STUDY ON ENERGY CONSUMPTION AND GREENHOUSE GASES EMISSION PATTERN OF PROK VDC OF MANASLU CONSERVATION AREA

A DISSERTATION SUBMITTED TO CENTRAL DEPARTMENT OF ENVIRONMENTAL SCIENCE, TRIBHUVAN UNIVERSITY FOR THE PARTIAL FULFILLMENT OF REQUIREMENTS FOR MASTER'S DEGREE IN ENVIRONMENTAL SCIENCE

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Letter of Recommendation

This is to certify that **Mr. Sagun Parajuli** has completed this dissertation work entitled "**STUDY ON ENERGY CONSUMPTION AND GHGs EMISSION PATTERN OF PROK VDC OF MANASLU CONSERVATION AREA**" as partial fulfillment of the requirement for the completion offinal year of the Master degree in Environmental Science under my guidance and supervision.

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Certificate of Approval

This dissertation presented by Mr. **Sagun Parajuli** entitled "**STUDY ON ENERGY CONSUMPTION AND GHGs EMISSION PATTERN OF PROK VDC OF MANASLU CONSERVATION AREA**" has been accepted as a partial fulfillment of the requirement for the final year of Master degree in Environmental Science.

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I, hereby declare that this dissertation entitled **"STUDY ON ENERGY CONSUMPTION PATTERN AND GHGs EMISSION OF PROK VDC OF MANASLU CONSERVATION AREA "** is based on primary information, and all the sources of information used are duly acknowledged. This thesis work has not been submitted to any other university for any academic purpose.

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Abstract

Energy consumption pattern and greenhouse gases emission are interrelated. The intensive use of fossil fuels and unsustainable use of biomass resources are emitting greenhouse gases which are causing greenhouse effect in the earth's atmosphere resulting global warming.The objective of this study was to know the current energy consumption pattern and greenhouse gases emission of the study area. The study also aimed to analyze the status of renewable energy technology and its role in reducing the consumption of traditional energy resourcesas well as reducing greenhouse gases emission. Prok village development committee of Gorkha District was taken as the study area, which lies within Manaslu Conservation Area. Key informant interview, household survey and direct observatory technique were used for data collection.The total annual energy consumption by sampled households in the studied area was found to be 5747.678 GJ with the annual per capita energy consumption of 27.11169 GJ. Fuelwood, electricity, kerosene, solar and LPG were the energy sources of the area, of which fuelwood was found to be the major energy source providing 99.67% of the total energy. The highest greenhouse gases were emitted from fuelwood which was 519.156 tons. Micro-hydro, metallic improved cooking stoves and solar home systems were the renewable energy technologies used in the area. 80% of the sampled households were using micro-hydro as renewable energy technology followed by 25% metallic improved cooking stoves and 20% solar home system which has reduced or substituted 55.275 tones of fuelwood consumption. The comparative observation before improved cooking stoves use and after its use showed reduction of an average of 3 kg/day of fuelwood in the households having metallic improved cooking stoves as improved cooking stoves installed. The comparative observation between metallic improved cooking stoves and traditional cooking stoves showed metallic improved cooking stoves more efficient than traditional cooking stoves in terms of fuelwood use ($t=11.26$ at $p \leq 0.05$), indoor environment, space heating and stove handling. A significant amount of greenhouse gases emission was reduced after the use of renewable energy technologies in the study area, which were 84 tons of CO_2 equivalent. Therefore, the renewable energy technologies used in the study area had positive impacts i.e. they had either reduced or substituted fuelwood as an energy source ultimately contributing towards the forest conservation for carbon sink, hence mitigating climate change.

Key words: *Energy consumption pattern, greenhouse gases, renewable energy technologies, metallic improved cooking stoves*

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Sagun Parajuli

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Abbreviations and Acronyms

AEPC	Alternative Energy Promotion Centre
ARI	Acute Respiratory Infection
BSP	Biogas Support Program
CBS	Centre Bureau of Statistics
CDM	Clean Development Mechanism
CEN	Clean Energy Nepal
CES	Centre for Energy Studies
CF	Community Forest
CH_4	Methane
CO_2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CTR/N	Centre for Rural Technology, Nepal
DNPWC	Department of National Parks and Wildlife Conservation
GHG	Green House Gas
Gg	Giga gram
GJ	Giga Joule
GON	Government of Nepal
ha	Hectare
HH	Household
ICS	Improved Cooking Stoves
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IOE	Institute of Engineering
IUCN	International Union for Conservation of Nature
LPG	Liquefied Petroleum Gas
masl	Meters Above Sea Level
MCA	Manaslu Conservation Area
MCAP	Manaslu Conservation Area Project
MoPE	Ministry of Population and Environment
MoF	Ministry of Finance
MJ	Mega joules
MICS	Metallic Improved Cooking Stoves
MW	Mega Watt
PM	Particulate Matter
PV	Photo Voltaic
REDP	Rural Energy Development Program
RET	Renewable Energy Technology
RETRUD	Renewable Energy Technology for Rural Development
SETM	Sustainable Energy and Technology Management
SIDA	Swiss International Development Agency
TCS	Traditional Cooking Stoves
TU	Tribhuvan University
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat
WMO	World Meteorological Organisation

CHAPTER I
INTRODUCTION

1.1 Background

Energy is a prerequisite for the survival, development, and economic welfare of human beings. It is at the center of economic, environmental and development issues in the today's world. It is used almost for every purpose in daily life and therefore indicates level of development and standard of living.

Nepal being the developing country is in the state of economic development challenged by the growing population of the country. The population growth and highly required economic growth has resulted the ever increasing energy demand (ADB and ICIMOD, 2006). The energy situation in Nepal is characterized by its low conventional energy consumption (Lamichhane et al., 2009). Nepal's energy resources are presently classified into three categories namely the traditional, commercial and alternative (WECS, 2010).

The energy demand at present in Nepal is met by the uncontrolled use of commercial energy and unsustainable use of traditional energy sources which have direct impact upon the environment and natural resources. The increasing emission of GHGs has been seen as one of the major problem associated with this energy use pattern. The intensive use of fossil fuels and unsustainable use of biomass resources from human activities are emitting GHGs which are causing greenhouse effect in the earth's atmosphere resulting global warming process which in turn have resulted the climate change as indicated by various scientific studies (Shakya and Shrestha, 2006).

According to Technical Summary prepared by Barker et al., (2007) for IPCC showed rise in global GHG emissions since pre-industrial times. Emissions of GHGs covered under the Kyoto Protocol have witnessed an increase of about 70% during 1970 to 2004.According to the reportCO_2 is the largest source of GHG emissions. The CO_2 concentrations in the atmosphere have increased by almost 100 ppm since their pre-industrial level reaching 379 ppm in 2005. The total CO_2e of all long-lived GHGs is now about 455 ppm CO_2e.

According to the report submitted by MoPE (2004), gross CO_2 emission from the country was 24,525 Gg in 1994/95. However, due to the carbon sequestration from reforestation activities and the re-growth of natural vegetation on abandoned lands, net emissions of CO_2 was found to be 9747 Gg which is negligible as compared to global CO_2 emissions. Although, Nepal's total GHG is negligible, Nepal is already encountering some of the negative impacts of global climate change. According to the studies done by Department of Hydrology and Meteorology, the average temperature in Nepal is increasing at the rate of approximately 0.06^{o}C per year (Pokhrel, 2002). However, temperature at Himalayas in increasing at a faster rate causing serious impacts in terms of retreating glaciers and increased seasonal variations in river flow (CEN, 2002).

Forests play an important role in the global carbon cycle. They can be both sources and sinks of carbon, depending on the specific management regime and activities (IPCC, 2000), climate change mitigate through reducing GHG emission, increasing carbon sequestration and carbon substitution (Chand, 2011). All these activities are relevant with the forest as the Forest ecosystems store more than 80% of all terrestrial aboveground Carbon and more than 70% of all soil organic Carbon (Batjes, 1996; Jobbágy and Jackson, 2000; Six et al., 2002).

Fuelwood is the major source of energy for the majority of rural people which is extracted from forest. Fuelwood harvesting has been identified as one of the most significant causes of forest decline in rural areas of developing countries (Bhatt and Sachan, 2004). Fuelwood is the biggest energy resources in Nepal providing about 77% of the total energy demandexerting immense pressure on the forest resources (WECS, 2010). In this scenario, efforts and initiatives geared towards a sustainable alternative energy program seems crucial as a mitigating measure for the harmful effects derived from the excessive use of natural resources for energy (Thapa and KC, 2009).

Renewable energy is virtually uninterruptible and available infinitely because of its wide spread complimentary technologies fitting well into Nepal's need to diversify supply. It is environmentally friendly with reduced or negligible emission of GHGs as well as negligible impact on the natural environment. Pico-hydropower, micro-hydropower, solar photovoltaic energy, biogas and ICS are most important RET in the context of Nepal (Shakya and Shrestha, 2006). Therefore proper RET options are both mitigative and adaptive responses to climate change and the sustainable energy (Sharma, 2009).

1.1.1 Renewable energy sources and technologies in Nepal

Energy forms that are not conventionally used or which are new and renewable are considered alternatives or renewable energy. They include resources like solar, wind and geothermal power and newer technologies that improve use efficiency such as Biogas, ICS, Micro hydro and biomass briquettes (Amatya and Shrestha, 1998).

1.1.1.1 Biogas

Biogas is the methane rich gas produced by the digestion of animal, human and bio solid waste. Nepal has history of over 50 years of biogas technology development. The country saw first introduction of biogas digester in 1955. In 1975/76, the first biogas promotion programme was launched by the Government of Nepal (BSP, 2006). In Nepal, animal waste is mainly used for the production of biogas. In some places, plants are directly integrated with toilet to produce biogas.

The estimated total technical potential of biogas plants is about 1.9 million plants of which 1,000,000 plants are thought to be economically viable. As of December 2008/09, more than 2, 00,000 biogas plants of varying capacities (4, 6, 8, 10, 15 and 20 m3) have been installed (WECS, 2010).

1.1.1.2 Solar energy

Traditionally people have been using solar energy without any technological invention for domestic proposes. With the growing energy needs more efficient devices are being developed to utilize solar energy. Using solar energy for lightning house has become popular in Nepal since 1993. More than 2,600 units of Solar Home Systems (SHS) with a total generation capacity of about 100 KW have been installed in Nepal. On an average, there is more than 6.5 hours of sunshine per day. As per WMO the solar isolation intensity of Nepal is about 4.5 $Kw/m^2/day$ (Shrestha et al., 2003).

According to AEPC 2010, a total of 185,017 of solar home system have been installed throughout the country.

1.1.1.3 ICS

Improved cooking stove do not provide or utilize renewable energy as such but it is a technology which has potential to save fuelwood uses for households cooking in Nepal. Improved cook stove was first introduced in Nepal in early 1950s. Indian models ‘Hydarabad and Magan stoves’ were firstly promoted in Nepal. In 1960s, self construction approach of ICS with mud was extended as a part of village development under the Tribhuvan Gram Bikash Karyakram (SETM, 2008).

According to the report published by WECS 2010, the total ICS both metallic and mud by government as well as non-government organization was 61373.

1.1.1.3.1 Types of ICS

Mud Brick ICS

It is the most widely used ICS technology that uses clay, rice husk, dung and a few metal rods. The most common version is the one with two potholes. A baffle is used to direct the flame and hot air to the second pot. It is the well accepted technology that can be built locally with a low cost. It has the efficiency above 15% (SETM, 2008).

Metallic ICS

It is similar to improved mud stove but made from metal to allow space heating as well. Some models have three potholes as well as a slot for baking bread. Adjustable air vent in the main door allows regulation of air flow and damper in flue pipe allows transfer of heat efficiently towards cooking pots. Good for cooking, water heating and space heating up to 40% less fuel wood consumption make it very much suitable in the high hills where space heating during winter is most. Government subsidy for high hills (above 2000m VDCs) Rs. 2,700 for 2 pot hole and Rs. 4000 for 3 pot hole is available (SETM, 2008).

1.1.1.4 Micro-hydro power (MHP)

The report published by WECS (2010), reported that the hydro power stations for generation of mechanical and electrical energy up to a capacity of 100kw come under micro-hydro in Nepal. Till 2008/09, there were about 1977 micro-hydro (including Pico- hydro) electrification schemes installed in various part of the country with the total installed capacity of about 13.9 MW.

1.1.2 Environmental benefits of RET

In case of Nepal the RET based on the locally available resources with increased efficiency and environment-friendly alternatives seems very feasible for controlling GHG emission and protecting the environment. Meanwhile in Nepal the potential CDM projects could be implemented through RET like Micro-hydro, Solar PV, solar thermal, biogas, wind etc. and efficiency improvement projects like improved cook stove, gasifier, briquettes etc. At present two biogas project have been registered with CDM Executive Board on 27th December, 2005 and got approval for 93,883 tons of emission reduction per year. The agreement has been done with the World Bank for the sale of 1 million tons of GHG emission reduction at the rate of US$7/tones CO_2e (BSP, 2006). In order to obtain maximum benefit from the CDM, Nepal should conduct intensive study on the present status of GHG emission, potential CDM projects based on the RETs and other alternative options (WECS, 2010).

1.2 Statement of the problem

Energy is a crucial input into the development process. In a country like Nepal, where sustainable economic growth is necessary and population growth is high, energy demand will continue to rise in the years to come. The energy demand at present in Nepal is met by the uncontrolled use of commercial energy and unsustainable use of traditional energy sources which have direct impact upon the environment and natural resources. The increasing emission of GHG has been seen as one of the major problem associated with this energy use pattern. The intensive use of fossil fuels and unsustainable use of biomass resources from human activities are emitting GHG which are causing greenhouse effect in the earth's atmosphere resulting global warming process which in turn have resulted the climate change as indicated by various scientific studies (Shakya and Shrestha, 2006).

