Energy Sector Management Assistance Program

Primary Household Energy for Cooking and Heating in 52 Developing Economies

Masami Kojima

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The financial and technical support by the Energy Sector Management Assistance Program (ESMAP) is gratefully acknowledged. ESMAP is a partnership between the World Bank and 19 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions.

ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets.

Abbreviations

CO	Carbon monoxide
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
LPG	Liquefied petroleum gas
MICS	Multiple Indicator Cluster Survey(s)
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 microns
SDG	Sustainable Development Goal
WBG	World Bank Group
WHO	World Health Organization

Summary

Recent household surveys from 52 developing economies that include questions about energy use show that the most commonly cited primary energy for cooking is wood, followed by gas—natural gas and, where natural gas is not available, liquefied petroleum gas (LPG)—and then by electricity. Biogas use is rare and the use of ethanol and solar cookers is essentially non-existent. Households in the economies with a very high share of the population relying on clean energy as the primary source for cooking overwhelmingly prefer gas over electricity.

In two-thirds of the economies more than half of the rich cook with clean energy, again preferring gas over electricity. As income rises and natural gas infrastructure becomes better established, urban households shift from LPG to natural gas, leaving LPG primarily for rural households. By contrast, in low-income and some lower-middle-income economies even the rich cook primarily with charcoal or kerosene (usually preferring charcoal over kerosene), while LPG is used by some well-off urban households. In one out of every six economies less than one-tenth of the population in the top 20 percent cites clean energy as their primary energy source for cooking.

The choice of gas is driven in many instances by historical fuel price subsidy policies, which in some cases have continued to this day. Where natural gas is not available and LPG has not been subsidized but electricity has historically been reliable and cheap, such as in Southern Africa, the rich cook with electricity. Aside from price and supply reliability, community-wide familiarity with a particular technology and fuel, and economies of scale arising from popular use, may be partially driving the pattern of each economy's showing dominant preference for gas or electricity.

Households are far less likely to use clean forms of energy for space heating, presumably because of the much greater demand for energy and hence the much higher cost of heating with gas or electricity. This makes it challenging to attain universal access to clean energy where much heating is needed in winter, but also underscores the importance of shifting households to clean cooking energy so as to be able to focus the attention of households and policymakers next on clean heating energy.

Context and Study Objective

The United Nations General Assembly in 2015 announced 17 Sustainable Development Goals (SDGs) with 169 associated targets to demonstrate the scale and the ambition of the 2030 Agenda for Sustainable Development (United Nations 2015). Among the 17 SDGs is SDG 7, "access to affordable, reliable, sustainable, and modern energy."[1] Of the six indicators associated with SDG 7, two concern household access to such energy by 2030, measured by the proportion of population with access to electricity and similarly the proportion of population with primary reliance on clean fuels and technology for cooking, heating, and lighting. Of the two indicators, access to electricity has seen much faster progress. According to *Tracking SDG 7: The Energy Progress Report 2021*, the number of people without access to electricity fell from 1.2 billion in 2010 to 0.76 billion in 2019, compared to the number of those lacking access to clean cooking solutions falling from 3 billion to 2.6 billion during the same period (IEA, IRENA, UNSD, World Bank, and WHO 2021).

Globally, at the high end of the income spectrum, only two types of energy are routinely used for cooking: electricity and gas. Gas would be either natural gas where a gas pipeline network is available, or LPG where natural gas is not available, the latter of which is predominantly in rural areas. Natural gas is always preferred over LPG because, with the exception of initial connection to a gas pipeline, natural gas is cheaper and more convenient. Over time, the entire world might move to exclusive use of electricity or gas. A few kitchen appliances, such as microwave ovens, are based entirely on electricity. Purely from the point of view of cooking, gas had almost universally been considered superior until recently. The versatility and accuracy provided by the flame heating of gas was considered to have no parallel. Gas stoves[2] respond immediately to temperature setting changes, giving precise control. By contrast, electric stoves respond more slowly to temperature setting changes, especially when the temperature is being lowered or when heat is turned off. And gas, but not electricity, enables the cook to char and flambé food.

For the foregoing reasons, top chefs and restaurants have historically preferred gas to electricity. However, induction cooktops—for many years considered out of reach on account of their costs—have come down in price and begun shifting these perceptions on account of its ability to control temperature. Induction cooking heats by transferring currents from an electromagnetic field located below the cooktop surface directly to the magnetic induction pots and pans above. An induction cooktop adjusts temperature quickly and achieves a more uniform distribution of heat. Because there is no transfer of heat itself, the burner of an induction cooktop does not get hot, the kitchen remains cooler than with other technologies, and the cooktop is the easiest to clean and has the highest efficiency of all technologies. From the point of view of safety and the potential for decarbonization, stoves using electricity are superior. Decarbonization of the electricity supply would enable clean cooking from both the global and local perspectives. In developing countries, however, one significant deterrent to use of electricity for cooking is a lack of reliable electricity supply.

The indicator for clean fuels and technology for cooking may be relatively straightforward to track but the results need to be interpreted with caution. First, cooking is not the only household activity that requires energy—as just one example, in cold-climate countries households use even more energy for heating. Second, the definition of what is clean is situation-specific and a binary choice between clean and unclean is not necessarily helpful, nor is the link to the ultimate goal of achieving universal access to "affordable, reliable, sustainable, and modern energy" obvious. Third, fuel and technology stacking can be the norm

[1] https://unstats.un.org/sdgs/report/2019/goal-07/.

[2] More precisely, gas cooktops, which apply heat to the base of pots and pans. By contrast, electric ovens provide better temperature control than gas ovens.

rather than the exception among many households in developing countries. A household spending nearly half of cooking time or cooking nearly half of all the meals using what is not classified as clean energy is nevertheless classified as having obtained access to clean fuels and technology, even if they are exposed to high levels of harmful pollutants from non-primary sources of cooking energy. Fourth, counting households based on self-reporting on their primary sources of energy for cooking risks over-estimation of clean energy use: studies have found that households tend to over-state the use of energy widely considered by their communities to be "clean." For these reasons, ESMAP (2020) points out that using primarily an indicator that relies on binary classification of households into those using clean cooking energy and those not using such energy can lead to overlooking otherwise effective, sustainable, and improved cooking solutions that meet specific local needs. A definition based on categorizing gaseous fuels, electricity, and solar energy as clean and anything else as not clean misses technologies that take a solid fuel and combusts it with minimal emissions of harmful pollutants, such as pelletized biomass used in advanced combustion stoves (ESMAP 2020, box 1.1).

The above limitations notwithstanding, this paper examines household energy use patterns in 52 developing economies by looking at primary sources of energy for cooking and heating using the most recent data available from the Multiple Indicator Cluster Surveys (MICS)[3] conducted by UNICEF. The objective is to understand differences in energy use patterns between urban and rural households, between the poor and the better-off, and across developing economies with different levels of income as measured by gross domestic product (GDP) per capita.

MICS are among the three named data sources cited by the United Nations to track the indicators for the household energy component of SDG 7.[4] UNICEF has been collecting internationally comparable data on health, sanitation, education, and other factors affecting women and children for MICS beginning in 1995. Since 2005, the surveys have included questions on the main sources of energy used for cooking, and questions about space heating and lighting were added in 2017.

One advantage of using data from MICS is that an identical methodology is used in every economy from start to finish—the same survey design, sampling framework, training of field workers, data collection and processing, quality control, and reporting—thereby enabling direct comparison of the findings across the economies surveyed. Another advantage of MICS compared to other standardized surveys, such as the Demographic and Health Surveys that also collect data on household energy (and starting in 2018 adopted questions that are identical to those in MICS), is the disaggregation of the results by wealth index quintile in MICS. Because wealth is one of the most important determinants of household energy choice, such disaggregation adds immeasurably to the value of the data collected.

Survey Description

The MICS results are disaggregated by location, wealth index, the education level of the head of the household, and a few other parameters specific to each economy such as religion and ethnic group. The wealth index quintiles are constructed from data on housing characteristics, household and personal assets, and water and sanitation using principal component analysis. For the 52 surveys analyzed in this paper, the median sample size was 11,158 households, ranging from 2,498 in Tonga to 61,242 in Bangladesh. All the percentages in MICS are of the number of people in the survey (the number of households multiplied by household size) and not of households. Unlike national household expenditure

[3] https://mics.unicef.org/.
[4] https://unstats.un.org/sdgs/metadata/files/Metadata-07-01-02.pdf.

surveys, MICS do not use household weights in calculating results. Each wealth index quintile contains the same number of people.

MICS consider electricity, LPG, natural gas, biogas, solar energy, and ethanol as clean forms of energy. Among them, only electricity and solar energy have zero emissions of harmful pollutants at the site of cooking. Depending on the degree of combustion, all other fuels could potentially emit small amounts of substances harmful to health, although if properly operated the amounts emitted could be made to fall below the detection limits and become immeasurable. The questionnaires administered to date unfortunately have not included advanced combustion stoves as a technology option. Not including them probably has not materially affected the results to date because their regular use has been relatively rare, but in the future there could be an increasing need to capture them. The technologies and fuels that households are asked about can be found in a 2016 catalogue (WHO 2016).

