FSG REIMAGINING SOCIAL CHANGE

Energy Portfolios of the Rural Poor

Findings From a Pilot Study in India

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This report has been developed and published with financial support from the Shell Foundation. The findings, conclusions, and recommendations contained within these pages are those of the authors and do not necessarily reflect the views, positions, or policies of the Shell Foundation.

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GLOSSARY OF TERMS

Above poverty line (APL): Households for which the monthly per capita expenditure was more than the government-defined threshold of ₹960 ($15). APL households are typically eligible for fewer government subsidies relative to poorer households.

Agrarian households: Households engaged in agriculture and/or animal husbandry.

Below poverty line (BPL): Households for which the monthly per capita expenditure was below the government-defined threshold of ₹960 ($15). BPL households are typically eligible for more government subsidies than more affluent households.

Economic uses: The applications of energy in activities that lead to the production of goods and services, which can be for one's own consumption or for the market, generating disposable income for the household. In this study, economic uses typically refer to agriculture, animal husbandry, and small business (e.g., retail shops).

Energy ladder: A framework used to describe the improvement in energy use of households in developing countries corresponding to an increase in the household's income. According to the energy ladder framework, as household incomes rise they move up the energy ladder, moving away from traditional fuels (such as biomass) to transitional fuels (such as kerosene and charcoal) before finally moving to modern fuels (such as grid-based electricity and LPG), which are superior to traditional or transitional fuels.

Fuel stacking: The behavior exhibited by households of using multiple fuels for a single household activity (e.g., firewood, dung cake, and LPG for cooking).

Modern energy sources: Energy sources that are more efficient and less polluting as compared to traditionally used energy sources, such as biomass. For the purpose of this study, the term relates to central grid electricity, liquefied petroleum gas (LPG), and solar energy.

Monthly per capita expenditure (MPCE): Total monthly consumption expenditure of a household divided by the number of members in the household. MPCE has been used as a proxy for affluence in this study.

Traditional energy sources: Energy sources that households have used for generations and are typically inefficient and more polluting than modern sources. For the purpose of this study, the term relates to dung cake, firewood/agricultural waste, kerosene, and diesel.

FOREWORD

We intend this paper to be a starting point in bringing the voices of rural energy consumers to private-sector efforts, philanthropic and donor interventions, and policy decisions on energy access. We at FSG realized that there was a need to better understand how choices are actually made by examining them from the rural energy consumer's perspective.

Shell Foundation agreed with us that this was a real need based on its extensive experience across the sector. We are grateful to them for their vital support of the pilot phase of our *Energy Portfolios of the Rural Poor* study in Bihar and Uttar Pradesh, the results of which are reflected in this paper.

Using a new framework for energy portfolios, we hope to show how rural consumers make decisions about both sources and uses of energy and point to a number of overlooked opportunities that could be activated to help rural consumers fully transition to greater use of—and benefit from—modern energy.

In the future, we intend to deepen our research and analysis in Bihar and Uttar Pradesh, working closely with actors and stakeholders in the energy ecosystem to help them understand these energy portfolios and develop enhanced strategies for activating desired consumer behavior. We will also explore possibilities for applying this approach to other geographies where rural consumers face complex energy choices, such as East Africa.

It is "early to bed and early to rise" for 24-year-old Savita Nisad. She lives in a remote, off-grid village in Bihar, a northern state in India. Savita is up at the crack of dawn every day, gathering firewood, cow dung, and crop residue from fields nearby to fuel the smoky clay stove she uses to cook her family's meals. Savita and her sister-in-law grow wheat and corn on an acre of land. They hire a tractor to till the land and rent a diesel-powered motor pump to irrigate the fields when the rains are not sufficient. Their husbands work as daily wage laborers in a distant city, sending home whatever little they save. The two women care for the joint family's five children.

At noon, when sunlight is strongest, Savita uses the family's 15-watt solar panel to charge her basic mobile phone, their only reliable link to the outside world. The panel, paired with a small, locally made battery, also lights their one-room mud and thatch hut for two hours every evening, after which they use a kerosene lamp.

Usually by the middle of the month, the family runs out of government-subsidized kerosene and spends a few evenings in the dark. "We make do with what is available and what we can afford," says Savita. "It's not enough, and we cannot run fans and TVs. If (grid) electricity ever comes to our village, it will surely change our lives."

THE ENERGY CONSUMER'S PERSPECTIVE

In 2016, modern energy sources such as solar energy or grid electricity were yet to reach more than 16 percent of people around the world (1.2 billion).[1] Additionally, 36 percent of people around the world (2.7 billion) continue to depend on traditional, inefficient biomass fuels for cooking, heating, and energy, with 80 percent of these households in rural areas.[2] The lack of these sources is especially felt in rural areas of most developing countries, notably in sub-Saharan Africa and developing Asia.

Of those households dependent on biomass fuels, the rural poor in India formed a substantial portion with 244 million people of the 1.2 billion without access to electricity[3] and 819 million of the 2.7 billion cooking with solid biomass fuels.[4]

These households tend to use their poor-quality sources for a multitude of uses, such as traditional biomass-burning cookstoves for cooking, open hearths for heating, kerosene lamps for lighting, diesel generator sets for appliances, and diesel-powered farm implements for agriculture. The everyday use of these inefficient and polluting sources has severe effects on the health of users and their families, their economic development, and on the environment.

But turning consumers away from using these inefficient and harmful fuel sources to modern energy sources is about more than just providing access. Many consumers with access to modern sources continue to use traditional energy sources: Households in grid-connected villages suffer from unreliable supply and turn to kerosene, while others with liquefied petroleum gas (LPG) cylinders ration their use and continue to burn biomass fuels.

Providing delivery infrastructure is not sufficient. To truly uncover why people who live in rural areas of developing countries continue to use inefficient sources, we must understand how these households make energy choices. Current research in the energy sector has long been supply-centric and fuel-specific, guiding interventions and policy decisions based on a narrow focus. A large body of research has been developed regarding the access, availability, affordability,

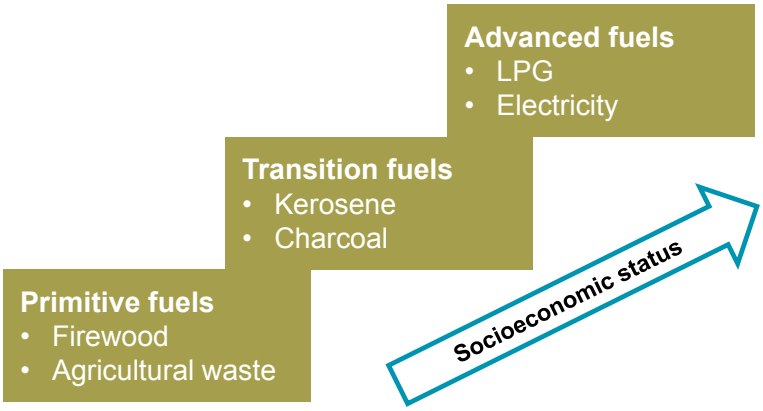
1 World Energy Outlook 2016, electricity database; The world population in 2016 was 7.4 billion – worldometers.info.

