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Performance and Financial Analysis of Replacing LPG Stoves by Electric Rice Steamers for Rice Cooking: A case study of Nepali Army (Swayambhu Baroodkhana Karyalaya)

by

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ABSTRACT

The selection of appropriate energy sources for the cooking process directly influences individuals and the overall economy. In Nepal, energy sources for cooking are derived from biomass resources, imported fossil fuels, and a limited number of renewable energy sources. Given Nepal's commitment to achieving zero carbon emissions by 2045 and negative carbon emissions by 2050, prioritizing electricity for cooking over traditional biomass and fossil fuels is crucial for achieving energy self-reliance. This study explores the advantages of replacing LPG cooking stoves with electric rice steamers, focusing on the Nepali army (Swayambhu Baroodkhana Karyalaya) as a sample space. The study evaluates the benefits of cooking using electric rice steamers over LPG cooking stoves. Based on the experiment conducted, the specific energy cost and the thermal efficiency of the rice steamer are about three times more efficient than the LPG cooking stoves. The insulation test of the rice steamer showed that it took over 3 hours to cool down from 95°C to 77°C when the rice steamer door is closed. The survey found that the food taste was better and warmer. The relative cost-benefit analysis was conducted and found that electric rice steamers were 15.4 times more beneficial than the LPG stoves. It was found that presoaking rice for 30 minutes and refraining from immediately opening the steaming cabinet after powering off the Rice Steamer can optimize its performance. Additionally, the study found that lentils can be boiled in the steamer, then cooked in an existing pressure cooker with spices and water, reducing LPG consumption. Considering these parameters, the study identifies practical and feasible opportunities for energy savings, highlights the benefits of cost reduction during operation and maintenance, and provides recommendations for improvements in design and usage practices. It is also recommended to adopt the national policy for testing domestic and foreign rice steamers/rice cookers for energy efficiency levels.

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LIST OF ABBREVIATIONS

°C	Degree Celsius
AEPC	Alternative Energy Promotion Centre
ARI	Acute Respiratory Infection
BAU	Business As Usual
BC	Black Carbon
BS	Bikram Sambat
CES	Center For Energy Studies
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
ESC	Energy Specific Cost
gm	Gram
GW	Giga Watt
HGR	High Growth Rate
IRR	Internal Rate of Return
IS	Indian Standards
kg	Kilogram
kW	Kilo Watt
LEAP	Long Range Energy Platform
LPG	Liquefied Petroleum Gas
MCB	Miniature Circuit Breaker
MGR	Medium Growth Rate
MPa	Mega Pascal
MW	Mega Watt
N_2O	Nitrous Oxide
NA	Nepali Army
NMVOC	Non-Methane Volatile Organic Compounds
NOC	Nepal Oil Corporation
NOx	Nitrogen Oxides
NPV	Net Present Value
OC	Organic Carbon
PBP	Payback Period

PM 2.5	Particulate Matter
SDG	Sustainable Development Goals
SEC	Specific Energy Consumption
SO_2	Sulfur Dioxide

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

It is estimated from the historical evidences that fire has been used for cooking meals for about 100,000 years (Bronowski, 1973). The choice of energy source for cooking has a critical importance for the economic, social, and sustainable development of a country. Sustainable Development Goal (SDG) 7 aims to achieve universal access to affordable, reliable and modern energy services by 2030 (AEPC, 2022). Energy has always direct impact upon the social and economic standpoint of the Nepali Society and it would continue in the upcoming future as well (WECS, 2014).

There must be balance between the supply and demand of energy. Supply of energy could be done by either utilizing the indigenous energy resources found inside the country or by importing the required amount of energy. The hydropower potential of Nepal could not be fully harnessed and hence around 42 GW is considered to be techno-economically feasible to develop (Gunatilake, Wijayatunga, & Roland-Holst, 2020). Nepal does not have till date extracted commercially natural sources of gases and oils.

Nepal hugely depends upon only one supplier country, India for the net import of the petroleum and gas. Since energy is an important driver of economic activities in the country, it becomes quite essential that there should be a secure supply of energy to meet national demand on both the short term and the long term. (Darlamee & Bajracharya, 2021). There has been a very good indication regarding the increase in the electricity production within Nepal in the upcoming years (Vaidya, 2020). Out of the total population of the country 92.51% of the population has access to the grid electricity. Last year, Nepal exported 1333120 MWh of the electricity produced to India (Nepal Electricity Authority, 2022).

In Nepal, firewood is still used as the main source of energy for cooking. Nepali Army was also using firewood for cooking till last decade. Thereafter, Nepali Army introduced kerosene based stoves all cooking purposes began. The kerosene and kerosene-based stoves were gradually replaced by Liquefied Petroleum Gas (LPG) and LPG stoves from 2068 BS onwards. '

The Fuel blockade' problem faced by Nepal in the year 2072 BS prioritized the search for alternative, indigenous sources of energy within the country. It also promoted the use of alternative cooking devices like induction stoves and rice cookers in public. Similarly, for the Nepali Army, using indigenous sources of energy (electricity) and electricity-based cooking devices is important from a strategic point of view.

The choice of energy source for cooking has a critical importance for the economic, social, and sustainable development of a country. Appropriate energy choices are paramount, since energy decisions directly influence development status of a country and the quality of life of inhabitants. Sustainable Development Goal (SDG) 7 aims to achieve universal access to affordable, reliable and modern energy services by 2030 (Nations, 2020).

1.2 Problem Statement

Government of Nepal has targeted to promote use of electricity while cooking. Electric Rice steamers are being slowly getting popular in Nepal, especially in those places where the number of persons to be fed is large. Nepal Army is also changing its source of energy for cooking purpose from LPG to electricity by replacing LPG stoves to electric rice steamers for cooking rice. The performance measurement and financial analysis of this cooking transformation was needed for finding the better cooking alternatives.

While observing cooking using electric rice steamers, it seemed that there lacked some essential automation features in design and operating procedure. The researcher could not find any previous studies related to performance and financial analysis for replacing LPG stoves with Electrical Rice Steamers in large scale cooking. The performance of electric rice steamer could be enhanced utilizing some design and operation practices was found as the study gap. It was observed that operator has to manually switch off MCB switch when steam whistle starts from the safety pressure release port. This led to unnecessary electricity consumption by over cooking instead of required and recommended time. Thereby, it required further study so that inclusion of some simple features like time-based auto Power Off switch, clear vertical water level indicator and some modification of electrical circuit could be recommended to enhance the efficiency of the electric rice Steamer.

Similarly, it was observed that the electric rice steamer door was being opened once the operator Switched Off the power source. This led to loss of heat present in the food that could have been used for cooking. Rice cooking was being done with very less rice soaking time. Similarly, the lentil was not being boiled using the electric rice, Steamer. Therefore, it was necessary to experimentally study for finding out better cooking practices.

Thus, the main motive of this research work is to conduct performance measurement and financail analysis of replacing LPG cooking stoves by electric rice steamers; systematically identify practical and feasible opportunities for saving energy and realize the benefit of cost reduction during daily operation and to recommend improvement in design and operating procedure for better cooking practices.

1.3 Objectives of Research

1.3.1 Main Objective

The main objective of this research is to conduct performance and financial analysis of replacing LPG cooking stoves by electric rice steamers and recommend better cooking practices and improvement in the existing design for performance enhancement of electric rice steamers.

1.3.2 Specific Objectives

The main objective of research would be met by obtaining following specific objectives.

i. To conduct experimental testing and performance analysis of LPG stoves and electric rice steamers in daily operational conditions.
ii. To perform financial analysis of replacing LPG stoves with electric rice steamers.
iii. To recommend better cooking practices and improvement in the existing design for performance enhancement of electric rice steamers.

1.4 Expected Outcomes

The following outcomes are expected on completion of this research work.

i. It would help promote the use of electricity as main source of energy for cooking purpose in governmental organization (military, police barracks etc) and non-governmental organization (hostels, cafeteria, schools, party palaces etc.)

ii. It would show the financial analysis using net present value method, relative cost benefit analysis where number of persons to be is large.

iii. It would bring out better cooking practices and recommend improvement in design for performance enhancement of electric rice steamers.

1.5 Scope and Limitations of Work

The scope of the study is limited to rice cooking due to available time and resources. The study is carried out only in “Swayambhu Baroodkhana Karyalaya ”(SBK, located at Swayambhu area in Kathmandu district.)

There are many types of electric rice cookers and steamers that are available in the market .This study is based on electric rice steamers (Model DMDQ-24, Two Door, 24 Plate, 24) manufactured by Shengshi Hoong Kitchen industry, China and being used in Swayambhu Baroodkhana Office.

Similarly, the study is limited to LPG stove and electric rice steamers. The performance and financial analysis of the LPG stove and electric rice steamers are compared however the additional accessories cost like the cost of transformers, 3 phase cable, backup generator is not considered.

The better insulating characterstics of electric rice steamer will reduce the LPG consumption during the reheating and keeping the food warm. The LPG consumption based on ambient temperature during different season will vary due to change on ambient temperature. These costs related to reheating, benefit of insulation and variation due to change in ambient temperature are beyond the scope of this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of Cooking Practices

Various heating methods ranging from three stone fires to electrical, microwave and induction ovens have been used over the years for cooking. Depending on the method used, the efficiency of operation may vary from 10% to 15% for conventional cooking to levels up to 80% for thermally efficient cooking devices. (Jyeshtharaj B. Joshi, 2012)

Rice is one of the world's major cereal crops next to wheat and maize, and is the staple food for nearly half of the world's population. Rice has been the main food in every meal for all Asians. The preparation of rice has traditionally been a tricky cooking process that requires accurate timing, and errors can result in inedible undercooked or burnt rice. The two important variables in rice cooking are the amount of water and the control of heating. The water to rice ratio is important in keeping the cooked rice from being either too hard or too soft. Controlled heating ensures that the rice is gently heated and gelatinized to the core without getting scorched. The cooking of rice is associated with complete gelatinization of the starch, complex formation, transformation and interactions involving biopolymer by heat treatment in the presence of water (Suzuki & Kubota, 1976).

2.1.1 Open Pan Cooking

In a vessel exposed to the air, rice and water are combined, typically with a large amount of extra water. When rice is cooked, it usually absorbs twice or three times its own weight in water. Nonetheless, in open pan cooking, this ratio is typically close to 1:5. After that, the extra water is drained off. This way of cooking uses fuel that is needlessly wasted. Cooking is inefficient mostly because it wastes heat in the environment and uses too much water (Jyeshtharaj B. Joshi, 2012).

2.1.2 Pressure Cooking

It makes use of the straightforward idea that water's boiling point is elevated. The amount of water utilized is equal to or slightly less than what rice requires. When compared to open pan cooking, this causes less water to be lost from the rice, increasing thermal efficiency. When the cooking process is coming to a conclusion and the steam whistles, water is lost. The hot walls of the cooking vessel might result in significant heat losses. High combustion ratios are used to cook food more quickly; however, this further reduces the food's thermal efficiency (Jyeshtharaj B. Joshi, 2012).

2.1.3 Steam Cooking

If the steam is fed directly to the cooking material, it may be possible to bypass the heat transfer step from steam to the cooking vessel and then to the meal. Steam cooking is employed where the scale of cooking is large enough and the use of steam is warranted (Jyeshtharaj B. Joshi, 2012).

2.2 Overview of Cooking Technologies

2.2.1 LPG stoves

LPG stoves use liquefied petroleum gas (LPG) as fuel, which is extracted during the crude oil refining process. These cooking stoves utilize LPG as the fuel for combustion, with LPG composed of propane, butane, propylene, butylene, and isobutane. The combination of these highly inflammable hydrocarbon gases influences the chemistry behind combustion. LPG is widely accepted as a fuel for household cooking. LPG stoves operate on the Venturi effect principle. In these stoves, air and LPG must be mixed before combustion in the throat portion, with the stoichiometric ratio for burning LPG in air being 15.6:1. As the LPG flows out of the cylinder regulator through the hose, the hose connects to a valve with an orifice plug. When the pipe narrows at the hole, regulated by the valve, the gas flow accelerates. This faster flow through narrow sections results in decreased pressure. The LPG gas then enters the mixing chamber, attracting surrounding air due to the sudden pressure drop around the LPG gas jet. The mixture of air and LPG is eventually expelled through finely and evenly distributed burner holes along the periphery, igniting upon combustion**.** (Khan & Saxena, 2013).