"Clean" in the indicator is defined purely from a local environmental point of view. The emission rate targets and recommendations made by the World Health Organization (WHO) in the *WHO Guidelines for Indoor Air Quality* (WHO 2014) are used to define clean fuels and technology. The targets are for emissions in mass per minute of particulate matter with an aerodynamic diameter of 2.5 microns ($PM_{2.5}$) and carbon monoxide (CO), accompanied by target ambient concentrations for $PM_{2.5}$. The final ambient concentration target for $PM_{2.5}$ is for 90 percent of all kitchens to have a maximum $PM_{2.5}$ annual average of 10 micrograms per cubic meter ($\mu g/m^3$). Based on these target values, electricity; gases such as natural gas, liquefied petroleum gas (LPG), and biogas; solar cookers and heaters; and alcohols such as ethanol are considered clean when the associated appliances are operated properly. There are also interim targets, which are less stringent. At the time of the publication of the guidelines, there was only limited evidence in the field of the impact on air pollution of advanced combustion stoves for solid biomass and no modeling had been attempted (WHO 2014). Since then, there have been more studies measuring emissions and pollutant concentrations using advanced combustion stoves for solid fuels.

As mentioned in the preceding section, the findings on the main sources of energy for cooking and heating need to be interpreted with caution, especially to understand the impact of household energy use on health.

- Each household is asked to name only one type of stove used for cooking, and for non-electric stoves, only one fuel used in that stove. There is ample evidence in the literature that stove and fuel stacking is widespread. Especially among those who use solid fuels in any capacity, the types of stove and fuel used depends on the dishes cooked and seasonality of fuel availability. This means that the "main" cooking fuel in one season may become a minor one in another season. For example, during the rainy season when dry wood is scarce, charcoal may substitute wood. Some fuel supplies, such as crop residues, are seasonable and not necessarily available throughout the year. Even when a clean form of energy is cited as the main cooking fuel, the impact on ambient concentrations of harmful pollutants is uncertain because of fuel stacking.
- Where cooking fuel choice is self-reported, as in this type of survey, there is a tendency to over-state use of clean fuels and technologies. Kojima (2021) cites examples of over-reporting of LPG use, and Piedrahita et al. (2016) found in northern Ghana that self-reporting of the use of clean technology for cooking was over-stated by the largest margin for the cleanest technology studied when compared to data provided by stove use monitors.
- There are other uses of household energy not captured by the survey, including preparation of animal feed and heating water, which can comprise a large share of household energy.

- There are other sources of emissions not linked to fuel combustion, such as smoking, dust, and semi-volatile organic compounds released by food when it is being cooked, although their toxicity varies.
- As mentioned above, even if a household uses only clean forms of energy for all their activities, ambient concentrations of pollutants depend on emissions by other households and non-residential activities such as agricultural field burning. It is for this reason that households using, for example, only LPG and electricity to meet all their energy needs may still be exposed to elevated concentrations of fine particulate matter even inside their homes.

MICS Survey Results

The 52 economies covered in this paper are listed in Table A.1 in the appendix, together with the dates of the survey data collection, the urban and rural split, data on electrification (which provides one indication of infrastructure development), and the percentage of people who had cited a clean fuel or technology (referred to as clean energy hereafter in this section) as the primary source of energy for cooking. All surveys available in recent years that asked questions about cooking are included in the analysis.[5]

The top two choices for primary cooking energy sources in each economy are shown in Table 1. Natural gas, LPG, and biogas are combined into a single category named gas in the table. The top-ranked primary energy source is used by more than half of the population in 22 economies and by more than two-thirds in 15 economies. The top two ranked choices combined are used by more than two-thirds of the population in 25 economies. The most common top-ranked choice was wood, closely followed by gas (Figure 1). The most common second-ranked choice was gas, cited in 19 economies, followed by charcoal, cited in 15 economies.

Table 1: Top two choices for primary cooking energy sources

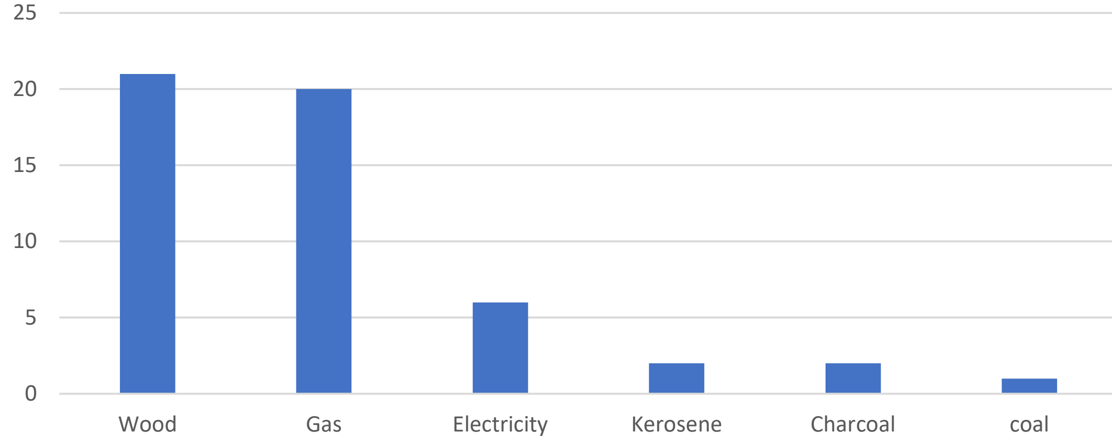
Economy	Top rank	% of population	Second rank	% of population
Algeria	Gas	98	Electricity	1
Bangladesh	Wood	40	Crop residue	36
Barbados	Gas	95	Electricity	5
Belize	Gas	80	Wood	15
Benin	Charcoal	70	Coal	24
Cameroon	Wood	75	Gas	16
Central African Republic	Wood	90	Charcoal	7
Chad	Wood	86	Charcoal	5
Congo, Dem. Rep.	Wood	59	Charcoal	35
Congo, Rep.	Wood	36	Gas and kerosene[a]	26
Côte d'Ivoire	Wood	56	Gas	26
Cuba	Electricity	55	Gas	37
Dominican Republic	Gas	86	Charcoal	3
Eswatini	Wood	62	Electricity	27
Gambia, The	Wood	71	Charcoal	25
Georgia	Gas	90	Wood	8

[5] The surveys conducted in Costa Rica in 2018, Eswatini in 2018, and Turkmenistan in 2019 did not include questions about cooking energy and hence are not included.

Economy	Top rank	% of population	Second rank	% of population
Ghana	Wood	52	Charcoal	31
Guinea	Wood	62	Charcoal	37
Guinea-Bissau	Wood	65	Charcoal	33
Guyana	Gas	69	Wood	7
Iraq	Gas	98	Kerosene	1
Kazakhstan	Gas	82	Electricity	17
Kiribati	Kerosene	43	Wood	36
Korea, Dem. People's Rep.	Coal	62	Wood	21
Kosovo	Charcoal	65	Electricity	29
Kyrgyz Republic	Electricity	51	Wood	19
Lao PDR	Wood	67	Charcoal	26
Madagascar	Wood	74	Charcoal	24
Malawi	Wood	84	Charcoal	14
Mali	Wood	83	Charcoal	14
Mauritania	Gas	39	Wood	36
Mexico	Gas	84	Wood	14
Mongolia	Electricity	48	Wood	18
Montenegro	Electricity	56	Wood	36
Nepal	Wood	54	Gas	42
Nigeria	Wood	69	Kerosene	13
North Macedonia	Electricity	61	Wood	23
Paraguay	Gas	51	Wood	23
São Tomé and Príncipe	Kerosene	46	Wood	40
Serbia	Electricity	67	Wood	17
Sierra Leone	Wood	67	Charcoal	31
Sudan	Gas	41	Wood	41
Suriname	Gas	89	Wood	4
Thailand	Gas	77	Charcoal	10
Togo	Wood	55	Charcoal	37
Tonga	Gas	79	Wood	14
Tunisia	Gas	96	Electricity	3
Turkmenistan	Gas	98	Electricity	2
Uruguay	Gas	94	Electricity	4
Vietnam	Gas	55	Wood	35
West Bank and Gaza	Gas	96	Electricity	3
Zimbabwe	Wood	69	Electricity	24

Source: World Bank staff calculations based on MICS survey findings reports available at available at http://mics.unicef.org/surveys.
a. Gas and kerosene were tied for the second rank.

