A CRITICAL ANALYSIS OF RURAL DOMESTIC ENERGY CONSUMPTION SCENARIO OF ASSAM : WITH SPECIAL REFERENCE TO JORHAT DISTRICT

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DEGREE OF DOCTOR OF PHILOSOPHY

UNDER THE SCHOOL OF MANAGEMENT SCIENCES

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University Registration No : 090 of 2001

Dedicated to

"My Respected Parents"

CERTIFICATE

This is to certify that the thesis entitled **"A Critical Analysis of Rural Domestic Energy Consumption Scenario of Assam : with Special Reference to Jorhat District"** submitted by **Ms. Reeta Sarmah** to Tezpur University for the award of the Degree of Doctor of Philosophy is a bona fide work carried out by her under our guidance and supervision.

This work has not been submitted to any other University or Institute for any Degree or Diploma.

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ABSTRACT

The energy crisis in rural areas is going to pose a major problem in the economic development of India and in maintaining a balance in the eco-systems. At present the rural people depend heavily on different types of bio-fuels depending on the availability, ease of use, type. of stoves used, and the technical know-how. However, it is seen that due to lack of knowledge about the appropriate use of different types of bio-fuels available in abundance in rural areas, the rural population seem to depend mostly on fuel wood and similar forest products. This study aims to portray the rural domestic energy consumption scenario of Assam. It is hoped that the result will help in formulating rural energy technology by linking the energy consumption and resource availability. Keeping this in mind the study was designed and conducted with the following objectives:

1. To identify and assess the locally available energy sources in rural areas and to quantify the heat content of the different types of bio-fuels.
2. To compare the consumption pattern of rural domestic energy with that of semi-urban and urban sectors.
3. To study the indigenous technology used for energy conversion in rural areas.
4. To study the impact of present rural energy system on the health of the rural women.
5. To develop a model to represent the rural domestic energy consumption scenario.

In order to collect data to have an insight into the energy scenario in the rural area. 12 villages from Jorhat district in Assam, India, were selected at random. The villages thus selected possess varied characteristics of rural Assam, and thus, these villages can be considered to represent rural Assam in general. 384 households comprising of large, small, marginal, and landless farmers were surveyed to obtain data on domestic energy consumption. Both electrified and un-electrified households were included in the samples taken for the study.

The biomass energy resources in the study area have been identified. Based on the cropping pattern and production, untapped energy has been estimated for available biomass. The per capita gross useful energy consumption in cooking, water heating and space heating was found to be above the minimum requirements estimated by the Advisory Board on Energy [ABE 1985] i.e. 0.9475 GJ/ Capita/yr useful energy in eight villages. On the other hand, in other four villages it was found to be lower than that of all India level. The yearly consumption of kerosene in lighting for the households is much lower than all India average of 1.028 GJ/ Capita/yr as estimated by National Council Of Applied Economic Research.

Impact of domestic fuel on rural women was analyzed by comparing the domestic energy consumption of rural sector with that of semi-urban and urban sectors. The diseases among rural women due to smoke exposure was found to be significant.

A season wise linear multiple regression model was attempted by taking into account the various parameters of rural domestic energy consumption. Regression coefficients of four predictor variables such as average population, monthly average income, monthly average temperature and monthly average rainfall were found to be significant at 0.1%, 5% and 1% level of probabilities respectively in cooking and water heating during summer season including pre-monsoon. Regression coefficients of average population, monthly average income and monthly average temperature were found to be significant at 0.1%, 0.1% and 1% level of probabilities respectively in cooking, water heating and space heating during winter season including post-monsoon. Also, regression coefficients of average population, monthly average income and average school going children were found to be significant at 1%, 0.1% and 5% level of probabilities respectively in rural domestic energy consumption in space lighting over the year. The model fits were found to be adequate on the basis of t-statistics, F-ratio and coefficient of multiple determinations, R^2 values.

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Introduction and Overview

CHAPTER I

INTRODUCTION AND OVERVIEW

1.1 Introduction

Energy is a basic necessity of life. About half of the world's population uses biomass (wood, dung and agricultural residues) as their main and often only household fuel source. These fuels are used for cooking, heating and lighting. Cooking is done usually in stoves manufactured in the home country and indigenous technology [Bagchi, 1984]. Renewable energy sources such as wind, solar, hydro (particularly micro-hydro) and biomass are receiving increased attention in developed as well as in developing countries. Such renewable energies offer the prospect of energy supply in a self-reliant way at national and local levels [WRI, 1994]. Besides biomass, rural people use solar energy for drying agricultural products. Availability of solar energy is location specific and technical use of solar energy is not economical for the rural poor. The recent energy policy review concluded that biomass energy has more socio-economic benefits as a rural energy source among all the renewables. Biomass energy sources are the most economical rural energy sources among all the renewable sources of energy. Because these sources offer an opportunity for sustainable (as biomass can be grown sustainably), self-reliant (biomass is available in all places), and equitable development (lead to local control and employment) [Ravindranath *et al.*, 1995].

1.2 Rural Energy Supply and Consumption in India

As in most developing countries, the rural energy scenario in India is dominated by the domestic sector, accounting for nearly 80 per cent of the total (commercial and traditional) energy consumed. Although the share of biomass in national total primary energy use is low, biomass is the predominant fuel, used principally for cooking. Fuel wood is the dominant biomass energy used, followed by crop residues and cattle dung. The analysis done by Forest Survey of India [FSI, 1988] on the sources of 18 Mt of fuel wood used for cooking in rural areas show that forests, tree plantations, farm trees, homestead gardens and village commons are the diverse sources and that each source contribute significantly. All the crop residues having the potential for use as fuel can be used as fuel in domestic and industrial sectors. The NCAER (National Council of Applied Economic Research) domestic fuel survey conducted in 1978-79 calculated that 85.2 per cent of the total energy consumed in the rural domestic sector is accounted for by cooking, water heating and space heating. According to the 1991 census, only 1.22 per cent of the households used LPG and 1.34 per cent used kerosene as a fuel for cooking. Fuel wood was used in nearly 82 per cent of the rural households for cooking. Approximately 31.1 per cent of households or 33.1 per cent of the rural population had electricity facility in the houses. This figure compares poorly with the urban domestic sector, where 86 per cent of the households have access to electricity. According to the REDB estimates the per capita fuel wood consumption was estimated to be in the range of 1.1 to 1.3 kg/day, followed by the crop residues in the range of 0.47 to 0.63 kg/day [TEDDY, 1996-97]. There is, however, considerable variation in the type and extent of biomass used across regions, depending on the local climate, vegetation type, and fuel wood availability.

1.3 Statement of the Problem

It is an established fact that roughly 60 to 70 per cent of all energy consumed in rural systems of India are used up in the domestic sector, primarily in the preparation of food. It is also evident that the energy crisis in rural areas is going to pose a major problem in the economic development of India and in maintaining a balance in the ecosystems. At present the rural systems depend heavily on different types of bio-fuels depending on the availability, ease of use, type of stoves and technical knowhow. However, it is seen that due to lack of knowledge about the appropriate use of different types of biofuels available in abundance in rural areas, the rural population seem to depend mostly on fuel wood and other forest products.

Bio-fuels, being the most important fuel for over 90 per cent of rural households, account for more than one-third of the energy need in rural areas of Assam, which is situated in north-eastern part of India (situated in Eastern Himalayan Region between 24° to 28°18′ North latitudes and 89°50′ to 97°4′ East longitudes). The rural households depend on locally available biomass resources to meet their domestic energy needs. They gather fuel wood from nearby forests or fields. The quality as well as quantity of fuel wood used in a rural household depends on the availability and several other factors such as the households capacity to buy/gather the fuel. Most parts of the rural areas of Assam are un-electrified or availability of electricity is very poor. Therefore, the rural people depend on commercial fuel such as kerosene for space lighting.

Presently over 90 per cent of the domestic energy requirement in rural Assam is met by fuelwood. The ever increasing demand for bio-fuels without any significant increase in forest area, and the wastages of agricultural residues are posing great challenges to the national economy. A huge amount of rice residues as well as dung goes waste due to lack of awareness of the rural people about the proper utilization of those as domestic fuels.

The potential health impact of indoor air pollution from low quality bio-fuel burning during cooking and improper technology of traditional cooking stoves could be a growing concern in the near future. The burning of wood stoves leads to emission of CO, CO_2, NO_x, hydrocarbons (HC_s) and particulate matters [DeKoning *et al.*, 1985]. The pollutants are released directly during cooking everyday and the rural women have to endure consistent harmful smoke exposure. Globally, there would be influence of greenhouse effect and locally the population may be affected by chronic lung diseases, heart problem, lung cancer, diseases of respiratory tract, childhood diseases, underweight birth and increased infant mortality (WHO, 1992).

A typical rural housewife has to pass most of her time in cooking with low quality biofuels. For this, she cannot spare any time for her own and to look after her children. Besides, efficiency of the traditional stoves used in the rural households ranges from 5-10 per cent only [Anon , 1986] The inhabitants of the remote villages of Assam, whose per capita income is very low, can not switch over to other commercial and clean fuels such as LPG, electricity etc

Minimising the deforestation, balancing the ecosystem and environment, proper utilisation of agricultural residues and dung, reducing drudgery of rural women, maintainance of hygenic condition in the kitchen are to be the additional concerns for the development of the rural areas So, there is a need to provide quality fuels and appropriate devices in the rural areas of Assam to conserve energy

With all these views in the preceeding paragraphs, the present study was designed and conducted with the following objectives

1.4 Objectives of the Study

i) To identify and assess the locally available energy sources in rural areas and to quantify the heat content of the different types of bio-fuels

ii) To analyse the consumption pattern of domestic energy in rural semi-urban, and urban sectors

iii) To study the indigenous technology used for energy conversion in rural domestic sectors

iv) To study the impact of present rural energy system on the health of the rural women

v) To develop a model to represent the rural domestic energy consumption scenario by taking into account the various parameters

1.5 Theoritical Orientation

There are several dimensions to energy issues related to the human system. There is the question of the physical forms of energy, their availability and uses, then there are technological questions of energy conversions and efficiencies, economics of energy usages, socio-economic dimension of the energy consumption patterns, impact of energy use on environment and human system etc.

It is useful to compare the rural energy situation of a region with that in other regions and to look for commonalities, if any. It helps in exploring the need for an alternative approach to energy planning, the potential role of biomass energy, the technical potentiality of biomass in meeting the energy needs for development in rural areas [Marrison *et al.*, 1994]. Due to wide variations in resources, cultural, social, geographical, and economical situations, what is appropriate to one region may not be so for another. These constraints must be kept in mind to analyse the essential features of energy situations (WEC, 1992).

The rural energy situation has become crucial in the developing countries, as reflected in the considerable decline in the standard of living [Chatterjee, 1981]. If rural people consume domestic energy at the present rate, the traditional sources of energy will be exhausted very soon. The alternatives are (i) to find new sources of energy, (ii) to reduce the consumption by conservation, (iii) find some other means. These alternatives present complex problems. New sources of energy are uncertain and may not be economically feasible with the available technology. A reduction in consumption will have great influence on all aspects of rural household energy system since it is an interdependent system. This interdependency exists on a local or regional level. To judge the nature of this interconnection, it is necessary to develop a framework of analysis of domestic energy consumption such as mathematical modelling [Annonymous, 1992].

One advantage of mathematical modelling is that when the parameters of the model are estimated with the help of empirical data, the output of the model can be obtained in the future for alternative set of variables The data, the model, and the output can be stored in the computer for repeated evaluations A large number of studies have been carried out on energy consumption models using regression, time-series and linear programming techniques

Linear multiple regression models can account for most of the variations in different seasons To investigate the variation in the rural domestic energy consumption as a function of population, annual income, number of school going children, and weather sensitive parameters like rainfall and temperature, a multiple regression model is considered appropriate in the present study The model involves creating an association between the dependent variable and the explanatory factors supposedly driving the dependent variable, these are termed as the independent variables

Given estimated equations, the next step is to test the validity of this particular set of relationships There exist a number of statistical procedures for doing this The dependent variables can be estimated for a number of periods If these predicted values are found to be reasonably close to the corresponding observed (actual) values the model is considered to be a valid one [Merrill, 1970]

To assess the energy profiles of rural domestic sector, a comparative analysis of the household energy consumption pattern and available biomass energy in twelve villages of Jorhat district of Assam has been presented This empirical study examines how the household energy consumption patterns in the twelve villages representing different categories are influenced by the locally available biomass energy sources Also, rural household energy consumption is compared with that of semi-urban and urban sectors The comparison of domestic energy consumption together with the study of domestic fuel technology and combustion practice helped in determining the potential health impact of indoor air pollution It also helped in designing a modified stove for minimising smoke and conserving energy

1.6 Scope and Limitations of the Study

Effective rural energy planning is a must for development of rural areas. Because such type of planning helps in improving energy utilization system by boosting up technological development. Appraisal of rural household energy consumption offers tremendous scope for providing necessary modifications, alternations in various aspects for development in rural areas.

The aim of the present study is to gain an insight into the domestic energy consumption in different activities of rural Assam. It is an attempt to assess the rural domestic energy system, to find out the impact of rural domestic energy on health and to identify the problems encountered in the utilization of present rural energy sources in the study area.

The study was conducted in the Jorhat district of Assam to provide research based information. It may be of some help to the rural energy planners at the State level and in turn at the national level and to those who are the actual plan implementers. So, the future rural energy-related programmes can be planned systematically and scientifically to make them more meaningful, effective and useful to ultimate clients. Of course, the quality of energy services and efficient use must be kept in mind.

The research findings of this study may also be useful to those research workers who would like to take up studies of this kind in other parts of the State or the country.

The following are some of the limitations of the present study :

i) As the study is of extensive nature, the study area restricted to Jorhat district only.

ii) The researcher had to rely on whatever information were provided by the respondents for computing rural domestic energy situation. The validity of the findings are dependent on their responses.

iii) A number of observations and secondary data were used for analysis and drawing conclusions. The reliability of these data were limited to the extent of the methodology. The tests used are reliable and valid.

Though these limitations existed, utmost care was taken to get reliable and valid data from the respondents and to make the methodology perfect.

1.7 Study Area

The present study was conducted in the Jorhat district of Assam At the initial stage Jorhat and Titabor sub-divisions were selected purposively. For subsequent selection, a multistage stratified sampling procedure was followed. Blocks were considered as the first stage units, villages as second stage units and contact households were considered as the ultimate stage units.

1.8 Organisation of the Thesis

The text of the thesis has been arranged in eight chapters as follows :

Chapter I : In this chapter, an introduction to rural energy supply and consumption in India has been presented. The problem under study, its objectives, scope, importance and limitations are also stated in this chapter. This chapter is concluded with an overview of the thesis.

Chapter II : This chapter deals with the review of literatures and studies conducted regarding rural energy system. The possible tools and techniques available for carrying out the study has also been presented.

Chapter III — In this chapter rural energy scenario in India has been presented The impact of prevailing energy system on environment, and women has been highlighted

Chapter IV — In this chapter, discussion has been made regarding the method adopted in carrying out the survey and the findings Statistical tools and techniques used to analyse the findings of the survey, energy conversion method, procedure adopted in designing modified stove are also discussed in this chapter

Chapter V — The findings of the study and relevant discussions have been presented under different headings in this chapter Village profile, energy profile, comparison of rural domestic energy consumption with that of semi-urban and urban sectors, impact of domestic fuels on rural women, linear multiple regression analysis of rural domestic energy consumption are presented

Chapter VI — This chapter deals with the design and fabrication of a modified stove The briquetting device, preparation of briquette have also been discussed here The findings of the experiments regarding efficiency and operation of the modified stove are also presented in this chapter

Chapter VII — This chapter deals with the discussion on integrated rural energy management Various forms of rural energy, use pattern, rural energy conservation, audit and plan, biomass energy awareness etc are discussed in this chapter

Chapter VIII — The findings of the study have been summerized in this chapter and discussions are made about possible future study in this area

References and appendices are placed at the end of the thesis

CHAPTER II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Numerous research studies have been conducted in India and abroad on different aspects of rural energy. Keeping in view the objectives of the present study, pertinent and relevant literatures as per availability to the researcher have been reviewed and reported under following heads :

2.1 Rural Energy

2.2 Rural Energy and Environment

2.3 Rural Energy Consumption Pattern

2.4 Methodology used by Researchers

2.5 Past Research Findings

2.1 Rural Energy

According to Leach (1987), rural energy needs services of the household sector (cooking, lighting, drinking water supply). Shaft power uses (pumping irrigation water and agro-processing industry) and process heat for agro-processing dominate rural energy requirements and regulate the quality of life in rural areas.

There appears to be need for an alternative approach which will result in the energy needs of rural areas being met in sustainable and equitable way [Reddy *et al.*, 1991]. The energy needs, especially household energy problems, are reflections of poverty. They persist not because they are insoluble but they have not been addressed with sufficient commitment and vigour [Hall *et al.*, 1992].

According to Planning Commission [PC, 1992], the dominance of biomass energy in rural India is projected to continue, along with its low efficiency of use and the resulting poor quality of life to the rural population. It is useful to compare the rural energy situation in India with that in other developing countries and to look for commonalities, if any. It helps to explore the need for an alternative approach to rural energy planning, the potential role of biomass energy, or at least the technical potentiality of biomass in meeting the energy needs of development. Developing countries are different from one another. So what is appropriate for one country may not be so for the other because of the wide variation in resource base besides the differences in cultural, social and economical situations [Anon., 1992].