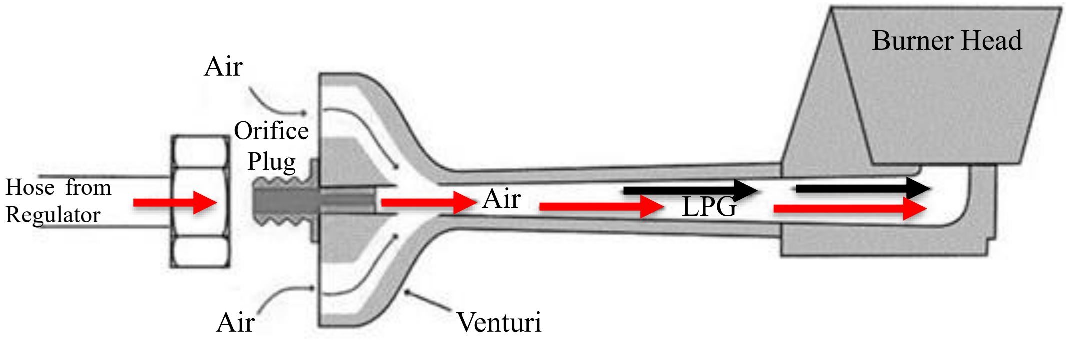

Figure 1: LPG stove working principle

The import and distribution of petroleum products in the country are led by the government-owned sector, the Nepal Oil Corporation (NOC). Currently, NOC holds a monopoly in importing, sorting, and distributing all petroleum products in Nepal. (Poudyal, Loskot, Nepal, Parajuli, & Khadka, 2019).

Figure 2: LPG stove with two burners (Overall size: 70 in.×36 in.×20 in.)

Figure 3: LPG Gas Cylinders with Regulators

Figure 4: LPG stover burner (Diameter = 6 in.)

Figure 5: LPG stover burner (Diameter = 6 in.)

2.2.2 Electric Rice Steamer

Electric Rice steamer is an automated electric kitchen appliance which is designed to boil or steam rice .Electric rice steamers is also known as rice cooker or rice steaming cabinet. Electric rice steamer consists of three major parts; a cooking cabinet, a heat source and a thermostat .Rice steaming cabinet comprises a cabinet body and a cabinet door, where the rice can be placed in different bowl. Heat source comprise of three 4 kW heating rod at the bottom. The heating rods are 6-7 cm above the bottom level. A water tank of depth 20 inches is at the bottom. The heating rods heats up the water content and steam are produced. The thermostat is kept to measure the temperature.

The electric rice steamer has two identical cabinet. The inner and outer wall of the cabinet body is made up of SS304 and it is insulated all around with polyurethane foam. On the both vertical wall of internal cabinet, there are extended bracket like extruded steel shapes to slide and hold the cooking trays. There are 12 groves holding 12 trays. It also has safety steam relief valve of 0.02MPa.

Figure 6: Electric rice steamer (one door open) 12 trays inside one cabinet

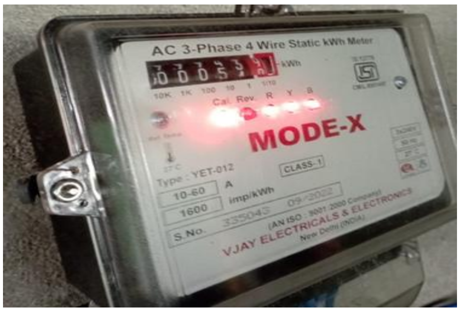

Figure 7: Phase kWh meter for measuring electricity consumption

The data of electric rice steamer available in domestic market is received from Total Machinery Pvt Ltd, Teku, Kathmandu. (three phase, 24kW, capacity -: 120 kg/batch, tray size-: 16 in.×24 in.).

Technical Parameters of Electric Rice Steamer

Table 1: Technical Specification of Electric Rice Steamer

S. N	Parameter	Specification
1	Name	Two Door 24 Plate Steamer/ Cabinet
2	Model	DMDQ-24
3	Voltage (V)	380
4	Power (kW)	24 (2*12)
5	Overall Size (cm)	139×58×153
6	Input steam pressure force (MPa)	0.02
7	Cooking Capacity (kg/min)	120/45

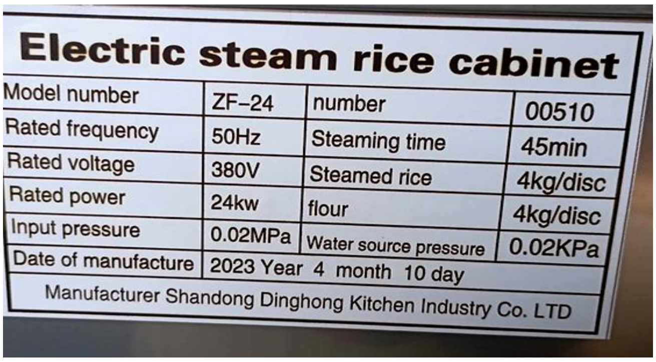

Figure 8: Electric Rice Steamer Name Tag

2.3 Kinetics of Cooking Process

The exploration of the "Kinetics of Cooking Process" involves a detailed investigation into the time-dependent factors influencing the cooking of food. This analysis focuses on understanding the rates and mechanisms of various physical and chemical transformations that occur during the cooking process. By examining factors such as temperature, cooking duration, and other relevant variables, researchers aim to gain insights into the optimal conditions for efficient and effective food preparation. The kinetics of the cooking process contribute valuable information for refining cooking techniques, optimizing resource utilization, and improving the overall quality of prepared meals. During cooking process, physio-chemical changes occur. The minimum cooking temperature for rice is greater than 74 °C and that for lentils is greater than 94 °C. (Jyeshtharaj B. Joshi, 2012)

2.4 Financial analysis of the Cooking Technologies.

For financial analysis, Cost Benefit analysis of the system would be conducted. Some commonly used measures of calculation approaches are as follows:

2.4.1 Payback period (PBP)

The payback period refers to the time duration required to recover the investment. In simpler terms, it is the time taken to reach the point of breakeven for any investment made. A shorter payback period typically suggests an attractive investment opportunity. However, it is important to note that the payback period evaluation has its shortcomings, as it doesn't take into account the time value of money.

In this thesis, a simple payback period method is used to calculate the payback period for the LPG gas replacement by the electric rice steamer. The cost of replacement of LPG gas by the electric rice steamer is calculated by taking the following cash flows in consideration.

(a) Cash Outflow (Investment)

  i. Cost of the Electric Rice Steamer

(b) Cash Inflow (Annual savings)

  i. Operation and Maintenance saved annually: The differences in the cost incurred for annual operation and maintenance cost of LPG gas stove and electric rice steamer.

Mathematically, the investment and the cash annual savings are described below:

(a) **Investment** = Cost of electric rice steamer

(b) **Annual Savings** = (Operation Cost of LPG stove + Maintenance Cost of the LPG stove) - (Operation Cost of electric rice steamer + Maintenance Cost of the electric rice steamer)

Thus, the pay pack period is calculated as follows:

$$PB = \frac{I}{S} \times 12 \qquad \text{Equation 5.2}$$

Where,

PB : Payback Period (Month)
I : Investment (NPR.)
S : Annual Savings (NPR. / year)

2.4.2 Net Present Value (NPV)

NPV calculates the current valuation of a future stream of cash flows that an investment would unfold. A stipulated time frame and a discount rate, equal to the minimum acceptable rate of return is taken as reference for the NPV calculation. An investment with positive NPV is generally considered good to invest. However, in this thesis, there is not any cash inflows associated with the LPG Stove and the electric rice steamer. There are only cash out flows chiefly on three overheads: Installation cost, Operation cost, Manpower cost and Maintenance cost. So, a comparative study of the NPV is necessary.

The formula to compute the NPV is given below:

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} \qquad \text{Equation 5.1}$$

Where,

R_t	:	Net Cash inflow/outflows during a single period
i	:	Discount rate of return
n	:	Total number of periods
t	:	t^{th} period

2.4.3 Cost-Benefit analysis

A **cost-benefit analysis** is the process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project decision to determine whether it makes sense from a business perspective. In this study relative cost benefit analysis is conducted.

2.5 Previous Studies

A study, "Cooking Cost Comparison using LPG, Rice Cooker, Induction and Infrared Cooker", conducted by Shrestha et al. at Center for Energy studies (CES) highlighted the need for Nepal to cut down the import of LPG and replace it with much cleaner and indigenous fuel available inside the country. The study showed that cooking 0.5 kg of rice in the induction stove is much cheaper than cooking the same amount of rice using the LPG stove. (Shrestha, Raut, & Shrestha).

A study conducted by (Khadka, 2022) computed the thermal efficiency of the LPG stoves and the Induction stoves. The average thermal efficiency of the LPG was found to be 48.27% and the average thermal efficiency of the induction stove was found to be 88.62%. The thermal efficiency of the induction stoves was found higher than the LPG stoves. It also compared the NPV of expenditures related with the LPG stoves and the induction stoves for a period of 12 years. It showed that LPG stoves tend to be more expensive than the induction stoves.

Sujuki et al. studied the cooking rate of rice over the temperature of 75-100 °C. They have also investigated the effect of raw rice soaking time on the cooking rate of rice. They found that the cooking of rice follows first order kinetics. They further found that the cooking process is controlled by the rate of gelatinization of starch below 110 °C and beyond 110 °C it is controlled by the diffusion of water through the cooked portion of rice grain. Juliano and Perez repeated the same experiments as Sujuki and al. over the temperature range of 80-120 °C. They have reported that the cooking process is controlled by the reaction rate below 90 °C and by diffusion through the swollen laver above 90°C

Past research has indicated that presoaking, storage and degree of milling influence the cooking time of whole rice grain. Santos, Guzman, Umali Mananes and Abanto (1980) carried out a study on tie and fuel conservation in rice cooking. They reported that it is possible to reduce the cooking time of rice with presoaking by 7- and 5-minutes using electricity and LPG respectively.

Sowbhagya and Ali (1991) also observed reduction of cooking time when rice was presoaked. Kim and Cho (1993) studied changes in water uptake rate, cooking and gelatinization properties during storage of mild rice for 3 months. They reported that rice grain became harder and cooking time was prolonged by 3-8 minutes as a result of storage. Cheigh, Kim, Pyun, and kwon (1978) reported that the cooking rate of rice followed the equation of a first-order reaction and the reaction rate constants increased with increasing polishing degree from 50% that of white rice (Kim, Pyun, Choi, Lee, I Kim, 1984). Bhattacharya (1993) carried out a study on energy consumption for cooking raw and parboiled rice using a pressure cooker with LPG stove. He reported that the lowest specific energy consumption was achieved by cooking large quantity at a time as well as adopting cooking methods of shorter duration.

The rates at which presoaked and unsoaked rice cook have been measured by (Chakkaravarthi, Lakshmi, Subramanian, & Hegde, 2008). An experiment with cooking rice in extra boiling water revealed that presoaked rice cooked faster than unsoaked rice, usually in around 9 minutes instead of 15. Rice that had been soaked ahead of time was often less energy-intensive and took less time to cook when using a pressure cooker with an electrical coil stove (Das, et al., 2006).

It has been observed that first-order kinetics governs the cooking process of rice. A single rate constant can be used to fit the kinetic data when cooking is done with presoaked rice and extra water. On the other hand, two rate constants were required to describe the cooking process for unsoaked rice.

2.6 Factors Influencing the Adaptation of Sustainable Cooking Methods

One of the prominent sectors for the energy demand in the context of Nepal is the cooking sector, during the past decade alone, the import of LPG has increased by more than three folds (Bhandari & Pandit, 2018). From the perspective of the nation, the primary obstacles to energy security are the cost of subsidies for the adoption of alternative energy sources and the rising demand for LPG. (Bhandari & Pandit, 2018). For high growth rate scenarios, the demand for LPG is expected to exceed 58 million GJ by 2035. To facilitate the replacement of LPG with electricity by that year, an extra 2626 MW of power generation would be needed (Bhandari & Pandit, 2018).

In recent years, LPG usage has increased in a very high growth rate, in urban areas more than 58.5% of the household rely on LPG for cooking (Central Bureau of Statistics, 2016). LPG is the second most used fuel for cooking purposes in the country (Bhandari & Pandit, 2018).

Nepal heavily relies on LPG and petroleum imports from India (Bhandari & Pandit, 2018). Energy security is one of the key issues between India and Nepal because of the socio-politics (Jewell, 2011). The trade deficit caused by the enormous volume of imported fuel puts the country in vulnerability where the country could be plagued of negative impacts on economy and society, intentional border blockades and intermittent or zero supply of fuels (Bhandari & Pandit, 2018).

This study also showed that the electricity has enormous potential to replace other fossil fuels like petrol, diesel, kerosene, and gas. Similarly, the study also highlighted about the creation of suitable mechanisms for incentives and subsidies in electricity to promote the usage of cleaner fuels and to move forth on the process of replacing the conventional fuels.

2.7 Study Gaps

The electricity has enormous potential to replace other fossil fuels like petrol, diesel, kerosene, and gas. Several studies on the fuel switching and interventions has been done in the context of Nepal. But there are very few studies that perform a cost-benefit analysis of replacing the LPG with the electricity (e.g., electric rice steamer) in the rural households of Nepal.