Forest ecosystems store more than 80% of all terrestrial aboveground Carbon and more than 70% of all soil organic Carbon (Batjes, 1996; Jobbágy and Jackson, 2000; Six et al., 2002). Out of the total energy demand in the year 2008/09, fuelwood provided about 77% of the total (WECS, 2010). The majority of the fuelwood is used to meet the household energy demand causing immense pressure to the forest resources. As a result, the percentage cover of forest is declining day by day from 45.5% in 1964 to 29% in 1994 (Acharya and Dangi, 2009). Forests are the major natural Carbon sink. In order to reduce the GHGs content in the atmosphere through the natural Carbon sink, conservation of forest is most which can be attained by reducing the dependency in fuelwood for energy by the adoption of suitable renewable energy technology. Manaslu Conservation Area being the rural mountainous area uses fuelwood energy as major energy source which may cause forest deterioration, therefore, decreasing amount of Carbon to be sinked. As RETs are environmentally friendly with reduced or negligible emission of GHGs as well as negligible impact on the natural environment (ShakyaandShrestha, 2006), this study attempts to assess the energy consumption pattern, status and the contribution of RET in reducing fuelwood consumption and its role in reducing GHGs emission.

1.3 Research question

This research was carried out in the Prok VDC of Manaslu Conservation Area, Gorkha district.

The study was based on following research question:

1. What are the types of energy sources used and GHGs emission from current energy consumption scenario in the study area?
2. What are the types of RETs of the study area?
3. Is there any significant difference in fuelwood consumption between TCS and ICS users?
4. Has RETs installed in the study area reduced GHGs emission?

1.4 Objectives of the study

The overall objective of the study was to find out the current energy consumption pattern and green house gases emission of the study area. The specific objectives of the study were as follows:

1. To study the current energy consumption pattern in Prok VDC.
2. To estimate GHGs emission from current energy consumption practices of Prok VDC.
3. To carry out the status of RET and to compare ICS and TCS in terms of amount of fuelwood consumption.
4. To estimate the GHGs emission reduction after the use of RET of the study area.

1.5 Scope of the study

Fuelwood is the major energy source in the rural areas of Nepal and is extracted from forests. Forests are the major natural Carbon sink. Forest ecosystems store more than 80% of all terrestrial aboveground Carbon and more than 70% of all soil organic Carbon (Batjes, 1996; Jobbágy and Jackson, 2000; Six et al., 2002). Therefore, reduction in fuelwood consumption can be attained by the adoption of suitable RET which in turn conserves the forest resources that eventually sequestrate Carbon which is major GHGs. Therefore, this study attempts to collect the data on the RET status and fuelwood consumption reduction after RET applications.

1.6 Overview of the contents

The final form of this report consists of seven main chapters along with additional supporting section like references and annexes.

Chapter I is the introductory and informatory sectionwhich includesthe background of the study, RETs in Nepal and environmental benefits of RETs. Further this chapter includes the objectives, statement of the problem and scope of the study and finally the overview of contents.

Chapter II includes reviews on literature. Literature on energy consumption of Nepal, fuel wood consumption pattern and ICS as RET were reviewed during this study.

Chapter III covers the detailed of methodology adopted for the research. It includes study area, research design, nature and sources of the data and methods of the data analysis.

Chapter IV presents the finding of the study. In this section the results are presented as according to the specific objectives. This includes specific findings on Energy consumption and GHGs emission pattern, status of RET and GHGs emission reduction after adopting RET.

Chapter V covers the discussion section. This includes the comparison of the result thus obtained with the result of related previous study and discussion on the result. The results on each specific objective are thus discussed.

Chapter VI includes finding, discussion and conclusions based on the present study. Finally few recommendations are also included in this chapter.

CHAPTER II
LITERATURE REVIEW

2.1 Energy consumption in Nepal

According to the report published by WECS, 2010, fuelwood is the biggest energy resources in Nepal providing about 77% of the total energy demand in the year 2008/09. Other sources of biomasses are agricultural residues and animal dung which contribute about 4% and 6%, respectively. Share of petroleum fuels in the total energy system is about 8%. This share is somehow similar with the past few years. Other sources of commercial energy are coal and electricity, both of which contribute about 4% in the total energy. The overall energy consumption of Nepal is mainly dominated by the use of traditional non commercial forms of energy such as fuelwood, agricultural residues and animal waste. The share of traditional biomass resources, commercial energy resources and renewable energy resources are 87%, 12% and 1%, respectively. The share of traditional fuel is decreased from 91% in 1995/96 to 88% in 2004/05 and to 87% in 2008/09. The remaining 13% of energy consumed is through commercial sources (Petroleum fuels, Coal and Electricity) and renewable supply.

Total energy consumption in the year 2008/09 was about 9.3 million tons of oil equivalent (401 million GJ) out of which 87% were derived from traditional resources, 12% from commercial sources and less than 1% from the alternative sources (WECS, 2010).

2.2 Fuelwood as a energy Source

Wells and Brandon (1992), Lama and Lipp (1994) and DNPWC (1999) had indicated biomass and forest resources are the important sources of household energy all over the world. About half of the world's households, mainly in developing countries use fuelwood. Different alternative energy sources to replace or reduce fuelwood use such as back-boilers, kerosene depots, small hydropower plants, solar water heaters, have been installed in Mountain areas of Nepal; and biogas, electricity, improved cook stoves, and solar power in the Terai. Studies show that these have reduced fuelwood consumption and thereby promoting increased conservation of forests and biodiversity.

Thakuri and Hada (2003), studied about the indoor air pollution and reduction effort in Gatlang VDC in Rasuwa. The community was completely depends on biomass fuel for cooking. They are using a very inefficient cooking stove consuming large amount of firewood. So the firewood consumption is very high i.e. the consumption of firewood per month is about 350 kg/HH in summer and about 450 kg/HH in winter season. The researchers reported that the indoor air pollution level is very high in those households which use biomass for cooking inefficient stove. This is the main factor for causing the various health problems like breathing problem, dry throat, wheezing and ARI in those households.

Bhattarai (2003), stated Nepal as one of the highest traditional fuel consuming country in the Asia because of its high dependency on traditional biomass fuels, mostly firewood and limited extent of charcoal and residues of crops and animals.

CBS (2003), stated the main source of energy of 94.1% rural household is firewood where as in urban areas the main source of energy are firewood, kerosene and other sources of commercial energy which account about 39%, 35% and 25% respectively.

Bhatta and Sachan (2004), analyzed the fuel wood consumption pattern for household along the altitudinal gradient in Garhwal Himalaya, Uttranchal. They found fuelwood consumption as 2.80, 2.00, 1.42, 1.10, and 1.07 kg/capita/day respectively, above 2000, 1500-2000, 1000-1500, 500-1000 and below500m altitude they mentioned that fuel wood consumption is affected by climate and season of the year. On average the firewood consumption was 2.0 to 3.0 fold higher in winter than in summer (considering 265 days as winter and 100 days as summer).

According to Starke (2004), in developing countries, wood is traditionally the main source of fuel for rural people who live adjacent to forest areas. About 2.50 billion people, mostly in Asia, use fuelwood or other biomass collected from forest for energy.

Rathore et al., (2004), studied the fuel and fodder consumption pattern according to socio-economic status (accessible to highway, annual income, literacy status and per capita income) in the Rui watershed of Jammu region; they found that occupation and annual income of the family did not significantly alter the fuel energy consumption pattern. However, literacy status of the family head was positively correlated with use of modern commercial energy sources.

WINROCK (2004), reported hill households in rural areas consume about 6 and 7.6 tons of firewood during summer and winter respectively, whereas, Terai households consumes about 3.7 tonnes and 5.4 tons of firewood in summer and winter respectively.

Neupane (2005), studied the Household energy consumption pattern in the rural area of Nepal in Dang, Hapur VDC. The study revealed that at Hapur VDC the consumption of fire wood dominated all for cooking purposes and kerosene and electricity for lighting purpose. The per capita fire wood, electricity and kerosene consumption was found to 719.5 kg, 33.5 unit and 66 L respectively

Thapa (2006), has reported about one billion people in Asia depend on biomass as the main source of energy. These biomasses are used in preparing food, animal feed, processing of 12 livestock products, agricultural and forest product processing, pottery, building materials, smiths and foundries, and various other rural industries and services along with space heating.

2.3 ICS as RET in Nepal

Suwal and Shrestha (1990), from the enquiries made in the 63 households in the Lumle Agricultural Centre Extension Command Area (ECA) showed that approximate average figure in the improvement in efficiency of fuel wood use could be more than one third by using the new stoves compared to traditional stoves.

Devkota (1993), explained that, an improved cooking stove is an alternate and efficient energy tool which uses the fuelwood efficiently. It was revealed that the use of improved cooking stoves could reduce the fuelwood requirement by at least 28% compared to the traditional stoves. In addition, it has benefit of reducing health risks. The uses of improved cooking stoves conserve heat and reduce heat dissipation with minimal waste. It was reported that 30-50% fuelwood could be saved through the proper use of improved stoves.

REDP (2000), studied on the application of biogas and ICS for forest saving showed that from biogas about 14268 tones of biomass per year had been saved which was equivalent to 8917 ha of forest and from ICS 420 tones of biomass per year equivalent to 262 ha of forest area. This was a remarkable saving and increment in the trees and forest area. The study further identified that the biogas and ICS had multiple benefits; it had reduced the pressure on the forest, improved the health of women and children and saved women working time. Its use had been successful in the rural part of Nepal despite some cultural barriers. Both biogas and ICS are important AETs for sustainable supply of biomass energy in the country like Nepal.

Acharya and Baral (2004), described the role of ICS in the participatory Biodiversity conservation. ICS were one of the innovated concepts that contribute to the reduction of the fuel wood use for house hold purpose. Most of the fuel wood in the study area was supplied from the CF. If ICS were used instead of traditional stoves, wood consumption would be reduced by 50%. At the same time ICS contribute to improving health conditions and to reduce health hazards by taking all the smoke outside kitchen.

Mahat (2004), found that the attitude of both men and women towards the use of ICS was positive. There was reduction in time and labor for cleaning utensils, cloths and house but fuelwood consumption was similar.

Banskota and Sharma (2005), after the adoption of ICS, there was 35% reduction in the fuel wood consumption in the Palpa district where the projects" Capacity Building of women for energy and water management in the Himalayas" supported by UNEP and SIDA and executed by ICIMOD exist.

AEPC (2006), quantity of fuel wood requirements has reduced with ICS as 85 users realized the saving on consumption of fuel wood. Only 2% users reported more consumption of fuel wood in ICS. The result of water boiling test is not as encouraging as user's perception and responses. The average efficiency test value of the 125 ICS is15.5% in more than 58% of the surveyed ICS, the efficiency is less than 15% while around 15% ICS efficiency greater than 20%. More than 90% of the ICS in Dhankuta have efficiency less than 15%. In Palpa, 30% of the ICS have efficiency more than 20%. It indicate that older the ICS, lesser the efficient.

CADEC (2006), conducted a survey in 34 mid hill districts where there people were using ICS. In those places 86.3% users reported less time consumption (23 minute a day), 87.8% reported smokeless, 21.1% reported firewood saving (by 23.5%), 19.9% reported easy cooking and 13.7% reported clean kitchen (non-hazy environment, less soot on walls, floor, and ceiling). In these districts 99.7% ICS were in operation with 91.1% in daily use and 73.6% ICS users were found satisfied during monitoring field visit. The saved time during cooking and collection of firewood is used in other income generating activities.

CRT/N (2006), reported that ICS is 25% efficient than the traditional stoves and has advantages of chimney having less smoke in the rooms. Further it reported that ICS requires smaller pieces of fuel and cooking one item at a time and it also not suitable for smaller sized pots.

Shakya and Shrestha (2006), following the standard methodology adopted by IPCC and various other organizations, estimated that GHGs emission avoidance from different RETs applications in Nepal as 1020709 tones of CO_2e. This showed that 0.53% of total RET contribution in total national energy consumption is helping to reduce 6.5% of the total national GHG emission.

Sharma and Banskota (2008), in a pilot project report submitted to Austrian Development Agency, Vienna showed that there was an average daily saving of 25-60% in Bhutan, Nepal and Pakistan by the use of Metallic ICS except in China where people were already using some form of improved stoves. They also showed that 15000 tons of CO_2e emission reduction from 2500 households taken in the project sites. For the comparison with TCS they have assumed 10% efficiency for TCS. The annual GHGs emission saved per households was highest in China, which was 23 tons of CO_2e and lowest in Nepal, which was 7 tons of CO_2e at 30% efficient MICS.

Rajbhandari et al., (2009), in their research has stated a 70% fuelwood saved after the installation of Matribhumi Stove a type of Improved Cooking Stoves.

Tuladhar et al.,(2009), in a research conducted in three districts Dolakha, Ilam and Dang has found that the average concentration of PM2.5 and CO in houses that use traditional cook stoves is very high but the mud brick ICS was able to reduce the $PM_{2.5}$ by 65.73 % and CO by 62.34 %. The study also founded that there was very high levels of indoor air pollution from burning of biomass fuels, particularly in houses with poor ventilation. The study had clearly shown the reduction of PM 2.5 and CO by ICS use and firewood consumption reduction, cleaner kitchens and reduced time for cooking.

Chand (2011), in a research carried out in Meghauli VDC of Chitwan district showed reduction in fuelwood consumption after the ICS installation. The fuelwood saved was 57.62 kg/month and CO_2 emission reduction was 1.265 million tons. Also there was decrement in the respiratory diseases after ICS installation.