Jackson (1992), opines that there are common features in developing countries encompassing a dominance of rural population, high population growth rates, high levels of dependence on biomass fuels and low commercial energy consumption. Most other developing countries are better endowed with land and biomass resources than India. Thus, while it looks as though biomass energy has a high potential to provide quality fuels in rural India and to contribute to an improved quality of life, rural energy planning should be location specific and based on technical potential to make a realistic beginning [Ranganathan, 1992].

2.1.1 Role of Biomass as Rural Energy

Among the renewables, biomass is a renewable fuel used in every corner of the developing world as a source of heat, particularly in the domestic sector [Anon., 1992]. Biomass energy includes all plant matters and animal dung. According to World Energy Council [WEC, 1993] modern bio-energy systems could be set-up in any location where plants can be grown or domestic animals can be reared. According to Pachuri (1993) the main sources of energy for rural people, who constitute 80 per cent of population of India, are biomass fuels like wood, crop residues and cattle dung. United States Department of Energy [USDOE., 1993a] establishes a dominant role of biomass as rural energy among all the renewables. It also suggests that biomass energy will be the most important renewable energy option for future. Biomass based village energy systems, where all the energy services of village ecosystem are met by bio-energy technologies, can be technically feasible [Ravindranath, 1993]

A study on potential role of biomass in India has shown that the electricity needs for lighting of half a million villages could be met sustainably through decentralized biomass electricity while requiring only a part of the existing degraded lands for biomass production [Ravindranath and Chanakya, 1986]

In addition to meeting the heat and lighting requirements, biomass has the potential to supply electricity at national level and liquid fuels for transportation Biomass energy options are feasible with improvement of currently available technology Additionally, the large-scale utilization of biomass energy can provide a basis for rural development and employment in both developed and developing countries [Cherail, 1993] A significant benefit of utilization of biomass is that if used in a sustainable way, bio-energy could lead to no net emission of CO_2, and would lead to a reduction of greenhouse gas emissions [Hall *et al*., 1990]

Hall (1991) observes that biomass energy production and utilization is also site specific and still faces many economic, social and institutional barriers that need to be resolved at both local and national level Venkataramana (1991) opined that in spite of all its attributes, biomass is not the complete answer to the energy problems of developing countries since it has its own limitations

According to Biomass Technology Group [BTG, 1993b] biomass has many advantages and can overcome the perceived problems In spite of many advantages, biomass energy has not commanded the attention of energy planners It is a fact that in many countries such as India and China, in spite of various subsidies and incentives over the past 10-15 years, biomass energy technologies have not achieved any serious market penetration

Ravindranath *et al.* (1995) referred biomass energy systems as an opportunity for sustainable, self-reliant and equitable development (leads to local control and employment) of rural areas.

2.1.2 Socio-economic Status and Type of Fuel Used in Rural Areas

It is important to understand the relationship between socio-economic status of households and type of fuel used in the domestic sector for cooking, water heating, space heating and space lighting. Reddy (1982) opined that domestic fuel consumption in rural as well as urban areas generally increases with increased income. It should be noted that in rural areas the type of biomass use changes little with income. Thus one could expect increased per capita use of biomass energy in rural areas since with increased income, households probably cook more dishes or may entertain more guests, than the landless, marginal farmers or poorer households.

The results of a study in urban areas on the relationship between income levels and biomass fuel use showed that biomass fuels, especially fuel wood, dominate energy use at very low-income levels. Biomass use declines as income levels increase. At mid income levels biomass use is not significant and at higher income levels it is nearly absent [TERI, 1992b; Reddy and Reddy, 1994].

Similar studies in villages of Haryana [Bhide, 1992] and Himachal Pradesh [Singh, 1993] showed that crop residues and twigs together are the dominant types of fuel, followed by fuel wood among the all land holding groups, except that large farms seem to depend a little more on fuel wood. Ravindranath (1993) analysed type of biomass used in Indian villages according to the land-holding size. The land-holding size was taken as an indicator of economic status; landless are the poorest and those having large farms are most effluent. According to him crop residue and dung use declines according to the operational land-holding size. Alternatively, use of fuel wood goes up for large farms.

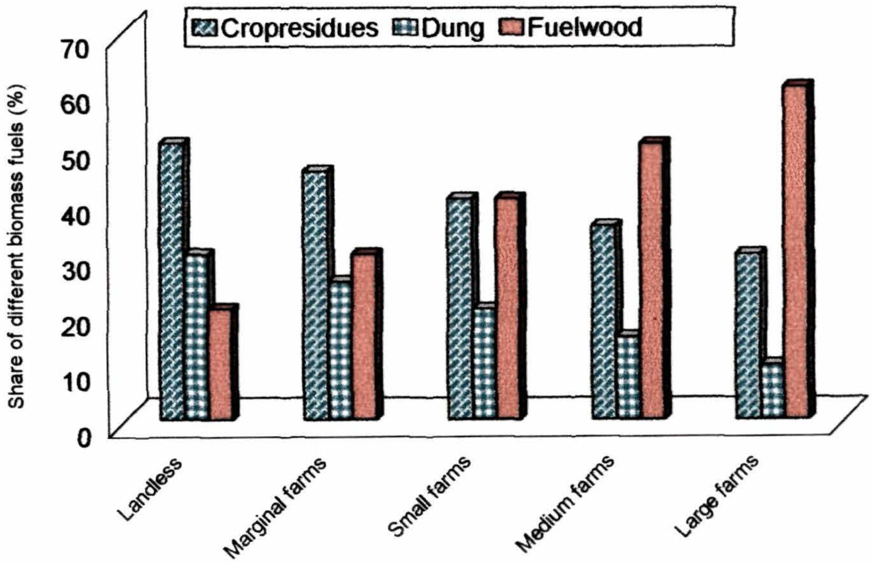

Fig. 2.1 **Relation Between Size of Farm (Proxy of Income) and Type Of Biomass Used in Some Typical Indian Villages (From Ravindranath 1993)**

A few case studies conducted by Chaturvedi (1993) in few Indian villages revealed that irrespective of income and socio-economic status, all households of the villages wholly depended on fuel wood from the forests. Thus, among rural households of a given area it appears that the types of fuels used were nearly uniform among all income groups.

2.1.3 Mode of Procurement of Biomass

Reddy (1982) viewed from a study conducted on six villages in South India that households depended on biomass gathered from public land or their own sources and only 20 per cent of households purchased fuel wood.

Human effort for gathering biomass may increase with declining supply due to degradation of fuel wood sources. An important aspect of gathering fuel wood is drudgery for women and children who often walk in the hot sun or rain on roads and fields often littered with stones and thorns, with a load on their head. It has important social and economic consequences for the family and the country as a whole. The shortages of cooking fuels would put increasing pressure on women and children [Reddy *et al.*, 1987].

Veena's study (1988) in selected villages of West India revealed that rural people obtain fuel wood and crop residues free from their own sources or from common land. The proportion of households gathering biomass was higher for landless people. Sometimes they obtain crop residues from farmers as wages.

According to Puri (1988), the forest was the dominant source of fuel wood in the rural Haryana. Among crop-residues-using households, 58 per cent obtained residues from their own sources and 25 per cent (mainly landless) obtained it as a part of their wages, while dung was wholly obtained from their own cattle. Bhide (1992) and Ranganathan *et al.* (1993) opined that for over three-quarters of rural households, gathering from forests continues to be the major mode of obtaining fuel wood.

2.1.4 Regional Variation in Biomass Use

Biomass use is likely to be determined by local climate (temperature and rainfall), vegetation type, fuel wood availability and access to fuel wood [PC, 1989].

India has been classified into 15 agro-climatic zones. The variation in the type and extent of biomass use according to agro-climatic zones are presented in Table 2.1.

Table – 2.1
Variations in Type of Biomass Fuel Used According to Different Agro-Climatic Zones in India

Sl No	Agro-climatic zones	Fuel wood (kg/cap/day)	Cattle dung (kg/cap/day)	Crop residues (kg/cap/day)	Energy value of biomass fuel use (GJ/cap/yr)
1	Western Himalayan	1 09	0 17	NA	6 82
2	Eastern Himalayan	1 90	0 20	0 37	13 16
3	Lower Gangetic	1 93	0 56	0 62	10 83
4	Middle Gangetic	0 45	0 41	0 30	5 94
5	Upper Gangetic	0 29	1 29	0 04	8 23
6	Trans Gangetic	0 38	0 57	0 34	6 54
7	Eastern Plateau and Hills	3 36	0 01	0 24	19 58
8	Central Plateau and Hills	0 95	0 65	0 26	9 69
9	Western Plateau and Hills	0 94	0 18	0 50	8 42
10	Southern Plateau and Hills	0 94	0 25	0 82	10 29
11	East Coast Plains and Hills	1 78	0 91	1 35	20 70
12	West Coast Plains and Hills	0 94	0 16	0 12	6 52
13	Gujarat Plains and Hills	0 87	0 23	0 31	7 38
14	Western Dry Regions	0 57	0 61	0 13	6 79
15	Island Regions	NA	NA	NA	NA

Data available only for 14 agro-climatic zones

NA Not Available

[*Source* Joshi *et al* (1992b)

A study in South Indian States showed that fuel wood use in the hilly and forest areas are nearly double than that in the plains, which have lower areas under forests [Ranganathan *et al.*, 1993]. Bhat *et al.* (1994) opined that the high rate of dung use in some regions with poor access to fuel wood has implications for the environment and quality of life.

2.2 Rural Energy and Environment

Rural energy consumption patterns have two critical components, namely socio-economic and environmental. Major environmental issues confronting the world today are considered to be deforestation, decline in bio-diversity, pollution of air and water, global warming leading to climate change and degradation of soil and water resources [Anon., 1994].

Non-sustainable use of forest biomass also leads to the loss of a range of forest products and plant diversity [Nishanka *et al.*, 1990]. According to Davidson (1992) fuel wood consumption is contributing to deforestation and soil erosion in highly populated areas.

Siddayao (1992) conceptualized that developing countries cannot ignore environmental issues while striving for economic growth. Since the poor are harmed more by pollution and resource degradation than the rich, energy planners are increasingly looking towards renewable sources of energy.

Environmental aspects are now increasingly becoming an important factor in the making of decisions on energy. Planning Commission [PC, 1992a] states that efficient use of energy resources and long term sustainability are the two key-factors in energy planning.

According to Smith (1993) fuel wood requirement of rural community may not be a factor contributing to 'deforestation' but surely contributes to forest 'degradation' due to the non-sustainable removal of woody biomass.

2.2.1 Impact of Current Pattern of Biomass Energy Use

Biomass energy use in the domestic sector is characterized by low efficiency of use, drudgery in gathering and use, emission of smoke in the kitchen, and ultimately poor quality of rural life. Kerosene is the fuel used by majority of the rural households, mainly for lighting. It has poor conversion efficiency and provides poor quality lighting. According to World Energy Council [WEC, 1993], there is a need to explore the potential for providing quality fuels and efficient devices to promote development in rural areas.

2.2.1.1 Deforestation and Forest Degradation

This has been the subject of intense debate and controversy between Forest Department and researchers. The Forest Department links fuel wood requirements to deforestation and forest degradation [FSI, 1988; PC, 1992a]. Forest Survey of India [Anon., 1988] concluded that the imbalance between demand and production of fuel wood is the one single cause that has contributed the most to forest depletion.

Total rural fuel wood use in domestic sector of rural India was estimated to be 181 Mt/year [Annonymous, 1988]. Based on this, some eminent authors forwarded the following arguments to understand the impact of the use of fuel wood in rural domestic sector.

(i.) Gathering by women and children is the dominant mode of procurement of fuel wood (as head-loads) and they are unlikely to fell trees [Bowonder *et al.*, 1988].

(ii.) Gathering of twigs and small branches does not require tree felling [Leach and Mearns, 1988].

(iii.) Monitoring of tree felling in South India at village level [Ravindranath *et al.*, 1991] and district level [Bhide, 1992] showed that it was largely aimed for sale at urban and industrial markets.

(iv.) Annual wood biomass productivity of forests is estimated to be 137 Mt [Ravindranath *et al.*, 1992b]. If sustainably harvested, it could meet 75 per cent of the rural domestic fuel wood needs.

(v.) Illegal cuttings were not so rampant in primary forests or in plantations, and social forestry measures in India may have arrested further degradation of forests or even that some of the forests have been rehabilitated [Seebauer, 1992].

(vi.) A study in Kerala State showed that only 5 per cent of the fuel wood used came from forests [Kutty, 1992]. Similarly, a study in Haryana State showed that only 9 per cent of the domestic energy use came from wood cut from trees (Bhide, 1992). A large study in Karnataka showed that only 6 per cent of fuel wood used in rural areas came from logs of felled trees [Ranganathan *et al.*, 1993].

(vii.) Twigs and branches obtained in a sustainable way from non-forest tree, shrub sources, social forestry plantations, village commons, crop lands and homestead gardens, dominate fuel wood supply scene [Ravindranath *et al.*, 1994a].

2.2.1.2 Loss of Biodiversity and Land Degradation

Houghton (1991) admitted that excessive removal of vegetation and damage to ground vegetation during removal of fuel wood could affect plant diversity. In India it is common to observe fuel wood gatherers collecting uprooted shrubs and over lopping trees on village common lands, which exposes the soil to tropical monsoon rains. As estimated by World Resources [WRI., 1992] 7 per cent of soil degradation on a worldwide basis was due to excessive use of fuel wood and removal of vegetation. In dry areas, stripping land of vegetation for fuel wood leads to soil erosion due to wind and water effects.

2.2.1.3 Indoor Air Pollution

National Institute of Occupation Health [NIOH., 1980] viewed that emission levels are high for dung cakes compared to fuel wood. A study conducted by Reddy

(1982) in south India showed that the number of hours spent by women in cooking ranged from 3.3 to 4.6 hours per household per day.

De Koning *et al* (1985) explained that there is an influence of the greenhouse effect globally. Besides, locally the population may be affected by chronic lung diseases, heart problems, lung cancer, diseases of respiratory tract, childhood diseases and increased infant mortality due to the emission levels of biomass combustion.

According to Smith (1987) ventilation parameters and stove type influence smoke exposures to women. Another study by Veena (1988) in 10 villages showed that women spend 3.1 – 3.4 hours in cooking per household per day. Rural women are, therefore, exposed to smoke from biomass combustion for longer periods.

It was concluded by Ravindranath *et al.* (1989c) from a vast study in Karnataka State that even if an improved stove consumes more fuel than a traditional stove, it is better to use improved stove because it does not emit much smoke.

Ramakrishna *et al* (1989), Ranganathan *et al* (1993) viewed that in most locations of rural India, cooking is done mainly indoors and majority of the households have no chimney to remove smoke. Ramakrishna (1990) tried to establish quantitative estimates of the influence of several environmental and cultural characteristics like stove type, kitchen location, fuel type etc. on exposures.

A review of health-effects of exposure to smoke concluded that there is growing scientific evidence to support many anecdotal accounts relating high biomass smoke levels to significant health-effects [Smith, 1991].

Raiyani (1993) discussed the indoor concentration to particulate matter during the cooking hours across the houses belonging to low socio-economic group in eastern Ahmedabad. It was concluded that households using cattle dung, wood and coal emit large amounts of particulate matters.

Smith (1994) went on further to saying that exposure to smoke depends on pollution concentration as well as the number of people involved. Since a large number of variables are involved in studies of air pollution and human health, it is difficult to prove that air pollution has a clearly demonstrable effect on human health at normal concentration. Bart *et al.* (1995) had tried to estimate dose response functions for respiratory diseases among children based on data from public clinics in Santiago, Chile. They found that prevalence of respiratory disease among Santiago's children is significantly affected by air pollution.

The survey conducted by National Family Health Survey (NFHS) of India in 1992-93 revealed that three-fourth of the households surveyed used wood or animal dung for cooking leading to 6.6 per cent prevalence rate of acute respiratory infection (ARI) among children under three years. The prevalence rate was higher in case of children living in mud houses [Mishra *et al.*, 1997].

Again according to Mishra *et al.* (1997), women above 30 years of age, attributes 20 per cent of complete blindness and 17 per cent of partial blindness attributable to cooking smoke from bio-fuels. Women who have higher age, less education and those who are economically and culturally less endowed have relatively higher prevalence of blindness. Similarly, the prevalence was higher for women staying in mud houses and without a separate kitchen [Mishra *et al.*, 1997].

Kersten *et al.* (1998) established that burning of biomass fuels in traditional stoves emit pollutants such as CO, CO_2, NO[1]$_X$, HC_S and particulate matters. Another study conducted reported obstructive diseases among women cooking in open fires [Parikh *et al.*, 1999].

2.2.1.4 Atmospheric Pollution and Climatic Change

Tropical deforestation is currently a significant environmental and developmental issue and the subject of much research. According to World Resources

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[1] NO_X oxides of nitrogen

[WRI, 1992], loss of tropical forests diminishes bio-diversity, contributes to climatic changes by releasing stored carbon into the atmosphere and often results in serious soil degradation.