2 World Energy Outlook 2016, biomass database.

3 World Energy Outlook 2016, electricity database.

4 World Energy Outlook 2016, biomass database.

FIGURE 1. THE ENERGY LADDER MODEL



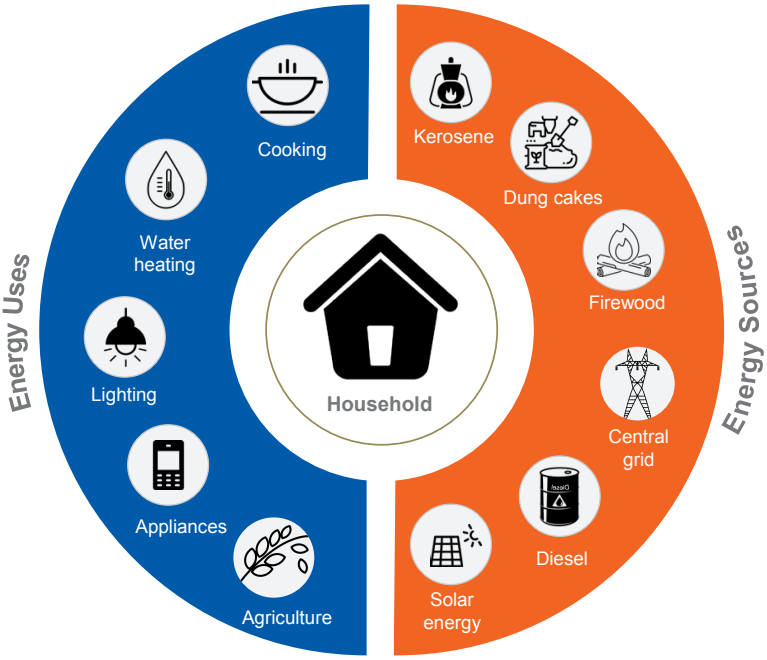
Source: "The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis," Van der Kroon, Brouwer, van Beukering

and use of specific modern energy sources such as solar energy, the central grid, and LPG. This perspective inadvertently avoids examining these choices from the point of view of the user: an individual living in a rural household. Other frameworks, such as the energy ladder (Figure 1), are centered on the premise of fuel switching: In the energy ladder, as a household grows more affluent, traditional fuels such as firewood are fully replaced by transition fuels such as coal, which are then replaced by advanced fuels such as LPG. This does not entirely capture the consumer's energy use as they tend to use multiple energy sources to meet energy needs, known as fuel stacking. It is therefore essential that we understand **how consumers make energy choices in energy-poor settings through a frame that captures their actual behavior**.

As a starting point to build a consumer-centric view of the wide gap that exists between energy needs and the use of modern energy sources, FSG collected data from 500 rural, energy-poor households in the Indian states of Uttar Pradesh (UP) and Bihar and interviewed more than 120 families to understand how they service their multiple energy needs.[5] This research uncovered the comprehensive and interconnected energy needs of the rural consumer and the decision-making processes they use for choosing energy sources. We call this collective set of multiple energy uses for a rural household and the multiple energy sources that service these energy needs an **energy portfolio** (Figure 2).

5 This research did not use a random sampling method, and is therefore not statistically representative of the population. See appendix for more details.

FIGURE 2. ILLUSTRATIVE ENERGY PORTFOLIO FOR A RURAL HOUSEHOLD



Source: FSG

In this paper, based on the pilot field research conducted in Bihar and Uttar Pradesh, we examine how an energy portfolio view illustrates the energy choices of rural households as it:

- Centers on the household,
- Shows the multiple uses and sources at the household level,
- Examines the tradeoffs inherent in making energy choices, and
- Most importantly, points to overlooked opportunities in addressing customer needs.

ENERGY PORTFOLIOS

Energy is needed for the day-to-day functioning of rural households (cooking, lighting, and running appliances) as well as for livelihoods (agriculture and small businesses). In rural settings, where access to energy sources is often poor and availability is unreliable, households struggle to service their energy needs adequately.

Those dependent on traditional, inefficient biomass fuels spend a considerable amount of time sourcing and preparing them for use. Biomass fuels gather moisture during the rainy season, decreasing their usability. Subsidized kerosene alone cannot service lighting needs for a full month. Even households with access to modern sources of energy face challenges. Those with grid electricity suffer from unreliable supply,[6] while solar energy users do not receive adequate power when available sunlight is low for up to two months every year during monsoons. Many households with LPG connections find it difficult to afford refilling the cylinders.

With these gaps in the provision and affordability of energy sources, many households resort to using multiple sources to service their energy needs. Energy portfolios (the set of connections between what households need energy for and what fuel sources they use) reflect the complex reality of the rural household's energy choices. These choices are made at a household level, taking into consideration the integration between uses and energy sources. Using a portfolio lens also helps uncover how households make these tradeoffs differently based on differences in household profile. Finally, portfolios help identify the effects of different types of triggers leading to the addition or reduction of energy sources households use.

Choices at the Household Level

The links between energy uses and energy sources occur at the level of each individual rural household. But supply-centric and fuel-centric frameworks do not examine energy choices from this vantage point. While frameworks such as the energy ladder examine the adoption of and linear transitions between energy sources, they do not account for how multiple needs and characteristics of households interact to affect choices. Other frameworks which examine fuel stacking behavior (multiple energy sources are used to meet an energy need) do not study the

6 CEEW - Access Report (2015) reports less than 20 percent of households in Uttar Pradesh, Bihar, Madhya Pradesh, Jharkhand, and Odisha receive more than 200 hours of electricity supply in a month.

links between different uses at the household level. These blind spots can be removed if we place the rural household at the center of the frame.

An energy portfolio view is built up from the household level, reflecting the reality of rural economies and communities. The household, not an individual or an organization, is the economic and consumption unit for the vast majority of energy choices in rural settings. This is because economic decisions for domestic activities such as cooking, heating, lighting, and appliances certainly lie at the household level, and even commercial activities such as agriculture and small rural businesses are traditionally conducted at the household level, making the household the most appropriate unit of analysis to study energy choices.

An Integrated View of Multiple Uses and Sources

An energy portfolio offers an integrated view of multiple uses and sources. This integrated view accounts for all energy uses at the household level, describes fuel stacking behavior for each use, and examines the connections between different uses.

A portfolio view starts with the uses of energy. Households take a demand-based view of their energy choices, starting with the various activities that need energy, making energy use the most appropriate starting point to understand these choices. Among households in Bihar and Uttar Pradesh, energy was typically used to service household needs such as cooking, water heating, indoor heating, indoor lighting, running non-lighting and non-cooling appliances, indoor cooling, and economic uses such as agriculture and small businesses.[7]

The energy choices of every rural household in our sample of 500 demonstrated that multiple uses were serviced by multiple energy sources (Figure 3). Most uses in households' energy portfolios were serviced by multiple fuels, resulting in fuel stacks. Households in our sample typically used two to three sources of energy for cooking, water heating, indoor heating, and lighting. These stacks were connected to each other: Common fuels were used across cooking and water heating uses—firewood, agricultural waste, dung cakes, and LPG. Similarly, the common fuels—grid electricity and solar energy[8]—were used for indoor lighting, running non-lighting and non-cooling appliances, and indoor cooling.