Silwal (2011), in a research carried out in Syafrubesi VDC found fuelwood as the major energy source providing 88.23% of the total energy demand. The efficiency test conducted in the study area also showed ICS as more efficient compared to TCS.

CHAPTER III

MATERIALS AND METHODS

3.1 Study area

Prok VDC of Gorkha District was selected as the study area. It lies within MCA. It is situated between latitudes of 28° 36' 46.5" North to 28° 26' 53.0" South and longitudes of 84° 51' 45.9" East to 84° 41' 11.4" West and is bounded by Tibetan autonomous region of China in north, Sirdibas VDC in south, Lho VDC in west and Bihi VDC in east.

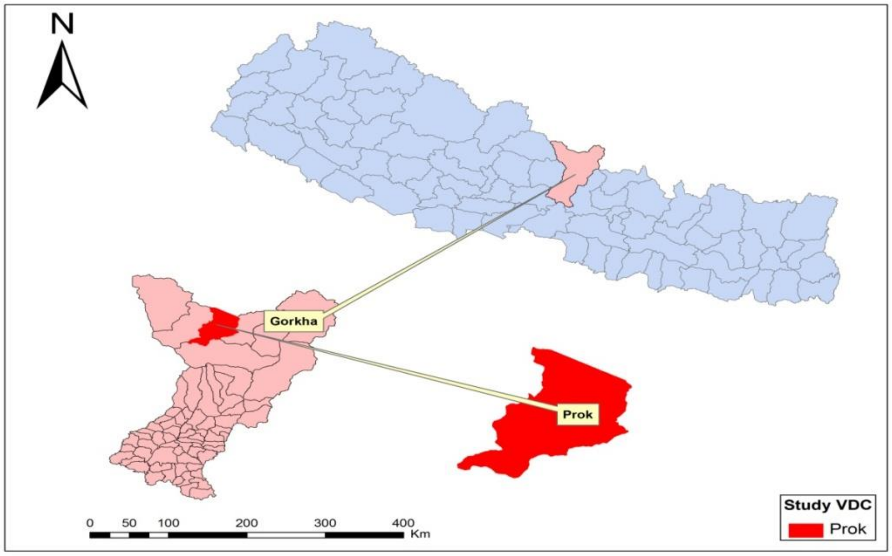


Fig 3.1: Map of the study area

According to the district profile report of Gorkha 2005, Prok VDC covers an area of 144.69 km^2. 19.78% of the total area is covered by forest and the area of agricultural land is 1.57%. Rest of the area is covered either by snow or is bare. Prok VDC has 187 households with total population of 575 out of which 273 are males and 302 are females. Density of the study area was 3.97 and population increment rate was – 2.4 (CBS, 2011). According to the district profile of Gorkha 2005,the total literate population in the year 2001 was 28.6% of which 44.55% were male and 11.65% were female.

Due to the topography and variation in altitude two climatic conditions are found in the Prok VDC. Temperate climatic conditions are found in the regions ranging from 1000m to 2000m altitude and subalpine climatic conditions are found in the regions ranging from 3000m to 4000m altitude. In temperate climatic zone summer temperature ranges from 22 to 25^{o}C and winter temperature ranges from -2 to 6°C. In this zone frost and snowfall are common in winter (January and February). In subalpine climatic zone winter is very cold and even in summer the temperature is not high with a mean annual temperature of 6 to 10°C. In this zone snowfall occurs about four to six months (December to May) (www.dnpwc.org.np).

3.2 Research design

The study has focused basically on current energy consumption pattern and GHG emission trend from the energy sources used and status of RET and ICS as renewable energy technology in reducing fuelwood consumption. Fieldwork was carried out in year 2012 between April 13 to May 8 to conduct household survey, key informant interview and self observation. Diagrammatic representation of research design is shown below.

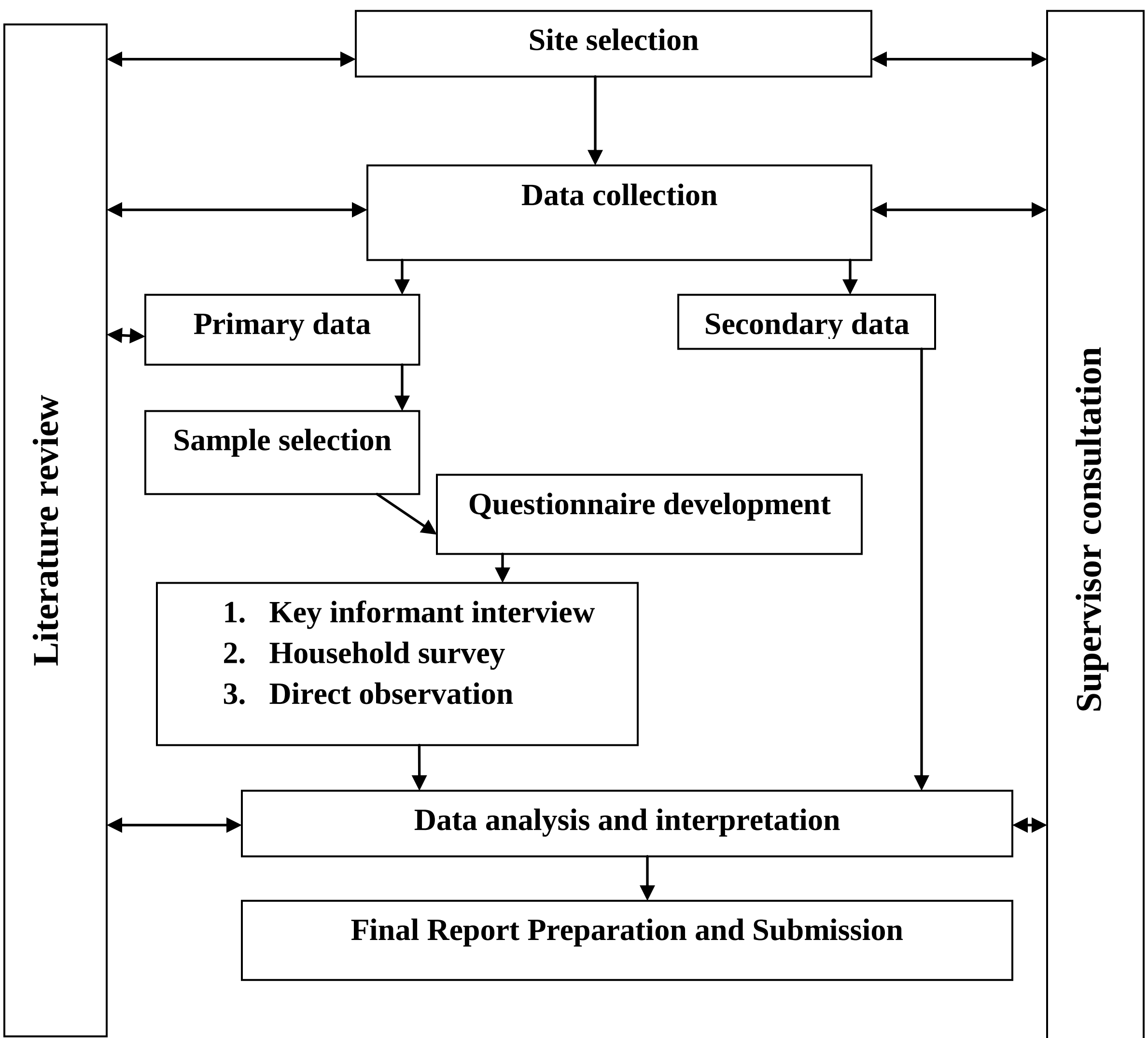


Fig 3.2: Diagrammatic representation of Research design

3.3 Data collection

3.3.1 Primary data

Primary data was collected using questionnaire in the households, taking interview with key informants using check list and direct observation method by weighing the fuelwood required for the family using TCS and ICS.

3.3.1.1 Sample size

Simple random purposive sampling was used to determine the sample size. For the selection of sampled HHs, 8 wards out of 9 wards of Prok VDC were taken for the data collection. According to CBS, 2011, the total HHs in the Prok VDC was 187. Therefore, 40 HHs out of 187 HHs was taken as sampled HHs which was 21.40% of the universe.

3.3.1.2 Questionnaire development

Questionnaire was developed in order to carry out the HH survey and checklist was prepared for the key informant interview with the supervisor assistance. Sample questionnaire is shown in annexes I and checklist on annexes II.

3.3.1.3 Key informants interview

It was another important technique for the data collection in this survey and was conducted during field study. Enquire was made to find out the Key informant and relevant information was gathered. Key informants taken were head of Buddhist Monarchy Management Committee, Lama of Buddhist Monarchy, former ward chairman, employee of Great Himalayan Trail, Wage labors and school teacher related to the field of this study.

Seven key informant interviews were conducted during the field study for data collection. Verification of data or information collected through HH survey was verified.

3.3.1.4 Household survey

It is very essential for collecting quantitative data especially to know the actual status of energy consumption, type of energy they rely on, status of RETs and ICS as renewable technology. A semi-structured questionnaire was used for data collection. The household survey included social variables like demography, occupation, caste, class and education. Door to door survey was carried out for the household questionnaire survey.

3.3.1.5 Direct observation

Direct observation was carried out to compare MICS and TCS in terms of fuelwood consumption. All Respondents who were available having MICS installed were taken as samples for MICS and TCS comparison and equal number of TCS using households from remaining sampled households were taken for the comparison.The weight of 1 Bhari was determined by taking average weight of 10 different Bharis of fuelwood.

Qualitative data such as type of houses, toilet availability and solid waste management practices were also observed in and around the surveyed HHs. The status of indoor environment in the households using MICS was also observed.

3.3.2 Secondary data

Secondary data for the study were collected from various research reports, journals, books and internet for the literature review and comparison of results obtained. ICIMOD e-library, AEPC library, central library and library of central department of environmental science, CRT/N library, BSP/N library and CES library were visited for the collection of materials stated above.

3.4 Data analysis and result presentation

Both quantitative and qualitative data were analyzed and analysis was descriptive using MS office excel. The test of significance for difference between two independent means was used as a statistical tool to test hypotheses in this research. MS-Excel computer program was used for calculations. Results presented were descriptive.

3.4.1 Estimation of GHGs emission from the energy consumption pattern

Estimation of GHGs emission from the current energy consumption was based on the IPCC, 1996 methodology and Smith et al., 2000. According to which,

For fuel wood, tones of CO_2 (t CO_2) = Tones of fuel wood × CO_2 Emission Factor (EF)

= Tones of fuel wood × 1.518 kg/kg

For kerosene, 1 litre of kerosene = 2.484 kg of CO_2

For LPG, tones of CO_2 = kg of LPG used × CO_2 Emission Factor = kg of LPG used × 3.1141 kg/kg

3.4.2 Estimation of GHGs emission reduction from the RET used

For ICS

Fuelwood saved = Total fuelwood consumed before ICS installation – Total fuelwood consumed after ICS installation

GHG emission reduction = fuelwood saved in kg × CO_2 emission factor (IPCC, 1996)

For Micro-hydro

GHG emission reduction = fuelwood saved in kg × CO_2 emission factor (IPCC, 1996)

For Solar

GHG emission reduction = fuelwood saved in kg × CO_2 emission factor (IPCC, 1996)

3.4.3 Hypothesis testing for comparing ICS and TCS use in terms of fuelwood consumption

Ten households for each were taken as samples for the comparison of average fuelwood consumption. The samples were taken purposively and direct observation was carried out in the sampled HHs. Hypothesis was set in order to check if there was any significant reduction of fuelwood consumption in households using MICS than in households using TCS. Student's t-distribution was used since the sampled household number "n" was less than 30.

Hypothesis setup

Null hypothesis H_o: $\mu_1 = \mu_2$ that is, there is no difference in fuelwood consumption between MICS using households and TCS using households

Alternative hypothesis H_1: $\mu_{1\,=}\,\mu_2$ that is, there is difference in fuelwood consumption between MICS using households and TCS using households

For the test to compare between MICS and TCS users in terms of fuelwood consumption weighed fuelwood was provided to the respondents using MICS as well TCS to prepare their daily meals. 10kg of fuelwood was provided to the MICS users and 20kg of fuelwood was given to the TCS users to prepare one time meal. If addition amount of fuelwood was required it was again weighed and noted. After the meal was prepared, the remaining amount of fuelwood was noted down for each MICS and TCS users. In this comparison, altitudinal variation was not considered because of low availability of MICS users.