Sampson (1993) referred the rates of deforestation as crucial to estimations of global carbon emissions. Inter-governmental Panel for Climate Change [IPCC, 1992] established that the inefficient combustion of biomass in traditional stoves has a major contribution to greenhouse gases (GHG). At the global level, the overall contribution of CO_2 emissions from biomass stoves to global warming is estimated to be equivalent to about 2 per cent [Ahuja, 1990].

2.2.1.5 Loss of Nutrient Value Due to Combustion of Cow Dung

Cattle dung manure provides organic matters and nutrients, such as nitrogen for crop production. The total nitrogen content of dung produced in India is estimated to be 1.35 Mt annually. Out of this 0.4 Mt is lost annually through the burning of dung as fuel. The loss of nitrogen on a per hectare of crop land basis is estimated to be 2.8 kg/ha [TSL, 1992].

Rajabapaiah *et al* (1993) established that not all the nitrogen in the dung applied would be available, as only 40-45 per cent is retained and the rest is lost due to aerobic decomposition.

The environmental impact of the use of dung as fuel, in terms of loss of nutrient value and organic matter to crop production, is important. Marrison *et al.* (1994) stressed on the provision of quality fuels to prevent direct burning of dung as fuel.

2.2.1.6 Loss of Nutrient Value Due to Combustion of Crop Residue as Fuel

According to Reddy (1982) the residues of crops which can not be used as fodder and which are likely to have significant amount of lignin, are burnt. Thus, the loss of nutrient value in the burning of such residues as fuel is insignificant.

Barnard (1990) recognized the environmental impact of burning of crop residues, particularly the impact on crop production due to loss of organic matter.

2.3 Rural Energy Consumption Pattern

Among developing countries, India was pioneer in rural energy studies both at micro and macro levels, in the aftermath of the first oil crisis [Ravindranath *et al.*, 1981; Reddy, 1982; NCAER, 1981, 1985]. Several studies are available on rural energy use pattern [Joshi *et al.*, 1982b; ABE, 1985; Leach, 1987; Veena, 1988; Bose *et al.*, 1991; Bhide, 1992].

Advisory Board on Energy [ABE, 1985] estimated the range of biomass share in rural India from 36 to 46 per cent. Among the biomass fuel, fuel wood is the most dominant fuel in cooking and kerosene in space lighting in rural India.

2.3.1 Major End Uses of Biomass Energy in Domestic Sector

Major end uses of biomass energy in rural domestic sector are cooking, water heating and space heating.

2.3.1.1 Cooking

National Council for Applied Economic Research [NCAER, 1985] estimated the proportion of households using biomass in cooking at national level as : fuel wood 51 per cent; crop residues 16 per cent; dung 21 per cent; others including commercial fuels 12 per cent.

Forest Survey of India [FSI, 1988]; Joshi *et al.* (1992b) and FAO (1993b) made a national level estimation of fuelwood use in cooking ranging from 93 Mt (110 kg/capita/yr) to 309 Mt (492 kg/capita/yr).

According to Planning Commission [PC, 1992] cooking is the single largest end use activity using biomass in rural households.

2.3.1.2 Water-heating

NCAER (1985) made national level estimation of biomass use for water heating in rural domestic sector ranging from 15 to 19 per cent of total biomass use.

Bose *et al* (1991) observed that if households have to depend on fuel wood and crop residues, they prefer to preserve fuel wood for cooking and use residues for heating water. This is because the density of fuel wood is higher than that of crop residues and dung cakes, thus requiring less fire tending and attention while cooking.

2.3.1.3 Space heating

According to Bose *et al.* (1991) 15 to 40 per cent of total biomass is required for space heating during winter in rural India.

2.3.2 Use of Crop Residues

According to McCauley (1989) the fuel potential of crop residues in India is about 52 Mt/yr and crop residue use alone for cooking was 40 Mt/yr. The dominant use of crop residues in rural India is in the form of fuel and fodder. NCAER (1985), Leach (1987) and Barnard (1990) recognized the importance and contribution of crop residues as a source of fuel for domestic use. They concluded that once fuel wood resources are depleted; households will be forced to shift to crop residues.

Woods *et al.* (1994) suggested that residues of all crops cannot be used as fodder. Stress should be given on using agricultural residues which have fuel potential and can be harvested and transported within the village.

2.3.4 Use of Dung

National Institute of Occupation Health [NIOH, 1980] established that emission levels are high for dung cakes compared to fuel wood. According to Advisory Board on Energy [ABE, 1985] cattle dung use in cooking is a dominant feature in South Asia. Hall (1991) viewed that traditional stoves using dung cake have lower thermal efficiency compared to those using wood. There is also significant drudgery in preparing dung cakes.

Azimi *et al* (1992) argued that though direct burning of dung is not at all suitable from emission point of view, villagers find the following advantages of using it :

i) It is available within the house, in the case of cattle owning households.

ii) It is available throughout the year as a by-product with no additional effort to procure, although it takes effort to prepare dung cakes.

iii) It can be stored easily for the rainy season.

iv) It provides slow and continuous heat.

v) It does not involve any cash expenditure.

2.4 Review of Available Literatures on Methodology

A brief review of the available literatures relating to the methodology relevant to the present study are cited hereunder. It covers reviews on measurement of rural household energy consumption, comparison of rural household energy consumption with that of semi-urban and urban sectors, impact of domestic fuel on rural women, development of efficient technologies, modelling of domestic energy consumption.

2.4.1 Rural Household Energy Consumption

Bowonder *et al.* (1985) carried out a survey on the cooking fuel consumption pattern in rural Gujrat to find out the gap between the demand and availability. Such a survey is essential to evolve alternatives to meet future requirements of domestic energy. Among the possible measures the most promising ones are conserving fuel wood by using better designed chullahs, introducing efficient fuels, utilizing village commons for generating bio-fuels etc.

Energy use pattern by different categories of farmers were assessed by undertaking an energy census and resources assessment survey for various villages in Bhopal [Singh, 1988]. This study was carried out to form a basis for a integrated energy supply system.

Bose *et al.* (1991) made a comparative analysis of the village level energy consumption pattern in eastern Uttar Pradesh based on census survey of households. This empirical study was carried out to examine how the energy consumption pattern representing agriculturally advanced, moderate and backward economic categories, respectively, are influenced by locally available biomass resources. It also examined the percentage share of biomass fuel in the total energy consumed for domestic activities.

Based on large-scale survey at national level, National Council of Applied Economic Research (NCAER, 1992) made an estimation of fuel wood, dung cake and agricultural residues in Mt/yr.

Mittal (1993) conducted a vast study at national level to examine the percentage of the total energy consumption in cooking in rural domestic sector. Bulk of this energy demand was met by non-commercial energy sources such as fuel wood, dung and crop residues.

Singh (1997) examined the energy use pattern of rural households in 21 villages of Sirmour district of Himachal Pradesh. The study was conducted to assess the type, quantity, pattern and technology of domestic energy consumption in cooking, water heating, space heating and space lighting.

Zehmming *et al.* (1997) investigated domestic energy consumption in rural areas of Yangzhong County of China by stratification sampling method. The investigation was carried out to estimate the average annual household energy consumption per household in GJ/capita/yr. The average energy consumption in the form of straw was separately estimated in GJ/capita/yr.

Kersten *et al.* (1997) included socio-economic conditions, descriptions of the types and number of stoves, fuel types and combustion characteristics, specific fuel consumption, fuel sources and availability in his studies of rural domestic energy consumption in tropical countries of Africa. Determining weights and dimensions of fuel units, wood residues, crop residues, fire places and combustion chambers, the useful domestic energy consumption was found out in kg/cap/yr.

Sarkar *et al.* (1998) carried out similar studies in rural Bangladesh to ascertain the source, type, quantity and quality of domestic energy. The factors on which rural household energy consumption depended such as types, economic status, sizes of family, level of fuel consumption were also analysed.

Xiaohua *et al.* (1999) and Wang (1990) carried out similar studies in Eastern China to examine the commonalities of rural household energy consumption with that of other developing countries.

2.4.2 Comparison of Rural Domestic Energy Consumption with Semi-urban and Urban Sectors

Rural energy consumption depends on a number of factors. To formulate effective rural energy policy, it is essential to compare existing rural energy consumption situation with comparison groups of different stages of development. The different stages of development are identified based on infrastructural facilities like condition of roads, availability of electricity, transportation, civic amenities like post office, bank, co-operative society, marketing facilities, LPG agencies, education facilities, medical facilities etc. [Sharma *et al.*, 1991].

NCAER (1985) revealed that the total energy consumed in cooking, water heating and space heating increased with the rise in income levels in both rural and urban areas.

Biswas *et al.* (1997) also compared the rural household energy consumption with that of urban sector and employed F-statistics to establish the significance of combustion of fuel wood in the two sectors.

Kersten (1998) employed F-statistics to test the variations of domestic fuel consumption in South-West Nigeria and established that wood usage was greater in rural sector than for better situated households of urban sector who utilize kerosene, LPG and electricity in cooking.

Xiaohua (1999) agreed that for effective rural energy planning, there must be comparison among groups. The major features in the difference of domestic energy consumption in comparison groups like rural and urban sectors were economy, living standards and facilities for energy supply, condition and availability of resources.

2.4.3 Impact of Domestic Fuels on Rural Women

World Health Statistics (1983) found that diseases of respiratory tract due to smoke emitted from traditional stoves are the main cause of death in developing countries.

According to Chretien (1984) infectious diseases of the respiratory tract in rural women and children are directly related to indoor air pollution.

The low efficiency of traditional stoves together with low quality fuel burning leads to higher smoke discharge in the kitchen. It leads to deterioration in the indoor air quality and adversely affects the health of women [Ramakrishna *et al.*, 1989].

Chronic lung diseases and corollary heart disease are common in North India and are found more among women staying in smoky environment even though they smoke much less than men [Ahuja, 1990].

Annonymous, (1990) classified indoor air pollution as one of the four most important environmental problems in the world, along with contaminated water, urban air pollution and deforestation.

In an interesting study carried out by Annonymous, (1990) in Ladakh women's lung capacities were found to be directly related to extent of smoke exposure. Both the pollution levels and the ill effects were substantially worse in the winter than in the summer in this high altitude environment due to the additional arrangement of space heating with the help of bio-fuel burning.

According to World Energy Council [WEC, 1993] recommendations on several studies of bio-fuel smoke are – respiratory infections in children, chronic lung diseases and lung cancer in adults, adverse pregnancy outcomes such as low birth weight, still birth etc.

Smith (1993) confirmed that exposure to smoke due to spending number of hours in cooking at the traditional stove each day is statistically associated with declined health of rural women.

Mittal (1993) established that inefficient utilization of bio-fuels has resulted in serious health hazards especially on women and children. So, it is imperative that traditional and inefficient stoves are replaced by more fuel-efficient devices with a view to conserve fuel wood; to improve health and hygienic conditions; reduce drudgery for rural women and children; and improve overall quality of rural life.

According to World Bank (Improving Women's Health in India, 1996) Report, the rural women are compelled to keep the home fires burning till late even in the stage of their pregnancy [India Today, 1997].

As per Annual Report (1998-99) of Ministry of Non-conventional Energy Sources, the time spent by rural women and girl children in cooking and gathering the biomass fuels has a social impact in terms of opportunity cost of the lost time that could otherwise have been spent in child care, enhancing literacy levels and in other productive activities.

2.4.4 Development of Efficient Techlologies

A brief review of available literatures relating to development of efficient technologies are presented here under.

2.4.4.1 Improved Stoves

Higher smoke discharge in the kitchen due to low efficiency of traditional stoves leads to deterioration in the indoor air quality and adversely affects the health of rural women. So, the urgent heed is to develop and promote technologies for efficient conversion and utilization of biomass fuels, with a view to extract more energy from the same quantity of materials, reducing households consumption of fuelwood and improving general standard of living of the rural population [Report MNES. 1998-99].

De Lepeleire (1981) proposed specific per day consumption (SDC, the ratio of the bio-fuel consumption over a period to the product of the number of persons and the number of days in that period) as a measure of wood stove performance. De Lepeleire felt that the overall efficiency varies with many more parameters other than quantity of wood, climate and size and shape of utensils.

Verhaat (1983) suggested the considerations that may influence efficient stove design as depicted in Fig. 2.2.

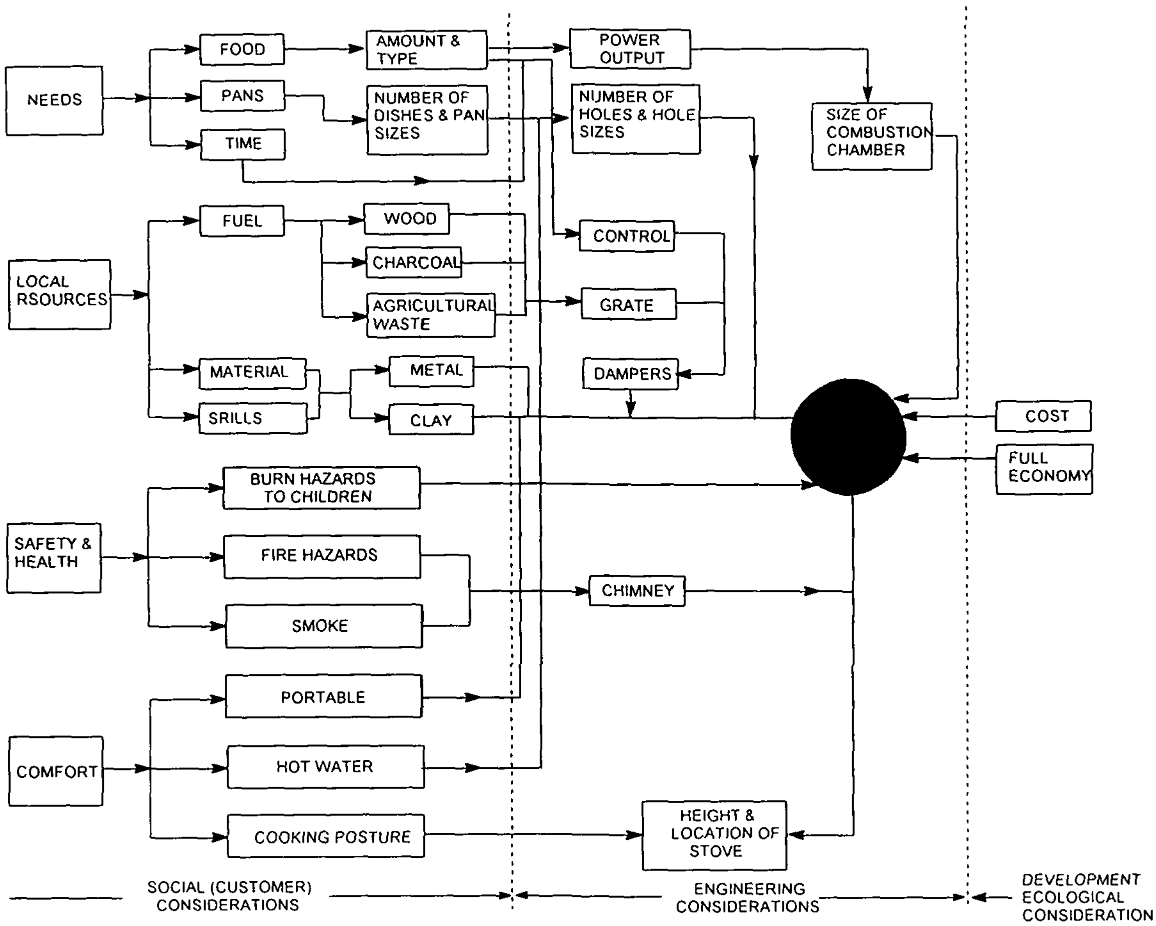

Fig. 2.2 Considerations That May Influence Stove Design [Verhaat P. 1983]

One of the standard methods to evaluate the performance of a stove is to measure its thermal efficiency as reflected by the water boiling test or PHU (per cent heat utilization) test [Lokras *et al.*, 1983].

Lokras *et al.* (1983) developed 3-pan ASTRA (Application of Science and Technology to Rural Areas) stove with a chimney, which has a thermal efficiency of 35 per cent.

According to Ravindranath *et al.* [1989a] the ASTRA stove is a high efficiency stove and it has been possible due to two principal design factors, namely :

i) Increased generation of temperature by controlled and optimized excess air in combustion; and

ii) Improved heat transfer efficiency by proper dimensional and structural design of the passage with respect to the pans.

In the Southern part of Karnataka, the traditional stove is a three pan mud stove with thermal efficiency of 14.7 per cent. Simultaneous cooking is possible in all the three stove openings since three dishes are traditionally cooked in the region [Ravindranath *et al.*; 1989c].

Maiti *et al.* (1993) developed new generation efficient chulhas and established that chulhas with linings are more efficient and can use different bio-fuels.

National Programme on Improved Chulhas [MNES, 1993a] was based on the fact that the traditional stove has a low efficiency of 5-10 per cent. The main goals of NPIC are :

i) fuel conservation,

ii) removal/reduction of smoke in the kitchen and to improve health status,

iii) check deforestation,

iv) reduction in drudgery of rural women and children,

v) reduction in cooking time, and

vi) employment opportunities for the rural poor.

The Ministry of Non-conventional Energy Sources [MNES, 1998-99] has been working in this direction ever since its inception, through a number of programmes aimed at promoting the development and deployment of efficient technologies for biogas production, improved stoves, biomass gasification and biomass briquetting.

