that use a solar device, 80.5% reported having no problems with it, though 10% reported maintenance issues, mainly problems replacing or fixing the battery (figure 49). Despite the MTF findings on Availability, only 1.4% of households reported duration as an issue.

FIGURE 48 • **Most households that use a solar device are satisfied with the electricity service from it**

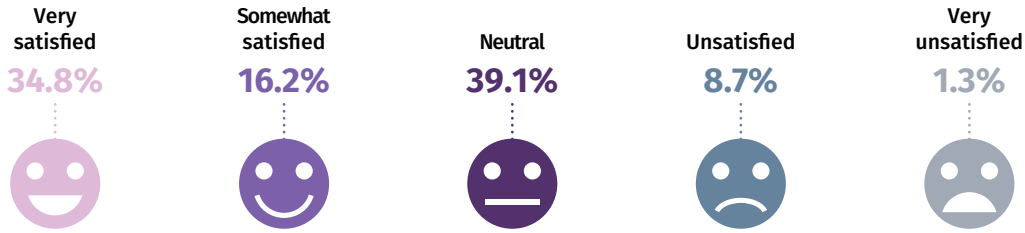
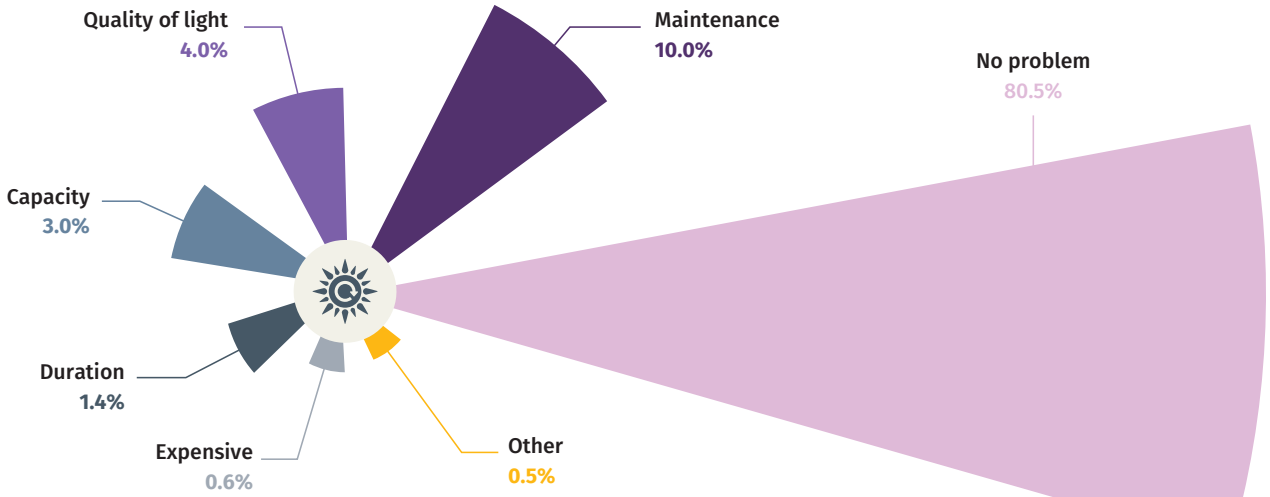
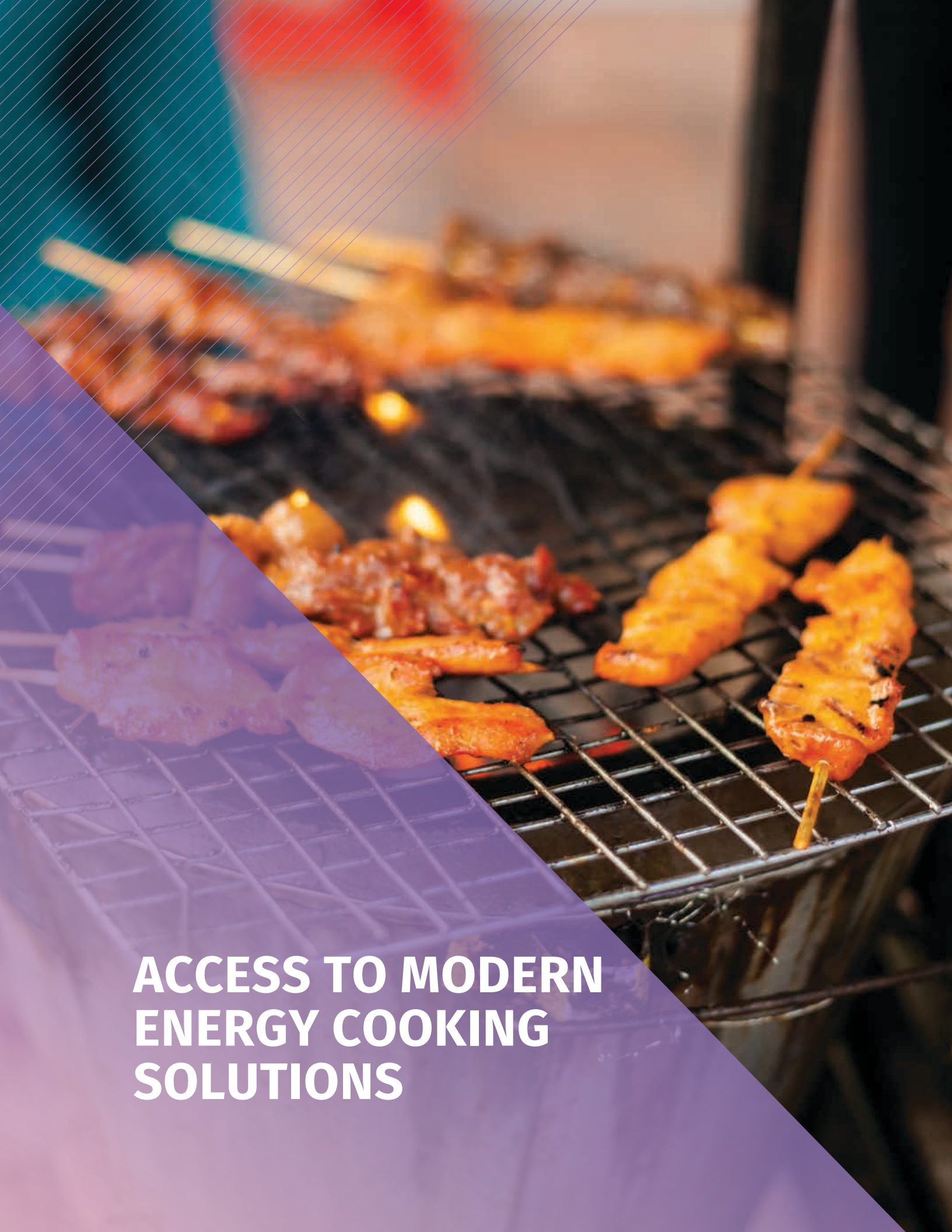


FIGURE 49 • **Most households that use a solar device did not have any problems with it**





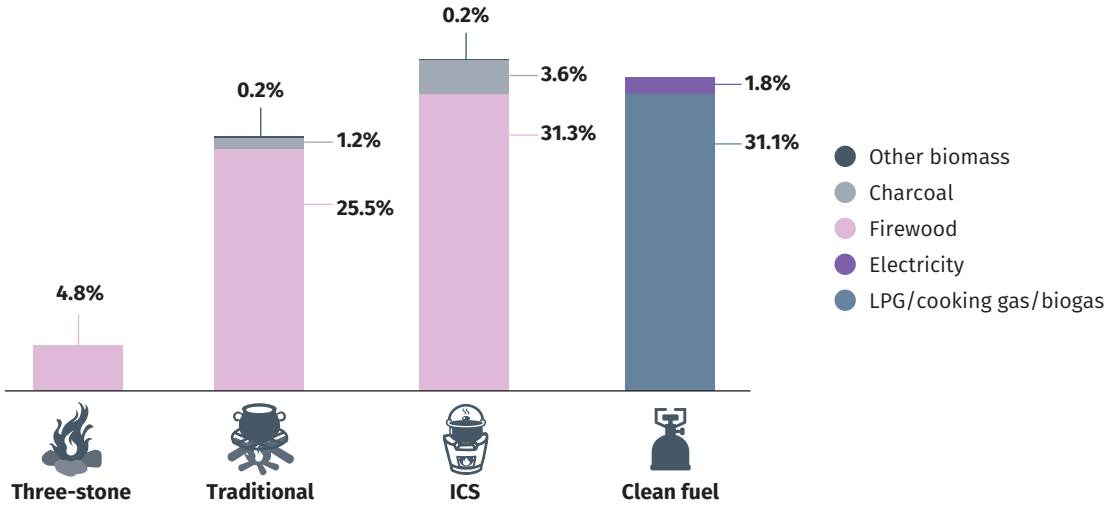
ACCESS TO MODERN ENERGY COOKING SOLUTIONS

ASSESSING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

TECHNOLOGIES

In Cambodia 66.7% of households use a biomass stove as their primary stove. Among them, 35.1% use an improved cookstove (ICS), 26.8% use a traditional cookstove, and 4.8% use a three-stone stove (figure 50). Nearly 62% of households with a biomass stove use firewood as their primary cooking fuel; the next most common fuel is charcoal (4.8%). In addition, 32.9% of households use a clean fuel stove as their primary stove—11.1% of them use it exclusively—and their most common fuel is liquefied petroleum gas (LPG) (30.9%), followed by electricity (1.8%) and biogas.[18]

FIGURE 50 • **A third of households use a clean fuel stove as their primary stove**

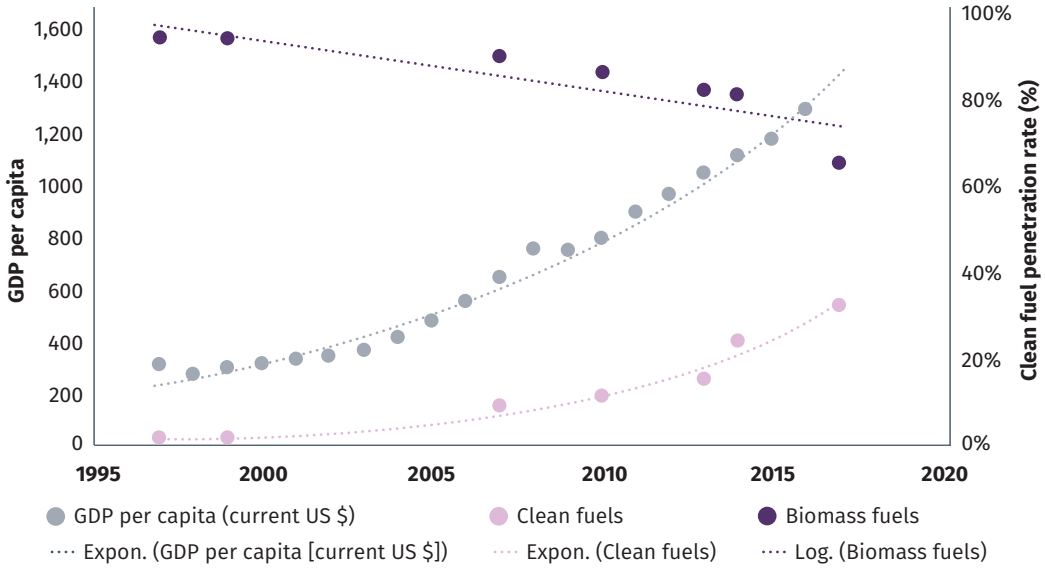


Note: Other biomass includes peat, animal waste (such as dung), plant biomass/crop residue, sawdust, and woodchips.

The share of households using biomass as a primary cooking fuel fell from 82.9% in 2014 to 67.1% in 2017 (figure 51). The share of households using clean fuels has increased consistently, rising 17% a year between 1997 and 2014 and at just over 20% a year between 2014 and 2017.

[18] Nine households in the survey reported that their primary fuel is biogas.

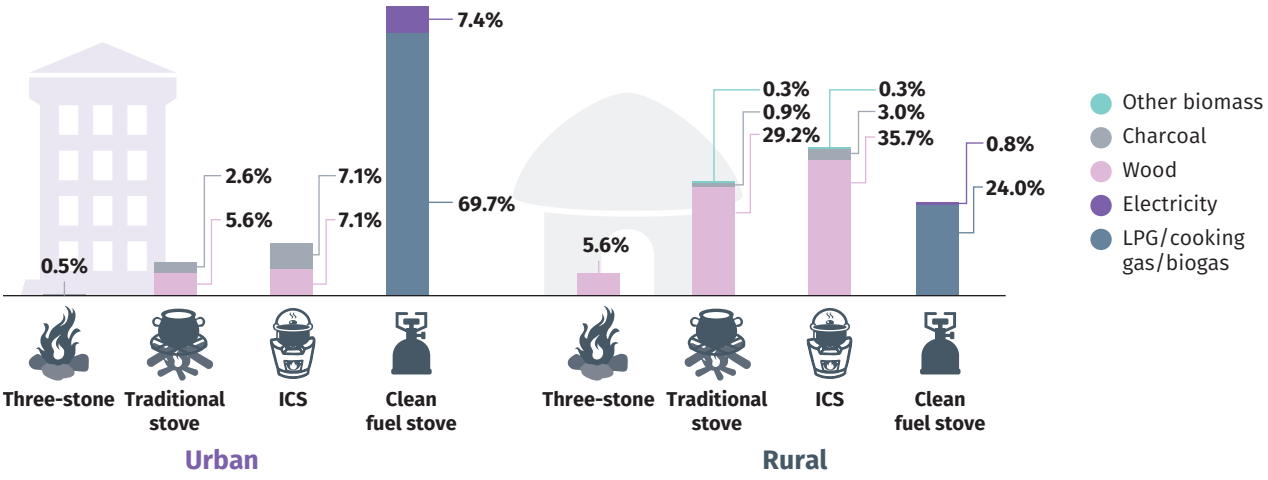
FIGURE 51 • **Clean fuel use is rising**



Source: 1997–2014, Cambodia Socio-Economic Survey; 2017, Multi-Tier Framework (MTF) survey; 1997–2017, World Development Indicators database.

Clean fuel stoves are more prevalent among urban households (77.1%) than among rural households (24.8%) as their primary stove (figure 52). Biomass stoves are prevalent in rural households, with ICSs the most common (39%), followed by traditional stoves (30.4%), and three-stone stoves (5.6%). Less than a quarter of urban households use a biomass stove, mainly ICSs (14.2%), followed by traditional stoves (8.2%). Firewood is the primary fuel for 61.7% of households, including 70.5% of rural households.