For statistical analysis, Test of Significance for Difference between Two Independent Means as given by Gupta, (2004) was used as follows:

$$t = \frac{\bar{X}1 - \bar{X}2}{s^2\sqrt{\frac{1}{n1} + \frac{1}{n2}}}$$

Where,

t= Students t-distribution

$\bar{X}1$ = mean of the sampled households using TCS

$\bar{X}2$ = mean the sampled households using MICS

s^2 = an unbiased estimate of the common population variance based on both samples

$$s^2 = \frac{1}{n1+n2-2}\left[(\sum X1^2) - \frac{(\sum X1)^2}{n1} + (\sum X2^2) - \frac{(\sum X2)^2}{n2}\right]$$

Where,

X_1= Fuelwood consumption of TCS using households

X_2 = Fuelwood consumption of MICS using households

CHAPTERIV

RESULTS

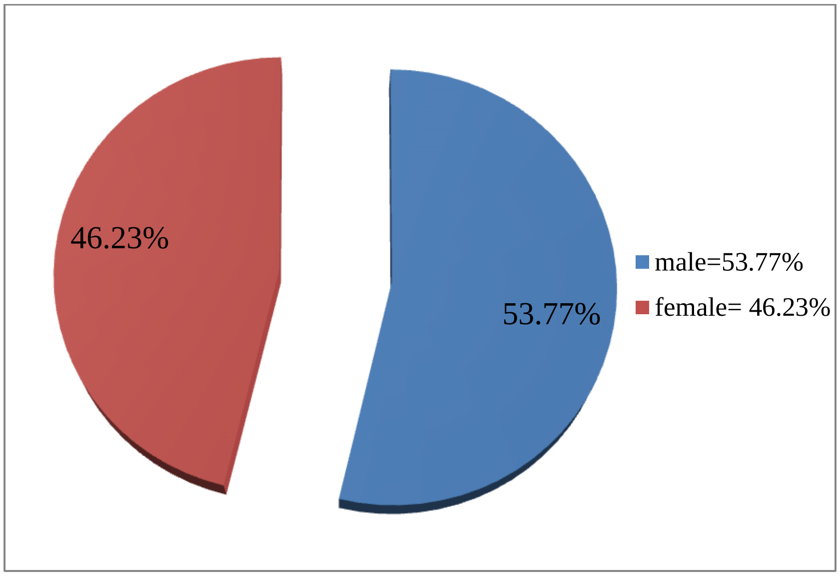
4.1 Socio economic status

4.1.1 Ethnicity and religion

Information was collected using the questionnaire from the 8 wards of the Prok VDC. Lama was the only ethnic group found on the study area and they were following Buddhism as the religion.

4.1.2 Sex composition

Out of the total population of the respondent households, 53.77% were male and 46.23% were female. The sex ratio of the respondent households was found to be 0.86.The sex composition of the study areais shown in the figure 4.1.

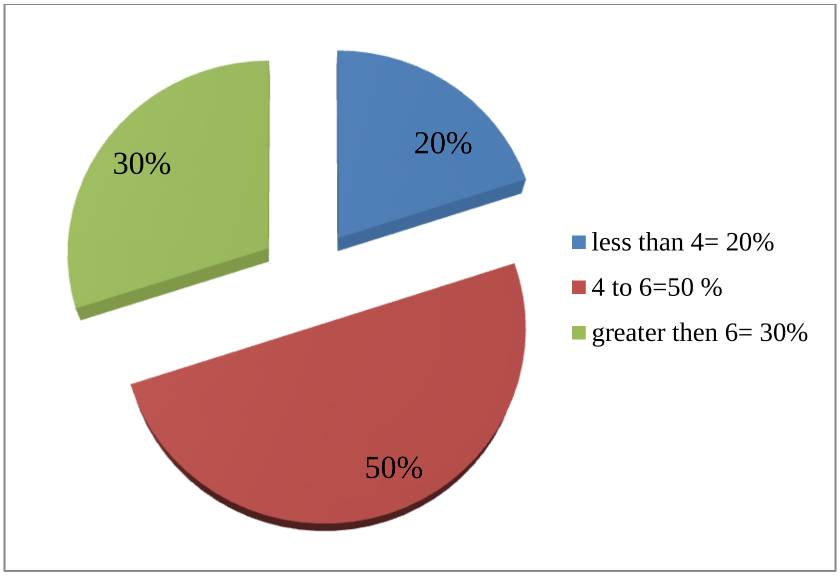


(Source: field survey 2012)

Figure 4.1: Sex composition

4.1.3 Family size

Average family size of the respondent's households was found to be 5.3. 50% of the total respondent had the family size in 4 to 6 range as shown in the figure 4.2.

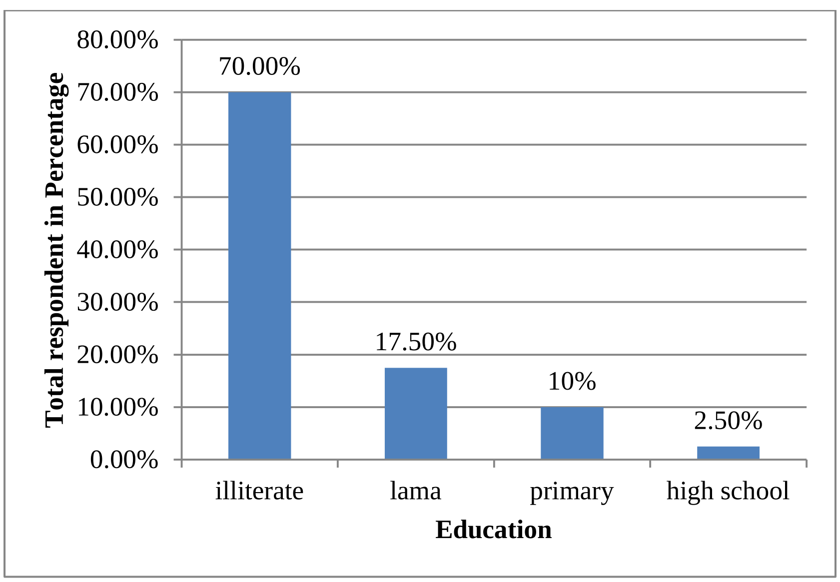


(Source: field survey 2012)

Figure 4.2**:** Average family size

4.1.4 Education status

Educational status of the Prok VDC was poor as 70% of the respondents were illiterate and 30% of the respondents were literate. 17.50% of the respondent attained Lama school for education and 10% were educated up to primary level. Only 2.50% of the total respondents were educated above high school as shown in the figure 4.3.

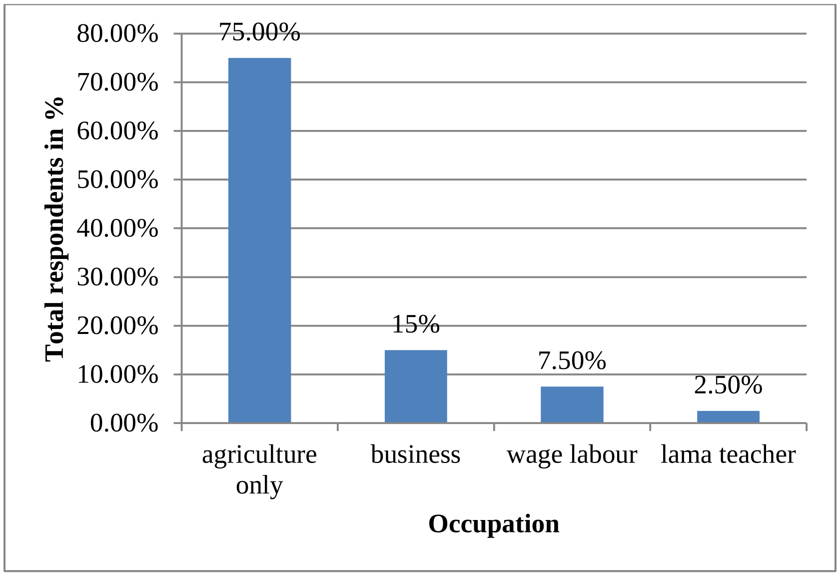


(Source: field survey 2012)

Figure 4.3: Educational status

4.1.5 Occupational status

Agriculture was the major occupation of the study area. All the respondents were actively engaged on agriculture. Out of total 70% of the respondents were involved only in the agriculture, 15% of the respondents were engaged in tourism business and agriculture, 7.5% worked as a wage labor as well as agriculture and 2.5% of the respondents worked as a Lama teacher in the Monastery of the study area which shown in the figure 4.4.

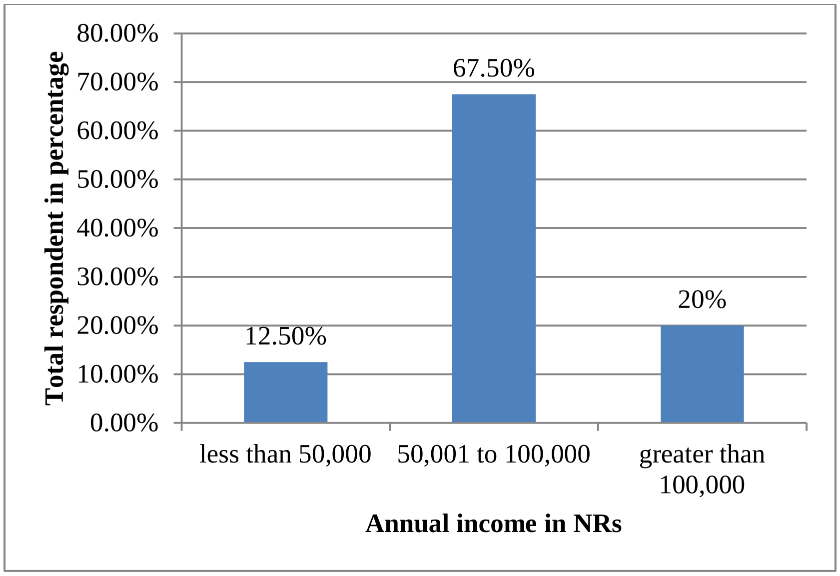


(Source: field survey 2012)

Figure 4.4: Occupational status

4.1.6 Annual income and income sources

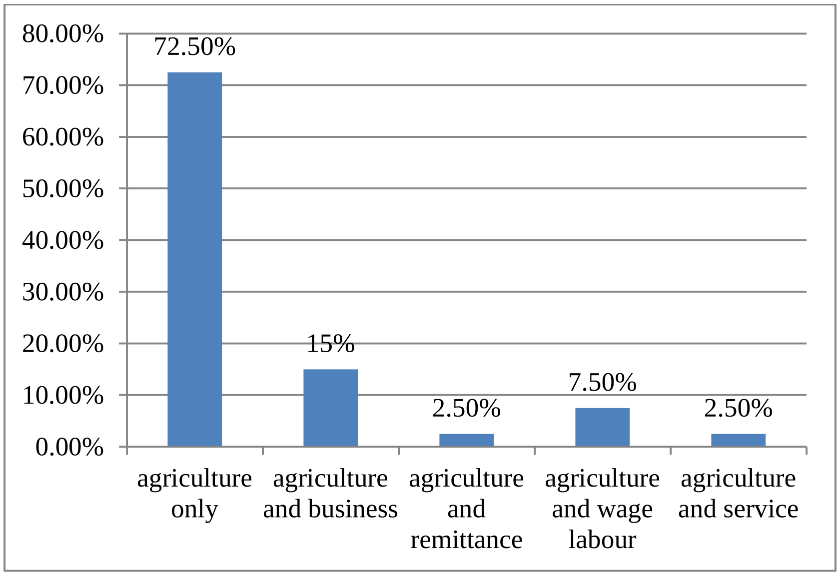
Most of the people were engaged in agriculture, therefore had the income for their subsistence only. Annual incomes of the respondents were categorized into less than 50,000, 50,001 to 100,000 and greater than 100,000. Of the total respondents, 67.5% had the annual income ranging from 50,001 to 100,000, 20 % has greater than 100,000 and 12.5% had less than 50,000 of annual income as shown in the figure 4.5. The average annual income of the respondents was found to be Rs 76,000.



(Source: field survey 2012)

Figure 4.5: Annual income

Agriculture being the major occupation, sources of income was mainly based on agriculture. From the figure 4.6, 72.50% of respondent had agriculture as the major source followed by 15% of agriculture with business, 7.5% of agriculture with wage labor, 2.5% each of agriculture with remittance and agriculture with service.



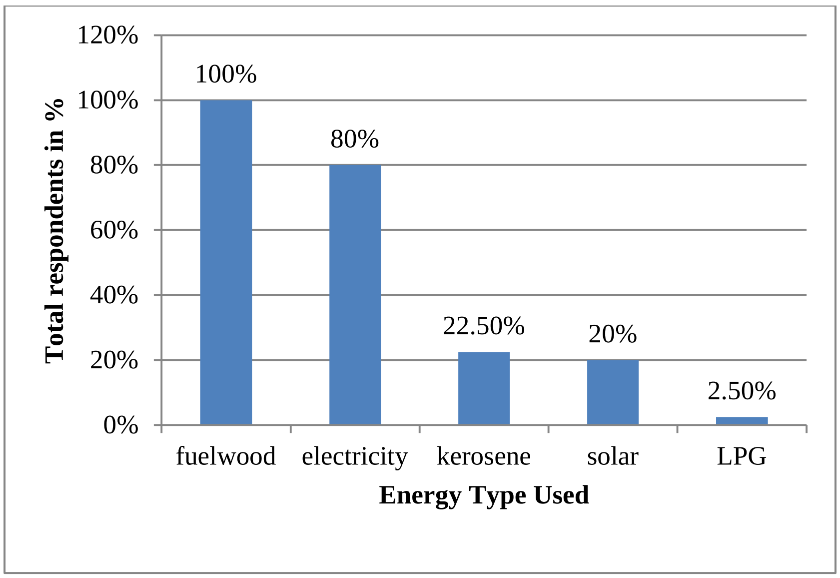
(Source: field survey 2012)

Figure 4.6: Sources of income

4.2 Energy status

4.2.1 Energy types used

Fuelwood, electricity, solar, kerosene and LPG were the sources of energy found in the study area as shown in the figure 4.7. Due to easy access to forest, fuelwood was the major energy source as the entire respondent uses fuelwood as the primary energy source for cooking, space heating and making alcohol. 80% of the respondents use electricity for lighting purpose only which were supplied by 2 micro hydro built by MCAP. Kerosene share 22.5% of total respondents which again is used only for lighting purpose. 20% of the respondents use solar energy for lighting purpose and only 2.5% of the respondents use LPG for cooking purpose.