2.4.4.2 Biomass Briquetting

Chatterji (1981) established that among the several technologies for the conversion of energy from various agricultural residues, briquettes production is the best adopted technologies for the developing part of the world.

According to Annonymous, (1990), two types of technologies had been attempted – i) binderless direct compaction technique, and ii) charring of the biomass and making briquettes with binders. Out of these two techniques, the later technology was found effective. There is, thus, need to evaluate the die and ram materials for designing a briquetting device to mix the raw materials available in rural areas.

Raman *et al.* (1993) suggested to consider briquetting as an energy intensive devices. At present, work is going on to try different options of briquetting agricultural residues.

Loose biomass can be directly compacted in the form of briquettes to serve as 'B' grade coal. Biomass briquettes made through manual process can be used as cooking fuel in the domestic sector [MNES, 1998-99].

2.4.4.3 Modelling of Rural Domestic Energy Consumption

Hanif (1983) developed an electrical energy consumption model using linear-programming technique. Parikh (1985) developed a model named INGRAM model using linear-programming technique to analyse the links between agriculture and energy in rural areas.

According to Satsangi (1988) it is necessary to model the energy consumption pattern of a particular region as a function of predictor variables for future estimation of energy requirements. He also suggested several techniques such as regression, time-series, linear-programming, econometric etc. to model the energy consumption in a particular region.

Al-Garni *et al* (1994) proposed a time-series model to explain the variation in electrical energy consumption in the city of Dhahran in Saudi-Arabia.

Reddy (1995) attempted to model the competing technologies in the residential sector of Bangalore city by viewing energy carrier substitution as the result of competition between the old and new technologies.

Ranjan *et al.* (1999) attempted to model the electrical energy consumption as a function of population and weather sensitive parameters using multiple regression technique.

2.5 Review of Past Research Findings

Under this sub-head, the review covers findings of some research works on energy end use approach, and on technology options for providing energy services to rural poor.

2.5.1 Energy End Use Approach

Ravindranath *et al* (1986) viewed that rural energy needs should not be neglected by energy planners. As 75 per cent of the population lives in rural areas and the maority of them are poor, provision of quality energy services to the rural population must receive as much or more attention from energy planners than urban and industrial needs.

According to Goldmerg *et al.* (1988); Asian Development Bank [ADB, 1993], the conventional approach followed by energy planners is to estimate the current consumption levels and growth rates, make population projections, elasticity of energy demand and then plan for enhancing the energy supply. No significant improvement of quality of life has resulted from such an approach.

Reddy *et al.* (1991) suggested the DEFENDUS (Development focussed end use oriented) paradigm as an alternative approach in rural energy planning. This approach to energy demand and supply focuses on people-based development by identifying technological opportunities through an analysis of the end uses of energy in rural areas.

Planning Commission [PC, 1992] suggested the bio-energy option in the context of the medium and long-term goals of rural energy planning.

According to Davidson (1992), increasing in energy efficiency alone would not lead to improvement in quality of life of rural poor as their current energy use levels are very low and they depend on low quality fuels.

2.5.2 Technology Options

Kochar *et al.* (1984) suggested that the scope and scale of rural energy planning could be decided at the district level as a part of overall development of energy technology. The effectiveness of rural energy plans depends on the capabilities at the district level and on the options for alternative energy technology.

Leach (1987) suggested that the ultimate choice of fuels or devices must be left to the individual housewife, farmer or entrepreneur in rural areas. But it is a responsibility of the Development Planner to create affordable and accessible energy alternatives to improve their quality of life, and make technology based devices easy to buy, use, and service.

According to Ravindranath (1993), biomass-based village energy systems where all the energy services of a village ecosystem are met by bio-energy technologies have proved to be economically feasible.

The technology options for providing energy services to rural areas are very limited. According to Joshi (1993), the technology development programme in rural areas needs to be linked with entrepreneurs. A goal oriented R & D programme based on local and renewable resources is necessary to meet the challenges in the rural areas.

Biomass energy technologies are currently available and that will become available in the form of biogas generation, improved stove. producer gas etc. According to Ahmed (1994), the large-scale utilization of biomass in improved technology can provide a basis for rural development and employment in both the developed and developing world. A further significant benefit is that, if used in a sustainable way, bio-energy could lead to zero net emission of CO_2 and a reduction of greenhouse gas emissions.

Woods *et al.* (1994) opined that bio-energy technology could become part of rural development package involving reclamation of degraded and waste lands, general employment at the local level and improving quality of life especially for women and the rural poor.

The rural energy technology was considered to be the technology for the common man. However, it is being stated by the rural people that more attention is now being given to high technology system [Bhatt *et al* , 1994].

Mapako (1997) opined that bio-energy technology options that use locally available resources lead to self reliance, local employment, reclamation of degraded and waste lands, enhancing bio-diversity, substitution of fossil fuels with reduction of carbon emissions.

According to Waqif (1997), the biomass can continue to be an important energy resource in the future.

Sootha (1998) viewed that the biomass resources play an important role and their study as a part of energy technology should be resource-based and focus on energy as well as non-energy uses.

CHAPTER III

Rural Energy Scenario in India

CHAPTER III

RURAL ENERGY SCENARIO IN INDIA

As in most developing countries, in India too, rural domestic energy consumption has a large share in the national energy consumption. Despite the availability of the commercial sources of energy such as electricity, petroleum, oil, diesel. LPG, coal the non-commercial sources of energy namely fuel wood, dung and agricultural residues still constitute the main sources of domestic energy in rural India catering to the needs of about 96 per cent of rural households. Of these traditional sources, fuel wood occupies a pre-eminent position catering to 56 per cent of the rural households [Khatib, 1993; Leach. 1992; Leach, 1993]. Besides, fuel wood also satisfies the energy needs of more than 30 per cent of urban households.

3.1 Rural Energy Use

There are large variations in the efficiency of energy end use and there are differences in the services requiring energy. For example, in the case of cooking, which is one of the chief energy-using activities, it can be seen from Fig. 3.1 that to cook a given quantity of food, the primary energy required declines significantly with a shift from traditional to modern fuels; for example by a factor of five on changing from traditional stoves to liquid petroleum gas (LPG) due to differences in the efficiencies of the devices. Thus, not only the energy-use level is low in rural India, but even the efficiency of use of a dominant fuel such as biomass is low. In the figure, values outside the bar represent daily per capita energy required in MJ.

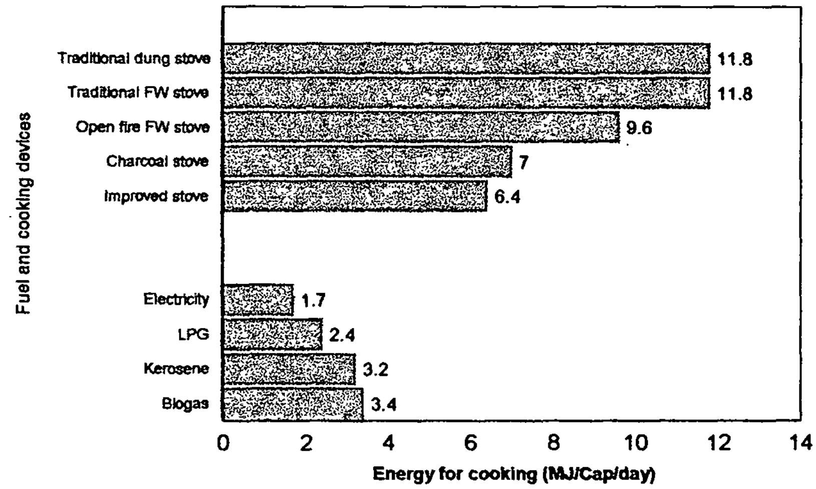

Fig. 3.1 Energy Required for Cooking in Rural India Using Different Fuel-Device Combinations. (From Dutt and Ravindranath 1993)

3.1.1 Dynamics of Biomass Energy

Historically, as technology developed there was a shift from biomass based fuels to fossil fuels and electricity. Thus the role and dependence on biomass energy in India is expected to decline with development. However, comparison over a period of nearly 20 years has shown that biomass energy use (fuelwood, crop residues and dung) has increased continuously as depicted in Fig. 3.2.

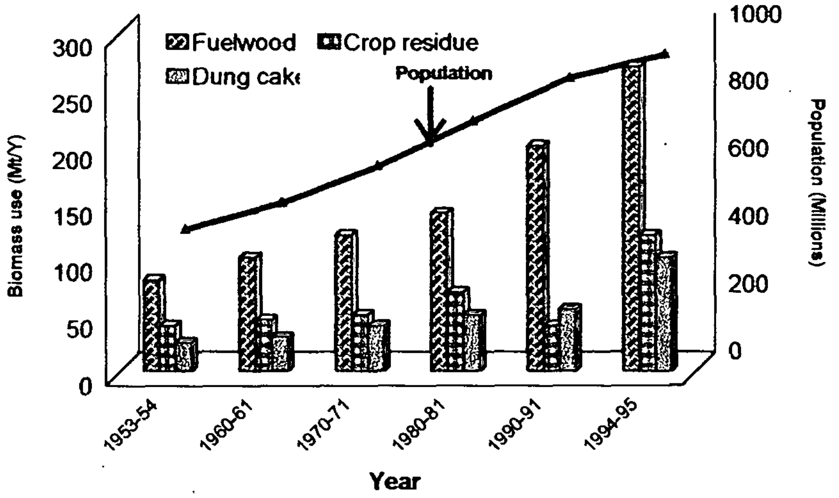

Fig. 3.2 Growth in Use of Fuel Wood, Crop Residues and Dung Cakes in The Domestic Sectors in India Along with Growth in Population (Ministry of Environment 1990; Joshi *et al.* 1992b)

Over the period 1970-90 the rural population increased by 43 per cent. Biomass energy use increased at nearly the same rate in the domestic sector [Joshi *et al.*, 1992b]. Thus, in absolute terms, bio-energy use has continuously increased and the per capita level of bio-energy use has remained nearly constant [Joshi *et al*, 1992b]. It is important to note that the large increase in commercial energy use has not decreased the total use of biomass energy (Fig. 3.3). Population growth, especially in rural areas, coupled with the absence of alternate fuel options or efficient devices, has contributed to the growth in biomass use. Projections on biomass fuels for 2004-05 show that 316 Mt of fuel wood may be required annually, with possibly all the dung produce in India being burnt as fuel [ABE, 1985].

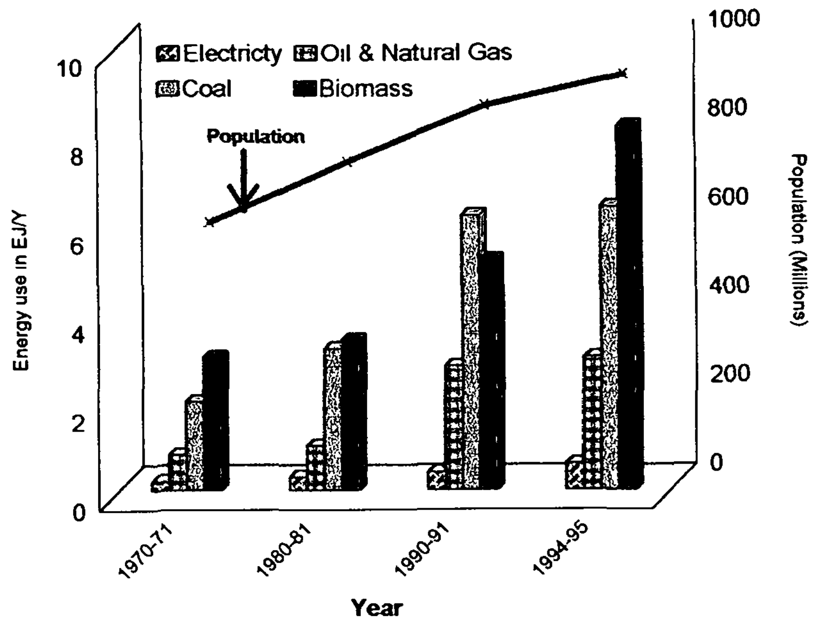

Fig. 3.3 Primary Evergy Use and Population Growth in India from 1970-71 to 1994-95 (Ministry of Environment 1990; PC 1992; TERI 1992b; CMIE 1994)

The crucial implication of increasing biomass energy demand is that the pressure on biomass resources, such as forests, trees, crop residues and cattle dung will increase rather than decrease, even though the use of fossil fuels in the country as a whole is increasing. It means that the absolute role of biomass energy has not diminished in India and is likely to continue to play an important role in the years to come. The current energy related development programmes in India are aimed at conserving biomass (efficient devices) and examining how biomass may be utilized to meet the increasing needs of fuel wood for the growing population [MNES, 1993a]

3.1.2 Sectoral Use of Biomass : Domestic and Industrial

The domestic sector dominates biomass energy use Fuel wood is the dominant source of energy in this sector in rural areas as shown in Table 3 1 Biomass energy use on a country wide basis has been estimated taking the lower and mean consumption estimates of Joshi *et al* (1992b) The lower estimates are considered because they seem to be consistent with the past trends projected for fuel wood

Table – 3.1
Sectoral and Per Capita Use of Biomass Energy in India

Type of biomass	Domestic sector (Mt/yr)[a]		Industrial sector (Mt/yr)		Total use (Mt/yr)	Per capita energy (GJ/yr)
	Rural	Urban	Rural	Urban		
Mean estimate[b]						
Fuel wood	252	30[c]	6[d]	10	298	5 29
Crop residue	99	-	-	57	156	2 68
Dung	109	5	-	-	114	1 85
Total	-	-	-	-	-	9 82
Low estimate[b]						
Fuel wood	181	30	6	10	227	4 03
Crop residue	40	-	-	57	97	1 77
Dung	32	5	-	-	37	0 60
Total	-	-	-	-	-	6 40

[a] Domestic sector involves mainly cooking

[b] Mean and low estimates are from Joshi *et al* (1992b)

[c] Per capita estimates of Ranganathan *et al* (1993)

[d] For brick industry in rural areas

In India, fuel wood is also used in rural industries such as brick and tile making, lime manufacture, and tobacco curing. Unfortunately, data on fuel wood use in rural industrial sector are not available at the national level. These rural industrial sectors, although not the dominant fuel wood users, are important in any effort for conserving wood. Because it is much easier to transfer technology to large establishments as compared to domestic users. For this, it is necessary to initiate studies to estimate the fuel wood use and explore the potential for efficiency improvements in industrial sector [Siddayao, 1992].

3.1.3 Share of Different Biomass Fuels

Biomass is used in all the villages of India and its share of total energy ranges from 79 to 99 per cent. It indicates 79 to 99 predominance of biomass in total rural energy use [Veena, 1988]. Dung is not used as fuel in the southern and western villages, but in north India dung cakes are a major fuel source. One of the reasons for this could be that the northern States have smaller areas under forest per unit of population as compared to the southern States (0.04 ha/capita in Uttar Pradesh; 0.038 ha/capita in Bihar and 0.003 ha/capita in Haryana in the north, compared to 0.1 ha/capita in States such as Andhra Pradesh and Karnataka in the south; FSI, 1992). In most of the rural areas of India, the availability of crop residues with fuel potential is high. But despite such large availability, it is not used as fuel. This clearly demonstrates that if fuel wood is available, households prefer it to cattle dung or crop residues. Table 3.2 shows that commercial energy accounted for less than 20 per cent of the total energy except in rural Gujrat (21% of total energy) where kerosene is also used for cooking. For Karnataka in the south [Ravindranath *et al.*, 1981] and Orissa in the east [Nishanka and Misra, 1990] even when animal energy (e.g., draught animal power) is included, biomass continues to dominate.

Table – 3.2
Biomass Energy Use in Relation to Total Energy Use in Rural India (GJ/cap/yr)

Energy source	UP	Haryana	Gujrat	Karnataka	Orissa
Wood	7 073 (63 80)	0 756 (8 00)	2 166 (30 20)	4 226 (43 50)	9 619 (49 90)
Crop residues	1 680 (15 14)	1 795 (19 0)	2 684 (37 4)	4 085 (42 0)	0 427 (2 2)
Dung	3 660 (17 66)	6 170 (65 20)	0 817 (11 40)	–	6 202 (32 10)
Biomass total	12 413 (96 60)	8 721 (92 20)	5 667 (79 00)	8 311 (85 50)	16 248 (84 20)
Kerosene	0 197 (1 08)	0 086 (0 90)	0 628 (8 70)	0 207 (2 10)	0 218 (1 10)
Diesel	0 235 (2 10)	0 415 (4 40)	0 068 (0 90)	–	0 096 (0 50)
Electricity	0 086 (0 50)	0 237 (2 50)	0 814 (11 40)	0 266 (2 70)	0 052 (0 30)
Commercial energy total	0 518 (3 68)	0 738 (7 80)	1 510 (21 00)	0 473 (4 80)	0 366 (1 90)
Animal[b]	–	–	–	0 123 (1 20)	0 976 (5 10)
Human[b]	–	–	–	0 810 (8 40)	1 710 (8 80)
Total energy	12 931 (100 00)	9 459 (100 00)	7 177 (100 00)	8 784 (100 00)	16 614 (100 00)

[a] Figures in brackets indicate percentage of total energy

[b] Data for animal and human energy use are available for Karnataka and Orissa only

In different regions of India, biomass energy dominates the village energy matrix The following sections present the use pattern of biomass and commercial fuels in rural areas

3.1.4 Major End Uses of Biomass Energy

The major end uses of biomass energy in the domestic sector of rural india are – cooking, water heating and space heating.

