DOES QUALITY OF ELECTRICITY SUPPLY MATTER FOR DEVELOPMENT?

An Evaluation of Service Level Benefits in Nepal

Shahidur R. Khandker, Douglas F. Barnes, Hussain A. Samad, and Bonsuk Koo

©2022 International Bank for Reconstruction and Development / The World Bank
1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000

Internet: www.worldbank.org

Publication date: February 2022
This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent.

The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Rights and Permissions

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

Any queries on rights and licenses, including subsidiary rights, should be addressed to World Bank Publications, The World Bank Group, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

Cover design and text layout: Duina Reyes
Cover photo: © Simone D. McCourtie / World Bank

CONTENTS

BOXES

TABLES

FIGURES

ACKNOWLEDGMENTS

The authors of this report gratefully acknowledge the Energy Sector Management Assistance Program (ESMAP), whose financial and technical support made this work possible. 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 wide access to affordable, reliable, sustainable, and clean energy for all. It helps to shape WBG strategies and programs to achieve the targets of the WBG Climate Change Action Plan.

This report is part of an evaluation of the Global Survey on Multi-Tier Energy Access Tracking Framework, which was launched in 2015. Surveys have been implemented in the following 20 countries: Bangladesh, Burkina Faso, Cambodia, Democratic Republic of Congo, Ethiopia, Honduras, Kenya, Liberia, Madagascar, Myanmar, Nepal, Niger, Nigeria, Papua New Guinea, Rwanda, São Tomé and Príncipe, Sierra Leone, Uganda, Zambia, and Zimbabwe. Dana Rysankova, Global Lead for Energy Access, has been quite interested in financing a country study evaluating the strengths and weaknesses of the existing multi-tier format for classifying energy access in developing countries. The reason is that most reporting on energy access has used a simple yes/no format for responses. While such binary information is helpful, evaluating levels of energy access may be a better measure of development impact.

The authors wish to thank Alisha Pinto, who was the lead author of the 2019 Multi-Tier Framework (MTF) country study in Nepal. They also extend thanks to Han Kyul Yoo, who helped in the early analysis of the data. The authors also appreciate the thorough review of an earlier version of this report, which was conducted by the Nepal Country Team and the South Asia Chief Economist Office. Those especially helpful were Subodh Adhikari, Barsha Pandey, Rabin Shrestha, Bipul Singh, and Xiaoping Wang.

Finally, editorial support provided by Norma Adams and production of the report by Duina Reyes are gratefully acknowledged.

ABBREVIATIONS

CFL	compact fluorescent lamp
ESMAP	Energy Sector Management Assistance Program
IGA	income-generating activities
IV	instrumental variables
LED	light-emitting diode
LPG	liquefied petroleum gas
MTF	Multi-Tier Framework
NEA	Nepal Electricity Authority
NPR	Nepalese rupee
OLS	ordinary least squares
PPP	purchasing power parity
PSU	primary sampling unit
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SHS	solar home systems
SLS	solar lighting systems
UNDP	United Nations Development Programme

SUMMARY OVERVIEW

High rates of electricity access are necessary for achieving the 2030 Sustainable Development Goals (SDGs). This is especially true for the SDGs that involve education, health, and poverty eradication. A new measure of energy access, known as the Multi-Tier Framework (MTF), has been developed by the World Bank's Energy Sector Management Assistance Program (ESMAP) and the United Nations Development Programme (UNDP). Unlike the previous approach to measuring energy access, which used the simple metric of whether or not a household had an electricity connection, the new measure is meant to better capture important dimensions of electricity access, such as availability, reliability, affordability, and quality of supply.

The MTF improves on the earlier approach by differentiating electricity access for households across multiple tiers of electricity service. The tiers range from no access (Tier 0) to service levels similar to those of developed countries (Tier 5). To better understand the heterogeneity of the quality of electricity access across countries, the World Bank has carried out MTF household surveys in various countries of South and Southeast Asia, Sub-Saharan Africa, and Latin America and the Caribbean.

Utilizing data from the 2017 Nepal MTF survey, this study empirically tests whether the tiers are a better measure of electricity access and whether being in the upper tiers results in higher levels of socioeconomic development. The findings show that the factors that influence a household's decision to connect to the grid also affect its overall movement up the tiers before reaching the highest level of access.

The findings reveal that simple grid access improves household welfare for the majority of the indicators considered. For households with electricity, nonfood expenditure is 43–47 percent higher than for households without electricity. However, households in the higher service tiers experience additional development benefits. The per capita expenditures of Tier-5 households improve by 249 percent compared to those without electricity. For nonfood expenditures, the benefits are 160 percent higher. The likelihood of using clean cooking methods also increases for households in the higher electricity tiers. Compared to households without electricity, the likelihood of using clean energy for cooking increases by about 28 percentage points for households with simple access to electricity and by 49 percentage points for households in Tiers 1–4. This figure increases even further to 89 percentage points for those in Tier 5.

The study's findings confirm that gaining electricity access and attaining higher tiers of service—particularly Tier 5—have a significant and increasing impact on household welfare. As Nepal's government continues to provide electricity to the remaining small number of households without electricity, it should also continue to increase its efforts toward improving the quality of power supply and the affordability of electricity. In off-grid areas, mini-grids and solar home systems (SHS) might be modernized to provide grid-comparable service. The promotion of greater appliance adoption among households with access to electricity is also a good idea. Higher rates of appliance adoption would not only increase the welfare benefits for the country but would also improve electricity sales, which are so important for electricity companies. To monitor progress, policy makers may wish to complement the standard MTF household survey with more frequent tier monitoring, combined with simple household appliance surveys.

1. INTRODUCTION

People desire electricity not for its own sake but for the wide-ranging services it provides—from lighting, communication and entertainment, refrigeration, and cooking to space conditioning and business development or improvement. That is, electricity is only useful when it powers the appliances, machines, and other devices that yield outcomes favorable to household well-being and quality of life. An extensive body of literature shows that having an electricity connection contributes to enhancing household income, productivity, and children's education, among other types of welfare benefits (Barnes 2014; Barnes, Golumbeanu, and Diaw 2016; Cabraal, Barnes, and Agarwal 2005; Chakravorty, Emerick, and Ravago 2016; Dinkelman 2011; Grogan 2016; Khandker, Barnes, and Samad 2012, 2013; Khandker et al. 2014; Kirubi et al. 2009; Kulkarni and Barnes 2017; Lipscomb, Mobarak, and Barham 2013; Rud 2017; Salmon and Tanguy 2016; Tanguy 2012; van de Walle et al. 2015; World Bank 2002a, b).

The findings of these studies also show that the welfare impacts of electrification vary by the level of service provided and the type of household connection (grid- or off-grid system) (Aklin et al. 2017; Mural et al. 2015; Peters, Vance, and Harsdorff 2011; Stojanovski et al. 2018). Many studies consider electricity as a key input into the development process, and most policy makers agree that a higher quality of electricity service is associated with better development outcomes. However, little quantitative evidence is available on how improvements in electricity access lead to the achievement of development goals.

REDEFINING ENERGY ACCESS

Universal access to electricity is a recognized goal for developing countries. However, measuring electricity access using a simple binary metric—whether or not a household has a connection—fails to capture its multidimensional nature. Unlike developed countries, where flipping an electric switch provides round-the-clock power supply and stable voltage levels, many developing countries do not experience access to electricity with such high levels of uniform service. Rather, the quality of service can vary widely, depending on the level of infrastructure investment, subsidy policies, and management issues. Households in some locations may experience high levels of service, while those in other areas may endure brownouts, blackouts, and voltage fluctuations harmful to appliances. Owing to outages, electricity may not be available during evening hours when service is most needed. Thus, the quality of connection—not simply a wire connected to a house with no guarantee of electricity running through it—matters in defining what is meant by electricity access.

The Sustainable Energy for All (SEforALL) initiative recognizes the difficulty of achieving the UN-led Sustainable Development Goals (SDGs) for eradicating poverty without having access to modern energy service that is affordable, reliable, and sustainably produced (SEforALL 2019). The assumption is that high-quality electricity service is a necessary enabling condition for achieving development outcomes for education, health, and socioeconomic growth. To capture the quality-of-connection dimension of electricity access, a consortium of multinational organizations, including the World Bank through its Energy Sector Management Assistance Program (ESMAP) and the United Nations Development Programme (UNDP), has come up with a new measure of energy access. It defines energy access as "the ability to obtain energy that is adequate; available when needed; reliable; of good quality; affordable; legal; convenient; healthy; and safe for all required energy applications across households, productive enterprises, and community institutions" (Bhatia and Angelou 2015). To measure progress toward achieving the energy access target under SDG 7,[1] the consortium developed a Multi-Tier Framework (MTF) approach, whereby tiers of access are defined by a combination of supply- and demand-side attributes.

UNDERSTANDING THE MULTI-TIER FRAMEWORK

The MTF approach to electricity access differentiates households into six thresholds or tiers of service—from Tier 0 (no access) to Tier 5 (full access)—along a continuum of improvement. The tiers are based on eight supply- and demand-side attributes: (i) capacity, (ii) daytime availability, (iii) evening availability, (iv) reliability, (v) quality, (vi) affordability, (vii) formality (of connection), and (viii) health and safety (Bhatia and Angelou 2015). Each attribute is tiered, based on the level of service. For example, the capacity attribute has tiers ranging from Tier 0 (less than 3 W) to Tier 5 (at least 2 kW); Tier 0 is typical of small, battery-powered devices, while Tier 5 is common for full grid service in developing countries. Daytime availability also has tiers ranging from Tier 0 (less than 4 hours) to Tier 5 (at least 23 hours). Each of the other six attributes has fewer than five tiers. For example, quality has only two tiers: Tier 3 is defined as voltage problems that have affected the use of appliances during the last 12 months and Tier 5 involves relatively stable voltage levels (table 1.1).

For each attribute, a household is assigned a tier.[2] A household's overall tier for electricity access is calculated by assigning it the lowest tier of any of the eight attributes. Thus, an aggregate Tier of 0 implies no access to electricity, while Tier 5 indicates the highest level of electricity service, which is comparable to that of developed countries.

1 SDG Target 7.1 aims to ensure universal access to affordable, reliable, and modern energy services (Targets 7.1.1 and 7.1.2 focus on electricity access and access to clean cooking fuels and technologies, respectively).

2 The capacity attribute is based on the electric appliances of households regardless of their connectivity and affordability, and equally applies to all households, including those without electricity access; daytime and evening availability apply to households with access to a source of electricity, while the remaining attributes apply to grid-connected and mini-grid households only.

TABLE 1.1 • MTF Tiers and Attributes for Measuring Household Electricity Access

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

Source: Bhatia and Angelou 2015.

Note: The duration attribute is replaced by availability, which examines electricity access by levels of daytime and evening duration.

Advantages of the MTF Approach

The MTF attributes cover both demand- and supply-side factors that might limit a household's overall tier status. Demand for electricity is determined by a host of household-level characteristics, including income, gender, and education of household head, as well as such community factors as access to roads, schools, and financial institutions.[3] Also, the relationship between electricity use and income is well documented. Households with higher incomes can purchase new appliances beyond the basics of lighting and communication. They can also refrigerate food, heat and even cool their homes, and pump water into overhead storage tanks. Thus, such demand-side factors as income might limit a household's overall tier status, even if it has Tier-5 supply characteristics.

Compared to the simpler binary measure of access, the MTF approach can predict the benefits of electricity. For example, knowing that more than 90 percent of all households in a country have an

3 In the energy development literature, these household- and community-level factors are grouped into five categories of capital—natural, physical, human, social, and financial—which determine the observed status of electricity access. The impact evaluation framework proposed by Colombo et al. (2018) attempts to associate these supply-side attributes with community-level welfare resulting from electricity access; however, it does not show whether the welfare changes result from the supply-side attributes as measured by the capital-based hierarchy. In contrast, our impact evaluation approach is based on the derived demand for electricity, which is a function of these five categories of capital fixed in the short run. Our approach also aims to identify the causality of the supply-side factors on demand for electricity and its ultimate effect on household welfare. For details on our proposed impact evaluation approach, see the identification issues and various methods found in Khandker, Koolwal, and Samad (2010). For our methods on quantifying the benefits of electrification, see Barnes and Samad (2017).

electricity connection may fail to consider that some lines might not have power flowing through them during critical daytime or evening hours. This is a disincentive for households to purchase appliances (e.g., TVs, refrigerators, or air conditioners). Since household benefits flow through appliances, their limited availability may reduce electricity's development impact on households (Asaduzzaman, Barnes, and Khandker 2009; Auffhammer and Wolfram 2014; Barnes and Samad 2017; Richmond and Urpelainen 2019).

The MTF access measure can also be used as a scorecard for how well a country's power companies are performing on their energy-access goals. Utilizing the MTF approach, electricity service in most developed countries would be classified as Tier 5. If the electric utility companies within countries have household service rated in the highest tier, then they can generally be considered high performing. For countries whose utility companies have household service ratings below the Tier-5 level of service, the lost benefits may be substantial.

MTF Household Surveys

To better understand the heterogeneity of electricity supply and demand, the World Bank carries out MTF household and/or enterprise surveys. To date, household and community surveys have been completed in the following countries: Bangladesh, Cambodia, Ethiopia, Honduras, India (two states), Kenya, Myanmar, Nepal, Nigeria, Rwanda, and Zambia.[4] The household surveys include detailed questions on the quality of electricity access as measured by the multiple dimensions. They include the capacity of service, daytime and evening availability, frequency of outages, voltage fluctuations, safety, and connection type (grid, mini-grid, or SHS). The collection of data on monthly kilowatt-hour consumption, along with information on the other attributes, makes it possible to explore the relationship between various types of electricity access and such household outcomes as expenditures (a proxy for income), kerosene consumption, education, employment, and women's time use.

STUDY PURPOSE AND OBJECTIVES

As mentioned, most research to date on the household welfare impacts of electricity has centered on the simple binary measure of whether or not a household has a connection rather than the more detailed measures of reliability, affordability, and quality of service. Utilizing the 2017 household MTF survey conducted in Nepal (Pinto et al. 2019) (box 2.1), this study empirically tests whether and to what extent the MTF tiers of access are a better measure for assessing electricity's socioeconomic impact compared to the binary approach. We hypothesize that, compared to the binary metric, the more detailed MTF approach is a better tool for assessing the state of electricity access in developing countries and its implications for development outcomes.[5]

The study also explores the linkages between the various tiers and monthly kilowatt-hour consumption to determine whether higher tiers of access lead to higher electricity consumption. This is an important policy consideration because it is through consumption that households are expected to accrue the development benefits of electricity. In addition, given the magnitude of the benefits from electricity access that might be attributed to higher tiers of access, the study assesses the possibility of institutionalizing the MTF approach on a more regular basis. The study will be of particular interest to policy makers in

4 Sample sizes range from 3,300 to 6,000.

5 In our study, the simple measure of access quantifies the number of households or enterprises with an electricity connection as a percentage of the total population, so it is easy for governments to monitor. The MTF approach is perhaps more challenging for policy makers to interpret given that its definition is based on multiple dimensions (Peltz, Pachauri, and Groh 2018); however, it provides much more detailed information for classifying household electricity access.

Nepal and other developing countries who are trying to determine whether electrification can capture the desired development impacts important for achieving the 2030 SDGs.

REPORT STRUCTURE

The report is organized into six sections. Section 2 presents the Nepal context for the study. Using the descriptive statistics from the 2017 MTF household survey data and alternate estimation techniques, Section 3 evaluates the factors that are important for assessing demand for electricity access. Section 4 compares binary and alternate MTF approaches for estimating electricity's impacts on development outcomes. Section 5 investigates electricity's potential for reducing poverty. Finally, Section 6 reviews the study's key findings and their implications for policy makers in Nepal and other developing countries facing similar challenges.

2. THE NEPAL CONTEXT FOR ASSESSING ELECTRICITY ACCESS

Nepal has made remarkable progress in moving toward universal access to electricity as part of its commitment to achieving Sustainable Development Goal (SDG) 7 by 2030 (Pinto et al. 2019). As of 2018, the country's overall rate of household electrification had reached 94 percent (IEA et al. 2020). The policy rationale is that better access to electricity contributes to improving public health, children's education, household income, and quality of life, in turn, helping to reduce income poverty.

Results of Nepal's Multi-Tier Framework (MTF) household survey confirm that the country's electricity access efforts are succeeding (box 2.1). At the time of the 2017 survey, 84.2 percent of households nationwide had an electricity connection (table 2.1). Nearly 72 percent were connected to the national grid, while 23 percent had access to off-grid sources, including micro- and mini-hydro grids, solar household systems (SHS), solar lighting systems (SLS), rechargeable batteries, and solar lanterns.

BOX 2.1 • **NEPAL'S MTF HOUSEHOLD SURVEY AT A GLANCE**

The Nepal Multi-Tier Framework (MTF) household survey, carried out by the World Bank's Energy Sector Management Assistance Program (ESMAP) in July–December 2017, is based on a nationally representative sample of 6,000 households—3,285 in urban areas and 2,715 in rural areas. Since the distribution of grid and non-grid households in the sample differs from that of the population, sampling weight—a factor applied to each household to adjust for differential selection probability of the sampled households—is used in the data analysis so that the findings are representative of the underlying populations in both rural and urban areas and at the national level. The sampling frame is the 2011 census conducted by Nepal's Central Bureau of Statistics. The survey produced statistically valid estimates for provinces, ecological regions, rural and urban areas, and the status of grid connection.

Source: Pinto et al. 2019.

As of 2017, simple access to electricity was high in both urban and rural areas, at 92.3 percent and 82.1 percent, respectively.[6] However, grid-based connections were significantly higher in urban areas (90 percent) versus rural areas (67 percent). Because mountainous terrain characterizes much of Nepal, 15 percent of the country's rural households had electricity from micro-hydro systems. Conversely, in urban areas, where grid-based electricity is more pervasive, only 2.5 percent of households were connected to mini-grid systems. The survey showed a limited prevalence of SHS as a source of household electricity in both rural and urban areas, at only 0.8 percent and 1.4 percent, respectively (table 2.1).