(Source: field survey 2012)

Figure 4.7: Energy type used by the respondents

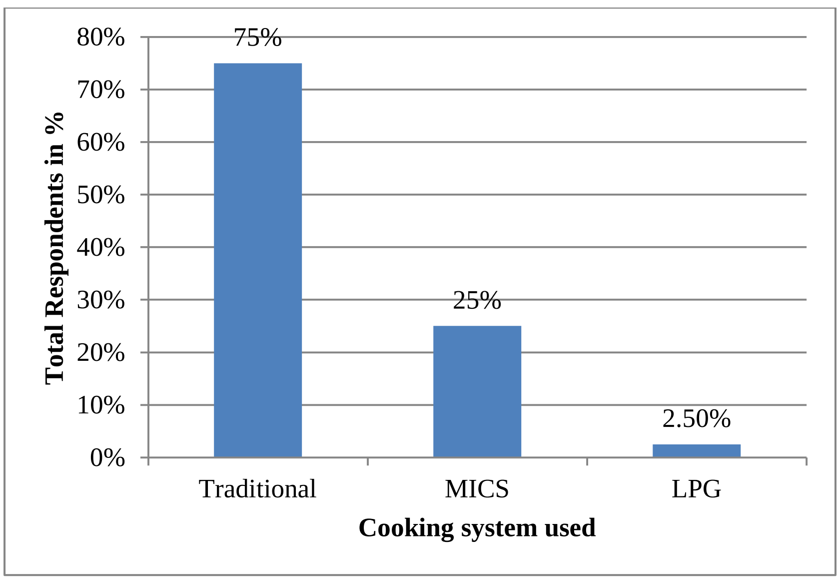
4.2.2 Supply of energy sources

The study area lies within the Manaslu Conservation Area. All the sampled respondents reported that they collect firewood themselves whenever they had free time from agricultural and other works during dry periods especially between February end to early May and in October from the government as well as form the private forest. 80% of the respondents collect firewood only from government forest and called Wung, Menopasa and Thangin forests of Prok VDC. 20% of the respondents collected firewood both from government and private forest .*Pinus* species and *Rhododendron* species were the main species of trees used for the fuelwood consumption in the study area.

The energy sources for lighting used in the study area are provided by the micro-hydro built with the assistance from MCAP. One micro-hydro is on Namrung village and other on the Tok village. SHS and kerosene are the other energy sources used for lighting. SHS was installed by the owner themselves in assistance with some local NGO and kerosene was brought from Philim or Arughat. LPG which used for cooking was brought from Arughat.

4.2.3 Cooking system used

MCAP has just recently started the MICS as ICS installation in the study area. MICS was distributed only to the respondents residing in the Namrung village by MCAP. Therefore traditional cooking stoves made up of iron were the major cooking stoves. Four pod stand stoves was the traditional cooking stoves used covering 75% of the total sampled households followed by 25% using MICS and 2.5% using LPG stoves as shown in figure 4.8.



(Source: field survey 2012)

Figure 4.8: Type of cooking system used

4.2.4 Energy consumption pattern

4.2.4.1 Annual energy consumption of the study area

The energy sources available in the Prok VDC were categorized in traditional, renewable and commercial types. The main energy types were fuelwood, electricity from micro hydro, kerosene, solar and LPG. The fuelwood collected was in Bhari which was later converted into kg. The total annual energy consumption of the sampled household was found to be 5747.728 GJ and annual per capita energy consumption was found to be 27.11 GJ which is shown in table 4.1.

Table 4.1: Energy consumption pattern of the study area

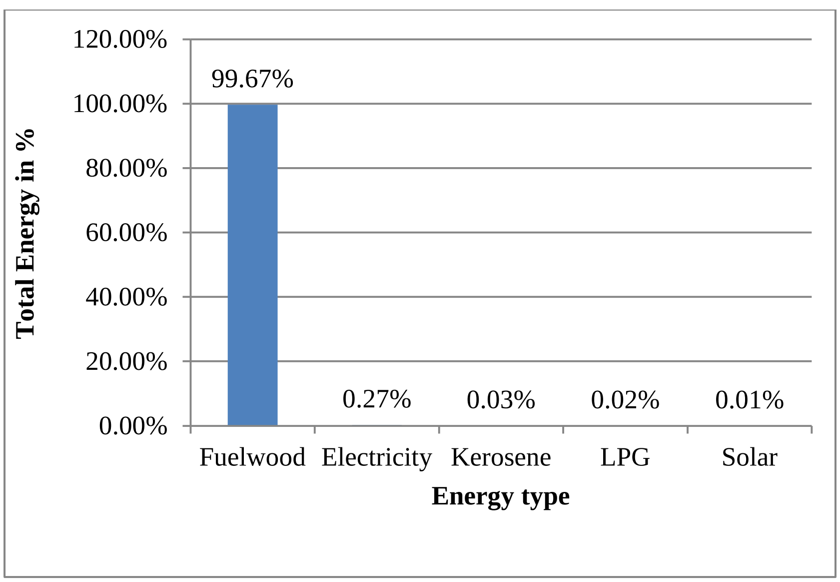
S.N	Energy resources	Energy consumption/day	Energy consumption/month	Energy consumption/yr	Annual energy consumption in GJ
1.	Fuelwood	950 kg/day	28500 kg/month	342 tones	5728.5
2.	Electricity	12000 Wh	360000 Wh	4.32MW	15.552
3.	Kerosene			0.0324 tones	1.50
4.	Solar	600 Wh	18000 Wh	0.216 MW	0.7776
5.	LPG			0.0284 tones	1.398416
Total					5747.728

(1 Bhari= 45 kg of fuelwood)

(Source: field survey 2012)

4.2.4.2 Energy consumption by fuel type

As the fuelwood was readily available in the study area it shared the maximum 99.67% of the total energy consumption of the study area followed by 0.27% of electricity, 0.03% of kerosene, 0.02% of LPG and 0.01% of solar as shown in figure 4.9.

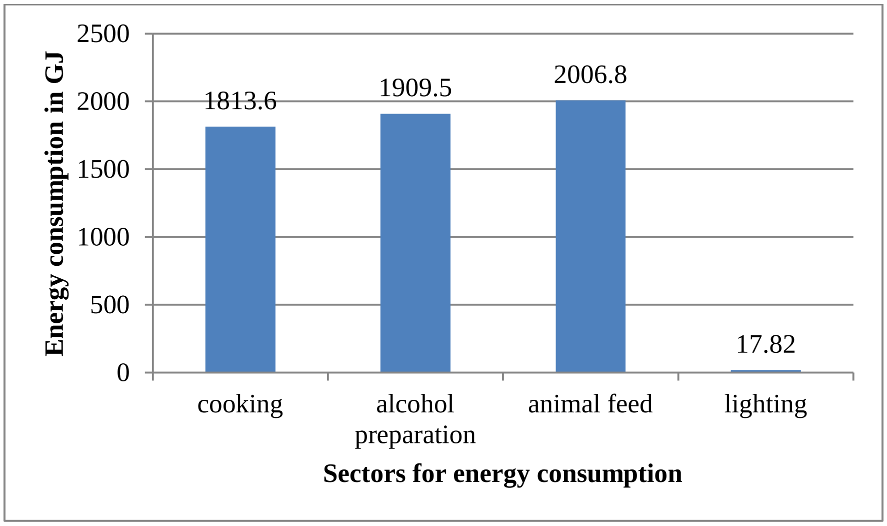


(Source: field survey 2012)

Figure 4.9: Share of Energy type

4.2.4.3 Sector wise energy consumption

Cooking food, alcohol preparation, animal feed preparation and lighting were the sectors of energy consumption in the study area. From the analysis, highest energy was consumed for the preparation of animal feed which was 2006.8 GJ followed by alcohol preparation, cooking and lighting as shown in figure 4.10. Fuelwood provided the energy required for cooking, alcohol preparation and animal feed preparation whereas the energy required for lighting purpose was met by SHS, kerosene and electricity from micro-hydro.

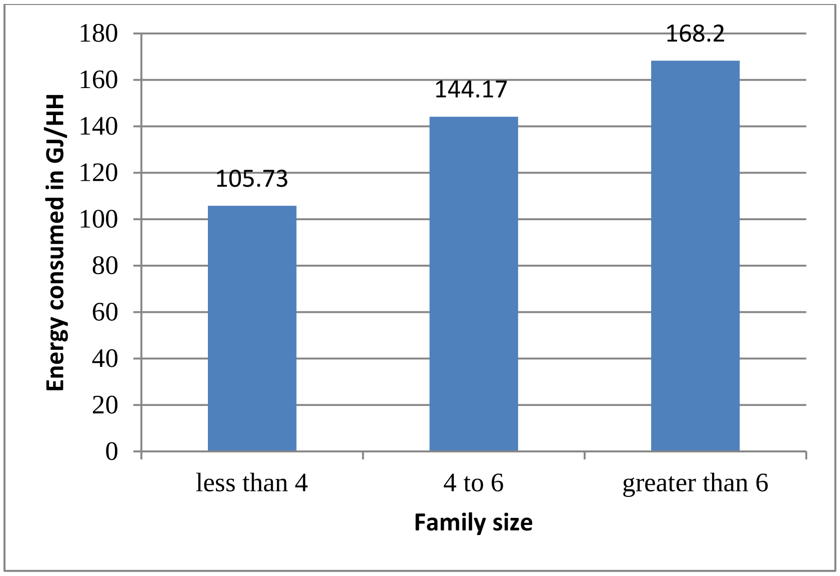


(Source: field survey 2012)

Figure 4.10: Sector wise energy consumption

4.2.4.4 Energy consumption with respect to family size

The highest annual average per HH energy consumed in the study area was in the HHs having family size greater than 6 which was 168.2 GJ/HH as shown in figure 4.11. Family size of 4 to 6 and less than 4 is consuming the energy equivalent 144.17 GJ/HH, 105.73 GJ/HH respectively.

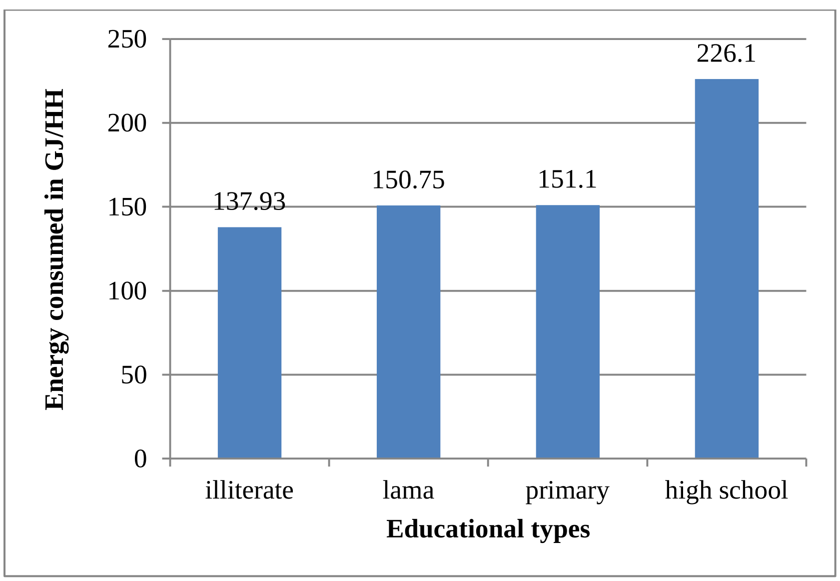


(Source: field survey 2012)

Figure 4.11: Energy consumption in HHs having different family size

4.2.4.5 Energy consumption with respect to educational status

The respondents HHs who were qualified up to high school showed the highest energy consumption per HH which was 226.1 GJ/HH as shown in figure 4.12. Lama, respondents who had taken primary education and respondents who are illiterate shared the remaining energy consumed in the study area which was 150.75 GJ/HH, 151.1 GJ/HH and 137.93GJ/HH respectively.

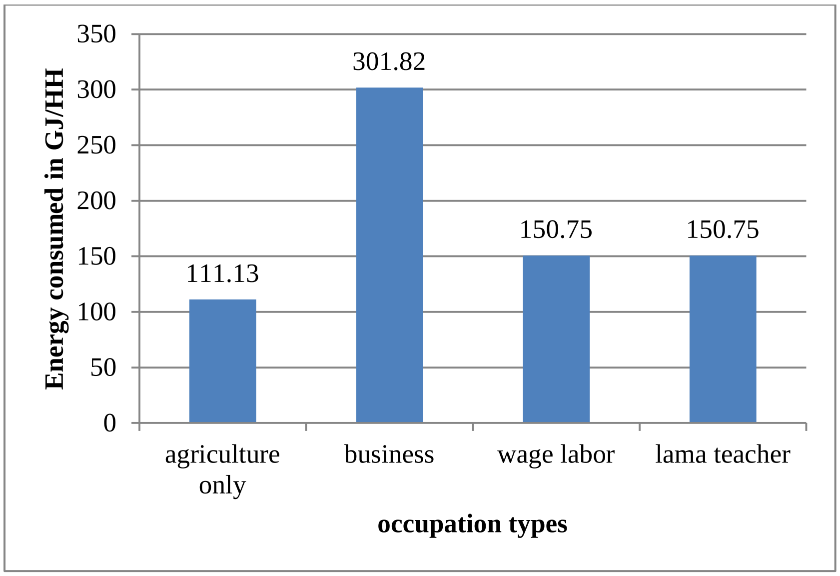


(Source: field survey 2012)

Figure 4.12: Energy consumption in terms of educational qualification

4.2.4.6 Energy consumption with respect to occupation

The energy consumption with respect to occupation showed that the respondents who were involved only on agriculture consumed the lowest energy than other occupations which was 111.13 GJ/HH and the highest energy was consumed by the respondent HHs involved in business which was 301.82GJ/HH. The share of energy consumed by respondents in term of occupation is given in figure 4.13.