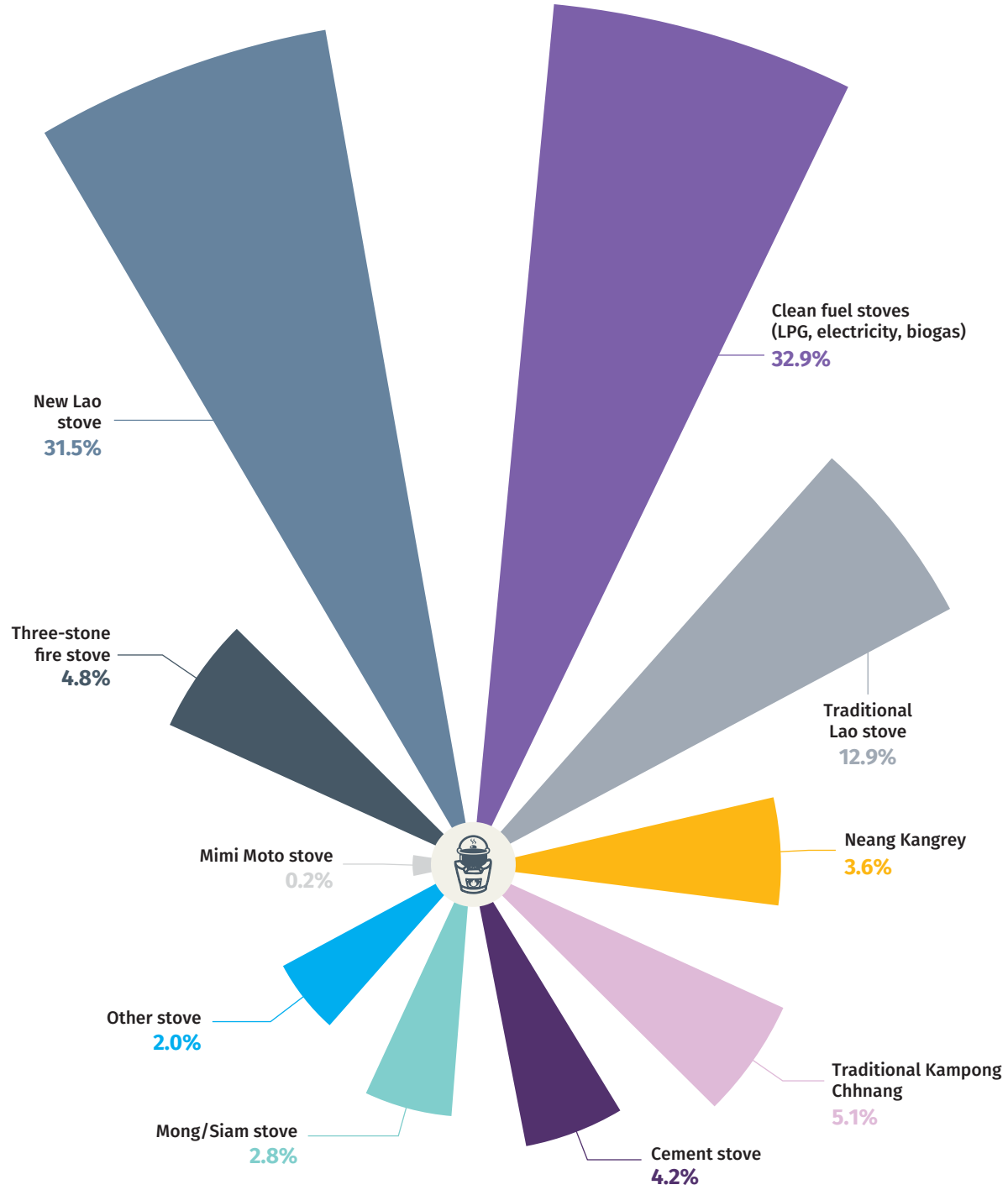
FIGURE 52 • **Roughly 77% of urban households use a clean fuel stove, while most rural households use a biomass stove as their primary stove**



Source: 1997–2014, Cambodia Socio-Economic Survey; 2017, Multi-Tier Framework (MTF) survey; 1997–2017, World Development Indicators database.

The most common ICSs (used as the primary cookstove) are the New Lao (31.5%) and the Neang Kangrey (3.6%), both with thermal efficiency of around 30% (figure 53).[19] The most common traditional stoves are the Traditional Lao (12.9%) and the Traditional Kampong Chhnang (5.1%).

FIGURE 53 • **A third of households use an improved cookstove as their primary stove**

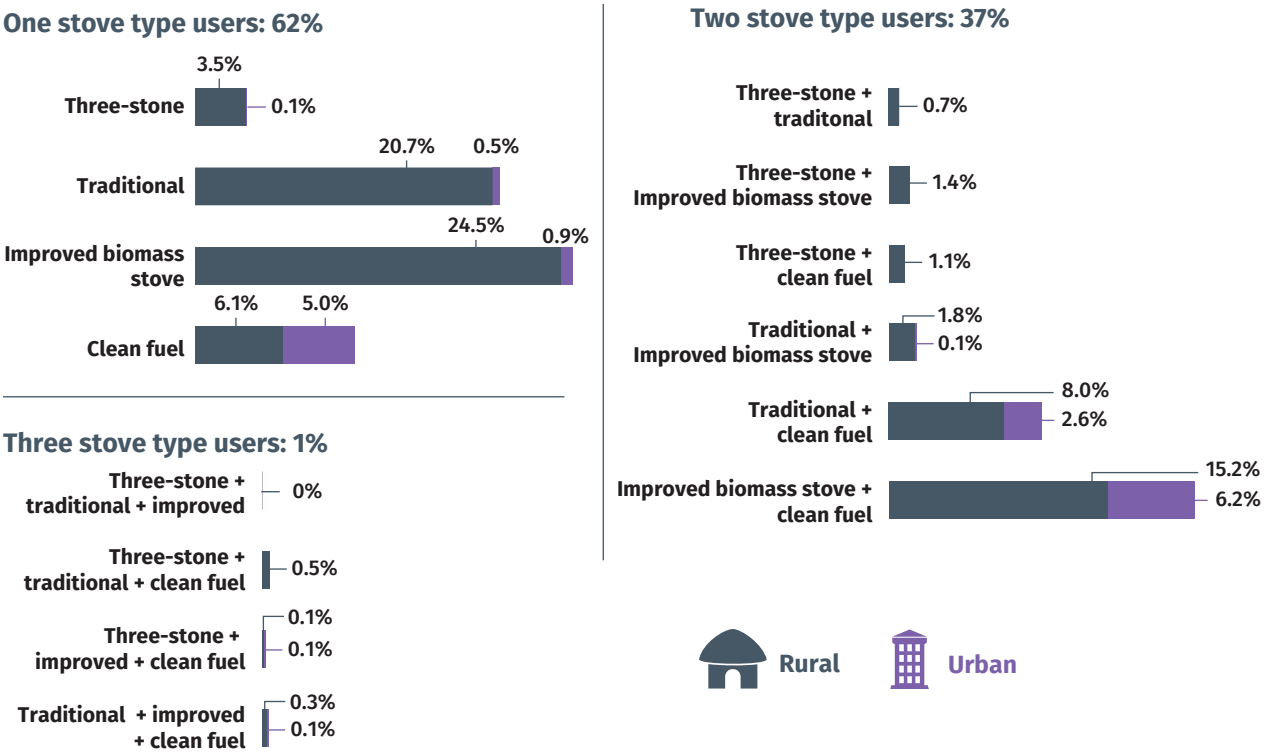


[19] World Bank, 2009, "Improved Energy Technologies for Rural Cambodia," Washington, DC (http://siteresources.worldbank.org/EXTEAPASTAE/Resources/ASTAE-IMPROVED-ENERGY-TECHNOLOGIES-Cambodia.pdf).

Stove stacking

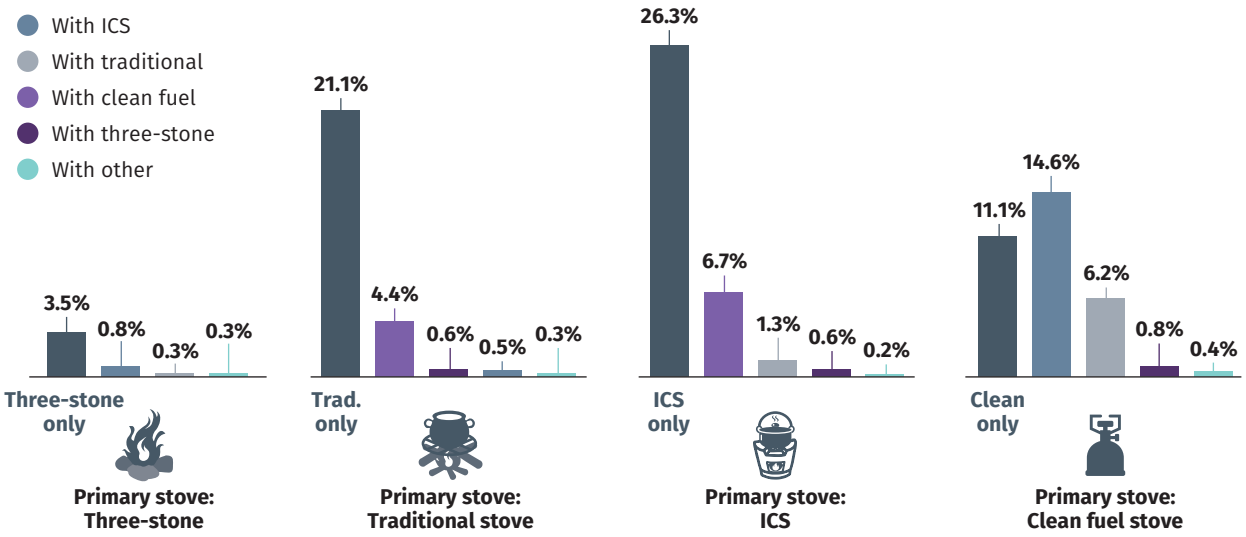
Stove stacking (using multiple cookstoves at the same time) reflects households' aspiration to use higher performing solutions, which are often used in addition to (rather than instead of) existing cooking solutions. Stove stacking occurs in 37.8% of households (figure 54). Most stove stacking involves a combination of clean fuel stoves and ICSs (21.3% of households) or a combination of traditional cookstoves and ICSs (10.6%). The average number of types of stove per household is 1.4.

FIGURE 54 • **More than 60% of households use only one type of stove**



About a quarter of households that use a three-stone stove as their primary stove also use either an ICS or other higher performing stove type (figure 55). And 4.4% of households use a traditional stove as their primary stove in combination with a clean fuel stove, while 6.7% of households use an ICS as their primary stove use in combination with a clean fuel stove. Two-thirds of households nationwide that use clean fuel stoves as their primary stove also use an ICS or a traditional stove in parallel. So adoption of cleaner cooking solutions is gradual, because biomass stoves continue to be valued by users, whether for cultural or economic reasons.

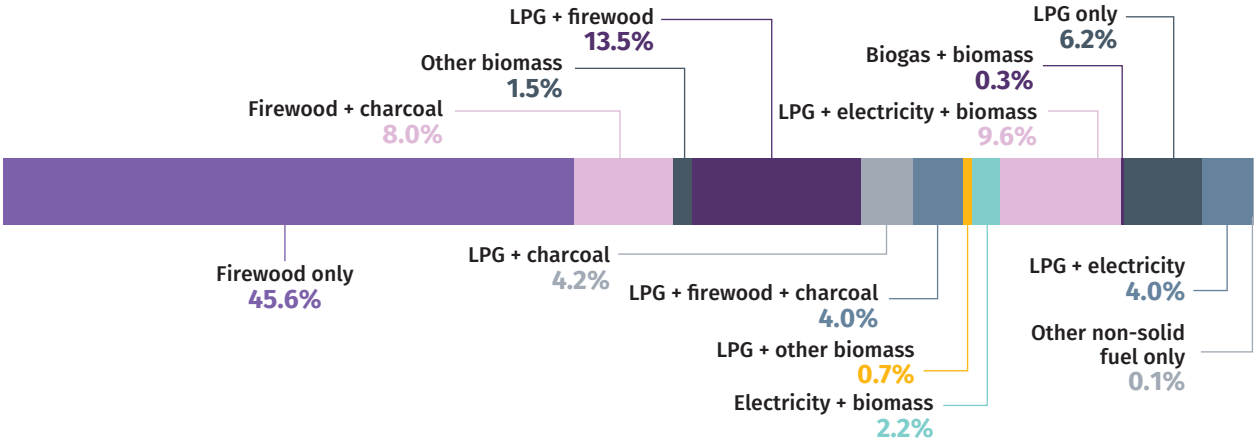
FIGURE 55 • **Stove stacking is most common among users of clean fuel stoves**



Fuel stacking

Fuel stacking refers to the practice of a household using more than one type of fuel to meet its cooking energy needs.[20] More than 55% of households use only biomass fuel, with firewood by far the most common (45.6%), while only 10.2% of households use clean fuels exclusively (6.2% use LPG only, 4% use LPG and electricity, and 0.1% use a combination of LPG, biogas, and electricity) (figure 56). Most fuel stacking involves a combination of LPG and firewood (13.5%) or a combination of LPG, electricity, and biomass (9.6%).

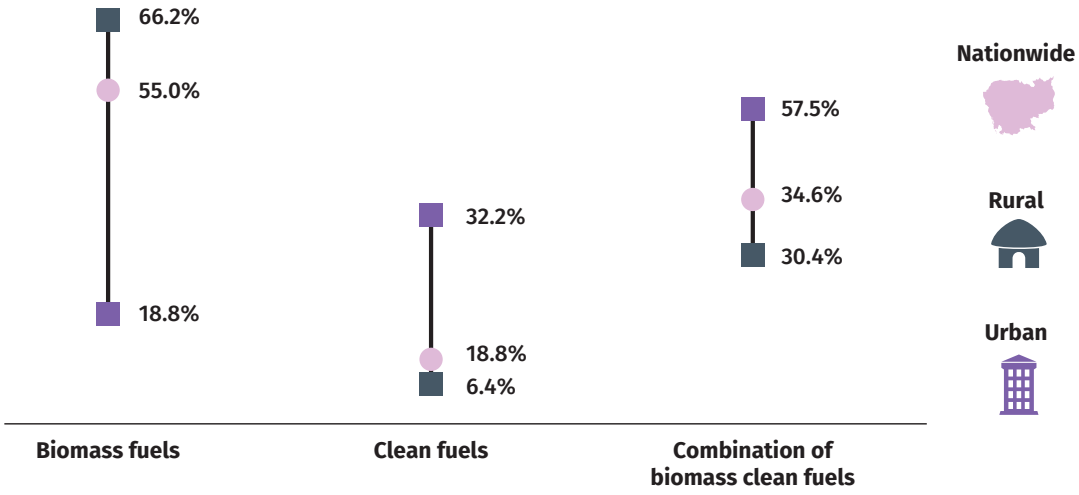
FIGURE 56 • **Firewood is by far the most common cooking fuel**



Only 32.2% of urban households and 6.4% of rural households use clean fuels exclusively: 18.8% of Cambodian households use clean fuels exclusively, while 57.5% of urban households and 30.4% of rural households use clean fuels in combination with biomass (figure 57). In addition, 66.2% of rural households use biomass exclusively, compared with 10.4% of urban households.

[20] For additional explanation on the origins and reasons behind fuel stacking, please refer to Bhatia and Angelou 2015 (page 46).

FIGURE 57 • **Fuel stacking is common in both urban and rural areas**

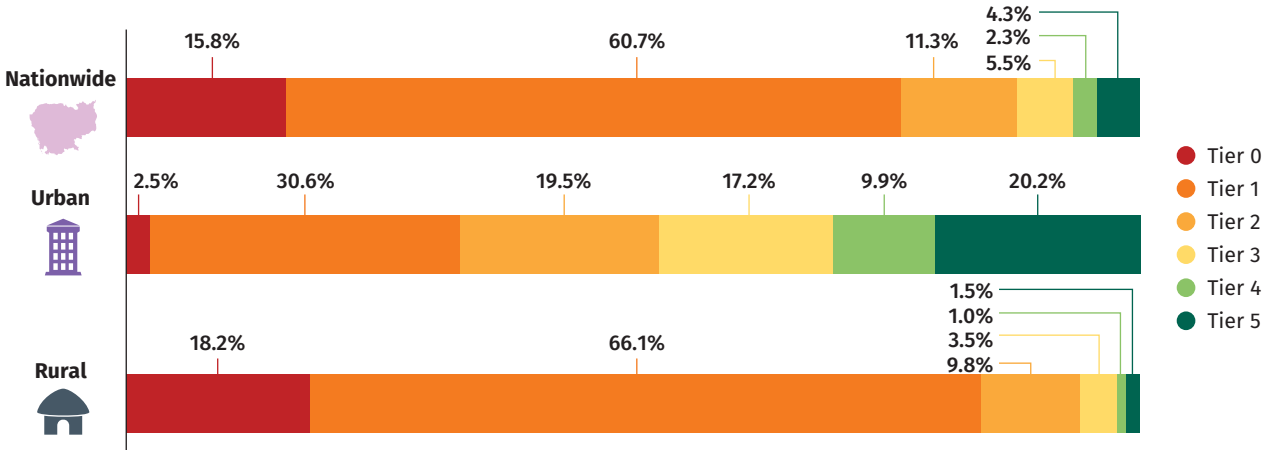


MTF TIERS

Since the MTF for cooking is still being finalized, this report presents only a preliminary estimated tier structure based on basic stove classification and taking into account defined attributes that can be measured. For details on this simplified methodology, see the attribute analysis below. The complete analysis will be carried out once the final cooking framework is published.

