2017

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Abstract

It has not been many years since a majority of Bhutanese were cooking with firewood as their fuel source. However, over the years the fuel mix has been changing and depicting increasing share of clean fuel such as electricity (hydropower generation) and liquefied petroleum gas (LPG). Subsequently there is a massive opportunity to switch into modern, clean and efficient cooking technologies such as induction cooktops and reduce the overall fuel/wood consumption. Induction cooktop is a fairly new concept in the country; therefore, users are often sceptical about investing in them due to lack of awareness on the cost-benefit analysis. Various criteria are available for evaluation but often not all the information required is available to the customer to come to a final decision. An understanding of end users' energy use pattern is important for energy management. Therefore, this paper will analyse the current energy use pattern for domestic rural and urban households for cooking, and present an optimized and energy efficient solution through adoption of an integrated cooking solution. This would result in an overall reduction of fuelwood consumption and thereby reduction in greenhouse gas emission, while at the micro level, individual end users can benefit from cleaner and energy efficient technology solution.

Keywords

induction, stove, cook, analysis, bhutan, purposes, integrated, cooking, lpg, cooktop

Disciplines

Engineering | Science and Technology Studies

Publication Details

Chheti, R., Chhoedron, D., Sunwar, T. & Robinson, D. A. (2017). Analysis on Integrated LPG Cook Stove and Induction Cooktop for Cooking Purposes in Bhutan. International Journal of Science and Research, 1071706 23-26.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Analysis on Integrated LPG Cook Stove and Induction Cooktop for Cooking Purposes in Bhutan

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Abstract: ***It has not been many years since a majority of Bhutanese were cooking with firewood as their fuel source. However, over the years the fuel mix has been changing and depicting increasing share of clean fuel such as electricity (hydropower generation) and liquefied petroleum gas (LPG). Subsequently there is a massive opportunity to switch into modern, clean and efficient cooking technologies such as induction cooktops and reduce the overall fuel/wood consumption. Induction cooktop is a fairly new concept in the country; therefore, users are often sceptical about investing in them due to lack of awareness on the cost-benefit analysis. Various criteria are available for evaluation but often not all the information required is available to the customer to come to a final decision. An understanding of end users' energy use pattern is important for energy management. Therefore, this paper will analyse the current energy use pattern for domestic rural and urban households for cooking, and present an optimized and energy efficient solution through adoption of an integrated cooking solution. This would result in an overall reduction of fuelwood consumption and thereby reduction in greenhouse gas emission, while at the micro level, individual end users can benefit from cleaner and energy efficient technology solution.***

Keywords: Energy efficiency, induction cooktop, Liquefied Petroleum Gas (LPG), Cooking stove

1. Introduction

Traditionally, firewood has been the major source of energy for many households in Bhutan [1]. Bhutan has recorded high per capita firewood consumption, at 1.17 tons [2]. However, electricity has been rapidly gaining prominence as one of the major sources of household energy. From 2004 to 2014, the share of electricity as a source of energy for the country increased from 14% to 27%. Bhutan is blessed with abundant hydropower resources and with an achievement of over 99% electrification. At the household level, by 2014, electricity had become the third most consumed fuel to meet cooking demand after LPG and firewood [3]. This is mostly due to Bhutan's ambitious rural electrification program and other initiatives such as the promotion of biogas plants and improved cook stoves by the Department of Renewable Energy. These are also complemented by other developmental initiatives by the Royal Government of Bhutan.

The Bhutan Energy Data Directory 2015 noted a clear dominance of firewood remains, with 84.7% of the total energy consumption in the building sector (includes heating and cooking) [3].

The Bhutan Living Standards Survey conducted in 2012, reported that for cooking purpose, 84% of households used electricity, 61% used LPG and 33% used firewood. Energy consumption pattern shows 29% of house hold energy is used for cooking [4]. Thus, it gives a clear picture of the usage of multiple sources of energy for cooking in Bhutanese households.

There are many factors which highlight that using an electric oven for cooking is often a better option than using LPG [4, 6]. In rural segments of the country, fuelwood based cooking is a common and effective solution considering the cost benefits; ease of access; and even social and cultural reasons. The market mechanism and accessibility issues can be controlled and influenced to achieve the desired result of having an integrated cooking solution which is beneficial to the end user as well as the nation. However, this can only be achieved successfully if supported by scientific and evidence based approach.

Distribution of households by use and source of energy are shown below in Fig. 1 for cooking for both urban and rural areas [7].

The theory of "Energy Ladder" shows the choice of fuel when people move up the ladder due to improvement in economic conditions [8]. Electricity is at the top of the ladder due to its cleanliness, convenience, efficiency and cost, followed by LPG which is also considered a clean fuel albeit non-renewable.