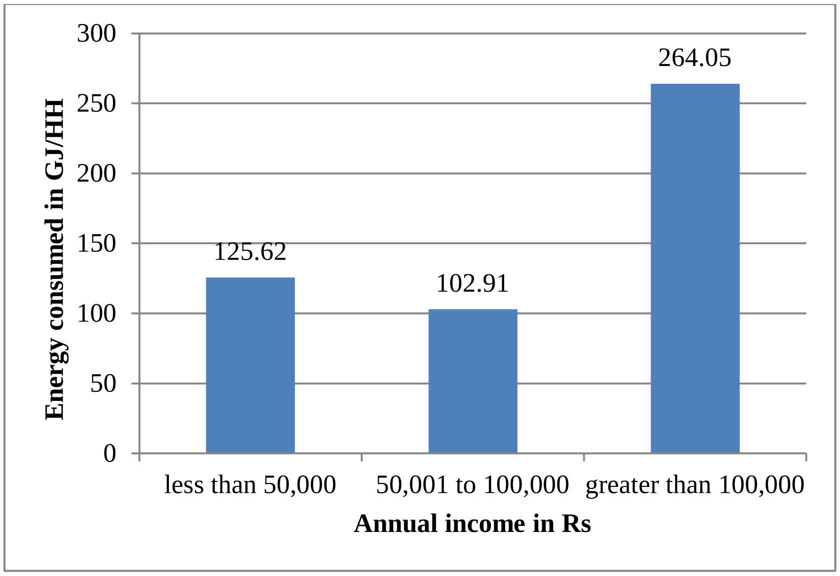


(Source: field survey 2012)

Figure 4.13: Energy consumption in terms of occupation

4.2.4.7 Energy consumption with respect to annual income

Energy consumption in term of annual income showed the highest energy consumed was by respondent HHs having annual income of greater than 100,000which was 264.05 GJ/HH followed by respondent HHs having annual income of less than 50,000 which was 125.62 GJ/HH. Respondents HHs having annual income of 50,001 to 100,000 showed the least energy consumption which was 102.91 GJ/HH (figure 4.14).



(Source: field survey 2012)

Figure 4.14: Energy consumption in terms of annual income

4.2.4.8 Expenditure on the current energy consumption

As the study area lies in the MCAP, fuelwood was quiet readily available. Fuelwood was collected mostly from the government forest. So the respondents who could not collect the fuelwood for themselves hired wage labor for fuelwood. Electricity was supplied by the micro hydro, therefore respondents having electricity need to pay NRs 80 to NRs 100 per households per month according to the bulbs used for lighting in the Prok VDC where micro-hydro is installed. Kerosene was bought either from Philim or Arughat of Gorkha district. SHS was installed by some HHs in the study area only some time back with the help of some local nongovernmental organization therefore annual cost could not be calculated, only installation cost was available. LPG was bought from Arughat.

For the economic analysis of the sampled households according to the current energy consumption, market price of various energy sources were taken in consideration. Table 4.2 shows the annual total annual expenditure by the respondents for different energy resources in the study area.

Table 4.2: Annual expenditure on the energy resources used in the Study area

S.N	Energy resources	Annual expenditure in Rs
1.	Fuelwood	22,500
2.	Electricity	38,400
3.	Kerosene	4,400
4.	Solar	15,000
5.	LPG	4,000

(Source: field survey 2012)

4.3 GHGs emission of the study area

4.3.1 Total annual GHGs emission

The total annual GHGs emission in terms of CO_2e from the sampled households according to the current energy consumption pattern was found to be 519.34 tons of CO_2e of which fuelwood contributes the highest as shown in table 4.3. The per capita annual GHGs emission of the sampled HHs of the study area was found to be 2.45 tons. The annual GHGs emission per HHs was found to be 12.98 tons/HH/year

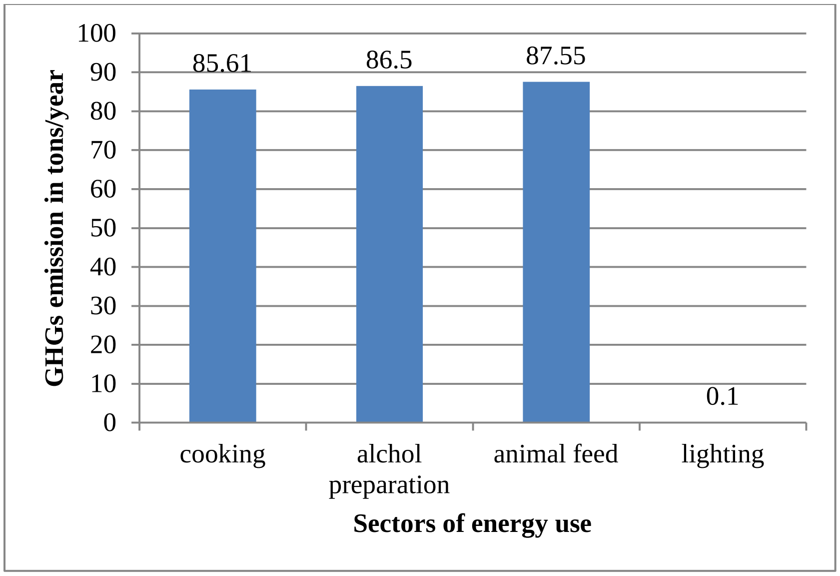
Table 4.3: Total annual GHGs emission from the energy sources used

Energy source	Total annual energy consumed by the sampled HHs	CO_2e	Total annual CO_2e emission in kg
Fuelwood	342000 kg	1.518 kg/kg	519,156
Kerosene	40 L	2.484 kg/L	99.36
LPG	28.4 kg	3.1141 kg/kg	88.44044
Total			519,339.8

(Source: field survey 2012)

4.3.2 Sector wise GHGs emission

The sector wise GHGs emission showed animal feed preparation emits the highest amount of GHGs which was 87.55 tons annually. The least amount of GHGs emission was done by lighting sector which was 0.1 tons. The sector wise GHGs emission is shown in the figure 4.15.

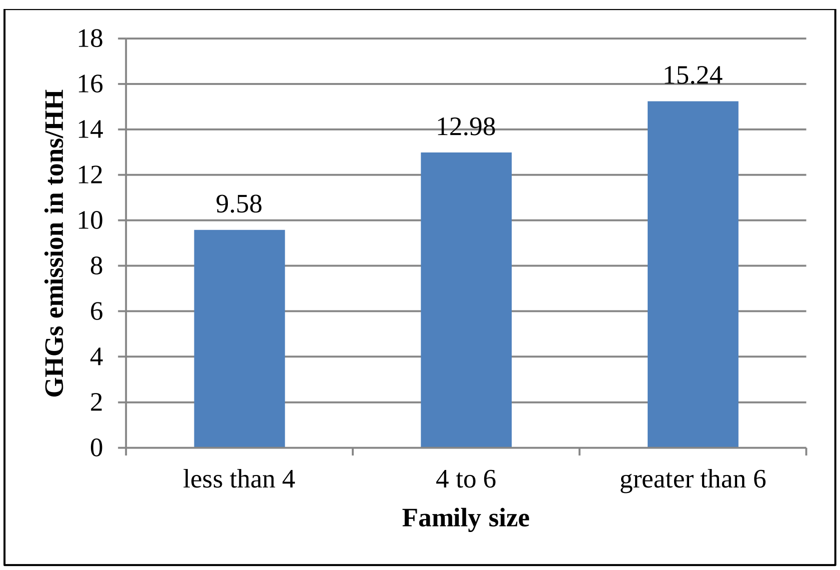


(Source: field survey 2012)

Figure 4.15: Sector wise GHGs emission

4.3.3 GHGs emission with respect to family size

The respondents HHs having family members greater than 6 were the highest emitter of GHGs which was 15.24 tons/HH/year as shown in figure 4.16.The respondent HHs having family size of 4 to 6 emitted 12.94 tons/HH/year of GHGs in the study area The respondents HHs having family size of less than 4 emitted 9.58 tons/HH/year of GHGs.

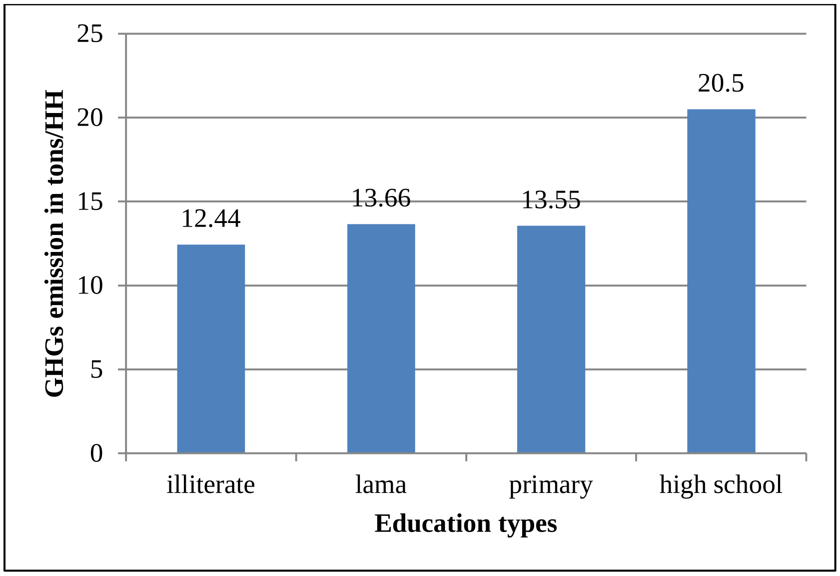


(Source: field survey 2012)

Figure 4.16: GHGs emission in terms of family size

4.3.4 GHGs emission with respect to educational status

The respondents HHs who were educated up to high school were the highest emitter of the GHGs which was 20.5 tons/HH/year. The lowest emission of GHGs was by the HHs who were illiterate which was 12.44 tons/HH as shown in figure 4.17.

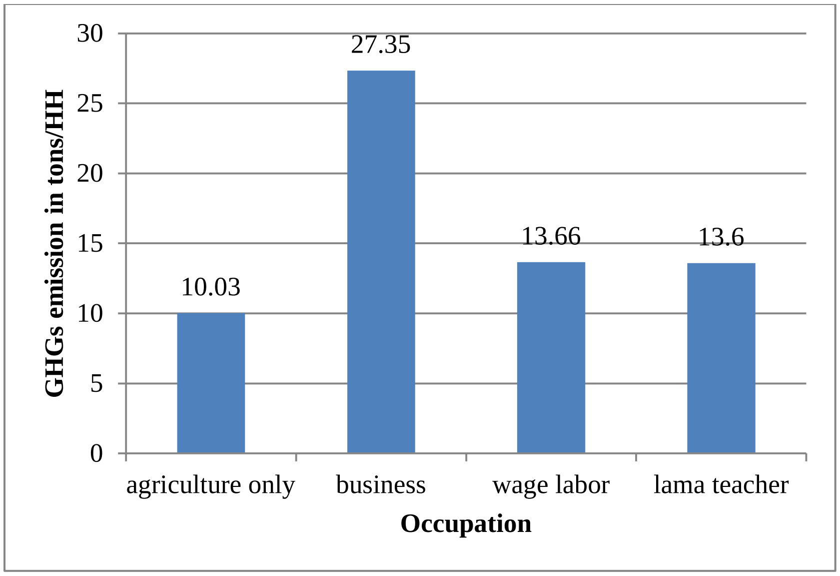


(Source: field survey 2012)

Figure 4.17: GHGs emission in terms of education

4.3.5 GHGs emission with respect to occupation

Respondents HHs who were involved only on agriculture emitted the lowest GHGs in the study area. The share of GHGs emission per HH involved only in agriculture, business, wage labor and lama teacher was 10.03 tons/HH/year,27.25 tons/HH/year,13.66 tons/HH/year and 13.6 tons/HH/year respectively as shown in figure 4.18.

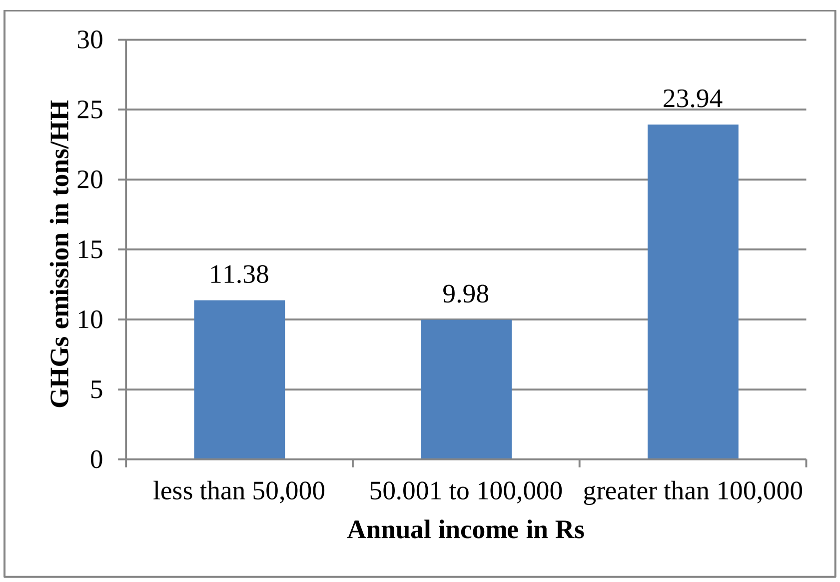


(Source: field survey 2012)

Figure 4.18: GHGs emission in terms of occupation

4.3.6 GHGs emission with respect to annual income

The RespondentsHHs having annual incomegreater than 100,000 were the highest emitter of GHGs in the study area. They emitted 23.94 tons/HH/year of GHGs followed by the respondent HHs having income less than 50,000 which was 11.38 tons/HH/year. The least emission per HH was by HHs having annual income of 50,001 to 100,000 which was 9.98 tons/HH/year as shown in figure 4.19.