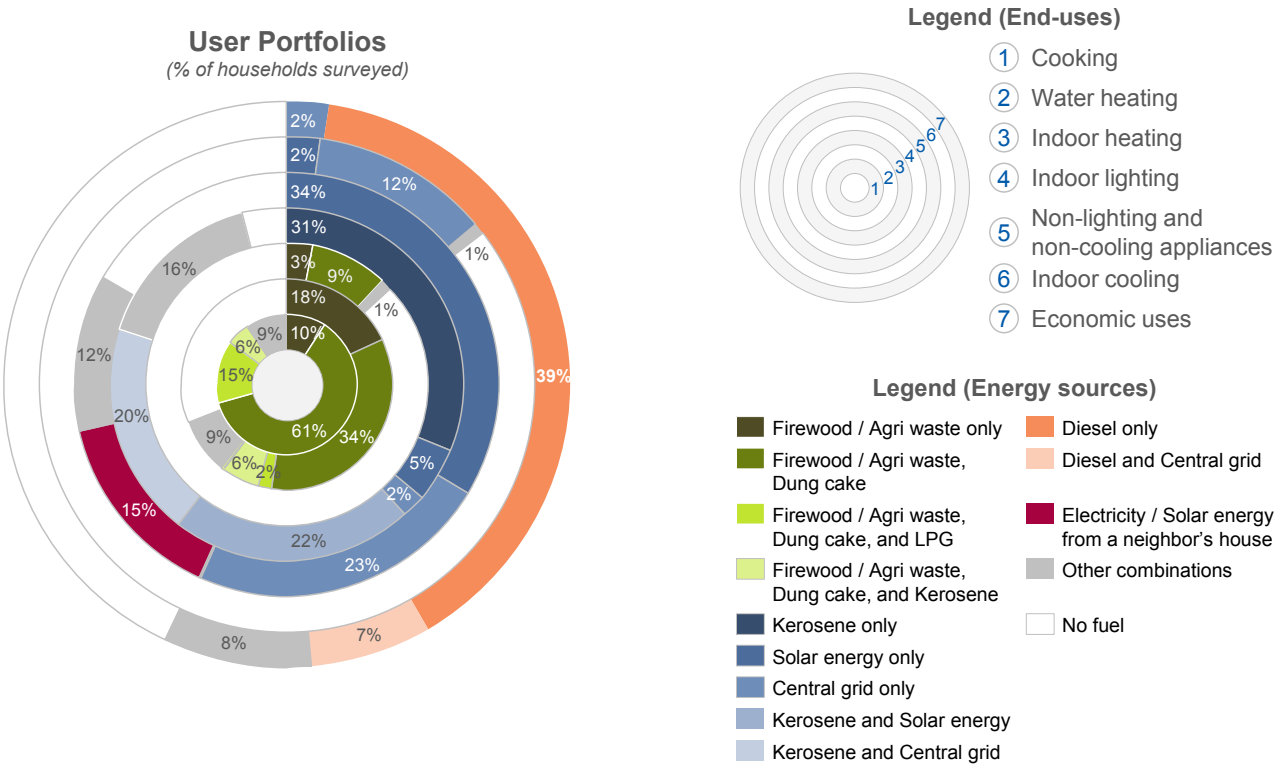
HOW TO READ ENERGY PORTFOLIO DEPICTIONS

Portfolios have been depicted in the form of concentric circular rings, with each ring representing an energy use. Each ring depicts the incidence of different energy source combinations used to service the energy need in the entire sample, or in distinct sub-samples that have been labeled above the concentric rings.

7 The study also examined the use of energy in animal husbandry practices and found it to be negligible.

8 Solar energy in this study refers to Solar Home Systems, either with or without energy storage capacity. The study collected data on solar-powered decentralized systems and solar lanterns, but the use of these was negligible.

FIGURE 3. INCIDENCE OF ENERGY SOURCES IN HOUSEHOLDS SAMPLED



Note: While data for energy sources used for outdoor lighting was collected, there was low variability for that use, with primary cells being the most commonly used energy source for most households.

Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

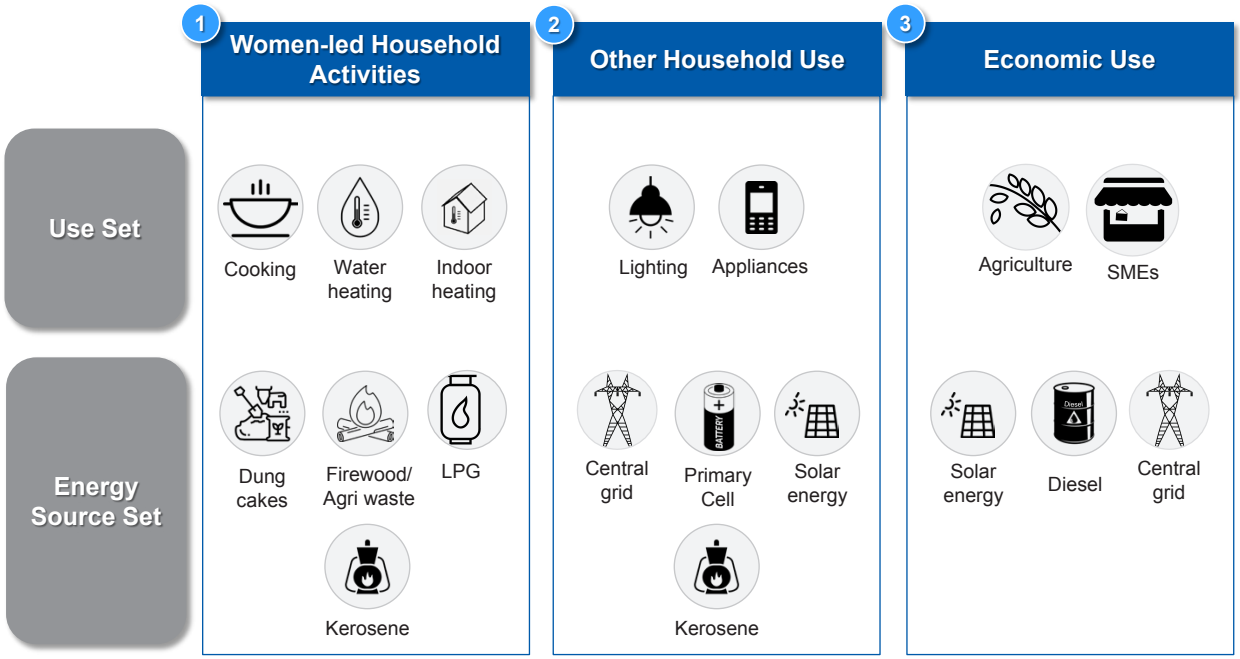
A portfolio view also helped show how households made decisions for different sets of linked energy uses. In Bihar and UP, households made energy source choices in three "mini portfolios:" women-led household activities, other household uses, and economic uses (Figure 4).

Within each mini portfolio, households optimized combinations of energy sources by considering access, reliable availability, and affordability. Convenience, habits, and aspirations also played a role in how energy choices were made for household activities.

WOMEN-LED HOUSEHOLD ACTIVITIES

These consisted of cooking, water heating, and indoor heating, for which free biomass fuels (fire-wood, agricultural waste, dung cakes) were typically used, with the occasional use of LPG (Figure 5). Biomass fuels were especially convenient for indoor heating, producing a high quantity of heat with very little monitoring required. LPG was preferred for food preparation because it took a shorter time to cook and required less cleaning.