6 The World Bank's 2013/14 household survey in Nepal shows that the share of households with electricity as the main source of lighting was 97.2 percent in urban areas and 72.9 percent in rural areas. Including other minor sources of electricity (e.g., rechargeable batteries and solar lanterns), up to 95 percent of households had a connection.

TABLE 2.1 • Percent of Households with Access to Electricity, by Source

(N = 6,000 (2,715 rural; 3,285 urban)

Household electrification variable	Rural	Urban	Nationwide
Access to grid, mini-grid, or SHS (%)	82.1	92.3	84.2
Grid (%)	67.0	89.6	71.7
Mini-grid (%)	14.5	2.5	12.0
SHS (%)	0.8	1.4	0.9
Grid-based consumption (kWh/month)[a]	37.4	67.5	57.5

Source: Nepal MTF household survey 2017.

Note: Households have access to other minor sources of electricity, such as rechargeable batteries, generator sets, solar lighting systems (SLS), and solar lanterns. However, for the evaluation purposes of this study, those sources are not considered. There are some overlaps in access: 0.3 percent of households have access to both grid and SHS, and 0.06 percent of households have access to both mini-grid and SHS.

a. Mean of electricity consumption is calculated for grid-connected households only (N = 4,047).

TABLE 2.2 • Percent of Households in MTF Access Tiers

MTF tier	Percent by locality		
	Rural	Urban	Nationwide
0	6.8	4.3	6.3
1	17.9	5.3	15.3
2	12.8	6.8	11.5
3	30.2	37.1	31.7
4	16.4	23.6	17.9
5	15.9	22.9	17.3
Households (no.)	**2,715**	**3,285**	**6,000**

MTF tier	Percent by main source of electricity			
	Grid	Mini-grid	SHS	Other sources[a]
0	0.04	0	0	9.7
1	1.4	38.1	36.6	90.3
2	13.1	15.0	62.8	0
3	38.5	33.9	0.6	0
4	23.3	9.9	0	0
5	23.6	3.1	0	0
Households (no.)	**4,047**	**815**	**38**	**759**

Source: Nepal MTF household survey 2017.

a. Other sources include rechargeable batteries, generator sets, solar lighting systems (SLS), and solar lanterns.

Although the MTF household survey reported a high level of access to electricity throughout Nepal, it also showed that achieving a high level of service was more challenging. Despite the country's high rate of grid electrification, only 17 percent of households nationwide had met the Tier-5 standards for electricity access, characterized by a stable power supply, minimal disruptions, and few voltage fluctuations (Pinto et al. 2019) (table 2.2). About 18 percent of households were classified as Tier 4, which is a fairly high level of service. Approximately 32 percent had a status of Tier 3, 27 percent were in Tiers 1 and 2, and about 6 percent were in Tier 0, with minimal service characterized mainly by small battery use. The remaining 5 percent had no access. Since 2017, the situation has improved, and electricity service levels appear to be headed in the right direction.

WHICH MTF ATTRIBUTES MATTER MOST?

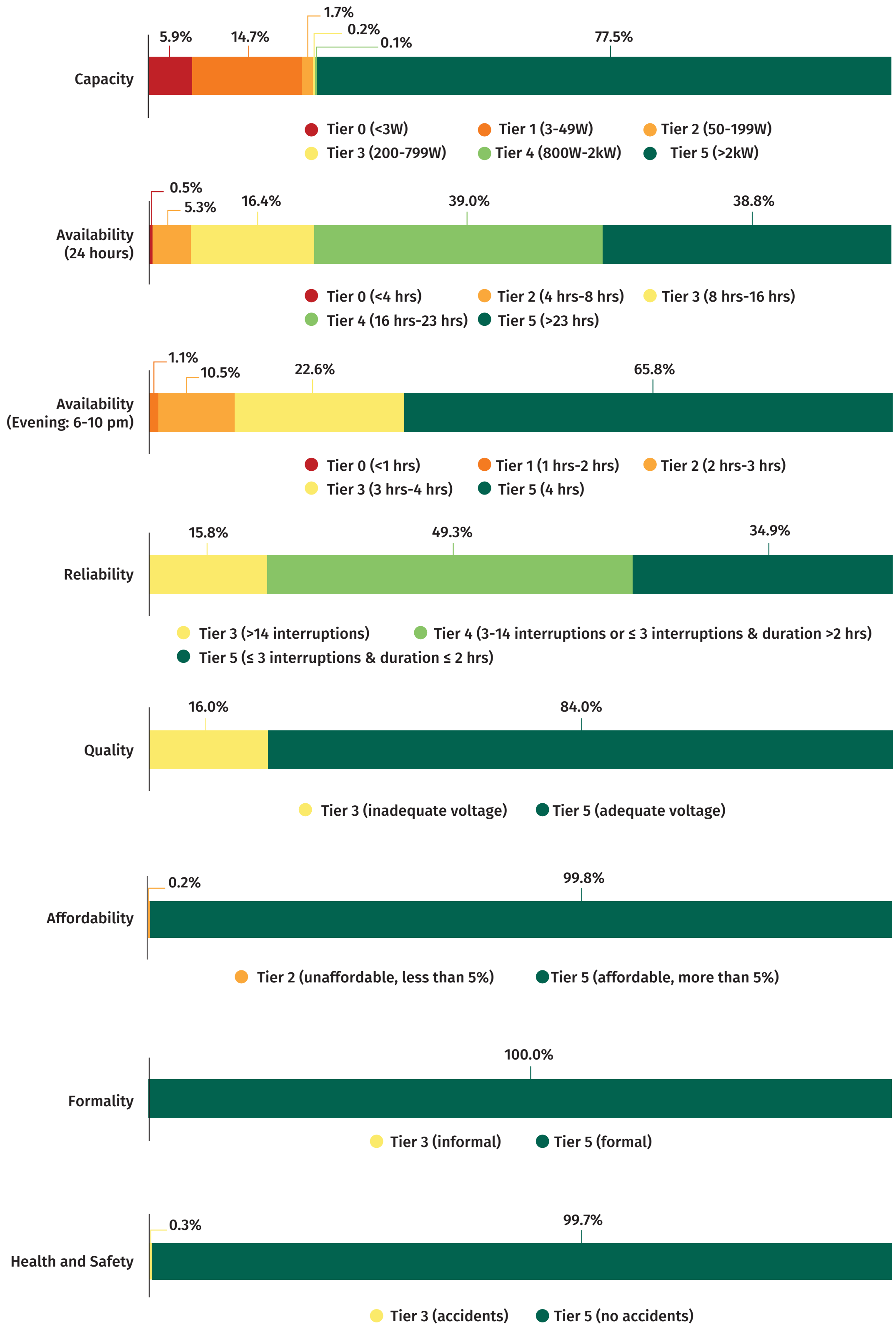
For households already connected to the national grid, the availability of electricity supply has been a major concern (Pinto et al. 2019). As of 2017, only 47 percent of grid-connected households received round-the-clock supply, while 40 percent had an irregular evening supply between the hours of 6 pm and 10 pm. This is the period when most people are home from work and ready to relax, read, or watch television. Unreliable evening service has caused Nepal's households to invest heavily in rechargeable batteries and solar lighting systems (SLS). Because of high, unscheduled power outages, households also invest in voltage stabilizers. If electricity supply were more regular, the money households spend on backup systems could be invested in electric appliances.[7]

The 2017 survey results also showed that households connected to mini-grids were more likely to be in the lower tiers of electricity access. About 38 percent of mini-grid customers were in Tier 1, compared to just 1.4 percent of grid-connected households. Owing to low capacity, households with solar home systems (SHS) fared even worse with about 90 percent in Tier 1. Households reliant on mini-grid or SHS were limited in the amount of electricity they could use, typically running only low-load appliances (e.g., lighting, mobile phone chargers, radios, and televisions). Compared to grid-connected customers, households connected to mini-grid systems were found to have lower incomes and consume generally lower levels of electricity.

7 For discussion on valuing the reliability of household electricity supply, see Alberini, Steinbuks, and Timilsina (2020).

FIGURE 2.1 • **Household Distribution of Attributes in the MTF Tiers**

(Means for all households in the survey)



Source: Pinto et al. 2019.

The MTF attributes found to matter most for the aggregate tier of electricity access in Nepal are capacity, availability, and reliability—all of which are measures of energy supply (figure 2.1). The attributes with the least relevance in the Nepal context are quality (voltage fluctuation), affordability, formality (legal or unregulated service), and health and safety. For these attributes, most households in Nepal are classified as Tier 5, meaning that most households with electricity access have connections that are safe, affordable, and legal. Thus, for Nepal's households, the MTF aggregate tier varies mainly according to the quality of electricity supply.

ADDRESSING ELECTRICITY SUPPLY ISSUES

Grid-based electricity consumption in 2017 averaged just 57.5 kWh per month nationwide (table 2.3).[8] However, the Government of Nepal is in the process of improving the electricity supply system, which will improve the reliability of electricity. One goal is to increase the installed generation capacity from its current level of 6,500 MW to 15,000 MW. Plans are also in place to possibly increase the overall per capita annual consumption of electricity from 600 kWh to 1,500 kWh by 2030.[9]

TABLE 2.3 • **Share of Households by Sources of Electricity in Each MTF Tier**

Tier	Grid (%)	Mini-grid (%)	SHS (%)	Other sources[a] (%)	No sources (%)	Grid consumption (kWh/month)[b]	N
0	0.5	0	0	16.4	83.1	n.a.	426
1	6.5	29.9	1.2	62.4	0	35.7	1,001
2	81.7	15.6	2.7	0	0	35.9	475
3	87.2	12.8	0	0	0	54.2	1,728
4	93.5	6.5	0	0	0	52.7	1,139
5	97.8	2.2	0	0	0	72.3	1,231
All households	**71.7**	**12.0**	**0.5**	**10.6**	**5.2**	**57.5**	**6,000**

Source: Nepal MTF household survey 2017.

Note: n.a. = not applicable.

a. Other sources include rechargeable batteries, generator sets, solar lighting systems (SLS), and solar lanterns.

b. Mean of electricity consumption is calculated for grid-connected households only (N = 4,047).

The MTF household survey found that the type of electricity connection, as well as the amount of electricity consumption, has a role to play in the tier of electricity service. Grid-connected households in Tier 5 used about 72 kWh per month, compared to 36 kWh per month for Tier-1 households. Those in the higher tiers of electricity service were also more likely to own and use more appliances. Such figures might lead one to conclude that higher tiers of electricity access are important for household socioeconomic benefits. However, due to issues of causality, these findings must be tested using more rigorous statistical techniques. In the next section, we explore the methods used to better understand the factors that determine households' access to both simple electricity connections and the tiers of electricity service.

8 One should note that only 674 grid-connected households out of 4,047 reported their electricity expenditure and consumption. Another 3,355 households reported expenditure on grid electricity consumption from recall. For the latter group of households, electricity consumption was calculated using the electricity tariff and a mandatory flat fee. The electricity consumption of the two groups of households did not vary significantly, at 61.6 kWh per month and 56.9 kWh per month, respectively (t-statistics of the difference = 1.27). For the rest of grid-connected households (18 households only), household consumption was imputed by regressing consumption for a range of variables expected to affect household electricity consumption, and then extrapolating consumption for missing values through prediction. The variables considered were education of household head; household size, agricultural land, and expenditure; electric appliances used by households; urban-rural location dummy; ecological and development regions; and provinces.

9 Of course, this is a national-level goal comprising all commercial and industrial, as well as residential, sectors.

3. ESTIMATING DEMAND FOR ELECTRICITY ACCESS

As previously stated, households do not buy electricity as an end product. Instead, they purchase it as a means to an end—a concept known as derived demand. Any analysis of electricity demand will likely benefit from considering the variation in electricity supply. Using descriptive statistics from the Nepal MTF household survey data, this section applies three alternate approaches for estimating electricity demand to evaluate the factors that are important for electricity access.

DESCRIPTIVE STATISTICS

Nepal's rural and urban areas feature similarities, as well as major differences that are accentuated by the extremely mountainous terrain found in most of the country. The only area that is not mountainous or hilly is the Terai region, which has borders with India.

TABLE 3.1 • **Means of Selected Explanatory Variables**

Explanatory variable	Rural	Urban	Nationwide
Male-headed households (%)	82.7	78.2	81.8
Educational level completed by household head (%)			
Primary	23.9	21.9	23.5
Secondary	24.0	30.0	25.3
Higher secondary or above	7.8	14.1	9.1
Value of household agricultural land (in 1,000 NPR)	2.0	3.8	2.4
Locality of households (%)			
Urban	n.a.	21.1	21.1
Hill areas	43.2	46.7	44.0
Terai areas	49.4	46.6	48.8
Household distance to grid pole (in 100 m)	11.0	3.1	9.4
Communities with mini-grid (%)	15.1	3.4	12.6
Communities with SHS (%)	6.1	15.7	8.1
Unavailability of service in the community (hours/day)			
Grid	8.9	4.1	7.9
Mini-grid	21.9	23.6	22.2
SHS	23.5	23.9	23.6
Price of grid electricity (NPR/kWh)	8.9	9.0	8.9
Price of mini-grid electricity (NPR/kWh)	8.4	8.9	8.5
Price of kerosene (NPR/liter)	100.4	96.1	99.5
Communities accessible year-round (%)	70.1	86.4	73.6
Villages with markets (%)	23.8	45.2	28.3
Households surveyed (no.)	**2,715**	**3,285**	**6,000**

Source: Nepal MTF household survey 2017.

Note: n.a. = not applicable. Table A.1 provides a detailed list of the explanatory variables.

The educational attainment of Nepal's household heads is quite low, even among developing countries, at just 66 percent (urban areas) and 58 percent (rural areas).[10] Households in urban areas reside an average of 310 m from an electricity pole, compared to 1,105 m for rural households. Unfortunately, the grid is extremely unreliable in Nepal. On average, grid electricity is unavailable nearly 9 hours a day in rural communities compared to 4 hours a day in urban locations, where households experience especially unreliable power during evening hours. The same pattern holds for those that have electricity from mini-grid systems and SHS (table 3.1).[11]

DEMAND ESTIMATION EQUATION

To estimate electricity demand, we first consider the following general equation:

$$E_{ij}=\alpha X_j+\beta H_{ij}+\mu_j+\pi_{ij}+\varepsilon_{ij}. \qquad (3.1)$$

E represents energy access demand, which encompasses simple access, kilowatt-hour consumption, and the MTF tiers. X_j denotes a vector of observed supply-side and community-level attributes. These include electricity price, availability of alternate power sources, reliability, and availability; as well as alternate fuel prices, market availability and accessibility, locality, distance to an urban center, and community shock.[12] H_{ij} measures a vector of observed household characteristics (e.g., age, education, and gender of household head; occupational status of household members; and types of assets indicative of household wealth). Also included is the household's distance to the nearest grid pole, which is an important supply characteristic independent of income affecting a household's decision to connect to the grid when it becomes available in the community. In addition to these supply- and demand-side variables, control variables are needed to ensure that the patterns are not location-dependent or based on fixed regional effects. The coefficients α and β stand for unknown parameters to be estimated; μ_j represents the unobserved set of community-level characteristics determining a community's latent electricity demand; and π_i is a set of unobserved household characteristics determining its latent demand for electricity. Finally, *i* indicates household, *j* indicates community/village, and ε_{ij} is the randomly distributed error.

ALTERNATE APPROACHES FOR DEMAND REPRESENTATION

One can represent the demand for electricity in equation (3.1) using the three alternate approaches: (i) connectivity, which is a binary variable; (ii) monthly kilowatt-hour consumption, which is a continuous variable; or (iii) the MTF tier, which is a categorical variable. The simple or binary variable (= 1 when a household is connected and 0 otherwise) is the traditional way to estimate a demand function for electricity access. Since is a binary outcome, either a probit or logit model can be used to estimate equation (3.1). Electricity consumption can also be considered an indication of electricity access. Thus, an approach that examines the factors that influence electricity consumption may be useful in identifying policies necessary for expanding electricity use. Since monthly kilowatt-hour consumption is a continuous variable with a value of zero for households without electricity and a positive value for

10 It should be remembered that the education of household heads in Nepal was attained decades ago when attending school was not common; today it is quite common for Nepal's young children to attend school, portending future improvements in educational levels.
11 These are sample means, not means restricted to mini-grid or SHS households, which are much higher.
12 This study acknowledges the wide range of electricity sources used by Nepal's households; however, for the purposes of this analysis, three sources are included: (i) grid-based, (ii) mini-grid, and (iii) solar home systems (SHS).

connected households, a tobit model can be used to estimate equation (3.1). Using the MTF tier approach, electricity access is measured as a hierarchical structure. The tier categories (Tiers 0–5) represent service levels from zero or minimal to one on par with the standards of developed countries. This categorical measure of access can be estimated using an ordered probit or logit model, on the assumption that Tiers 0–5 measure some type of ordering from lower to higher levels of efficiency.

Probability of Electricity Connections

Estimating access demand using simple electricity connections involves a two-part analysis. The first part considers electricity access regardless of its source; thus, it includes all households using electricity from the grid, micro-hydro systems, and SHS (table 3.2). The second part compares households that have adopted grid electricity with all others (table 3.3). This is done, as mentioned in Section 2, because 72 percent of households with electricity are connected to the national grid.

The socioeconomic factors that increase the likelihood of adopting electricity from both the grid and off-grid sources are wide-ranging in Nepal. Education of the household head is strongly associated with electricity adoption. For example, a rural household's likelihood of connecting to any electricity source increases by 7.2 percentage points if its household head has completed secondary schooling. In urban areas, where electricity saturation is higher, education plays a smaller role in the adoption of electricity.

Economic wealth also plays a significant role in the adoption of electricity. For a rural household, a 100 percent increase in land assets improves its likelihood of having electricity from any source by 4.2 percentage points. Its likelihood of adopting grid-based electricity because of landholding also increases, but only by 0.1 percentage point (table 3.3). In urban areas, by contrast, land ownership is less significant in predicting who will have electricity.