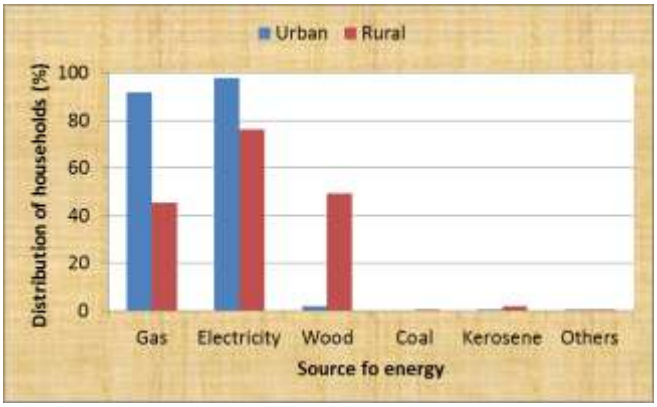

Figure 1: Distribution of households by sources of energy for cooking

In the case of Bhutan, LPG consumption is an issue due to factors such as LPG being imported; implication of transportation involved; volatility of cost; dependence on subsidy; and its non-renewable nature.

The import figures show that LPG consumption in the country has increased at a compounded annual growth rate (CAGR) of 4.3% from 2006 to 2016. At this rate, LPG consumption would double by 2023.

In the case of firewood, it is one of the oldest cooking fuels, and is generally considered a renewable resource. However, there are several disadvantages of using firewood such as environmental risks including indoor air pollution from inefficient burning of wood, leading to some chronic non-communicable diseases [2].

Table I: Energy consumption pattern and cost of induction and LPG cooking in Ngultrum

Dish	LPG Cook stove		Induction Cooktop			
	Energy consumed (kWh)	Total Cost of LPG (Nu)	Energy consumed (kWh)	Cost (Block I)	Cost (Block II)	Cost (Block III)
Rice 2 cups	0.3942	0.9528	0.2800	0.3584	0.7056	0.9324
Water 2L	0.3942	0.9528	0.3030	0.3878	0.7636	1.0090
Water 3L	0.5256	1.2704	0.3930	0.5030	0.9904	1.3087
Water 5L	0.9197	2.2233	0.4830	0.6182	1.2172	1.6084
Milk 3L	0.6569	1.5881	0.4330	0.5542	1.0912	1.4419
Milk 5L	1.0511	2.5409	0.5170	0.6618	1.3028	1.7216

Considering the above mentioned drawbacks and the facts of increased electrification in the country from hydropower resources, it offers a good platform for the nation to pursue electrical cooking technologies.

2. Experimental Method: Case Study

A. Brief description of project site

The case study was carried out in the residence of one of the faculty members from the College of Science and Technology, Bhutan. The measurement was taken for a period of 10 days and readings were taken daily in the evening at 7pm.

B. Working principle of induction cooktop

The induction cooktop works on the principle of electromagnetic induction. It directly induces heat into the cooking vessel when switched on. Induction cookers are energy efficient, user friendly, odourless, and time and cost-effective [9]. It is safe to use as it heats the cooking vessel only when it comes in contact with the cooking plate. However, the drawback of induction cooker is that utensils must have steel or iron bottoms with flat surfaces. There is also limitation in the total weight that an induction cooktop can safely handle.

C. Efficiency of cook stoves

The efficiency of the induction cooktop can be as high as 80-84% compare to electrical resistance based cooktop which is 50-60% and LPG cooktop with only 40% [8,9,10]. The efficiency has been measured to be around 76% [12]. The lower efficiency of LPG cooktop is mainly due to conversion losses of LPG fuel from chemical energy to thermal energy, and energy losses from space between the pot and the burner.

D. Energy and cost analysis

During the case study, various cooking was carried out for different dishes such as rice and boiling of water and milk, in varying quantities, and on both an LPG cook stove and induction cooktop. The average results are presented in Table I.

In the calculation of quantities in Table I, the cost of an LPG cylinder (14.2kg) was taken as Nu. 450/-, the prevailing average cost at the point of purchase. The cost of transportation of LPG is considered as Nu. 200/- per cylinder. On the other hand, for the energy calculation of the induction cooktop, the existing electricity tariff containing a three tier (Blocks I, II and III) energy tariff system is considered, with rates as shown in Table III. This tariff represents the applicable electricity charges in Ngultrum per kWh for Bhutanese domestic households [13].