Figure 1: Number of economies citing different energy sources as their top-ranked primary cooking energy



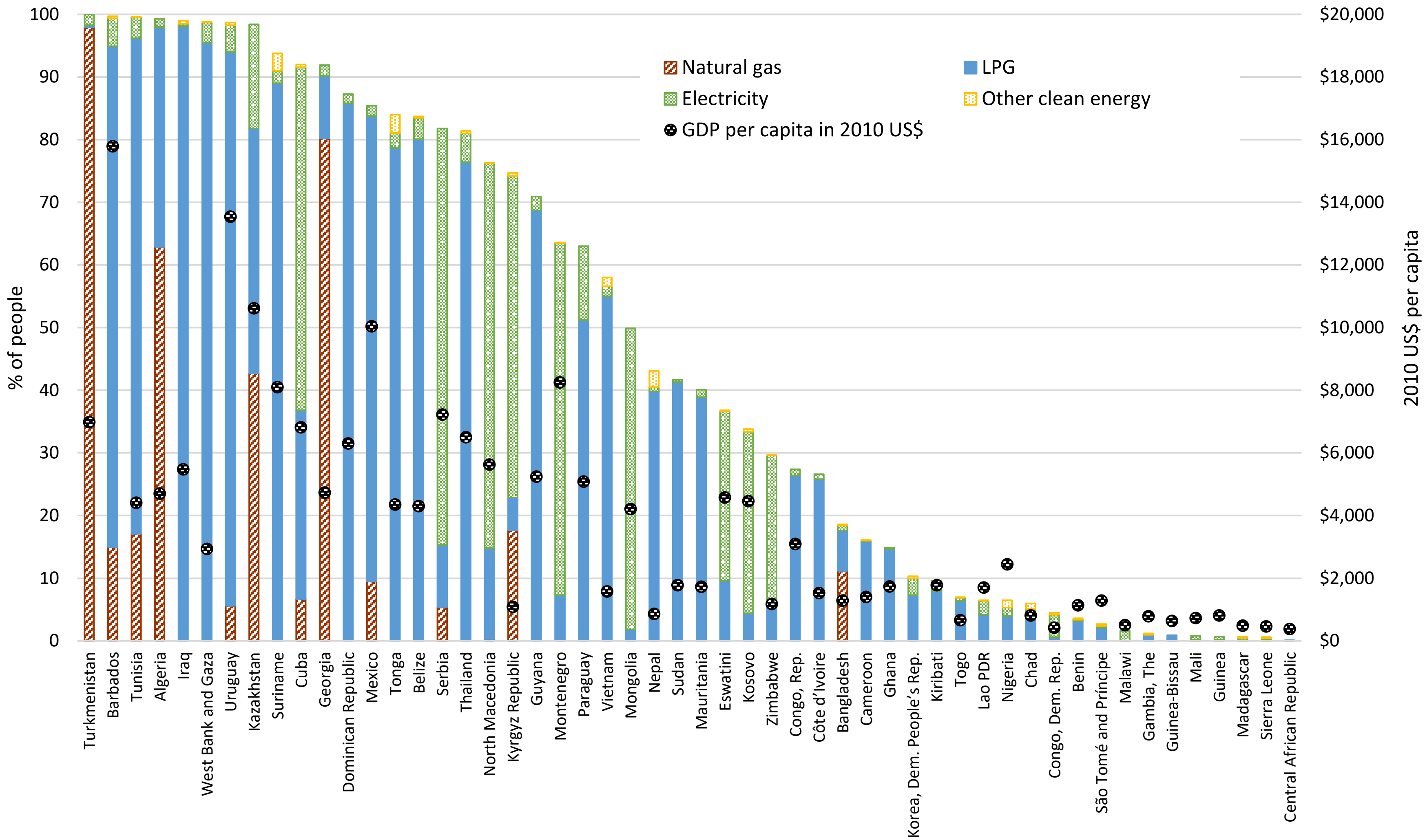
Source: World Bank staff calculations based on MICS survey findings reports available at available at http://mics.unicef.org/surveys.

Figure 2 shows the percentage of people citing clean energy for cooking, ranked in order of decreasing share of the population using clean energy. Also shown is GDP per capita in the year of the survey expressed in 2010 U.S. dollars converted at the official exchange rate as one indication of the economic status of the economy. Most economies where more than half of the total population used clean energy for cooking had GDP per capita of US$4,000 or higher. There are three exceptions, the most notable of which was the Kyrgyz Republic with barely more than US$1,000 per person, followed by Vietnam, and finally the West Bank and Gaza. There are also three economies with per capita GDP of US$3,000 or higher in which a majority of people used polluting forms of energy for cooking: Eswatini, Kosovo, and the Republic of Congo. With one exception, the top 15 economies with clean cooking relied predominantly on gas, and on natural gas in Turkmenistan, Algeria, Kazakhstan, and Georgia. Electricity was the dominant form of energy for cooking only in Cuba. By contrast, five of the next nine economies making up the rest of the 24 economies with half or more of the population cooking with clean energy relied predominantly on electricity, signaling reliability and ready availability.

Cooking patterns of urban residents show strong preference for gas over electricity or vice versa (Figure 3). Natural gas is cheaper and more convenient than LPG, resulting in selection of natural gas over LPG by urban households preferring to cook with gas and connected to a natural gas pipeline. Turkmenistan, Algeria, Kazakhstan, and Georgia appear fall under such a category.

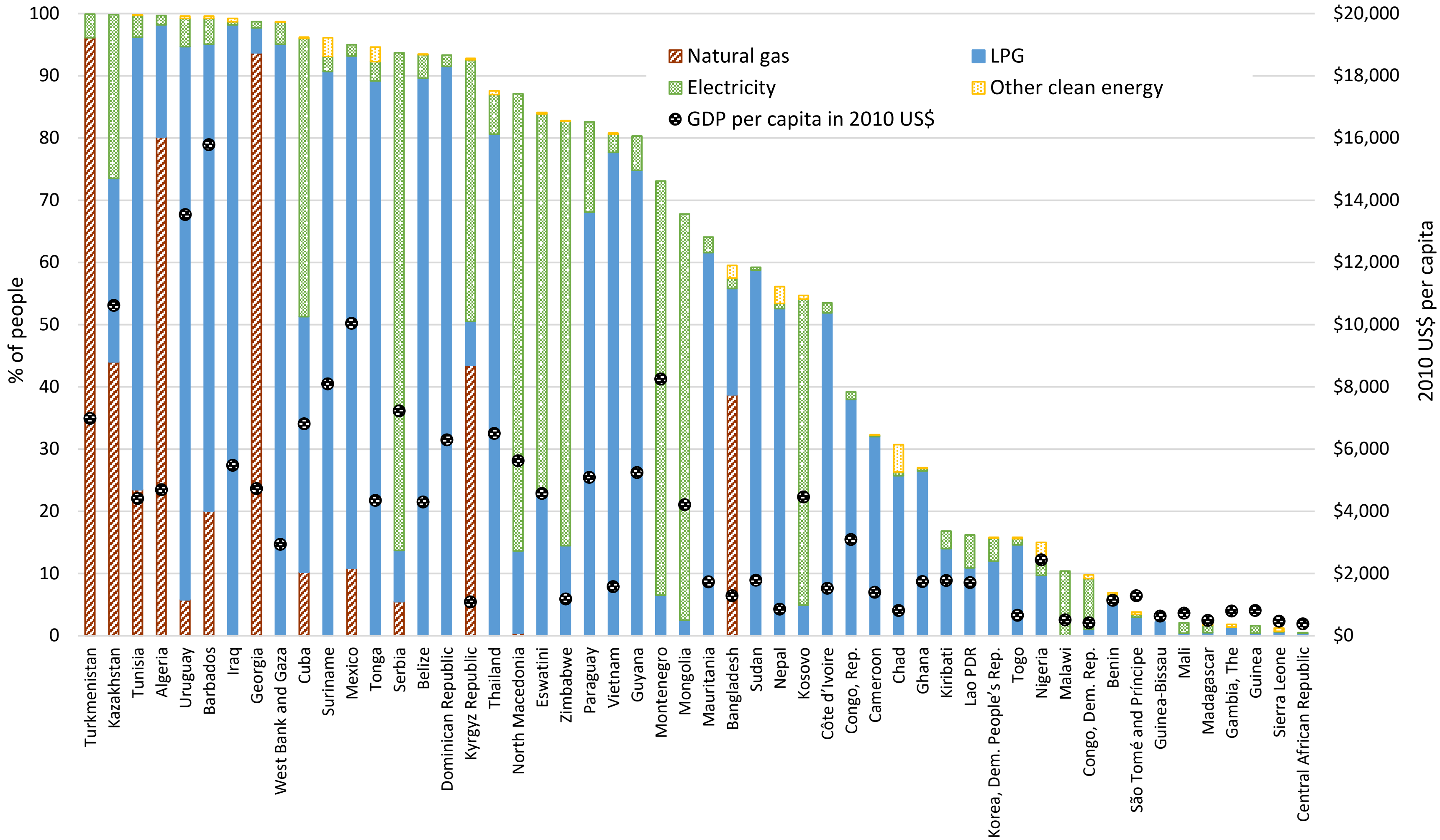
Rural areas in lower-income economies tend to lack paved roads (needed for trucking LPG cylinders) and electricity. Disposable cash income is generally limited, while freely available biomass (wood, crop residues, straws) is more plentiful. All these factors make use of clean energy less prevalent (Figure 4). In the 23 economies where less than 10 percent of rural residents used clean energy, 18 had an electrification rate lower than 40 percent. At the opposite end of the spectrum are ten economies where urban residents had access to natural gas but many fewer rural residents did, and a greater share of rural residents used LPG than urban residents, which is also the pattern in high-income economies.