TABLE 3.2 • **Change in the Probability of Adopting Electricity from Grid, Mini-grid, or SHS Due to Household and Community Characteristics**

Explanatory variable	Nationwide (percentage points change)
Male-headed household (yes = male, no = female)	−3.6
Educational level completed by head (yes or no)	
Primary	3.3
Secondary	6.4
Higher secondary	5.5
Increase in household agricultural land value (by 100%)	2.9
Living in urban locality (yes = urban, no = rural)	2.4
Increase in household distance from grid pole (for every 100 m)	−0.03
Availability of mini-grid in the community (yes or no)	7.4
Availability of SHS in the community (yes or no)	0
Grid-service outages in the community (hours/day)	−1.6
Mini-grid service outages in the community (hours/day)	−1.8
SHS unavailability in the community (hours/day)	−1.6
Increase in price of grid electricity (1 NPR/kWh)	−3.6
Increase in price of mini-grid electricity (1 NPR/kWh)	0

Explanatory variable	Nationwide (percentage points change)
Increase in price of kerosene (1 NPR/liter)	−0.1
Year-round accessibility to community (yes or no)	2.6
Availability of markets in the community (yes or no)	3.5
Households surveyed (no.)	6,000

Source: Nepal MTF household survey 2017.

Note: All reported figures are probit coefficients. Those unequal to zero are significant above the 0.05 level and those at zero are not significant. The coefficients represent the marginal effects (percentage points change in probability) for one unit change in the explanatory variables on the adoption of electricity. Table A.2 provides detailed statistical findings for all explanatory variables.

It is perhaps surprising that a community's supply characteristics may have more impact on gaining access to electricity than a household's demand features. Community-level factors that are strongly associated with household electricity connections include the distance from grid poles and the reliability of power supply. Every 100 m distance from an electricity pole reduces a household's likelihood of having a grid-based connection by 0.1 percentage point in rural areas and 1.1 percentage points in urban areas (table 3.3). A higher number of outages in the community also leads to a decreased likelihood that households have electricity. Nationwide, a reduced power supply of just one hour per day decreases household demand for an electricity connection by nearly 2 percentage points (table 3.3). This pattern is similar for both the national grid and mini-grid systems.

TABLE 3.3 • **Change in the Probability of Adopting Grid Electricity Due to Household and Community Characteristics**

Explanatory variable	Nationwide (percentage points change)
Male-headed household (yes = male, no = female)	−4.6
Educational level completed by head (yes or no)	
Primary	4.8
Secondary	10.8
Higher secondary	13.6
Increase in household agricultural land value (by 100%)	3.0
Living in urban locality (yes = urban, no = rural)	3.7
Increase in household distance from grid pole (for every 100 m)	−3.9
Availability of mini-grid in the community (yes or no)	−4.7
Availability of SHS in the community (yes or no)	−5.1
Grid-service outages in the community (hours/day)	−1.7
Increase in price of grid electricity (1 NPR/kWh)	−3.1
Increase in price of kerosene (1 NPR/liter)	0
Year-round accessibility to community (yes or no)	2.3
Availability of markets in the community (yes or no)	7.0
Households surveyed (no.)	**6,000**

Source: Nepal MTF household survey 2017.

Note: All reported figures are probit coefficients. Those unequal to zero are significant above the 0.05 level and those at zero are not significant. The coefficients represent the marginal effects (percentage points change in probability) for one unit change in the explanatory variables on the adoption of electricity. Table A.3 provides detailed statistical findings for all explanatory variables.

Predictably, the price of electricity also plays a role in determining whether households adopt electricity, as does the price of alternative fuels for lighting. While the electricity tariff and service charge do not vary by location in Nepal, they do vary by consumption slab (monthly kilowatt-hours of electricity use) and measure of connection (amperes).[13] The price used in this analysis is the community average of the amount paid by households for the consumption of 1 kWh per month.[14] Fixed charges are sometimes a disincentive for households to even connect to grid-based systems (Golumbeanu and Barnes 2013).

For electricity from all sources (grid, mini-grid, and SHS), an increase of just a 1 NPR in the price of grid electricity reduces nationwide electricity demand for access by 3.6 percentage points (table 3.2). In urban areas, the price of electricity is not related to the demand for connections, probably because urban areas have reached a near saturation point. However, in rural areas, where households are quite sensitive to the price of electricity, a 1 NPR increase in the electricity price decreases the demand for connections by 8 percentage points. This pattern is also prevalent for mini-grid systems, for which a 1 NPR increase in price reduces the likelihood of gaining electricity access by 19.6 percentage points.

The conclusion is that household socioeconomic levels and supply-side characteristics are very important for predicting whether households adopt electricity. Although both types of factors are relevant, supply outages and electricity prices (including fees) are especially important in preventing Nepal's rural households from adopting electricity. Since a high percentage of households nationwide already have simple access to electricity, the implication is that the remaining households without electricity would be more likely to take up a connection with improved socioeconomic conditions, a more regular supply of electricity, and less onerous fixed charges for low-voltage consumers.

Demand for Electricity Consumption

Nepal is unique in having high levels of alternatives to the national grid, including limited-capacity mini-grid systems and SHS, making it difficult to obtain accurate electricity consumption figures.[15] In this study, the kilowatt-hour demand analysis has been limited to those without any form of electricity (15.8 percent) and those with electricity from the grid (71.7 percent), covering about 88 percent of households nationwide. Also, the kilowatt-hour consumption has been imputed for a small share of surveyed households that did not report their kilowatt-hour consumption. The use of consumption as the dependent variable did not materially change the results of the analysis of households with and without an electricity connection.

Like the findings for binary access, education and agricultural landholdings are important factors for raising the level of electricity consumption. For example, household heads that have completed secondary education are likely to consume nearly 0.4 percent higher levels of electricity compared to those without a secondary education (table 3.4). Among urban landowners, agricultural landholdings are often considered a good investment. Also, some people who have migrated from rural to urban areas may rent out their land to local farmers. Among urban households, ownership of agricultural land plays a small but statistically significant role in electricity consumption: An increase of 100 percent in the value of urban households' agricultural land means a 0.1 percent higher level of electricity consumption.

---

13 For example, residential customers that consume 21–30 kWh per month from a 5-ampere connection pay a tariff of NPR 7 per kWh and a service charge of NPR 50 per month. As consumption and connections vary, so do the tariff and service charge.

14 This is calculated by dividing the amount paid by households for monthly electricity consumption, and then taking the average of the amount at the community level. This gives more variation in electricity pricing than would a simple tariff, which does not vary by location.

15 The kilowatt-hour consumption figures for households with electricity from mini-grids and SHS were not accurate enough to be included in this study; thus, as a practical matter, these systems have been eliminated from the analysis.

TABLE 3.4 • **Change in Electricity Consumption Due to Household and Community Characteristics**

Explanatory variable	Nationwide (% change)
Educational level completed by head (yes or no)	
Primary	0.3
Secondary	0.4
Higher secondary	0.4
Increase in household agricultural land value (by 100%)	0
Living in urban locality (yes = urban, no = rural)	−0.2
Availability of mini-grid in the community (yes or no)	0
Availability of SHS in the community (yes or no)	−0.6
Grid-service outages in the community (hours/day)	−0.2
Increase in price of grid electricity (1 NPR/kWh)	1.5
Increase in price of kerosene (1 NPR/liter)	−0.1
Availability of markets in the community (yes or no)	0.2
Households surveyed with grid or no electricity (no.)	**5,145**

Source: Nepal MTF household survey 2017.

Note: The coefficients are from a Tobit analysis of monthly consumption of electricity. The percent change represents the marginal effects at the point of truncation. A value of zero means that the impact was not significant. Table A.4 provides detailed statistical findings for all explanatory variables.

Not surprisingly, the presence of mini-grid systems or SHS in a community means less household consumption of grid-based electricity. In communities where mini-grids and grid-based systems are in direct competition, grid-connected households that experience brownouts and blackouts may resort to using mini-grids or SHS. Households with unreliable electricity generally have lower consumption, meaning that, when electricity is not available, it cannot be used. One should also recall that poor electricity supply deters households from connecting to the grid system.[16]

Determinants of the MTF Tiers

The third approach to quantifying energy access has been to use the MTF tiers based on supply- and demand-side attributes. As previously explained, the MTF tiers of energy access are based on whether the electricity supply is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, and safe to use (table 1.1 and figure 2.1). The goal of the MTF analysis is to assess what determines various tiers of access. The coefficients, based on an ordered logit estimation, are the log of the odds of moving up the tiers for overall tier status, which has been changed to marginal or incremental effects for the individual tier.[17] This analysis is limited to households with grid electricity not only because grid access is the focus of the study, but also because we are interested in examining why households connected to the best form of access (grid electricity) are in tiers lower than the highest one (Tier 5).

16 The price of electricity should have an impact on suppressing the demand for electricity. But here we get a positive sign, implying a reverse causality. The reason is that the electricity tariff depends on the level of electricity consumption and not the other way around.

17 An ordered logit model is applied, based on the assumption that the error structures in equation (3.1) follow a logistic distribution with an S-shaped curve of the errors. Odds ratio refers to the probability of attaining a tier or not.

TABLE 3.5 • **Likelihood of Attaining a Higher Service Tier for Grid-connected Households**

Explanatory variable	Probability of moving up one tier (percentage points change)				
	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Educational level completed by head (yes or no)					
Primary	0	0.4	2.0	2.3	−1.1
Secondary	0	0.4	2.1	2.3	−1.1
Higher secondary	0	0.7	3.8	4.3	−2.1
Increase in household distance from grid pole (for every 100 m)	0	0.7	3.7	4.2	−2.0
Availability of mini-grid in the community (yes or no)	0	2.6	14.2	16.1	−7.7
Grid-service outages in the community (hours/day)	0	0.3	1.5	1.7	−0.8
Increase in price of grid electricity (1 NPR/kWh)	0	−0.7	−3.6	−4.1	2.0
Availability of markets in the community (yes or no)	0	−0.5	−2.8	−3.2	1.5
Households (no.) 4,047					

Source: Nepal MTF household survey 2017.

Note: The estimates are from an ordered logit equation. They represent the percentage points change in the probability of moving up one tier. A value of zero means the coefficients were not significant at the 0.05 level. A positive value (e.g., 1.2) would mean that, for every unit change in the dependent variable (e.g., completion of higher secondary education), the probability of the household moving up one tier (e.g., from Tier 1 to Tier 2) would increase by 1.2 percentage points. Table A.5 provides detailed statistical findings for all of the explanatory variables.

The findings are reported in table 3.5, where the second column shows the average of the log of odds of moving to a higher tier, and the successive columns show the marginal effects on the probability of moving to a specific tier. Like the findings for binary access, a household's distance to the grid pole and duration of power outages lower the odds of moving up the tiers. In terms of individual tiers, the effects of a determinant on attaining a sub-optimal tier (Tiers 1–4) generally have the opposite signs to that of attaining the highest tier (Tier 5). For example, power outages increase the odds of being in Tiers 1–4 and decrease the odds of being in Tier 5. More specifically, one additional hour of grid-service outage in the community raises a household's probability of being in Tier 4 by 1.7 percentage points and lowers its probability of being in Tier 5 by 0.8 percentage points. The presence of a mini-grid system in the community, which might imply unavailability of grid-based service, increases the household's probability of being in Tiers 1–4 and decreases the likelihood of its being in Tier 5.

Markets and other community infrastructure increase the likelihood that households will be in the highest tier. Reliability of grid electricity service is extremely important for households to reach Tier 5. Summing up, the factors that influence a household's decision to connect to the grid also affect its overall movement up the tiers, as well as reaching optimal (Tier 5) electricity access.

4. ESTIMATING ELECTRICITY'S IMPACT ON DEVELOPMENT OUTCOMES

Most past studies on the development impacts of electricity have compared the simple benefits of households with or without electricity. This is a binary measure that does not take into consideration the quality of electricity service. In this section, we first present the descriptive statistics comparing households with and without electricity. Next, we use multivariate regression analysis to compare both the binary and MTF impact estimates. This is necessary in order to tease out some of the inherent biases in the cross-sectional comparisons. It also has the advantage of being able to ascertain whether levels of electricity service have an impact on development.

DESCRIPTIVE STATISTICS

The outcome measures of particular interest in this study are income, as measured by food and nonfood expenditures and the employment hours of adults. In addition, it is important to examine the impact of electricity service on women's fuel-collection and food-preparation time, women's engagement in income-generating activities (IGAs), household kerosene consumption, and household use of clean cookstoves.[18]

The simple comparisons of households with and without electricity provide some expected results. Compared to households without electricity, households with access to the grid, mini-grid, or solar home systems (SHS) are better off in terms of per capita food, nonfood, and total expenditure. For example, the total per person expenditure is NPR 7,195 for grid-connected households, compared to only NPR 5,651 for non-electrified households (table A.6a).

Fuel collection, kerosene consumption, and the use of clean cookstoves may be more directly related to the use of electricity (World Bank 2002a). Switching from one fuel to another has more immediate impacts on a household's energy profile. Those with electricity spend less time on fuel collection, are more likely to use less kerosene, and have a higher percentage use of clean cookstoves compared to households without electricity (Chauduri and Desai 2020). For example, 50.0 percent of grid-connected households, compared to only 1.5 percent of households without electricity, use clean cookstoves (table A.6a).

Similarly, monthly kerosene consumption for households with electricity (grid-based, mini-grid system, or SHS) is less than 0.5 liters, compared to nearly 2.7 liters for households without electricity (table A.6a). This reduction in kerosene consumption, which is related to household lighting, may also result from a greater likelihood that households with electricity use liquefied petroleum gas (LPG) or more energy-efficient cookstoves.

Women in households with electricity also spend less time on fuel collection and food preparation. In addition, the findings show that such changing household cooking patterns and time savings lead to greater IGA for women. Women in households with electricity typically spend 21.4 minutes per day on IGA, compared to only 7.5 minutes per day for women in households without electricity (table 4.1a).

18 The reported results can be considered short-, medium-, or long-term outcomes, depending on the nature of the variable. For example, income, which builds up over time, can be considered a medium- or long-term outcome; while kerosene consumption is more short-term in nature since it is used as a backup lighting source once a household adopts electricity.

Another indicator of household welfare is the employment hours of men and women in households with or without electricity. The distribution of hours spent on farm and nonfarm activities varies by gender and electrification status (table 4.1a). Men generally spend more time on productive activities than do women. However, in households without electricity, both men and women spend comparatively more time on farm activities. By contrast, households with electricity tend to spend more time on nonfarm activities. Another interesting finding is that households using mini-grid systems or SHS tend to spend more time on farm activities than those with grid electrification.

TABLE 4.1A • **Development Outcome Variables, by Electricity Source**

Outcome variable	Grid households (mean)	Mini-grid or SHS households (mean)	Grid, mini-grid, or SHS households (mean)	Households without electricity (mean)
Household per expenditure (N = 6,000)				
Food (NPR/month)	3,459	3,129	3,410	3,136
Nonfood (NPR/month)	3,736	2,709	3,583	2,514
Total (NPR/month)	7,195	5,838	6,994	5,651
Employment hours per month (adults, ages 15–65)				
Men in farm sector (N = 8,500)	65.2	95.7	70.1	86.5
Men in nonfarm sector (N = 8,500)	84.0	50.6	78.1	73.2
Women in farm sector (N = 9,904)	38.6	80.9	45.5	34.4
Women in nonfarm sector (N = 9,904)	19.7	20.4	19.8	13.6
Women's outcomes (ages 15–49) (N = 6,000)				
Fuel collection and food preparation time (hours/week)	1.1	3.1	1.4	3.7
Time spent in IGAs (minutes/day)	19.5	32.1	21.4	7.5
Kerosene consumption and cooking behavior (N = 6,000)				
Household consumption of kerosene (liters/month)	0.433	0.278	0.411	2.664
Households that use clean cookstoves (%)	50.0	9.7	44.0	1.5

Source: Nepal MTF household survey 2017.

Note: Table A.6a provides detailed statistics.

TABLE 4.1B • **Development Outcome Variables, by Tier**

	Mean					
Outcome variable	**Tier 0**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
Household per expenditure (N = 6,000)						
Food (NPR/month)	3,015	2,583	3,153	3,476	3,074	3,971
Nonfood (NPR/month)	2,368	2,160	3,867	3,622	3,229	4,107
Total (NPR/month)	5,383	4,744	7,021	7,098	6,303	8,878
Employment hours per month (adults, ages 15–65)						
Men in farm sector (N = 8,500)	92.8	95.7	66.9	73.5	72.7	54.4
Men in nonfarm sector (N = 8,500)	66.2	53.9	72.3	68.9	99.9	87.6
Men total (N = 8,500)	159.1	149.6	139.2	142.3	172.6	142.0
Women in farm sector (N = 9,904)	36.6	82.1	52.3	45.2	56.6	24.6
Women in nonfarm sector (N = 9,904)	14.4	21.0	14.4	16.0	19.4	29.2
Women total (N = 9,904)	51.1	103.1	66.7	61.2	76.0	53.8
Women's outcomes (ages 15–49) (N = 6,000)						
Fuel collection and preparation time (hours/week)	3.6	2.5	1.6	1.5	1.2	1.0
Time spent in IGAs (minutes/day)	12.4	18.9	21.3	21.2	17.8	29.4
Kerosene consumption and cooking behavior (N = 6,000)						
Household consumption of kerosene (liters/month)	2.24	0.10	0.56	0.61	0.26	0.17
Households that use clean cookstoves (%)	2.2	7.5	33.9	42.6	46.2	60.6

Source: Nepal MTF household survey 2017.

Note: Table A.6b provides detailed statistics.