The scenario on ground can be better visualized through the collection of the primary data and these data help to have more realistic study than the models that rely exclusively on secondary data. This study analyzes the scenario in multiple faces i.e., provides a real overview of LPG consumption by LPG stove in daily operations, yearly savings/benefits, and NPV if electric rice steamer replace LPG for cooking purposes. Similarly, this study also highlights about the creation of suitable mechanisms for incentives and subsidies in electricity to promote the usage of cleaner fuels and to move forth on the process of replacing the conventional fuels.

CHAPTER THREE: RESEARCH METHODOLOGY

The research methodology describes all specific methods used to conduct the research study, emphasizing their critical role in the successful completion of the research. The successful completion of research work depends on the selection of an appropriate methodology and the relevance of such methods to obtain answers to the identified research problem. It basically describes the data collection methods and the process of analyzing data to obtain answers to research questions.

The research process begins with a thorough literature review to gain insights into existing knowledge. This is followed by concept development, where ideas and strategies are formulated based on the literature. The next step involves the design and setup of both the LPG stove and Rice Steamer for rice cooking, with careful consideration given to selecting appropriate locations for these appliances. The following method was used to collect the data for the experiment setup:

3.1 Data Collection Method

The data required to answer the research question is collected either by direct observation i.e., primary data in the experiment design for current research. It also takes in account of previous pre-existing publications/works i.e., secondary data in the considered area of interest.

3.1.1 Collection of Primary Data

For this study "Steam Jeera Masino Rice" (batch no 327/2080/1/2) packed and marketed by Shyambaba Rice and Flour Mill Pvt Ltd, Sunsari was used. The quantity of rice and water used for the cooking was noted with precision. For LPG stove cooking pot with water and rice inside was measured before and after cooking. Similarly, quantity of LPG gas consumed was measured using digital display balance. For electricity consumption by electric rice steamers, there is separate wattmeter installed with each electric rice steamer. The difference in kWh is noted in log book to find out the electricity consumption. The quantity of rice added and water in electric rice steamer is measured using electronic display mechanical balance.

3.1.2 Collection of Secondary Data

The secondary data required for the research study was obtained from reliable previous publications/works which includes books, journal articles and conference proceedings and presentation.

Above data collection method focuses on quantifying LPG usage and electric rice steamer performance, encompassing factors such as quantity of rice and water, energy consumption, and cooking time. Performance measurement of both the LPG stove and Rice Steamer involves evaluating parameters like thermal efficiency, specific energy consumption, cooking consistency, and thermal insulation. Financial analysis, employing metrics such as NPV and Payback Period, sheds light on the economic aspects. Further enhancements to the Rice Steamer's performance are explored, including techniques like presoaking rice and timer-based cut-offs. The study concludes with deductions drawn from the analysis and comprehensive documentation for the final presentation. The following flowchart is used to study the performance and financial analysis of LPG and electric rice steamer.

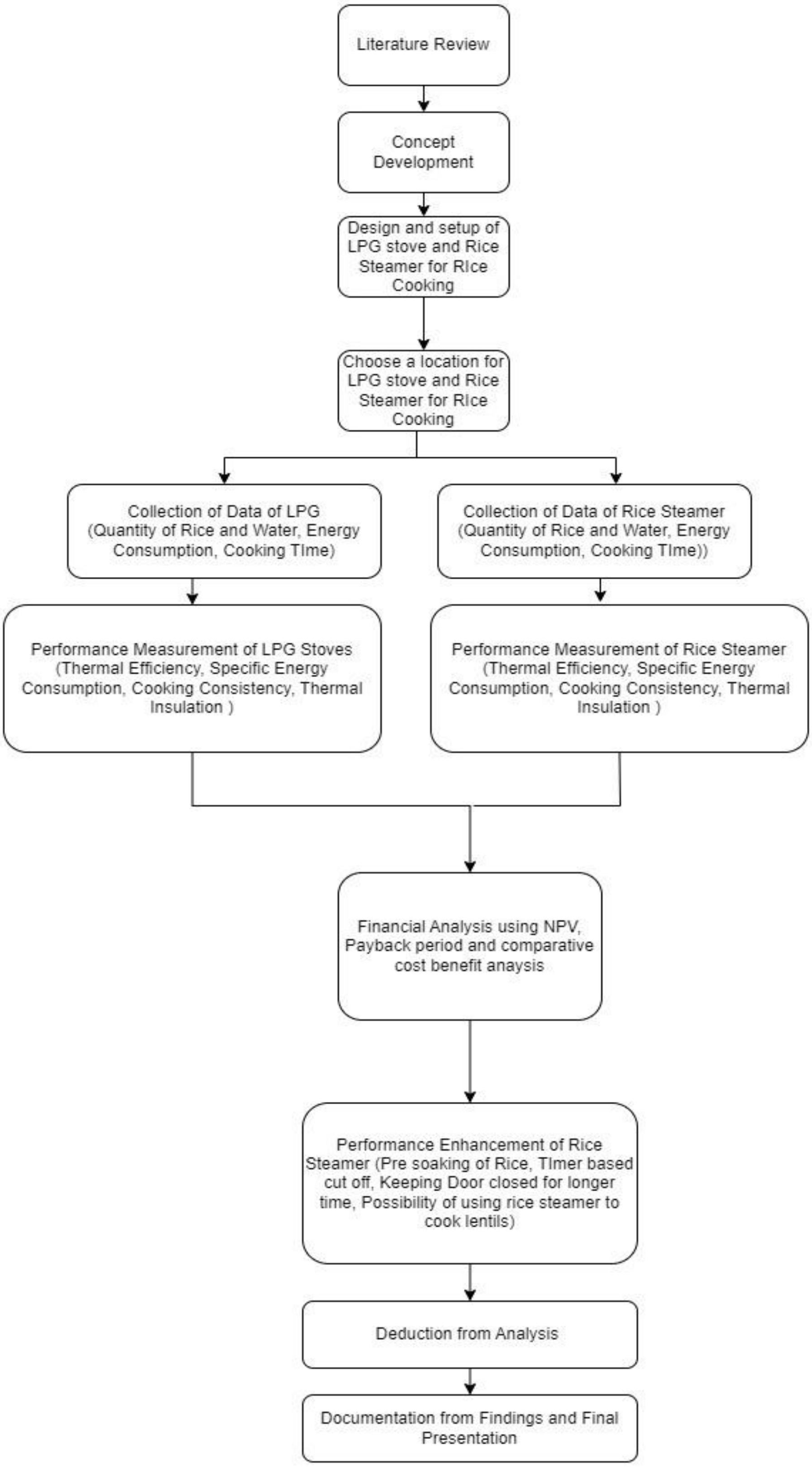

Figure 9: Research Methodology Flowchart

3.1.3 Performance Measurement Criteria

After the collection of primary and secondary data, the following energy efficiency metrics paramter were calculated: The following performance criteria were used to study the performance of LPG stove and Electric Rice Steamer for rice cooking:

1. **Cooking Characteristics**
    a. Cooking Time
    b. Cooking Consistency and Taste
2. **Energy Efficiency**
    c. Specific Energy Consumption (SEC) of rice cooking
    d. Energy Specific Cost (ESC) of rice cooking in the electric rice steamers.
    e. Thermal Efficiency using water boiling test
3. **Appliance Dimensions**
    f. Capacity and size
4. **Convenience and Feature**
    g. Keeping Warm
    h. Ease of use
    i. Human Resource Required
    j. Safety features
5. **Additional Functionality**
    k. Additional usages

A) Specific Energy Consumption (SEC) of rice cooking

The quantity of energy consumed by the appliance per unit mass of rice cooked is called the Specific Energy Consumption (SEC) of that appliance. It has the unit J/Kg rice or kWh/kg rice. The SEC value for each type electric rice steamer would be calculated by using the following formula.

$$\text{SEC of electric rice steamer} = \frac{\text{Total Energy Cosumed in particular cooking(J or kWh)}}{\text{Total mass of rice cooked(kg)}}$$

The SEC value would be calculated separately for each cooking set up of the same appliance. Thereafter, the SEC values would be averaged as the simple arithmetic mean to get the unique value for an appliance. Hence, different appliance would have different but unique SEC values. These SEC values would be compared to observe the energy economy of the same genre of appliances considered. This may also be considered as another reliable performance measurement parameter.

Each appliance would be analyzed separately for each cooking to evaluate the total energy consumed in particular cooking (J or kWh) and the total mass of rice cooked (Kg) for cooking the rice in the following format.

Table 2: Experimental data of LPG Stove Rice Cooking

Experimental data of LPG Stove Rice Cooking			
Date (YY/MM/DD)		**Quantity of rice cooked (Kg)**	**Quantity of LPG gas consumed (Kg)**
Total			
LPG consumed per kg of rice (Kg/Kg of rice)			

For Electric Rice steamer and LPG stove:

Table 3: Specific Energy Consumption Calculation for Rice Cooking

SN.	**Particular**	**Total energy consumed in particular cooking, J or kWh (A)**	**total mass of rice cooked (kg) (B)**	**Specific Energy Consumption, J or kWh/Kg rice (C=B/A× 100%)**	**Remarks**
1	Cooking experiments no 1				
2	Cooking experiments no ..				
Average SEC Value					

Subsequently, the comparison table and charts would be generated to have a quick overview and draw the conclusion in the following format.

Table 4: Comparison of Specific Energy Consumption for Electric Rice Steamer and LPG Stove

SN.	**Particular**	**SEC, J or kWh/kg rice**	**Remarks**
1	Electric Rice Steamer		
2	LPG Stove		

B) Energy Specific Cost (ESC) of rice cooking in the electric rice steamers.

The Energy Specific Cost (ESC) rice cooking is very much similar to the SEC of an appliance except that total cost of energy is used instead of total energy in the formula of SEC.ESC would be expressed in Rs/Kg rice for the sake of convenience and easy of understanding. This would be calculated using the following formula

ESC of electric rice steamer (Rs/Kg) = SEC (kWh/kg) ×Unit Cost of Electricity (Rs/kWh).

The ESC value would be calculated after getting the unique value of SEC for an appliance. Similar to the SEC value, each appliance would have separate and unique ESC value thus may also be considered as another reliable performance measurement parameter for an appliance. It is more convenient to use ESC value to compare one genre of appliance to another genre of appliance used for the similar application. For example, Electric Rice steamer with LPG stoves where both of them are used for cooking rice. The ESC value comparison provides the comparative economy of the appliances.

The ESC value can be calculated once the SEC table for each appliance has been generated. This can be calculated as below from the SEC table by multiplying by the respective unit energy cost of electrical or LPG energy.

Table 5: Comparison of Energy Specific Cost for Electric Rice Steamer and LPG Stove

SN.	**Particular**	**SEC, J or kWh/Kg rice (A)**	**Unit cost of Energy, Rs/kWh (B)**	**Energy Specific Cost, Rs/Kg rice cooked (C=A×B)**	**Remarks**
1	Electric Rice Steamer				B= unit cost of electricity as per tariff scheme
2	LPG Stove				B= unit cost of LPG

C) Thermal Efficiency using water boiling test

Table 6: Thermal Efficiency using water boiling test

Thermal Efficiency of LPG cooking		
Particular	**Unit**	**Values**
Wt. of Pot (Aluminum)	Kg	
Wt. of water	Kg	
Wt. of LPG cylinder (21.9 +22.25+24.4)	Kg	

Thermal Efficiency of LPG cooking		
Particular	**Unit**	**Values**
Temperature of Pot + Water	C	
Start time	Hrs.	
Temperature of Pot + Water	C	
Wt. of LPG cylinder (21.75+21.91+23.25)	Kg	
Finish Time	Hrs.	
Specific Heat Capacity of Water	KJ/Kg/C	
Specific Heat Capacity of Aluminum	KJ/Kg/C	
Calorific Value of LPG	KJ/Kg	
Heat Delivered by LPG	KJ	
Heat Absorbed by water	KJ	
Thermal Efficiency	**%**	

3.2 Comparative study of the electric rice steamers and LPG stoves.

The different values of SECs, ESCs and other parameter mentioned in above table are calculated in the above sequence are compared in this section. The SECs values would be compared among the same category appliance, while ESCs values would be used to compare different category appliances. This comparison is done in extracting the comparative performance economy of the appliances among themselves while using for the same rice cooking purpose.

Table 7: Comparison Table based on Specific Energy Consumption and Energy Specific Cost

SN.	Particular	SEC value of cooked Rice(kWh/kg)	ESC value of cooked Rice (Rs/kg)	Remarks
1	Electric Rice Steamer			
2	LPG Stove			

3.3 Financial analysis of the electric rice steamers.

For the financial analysis, a Cost-Benefit analysis of the system was conducted, comparing the Payback Period, Net Present Value and relative Cost- Benefit Analysis for the different cooking technologies. This financial assessment involved a comparison between the Electrical rice steamer system and the existing LPG stove system currently in use for daily cooking purposes. The evaluation includes considering the capital investment cost as well as the ongoing operation and maintenance cost for the utilization of these systems, taking into account their effective life cycle.