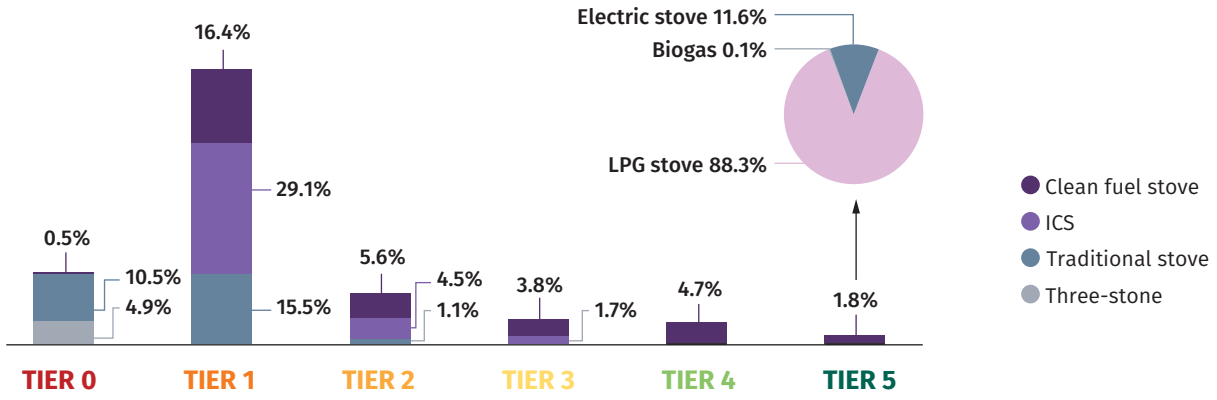
Nationwide, 84.2% of households are in Tier 1 or above for access to modern energy cooking solutions, but only 6.6% are in Tiers 4 and 5 (figure 58). The disparity between urban and rural areas is large. Only 2.5% of urban households are in Tier 0, compared with 18.2% of rural households. The gap is wider for higher tiers: 30.6% of urban households are in Tier 1, compared with 66.1% of rural households, while 30.1% of urban households are in Tier 4 or 5, compared with 2.5% of rural households.

FIGURE 58 • **More than 84% of households are in Tier 1 or above for access to modern energy cooking solutions**



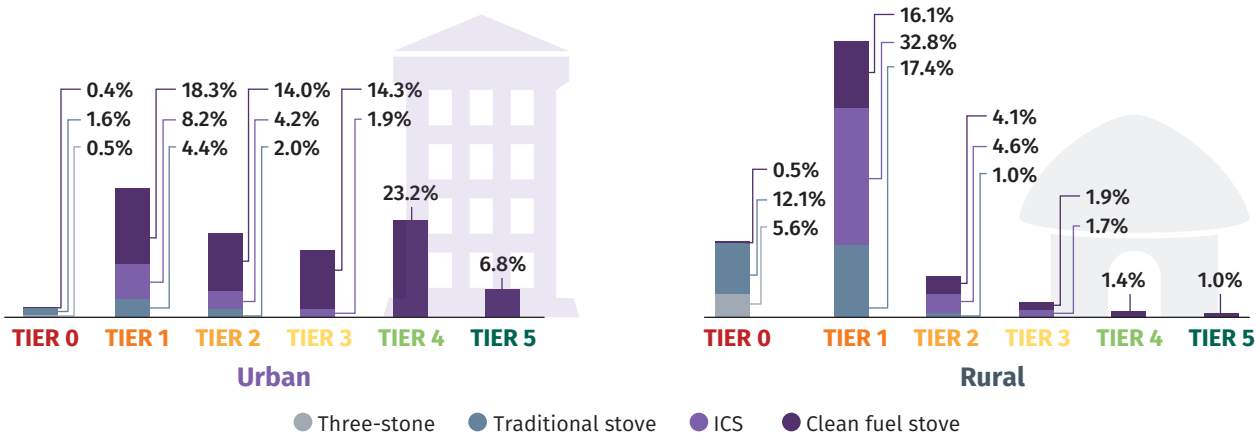
The high penetration of clean fuel and ICSs has moved households to higher tiers for access to modern energy cooking solutions. All households in Tiers 4 and 5 use a clean fuel stove as their primary stove (see figure 60 below). Of the 6.6% of households in Tiers 4 and 5, 88.3% use an LPG stove as their primary stove, and 11.6% use an electric stove (figure 59).

FIGURE 59 • **Clean fuel stoves move households to higher tiers for access to modern energy cooking solutions**



Urban households are in higher tiers mainly because of the high penetration of clean fuel stoves, but using a clean fuel stove does not automatically put households in Tier 4 or 5. Some 77.1% of urban households use a clean fuel stove as their primary stove, but only 30.1% of urban households are in Tier 4 or 5 for access to modern energy cooking solutions, while 24.8% of rural households use a clean fuel stove as their primary stove, and only 2.5% of rural households are in Tier 4 or 5 (figure 60). Convenience, Safety of Primary Cookstove, and Affordability can keep households in lower tiers. Households that use a clean fuel stove in combination with other biomass stoves spend a significant amount of time acquiring (through collection or purchase) firewood or charcoal and thus are not in Tier 4 or 5 because of Convenience. Households that use a clean fuel stove exclusively but cannot obtain LPG nearby and must spend more than 5 hours a week to acquire it are in Tier 3 or below also because of Convenience. Households that are concerned about the possibility of an explosion tend to keep their LPG stove and canister in separate locations. As a result, a household member preparing a meal has to assemble the stove with an LPG canister. When that process takes more than 1.5 minutes per meal, the household is in Tier 3 or below because of Convenience. Households for which LPG accounts for more than 5% of monthly spending are in Tier 3 or below because of Affordability. As more data and empirical evidence become available, the threshold and framework may be revised accordingly.

FIGURE 60 • **More urban households than rural households are in Tiers 4 and 5 for access to modern energy cooking solutions**

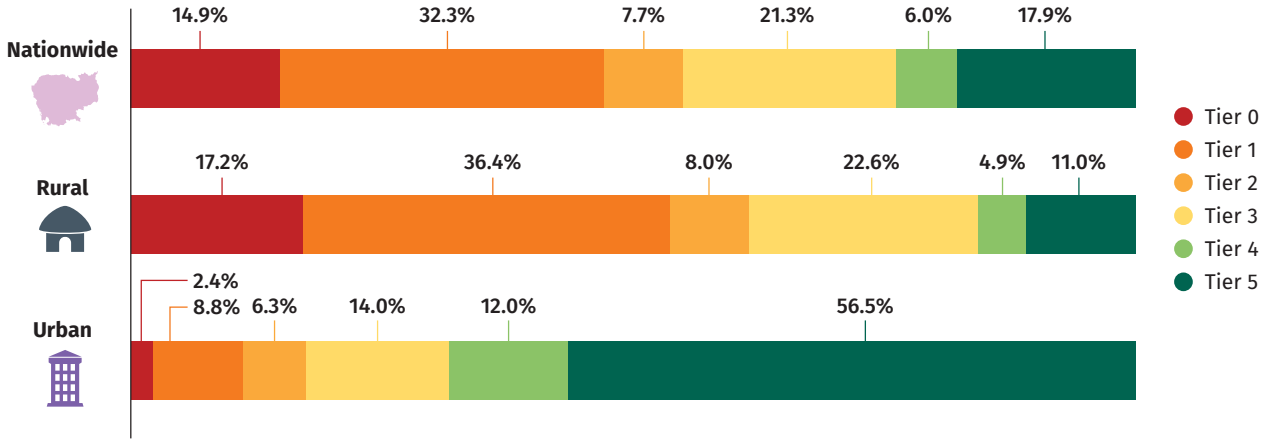


MTF ATTRIBUTES

Cooking Exposure

Cooking exposure is a proxy indicator to measure the health impacts of cooking activity. It is calculated by, first, determining the level of emissions based on a combination of fuels and stove technologies and then, the ventilation of a household's cooking space (which can mitigate pollutants from cooking). The final Cooking Exposure tier is assigned as a composite of the emissions and ventilation tiers (see annex 3 for more information). Nationwide, 23.9% of households are in Tier 4 or 5 for Cooking Exposure, and there is a wide gap between rural (15.9%) and urban households (68.5%), due mainly to the penetration of clean fuel stoves (figure 61). A substantial share of rural households are in Tier 0 or 1, and more than half of them use either a three-stone or traditional stove exclusively.

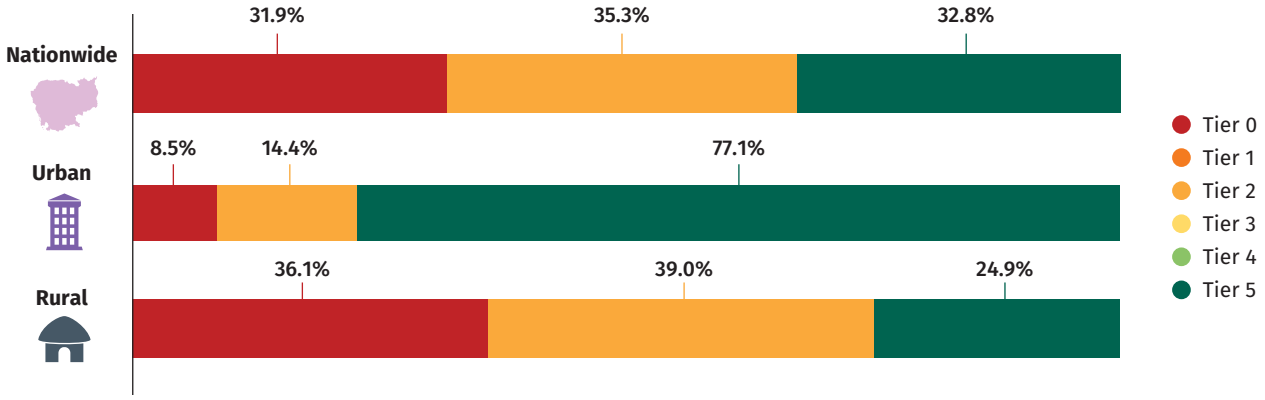
FIGURE 61 • **More urban households than rural households are in Tier 4 or 5 for Cooking Exposure**



Stove emissions

In the absence of the finalized MTF for cooking, five stove types have been identified to inform tier classification, with each stove type matched with a stove emissions tier (see box 3). The 31.9% of households that use either a three-stone or traditional stove as their primary stove are in Tier 0, the 35.3% of households that use an ICS are in Tier 2, and the 31% of households that use an LPG or biogas stove and the 1.8% of households that use an electric stove are in Tier 5 (figure 62).

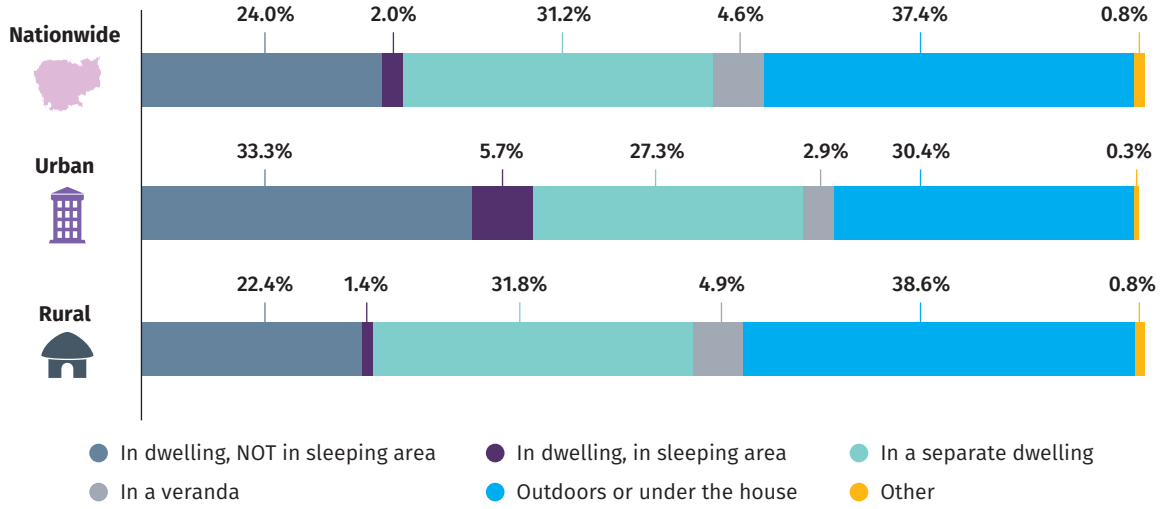
FIGURE 62 • **A third of households use clean fuel for their primary stove**



Cooking location

The cooking location for the primary stove is outside for 42% of households that do not use an electric stove as their primary stove—including 43.5% of rural households and 33.3% of urban households (figure 63).

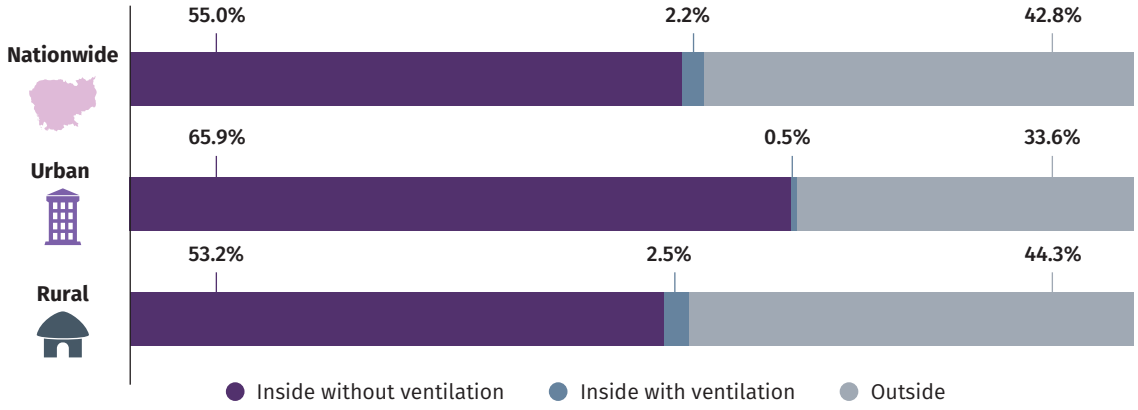
FIGURE 63 • **Over 40% of households use their primary stove mainly outside**



Ventilation

Among households whose primary stove is a biomass or LPG stove, urban households have poorer ventilation than rural households do (figure 64). However, among households whose primary stove is a biomass stove, rural households have poorer ventilation than urban households do: 55.7% of rural households that use a biomass stove as their primary stove cook inside, and more than 95% do so without ventilation. Ventilation is critical for rural households because 75.2% of them use a biomass stove, compared with 22.9% of urban households.