3.1.4.1 Cooking

Fuel wood is used in majority of the households in rural India. According to Ranganathan (1993), 99 per cent of rural households use fuel wood in cooking. It is common to observe a mixed pile of fuel wood and crop residues stored in front of the kitchen in rural India. Biomass use for cooking in rural India is listed in Table 3.3.

Table – 3.3
Biomass Energy Use for Cooking in Rural India (capita^{-1} day^{-1})

End use	Estimates	Fuel wood (kg)	Crop residues (kg)	Dung cake (kg)	Total biomass (MJ)	Total biomas energy .. GJ Cap^{-1} yr^{-1}
Cooking	Low	0.79	0.17	0.14	16.00	5.80
	Mean	1.10	0.43	0.47	28.50	10.40

Source : (Joshi *et al.*, 1992b)

Majority of the Indian villages fall within a range of biomass use for cooking of 13-23 MJ capita^{-1} day^{-1}. Total and per capita annual rural fuel wood use for cooking as found out from studies carried out by various agencies at different times are presented in Fig. 3.4.

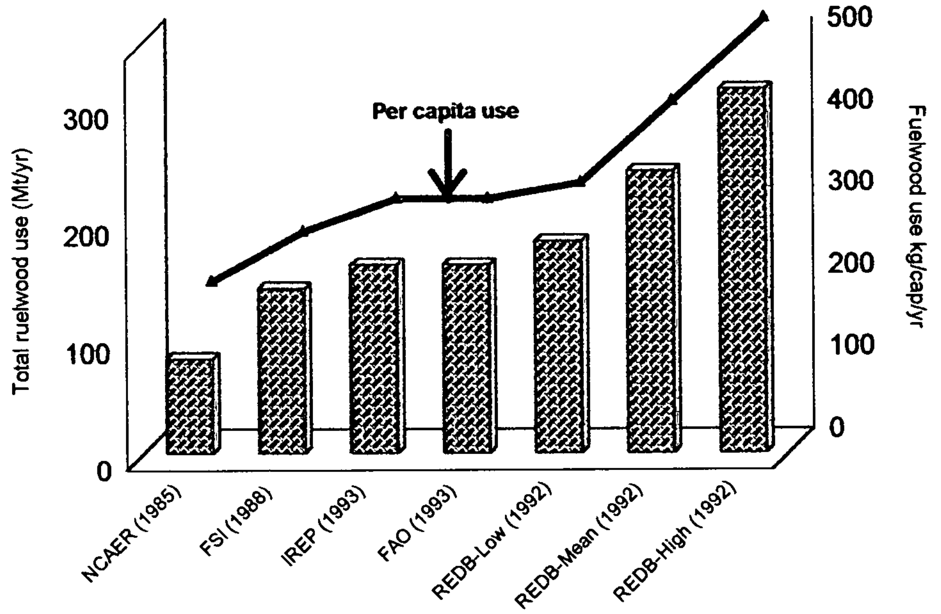

Fig. 3.4 **Total and Per Capita Annual Rural Fuel Wood Use for Cooking in India from Various Studies (Estimated for The 1991 Population)**

Sources : NCAER (1985), FSI (1988), FAO (1993), IREP (1993), REDB (Low, mean and high) from Joshi *et al*, (1992b)

3.1.4.2 Heating Bath-water

Very often the analysis of biomass use in the domestic sector is restricted to cooking alone. The possible reason could be that according to estimates, heating bath-water accounted for only 3.6 per cent of the household energy consumption. Cooking alone used 88 per cent of the total household energy consumption [NCAER, 1985].

It has been estimated that in some villages of India biomass use for bath-water heating ranged from 15 to 19 per cent of total biomass use. Currently it has been observed that most people in some particular villages of India bathe only once or twice in a week. This is possibly more due to the effort involved in fetching water than in collecting fuel wood [Bagchi, 1984]. Moreover, it has been noticed in southern villages of the country that if households have to depend on fuel wood and crop residues they prefer to reserve fuel wood for cooking. They use residues for heating bath-water. This is because the density of fuel wood is higher than that of crop residues or dung cakes. This requires less fire tending and intensity while cooking [Bose *et al.* 1991].

3.1.5 Sources of Fuel Wood in India

One of the intriguing questions for rural energy researchers in India is to explain the sources of fuel wood and the gap between the demand and supply. Many reports and studies have estimated the fuel wood use or requirements over the years. But none of them has assessed the issue of the origin of the cooking fuel [ABE, 1985; FSI, 1988; Joshi *et al.*, 1992b]. According to a survey (during 1978-79) the dominant sources are 26 per cent each from forests and own farms, 17 per cent from roadside collections and other sources, including neighbour's farms, and the rest obtained as a part of wages and not gathered [NCAER, 1985]. It is difficult to draw any conclusions as to the sources of fuel wood for the present period from these studies. FSI(1988) explained the source of only 19 Mt, as supplied by the forest department, out of a total of 157 Mt for the year 1985-86. Finally, it was concluded that over exploitation of forests for meeting cooking fuel needs was the main reason for forest degradation.

Analysing the supply side of fuel wood, Leach (1987) suggested that only 12 per cent of the fuel wood was from logs involving the felling of trees. The other 88 per cent was from cutting of branches.

The Karnataka State study [Ranganathan *et al.*, 1993] could not conclusively establish the sources of fuel wood, as the annual woody biomass productivity from forests was estimated to account for only 18 per cent of the total supply of 20 Mt/yr. It is not clear where the remaining fuel wood requirement is obtained from and how the rate of extraction is sustained. A biomass budget for Karnataka state shows that fuel wood accounts for nearly 50 per cent of the total biomass used in the domestic sector (11 Mt/yr). The forest department supplied only 4 per cent of the fuel demand while the unreserved forests and other sources such as village trees were the dominant sources of fuel wood [Gadgil and Sinha, 1986].

There are several fuel wood sources and that the contribution of different sources is exactly not known. The sustainability of the extraction rates is also not known as even twigs and branches can be collected in a non-sustainable mode. So, it is an urgent need to understand the sources of fuel wood and the rates of extraction at national level in order to assess the consequences of fuel wood use on deforestation and to plan for meeting both short-term and long-term fuel wood needs. Currently, fuel wood conservation and production programmes are based on the assumption that fuel wood demand contributes to deforestation.

Sources of fuel wood can be forests, degraded forests, tree plantations, strips or rows of trees along roads, streams, railway lines, flooded rivers, crop land boundary, common lands, and homestead gardens. The annual use of fuel wood in India is estimated to be 227 Mt/yr. Out of this amount 181 Mt is used in the domestic sector for cooking in rural India.

In India rural and tribal households are allowed to extract headloads of fallen twigs and branches from forests as fuel for family consumption and often for sale in nearby markets. It is often alleged that rural and tribal communities extract fuel wood in a non-sustainable way, leading to forest degradation. Most forests in India are undoubtedly subjected to higher use due to high population density and dependence on biomass. Thus it could be assumed that a minimum of 42 Mt of fuel wood potentially available from the forests is removed [Ravindranath *et al.*, 1994a] annually.

In many states, Forest Departments provide fuel wood through fuel wood depots to local communities. This mostly comes from the felling of trees, since only cut logs and branches are sold in the depots. According to an estimate 19 Mt of fuel wood is supplied annually from the forest [FSI, 1988]. 9.5 Mt of branches and twigs would be available when trees are felled to produce 21 Mt of timber. Generally, whenever trees are felled the twigs and small branches are sold to local communities or left to be collected freely by them [FSI, 1990].

Thus the total contribution of forests to meet the fuel wood demand is estimated to be 70.5 Mt, out of which only 27.00 per cent is expected to come from the felling of trees, possibly leading deforestation (Table 3.4).

Table – 3.4
Summary Table of Sources of Fuel Wood Used in The Domestic Sector, Mainly for Cooking

Sources	Details	Total fuel wood contribution in Mt/yr
Forests (64 Mha)	1 Felling of trees	19 0
	2 Lopping of twigs and branches	42 0
	3 Logging wastes	9 5
	Total	70 5
Tree plantation (17 Mha)	Tops + twigs + small branches	40 0
Farm tree	Twigs + branches	46 0
Homestead garden	Twigs + branches	16 0
Degraded land[a] (52 8 Mha)	0 5 t wood/ha/yr	26 4
Land for shrub estimation (78 5 Mha)	0 25 t/ha/yr (Shrubs, climbers etc)	19 6
Total wood supply		218 5

Sources Kapoor (1992) and Chambers *et al* (1989)

[a]Degraded land is the land whose current biological production is lower than its potential and is declining

3.1.6 Non-tree Biomass

It is common to observe rural people collecting twigs, branches and roots of shrubs and climbers as fuel Some dominant examples are *Prosopis juliflora Lantana camara Cassia auriculata* and *Tecoma stans*, where all parts of such shrubs are collected as fuel Unfortunately no studies are available on the distribution and growth of such shrubs and their contribution to fuel supplies In many rural areas of South India *Prosopis* is already meeting the cooking fuel requirements of a significant proportion of rural households The surplus is sold as fuel wood According to a field study in villages of Andhra Pradesh and Orissa [Rabindranath *et al*, 1994b], 68 per cent of village households met all their cooking energy requirements from *Prosopis* and 18 per cent of households met three-quarters of their fuel requirement from *Prosopis*

Lautana is also present in most regions, particularly in open and degraded forests and the dried *Lantana* is used extensively as fuel A significant proportion of villages meet their domestic fuel requirements from species such as *Prosopis* and *Lantana* These are not necessarily favoured species, because of the presence of thorns in the case of *Prosopis* and low density in the case of *Lantana* However some research projects have initiated in India to breed thornless, hardy *Prosopis* varieties for rural poor Table 3 5 presents the biomass fuel potential of shrubs in northern India

Table – 3.5
Biomass Fuel Potential of Shrubs in Northern India

Shrub species[a]	Fuel potential (t/ha/yr)
Tamarix dioca	1 1
Sesbania aegyptica	21 3
Adathoda vasica	0 5
Vitex negundo	2 8
Nyctanthus arbortristis	5 7
Prosopis juliflora[b]	12 0
Prosopis juliflora[c]	22 0

Sources [a] Shrub species other than *Prosopis* Singh (1988)
[b] *Prosopis juliflora*, Gurumurthy *et al* (1984)
[c] *Prosopis juliflora*, Chaturvedi (1993)

Unfortunately no studies on the productivity of *Prosopis juliflora* and *Lantana camara* in their natural habitats in different regions of India are available

3.1.7 Crop Residues

The importance and contribution of crop residues as a source of fuel for domestic use has been recognised in several studies [NCAER, 1985, Leach, 1987, Barnard, 1990] The general conclusion of such studies is that once fuel wood resources are depleted, households will be forced to shift to crop residues The dominant use of crop residues is in the form of fuel and fodder in rural India The rural people donot use crop residues as fuel where there is a forest to provide wood [Bose *et al*, 1991] According to the available data, the extent of residue used as fuel in Indian villages ranged from 28 per cent to 71 per cent of the total available residues with fuel potential. In some Indian villages, the use of residues was more than the production. They collected residues from nearby villages [Krishnakumar, 1993].

3.1.7.1 Crop Residue Production and Its Use at the National Level

Crop residue production and end uses in India for fuel and fodder are given in Table 3.6.

Table – 3.6
Crop Residue Production and Use as a Source of Fuel in India[a] (Mt Dry/Yr) During 1992-93

	Fodder for livestock	Domestic fuel	Fuel in industry and establishments	Other uses[b] or unused
Paddy + wheat + millets	254	2	16[c]	5.5
Pulses	19	10	-	-
Oil seeds	12	16	-	0.8
Fibre crops (cotton, jute)	-	12	-	-
Mulberry	-	2	-	-
Sugarcane	-	-	28[d]	19.3
Coconut + arecanut	-	7	-	2.2
Coffee + tea	-	3	-	-
Total	285	52	44	27.8

[a] Based on number of field studies and observations by Ravindranath (1993)

[b] Other uses include : thatch material (rice straw and coconut leaf)

[c] Rice husk use in brick firing and rice parboiling

[d] Sugarcane bagasse (dry) use as fuel in sugarmills

Crop residues from cereals, which are low in lignin, are used as fodder for cattle. The woody stalks of the pulses are used as fuel (10 Mt annually). The residues of oil seed crops, such as groundnut (husks), niger, castor and the stalks of fibre crops such as cotton and jute are all used as fuel. Mulberry stalks provide a continuous supply of fuel to farmers growing mulberry for its leaves to silkworms. The productivity of mulberry is estimated to be about 10 t/ha/yr [Ravindranath and somashekar, 1991].

The area under coconut plantation in India was 1.5 Mha in 1991. In some southern villages of India, the annual contribution of coconut residues as fuel was estimated to be 40 per cent of the biomass fuel used for cooking [Ravindranath and Somashekar, 1991]. Coconut produces several types of residues and their potential fuel productivity is 5.4 t/ha/yr (for yong plantations) to 11.7 t/ha/yr (for mature plantations) at a density of 100 trees/ha [Ravindranath *et al.*, 1991]. Thus these crops such as mulberry and coconut have a large potential for providing fuel for domestic use for the farmers.

The fuel potential of crop residues in India is estimated to be about 52 Mt annually. However, crop residue use for cooking at national level was at 40 Mt/yr [Joshi *et al.*, 1992b] as shown in Table 3.1. The point to be noted is that the residues of all crops are unsuitable for use as fodder. Crops which can be harvested and transported within the village,and are having significant lignin all can be used as fuel [Reddy *et al.*, 1987].

3.1.8 Cattle Dung Production and Fuel Use

Cattle dung use is a dominant feature in south Asia. In India it is used only in certain parts. Traditional stoves using dung cake have lower thermal efficiency compared to those using wood (Fig. 3.5). There is also significant drudgery in preparing dung cakes. Dung has the following advantages for household energy supply :

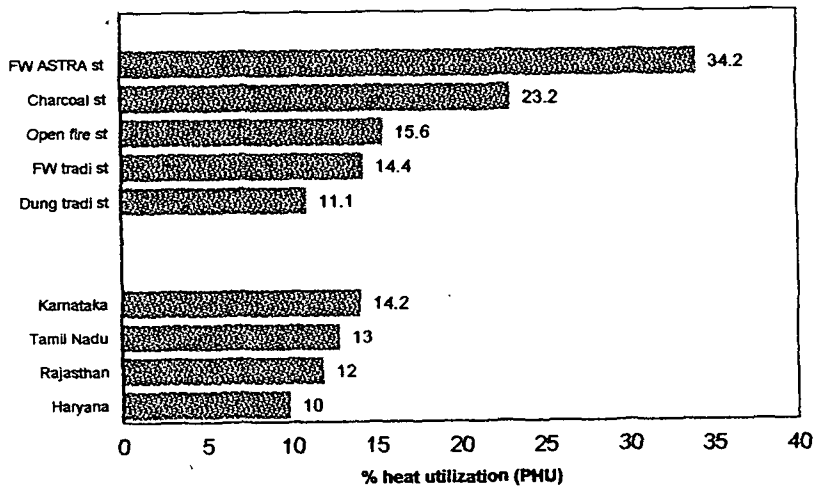

Fig. 3.5 Thermal Efficiency of Different Types of Stoves in Different Regions in India [From Joshi et al. 1989; Ravindranath et al. 1989a; Dutt and Ravindranath 1993)

i) It is available within the premises of the house, in the case of cattle-owning households. In major dung-using States, such as Uttar Pradesh, Bihar and Madhya Pradesh, 80, 59 and 70 per cent of rural households, respectively, own cattle [ABE, 1985].

ii) It is available throughout the year as a by-product with no additional effort to procure, although it takes effort to prepare dung cakes.

iii) It can be stored easily for the rainy season.

iv) It provides slow and continuous heat.

v) It does not involve any cash expenditure.

In the absence of fuel wood, dung is thus a convenient fuel from the supply point of view for the rural housewife.

3.1.8.1 Dung Yield

Dung yields vary from location to location. Many national level estimates were based on high yields obtained from animals with high feeding levels [ABE, 1985; PC, 1992]. There are also seasonal variations as animals have access to more grass during the rainy season compared to winter; thus resulting in higher yields in the rainy season. What is important from a dung cake or biogas point of view is not the total dung yield per day but the collection rate during the period of the day when the cattle are tied in the shed. When the cattle are grazing or working in the field, the dung produced cannot be easily collected or transported due to the high level of human effort involved.

3.1.8.2 Dung Production

Livestock population and dung production in India is shown in Table 3.7. The total cattle population in 1992 was estimated to be 257 million, giving cattle to rural human population ratio of 0.41. The dung of sheep and goats is not used as fuel as their rate of production is low and can not be easily made into cakes due to the lower moisture content. But such dung can be used as feedstock for biogas production. The total collectable fresh dung production nationally averages about 1.2 Mt/day. The solid contents of dung is 18 per cent (82 per cent moisture). If a 10 per cent moisture is assumed (for dung cakes ready for burning), the dung cake potential on an annual basis is 123 Mt of air-dry weight. Currently over a quarter of this is burnt annually in India.