CHAPTER FOUR: RESULTS AND DISCUSSION

In this chapter, the results obtained after processing the collected data according to the adopted thesis methodology are presented, and a necessary discussion of the results are also provided. The results of thermal efficiency computed for the LPG stove and the Electric Rice Steamer are included, along with a description of their significance. Similarly, the results observed with NPV analysis and the payback period are also mentioned.

4.1 Performance Measurement Criteria

The following performance criteria were used to study the performance of LPG stove and Electric Rice Steamer for rice cooking:

6. **Cooking Characteristics**
   a. Cooking Time
   b. Cooking Consistency and Taste
7. **Energy Efficiency**
   c. Energy Consumption
   d. Thermal efficiency
8. **Appliance Dimensions**
9. Capacity and size
10. **Convenience and Feature**
    f. Keeping Warm
    g. Ease of use
    h. Human Resource Required
    i. Safety features
11. **Additional Functionality**
    j. Additional usages

4.2 Performance Measurement of LPG Stoves

4.2.1 Cooking time

During the experimental LPG stove cooking, the cooking time is calculated from the moment water starts heating after turning on the LPG stove to untill the stove is switched off. It was observed that the water started to boil within approximately 30 to

35 minutes. Subsequently, presoaked rice (soaked for about 15 minutes) was added to the cooking pot. After boiling the rice in water for an additional 10 to 15 minutes, the LPG stove was switched off. The cooking pot, moved by two individuals, was then used to drain the excess water using a jute cloth. Afterward, it was left undisturbed for around 10 minutes before becoming ready to be consumed. Thus, the total cooking time was approximately 50 minutes.

Figure 10: LPG stove cooking setup

Figure 11: LPG stove gas supply

4.2.2 Cooking Consistency and Taste

Rice cooking was not consistent and there were the cases of over cooking of rice at the bottom of the cooking pot.

4.2.3 Specific Energy Consumption

Table 8: Experimental Data on LPG Stove Rice Cooking

Experimental data of LPG Stove Rice Cooking			
Date (YY/MM/DD)		Quantity of rice cooked (Kg)	Quantity of LPG gas consumed (Kg)
4/24/2080	Evening	26	3.1
4/25/2080	Evening	28	3.5
4/26/2080	Evening	27	3.3
4/27/2080	Evening	26	3.15
4/28/2080	Evening	25	3.05
4/29/2080	Evening	27	3.41
4/30/2080	Evening	29	3.23
4/31/2080	Evening	30	3.43
Total		**218**	**26.17**

Experimental data of LPG Stove Rice Cooking		
Date (YY/MM/DD)	**Quantity of rice cooked (Kg)**	**Quantity of LPG gas consumed (Kg)**
LPG consumed per kg of rice (Kg/Kg of rice)	**=26.17/218**	**0.12**

When we divide the LPG consumed (26.17 kg) by the rice cooked (218 kg), we obtain the LPG consumption per kilogram of rice (0.120 kg/kg of rice). Considering the calorific value of LPG as 46600 KJ/kg, the Specific Energy Consumption for LPG stove rice cooking in the experimental setup is calculated as 5594.13 KJ/kg of rice. Taking the price of an LPG cylinder (14.2 kg) as Rs. 1800, the Energy Specific Cost of LPG stove rice cooking in the experimental setup is Rs. 15.21 per kilogram of rice.

4.2.4 Thermal Efficiency using Water Boiling Test

In Nepal, there are no codified standards specifically established for testing the thermal efficiencies of cooking stoves. For LPG cooking stoves, thermal efficiencies are assessed using the Boiling Test, a method based on Indian Standards (IS) 4246:2002. However, slight variations are incorporated to align with the actual cooking setup used in the context.

The LPG cooking stove is connected to the LPG supply pipeline, which is linked with three LPG cylinders, and pressure is controlled by a pressure regulator. Only one burner was used for testing the cooking stove. The aluminum cooking pot (14.69 kg, diameter 560 mm, height 350 mm) was utilized. The cooking pot, along with its cover, had a mass of 14.69 kg, and 80 kg of water was measured and poured into the cooking pot. The water was stirred well, and when the temperature became constant, it was measured using a Pt 100 thermostat connected to a digital display unit. The temperature was verified using an industrial thermometer and an infrared temperature gun. The initial masses of all three LPG cylinders were measured and noted. The gas supply was turned on and ignited. The water was warmed up to 80°C, and for uniformity in temperature, stirring was initiated before turning off the LPG supply. The final masses of all three LPG cylinders were measured and noted. The following pictures depict the setup for the LPG stove cooking.

Figure 12: Weighted dry rice in aluminum cooking pot

Figure 13: LPG Cylinder measurement

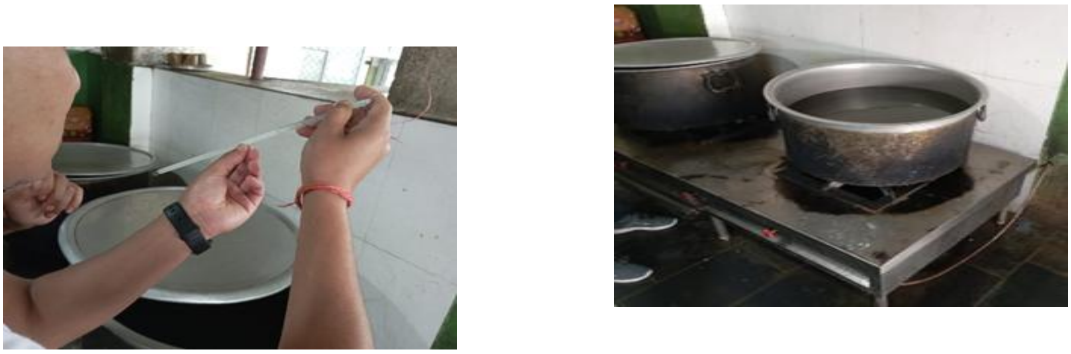

Figure 14: Experimental test set up for LPG stove cooking

The Table 9 displays the collected data and the calculation of the thermal efficiency of the LPG stove cooking setup. This experiment is computed based on the actual LPG gas consumption observed during the real cooking process.

$$\eta = \frac{[(M_w \times S_w + M_{Al} \times S_{Al}) \times \Delta T]}{1000000}$$

where, M_W = Mass of Water (Kg)

S_W = Specific Heat of Water (KJ/Kg/C)

M_{Al} =Mass of Aluminum (Kg)

S_{Al}= Specific Heat of Aluminum (KJ/Kg/C)

Table 9: Thermal Efficiency of LPG Cooking

Thermal Efficiency of LPG cooking		
Particular	**Unit**	**Values**
Wt. of Pot (Aluminum)	Kg	14.69
Wt. of water	Kg	80
Wt. of LPG cylinder (21.9 +22.25+24.4)	Kg	68.55
Temperature of Pot + Water	C	25.8
Start time	Hrs.	08:58:00
Temperature of Pot + Water	C	90
Wt. of LPG cylinder (21.75+21.91+23.25)	Kg	66.91

Thermal Efficiency of LPG cooking		
Particular	**Unit**	**Values**
Finish Time	Hrs.	09:28:00
Specific Heat Capacity of Water	KJ/Kg/C	4.182
Specific Heat Capacity of Aluminum	KJ/Kg/C	0.89
Calorific Value of LPG	KJ/Kg	46600
Heat Delivered by LPG	KJ	76424
Heat Absorbed by water	KJ	22318.10922
Thermal Efficiency	**%**	**29.20%**

The thermal efficiencies of LPG cooking stoves on the market, as determined by an experimental study conducted at IIT Guwahati, ranged from 67 to 69% (Pantangi, Kumar, Mishra, & Sahoo, 2007). Although the observed thermal efficiency appears to be lower than anticipated, it is important to note that this experiment was conducted in a real-world setting. In the context of traditional cooking, the efficiency of cooking is typically between 15 and 25 percent (Jyeshtharaj B. Joshi, 2012). Throughout the experiment, there were no alterations made to the cooking pot, burner, cooking stove, pot placement, flame control, flame stability, or type of LPG, maintaining close proximity to real-life conditions. The losses in the setup may be attributed to the following reasons:

a) **Flame control and flame stability** :Excessive flames were observed extending beyond the cooking pot, prompting kitchen staff to ensure that the flame emanated from the base of the pot during cooking. The flame stability faced challenges due to gusts of air in the semi-open space where the cooking setup was situated.

b) **Cooking Pot**: The cooking pot had a flat bottom, and it was made of aluminum, a good thermal conductor. However, there were layers of deposited smoke on the bottom, which might have hindered efficient heat transfer from the flame to the rice.

c) **Burner and Incomplete combustion**: The size and design of the burner, along with potentially clogged burner holes and gas leaks to the air, could contribute to heat loss. The presence of dark smoke deposits on the cooking pot suggests that, at times, the oxygen supply might not have been sufficient, leading to incomplete combustion.

d) **Extended Cooking Time and Boil Over**: One observation in this study was that the food was cooked for a longer time than necessary. Before Placing the rice into boiling water, it was noticed that the water was boiled for a longer duration than required.

e) **Maintenance**: Regular cleaning and maintenance are performed on the stove's burners, gas lines, and other components, and the focus is on operational functionality rather than optimizing energy efficiency.

f) **Additional factors**: Various others factors like LPG gas composition, LPG loss to air from small hairline cracks in pipelines, humidity etc may be contributing to heat loss.

4.2.5 Capacity and Size

The dimensions of the LPG stove are 56 inches in length, 26 inches in width, and 20 inches in height, and it features two cooking burners. The cooking pot has a diameter of 56 cm and a height of 35 cm.

Figure 15: Aluminum cooking pot with cover

The cooking pot has a maximum capacity of 35 kg of rice. Typically, it is utilized for cooking between 25 kg to 30 kg of rice. For instances where more than 35 kg of rice needs to be cooked, a new cooking session is required. Depending on the quantity of additional rice to be prepared, either a pressure cooker (with a capacity up to liters) or the same cooking pot is used.

4.2.6 Keeping Warm

There was no insulation to keep the cooked rice warm in the cooking pot. As a result, the cooked rice would cool down after some time.

4.2.7 Ease of Use

The cooking area is warm and humid. Moving around 125 kg (water 80 kg, rice 30 kg, cooking pot 14.68 kg) of the cooking pot to drain excess water when the rice is about to be cooked requires extra caution.

4.2.8 Human Resource Required

The cooking process demands significant human effort. Tasks such as carrying around 125 kg of the cooking pot from the LPG stove to drain excess water, regular stirring during rice cooking, and washing the cooking pot require substantial human resources. For this calculation, two persons are required as human resource, and thirty percent of their cost is allocated to rice cooking.

4.2.9 Safety Features

For safety precautions, the LPG cylinders are kept outside, and LPG gas is brought inside using a gas pipe. Handling boiling water and removing excess water when rice is boiling for 10 to 15 minutes requires extra precaution.

4.2.10 Additional Usages

The LPG stove is not only used for cooking rice but also for preparing/frying vegetables, dal, curry, etc. Therefore, there is no need to discard the LPG stove after introducing the Electric Rice Steamer, given its multiple uses. It can serve as a backup arrangement in the absence of electricity.

4.3 Performance measurement of Electric Rice Steamer

4.3.1 Cooking Time

Table 10: Electric Rice Steamer Cooking Time

Date (YY/MM/DD)	Quantity of rice cooked (Kg)	Start Time (Power Switched on Time)	Closed Time (Power Switched OFF Time)	Cooking Duration
2080/05/22 (M)	52	7:30	8:30	1:00
2080/05/22(E)	25	15:10	16:10	1:00
2080/05/23 (M)	24	7:30	8:30	1:00
2080/05/23 (E)	26	15:10	16:10	1:00

Date (YY/MM/DD)	Quantity of rice cooked (Kg)	Start Time (Power Switched on Time)	Closed Time (Power Switched OFF Time)	Cooking Duration
2080/05/24 (M)	40	7:20	8:20	1:00
2080/05/24(E)	25	15:15	16:15	1:00
2080/05/25 (M)	42	7:30	8:30	1:00
2080/05/25 (E)	25	15:20	16:20	1:00
2080/05/26 (M)	40	7:20	8:20	1:00
2080/05/26(E)	35	15:10	16:10	1:00
2080/05/27 (M)	35	7:30	8:30	1:00
2080/05/27 (E)	20	15:00	16:00	1:00

4.3.2 Cooking Consistency and Taste

Rice cooking was consistent and there was no over cooked rice at the bottom of the cooking pot. Manual stirring was not required for obtaining cooking consistency. While surveying with 10 persons as shown in APPENDIX A, they replied that the taste, texture of the rice cooked using electric rice steamer was far better than rice cooked from LPG stove.

