COST-BENEFIT ANALYSIS OF REPLACING LPG STOVES WITH INDUCTION STOVES IN RURAL HOUSEHOLDS OF KAVRE DISTRICT, NEPAL

By

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ABSTRACT

COST-BENEFIT ANALYSIS OF REPLACING LPG STOVES WITH INDUCTION STOVES IN RURAL HOUSEHOLDS OF KAVRE DISTRICT NEPAL

Grishma Raj Dahal

Nepal imports nearly 260,000 tons of Liquified Petroleum Gas (LPG) and other fossil fuels annually from India. This fuel dependency is one of the main reasons for Nepal's trade deficit with India. The Government of Nepal has recently started promoting electric induction stoves for cooking as an alternative to LPG. Induction stoves are pollution free at the point of use, and they are meant to reduce Nepal's dependence on LPG.

This study includes a cost-benefit analysis for replacing LPG stoves with induction stoves for households in rural areas of Kavre District, Nepal. The study involved the use of data for LPG and electricity consumption for households that use LGP and have not yet adopted induction stoves. It includes the estimated expected post-adoption (future) electricity consumption based on the cooking energy associated with the existing (pre-adoption) LPG usage.

The results show that about two-thirds of households in the study would not benefit economically from the adoption of electric induction stoves if there is no subsidy on the electricity. The amount of subsidy would depend on baseline electricity consumption and the LPG usage of the households. Future analysis of the economics of a

transition to induction cooking could be improved through the collection of more precise data on LPG consumption, baseline electricity consumption, LPG prices, and the economic discount rate.

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INTRODUCTION

A majority of the population in Nepal lives in rural areas and is dependent on biomass for cooking and non-cooking purposes. Over the past few decades, providing access to clean cooking approaches has emerged as an essential energy policy topic (Water and Energy Commission Secretariat (WECS), 2014). Many intervention programs and efforts have focused on improved biomass cookstoves that seek to utilize biomass fuel more efficiently (Vaidya, 2020). Currently, the priority is to replacing conventional fuels with cleaner fuels (Vaidya, 2020). This fuel switching approach is opening new doors to modern cooking fuels such as electricity (Vaidya, 2s020). This study has performed a cost-benefit analysis of replacing LPG stoves by induction stoves. The study included a cluster of households in Kavre District, Nepal. The results show that most households can gain economic benefit from the transition only if a subsidy is provided. The transition can be smoother and more efficient in the future if households are made aware of the benefit.

An increase in electricity production in Nepal in the upcoming years is likely (Vaidya, 2020). During the fiscal year of 2019, the Nepal Electricity Authority (NEA) achieved the highest generation of hydropower in the history of the country (NEA, 2019). This trend is expected to continue as several hydropower projects (e.g., Upper Tamakoshi Hydroelectric Project – 456 MW) are expected to be completed soon (Vaidya, 2020).

Nepal’s approach towards providing electricity access to its people is comparatively better than many other developing nations (Vaidya, 2020). The grid

electrification rate increased from 25% (in 2000) to 78% in 2019 (NEA, 2019). The increase indicates that the electrification rate may increase further in the future. “Mr. Sagar M. Gyawali, Assistant Manager at NEA, suggests that the existing distribution network of the country can support up to 500,000 induction cooktops” (Vaidya, 2020). Electric cookstoves are the clean source of fuel at the point of use. Households would have cleaner access to fuel, and indoor air pollution would be less. The other advantage of the electric cookstoves is it would help in reducing the trade deficit with India by decreasing fuel imports.

Nepal imports most of its LPG from India. The households that use it need to refill their cylinders frequently, mostly within one to two months. As a result, fuel imports are a regular and a continuous phenomenon. Electric cookstoves have a long-life span, and they do not involve frequent imports as is the case with LPG. Decreasing imports will reduce the trade deficit (Ovamba & Denis, 2018). So, electric cookstoves could be a good, clean source of fuel at the point of use while also reducing the trade deficit if sufficient subsidy on the electricity rate is provided. A “sufficient” subsidy refers to the percentage of subsidy in the electricity rate that would lead households to a positive cost-benefit outcome over the lifetime of electric stove usage. The electricity rate refers to the billing rate structure for residential customers of Nepal.

The Global Alliance for Clean Cooking conducted a kitchen performance test (KPT) survey for four different seasons in 2018 and 2019 in rural households of Kavre District, Nepal. The purpose of this survey was to gather information on the different

types of fuel and cook fuel stoves the households were using. This information can help to identify fuel-switching opportunities. The transition from traditional fuels to electric induction stoves is an example of fuel switching. The study has analyzed LPG consumption, base electricity consumption data and fuel expenditure levels, to perform a cost-benefit analysis of replacing LPG stoves with induction stoves in the households.

LITERATURE REVIEW

This section includes information on the demography of Nepal, energy scenario and policy, rural electrification policy, history and current use of LPG in Nepal, previous studies performed on fuel transition, study gaps, and the scope of this thesis work.

Demography of Nepal

Diversity in culture, religion and language is the identity of Nepal (Y. B. Gurung, 2017). "Nepal is a multi-ethnic, multi-cultural, multi-religious, and multi-lingual country" (Y. B. Gurung, 2017) . The cast and ethnicity are different in different geographical regions. For example, a majority of *Brahmins* and *Chhetriyas* live in the Hilly region of Nepal. In the Himalayan region, *Bhote*, *Sherpas* and *Thakali* have the majority.

Overview

Nepal is a landlocked country. It lies in South Asia. It borders China and India in the north and the south, respectively (Nepal Tourism Board, 2020). It lies between the latitude of 26° to 31° N and longitude of 80° to 89° E (WorldAtlas, 2020). There are five development regions, seven federal political states, and seventy-seven districts in Nepal. Geographically, it is divided into three eco-development regions: Himalayan (mountain), Hill (*chure*), and Terai (plain) region (Nepal Tourism Board, 2020). Figure 2 shows the location (Kavre District) where the survey was conducted.

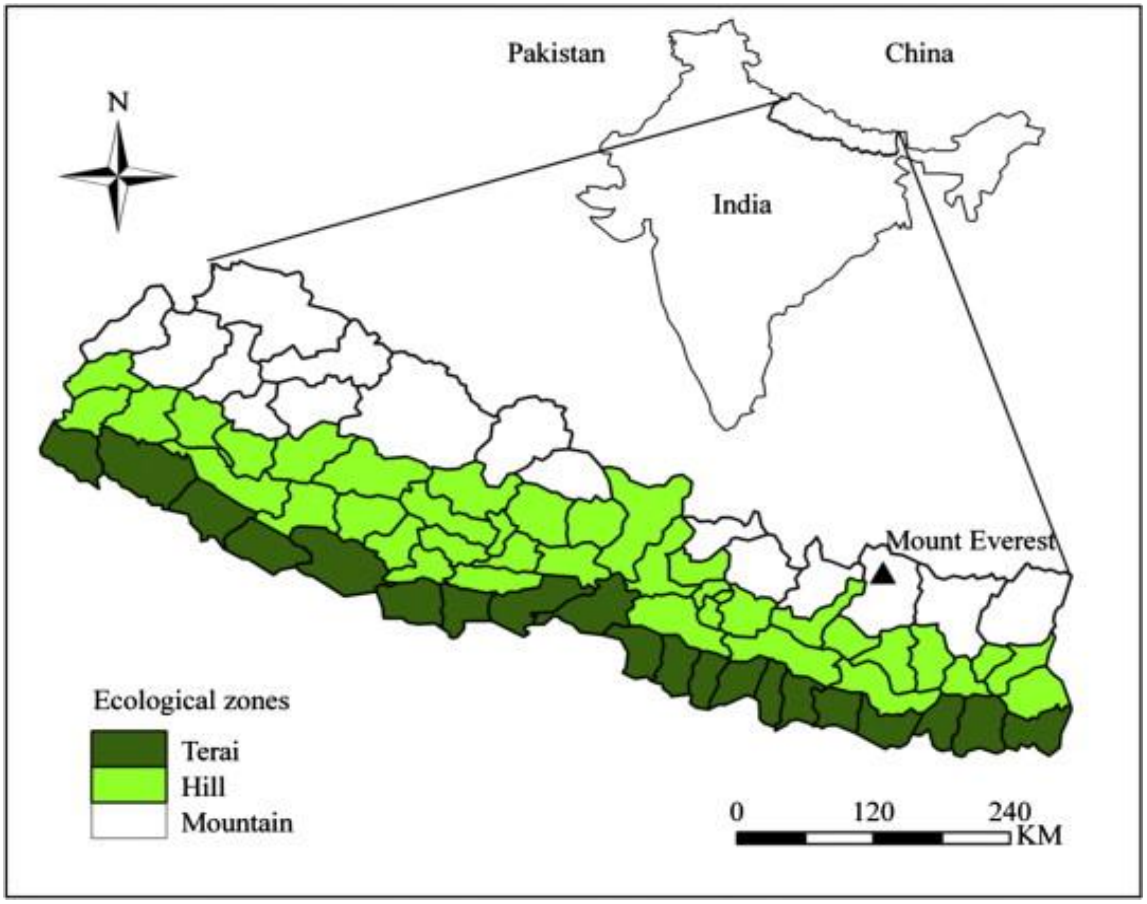

Figure 1. Map of Nepal and eco-development zones (Devkota et al., 2020)

Figure 2. Map of Nepal showing the Kavre District (highlighted in red) (Nepal Foreign Affairs, 2020)

The country experiences all four seasons, as it lies in the subtropical monsoon climate (Poudyal et al., 2019). The south contains tropical areas, alpine regions lie in the north, and there is a sizeable topographical variation between the upper Himalayan region and the lower plains region (Poudyal et al., 2019).

The population census is carried out every ten years. According to the Census Status of 2011, the population of Nepal was 26.5 million (National Planning Commission, 2011). The average annual population growth rate over the past decade was 1.35% (National Planning Commission, 2011). Out of the total population, 82.8% of

the population lives in rural areas (S. Malla, 2013). Nearly half of the population lives in the Terai region, 43% in the hills, and 7.5% in the Himalayan (mountainous) region (S. Malla, 2013). Geographically, most of the population lives in the plains region, which is followed by the hilly region (S. Malla, 2013). Of the total population and total households, respectively, 17% and 20% live in urban areas (S. Malla, 2013). Among the five development regions, the central development region consists of 30% of the rural population and 64% of the urban population (S. Malla, 2013). From 2001 to 2011, between the two census periods, the population grew by an annual rate of 1.4% (S. Malla, 2013). The total population and the households increased by 15% and 33%, respectively, between these two census periods (S. Malla, 2013).

Social demographics

Out of the total population, 81.34% of the people are Hindu, followed by 9.04% Buddhists, 3.04% Kirat, and 1.41% Christian (Central Bureau of Statistics, 2014b). The percentage share of Christianity has been increasing in the last ten years (Central Bureau of Statistics, 2014b). One hundred and twenty-three languages were identified according to the census data of 2011 (Central Bureau of Statistics, 2014b). Comparatively, people from Midwest Mountain, Central Terai, Western Hill, and Western Terai are behind in terms of socio-economic indicators (Central Bureau of Statistics, 2014b).

Economic demographics

Nepal's economy saw an improvement during the fiscal year 2016/2017 (Ministry of Finance, 2019). The economy thrived due to a favorable monsoon, an increase in

capital investment, management of energy, and improvement in the investment environment (Ministry of Finance, 2019). GDP was predicted to rise by 6.94%, which is the highest since fiscal year 1993/94 (Ministry of Finance, 2019). The economy that saw a downfall due to multiple reasons like a major earthquake, a border blockade by India, and other factors was recovering and expanding (Ministry of Finance, 2019).

Annual growth of 5.29% and 7.74% was predicted in agriculture and non-agriculture sectors (Ministry of Finance, 2019). Similarly, growth rates of 6.9% and 10.97% were predicted during the fiscal year of 2016/2017 in the service and industrial sectors, respectively (Ministry of Finance, 2019).

The contribution of agriculture and industry in the total gross domestic product (GDP) has decreased over the past two decades (National Planning Commission, 2011). The service sector currently holds the highest percentage of Nepal’s economy (S. Malla, 2013). According to data from 2010, the service sector contributed half of the GDP, while the contributions of agriculture and industry were 36% and 14%, respectively (S. Malla, 2013). The main industrial activity in the country is the processing of agricultural products (S. Malla, 2013).

Agriculture contributes to 33% of the total GDP of the country (Poudyal et al., 2019). The contribution of Agriculture to the GDP has changed over time. In 2013, agriculture contributed 36% to the total GDP (S. Malla, 2013). It has changed to 33% in 2019 (Poudyal et al., 2019). More than 67% of the population are engaged in agriculture for their livelihood (Poudyal et al., 2019). The government of Nepal has a long term

vision of uplifting Nepal to become a middle-economy country by 2030 (Ministry of Finance, 2019). The plan targets substituting subsistence-based farming in the country with large-scale commercial production from agriculture (Poudyal et al., 2019). The Special Economic Zone Act addresses industrialization in Nepal (Government of Nepal, 2018). These activities will create additional energy demands, and Nepal's neighbors, China and India, have already invested in energy projects of Nepal through 898 and 629 energy projects, respectively (Alam et al., 2017).

Energy Scenario of Nepal

The three major categories of energy resources in Nepal are traditional, commercial, and renewable energy resources (Pokharel, 2003). Biomass, firewood, agriculture residues, and animal dung are some examples of traditional energy resources (A. Gurung et al., 2012). Petroleum, electricity, and coal represent some examples of commercial energy resources (A. Gurung et al., 2012). Commercial energy shares 11% of the total energy consumption, but it plays a vital role in industrial and economic development (Ministry of Finance, 2019). Mini and micro-hydro, solar, improved cooking stoves, wind energy, biogas, and biomass briquettes are some examples of renewable energy technologies in Nepal. Renewable energy technologies (RETs) are also termed as alternative energy resources or supplemental energy resources (Pokharel, 2003).

Conventional fuels are widely used in Nepal (Poudyal et al., 2019). Traditional

energy sources share 78% of the total energy consumption (Poudyal et al., 2019). On-grid electricity generation and renewable energy technologies contribute 3% each, and the remaining 4% of the consumption is provided by coal (Poudyal et al., 2019). Energy use in Nepal is low and is dominated by conventional energy resources. Sector-wise, the residential and industrial sectors contribute 48% and 38% of the total energy consumption, respectively (Poudyal et al., 2019). Nepal's economy is heavily relied on agriculture but contributes to only 2% of the total energy demand (Poudyal et al., 2019). Energy consumption by the transportation sector is insignificant, which indicates that the sector in underdeveloped (Poudyal et al., 2019).

If biomass is included, then household energy demand is 87% of the total national energy demand. However, when biomass is excluded, household energy contributes to only 21% of total energy consumption (S. Malla, 2013). There is also a notable difference in household energy consumption patterns between urban and rural households. Most of the rural households in Nepal are dependent on biomass for cooking purposes (S. Malla, 2013). But, biomass is slowly being replaced by commercial and renewable sources of energy such as biogas, electricity, and LPG (S. Malla, 2013). Nonetheless, studies have shown that biomass would remain a primary source of fuel for some years (S. Malla, 2013). The main factors for low consumption of energy and electricity are political instability, poor electricity supply infrastructures, load shedding issues, low income, lack of accessible energy resources, illiteracy and dependency on commercial fuels (S. Malla, 2013).

The types of fuel and the energy consumption patterns of households are interlinked. The fuel consumption pattern mainly depends on energy access levels and poverty, but an improvement has been noticed regarding energy access (S. Malla, 2013). For example, the percentage of households that have access to electricity increased from 37% (2004) to 70% (2010). However, Nepal had a per capita income of US$ 862 in 2016 (Panthi, 2018), which is a low figure. Nepal has a low level of household income (A. Gurung et al., 2012). A majority of rural households still lack access to electricity. The rural Terai region of Eastern Nepal and the rural hills of Central Nepal have the lowest levels of energy development because of the two main reasons. First, most of the households in these regions do not have access to electricity. Second, they rely mostly on traditional energy resources for cooking and heating (S. Malla, 2013).

The annual average household consumption in Nepal in fiscal year 2015/2016 was about NRs 300,000 ($3000, at an exchange rate of NRs 100 for one U.S. Dollar) (Central Bureau of Statistics, 2014). Most of this expense is used to purchase food, followed by the rent, durables, education, alcohol and tobacco, utilities and cultural expenditure (Central Bureau of Statistics, 2014). The annual consumption of urban households is 1.7 times greater than the rural households (Central Bureau of Statistics, 2014a).

The main source of lighting is grid electricity, as 76.3% of the total households have access to electricity (Central Bureau of Statistics, 2014). Among them, 93.1% of urban and 64.95% of rural households have access to electricity (Central Bureau of

Statistics, 2014). Solar photovoltaics is also gaining popularity. Approximately 21% of rural households and 2.55 % of urban households use off-grid solar energy (Central Bureau of Statistics, 2014).

Firewood is the most widely used for cooking purposes in rural areas. More than 76% of the rural population uses firewood for cooking. In urban areas, LPG is used widely (Central Bureau of Statistics, 2014a). In the FY 2015/2016, in urban areas 53.3% used LPG gas, and 37.9% used electricity, compared to 58.3% LPG and 33.0% electricity usage during FY 2014/2015. LPG gas is the second most popular cooking fuel in Nepal (Central Bureau of Statistics, 2014a). The annual energy consumption contributed by different types of fuels is given in Table 1.

Table 1. Annual energy consumption by different types of fuels in different years (in ToE: thousands of tons of oil equivalent) (Acharya & Marhold, 2019)

Fuels	**2008/ 2009**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**
Firewood	7,301	7,467	7,606	6,274	7,153	8,154	8,264	8,376
Petroleum	775	965	1,058	1,083	1,182	1,264	1,468	1,275
Cow Dung	540	551	563	448	511	426	432	438
Charcoal	181	286	293	348	415	320	465	536
Agriculture	244	324	331	310	353	403	408	414
Electricity	182	213	229	248	257	374	397	436
Renewable	60	70	75	109	166	291	291	292

The percentage distribution of the urban and rural households concerning the primary fuel for cooking and lighting are given in Tables 2 and 3, respectively.

Table 2. The percentage share of different fuels for lighting purpose in rural and urban households of Nepal (Central Bureau of Statistics, 2014a).

Households	**Electricity**	**Solar**	**Biogas**	**Kerosene**	**Other**
Urban	93.1	2.4	0.0	3.3	1.2
Rural	64.9	20.8	0.1	8.0	6.2

Table 3. The percentage share of different fuels for cooking purpose in rural and urban households of Nepal (Central Bureau of Statistics, 2014a)

Households	**Firewood**	**Cowdung**	**Leaves/straw**	**Cylinder**	**Biogas**
Urban	37.9	3.4	1.0	53.3	3.7
Rural	76.5	10.3	2.3	8.7	2.0

The residential sector accounts for 89% of primary energy consumption (Lohani, 2011). Biomass is the primary source of energy in the residential sector (Lohani, 2011). Approximately 75% of rural households use firewood (Lohani, 2011).

Traditional cooking technologies rely heavily on biomass in Nepal. People spend

a significant amount of time collecting fuel (Sapkota et al., 2014). Sometimes, because of the time spent on fuel collection, women and children are also prevented from educational opportunities and social and income-generating activities (Sapkota et al., 2014). The emissions from biomass may cause health problems, too (Sapkota et al., 2014). Some common examples of health problems are respiratory disease, child mortality, and eye ailments (Sapkota et al., 2013).

Renewable energy technologies (RETs) such as hydropower, solar photovoltaics, and improved cooking stoves (ICS) have a huge potential to replace traditional energy resources like biomass and firewood. Nepal has a high potential for renewable energy resources (Sapkota et al., 2014). The potential of hydroelectricity that is commercially exploitable is 42,000 MW, and micro-hydro, solar, and wind power have potentials of 100 MW, 2100 MW, and 3000 MW, respectively (Sapkota et al., 2014). Also, studies have shown that about 1 million biogas plants can be developed (Sapkota et al., 2014).

Because of geographical challenges (i.e., hills and mountains) and the sparse population distribution of rural communities, the transmission and distribution of grid electricity in rural areas of Nepal is costly and difficult (Mainali & Silveira, 2012). But on the other hand, there is a huge scope of providing clean and sustainable energy to rural communities because of the abundant resources of RETs (Pandey, 2009). RETs can play a major role in the sustainable development of rural communities (Sapkota et al., 2014).

Electricity in Nepal

Nepal has a sound potential of electricity generation from hydropower plants as more than 6000 perennial rivers and rivulets flow in Nepal with an average annual runoff volume of 225 billion cubic meters (Pandey, 2009). Theoretically, Nepal can produce 83 GW of electricity, among which 42 GW is technically exploitable (A. Gurung et al., 2012). Though there is a high potential of electricity generation, financial and technical constraints have limited utilization of this resource (Pandey, 2009). This has resulted in a low electrification rate as compared to other south Asian countries. There is also a difference in electricity consumption in rural and urban areas. Rural areas have lower electrification rates compared to urban areas because providing electricity in rural areas becomes comparatively challenging because of technical and financial constraints (Pandey, 2009).

Electricity generation in Nepal started about a century ago, and still, 6.6 million people in Nepal do not have access to electricity (Poudyal et al., 2019). Even people having electricity access are facing load-shedding issues. This is one of the reasons that even when the national electricity grid is available, natural disasters like earthquakes, storms, and floods sometimes lead to power outages (Poudyal et al., 2019). Inaccessible electricity is one of the factors that result in low use rates. Nepal has a low level of per capita electricity consumption, 139 kWh per capita per year (Poudyal et al., 2019).

According to the data of FY 2018/2019, the total electricity production from the hydropower plants, including the small power stations, was 2,548.11 GWh (NEA, 2019).

This is the highest production level attained by the Nepal Electricity Authority (NEA) even though the largest hydropower plant with a production capacity of 144 MW was shut down for ten days (plant shutdown) and 24 days (unit shutdown) (NEA, 2019).

