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Analysis of Infrared stove, Induction Cooktop and LPG for Cooking Selective Dishes in Bhutan

Roshan Chhetri[1], Passang Lham[2], Divyash Chhetri[3]

[1]College of Science and Technology, Royal University of Bhutan, Phuentsholing, Bhutan
roshanchhetri.cst@rub.edu.bt, roshanchhetri@yahoo.com

[2]College of Science and Technology, Royal University of Bhutan, Phuentsholing, Bhutan
02180245.cst@rub.edu.bt, passanglham2018@gmail.com

[3]College of Science and Technology, Royal University of Bhutan, Phuentsholing, Bhutan
02200174.cst@rub.edu.bt, divyashchhetri@gmail.com

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Abstract

The transition from liquified petroleum gas (LPG) stoves to electric stoves is a recent trend in Bhutan. However, the choice of electric stoves between the induction cooktop and the infrared stove is difficult to the people. Over the years the fuel mix has been changing and depicting increasing share of clean fuel such as electricity and LPG. Individual has found massive opportunity to switch into modern, clean and efficient cooking technologies such as induction cooktops and infrared stove thus reducing the overall fuel wood consumption and LPG. Induction cooktop and Infrared stove have recently entered Bhutanese home, however, many are often sceptical about investing in them due to lack of awareness on the cost-benefit analysis.

Induction cooktop and Infrared stove are both a representation of an improvement compared to the conventional LPG and other fuel stove. These will be even better in future with technological advancements. Both infrared stove and induction cooktops need flat based cookware with some differences and similarities.

Infrared and Induction cooking are both prodigious methods of cooking. Users need to understand the energy use pattern and their merits and demerits to make final choice. Therefore, this paper aims to analyses parameters like, energy consumption, time, cost and life of infrared stove, induction cooktops and LPG in cooking few selective dishes in Bhutanese context. Induction cooktop is instant and better in terms of time and energy consumption, but life is short as the electronic components get damaged due to heat. Infrared offers more benefits while using for longer time cooking more dishes as the food is cooked faster. It produces some heat and is more suitable to northern part (cold region) compared to southern part of Bhutan. Electric cooking are better for the environment thereby reducing greenhouse gas emission, while at the micro level, individual end users can benefit from cleaner and energy efficient technology solution.

I. Introduction

Electricity meets around 30% of the country' s energy consumption. The primary energy used for cooking in Bhutan includes electricity, LPG, biogas, and firewood. Electricity and LPG are extensively used in urban areas while the rural areas uses other energies like, biogas, firewood and kerosene along with electricity and LPG [1]. Bhutan has recorded high per capital firewood consumption, at 1.17 tons [2]. However, electricity and LPG has been rapidly gaining prominence as one of the major sources of household energy. Presently the transition from LPG stoves to electric stoves is a trend for many families. The choice of electric stove between the induction cooker and the infrared stove has to be cost and efficient smart. Fuel wood inflicts pressure on the environment, and imported fossil fuels pinches the balance of payments. Bhutan is blessed with abundant hydropower resources and with an achievement of over 99.97% electrification as of 2020. Bhutan is one of the smallest economies among the eight South Asian countries but is also among the fastest-growing economies in the world. As the economy grows, living standard improves, use of modern electrical appliances increases and energy consumption rises. The per capita energy consumption increased from 0.6 toe per capita in 2010 to 0.69 toe per capita in 2017, which is indicative of increasing industrialisation and improving living conditions

The Bhutan Living Standards Survey conducted in 2017, reported that Electricity is the most widely used source of energy for cooking in both urban (99.1%) and rural (92.5%) households. In urban 95% used LPG for cooking compared to 57.8% in rural. One-third (33.3%) of rural households

use firewood for cooking. [2]. 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 electricity for cooking is often a better option than using other fuel. 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. Electricity is at the top of the ladder due to its cleanliness, convenience, efficiency and cost.

Firewood is one of the oldest cooking fuels. 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]. LPG being imported, implication of transportation involved, volatility of cost, dependence on subsidy, and its non-renewable nature

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 explore and pursue electrical cooking technologies.

II. Experimental Method: Case Study

A. Brief description of project site

The case study was carried out at College of Science and Technology, Phuentsholing Bhutan which is around 250m above sea level with moderate temperature. The measurement was taken over a period of one month and readings were taken in the evening at 7pm. The experiment was performed in kitchen with closed window and without using exhaust fan to ensure the stove flame is not flutter affecting the burning efficiency. The dishes chosen are rice, egg, milk and boiling water.