4.3.3 Specific Energy Consumption by the Electric Rice Steamer

Table 11: Calculations for Specific Energy Consumption and Energy Specific Cost of Electric Rice Steamer

Date (YY/MM/DD)	Quantity of rice cooked (Kg)	Starting Unit (kWh)	Closing Unit (kWh)	Units of electricity consumed (kWh)	Remarks
2080/05/22 (M)	52	31	57	26	2 chamber, 2x12 KW heater
2080/05/22(E)	25	57	66	9	1 chamber, 1x12 KW heater
2080/05/23 (M)	24	66	75	9	1 chamber, 1x12 KW heater
2080/05/23 (E)	26	75	87	12	2 chamber, 2x12 KW heater
2080/05/24 (M)	40	87	105	18	2 chamber, 2x12 KW heater
2080/05/24(E)	25	105	116	11	1 chamber, 1x12 KW heater
2080/05/25 (M)	42	116	133	17	2 chamber, 2x12 KW heater
2080/05/25 (E)	25	133	144	11	1 chamber, 1x12 KW heater
2080/05/26 (M)	40	144	164	20	2 chamber, 2x12 KW heater
2080/05/26(E)	35	164	182	18	2 chamber, 2x12 KW heater
2080/05/27 (M)	35	182	198	16	2 chamber, 2x12 KW heater
2080/05/27 (E)	20	198	207	9	1 chamber, 1x12 KW heater
Total	**389**			**176**	
Daily Consumption (Average Value)	**64.83**			**29.33**	
Monthly Consumption	1944.9			880.00	

Calculations including the Electricity Demand Charge				
Total Monthly Rice, Kg	**Electricity (KWh)**	**Unit Electricity Price (Rs) (Ashad-Mangsir)**	**Electricity Demand Charge (Rs)**	**Monthly Electricity Charge (Rs)**
1944.9	880	10.5	1800	**11040.00**

Calculation based on monthly rice cooking and monthly electricity consumption		
Electricity Consumed per Kg of rice cooked	0.45	**kWh/kg Rice**
Specific Energy Consumption (SEC) of Steamer Cooking	1628.79	**kJ/kg Rice**
Energy Specific Cost (ESC) of Steamer Cooking	5.68	**Rs/kg Rice**

From Table 11, the monthly electricity consumption (880 kWh) is multiplied by the unit electricity price (Rs. 10.5) and the Monthly Demand charge (Minimum Rs. 1800 for 3 phases, greater than 10 amp). This gives the monthly electricity charge (Rs. 11040). When the monthly electricity charge is divided by the monthly rice cooked, we get electricity consumed per kilogram of rice (0.45 kWh/kg of rice). Taking the conversion factor from kWh to kJ as 3600, we get the Specific Energy Consumption (1628.79

KJ/kg of rice) of the Electric Rice Steamer for rice cooking in the experimental setting. Considering the per-unit electricity price as Rs. 10.5 and the monthly demand charge as Rs. 1800, the Energy Specific Cost of Electric Rice Steamer cooking in the experimental setup was Rs. 5.68 per kilogram of rice.

4.3.4 Thermal Efficiency Using Water Boiling Test

The testing procedures are outlined in <GB 12021.6-2008>, which is referred to as the "minimum allowable values of energy efficiency for an automatic electric rice cooker." It adopts thermal efficiency as the primary energy efficiency parameter. The test procedure begins with ensuring that the water temperature is equal to ambient temperature. The heating process is then continued until the water temperature precisely reaches the threshold of 90 °C, at which point the power is cut off. The water temperature may briefly rise further due to delayed heat transfer, and the achieved maximum water temperature is recorded.

For electricity consumption by electric rice steamers, a separate wattmeter is installed with each electric rice steamer. The difference in kilowatt-hours (kWh) is noted in a logbook to determine the electricity consumption. The quantity of rice and water added to the electric rice steamer is measured using an electronic display mechanical balance.

Table 12: Thermal Efficiency using rice-steamer set up

Thermal Efficiency for electric steamer		
Particular	**Unit**	**Values**
Wt. of water	Kg	30.8
Initial reading on the electric-meter	kWh	238.2
Temperature of Pot + Water	C	29
Start time	Hrs.	14:02
Temperature of Pot + Water	C	95
Final reading on the electric meter	kWh	240.3
Finish Time	Hrs.	1415
Specific Heat Capacity of Water	KJ/Kg/C	4.182
Difference in reading on the electric-meter	kWh	2.1
Heat Delivered by electric steamer	KJ	7560
Heat Absorbed by water	KJ	8501.17
Thermal Efficiency	**%**	88.93

Figure 16: Manually filling water for the water boiling test

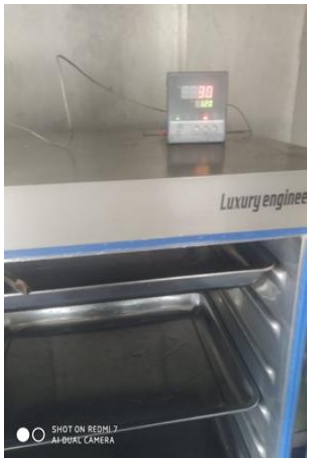

Figure 17: Temperature Measurement at top tray (using PT 100 Thermocouple)

4.3.5 Insulation Testing

In contrast to the conventional cooking, the rice steamers are also utilized to maintain the warmth of cooking for a prolonged time .The capacity of the steamer to maintain the warmth in rice is accounted by the insulation property of the steamer system .The insulation testing is done by simple method of measuring temperatures against various steps of time after the completion of cooking .

shows the readings of temperature vs time for observing the insulation property of the steamer system.

4.3.6 Capacity and Size

The Rice Steamer was equipped with three 4 kW steel heating rods in one compartment, featuring two separate compartments with individual doors. The total power capacity was 24 kW, and the outer dimensions measured 139 cm x 58 cm x 153 cm. The cooking pot's capacity reached a maximum of 100 kg of rice when utilizing both compartments. Based on the rice cooking needs, if the rice quantity was less than 50 kg, only one compartment (12 kW) was utilized, effectively increasing the maximum cooking capacity at one time to 120 kg from the 35 kg achievable with an LPG stove.

4.3.7 Keeping Warm

The Rice Steamer is equipped with all-around insulation, specifically polyurethane foam as specified in the specifications, ensuring a minimum heat-preserving time of 3 hours. The cooking downtime was determined through a process where the single cabinet of the rice steamer was filled with 25 kg of water, following its optimum water level. A Pt 100 thermostat was positioned inside the cabinet on the top tray, while the remaining tray was removed, and the door was closed. The initial temperature was 28 °C, and upon switching the power ON, the temperature began to rise. It reached 95 °C after 12 minutes. When the temperature on the digital display hit 95 °C, the power was switched OFF, yet the temperature continued to rise until 97 °C. The starting time was recorded when the water reached 95 °C and the power was switched OFF. The subsequent graph illustrates the temperature cooling pattern over 3 hours, with the temperature at the top of the rice steamer cabinet measured at 77 °C after this period.

In practical use, operators frequently open the door to retrieve cooked rice from the rice steamer. This leads to a rapid decrease in temperature, but operators make an effort to keep the door closed to ensure that the rice remains warm for those who come later.

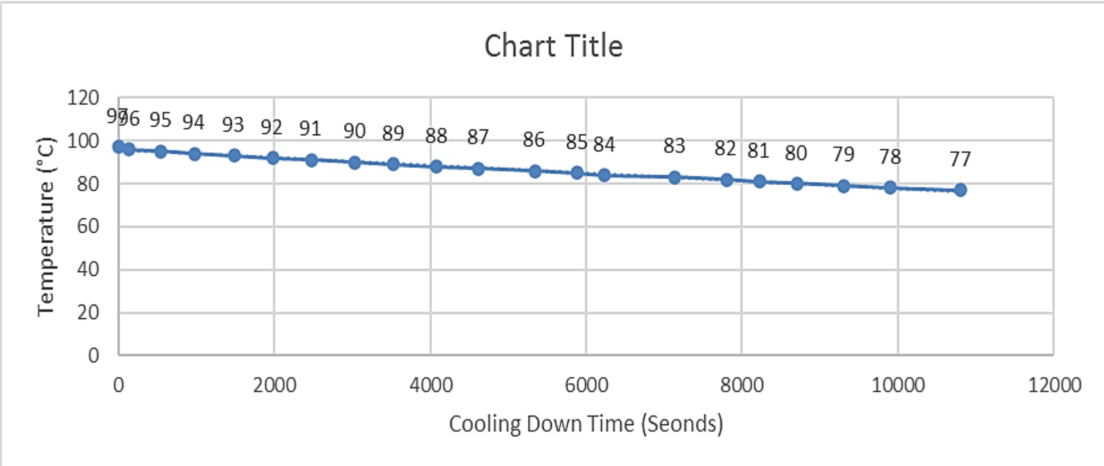

Figure 18: Variation of temperature with cooling down time

4.3.8 Ease of Use and Human Resource Required

The cooking process requires minimal human effort, and a single operator can easily complete all the rice cooking tasks.

4.3.9 Safety Features

For safety precautions, the Rice Steamer is equipped with a pressure gauge and a relief valve (0.2 MPa). However, operators were not familiar with how to read the pressure gauge. The relief valve serves more as an indicator of rice cooking progress. When a large volume of steam starts coming out from the relief valve, the operator switches OFF the power.

4.3.10 Additional usages

Currently, the rice steamer is exclusively used for cooking rice. Operators are not aware of additional uses, such as steaming potatoes and lentils, with the rice steamer.

4.3.11 Comparision of Performance Metrics of Cooking Technologies

Table 13: Performance Metrics Comparision of Cooking Technologies

Parameter	LPG Stove set up	Electric Rice Steamer set up
Specific Energy Consumption (kJ/Kg Rice)	5594.130	1752.45
Energy Specific Cost (Rs/Kg Rice)	15.21	5.11
Cooking Time	50 minutes	45 minutes
Thermal efficiency	29.20%	88.93%
Capacity and size	35 kg/shift	100 kg
Cooking Consistency	uneven, more water content	evenly cooked, better in taste
Warm Keeping	no insulation	insulation, warm for 3 hours
Ease of use	Comparatively difficult	Easier
Human Resource Required	More	Less
Safety features	LPG fire safety required	Electric safety required
Additional usages	used for frying, cooking curries	could be used for lentils and boiling potatoes

The Table 13 illustrates a comprehensive comparison between the LPG Stove and Electric Rice Steamer setups across multiple parameters. The Electric Rice Steamer outperforms the LPG Stove in terms of specific energy consumption, with significantly lower figures (1752.45 kJ/Kg Rice compared to 5594.13 kJ/Kg Rice for LPG). Additionally, the energy-specific cost is substantially lower for the Electric Rice Steamer (Rs 5.11/Kg Rice) compared to the LPG Stove (Rs 15.21/Kg Rice). The Electric Rice Steamer also exhibits advantages in cooking time, thermal efficiency, capacity, and cooking consistency, providing evenly cooked rice with better taste. With insulation for warmth retention and ease of use, requiring fewer human resources, and offering safety features, the Electric Rice Steamer proves to be a more efficient and user-friendly alternative, making it a favorable choice over the LPG Stove.

CHAPTER FIVE: FINANCIAL ANALYSIS

5.1 Financial Analysis

Financial analysis assesses the viability, stability, and profitability of a business or any project. In this study, a financial analysis is conducted to compare the Net Present Value (NPV) of the investment made in LPG stoves and Rice Steamer over a period of 10 years. Additionally, as part of the financial analysis, a cost-benefit analysis of replacing LPG with the Rice Steamer is also carried out.

5.2 LPG Stove cooking Annual Projection

The assumed sustainability life of the LPG stove is 10 years, with a discounted rate of 8%. Maintenance of three LPG gas cylinders is required for the operation of the LPG stove. The calculation is based on cooking for a hundred persons per day using the same cooking pot and stove for cooking 70 kg of rice, as the cooking capacity of the pot is 20 to 30 kg per shift. The cost of the cooking pot is Rs 5,000, and the cost of the cooking stove is Rs 10,000. Table 14 illustrates the total investment cost, which is Rs 23,600.