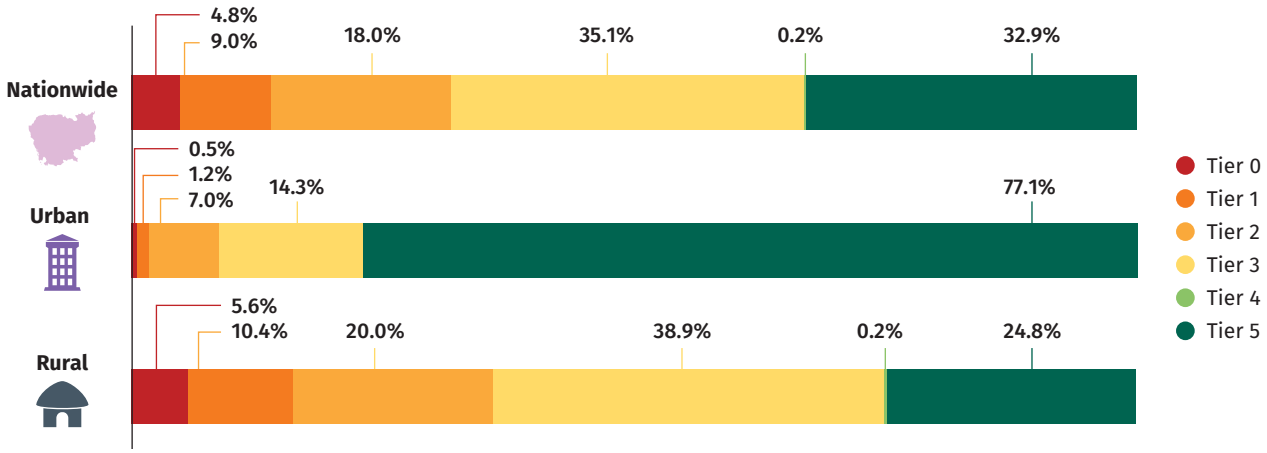
FIGURE 64 • **More rural households that use a biomass stove or liquefied petroleum gas or biogas stove cook outside**



Cookstove Efficiency

The high penetration of clean fuel and ICSs means that many households are in Tiers 3 and 5 for Cookstove Efficiency. Some 16% of rural households are in Tier 0 or 1, compared with 8.7% of urban households (figure 65). By using less-efficient stoves, rural households need to consume more firewood than urban households do.[21]

FIGURE 65 • **More than 68% of households are in Tier 3 or above**

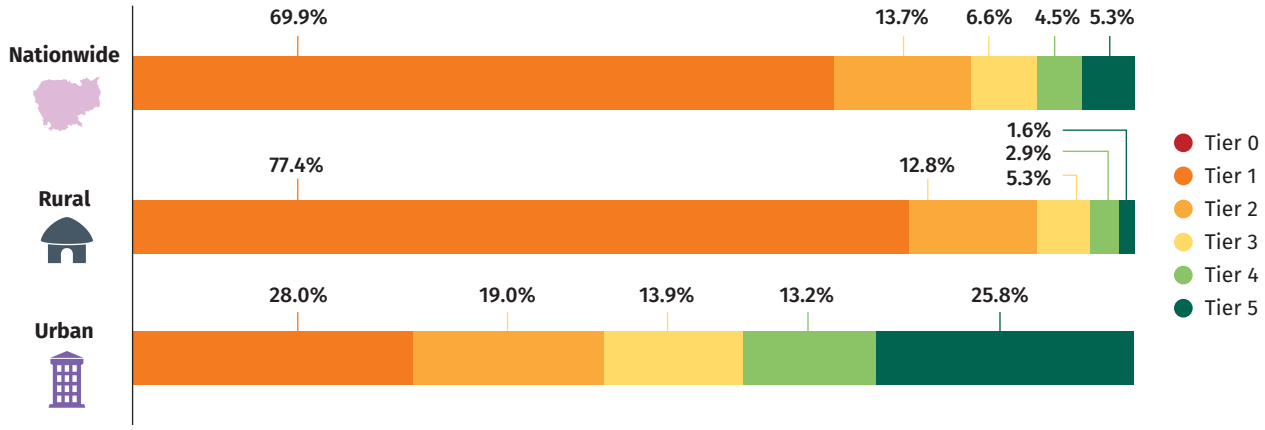


[21] Further analysis that controls for household socioeconomic status and other variables is needed to fully understand fuelwood consumption.

Convenience

Some 69.9% of households are in Tier 1 for Convenience because household members spend at least 7 hours a week acquiring or preparing fuel or 15 minutes a meal preparing the stove. And 28% of urban households are in Tier 1, compared with 77.4% of rural households, while 25.8% of urban households are in Tier 5, compared with 1.6% of rural households (figure 66). A large percentage of urban households use a clean fuel stove as their primary stove (which requires much less time to acquire and prepare fuels for and to prepare for cooking). And urban households are more likely to purchase fuel, while rural households are more likely to gather firewood, which is more time-consuming.

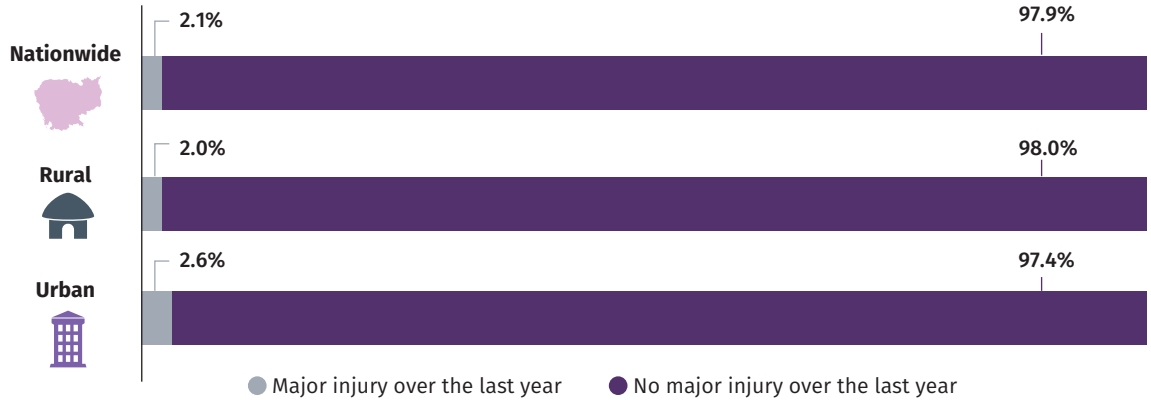
FIGURE 66 • **Nearly 40% of urban households are in Tier 4 or 5 for Convenience**



Safety of Primary Cookstove

Most households did not recall a major injury over the last year that required medical attention. But 2.1% 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—within the past year (figure 67). Nationwide, 1.6% of households that use either a traditional stove or an ICS as their primary stove and 0.5% of households that use a clean fuel stove are in Tier 3 for Safety.

FIGURE 67 • **Safety is not a major hurdle**



Fuel Availability

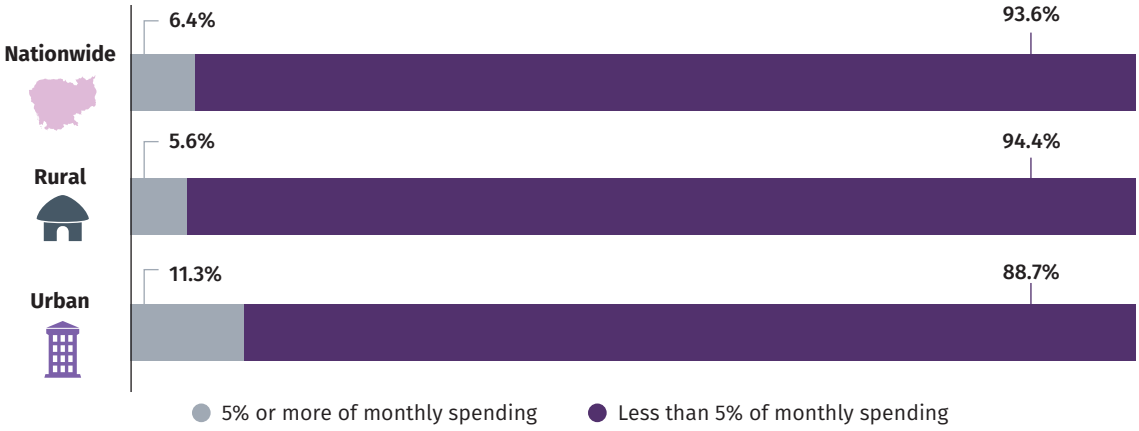
Fuel Availability is not a major issue for households. Only 5.6% of households stated that fuel was only sometimes or rarely available (figure 68). There was no significant difference between rural and urban households: 96.3% of urban households and 94% of rural households responded that their primary fuel was always or mostly available.

FIGURE 68 • **Cooking fuel is always or mostly available for more than 90% of households**

Affordability

Affordability prevents households from reaching a higher tier for access to modern energy cooking solutions. For 6.4% of households, cooking stoves and fuels account for more than 5% of monthly spending (figure 69). Affordability is more burdensome to urban households (11.3%) than rural households (5.6%).

FIGURE 69 • **More urban households are in a lower tier because of Affordability**



Households that use a clean fuel stove tend to spend a larger share of their monthly expenditure on cooking fuel, particularly LPG, than households that use other biomass stoves do (figure 70). Of households surveyed, 10.7% that use a clean fuel stove as their primary stove spend more than 5% of their monthly budget to purchase cooking fuel while 1.3% of three-stone stove users, 5.5% of traditional stove users, and 3.9% of ICS users do. Households with a clean fuel stove allocate around 2.6% of their monthly household budget to fuel, compared with less than 1% for households that use a biomass stove. Affordability of fuel is more of an issue for urban households because they use LPG stoves more than rural households do. Urban households that use firewood as cooking fuel are more likely than rural households to purchase it (figure 71). Among urban households that use firewood, 29.1% purchase it, compared with 13.8% of rural households. Since rural households mainly collect firewood for cooking, Affordability is not an issue.

FIGURE 70 • **Close to 10% of households using clean fuel stoves as primary spend more than 5% of household budget on cooking fuel**

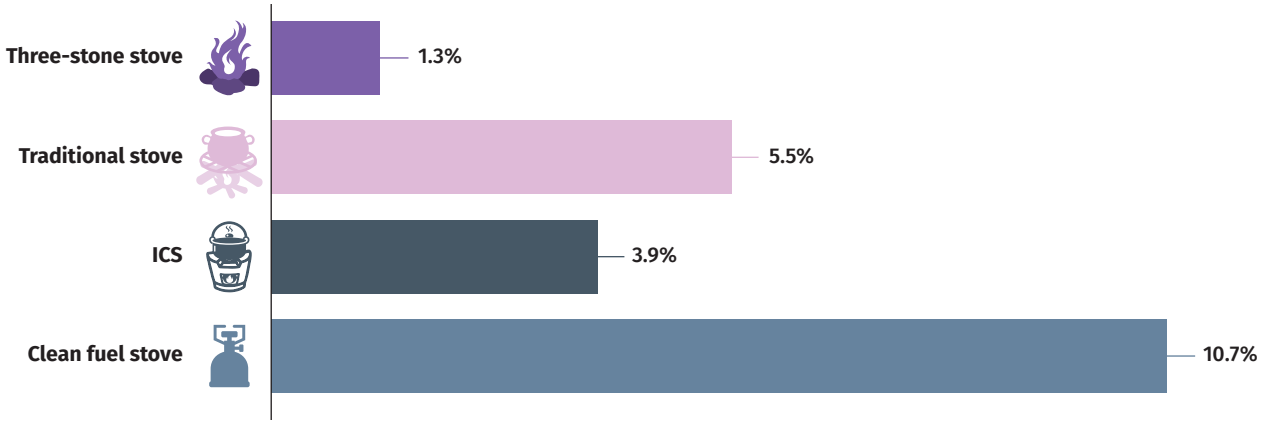
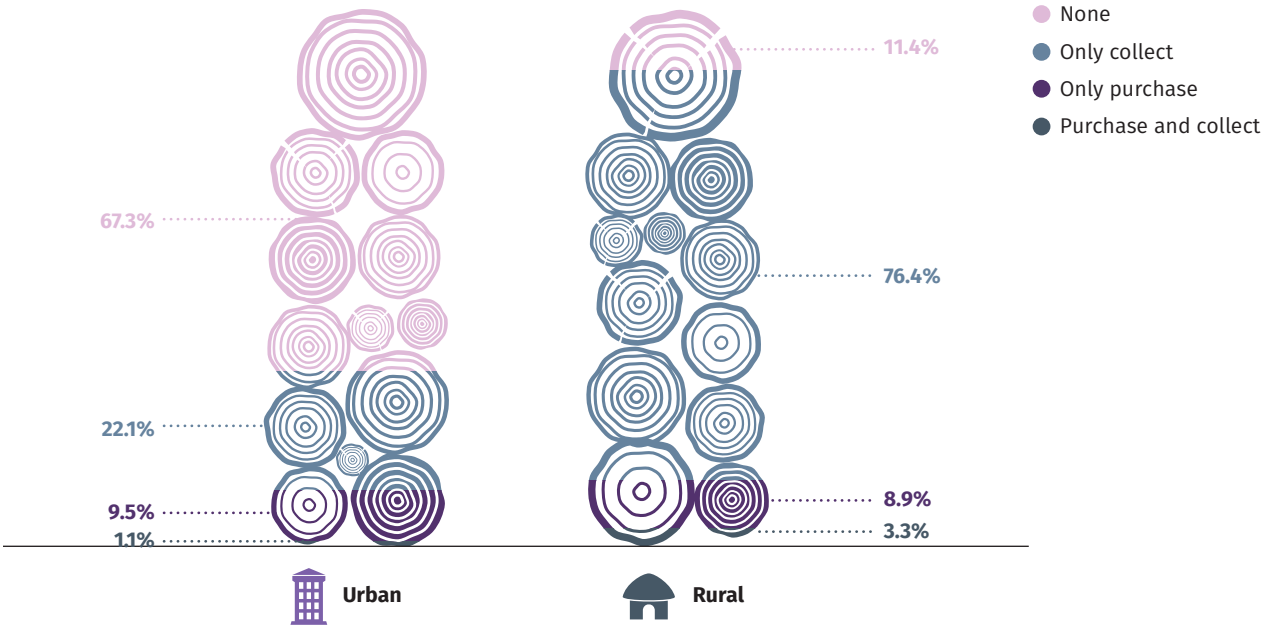


FIGURE 71 • **More rural households obtain cooking fuel by collecting**



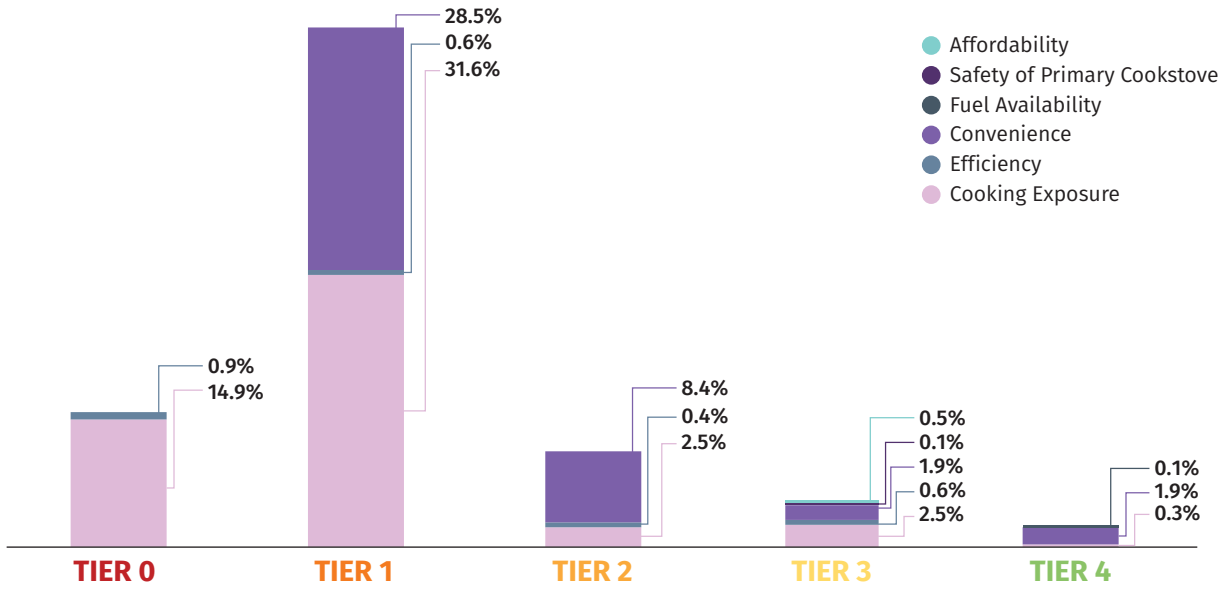
IMPROVING ACCESS TO MODERN ENERGY COOKING SOLUTIONS

Because of Cooking Exposure, 51.8% of households are not in a higher tier (figure 72). Some 14.9% of households are in Tier 0 because of Cooking Exposure, and 96.2% of them use a three-stone or traditional stove as their primary stove, while 3.2% use a clean fuel stove as their primary stove in combination with other biomass stoves. Households that use a clean fuel stove in combination with a biomass stove cannot realize the full benefits of using a clean fuel stove, such as less indoor air pollution and less time spent acquiring fuel, and thus remain in lower tiers.