FIGURE 4. ENERGY USES AND SOURCES FOR DISTINCT DECISION-MAKING PROCESSES IN A HOUSEHOLD



Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

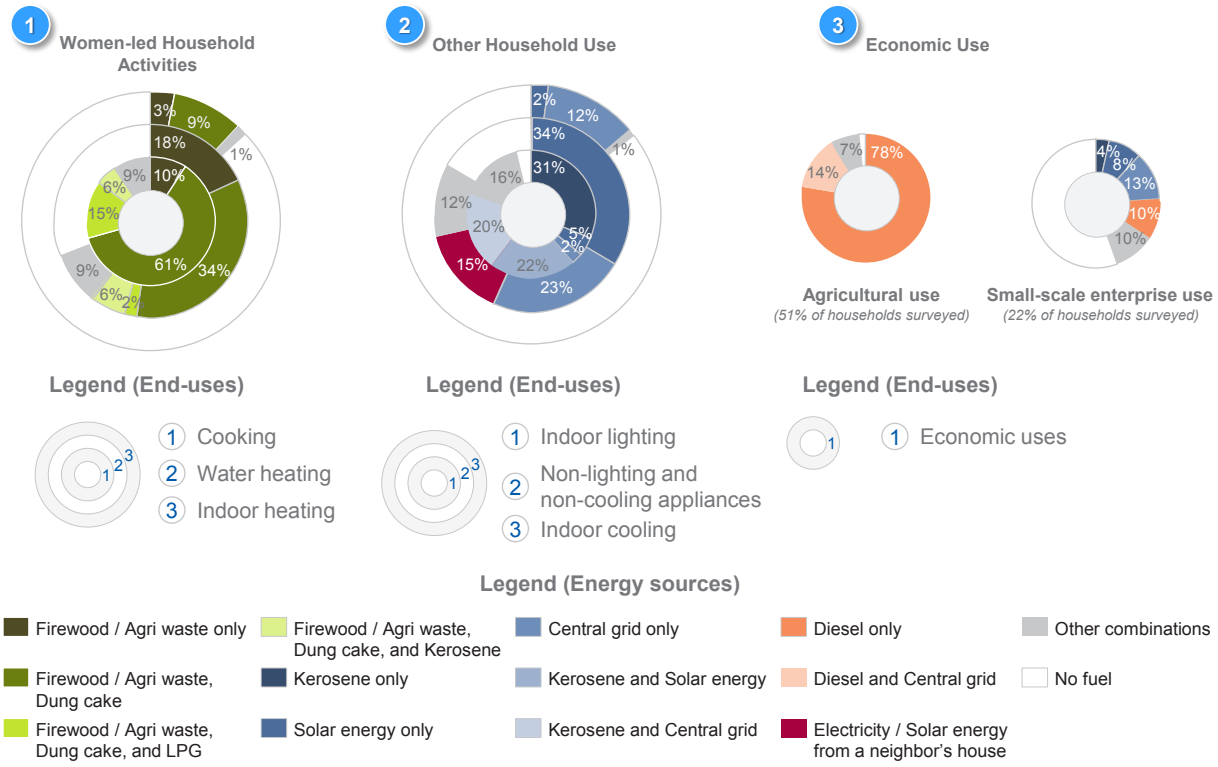
Women were primarily responsible for sourcing and use, but decisions on payment and financing lay with the male heads of households.

Households were less likely to pay for fuels used in women-led household activities. While households had the option of using free fuels such as firewood and dung cakes for these activities, the non-monetary costs of acquisition and use were not considered. Many women spent more than an hour a day on average on these activities. Although LPG would reduce the time and labor involved, it required a monetary investment that households did not prioritize. Even as government schemes and subsidies made LPG more affordable, a large section of households still could not pay for refilling LPG cylinders on a regular basis.

Abundant access to free biomass fuels made them the default choice for most households, even though LPG was viewed as a higher-quality and more convenient cooking fuel. Many households still did not have access to LPG as distribution infrastructure had not reached all villages, while biomass fuels were always accessible except during the rainy season (for which many households stored dung cakes).

Many women who were used to cooking with biomass fuels felt little motivation to move away from them, and some viewed LPG as aspirational but beyond their means.

FIGURE 5. MINI PORTFOLIOS IN ENERGY CHOICES



Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

OTHER HOUSEHOLD USES

These included indoor lighting, indoor cooling, and running appliances, for which households stacked kerosene, grid, and solar, as all three energy sources had availability and reliability issues (Figure 5). Kerosene was used in oil lamps for indoor lighting, while the central grid and solar energy conveniently enabled high-quality lighting, indoor cooling, and appliance use.

All members of the household contributed to decisions on sourcing and use. Decisions on payment and financing lay with the heads of households, typically the chief wage earner.

Kerosene was accessible through ubiquitous public distribution system shops in both grid-connected and off-grid villages. But subsidized kerosene alone was not enough to meet households' lighting requirements for a full month. Moreover, households often received a fraction of the kerosene quantity they expected: of their 1.5- to 2.5-liter monthly quotas, they often received only 1 liter or even none at all, when a household of six members needs 4 to 5.5 liters a month to meet its lighting requirements. This gap stemmed from both leakages in the public distribution system and the government's efforts to reduce dependency on subsidized kerosene. In these cases, some households would buy kerosene in the expensive open market.

The availability of grid electricity was unreliable in many connected settlements. Electricity came through for limited hours and at low voltage, especially during peak usage times (6 pm–10 pm). Households then turned to another option: solar energy. Nearby urban centers sold do-it-yourself home systems with solar panels and batteries. But solar energy could not be depended on all year round either, as the panels received limited sunlight for two months of the year during the rains.

Cash-strapped households struggled to cover energy bills because of a lack of clarity on tariffs as well as long and unpredictable billing cycles. Many households did not know how their energy bills were determined and were unable to estimate their usage, and therefore did not save enough cash to pay bills. In some cases, households received energy bills only every six months or once a year, and did not have enough liquidity to cover the accumulated amount. Although solar energy offered a near absence of usage costs, most households found the upfront costs high, and they lacked access to financing.

Households considered the quality of lighting from grid and solar vastly superior to that of kerosene: Its flickering, low-intensity flames made it hard to see at night and carried the risk of burns or fire. Households also considered grid and solar energy to be significantly more versatile and recognized the variety of uses these could be put to through appliances. But easy access and subsidy-driven affordability of kerosene, and the unreliability of modern energy sources, meant that kerosene continued to be used for lighting even when households had grid connections or solar home systems. Many grid-connected users were simply accustomed to using kerosene and did not feel strongly enough to move away from it, while many off-grid households viewed a grid connection as aspirational.

ECONOMIC USES

These included applications in agriculture and small businesses, for which households typically used a single source of energy: diesel, grid, or solar. Agrarian uses were highly dependent on diesel, while some small businesses used grid, diesel, or solar energy, depending on the type of business (Figure 5).

Members of the household directly involved in economic and income-generation activities contributed to decisions on sourcing, use, payment, and financing.

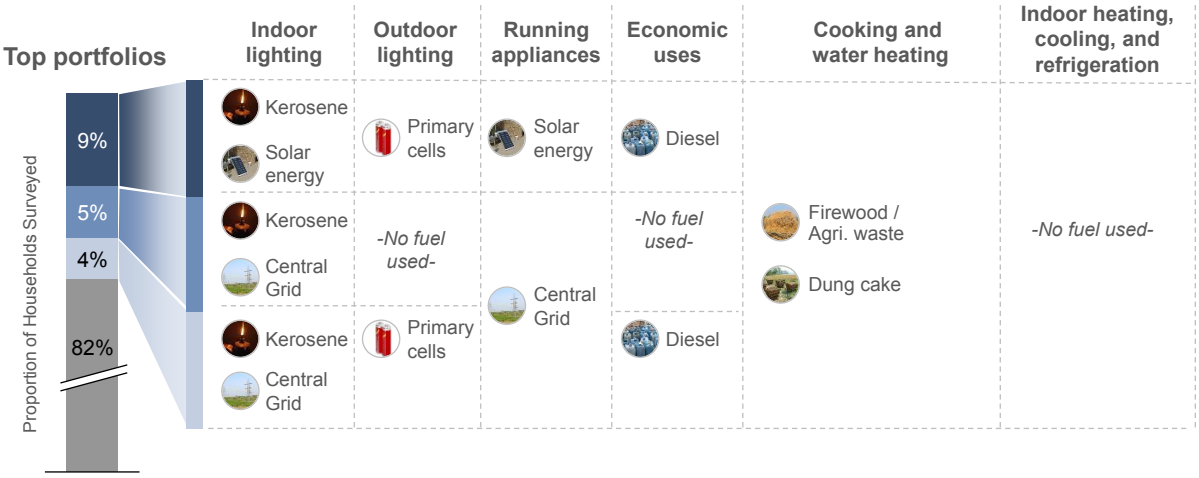
Households required access to highly reliable sources to service energy-intensive commercial uses. Energy use in commercial purposes declined where no reliable sources were available. In our sample, 55 percent of small and medium-sized enterprises did not use any energy source to service their economic needs: They avoided energy-dependent models where energy sources had issues of access and/or reliability.