5.2.1 Investment Cost

Table 14: Total Investment Cost

Particulars	Quantity	Units
Stock Cylinder to be maintained	3	Cylinder
Cost per cylinder empty	1200	Rs/Cylinder
No of Cooking Pot required	1	Pcs
Price of Cooking Pot (used repeatedly)	5000	Rs/Cooker
Stove required (used repeatedly)	1	Stoves
Cost per Stove	15000	Rs/Stove
Total cost of cylinder	3600	Rs
Total Cost of Open cookers	5000	Rs
Total Cost of Stoves	15000	Rs
Total Investment Cost	23600	Rs

The calculated value of LPG consumed per kilogram of rice cooking is taken as 0.12 kg per kilogram of rice. The cost of a 14.2 kg LPG gas cylinder is considered as Rs 1400, and the deposit charge for one empty cylinder is Rs 1200. The operator and cleaner cost per person is taken as Rs 17,300 (Minimum salary of the Nepal Government). The number of people required for preparation, cooking, and cleaning the stove and cooking pot is assumed to be two persons, and 30% of their cost is allocated for rice cooking as they are also involved in other cooking activities. The annual maintenance cost is taken as 5% of the investment cost. Table 15 illustrates the total operation and maintenance cost to be Rs 516,266.45 per year.

5.2.2 Operation & Maintenance Cost (Annual)

Table 15: Operation and Maintenance Cost (Annual)

Particulars	Quantity	Units
Manpower Required for LPG Cooking and cleaning	2	People/day
Daily Manpower Cost (30% allocated to rice cooking)	346.000	Rs/day
Annual LPG Consumption	3067.17	Kg/Year
Annual Maintenance cost (% of Initial Investment)	5	%
Annual LPG Cost	388796.45	Rs/Year
Annual Manpower Cost	126290.00	Rs/Year
Annual Maintenance Cost	1180.00	Rs/Year
Total O&M Cost	516266.45	Rs/Year

Based on the above total investment cost and total O&M cost, the calculated yearly cash flow and NPV Calculation is shown in Table 16.

5.2.3 Yearly Cash Flow and NPV

Table 16: Annual cash flow and NPV

Year	Investment Cost, Rs	O&M Cost, Rs	Yearly Discounted cash flow, Rs
0	-23600	0	-23600
1	0	-516266.453	-478024.49
2	0	-516266.453	-442615.27
3	0	-516266.453	-409828.95
4	0	-516266.453	-379471.25
5	0	-516266.453	-351362.27
6	0	-516266.453	-325335.43
7	0	-516266.453	-301236.51
8	0	-516266.453	-278922.70
9	0	-516266.453	-258261.75
10	0	-516266.453	-239131.25
	Total NPV		**-3487789.92**

Based on the above facts, assumptions, and available data, the NPV value of LPG cooking, including the cost of investment, operation, and maintenance, is calculated and found to be Rs -3,487,789.92.

5.3 Rice Steamer cooking Annual Projection

The assumed sustainability life of the Rice Steamer is 10 years, with a discounted rate of 8%. The calculation is based on cooking for a hundred persons per day, and one Rice Steamer can cook 70 kg of rice, considering the cooking capacity of the cooking pot as 120 kg per shift. Table 17 illustrates the total investment cost, which is Rs 167,000.

5.3.1 Investment Cost

Table 17: Total investment cost for rice steamer cooking

Particulars	Quantity	Units
Rice Steamer required	1	Set
Cost per Steamer	142000	Rs/Set
Installation Cost	25000	Rs
Total Investment Cost	167000	Rs

The electricity cost per kWh is taken as Rs 10.5 per kWh, and the electricity demand cost for 3-phase, greater than 10 amps, is considered as a minimum of Rs 1800. The electricity consumption per kg of rice cooking is 0.423 kWh/kg of rice. For cooking 100 persons (at 700 grams each), the electricity consumed per day is 29.584 kWh/day. The cost of Steamer Cooking per day is Rs 371.9. The operator and cleaner cost per person are taken as Rs 17,300 (Minimum salary of the Nepal Government). The number of people required for preparation, cooking, and cleaning the stove and cooking pot is assumed to be two persons, and 30% of their cost is allocated for rice cooking as they are also involved in other cooking activities. The annual maintenance cost is taken as 5% of the investment cost, resulting in a total operation and maintenance cost of Rs 187,028.9 per year, as shown in Table 18.

5.3.2 Operation and Maintenance Cost (Annual)

Table 18: Operation and Maintenance cost for a rice-steamer

Particulars	Quantity	Units
Manpower Required for Steamer Operation	1	People/day
Daily Manpower Cost (30% rice cooking)	173.00	Rs/day
Annual Electricity Consumption	11559.89	Kg/Year
Annual Maintenance cost (% of Initial Investment)	1.50%	
Annual Electricity Cost	121378.92	Rs/Year
Annual Manpower Cost	63145.00	Rs/Year
Annual Maintenance Cost	2505.00	Rs/Year

Particulars	Quantity	Units
Total O&M Cost	187028.92	Rs/Year

5.3.3 Yearly cash flow and NPV

Based on the above total investment cost and total O&M cost, the calculated yearly cash flow and NPV Calculation is shown in Table 19.

Table 19: Yearly cash flow and NPV for rice steamer cooking

Year	Investment Cost, Rs	O&M Cost, Rs	Yearly Discounted cash flow, Rs
0	-167000	0	-167000.00
1	0	-187028.920	-173174.93
2	0	-187028.920	-160347.15
3	0	-187028.920	-148469.59
4	0	-187028.920	-137471.84
5	0	-187028.920	-127288.74
6	0	-187028.920	-117859.94
7	0	-187028.920	-109129.58
8	0	-187028.920	-101045.91
9	0	-187028.920	-93561.02
10	0	-187028.920	-86630.58
	Total NPV		**-1421979.28**

Based on the above facts, assumptions, and available data, the NPV value of Rice Steamer cooking for the 10-year sustainability of the cooking apparatus, including the cost of investment, operation, and maintenance, is calculated and found to be Rs. -1,421,979.28. From the individual NPV calculations, it can be concluded that steamer cooking is more feasible compared to LPG cooking, as the NPV of steamer cooking is less negative than that of LPG cooking.

5.4 Relative Cost Benefit Analysis

A relative benefit-cost analysis is conducted, where the costs and benefits of using the steamer over LPG cooking are calculated on a yearly basis throughout the 10-year sustainability of the cooking arrangements. In the initial year, the cost of using the steamer over LPG cooking is higher due to the dominance of the steamer's initial cost. However, in subsequent years, a significant yearly benefit is claimed by steamer cooking over LPG cooking, attributed to the less costly operation and maintenance of the steamer compared to the LPG cooking apparatus. These relative figures of yearly costs and benefits are tabulated in Table 20 for the sustainability period of 10 years. The ratio of the cumulative benefits to cost yields 15.4, indicating that the replacement of LPG cooking by steamer cooking is highly beneficial.

Table 20: Relative cost benefit analysis of choosing steamer over LPG open cooking

Year	Steamer Over LPG Open Cooking	
	Relative Discounted Cash flow	**Cost, Benefit**
0	-143400.00	Cost
1	304849.57	Benefit
2	282268.12	Benefit
3	261359.37	Benefit
4	241999.42	Benefit
5	224073.53	Benefit
6	207475.49	Benefit
7	192106.94	Benefit
8	177876.79	Benefit
9	164700.74	Benefit
10	152500.68	Benefit
Total	2065810.64	Benefit
Total Cost		143400.00
Total Benefit		2209210.64
Benefit-Cost Ratio		**15.40**

5.5 Payback period calculation

In this thesis, the simple payback period method is employed to calculate the payback period for replacing LPG gas with the electric rice steamer. The cost of replacing LPG gas with the electric rice steamer is determined by considering the following cash flows.

Table 21: Calculation of Payback period for LPG stove and Rice steamer

	LPG Stove	**Rice Steamer**	**Difference of Rice steamer compared to LPG Stove**
Total Investment Cost (Rs)	23600	167000	-143400
O&M Cost (Rs)	516266.453	187028.92	329237.533
$Payback\ Period = \frac{143400}{329237.533} \times 12 = 5.22$ months			

The above payback analysis is carried out to find out payback period of using steamer over LPG cooking. The payback period of 5.22 months indicates that the replacement of LPG cooking by Steamer cooking is highly beneficial.

CHAPTER SIX: BETTER COOKING PRACTICES (DESIGN AND OPERATION)

6.1 Determining Better Cooking Practices

6.1.1 Cooking based on time-duration

While observing the cooking process using rice steamers, it was noticed that the operator had to manually switch off the MCB when steam whistles started coming out from the safety pressure release port. This led to unnecessary electricity consumption by prolonging the cooking time.

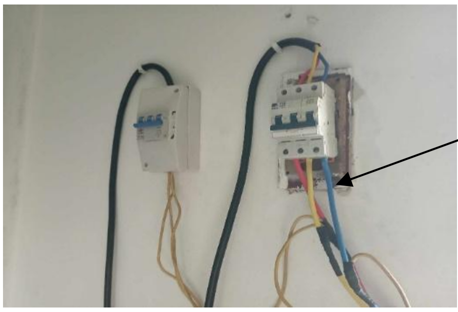

Figure 19: MCB of Rice steamer

6.1.2 Cooking with pre-soaking about 30 minutes

While observing the rice cooking process using rice steamers, it was noticed that the operator did not presoak the rice for the recommended 30 minutes. The time duration for the rice cleaning process, loading the rice into the steamer, and the moment when the rice came in contact with water until the operator switched on the power was about 5 to 6 minutes. Providing proper instructions for presoaking the rice for 30 minutes could easily reduce the overall cooking time

6.1.3 Observed losses due to opening the door immediately after power switched-OFF

It was observed that the rice steamer door was being opened once the operator switched off the power source. This led to the loss of heat present in the food that could have been used for further cooking. Rice cooking was being done with very little rice soaking time.

6.1.4 Cooking using the heat inside the rice steamer (food and water)

To improve the cooking process, the following changes were implemented:
The time between the rice coming in contact with water during rice cleaning, setting in the panel, and then switching ON the power was maintained at 25-30 minutes (presoaking).

The electricity was supplied for 45 minutes. The MCB switch was turned OFF after 45 minutes, but the door was not opened for an additional 15 minutes. This was done to utilize the heat of the rice and steam inside the rice steamer for cooking. Since the Rice Steamer is well-insulated, the temperature drop was minimal. By adopting this strategy, the power-ON time was reduced by 15 minutes.

Table 22: Using heat inside food and cabinet to reduce switched-On time

Date (YY/MM/DD)	**Quantity of rice cooked (Kg)**	**Start Time (Power ON)**	**Power Off Time**	**Door Opened Time**	**Power Consumed**	**Cooking Duration (with 15 minutes cooking with heat inside) (Hour)**
2080/05/28(M)	32	7:15	8:00	8:15	19	1:00
2080/05/28(E)	24	15:10	15:50	16:10	10	1:00
2080/05/29 (M)	52	7:30	8:15	8:30	24	1:00
2080/05/29 (E)	20	15:10	15:55	16:10	8	1:00
2080/05/30(M)	24	7:20	8:05	8:20	10	1:00
2080/05/30(E)	26	15:15	16:00	16:15	12	1:00
2080/05/31(M)	40	7:30	8:15	8:30	18	1:00
2080/05/31(E)	24	15:20	16:05	16:20	10	1:00
2080/06/01 (M)	40	7:20	8:05	8:20	18	1:00
2080/06/01(E)	36	15:10	15:55	16:10	16	1:00

This established that the performance of the Rice Steamer could be further enhanced by presoaking the rice for the recommended 30 minutes and by not opening the steaming cabinet immediately after the power is switched OFF. There is further scope for determining the optimum water level at the bottom and the process of water mixing with the rice.

6.1.5 Use of rice steamer to boil lentils

Currently lentil (7 kg) was cooked in low flame for about 2 and half hours. Then a broad base wooden stick was used to beat continuously for some smashing the soft lentil. It used more heat energy, muscle power and using more time.

It was observed that the second most energy consuming during cooking in barrack was cooking lentils. Since, lentils minimum cooking temperature is much higher (94 ⁰C) than rice (74 ⁰ C), the lentil cooking seems to take longer times. So, heat loss was much more in LPG cooking.

Based on the minimum cooking temperature of lentils which is greater than 94 °C and for duration. (Jyeshtharaj B. Joshi, 2012) Rice Steamer was experimented to boil lentils. There are three 4000 KW electrical heater situated inside the water at bottom of the rice steamer. The steam coming out after being heated first heats the bottom tray and the steam further moves up heating the remaining upper trays. The upper most tray gets heated at the last. Therefore, the bottom tray was selected to boil the lentils. It was found that lentil could be boiled in the rice steamer thereafter it could be cooked in existing pressure cooker with required spices and water reducing the LPG consumption (further study could be conducted).