NEA purchased a total of 2,190.05 GWh of electricity from independent power producers (IPPs) (NEA, 2019). Power is purchased from India, too, to address the increasing electricity demand (NEA, 2019). The total energy imported from India during FY 2017/2018 was 2813.07 GWh, which indicated an increase of 8.96% compared to the electricity imported from India in 2016/2017 (NEA, 2019). Of the total hydropower energy available in Nepal, NEA's generation contributed 33.75%, imports from India shared 37.25%, and the IPPs accounted for 29.00% (NEA, 2019). The peak hour demand was 1444.10 MW (NEA, 2017). The supply of energy from India does not cover the demand, even though the average rate of electricity imported from India in 2017 was 400 MW (Acharya & Marhold, 2019).

Over 1/3rd of electricity used in Nepal is imported from India, and most of it is sold within the country (Poudyal et al., 2019). Of the total electricity imported, 44% is sold to households (Poudyal et al., 2019). Domestic consumers contribute 41.6% of the total revenue collected from electricity sales (Poudyal et al., 2019). Of the total expenditure in energy imports, 55.6% is shared by power purchases, 13.3% by depreciation, 9.3% by operation and maintenance, 7.6% by interest, and 7.1% by other miscellaneous factors such as royalties (Poudyal et al., 2019). There is a total system loss of 20%, which is quite significant (Poudyal et al., 2019).

The capacity of diesel power plants that are connected to the national grid is only 53 MW (Acharya & Marhold, 2019). Diesel is not widely used because of public criticism and because the hydropower is widely available (Acharya & Marhold, 2019). The annual report of NEA mentions that electricity sales to domestic users contribute 45.08% of the total sales, and the majority of the consumption is allocated to lighting (Acharya & Marhold, 2019). But still, a majority of the population uses traditional pollutant-emitting fuel sources because they do not have access to cleaner fuel sources.

There is a very high potential of hydropower generation in Nepal. The geography of Nepal, while favorable for hydropower generation, is also a barrier for providing electricity to rural communities (Poudyal et al., 2019). Microhydro schemes and technology have become one of the more popular RETs (A. Gurung et al., 2012). In Nepal, micro-hydropower plants are defined as power plants up to the capacity of 100kW energy output (Pokharel, 2001).

In the past, various Microhydropower (MHP) Technologies such as propeller, Pelton, and crossflow turbines were popular for power generation (Pokharel, 2003). Rural communities in Nepal have played an important role in installing MHPs. Regarding the institutional arrangement of MHP schemes, local entrepreneurs or private/local companies can own the MHP projects and install them without the requirement of any kind of government approval or license (WECS, 2010).

MHP technology thrived in Nepal in the 1980s when the government of Nepal (GoN) started to provide subsidies for MHP projects as a part of the rural electrification

project (Pokharel, 2003). Different schemes were provided depending on the location and remoteness of the MHP projects (A. Gurung et al., 2012). After the introduction of the Alternative Energy Promotion Center in 1996, MHP projects have thrived and have become more popular (WECS, 2010). Data from 2010 shows that there were more than 2000 MHP plants with a total capacity of 15.3 MW (AEPC, 2010). Besides this, there are more than 6000 units for generating mechanical power for milling purposes in rural areas of Nepal (AEPC, 2010).

Rural Energy/ Electrification Policy

The campaign of rural electrification in Nepal started in 1971 (Mainali & Silveira, 2011). In 1996, the United Nations Development Program (UNDP) supported the Rural Energy Development Program (REDP) in Nepal (Karki & Shrestha, n.d.). The community rural electrification program (CREP) was initiated in the year 2003 (CREP, 2011).

REDP helps rural communities to adopt new RETs (REDP, 2011). Under the REDP, about 240 MHP plants with a total capacity of 3900 kW were completed by the end of 2010 (UNDP, 2009). Though only 40% of the economically exploitable micro-hydro based electricity has been exploited, their adoption and implementation have changed the living style of rural communities significantly (A. Gurung et al., 2011). There are numerous benefits from MHP systems, including the creation of local employment opportunities and improvement in health conditions of household members

(because of less exposure to smoke generating fuels) (A. Gurung et al., 2011).

Government of Nepal (GoN) introduced different policies on rural energy and electrification. Some of them include Hydropower Development Policy (1992) (Ministry of Water Resource Nepal, 1992), Water Resource Act (1992) (Government of Nepal, 1992), Rural Energy Policy (2006) (Government of Nepal, 2010), Energy Sector Synopsis Report (2010) (Government of Nepal, 2011), the Scaling Up Renewable Energy Program (2011) (Government of Nepal, 2013c), and the National Energy Strategy of Nepal (2013) (Government of Nepal, 2013a).

Some of the recent energy policies are:

1. Renewable Energy Subsidy Policy (2013) (Government of Nepal, 2013b)
2. Renewable Energy Capacity Needs Assessment for Nepal (2016) (Government of Nepal, 2018)

Politically, Nepal was recently divided into seven federal states. This is an opportunity to redefine the energy systems (Poudyal et al., 2019). But because of a large diversity in geography and federal states, creating equality among the states in energy infrastructure is a challenge (Poudyal et al., 2019). The National Planning Commission of Nepal (NPC) has proposed to generate 383 MW of electricity from 277 hydropower plants, which are dispersed among all federal states (National Planning Commission, 2017). The Ministry of Energy, Nepal, also published guidelines in February 2018 for connecting renewable resources to the national grid (Poudyal et al., 2019).

The Rural Energy Policy – 2006 (Government of Nepal, 2006) and Subsidy

Policy for Renewable Energy-2069 (Government of Nepal, 2013b) mainly focus on the improvement of the living standards of rural communities. The main objectives of this policy are:

a. To reduce the dependency and use of traditional energy resources and hence mitigate environmental hazards by increasing access to cost-effective and clean energy.

b. To increase employment opportunities by developing rural energy resources.

c. To improve the living standards of rural communities by relating the energy with socio-economic benefits.

The main policies of the rural electrification from the Rural Energy Policy - 2006 are summarized below (Adhikari et al., 2012).

a. Emphasizing environmentally friendly RETs

b. Increasing capacity of local RETs

c. Fund establishment at the central level for mobilizing financial resources

d. Implementing AEPC for capacity development of local bodies

e. Emphasizing affordable and sustainable resources of rural energy

f. Making arrangements for increasing human resource capacity

g. Implementing economic activities in an integrated way

h. Involving private and government sectors in rural energy

i. Encouraging rural energy-based economic and industrial activities

j. Management of community through social mobilization

k. Encouraging private sector participation

l. Increasing the efficiency of rural energy technology

m. Conducting programs for promotional activities

n. Quality standard tests for ensuring the quality of rural energy

Induction Stoves

Induction stove cooking is slowly becoming popular in Nepal. The studies and research suggest that it has the potential to replace traditional fuels soon. Induction cooking is a process in which localized heat is produced on a metallic object (Sadhu et al., 2010). AC electricity is supplied to the heating loop or a coil placed under the cookware (Sadhu et al., 2010). The AC power creates a varying magnetic field which heats the cookware (Sadhu et al., 2010). Induction heating has multiple uses. Some of the examples are melting, hardening of metals, brazing and soldering (Sadhu et al., 2010). In induction stoves, less heat is lost in heating the foods, which yield efficiency as high as 90% (Sadhu et al., 2010). Due to the high efficiency, there is a significant amount of electricity bill savings by adopting induction stoves for cooking purposes (Sadhu et al., 2010).

Induction cooking technologies are being popular in Nepal, mostly in urban areas.

It is one of the most efficient technologies for stovetop cooking (Sweeney et al., 2014). The main principle behind this technology is magnetic induction (Sweeney et al., 2014). Eddy currents, in the presence of the oscillating magnetic field, are excited in ferromagnetic cookware (Sweeney et al., 2014). The heat generated from the induced currents is utilized for cooking purposes (Sweeney et al., 2014). Because of this phenomenon, less heat is lost because of inefficient thermal conduction between the heating element and cookware (Sweeney et al., 2014). A schematic figure of the induction stove is shown in Figure 3.

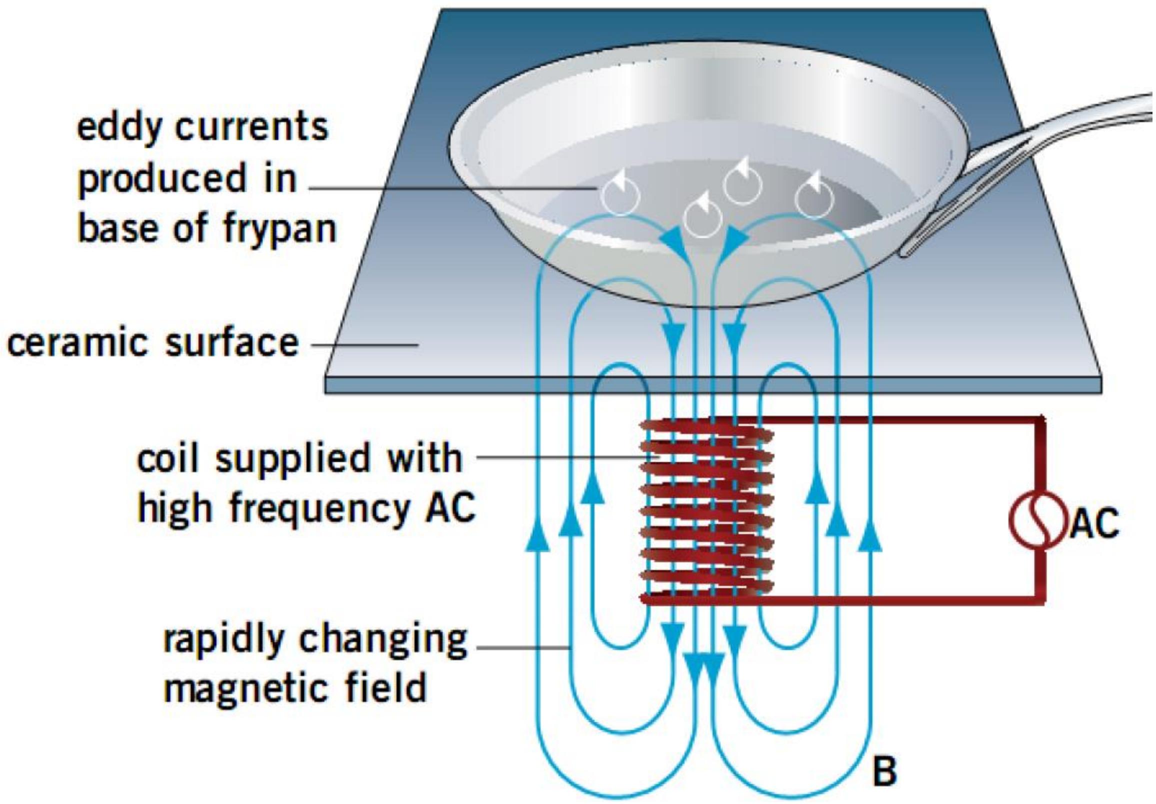

Figure 3. The working mechanism of induction stoves (Kitchen Apparatus.com, 2020)

A typical induction cooker is made of switching power electronics, which provides high-frequency current to a coil wire, which is embedded in the cooking surface (Sweeney et al., 2014). The oscillating magnetic field and the cookware are magnetically coupled (Sweeney et al., 2014). The low resistance of the metal maintains a flow of current into the cooking vessel (Sweeney et al., 2014). The power dissipated during the process is given by Ohm's law, i.e., I^2R, where I is the current, and R is the resistance (Sweeney et al., 2014). Magnetic permeability, the resistivity of the vessel (cookware), and the frequency of the excitation are the main factors in which the resistance of the vessel is dependent (Sweeney et al., 2014).

For the generation of sufficient heat, the vessel or the cookware should be such that it has high permeability and resistivity (Sweeney et al., 2014). The typical operating frequencies of induction cookers range between 25 kHz to 50 kHz (Sweeney et al., 2014). Induction stoves only function with cookware made of cast iron or some alloys of stainless steel. It is not compatible with copper and nonmagnetic cookware (Sweeney et al., 2014).

In induction cookstoves, a flat pancake coil is under the cooker, and a medium frequency current helps the coil inducing eddy current and generating heat (Meng et al., 2009). The maximum coupling is only possible where there is a minimum gap between the coil and the vessel (Sadhu et al., 2010). But in the meantime, the gap should also be large enough for providing sufficient insulation and airflow (Sadhu et al., 2010). The choice for the vessel material is dependent on resistivity (which needs to be high) and

relative permeability (Sadhu et al., 2010). Generally, the heating coils are made of bundled conductors, which are cooled by introducing forced air (Sadhu et al., 2010).

Scenario of LPG

Nepal's energy sector depends highly on fossil fuels. The import of fossil fuels or commercial energy resources like petroleum, oil, and coal is increasing at an annual rate of 10% (Poudyal et al., 2019). A large amount of LPG, electricity, and petroleum products are imported from India to meet this demand (Poudyal et al., 2019). Also, the dependency on petroleum products creates a trade deficit (Poudyal et al., 2019). The "petroleum sector in Nepal is a monopoly" as Nepal Oil Corporation (NOC) is owned by the state, and it is responsible for importing, sorting, and distributing all petroleum products in Nepal (Poudyal et al., 2019). In the fiscal year of 2017/18, Nepal imported 2.07 kilo-liters (kL) of petroleum products, whereas the demand is increasing at a rate of 13% per annum (Khanal, 2019).

According to NOC, Nepal consumes about 1.5 million tons of LPG per year (Poudyal et al., 2019). Hotels and restaurants are two main sectors that consistently use LPG, i.e., several gas cylinders per day (Poudyal et al., 2019). Most households that use LPG keep 2-3 extra LPG cylinders (Poudyal et al., 2019). Rural households rely mainly on kerosene or fuelwood instead, and the price of LPG gas may be one of the main reasons (Poudyal et al., 2019). For every 10 LPG cylinders imported to Nepal, the Kathmandu Valley (the capital city of Nepal) consumes 6 of them (Poudyal et al., 2019).

The last two decades of data on the price of petroleum products show that the price of kerosene has increased by a factor of two, whereas the price of the LPG has increased by a factor of three (Poudyal et al., 2019).

Household Fuel Switching: Theories and Behavior in Nepal

The change in energy consumption patterns of the residential sector in Nepal is associated with changing patterns of energy generation, energy availability, and living standards of people (Bhandari & Pandit, 2018). Household fuel switching from traditional and polluted sources of fuel to cleaner sources is dependent on household age, education, size, and availability and price of the fuel (Bhandari & Pandit, 2018). The two main models that are popular for analyzing household energy choice and fuel transition are the energy ladder and energy stacking models (Elias & Victor, 2005). One concept behind these models is they categorize energy resources into traditional, transitional, and modern types of fuels (Joshi & Bohara, 2017).

The energy ladder model is often used to analyze household energy consumption patterns in developing countries (Adamu, 2020). With an increase in wealth, households are expected to substitute existing (frequently dirty) fuels with less polluting fuels (Masera et al., 2000) . Fuels and rising income hold a hierarchical relationship (Toole, 2015). In the energy ladder model, household income, relative fuel prices and fuel accessibility are the main influencers in determining the household’s fuel-switching behavior. But several studies have noted the constraints of the energy ladder model

(Masera et al., 2000).. In reality, households do not completely abandon one fuel and transit to another fuel. Hosueholds are generally reluctant to completely shift from one fuel to another (Toole, 2015). The energy ladder theory does not fully incorporate the influence of cultural and habitual factors in analyzing the fuel transition (Toole, 2015).

The alternative model to the energy ladder model is the energy stacking model (Joshi & Bohara, 2017). The use of multiple fuels is known as 'stacking' (A. V Shankar et al., 2020). As the living standard grows, households adopt modern fuels but also often continue to use traditional fuels (Choumert et al., 2017). Households prefer a variety of fuels to a single fuel. According to this model, the fuel switching process also depends on the socio-economic aspects of households (Joshi & Bohara, 2017). Different studies have found different factors besides income that influence fuel switching processes. A study done in Nigeria shows that age, expenditure on food, and per capita expenditure were found to be major determinants for the use of electricity and gas (Yuni et al., 2017). Social factors like household size, household's age structure, time spent at home, level of urbanization, dwelling type and size, education and knowledge and the inertia to change play a major role in determining fuel switching behavior (Bhattacharjee, 2011). The economic condition of the household, energy price, and energy-efficient equipment affordability are the economic factors that determine the fuel switching or energy use (Bhattacharjee, 2011).

The fuel switching process in developing countries does not linearly follow the energy ladder model theory (Elias & Victor, 2005) . Studies show that energy stacking is

the dominant fuel usage theory adopted by households in developing countries (Acharya & Marhold, 2019). Except some cases, in general, households do not completely replace the fuel they are using. Even when the fuels are pollution emitting, households cannot completely abandon those fuels. There are other socio-cultural factors that hinder a complete fuel switching process. The energy ladder model primarily focuses on income and does not incorporate the social factors that influence fuel switching. In Nepal, the pursuit of energy security through energy stacking is a common phenomenon (Sharma, 2019). The major determinants of the household's energy demand are the presence of alternative fuels that are cleaner and easy to use, literacy status, size of landholding, size of households, and the presence of ruminants (Sharma, 2019).

The energy stacking model is a more realistic model to analyze the fuel switching process in the households. But saying so, the theories proposed by the energy ladder model cannot be completely neglected. Income is not a sole factor that influences fuel switching, but it is one of the factors. Studies have shown that income is a major driver for fuel transitions (Muller & Yan, 2016). A study performed in Zimbabwe found that households performed fuel switching as their income increased (Hosier & Dowd, 1987) . Fuel switching from natural gas to kerosene was a result of a rise in income in Burkina Faso (Ouedraogo, 2006). The fuel transition from fuelwood to kerosene, natural gas, and electricity happened as a result of income rise (Baiyegunhi & Hassan, 2014) . The energy transition from fuelwood and kerosene and from kerosene to LPG (Liquified Petroleum Gas) in India was largely driven by expenditure levels (Gupta et al., 2006). When the fuel

price increases, fuel consumption decreases (Muller & Yan, 2016). This means that income, fuel expenditure, and fuel prices play a major role in fuel choice and fuel transition. If appropriate arrangements of price and subsidy are made for electricity, there is a possibility of a shift from traditional fuels toward electric cooking (Sharma, 2019).

Scenario Build Up, Case Studies and Research GAP

The following section elaborates the related literature reviews and research gap in the field of cost benefit analysis of replacing LPG with Induction cooking stoves.

Scenario build up

Cooking energy plays a vital role in determining the energy demand of Nepal (Bhandari & Pandit, 2018). During the past decade, the import of LPG has increased by a factor of 3.3 (Bhandari & Pandit, 2018). The main challenges for energy security from the country's perspective are the subsidy burden to adopt modern fuels and the increasing demand for LPG (Bhandari & Pandit, 2018). By 2035, LPG demand is projected to be 58.2 million GJ for high growth rate (HGR) scenarios (Bhandari & Pandit, 2018). To enable substitution of LPG with electricity by 2035, an additional power generation of 2626 MW would be required (Bhandari & Pandit, 2018). This is nearly 135% more than the current electricity production in Nepal.

In recent years, LPG usage increased substantially, and 25.8% of the households currently consuming LPG in Nepal (Bhandari & Pandit, 2018). In urban areas, it is mainly used for cooking (58.5%) (Central Bureau of Statistics, 2016). LPG is the second

most-used fuel for cooking purposes in the country (Bhandari & Pandit, 2018). In FY 2004/2005, nearly 80,000 tons of LPG were imported from India (Bhandari & Pandit, 2018). Over a decade, the demand for LPG rose, and the demand for LPG as of 2014/2015 data was about 260,000 tons (Nepal Oil Corporation, 2017).

Nepal relies heavily on gas and petroleum imports from India (Bhandari & Pandit, 2018). Energy security is one of the key issues between India and Nepal because of socio-political reasons (Jewell, 2011). The full dependency on fuel imports results in the trade deficit, negative impacts on economy and society, intentional border blockades, and intermittent or zero supply of fuels (Bhandari & Pandit, 2018). The historical trend of LPG consumption in Nepal is given in Figure 4 (Bhandari & Pandit, 2018).

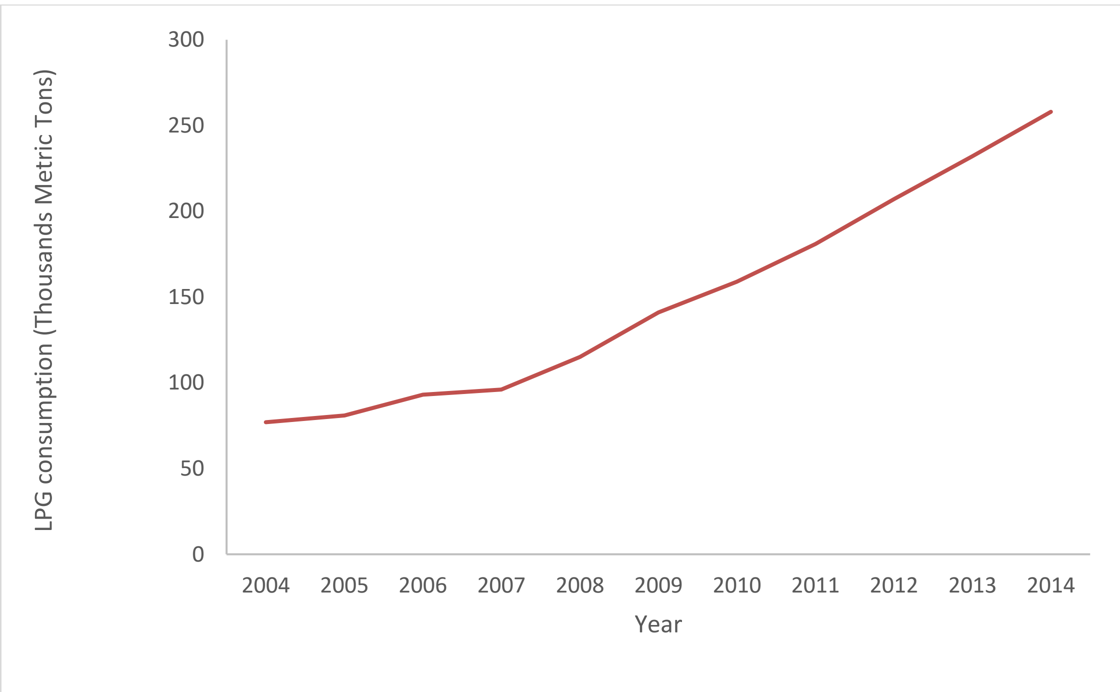

Figure 4. Historical trend of LPG consumption in Nepal

Surveys show that, on average, households consume 28.4 kg to 42.6 kg of LPG

per month, which is mainly used for cooking and heating purposes (Bhandari & Pandit, 2018).