Figure 2: Share of the population using different forms of clean energy as the primary source for cooking



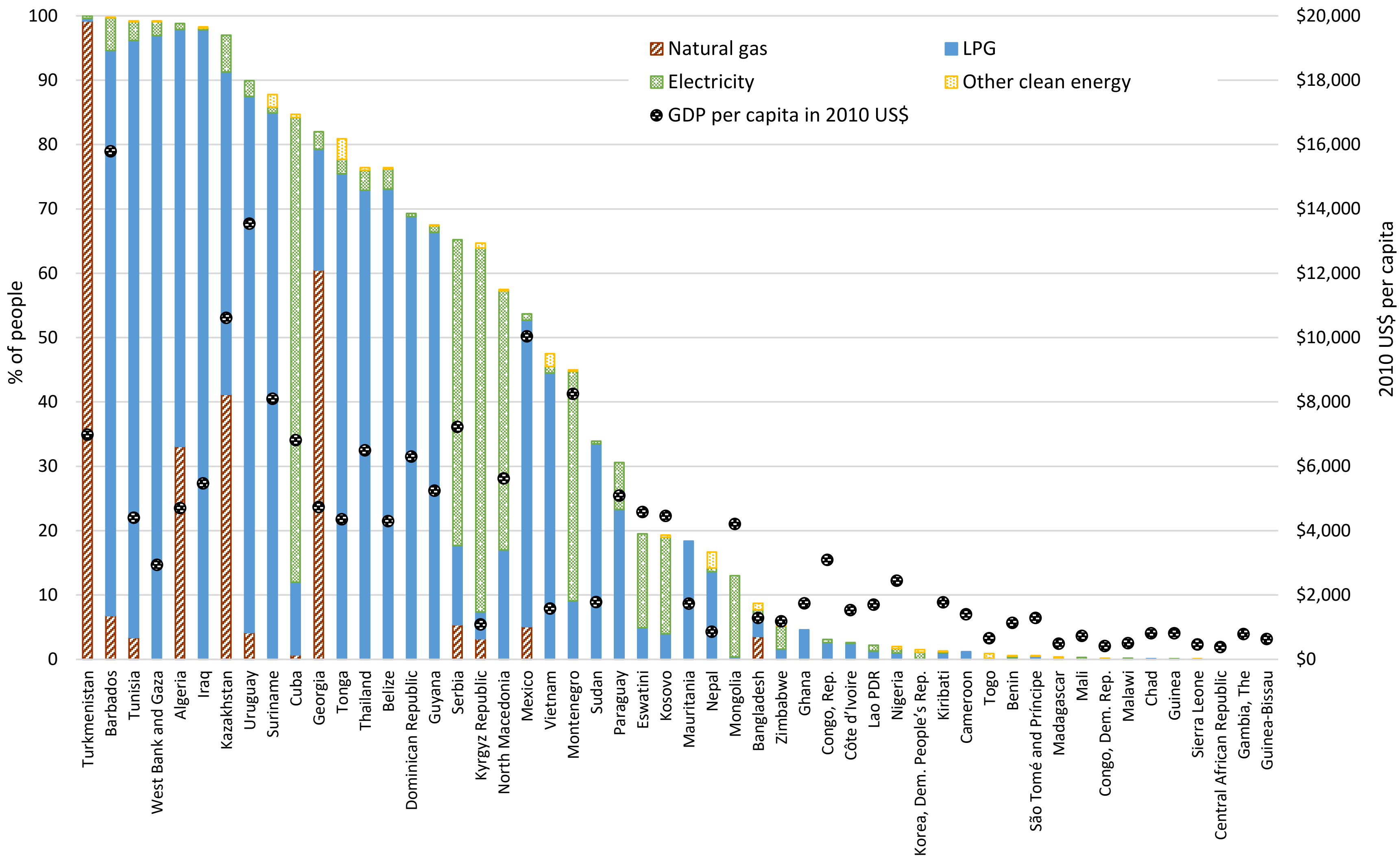
Source: World Bank staff calculations based on MICS survey findings reports available at available at http://mics.unicef.org/surveys.
Note: "Other clean energy" is largely biogas but also includes solar energy, in rare cases alcohol, and unspecified forms of clean energy. There is no information available on GDP for the Democratic People's Republic of Korea. GDP per capita in 2018 is used for Cuba because the 2019 value is not yet available.

Figure 3: Share of the urban population using different forms of clean energy as the primary source for cooking



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: "Other clean energy" is largely biogas but also includes solar energy, in rare cases alcohol, and unspecified forms of clean energy. There is no information available on GDP for the Democratic People's Republic of Korea. GDP per capita in 2018 is used for Cuba because the 2019 value is not yet available.

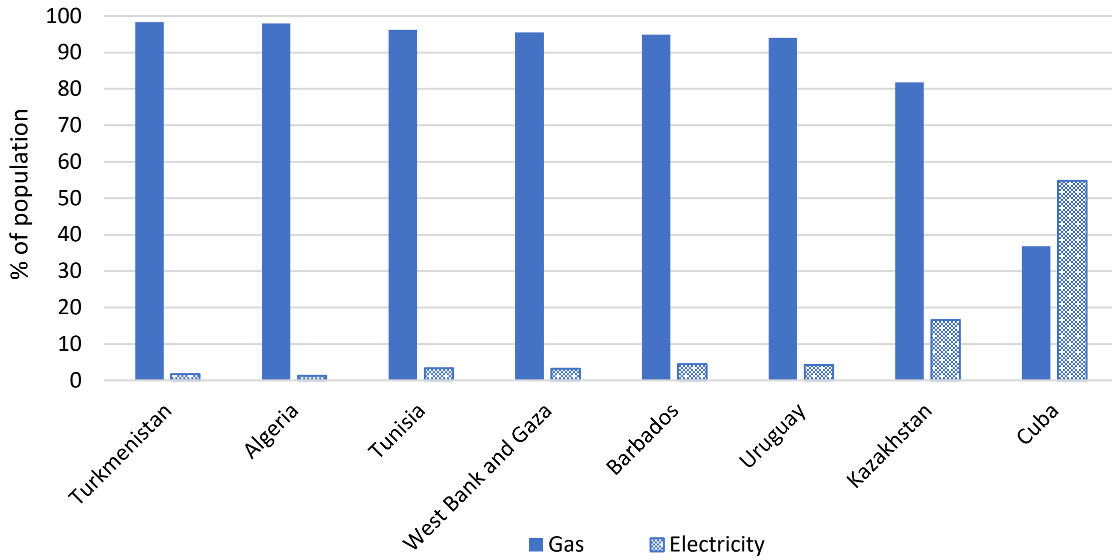
Figure 4: Share of the rural population using different forms of clean energy as the primary source for cooking



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: "Other clean energy" is largely biogas but also includes solar energy, in rare cases alcohol, and unspecified forms of clean energy. There is no information available on GDP for the Democratic People's Republic of Korea. GDP per capita in 2018 is used for Cuba because the 2019 value is not yet available.

When different primary sources of energy for cooking are ranked in each economy by the share of the population citing them, only eight economies saw electricity and gas (LPG, natural gas, and biogas combined) rank in the top two. In such cases, people did not choose electricity and gas in comparable proportions. Instead, in all economies but one, gas was chosen overwhelmingly over electricity (Figure 6).

Figure 5: Economies with gas and electricity as top two choices for primary cooking energy sources