Figure 20: Lentils steaming at the bottom tray of Rice steamer

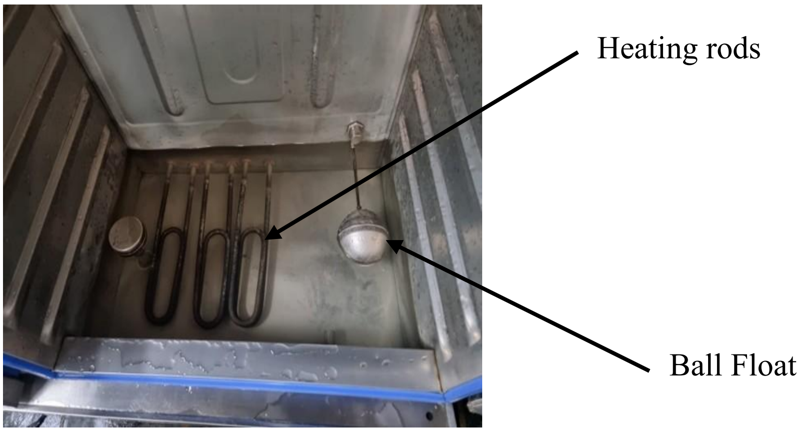

Figure 21: Heating rod, ball float (3 Nos X 4 kW)

6.2 Determining betterment in Design

6.2.1 Time based auto Switched OFF

From the beginning of this experiment, it became apparent that there should be an auto Switched OFF system in the Rice Steamer. The experiment was conducted in two ways, with the researcher using a stopwatch to measure cooking time. There is further scope for studying time-based cooking with the steamer. The existing Rice Steamer could be enhanced by incorporating a simple time-based auto-switched-off system for more efficient cooking.

6.2.2 Temperature based auto Switched OFF

The following circuit was tested during the experiment. There is further scope of study in this area.

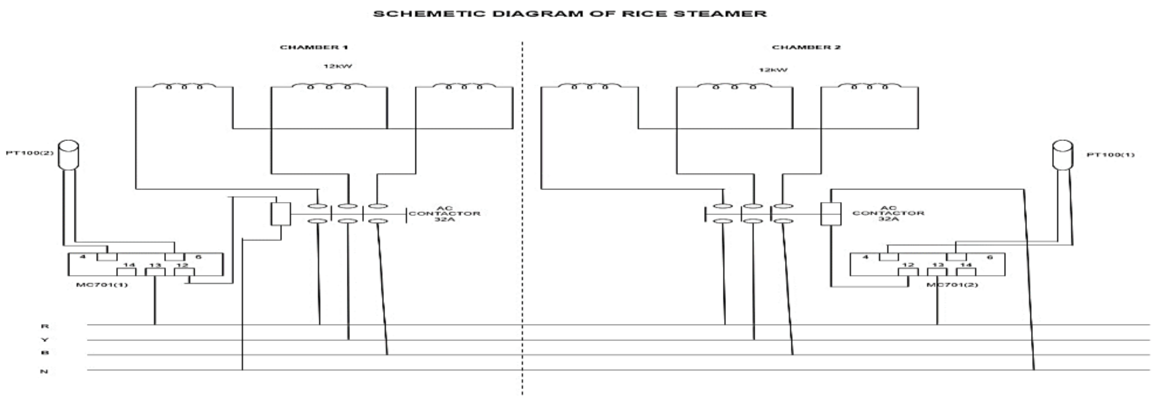

Figure 22: Schematic diagram of Rice Steamer for auto switched OFF

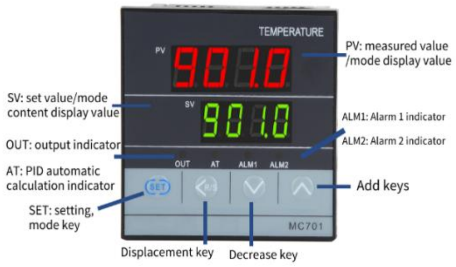

Figure 23: Selected thermostat MC701

6.2.3 Controlled Cooking (between 98° C and 90° C)

A controlled cooking trial was conducted by switching OFF the power when the temperature at the topmost tray reached 98 °C and switched on whenever the temperature fell below 90 °C. The Pt 100 sensor was placed at the top tray during the experiment. This control method can be achieved using a thermostat such as MC701, as mentioned earlier. Another option involves switching OFF one or two of the three 3kW heating rods after the temperature at the top tray reaches 98 °C. This showed a decrease in the switched-on time, but design modification requires further research. During the controlled cooking trial, the power was switched OFF whenever the temperature at the topmost tray reached 98 °C and switched on whenever the temperature fell below 90 °C (sensor position at the top tray).

Figure 24: Sensor Position during controlled cooking

6.2.4 Other needed design improvements

During the experiments, some of the following design improvements were observed that seemed necessary for local conditions.

a. Descaling vessel for heating rod and floating rod
b. Clear vertical water level indicator instead of water pressure dial gauge
c. Alarm system when water level is below heating rods.
d. Some electronic built in sensors to enhance the efficiency of the Rice Steamer.
e. Energy Efficiency rating system for domestic and foreign manufacturer of rice steamers (including rice cooker) should be introduced.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

From this study, a comprehensive analysis of replacing LPG cooking stoves with electric rice steamers for rice cooking across multiple parameters. The Electric Rice Steamer outperforms the LPG Stove in terms of specific energy consumption, with significantly lower figures (1752.45 kJ/Kg Rice compared to 5594.13 kJ/Kg Rice for LPG). Additionally, the energy-specific cost is substantially lower for the Electric Rice Steamer (Rs 5.11/Kg Rice) compared to the LPG Stove (Rs 15.21/Kg Rice). The thermal efficiency of electric steamer is also found to be higher in comparision to the LPG stoves, the food can be stored for longer period. Similarly, the cost of steamer cooking is only 35 percent of that of LPG cooking per kg of rice cooked. The insulation test of rice steamer showed that it took over 3 hours to cool down from 95°C to 77 °C when the the rice steamer door is not opened. The survey found that the food test was preferred more by the consuers.

Based on the individual NPV calculations, it can be concluded that the steamer cooking is more feasible as compared to LPG cooking. The ratio of cumulative of cost and benefits analysis yields 15.4 indicating that the replacement of LPG cooking by Steamer cooking is highly beneficial.

Based on this definition, it is quite justifiable to use rice steamers for cooking processes compared to LPG stoves despite their high initial cost. In long term effect, the advantage gained through rice-steamer far outweighs the LPG stoves. The Electric Rice Steamer also exhibits advantages in cooking time, thermal efficiency, capacity, and cooking consistency, providing evenly cooked rice with better taste. With insulation for warmth retention and ease of use, requiring fewer human resources, and offering safety features, the Electric Rice Steamer proves to be a more efficient and user-friendly alternative, making it a favorable choice over the LPG Stove.

7.2 Recommendations:

Adoption of Electric Rice Steamers: Considering the positive outcomes in terms of energy efficiency and cost benefits, it is recommended to adopt electric rice steamers for rice cooking, particularly in settings with high rice consumption, such as in Nepali army's facilities. It is also recommended that the existing LPG stoves should be kept as back up for conditions such as power system failure for longer duration.

Promotion of Sustainable Cooking Practices: The study emphasizes the importance of promoting sustainable cooking practices, aligning with Nepal's commitment to zero carbon emissions. Encouraging the use of electric rice steamers contributes to achieving these environmental goals.

Further Research on Cooking Technologies: As technology evolves, continuous research on cooking technologies and their efficiency should be conducted. This ensures that the most sustainable and cost-effective solutions are implemented.

Government Support and Policy: Policymakers should consider providing support and incentives for the adoption of energy-efficient cooking technologies. Government initiatives can play a crucial role in facilitating the transition to more sustainable practices.

Awareness and Training Programs: Initiatives to raise awareness among users and provide training on the efficient use and maintenance of electric rice steamers should be implemented. This ensures optimal performance and longevity of the cooking appliances.

It was observed that the cooking using electric rice steamers, it seemed that some essential automation features in design and operating procedures were lacking.

The performance of the electric rice steamer could be enhanced by incorporating some design and operational practices. It was observed that the operator had to manually switch off the MCB switch when the steam whistle started from the safety pressure release port, leading to unnecessary electricity consumption by cooking for extra minutes than required. Therefore, further study is needed to include simple features like a time-based auto power-off switch, a clear vertical water level indicator, and some modifications to the electrical circuit to enhance the efficiency of the Electric Rice Steamer.

By implementing these recommendations, there is an opportunity to not only enhance the efficiency and sustainability of cooking practices but also contribute to the overall environmental goals and economic well-being.

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APPENDIX: A

1. How often do you consume rice?

Daily	
Several times a week	
Once a week	
Rarely	

2. Have you noticed any difference in taste or texture when rice is cooked using an electric rice steamer compared to other methods?

Yes	
No	
Not sure	

3. If yes, how would you describe the taste and texture of rice cooked by an electric rice steamer?

Better	
Similar	
Worse	

4. Considering your experience, would you recommend using electric rice steamers for rice cooking to others?

Yes	
No	
Undecided	

5. Please share any additional comments or observations you have regarding your experience with rice cooked by an electric rice steamer.

APPENDIX: B

THERMAL EFFICIENCY TEST

F-1 PROCEDURE

F-1.1 The test shall be carried out by weighing the gas used. The gas shall be taken from a small bottle containing LPG weighing 1 kg to 2 kg. The bottle shall be fitted with an 'On/Off' valve and shall be connected to a regulator which, in turn, shall be connected to a pressure gauge and to the appliance. A second 'On/Off' gas valve shall be inserted in the gas ways upstream of the regulator as near as possible to the gas bottle. A typical layout of set-up necessary for this test is shown in Fig. 4.

F-1.2 The gas shall be passed at 2942 kN/m^2 (30 gf/cm^2) inlet pressure through the stove for a few minutes to purge the system of air and to establish the gas pressure required. Only one burner of the appliance shall be tested at a time and during the test all gas delivered to the stove shall flow through the jet of the burner being tested. The pan shall be selected and loaded in accordance with the requirements given in Table 1 and placed centrally over the burner being tested. The temperature of the water t_1 contained shall be noted and recorded as long as it remains constant. The bottle shall be disconnected, weighed, reconnected and valves (1) and (2) opened. The gas control tap shall then be opened and the gas shall be ignited. The water shall be allowed to warm up to about 80 °C when stirring is commenced and continued until the end of the test. The burner shall be put off when the temperature of water reaches 90 °C ± 1 °C. The stirring shall be continued and the maximum temperature t_2 shall be noted.

Next, the valves on the bottle and the gas line shall be closed and the bottle shall be disconnected and re-weighed. It is thus possible to estimate the mass of gas used during the period taken for the water to heat up. Thermal efficiency shall be calculated by the following formula:

$$E = \frac{100\,(G+W)\,(t_2 - t_1)}{MK}$$

where

E = thermal efficiency of the burner in percent,

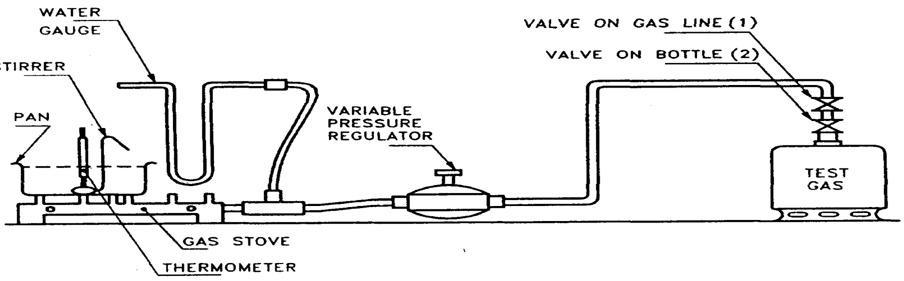


FIG. 4 TEST SET-UP FOR THERMAL EFFICIENCY BY WEIGHT

G = quantity of water in the vessel in kg,

W = water equivalent of the vessel complete with stirrer and lid,

t_2 = final temperature of water in °C,

t_1 = initial temperature of water in °C,

M = gas consumption in kg, and

K = calorific value of the gas in kcal/kg.

Table 1 Aluminium Pans for Thermal Efficiency Test

(*Clauses* 25.2 *and* F-1.2)

Gas Rate at STP l/h (1)	Pan Diameter (External) mm ± 5% (2)	Pan Height (External) mm (3)	Total Pan Mass with LID g ± 10% (4)	Mass of Water in Pan kg (5)
Up to 40	180	100	356	2.0
41-50	205	110	451	2.8
51-60	220	120	519	3.7
61-70	245	130	632	4.8
71-80	260	140	750	6.1
81-95	285	155	853	7.7
96-107	295	165	920	9.4

NOTES

1 Distilled water (*see* IS 1070) shall be used for test.

2 The pan shall be cylindrical with flat bottom.

3 The finish of the pan bottom from inside shall always be bright.

4 Above 107 l/h, pans shall be specially constructed to conform, as far as possible, with the principles used in formulating this table.

