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Household Energy Use–Clean and Energy Efficient Cooking Solution – a case study of Chhukha Dzongkhag

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Abstract:

Bhutanesecooking pattern as of now isliquefied petroleum gas (LPG), firewood and kerosene which are sufficiently not clean. As Bhutan is increasingly intrested in switching for clean and efficient household energy, it is never too early to go for electricity and induction cooking. In this paper cost, time, environmental impact and loading of distrubution transformer are substantially analysed and came up with the conclusion that induction cooking is the best cooking solution besides exsisting cooking technologies. With the introduction of induction cooking in the country, people will often feel scaptic to go for induction cooking. This paper disseminate and create awareness on cost and time benefit analysis which will make people easy to decide on the more efficient cooking energy. This solution solves the overall increasing use of dirty energy consumption and thereby at the macro level helping to acheive the country's mission of maintaining carbon neutal country for all the times to come

Keywords **—Clean and efficient energy, induction cooktops, GHG emission, transformer loading**

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I. INTRODUCTION

The pattern of energy for cooking over the last few years have changed drastically, shifting to more clean and efficient energies from traditional and inefficient energies like biomass. The country has also achieved 99.87% electrification due to abundance of hydropower resourses[1]. In every household the primary energy used for cooking includes electricity. Other energies like LPG, biogas, fuels and firewood are also being used as a secondary energy. Electricity and LPG are the two energies majorly used in urban areas while the rural areas use electricity and other energies including firewood and kerosene[1]. These are the reasons for the price of electricity being highly subsidized by Royal Government and the other petroleum products and LPG imported from India at subsidized rate [2].

Global warming and the GHG emissions are the current rising issues not only in Bhutan but in the world. With this rising concern country needs to focus on the energy policies that is shifting from so called 'dirty and inefficient energies' such as biomass to 'clean and efficient energies' such as electricity and LPG. Households in the country face certain barriers (lack of access to clean and efficient sources of energy, affordability problems, or abundant availability of the cheap sources of the energies) in the change of the energy usage pattern and in moving towards the use of clean energy. That is why the country still consists of some households using biomass as the principle energy for cooking.

Cooking activity is a main component of people's daily life, and this activity usually consumes plenty of energy. It is very important to provide clean and efficient energy for this daily activity to avoid any indoor air pollution leading to the bad health of the people of the each house. So our project aims to provide the clean and energy efficient solution for cooking. Project provides solution based not only on how clean the energy is but also based on different criteria like energy saving, time saving, efficiency and the cost benefit. The solution provided would not only help the individual household but the whole nation in shifting from the old inefficient technologies to new efficient technologies for cooking. Moreover the project focuses on induction cooking as it is considered as one of the new technology in cooking which is more efficient, clean and energy saving with time saving.

II. SAMPLE AND SURVEY METHODOLOGY

The sample for household energy for cooking was designed to provide estimates on the availability and accessibility of the different types of energy for cooking in the country at Dzongkhag level. A few places within ChhukhaDzongkhag were chosen which were again categorized under rural and urban.

The population of ChhukhaDzongkhag is 88,342 based on Dzongkhag population projection according to BLSS 2012 and the number of households in chhukhaDzongkhag is 12,792. To obtain good sample which is covering whole Dzongkhag, sample size was necessary to calculate. The sample size for the survey to be conducted was calculated with a margin of error of 5% and a confidence level of 95 %. The sample size calculated was 373 households out of 12,792 households. Additional 20% households were added to the actual calculated sample size to allow for certain limitations like refusals and the unusable data. So the final sample size for the survey came out to be 463 numbers of households which were selected from the 11 Gewogs under chhukhaDzongkhag. The figure below shows the number of households within chhukhadzongkhag which were covered for the data collection.The data collection was done in two ways. About 70% of the households were made to fill the questionnaire form and about 30% were door to door survey interviewing one of the members of the family.

The questionnaire comprised of two main headings: characteristics of the households and the household energies used for cooking. The questionnaire gives the characterisctis of households like if the households members are educated and employed. It also gives the range of monthly income of the individual households and the number of the members in the households. It even gives the information on how often each house cooks in a day. The household energies included four energies which are LPG, electricity, firewood and the kerosene. The survey was mainly conducted to do analysis on these four energies for cooking based on the time,cost, user preference and the environmental impact.