Table II: LPG cylinder cost components

Item	Cost
Cost of a LPG cylinder (14.2 kg)	Nu. 450/-
Actual average transportation cost	Nu. 200/-
Total cost of a LPG cylinder	Nu. 650/-

Table II: Energy tariff rates for cost calculations

Energy demand block	Rate
Block-I (0 - 100 kWh)	1.28
Block-II (101 - 300 kWh)	2.52
Block-III (> 300 kWh)	3.33

The actual energy consumed by both the LPG cooktop and induction cooktop was compared in equivalent units (kWh). The following formula was used to convert the energy consumed by LPG cooktop into equivalent kWh.

Energy (kWh) = mass (kg) × net calorific value of LPG (kcal/kg)/ 860.42 kcal (1)

A conversion factor between 1 kWh and its equivalent is 860.42 kcal and a net calorific value of 11,304.98 kcal/kg is used for LPG [14].

The energy consumed by an LPG cook stove while cooking rice for a typical Bhutanese family is higher than electricity consumed to cook the same amount of rice in induction cooktop. Similar observation was made for boiling of water and milk. However, if the household energy consumption is above the Block III tariff (>300kWh), it becomes cheaper to cook using LPG (Table IV).

Theoretical approaches have been carried out and subsequently validated illustrating that electricity is cheaper than LPG for electricity consumers of tariff Block I and II, by Nu. 2.04 and Nu. 0.80 per unit respectively. However, for Block III consumers, it is cheaper to use LPG by Nu. 0.01 per unit.

Table IV: Theoretical comparison of per unit energy cost

Type of fuel	Energy content (kWh)	Unit cost-Energy (Nu./kWh)		
		Block I	Block II	Block III
1 LPG Cylinder (14.2 kg)	195.64	3.32	3.32	3.32
Electrical Energy (kWh)	1	1.28	2.52	3.33
Per unit cost difference (Nu./kWh)		-2.04	-0.80	0.01

Table V: Comparison of LPG cook stove and Induction cooktop

Particulars	LPG cook stove	Induction cooktop
Efficiency	low	High
Delivery charges of fuel	High	Nil
Cost of stove and pots	Less	15-25% more than LPG stove and pots are expensive
Outside air to burn	Required	Not required
Permissible weight of food for cooking	High	4-5 kg including the weight of pot
Even heating	Yes	Yes
Cleaning	Easy	Very easy
Type of pots	Any metal	Ferrous metal base (iron and steel) only
Safety	Risk of gas leakage leading to fire. Open flame pose risk for toddlers and pets	No open flame

In general, a decision on choice of cooktop type can be made with some of the following considerations:

- Induction cooktop is a better option if safety, efficiency and operating costs (LPG may be comparable in some areas).
- If the initial upfront cost is a concern, LPG stoves are cheaper in general.
- If cleaning up is a big issue, induction cooktop is the best option.

3. Results and Discussion

When comparing the energy consumption and cost of energy, it is seen in Table I, using Induction is cheaper and Table IV shows that cooking using induction cooktop is cheaper than LPG cook stove if the energy consumption is less than 300 kWh. Thus, cooking on an induction cooktop is cheaper, easier and safer compared to LPG.

The choice of appliances usually depends on a number of factors including price, appearance, kitchen layout and personal preference. However, energy availability, reliability of supply and efficiency should be a priority when selecting appliances. Good cooking practices, together with careful selection of appliances, can significantly reduce monthly expenditure on cooking, as well as contribute to reduction in greenhouse gas emissions.

4. Conclusion

Climate change and energy efficiency are important issues and topical throughout the world. Bhutan produces large amounts of clean electrical energy through hydropower generation and over 99% of households have access to electricity. There poses ample opportunity to promote induction cooktops as a complement to existing cooking stoves. The promotion of induction cooktops in the country is expected to lead to reduction in the dependency on imported LPG, as well as reduction in firewood consumption.

However, induction based cooking technology is a relatively new concept and initial investment is still high. In addition, induction cooktops require cooking using specific type of utensils (pots and pans of ferrous metal), which limits the cooking experience. Therefore, to reap benefit from the introduction of induction cooktops, it would be recommendable for incentivizing the users to encourage usage of induction cooktops. Further, there is a need to train technicians in maintenance and repair works, and consider

building and distribution design improvements to incorporate such facilities for sustainability of the induction based cooking. Awareness programmes would also be vital. Since induction cooktops can be very efficient for many dishes, it will greatly complement LPG based cooking. However, detailed cost benefit analysis is crucial to assess the benefit at an individual and national level. Also, a detailed study would be required to evaluate the additional loading on the distribution power infrastructure if a majority of consumers opt for use of induction cooking appliances. A baseline study to map the household energy consumption pattern may be crucial to project the energy saving potential and the impact on the country's economy and environment.

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