B. Working principle of Infrared stove

The Infrared stove operates on the principle of infrared heat radiation, the electric current will heat the inner cores (resistor coil) to produce heat and then transfer to the cooktop surface that heats the cooking pot. Thus, infrared cook stoves can use all types of cooking pots for cooking.

C. 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 cooktop are energy efficient, user friendly, odourless, and time and cost-effective [4]. 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 cooktop 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.

D. Efficiency of cook stoves

The infrared stove offers consistent heat flow and its efficiency is around 70% which means 30% of electricity consumed by electric stove is not used in cooking food. However, the induction cooktop can be as high as 80-84%. Overall, both offers high efficiency compared to LPG cooktop with only 40% [3,4,5]. The lower efficiency of infrared stove as some heat energy is lost from space between the pot and the stove. This can be improved using proper size of pot but practically difficult.

E. 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 infrared stove and induction cooktop. The average results are presented in Table I.

The energy calculation of the infrared stove and induction cooktop is done based on the existing electricity tariff containing a three tier (Blocks I, II and III) energy tariff system is considered, with rates as shown in Table II. This tariff represents the applicable electricity charges in Ngultrum per kWh for Bhutanese domestic households [6].

From Table I, Infrared stove consumes slightly more energy compared to Induction cooktop for same amount of cooking. How ever when compared to subsidised LPG it is still cheaper as the base tariff for LPG is Nu 4.6 based on present market. When compared to non-subsidised LPG electricity cooking is cheaper.

Table I – Energy consumption pattern and cost of Infrared stove, induction cooktop and LPG cooking in Ngultrum

Dish	Infrared stove				Induction Cooktop				LPG			
	Energy consumed (kWh)	Cost (Block I)	Cost (Block II)	Cost (Block III)	Energy consumed (kWh)	Cost (Block I)	Cost (Block II)	Cost (Block III)	Energy consumed (kWh)	Cost (Block I)	Cost (Block II)	Cost (Block III)
Rice 2 cups	0.6	0.768	1.608	2.16	0.28	0.3584	0.7504	1.008	0.28	1.288	1.288	1.288
Water 2L	0.625	0.8	1.675	2.25	0.24	0.3072	0.6432	0.864	0.24	1.104	1.104	1.104
Kewa datchi (3 heads)	0.54	0.6912	1.4472	1.944	0.22	0.2816	0.5896	0.792	0.24	1.104	1.104	1.104
boiled egg (3 nos)	0.4	0.512	1.072	1.44	0.19	0.2432	0.5092	0.684	0.2	0.92	0.92	0.92
Milk 1L	0.27	0.3456	0.7236	0.972	0.14	0.1792	0.3752	0.504	0.15	0.69	0.69	0.69

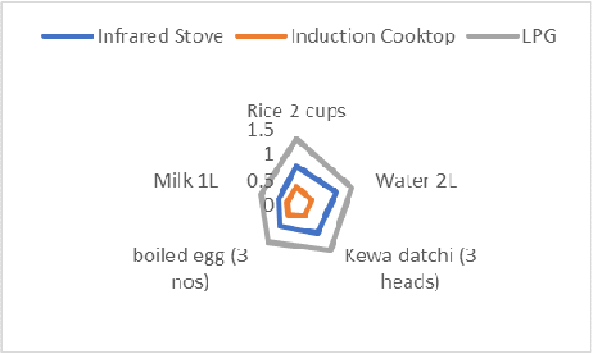

Fig 1: Cost of energy considering block I tariff

Table II – Energy tariff (2020-2021) rates for cost calculations

Energy demand block	Rate (Nu)
Block-I (0 - 100 kWh)	1.28
Block-II (101 - 500 kWh)	2.68
Block-III (> 500 kWh)	3.60

To see further, comparison is also made with LPG. In the calculation of quantities in Table III, the cost of an LPG cylinder (14.2kg) is taken as Nu. 668/-, the prevailing average cost at the point of purchase. The cost of transportation of LPG is considered as Nu. 250/- per cylinder.

Table III – LPG cylinder cost components

Item	Cost
Cost of a LPG cylinder (14.2 kg)	Nu. 668/-
Actual average transportation cost	Nu. 250/-
Total cost of a LPG cylinder	Nu. 918/-

The actual energy consumed by both the LPG cooktop and electric cooking (infrared stove/induction cooktop) is 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 [7].