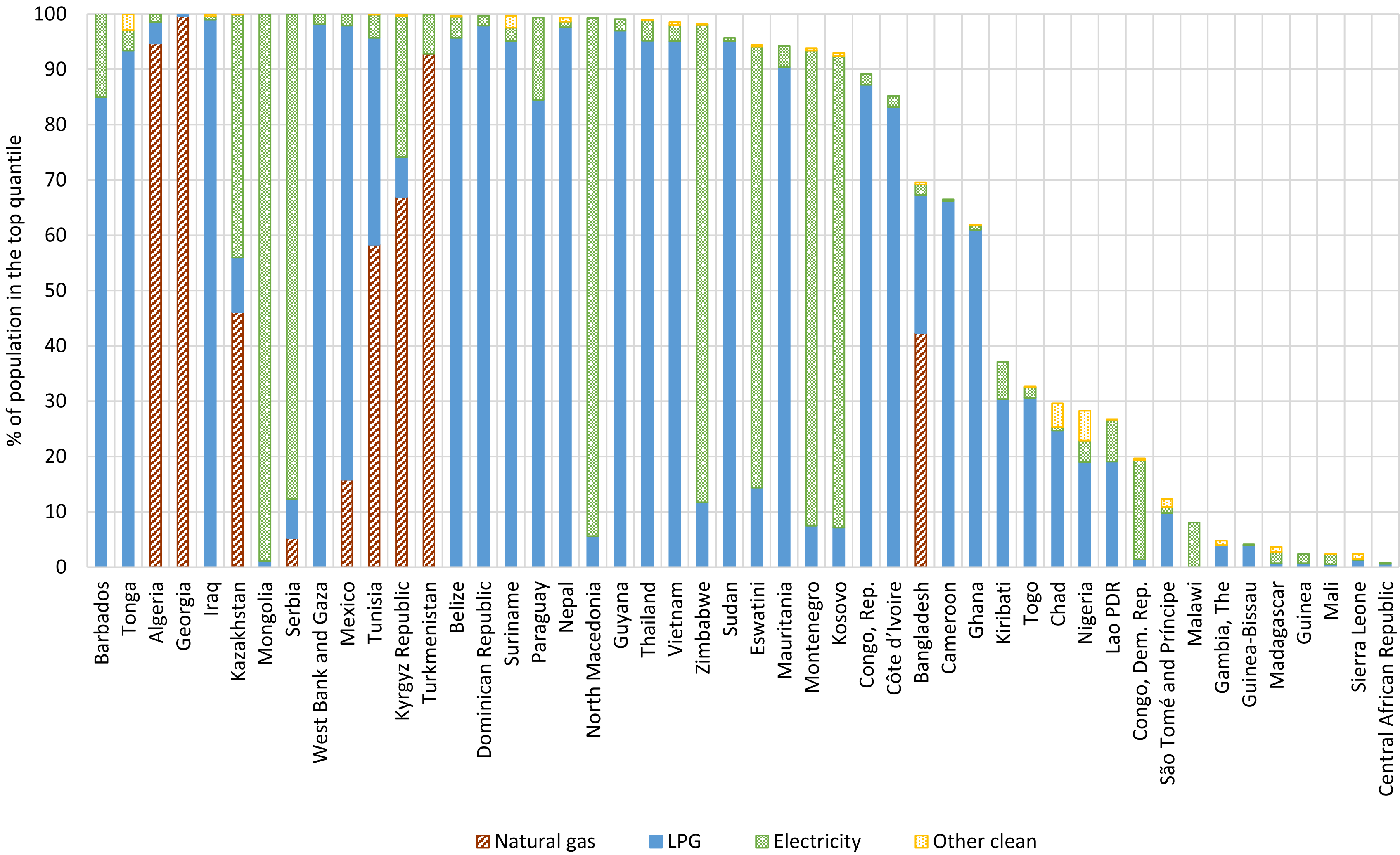


Source: World Bank staff calculations based on MICS survey findings reports available at available at http://mics.unicef.org/surveys.

The future of household energy for cooking could be gleaned some from examining energy use patterns among the top 20 percent of the population, shown in Figure 6. Although MICS survey reports do not provide the split between urban and rural for the wealth index, the top quintile is expected to be dominated by urban residents. In total, 48 economies reported household energy use by quintile, more than half of which found 90 percent or more of the top quintile citing clean energy for cooking. Across the sample, surveys in 41 economies found that 80 percent or more of the people living in households using clean energy for cooking relied on gas (37 economies) or electricity (3 economies) as the primary source of energy, demonstrating the preference of households for cooking with gas.

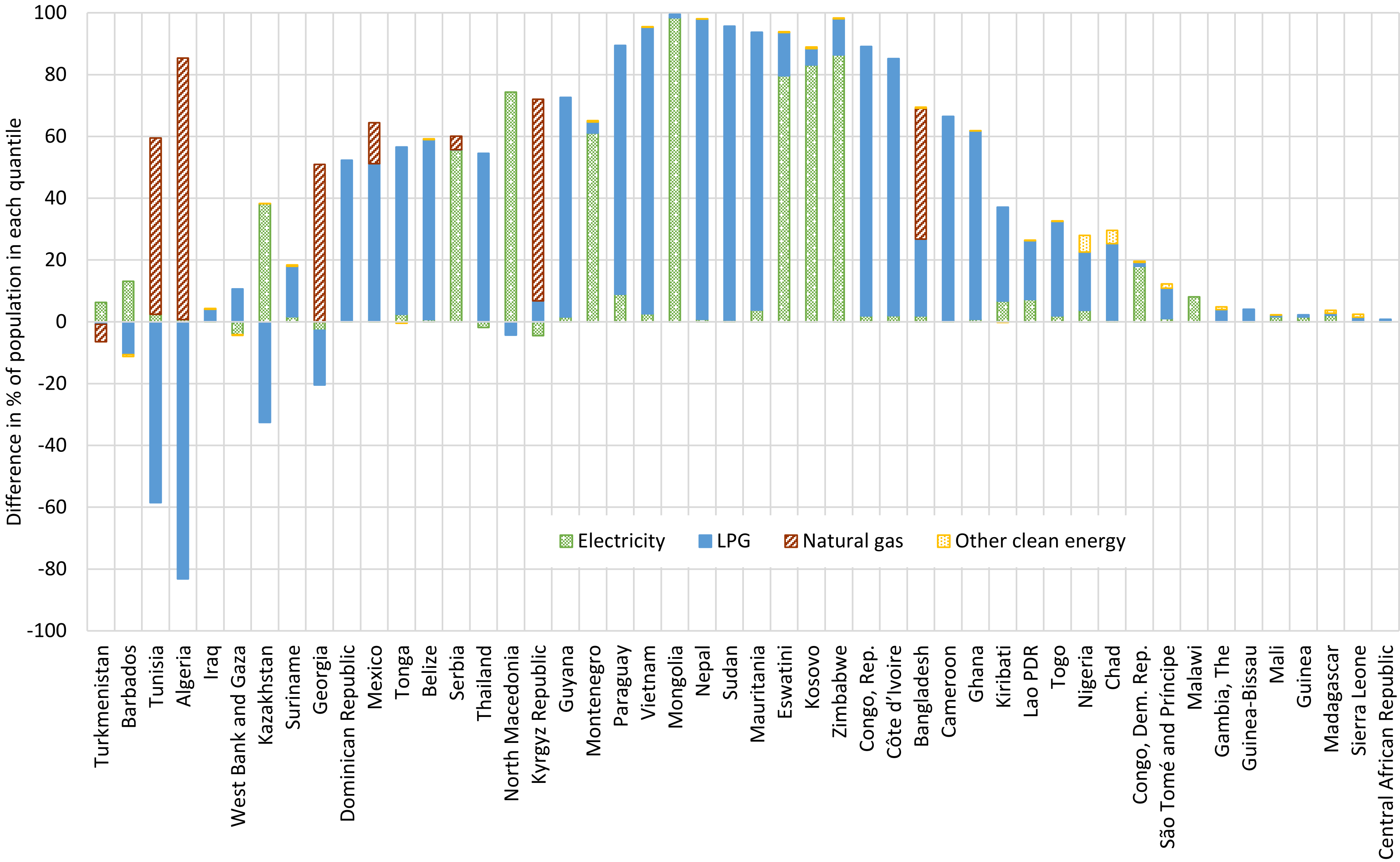
Another way of gleaning how household energy patterns might evolve is to look at the difference between the top and the bottom quintile. Figure 7 shows which form of clean energy is used more as wealth rises from the bottom 20 percent to the top 20 percent, and Figure 8 shows which forms of polluting energy are used less. Each figure takes the percentage of people in the top quintile citing the given form of energy as their primary cooking energy and subtracts the corresponding share found in the bottom quintile. In gas-rich economies, households abandon LPG in favor of natural gas, although that is typically not possible in rural areas and the difference may, to a large extent, reflect the fact that the poor live in rural areas with no natural gas pipeline network while the rich live in urban areas with access to natural gas. An interesting case is Kazakhstan, where the electrification rate in rural areas was 99.9 percent, the share of people using clean energy was nearly the same between urban and rural areas, and even in the bottom quintile 94 percent of all people cited clean energy for cooking. Yet nearly eight times as many people in the top quintile cited electricity as their primary cooking energy source than in the bottom quintile. Across the sample economies, an even split between gas and electricity was rare and one was favored overwhelmingly over the other.

Figure 6: Clean cooking energy used by the top quintile



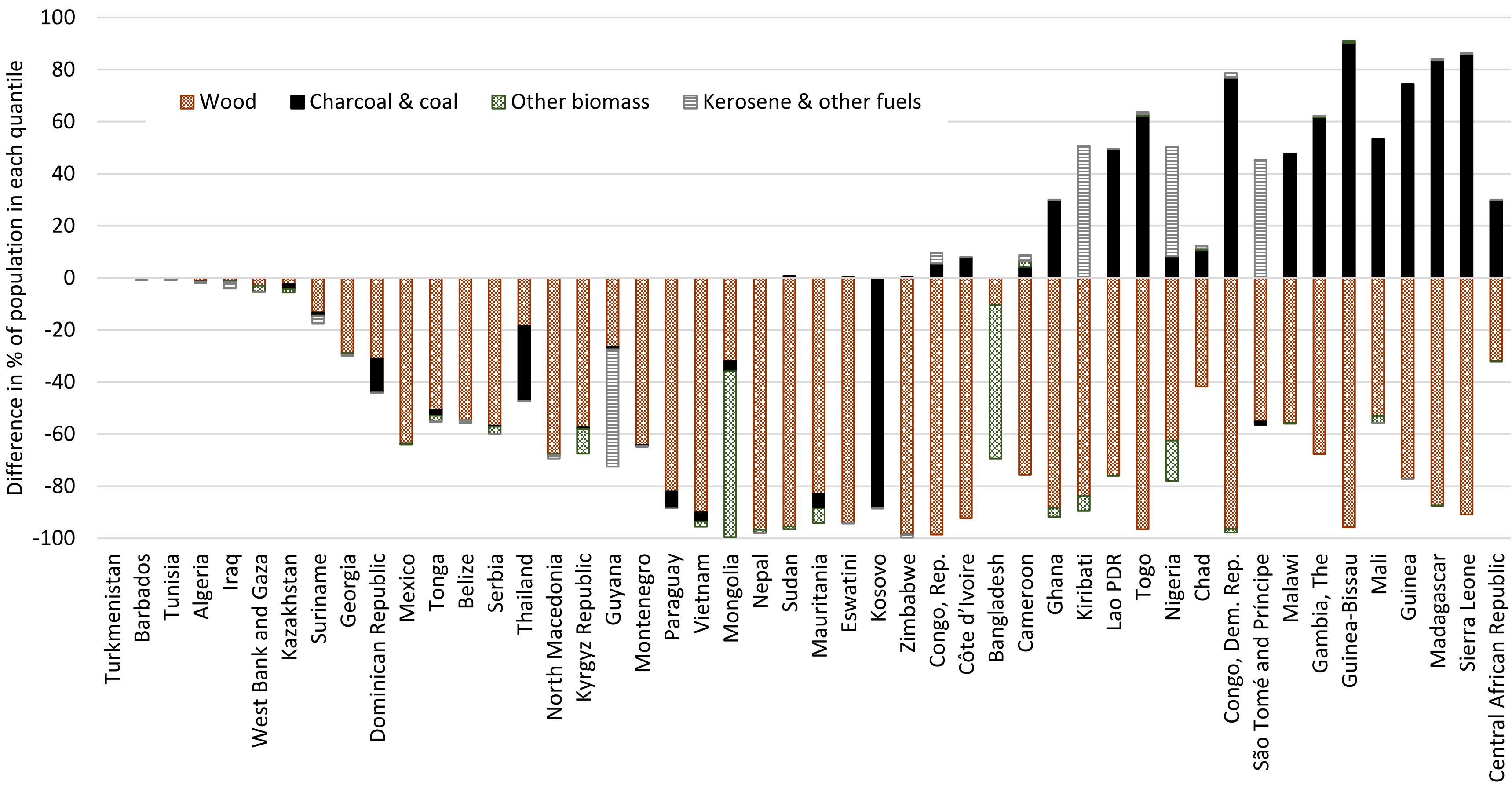
Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: "Other clean energy" is largely natural gas where the share is material, but also includes biogas, solar energy, in rare cases alcohol, and unspecified forms of clean energy.