Table – 3.7
Livestock Population (1992) and Dung Production at National Level

State	Cattle population (million)	Sheep + goats population (million)	Total dung production (million kg/day)
Andhra Pradesh	21.91	13.08	103.8
Assam	7.31	1.77	33.6
Bihar	20.85	13.53	99.2
Gujrat	11.43	5.65	53.7
Haryana	5.69	1.36	26.1
Himachal Pradesh	2.79	2.75	13.7
Jammu and Kashmir	2.88	2.91	14.1
Karnataka	14.95	9.34	71.0
Kerala	,3.5	2.01	16.6
Madhya Pradesh	33.67	8.52	154 9
Maharashtra	20.13	10.37	94.7
Orissa	14.26	6.92	66.9
Punjab	7.85	0.61	35.6
Rajasthan	15.14	28.91	79.7
Tamil Nadu	13.57	10.78	65.4
Uttar Pradesh	41.96	11.99	193.6
West Bengal	16.64	12.27	79.8
Other States	2.48	0.77	11.5
Total	257.01	143.54	1213.9

Source : TERI (1992b) Estimation : 4.5 kg/bovine/day and 0.4 kg/day/sheep or goat

After preparation of the dung cakes they are stored in heaps for use in rainy season. Thus theoretically all the available dung could be used, if necessary.

3.1.9 Socio-economic Aspects of Biomass Energy Use in Rural India

Socio-economic aspects of biomass use as fuel are very crucial to the goals of development and better quality of life. Socio-economic status of the household may depend on the following factors :

3.1.9.1 Access to Biomass Energy

It is necessary to appreciate the access problem to different sources of biomass fuels for households with different socio-economic status in rural India. Rural communities are allowed to collect head-loads of dry or fallen twigs from forests that are protected by the Forest Department. Thus all categories of households have equal access, though sometimes influential families with the connivance of forest officials have greater access to fuelwood. The village commons in India have become 'no-man's-lands' with equal and uncontrolled access to all households for biomass. With the decline of local management systems for the village commons, leading to their degradation, poorer households such as the landless and marginal farmers have lost their main source of fuelwood [Jodha, 1990]. Trees on farmlands are usually used by the land owners themselves. In South India, there are no restrictions on any person collecting fallen twigs from trees. The uniform trend in type of biomass used by different landholding groups shows that access to biomass sources is generally the same for all in a given location.

In the past, crop residues that did not have fodder value were freely distributed or burnt in the field. At present, rural people use crop residues as fuel in some locations. Moreover, poorer households obtain crop residues as a part of their wages in some rural areas. Dung cakes are prepared from the dung of household cattle. The proportion of households owning cattle was over 70 per cent in all the dominant dung using areas of North India [ABE, 1985]. Even the landless use dung cakes at the same rate as the landed ones. They either own cattle or gather dung from fields and village streets.

3.1.9.2 Quality of Biomass Fuels

The quality of different types of biomass used as fuels differs with respect to density, calorific value, moisture content, and emission of pollutants

A . Calorific Value

Crop residues and dung cakes have a lower calorific value compared to fuel wood It indicates a larger volume of fuel to be used for cooking A study of 22 commonly used tree species showed that three-quarters had calorific values of 14-19 MJ/kg for oven dry wood [Jain, 1991]

B . Density

Crop residues and dung cakes have lower densities than that of wood (0 64) Among tree components, stem wood has a higher density than twigs (depending on lignin content) For the housewife, lower density means handling more volume and continuous feeding and tending of the fire Thus a housewife prefers fuel wood to crop residues or dung

C . Moisture Content

The presence of moisture leads to extra smoke and increased tending of the fire Moisture also results in waste of heat to evaporate the water Good air dried wood contains 10-20 per cent moisture The housewives would prefer such properly dried wood But often they have to use fuel wood with higher moisture contents, especially during the rainy season, thereby increasing drudgery Arr-dried dung cakes ready for burning contain 10 per cent moisture

D . Emission of Pollutants

When burnt in stoves, biomass fuels emit pollutants such as particulate matter, carbon monoxide, nitrogen oxides, hydrocarbons etc When compared with the combustion of fossil fuels, the emission of pollutants from wood combustion is higher. Emission levels are higher for dung cakes compared to firewood [NIOH, 1980].

3.1.9.3 Socio-economic Status and Type of Fuel Use

It is important to understand the relationship between socio-economic status of households and the type of fuel used in the domestic sector for cooking. Urban areas provide an excellent example since a range of solid, liquid and gaseous fuels, and electricity are available. As the income levels increase there is a shift away from biomass to liquid fuels and liquid petroleum gas (LPG) at mid incomes and to gaseous fuels and electricity at higher income levels. It is possible to construct an energy ladder from least to most preferred fuel [Fig. 3.6, Smith *et al.*, 1994]. Thus households would usually prefer to switch over fuels as in Fig 3.6.

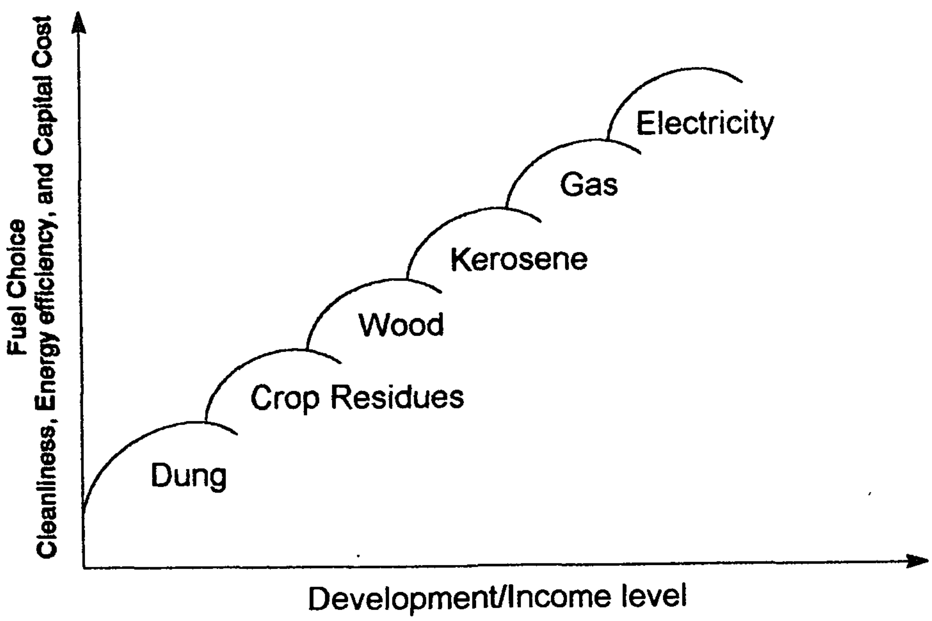

Fig. 3.6 Energy Ladder Typical in India Indicating the Shifts in Choice of Fuel With Increase in Income/Development Level (Smith *et al.* 1994)

3.1.9.4 Socio-economic Status and Quantity of Fuel Use

Fuel type use may change as countries develop and income levels improve. It is important to understand the impact of increased incomes on quantity of fuels used. A study has shown that domestic fuel consumption in rural as well as urban areas generally increases with increased incomes [Bhide, 1992]. However, it should be noted that in rural areas the type of biomass use changes little with income. The reason for increased per capita use of biomass energy with increased incomes in rural areas may be probably households cook additional food (apart from daily meals) more frequently or may entertain guests, than the landless, marginal farmers or poorer households. Thus the *implications of such a pattern is that with development, the demand for biomass energy* per capita might increase if higher quality fuel is not made available [Grassi, 1992].

A . Mode of Procurement of Biomass

Biomass fuels are obtained from several sources. In South India, the villagers depend on gathering biomass from public land or from their own sources, and only 20 per cent of households purchase fuel wood [Reddy, 1982]. Fuel wood and crop residues are obtained free from their own sources or gathered from common land in Western India. The proportion of households gathering biomass is higher for landless and smaller landholding households [Kapoor, 1992]. In Northern India, the forest is the dominant source of fuel wood. Among crop residue using households, 58 per cent obtain residues from their own source and 25 per cent (mainly landless) obtain them as a part of their wages. Dung is wholly obtained from their own cattle [Puri, 1988].

B . Human Effort for Gathering Fuel

The human effort involved in gathering fuel wood has received significant attention as it leads to drudgery for the gatherers, because they have to walk in the hot sun or rain on roads and fields often littered with stones and thorns, with a load on their head. At the national level, it has been concluded that the average number of hours spent on gathering biomass is about 2 hours/day/household. Such human effort for gathering biomass may increase with declining supply due to degradation of fuel wood sources. Table 3.8 presents human effort in gathering fuel wood in a number of locations in rural India.

Table – 3.8
Human Effort in Gathering Fuel Wood for Domestic Use

Location	Hours spent/week/household
6 villages in South India (1982)[a]	15.1
10 villages in Western India (1988)[b]	11.2
8 villages in Northern India (1988)[c]	14.3
6 villages in Eastern India (1990)[d]	35.0

[a] Reddy (1982), [b] Veena (1988), [c] Puri (1988), [d] Nishanka and Misra (1990)

An important aspect of gathering fuel wood is the dominance of woman and child labour, which has important social and economic consequences for the family and the country as a whole [Reddy, 1982]. Thus shortage of cooking fuels would put increasing pressure on women and children. The rural women are exposed to drudgery in gathering fuel as well as exposure to smoke during use. Any scarcity of fuel wood or shift to lower quality fuels will thus affect the quality of life of women most adversely.

3.1.10 Commercial Energy Use in Rural India

Commercial energy use in India accounted for 63 per cent of the total primary energy. Out of the total commercial energy use industry consumes 50.5%, followed by transport (24.5%), household (13.7%), and others (2.3%). This clearly shows that urban and industrial sectors dominate commercial energy use. Thus it is necessary to understand the extent of use of different commercial energy sources and their features in rural areas.

All the well-known energy databases or reports (CMIE, 1994; PC, 1992; TSL, 1992; TERI, 1992b) provide very little information on commercial energy use in rural areas. None of these reports give any data on kerosene or electricity use for lighting in rural India. Estimates on commercial energy use in rural India are made based on some case studies.

3.1.10.1 Electricity Use

Table 3 9 presents the estimated data regarding use of electricity, diesel, and kerosene in rural India in 1991 Electricity use in rural areas is estimated to be 67 7 TWh[1], which accounts for only 23 per cent of national total (although 80 per cent of the population live in rural areas) with a per capita energy use of 108 KWh However, the achievement of rural electrification in India is truly commendable, with 84 per cent of the 0 55 million villages already electrified [TSL, 1992] But only a quarter of the rural houses are electrified Rural electrification seems to be largely aimed at providing energy for pumping irrigation water [PC, 1992] The rate of consumption of electricity is 5362 KWh/pump [CEA, 1991] It is also interesting to note that the share of agriculture in total electricity use has increased from 10 per cent in 1970-71 to 28 per cent in 1991-92 [CMIE, 1994] This shows the growing importance of the power needs of the agricultural sector

Table – 3.9
Estimated Electricity, Diesel and Kerosene Use in Rural India (1991)

Activity	Number of HH[a] or units or villages	Electricity, diesel and kerosene use (units)	Total electricity/ kerosene/diesel use per year
Lighting (electricity)	28 million HH	408 KWh/HH/yr	11 4 TWh/yr
Agriculture	91 million pumps	5362 KWh/HH/yr	48 8 TWh/yr
Agro-processing	0 484 million electrified villages	15450 KWh/HH/yr	7 5 TWh/yr
Total	-	-	67 7 TWh/yr
Diesel pumps	5 5 million pumps	854 kg diesel/yr	4 7 Mt
Kerosene in lighting	627 million	6 6 litres/capita/yr	3 35 Mt

[a] HH = Households

Source CEA (1991)

[1] TWh Tera-watt hour (10^{12} watt-hour)

3.1.10.2 Diesel use

Diesel use in rural India is largely for pumping irrigation water and, nationally, agriculture accounts for 9 per cent of total oil use. Diesel is also used to fuel tractors for draught power in agriculture and rural transport and agro-processing.

Even though 84 per cent of villages are electrified in India, there are 5.5 million diesel pumps. This can be viewed against the fact that electrical pumps are cheaper to operate than diesel pumps [Rajagopalan and Demaine, 1994]. The use of diesel pumps could be due to non-availability of electrical connection from the grid, low reliability of electricity supply.

3.1.10.3 Kerosene

Kerosene is the fuel used by most households (about 97%) in rural India [NCAER, 1985]. Kerosene is used chiefly for lighting in rural areas in both electrified and non-electrified households. National level use of kerosene in rural India during 1978-79 was 5.1 lit/capita/yr [NCAER, 1985], which rose to 6.6 lit/capita/yr in 1993 [Ranganathan *et al.*, 1993]. Another national level estimates ranged from 6.9 to 8.5 lit/capita/yr [Bose *et al.*, 1991]. The rural kerosene use would be around 3.4 Mt annually (at 6.6 lit/capita/yr). Kerosene use for lighting is characterized by low conversion and luminous efficiency [ADB, 1993]. The luminous efficiency of a kerosene wick lamp is 0.1 lumens/W, compared to 12 lumens/W for a 60 W incandescent bulb [ADB, 1993]. Information on kerosene use in rural areas for cooking is limited. In contrast, kerosene is the preferred cooking fuel next to LPG in urban areas.

3.1.11 Environmental Impacts of Biomass Energy

The extraction, conversion, and utilization of various forms of energy is recognized as one of the major contributors to environmental degradation at global as well as the local level. It may be the greenhouse gas emissions and local air pollution due to combustion of fossil fuels, or forest degradation due to fuel wood use. It is necessary to understand the environmental implications of biomass use as an energy source via :

i) Contributions to deforestation and forest degradation, leading to and soil degradation loss of biodiversity.

ii) Atmospheric pollution from emissions of greenhouse gases during combustion of wood, with its implications for climate change;

iii) Release of pollutants (indoor air pollution) leading to domestic health hazards (particularly for women); and

iv) Loss of nutrients due to combustion of cattle dung and crop residues.

3.1.11.1 Deforestation and Forest Degradation

Deforestation has been the subject of intense debate and controversy in India. The imbalance between demand and production of fuel wood is the single cause contributing the most to forest depletion [FSI, 1988]. Total rural fuel wood use in the domestic sector was estimated to be 181 Mt annually (Table 3.1). So far no study has provided any significant evidence to prove that rural or tribal needs for fuel wood are met by clear felling of forests. It is apt to quote Leach and Mearns (1988), "if all fuel wood and charcoal use is stopped tomorrow, deforestation rates would hardly be altered". A study of fuel wood use in urban centers and deforestation, using satellite data concluded that open forests have increased and closed forests are being converted to open forests in the vicinity of urban centers and that this decline is attributed to fuelwood extraction [Bownder *et al.*, 1988; Alam *et al.*, 1985].

Twenty nine per cent of the total urban use of fuel wood (40 Mt, Table 3.1) comes from sources termed as forests [Ranganathan *et al.*, 1993]. To obtain 11 Mt of fuel wood, the area that may have to be clearfelled is 92,000 ha. It may be necessary to clearfell 1,50,790 ha of forests, or plantations on forest land annually for the use of 19 Mt of fuel wood [FSI, 1988]. This rate of clearfelling of forests would lead to significant deforestation. So, it is wrong to conclude that fuel wood demand does not contribute to deforestation or forest degradation in India, as every million tonne of cut wood or logs supplied requires clearfelling of nearly 8,000 ha of forests or plantations annually. It should be noted that the total fuel wood used in India was 227 Mt in 1991 and is increasing along with population growth. However, urban fuel wood demand contributes relatively more to forest decline than rural demands [Seebauer, 1992)

3.1.11.2 Loss of Biodiversity and Land Degradation

In dry areas, stripping land of vegetation for fuel wood leads to soil erosion due to wind and water effects, and on a world-wide basis such an overexploitation is estimated to contribute to 7 per cent of soil degradation [WRI, 1992]. In India it is common to observe fuel wood gatherers collecting uprooted shrubs and overlopping trees on village common lands, which exposes the soil to tropical monsoon rains. Excessive removal of vegetation and damage to ground vegetation during removal of fuelwood could affect plant diversity.

3.1.11.3 Domestic Air Pollution From Biomass Combustion

In most locations in India, cooking is done mainly indoors and majority of the rural houses usually have no chimney system to remove smoke [Ramakrishna *et al.*, 1989; Ranganathan *et al.*, 1993]. A study in south India showed that the number of hours spent in cooking ranged from 3.3 to 3.6 hours/household/day [Reddy, 1982]. In Western India the number of hours spent in cooking ranged from 3.1 to 3.4 hours/household/day [Veena, 1988]. So, women are exposed to smoke from biomass combustion for long periods.