Where appropriate and reliable sources were available, the choice of energy sources for the production of goods and services was highly dependent on the type of use and was made based on a cost-benefit estimate. Households were willing to pay for improved sources if they believed usage would lead to increased income or productivity. Households used diesel fuel for agrarian purposes primarily because they rented agricultural implements and because the portable farm implements they used were largely diesel powered.

Different Types of Households Make Tradeoffs Differently

Rural energy customers were not homogeneous: They made tradeoffs differently, and thus held a wide range of portfolios. The top three energy portfolios in our sample only accounted for 18 percent of surveyed households (Figure 6).

FIGURE 6. DISTRIBUTION OF TOP ENERGY PORTFOLIOS IN SAMPLE

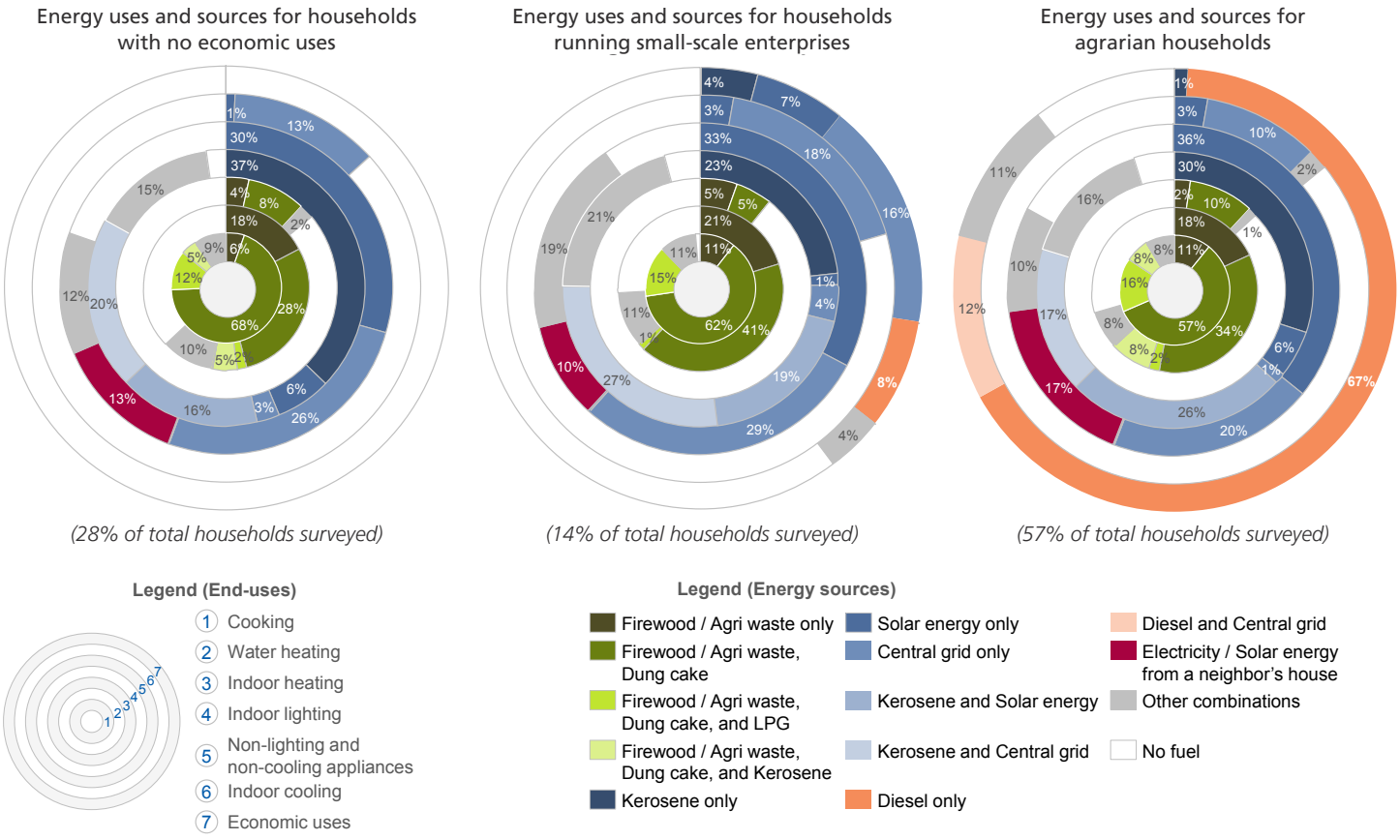


Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

Many frameworks, such as the energy ladder, present affluence as the only differentiator of energy choices, but our research revealed that other determinants also played a role. While the level of wealth placed constraints on the kind of fuels households could use, economic activities (Figure 7) and the demographic composition of a household heavily influenced service needs, access to biomass fuels, and the tendency to value modern energy sources.

Households that were engaged in agriculture used diesel fuel to power farm equipment. The few farmers who owned tractors and pumps rented them out to others to generate additional income for themselves, creating an informal rental model to mechanize agricultural practices in

FIGURE 7. DIFFERENCES IN ENERGY PORTFOLIOS BY HOUSEHOLD OCCUPATION



Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

rural Bihar and Uttar Pradesh. Small, rural enterprises used electricity or diesel fuel to support business needs. Retail shops and other stationary enterprises operated on electricity while diesel fueled those that required portability, such as a flour mill rental business. In under-electrified or off-grid areas, entrepreneurs preferred to use diesel to ensure reliability in larger businesses, and those with only basic lighting needs, such as retail shops, remained closed after dark.

The economic activities of a household also affected the types of fuels available to households for other purposes. Households that ran small enterprises using electricity also used their grid connections to service multiple household needs. Agrarian households had a higher tendency to use biomass fuels such as agricultural waste and dung cakes because these were freely available in their fields or from livestock. Their use of agricultural waste peaked during the harvest season when it was available in surplus quantities.

Households where the chief wage earner had attained a higher level of education were more likely to use appliances and to have modern energy sources such as solar energy, central grid electricity, and LPG. These household members understood how to install and use new energy sources and appliances without mishap and had observed other households (sometimes in urban areas) benefit from using these sources.

A household's ability to afford sources also led to differences in portfolios. Households with higher monthly per capita expenditures[9] were capable of using energy sources with significant upfront or recurring costs, such as solar home systems, grid connections, and LPG, and were less likely to use biomass fuels. The poorest households received more government subsidies and were the first to be offered benefits from government schemes, leading to a higher incidence of subsidized fuels such as grid electricity and LPG.[10] Households that were below the poverty line (BPL) but were not the poorest of the poor did not receive all of these subsidies and benefits because they often lacked the right documentation. Village governing bodies also prioritized poorer households while distributing limited subsidies. This created an underserved middle that had low usage of subsidized energy sources such as the grid and LPG. Naturally, this segment was especially attractive for solar energy companies and had the highest incidence of solar energy use.