In FY 2014/2015, petroleum imports accounted for 20% of the total import budget, which is about $ 1068.5 million (Ministry of Finance Nepal, 2017). The expenditure on petroleum products accounts for 28% of GDP. One hundred and ninety-four million U.S. Dollars were spent on importing 258,299 tons of LPG (Ministry of Finance Nepal, 2017).

<u>Case studies</u>

Many studies have been conducted in Nepal on fuel interventions, fuel choice, and fuel switching behavior of the households. But there are very few studies that focused on switching from LPG to electricity (Pradhan & Limmeechokchai, 2017). A few studies have been conducted on electric cooking in households (Pradhan & Limmeechokchai, 2017).

A cost-benefit analysis of indoor air pollution mitigation interventions was conducted in Nepal, Kenya, and Sudan. For Nepal, the location chosen was *Rasuwa*, a mountainous region in Northern Nepal (M. B. Malla et al., 2011). It was based on WHO guidelines of cost-benefit analysis (M. B. Malla et al., 2011). This study also analyzed the health benefits and calculated the monetary value of it (M. B. Malla et al., 2011). This study concluded that over ten years, the benefit would exceed the cost.

A study to value the indoor air pollution reduction in monetary terms was conducted in Kathmandu in 2007. The health effects of indoor air pollution were

analyzed for chronic bronchitis, asthma, and (Acute Respiratory Infection) ARI, though the study mentions that it was medically difficult to identify such cases from the household samples (Pant, 2007). Fuel switching from traditional stoves to cleaner cooking technologies helps to improve the health conditions of rural households (Pant, 2007). This study concluded that the adoption of improved cookstoves could reduce the health costs by NRs 1,354 per year, which is more than the market price of the improved cookstove (Pant, 2007). Similarly, the study shows that the health savings from adopting the biogas are NRs 699 per year (Pant, 2007).

A study on using electricity for cooking in Nepal was conducted in 2018 (Bhandari & Pandit, 2018). The Long-range Energy Alternative Planning (LEAP) model was selected for this analysis. LEAP is a scenario-based environmental modeling tool to calculate future energy demand and local, national, regional, and global emissions and supply (Bhandari & Pandit, 2018). LEAP is compatible with different modeling technologies from bottom-up, end-use to top-down, and provides a range of accounting, simulation, and optimization techniques (Heaps, 2017). There is flexibility in data input (Bhandari & Pandit, 2018). The study concluded that the yearly cost of electricity in all scenarios, i.e., business as usual (BAU), medium growth rate (MGR), and high growth rate (HGR) scenarios was cheaper than LPG (Bhandari & Pandit, 2018). Several studies have been conducted for calculating the electricity demand using the LEAP model (Bhandari & Pandit, 2018). For example, the LEAP model was used for simulating the electrical supply and demand system for nearly two decades of duration (Park et al.,

2013). Using the translog production function, the elasticity of fuel substitution between hydroelectricity, coal, gas, petrol, diesel, and kerosene was calculated (Awasthi & Adhikari, 2020). The study concluded that all fuels except kerosene contribute to positive economic benefit (Awasthi & Adhikari, 2020). For the study period, the elasticity output of hydroelectricity was found to be the largest (Awasthi & Adhikari, 2020). This study also concluded that electricity has the potential to substitute other conventional fuels like petrol, diesel, kerosene, and gas (Awasthi & Adhikari, 2020). This study also encourages the creation of suitable mechanisms for incentives and subsidies in electricity if electricity is to replace the use of conventional fuels (Awasthi & Adhikari, 2020).

Study Gaps

There are many studies on fuel switching and fuel interventions in Nepal, as mentioned above. But there are very few studies that perform a cost-benefit analysis of replacing the LPG with the electricity (e.g., induction stoves) in the rural households of Nepal. In one of the studies, the LEAP model was used as a modeling tool to study the feasibility of replacing LPG with the electricity. In this study, the scenarios were analyzed using historical data sets and the trends of residential energy demand. Energy models extract data from various sources to define the energy sectors in terms of energy demand and supply (Bhandari & Pandit, 2018). In those models, a simulation was performed by considering different variable changes such as the national population, economic activity, and energy intensity supply (Bhandari & Pandit, 2018). The data taken for this model are secondary data. Secondary data do not always correctly predict the

current and future scenario as primary data does. Primary data may be more effective for making such predictions. This study mentions that LPG demand will decrease in the future. But it does not mention the amount or percentage subsidy on electricity that should be provided to encourage the households to replace LPG with electricity. It concludes that the household energy demand would still be dominated by traditional energy sources like biomass in the future. However, this conclusion would be stronger it it were verified with primary data. Also, the people are not directly surveyed to find the scopes, opportunities, and prerequisites for the fuel transition.

Models, in a way, are a mathematical way of guessing the things that might happen in the future, referring to the similar conditions that have happened earlier. Primary data collection techniques like surveys can give a more realistic scenario than models that rely exclusively on secondary data. This study directly analyzes the real scenario in three different rounds. It provides a real overview of LPG consumption patterns, baseline electricity usage, additional and final electricity usage (after the adoption of induction stoves), yearly savings/benefits, and NPV if induction stoves replace LPG for cooking purposes. The survey was performed is in Kavre District, Central Development Region, Nepal. The direct survey of the households and the cost-benefit analysis from the data collected provide an opportunity to examine fuel switching dynamics in a village setting.

DATA AND METHODS

The Global Alliance for Clean Cookstoves (GACC) Nepal conducted a Kitchen Performance Test (KPT) survey in rural households of Kavrepalanchowk (Kavre) District, Panchkhal Municipality, Nepal. Other surveys, like health and air pollution surveys, were also conducted. Seventy-two households were included in the KPT survey. The total number of households in the location was seven hundred and seventy-two.

The KPT survey was performed in a total of four different seasons of 2018 and 2019. The included seasons were summer, winter, spring, and rainy. In Nepal, the summer season is considered from April to June, rainy from July to October, winter from November to February, and spring from March to May.

The survey mainly collected information on the fuel consumption patterns of the households, i.e., stoves and fuels used by the households for the cooking and non-cooking purposes and their duration of use. The survey also collected the information on different cooking and non-cooking events that the households performed on the stoves.

Almost all the households surveyed used LPG. The number of households that did not use LPG varied during each round of the survey. This goal of this study is to perform a cost-benefit analysis of fuel-switching from LPG stoves to electric induction stoves. None of the households have adopted electric induction cooking yet. But this study has assumed that in the future, the households would switch to electric induction cooking, and this cost-benefit analysis would help them understand the financial aspects of the switch. The following steps were followed to determine if the shift from LPG to

induction stoves would result in net benefits to the end-users:

1. Calculation of daily, monthly and yearly LPG usage
2. Calculation of total electricity usage after induction stoves replace LPG
3. Calculation of baseline electricity usage
4. Calculation of yearly costs incurred, and benefits gained from the transition
5. Net present value (NPV) analysis

The average daily LPG usage is calculated based on the difference between the weights of the LPG cylinder taken during different survey days. For each round, the survey was conducted three times at an interval of two days. Monthly and yearly LPG usage was calculated simply by using the average daily LPG usage and multiplying it by the number of days in a month and a year, respectively. No special events or days of a year were considered where daily LPG usage could have been either less or more than the average value. The possible scenarios where households could have been using less or more LPG than the average value and its effect on NPV have been analyzed as a part of sensitivity analysis. Use of induction stoves would lead to additional electricity usage relative to LPG cooking. The energy consumed by the inductions stoves was calculated by converting the energy consumed by LPG (in Mega Joules, MJ) to kWh while also accounting for differences in efficiency between the two cooking methods. The different variables considered for this conversion are average daily LPG usage (weight), the calorific value of LPG, and the respective efficiencies of induction stoves and LPG gas burners. These efficiencies were considered to be 80% (induction) and 50% (LPG),

respectively. Multiple literature sources - (Ogedengbe & Ajibade, 2017), (Sweeney et al., 2014), (Meng et al., 2009), (Banerjee et al., 2016) and (Jugjai, 2018) were reviewed, and the average values were taken for the efficiency of induction stoves and LPG stoves. The total electricity usage was calculated by adding the additional electricity usage to the baseline electricity usage. Baseline electricity usage is the current amount of electricity that the households are consuming, i.e., electricity consumption before the introduction of induction stoves. The avoided costs of the LPG were considered as the benefits gained by the households. The total cost of electricity incurred to the households after the addition of the induction stoves was calculated from the rate schedule of the electricity as published by Nepal Electricity Authority (NEA) for domestic customers. These calculations were followed by the calculation of NPV.

The NPV was calculated drawing information from all rounds of the survey. It was calculated referring to the electricity rate tiered to a 15-A energy meter. Generally, to use induction stoves, the capacity of the energy meter should be more than 5 A. The cost of the new meter is not considered in the analysis because most often, the electricity authority provides the meter. Also, the fixed cost of the meter is negligible compared to the monthly cost of electricity or LPG. The electricity rates are tiered. This means the rate for the customers is lower for those who consume a small amount of electricity and higher for those who consume more.

Calculation of average daily, monthly and yearly LPG usage

At an interval of two days, different surveyors went to different households and measured the weight of the LPG cylinder for three different days. People were found using LPG as their first, second, or third priority for performing different cooking events in the kitchen. Priority refers to the preference. For example, some households were using LPG stoves as their first preference. This means that they are spending maximum time on LPG stoves on performing different cooking activities. Though these households are also using other types of stoves (e.g., three-stone stoves, metal-tripod stoves), they are spending less time on them. These data were taken during the survey. Similarly, the households using LPG as their second priority or preference means that they are performing most of cooking activities and spending most of the time using some other types of stoves. A similar definition applies to the households which are using LPG stoves as their third preference.

Regardless of the preference, the difference in the weight of LPG for three consecutive days was averaged to find the average LPG usage per day in that particular season. This calculation was performed for each household that was using LPG. The average daily usage was converted to monthly and yearly average usage. The weighted difference was measured in kilograms (kg). General mathematical expression for calculating daily average LPG usage for each household is given by Equation 1:

$$Daily\ Average\ LPG\ use\ (weight)\ for\ each\ household = \big((weight\ of\ LPG\ fuel\ on\ first\ day - weight\ of\ LPG\ fuel\ on\ second\ day) + (weight\ of\ LPG\ fuel\ on\ second\ day - weight\ of\ LPG\ fuel\ on\ third\ day)\big)/2 \ldots\ldots\ldots \quad (1)$$

The average daily usage was converted to the monthly and yearly average usage by multiplying with the average number of days in a month (30) and the number of days in a year (365), respectively.

The questionnaire of the survey is attached in Appendix A. Sections D, E, F, and K on the questionnaire give information on the weights of the LPG taken on different survey days.

Calculation of total electricity usage after LPG replacement

The average daily LPG usage, as calculated above, is used as one of the variables to calculate the electricity consumed in cooking. A key factor for predicting the total electricity usage is the baseline electricity usage. Baseline electricity usage refers to the electricity that the households are using currently, without the introduction of new induction stoves. The total electricity usage after induction stove adoption was calculated by converting the energy being consumed by the LPG (MJ) to electrical energy (kWh) and adding the baseline electricity usage to it. The difference in the efficiencies between two cooking methods was considered while performing the conversion.

The following steps were followed convert the average daily LPG usage (kg) to average daily electrical energy.

1. Conversion of average daily LPG usage (kg) into megajoules (MJ)

2. Conversion of average daily MJ consumed by LPG into kWh

3. Accounting for the difference in efficiency between the two cooking methods to obtain the estimated electricity required (in kWh) to provide the same amount of heat to the pot as was provided in the LPG cooking case.

This average daily electrical energy that would be consumed with the addition of the new induction stoves was added to baseline electricity usage to find the total electricity usage for each household.

The steps mentioned above for converting average daily LPG usage (kg) to average daily electrical energy are elaborated below:

Conversion of average daily LPG usage (kg) into megajoules (MJ)

The calorific value is equivalent to the amount of heat given by the fuel when it is burned completely (Sarkar, 2015). "Calorific value is the heat energy released per unit mass of fuel burned" (Soares, 2014). "The calorific value of a fuel is the quantity of heat obtained per kilogram (solid or liquid) or per cubic meter (gas) when burnt with an excess of oxygen in a calorimeter" (Carvill, 2003). It is the heat generated during its complete combustions, which can be expressed in KJ/kg and mathematically, it can be expressed as (Woodyard, 2004):

$$Calorific\ Value\ of\ LPG = (8100C + 34000\left(H - \frac{O}{8}\right))/100 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where,

Calorific value is in kilocalories per kg of fuel (kcal/kg of fuel), C, H, and O are

the percentages of carbon, hydrogen, and oxygen in 1 kg of fuel, and 8100 kcal/kg and 34000 kcal/kg are constants.

If water is present as a liquid in the byproduct after the combustion, the higher calorific value is obtained, and if it is present as vapor, the lower calorific value is obtained (Prasad, 2014). Mathematically, the relationship between these two types of calorific value can be represented as (Prasad, 2014):

$$LCV = HCV - 207.4\frac{kJ}{kg} * \ Hydrogen\ (by\ mass)\text{………….(3)}$$

HCV is equivalent to Gross Calorific Value (GCV), and LCV is also known as Net Calorific Value (NCV) (Soares, 2014). The average daily amount of LPG used (kg/day) can be converted to average daily energy consumed (MJ/day) by using calorific value. Different literature sources provide different calorific values of LPG gas. The gross calorific value of LPG is 49,728 KJ/kg (Nayak et al., 2016). The standard calorific value of LPG is 45.7 MJ/kg (K. S. Shankar & Mohanan, 2011). The Lower Heating Value (LHV) of LPG is 28.06 MJ/liters (Suyabodha, 2017). The calorific values of LPG in terms of LHV and HHV are 45.7 MJ/kg and 50.15 MJ/kg, respectively (Chitragar et al., 2016). Some other properties of LPG gas are given in Table 4. For this study, the calorific value of LPG is taken as 45.7 MJ/kg.

Table 4. Physical and chemical properties of LPG gas (K. S. Shankar & Mohanan, 2011)

S.N	**Particulars**	**LPG**
1	Chemical Formulae	60% Butane + 40% Propane
2	Gross Calorific Value (KJ/kg)	49,728
3	Ignition Temperature (°C)	488-502
4	Boiling Point (°C)	-22
5	Ideal Combustion Ratio (Air to Gas)	28 to 1
6	Volume of Gas/volume of liquid	250
7	Volume of air required to burn the unit volume of gas	26

Calculation of total electricity usage after induction stoves replace LPG

The electricity consumption or use is generally measured in kilowatt-hours (kWh). Mathematically, MJ can be simply converted to kWh by multiplying by a factor of 0.27778 kWh/MJ. But to deliver the necessary heat for the same cooking task (e.g., cooking foods or boiling water), the energy consumed by the LPG and the induction stoves will be different. This is true because the efficiency of the induction stoves and LPG are different. So, to convert the energy consumed by LPG (MJ) to the additional electrical energy (kWh) consumed by the induction stoves (when the induction stoves replace LPG), the efficiency of both induction and LPG stoves need to be considered. In a simple language, the efficiency of LPG needs to be replaced by the efficiency of induction stoves while calculating the electricity consumption by the induction stoves. “The efficient use of energy is a priority when a technology migration plan is being executed” (Villacís et al., 2015). With the induction stoves, it is possible to achieve 90% efficiency while cooking foods compared to about 74% efficiency for electric stoves and 40% for gas stoves (Sweeney et al., 2014). For the purpose of this study, as mentioned

earlier, an efficiency of 50% is used for LPG gas stoves. A test conducted by Electric Power Research Institute (EPRI) for California Energy Commission (CEC) shows that the efficiency of the induction stoves ranges from 74.9 to 77.6 % (Sweeney et al., 2014). This variation is due to the types of induction stoves used, power at which the induction stove is running, and the type of vessel (small or large) used for the test. An efficiency test of induction stoves was performed considering three different pots made from different materials i.e. stainless steel, enameled iron, and aluminum (Villacís et al., 2015). The efficiency was different for each type of pot. Even for pots with the same materials, the efficiency was different before and after the test. The efficiencies were measured multiple times. The efficiencies as mentioned above are summarized in Table 5.

Table 5. The efficiency of induction stoves before and after the test when tested using pots made of different materials (Villacís et al., 2015)

S.N	**Body pot material**	**Efficiency before test**	**Efficiency after test**
1	Stainless Steel	86.62%	83.98%
2	Enameled Iron	91.35%	83.05%
3	Aluminum	82.10%	83.57%

This test shows that the induction stoves deliver the highest efficiency when used with the enameled iron (Villacís et al., 2015).

"It is important to follow a standard test procedure when evaluating efficient products so that their performance can be compared with other devices in an unbiased way" (Sweeney et al., 2014). There are different methods to find the efficiency of induction stoves. In the U.S., the "hybrid test block" method is used to measure the efficiency of the induction stoves (Sweeney et al., 2014). EPRI has developed a standard

test procedure based on ASTM F1521 and ANSI Z83.11, where 4.54 kg of water is heated from 21°C to 93°C in a 24-cm diameter stainless steel stockpot (Sweeney et al., 2014). A similar procedure was followed to calculate the efficiency of the induction stoves for three different pot materials, as mentioned above (Villacís et al., 2015). This procedure is also known as a water boiling test. The general concept behind this procedure of calculating the efficiency of the induction stove is to relate the electrical power consumed by the induction stoves to the energy gained by the water within a time when the above condition of the final temperature of the water (i.e., 93°C) is met. The efficiency of the induction stoves after the water boiling test can be calculated by using Equation 4 (Villacís et al., 2015):

$$Efficiency\ of\ induction\ stove = \frac{(c1*m1+c2*m2+c3*m3)*(Final\ Temperature - Initial\ Temperature)*100}{(P*t)} \quad \ldots\ldots\ldots\ldots(4)$$

Where,

Efficiency of an induction stove is in percentage (%), c1, c2, and c3 are the specific heat capacities of the water, the pot, and the glass lid (used to cover the pot), respectively, P is the electrical power consumed by the induction stoves, and t is time, i.e., duration of the test.

The GACC Nepal team also conducted a water boiling test for four different types of induction stoves and cooking pots. The boiling test was done for a total of three rounds (named as first, second, and third-round) for each type of induction stove and cooking pot. For each pot, each round of the test was conducted under three different settings of

the induction stoves, i.e., low, medium, and high setting. The measured variables for the test were the power rating of the induction stoves in low, medium, and high setting, a time duration of the test, the power consumed by the induction stoves (via a wattmeter), and the corresponding voltage and the current. A total of forty-eight tests were conducted, and most of the tests show that the efficiency of the induction stoves was higher than 100%, which is not valid. This might be due to the wrong data entry or wrongly followed procedure compared to the standard procedure.

The types of induction stoves and pots (vessels) used for testing the efficiencies of the induction stoves for all rounds are summarized in Table 6.

Table 6. Types (brands) of the induction stoves distributed by the GACC Nepal project to the surveyed households and the nearby communities

S.N	**Brands of Induction Stoves**
1	Bajaj
2	Prestige
3	CG
4	Usha

The efficiency of induction stoves is a function of type (brand) of the stoves, the cooking pot used on the stoves, and the power setting on which induction stove is being used (i.e. low, medium, or high).

Though efficiency is dependent on these variables, it is difficult to predict people's behavior on how they will use the induction stoves. It is difficult to assume when they will use the low, medium, or high setting on the induction stoves. It is also difficult to assume which cooking pots they will be using in what setting. So, this study will assume an 80% efficiency for the induction stove, for the base case scenario. The

other values of the induction stove's efficiencies as calculated from the primary sources (i.e., the survey as described above) and the secondary sources (i.e., literature reviews) will be addressed as a part of the sensitivity analysis.

The efficiency of the LPG gas stoves is another main factor for converting the energy consumed by the LPG (MJ) to the electrical energy (kWh). The different LPG burner heads and their efficiencies are summarized in Table 7 (Khan & Saxena, 2013).

Table 7. Types and LPG burner heads and their efficiencies

S.N	**Types of LPG Heads**	**Efficiency**
1	Regular cast iron burner	48%
2	Flat face burner	58%
3	Flower face burner	50%

The efficiency of LPG stoves was found to be increased by 4% when the brass burner was used instead of the cast iron burner (Khan & Saxena, 2013). Insulation also plays a vital role in increasing the efficiency of LPG stoves. On insulating the bottom base and sides of the mixing chamber of LPG stoves, the thermal efficiency increased from 49% to 54% (Saxena et al., 2012). For the base case scenario, the efficiency of the LPG stove burner will be taken as 50%, and other values of efficiencies and their effect on NPV will be analyzed as a part of sensitivity analysis.

Baseline Electricity Usage

As noted above, the baseline electricity usage is based on the current electricity consumption. This is the electricity the households are consuming before adopting the induction stoves. It will be calculated by relating the following three types of information

taken from the KPT survey:

1. Price (NRs) households are paying for the electricity.
2. Duration for which the households are paying the price
3. Rate schedule published by the Nepal Electricity Authority (NEA).