Development outcomes generally improve as households move up the tiers of access. For example, for households in Tier 5, the total monthly expenditure per person is NPR 8,878, compared to NPR 5,383 for households in Tier 0 (table 4.1b). The monthly use of kerosene decreases from 2.24 liters for those without electricity to 0.17 liters for those in Tier 5. Similarly, the share of households using clean cookstoves (i.e., LPG and electric stoves) is 61 percent for Tier-5 households versus only 2.2 percent for those households in Tier 0. The findings for employment are not as clear-cut as for the other development outcomes. For households in the lower tiers, employment hours in the farm sector are comparatively higher than for households in the higher tiers; however, their overall employment levels are lower (table 4.1b).

Of course, such comparisons do not confirm that electrified households are more well-off because of electricity. Households with electricity quite possibly were better off even before its adoption. Establishing the causal linkage between electrification status and household welfare requires rigorous estimation and controlling for other contributing factors.

ESTIMATION TECHNIQUES

Because a household's electricity demand is based on the possession of appliances, electricity consumption and use are determined by household income and other factors. The problem involves an identification issue: How does electricity access affect outcomes independent of income, household wealth, and other factors important for electricity demand? The outcomes examined include household expenditures, employment, women's time allocation, kerosene consumption, and the use of clean cookstoves.[19]

We consider the following household-welfare equation, conditioned by the simple measure of electricity access,

$$Y_{ij}=\alpha X_j+\beta H_{ij}+\gamma E_{ij}+\mu_j+\pi_{ij}+\varepsilon_{ij}\ , \qquad (4.1)$$

where is a measure of a development outcome (e.g., expenditure or education) of household i in community j; denotes electricity access or consumption; and the other variables are those as explained in the demand equation (3.1). For tiered access to electricity, we can write the equation for outcomes as follows:

$$Y_{ij}=\alpha X_{ij}+\beta H_{ij}+\gamma 1\ T1_{ij}+\gamma 2\ T2_{ij}+\gamma 3\ T3_{ij}+\gamma 4\ T4_{ij}+\ \gamma 5\ T5_{ij}+\mu_j+\pi_{ij}+\varepsilon_{ij}, \qquad (4.2)$$

where T_{nij} (n = 1, 2…5) represent dummy variables for access tiers and γ_n (n = 1, 2…5) stand for the contribution of each tier to the outcome of interest. An ordinary least squares (OLS) implementation of equation (4.1) or (4.2) may yield biased estimates of electrification impacts due to endogeneity bias. Endogeneity may arise because of unobserved household- or community-level characteristics (π_{ij} and μ_j) that may be correlated with both outcome variables (Y_{ij}) and treatment variables (*Eij* or T_{nij}). For example, the implementing agency may choose to extend electrification projects to locations with greater growth potential, whose initial outcomes are comparatively better than those without electricity. Or wealthier or more highly educated households may adopt grid electricity when it first becomes available in a community ahead of other households. Since the effects of these factors cannot be separated from that of electrification alone, the impacts from an OLS estimation would be biased.

To handle endogeneity bias, we implement a two-stage, instrumental variables (IV) regression of equations (4.1) and (4.2), which involves the identification of variables (i.e., instruments) exclusively included in equation (3.1) and excluded from equations (4.1) and (4.2).[20] The selected IV for this study are as follows: household distance to grid pole (expressed in 100 m); community price of grid electricity (NPR per kWh); community price of mini-grid electricity, including any service fees (NPR per kWh); unavailability of grid service in the community (hours per day); unavailability of mini-grid service in the community (hours per day); and unavailability of SHS service in the community (hours per day). The findings from instrument testing show that the IV selected for use in this study are valid (Appendix B).

19 Electricity might also have an effect on productivity, but that is not the focus of this study.
20 The properties of the selected instruments must (i) influence the treatment variable (e.g., access to electricity) and (ii) not influence the outcome variables directly. The outcomes are affected indirectly through the intervention. Instruments are used only at the first stage, equation (3.1). The second stage, equations (4.1) and (4.2), uses the predicted access values from equation (3.1), not the actual ones.

COMPARING RESULTS OF THE IMPACT ESTIMATES

Given that households with electricity are better off than households without any access, this study would like to determine how much electricity access contributes to the overall welfare of households in Nepal. The study examines the results of the binary and MTF impact estimates and then combines the impacts of Tiers 1–4 to better understand the development impact of Tier 5.

Simple or Binary Access

Three models are used to evaluate simple access to various sources of electricity: Model 1 measures the average impact of electricity from any source (grid, mini-grid, or SHS); Model 2 assesses the impacts of grid and off-grid sources (mini-grid or SHS) separately; and Model 3 estimates the effect of grid electricity compared to those connected to lower-capacity power sources or without electricity. While the findings are fairly similar across all models, grid electricity is a dominant source, and the Government of Nepal is still supporting grid expansion across the country. For this reason, most of our discussion focuses on the Model 3 findings.

The simple access to grid electricity improves household welfare for nearly all development outcomes. For grid-connected households, nonfood expenditure is 47 percent higher than that of households without electricity; but the grid has no impact on food expenditure (table 4.2a, Model 3).[21] Households with mini-grid or SHS have a nonfood expenditure 16.6 percent higher than those without electricity, as well as a lower food expenditure (table 4.2a, Model 2B). For households with grid electricity, men's employment hours in the nonfarm and farm sectors are 72 percent higher and about 45 percent lower than those of men in households without electricity. Total employment is not affected by grid access. This pattern suggests that, with grid electricity, men's employment may have transitioned from the farm to the nonfarm sector (table 4.2b).

TABLE 4.2A • **Changes in Household Expenditure Due to Electricity Adoption**

Electricity access model	Per capita (% change)		
	Food	Nonfood	Total
Model 1. Any source (grid, mini-grid, or SHS)[a]	0	33.0	0
Model 2A. Grid[a]	0	42.6	22.1
Model 2B. Mini-grid or SHS[a]	−31.3	16.6	0
Model 3. Grid[b]	0	47.0	30.6

Source: Nepal MTF household survey 2017.

Note: Table A.7a provides more detailed statistical impacts. The number of household observatrions is 6,000 for Models 1 and 2 and 5,147 for Model 3.

a. Compared to those without electricity.

b. Compared to those with lower-capacity systems (rechargeable batteries, generator sets, and solar lanterns) or without electricity.

21 Per capita expenditure does not include energy expenses.

TABLE 4.2B • Changes in Monthly Household Employment Hours Due to Electricity Adoption

Electricity access model[a]	Adults, ages 15–65 (% change)				
	Men in farm sector	Men in nonfarm sector	Men overall	Women in nonfarm sector	Women overall
Model 1. Any source (grid, mini-grid, or SHS)[a]	0	36.7	31.3	0	99.8
Model 2A. Grid[a]	0	57.4	0	0	100.2
Model 2B. Mini-grid or SHS[a]	0	0	0	0	99.3
Model 3. Grid[b]	−44.8	71.8	0	0	67.4

Source: Nepal MTF household survey 2017.

Note: Table A.7a provides more detailed statistical impacts. Models are for individual cases from 8,500 to 9,904.

a. Compared to those without electricity.

b. Model 3 Compared to those with lower-capacity systems (rechargeable batteries, generator sets, and solar lanterns) or without electricity.

TABLE 4.3 • Changes in Household Behavior Due to Electricity Adoption

Electricity access model	Women's time use (ages 15–49)			
	Fuel collection and food preparation (hours/week)	Income generating activities (minutes/day)	Kerosene consumption (% change)	Cooking with clean stoves (percentage points change in stove use)[a]
Model 1. Any source (grid, mini-grid, or SHS)[b]	0	0	−76.5	21.6
Model 2A. Grid[b]	−1.109	0	−73.6	27.9
Model 2B. Mini-grid or SHS[b]	0	0	−49.2	10.7
Model 3. Grid[c]	0	17.7	−66.8	27.5

Source: Nepal MTF household survey 2017.

Note: Table A.7b provides more detailed statistical impacts. The models are for individuals; the number of cases vary from 5,147 to 6000.

a. The majority of clean stoves in Nepal are LPG-fueled.

b. Compared to those without electricity.

c. Compared to those with lower-capacity systems (rechargeable batteries, generator sets, and solar lanterns) or without electricity.

With grid electricity, women's employment hours increase by more than 67 percent (table 4.2b). Compared to women in households without electricity or limited to lower-capacity systems, women in households with grid access spend about 18 minutes more per day on income generating activities (IGA) (table 4.3, Model 3). Also, compared to those without electricity, women in households with grid access spend over an hour less per week on fuel collection and food preparation (table 4.3, Model 2). The reason may be that women in grid-connected households are likely to switch to a more efficiant mode of cooking.

The use of grid electricity is strongly related to lighting and cooking activities. Those with electricity from the grid use 67 percent less kerosene than households without electricity (table 4.3, Model 3). This reduction may result from a combination of greater cooking efficiency and less use of kerosene lamps for lighting. Households with grid electricity are also more likely to cook with cleaner stoves. The use of clean cookstoves is 27.5 percentage points higher for grid-connected households, compared to households without electricity (table 4.3, Model 3). The use impact for households with off-grid sources is similar but slightly weaker (table 4.3, Model 2B).

To summarize, out of the 13 development outcomes considered in this study, 8 are impacted by having grid electricity and 6 by having an off-grid power source, and these benefits are statistically significant.

While simply adopting a grid or off-grid electricity connection is clearly beneficial for households, the quality of service may not be uniform. The quality of service may also be important for development outcomes.

Multi-Tier Framework

Do households with access to higher electricity service levels, as articulated in the MTF, experience additional development benefits?[22] The study's findings show that, for per capita expenditure, the impact is substantial and statistically significant for Tier-5 households. Compared to households without electricity, Tier-5 households have per capita food and nonfood expenditures that are 249 percent and 160 percent higher, respectively. The only other household tier with a statistically significant impact for per capita expenditure is Tier 1, which has a food expenditure 186 percent higher than that of Tier 0 (table 4.4a).

For productive activities, the tiers of electricity access do not matter significantly, with some exceptions. Men's overall time allocation to productive activities is higher by about 27 percent for Tier 4 households (table 4.4b).

TABLE 4.4A • **Changes in Household Expenditure from Moving Up One Tier**

Tier attained	Per capita (% change)		
	Food	Nonfood	Total
1	185.8	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	249.0	159.5	194.1
Households (no.)	**6,000**	**6,000**	**6,000**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.8a provides more detailed statistical impacts.

TABLE 4.4B • **Changes in Monthly Household Employment Hours from Moving Up One Tier**

Tier attained	Adults, ages 15–65 (% change)					
	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	27.3	0	0	0
5	−43.5	0	0	0	0	0
Individuals (no.)	**8,500**	**8,500**	**8,500**	**9,904**	**9,904**	**9,904**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.8a provides more detailed statistical impacts.

22 The first stage of this analysis employs an ordered logit model, using the same instruments as those for estimating the effects of simple access.

Kerosene consumption is lower for households in the higher tiers; however, its decrease is not uniform across all tiers (table 4.5). Finally, households in the higher tiers are more likely to use clean methods of cooking. Compared to households without any access to electricity, the probability of using clean cookstoves is 136 percentage points higher for households in Tier 3 and 188 percentage points higher for those in Tier 5 (table 4.5). Likewise, the change in fuel-collection and food-preparation time is reduced for households moving to higher energy-access tiers.

TABLE 4.5 • **Changes in Household Behavior from Moving Up One Tier**

Tier attained	Women's time use (ages 15–49)			
	Fuel collection and food preparation (hours/week)	Income generating activities (minutes/day)	Kerosene consumption (% change)	Cooking with clean stoves (percentage points change in stove use)[a]
1	0	0	−73.2	0
2	1.289	0	187.9	0
3	−0.909	0	−79.2	136.2
4	0	0	0	0
5	−0.841	0	−90.8	187.6
Households (no.)	**6,000**	**6,000**	**6,000**	**6,000**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.8b provides more detailed statistical impacts.

a. The majority of clean stoves in Nepal are LPG-fueled.

Reduced Two-Tier Model

While each of the five tiers provides some insights into the impacts of electricity, this study finds that, in the context of Nepal, they also provide too fine an instrument for measuring the impact of electricity for development.[23] Taken individually, the impacts of Tiers 1–4 are fairly weak. It is only Tier 5 that seems to have a sufficiently strong relationship with development outcomes. For that reason, this study also combines and compares Tiers 1–4 households with Tier 5 households to understand the difference between the development impact of the highest-quality electricity service and the lower service levels.

Combining Tiers 1–4 sharpens the findings; more specifically, this produces statistically significant results for 9 out of the 13 outcomes considered, and table B.2 provides the test for statistical significance from combining Tiers 1 through 4 (Appendix B). This means that Tiers 1–4 can be combined to form one category without losing statistical significance.

Commensurate with these results, the impacts of hierarchical electricity access are analyzed using three, instead of six, categories: (i) those without electricity or with electricity whose service quality is below Tier 1 (the excluded group); (ii) those in Tiers 1–4 (the middle tiers); and (iii) those in Tier 5 (the highest tier). This method of estimation substantially improves the results of the analysis (tables 4.6a, 4.6b, and 4.7).

23 This may not be the case for other developing-country contexts.

TABLE 4.6A • Changes in Household Expenditure from Moving Up One Tier[a]

Tier attained	Per capita (% change)		
	Food	Nonfood	Total
1–4	77.6	0	0
5	0	126.6	0
Households (no.)	**6,000**	**6,000**	**6,000**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.9a provides more detailed statistical impacts.

a. Tier movement is from Tier 0 to the combined middle tiers (Tiers 1–4) or from Tiers 1–4 to the highest tier (Tier 5).

TABLE 4.6B • Changes in Household Monthly Employment Hours from Moving Up One Tier[a]

Tier attained	Adults, ages 15–65 (% change)					
	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
1–4	0	0	0	409.8	0	527.6
5	0	0	0	403.2	0	501.0
Individuals (no.)	**8,500**	**8,500**	**8,500**	**9,904**	**9,904**	**9,904**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.9a provides more detailed statistical impacts.

a. Tier movement is from Tier 0 to the combined middle tiers (Tiers 1–4) or from Tiers 1–4 to the highest tier (Tier 5).

Using the reduced two-tier model indicates a greater benefit for women in Tier-5 households. For example, the amount of time per day allocated to productive activities is 65.9 minutes higher for women in Tier-5 households, compared to those in households without electricity (table 4.7). This finding is in contrast to that reported in table 4.5, which shows no tier-specific impacts on women's time allocation.

Similarly, the estimated reduction in kerosene consumption for households in Tiers 1–4 is nearly 98 percent over those in Tier 0. Finally, the use of clean cookstoves is about 49 percentage points higher for households in Tiers 1–4 and nearly 89 percentage points higher for Tier-5 households, compared to those with minimal or no electricity access (table 4.7).

TABLE 4.7 • Changes in Household Behavior from Moving Up One Tier[a]

Tier attained	Women's time use (ages 15–49)			
	Fuel collection and food preparation (hours/week)	Income generating activities (minutes/day)	Kerosene consumption (% change)	Cooking with clean stoves (percentage points change in stove use)[b]
Tiers 1–4	0	0	−97.5	48.7
Tier 5	0	65.9	−97.9	88.7
Households (no.)	**6,000**	**6,000**	**6,000**	**6,000**

Source: Nepal MTF household survey 2017.

Note: The model excludes households with electricity from mini-grid or SHS. Table A.9b provides more detailed statistical impacts.

a. Tier movement is from Tier 0 to the combined middle tiers (Tiers 1–4) or from Tiers 1–4 to the highest tier (Tier 5).

b. The majority of clean stoves in Nepal are LPG-fueled.

The implication is that the Government of Nepal and other developing-country governments should strive for the highest level of electricity service because it has the greatest welfare benefits. Households with electricity-service levels comparable to those of developed countries are probably more likely to invest in a diversity of modern, high-capacity appliances, compared to households at lower service levels. That said, as an overall strategy, governments should pursue electricity service for as many households as possible, even if it falls below the highest level of service.

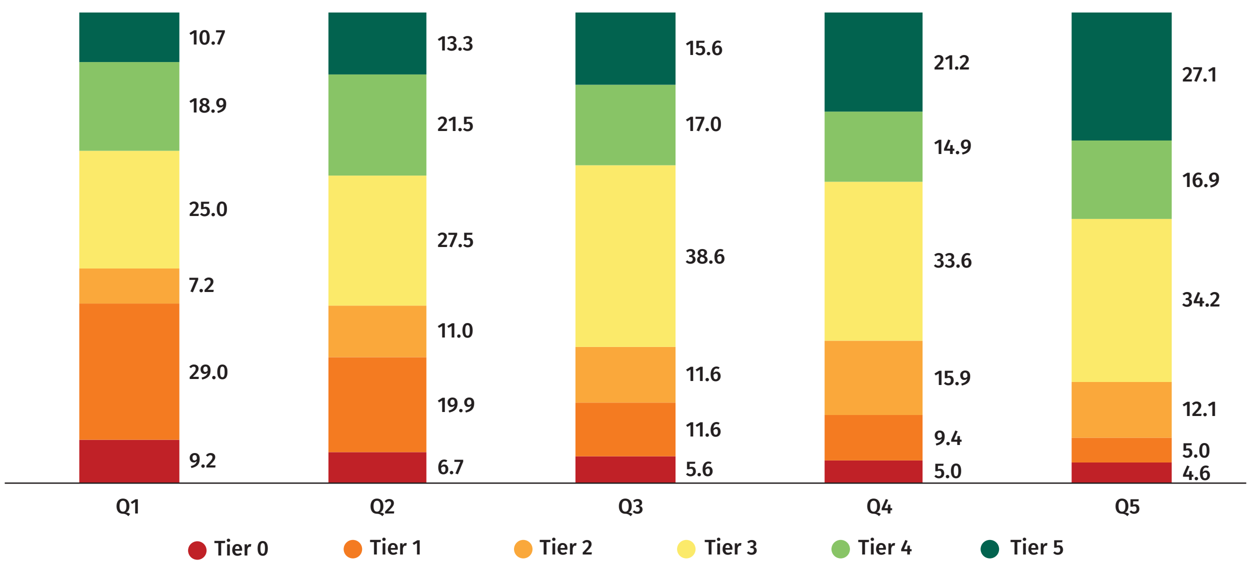
5. WHAT IS ELECTRICITY'S IMPACT ON POVERTY REDUCTION?