Energy Portfolios Change in Response to Triggers

Energy portfolios were not static and changed in response to various triggers. Frameworks that focus on supply or fuel, rather than the customer, consider external factors such as access or affordability as the only triggers that perpetuate changes in energy choices. Others, like the energy ladder, describe changes in affluence level as the only trigger for fuel switching.

In fact, households adjusted their portfolios in response to both external triggers (access and affordability) as well as internal triggers (changes in occupation, household composition, income levels, and new uses).

External triggers that affected household energy choices and spurred the inclusion of modern energy sources in the portfolios of households in Bihar and Uttar Pradesh included:

- **Improvements in access:** Spurred by the Indian government's initiative to increase access since 2015, many more villages were connected to the grid, new LPG retail centers were set up, and more rural retailers stocked a greater variety of solar products than ever before.

9 MPCE was used as a proxy for affluence in this study.

10 Households living below the poverty line in India are eligible for an LPG connection and cook-stove for ₹1,000 ($16), while others must pay ₹4,500 ($70) for the same. In Bihar, grid connections are first offered to households living below the poverty line and their electricity bill is capped at ₹100–180 ($2–3) per month.

- **Greater affordability:** Government schemes and subsidies targeted at the poorest households increased the inclusion of central grid and LPG in the last five years. In Bihar, grid connections prioritized BPL households, with the bill capped at ₹100–180 ($2–3) per month. BPL households in both states were eligible for an LPG connection and cook-stove for ₹1,000 ($16), while others paid ₹4,500 ($70) for one. Rural women were eligible for a free stove and their first cylinder under the government's Ujjwala scheme, which was rolled out prior to the Uttar Pradesh state elections in 2017. The decline in the costs of photovoltaic panels allowed more BPL households to afford them.
- **Barriers in the access, affordability, and reliability of traditional sources:** Steady reductions in the quotas of subsidized kerosene and uncertain availability through the public distribution systems prompted many off-grid households to invest in a solar home system. Reduced availability of free biomass fuels due to deforestation and restrictions placed by the local forest department was a trigger for many households to seek out more dependable and cleaner alternatives such as LPG.

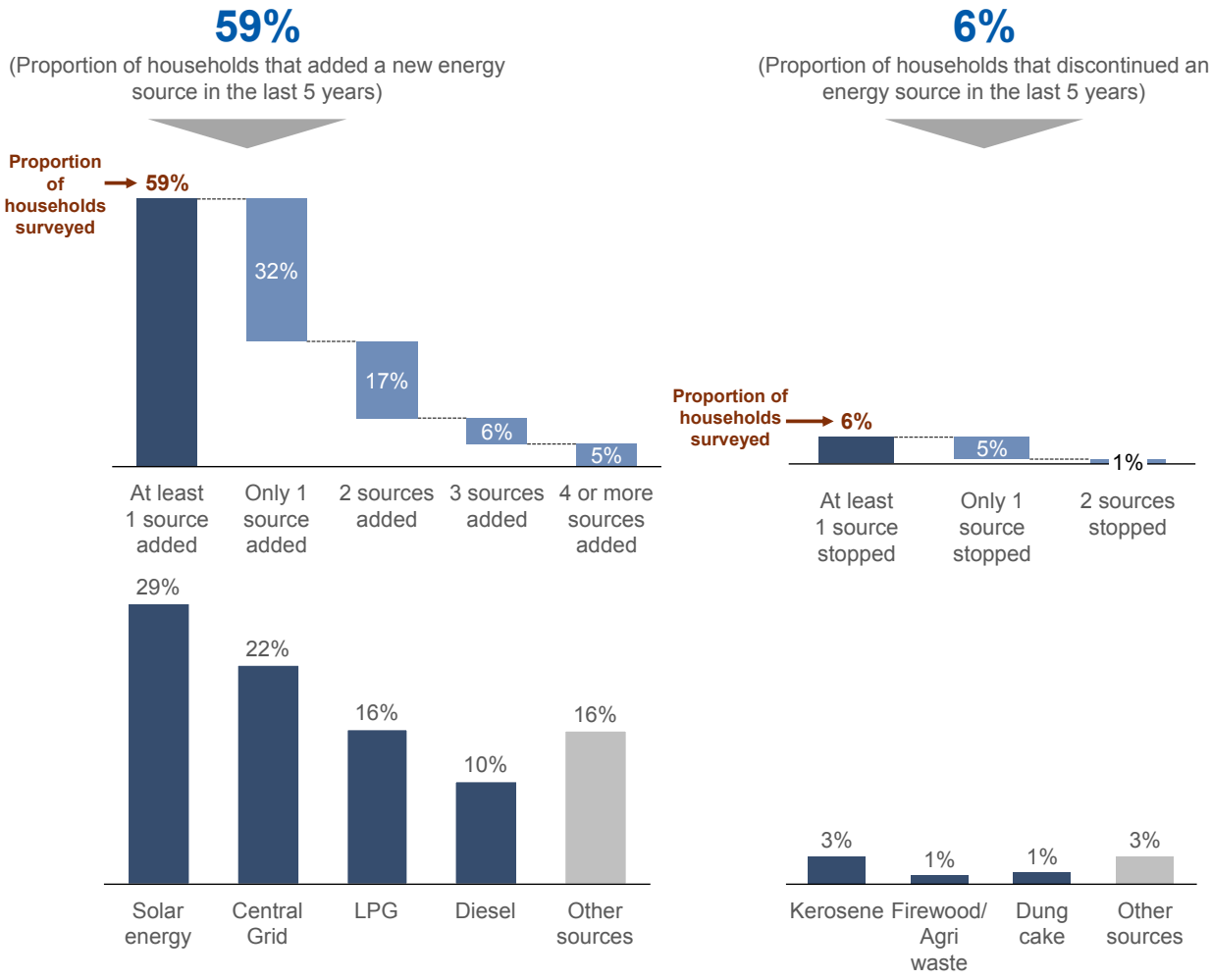
Households adjusted their energy portfolios responding to internal triggers as well. Many households included better, cleaner sources in their energy portfolios as they became more affluent, a causality that existing frameworks such as the energy ladder already account for. But increased affluence was not the only internal trigger for change. Others included:

- **Changes in occupation:** Occupation shifts changed the energy requirements of households, triggering a need for different energy sources. Seasonal migrant workers who changed occupation and location frequently also brought back information about new appliances or new sources such as LPG.
- **Changes in household composition:** LPG was a common addition to the portfolio during weddings, with cylinders and stoves often presented as a gift if the new bride were accustomed to cooking with it.
- **New uses:** New uses, such as the need to charge mobile phones, required many households in off-grid villages to add solar energy.

Together, external and internal triggers resulted in portfolio transitions for 59 percent of households in our sample. In the last five years, these households started using modern energy sources such as solar (29 percent), grid (22 percent), and LPG (16 percent). But households did not transition linearly from one fuel to the next. They rarely dropped energy sources from their portfolio as readily as the energy ladder frame would indicate: Only 6 percent of households in our sample stopped using a source in the last five years. Instead, households layered on the new sources to their portfolios in a purely additive manner, stacking more fuels for each use (Figure 8).