Of the households in Tier 1 because of Cooking Exposure, 49.8% use an ICS as their primary stove. But they use an ICS in a combination with a traditional or three-stone stove or have poor ventilation, so they remain in Tier 1, even though an ICS produces fewer emissions.

Of the 32.9% of households that use a clean fuel stove as their primary stove, 49.9% are in Tier 1, 16.7% are in Tier 2, 11.7% are in Tier 3, and 20.2% are in Tier 4 or 5. There are three reasons that a household that uses a clean fuel stove as its primary stove is not in Tier 4 or 5. First, of the one third of Cambodian households that use a clean fuel stove as their primary stove, 66.4% of them use it in combination with a biomass stove. Even if their primary stove is fueled by clean fuel, the improvement in indoor air quality is limited, and they still need to spend time collecting and preparing fuels for cooking. Second, even if a household uses a clean fuel stove exclusively, it can still be constrained by the Convenience attribute—as is the case for 49% of households in Tier 3 or below. Among households constrained by the Convenience attribute, 43.2% reported spending more than 3 hours a week purchasing cooking fuels. And 78% of households that use a clean fuel stove exclusively reported spending at least 15 minutes to prepare the stove for cooking. Third, Affordability prevents 2.7% of households that use a clean fuel stove exclusively from moving up to Tier 4 or 5.

FIGURE 72 • **Cooking Exposure and Convenience are major constraints to improving access to modern energy cooking solutions**



INCREASING PENETRATION OF CLEAN FUEL STOVES

In Cambodia 39.5% of urban households and 17.9% of rural households use a clean fuel stove with an ICS, and 16.1% of urban households and 9.4% of rural households use a clean fuel stove with a traditional stove. In addition, 32.5% of urban households and 7.2% of rural households use a clean fuel stove exclusively—nationwide, 11.1% of Cambodian households use a clean fuel stove exclusively. Of urban households that use a clean fuel stove as their primary stove, 57.9% do so in combination with a biomass stove. Some households may not be able to receive the health and other benefits attributed to the use of clean fuels and technologies because they are still using other types of stoves. So it is important to understand and address why households that cook with clean fuel stoves also use biomass stoves in parallel

Affordability is likely to be a major obstacle in expanding the use of clean fuel stoves. Households that use clean fuel stoves spend more on fuels than households that use other biomass stoves do. For about 10% of households that use a clean fuel stove, fuel (mostly LPG) accounts for more than 5% of their monthly spending. Households that use a clean fuel stove as their primary stove spend an average of 2,370 riels (59 cents) a month on fuel, while households with a three-stone stove spend 890.7 riels (22 cents), households with a traditional stove spend 1,016.8 riels (25 cents), and households with an ICS spend 969.2 riels (24 cents) (figure 73). Affordability is also reflected in how households obtain firewood for cooking: 85.6% of households in the bottom spending quintile only collect firewood for cooking, compared with 51.2% of households in the top quintile (figure 74). So, to expand the use of clean fuel stoves, the affordability of clean fuels needs to be considered, particularly for rural households, which tend to have lower incomes.

FIGURE 73 • **Households that use a clean fuel stove are significantly wealthier than households that use other stove types**

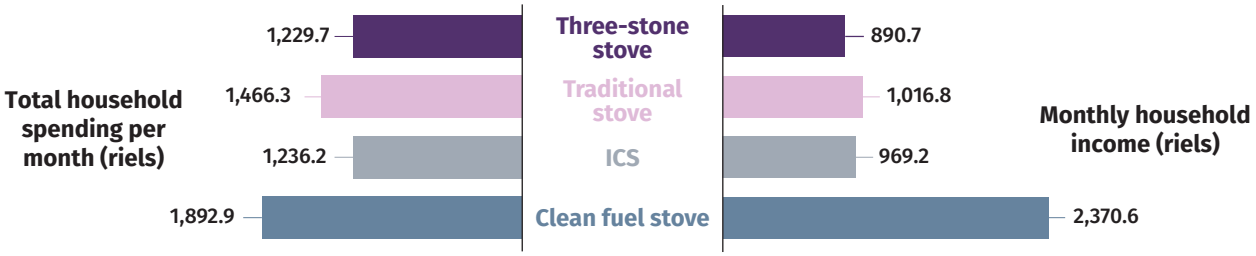
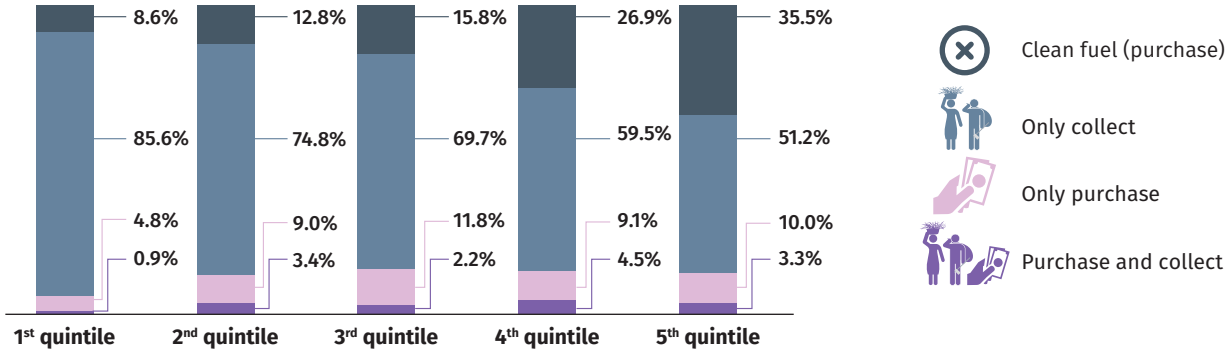


FIGURE 74 • **Less affluent households are more likely to obtain cooking fuel by collecting**



INCREASING THE USE OF IMPROVED COOKSTOVES AS THE PRIMARY COOKING SOLUTION

More than a third of households use an ICS as their primary stove, a rate that reflects rapid expansion, the majority of households—especially rural households—depend on biomass for their cooking needs. In rural areas 75.2% of households use a biomass stove, and 51.7% of them use an ICS as their primary stove.

Increasing the use of ICSs is the most feasible and immediate solution for households that use three-stone or traditional stoves, particularly rural households. Considering that 4.1% of rural households use only a three-stone stove, and 24.5% use only a traditional stove, the potential benefit of ICSs is great. Households that switch from a three-stone or traditional stove to an ICS will save time on fuel collection (for those collecting firewood) and spend less (for those purchasing fuelwood) (figures 75 and 76). Households that use a clean fuel stove exclusively spent only 45 minutes a week purchasing fuel.

FIGURE 75 • **Traditional stove users consume more fuels than improved cookstove users do**

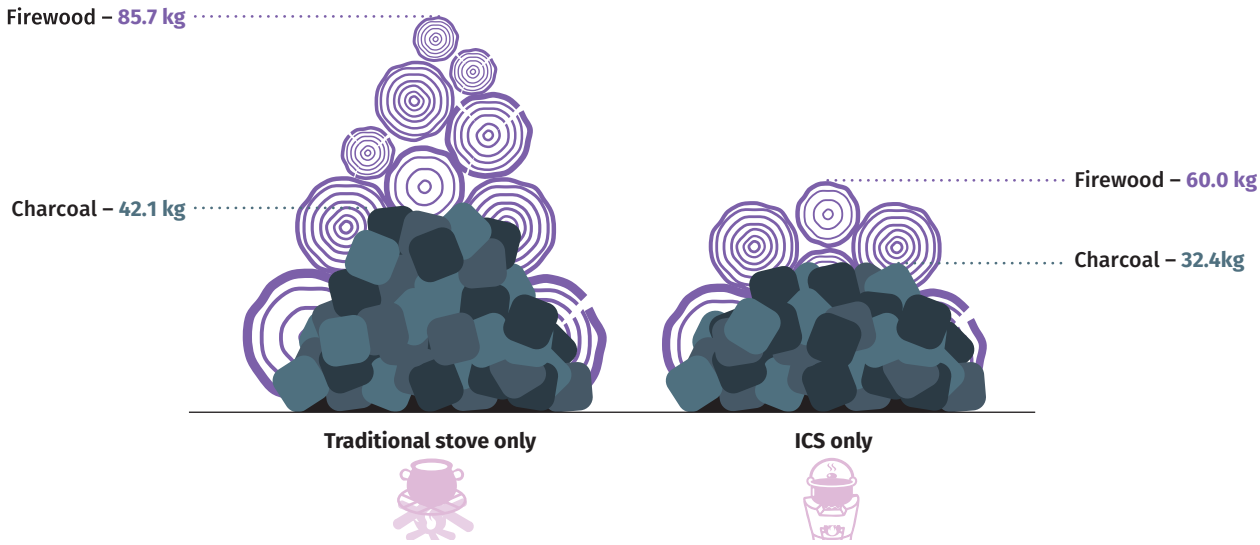
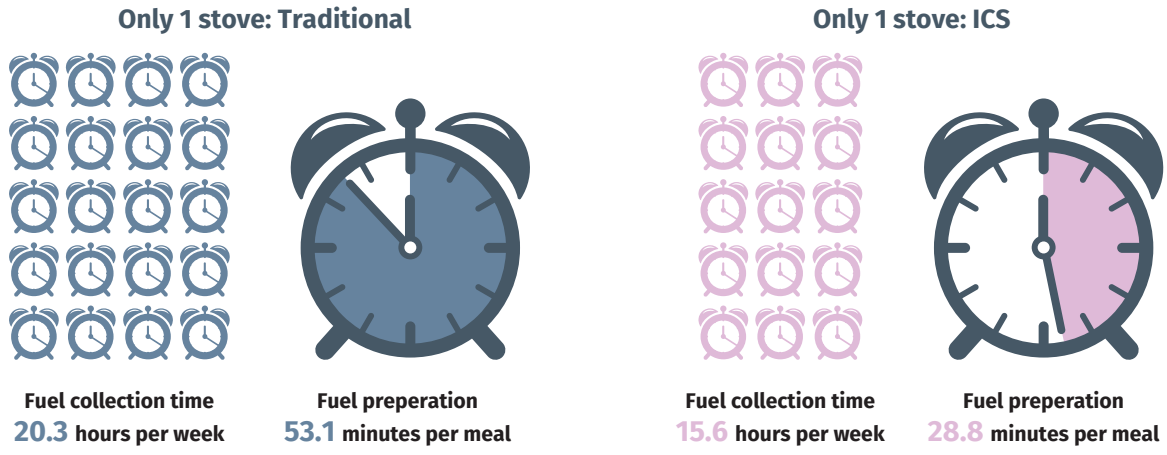


FIGURE 76 • **Using an improved cookstove can save time collecting fuel**



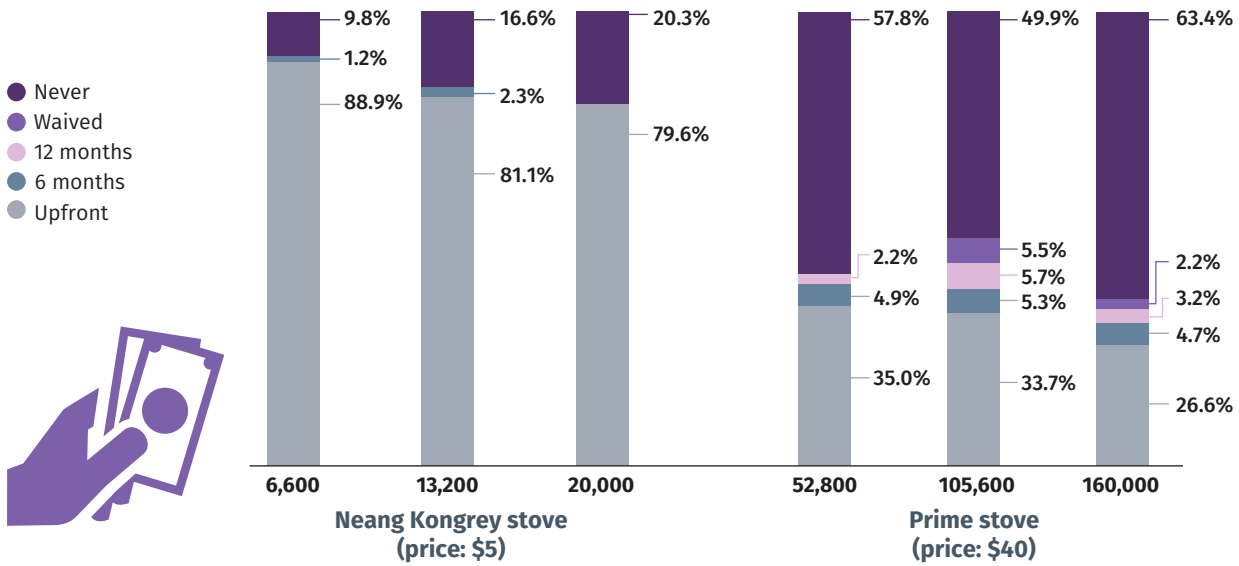
Given the negative effects of indoor air pollution on health, access to higher tier stoves should be expanded. Since higher performance stoves tend to be more expensive, barriers to Affordability will need to be overcome. Households appear to be willing to pay for a basic ICS, as reflected by the 26.3% of households that already use an ICS as their primary stove and the 25.2% that use one as their secondary stove. The same high interest is reflected in responses to the MTF willingness to pay (WTP) module.