The KPT survey collected data on electricity cost and duration of use for all surveyed households. These variables were used to calculate the monthly electricity consumption for each household who are using LPG and have access to electricity. The rate schedule from the NEA and the electricity cost incurred by the households would give the monthly consumption of electricity in kWh. The NEA has a tiered rate schedule. The rate schedule for domestic (residential) customers depends on the monthly electricity consumption (kWh) and the energy meters the households are using. The larger the size of the energy meter, the higher the rate for the electricity (NRS/kWh). The NEA rate structure is described in more detail in the following section.

Calculation of yearly costs incurred, and benefits gained from the transition

The only cost assumed to be incurred by the households from this transition is the total electricity cost. Other costs such as the operation and maintenance (O&M) costs of the induction stoves have been neglected because:

a. Generally, induction stoves are reliable throughout their lifetime.
b. People choose buying new one rather than repairing it.

The yearly electricity costs incurred by the households in the first year of the

transition was calculated. The cost was discounted over the lifetime of the induction stoves. The benefit was considered as the avoided cost of LPG. The discounted costs and benefits over the lifetime of the project (i.e., the lifetime of the induction stoves) were used to find the NPV. Equation 5 was used to find the yearly electricity costs incurred to the households:

$$Yearly\ Electricity\ Price = \left(\frac{Average\ Daily\ LPG\ use * Calorific\ Value\ of\ LPG * k * 30\ days * Monthly\ Electricity\ Price * Efficiency\ of\ LPG\ gas\ burner}{Efficiency\ of\ Induction\ Stoves} + Baseline\ electricity\ usage\ per\ month\right) * 12\ months \ldots.(5)$$

Where, the yearly electricity price is in Nepali Rupees (NRs); the average daily LPG use is in kg, the calorific value of LPG is 45.7 MJ/kg; k is 0.27778, a constant to convert MJ to kWh; monthly electricity is the electricity price incurred by the households in NRs/kWh as published by Nepal Electricity Authority (NEA); the efficiency of the LPG gas burner is 50% for the base case scenario; the efficiency of induction stoves is 80% for the base case scenario; and the baseline electricity is in kWh/month. Baseline electricity usage means the average monthly electricity which is currently being consumed by households prior to adopting the induction stoves. The baseline electricity usage (kWh/month) was determined by relating the total electricity price the households are paying per month and the tiered electricity rate issued by the NEA.

The monthly electricity price for Nepal for different types of customers is published by NEA. The rate schedule is mainly divided into three sections (Nepal Electricity Authority(NEA), 2018).

a. The rate for domestic consumers (NRs/kWh)

b. The rate for other consumers

c. The time of day (ToD) tariff rate

d. The rate for community wholesale consumers

The rate for domestic consumers is further divided into the rate for consumers using a single-phase line and consumers using a three-phase line. The rate for the domestic consumers using a single-phase line is dependent on two factors: a) total units (kWh) consumed by the consumers (households) per month and b) the ampere rating of the electricity meters that they possess. The rate for the three-phase line is further categorized as a rate for low and medium voltage users.

The “other” type of consumers includes industrial, commercial, and non-commercial and the consumers related to irrigation, water supply, temple and entertainment business. The tariff rate is structured as a sum of demand charge (NRs per KVA/month) and energy charge (NRs/kWh). The rate for these types of customers is further categorized as low voltage and high voltage customers.

The rate structure that follows the ToD tariff rate is for the industrial, commercial, and noncommercial customers and other types of customers related to irrigation, temple, trolley bus, street light, community water supply and transportation. The detailed price structure, as published by the NEA, is attached in Appendix B.

The avoided costs of the LPG is the benefit gained by the household. The avoided cost of LPG is only the significant monetary benefit that households would gain from the

adoption of induction stoves. The benefits gained from avoiding O&M and labor costs are not included as they are negligible.

There are different brands of LPG available in Nepal, which differ in prices and size. The KPT survey did not collect any information on types (brands) and total size (weight) of the LPG that households were using. But it is very common in Nepal that people use an LPG gas cylinder with a net weight of 14.2 kg. Some of the LPG brands available in Nepal are *Koshi Gas*, *Prima Gas* and *Nepal Gas*.

Though different brands have different prices, Nepal Oil Corporation (NOC) has adjusted the price of LPG to a standard value for January 2020 (Nepal Oil Corporation, 2020). The standard price of LPG having a net weight of 14.2 kg is 1350 NRs (Nepal Oil Corporation, 2020).

Though these prices differ from the market price of LPG for several reasons, the standard value price of LPG as set by NOC for January 2020 will be taken as the price of LPG for the base case scenario. As a part of sensitivity analysis, the cost-benefit will also be analyzed by fluctuating the price of LPG from the standard value.

The annual savings that each household would achieve by replacing the LPG with the induction stoves is calculated as given by Equation 6.

$$Annual\ Savings = \frac{LPG\ price\ per\ cylinder * Average\ Daily LPG\ use * 365}{Net\ Weight\ of\ LPG} \text{............(6)}$$

Where LPG price per cylinder is NRs 1350 for the base case scenario, average daily LPG use is in kg, which will be calculated from the KPT survey data, the net weight of LPG is 14.2 kg, and 365 is the number of days in a year.

Net Present Value (NPV) analysis

The Net Present Value (NPV) is used to find out the worthiness of capital investment by finding out the effect of the investment on a shareholder's wealth in present value terms (Jory et al., 2016). The main objective of this study is to perform a cost-benefit analysis of the households who are to replace the LPG with induction stoves. Since this is the only project which will be analyzed, the Net Present Value (NPV) analysis would be the most suitable tool that can be used to perform the CBA (Sassone & Schaffer, 1978). If the NPV is greater than zero over the lifetime of the induction stoves, then the project would be beneficial to the households.

The procedure for calculating NPV can be mathematically written as shown in Equation 7 (Sassone & Schaffer, 1978):

$$\text{NPV} = \frac{Bo-Co}{(1+d)^0} + \frac{B1-C1}{(1+d)^1} + \cdots + \frac{Bt-Ct}{(1+d)^t} + \frac{Bn-Cn}{(1+d)^n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where,

Ct is the dollar value of costs incurred at time t,

Bt the dollar value of benefits incurred at time t,

d the discount rate (10%), and

n the life of the project in years.

For this study, the unit of the costs would be Nepali Rupees (NRs).

As mentioned in the earlier sections, the benefits are the avoided cost of LPG. The costs incurred by the households are the electricity costs the households need to pay for after the adoption of the induction stoves. The households need not buy the induction

stoves because the project (GACC Nepal project) is supposed to distribute the induction stoves for free. Here, the lifetime of the project means the lifetime of the induction stoves. It is estimated to be eight years for the base case scenario. The lifetime will be varied as a part of the sensitivity analysis.

A cost-benefit analysis performed on mitigating the indoor air pollution in Nepal has assumed the discount rate to be 10% (B. Malla, 2011). Though this discount rate is high for societal analysis, this is appropriate from the household perspective (B. Malla, 2011).

RESULTS AND DISCUSSION

This section provides key insights on the overview of the results, first-year cost/benefits incurred by the households from the fuel transition, and the NPV incurred by the households over the lifetime of the project.

Overview of the survey

As mentioned above, this survey was performed in three rounds in rural households of Kavre district, Panchkhal VDC, Nepal. Seventy-two households were surveyed on all four seasons. The average age of the household members who participated in the survey was 44 years. The ratio of male to female participants was about 1:4. The average income of the households was NRs 30,000 per month. Most of the income was generated from working within the country, i.e., not from overseas.

Households were found to wear more clothes to stay warm rather than heating the indoor space. Most of the households used fans during the summer season. All households had access to electricity—all households used at least an electric bulb as a lighting source. Some of the households also used battery-powered lights. Two of the households also reported that they use the electricity for income-generating activities, i.e., for chicken farms and for running a rice mill. The participants also reported that they performed trading of crops for other household items.

Some of the households also used biogas but only for cooking purposes. The average duration of biogas use was about an hour per day. Surprisingly, most of the

households used human waste as feeding material for biogas.

Different households were found to use a different mix of fuels and stoves. Wood, crop/agricultural residues, biogas, LPG fuel, electricity for rice cookers were some of the main fuels that the households used. Corncobs, rice-husks, corn stalks, mustard/pulses/stalks or cereal straws are some examples of the agricultural residues that the households were using.

Some of the households also used homemade charcoal, paper, plastic, and cardboard. Most of the households were found to use LPG as their first-choice fuel to make meals. LPG was followed by single pot portable rocket stoves, biogas, and electric rice cookers. Other types of stoves used by some of the households were single pot portable metallic rocket stoves and three-stone stoves.

Most of the households reported that they perform animal husbandry. The foods for the animals were made outside the house in the early mornings. In most of the cases, the food was made using the three-brick/stone stove. The households were found to be performing different cooking and non-cooking events using the stoves. Some of the cooking events included making breakfast, lunch, and dinner, making hot drinks/tea, and reheating water. Boiling the water for bathing is an example of a non-cooking event.

The main cooking events they perform specifically on LPG were the preparation of breakfast, lunch, dinner, snacks, and making hot drinks/tea. Some of the households also reported that they performed events like boiling water and milk, reheating food, and preparing baby food.

For most of the households, LPG was the first choice. Households were found to have at most four different preferences for the stoves for performing different cooking and non-cooking events as described above. For example, if a household used the LPG as its first-choice stove, the second-choice stove may be an electric rice cooker; the third-choice stove may be a biogas, and a fourth-choice stove may be a three-stone stove.

Average Energy Consumption per day

The average daily energy consumed by the households by using the LPG was calculated in terms of MJ per day. The energy consumption values calculated for the first, second, and third rounds of the survey are given in Figures 5, 6 and 7, respectively. The y-axis and the x-axis give energy consumption and the respective households, respectively. During the survey, the households were identified by unique identification numbers. The numbers are not shown in the graph as they are not important and to protect the identities of the households.

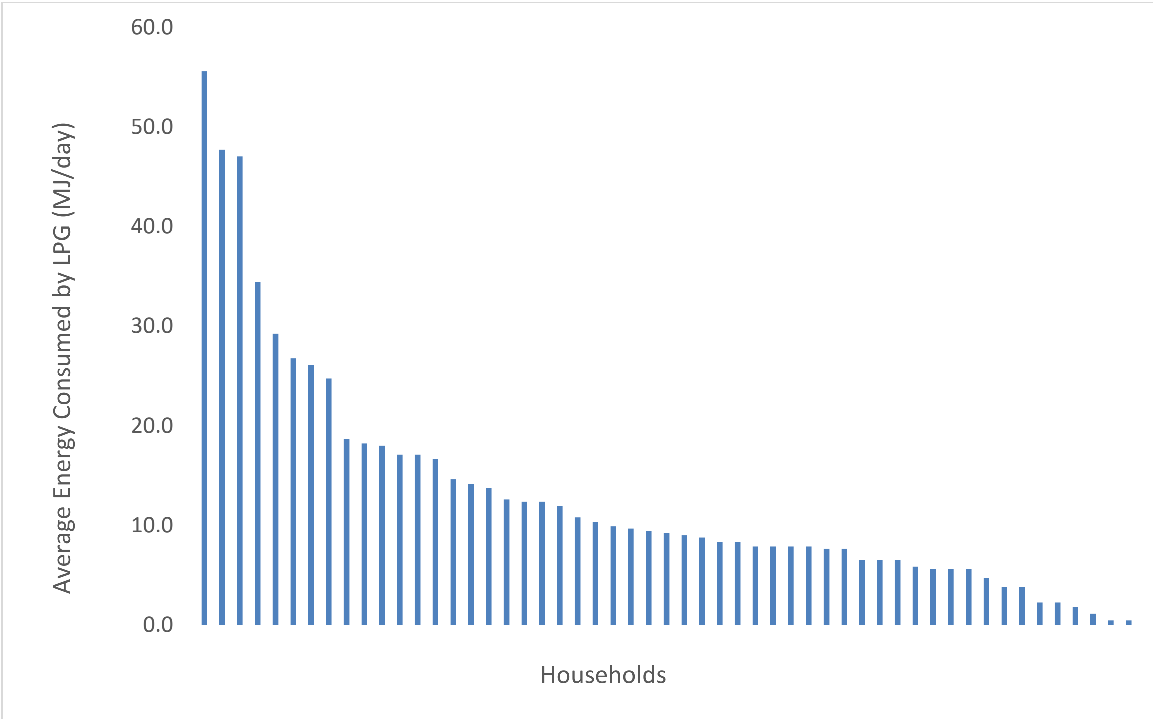

Figure 5. Average daily energy consumed by the households by using LPG (first round of the survey)

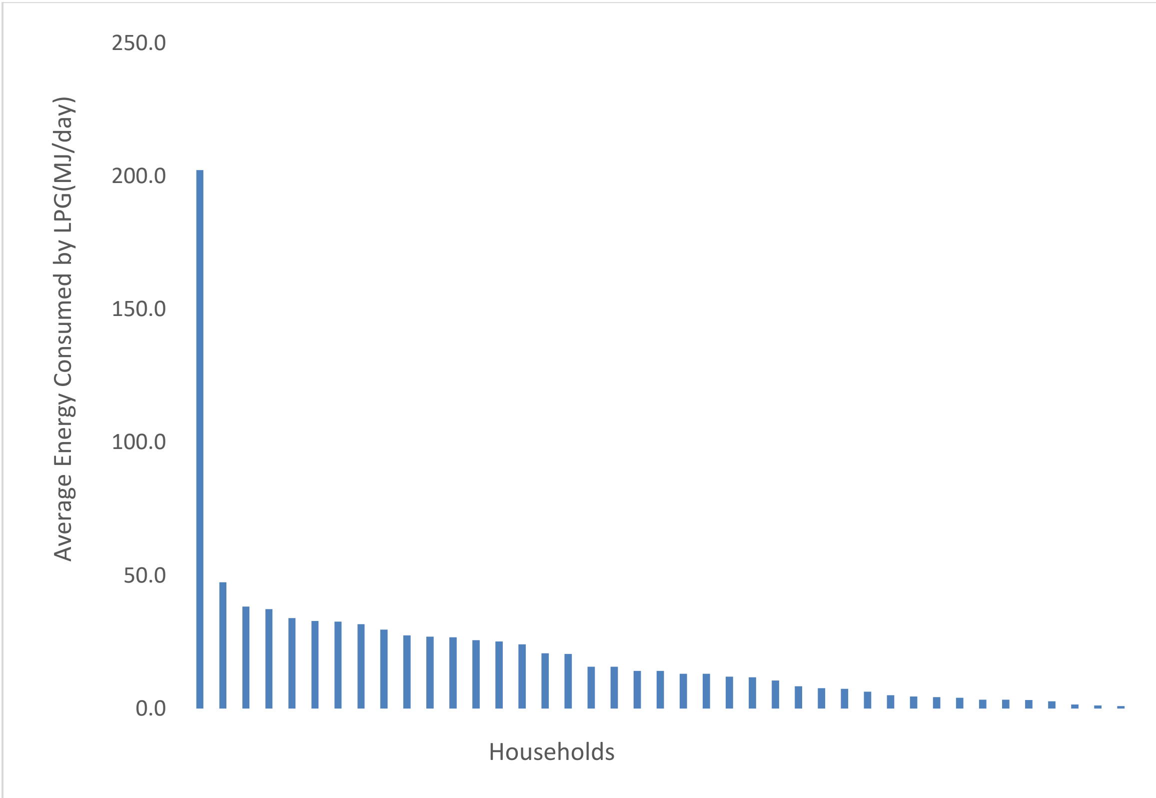

Figure 6. Average daily energy consumed by the households by using LPG (second round of the survey)

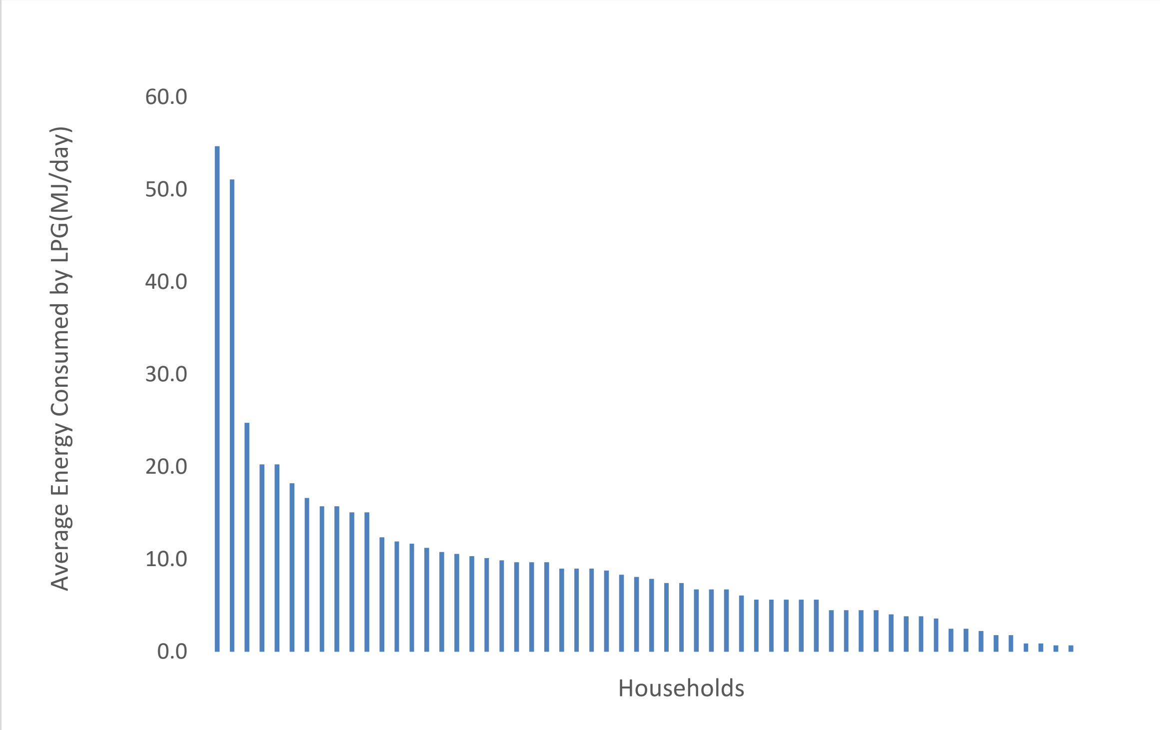

Figure 7. Average daily energy consumed by the households by using LPG (third round of the survey)

The average LPG and energy consumption for each round of the survey are given in Table 8.

Table 8. Average daily LPG use in terms of mass and energy for each round of the survey

S.N	**Variable**	**Round 1**	**Round 2**	**Round 3**	**SD**
1	Average Energy (MJ/day)	13	18	10.	4.04
2	Average Mass (kg/day)	0.27	0.40	0.20	0.1

The average LPG use in terms of mass and energy during the third round of the survey is less than the other two rounds. The third-round survey was carried out during the summer season. Though the survey results do not explain the variation in LPG usage, one possible factor resulting in this variation may be the local weather conditions.

During the summer season, people spend comparatively less time on performing the events like reheating foods and boiling water for bathing/drinking, which might have led to reduced use of LPG and hence less energy consumption.

Baseline Electricity Usage

As mentioned above, the baseline electricity consumption refers to the current electricity consumption of households. Figures 8, 9 & 10 show the baseline electricity consumption of the households for the first, second, and third rounds of the survey. The y-axis gives the current (baseline) electricity consumption, while the x-axis shows the individual households. The household's identification numbers are not shown as they are not significant. Figure 6 shows 41 households, and figure 9 shows 39 households. This is because the two households that used LPG did not have any baseline electricity usage.

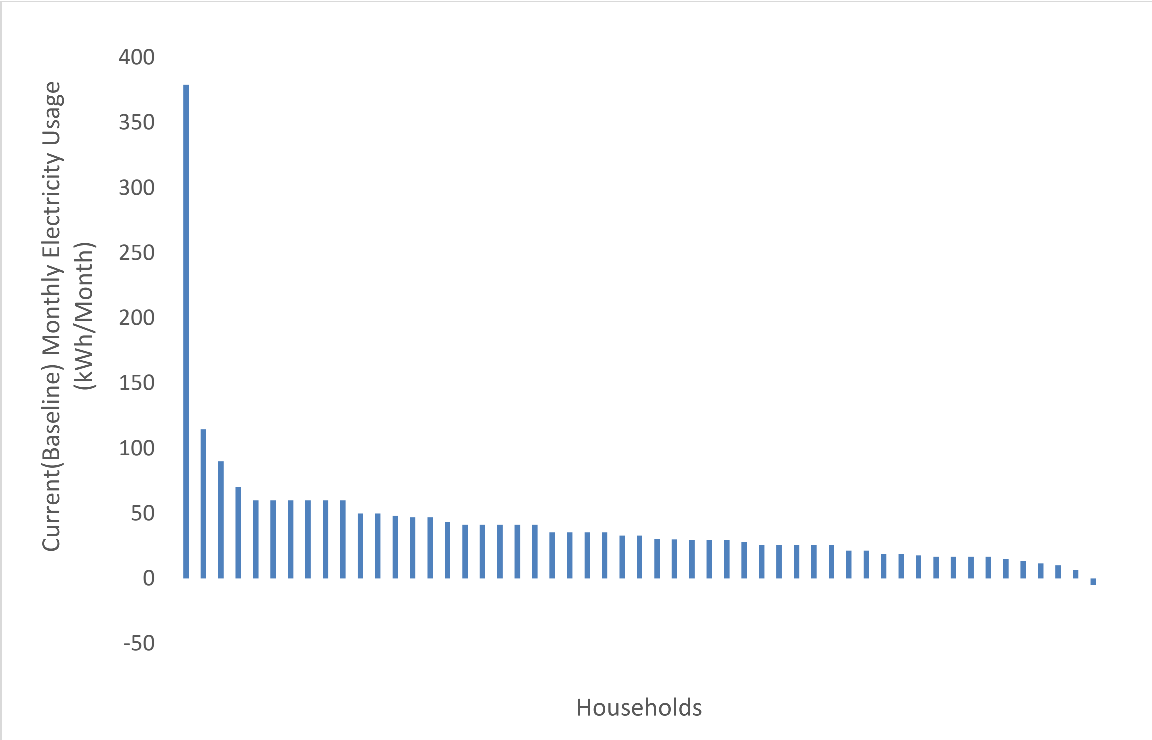

Figure 8. Monthly baseline electricity consumption for different households (first round of survey)

The baseline electricity consumption for the last household is negative. It indicates that the monthly electricity bill for the household, as reported by the household itself, is likely incorrect.