It is not surprising that electricity impacts quality of life. The more important question is whether the economic and educational consequences of electricity supply are sufficient to uplift lower-income groups from poverty. This section specifically examines whether the tiers of electricity service have an impact on those in poverty in Nepal (Kanagawa and Nakata 2008; Lenz et al. 2017; Meier et al. 2010; Pueyo and Maestre 2019).

Higher-quality electricity access and its resulting higher consumption appear to impact household welfare as measured by expenditures and productivity. The tier distribution by households shows that a higher level of electricity consumption and quality of service is generally related to higher expenditures (figure 5.1). About 11 percent of households in the lowest-expenditure quintile and 27 percent of those in the highest expenditure quintile are in Tier 5. That is, higher income, as measured by per capita expenditure, means higher tier levels of electricity access and service.

FIGURE 5.1 • **MTF Tier Representation of Expenditure Quintiles in Nepal, 2017**

(Means percent for each electricity tier)



This strong correlation between higher income and higher electricity tiers of service is interesting, but it does not imply causality. To better assess this relationship, it is necessary to estimate the impact of electricity consumption, along with other factors, on household income and consumption. Once this is done, it might be possible to estimate the impact of the electricity tiers on poverty levels. We assess the impact of electricity consumption on household-level per capita expenditure using the specification of equation (4.1) and implementing the instrumental variables (IV) method using the same instruments as we did for access based on the simple measure.[24]

24 We could also use the MTF model of equation (4.2), along with demand equation (3.1), to estimate the impact of higher tiers on overall household consumption to illustrate the effects of electricity consumption. In fact, as presented in tables 4.4a and 4.6a, we have the estimates of the impact of tier access on household expenditure. However, this is an indirect way to measure the electricity consumption effect of household welfare. Thus, we use a direct measure of the impact of electricity consumption on welfare following the method discussed here.

The results in table A.10 indicate that monthly kilowatt-hour consumption has substantial impacts on household per capita nonfood and total expenditure. It does not appear to impact food expenditures, perhaps because they are basic necessities. The full sample used in Model 1 (i.e., households with mini-grids and solar home systems [SHS], which generally have lower levels of electricity consumption) are excluded in Model 2.[25] The results are that a 10 percent increase in electricity consumption raises a household's per person nonfood consumption by 1.2 percent and total expenditure by 0.9 percent. With these figures, it is possible to calculate the poverty-reduction impacts of electricity consumption and the sensitivity of poverty to variations in electricity consumption.

SENSITIVITY OF POVERTY TO CHANGE IN ELECTRICITY CONSUMPTION

The poverty line used in this study is based on US$1.90 per day (World Bank 2020), which, according to the Nepal MTF household survey, gives a poverty headcount ratio of 48.1 percent. This poverty figure is an overestimate of the country's actual poverty, which was documented as 16 percent in 2010.[26] While the survey asks key questions on expenditures, many of those found in national income or expenditure surveys were omitted because of the time and effort needed to collect such rich data. That said, we made use of the calculated poverty estimate, keeping this caveat in mind. Based on the best available data, these results are more indicative of the sensitivity of poverty, not the level of poverty, to the change in electricity consumption.

TABLE 5.1 • **Impact of Simulated Increases in Electricity Consumption on Poverty Reduction in Nepal[a]**

Poverty level	Measure
Level of poverty rate compared to consumption (NPR/day)[b]	
Actual household per capita consumption	221.6
Poverty line	196.5
Existing poverty rate and impact of interventions (% of population)	
Current poverty rate	48.1
Pre-intervention poverty rate	57.2
Poverty rate after raising consumption of all grid-connected households to Tier-5 consumption	33.4
Poverty rate after raising consumption of all sampled households to Tier-5 consumption	22.6

Source: Nepal MTF household survey 2017.

a. Based on the findings reported in table A.10.

b. Equivalent to US$1.90/day in purchasing power parity (PPP).

The results suggest that Nepal has the potential to substantially reduce its poverty by providing all households with electricity service comparable to that of Tier 5. Raising monthly electricity consumption to the average level (57.5 kWh) for all households that consume less than that would reduce Nepal's poverty rate by 9.1 percentage points (from 57.2 percent to 48.1 percent) (table 5.1). Furthermore, if the electricity consumption of households in Tiers 1–4 were raised to that of households in Tier 5 (72.3 kWh

25 For this analysis, it is better to use the whole sample, which is more representative of Nepal overall.
26 See https://data.worldbank.org/indicator/SI.POV.DDAY?end=2015&locations=1W-NP&start=1981&view=chart.

per month in 2017), Nepal's aggregate poverty would be further reduced by another 14.7 percentage points to 33.4 percent (table 5.1). Moreover, if those households without electricity access were connected to the grid and the kilowatt-hour consumption of all households were raised to the level of Tier-5 households, the country's poverty rate could be reduced by another 10.8 percentage points to 22.6 percent (table 5.1).

RAISING ELECTRICITY CONSUMPTION

Nepal's Tier-5 electricity consumption level, at 72.3 kWh per month, is fairly small compared to the country's aspirational goal of reaching 260 kWh per month.[27] It is also far less than that of other countries.[28] Household expenditure on electricity consumption as a percentage of total expenditure is sometimes used as a measure of the adequacy of energy consumption. The overall electricity expenditure in Nepal is only 1.3 percent of household total expenditure, which is lower than the 3–5 percent levels commonly found in other developing countries (table 5.2). The implication is that Nepal has room to increase electricity consumption without squeezing out other necessary household expenditures.

TABLE 5.2 • **Average Electricity Expenditures as a Percentage of Total Expenditure by Income Quintile and MTF Tier**

Income quintile	Electricity's share of all expenditures (%)
1	1.6
2	1.5
3	1.2
4	1.2
5	1.0
MTF tier	
1	1.5
2	1.1
3	1.3
4	1.5
5	1.2
Overall average (%)	1.3
Households (no.)	**4,045**

Source: Nepal MTF household survey 2017.

Electricity consumption increases with household income (table 5.3), but raising incomes is not an easily achievable policy goal. More realistic ways to increase the electricity consumption of households might include improving the reliability of electricity service and the availability and affordability of appliances (Auffhammer and Wolfram 2014; Dhanaraj, Mahambare, and Munjal 2018; Jensen and Oster 2009; Meier et al. 2010; Richmond and Urpelainen 2019).

27 This level is based on government's 2030 target of 1,500 kWh in annual per capita energy consumption and assumes that household consumption represents 45 percent of total nationwide consumption (see https://energypedia.info/wiki/Nepal_Energy_Situation).

28 In neighboring Bangladesh, for example, the average household electricity use is 160 kWh per month. As a developed country comparison, the average household electricity consumption in the United States is 914 kWh per month (2018 figure) (EIA 2019).

To explore the relative roles of electric appliances in electricity consumption, this study modeled electricity consumption as a function of common household appliances and other factors, implemented by ordinary least squares (OLS) (table 5.3). Model 1 includes only electric appliances, while Model 2 includes both appliances and a host of other variables, including household head's age, sex, and education; land assets; geography (Hill or Terai region); and locality (rural or urban). The results for both models are quite similar.

TABLE 5.3 • **Increased Monthly Household Consumption of Electricity Due to Appliances Use**

Appliance type	Average number of appliances per household (mean)	Electricity consumption attributed to appliance use (kWh/month)
TVs	0.7	4.1
Refrigerators	0.2	27.9
Fans	1.5	3.8
Electric irons	0.2	8.0
Electric water pumps	0.1	17.6
Blenders	0.1	9.5
Computers	0.1	26.2
Incandescent light bulbs	0.9	1.5
Fluorescent light bulbs	0.3	4.2
CFL bulbs	3.4	3.7
LED bulbs	1.3	2.0
Households (no.)	**4,045**	**4,045**

Source: Nepal MTF household survey 2017.

Note: The numbers for appliance use are regresssion coefficients. They represent the additional kilowatt-hours per month for a 1-unit increase in household appliances ownership. The model uses controls for other household- and community-level variables, such as household head's sex, age, education, land asset, and household locality (urban, Hill, or Terai area). Table A.11 provides detailed statistical impacts for other explanatory variables.

The use of various appliances significantly affects a household's electricity consumption. It is also generally accepted that households using more efficient appliances are more likely to have higher levels of benefits and lower electricity use (Chaplin et al. 2017; Lee, Miguel, and Wolfram 2020). For example, having refrigerators for food preservation means a household will consume an extra 28 kWh per month (table 5.3); however, refrigerator ownership in Nepal is low, at just 20 percent. Computers and internet access benefit households by enhancing knowledge, education, entertainment, and access to the news. The use of computers contributes 26 kWh toward monthly electricity consumption, but computers are owned by only 10 percent of Nepal's population. Additional appliances of significant importance to household welfare and their monthly kilowatt-hour consumption levels include television sets (3–4 kWh), fans (4–7 kWh), electric water pumps (15–18 kWh), blenders (8–9 kWh), and a wide variety of light bulbs (1–4 kWh). Programs to make energy-efficient modern appliances available to households at affordable monthly costs could dramatically improve the benefits of electricity investment in Nepal.

6. DISCUSSION AND POLICY IMPLICATIONS

The Multi-Tier Framework (MTF) has aimed to redefine the measurement of electricity access in developing countries from "simple" to "meaningful." The main question addressed in this research is whether "meaningful" access will redefine the important impacts that electricity has on households in developing countries. In developed countries, access to electricity means having power immediately available that is of uniform quality without any fluctuation; however, this is not the case in developing countries. The question is how much of a difference the MTF approach makes for measuring the benefits of electricity. Put another way, how important is it to quantify electricity's impact by levels of access and service as defined by the MTF tiers?

To answer this question, this empirical study examined the benefits of simple electricity connection vis-à-vis those of the MTF tiers for a nationally representative survey conducted in Nepal, comprising 6,000 urban and rural households. The study hypothesized that having reliable and affordable power offering higher service levels would enhance the socioeconomic benefits for households.

The survey findings demonstrate the value of defining electricity access in a hierarchical way that extends beyond simple connections. This is not to say that simple electricity connections have no development impacts. This research confirms the results of past studies that found simple electricity access has a measurable impact on household welfare, especially in areas where complementary conditions are in place (Barkat et al. 2002; Barnes 2014; Barnes, Golumbeanu, and Diaw 2016; Bensch, Kluve, and Peters 2011; Grogan and Sadanand 2012; Hamburger et al. 2019; Lee, Miguel, and Wolfram 2020; World Bank 2008).

This research goes further by measuring the incremental impact of tiers of electricity service on development outcomes. The findings confirm that gaining electricity access and attaining higher tiers of access— particularly Tier 5—have a significant impact on household welfare. In Nepal, additional benefits are possible by providing more households with a Tier 5 service level. In many parts of the country, the electricity lines are already in place, and service improvements would greatly enhance the benefits of having electricity.

BENEFITS OF HIGHER ELECTRICITY CONSUMPTION

The many benefits to households from accessing higher tiers include improvements in household expenditures (a proxy for household income), labor supply, women's time allocation for productive activities, and cooking behavior. For example, the nonfood expenditures of Tier-5 households are 160 percent higher than those of households without any access to electricity (Tier 0). Compared to Tier-0 households, Tier-5 households consume 91 percent less kerosene. In Tier-3 and Tier-1 households, kerosene consumption is lower by 79 percent and 73 percent, respectively. This is an important finding because it shows that improving the level of electricity service will result in further income gains (measured by expenditure) above and beyond the effects of simply providing households an electricity connection.

The consumption benefits imply that access to electricity has a poverty-reduction impact in Nepal, which the findings confirm. The increases in household expenditures that might result from accessing the highest level of electricity service (Tier 5) across all of Nepal would result in reducing poverty by more than 50 percentage points. The electricity benefits are channeled through higher levels of monthly kilowatt-hour consumption, indicating that the number of appliances used in the household may also have some relationship with poverty reduction.

Households in the higher electricity tiers also tend to use cleaner fuels, such as liquefied petroleum gas (LPG) or better cooking appliances like improved stoves. This suggests that a change in the household environment (e.g., greater lighting or more appliances) leads to cleaner cooking. The simple adoption of electricity increases the likelihood of using clean cooking methods by about 28 percentage points. The results using the reduced two-tier model are even more striking. For those in Tier 5 and Tiers 1–4, the respective increases in adoption rates for clean cooking methods are 89 percentage points and 49 percentage points.

APPLIANCES AND HOUSEHOLD WELFARE

This research finds additional benefits from the increased use of appliances in Nepal. The connection between appliance ownership and household welfare is an underappreciated issue in the literature on the impacts of electricity on development. After all, the impact of electricity on households is mediated through the appliance stock in households. Electricity flows through appliances that provide convenience, lighting, and other benefits that translate into better levels of education, income, and productivity.

Nepal's low rate of appliance adoption might be caused by multiple factors, including high cost, lack of product diversity, low availability in the local market (particularly in rural areas), or lack of after-sales service. High costs might be dealt with by providing small loans to consumers for the purchase of appliances. Also, the utility companies might form alliances with private retailers to promote the sale of appliances. In addition, the government might play an effective role by providing incentives for local manufacturers, lowering the duty on imported appliances, or providing financing plans that can make high-end appliances more affordable to households. Furthermore, the reliability of the power supply is an important factor for incentivizing households to purchase and use appliances.

Improving Nepal's appliance ownership—which undoubtedly would raise households' consumption of electricity—may be one way to achieve higher levels of impact and leverage the significant investments by the government and power industry in extending electricity access. Ways to raise households' electricity consumption might include promoting electricity's use for productive and income-generating activities (IGA), as well as promoting the convenience of electric appliances for undertaking a wide array of household tasks. In short, raising household levels of electricity consumption extends beyond engineering solutions.

ROLE OF OFF-GRID SOLUTIONS

In off-grid communities, the use of micro-hydro and solar home systems (SHS) for generating household electricity has been found to provide lower levels of service than grid systems. However, much of Nepal is mountainous, making grid extension to all locations quite difficult. Nepal's past mini-grid accomplishments have been a model for other developing countries. Also, the sale of SHS to areas without any possibility of getting mini-grid or grid electricity is a good policy.

Now that off-grid solutions are well established in Nepal, the time might be ripe for modernizing the mini-grid systems so that they provide service levels more comparable to those of the grid. Decades ago, mini-grids in China played a very useful role in providing electricity to the country's remote populations. Today, most of those mini-grids have been upgraded and integrated into the national grid. Selling electricity to the national grid now provides owners of those micro-hydro systems a significant source of income.

Similarly, in Nepal, mini-grid systems and SHS have played an extremely important role in providing remote locations benefits that otherwise would not have been possible. Even though the future role of mini-grids and SHS in Nepal may change, it remains quite important to continue enhancing these off-grid solutions.

LOOKING AHEAD

Nepal's electricity system has been developing and expanding at a rapid pace (World Bank 2019). Now that basic electricity infrastructure has reached most parts of Nepal, the goal can turn more toward improving the quality of power supply, while at the same time continuing expansion of access. This will help move grid-connected households currently in the lower tiers to the higher ones, thereby enhancing the development benefits of electricity access.

To address power supply issues, the government and policy makers have been attempting to improve transmission and distribution networks. According to the Nepal Electricity Authority (NEA), the incidence of load shedding in 2018—one year after the MTF household survey was completed—was low for most of the country. The NEA claims to have improved reliability through better load management, the completion of several transmission lines, and the import of electricity from India. To ensure the distributional equity of grid electricity, the government is working on greater coordination between central, provincial, and local governments. To what extent these steps have resolved quality and service reliability issues remains to be determined, perhaps through a follow-up survey.

Although the World Bank's Energy Sector Management Assistance Program (ESMAP) planned to have stocktaking exercises every two-to-three years following the 2017 MTF household survey, the completion of large surveys might not be feasible within such short intervals. However, it might be possible to field a scaled-down version that is less expensive and easier to implement, with MTF attribute–specific instruments as a monitoring tool. More frequent MTF-based tracking could closely follow the progress of the electricity companies in achieving a high quality of electricity access. Such tracking could be in the form of stand-alone surveys administered by the electricity companies or included in larger national-level surveys completed at regular intervals.

In conclusion, this study finds that the benefits of having high-quality electricity access, as measured by the MTF, go beyond those revealed through using the simpler binary access measure. The goal for Nepal is not only to provide electricity but also to increase the benefits from such large infrastructure investments. To measure progress in the development benefits of electricity, policy makers might want to complement the standard MTF household survey with more frequent monitoring of the electricity tiers, combined with simple household appliance surveys. Finally, policies that encourage the adoption of appliances for those households that already have electricity will increase the benefits for the country, while also improving the financial status of the electricity companies.