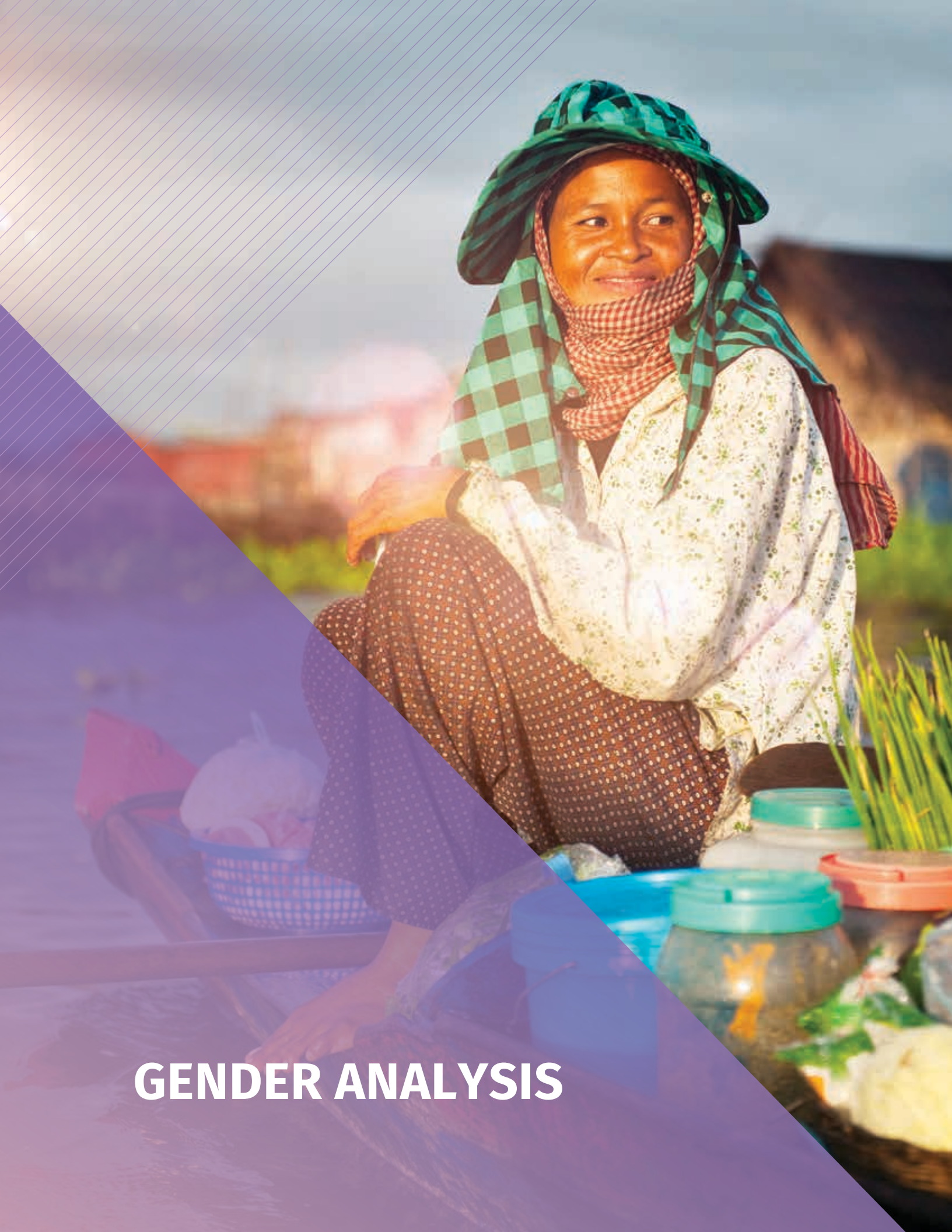
Households were asked whether they would pay full or reduced price for an ICS (either a Neang Kangrey stove or a New Lao stove, both of which cost (20,000 riels, or $5)—the two ICSs with the highest penetration rates (3.6% and 31.5%), and 79.6% were willing to pay for the Neang Kangrey stove upfront at full price (figure 77). Reducing the price increases the WTP only moderately—most likely because the price is already low. An additional 1.5% of households are willing to pay when the price is two-thirds of the full price, and an additional 9.3% are willing to pay when the price is a third of the full price.

For an advanced biomass stove—the prime stove (160,000 riels, or $40), a gasifier cookstove—reducing the price and offering up to a 24 month payment plan made a difference in WTP. Offering a payment plan appears to be a more effective strategy than reducing the price. However, WTP was highest when the price was reduced to two-thirds of the full price with a payment plan of up to 24 months (50.1% of households). But 33.7% of households were willing to pay full price with a payment plan.

The main reasons the prime stove was rejected was price: about 44% said they could not afford one, while 35% said they did not need one, 14% considered the stove unreliable (saying they lacked the experience needed to use it), and 4% were intimidated by the idea of using it (3% listed “other” as a reason). Given the potential health benefits of an advanced biomass stove, a clear strategy should be formulated for their adoption. A combination of targeted awareness campaigns and affordability measures could increase the penetration of higher performance ICSs.

FIGURE 77 • **Many households are willing to pay upfront for an inexpensive improved cookstove**



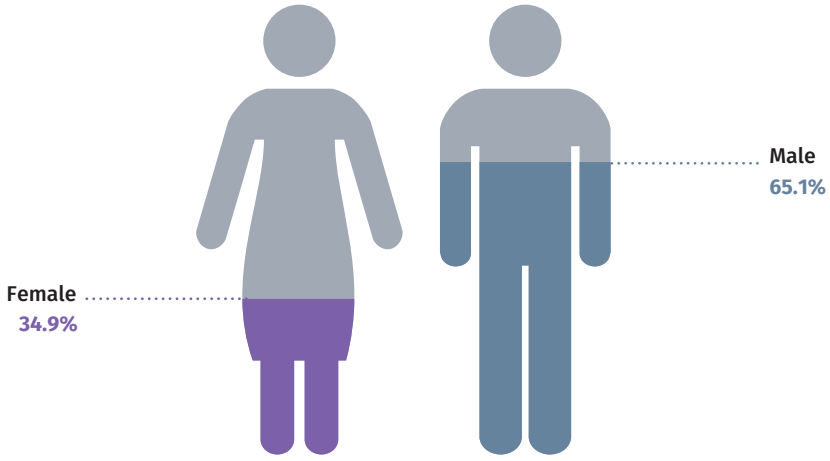


GENDER ANALYSIS

Nationwide, 34.9% of households are headed by women (figure 78). The average age of female household heads is 52, compared with 36 for male household heads. The average size of female-headed households is 3.9 members, compared with 4.6 for male-headed households. About 16% of male-headed households and 14% of female-headed households reside in urban areas.

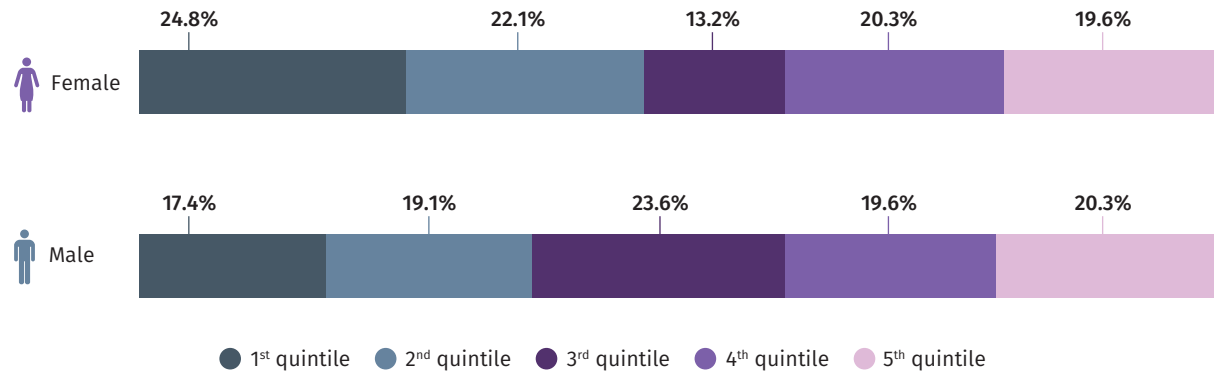
Male household heads achieve or complete a higher level of education than female household heads. Nearly 25% of female household heads never attended school or completed only lower secondary education. Roughly 28% of male household heads received a primary education, compared with 14% of female household heads. Only 1% of female household heads completed a bachelor's degree (or higher). These results correlate with those for household income: male-headed households have a higher average income than female-headed households do.

FIGURE 78 • **Men head 65.1% of households**



Nationwide, average monthly spending is 1,418,064 riels for female-headed households and 1,576,124 riels for male-headed households, an insignificant difference (figure 79). The percentage of households in each spending quintile is similar, though more female-headed households (46.9%) than male-headed households (36.5%) are in the bottom two quintiles. The share of households in the top two quintiles is the same for both female- and male-headed households (39.9%).

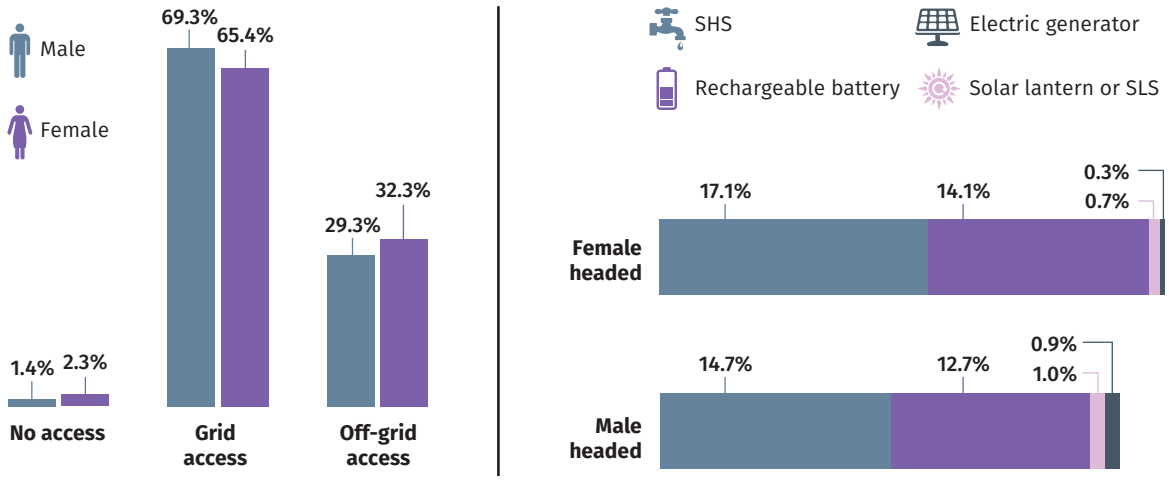
FIGURE 79 • **About 47% of female-headed households and 37% of male-headed households are in the bottom two spending quintiles**



ACCESS TO ELECTRICITY

Female-headed households have lower access to electricity for all technologies except for some off-grid solutions (figure 80). In rural areas electricity access rates through solar home systems (SHSs) and rechargeable batteries are higher for female-headed households than for male-headed households. Female household heads without access to the grid use an off-grid solar device to compensate.

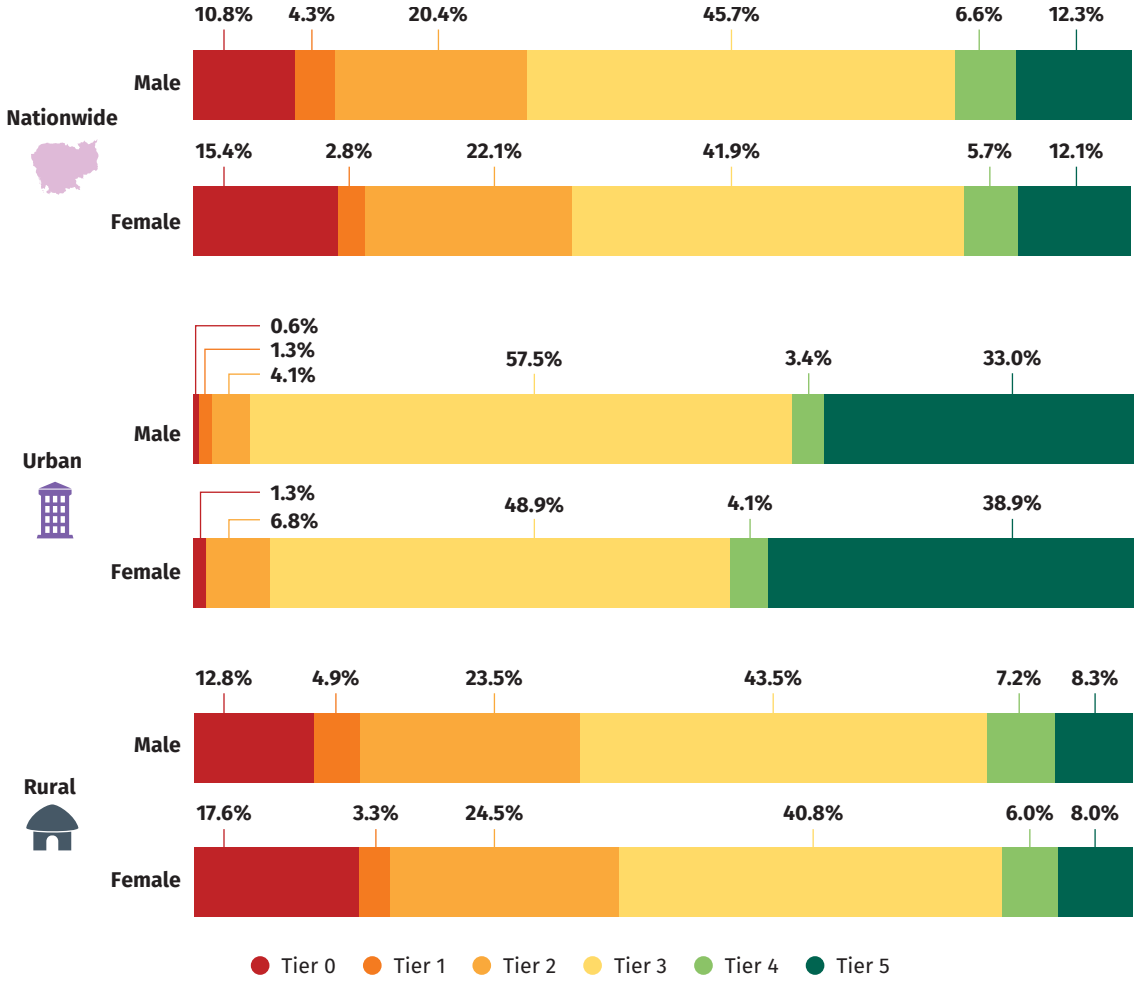
FIGURE 80 • **More female-headed households than male-headed households use off-grid solutions**



Because more male-headed households are connected to the grid, male-headed households also tend to be in higher tiers for access to electricity than female-headed households are. Female-headed households tend to be in a lower tier for Capacity (because they are less likely than male-headed households to have a grid connection and more likely to have an SHS). Nearly 13% of female-headed households have less than 4 hours of electricity supply a day, compared with 8% of male-headed households. Affordability compounds the difficulties that female-headed households face.

The gender gap in access to electricity is more prevalent in rural areas, where 17.6% of female-headed households are in Tier 0, compared with 12.8% of male-headed households (figure 81). The gender gap is narrower in urban areas because most households—both male- and female-headed—are connected to the grid: 91.9% of female-headed households and 94% of male-headed households are in Tier 3 or above.

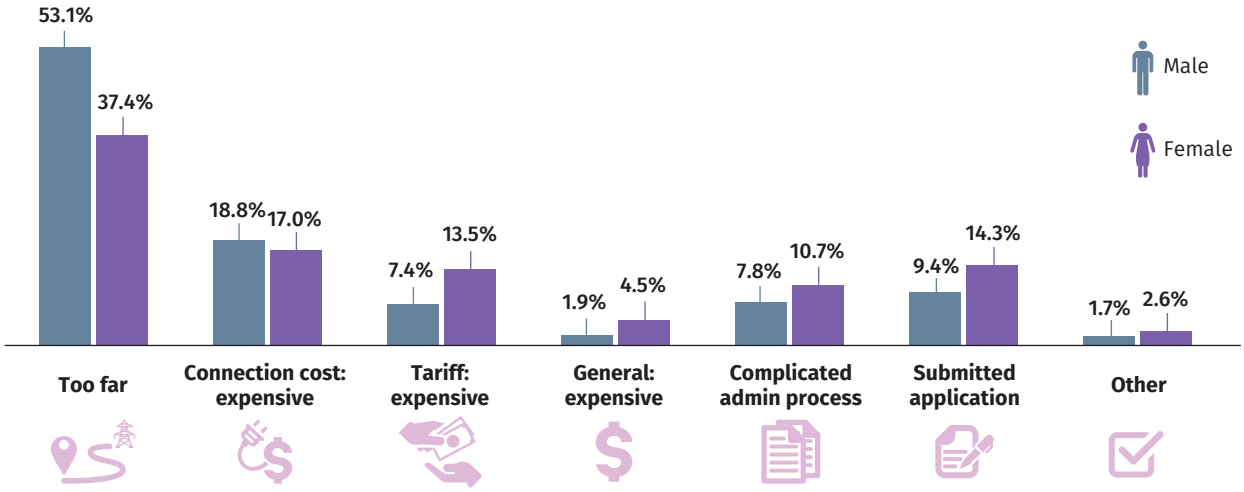
FIGURE 81 • **Male-headed households tend to be in higher tiers for access to electricity than female-headed households are**



For 37.4% of female-headed households and 53.1% of male-headed households in Tier 0 the main barrier that prevents them from moving to a higher tier is distance from grid infrastructure (figure 82). Cost of connection and monthly tariff are also barriers for both female- and male-headed households.