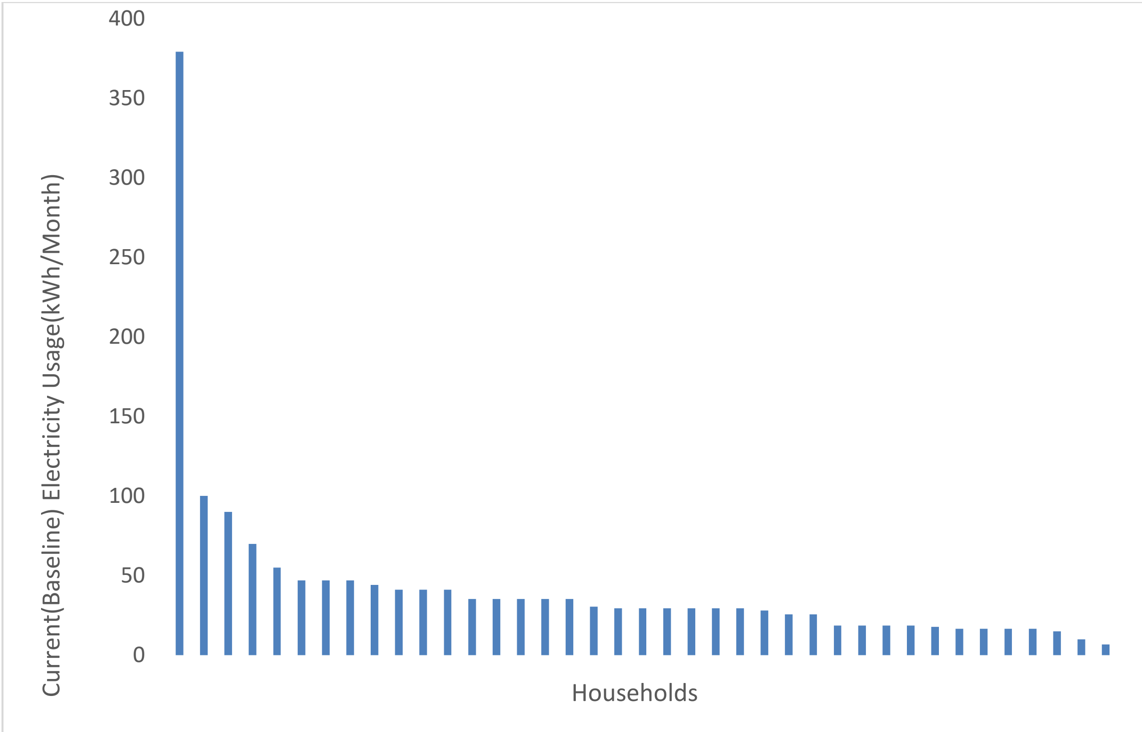

Figure 9. Monthly baseline electricity consumption for different households (second round of survey)

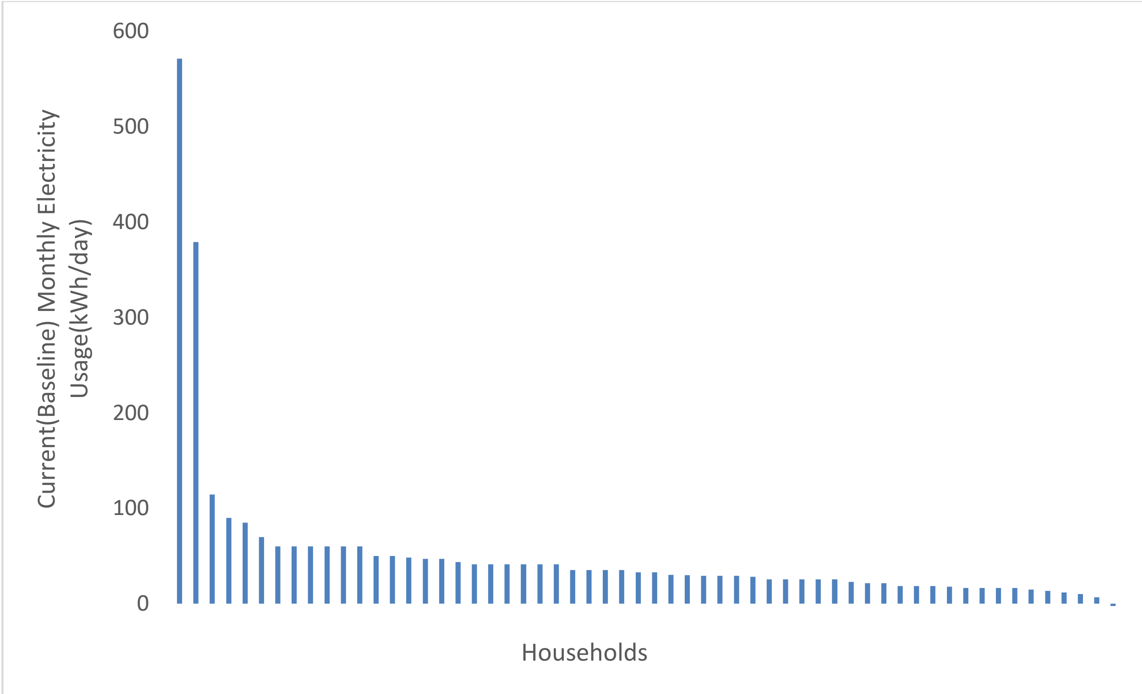

Figure 10. Monthly baseline electricity consumption for different households (third round of survey)

All the households had access to electricity. Hence, all the households consume some amount of electricity. The average electricity consumption is summarized in Table 9.

Table 9. Average monthly baseline electricity usage for different rounds of the survey

S. N	**Variable**	**Round 1**	**Round 2**	**Round 3**	**S.D**
1	Average Baseline Electricity Usage (kWh/month)	42.15	42.46	51.25	5.17

The average monthly baseline electricity consumption for the third round of the survey is higher in comparison to the other two rounds of the survey. The households have reported that they use fans during the summer to stay cool inside the room. This

might be one of the main reasons that the average monthly electricity use in the summer season was higher than the other two seasons. The standard deviation between the average values is found to be 5.2 kWh/month.

Figure 11 shows the increase in electrical consumption after the transition to induction stoves and the corresponding increase in different electricity charges. As mentioned above, the efficiency of induction stoves is considered 80%. The other efficiencies are analyzed as a part of the sensitivity analysis.

Figure 11. Increase in electricity price with an increase in electricity consumption after induction stoves adoption

This figure shows that the energy charge and the total electricity price would increase steeply as the baseline electricity consumption increases. This is because of the rate structure of the NEA. The detailed rate structure is given in Appendix B.

<u>First year cost/benefits</u>

The likely cost or benefit incurred by the households in the first year if they adopt induction stoves is represented by Figures 12, 13 & 14. The figures represent the results from the first, second, and third rounds of the survey, respectively. The y-axis will show the first-year benefits incurred by the households if they are to adopt induction stoves, whereas the x-axis shows the households. When the households start using the induction stoves, they would probably require a larger electric meter with higher amperage rating (e.g., most of the households are currently using 5A meter, but after adopting the induction stoves, they may require a 15A, 30 A or 60A meter). The analysis is performed assuming that the households would shift to 15A electric meter.

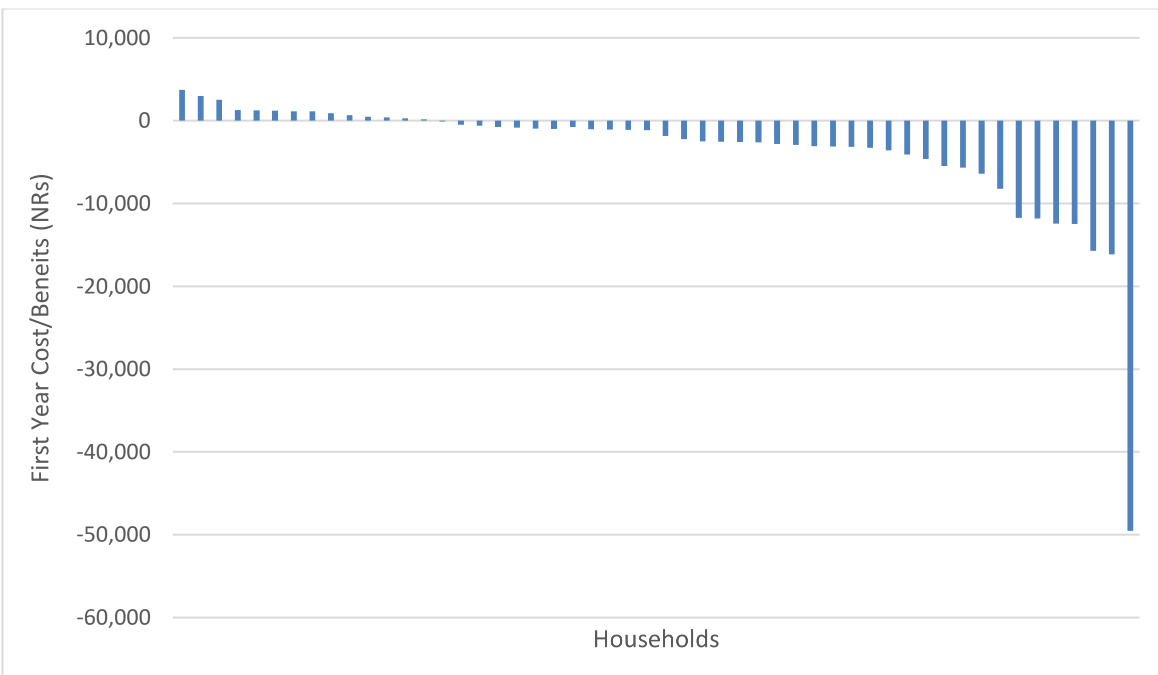

Figure 12. First-year costs and benefits incurred by the households (referring to the first round of the survey). Note that negative values indicate a net cost to the households.

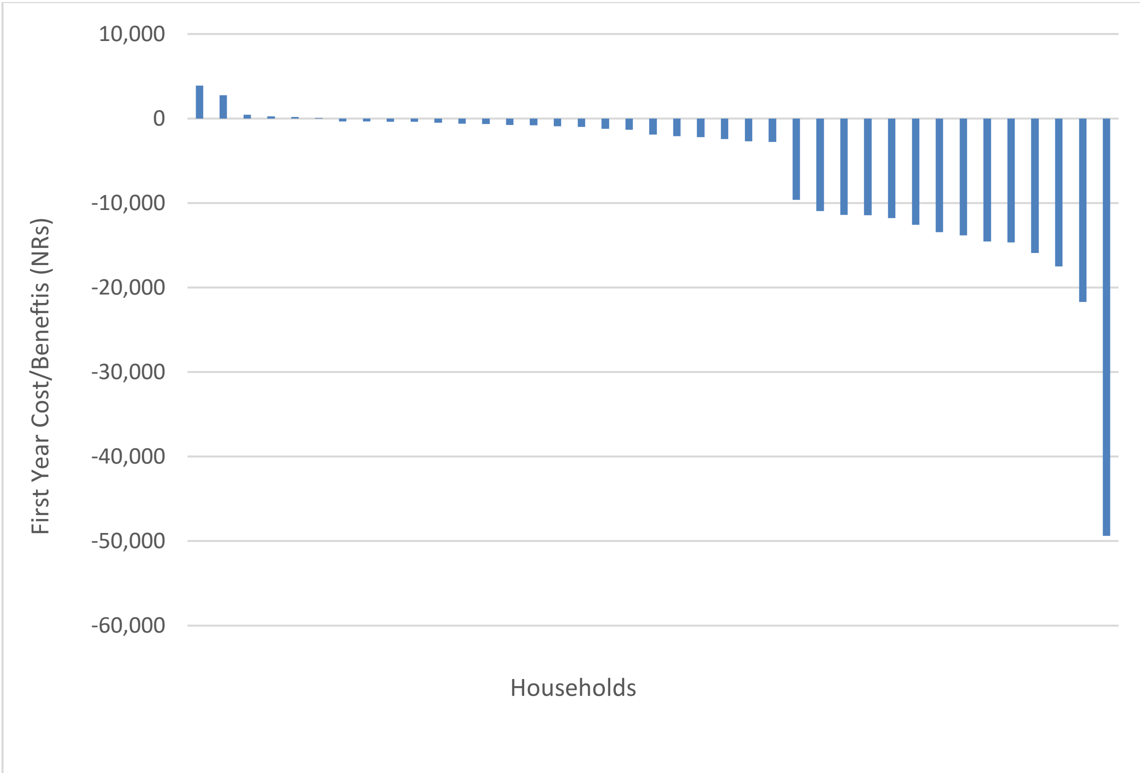

Figure 13. First year benefits incurred by the households (referring to the second round of the survey). Note that negative values indicate a net cost to the households.

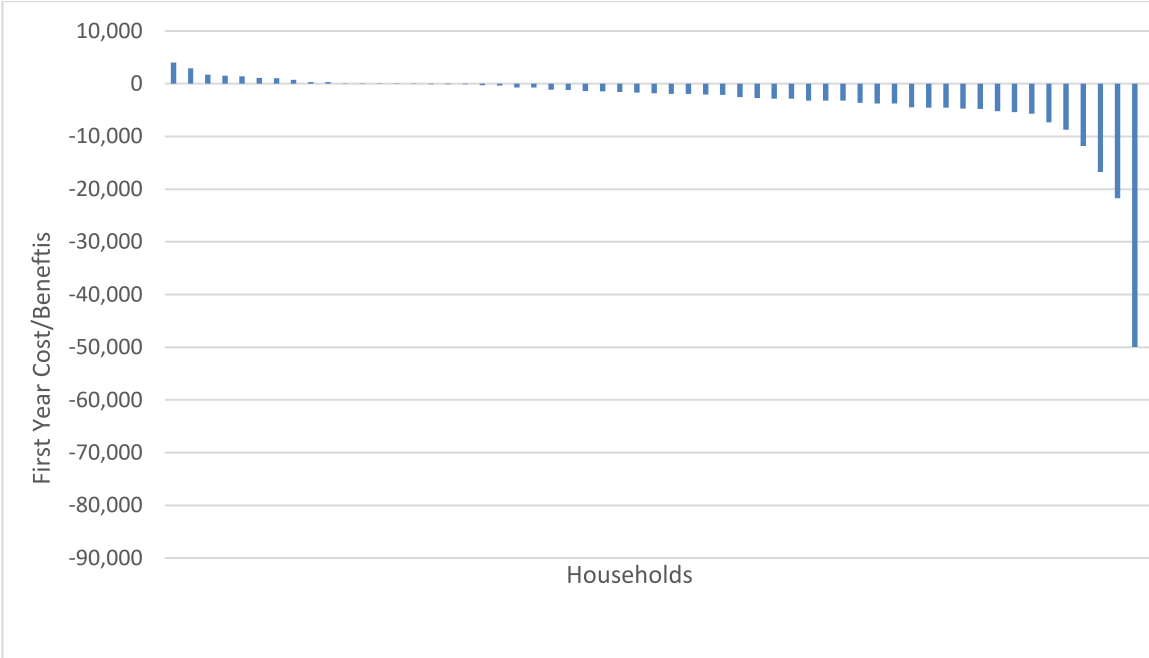

Figure 14. First-year benefits incurred by the households (referring to the third round of the survey). Note that negative values indicate a net cost to the households.

The figures above show that most of the households would have negative benefits if the induction stoves replace the LPG. It is because the cost of purchasing the additional electricity to operate the stove is more than the avoided costs of the LPG. The benefits/costs incurred by the households mainly depends on two factors: the monthly LPG consumption and baseline electricity usage (kWh/month). Figure 15 represents the relation between baseline electricity consumption, monthly LPG usage, and the subsidy requirements.

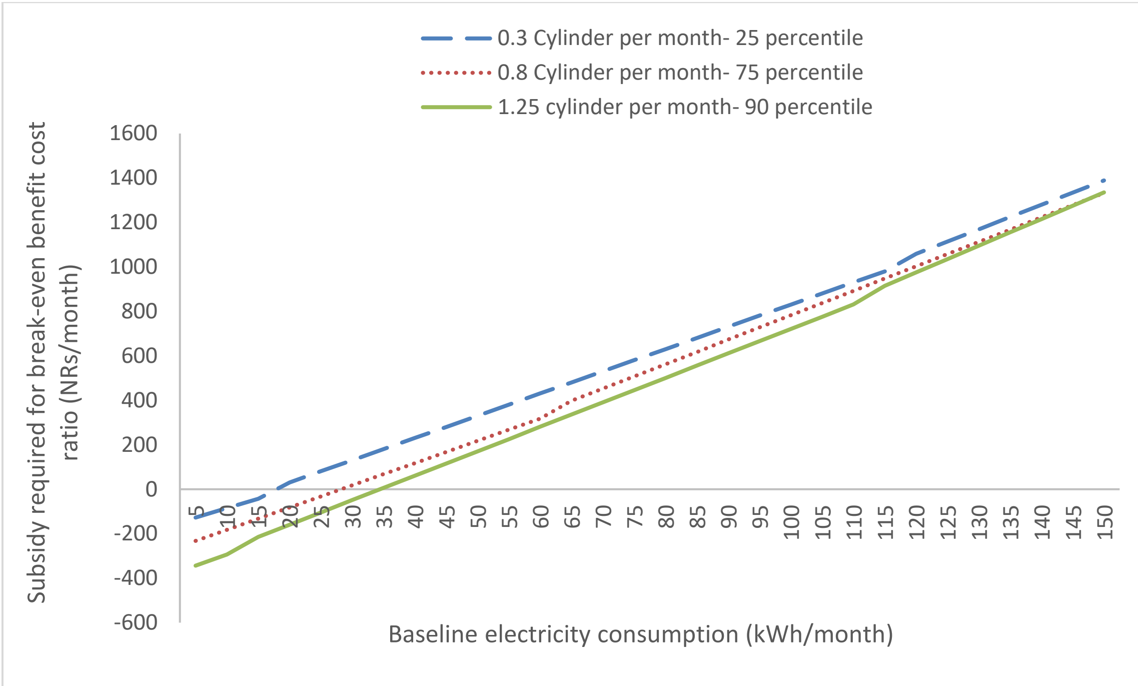

Figure 15. Relation between LPG consumption, baseline electricity consumption, and the monthly savings (negative y-axis values) or subsidy requirement (positive y-axis values) to achieve a break-even cost from LPG replacement.

There are different scenarios where households could have high baseline electricity usage but low LPG consumption, high LPG consumption and low baseline electricity usage, low LPG and baseline electricity consumption, and high LPG and baseline electricity consumption. The households having low baseline electricity consumption and comparatively higher LPG consumption would have higher benefits. This is because the avoided cost of LPG would be greater than the additional electricity cost. But, as the baseline electricity consumption increases, the LPG consumption would have less effect on the amount of costs/benefits incurred by the households.

A majority of households will incur the negative benefits (i.e., costs) because they have a higher baseline electricity consumption. Additional costs on electricity after

replacing LPG would ramp up the previous cost of electricity. Most of the households use electric rice cookers, which leads to high electricity consumption. Electric rice cookers are different from induction stoves. The households also perform small scale businesses like poultry farming and milling, which are the other factors for high electricity use.

NPV of Induction stoves to the households

An NPV analysis was performed for each household. The period for the NPV analysis is the lifetime of the induction stoves, which is assumed to be eight years for the base-case scenario. A graphical representation of the NPV calculated for different households referring to the first, second, and third round of the surveys is shown in Figures 16, 17 & 18, respectively. To summarize, there would be few households that would gain a net positive benefit at the end of this project (i.e., at the end of the induction stove's life cycle). Most of the households would still have a net negative benefit at the end of the project. This means that the households would be paying the money for the project rather than being benefitted.

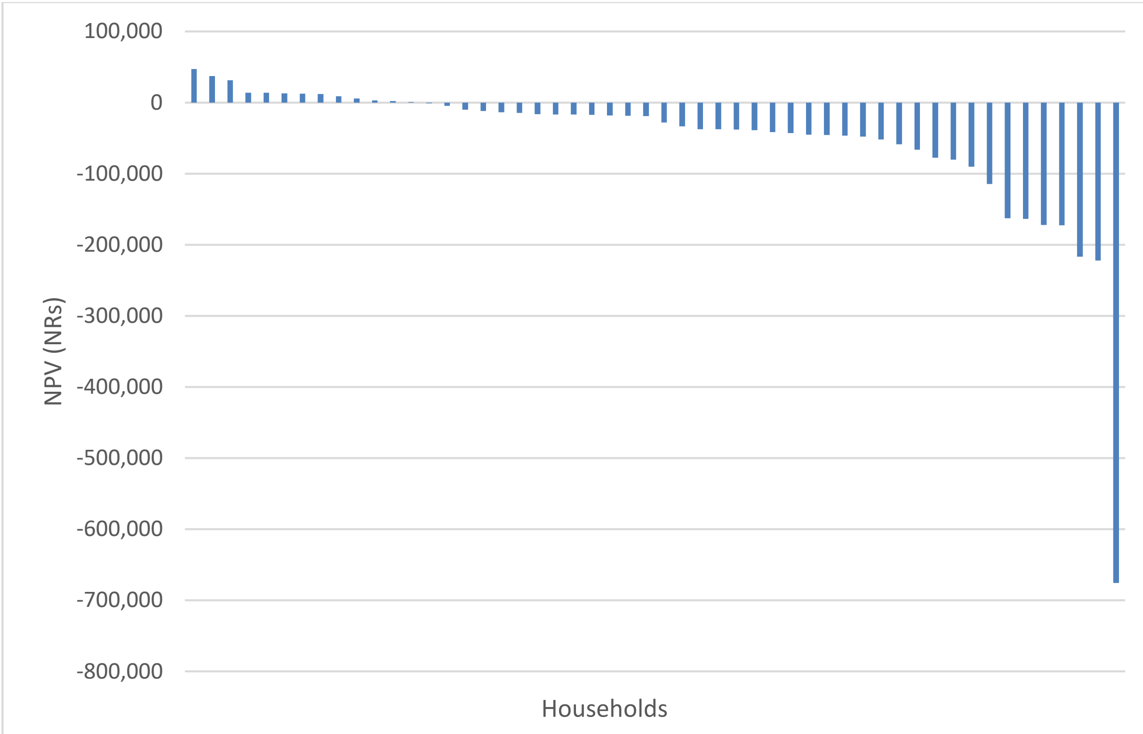

Figure 16. NPV incurred by the households over the life of the induction stove (referring to the first round of the survey). Note that negative values indicate a net cost to the households.