Appendix A. Statistical Tables

TABLE A.1 • **Descriptive Statistics of the Explanatory Variables**

Explanatory variable	Rural	Urban	Nationwide
Sex of household head (1 = male, 0 = female)	0.827 (0.378)	0.782 (0.413)	0.818 (0.386)
Age of household head (years)	49.475 (14.130)	49.468 (13.587)	49.473 (14.016)
Head completed primary level of education	0.239 (0.426)	0.219 (0.414)	0.235 (0.424)
Head completed secondary level of education	0.240 (0.427)	0.300 (0.458)	0.253 (0.435)
Head completed higher secondary or higher level of education	0.078 (0.268)	0.141 (0.348)	0.091 (0.288)
Number of adult males (18 years or older) in household	1.404 (0.869)	1.440 (0.935)	1.411 (0.883)
Number of adult females (18 years or older) in household	1.604 (0.826)	1.656 (0.854)	1.615 (0.832)
Value of household agricultural land (in thousand NPR)	1.983 (6.749)	3.814 (15.280)	2.369 (9.258)
Household is in urban location			0.211 (0.408)
Household is in Hill areas	0.432 (0.495)	0.467 (0.499)	0.440 (0.496)
Household is in Terai areas	0.494 (0.500)	0.466 (0.499)	0.488 (0.500)
Household distance to grid pole (in 100 m)	11.048 (38.005)	3.096 (20.098)	9.372 (35.147)
Community has mini-grid	0.151 (0.358)	0.034 (0.181)	0.126 (0.332)
Community has SHS	0.061 (0.239)	0.157 (0.364)	0.081 (0.273)
Unavailability of grid service in the community (hours/day)	8.944 (9.781)	4.083 (6.214)	7.919 (9.357)
Unavailability of min-grid service in the community (hours/day)	21.852 (5.328)	23.621 (2.603)	22.225 (4.935)
Unavailability of SHS service in the community (hours/day)	23.515 (1.725)	23.944 (0.541)	23.605 (1.562)
Community price of grid electricity (NPR/kWh)	8.869 (0.206)	9.046 (0.442)	8.907 (0.283)

Community price of mini-grid electricity (NPR/kWh)	8.377 (0.128)	8.888 (0.990)	8.484 (0.513)
Community price of kerosene (NPR/kWh)	100.373 (8.526)	96.094 (13.547)	99.471 (9.954)
Community price of fuelwood (NPR/kg)	7.942 (4.460)	9.366 (4.806)	8.242 (4.572)
Community price of LPG (in 100 NPR/kg)	15.035 (2.172)	14.820 (2.124)	14.989 (2.163)
Village is accessible year-round	0.701 (0.458)	0.864 (0.343)	0.736 (0.441)
Village has market	0.238 (0.426)	0.452 (0.498)	0.283 (0.451)
Community had floods during the last 12 month	0.364 (0.481)	0.271 (0.444)	0.344 (0.475)
Village distance to district center (km)	34.272 (27.709)	18.119 (17.876)	30.867 (26.769)
Development region is Eastern	0.257 (0.437)	0.228 (0.420)	0.251 (0.434)
Development region is Central	0.284 (0.451)	0.361 (0.480)	0.300 (0.459)
Development region is Western	0.208 (0.406)	0.208 (0.406)	0.208 (0.406)
Development region is Mid-western	0.154 (0.361)	0.117 (0.32)	0.146 (0.353)
Development region is Far-western	0.097 (0.296)	0.087 (0.281)	0.095 (0.293)
N	2,715	3,285	6,000

Source: Nepal MTF household survey 2017.

Note: Standard deviations are shown in parentheses.

TABLE A.2 • **Relationship between Community and Household Characteristics and Simple Access to Electricity**

(Probit estimates for electricity from all sources, including national grid, mini-grid, or SHS)

Explanatory variable	**Rural**	**Urban**	**Nationwide**
Explanatory variable	Rural	Urban	Nationwide
Sex of household head (1 = male, 0 = female)	−0.047** (−2.642)	−0.005 (−1.545)	−0.036** (−2.929)
Age of household head (years)	0.002** (2.580)	0.0003** (2.394)	0.001** (3.369)
Head completed primary level of education	0.037** (2.259)	0.007** (2.544)	0.033** (2.929)

Explanatory variable	Rural	Urban	Nationwide
Head completed secondary level of education	0.072** (4.214)	0.014** (4.740)	0.064** (5.467)
Head completed higher secondary or higher level of education	0.055** (2.289)	0.016** (6.994)	0.055** (3.538)
Number of adult males (18 years or older) in household	0.018* (1.766)	0.002 (0.786)	0.012* (1.720)
Number of adult females (18 years or older) in household	0.009 (0.901)	0.005** (2.586)	0.010 (1.393)
Log value of household agricultural land (in thousand NPR)	0.042** (3.214)	0.003 (1.543)	0.029** (3.301)
Household is in urban location			0.024** (2.284)
Household is in Hill areas	−0.095** (−3.311)	−0.004 (−0.753)	−0.073** (−3.864)
Household is in Terai areas	−0.054 (−1.588)	0.006 (1.281)	−0.034 (−1.522)
Household distance to grid pole (in 100 m)	−0.0003* (−1.950)	−0.001** (−2.884)	−0.0003** (−2.069)
Community has mini-grid	0.096** (5.750)	0.008** (3.482)	0.074** (7.522)
Community has SHS	0.028 (0.901)	−0.019** (−2.521)	0.003 (0.130)
Unavailability of grid service in the community (hours/day)	−0.020** (−15.465)	−0.002** (−10.207)	−0.016** (−19.726)
Unavailability of mini-grid service in the community (hours/day)	−0.023** (−9.275)	−0.003** (−5.011)	−0.018** (−10.742)
Unavailability of SHS service in the community (hours/day)	−0.017** (−3.543)	−0.059** (−2.906)	−0.016** (−4.288)
Community price of grid electricity (NPR/kWh)	−0.080** (−2.888)	0.008 (1.439)	−0.036** (−2.213)
Community price of mini-grid electricity (NPR/kWh)	−0.196* (−1.921)	−0.004 (−1.597)	−0.003 (−0.316)
Community price of kerosene (NPR/kWh)	−0.003* (−1.705)	0.00005 (0.234)	−0.001* (−1.879)
Community price of fuelwood (NPR/kg)	0.001 (0.989)	−0.0004 (−1.482)	0.001 (0.674)
Community price of LPG (in 100 NPR/kg)	−0.001 (−0.323)	−0.001** (−2.008)	−0.002 (−1.031)
Community is accessible year-round	0.037** (2.182)	0.008 (1.547)	0.026** (2.112)
Community has market	0.037** (2.703)	0.007** (2.377)	0.035** (3.911)
Community had floods during the last 12 month	−0.016 (−0.901)	−0.010** (−3.264)	−0.018 (−1.380)

Explanatory variable	Rural	Urban	Nationwide
Community distance to district center (km)	0.0001 (0.428)	0.00002 (0.264)	−0.00001 (−0.065)
Regional fixed-effects	Yes	Yes	Yes
R^2	0.567	0.534	0.556
Log likelihood	−552.76	−413.79	−1160.59
Observations	2,715	3,285	6,000

Source: Nepal MTF household survey 2017.

Note: Simple access to electricity means households with and without electricity service. Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. * and ** represent statistical significance of 10% and 5% or better, respectively.

Table A.3 • Relationship between Community and Household Characteristics and Simple Grid Access to Electricity

(Probit estimates for electricity from the national grid)

Explanatory variable	Rural	Urban	Nationwide
Sex of household head (1 = male, 0 = female)	−0.001** (−1.976)	−0.016 (−1.537)	−0.046** (−2.361)
Age of household head (years)	0.00003** (2.651)	0.001** (2.145)	0.002** (3.517)
Head completed primary level of education	0.001** (2.396)	0.013 (1.455)	0.048** (3.015)
Head completed secondary level of education	0.003** (3.354)	0.039** (3.906)	0.108** (4.480)
Head completed higher secondary or higher level of education	0.003* (1.860)	0.041** (5.882)	0.136** (2.998)
Number of adult males (18 years or older) in household	0.0001 (0.326)	0.004 (0.695)	0.003 (0.351)
Number of adult females (18 years or older) in household	0.0001 (0.424)	0.014** (2.553)	0.010 (1.074)
Log value of household agricultural land (in thousand NPR)	0.001** (3.192)	0.009 (1.506)	0.030** (3.373)
Household is in urban location			0.037** (2.683)
Household is in Hill areas	−0.002** (−3.130)	−0.026 (−1.597)	−0.082** (−4.213)
Household is in Terai areas	−0.004** (−3.179)	−0.009 (−0.569)	−0.097** (−4.165)
Household distance to grid pole (in 100 m)	−0.001** (−6.344)	−0.011** (−6.230)	−0.039** (−7.041)
Community has mini-grid	−0.001** (−2.033)	−0.023 (−0.830)	−0.047** (−2.740)
Community has SHS	−0.001** (−3.559)	−0.047** (−2.339)	−0.051** (−3.787)

Explanatory variable	Rural	Urban	Nationwide
Unavailability of grid service in the community (hours/day)	−0.0003** (−10.990)	−0.008** (−9.335)	−0.017** (−13.276)
Community price of grid electricity (NPR/kWh)	−0.002** (−3.831)	0.029 (1.570)	−0.031* (−1.904)
Community price of kerosene (NPR/kWh)	−0.00005* (−1.660)	0.001 (0.963)	−0.001 (−1.574)
Community price of fuelwood (NPR/kg)	0.0005** (2.161)	−0.001 (−1.590)	0.0003 (0.429)
Community price of LPG (in 100 NPR/kg)	−0.0003** (−5.023)	−0.004** (−2.166)	−0.011** (−4.429)
Community is accessible year-round	0.0003 (0.786)	0.037** (2.706)	0.023* (1.699)
Community has market	0.002** (4.235)	0.025** (2.619)	0.070** (5.090)
Community had floods during the last 12 month	−0.0001 (−0.478)	−0.044** (−4.153)	−0.012 (−0.912)
Community distance to district center (km)	0.00003** (3.974)	−0.0004** (−2.193)	0.001** (3.457)
Region fixed-effects	Yes	Yes	Yes
R^2	0.804	0.654	0.783
Log likelihood	-337.76	-378.30	-775.07
Observations	2,715	3,285	6,000

Source: Nepal MTF household survey 2017.

Note: Simple access to electricity means households with and without electricity service. Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. * and ** represent statistical significance of 10% and 5% or better, respectively.

TABLE A.4 • **Factors Influencing Electricity Consumption from the National Grid System**

(Tobit estimates of the log of monthly consumption of electricity in kilowatt-hours)

Explanatory variable	Rural	Urban	Nationwide
Sex of household head (1 = male, 0 = female)	−0.001	−0.001	−0.001
	(−0.784)	(−0.685)	(−1.033)
Age of household head (years)	0.000	0.000*	0.000
	(0.643)	(1.691)	(1.421)
Head completed primary level of education	0.004**	0.001	0.003**
	(2.419)	(1.209)	(2.780)
Head completed secondary level of education	0.003**	0.004**	0.004**
	(2.002)	(3.745)	(3.217)
Head completed higher secondary or higher level of education	0.003 (1.493)	0.005** (3.389)	0.004** (2.375)
Number of adult males (18 years or older) in household	0.001 (0.830)	−0.000 (−0.497)	0.000 (0.660)

Explanatory variable	Rural	Urban	Nationwide
Number of adult females (18 years or older) in household	−0.001* (−1.794)	0.000 (0.506)	−0.001 (−1.321)
Log value of household agricultural land (in thousand NPR)	0.001 (1.146)	0.001** (2.238)	0.001 (1.600)
Household is in urban location			−0.002**
			(−2.154)
Household is in Hill areas	0.006**	0.004**	0.005**
	(3.515)	(3.808)	(4.254)
Household is in Terai areas	0.008**	0.010**	0.008**
	(3.748)	(7.344)	(5.269)
Household distance to grid pole (in 100 m)	−0.005**	−0.002**	−0.004**
	(−8.680)	(−7.519)	(−9.962)
Community has mini-grid	0.005	0.008**	0.004
	(1.406)	(2.262)	(1.472)
Community has SHS	−0.007**	−0.004**	−0.006**
	(−2.224)	(−2.372)	(−3.543)
Average duration of unavailable grid service is in community (hours/day)	−0.002** (−7.775)	−0.001** (−8.519)	−0.002** (−9.772)
Community price of grid electricity (NPR/kWh)	0.012**	0.011**	0.015**
	(4.545)	(7.088)	(8.749)
Community price of kerosene (NPR/liter)	−0.000**	0.000	−0.000**
	(−2.946)	(0.782)	(−2.126)
Community price of fuelwood (NPR/kg)	0.000**	0.000**	0.000**
	(3.067)	(3.358)	(4.648)
Community price of LPG (in 100 NPR/kg)	−0.001**	0.000*	−0.000
	(−2.012)	(1.919)	(−0.879)
Village is accessible year-round	−0.003*	0.002*	−0.001
	(−1.820)	(1.734)	(−0.925)
Village has market	0.002	0.003**	0.002**
	(1.482)	(3.209)	(2.335)
Community had floods during the last 12 month	−0.002	−0.001	−0.001
	(−1.307)	(−0.651)	(−0.972)
Community distance to district center (km)	0.000	−0.000	0.000
	(0.906)	(−1.358)	(0.318)
Region fixed-effects	Yes	Yes	Yes
R^2	0.430	0.320	0.402
Log likelihood	− 3568396.7	− 1235239.6	− 4889586
Observations	2,072	3,073	5,145

Source: Nepal MTF household survey 2017.

Note: Average marginal effects at the point of truncation are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Household use of various electric appliances is used as an additional control. * and ** represent statistical significance of 10% and 5% or better, respectively.

TABLE A.5 • Predictors for the MTF Grid Electricity Tiers of Service

(Ordered logit estimates of the likelihood of moving one tier)[a]

Explanatory variable	Overall	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Sex of household head (1 = male, 0 = female)	0.177	−0.0001	−0.002	−0.013	−0.015	0.007
	(1.317)	(−0.918)	(−1.267)	(−1.314)	(−1.313)	(1.309)
Age of household head (years)	−0.006	0.00001	0.0001	0.0004	0.0005	−0.0002
	(−1.408)	(0.942)	(1.392)	(1.392)	(1.413)	(−1.388)
Head completed primary level of education	−0.273**	0.0002	0.004**	0.020**	0.023**	−0.011**
	(−2.257)	(1.129)	(2.121)	(2.234)	(2.247)	(−2.218)
Head completed secondary level of education	−0.279**	0.0002	0.004**	0.021**	0.023**	−0.011**
	(−2.011)	(1.068)	(1.973)	(1.990)	(1.992)	(−2.003)
Head completed higher secondary or higher level of education	−0.517** (−2.996)	0.0003 (1.168)	0.007** (2.765)	0.038** (2.930)	0.043** (2.956)	−0.021** (−2.956)
Number of adult males (18 years or older) in household	0.097	−0.0001	−0.001	−0.007	−0.008	0.004
	(1.519)	(−0.989)	(−1.444)	(−1.524)	(−1.515)	(1.508)
Number of adult females (18 years or older) in household	0.141**	−0.0001	−0.002*	−0.010**	−0.012**	0.006**
	(2.096)	(−1.106)	(−1.829)	(−2.091)	(−2.110)	(2.071)
Log value of household agricultural land (in thousand NPR)	−0.028 (−0.452)	0.00002 (0.431)	0.0004 (0.441)	0.002 (0.452)	0.002 (0.452)	−0.001 (−0.449)
Household is in urban location	0.086	−0.00005	−0.001	−0.006	−0.007	0.003
	(1.009)	(−0.799)	(−0.953)	(−0.996)	(−1.027)	(0.995)
Household is in Hill areas	−0.483**	0.0003	0.007**	0.036**	0.041**	−0.019**
	(−2.907)	(1.193)	(2.740)	(2.849)	(2.820)	(−2.836)
Household is in Terai areas	−2.683**	0.001	0.037**	0.198**	0.225**	−0.108**
	(−12.743)	(1.304)	(4.857)	(9.336)	(12.119)	(−8.216)
Household distance to grid pole (in 100 m)	−0.503**	0.0003	0.007**	0.037**	0.042**	−0.020**
	(−6.550)	(1.293)	(3.613)	(5.997)	(6.971)	(−5.171)
Community has mini-grid	−1.917**	0.001	0.026**	0.142**	0.161**	−0.077**
	(−6.843)	(1.284)	(4.142)	(6.491)	(6.633)	(−6.394)
Community has SHS	−0.073	0.00004	0.001	0.005	0.006	−0.003
	(−0.490)	(0.460)	(0.499)	(0.491)	(0.486)	(−0.492)
Unavailability of grid service in the community (hours/day)	−0.197** (−7.290)	0.0001 (1.233)	0.003** (3.853)	0.015** (8.178)	0.017** (6.663)	−0.008** (−8.530)
Community price of grid electricity (NPR/kWh)	0.494**	−0.0003	−0.007**	−0.036**	−0.041**	0.020**
	(2.980)	(−1.198)	(−3.080)	(−2.970)	(−2.846)	(3.066)

Explanatory variable	Overall	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Community price of kerosene (NPR/kWh)	−0.001	0.00001	0.00002	0.0001	0.0001	−0.0001
	(−0.380)	(0.373)	(0.382)	(0.380)	(0.380)	(−0.380)
Community price of fuelwood (NPR/kg)	0.005	−0.00001	−0.00007	−0.0004	−0.0004	0.0002
	(0.450)	(−0.424)	(−0.452)	(−0.449)	(−0.451)	(0.449)
Community price of LPG (in 100 NPR/kg)	−0.088**	0.00005	0.001**	0.007**	0.007**	−0.004**
	(−2.917)	(1.201)	(2.546)	(2.841)	(2.907)	(−2.752)
Community is accessible year-round	0.063	−0.00004	−0.001	−0.005	−0.005	0.003
	(0.473)	(−0.447)	(−0.471)	(−0.473)	(−0.472)	(0.469)
Community has market	0.383**	−0.0002	−0.005**	−0.028**	−0.032**	0.015**
	(3.672)	(−1.237)	(−2.796)	(−3.594)	(−3.666)	(3.401)
Community had floods during the last 12 months	0.498**	−0.0003	−0.007**	−0.037**	−0.042**	0.020**
	(4.128)	(−1.260)	(−2.988)	(−3.975)	(−4.195)	(4.025)
Community distance to district center (km)	0.003	−0.00001	−0.00004	−0.0002	−0.0003	0.0001
	(1.416)	(−0.969)	(−1.346)	(−1.412)	(−1.419)	(1.417)
Region fixed-effects	Yes					
Log likelihood	−3973817.3					
Pseudo R^2	0.189					
Observations (no.)	4,047					

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported for tier transitions (columns 3–7). Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The figures for each tier represent a movement of one tier (e.g., from Tier 0 to Tier 1, from Tier 1 to Tier 2, and so forth).