After the development of the questionnaire the first test of the survey was conducted in the College of Science and Technology campus with 19 numbers of the households. The questionnaire was slightly modified after the test survey for more informations needed to collect. The main survey was conducted in different regions within ChhukhaDzongkhag.

II.I Survey results

II.I.I Household characteristics

The number of members in the household ranges from the minimum of 2 people to maximum of 6 people giving an average of 4 people in each household. Almost 80% of the households were employed with the average monthly income of the households was Nu.

5001 to Nu. 15000. Every households cooked atleast one time in a day. And about 60% of the households cooked three times a day.

II.I.II Household energies used for cooking

Almost all the households were electrified and 100% of the households used electricity as their primary energies for cooking. Though the households were electrified they used LPG as their secondary energy for cooking. Accoding to the survey about 86% of the households had LPG as their secondary energy for cooking. Then the 7% of the household used firewood as the energy for cooking and the rest 6% used kerosene. So it was observed that the most of the household have electricity and the LPG as the energy for cooking.

TABLE 1 RESULT OF THE SURVEY.

Types of energy	Number of users	Annual expenditure	Average time to cook using (mins.)	Annual time consumed for collecting(hours)
Electricity	323	668.16	35	0
Firewood	23	5525	25	26
LPG	278	3767.5	27	18
Kerosene	19	1200	39	11

Through survey it was observed that the maximum expenditure spent annually was on firewood and least on the electricity. Even the time spent annually on collecting the particular energy was more for firewood and least for the electricity. The time for collection for the electricity was zero or the households need no time to collect electricity. For the time taken to cook with different energies, firewood took least time to cook and more time was needed to cook with electricity. **Table 1** shows the overall result of the survey conducted.

III. EXPERIMENT

Inorder to calculate the energy consumed, time taken and efficiency of the different cooking energy we have conducted an experiment. The experiment was conducted at College of Science and Technology (CST) kitchen. During experiment following conditions should be fulfilled.

- Same amount of rice and vegetables are used for different cooking energies.
- The temperature is maintained constant. To achieve this we hace done our experiment at same time.

The experiment was conducted using induction cookstove, rice cooker, curry cooker and LPG to cook 1kg of rice and curry. The result is shown in **Table 2.**

The energy consumed to cook using different energy are ploted as shown in **Fig 1.** From the graph we can see that the induction cookstove consumes less energy compared to others. In our experiment the energy consumed by the LPG is maximum (more than actual) because the gap between utensil and the energy source was more

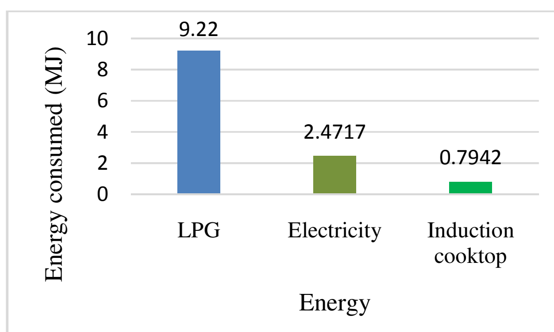
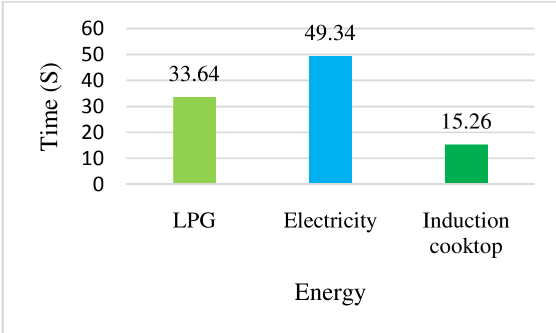


Fig.1 Energy consumed.



. Fig.2 Time taken to cook using different energies

which leads to decrease in its efficiency. In terms of time, rice cooker, curry cooker and LPG takes more than twice the time taken by the induction cookstove.

III.I Efficiency calculation

The efficiency of different cooking energy is calculated from the experiment. The information of the experiment to calculate efficiency is shown in **Table 3.** To calculate the efficiency we need energy consumed and energy required. To find the energy required we have considered 1 liter of water and calculated the energy altually required by using its specific heat capacity (C_p).