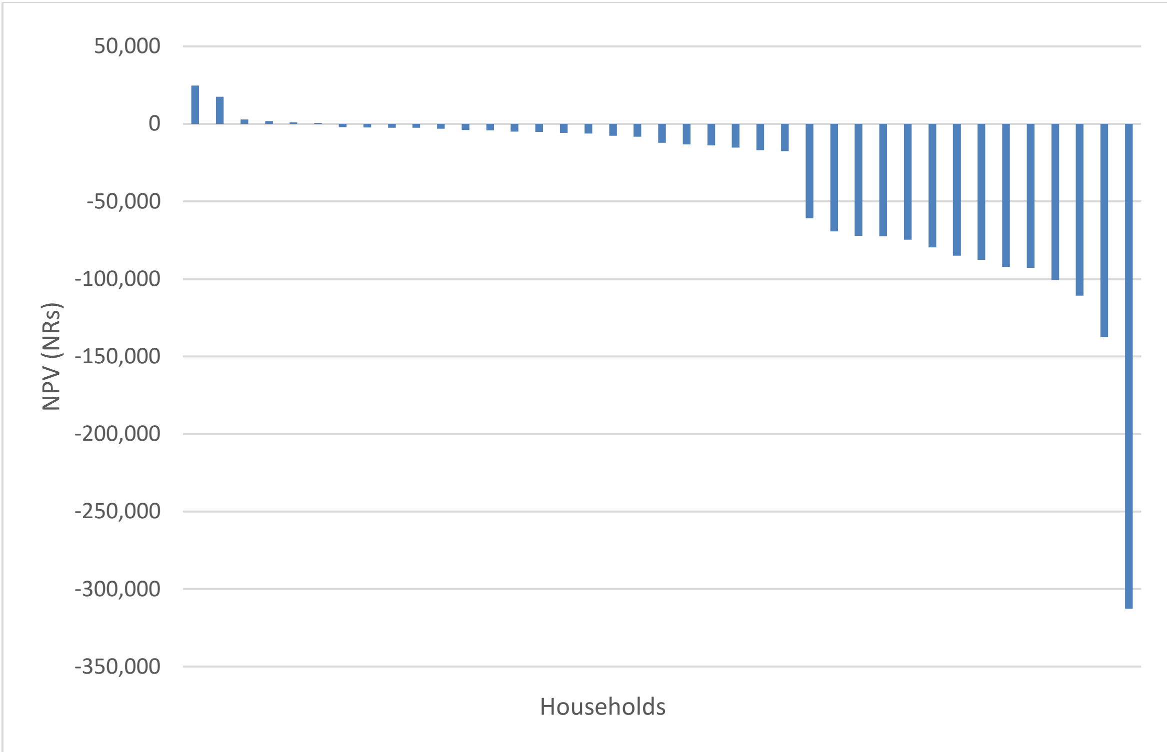

Figure 17. NPV incurred by the households over the life of the induction stove (referring to the second round of the survey). Note that negative values indicate a net cost to the households.

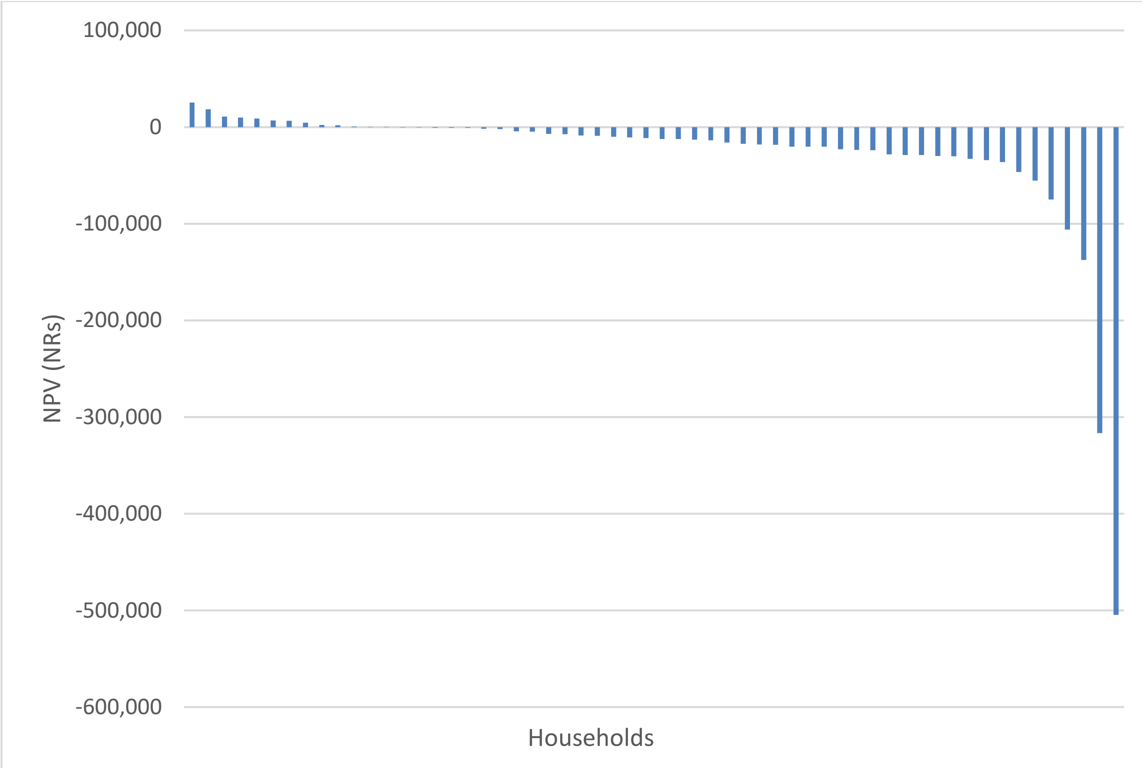

Figure 18. NPV incurred by the households over the life of the induction stove (referring to the third round of the survey). Note that negative values indicate a net cost to the households.

Almost 2/3rd of the households would incur negative benefits/costs at the end of the project. The households that incur costs during the first year of the project would continue to incur costs every year and vice versa. The households which incur costs during the first year would continue to incur the costs until the end of the project and vice versa. The main reasons for the cost or benefits incurred by the households are described in the above section.

SENSITIVITY ANALYSIS

A sensitivity analysis was performed by changing different variables in order to understand their effect on the NPV. The NPV analysis will tell us if the households will benefit or lose money at the end of the project (i.e., at the end of the lifetime of the induction stoves). The average values for LPG and electricity consumption were taken to perform this analysis. Variations in the following factors were considered to perform sensitivity analysis:

1. Variation in LPG use
2. The efficiency of the Induction Stoves
3. Discount Rate
4. Price of LPG
5. Impact of subsidy on electricity

Variation in LPG use

The sensitivity analysis with respect to variation use is described in the following section.

Percentage increase and decrease in LPG use

The variation in NPV concerning the LPG usage was analyzed. This sensitivity analysis was significant because households could have been using more or less LPG than the amounts estimated based on responses from the survey. A percentage increase of up to 25% at increments of 5% from the -40% was considered. The change in NPV

incurred by the households under a higher and lower LPG usage scenario is represented by Figure 19.

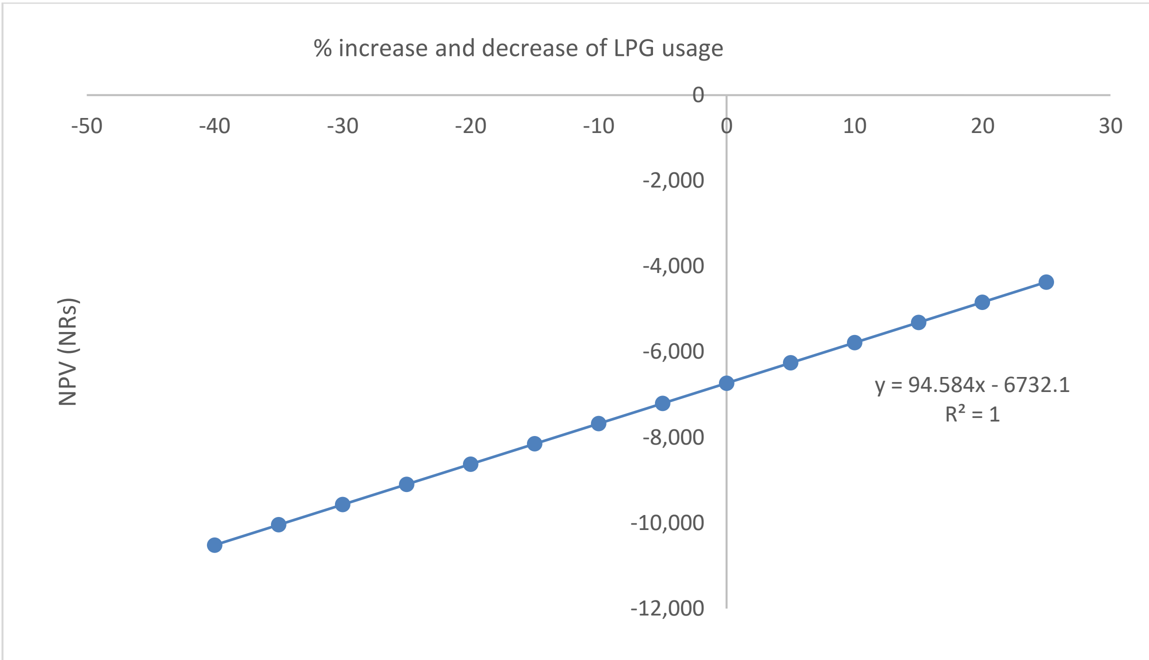

Figure 19. Scenario of NPV when LPG usage is higher than the average base usage

At a constant baseline electricity usage, if the households are currently using a higher amount of LPG than measured by the survey, replacing it by induction stoves would give more benefits. This is because the monetary benefits by avoiding the LPG usage is more than the additional electricity price the households would pay to replace the LPG usage.

Assuming a constant baseline electricity usage, if households use less LPG than was measured by the survey, replacing it with an induction stove would give fewer benefits compared to the base-case scenario. This is because the avoided cost of the LPG

is less than the cost of electricity the households would pay for after adopting the induction stove.

Efficiency of Induction Stoves

The efficiency of the induction stoves may vary according to the manufacturing company (brand), the power setting in which they are used and the vessel/pots being used on them. The efficiency of the induction stoves assumed for the base case scenario was 80%. The relation between different efficiencies of induction stoves and the NPV is represented by Figure 20.

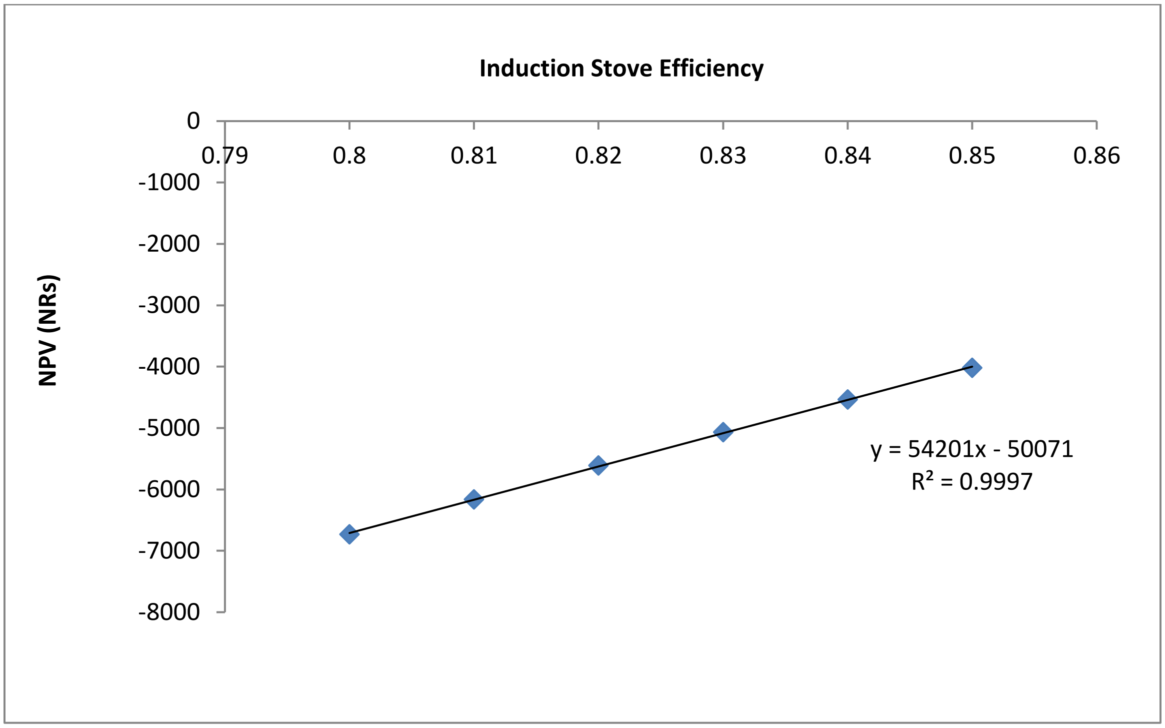

Figure 20. Scenario of NPV if the efficiency of the induction stove is more than the efficiency used in the base-case scenario (80%).

Discount Rate

The discount rate may vary in real market conditions. It may be different from the assumed standard value of the discount rate for the base case scenario, which is 10%. Thus, the impact of the different discount rates on NPV is presented in Figure 21.

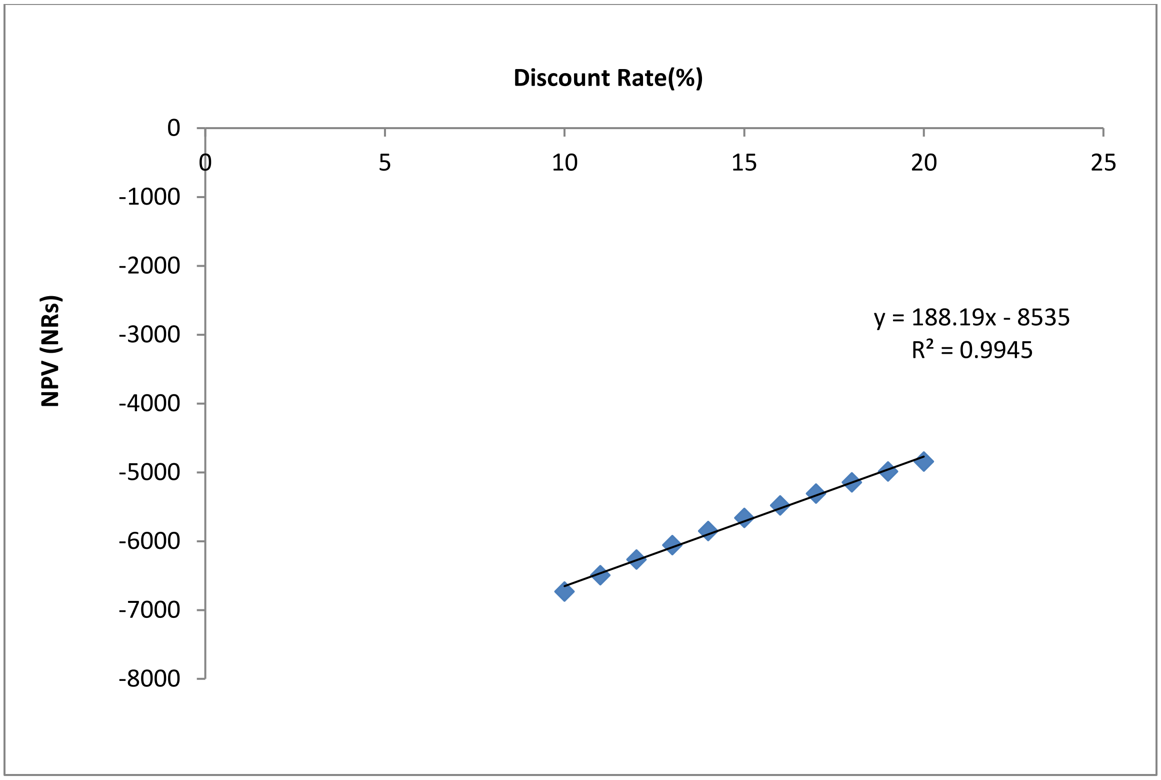

Figure 21. NPV incurred by the households if the discount rate is higher than the base case scenario

Price of LPG

The price of LPG is another variable that fluctuates in real market conditions. Figure 22 shows the relation between the percentage decrease in the LPG price and the NPV.

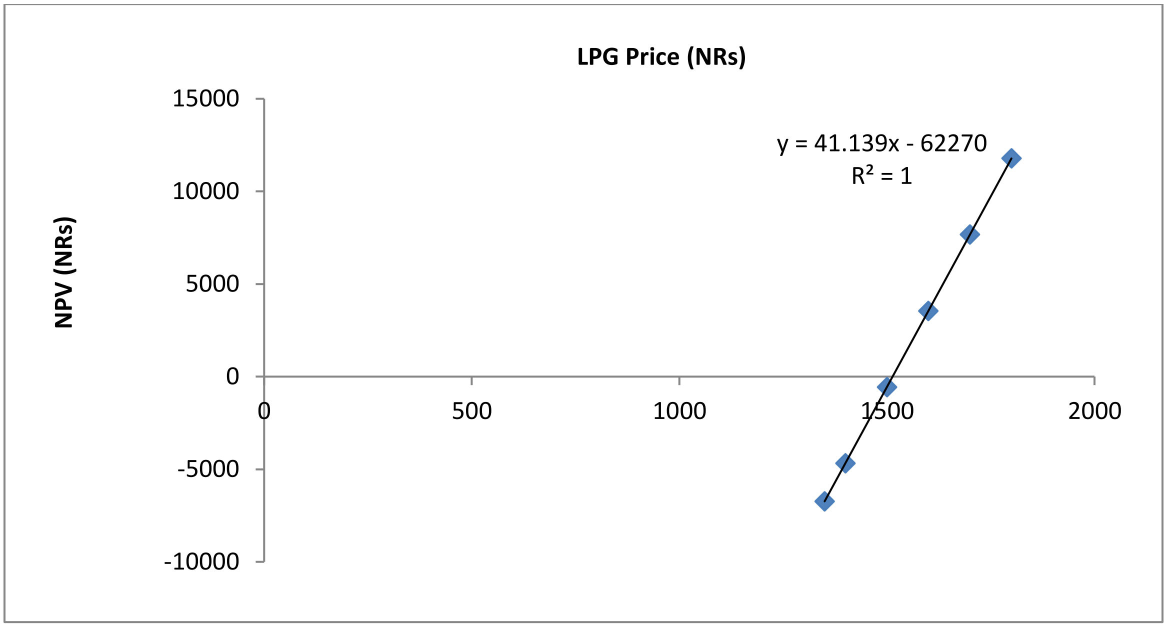

Figure 22. NPV incurred by the households if the price of LPG is lower than the base-case scenario.

This figure shows that if households pay more than the standard cost for LPG (i.e., NRs 1350 per cylinder), then the NPV increases because the savings would be more.

Subsidy on electricity

The base-case analysis shows that most households will incur a negative benefit (i.e., a net cost) over the life cycle of the project. This is due to multiple factors, including the cost of LPG and the cost of electricity. Figure 23 shows the different levels of subsidy on the total price of electricity and its impact on NPV.

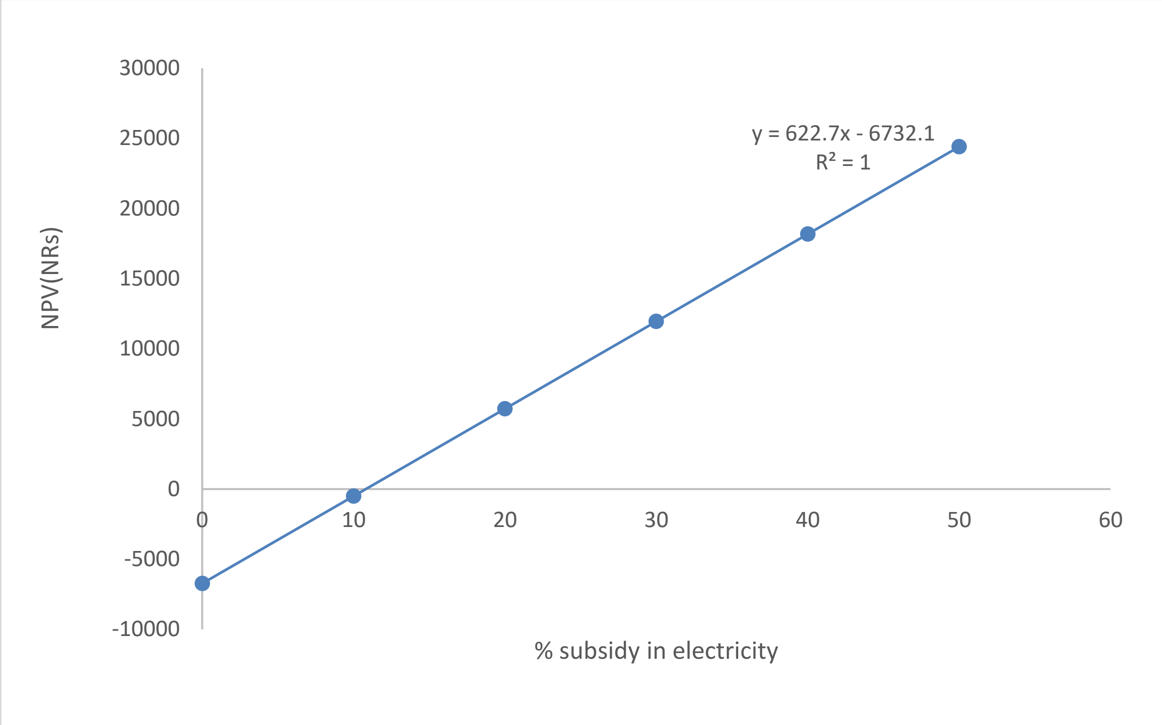

Figure 23. NPV incurred by the households according to different subsidy levels on the electricity rate

Providing approximately 12% or more subsidy on the cost of electricity would be sufficient for the households to experience an economic benefit over the lifetime of the project. This subsidy is for an average household and may not be true for all households. Depending on the daily LPG consumption and baseline electricity usage, some households may even require a subsidy of over 50% on the electricity rate to gain an economic benefit over the lifetime of the project.