Biomass fuels emit pollutants such as carbon monoxide, carbon di-oxide, nitrogen oxides, hydrocarbons, particulate matters etc. When compared with the combustion of fossil fuels, the emission of pollutants from biomass combustion is higher. A comparative study of daily exposure during cooking in India showed that the exposure to particulate matter was 17-26 mg hr/m^3 for biomass compared to 0.4 mg hr/m^3 for LPG or 2.4-3.6 mg hr/m^3 for kerosene [Smith *et al.*, 1994]. Emission levels are found to be high for dung cakes compared to fuel wood [NIOH, 1980]. There is growing scientific evidence to support the many anecdotal accounts relating high biomass smoke levels to significant adverse health effects [Smith, 1991]. Cooking in smoke filled kitchen is very inconvenient and women certainly do not like it. On monitoring fuel-efficient and smokeless stoves in South Indian villages, the households reported less fuel consumption in improved stoves compared to traditional stoves and smoke lessness [Ravindranath *et al.*, 1989c]. From this finding it was concluded that even if an improved stove consumes more fuel than a traditional stove, women seem to prefer it because it removes smoke. Great importance is attached to smokelessness. The burning rate (kg of fuel burnt per hour) of the biomass also affects emissions of smoke and pollutants as well as thermal efficiency. Women seem to adopt higher burning rates since it decreases the cooking duration and also improves combustion with reduced smoke [Ravindranath *et al*. 1989a]. Higher burning rates also lead to higher specific fuel consumption, so that attempts to reduce pollution from smoke would have implications for total biomass fuel use.

3.1.11.4 Carbon Emissions From Biomass Combustion

The carbon emissions from combustion due to clearfelling of forests and forest degradation in India for the year 1986 has been estimated to be 27 Mt C[1], which accounts for 46 per cent of the gross emissions from forests. A new concern about the contribution of wood combustion to greenhouse gases (GHG) is the emission of products of incomplete combustion (PIC) resulting from inefficient combustion of traditional stoves. These PICs are even more powerful GHG than CO_2 [IPCC, 1992]. An estimate of global warming potential of non-CO_2 greenhouse gases such CO, CH_4 and non-methane hydrocarbons, could be in the range of 20-110 per cent as much as that of CO_2 itself, depending on the time. At the global level the overall contribution of CO_2 emissions from biomass stoves to global warming has been estimated to be equivalent to about 2 per cent [Ahuja, 1990]. This includes an assumption that one-eighth of net deforestation results from meeting the biomass energy needs of cooking globally.

[1] Mt C Million tonnes Carbon

3.1.11.5 Loss of Nutrient Value of Dung

India has 19 per cent (257 million) of the world's cattle (including buffaloes) population Apart from providing milk for human consumption and draught power for agriculture, cattle also provide fuel in the form of dung (Table 3 1) and nutrients as manure In some parts of India, such as the hilly regions, cattle are reared only for the dung to be used as manure Cattle dung manure provides organic matter and nutrients, such as nitrogen for crop production The total nitrogen content of dung production in India is estimated to be 1 35 Mt annually, out of this 0 4 Mt is lost annually through the burning of dung as fuel (Table 3 10)

Table – 3.10
The Contribution of Cattle Dung As a Source of Nitrogen (N) to Crop Production

	Values for total dung production	Values for the dung quantity burnt as fuel	Values for the dung manure applied currently for crop production
National total dung production (Mt/yr)	443 00	132 00	311 00
N content in dung in Mt	1 35	0 40	0 95
N actually applied through dung per ha of cropland (kg/ha)	9 60	2 80	6 80
Quantity of leaves required to substitute N currently provided by dung/ha (in fresh kg)	717 00	217 00	500 00

Source Rajabapaiah *et al* (1993)

The loss of N on per hectare of cropland basis is estimated to be 2 8 kg/ha To supply the amount of N lost through combustion of dung, 217 kg of green leaves are required per hectare

Furthermore not all the nitrogen in the dung applied will be available as only 40-45 per cent is retained and the rest is lost during aerobic decomposition If a farmer maintains a cow or buffalo with a mean dung yield of 5 kg (of fresh weight/day). the annual N contribution would be 5.5 kg/animal/yr. Thus dung as a by-product of maintaining cattle for milk production or draught power seems rational. To obtain 5.5 kg N from tree leaves, 428 kg of fresh leaves have to be harvested [Rajabapaiah *et al.*, 1993]. This partly explains the rationale for rural communities attaching importance to the manurial value of cattle dung. Currently many farm households are forced to depend on dung as a fuel in the absence of fuel wood. The environmental impact of the use of dung as a fuel, in terms of loss of nutrient value and organic matter to crop production, is important. Therefore, the provision of quality fuels such as liquid or gaseous fuels is necessary to prevent dung from being used as fuel.

3.1.11.6 Crop Residue Use as a Fuel and Loss of Nutrient Value

In India the main uses of crop residues are as fodder and fuel. Crop residue use as a fuel in the domestic sector was estimated to be 40 Mt/yr (Table 3.1). The environmental impact of burning of crop residues, particularly the impact on crop production due to loss of organic matter has been recognised. In many farming systems the proportion of crop residues being ploughed back into crop fields is limited due to physical difficulties in incorporating them into soil [Barnard, 1990]. In India burning of the residues of cereals and pulses as fuel is small since cereal residues are used as fodder and pulse residue is left in the field or fed to cattle. The residues of crops, which cannot be used as fodder and which are likely to have significant quantities of lignin (such as woody residues of pea, coconut, cotton and coffee) are burnt. Thus the loss of nutrient value in the burning of such residues as fuel is insignificant, although some loss takes place for reasons other than fuel purposes.

3.1.12 Assessment of Bioenergy Programmes in India

The main sources of energy for the rural people, who constitute the majority of the population of the country are biomass fuels like fuel wood, agricultural residues, and cattle dung. The rural people are not merely the consumers but also the producers and owners of these biomass fuels. However, the extraction of energy from biomass resources has, over the years, become unsustainable due to the ever increasing population pressure on the one hand and the low level of efficiency of traditional stoves for burning these fuels to extract energy on the other. Higher smoke discharge in the kitchens due to the low efficiency of traditional stoves leads to deterioration in the indoor air quality and adversely affects the health of rural women. The time spent by rural women and children in gathering the biomass fuels also has a social impact in terms of opportunity cost of the lost time that could otherwise have been spent in child care, enhancing literacy levels and in other productive activities. The age-old practice of burning dried cattle dung cakes in the kitchen is depriving the soils of the much-needed organic manure, thereby affecting the agricultural productivity. The Ministry of Non-Conventional Energy Sources (MNES) has been working through a number of programmes aimed at promoting the development and deployment of efficient technologies for biogas production, improved chulhas, biomass briquetting and biomass gasification.

3.1.12.1 Biogas Production

India is the pioneer of biogas programmes, with the floating drum biogas plant being developed in 1952. It was the first renewable energy technology to be launched in India, much before the global recognition of the need for alternative energy sources. By 1980 about 80,000 family biogas plants had been built. Biogas programme is presently dominant bio-energy programme in India. The biogas programme received a boost with the launching of the National Project on Biogas Development (NPBD) in 1981-82 with funding and administrative support from the Directorate of Non-Conventional Energy Sources (DNES). The main goals of the programmes are to :

i) Provide cooking energy in a clean and non-polluting form;

ii) Produce enriched manure to supplement the use of chemical fertilizers;

iii) Improve the quality of life for rural women; and

iv) Improve sanitation and hygiene.

Several basic designs of biogas plants have been developed by different agencies. These are the Fixed Dome Deenbandhu Model, the Floating Gas Holder KVIC (Khadi and Village Industries Commission) Model and Bag Type Digester. These biogas plant models are promoted under two projects; one is the National Project on Biogas Development (NPBD), which seeks to promote biogas plants for household use. The other is the Community, Institutional and Night – Soil Based Biogas Plant Programme. It aims at promoting biogas plants for use at the community and institutional levels. These programmes help in recycling cattle dung to harness its fuel value without destroying its value as manure.

3.1.12.2 Improved Stoves

The main driving force for launching improved stove programmes was to conserve fuel wood and to protect forests. A variety of biomass based. efficient, smokeless chulhas have been developed to meet the requirements of different types and mix of fuel materials, varied food habits, household sizes and communities. The governments of developing countries are justified in relying on efficient stove programmes to alleviate the cooking energy problem to some extent. India and several other developing countries, such as China, Kenya, Indonesia, Mexico and Sri Lanka have launched improved stove programmes. The Indian programme was initially launched as a demonstration project in 1983. Later it was converted into full-fledged National Programme on Improved Chulha or stoves (NPIC) from April 1985. The main goals of NPIC [MNES 1993a] are presented in see 2.4.4.1.

The thermal efficiency of the improved chulhas approved for promotion is about 20 to 35 per cent, as compared to 6 to 10 per cent in the traditional chulhas.

3.1.12.3 Biomass Briquetting

Loose biomass is either charred and compacted or directly compacted in the form of briquettes to serve as "B grade" coal [MNES, 1998-99]. Biomass briquettes made through manual process can be used as cooking fuel in the rural domestic sector, whereas briquettes produced through mechanical presses can be used in boilers and furnaces. Die and punch type machines of capacities up to 1500 kg/hr are manufactured in the country for production of briquettes from agricultural residues and agro industries by-products.

3.2 Conclusion

Although the share of biomass in national total primary use is low. it is the dominant source in rural India. Fuel wood is the dominant biomass energy used, followed by crop residues and cattle dung.

Biomass energy used in the domestic sector is characterized by low efficiency of use, drudgery in gathering and use, emission of smoke in the kitchen, and ultimately a lower quality of rural life. Kerosene is the fuel used by majority of the rural households, mainly for lighting. It has poor conversion efficiency and provide poor quality lighting. Electricity is used only by a quarter of rural households for lighting.

CHAPTER IV

Research Methodology

CHAPTER – IV

RESEARCH METHODOLOGY

4.1 Introduction

Keeping in view the objectives of this research work, the relevant data were collected from the sample households in the study area. The data were of varied nature and needed grouping and clustering. The data were to be statistically analysed and from the findings inferences had to be drawn. The following sections present the methodologies used for conducting the survey in sampled localities, method of analyzing the data and presentation of the result.

4.2 Locale of the Study

The State of Assam is situated in the Eastern Himalayan region between 24° to 28°18′ North latitudes and 89°50′ to 97°0′ East longitudes. The geographical area is 78,523 square kilometre. The State can be divided into three broad physiographic zones namely – (i) the Brahmaputra valley in the North, (ii), the Barak valley in the South, and (iii) the Hill regions that lie between these two valleys. The State enjoys a hot and humid climate with heavy rainfall and humidity as high as 85.90 per cent or more in the majority of the district. Based on rainfall, terrain and soil characteristics the State has been broadly delineated into six agro-climatic zones [Annon, 1992].

1. North Bank Plains : Comprises the districts of Dhemaji, North Lakhimpur, Sonitpur and Darrang. Total area is 14424 square kilometre, comprising 18.37 per cent of the State area.

2. Upper Brahmaputra Valley : Comprises the districts of Sibsagar. Jorhat, Tinsukia, Dibrugarh and Golaghat. Total area is 16015 square kilometre, comprising 20.40 per cent of the State area.

3. Central Brahmaputra Valley : Comprises the districts of Nagaon and Morigaon with an area of 5566 square kilogmetre, about 7.08 per cent of the State area.

4. Lower Brahmaputra Valley : Comprises the districts of Kamrup, Barpeta, Nalbari. Kokrajhar, Dhubri, Goalpara and Bongaigaon The total area is 20324 square kilometre. comprising 25.75 per cent of the State area.

5. Barak Valley : Comprises the districts of Cachar, Karimganj and Hailakandi,total area 6962 square kilometre, comprising 8.9 per cent of the State area.

6. Hills Zone : Comprises the districts of Karbi Anglong and North Cachar Hills with a total area of 15232 square kilometre which is 19.4 per cent of the State area.

Rural Assam –Virtually, agriculture is the chief occupation of Assam. Rice is the main cultivation as 90 per cent of the population are rice eater. The average size of operational land holding in the rural Assam is 1.37 hectares, the highest average being 2.04 hectares in hill districts. More than 50 per cent of the State's income is derived from agriculture and more than $^{3}/_{4}$th of rural population depend on agriculture for livelihood. More than 90 per cent of the area under agriculture is rainfed. Natural calamities particularly flood is a chronic problem in the State.

The district of Jorhat in Upper Brahmaputra valley was selected purposively to conduct the present study as it is more accessible from the seat of the researcher (Fig. 4.1).

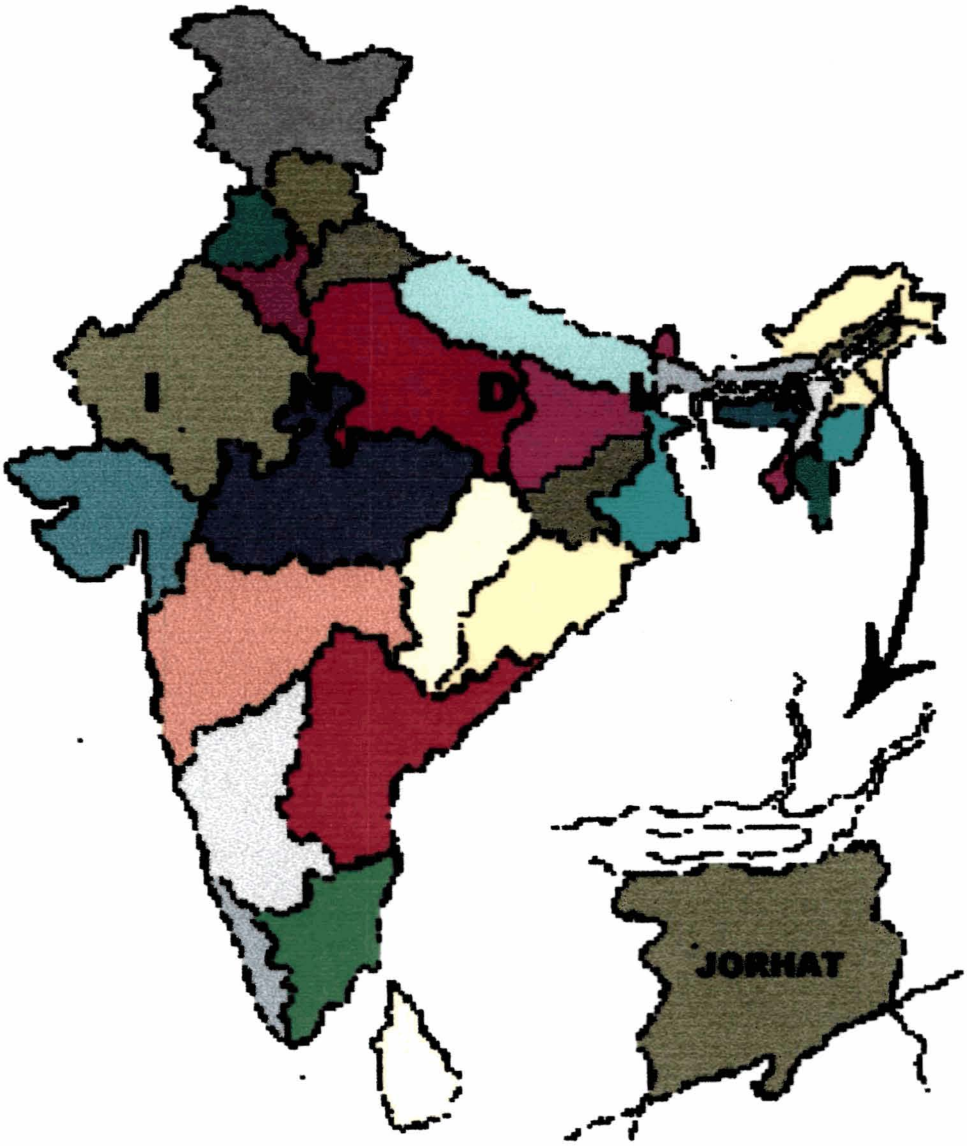

Fig. 4.1 Map Showing Location of Study

4.2.1 Sampling Plan

At the initial stage, two sub-divisions of the district Jorhat and Titabar were selected as the study area purposively. For subsequent selection, a multistage stratified sampling procedure was followed. Rural Development Blocks were considered as the first stage units, villages as the second stage units, and contact households were considered as the ultimate stage units. The stagewise selection has been shown in Fig. 4.2.