TABLE 2. CALCULATION OF THE ENERGY CONSUMED BY DIFFERENT COOKWARES

Sl No.	Energy		Time taken	Energy Consumed(MJ)	Cost (Nu.)
1	LPG	Rice (1Kg)	17'41"	5.071	3.71
		Curry	15'58"	4.149	3.04
2	Electricity	Rice (1Kg)	27'11"	1.1417	0.405
		Curry	22'10"	1.33	0.473
3	Induction cooktop	Rice (1Kg)	6'58"	0.7942	0.28
		curry	8'18"	0.946	0.33

TABLE 3. EFFICIENCY OF DIFFERENT COOKING APPLIANCE.

Sl. No.	Energy		Initial Temperature	Final Temperature	Time Taken	Energy Consumed (MJ)	Energy required (MJ)	Efficiency (%)
1	LPG		26˚C	98˚C	4'28"	1.383	0.301248	21.8
2	Electricity	Rice cooker (700W)	29˚C	98˚C	13'10"	0.553	0.288696	52.2
		Curry Cooker (1000W)	26˚C	98˚C	7'37"	0.457	0.301248	65.9
		Boiler (1500W)	26˚C	98˚C	5'20"	0.48	0.301248	62.76
3	Induction Cooktop		26˚C	98˚C	3'30"	0.399	0.301248	75.5

The specific heat capacity of water is 4.184 kJ/kg °C which means that the energy required to rise its temperature by 1°C for 1kg (1 liters) of water is 4.2kJ. The actual energy required (Ea) to rise the temperature of 1 liters of water from a°C to b°C is given by following formula.

$$E_a = (b - a)c_p \, kJ$$

IV. COST BENEFIT ANALYSIS

From **Table 2** we know that to cook same amount of food we require different amount of energy depending upon the type of energy and cook stove used. **Table 4** shows the annual expenditure of different energy.

IV.I CALCULATION

We have used LPG cylinder of 14.2kg whose cost was Nu 485/-. Following calculation are done to calculate the amount spent for cooking annually using LPG.

$$Energy\ in\ 14.2kg\ of\ LPG\ =\ 14.2 \times 46.1\ MJ$$

$$Cost\ per\ unit\ of\ energy\ = \frac{485}{654.63} MJ$$

$$= Nu\ 0.74\ per\ MJ$$

TABLE 4 ANNUAL EXPENDITURE ON DIFFERENT COOKING ENERGIES.

Energy	**cost**
LPG	7290
Electricity	948.24
Induction	658.8

IV.I.I Calcualtion for energy consumed (E_c).

The energy comsumed while heating the water from a°C to b°C depends on the calorific value of LPG. The calorific value of LPG is 46.1MJ/kg. We have calculated the amount of LPG used by finding the difference between initial (w_i) and final weight (w_f) of LPG. The amount used is multiplied with the calorific value of LPG to get the energy consumed as shown in the following equation.

$$E_C = (w_i - w_f) \times calorific\ value$$

For rice cooker, curry cooker and induction the energy consumed depends on the rating of the cookstoves and the time taken. In our experiment we have used 700W rice cooker, 1000W curry cooker and 1900W induction cookstove. The time required to rise the temperature of water from a°C to b°C is shown in the **Table 3.** The energy consumed is given by following equation.

$$E_C = wattage \times time\ taken\ in\ hours$$

The efficiency of the energy is calculated as follows.

$$Efficiency = \frac{E_a}{E_C}$$

V. ENVIRONMENTAL IMPACT

Cooking energies like LPG, kerosene and

TABLE 5 CO2 EMISSION BY DIFFERENT COOKING ENERGIES.

Energy	**CO2 emitted (gm/kJ)**
LPG	0.059782
kerosene	0.06144
Firewood	0.09

firewood produces greenhouse gas which affects the environment. The main greenhouse gas produce from these energies are carbondioxide (CO_2). **Table 5** shows the amount of CO_2 produced from different energies. From the **Table 5** we calculated the amount of CO_2 produced annually from different cooking energies. The calculation are done as follows,

$$Energy\ required\ to\ cook\ for\ 1\ year\ (E) = energy\ required\ for\ 1\ meal \times 3\ \times 365\ J$$

$$CO_2\ produced\ annual = E \times CO_2\ emission$$

The amount of CO_2 produced from different cooking energy is shown in **Fig 3.**

From the **Fig.3** we can see that the induction cookstove produces less amount of CO_2 compared to other cooking energies. We can reduce environmental impact and also reduce health issues if we can encourage people to use clean energy like induction cookstoves.