CONCLUSIONS AND RECOMMENDATIONS

Fuel switching from conventional pollutant-emitting fuels to cleaner sources of energy can be beneficial from health, economic, and environmental perspectives. Studies have shown that social, economic, and educational factors can play an important role in the fuel-switching process.

This study performed a cost-benefit analysis for fuel switching from LPG to electric induction stoves. The results conclude that in the absence of a subsidy in electricity, the fuel switching process will not be economically beneficial to households like those included in the survey. As the results show, induction stoves could be economically beneficial to a large fraction of households only if a subsidy is provided. With the current electricity rate, the benefits gained by most households over the lifetime of the project will be less than the total costs incurred. The amount of subsidy would depend on the baseline electricity consumption and the baseline LPG consumption.

The LPG would have less role as compared to the baseline electricity consumption in deciding the subsidy requirements for each household. Higher the baseline electricity consumption higher will be the subsidy requirements. When the baseline electricity consumption is low, the LPG consumption would also play a major role in deciding the subsidy amount. Higher the LPG consumption, lower will the subsidy requirements at a low baseline electricity consumption. This is because the avoided cost of higher LPG consumption would be more than the additional cost of electricity. When the baseline electricity consumption increases, the LPG consumption would be a

negligible factor in deciding the subsidy amount.

This study recommends performing a more detailed survey on LPG consumption in different rural household clusters at various locations to gather additional information about variations in the use of this fuel. The KPT survey measured LPG consumption for three different days for each round. This study recommends taking LPG measurements at least for a month for each different season. Such a survey would give more reliable data on LPG consumption patterns.

Also, after the adoption of induction stoves, households might perform additional cooking and non-cooking tasks using the induction stoves. These tasks could lead to higher energy use than the amounts currently calculated. This would lead to higher electricity costs after adoption. This study recommends collecting data on extra/additional cooking and non-cooking events that households could perform using induction stoves.

Also, for similar surveys conducted in the future, this study recommends collecting detailed data on different brands of LPG stoves used by households, the market price of LPG, and the discount rates in the market. This will give a more real sense of the total avoided cost of LPG.

It is also recommended to conduct a study on the possibility of different types of energy meter usage after adopting the induction stoves. Energy meters record the electricity usage of the households. Most households in the survey use energy meters whose capacity is 5A. But after the intervention, they would need to shift to the energy

meters whose capacity is either 15A, 30 A, or 60 A. Induction stoves draws higher power from the grid. So, a larger energy meter, compatible with the induction stove is needed.

Also, if a large community is to shift from LPG stoves to induction stoves, then there could be an unexpected peak demand for electricity during the peak cooking hours because of the use of induction stoves. So a regular mapping of distribution systems based on their capacity is important (Vaidya, 2020). The promotion of electric cooking in rural areas where electricity consumption is low and load centers are underloaded would be a good starting point for replacing traditional pollution-emitting fuels with cleaner fuel sources (Vaidya, 2020).

It is recommended that awareness and educational programs are provided to households regarding the advantages and long-term benefits of induction stoves. Also, training and education on safety are very important. The uses of a substandard electrical appliance may be seriously risky and may cause fire or electric shock (Vaidya, 2020). Households should be guided toward using electrical appliances that meet safety and quality standards, as suggested by the Nepal Bureau of Standards and Metrology (Vaidya, 2020).

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APPENDIX A- Questionnaire used in the survey

Appendix A: Questionnaire used in the survey

Maximizing Health Benefits in Urban Nepal (v.181210) HH ID ____________

Energy Mapping Survey

A. Participant Identification				
A1	Date [dd-mm-yy]			
A2	Time of visit [hh:mm] 24-hr time			
A3	Household ID			
A4	Surveyor Name/ ID			
[Note: Please ask to speak to the current main cook]				
A5	Name of current main cook			
A6	Age of current main cook			
A7	Sex of current main cook	Please Select one		
A8	Name of household head			
A9	Sex of household head	Please Select one		
A10	District	Kavrepalanchok	Please select the o	
A11	VDC/Municipality	[Use codes from sheet]	Please select one i	
A12	Ward number			
A13	Village/cluster name	[Use codes from sheet]	Please select one c	
A15	Please note any significant features near to household such as a temple, tree or road that will help locate the home in subsequent visits.			
A16	Telephone number			

Photo Checklist (please take photos of the following with house ID)

	Description	Photo Taken?
	All stoves with sign showing stove code and house ID	
	Wood pile(s) and storage with household ID	
	Electricity bill of past two months (if available)	
	Picture of outside of house with house ID	

Please note: In order to maintain confidentiality of each participant, information from this cover sheet will be entered and stored separately from the data in the completed questionnaire

All notes and guides for field team on the form are in written *in italics* and placed in [square brackets] please ensure you read all of these carefully.

Visit 1

B. Energy Services			
Meals for the Family			
B1	What devices do you use to prepare **meals** in your home in **the current season**? *[MA, Enter stove codes]*		Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas
B2	Are there devices that you use during other **times of the year for meals**? *[MA, Enter stove codes, if "No" enter 99]*		Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas 99 Pleas Pleas Pleas Pleas Pleas Pleas
Animal Food Cooking			
B3	Do you use your stoves to prepare animal food at any time of the year?		Yes No (skip to B.11) Please select one
B4	How long do you typically spend cooking animal food each day during **this time of year**?		[Hours per day]
B5	Do you do all the animal cooking at one time, or is it done more than once per day? *SA*		Multiple times per day Once per day I don't know Please select one option
B6	When do you typically prepare animal food during this time of year? *MA*		Mornings (5:00-10:00) Late Mornings (10:01-12:00) Early Afternoon (12:01-15:00) Late Afternoon (15:01-18:00) Evening (19:01 or later)
B7	Does the amount of time you spend cooking animal food change during different seasons? *SA*		Yes *Describe why it changes:* No I don't know Please select one option
B8	Where do you prepare animal food during this time of year? *SA*		Always outside Always in the kitchen Inside and outside, it depends *[Describe why both here]:* Please select one option

B9	Does the place where you typically prepare animal food change during different seasons? if YES how does it change and why?	Please select an option	No, it is always the same Yes, where I typically cook animal food changes depending on the season. *[record when and why]*:
B10	What stoves do you use to cook the animal food *[MA, Use stove codes]*	Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas	
B11	How big is the pot used to cook animal food *(surveyor – please record dimensions)*	________diameter (cm)	________depth (cm)
B12	How many of the following animals does this household **currently** own and **cook food for**? *[Read down the list and enter the number cooked for. If the household does not own any of the type of animal enter 0]*	Cows:	
		Buffalo:	
		Oxen:	
		Goats:	
		Pigs:	
		Other (___________):	
Space Heating			
B13	When the weather gets colder, what do you do to stay warm? *(choose all that apply)* *If Yes to "heat rooms by burning fuel"*	Wear more clothing	[ ]
		Heat rooms by burning fuel	[ ] *[go to B12.1]*
		Heat rooms with an electric heater	[ ]
		Nothing	[ ]
		Something else [describe]:	[ ]
	B12.1 *(conditional)* What devices do you use to burn fuel to heat the rooms *[Use stove codes]*	Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas	
	B12.2 *(conditional)* Are you heating rooms of your house during this season?	[ ] Yes [ ] No	Please select one option
Space Cooling			
B14	When the weather gets hot, what do you do to stay cool? *[Open response]*		
Water Heating			
B15	Do you ever use your stoves to heat large pots of water for non-meal needs, like bathing?	[ ]	Yes Please select one option *Describe:*
		[ ]	No
Lighting			
B16	What is the main lighting source currently? *[SA, use lighting codes]*	Main	Please s Please s Please s Please s Please s Please s Please s Please s

B17	What is your second most used lighting source currently? *[SA, use lighting codes]*	Others	Please s Please s Please s Please s Please s Please s Please s Please s
	Income Generation		
B18	Do you use electricity, stoves, or fuel for any income generating activities? *[Open Response]*		
B19	Has the change in electricity reliability affected this in any way? *[Open Response]*		

C. Energy Sources

C1	What stove do you use most **at this time of year**? *[MA, use stove codes]*	Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas		
C2	Do you use any other stoves at least once per week? *[Use stove codes- if no secondary stove enter 77]*	Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas Pleas		
C3	**During the current season**, what fuels do you use in your stoves? *[choose all that apply – Left Side]* Do you use other fuels during the year? *[choose all that apply – Right Side]*	**Fuel Type**	Current Season	Other Season
		Wood	☐	☐
		Crop/Agricultural residues	☐	☐
		Biogas	☐	☐
		LPG	☐	☐
		Kerosene	☐	☐
		Charcoal (Homemade)	☐	☐
		Charcoal (From Market)	☐	☐
		Dried Dung Cake	☐	☐
		Electricity	☐	☐
		Other:______________	☐	☐

Biogas

☐ Does Not Use Biogas Ever (Skip Section)

C4	How long do you use your biogas stove for each day in the **current season?**	minutes
C5	How many meals do you cook on your biogas stove each day?	
C6	What types of tasks, meals and non-meals, do you use biogas for? *[Use Event Codes]*	Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se
C7	Do you typically use your biogas until it runs out of gas each day?	Please seledct one option
C8	How long do you use your biogas stove in a day during the **season when it makes the least gas**?	minutes
C9	How long do you use your biogas stove in a day during the **season when it makes the most gas**?	minutes

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C10	What do you put in your biogas digester in this season? *[MA]* How frequently do you feed this into the digester per week ? *[If fed each day, enter 7, if they don't know enter 99]*	Cow, buffalo, oxen dung		days
		Ag. residues		days
		Urea		days
		Yeast		days
		Urine		days
		Human waste		
		Other:_________		days
C11	Do you do anything to increase the production of the biogas digester at any time of the year, if so what? *[open response]*			
C12	If your biogas production is low or cannot perform as needed, what stove would you use instead? *[open response]*			

Charcoal
[ ] Does Not Use Charcoal Ever (Skip Section)

C13	How often do you use your charcoal stove?	Daily	
		5-6 times per week	
		3-4 times per week	
		1-2 times per week	
		Less than once per week	
		Don't use charcoal	[ ] *[go to C15]*
C14	What types of tasks, meals and non-meals, do you use charcoal for? *[Use Event Codes]*	Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se	

LPG
[ ] Does Not Use LPG Currently Ever (Skip Section)

C15	How often do you typically re-fill your LPG cylinder? *[if don't use, enter 99]*	_________ Times per	Please select one option
C16	What do you use LPG for, including non-meal tasks? *[Use Event Codes]*	Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se	

Wood
[ ] Does Not Use Wood Ever (Skip Section)

C17	How do you get the wood used in your house? *MA*	[ ]	I collect it from my property
		[ ]	I collect it outside my property, but have no limit on how much I can collect.
		[ ]	I collect it from a community forest or other area that limits how much I can collect. *[Go to 17.1]*
		[ ]	I purchase it
		[ ]	Other:______________
	C17.1. *[conditional]* How long does the amount of wood you collect on a single trip to the forest last?	Please select one option	[ ] day [ ] week [ ] month [ ] year
	C17.2. *[conditional]* How many times per year are you allowed to collect from the forest, when are you allowed to collect?		Times per Year

	[Open response]		When do you collect?
	C17.3. *[conditional]* Do you ever have to adjust your use of wood, so that you do not run out? If so, what other fuels or stoves do you use instead? *[open response]*		
C18	What types of tasks, meals and non-meals, do you use wood for? *[Use Event Codes]*	Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se Please Se	

Agricultural Residues

[ ] Does Not Use Ag Residue Ever (Skip Section)

C19	What types of agricultural residues do have in your fields at this time of year? *[Note this is all agricultural residues not just those used on the stoves. MA]*	Corn Cob	☐
		Rice Husk	☐
		Corn Stalk	☐
		Mustard/pulses/stalk or cereal straw	☐
		No agricultural residues at this time of year.	☐
		Other [please describe]: ___________	☐

C20

Do you grow or use any of these agricultural residues ***at any time of the year***? *[MA]*

If YES, what do you use it for? *[MA]*

	Grow this residue?	Animal food [uncooked]	Animal bedding	Stove fuel	Construction Material	______	______
Corn Cob	☐	☐	☐	☐	☐	☐	☐
Corn Stalk	☐	☐	☐	☐	☐	☐	☐
Rice Husk	☐	☐	☐	☐	☐	☐	☐
Mustard/pulses/stalk or cereal straw	☐	☐	☐	☐	☐	☐	☐
Other: ___________	☐	☐	☐	☐	☐	☐	☐
Other: ___________	☐	☐	☐	☐	☐	☐	☐

Electricity

C21	Does this house have electricity?	☐ Yes ☐ No *[Go to Section F]*		***If Yes*** *– make sure to take a photo of their bill for last two months*
C22	If you purchase ANY electricity, how much do you typically pay **during this time of year?** *[If they don't use central grid power this season*	Expenditure [Rupees]	Per *[Enter duration the expenditure is for. For example, if it is for 3 months enter a 3 in the box on left and circle month]*	Please select one

	please enter a 999 in the 'expenditure' box]			Days	Weeks	Months	Year
C23	At this time of year how often do you lose access to electricity? On each of those occasions approximately how many hours is the electricity not available?	*[For example if the household loses electricity 4 times per week and on each occasion this lasts for approx. 3 hours. Enter a 4 under 'times' circle week and then enter a 3 under 'hrs ']*					
		Times		Circle one duration below		Hours on each occasion	
				I dont know			

Please read down the list of ***electrical appliances*** *and ask how many of the following the household owns/owned. If they own/owned it, ask them how much they use it currently*

Electric Appliance	How many of the following do they **currently** own?	How often do you **currently** use it?		Has your use of this increased, decreased, or stayed the same since load shedding has reduced?	How many of the following did you own **before the earthquake**?
	Quantity, 99 = Do not own	Hours per... (If running all day, enter 24 here and "days" for units; if don't know = 99)	1 = Day, 2 = week, 3 = month	1= More, 2=Less, 3 = no change, 4 = did not own	Quantity, 99 = Did not own
Electric Stove or Induction Stove			Please sel	Please sel	
Rice Cooker			Please sel	Please sel	
Fan			Please sel	Please sel	
Heater			Please sel	Please sel	
Electric Blanket			Please sel	Please sel	
Refrigerator			Please sel	Please sel	
Air Conditioner			Please sel	Please sel	
Television			Please sel	Please sel	
Water Pump (run off grid electricity)			Please sel	Please sel	
Water Pump (run off of fuel or generator)			Please sel	Please sel	
Electric kettle			Please sel	Please sel	
Iron			Please sel	Please sel	
Other:_________			Please sel	Please sel	
Other:_________			Please sel	Please sel	

D. Fuel measurements: Visit #1				
D0.1	ID # scale:		D0.2	ID # moisture meter:
D1. FIRST stove *[Please ask the main cook which fuels he/she uses on this stove. Ask him/her to show you how much they use of each fuel in one day. Add up to 3 times more of that fuel to the pile to make an inventory for this stove. If a particular fuel type is not used please enter a 0.]*				
1.1	Stove type [use codes from sheet]	Please select one option		
1.2	New wood total [kg]		1.7	New Corn Stalk total [kg]
1.3	New LPG total [kg]		1.8	New Rice Husk total [kg]
1.4	New charcoal total [kg]		1.9	New Straws total [kg]
1.5	New corn cob total [kg]		1.10	New Electricity Monitor (kWh)(ID:_____):
1.6	New _________ total [kg]:		1.11	New _________ total [kg]:
Wood Moisture Readings: Stove #1 *[Take three samples of fuel used on this stove]*				
1.12	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
1.12	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
1.12	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #1 *[Take three samples of fuel used (other than the above) on this stove]*				
Type: _______________				
1.13	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
1.13	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
1.13	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #1 *[Take three samples of fuel used on this stove]*				
Type: _______________				
1.14	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
1.14	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
1.14	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
1.15	Notes/observations.			

D2. SECOND stove *[Please ask the main cook which fuels he/she uses on this stove. Ask him/her to show you how much they use of each fuel in one day. Add up to 3 times more of that fuel to the pile to make an inventory for this stove. If a particular fuel type is not used please enter a 0.]*				
2.1	Stove type [use codes from sheet]	Please select one option		
2.2	New wood total [kg]		2.7	New Corn Stalk total [kg]
2.3	New LPG total [kg]		2.8	New Rice Husk total [kg]
2.4	New charcoal total [kg]		2.9	New Straws total [kg]
2.5	New corn cob total [kg]		2.10	New Electricity Monitor (kWh)(ID:_____):
2.6	New _________ total [kg]:		2.11	New _________ total [kg]:
Wood Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				
2.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
2.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
2.12c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				

Type: ______________				
2.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
2.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
2.13c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				
Type: ______________				
2.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
2.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
2.14c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
2.15	Notes/observations.			

D3. Third stove

[Please ask the main cook which fuels he/she uses on this stove. Ask him/her to show you how much they use of each fuel in one day. Add up to 3 times more of that fuel to the pile to make an inventory for this stove. If a particular fuel type is not used please enter a 0.]

3.1	Stove type [use codes from sheet]	Please select one option	
3.2	New wood total [kg]	3.7	New Corn Stalk total [kg]
3.3	New LPG total [kg]	3.8	New Rice Husk total [kg]
3.4	New charcoal total [kg]	3.9	New Straws total [kg]
3.5	New corn cob total [kg]	3.10	New Electricity Monitor (kWh)(ID:_____):
3.6	New ________ total [kg]:	3.11	New ________ total [kg]:

Wood Moisture Readings: Stove #3 *[Take three samples of fuel used on this stove]*				
3.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
3.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
3.12c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #3 *[Take three samples of fuel used on this stove]*				
Type: ______________				
3.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
3.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
3.13c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #3 *[Take three samples of fuel used on this stove]*				
Type: ______________				
3.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
3.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
3.14c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
3.15	Notes/observations.			

D4. FOURTH stove

[Please ask the main cook which fuels he/she uses on this stove. Ask him/her to show you how much they use of each fuel in one day. Add up to 3 times more of that fuel to the pile to make an inventory for this stove. If a particular fuel type is not used please enter a 0.]

4.1	Stove type [use codes from sheet]	Please select one value

4.2	New wood total [kg]	4.7	New Corn Stalk total [kg]
4.3	New LPG total [kg]	4.8	New Rice Husk total [kg]
4.4	New charcoal total [kg]	4.9	New Straws total [kg]
4.5	New corn cob total [kg]	4.10	New Electricity Monitor (kWh)(ID:_____):
4.6	New ________ total [kg]:	4.11	New ________ total [kg]:

Wood Moisture Readings: Stove #4 ***[Take three samples of fuel used on this stove]***				
4.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
4.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
4.12c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #4 ***[Take three samples of fuel used on this stove]***				
Type: _______________				
4.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
4.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
4.13c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #4 ***[Take three samples of fuel used on this stove]***				
Type: ______________				
4.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
4.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
4.14c	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
4.15	Notes/observations.			