F-2 In performing the thermal efficiency test, the following points shall be noted:

a) The set-up shall be carefully checked for leak, before and after the test. If a leak is found after the tests, the results should be cancelled and the test repeated.

b) The room shall be free from draught.

c) The initial temperature of the room shall be between 25 °C and 30 °C. The water temperature shall be within ± 2 °C of the actual room temperature.

d) The net calorific value of gas is used. If this is not determined experimentally, the value may be taken as 10 900 kcal/kg for calculation.

e) At the start of the test, the burner shall be at room temperature.

f) The temperature of the water shall be measured by means of a mercury-in-glass thermometer of accuracy of 0.5 C the bulb of which is immersed to half the depth of the water in vessel.

g) Stirring shall be effected by means of a horizontal loop of 3 mm metal rod attached to an upright, which passes through a 6 mm, hole drilled in lid.

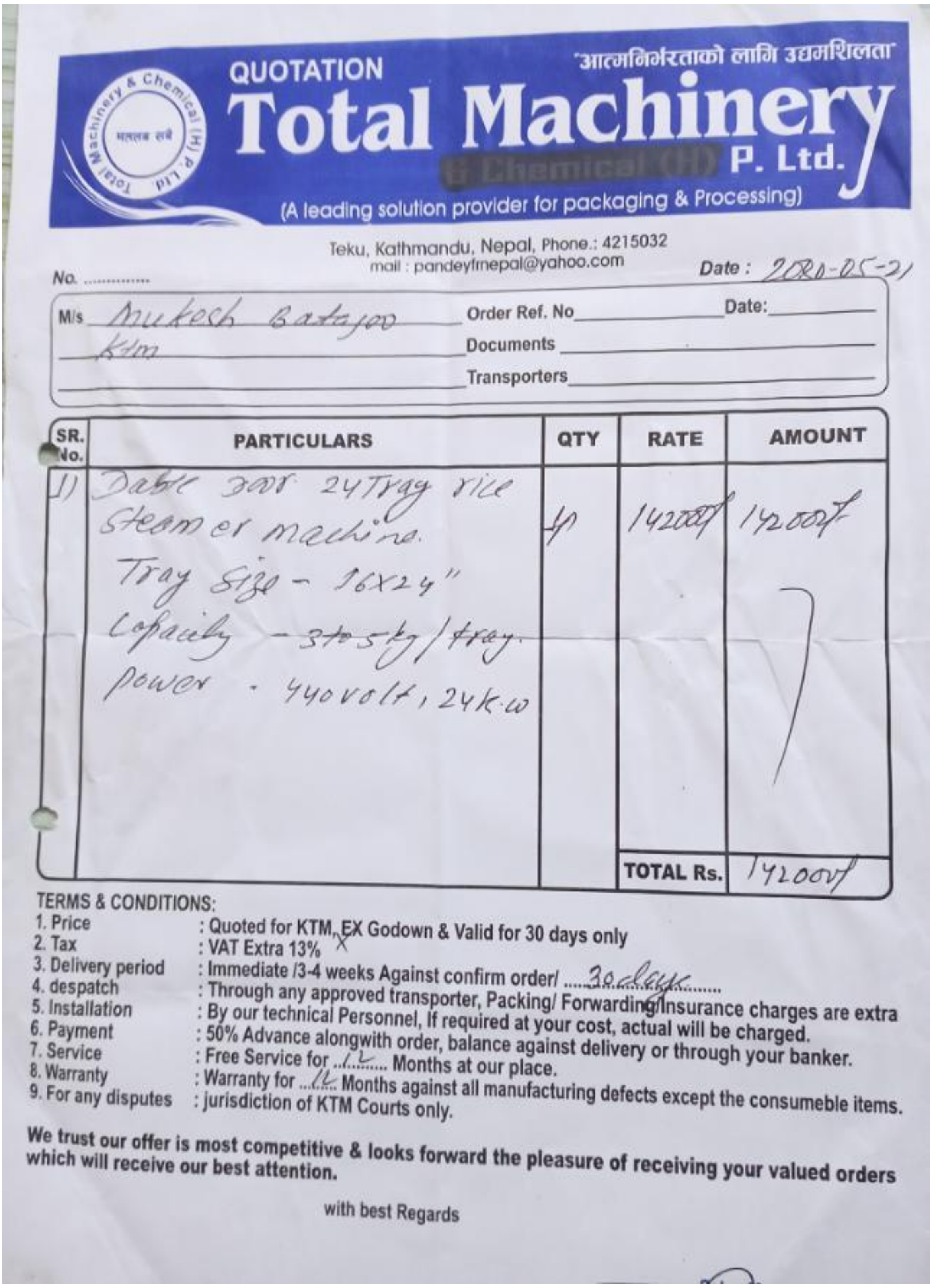
h) This test need not be performed on burners with a gas rate of less than 20 l/h at 2 942 kN/m^2 (30 gf/cm^2) inlet pressure.

j) Accuracy of weighing balance used shall be of 0.1 g for consumption measurement and 1 g for the other weights.

k) Specific heat of aluminium is 0.214.

m) For conducting thermal efficiency test, gas from the commercial cylinder (bottle) of LPG, the first two-thirds of which has been allowed to evaporate (to waste or in vapour withdrawal use), the remaining one-third shall be used for test. The use of last 1 or 2 kg of gas shall be avoided as this may contain heavy ends.

APPENDIX: C
QUOTATION OF RICE STEAMER



QUOTATION

'आत्मनिर्भरताको लागि उद्यमशिलता'

Total Machinery [redacted] **P. Ltd.**

(A leading solution provider for packaging & Processing)

Teku, Kathmandu, Nepal, Phone.: 4215032
mail : pandeyfmepal@yahoo.com

No. .... Date : 2080-05-21

M/s Mukesh Batajoo
Ktm

Order Ref. No________ Date:________
Documents________
Transporters________

SR. No.	PARTICULARS	QTY	RATE	AMOUNT
1)	Dable door 24Tray rice Steamer machine. Tray Size - 16x24" Capacity - 3to5kg/tray. power - 440volt, 24k.w	1p	142000/-	142000/-
			TOTAL Rs.	142000/-

TERMS & CONDITIONS:

1. Price : Quoted for KTM, EX Godown & Valid for 30 days only
2. Tax : VAT Extra 13%
3. Delivery period : Immediate /3-4 weeks Against confirm order/ ....30 days........
4. despatch : Through any approved transporter, Packing/ Forwarding/Insurance charges are extra
5. Installation : By our technical Personnel, If required at your cost, actual will be charged.
6. Payment : 50% Advance alongwith order, balance against delivery or through your banker.
7. Service : Free Service for ..12..... Months at our place.
8. Warranty : Warranty for ...12.. Months against all manufacturing defects except the consumeble items.
9. For any disputes : jurisdiction of KTM Courts only.

We trust our offer is most competitive & looks forward the pleasure of receiving your valued orders which will receive our best attention.

with best Regards

APPENDIX: D
TEST PROCEDURES AND STANDARDS
GB 12021.6-2008

The testing procedures and MEPS are included in <GB 12021.6-2008>, which is called "minimum allow- able values of energy efficiency and energy efficiency grades for automatic electric rice cookers". <GB 12021.6-2008> adopts thermal efficiency (η) as the main energy efficiency parameter. It is used to set the MEPS and requirements of energy efficiency tiers of rice cookers. The thermal efficiency is the ratio between thermal energy taken by the food and the input energy. Water has been adopted as the me- dium to test and calculate the thermal energy taken by the food[5]. Actually, no rice is used for the ener- gy efficiency testing of the rice cookers.

The efficiency test is performed under the configuration of "standard rice cooking function". If the rice cooker is multi-functional, the test is performed by the most efficient cooking function indicated in the instruction manual provided by the manufacturer. Tap water is filled up to 80% of the inner pot volume. The temperature of the water should be equal to ambient temperature before starting the test proce- dure.

The cooking cycle is then initiated until the water temperature reaches exactly the threshold of 90°C, at which the power is cut off. The temperature of the water continues to rise for a short period due to the delay in heat transfer to the water. The achieved maximum water temperature is then recorded. The thermal energy taken by the water is calculated according to the temperature rise. As the input power of the cooker is also measured during the heating process, the thermal efficiency can be calculated correspondently.

To measure warm-keeping energy consumption, the water is heated to 90°C in the same way as for the cooking test. The rice cooker is then switched to the keep-warm mode. The energy consumption is measured after 4 hours, 4.5 hours and 5 hours. Based on the three measured values, the average en- ergy consumption is calculated and adopted as the final warm-keeping energy consumption. During the test, the temperature of the test medium should be between 60°C and 80°C.

The standby energy consumption is the average energy consumption of the first 4 hours after the rice cooker is set in standby mode.

TEST PROCEDURES AND STANDARDS

ENERGY AUDIT GUIDELINE FOR DOMESTIC APPLIANCES (NEPAL)

Energy Audit Guidelines for Domestic Appliances

Annex 8: Data Collection and Calculation Sheet for Rice Cooker

Make	**Value**
Model	
Rated Volts, V	
Rated Current, A	
Rated power, Watts	
Measured Volts, V	
Measured Current, A	
Measured power, Watts	
Measured pf	
Time	
Measured energy in Wh = Measured power, Watts * Time in hours	

5. Test Methodology and Technical Standard

General

5.1 All test standards and specifications specified in this document are only related to checking compliance with the energy efficiency and general performance requirements. It is not the intention of this document to detail out the test standards and requirements for checking compliance with the Electrical Products (Safety) Regulation of the Hong Kong Special Administrative Region. The participant should conduct appropriate tests, where necessary, in addition to those specified in this document in order to obtain Certificates of Safety Compliance for his electric rice cookers.

Tests Required to be Carried Out

5.2 The tests for the aforementioned requirements in sections 6 should be carried out according to the test methods as specified in "GB 12021.6 - 2008 << 自動電飯鍋能效限定值及能效等級 >> Minimum allowable values of energy efficiency and energy efficiency grades for automatic electric rice cookers". If there is more than one type of inner pot, tests should be conducted for each type of inner pot test for the electric rice cooker. All the test results must be in compliance with requirements stated in sections 6.

Test Condition

5.3 During the tests described in clause 5.2, the electric rice cooker shall be tested at a voltage of 220V ± 1% and a frequency of 50Hz ± 1Hz. Unless the Director approves, the following test conditions must comply with –

(a) relative humidity : 45% ～ 75 % ;

(b) atmospheric pressure : 86 kPa ～ 106 kPa ;

(c) ambient temperature : 23°C± 2°C and without influence of air flow and heat radiation in the test venue.

Initial Test Conditions

5.4 Before each test, the inner pot, hot plate, electric rice cooker case and ambient temperature difference should not exceed 5°C, or electric rice cooker does not work at least 6 hours.

Heat Efficiency Test Method

5.5 The initial water temperature T_1 should be consistent with the ambient temperature. It is measured while the amount of water added to the inner pot using the weighing method is reached to 80% of its rated capacity. Without affecting the normal cooking state of the electric rice cooker, pass the thermocouple through the lid and fix the test point of the thermocouple within a diameter of 50mm from the centre point of the cylinder and at a distance of (10 ± 5) mm from the bottom of the inner pot. Supply mains electricity under the conditions specified in clause 5.3 and measure the energy consumption of the electric rice cooker with an energy meter.

Cut off the power supply immediately and read the energy consumption when the water temperature inside the pot reached 90°C. Due to the heat capacity of the heating element and the delay reason, the water temperature inside the pot will continue to rise after the power is turned off. Observe the water temperature inside the pot to drop and read the highest water temperature T_2. Calculate the heat efficiency with equation 1.

$$n = \frac{1.16G\,(T_2-T_1)\,*100}{E} \quad \text{.......................................} \quad \text{(equation 1)}$$

where

n = Heat Efficiency (%), accurate to one decimal place;

G = mass of water required for the test (kg);

T_1 = initial water temperature (°C);

T_2 = highest water temperature (°C);

E = energy consumption (W · hr) under the test.

Power Consumption for Warm-keeping Test Method

5.6 Heat up the inner pot after an amount of water equal to 80% of the rated capacity is added. Try to fix the test point within a diameter of 50mm from the centre point of the cylinder and at a distance of (10±5) mm from the bottom of the inner pot. When the water temperature reaches 90 °C, force the electric rice cooker into the warm-keeping mode and start to take record of the energy consumption. Measure water temperature values at the 4^{th} hour, the 4.5^{th} hour and the 5^{th} hour; three specific time hours respectively. Take the average of these three temperature readings as the warm-keeping temperature. During the test, the warm-keeping temperature must be between 60 °C to 80 °C. The power consumed during the 5 hours test period is hence measured for the derivation of the energy consumption for warm-keeping per hour.

Standby Energy Consumption Test Method

5.7 The energy consumed at a duration of 4 hours by the electric rice cooker at the standby mode is measured. The standby energy consumption per hour is calculated.

Performance and Financial Analysis of Replacing LPG Stoves by Electric Rice Steamers for Rice Cooking: A case study of Nepali Army

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