VI. COST RECOVERY ANALYSIS

If the cooking pattern does not switch to induction cooking then government have to pay to the utility company for the 100 units of electricity. If it switches to the induction cooking, it will consume less energy than energy consumed by curry cooker and rice cooker. This makes government to pay less electricity bill than they have to pay before using induction cooktops. Also Bhutan is the carbon neutral country and inorder to keep the promise to be a carbon neutral country for all generations to come, government has to encourage people to use electricity by giving subsidy rate like giving 100 units free. Instead

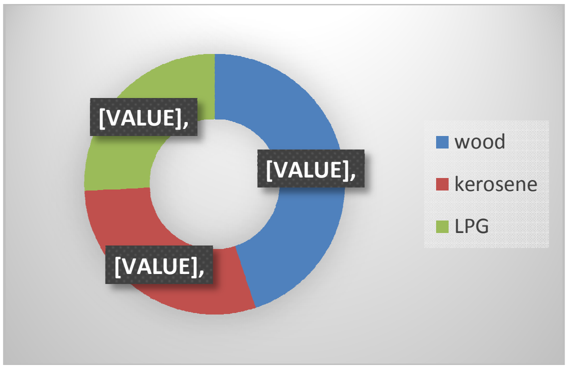


Fig.3 Annual production of CO2

of giving certain units free for all time, its better to switch to induction cooking pattern. So if induction cooktop of average quality (Nu. 2000) is distributed to all the rural household from the subsidy rate of 100 units. Then following calculation was performed to calculate the time required to recover the investment made by government.

$$Recovery\ time = \frac{2000}{(948.24 - 658.8)}$$

$$= 6.9\ \ years$$

VII. TRANSFORMER LOADING

If all the induction cookstoves are used at the same time by all the users then percentage loading of distribution transformer increases. To calculate the percentage loading of the transformer, it requires the number of households, kVA ratings of the transformers and rating of the loads in kW. In this project distribution transformer of Laptshakha town was selected to do analysis on the change in percentage loading. The transformer rating was 250kVA which was initially 80% loaded. The number of householdsconnectd to the transformer was 168. Following calculations were performed to calculate the change in percentage loading of the transformer.

$$Power\ of\ transformer\ in\ watt$$
$$= \sqrt{3} \times kVA \times 0.8$$
$$= 346kW.$$

Load connected before induction = 0.8×346 kW
= 276.8 kW

The induction cookstoves which is considered in this paper exceeds the watage of rice cooker and curry cooker by 200W.

Load after induction =276.8+(0.2×168)kW
=310.4kW

Where 168=no. of household

$$\%\ loading\ after\ inducti = \left(\frac{310.4}{346}\right) \times 100\%$$

=89.7%

From our calculations and findings the existing transformer can handle the additional load even if all the households of the village use the induction cooktops at the same time. But it will never happen that all the households will use the induction at a same time. So the transformer will operate without problem.

VIII. CONCLUSION

The firewood, kerosene and LPG are one of the factors that lead to the climate change and moreover Bhutan need to take measures to keep carbon neutral for all the times to come. Bhutan has electrified 99.87% of households and these make easy to introduce induction cooktop to curb the issues of clean household energy. The results from the experiment suggest that induction cooking is more efficient in terms of time and cost from the existing cooking technologies like rice cooker and curry cooker. Therefore the introduction of induction cooktops will bring down the scale of firewood consumption and give better option over expensive imported LPG. It will also help to maintain the benchmark of carbon neutral in the country by complementing the existing cooking stoves.

Introduction of induction cooktop is fairly a new idea in Bhutan and for the customer validation, it requires various sensitization and support from government by making policy to go for an induction cooking. The initial cost of the induction cooktop is relatively high but it can be substitute from the tariff subsidy of 100 units free which is given by the government.

The loading of transformer directly depends on the kVA rating of transformer and number of households connected to it. So the current distribution system can handle the additional load of induction cookstoves and can perform well without problem.

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