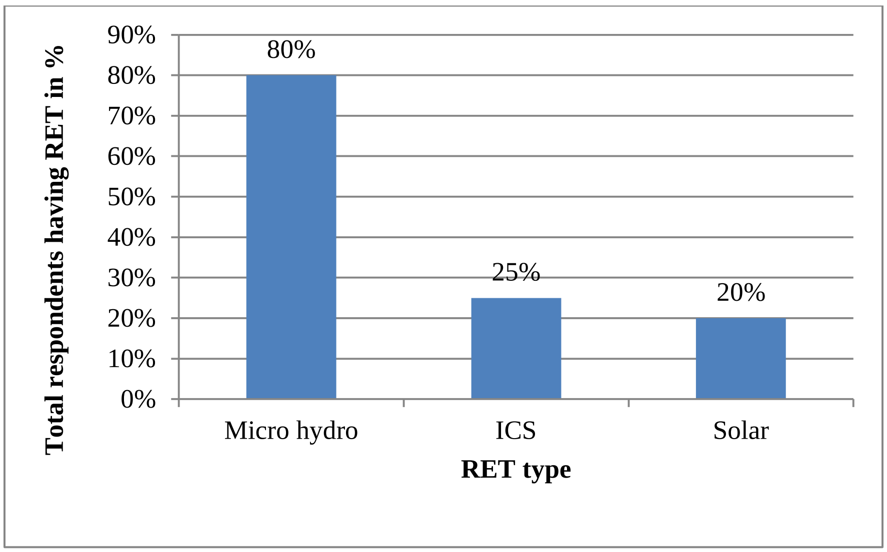


(Source: field survey 2012)

Figure 4.19: GHGs emission in terms of annual income

4.4 Status of RET

Micro hydro was the main RET used in the study area built with the assistance of MCAP. 80% of the sampled households used micro hydro for lighting purpose. ICS was the second most RET used with 25% of the total sampled households using it which was distributed by MCAP and some were self buyer. 20% of the sampled households were using solar which was provided by some local nongovernment organization in subsidy. Types of RET and its share is shown in the figure 4.20.



(Source: field survey 2012)

Figure 4.20: Types of RET in the study area

4.4.1 ICS as RET

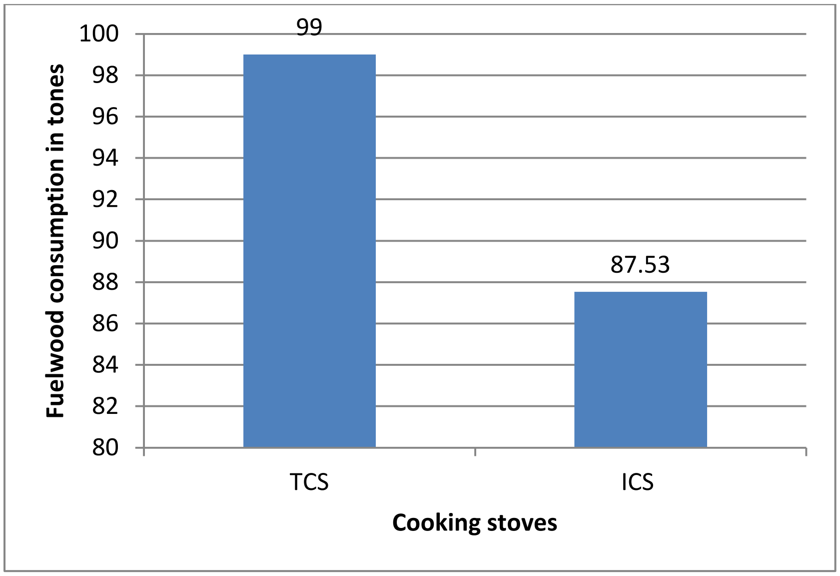
4.4.1.1 Status of ICS

Fuelwood was the major energy source of the sampled households of the study area. 25% of the total sampled households used MICS as ICS as the RET. ICS installation in the wards 7, 8 and 9 were done with the assistance from MCAP where as in ward 1, 2 and 3 it was done by the household themselves.

4.4.1.2 ICS using households before and after

All the respondents said there was a positive impact on their health as well as fuelwood consumption reduction after the MICS as ICS installation. According to the respondents, there was decrement in the frequency and time spent in fuelwood collection. Handling of stoves was easier after MICS installation than before was reported by the respondents of sampled households. MICS use had also positive impact on the health of the people of the sampled households. Health problems such as asthma, coughing, eye irritation and throat irritation was decreased as compared to before and also the indoor environment improved considerably.

An average of 3 kg/day of fuelwood consumption was reduced after the introduction of MICS in the sampled households having MICS. Before the installation of ICS, the annual fuelwood consumption was 99 tons/year but after its installation, the demand reduced to 87.83 tons/year saving 1.15 tons/HH/year as shown in figure 4.21.



(Source: field survey 2012)

Figure 4.21: Fuelwood consumption before and after ICS installation

4.4.1.3 ICS using households and TCS using households

The MICS using HHs and TCS using HHs were compared in terms of fuelwood consumption. From the calculation, “t” was found to be 11.26, which was significant at 95% confident limit. Therefore according to the hypotheses set for the research, alternate hypotheses was accepted which means there is a significant difference in terms of fuelwood consumption between MICS and TCS using HHs. From this one can say that MICS was more efficient than TCS.

4.5 GHGs emission reduction after the installation of RETs

A significant amount of GHGs emission was reduced after the installation of RETs in the study area. A total of 84 tones CO_2e GHGs emission was reduced after the RETs installation. The annual GHGs emission reduction per HHs of the study area was found to be 8.4 tons/HH. Micro-hydro, the mostly used RET by the respondents of the sampled HHs was the highest GHGs emission reducer; reducing 53.25 tones followed by ICS which reduced 17.42 tones of CO_2e.

SHS was the least contributor in reducing GHGs emission. It had reduced 13.33 tons of CO_2e emissions.

Micro-hydro and SHS had substituted both fuelwood and kerosene used for the lighting purpose whereas ICS had decreased the fuelwood consumption for cooking purpose. The detailed energy sources saved after RETs installation and GHGs emission reduction in terms of CO2e is shown in the table 4.4.

Table 4.4: Total GHGs emission reduction in terms of CO_2e after RETs installation

Type of RET	Energy consumed before RET installation(A)	Energy consumed after RET installation(B)	Energy saved after RET installation(A-B)	CO_2e factor	CO_2e emission reduction after RET installation ((A-B)×CO_2e factor)
ICS	97,875 kg (fuelwood)	86,400 kg (fuelwood)	11,475 kg (fuelwood)	1.518 kg/kg (fuelwood)	17.42 tons
Micro-hydro	35,040 kg (fuelwood) 20 L (kerosene)	0	35,040 kg (fuelwood) 20 L (kerosene)	1.518 kg/kg (fuelwood) 2.484 kg/ltr (kerosene)	53.25 tons
SHS	8,760 kg (fuelwood) 14 L (kerosene)	0	8,760 kg (fuelwood) 14 L (kerosene)	1.518 kg/kg (fuelwood) 2.484 kg/L (kerosene)	13.33 tons
Total					84 tons

(Source: Field survey 2012)

CHAPTER V

DISCUSSIONS

5.1 Socio economic status

Ethnical composition of the sampled households of the study area showed that Lama was one and only ethnic group following Buddhism. Literacy rate was only 30% which was low as compared to the country literacy rate of 60.9%. Sex composition was also different as compared to the country and sex ratio was low as compared to the country's sex ratio which shows the population imbalance in the study area. Average family size of the sampled households of the study area was found to be 5.3 which were greater than the average family size of the country which is 4.7 (CBS, 2011).

Agriculture was the major occupation of the study area following country's trend. All of the respondents answered agriculture as the major occupation. The respondents who were involved only in agriculture was 70%, this may be due to the unavailability of other occupation in the study area. As most of the sampled households were not in the trekking route, only 15 % of the respondents were involved in tourism related business i.e. hotels who resides in the trekking route. Therespondents who worked as wage labor for collecting fuelwood and farmland labor were 7.5%. Of the total respondents, 2.5% worked as the lama teacher.

Respondents involved in tourism business who had hotels had the annual income higher than 100,000 which comprises 20% of the total respondents. Respondents having large agriculture fields and involved in lama teaching had the annual income between 50,001 to 100,000 consisting 67.5% of the total respondents. Of the total respondents, 12.5% had the annual income below 50,000 and working as a wage labor was their major source of income.

Each and every households of the study area had the toilet which were built after subsidy and educational campaign provided by MCAP.

5.2 Energy consumption pattern

The total annual energy consumed in the sampled HHs of the study area was found to be 5747.73 GJ. The annual average per capita energy consumption was 27.11 GJ which was high as compared to national per capita energy consumption of 15 GJ (MoF, 2007/08). The result obtained of the study on per capita energy consumption may be due to less number of HHs than of the country and also easier access of fuelwood and colder climate. The annual energy consumption per HHs was 143.7 GJ/HH. Energy consumption pattern of the study area followed the general trend of the country which is dominated by the fuelwood. Fuelwood share 99.67% of the total energy consumed by the sampled households and 100% of the sampled households used fuelwood as their primary source of energy. Since the study area lies in the rural part which did not had an easy access to other commercial fuels, less than 1% of the total annual energy consumed was provided by other sources. Share of petroleum energy, kerosene and LPG was very low. Only, 0.03% of kerosene and 0.02% of LPG provided total annual energy to the sampled household which again is due to the unavailability of those resources in the study area. 0.01% of total energy is met by solar energy which is used only for lighting purpose as the development of RETs in the area is just at a starting phase.

The energy consumption with respect to family size showed the family size greater than 6 consumed the highest energy per HH which was 168.2 GJ/HH/year and the least was by family size of less than 4. The result indicated as the family size increases, energy consumption increases. The energy consumption in terms of educational status showed the respondent HHs having higher education consumed higher energy which was 226.1 GJ/HH/year and least was 137.93 GJ/HH/year by illiterate respondents HHs. The HHs having primary education showed similar energy consumption pattern. The result obtained was may be due to involvement of high school qualified respondent HHs in business. Similarly, with respect to occupation the energy consumption pattern showed the highest energy consumed was in the HHs who were involved in business which was 301.82 GJ/HH/year and least was in the HHs who were invoved only in agriculture which was 111.13 GJ/HH/year. The result so obtained was may be because the HHs involved in business use the energy for other purposes except them. In terms of annual income, respondent HHs having annual income of above 100,001 consumed higher energy which was 264.05 GJ/HH/year and least by HHs having annual income ranging between 50,001 to 100,000 which was 102.92 GJ/HH/year. The high energy consumption by HHs having annual income above 100.001 may be due to the reason that they were involved in business and energy is consumed for serving tourist as well and the least energy consumption was may be due to the use of fuelwood as major energy source.

5.3 Greenhouse gases emission trend from the current energy consumption pattern

Fuelwood was the major contributor to meet the energy demand of the study area therefore GHGs emission from the fuelwood was highest. The total annual greenhouse gases emission from the total sampled households was found to be 519.34 tons of which 519.16 tons of GHGs emissions was from fuelwood alone. Kerosene and LPG contributed only 0.1 tons of GHGs and 0.08 tons of GHGs respectively. The per capita annual GHGs emission of the study area was 2.45 tons and annual GHGs per HHs was 12.98 tons respectively. The high amount of GHGs emission from fuelwood was due to the higher use of fuelwood for meeting energy demand. Since, availability of kerosene and LPG were not frequent, their contribution in the total energy use was quite low hence low GHGs emission.

GHGs emission with respect to family size, educational status, occupation and annual income showed highest GHGs emission was by family size of greater than 6, high school educated, HHs involved in business and HHs having annual income higher than 100,001 which were 15.24 tons/HH/year, 20.5 tons/HH/year, 27.35 tons/HH/year and 23.94 tons/HH/year. The result obtained was may be due to the high amount of energy used by them compared to others.

5.4 ICS as RET in reducing fuelwood consumption and GHGs emission

ICS is a renewable energy technology rather than energy provider. Only 25% of the total sampled households had the ICS technology installed in the households. An average of 3kg/day of fuelwood consumption was reduced after its installation in the households. A total of 1.15 tons/year/HH of fuelwood consumption was saved after use of ICS for cooking in the households having ICS which was less compared to the research of Khanal and Bajracharya, (2010) and more compared to Chand, (2011). Khanal and Bajracharya, (2010), reported decrement of 3.64 tons/year/HH and Chand, (2011), reported 57.62 kg/month in ICS installed HHs which is 82 kg/month in ICS installed HHs of this study. The study demonstrated a reduction of 1.74 tones/year of GHGs emission after its installation which was less compared to Khanal and Bajracharya, (2010) as it reported 6.66 tons/year. The cold climatic condition of the study area might be the reason behind the low fuelwood reduction and GHGs emission compared to other researches above.

The comparison between ICS and TCS in term of fuelwood consumption showed ICS more efficient than TCS. There was a significant difference in fuelwood consumption in the households using ICS and TCS from the comparative observation made between the households using ICS and TCS at 95% confidence limit (t=11.26). Fuelwood consumption reduction and improved indoor environment was observed in the households using ICS than in the households using TCS. Since the TCS used in the study area was of four pod standswithout chimney, heat energy may get loss than of ICS having chimney therefore being more efficient in terms of fuelwood consumption and indoor air pollution.