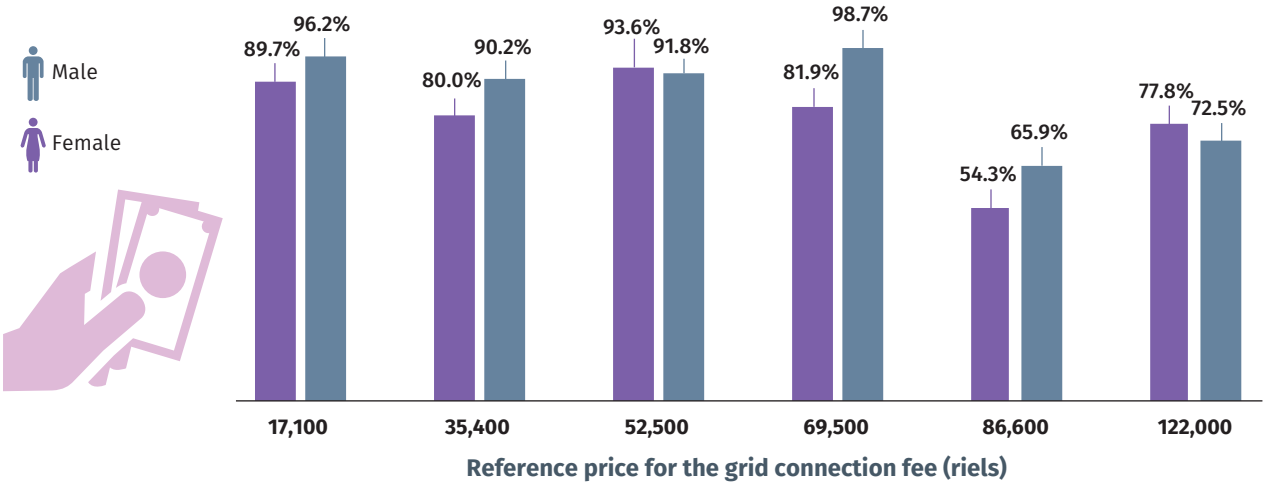
A higher percentage of female-headed households (14.3%) than of male-headed households (9.4%) submitted an application for a connection but have not yet been connected, and more female-headed households than male-headed households face administrative obstacles, suggesting that there can be cultural, gender-based, and education barriers to connecting female-headed households to the grid.

FIGURE 82 • **Distance is the major barrier for connecting to the national grid**



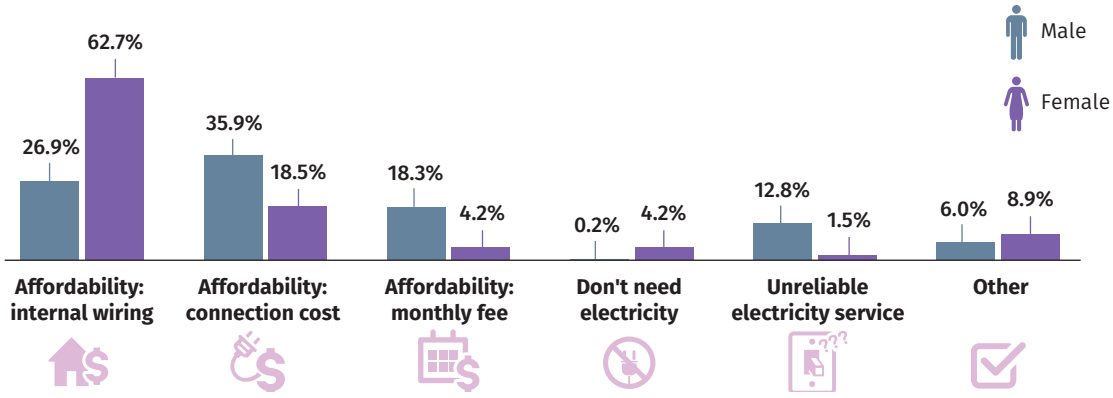
Willingness to pay (WTP) for a grid connection is high for both male- and female-headed households but varies by gender: 72.5% of female-headed households and 77.8% of male-headed households are willing to pay the full connection price upfront (figure 83).

FIGURE 83 • **Willingness to pay upfront for a grid connection varies little by gender**



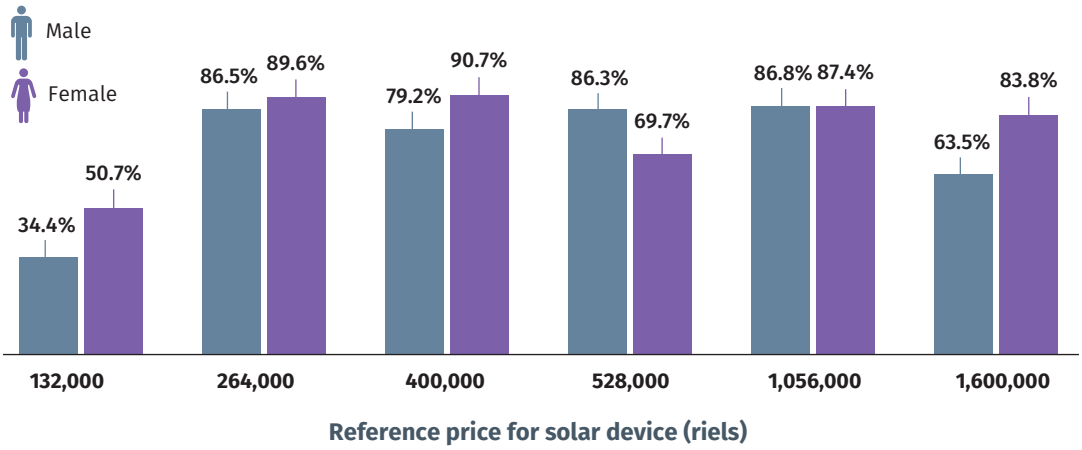
Affordability is the main barrier to access to the grid—particularly affordability of internal wiring and particularly for female-headed households (figure 84).

FIGURE 84 • **Affordability of internal wiring constrains the willingness of female-headed households to pay for grid connection**



Despite the fact that female household heads are more likely than male household heads to own an SHS, female household heads have a lower WTP for an off-grid solar device. Some 83.8% of female household heads and 63.5% of male household heads are not willing to pay full price for an SHS—even under a payment plan (figure 85). Even for the lowest price (132,000 riels), only 50.7% of female-headed households are willing to pay for the product, compared with 34.4% of male-headed households.

FIGURE 85 • **Female household heads showed a lower willingness to pay for an off-grid solar device**



Note: The average exchange rate between August 1, 2017, and November 1, 2017 was 1 U.S. dollar = 3,984.6 riels

ACCESS TO MODERN ENERGY COOKING SOLUTIONS

No significant difference exists in stove type use between male- and female-headed households in urban areas, but a gap exists in rural areas (figures 86 and 87). Improved cookstove (ICS) ownership is lower among female-headed rural households (33.6%) than among male-headed rural households (41.7%), although clean fuel stove use by the two groups is nearly the same.

FIGURE 86 • **Slightly more male-headed households than female-headed households own an improved cookstove**

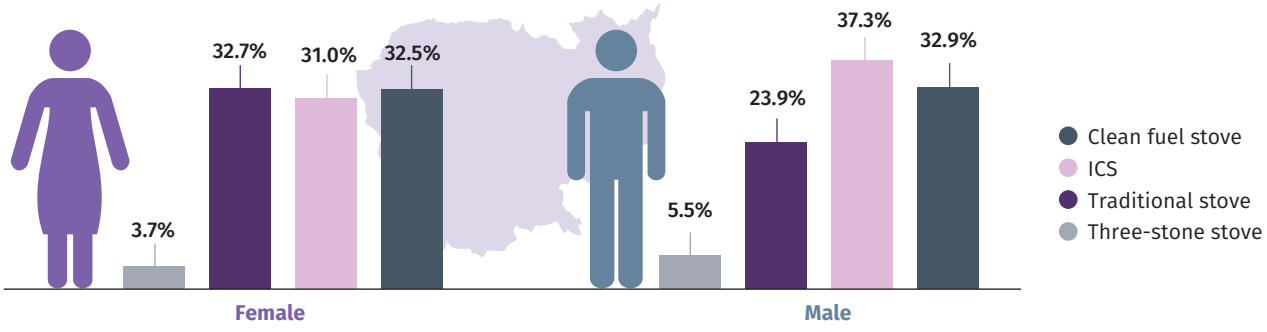
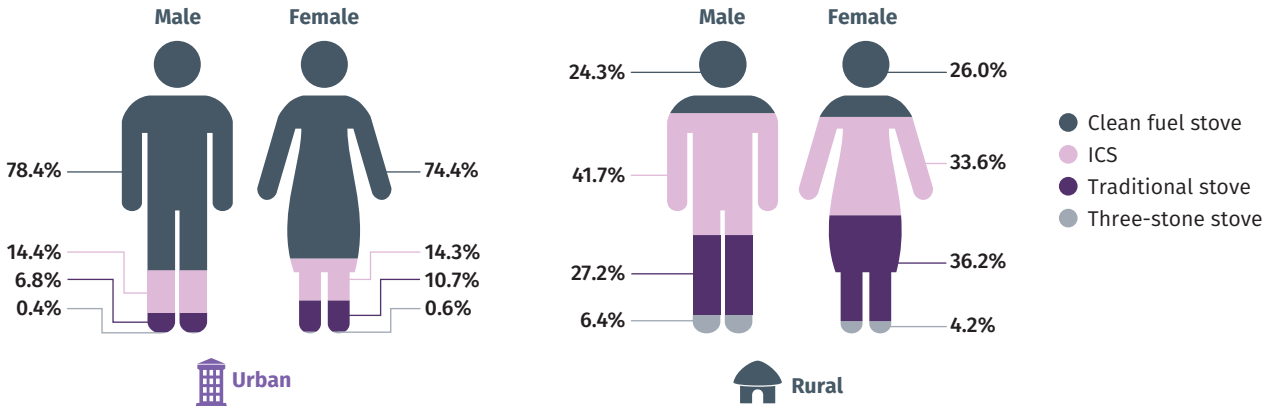


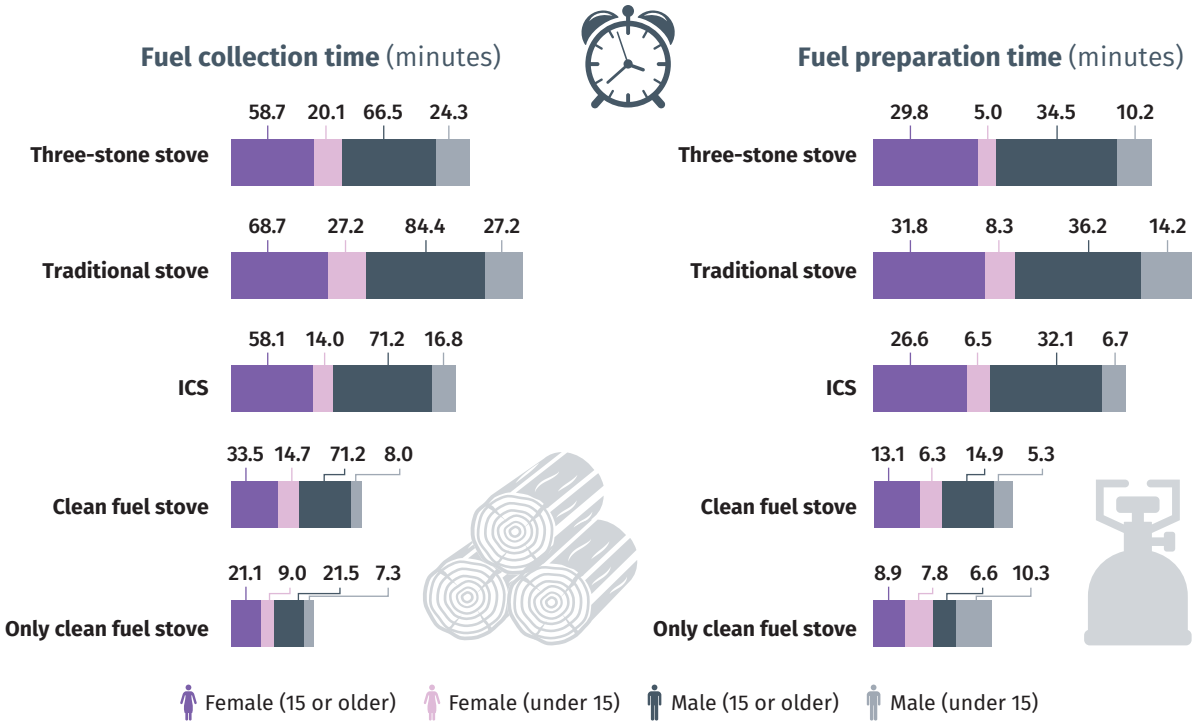
FIGURE 87 • **Among rural households, a larger share of male-headed households than of female-headed households own an improved cookstove**



TIME USE ANALYSIS

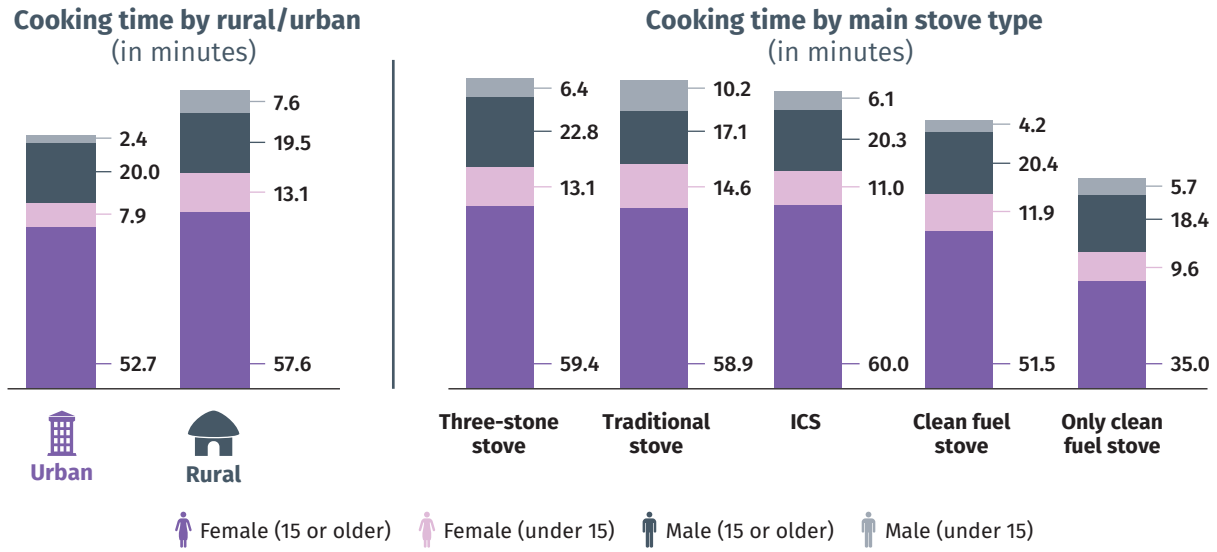
By switching to an ICS, both men and women would expect to reduce time spent acquiring (through collection or purchase) and preparing fuel. Women ages 15 and older in households that use a clean fuel stove exclusively spend 30 minutes acquiring and preparing fuel, compared with 88.5 minutes for women in households that use a three-stone stove as their primary stove (figure 88).