TABLE A.6A • Descriptive Statistics for Development Outcome Variables, by Electricity Source

(Means of the outcome variables)

Outcome variable	Grid households	Mini-grid or SHS households	Grid, mini-grid, or SHS households	Households with other sources of electricitya	Households without electricity	All households
Household per expenditure (N = 6,000)						
Food expenditure (NPR/month)	3,459.1 (2,498.6)	3,129.0 (3,796.9)	3,410.4 (2,732.4)	2,378.4 (1,253.7)	3,135.9 (1,796.1)	3,287.1 (2,592.9)
Nonfood expenditure (NPR/month)	3,735.5 (2,716.3)	2,708.6 (2,332.7)	3,583.3 (2,687.6)	2,016.0 (1,515.9)	2,514.9 (2,107.4)	3,362.1 (2,612.8)
Total expenditure (NPR/month)	7,194.9 (4,167.8)	5,837.6 (4,819.9)	6,993.7 (4,297.4)	4,349.4 (2,297.5)	5,650.8 (3,110.1)	6,649.2 (4,149.7)
Employment hours per month (adults, ages 15–65)						
Men in farm sector (N = 8,500)	65.2 (98.9)	95.7 (108.9)	70.1 (101.2)	98.9 (107.7)	86.5 (108.4)	73.8 (102.6)

Outcome variable	Grid households	Mini-grid or SHS households	Grid, mini-grid, or SHS households	Households with other sources of electricitya	Households without electricity	All households
Men in nonfarm sector (N = 8,500)	84.0 (106.1)	50.6 (92.1)	78.1 (107.7)	55.0 (94.4)	73.2 (100.3)	76.0 (103.8)
Men total (N = 8,500)	149.3 (100.4)	146.3 (103.2)	148.8 (100.9)	153.9 (98.2)	159.7 (95.4)	149.8 (100.4)
Women in farm sector (N = 9,904)	38.6 (83.96)	80.9 (108.4)	45.5 (89.4)	89.4 (111.4)	34.4 (80.9)	49.5 (92.5)
Women in nonfarm sector (N = 9,904)	19.7 (62.3)	20.4 (65.0)	19.8 (62.7)	19.6 (64.7)	13.6 (50.5)	19.5 (62.5)
Women total (N = 9,904)	58.2 (96.7)	101.3 (112.5)	65.3 (100.7)	109.1 (114.1)	48.0 (90.3)	65.3 (100.7)
Women's outcomes (ages 15–49) (N = 6,000)						
Fuel collection and preparation time (hours/week)	1.1 (3.4)	3.1 (6.8)	1.4 (4.2)	2.8 (4.4)	3.7 (5.0)	1.7 (4.3)
Time spent in IGAs (minutes/day)	19.5 (79.2)	32.1 (98.9)	21.4 (82.5)	25.6 (86.2)	7.5 (38.6)	21.1 (81.3)
Kerosene consumption and cooking behavior (N = 6,000)						
Household consumption of kerosene (liters/month)	0.433 (1.359)	0.278 (1.164)	0.411 (1.333)	0.054 (0.428)	2.664 (2.675)	0.490 (1.470)
Household uses clean cookstoves	0.500 (0.500)	0.097 (0.296)	0.440 (0.496)	0.030 (0.170)	0.015 (0.120)	0.374 (0.484)

Source: Nepal MTF household survey 2017.

Note: Standard deviations are in parentheses. Employment variables are based on main occupation, so they are underestimated if individuals are engaged in multiple employment activities.

a. Other sources include rechargeable batteries, generator sets, solar lighting systems (SLS), and solar lanterns.

TABLE A.6B • Descriptive Statistics for Development Outcome Variables, by MTF Tier

(Means of the outcome variables)

Outcome variable	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Outcome variable	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Household per expenditure (N = 6,000)						
Food expenditure (NPR/month)	3,014.6 (1,701.5)	2,583.6 (2,131.3)	3,153.4 (1,929.6)	3,475.6 (2,846.3)	3,074.0 (2,928.5)	3,970.5 (2,562.3)
Nonfood expenditure (NPR/month)	2,367.9 (2,022.8)	2,159.9 (1,650.1)	3,867.4 (2,787.3)	3,622.1 (2,841.5)	3,229.0 (2,150.2)	4,107.2 (2,887.1)
Total expenditure (NPR/month)	5,382.5 (3,001.1)	4,743.5 (3,032.6)	7,020.8 (3,952.8)	7,097.7 (4,413.8)	6,302.9 (4,032.5)	8,877.6 (4,396.4)
Employment hours per month (adults, ages 15–65)						
Men in farm sector (N = 8,500)	92.8 (108.5)	95.7 (107.6)	66.9 (96.8)	73.5 (101.4)	72.7 (105.4)	54.4 (94.2)

Outcome variable	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Men in nonfarm sector (N = 8,500)	66.2 (97.0)	53.9 (94.4)	72.3 (101.7)	68.9 (100.0)	99.9 (113.1)	87.6 (104.7)
Men total (N = 8,500)	159.1 (94.2)	149.6 (100.8)	139.2 (100.1)	142.3 (100.7)	172.6 (96.8)	142.0 (101.5)
Women in farm sector (N = 9,904)	36.6 (83.1)	82.1 (109.1)	52.3 (88.7)	45.2 (89.3)	56.6 (99.5)	24.6 (69.0)
Women in nonfarm sector (N = 9,904)	14.4 (52.7)	21.0 (66.5)	14.4 (53.7)	16.0 (56.6)	19.4 (63.3)	29.2 (73.7)
Women total (N = 9,904)	51.1 (92.9)	103.1 (113.5)	66.7 (96.1)	61.2 (98.7)	76.0 (109.2)	53.8 (93.5)
Women's outcomes (ages 15–49) (N = 6,000)						
Fuel collection and preparation time (hours/ week)	3.6 (5.1)	2.5 (3.9)	1.6 (3.1)	1.5 (4.9)	1.2 (3.6)	1.0 (4.1)
Time spent in IGAs (minutes/day)	12.4 (51.1)	18.9 (73.7)	21.3 (75.0)	21.2 (90.4)	17.8 (66.6)	29.4 (95.1)
Kerosene consumption and cooking behavior (N = 6,000)						
Household consumption of kerosene (liters/ month)	2.24 (2.62)	0.10 (0.54)	0.56 (1.39)	0.61 (1.58)	0.26 (0.732)	0.17 (1.37)
Household uses clean cookstoves	0.022 (0.146)	0.075 (0.263)	0.339 (0.474)	0.426 (0.495)	0.462 (0.499)	0.606 (0.489)

Source: Nepal MTF household survey 2017.

Note: Standard deviations are in parentheses. Employment variables are based on main occupation, so they are underestimated if individuals are engaged in multiple employment activities.

TABLE A.7A • **Impacts of Simple Access to Electricity on Expenditure and Employment** *(IV estimates)*

Intervention variable	Log household per capita expenditure (NPR/month			Log employment hours per month (adults, ages 15–65)					
	Food	Nonfood	Total	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
Model 1									
Household has access to grid, mini-grid, or SHS	−0.135 (−1.29)	0.330** (3.71)	0.120 (1.51)	−0.053 (−0.23)	0.367* (1.63)	0.313* (1.73)	0.882** (2.35)	0.116 (0.95)	0.998** (2.95)
R^2	0.234	0.233	0.267	0.100	0.083	0.314	0.144	0.039	0.129
N	6,000	6,000	6,000	8,500	8,500	8,500	9,904	9,904	9,904
Model 2									
Household has access to grid	−0.032 (−0.29)	0.426** (4.58)	0.221** (2.78)	−0.231 (−0.88)	0.574** (2.19)	0.344 (1.62)	0.862** (2.19)	0.140 (1.06)	1.002** (2.76)

Intervention variable	Log household per capita expenditure (NPR/month			Log employment hours per month (adults, ages 15–65)					
	Food	Nonfood	Total	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
Household has access to mini-grid or SHS	−0.313** (−2.57)	0.166* (1.71)	−0.056 (−0.59)	0.150 (0.57)	0.129 (0.59)	0.279 (1.45)	0.906** (2.14)	0.087 (0.67)	0.993** (2.65)
R^2	0.241	0.237	0.274	0.101	0.082	0.031	0.144	0.039	0.129
N	6,000	6,000	6,000	8,500	8,500	8,500	9,904	9,904	9,904
Model 3a									
Household has access to grid	0.089 (0.85)	0.470** (5.59)	0.306** (4.14)	−0.448* (−1.95)	0.718** (3.08)	0.271 (1.29)	0.494 (1.42)	0.180 (1.50)	0.674** (2.06)
R^2	0.223	0.234	0.263	0.107	0.075	0.034	0.160	0.041	0.142
N	5,147	5,147	5,147	8,500	8,500	8,500	9,904	9,904	9,904

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price (NPR/kWh) for electricity from the grid and mini-grid; and unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in the Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. Model excludes households that are connected to mini-grid or have SHS.

TABLE A.7B • Impacts of Simple Access to Electricity on Women's Time Use and Household Behavior

(IV estimates)

Intervention variable	Women's time use (ages 15–49)		Household behavior	
	Fuel collection and food preparation (hours/week)	Time spent in IGA (minutes/day)	Log household consumption of kerosene (liters/month)	Household uses clean cookstoves[a]
Model 1				
Household has access to grid, mini-grid, or SHS	−0.600 (−1.00)	11.6 (1.37)	−0.765* (−1.96)	0.216** (4.02)
R^2	0.102	0.034	0.187	0.334
N	6,000	6,000	6,000	6,000
Model 2				
Household has access to grid	−1.109* (−1.77)	12.0 (1.40)	−0.736** (−2.25)	0.279** (4.39)
Household has access to mini-grid or SHS	0.279 (0.32)	11.02 (1.14)	−0.492** (−2.16)	0.107** (2.33)
R^2	0.111	0.034	0.148	0.340
N	6,000	6,000	6,000	6,000
Model 3[b]				

Intervention variable	Women's time use (ages 15–49)		Household behavior	
	Fuel collection and food preparation (hours/week)	Time spent in IGA (minutes/day)	Log household consumption of kerosene (liters/month)	Household uses clean cookstoves[a]
Household has access to grid	−0.721	17.7**	−0.668**	0.275**
	(−1.29)	(2.52)	(−2.10)	(4.58)
R^2	0.123	0.033	0.155	0.320
N	5,147	5,147	5,147	5,147

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The majority of clean stoves in Nepal are LPG-fueled.

b. Model excludes households that are connected to mini-grid or have SHS.

TABLE A.8A • **Impacts of the MTF Tiers for Electricity on Household Expenditure and Employment**[a] *(IV estimates)*

Tier attained[b]	Log household per capita expenditure (NPR/month)			Log employment hours per month (adults, ages 15–65)					
	Food	Nonfood	Total	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
1	1.858*	0.825	1.296	−0.304	0.442	0.116	−0.255	−0.003	−0.246
	(1.75)	(0.91)	(1.40)	(−1.06)	(0.89)	(0.58)	(−0.52)	(−0.01)	(−0.41)
2	−1.404	−0.568	−0.927	0.367	0.026	0.161	−0.308	0.201	−0.134
	(−1.42)	(−0.71)	(−1.24)	(1.03)	(0.07)	(1.04)	(−0.63)	(0.95)	(−0.26)
3	1.248	1.035	1.121	−0.403	0.238	−0.044	0.087	−0.095	0.029
	(1.44)	(1.42)	(1.53)	(−1.44)	(0.60)	(−0.29)	(0.21)	(−0.44)	(0.06)
4	−0.770	−0.165	−0.381	0.289	0.276	0.273**	−0.018	0.017	−0.057
	(−1.02)	(−0.26)	(−0.67)	(0.89)	(0.83)	(2.03)	(−0.05)	(0.08)	(−0.14)
5	2.490**	1.595**	1.941**	−0.435**	0.297	−0.024	−0.366	0.122	−0.194
	(3.47)	(2.87)	(3.39)	(−2.05)	(0.98)	(−0.19)	(−1.19)	(0.74)	(−0.53)
R^2	0.220	0.225	0.259	0.036	0.027	0.006	0.057	0.034	0.037
N	6,000	6,000	6,000	8,500	8,500	8,500	9,904	9,904	9,904

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The model excludes households that are connected to mini-grid or have SHS.

b. The figures for each tier represent a movement of one tier (e.g., from Tier 0 to Tier 1, Tier 1 to Tier 2, and so forth).

TABLE A.8B • Impacts of the MTF Tiers of Electricity on Household Behavior[a]

(IV estimates)

Tier attained[b]	Women's time use (ages 15–49)		Kerosene consumption and cooking behavior	
	Fuel collection and food preparation (hours/week)	Income generating activities (minutes/day)	Log household consumption of kerosene (liters/month)	Household uses clean cookstoves[c]
1	−0.614	11.3	−0.732**	1.097
	(−0.98)	(0.16)	(−2.73)	(1.33)
2	1.280**	−65.5	1.879**	−0.702
	(2.24)	(−0.98)	(3.98)	(−0.78)
3	−0.909*	34.6	−0.792**	1.362*
	(−1.66)	(0.62)	(−3.57)	(1.92)
4	0.430	−35.7	0.720	0.011
	(0.79)	(−0.67)	(1.13)	(0.01)
5	−0.841*	24.9	−0.908*	1.876**
	(−1.83)	(0.53)	(−1.76)	(3.55)
R^2	0.047	0.032	0.169	0.288
N	6,000	6,000	6,000	6,000

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; and unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. Model excludes households that are connected to mini-grid or have SHS.

b. The figures for each tier represent a movement of one tier (e.g., from Tier 0 to Tier 1, Tier 1 to Tier 2, and so forth).

c. The majority of clean stoves in Nepal are LPG-fueled.

TABLE A.9A • Impacts of the Combined MTF Tiers of Electricity on Expenditure and Employment[a]

(IV estimates)

Tier attained[b]	Log household per capita expenditure (NPR/month)			Log employment hours per month (adults, ages 15–65)					
	Food	Nonfood	Total	Men in farm sector	Men in nonfarm sector	Men overall	Women in farm sector	Women in nonfarm sector	Women overall
Tiers 1–4	−0.776**	0.745	−0.323	0.663	0.286	0.949	4.098*	1.178	5.276**
	(−2.34)	(1.47)	(−0.65)	(0.47)	(0.26)	(0.99)	(1.82)	(1.42)	(2.53)
Tier 5	−0.496	1.266**	0.352	−0.197	1.405	1.207	4.032**	0.978	5.010**
	(−1.53)	(3.36)	(1.05)	(−0.19)	(1.43)	(1.52)	(2.34)	(1.49)	(3.13)
R^2	0.101	0.183	0.173	0.092	0.076	0.023	0.043	0.005	0.025
N	6,000	6,000	6,000	8,500	8,500	8,500	9,904	9,904	9,904

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; and unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The model excludes households that are connected to mini-grid or have SHS.

b. The figures for the combined middle tiers (Tiers 1–4) represent a movement from the lowest tier (Tier 0), while those for the highest tier (Tier 5) represent a movement from Tiers 1–4.

TABLE A.9B • Impacts of the Combined MTF Tiers of Electricity on Household Behavior[a]

(IV estimates)

Tier attained[b]	Women's time use (ages 15–49)		Kerosene consumption and cooking behavior	
	Fuel collection and food preparation (hours/week)	Income generating activities (minutes/day)	Log household consumption of kerosene (liters/month)	Household uses clean cookstoves[c]
Tiers 1–4	−0.615	57.2	−0.975**	0.487**
	(0.13)	(0.16)	(−2.66)	(1.99)
Tier 5	-2.503	65.9*	−0.979**	0.887**
	(−0.89)	(1.71)	(−2.67)	(3.94)
R^2	0.037	0.012	0.214	0.273
N	6,000	6,000	6,000	6,000

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; and unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The model excludes households that are connected to mini-grid or have SHS.

b. The figures for the combined middle tiers (Tiers 1–4) represent a movement from the lowest tier (Tier 0), while those for the highest tier (Tier 5) represent a movement from Tiers 1–4.

c. The majority of clean stoves in Nepal are LPG-fueled.

TABLE A.10 • Impacts of Grid Electricity Consumption (log kilowatt-hours) on Household Expenditure

(IV estimates)

Estimation model	Log household per capita food expenditure (NPR/month)	Log household per capita nonfood expenditure (NPR/month)	Log household per capita total expenditure (NPR/month)
Model 1	0.054	0.120**	0.092**
	(1.62)	(4.48)	(3.75)
R^2	0.246	0.262	0.295
N	6,000	6,000	6,000
Model 2[a]	0.029	0.166**	0.107**
	(0.76)	(5.56)	(4.02)
R^2	0.229	0.270	0.293
N	5,145	5,145	5,145

Source: Nepal MTF household survey 2017.

Note: Marginal effects are reported. Figures in parentheses are t-statistics based on robust standard errors clustered at the PSU-level. Excluded instruments are household distance to grid pole (in 100 m); community price of electricity (NPR/kWh) from the grid and mini-grid; unavailable service in the community (hours/day) for grid, mini-grid, and SHS. Estimation includes other control variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

a. The model excludes households that are connected to mini-grid or have SHS.

TABLE A.11 • Contribution of Appliances to Household Electricity Consumption

(OLS estimates of monthly household kilowatt-hour consumption)

Explanatory variable (number of appliances)	Model 1	Model 2	Mean of appliance variables
Radios	−1.305	0.584	0.176
	(−0.56)	(0.25)	(0.388)
TVs	3.593*	4.105*	0.725
	(1.83)	(2.08)	(0.527)
Mobile phones	0.454	−0.900	2.127
	(0.63)	(−1.07)	(1.394)
Refrigerators	26.558**	27.896**	0.201
	(10.13)	(10.55)	(0.418)
Fans	6.613**	3.848**	1.474
	(9.82)	(4.55)	(1.498)
Electric irons	7.553**	8.048**	0.236
	(3.06)	(3.25)	(0.442)
Rice cookers	−3.859	−1.696	0.199
	(−1.54)	(−0.66)	(0.406)

Explanatory variable (number of appliances)	Model 1	Model 2	Mean of appliance variables
Electric water pumps	14.576**	17.628**	0.134
	(5.24)	(6.23)	(0.356)
Blenders	8.239**	9.501**	0.094
	(2.17)	(2.50)	(0.295)
Computers	25.246**	26.172**	0.103
	(8.23)	(8.49)	(0.341)
Electric kettles	−3.904	−3.919	0.066
	(−1.05)	(−1.06)	(0.260)
Incandescent light bulbs	1.162*	1.493**	0.851
	(1.89)	(2.37)	(1.553)
Fluorescent light bulbs	4.562**	4.203**	0.289
	(5.39)	(4.90)	(1.147)
CFL bulbs	3.478**	3.669**	3.421
	(9.44)	(9.82)	(2.933)
LED bulbs	2.081**	2.010**	1.331
	(4.85)	(4.58)	(2328)
R^2	0.287	0.298	
N	4,043	4,045	
Household grid consumption explained by models (kWh/month)	39.5	41.5	

Source: Nepal MTF household survey 2017.