END OF VISIT #1

Visit #2

E. VISIT #2		
E1	Date [dd-mm-yy]	
E2	Time of visit [hh:mm] 24-hr time	
E3	Household ID	
E4	Surveyor Name/ ID	

F. Fuel weights: Visit #2				
F0.1	ID # scales		F0.2	ID # moisture meter
F1. FIRST stove				
F1.1	Stove type [use codes from sheet]	Please select one option		
F1.2	Unused wood total [kg]		F1.7	Unused Corn Stalk total [kg]
F1.3	Unused LPG total [kg]		F1.8	Unused Rice Husk total [kg]
F1.4	Unused charcoal total [kg]		F1.9	Unused Straws total [kg]
F1.5	Unused corn cob total [kg]		F1.10	Electricity Monitor (kWh)(ID:_____):
F1.6	Unused ________ total [kg]:		F1.11	Unused ________ total [kg]:
F1.2b	New wood total [kg]		F1.7b	New Corn Stalk total [kg]
F1.3b	New LPG total [kg]		F1.8b	New Rice Husk total [kg]
F1.4b	New charcoal total [kg]		F1.9b	New Straws total [kg]
F1.5b	New corn cob total [kg]		F1.10b	New Electricity Monitor (kWh)(ID:_____):
F1.6b	New ________ total [kg]:		F1.11b	New ________ total [kg]:

Wood Moisture Readings: Stove #1 *[Take three samples of fuel used on this stove]*				
F1.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F1.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F1.12b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #1 *[Take three samples of fuel used on this stove]*				
Type: ______________				
F1.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F1.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F1.13b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #1 *[Take three samples of fuel used on this stove]*				
Type: ______________				
F1.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F1.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F1.14b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3

Cooking Events: FIRST Stove: Visit #2

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	F1.15.1	F1.15.2	F1.15.3	F1.15.4	F1.15.5	F1.15.6	F1.15.7
Event *[use codes]*							
Duration [hrs]							

F1.16	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

F2. SECOND stove			
F2.1	Stove type [use codes from sheet]		
F2.2	Unused wood total [kg]	F2.7	Unused Corn Stalk total [kg]
F2.3	Unused LPG total [kg]	F2.8	Unused Rice Husk total [kg]
F2.4	Unused charcoal total [kg]	F2.9	Unused Straws total [kg]
F2.5	Unused corn cob total [kg]	F2.10	Electricity Monitor (kWh)(ID:_____):
F2.6	Unused ________ total [kg]:	F2.11	Unused ________ total [kg]:
F2.2b	New wood total [kg]	F2.7b	New Corn Stalk total [kg]
F2.3b	New LPG total [kg]	F2.8b	New Rice Husk total [kg]
F2.4b	New charcoal total [kg]	F2.9b	New Straws total [kg]
F2.5b	New corn cob total [kg]	F2.10b	New Electricity Monitor (kWh)(ID:_____):
F2.6b	New ________ total [kg]:	F2.11b	New ________ total [kg]:

Wood Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				
F2.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F2.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F2.12b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				
Type: ______________				
F2.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F2.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F2.13b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #2 *[Take three samples of fuel used on this stove]*				
Type: ______________				
F2.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F2.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F2.14b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3

Cooking Events: Stove #2

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	F2.15.1	F2.15.2	F2.15.3	F2.15.4	F2.15.5	F2.15.6	F2.15.7

Event *[use codes]*							
Duration [hrs]							

F2.16	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

F3. THIRD stove			
F3.1	Stove type [use codes from sheet] Please select one option		
F3.2	Unused wood total [kg]	F3.7	Unused Corn Stalk total [kg]
F3.3	Unused LPG total [kg]	F3.8	Unused Rice Husk total [kg]
F3.4	Unused charcoal total [kg]	F3.9	Unused Straws total [kg]
F3.5	Unused corn cob total [kg]	F3.10	New Electricity Monitor (kWh)(ID:_____):
F3.6	Unused _________ total [kg]:	F3.11	Unused _________ total [kg]:
F3.2b	New wood total [kg]	F3.7b	New Corn Stalk total [kg]
F3.3b	New LPG total [kg]	F3.8b	New Rice Husk total [kg]
F3.4b	New charcoal total [kg]	F3.9b	New Straws total [kg]
F3.5b	New corn cob total [kg]	F3.10b	Electricity Monitor (kWh)(ID:_____):
F3.6b	New _________ total [kg]:	F3.11b	New _________ total [kg]:

Wood Moisture Readings: Stove #3 ***[Take three samples of fuel used on this stove]***				
F3.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F3.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F3.12b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #3 ***[Take three samples of fuel used on this stove]***				
Type: _______________				
F3.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F3.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F3.13b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #3 ***[Take three samples of fuel used on this stove]***				
Type: _______________				
F3.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F3.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F3.14b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3

Cooking Events: Stove #3

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	F3.15.1	F3.15.2	F3.15.3	F3.15.4	F3.15.5	F3.15.6	F3.15.7
Event *[use codes]*							
Duration [hrs]							

F3.16	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

F4. FOURTH stove			
F4.1	Stove type [use codes from sheet] Please select one option		
F4.2	Unused wood total [kg]	F4.7	Unused Corn Stalk total [kg]
F4.3	Unused LPG total [kg]	F4.8	Unused Rice Husk total [kg]
F4.4	Unused charcoal total [kg]	F4.9	Unused Straws total [kg]
F4.5	Unused corn cob total [kg]	F4.10	Electricity Monitor (kWh)(ID:_____):
F4.6	Unused _________ total [kg]:	F4.11	Unused _________ total [kg]:
F4.2b	New wood total [kg]	F4.7b	New Corn Stalk total [kg]
F4.3b	New LPG total [kg]	F4.8b	New Rice Husk total [kg]
F4.4b	New charcoal total [kg]	F4.9b	New Straws total [kg]
F4.5b	New corn cob total [kg]	F4.10b	Electricity Monitor (kWh)(ID:_____):
F4.6b	New _________ total [kg]:	F4.11b	New _________ total [kg]:

Wood Moisture Readings: Stove #4 *[Take three samples of fuel used on this stove]*				
F4.12a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F4.12b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F4.12b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #4 *[Take three samples of fuel used on this stove]*				
Type: _______________				
F4.13a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F4.13b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F4.13b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3
Ag. Residue Moisture Readings: Stove #4 *[Take three samples of fuel used on this stove]*				
Type: _______________				
F4.14a	Sample 1	a) Reading 1	b) Reading 2	c) Reading 3
F4.14b	Sample 2	a) Reading 1	b) Reading 2	c) Reading 3
F4.14b	Sample 3	a) Reading 1	b) Reading 2	c) Reading 3

Cooking Events: Stove #4

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	F4.15.1	F4.15.2	F4.15.3	F4.15.4	F4.15.5	F4.15.6	F4.15.7
Event *[use codes]*							
Duration [hrs]							

F4.16	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

G. Seasons			
G1	Do you currently use more, less or the same amount of fuel **as at other times of the year**? Please think about all energy needs, including those for animals. [SA]	More [Answer 4C5]	1
		Less [Answer 4C6]	2
		Same [Go to 4D1]	3
G2	For what reasons do you currently use **more** fuel at this time of year? Once again, please think about all energy needs, including those for animals. *[Do not prompt. MA select all that apply]*	To heat the room(s) for people	
		To heat rooms for animals	
		To heat bathing water	
		Making more animal feed	
		Fuel is plentiful	
		Cook different types of food	
		Cook for more people	
		Many festivals happening at this time of year.	
		Other *[Circle 99 and describe below]*	
G3	For what reasons do you currently use **less fuel on your stoves** at this time of year? Please think about energy needs, including those for animals *[Do not prompt. MA select all that apply]*	Do not need to heat room(s) for people	
		Do not need to heat rooms for animals	
		There is less fuel available	
		Do not need to make animal feed.	
		Cook different types of food	
		Cook for less people	
		There is little food available	
		There are no festivals happening this time of year.	
		Other *[Circle 99 and describe below]*	

H. People currently eating from the stove		
H1	How many people usually EAT food from your household stoves each day at this time of year? This can include people outside your direct family but eat from your stove on a regular basis at this time of year.	

		How many currently eat food made on stoves in this home? *[Numeric]*	How many currently eating food made from stoves in this home **are visitors**? A visitor is anyone that lives in another place more than 6 months of the year *[Numeric]*	How many currently eating food made from stoves **are helping in your fields**? *[Numeric]*
H2	children aged 0-14 years old			
H3	females 15+ years old			
H4	males 15-59 years old			
H5	males 60+ years old			

END OF VISIT #2

Visit #3

J.VISIT #3		
J1	Date [dd-mm-yy]	
J2	Time of visit [hh:mm] 24-hr time	
J3	Household ID	
J4	Surveyor Name/ ID	

K. Fuel weights: Visit #3			
K0.1	ID # scales	K0.2	ID # moisture meter
K1. FIRST stove			
K1.1	Stove type [use codes from sheet]	Please select one option	
K1.2	Unused wood total [kg]	K1.7	Unused Corn Stalk total [kg]
K1.3	Unused LPG total [kg]	K1.8	Unused Rice Husk total [kg]
K1.4	Unused charcoal total [kg]	K1.9	Unused Straws total [kg]
K1.5	Unused corn cob total [kg]	K1.10	Electricity Monitor (kWh)(ID:_____):
K1.6	Unused ________ total [kg]:	K1.11	Unused ________ total [kg]:
Cooking Events: Stove #1			

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	K1.12.1	K1.12.2	K1.12.3	K1.12.4	K1.12.5	K1.12.6	K1.12.7
Event *[use codes]*							
Duration [hrs]							

K1.13	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

K2. SECOND stove			
K2.1	Stove type [use codes from sheet]		
K2.2	Unused wood total [kg]	K2.7	Unused Corn Stalk total [kg]
K2.3	Unused LPG total [kg]	K2.8	Unused Rice Husk total [kg]
K2.4	Unused charcoal total [kg]	K2.9	Unused Straws total [kg]
K2.5	Unused corn cob total [kg]	K2.10	Electricity Monitor (kWh)(ID:_____):
K2.6	Unused ________ total [kg]:	K2.11	Unused ________ total [kg]:
Cooking Events: Stove #2			

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	K2.12.1	K2.12.2	K2.12.3	K2.12.4	K2.12.5	K2.12.6	K2.12.7

Event *[use codes]*							
Duration [hrs]							

K2.13	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

K3. THIRD stove			
K3.1	Stove type [use codes from sheet] Please select one option		
K3.2	Unused wood total [kg]	K3.7	Unused Corn Stalk total [kg]
K3.3	Unused LPG total [kg]	K3.8	Unused Rice Husk total [kg]
K3.4	Unused charcoal total [kg]	K3.9	Unused Straws total [kg]
K3.5	Unused corn cob total [kg]	K3.10	Electricity Monitor (kWh)(ID:_____):
K3.6	Unused ________ total [kg]:	K3.11	Unused ________ total [kg]:

Cooking Events: Stove #3

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	K3.12.1	K3.12.2	K3.12.3	K3.12.4	K3.12.5	K3.12.6	K3.12.7
Event *[use codes]*							
Duration [hrs]							

K3.13	Notes/observations for FIRST stove/fuel use .*[Explain other types of stove use and events here]*.

K4. FOURTH stove			
K4.1	Stove type [use codes from sheet] Please select one option		
K4.2	Unused wood total [kg]	K4.7	Unused Corn Stalk total [kg]
K4.3	Unused LPG total [kg]	K4.8	Unused Rice Husk total [kg]
K4.4	Unused charcoal total [kg]	K4.9	Unused Straws total [kg]
K4.5	Unused corn cob total [kg]	K4.10	Electricity Monitor (kWh)(ID:_____):
K4.6	Unused ________ total [kg]:	K4.11	Unused ________ total [kg]:

Cooking Events: Stove #4

- What have you used this stove for since the last visit?
- Approximately how long did each event last?
- Please include all tasks such as re-heating food, heating your home, making animal feed, warming bath water, brewing drinks, etc as well as all cooking events.

	K4.12.1	K4.12.2	K4.12.3	K4.12.4	K4.12.5	K4.12.6	K4.12.7
Event *[use codes]*							
Duration [hrs]							

K4.13	Notes/observations for stove/fuel use .*[Explain other types of stove use and events here]*.

L.Household Income: Visit #3			
L1	Which of these income ranges best describes the **current monthly income in your household**? I am asking about total income from all household members from all sources such as salary, bonus, and money transferred from overseas. *[Choose one]* *[NOTE:Help the respondent calculate this if necessary, and confirm this is a MONTHLY figure. SA]*	No money earned- live off land and trade goods.	1
		Less than 2000 rupees per month	2
		2000- 4000 rupees per month	3
		4001-6000 rupees per month	4
		6001- 8000 rupees per month	5
		8001-10,000 rupees per month	6
		10,001-12,000 rupees per month	7
		12,001-16,000 rupees per month	8
		16,001-20,000 rupees per month	9
		20,001-30,000 rupees per month	10
		30,001-40,000 rupees per month	11
		40,001-60,000 per month	12
		More than 60,000 rupees per month	13
		Refused to answer	14
		Don't know	15
L2	What proportion of this money comes from overseas? *[Choose one]*	Less than 1/4	1
		¼	2
		½	3
		3/4	4
		All of it	5
		None of it	6
		Refused to answer	7
		Don't know	8
L3	Do you trade goods such as crops for other household items at this time of year?	Please select one option	

END OF VISIT #3
Please Check Photo Checklist

APPENDIX B- Consumer tariff rate published by NEA

Appendix B: Electricity tariff rate published by Nepal Electricity Authority (NEA) for domestic (residential) and commercial customers

A YEAR IN REVIEW | FISCAL YEAR 2017/18

ANNEX-1

ELECTRICITY TARIFF

TARIFF RATES

1. Domestic Consumers

(a) Service and Energy Charge (Single Phase)

kWh (Monthly) Units	5 Ampere		15 Ampere		30 Ampere		60 Ampere	
	Service Charge	Energy Charge	Service Charge	Energy Charge	Service Charge	Energy Charge	Service Charge	Energy Charge
0-20	30.00	3.00	50.00	4.00	75.00	5.00	125.00	6.00
21-30	50.00	7.00	75.00	7.00	100.00	7.00	150.00	7.00
31-50	75.00	8.50	100.00	8.50	125.00	8.50	175.00	8.50
51-150	100.00	10.00	125.00	10.00	150.00	10.00	200.00	10.00
151-250	125.00	11.00	150.00	11.00	175.00	11.00	225.00	11.00
251-400	150.00	12.00	175.00	12.00	200.00	12.00	250.00	12.00
Above 400	175.00	13.00	200.00	13.00	225.00	13.00	275.00	13.00

(b) Service and Energy Charge (Three Phase)

Low Voltage (230/400 V)

kWh	Up to 10 KVA		Above 10 KVA	
	Service Charge	Energy Charge	Service Charge	Energy Charge
Up to 400	1100.00	12.50	1800.00	12.50
Above 400		13.50		13.50

(c) Service and Energy Charge: Three Phase

Medium Voltage (33/11 KV)

kWh	Up to 10 KVA	
	Service Charge	Energy Charge
Up to 1000	1100.00	11.00
1001-2000		12.00
Above 2001		13.00

Billing Method (For 5 Ampere)

S. No.	Electricity Consume Block	Rate Rs. Per Unit	Billing Method
1	Up to 20 units	3.00	Minimum Monthly Service Charge Rs. 30.00 for up to 20 units and Energy Charge Rs. 3.00 per unit
2	21 to 30 units	7.00	Minimum Monthly Service Charge Rs. 50.00 and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units
3	31 to 50 units	8.50	Minimum Monthly Service Charge Rs. 75.00 and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units and Rs. 8.50 per unit for 31 units to 50 units
4	51 to 150 units	10.00	Minimum Monthly Service Charge Rs. 100.00 and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units and Rs. 8.50 per unit for 31 units to 50 units and Rs. 10.00 per unit for 51 units to 150 units
5	151 to 250 units	11.00	Minimum Monthly Service Charge Rs. 125.00 and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units and Rs. 8.50 per unit for 31 units to 50 units and Rs. 10.00 per unit for 51 units to 150 units and Rs. 11.00 per unit for 151 units to 250 units
6	251 to 400 units	12.00	Minimum Monthly Service Charge Rs. 150.00 and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units and Rs. 8.50 per unit for 31 units to 50 units and Rs. 10.00 per unit for 51 units to 150 units and Rs. 11.00 per unit for 151 units to 250 units and Rs. 12.00 per unit for 251 units to 400 units
7	Above 400	13.00	Minimum Monthly Service Charge Rs. 175.00 minimum charge and Energy Charge per unit Rs. 3.00 for per unit up to 20 units and Rs. 7.00 per unit for 21 units to 30 units and Rs. 8.50 per unit for 31 units to 50 units and Rs. 10.00 per unit for 51 units to 150 units and Rs. 11.00 per unit for 151 units to 250 units and Rs. 12.00 per unit for 251 units to 400 units and Rs. 13.00 per unit for above 400 units

Similarly, billing will be made for 15, 30 and 60 Ampere.

2. Other Consumers

2.1 Low Voltage (230/400 V)

Consumer Category	Tariff Rate	
	Demand Charge	Energy Charge
	Rs. per KVA/ month	Rs./unit
1. Industrial		
a) Rural and Domestic	60.00	7.80
b) Small Industry	110.00	9.60
2. Commercial	325.00	11.20
3. Non-Commercial	215.00	12.00
4. Irrigation		4.30
5. Water Supply		
a) Community Water Supply	155.00	5.20
b) Other Water Supply	230.00	7.20
6. Temple		6.10
7. Street Light		
a) Metered		7.30
b) Non-Metered	2475.00	
8. Temporary Supply		19.80
9. Non-Domestic	350.00	13.00
10. Entertainment Business	350.00	14.00

2.2 High Voltage

Consumer Category	Tariff Rate	
	Demand Charge	Energy Charge
	Rs./KVA/month	Rs./unit
A. High Voltage (66 KV or above)		
1. Industrial	240.00	7.50
B. Medium Voltage (33 KV)		
1. Industrial	255.00	8.40
2. Commercial	315.00	10.80
3. Non-commercial	240.00	11.40
4. Irrigation	55.00	4.80
5. Water Supply		
a) Community Water Supply	220.00	6.00
b) Other Water Supply	220.00	6.60
6. Transportation		
a) Trolley Bus	230.00	5.60
b) Other Transportation	255.00	8.60
7. Non-Domestic	350.00	12.55
8. Entertainment Business	350.00	13.50
C. Medium Voltage (11 KV)		
1. Industrial	255.00	8.60
2. Commercial	315.00	11.10
3. Non-commercial	240.00	11.50
4. Irrigation	55.00	4.90
5. Water Supply		
a) Community Water Supply	220.00	6.20

b) Other Water Supply	220.00	6.80
6. Transportation		
a) Trolley Bus	230.00	5.60
b) Other Transportation	255.00	8.80
7. Temple	220.00	9.90
8. Temporary Supply	330.00	12.00
9. Non-Domestic	350.00	12.90
10. Entertainment Business	350.00	13.90

Under Non-Domestic: Embassy, Foreign Mission, INGO, Private Campus, Star Hotel, Shopping Mall etc.

Under Entertainment: Cinema Hall, Fun Park, Theater etc.

3. Time of Day (ToD) Tariff Rate

a) Electricity Tariff Rate from Baishakh to Mangsir

Consumer Category	Tariff Rate			
	Demand Charge Rs. per KVA/ month	Pick Time (17.00-23.00)	Off Pick Time (23.00-5.00)	Normal time (5.00-17.00)
A. High Voltage (66 KV or above)				
1. Industrial	240.00	9.30	4.15	7.50
B. Medium Voltage (33 KV)				
1. Industrial	250.00	10.20	5.25	8.40
2. Commercial	315.00	12.30	6.75	10.80
3. Non-Commercial	240.00	13.20	7.00	12.00
4. Irrigation	55.00	6.30	3.15	4.70
5. Water Supply				
a) Community Water Supply	220.00	7.30	3.60	5.90
b) Other Water Supply	220.00	10.20	5.25	8.40
6. Transportation				
a) Trolley Bus	230.00	7.00	3.70	5.50
b) Other Transportation	255.00	9.35	3.70	8.40
7. Street Light	80.00	8.40	3.50	4.20
C. Medium Voltage (11 KV)				
1. Industrial	250.00	10.50	5.40	8.55
2. Commercial	315.00	12.60	6.90	11.10
3. Non-commercial	240.00	13.50	7.15	12.25
4. Irrigation	55.00	6.40	3.50	4. 75
5. Water Supply				
a) Community Water Supply	220.00	7.45	4.40	6.10
b) Other Water Supply	220.00	10.50	5.40	8.50
6. Transportation				
a) Trolley Bus	230.00	7.15	4.20	5.60
b) Other Transportation	255.00	9.65	4.20	8.50
7. Street Light	80.00	8.80	3.75	4.40
8. Temple	220.00	11.30	5.15	9.10
9. Temporary Supply	330.00	14.40	6.60	11.75

b) Electricity Tariff Rate from Paush to Chaitra

Consumer Category	Tariff Rate		
	Demand Charge Rs. per KVA/ month	Pick Time (17.00-23.00)	Normal Time (23.00-5.00)
A. High Voltage (66 KV or above)			
1. Industrial	240.00	9.30	7.50
B. Medium Voltage (33 KV)			
1. Industrial	250.00	10.20	8.40
2. Commercial	315.00	12.30	10.80
3. Non-Commercial	240.00	13.20	12.00
4. Irrigation	55.00	6.30	4.70
5. Water Supply			
a) Community Water Supply	220.00	7.30	5.90
b) Other Water Supply	220.00	10.20	8.40
6. Transportation			
a) Trolley Bus	230.00	7.00	5.50
b) Other Transportation	255.00	9.35	8.40
7. Street Light	80.00	8.40	4.20
C. Medium Voltage (11 KV)			
1. Industrial	250.00	10.50	8.55
2. Commercial	315.00	12.60	11.10
3. Non-commercial	240.00	13.50	12.25
4. Irrigation	55.00	6.40	4.75
5. Water Supply			
a) Community Water Supply	220.00	7.45	6.10
b) Other Water Supply	220.00	10.50	8.50
6. Transportation			
a) Trolley Bus	230.00	7.15	5.60
b) Other Transportation	255.00	9.65	8.50
7. Street Light	80.00	8.80	4.40
8. Temple	220.00	11.30	9.10
9. Temporary Supply	330.00	14.40	11.75

4. Community Wholesale Consumer:

Voltage Level	Energy Charge (Rs./unit)
a) Medium Voltage (11KV/33KV)	
Upto (N* x 30) units	4.25
Above (N* x 30) units	6.00
b) Lower Voltage Level (230/400 Volt)	
Upto (N* x 30) units	4.25
Above (N* x 30) units	6.25

N*= Total Number of Consumers of a Community Group

Notes:

a) Low Voltage refers to Electricity Supply of 230/400 V, Medium Voltage refers to 11 KV and 33 KV and High Voltage refers to 66 KV or above.

b) If Demand Meter of any consumer reads kilowatts (kW), then KVA=kW/0.8. Consumers having kW demand meter shall mandatorily install capacitors within the given time. Otherwise their KVA demand shall be calculated as KVA=kW/07.

c) 10% rebated in total bill amount will be given to the Government of Nepal approved Industrial Districts, if the bill is paid within 21 days of billing date.

d) If the Crematory House, Governmental Hospital and Health Centers (except Residential Complex or part thereof) under the Government of Nepal pay the bill within 21 days, 20 percent rebate will be given in total bill amount.

e) Consumers supplied at High Voltage (66 KV or above) and Medium Voltage (33 KV and 11 KV) should compulsorily install ToD Meter.

f) If New Additional Consumers applying for 11 KV supply are to be supplied at 33 KV, they will be charged as per 11 KV Tariff Structure.