5.5 RET in reducing GHGs emission

The total GHGs emission reduction after the adoption of RET in the study area were found to be 84 tons/year. Micro-hydro was the major RET used in the study area. 80% of the sampled households were using it. The total GHGs emission reduced after its installment was 53.25 MT/year in micro-hydro installed HHs which was less compared to Gurung et al., (2011) which reported reduction of 475 kg/year/HH of fuelwood which reduces 153.18 tons/year of GHGs emission. The study conducted by Gurung et al., consists of sample size of 213 HHs of micro-hydro users and use of electricity from micro-hydro had substituted energy for purposes other than lighting which might be the reason for low GHGs emission reduction in this study. MICS contributed 17.42 tons/year of GHGs emission reduction from 25% of the sampled HHs. Solar were used by 20% of the sampled households which contributed about 13.3 tons/year of GHGs emission reduction which was more compared to Panthi, (2011), who reported 5.93 tons/year of reduction of GHGs emission. The higher reduction of GHGs emission might be due to the reduction of share of fuelwood in the Prok VDC whereas kerosene was only substituted in Panthi, (2011) research.

Out of the three RETs used by the sampled HHs of the study area, micro-hydro had contributed more in terms of GHGs emission reduction, it may be due to the fact that 80% of the sampled households were using it which was more than the other two.

The result thus indicates that the RETs installed in the study area had helped to mitigate climate change by reducing the fuelwood and kerosene demand which ultimately implies to reduction of GHGs emission. As GHGs are the contributors to the climate change, their least emission is likeable to mitigate climate change by the application of suitable RETs.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Energy use and GHGs emission are interrelated. The use of inefficient energy sources is causing higher GHGs emission causing climate change. The efficient RETs have the potential to mitigate climate change by reducing the effects from GHGs emission through the efficient use of energy sources. Therefore, RETs have positive impacts in terms of efficient energy use, lowering GHGs emission and hence could mitigate climate change in local, regional and global level.

The energy consumption pattern of the study area followed the national trend. The total annual energy consumed in the study area was 5747.73 GJ, annual per capita energy was 27.11 GJ and annual per capita HH energy consumption was 143.7 GJ/HH/year respectively. Fuelwood was the dominant energy resource comprising 99.67% of the total energy consumed. Rest of the energy sources provided less than 1% of the total energy consumed. The relation of energy consumption with socio economic indicators showed higher the family size, educational qualification, annual income higher is the energy consumption. Fuelwood was the major contributor of the GHGs emission which emitted 519.16 tons out of 519.34 tons of GHGs. Micro-hydro, MICS as ICS and SHS were the RETs installed in the study area of which 80% were using micro-hydro as RET. MICS as ICS have reduced 3 kg/day of fuelwood than TCS after its installation in the MICS using HHs and was found efficient than TCS at 95% confident limit (t=11.26) in terms of fuelwood consumption. Improved indoor environment, reduction in respiratory issues and eye irritation was reported in the HHs where MICS was installed. A significant amount of GHGs emission was reduced which was 84 tons after the installation of RETs in the area. Micro-hydro was the highest contributor on GHGs emission reduction with 53.25 tons. The reduction on GHGs emission by the installation of RETs in the study area clearly indicates, RETs are helpful in mitigating climate change through efficient energy use.

6.2 Recommendations

From the research conducted following recommendations are suggested:

For people of Prok VDC

- There is a need of energy substitution of traditional energy by more efficient RET. Micro-hydro, solar and ICS are the suitable RET for the study area for efficient energy use.

- Fuelwood being the dominant energy resource to meet the energy demand, ICS is the most suitable RET to reduce fuelwood consumption and Indoor pollution

For policy makers and concerned authorities:

- Awareness program focusing villagers on usefulness of RET.
- Provision of subsidies for the ICS installation.
- Feasibility studies for installing high altitude biogas plant should be carried out

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ANNEXES

Annexes I

CENTRAL DEPARTMENT OF ENVIRONMENTAL SCIENCE
TRIBHUVAN UNIVERSITY

Questionnaire for household survey for the "Study on Energy Consumption and Green House Gases Emission Pattern of Prok VDC of Manaslu Conservation Area".

Household no: Date:

Name of the Interviewer:

1. General information

Name of Respondent ………………… Age of Respondent…………

Gender……… Ethnic Group……………..

Village………….. Ward No……………..

Education: Illiterate, Pre primary, Primary, Secondary, Higher secondary, University

Occupation: Agriculture, Government Job, Private Job, Business, Wage labor, Others (specify)……….

1.1 Family composition

Gender	Age groups			
	Below 5 years	5-15 years	15-60 years	Above 60
Male				
Female				

1.2 Income

What is the annual income of your family? ………………………………

Sources of income	Amount

2. Information on Energy use

2.1 What are the sources of energy in your home?

- Fuelwood
- Electricity
- Kerosene
- Biogas
- Solar
- Animal dung
- Agricultural residue
- LPG
- Others specify…………………..

2.3 Energy type and usages in your home.

S.N	Energy types	Purpose	Usages
1.			
2.			
3.			
4.			

**Purpose (Household/ Business)

3. Energy types and Economic Valuation

3.1 Information on Fuelwood

3.1.1Where and how much Fuelwood do you Acquire?

Type of Forest	Collection (Bhari)	Name of forest
Government forest		
Community forest		
Private forest		
Others………………..		

* 1 Bhari = ………………kg of fuelwood

3.1.2 Is there any rules for collecting fuelwood from the government and community forests?

…………………………………………………………………………………………………….

3.1.3 Which season do you collect the fuelwood from the forests?

………………………………………………………………………….

3.1.4 How many times in a year do you collect the fuelwood?

a) 1 b) 2 c) 3 d) more than 3

3.1.5 What quantity of fuelwood do you collect at a time?

…………………………………………………………..

3.1.6 Do you have to pay for the fuelwood collection from government and community forest? If yes, how much do you pay for 1 Bhari in Rs? ....

3.1.7 Do you buy fuelwood from the market? If yes, what is the cost for 1 Bhari in Rs?

……………………………………………………………………..

3.1.8 Which species of trees do you mostly use for fuelwood?

S.N	Name of the species	Rank (basis of utilization)
1.		
2.		
3.		
4.		
5.		

3.2 Information on kerosene

3.2.1 What purposes do you use kerosene?

a) Lightning b) Cooking c) Others (specify)……………………

3.2.2 How much kerosene do you use monthly in litres?

………………………..……….……………………

3.2.3 Where do buy kerosene and what is the cost of it in your market?

…………………………………………………

3.3 Information on LPG

3.3.1 What purposes do you use LPG?

a) Lightning b) Cooking c) Others (specify)…………………

3.3.2 How many days on average did one cylinder runs?

……………………………….

3.3.3 Where do you buy and what is the cost of one cylinder in your market in Rs?

…………………………………

3.4 Information on Electricity

3.4.1 What purposes do you use electricity?

a) Lightning b) Cooking c) Others (specify)……………………

3.4.2 How much do you use it in one month in units?

……………………………….

3.4.3 What is the source and what is the cost in Rs?

…………………………………

3.5 Information on other energy sources

3.5.1 Specify its purposes

………………………………………………………………………………………………………
………………………………………………………………………………………………………

3.5.2 Specify the units per month

………………………………………………………………………………………………………

3.5.3 Specify the cost

………………………………………………………………………………………………………

4. Status of renewable energy technology

4.1 Do you use any renewable energy technology? If yes, what are they

i. Biogas
ii. Solar
iii. Wind mill
iv. ICS
v. Micro hydro
vi. Others, if any, specify………………

4.2 How much of fuelwood or kerosene or other energy sources has been substituted after RET installed in your house?

Fuelwood (kg)…………………..

Kerosene (ltr)…………………..

Others (specify)…………..

4.3 Do you have ICS installed in your house, if yes proceed or else go to question no.

i. Type of ICS (with chimney/ without chimney)
ii. When did you install it? ....
iii. What was the installation cost in Rs? ....
iv. Did you got any help? If yes (i), if no stop
v. Did you required to maintain it after installation? if yes,

How much money did you spent? .... (Rs)

4.4 What sort of help did you got and which organization helped you?

Name of the organization……………………………………………………

i. Financial……………….(Rs)
ii. Technical (specify)……………………………………………….

4.5What motivated you to opt for the Alternative Energy Program and this Particular Device?

SN	Reason	Yes/No
1	High subsidy rate	
2	Peer motivation	
3	Scarcity of fuel woods	
4	Health benefits	
6	Others	

4.6 Perception towards ICS

Factors	Yes/No
Fuelwood Reduction	
Improve in Kitchen Environment	
Time Save in Cooking	
Financial Benefit	

4.7 Comparative observation

Activity	Before ICS	After ICS
Frequency of collection of firewood	More/less	More/less
Time spent in collection	…………hrs/week/day	……………hrs/week/day
Fuelwood requirement	………..Bhari/week, month,yr	………..Bhari/week, month,yr
Handling of stove	Easy/ difficult	Easy/ difficult
Frequency of repair and maintenance of the stove	Less/ more	Less/ more
Environment (Forest cover)	Improved/degraded	Improved/degraded
Health problems (respiratory only)	Yes/no If yes, specify……………… ……………………………..	Yes/no If yes, specify……………… ……………………………..

5. Self observation

Type of House?

i. Thatched roof ii. Tile/slated roof

iii. Mixed iv. RBC/RCC roof

v. Straw roof

Others

State of waste management (managed/ unmanaged)

Toilet availability (available/ unavailable)

Drinking water availability (readily available/ difficult in availability/ unavailable)

Nearby Forest cover (worse/bad/good/better)

Annexes II

Checklist for Key informant interview

Name of the interviewer…………………………… Date…………………………

Name of the respondent…………………………… Age…......

Ethnicity…………………………………………... Occupation………………….

Address…………………………………………… Name of the organization

Post in the organization……………………………. ………………………………

Information on energy use

What are the sources of energy used in the area?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

What is the name of the forest from where fuelwood is collected and what are the species used for burning?

……………………………………………………………………………………………………
…………………………………………………………………………………………….......

When do you collect the fuelwood (months)? What is the amount in kg that 1 *bhari*weighs? Which member of the family in your area generally goes to collect the fuelwood?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Who is the member of the family that does kitchen work and collects water?

…………………………………………………………………………………………………..

What is the status of RETs in this area? What are RETs installed in your area? What is the name of the organization that helped in their installation? Is that organization providing assistance currently?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Is ICS installed in your area? if yes, could you provide me the information on the HHs having ICS installed?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

What do you think about the status of forest cover before and after RETs installment in your area? Had the RETs installed in the area helped to reduce fuelwood therefore increasing forest cover?

……………………………………………………………………………………………………

Annexes III

Table A.IIIa: Nepal's National GHG Inventory in 1994/95(Gg)

Greenhouse Gas (Source and Sink Categories)	CO_2 Emission	CO_2 Removal	CH_4 Emission	N_2O Emission
1. Energy	1465		71	1
A. Fuel combustion	1465		71	1
Energy and Transformation Ind.	71			
Industry, Mining and Construction	320			
Transport	456			
Other sectors	618		71	1
B. Fugitive Emissions from fuels	0			
2. Industrial processes	165			
A. Mineral Production	165			
Cement Production	163			
Lime Production	2			
3. Solvent and Other Product Use	0			
4. Agriculture			867	29
A. Enteric Fermentation			527	
B. Manuare Management			34	2
C. Rice Cultivation			306	
D. Agricultural Soils				27
5. Land Use Change and Forestry	22895	-14778		
A. Changes in Forest 7 Other Woody Biomass Stocks	0			
B. Forest and Grassland Conversion	18547			
C. Abandonment of Managed Land				
D. CO2 Emission and Removals from Soil	4348			
6. Wastes			10	1
A. Solis Waste Disposal on Land			9	
B. Wastewater Handling			1	
C. Waste Incineration				
D. Other				1
Total Emission and Removal	24525	-14778	948	31
Net Emission	9747		948	31

(Source: MoPE, 2004)

Table A.IIIb: Emission factors of combustion for various fuels

Fuel Source	EFi	CO_2 e		Source
Kerosene	CO_2	2.457 kg/L	2.457 kg/L	
	CH_4	0.35 g/L	0.007 kg/L	
	N_2O	0.063 g/L	0.020 kg/L	
Fuelwood	CO_2	1.406 kg/kg	1.406 kg/kg	
	CH_4	4g/kg	0.084 kg/kg	
	N_2O	0.091 g/kg	0.028 kg/kg	
Crop Residue	CO_2	1.2874 kg/kg	1.2874 kg/kg	
	CH_4	7.488 g/kg	0.1572 kg/kg	
	N_2O	0.04896 g/kg	0.01518 kg/kg	
DUNG	CO_2	1.0476 kg/kg	1.0476 kg/kg	
	CH_4	6.12 g/kg	0.12852 kg/kg	
	N_2O	0.316 g/kg	0.9784 kg/kg	
LPG	CO_2	3.0689 kg/kg	3.0689 kg/kg	
	N_2O	0.146 g/kg	0.0452 kg/kg	

(Source: IPCC, 1996 and Smith et al., 2000)

Table A.IIIc: Energy content of various fuels

Fuel type	Unit	KCAL(000)	GJ	TCE	TOE	OTHER
Traditional						
Fuel wood	Tonne	4000	16.75	0.57	0.39	1.43
	m^3	2800	11.72	0.4	0.27	0.7
Commercial						
LPG	KI	-	30.08			0.611
	Tonne	11760	49.24	1.68	1.14	1.637
KRS	KI	8660	36.26	1.24	0.84	0.78
	Tonne	11130	46.06	1.59	1.08	1.29
Electricity	MWh	860	3.6	0.12	0.08	5.78

Source: (WECS 2010)

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Annexes IV

Photo plates taken during field survey

Picture: Researcher in household survey

Picture: Researcher with Key Informants

Picture: Researcher with TCS using respondent for household survey

Picture: Respondent with MICS

Picture: Researcher weighing fuelwood for fuelwoodcomparision between TCS and ICS users