Figure 7: Difference in the share of the population using clean energy as the primary source of cooking between the top and bottom quintile



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: The economies are listed in the same order as in Figure 2. Beni, Cuba, Democratic People's Republic of Korea, Lao People's Democratic Republic, and Uruguay are omitted because their respective reports do not contain results by wealth index quintile. The percentage of the population using a given form of energy in the bottom wealth index quintile is subtracted from that in the top wealth index quintile. Other clean energy = biogas, solar energy, and unspecified forms of clean energy.

Figure 8: Difference in the share of the population using polluting energy as the primary source of cooking between the top and bottom quintile



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: The economies are listed in the same order as in Figure 2. Beni, Cuba, Democratic People's Republic of Korea, Lao People's Democratic Republic, and Uruguay are omitted because their respective reports do not contain results by wealth index quintile. The percentage of the population using a given form of energy in the bottom wealth index quintile is subtracted from that in the top wealth index quintile. "Charcoal & coal" is mostly charcoal and the share of people in the bottom or top quintile using coal as the primary cooking fuel exceeded 1 percent only in Côte d'Ivoire, Kazakhstan, Madagascar, Mali, Mongolia, and Vietnam. "Other biomass" consists of animal dung, crop residues, grass, straws, and shrubs. "Other fuels" in "kerosene & other fuels" include "gasoline/diesel" in Ghana, Sierra Leone, and Suriname; refuse and plastics; and otherwise unspecified fuels. Gasoline and diesel are never used in cooking, and in Suriname it may be that they were confused with kerosene because only lower quintiles used "gasoline/diesel," In Ghana and Sierra Leone, however, only the top quintile used gasoline/diesel, suggesting that they could have been used for generating electricity, although only 0.1 percent of the population in the top quintile reported using gasoline/diesel as the primary cooking fuel in these economies.

Among the economies where there was essentially no clean cooking in the bottom quintile, increasing wealth shifted a sizable fraction of households to charcoal. In the 11 economies where less than 1 percent of the bottom quintile used clean cooking, more than 90 percent of all people in the same quintile used three-stone fires as their primary cookstoves. Benin (for which quintile information was not available), the Democratic People's Republic of Korea (for which quintile information was aggregated by summing quintiles 2 and 3 as a single group and quintiles 4 and 5 as another group), and Mongolia were the only economies where coal use was significant. In the latter two economies, coal use rose with quintile and then fell. Kiribati, Nigeria, and São Tomé and Príncipe were the exceptions to the observation about charcoal, whereby the top quintile chose kerosene instead of charcoal. Nigeria (where kerosene was heavily subsidized for many years but not LPG and natural gas is not available to households) and São Tomé and Príncipe were the only economies out of 52 where kerosene use rose steadily with wealth. In economies where 30 percent or more of people nationally cooked with clean energy, solid fuels and kerosene were universally abandoned as the main cooking fuels with rising wealth.

Within a given economy, a more granular look at primary cooking energy as a function of wealth quintile shows several different patterns:

- In 15 economies the use of both gas (combination of LPG, natural gas, and biogas) and electricity increased steadily with quintile, although in only one economy did electricity use exceed 10 percent (Kosovo where 85 percent of the top quintile cited electricity as the primary cooking energy source).
- In 14 economies LPG use increased with quintile with no consistent or marked effect on electricity use.
- In eight economies (Barbados, Eswatini, Mongolia, Montenegro, North Macedonia, Serbia, Turkmenistan, and Zimbabwe), gas use (LPG use or LPG and natural gas combined) increased for the first three or four quintiles but then fell, while electricity use increased in the top quintile. Barbados and Turkmenistan were the only economies where gas use was still by far the most dominant in the top quintile. In all other economies, electricity use rose from as low as 0 percent in Eswatini, Mongolia, and Zimbabwe in the bottom quintile to 80–99 percent in the top quintile. LPG use in Eswatini was essentially static at 14–15 percent in the top three quintiles.

In four economies, LPG use fell steadily with quintile. In Algeria, Georgia, and Tunisia, natural gas use replaced LPG, and electricity use did not change much. The increase in natural gas at the expense of LPG most likely signals a shift in households to major urban centers with natural gas pipelines as wealth rises in these economies. In Kazakhstan, natural gas use rose up to the third quintile and then fell, overtaken by electricity use.

As expected, there was limited use of biogas and alcohol. A total of 23 economies reported a non-zero share of the total population using biogas as the primary cooking fuel (Table 2), but 17 of the 23 economies cited 0.4 percent or less of the total population using biogas, while the share in the five highest ranking economies varied from 1.2 percent in Nigeria to 2.9 percent in Tonga. One may expect biogas to be a fuel primarily in rural areas, but among the top five economies for biogas use, Suriname, Nepal, and Nigeria had a greater share of the urban population using biogas than the rural population. In the remaining 18 economies, the rural share was greater in only four economies. As for alcohol, there were only two cases of a non-zero percentage of the total citing alcohol as the primary cooking fuel, 0.3 percent in Cuba and 0.1 percent in Zimbabwe.

Table 2: Share of the total population using biogas as the primary cooking fuel and the location with a greater share

Economy	Share	Greater share in	Economy	Share	Greater share in
Tonga	2.9%	Rural	Gambia	0.2%	Urban
Suriname	2.8%	Urban	Kyrgyz Republic	0.2%	Rural
Nepal	2.4%	Urban	Madagascar	0.2%	Neither
Vietnam	1.4%	Rural	Sierra Leone	0.2%	Urban
Nigeria	1.2%	Urban	Bangladesh	0.1%	Urban
Chad	0.9%	Urban	Congo, Dem. Rep.	0.1%	Urban
Uruguay	0.4%	Urban	Eswatini	0.1%	Urban
Barbados	0.3%	Urban	Korea, Dem. People's Rep.	0.1%	Rural
São Tomé and Príncipe	0.3%	Urban	North Macedonia	0.1%	Rural
Thailand	0.3%	Urban	Togo	0.1%	Urban
Belize	0.2%	Rural	Zimbabwe	0.1%	Neither
Benin	0.2%	Urban			