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 is made for boiling of water and milk. However, if the household energy consumption is above the Block III tariff (>500kWh), it becomes cheaper to cook using LPG (Table I) over infrared stove.

Theoretical approaches have been carried out and subsequently validated illustrating that electricity is cheaper than LPG for electricity consumers of all tariff Block which is shown if table IV.

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	4.6	4.6	4.6
Electrical Energy (kWh)	1	1.28	2.68	3.60
Per unit cost difference (Nu./kWh)		-3.32	-1,92	-1.0

Issue with Induction cooktop

The figure below are power circuit and control circuit from induction cooktop. After some years, the resistors are getting damaged due to heat and the cooktop cannot be use.

Fig 2a: Induction cooktop control circuit

Fig 2b: Induction cooktop control circuit

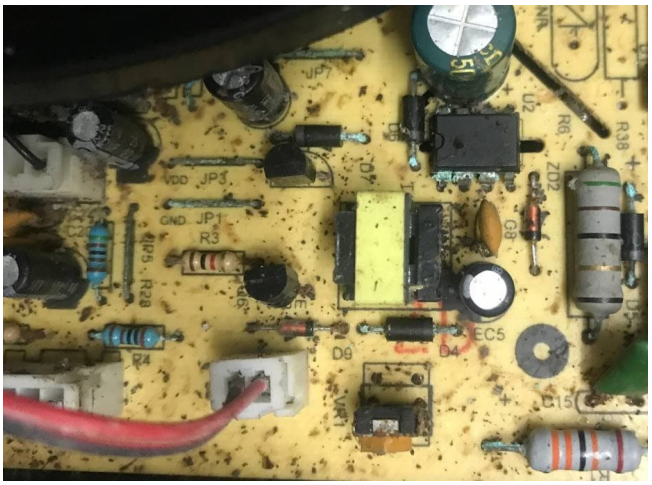

Fig 3a: Induction cooktop power circuit

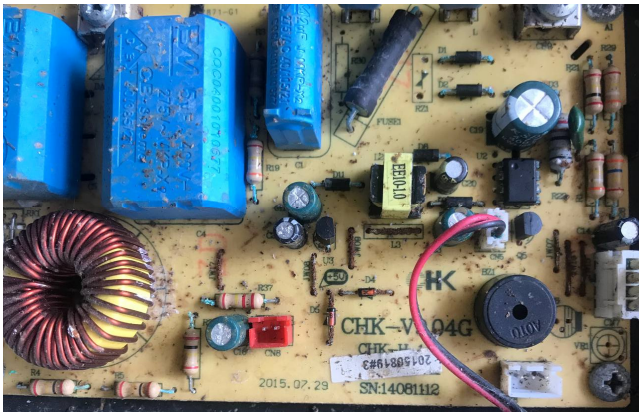

Fig 3b: Induction cooktop power circuit

Comparison of infrared stove and Induction cooktop

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

Some of the priority factors to buy and use the induction cooktop are:

- Fast cooking
- Suitable for cooking liquid food, soup etc
- Higher safety (young children and elderly).
- Use of cook specific pots

Infrared cook stove have the same function as a regular electric stove and saves about 2 times more electricity. Some important factors to buy and use infrared stove are:

- Need to cook better, ripe and more evenly cooked dishes.
- Mainly serving rice dishes for families: salty dishes such as storage, rim, stew, or fried dishes.
- Appropriate to roast and bake food items. (Bake bread roast meat, fish , corns .)
- Suitable for barbeque using an iron net/ mess wire
- possible to use all kinds of existing household pots and pans (cost savings).
- Can be used for space/ room heating during the cold season.

However, it is not without any drawbacks. Infrared stove takes time to initially get heated and to cool down when the cooking is over. The cooling fan runs for long time and remains noisy. Since any object can be heated directly, the dropped items on the cooking top burns creating nuisance for cleaning. As infrared stoves and induction cooktop use depends on continuous power, during a power failure the set is unusable. Infrared stoves take more time to heat up compared to induction cooktop and LPG stoves.

Infrared stoves are often much easier to clean than gas stoves. Some electric stoves feature a simple smooth-top, flat glass plane that can be wiped down with a sponge or rag after use. Infrared stoves is pretty simple to operate and less expensive compared to induction cooktop with utensils and LPG gas set. As both the stoves are handy and compact, it saves space in the kitchen compared to that of LPG stove. The space of LPG cylinder (usually beneath the ovens) is now available for other storage when electric stoves are used

In general both infrared stove as well as Induction cooktop is a better option for safety, efficiency and operating costs (LPG may be comparable in some areas). If the initial upfront cost is a concern, infrared stoves are cheaper as investment in cook specific pots is not required. If cooking is continuous for long hours, heat will damage the resistors and diode of Induction cooktop. Hence the life of induction cooktop is less compared to infrared stove. Referring to fig 2a, 2b, 3a and 3b, it is clear that induction cooktop has issues with electronic components like resistor and diode which get damaged due to heat when used for longer duration. Maintenance and repair is easy for infrared compared to induction cooktop.