FIGURE 88 • **Clean fuel stoves and improved cookstoves considerably reduce the time for fuel collection and preparation**



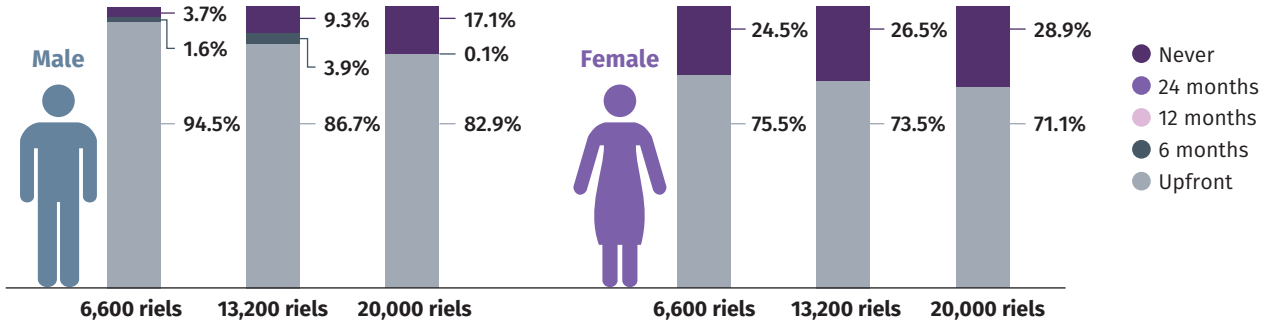
Female household members in all age groups spend significantly more time cooking than their male counterparts do (figure 89). Women are thus much more likely to be affected by indoor air pollution and are more likely to benefit from a household reaching a higher tier for cooking exposure.

FIGURE 89 • **Women spend much more time cooking than men do, whatever the primary stove**



WTP among households where no ICS was identified or present and heads of household used either a three-stone or a traditional stove[22]. Nearly all male-headed households were willing to pay at least a third of the full price of an ICS, and 82.9% of male-headed households were willing to pay 100% of the full price upfront (figure 90). WTP for an ICS was generally lower among female-headed households: 75.5% were willing to pay a third of the price upfront, and 71.1% were willing to pay the full price upfront.

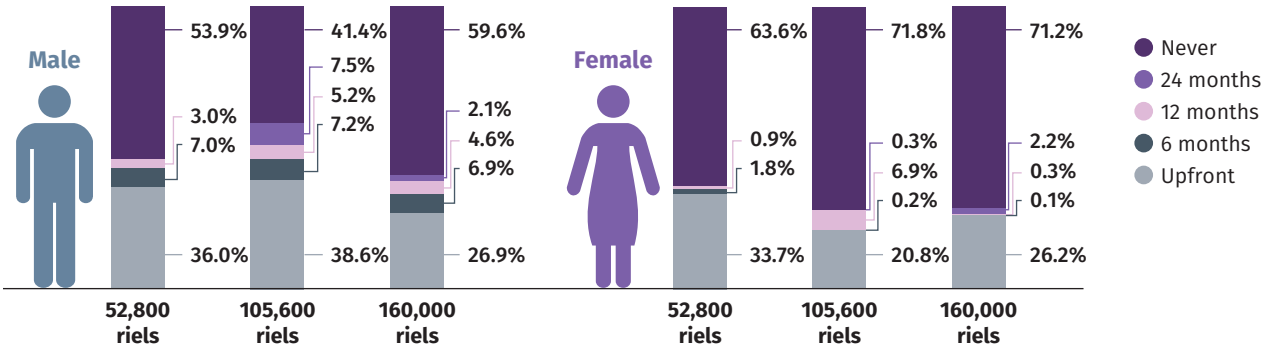
FIGURE 90 • **Nearly all male-headed households were willing to pay at least a third of the full price of an improved cookstove**



Note: Refers to a Neang Kangrey stove priced at $5.

About a quarter of both male- and female-headed households were willing to pay full price for an aspirational cookstove (about $40) upfront, and about a third were willing to pay a third of the price upfront (figure 91). The affordability of an aspirational cookstove is likely the reason for the low popularity of the higher priced stove—regardless of the gender of the household head. But the fact that a quarter of female-headed households are willing to pay the full price upfront despite their lower average income suggests that women may be beginning to value the health and efficiency benefits of such stoves.

FIGURE 91 • **Willingness to pay for a higher price aspirational cookstove showed narrower differences between male- and female-headed households**



Note: Refers to a prime stove priced at $40.

[22] Only households without a clean fuel cookstove or a LPG, electric, or biogas stove were asked.

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 Cambodia.

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.

ANNEX 2:
Cookstove Typology

Three-stone stove. A pot balanced on three stones over an open fire. It is the most traditional method of cooking in Cambodia.

Traditional biomass stove. Locally produced using available and low-cost materials and fuels, reflecting cultural practices. In Cambodia four types of stoves were identified as traditional: Mong/siam, Traditional Kampong Chhnang, Traditional Lao, and cement (also known as "the traditional stove").

Mong/Siam stove	Traditional Lao stove
Material: Baked clay **Production:** Manual **Size:** Multiple sizes **Specification:** Portable (weight 1.5–4 kg) **Fuel:** Fuelwood and biomass **Efficiency:** 15%	**Material:** Metal covered baked clay **Production:** Semi-manual **Size:** Multiple sizes **Weight:** 3–8 kg **Fuel:** Charcoal **Efficiency:** 25%

Improved biomass stove. Uses newer stove technology to improve efficiency, cleanliness, and safety. In Cambodia two types of stoves were identified as improved biomass: Neang Kangrey stove (NKS) and New Lao stove (NLS).

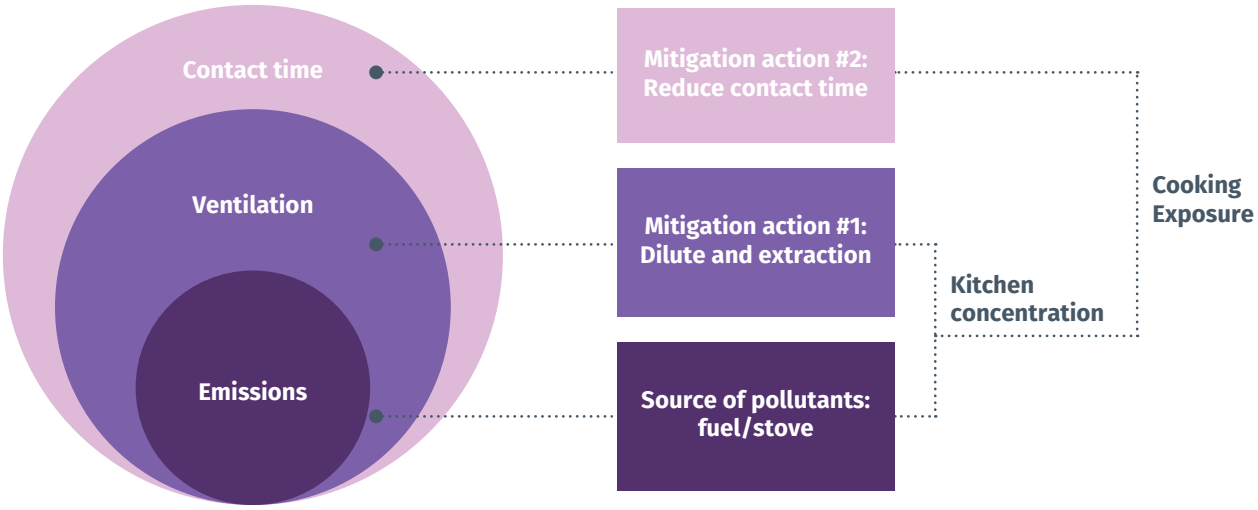
New Lao stove (NLS)	Neang Kangrey stove (NKS)
(photo not available)	
Efficiency: 26% **Fuel:** Firewood **Time to boil 5 L of water:** 25 minutes **Carbon dioxide emissions** (to complete 1 WBT with 5 L of water): 39 G **PM 2.5 emissions** (to complete 1 WBT with 5 L of water): 3.5 MG	**Material:** Metal covered baked day **Production:** Stove artisans **Size:** 25.4 cm height, 30 cm diameter **Weight:** approximately 12 kg **Fuel:** Charcoal **Efficiency:** 29–30%

Advanced biomass stove. Uses a fan to force emissions back into the flame for more complete burning. One household in the MTF survey dataset used an advanced biomass stove, Mimi Moto.

MImi Moto stove

Clean fuel stove. Uses clean and efficient fuels such as LPG, electricity, or biogas.

ANNEX 3:
Cooking Exposure attribute



Due to limited data availability, in Cambodia the Cooking Exposure tier is calculated using the level of emissions from the combination of fuel and stove technology and the ventilation level. If a household uses multiple cookstoves, then the Cooking Exposure tier is calculated independently for each stove-fuel combination. The final tier is a weighted average based on the share of use of each stove for overall household cooking activity.

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 4: Sampling strategy

The sample selection for the household survey was based on a two-stage stratification strategy to obtain consistent and uniform levels of significance during the data analysis stage and aimed at being nationally representative. The total target sample size was 3,300 households.

Cambodia does not have universal electricity coverage at both the village and household levels. In other words, even in grid-connected villages, household electrification does not always reach 100%. So the sample was stratified to include both electrified and non-electrified households (at a 1:1 ratio) in order to explore why some households in connected villages did not have access to the grid.

The sample was also stratified to include a 1:1 ratio of urban and rural households.

Angkor Research also conducted community (village chiefs) and facility (education, health, worship, government) interviews in areas where the household survey was already implemented. Mini-grid operator surveys were also included, with an initial target sample size of 24 consolidated licenses (generation, transmission, and distribution) and 100 solely distribution licenses.

VILLAGE SELECTION (PRIMARY SAMPLING UNIT)

Villages in Cambodia average approximately 224 households[23] and were thus suitable as enumeration areas. By sampling 12 households per village, the target sample size (3,300 households) was reached by collecting data in 275 enumeration areas (tables A4.1 and A4.2).

Several combinations of households and enumeration areas in each stratum (urban electrified, urban non-electrified, rural electrified, and rural non-electrified) were tested. The most stable combination in terms of statistical power was used to create the village sample (table A4.3). Sample stability was important in case the field teams found that selected villages did not have the expected electrification status (for example, a village selected as part of the non-electrified villages had actually gained access to the grid) or had a much lower or higher electrification rate than anticipated.

Following this sample structure, the field teams conducted interviews with 10 electrified households and 2 non-electrified households in each urban electrified enumeration area, interviews with 12 non-electrified households in each urban non-electrified enumeration area, interviews with 9 electrified households and 3 non-electrified households in each rural electrified enumeration area, and interviews with 12 non-electrified households in each rural non-electrified enumeration area.

Fewer non-electrified enumeration areas than electrified enumeration areas were selected in both urban and rural areas because more non-electrified households were interviewed in non-electrified enumeration areas (because non-electrified enumeration areas included only non-electrified households; table A4.2).

TABLE A4.1 • **Number of electrified and non-electrified households interviewed by enumeration area**

Enumeration area	Electrified households	Non-electrified households
Urban electrified	10	2
Urban non-electrified	0	12
Rural electrified	9	3
Rural non-electrified	0	12

TABLE A4.2 • **Number of enumeration areas selected per stratum, by electrification status**

Enumeration area	Total		
Urban electrified	84	137	275
Urban non-electrified	53		
Rural electrified	90	138	
Rural non-electrified	48		

[23] Based on 2013 data from the Ministry of Planning, National Institute of Statistics.

The dataset of villages and populations from the 2013 Cambodia Inter-Censal Population Survey was used as the sampling frame to select the target enumeration areas for the MTF survey. However, the dataset does not include information on village grid status. That information was provided by the Electricity Authority of Cambodia and merged into the sampling frame. Data and recommendations from the National Institute of Statistics on village urban–rural classification were also incorporated into the sampling frame.

Enumeration areas were randomly selected using the probability proportional to size methodology, which ensures that within each stratum, all households have the same chance to be selected. It also ensures representativeness within each stratum. Probability proportional to size methodology also has the advantage of producing a self-weighted sample within each stratum, which simplifies the calculations if weighting coefficients are needed. All these villages are located in urban areas; four were non-electrified, and one was electrified. A total of 270 villages (275 enumeration areas) were thus selected.

HOUSEHOLD SELECTION

During the fieldwork, and within each enumeration area, Angkor Research teams selected target households using a modified version of the Extended Programme on Immunisation–random walk selection method, commonly called the EPI-Walk method. Using this selection procedure, the village population is ascertained and a sampling interval (or ratio) is calculated based on the predetermined required number of household interviews and the current number of households in the enumeration area, as provided by the village chief.

A sketch map is then drawn in collaboration with the village chief, showing the approximate locations of all dwellings, roads, and paths in the village. Four to six key intersections are identified and numbered. One of these intersections is chosen at random as the starting point. Fieldwork teams begin interviewing at the house closest to that point.

From there, interviewers turn right and walk down the road or path, selecting every nth household based on the previously computed sampling interval. At the end of the road they turn around on the opposite side of the road and continue the count. Whenever interviewers come to an intersection they always turn right. In this way, the entire village is covered and all households have an equal chance of being included in the sample. This method ensures the randomness of household selection.

In non-electrified enumeration areas, only non-connected households were interviewed. The sampling interval was thus calculated based on the target sample size of 12 households. For example, if a target non-electrified village had 120 households, the sampling interval to use with the modified version of the EPI-Walk method was 10 (the field team interviewed every 10th household after the randomly chosen starting one).

However, in electrified enumeration areas, because not all households were expected to be electrified, more households were approached to ensure that all types of situations were captured by the survey. In these enumeration areas the modified EPI-Walk sampling method was implemented to screen 50 households and determine how many were connected to the grid. The household interview was then conducted immediately after the screening process, depending on the screening result and on the number of interviews to be completed with each type of household (based on village electrification status and urban–rural status). If the 50 screenings did not identify enough households for the electrified or non-electrified categories, the field team conducted an additional 30 screenings (for a total of 80 households approached and screened) still using the random EPI-Walk sampling method. If the 30 additional screenings still did not identify enough eligible households, the field team interviewed households from the other category, up to the total enumeration area sample size of 12 households. For example, if only 1/80 household was found to be non-electrified in a rural electrified enumeration area, it would not be possible to reach the target three interviews for the non-electrified household category: the only non-electrified household would thus be interviewed, and two additional interviews would be conducted with electrified households.

In electrified enumeration areas, because the modified version of the EPI-Walk permits randomly selection of households in the entire village, the ratio of electrified and non-electrified households among the screenings can be used as a reliable estimation of the actual electrification rate of the enumeration area.

The proposed sample framework is summarized in table A4.3. A total of more than 3,700 interviews were planned to cover all the MTF Access Tracking Framework Global Survey activities in Cambodia.

TABLE A4.3 • **Sample framework**

Strata	Rate	Size	Selection method
Province	—	25	—
Enumeration areas	—	275 (270 villages)	—
Urban electrified	—	84 (83 villages)	Random (probability proportional to size selection within stratum)
Urban non-electrified	—	53 (49 villages)	
Rural electrified	—	90 (90 villages)	
Rural non-electrified	—	48 (48 villages)	
Household interviews			
Urban electrified households	10 / (1)	840	Modified EPI-Walk + screening
Urban non-electrified households	2 / (1) + 12 / (2)	804	Modified EPI-Walk
Rural electrified households	9 / (3)	810	Modified EPI-Walk + screening
Rural non-electrified households	3 / (3) + 12 / (4)	846	Modified EPI-Walk
Total: household interviews		**3,300**	

* *The average exchange rate between August 1, 2017, and November 1, 2017 was 1 U.S.* dollar = 3,984.6 riels.

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Multi-Tier
FRAMEWORK

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