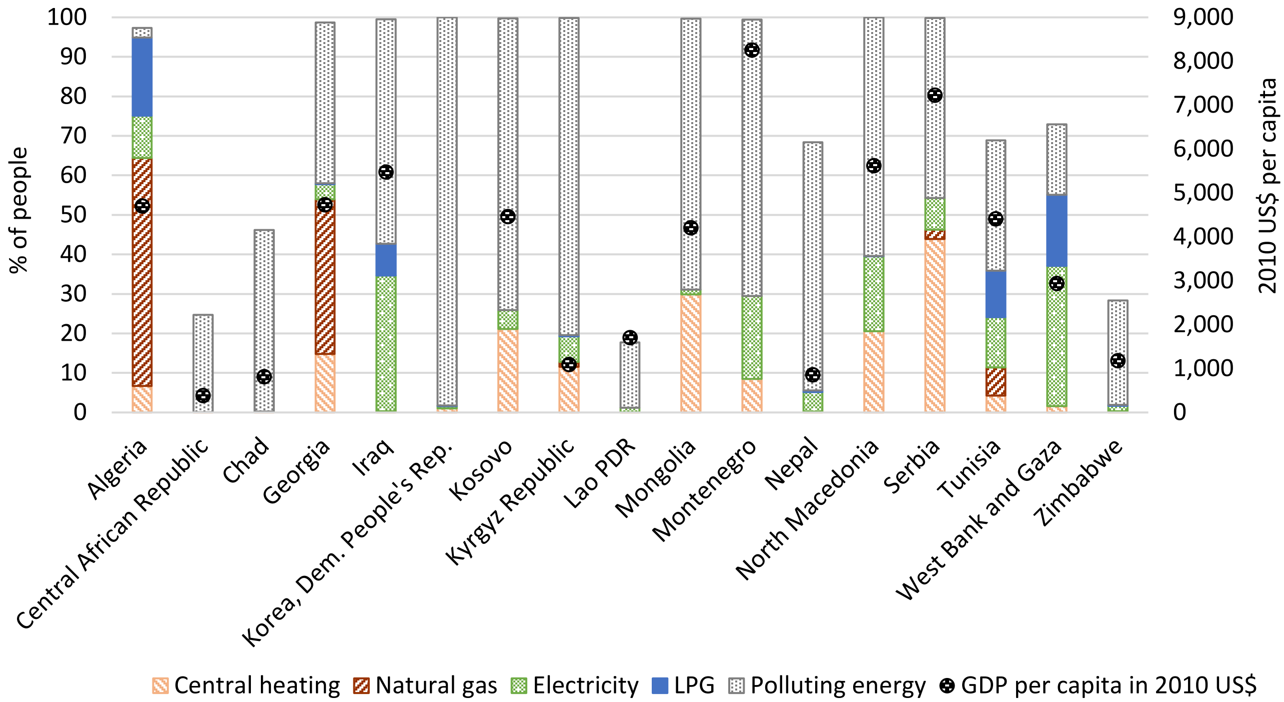
Source: MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: All MICS data are shown to the first decimal point so that a share smaller than 0.1 percent appears as zero. The column under "Greater share in" lists whether rural or urban areas had a greater share of the population using biogas as the primary cooking fuel. "Neither" means the same share of the population cited biogas in urban and rural areas.

The share of the population using clean energy for heating was much smaller than that for cooking in each economy, making space heating the determinant of clean energy use overall—that is, the percentage of people living in homes with clean cooking, space heating, and lighting was very close to that for clean heating. Only 17 economies reported material use of energy for space heating (Figure 9). Where different energy sources do not add up to 100 percent in Figure 9, those who did not report space heating account for the difference.

As expected, use of clean energy for space heating was much rarer in rural areas. Figure 10 takes the same 17 economies shown in Figure 9 and confines analysis only to those households who had reported energy sources for space heating (that is, excluding those who did not report space heating) and shows the share citing clean energy for heating. In 12 out of 17 economies in Figure 10, less than a fifth of the rural population who needed space heating used clean energy. Georgia, Iraq, the Kyrgyz Republic, and Tunisia provided the sharpest contrast between cooking and heating patterns in rural areas, where the share of the rural population using clean cooking energy was higher than the share using clean heating by 60 percentage points or more.

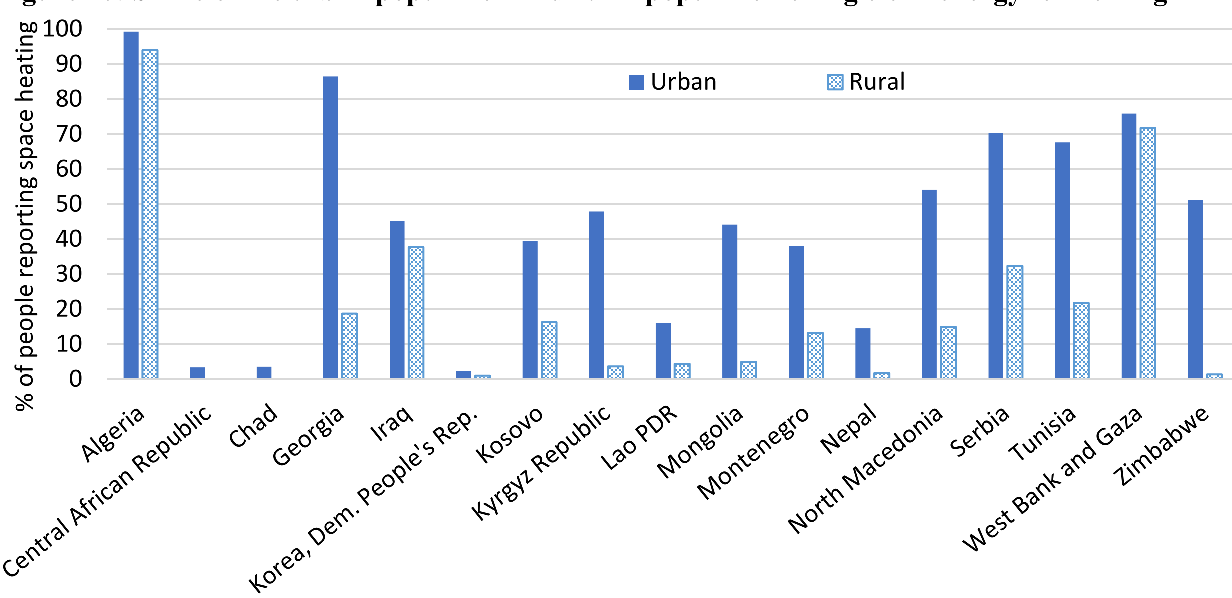
The fuels most widely used in rural areas tended to be the fuels used by the bottom quintile. In the Central African Republic, Chad, Georgia, the Democratic People's Republic of Korea, Kosovo, the Lao People's Democratic Republic, Montenegro, Nepal, North Macedonia, and Serbia, wood was the most common heating fuel among those in the bottom quintile, whereas the bottom quintile used coal in the Kyrgyz Republic, dung in Mongolia, and charcoal in Tunisia. In Mongolia, the fuel use shifted from dung in the bottom quintile to coal in the third quintile before shifting to central heating in the top quintile. In Tunisia, the fuel shifted from charcoal to almost equal proportions of people using electricity, LPG, and central heating in the top quintile. Iraq was unusual in that the bottom quintile used electricity for heating, the use of which was replaced by kerosene as the wealth quintile rose.

Figure 9: Share of the total population using different primary sources of energy for space heating



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: "Polluting energy" consists of all solid fuels and kerosene. Where the sum of the five types of energy does not add up to 100 percent, the balance is the share of households who did not report space heating.

Figure 10: Share of the urban population and rural population citing clean energy for heating



Source: World Bank staff calculations based on MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: "Clean energy" consists of central heating, electricity, natural gas, and LPG. The share shown is the percentage of total urban (or rural) population reporting space heating who had cited clean energy as the primary source of energy for heating.

Discussion

The MICS data show that with rising income households shift to gas or electricity for cooking, and eventually LPG use becomes more prevalent in rural than in urban areas where many households are connected to natural gas pipelines. Interestingly, household preference for gas or electricity is not evenly distributed: aside from Cuba and Kazakhstan, there are no other economies where gas is not overwhelmingly dominate the primary source of cooking energy.

Historical price subsidy policies account for much of the choice of gas or electricity for cooking. Several economies with widespread use of LPG—such as Bangladesh, Cameroon, Côte d'Ivoire, the Dominican Republic, Ghana, Iraq, Mexico, Nepal, Sudan, and Thailand—have in the past provided and in some cases continue to provide large subsidies for LPG, enabling LPG to be established as the dominant cooking fuel. Sudan in particular continues to offer a very large price subsidy, while unreliable electricity in Sudan and several others makes electricity inconvenient and unattractive for cooking. Similarly, the economies in Europe and Central Asia and North Africa with widespread adoption of natural gas have historically provided large subsidies to natural gas (Laderchi, Olivier, and Trimble 2013), skewing energy choice. The government of Turkmenistan even made natural gas available free of charge to households for many years (Kojima 2016).

High-income households in economies such as Eswatini with relatively cheap and reliable electricity in the past, no price subsidies for LPG, and no natural gas pipeline network in place have historically used electricity for cooking. Although the data from only Eswatini and Zimbabwe are available, this pattern appears throughout Southern Africa, where electricity is the energy of choice for better-off households for all their energy needs. In economies with a long history of large LPG or natural gas price subsidies and some continuing to the present, gas use is popular even in the presence of reliable electricity, in part because of the perceived "superior" quality of gas as a cooking fuel. Economies of scale in appliance manufacture or imports and sale, and community-wide familiarity with the technology and fuel may be partially driving this pattern of each economy's showing dominant preference for gas or electricity. In the 13 economies with no natural gas network connecting households and where less than 40 percent of even the top quintile cooked with clean energy, the transition to clean cooking was nascent: households shifted to charcoal as income rose in 10 economies and to kerosene in the remaining three, while a small minority of the rich cooked with LPG or electricity.

The analysis finds that biogas or (bio)ethanol—both considered clean and potentially renewable forms of energy—is rarely used as the primary cooking fuel. It is difficult to produce biogas on the scale required and hence biogas will constitute a niche market for the reasons explained in the next paragraph. Bioethanol is costly to produce: to compete on price with petroleum products, all large-scale fuel ethanol programs in the world have required a mandate, a subsidy, or both, even when oil prices were much higher than today (Kojima and Klytchnikova 2008). It is telling that bioethanol is not used as a cooking fuel even in Brazil, the world's largest and lowest-cost producer. Bioethanol is relatively safe and has a lower risk of burns compared to biomass stoves—although sub-standard stoves raised safety concerns in Madagascar—and, similarly to kerosene, can be purchased in small amounts. However, a lack of low-cost ethanol supply and limited fuel availability, the need to refuel correctly to prevent spillage, and transport and pricing issues (if there is no clear separation of fuel ethanol from alcoholic beverage markets) have plagued programs to launch ethanol as a household fuel (Benka-Coker et al. 2018; Puzzolo et al. 2016).