The tendency to layer on more sources indicates that rural households continue to experience a lack of energy security. Better outcomes cannot simply be achieved by focusing on the adoption

FIGURE 8. ADDITION AND DISCONTINUATION OF ENERGY SOURCES IN SAMPLE



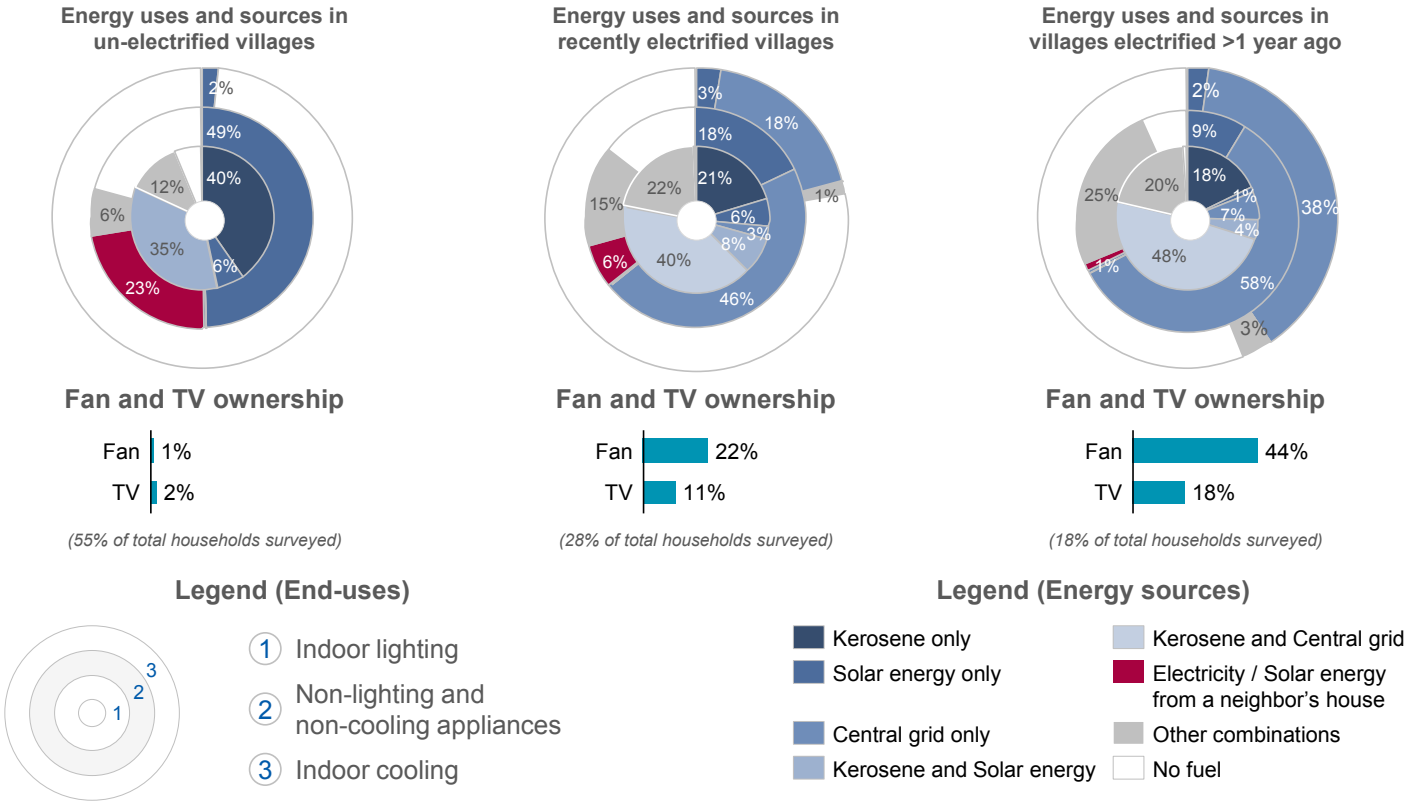
Note: The numbers may not add up due to rounding.

Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis

of new sources by rural households through increased access. Emphasis must also be placed on encouraging households to move to better, cleaner sources by identifying and addressing the barriers that prevent them from relying more fully on these energy sources.

Households took time to fully respond to triggers. As we already know, households rarely switched over to a new source in the short to medium term. They showed similar behavior when using an existing energy source for a new application, changing their usage patterns slowly and incrementally. Once a village was connected to the grid, households would take a year or more to add appliances such as fans and televisions in order to save up for these new investments and to assess the reliability, quality, and uses of the new source (Figure 9).

FIGURE 9. LIGHTING AND APPLIANCE PORTFOLIOS AT DIFFERENT STAGES SINCE GRID ACCESS



Sources: FSG field survey in Bihar and Uttar Pradesh (n=505); FSG analysis

Some changes to a household's energy portfolio had long-term impacts for lifestyles and affluence levels by way of virtuous cycles, where a trigger induced a change in the energy portfolio. The change in portfolio fed back to change the household's energy use patterns, affluence, occupation or education levels, which then triggered another positive change in the energy portfolio and so on.

For households that invested in solar pumps or other renewable energy for agriculture, the low operating cost and increase in productivity built substantial savings in some cases and resulted in a change in income levels over a period of time. For rural small and medium enterprises (SMEs), new use of grid or solar power increased hours of operation and allowed for additional value-adding appliances such as refrigerators, which helped expand the value and inventory of goods and initiated a change in the customer's income levels over a period of time. In households that adopted improved cooking solutions, the women of the house had more time for education, paid labor, and child care, because the time spent gathering biomass fuels and cooking decreased by up to three hours a day.

VIRTUOUS CYCLES IN ECONOMIC USES OF ENERGY

Malkeet Chaudhary, a corn and wheat farmer in a remote, off-grid village in Saharsa district, Bihar, first saw a solar panel three years ago, when someone in his village placed one out in the sun to charge. He was surprised to find that a 15-watt stand-alone panel could charge his and his father's mobile phones and would only cost his family ₹1,200 ($19). Soon after he purchased it, Malkeet realized that the panel, when paired with a small locally-made battery, could also light their home for a few hours every evening.

Having experienced the benefits of solar power first-hand, Malkeet went on to purchase a 1HP submersible solar-powered pump to cultivate a vegetable patch on a part of his farm land. Vegetable cultivation requires regular irrigation, which rented diesel pumps could not accomplish. He invested ₹42,000 ($656) to purchase the pump, benefiting from a government subsidy that covered 75 percent of the actual upfront costs. Malkeet's family consumes some of the produce and the remaining is sold locally, boosting household income and affluence. Malkeet invested some of the surplus income to purchase additional farm land and equipment. The solar pump set him off on a virtuous cycle of affluence, through which he is now better placed to expand his business.

OVERLOOKED OPPORTUNITIES TO ADDRESS CUSTOMER NEEDS

By focusing on rural energy consumers and examining their energy portfolios, we can identify previously overlooked opportunities to reduce dependence on traditional fuels and encourage the adoption and use of modern and improved energy sources.

Increasing Modern Energy Sources' Share of Portfolio

Even when they added modern energy sources to portfolios, households did not transition to depending entirely on cleaner and safer energy sources, but continued to use a diverse range of sources in the short- to medium-term (Figure 8). **There is an opportunity to enable continued and greater use of modern energy sources in situations where access to these sources already exists**. But the affordability and reliability of these sources are barriers to continued and greater use.

Few households could afford to solely use a new, improved energy source at their desired levels. Poorer households could not afford to pay for recurring fuel costs on a regular basis. Households accustomed to using free firewood or living without grid electricity struggled to cover the new expense of ₹600/month ($9) for LPG or ₹200/month ($3) for grid electricity. A few newly connected households rationed their use of the grid and used cheaper, subsidized kerosene, which helped them bridge the affordability gap. Several low-income households that had adopted LPG could not always refill their cylinders and fell back to using free firewood and dung cakes in times of cash shortage.