Note: Model 1 includes appliance variables only. Model 2 includes other household- and community-level variables, such as household head's sex, age, and education; number of adult males and females in the household; log value of household's agricultural land; household locality (urban or rural); whether household is located in Hill or Terai area; whether community is accessible year-round, has markets, and experienced flooding within the last 12 months; and community distance to district center. In addition, regional fixed-effects are controlled for. * and ** represent statistical significance of 10% and 5% or better, respectively.

Appendix B. Findings from Instrument Validity Testing

This appendix reports the findings from a range of validity tests for the instruments used in instrumental variables (IV) regression. First, the findings show that the instruments are jointly significant with a p-value equal to 0 and a high F-statistics [F(3, 64) = 241.63], implying that the instruments are strong (table B.1 note).

TABLE B.1 • **Validity Tests for Instruments Used in Outcome Equations**[a]

Outcome variable	Endogeneity test	Over-identification test (Hansen J statistics)
Log household per capita food expenditure	$X^2(1) = 0.552$,	$X^2(2) = 3.337$,
	$p = 0.457$	$p = 0.189$
Log household per capita nonfood expenditure	$X^2(1) = 8.847$,	$X^2(2) = 0.055$,
	$p = 0.003$	$p = 0.973$
Log household per capita total expenditure	$X^2(1) = 6.579$,	$X^2(2) = 1.926$,
	$p = 0.010$	$p = 0.382$
Log men's employment hours in farm sector	$X^2(1) = 0.537$,	$X^2(2) = 1.259$,
	$p = 0.464$	$p = 0.533$
Log men's employment hours in nonfarm sector	$X^2(1) = 6.353$,	$X^2(2) = 2.069$,
	$p = 0.012$	$p = 0.356$
Log men's employment hours in all sectors	$X^2(1) = 5.897$,	$X^2(2) = 0.717$,
	$p = 0.015$	$p = 0.699$
Log women's employment hours in farm sector	$X^2(1) = 1.240$,	$X^2(2) = 7.303$,
	$p = 0.265$	$p = 0.026$
Log women's employment hours in nonfarm sector	$X^2(1) = 3.111$,	$X^2(2) = 2.637$,
	$p = 0.078$	$p = 0.268$
Log women's employment hours in all sectors	$X^2(1) = 4.096$,	$X^2(2) = 7.493$,
	$p = 0.043$	$p = 0.024$
Women's fuel collection and preparation time	$X^2(1) = 0.232$,	$X^2(2) = 8.069$,
	$p = 0.630$	$p = 0.018$
Women's time spent on IGA	$X^2(1) = 6.728$,	$X^2(2) = 4.782$,
	$p = 0.010$	$p = 0.092$
Log household kerosene consumption	$X^2(1) = 8.396$,	$X^2(2) = 7.971$,
	$p = 0.004$	$p = 0.019$
Household uses clean cookstoves	$X^2(1) = 0.552$,	$X^2(1) = 0.552$,
	$p = 0.552$	$p = 0.552$

Source: Nepal MTF household survey 2017.

Note: F-test for excluded instruments: F(3, 64) = 241.63, p = 0.000; under-identification test (Kleibergen-Paap's rk LM statistic): X2(3) = 80.062, p = 0.000; weak identification test (Kleibergen-Paap rk Wald F statistic): F(3, 64) = 241.6; Stock-Yogo's critical value for 5% maximal IV relative bias = 13.91.

a. Reported in tables A.7a and A.7b (Model 3).

Second, the instrument relevance test (also called the under-identification test), which checks whether the instruments are correlated with the endogenous regressor, has been done. This test is implemented by Kleibergen-Paap's rk LM statistic, distributed as X^2 under the null hypothesis that the estimation equation is under-identified; that is, the instruments do not significantly affect the endogenous variables. Table B.1 note shows that the null hypothesis is rejected; that is, the instruments are relevant.

Third, the weak instrument test is performed, which shows whether the correlation between the instruments and the endogenous variable is sufficiently strong. The test is implemented by Kleibergen-Paap's rk Wald statistic, distributed as F statistic, which is then compared against another statistic called Stock-Yogo's critical value for various ratios of IV-to-OLS bias under the null hypothesis that the instruments are weak. For example, if the F statistic is greater than Stock-Yogo's critical value defined for an IV bias that is 5 percent of the OLS bias, we can reject the null hypothesis that the bias of the IV estimate due to a weak instrument is greater than 5 percent of the corresponding bias in the OLS estimate. An F value of 11 or higher is considered sufficient to reject the null hypothesis for all practical purposes. Table B.1 note shows a very high value of F statistic, implying that the instruments pass the weak identification test.

TABLE B.2 • **Test Statistics for Equality of MTF Tiers 1–4 Based on Outcome Regressions**

Outcome variable	F (or X^2)	p > F (or p > X^2)
Household per expenditure (N = 6,000)		
Food expenditure (NPR/month)	F(3, 399) = 2.35	0.072
Nonfood expenditure (NPR/month)	F(3, 399) = 0.60	0.617
Total expenditure (NPR/month)	F(3, 399) = 1.09	0.354
Employment hours per month (adults, ages 15–65)		
Men in farm sector (N = 8,500)	F(3, 8479) = 0.65	0.585
Men in nonfarm sector (N = 8,500)	F(3, 8479) = 0.35	0.787
Men total (N = 8,500)	F(3, 8479) = 1.61	0.184
Women in farm sector (N = 9,904)	F(3, 9883) = 2.34	0.071
Women in nonfarm sector (N = 9,904)	F(3, 9883) = 1.52	0.207
Women total (N = 9,904)	F(3, 9883) = 0.78	0.506
Women's outcomes (ages 15–49) (N = 6,000)		
Fuel collection and preparation time (hours/week)	F(3, 5979) = 2.42	0.064
Time spent on IGA (minutes/day)	F(3, 399) = 0.77	0.512
Kerosene consumption and cooking behavior (N = 6,000)		
Household kerosene consumption (liters/month)	F(3, 3597) = 9.40	0.000
Household uses clean cookstoves	$X^2(3)$ = 2.76	0.431

Source: Nepal MTF household survey 2017.

Table B.1 also reports the results of the endogeneity test, whereby the test statistic is distributed as X^2 under the null hypothesis that the specific regressors are exogenous. For a majority of outcomes, the exogeneity of the regressors is rejected at the 10 percent level or better. Finally, an over-identification test is performed. This test can only be performed if the model is over-identified; that is, the number of instruments is higher than the number of endogenous variables, which is true in this case. The test is implemented by Hansen's J statistic, distributed as X^2 under the null hypothesis that the over-identification restriction is satisfied, meaning that the instruments are not correlated with the error term of the outcome equation. For a majority of the outcomes, the null hypothesis cannot be rejected at the 10 percent significance level, implying that the over-identification restriction is satisfied. Thus, based on the results of these tests, the IV model is found to be reasonably robust.

Finally, we also test if Tiers 1–4 can be combined. If Tiers 1–4 cannot be combined, the the findings in tables A.9a and A.9b may not be statistically valid. As Table B.2 shows, for a majority of the outcomes, those tiers can indeed be combined ($p > 0.10$).

REFERENCES

Aklin, Michaël, Patrick Bayer, S. P. Harish, and Johannes Urpelainen. 2017. “Does Basic Energy Access Generate Socioeconomic Benefits? A Field Experiment with Off-grid Solar Power in India.” *Science Advances* 3 (5): e1602153.

Alberini, A., Steinbuks, J., and G. Timilsina. 2020. "How Valuable Is the Reliability of Residential Electricity Supply in Low-income Countries? Evidence from Nepal." Policy Research Working Paper No. 9311. World Bank, Washington, DC.

Asaduzzaman, M., D. Barnes, and S. Khandker. 2009. *Restoring Balance: Bangladesh’s Rural Energy Realities*. Energy Sector Management Assistance Program, Special Report 006/09. Washington, DC: World Bank.

Auffhammer, Maximilian, and Catherine D. Wolfram. 2014. “Powering Up China: Income Distributions and Residential Electricity Consumption.” *American Economic Review* 104 (5): 575–80.

Barkat, Abul, S. H. Khan, M. Rahman, S. Zaman, A. Poddar, S. Halim, N. N. Ratna, M. Majid, A. K. M. Maksud, A. Karim, and S. Islam. 2002. “Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh.” Human Development Research Center. Dhaka: NRECA International.

Barnes, Douglas. 2014. *Electric Power for Rural Growth: How Electricity Affects Life in Developing Countries. Second Edition*. Washington, DC: Energy for Development.

Barnes, D., R. Golumbeanu, and I. Diaw. 2016. *Beyond Electricity Access: Output-Based Aid and Rural Electrification in Ethiopia*. Washington, DC: World Bank.

Barnes, Douglas, and Hussain Samad. 2017. *Handbook for Measuring the Impact of Energy Access in Developing Countries*. Washington, DC: Inter-American Development Bank.

Bensch, Gunther, Jochen Kluve, and Jörg Peters. 2011. “Rural Electrification in Rwanda: An Impact Assessment Using Matching Techniques.” *Journal of Development Effectiveness* 3 (4): 67–588.

Bhatia, Mikul, and Nicolina Angelou. 2015. *Beyond Connections: Energy Access Redefined*. Energy Sector Management Assistance Program. Washington, DC: World Bank.

Cabraal, R. Anil, Douglas F. Barnes, and Sachin G. Agarwal. 2005. “Productive Use of Energy for Rural Development.” *Annual Review of Environmental Resources* 30: 117–44.

Chakravorty, Ujjayant, Kyle Emerick, and Majah-Leah Ravago. 2016. “Lighting up the Last Mile: The Benefits and Costs of Extending Electricity to the Rural Poor.” Discussion Paper No. 16–22. Washington, DC: Resources for the Future.

Chaplin, Duncan, Arif Mamun, Ali Protik, John Schurrer, Divya Vohra, Kristine Bos, Hannah Burak, Laura Meyer, Anca Dumitrescu, Christopher Ksoll, and Thomas Cook. 2017. *Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation*. Washington, DC: Mathematica Policy Research.

Chauduri, Pallavi, and Sonalde Desai. 2020. "Gender Inequalities and Household Fuel Choice in India." *Journal for Cleaner Production* 265 (August): 121487.

Colombo, Emanuela, Francesco Romeoa, Lorenzo Mattaroloa, Jacopo Barbieria, and Mariano Morazzob. 2018. "An Impact Evaluation Framework Based on Sustainable Livelihoods for Energy Development Projects: An Application to Ethiopia." *Energy Research and Social Science* 39: 78–92.

Dhanaraj ,Sowmya, Vidya Mahambare, and Poonam Munjal. 2018. "From Income to Household Welfare: Lessons from Refrigerator Ownership in India." *Journal of Quantitative Economics* 16: 573–88.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101 (7): 3078–108.

EIA (Energy Information Administration). 2019. Independent Statistics and Analysis, U.S. Energy Information Administration, Washington, DC.

Golumbeanu, R., and D. Barnes. 2013. "Connection Charges and Electricity Access in Sub-Saharan Africa." Policy Research Working Paper 6511. Washington, DC: World Bank.

Grogan, Louise. 2016. "Household Electrification, Fertility, and Employment: Evidence from Hydroelectric Dam Construction in Colombia." *Journal of Human Capital* 10 (1): 109–59.

Grogan, Louise, and Asha Sadanand. 2012. "Rural Electrification and Employment in Poor Countries: Evidence from Nicaragua." *World Development* 43: 252–65.

Hamburger, David, Joel Jaegera, Patrick Bayer, Ryan Kennedy, Joonseok Yang, and Johannes Urpelainen. 2019. "Shades of Darkness or Light? A Systematic Review of Geographic Bias in Impact Evaluations of Electricity Access." Energy Research & Social Science Vol. 58, December.

IEA, IRENA, UNSD, WBG, WHO (International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank Group, World Health Organization). *2020. Tracking SDG7: The Energy Progress Report 2020*. Washington, DC: World Bank Group.

Jensen, Robert, and Emily Oster. 2009. "The Power of TV: Cable Television and Women's Status in India." *The Quarterly Journal of Economics* 124 (3): 1057–94.

Kanagawa, Makoto, and Toshihiko Nakata. 2008. "Assessment of Access to Electricity and the Socio-economic Impacts in Rural Areas of Developing Countries." Energy Policy 36 (6): 2016–29.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. 2012. "The Welfare Impacts of Rural Electrification in Bangladesh." *Energy Journal* 33 (1): 199–218.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. 2013. "Welfare Impacts of Rural Electrification: A Panel Data Analysis from Vietnam." E*conomic Development and Cultural Change* 6 (3): 659–92.

Khandker, Shahidur R., Gayatri Koolwal, and Hussain Samad. 2010. *Handbook on Impact Evaluation: Quantitative Methods and Practices.* Washington, DC: World Bank.

Khandker, Shahidur R., Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes. 2014. "Who Benefits Most from Rural Electrification? Evidence from India." Energy Journal 35 (2): 75–96.

Kirubi, Charles, Arne Jacobson, Daniel M. Kammen, and Andrew Mills. 2009. "Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya." *World Development* 37 (7): 1208–21.

Kulkarni, V., and D. Barnes. 2017. "Education in Rural Peru: Exploring the Role of Household Electrification in School Enrollment." *Journal of Research in Rural Education* 32 (10): 1–19

Lee, Kenneth, Edward Miguel, and Catherine Wolfram. 2020. "Experimental Evidence on the Economics of Rural Electrification." *Journal of Political Economy* 128 (4): 1523–65.

Lenz, Luciane, Anicet Munyehirwe, Jorg Peters, and Maximiliane Sievert. 2017. "Does Large-scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda's Electricity Access Roll-out Program." *World Development* 89 (C): 88–110.

Lipscomb, Molly, A. Mushfiq Mobarak, and Tania Barham. 2013. "Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil." *American Economic Journal: Applied Economics* 5 (2): 200–31.

Meier, Peter, Voravate Tuntivate, Douglas F. Barnes, Susan V. Bogach, and Daniel Farchy. 2010. *Peru: National Survey of Rural Household Energy Use*. Energy and Poverty Special Report, Energy Sector Management Assistance Program. Washington, DC: World Bank.

Mural, Rashmi, Sangeeta Malhotra, Debajit Palit, and Krishnapada Sasmal. 2015. "Sociotechnical Assessment of Solar Photovoltaic Systems Implemented for Rural Electrification in Selected Villages of Sundarbans Region of India." *AIMS Energy* 3 (4): 612–34.

Peltz, Setu, Shonali Pachauri, and Sebastian Groh. 2018. "A Critical Review of Modern Approaches for Multi-dimensional Energy Poverty Measurement." *Energy and Environment* Vol. 7, Issue 6.

Peters, Jörg, Colin Vance, and Marek Harsdorff. 2011. "Grid Extension in Rural Benin: Micromanufacturers and the Electrification Trap." *World Development* 39 (5): 773–83.

Pinto, Alisha, Han Kyul Yoo, Elisa Portale, and Dana Rysankova. 2019. Nepal—Beyond *Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework*. Washington, DC: World Bank.

Pueyo, Ana, and Mar Maestre. 2019. "Linking Energy Access, Gender, and Poverty: A Review of the Literature on Productive Uses of Energy." *Energy Research & Social Science* 53: 170–81.

Richmond, Jennifer, and Johannes Urpelainen. 2019. "Electrification and Appliance Ownership over Time: Evidence from Rural India." *Energy Policy* 133 (October): 110862.

Rud, Juan. 2017. "Electricity Provision and Industrial Development: Evidence from India." *Journal of Development Economics* 97 (2): 352–67.

Salmon, Claire, and Jeremy Tanguy. 2016. "Rural Electrification and Household Labor Supply: Evidence from Nigeria." *World Development* 82: 48–68.

SEforALL (Sustainable Energy for All). 2019. *Annual Report 2018.* Vienna: Sustainable Energy for All.

Stojanovski, Ognen, Mark Thurber, George Muwowo, Frank A. Wolak, and Kat Harrison. 2018. "Assessing Opportunities for Solar Lanterns to Improve Educational Outcomes in Rural Off-grid Regions: Challenges and Lessons from a Randomized Controlled Trial." Asian Development Bank Working Paper 910. Tokyo: Asian Development Bank.

Tanguy, Bernard. 2012. "Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa." *World Bank Research Observer* 27 (1): 33–51.

van de Walle, Dominique, Martin Ravallion, Vibhuti Mendiratta, and Gayatri Koolwal. 2015. "Long-term Gains from Electrification in Rural India." *World Bank Economic Review* 31 (2): 385–411.

World Bank. 2002a. *Energy Strategies for Rural India: Evidence from Six States.* Energy Sector Management Assistance Program Report No. 258/02. Washington, DC: World Bank.

World Bank. 2002b. *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits.* Energy Sector Management Assistance Program Report No. 255/02. Washington, DC: World Bank.

World Bank. 2008. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits.* Independent Evaluation Group (IEG) Impact Evaluation. Washington, DC: World Bank.

World Bank. 2019. *Nepal Development Update.* December. World Bank, Washington, DC.

World Bank. 2020. Poverty and Equity Data Portal. World Bank, Washington, DC. http://povertydata.worldbank.org/poverty/country/NPL.