The disadvantages of biogas that have limited their penetration, especially in Sub-Saharan Africa, include the need for regular maintenance and daily operations, adequate supply of manure (a small plant would require two large animals), sufficient labor, sufficient land and space to construct the digester, and sufficient water, and increased breeding of insects. In cold settings, low temperatures can impair or stop digestion and gas production. In the first phase of the Africa Biogas Partnership Program, biodigesters operated on average for only three years. The fact that not just the cookstove but many other parts can break down also adds to the challenges. Producing enough gas to meet the household needs is another difficulty. In a Kenyan case study, respondents noted that the biogas produced was insufficient for longer cooking tasks, particularly staples like ugali (thick maize porridge), beans, and matoke (green bananas). Biogas has been more successful in Asia than in Sub-Saharan Africa, where construction costs are higher, incomes are lower, and cattle are less frequently stabled. Co-benefits include financial savings from using bio-slurry products as a fertilizer (Puzzolo et al. 2016; Clemens et al. 2018; Shankar et al. 2020).

Electricity should become more competitive with gas for cooking in the future. For several decades now, electric kettles, electric rice cookers, and microwave ovens have been widely used globally even by households who rely primarily on gas for cooking. Induction cooktops have become increasingly available, although even in the United States only 1 percent of stoves had induction cooktops in 2019, according to a report by the Association of Home Appliance Manufacturers (Lynch 2019). Aside from a lack of awareness, the inconvenience of having to rewire to switch from gas to electricity, and the general reluctance to embrace a new technology, other barriers include the high cost of induction cookstoves and their incompatibility with copper, aluminum, and ceramic cookwares.

If adoption of induction cookstoves has not taken off in high-income economies, it would be even slower in developing economies. The Ecuadorian government's attempt between 2014 and 2018, extended by another year to 2019, to promote induction cookstoves gives an illustration of the challenges faced. The government provided generous electricity tariff incentives for this purpose. Households were provided with up to 80 kilowatt-hours of free electricity a month for cooking above the average consumption during the 12 months prior to enrolling in the program—calculated to be equivalent in cost to 16.5 kg of LPG—and another 20 kilowatt-hours for water heating. Consumption above these limits received a 50-percent discount. The government also provided financing with a repayment period of three years to enable program participants to purchase induction cookstoves and electric water heaters at preferential rates, which could be paid through monthly electricity bills. Despite these large incentives, the program met with limited success. Against the initial goal of converting 3 million households to induction cookstoves and another 750,000 to electric water heating, only 642,000 beneficiaries had been recorded as of the end of 2018 (Verdezoto et al. 2019). The incremental cost of switching to electricity, including the acquisition cost of induction cookstoves, was a significant factor. The continuing price subsidies for LPG also did not help.

The above notwithstanding, going forward, two interesting developments to watch are advanced combustion biomass stoves and induction cookstoves. Impressive technological advances have been made in slashing emissions from advanced combustion stoves burning densified biomass pellets. Once advanced combustion stoves go beyond the pilot project stage and enough households start using them for cooking, they will presumably be captured in household surveys as a form of clean cooking. As for induction cookstoves, their declining costs are increasing their market share in several markets. Europe was the largest induction cookware market in 2019, while the highest growth between 2020 and 2024 is expected to occur in the Asia Pacific region.[6] Households already cooking with electricity are likely to be the first to adopt induction cooking. As more and more households switch, the economies of scale achieved can help drive down costs further, enabling others who are currently using other forms of energy to switch.

[6] https://www.technavio.com/induction-cookware-market-industry-analysis.

Aside from the convenience, superior cooking quality than the traditional electric cooking, safety, and zero emissions of harmful pollutants from fuel combustion, electrification of energy-consuming activities is critical to the net-zero-emission pledges made by about four dozen governments (IEA 2021), because it is possible to decarbonize electricity generation. As such, shifting households from petroleum gas (natural gas or LPG) also brings global environmental benefits. If biomass is harvested sustainably, advanced combustion stoves with little black carbon being emitted also reduce the carbon footprint to close to zero. Both induction cookstoves and advanced combustion biomass cookstoves can be part of the net-zero-emission pathways, and the rapidly growing policy focus on alignment with the temperature goal of the Paris Agreement, such pathways could provide yet another incentive to accelerate attainment of access to clean energy.

Appendix

The table below shows the start and the end of the survey, the year selected for GDP per capita, and the share of the population living in urban and rural areas, that with access to electricity, and that using clean energy for cooking.

Table A.1: Economies studied and household characteristics

Economy	Survey			% of population			
	Start	End	Year selected	Urban	Rural	Access to electricity	Clean cooking
Algeria	Dec-18	Apr-19	2019	63	37	98	99
Bangladesh	Jan-19	Jun-19	2019	22	78	2	19
Barbados	May-12	Oct-12	2012	63	37	—	100
Belize	Sep-15	Jan-16	2015	46	54	92	84
Benin	Jun-14	Sep-14	2014	49	52	34	4
Cameroon	Jun-14	Oct-14	2014	48	52	57	16
Central African Republic	Dec-18	Jun-19	2019	35	65	13	0
Chad	May-19	Dec-19	2019	19	81	8	6
Congo, Dem. Rep.	Dec-17	Jul-18	2018	44	56	27	5
Congo, Rep.	Nov-14	Feb-15	2015	67	33	60	27
Côte d'Ivoire	Apr-16	Jul-16	2016	47	53	64	27
Cuba	Mar-19	Aug-19	2018	63	37	100	92
Dominican Republic	Jun-14	Aug-14	2014	75	25	97	87
Eswatini	Jul-14	Oct-14	2014	37	63	65	37
Gambia, The	Dec-17	Jan-18	2018	68	32	63	1
Georgia	Sep-18	Dec-18	2018	59	41	100	92
Ghana	Oct-17	Jan-18	2017	51	49	82	15
Guinea	Aug-16	Nov-16	2016	35	65	34	1
Guinea-Bissau	Nov-18	Mar-19	2019	36	64	36	1
Guyana	Apr-14	Jul-14	2014	27	73	87	71
Iraq	Feb-18	Mar-18	2018	72	28	100	99
Kazakhstan	Sep-15	Nov-15	2015	53	47	100	98
Kiribati	Nov-18	Jan-19	2018	54	46	48	10
Korea, Dem. People's Rep.	Aug-17	Oct-17	2017	61	39	100	10
Kosovo	Dec-19	Mar-20	2019	42	58	100	34
Kyrgyz Republic	May-18	Jul-18	2018	36	64	100	75
Lao PDR	Jul-17	Nov-17	2017	32	68	94	7
Madagascar	Aug-18	Nov-18	2018	25	75	39	1
Malawi	Nov-13	Apr-14	2014	14	86	10	2
Mali	Jul-15	Oct-15	2015	21	79	40	1
Mauritania	Jul-15	Nov-15	2015	47	53	40	40
Mexico	Sep-15	Dec-15	2015	77	23	99	85
Mongolia	Sep-18	Dec-18	2018	68	33	98	50
Montenegro	Oct-18	Dec-18	2018	67	33	100	64

Economy	Survey Start	Survey End	Year selected	% of population Urban	Rural	Access to electricity	Clean cooking
Nepal	May-19	Nov-19	2019	67	33	91	43
Nigeria	Sep-16	Jan-17	2016	37	63	54	7
North Macedonia	Nov-18	Mar-19	2019	64	37	100	76
Paraguay	Jun-16	Sep-16	2016	63	38	98	63
São Tomé and Príncipe	Aug-19	Oct-19	2019	67	33	81	3
Serbia	Sep-19	Dec-19	2019	67	33	100	82
Sierra Leone	May-17	Aug-17	2017	45	55	23	1
Sudan	Sep-14	Oct-14	2014	30	70	45	42
Suriname	Feb-18	Mar-18	2018	75	25	97	94
Thailand	May-19	Nov-19	2019	48	52	100	81
Togo	Jul-17	Oct-17	2017	44	56	55	7
Tonga	Oct-19	Dec-19	2019	23	77	95	84
Tunisia	Feb-18	Mar-18	2018	68	32	100	100
Turkmenistan	Sep-15	Jan-16	2016	39	61	100	100
Uruguay	Nov-12	Nov-13	2013	91	9	—	99
Vietnam	Dec-13	Apr-14	2014	32	68	99	58
West Bank and Gaza	Dec-19	Jan-20	2019	85	15	100	99
Zimbabwe	Jan-19	Apr-19	2019	32	69	56	30

Source: MICS survey findings reports available at http://mics.unicef.org/surveys.
Note: Where a survey overlaps two years, the year selected for the purpose of identifying gross domestic product per capita is the year with more months. — = not available.

In several economies with no gas pipeline network available to households (such as Benin, Cameroon, the Democratic Republic of Congo, Mali, and Togo), natural gas was nevertheless cited as the primary source of energy for cooking for some households. In these cases, natural gas was assumed to represent LPG.

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