Recurring costs were exacerbated by gaps in last-mile connectivity. For many households, replacing a damaged component in their solar home system or refilling their LPG cylinder entailed a long, arduous, and expensive journey. In the villages we surveyed, the delivery infrastructure required to bring solar power or LPG often stopped at the nearest urban center, sometimes as far as 40 kilometers away.

Modern energy sources were included as a part of many households' portfolios, where access has improved. But delivery is not always reliable.[11] Many grid-connected households facing this unreliability used solar energy or kerosene to service their daily lighting requirements instead.

11 CEEW - Access Report (2015) reports less than 20 percent of households in UP, Bihar, Madhya Pradesh, Jharkhand, and Odisha receive more than 200 hours of electricity supply in a month.

Expanding Beneficial Uses of Energy for Households

While modern energy sources have reached many new households, they have only been able to service a limited number of current uses and have enabled very few new ones (Figure 5). Despite the potential of modern sources to service a household's many energy needs, their use has been limited: Grid and solar energy were primarily used for lighting, a few households added appliances over time, and LPG was used only for cooking.

There is an opportunity to expand the type and number of beneficial uses modern energy sources could be put to in situations where access to these sources already exists. The expansion of the central grid has not decreased the use of biomass fuels in cooking or diesel in agriculture and has had limited impact on small businesses (Figure 5). Grid electricity use could be expanded if certain use-specific barriers are addressed. Similarly, the use of solar energy was limited to lighting and powering appliances (Figure 5).

Even though electricity could potentially be used for cooking, induction cookers have a high cost and low awareness among rural users, leading to low use. The prevailing rental model of diesel-powered equipment in rural Bihar and UP limits farmers from leveraging the grid in agrarian use. SMEs were reluctant to start and operate electricity-heavy or electricity-dependent businesses because of erratic supply and high commercial rates.[12]

Like induction cookers, solar cookers also had limited use due to low awareness and the high cost of the device. Solar-powered agricultural implements were deemed unaffordable by most farmers, and the lack of portability in such implements prevented them from being used in rental models, which would accelerate cost recovery. Marginal farmers were particularly averse to obtaining financing for implements. Farmers unfamiliar with solar energy also did not factor in the economic benefits from using an implement with no recurring costs into their decision-making process.

There is an opportunity to grow the energy portfolios of rural households in beneficial ways through entirely new uses of energy, through the addition of cooling, refrigeration, heating, and entertainment appliances, in situations where access to these sources already exists. But these new uses of energy were present in very few of the households that had added grid or solar power to their portfolios due to limited affordability and curtailed value-addition.

A price-anchoring effect limited households with a grid connection or solar energy from adding appliances. The perceived prices of higher-end electrical and electronic appliances quoted by households were often two to three times higher than actual market prices. Opaque tariffs and

12 Commercial tariffs in Uttar Pradesh were ₹7 to ₹9/unit (10–14 cents), compared with ₹2/unit (3 cents) for domestic consumption by BPL households.

unpredictable billing cycles were an added barrier for grid-connected households in purchasing appliances: Households were not able to correctly estimate the impact of a new appliance on already uncertain energy bills and opted to minimize their risks of defaulting. Households with solar home systems were often limited by the generation and storage capacity of their systems. New appliances required higher-capacity, and more expensive, solar home systems to power them.

Households refrained from adding appliances if they could only be used for a few hours a day. Blackouts and brownouts prevented grid-connected households from purchasing appliances for new uses such as cooling, refrigeration, and entertainment. Erratic power supply and fluctuating voltages deterred small retail shops from investing in new appliances such as refrigerators, which could add value to their business.

ACTIVATING OPPORTUNITIES

We began this work with the intention of studying energy choices from the rural energy consumer's perspective and uncovering new opportunities that may have previously been ignored. Using a portfolio lens led us to understand that increasing the share of modern sources in rural households' energy portfolios and expanding their beneficial uses could significantly improve the quality of life and income levels for these communities. These challenges, which were found by examining the consumer's choices through an energy portfolio lens, pointed us in the direction of three relatively unexplored opportunities for the sector.

But acting on these opportunities in a systematic manner requires a more refined understanding of where these may lie for a range of settlement types and customer segments. Each of the opportunities would also have specific barriers to activation that would need to be revealed so that appropriate interventions can be developed. Understanding the size, nature, and viability of these opportunities would help us discover the extent of need and help identify the actors and stakeholders that could play a more effective role in activating them.

As we end this phase of our research with rural households, we conclude with the intention to draw on our current understanding of dynamic energy portfolios and further develop our findings over the next year. We hope to study the experiences of a larger, more representative sample of energy-poor rural households and build on the early opportunities identified in this paper. A portfolio lens is but a starting point for us to understand the needs of and challenges faced by the rural energy consumer, and more work needs to be done to activate opportunities that have thus far been ignored.

In doing so, we hope to uncover more effective pathways to meet the challenges of providing clean and safe energy to rural populations living in poverty.

APPENDIX: SAMPLING PLAN AND SAMPLE CHARACTERISTICS

Our insights were driven by primary research across five districts in the states of Uttar Pradesh and Bihar in India (Figure 10). We developed these on the basis of:

- Quantitative research by collecting data on the energy consumption patterns of 505 households
- Qualitative research through in-depth interviews with 120 rural energy consumers

The research methodology involved a two-tiered approach, ensuring dispersion across settlement types and household types. First, villages with different levels of electrification and expectations of grid connectivity were selected. Then, households with diverse types of energy use and household occupations were selected within chosen villages. The final selection of households for data collection was done through a two-stage process to ensure sufficient dispersion.

- We administered a quantitative interview questionnaire to a long list of households in each selected village.
- Respondents for in-depth interviews were shortlisted from this list based on criteria to select a sample with diverse energy uses and household occupations.

The sample had limitations in terms of its size as well as not being representative. The sample was targeted in distribution across electrification levels of villages and household occupations. We also chose to sample some of the most energy-poor districts in the states of Uttar Pradesh and Bihar, leading to further lack of representativeness. For example, households in our Uttar Pradesh sample had a lower average monthly expense (MPCE) as compared with census data for the state.

FIGURE 10. SAMPLE CHARACTERISTICS

	1 Amroha	2 Sitapur	3 Sonbhadra	4 Paschim Champaran	5 Saharsa
Average Monthly Per Capita Expenditure	₹758	₹878	₹678	₹895	₹1,123[1]
Median Household Size	6	5	6	6	7
Typical Education Level	41% illiterate; 15% have studied until Grade 10 or above	37% illiterate; 20% have studied until Grade 10 or above	60% illiterate, 10% have studied until Grade 10 or above	47% illiterate, 17% have studied until Grade 10 or above	45% illiterate, 16% have studied until Grade 10 or above
Typical Occupation	Sugarcane or subsistence farming	Sugarcane or subsistence farming	Subsistence farming, migrant labor	Sugarcane or subsistence farming	Subsistence farming, migrant labor

[1]An additional electrified village was listed in Saharsa which was relatively more affluent, resulting in a comparatively higher average MPCE.

Sources: FSG field survey (n=505), in-depth interviews (n=120) in Bihar and Uttar Pradesh; FSG analysis


Swaraj 724 FE


NEHA
Herbals
NEHA
LG


Mountain Dew
Sprite


TATA SKY

THIS REPORT WAS PUBLISHED JANUARY 2018

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- Cover photo and photo collages on pages 27 and 28: Akshay Kohli, FSG
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