III. Results and Discussion

Comparing the cost of energy consumption in Bhutan and cost of complete set of cooking set, using infrared stove is overall cheaper. As seen from table I, Induction cooktop is cheapest, followed by infrared stove and finally LPG.

Induction cooktop and LPG heats too fast compared to infrared stove which is slow at initial stage. However if it needs to be used continuously for long time, Infrared stove is fine and it will retain heat for long time. Regarding safety, induction cooktop wins as it only heats the required cookware but infrared stove heats everything which increase the risk. Induction cooktop does not cook evenly and some possibility of less tastier food whereas Infrared stove cooks evenly increasing the taste. Induction cooktop needs special type of cookware which increases the overall cost whereas all types of heat-proof and flat surfaced cook wares can be used on infrared stove. Induction cooktop does not have BBQ facilities whereas infrared stove have such option. Infrared stove is noisy and consume more power as the fan runs for the long time period. If accidently press on the ON button, it can trigger the fan to run for same amount of time as after cooking the whole meals.

LPG emits greenhouse gas while burning as well as it account greenhouse while transporting from industry to house. The cost of LPC delivery was quite high during lockdown due to pandemic. Using electricity for cooking will not emit smoke which is a health benefit. Control is easy as well. Fuel price is changing frequently and controlled by other country whereas electricity price is fixed atleast for a year. LPG refill consume times which is not in the case of electricity. However electricity is not reliable as of now. LPG cylinder blast and cause more damage compared to other electricity hazards (can be improved with proper wiring).

At the present tariff, electric cooking is around 30% less energy compared to LPG. Considering the initial cost of utensils, and life of induction cooktop, infrared stove is a better option for individual. Looking into reduction of greenhouse gas and import of LPG and availability of clean electricity, electric cooking is better option for the government point of view. Use of electrical appliance for cooking consumes more energy which increases revenue to BPC as well.

The choice of appliances usually depends on a number of factors including price, appearance, kitchen layout and personal preference. 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. The temperature and cooking time of food are influenced by the atmospheric pressure and is inversely proportional to the altitude.

IV. Conclusion

Climate change and energy efficiency has become concern issues and topical throughout the world. Bhutan produces large amounts of clean electrical energy through hydropower generation and over 99.97% of households have access to electricity. There is ample opportunity to promote electric cooking as a complement to existing cooking techniques. The promotion of electric cooking in the country is expected to lead to reduction in the dependency on imported LPG (reducing greenhouse gas on use of LPG and transportation), as well as reduction in firewood consumption.

Induction cooktop has picked up in Bhutan. However, initial investment is still high as it requires cooking using specific type of utensils (pots and pans of ferrous metal). It is suitable for hot region as not much heat is lost into the surrounding. It cannot be used for long duration as the electronics components get damaged over the time. Further, no trained technicians are available to carry out maintenance and repair works.

Infrared stove is now available within Bhutan with higher rating up to 2.5kW. It produces more heat loss compare to induction cooktop. Infrared stoves consume high power and produce heat which make it more suitable in cold region. All types of utensils can be used which makes it user friendly. The new building design should consider space arrangement for effective and convenient use of these appliances. Awareness programmes would also be vital. Based on electricity reliability, LPG may remain as standby source of energy in household. A detailed study would be required to evaluate the additional loading on the distribution of power infrastructure as majority of consumers are opting for these 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. Government may study reduction of greenhouse gas and dependency on imported LPG and look towards subsidizing the use of infrared stoves and electricity tariff.

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Roshan Chhetri is an Asst Prof at College of Science and Technolgy (CST), Royal University of Bhutan. He received Diploma in EE from Royal Bhutan Polytechnic, Bhutan, BTech (EEE) from REC (NIT) Warangal, Andhra Pradesh, India and MScE in Electrical Engineering from University of New Brunswick (UNB), Canada. He has published and presented more than 25 papers in national and internaltional journals and conference. His research interest are in Power System, Unit commitment and Renewable energy and Energy Audit.