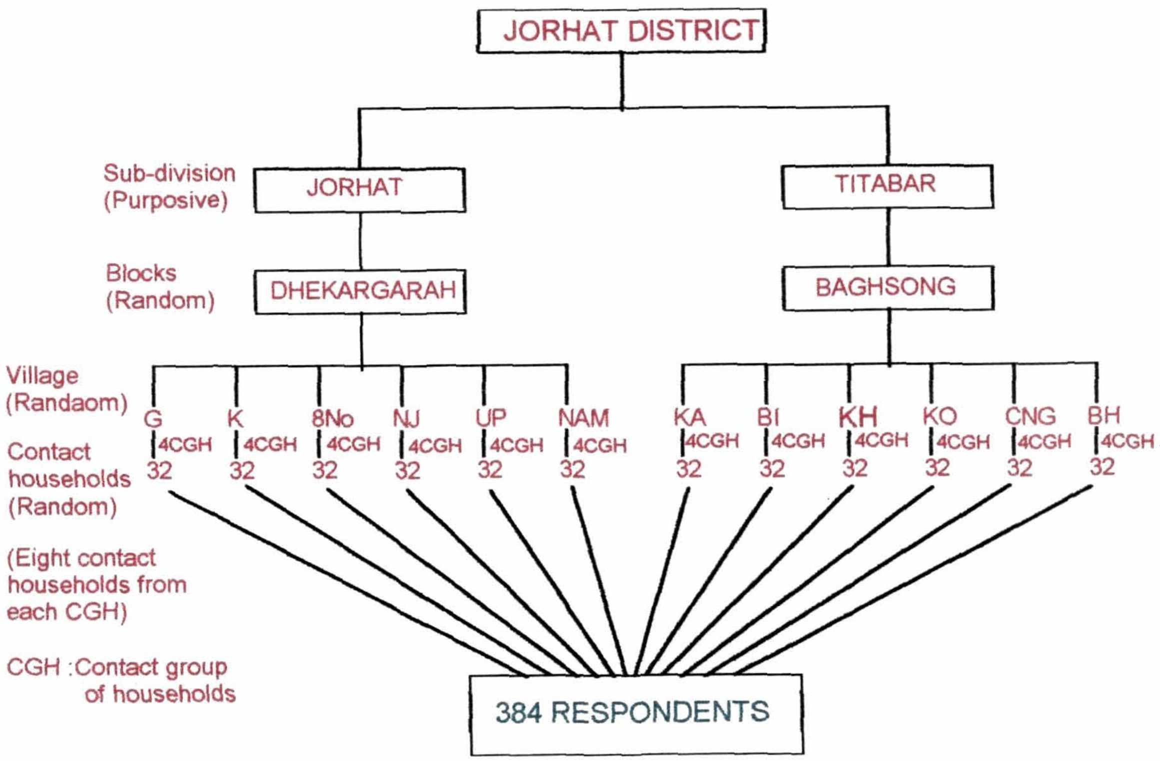

Fig. 4.2 Sampling Plan of the Investigation

Stage I : From each of the sampled sub-divisions, one block was selected randomly. These were Dhekargarah Rural Development Block in Jorhat sub-division and Baghsong Block in Titabar sub-division, respectively.

Stage II : From each of the Rural Development Blocks some villages were selected randomly. Six villages namely Gariabhonga (G), Khongia (K), 8 No. Spur (8 No), Na-Jankhona (NJ), Upper Deorigaon (UP) and Nam-Deorigaon (NAM) from Dhekargarah Block and Kathalbari (KA), Birina (Bi), Kheremora (KH), Kondar (KO), Chowdung gaon (CNG) and Bahek (BH) from Baghsong Block were selected as these villages represent different categories of society and different cultural systems.

Stage III : Four groups of contact households (large, small, marginal and landless farmers) were taken. From each group of contact households eight households were selected randomly. Thus from four groups of contact households 32 contact households were selected from each village. Ultimately, 384 households were obtained from 12 villages.

4.3 Collection of Data

Data were collected from all the households during the agricultural year 1997-98. The data were collected through personal interview method. The parameters or variables on which information was sought at village level and household level are given in Appendix I.

The village schedule was to elicit information about the village profile from the Block Development Officers and other officials of the Block, members of the Panchayat and the village local body. The household schedule was designed to gather information on the linkages between the availability of energy resources and consumption. For establishing proper rapport, help of the officials of Assam State Electricity Board, District Statistical Officers was also taken. Considerable difficulties were faced in eliciting information in standard units of biomass availability and consumption for fuel purposes. Hence local units were resorted to collect information. For example, the people found it easy to report a headload of paddy bundles as "Dangori" which was later converted to kg by weighing the typical headload.

Also information on domestic fuel technology, combustion practice, fuel wood collection activities including distance covered in collection, hours spent in collection, frequency of collection, specific problem cited in collection were gathered.

To compare rural domestic energy consumption with that of semi-urban and urban sectors and hence to analyse health status of rural women the parametres on which information was sought are given in Appendix II.

To model the seasonal variation of rural domestic energy consumption, the information on population, number of school going children, income of households, rainfall and temperature (gathered from Meteorology Department, Assam Agricultural University) were collected.

Data were collected from all the households (32 households from each village). The investigator visited each of the households only once and spent around 30 minutes for filling up the household schedule.

4.4 Analysis of Data

The survey data were tabulated and consistency checks were carried out by using a plausible range of values for each parameter.

4.4.1 Available Biomass Energy Resources

The methodology adopted for estimating different biomass energy resources are discussed in the following section.

4.4.1.1 Rice Residues

Paddy straw and husk are main agricultural residues found in the twelve villages. The quantity of rice husk production has been estimated using the residue to grain ratio. husk:grain = 0.4:1.00. Using this conversion ratio, production of husk was estimated. Later, production of husk in kg/yr was multiplied by its calorific value (14.3 MJ/kg) to obtain available energy in GJ/yr. Estimation was done for all the twelve villages.

Available energy lying untapped in paddy straw was estimated separately for post-harvest and left-over[1] straw. While weighing a head load of paddy bundle, locally called "Dangori" gives about 10 kg of straw. Also 1 pura (0.545 hectare) of cultivating land produces 117 numbers of dangori. Therefore, production of post-harvest straw per hectare of land is estimated to be 2127.30 kg. Using this conversion factor, yearly production of paddy straw (post harvest) has been estimated for the twelve villages. Later,

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[1] Left over The straw which is left in the paddy field after harvesting

it was multiplied by its calorific value (13.4 MJ/kg) to obtain available energy from post-harvest straw in GJ/yr after deducting non-fuel uses.

For determining available energy from left over straw, three different varieties of paddy having longer, medium and shorter stems in length were taken. Thus 1 square metre (10.19×10^{-5} hectare) of land produces 600 grams, 700 grams and 800 grams of shorter, medium and longer paddy straw, respectively. The three different sizes of straw were averaged (700 grams). So. the production of left over straw was found to be 6860 kg per hectare. Later it was multiplied by calorific value (13.4 MJ/kg) to obtain avlable energy of left over straw in GJ/yr for all the twelve villages.

4.4.1.2 Cow-dung

Average daily wet dung production in the twelve villages was estimated on the basis of dung output by bullocks, milch cow and calves. The total availability of dung after deducting its non-fuel uses (such as fertilizer, building material) provided an estimate of the dung availability. Average dung output per day per bullock was estimated to be 6.42 kg and that of milch cow and calves were found to be 4.8 kg and 2.2 kg, respectively. Hence, average dung output per animal was estimated at 4.5 kg/day. Hence, total dung output in each of the twelve villages was estimated from animal population data collected. Later, it was multiplied by its calorific value (9.0 MJ/kg) and estimated for one year to obtain available eergy from dung in GJ/yr after deducting non-fuel uses.

4.4.1.3 Fuel Wood

The survey was carried out to quantify fuel wood consumption in domestic sector. So, no quantitative data were collected for the area from which the villagers gather fuel wood. But the sources, availability and future predictions of fuel wood information were analysed on the basis of percentage of respondents.

4.4.2 Rural Domestic Energy Consumption Pattern

Data on three end uses of energy were analysed in rural domestic sector

i) Cooking and water heating (combined)

ii) Space heating

iii) Space lighting

Estimation of domestic energy consumption was done for summer and winter seasons separately The information on fuel wood consumption had to be collected in local units of measures For example, the villagers found it easy to report head loads of wood used in a week Later quantity of wood in a typical head load was weighed in kg, and per day consumption in kg was found out Then it was multiplied by its calorific value (15 MJ/kg with 20% moisture content) to obtain in GJ/day Hence, domestic energy requirements in the form of fuel wood in cooking and water heating for summer and winter seasons, and space heating for winter season were estimated The total fuel wood consumption in those three end uses were estimated in GJ/yr for all the twelve villages Subsequently, kerosene and electricity consumption in space lighting in kg per day and unit per month per household were collected Daily consumption of kerosene per household was actually obtained in volumetric measurement and that was converted into weight (1 litre of kerosene = 0 8 kg) The daily consumption of kerosene in kg per household was multiplied by 365 and calorific value (44 MJ/kg) to find the annual consumption

Data regarding average unit consumption of electricity in kwh per month per household was converted into MJ (1 KWH = 3 6 MJ) and then multiplied by 12 to obtain annual electricity consumption per household Hence, gross domestic energy consumption in cooking, water heating, space heating and space lighting was found out and per capita per year consumption was estimated for all the twelve villages

To assess the fuel wood collection activities in the sampled villages data on distance covered on collection, hours spent in collection, frequency of collection and specific problems cited in collection were analysed (Appendix I) by taking into account the number of households and percentage of respondents.

4.4.3 Comparison of Rural Domestic Energy Consumption with that of Semi-urban and Urban Sectors

Rural domestic energy consumption was compared with that of semi-urban and urban domestic sectors to analyse the impact of domestic fuel on health of rural women. The three sectors were identified based on infra-structural facilities like condition of roads, availability of electricity, transportation, civic amenities like post office, bank, cooperative society, marketing facilities, LPG agencies, educational facilities, medical facilities etc. Based on the existing facilities and distance required to traverse to avail these facilities, the three sectors were identified in which 0-5 km represents urban, more than 5 km represents semi-urban, and more than 10 km represents rural sectors.

Analysis of data regarding domestic energy consumption of fuel wood, kerosene, electricity are presented in Sec. 4.4.2. LPG serves as a dominant fuel in cooking in semi-urban and urban sectors. Data on number of LPG cylinders required in a month per household were converted into energy form. One LPG cylinder for domestic use contains 14.2 kg of fuel and this converts to 624.8 MJ of energy. The conversion of energy per household per month was multiplied by 12 to find the annual energy consumption of LPG in cooking. The energy consumption of households in a sector was added to obtain annual energy consumption.

To find out significant variations in domestic energy consumption in the three sectors, analysis of variance i.e. F-test was employed (Appendix III). The per capita consumption of each type of domestic fuel was taken for each of the sectors. The F-ratio is calculated for different fuels and compared with the table values of F for different types of fuel to verify the level of significance.

4.4.3.1 Impact of Domestic Fuels on Rural Women

Apart from comparison of domestic energy consumption in the three sectors, the factors analysed to study the health condition of women were :

i) Types of cooking fuels and income groups

ii) Domestic fuel technology

iii) Hours spent by women in cooking

iv) Effects on health

i) Types of Cooking Fuels and Income Groups

All the households in the three sectors were divided into four groups on the basis of income level such as low, lower medium, upper medium and higher [Annon.1992].

Income group	Range (Rs/year)
Low	< 6000
Lower medium	6000-18000
Upper medium	18000-24000
Higher	> 24000

Accordingly number of households using particular types of cooking fuel was determined. Also per cent of households using each type of fuels was estimated. This was done to see the linkage between standard of living (through income range) and quality of cooking fuels used by different sectors.

ii) Domestic Fuel Technology

The information on percentage of households using different types of stoves were collected to analyse the impact of domestic fuels on health as given below :

Sector	3 brick	Home made	Improved	Kerosene	LPG	Total
Rural domestic						
Semi-urban domestic						
Urban domestic						

iii) Hours Spent by Women in Cooking

To analyse the health status of women related to cooking, it is important to know the number of hours spent by her in a day for cooking. Data were analysed for different ranges of cooking hours as given below :

Hours spent in cooking per day	Number of women			% of cases		
	Rural	Semi-urban	Urban	Rural	Semi-urban	Urban
Total cases (N)						
> 5 hours						
4-5 hours						
3-4 hours						
2-3 hours						
1-2 hours						
No response						

iv) Effects on Health

The main health problems of rural women were analysed by taking into account the above three factors. Later on the effects were determined in consultation with the Medical Authority of the Rural Development Block. The percentage of respondents against observed health problems were analysed as given below :

Health problems	% of cases
Chest pain	
Wheezing	
Underweight baby delivery	
Dry cough	
Running nose	
Eye irritation	
Lung diseases	
Heart problems	

Observed health problems are presented in the form of bar diagram.

Analysis of variance was employed to test the significance of diseases among rural women due to smoke exposure during cooking hours. Four groups were taken according to the range of hours in cooking. Calculated F-ratio was compared with the table value of F to test the significance of diseases among rural women.

4.4.4 Future Energy Options in Cooking

Since there is a need for newer sources of energy in the rural sector, informations regarding options preferred by women respondents for future energy source type were analysed as given below :

Future energy options preferred	Number of households		
	Rural	Semi-urban	Urban
LPG			
Kerosene			
Fuel wood in improved stove			
Biogas			
Briquetted biomass			
Electricity			
None of these			

4.5 Modelling of Rural Domestic Energy Consumption

After a brief review of literatures and discussions, a number of variables were identified for modelling rural domestic energy consumption. The variables included in the present study were categorized into two sets viz., dependent and independent variables.

4.5.1 Dependent Variable

The rural domestic energy consumption should aim at conserving biomass (efficient technology) to meet the increasing needs of fuel wood for growing population and in turn the quality of rural life should be improved. So, for future estimation of rural domestic energy requirements, the rural domestic energy consumption was taken as dependent variable. In order to measure the energy consumption at household level, three end uses were considered. These end uses are:

i) Cooking and water heating

ii) Space heating

iii) Space lighting

As the domestic energy consumption is not uniform over the year, a seasonwise domestic energy consumption was analysed separately for summer including premonsoon (April-September) period, and for winter including post-monsoon (October-March) period.

In order to estimate rural domestic energy consumption, households were sampled from each of the selected villages for collecting information on the factors as Stated in Section 4.2.

4.5.2 Independent Variables

Decision to adopt rural energy technology is basically influenced by a number of factors. To ascertain the nature and extent of association of variables affecting the level of rural domestic energy consumption, the following independent variables were selected:

For cooking and water heating (combined) during summer season including premonsoon.

i) Average population

ii) Monthly average income

iii) Monthly average temperature

iv) Monthly average rainfall

For cooking and water heating (combined) and space heating during winter season including post-monsoon :

i) Average population

ii) Monthly average income

iii) Monthly average temperature

iv) Monthly average rainfall

As the seasonal variation is negligible in domestic energy consumption in space lighting, the independent variables selected over the year were

i) Average population

ii) Monthly average income

iii) Average number of school-going children

iv) Monthly average temperature

v) Monthly average rainfall

The rural domestic energy consumption in cooking, water heating and space heating was modeled seasonally, whereas that of space lighting was modelled over the year

4.5.3 Operationalization and Measurement of Variables

The operational definition of the variables and their respective measurement technique are given as

4.5.3.1 Dependent Variable

Rural domestic energy consumption has been taken as the dependent variable in the model to be formulated This variable covers consumption in relation to cooking and water heating, space heating, and space lighting

4.5.3.2 Independent Variables

The independent variables incorporate in the middle are discussed discussed below

A. Average population

The data on family size per household was collected to develop the rural domestic energy consumption model. The growth of population over the period 1995-99 (collected from the District Statistical Office) is approximately linear and can be expressed as (using regression) :

Population (lakhs) = 22.2345 + 0.496t, where t (1,2,3, ...) represents number of years starting from 1995.

B. Monthly average income

It refers to the average income in Rupees of the respondents per month.

C. Monthly average temperature

It refers to the average temperature in °C in a month which was found from daily temperature for Jorhat district recorded by the Meteorology Department of Assam Agricultural University, Jorhat. To develop rural domestic energy consumption model, the temperature records over the period 1995-1999 were obtained.

D. Monthly average rainfall

It refers to the average rainfall in mm in a month for Jorhat district recorded by the Meteorology department of Assam Agricultural University, Jorhat. To develop rural domestic energy consumption model, the rainfall records over the period 1995-1999 were obtained.

E. Average number of school-going children

The rural domestic energy consumption in space lighting is strongly influenced by number of school going children in a household. Number of school going children in a household were observed and finally average number of school going children for the sector were obtained over the period 1995-1999.

4.6 Availability of Physical Facilities

The availability of physical facilities referred to here are :

i) Availability of and accessibility to the forest for collection of fuel wood.

ii) Availability of electricity/possibility of electricity in the near future.

iii) Availability of public distribution system (rationed shop) to procure kerosene.

iv) Availability of educational facilities to ascertain the number of school-going children.

v) Availability of medical facilities like primary health center for medical check-up of rural poor.

4.7 Statistical Techniques

A. Pearson's Product Moment Co-efficient of Correlation (r)

The relationship between each dependent variable and the selected independent variables and also the inter-relationship among the variables under the study were worked out by following "Pearson's Product Moment Method" (Appendix III).

B. Fisher's t-ratio

In order to test the significance of observed correlation co-efficient, the Fisher's t-ratio was found out by using the formula given in Appendix III.

C. Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) was employed (Appendix III) to test the significant variations of fuel consumption in rural, semi-urban and urban domestic sectors. The significance of diseases among rural women due to smoke exposure during cooking hours·was tested with the help of ANOVA.

D. Multiple Regression Analysis

To study the contributory effects of selected independent variables in explaining the variation in each of the independent variables, multiple regression analysis was carried out . This is a method for studying the effects and the magnitude of the effects of more than one independent variables using the principle of correlation and regression (Kerlinger, 1973). Kerlinger further assertes the multiple regression analysis as an efficient and powerful hypothesis testing and inference making technique. Since, it helps scientist's study with relative precision, complex interrelations.it helps to explain the presumed phenomenon represented by the dependent variable.

The variation in the rural domestic energy consumption in Jorhat district, was analysed with the help of multiple regression model. The general form of the model equation is

$$Y = a + \sum_{i}^{n} b_i x_i$$

Where, Y = monthly average rural domestic energy consumption

n = number of independent variables fitted to the regression model

a = intercept

b_i s are regression co- efficients for respective independent variable

The explanatory variables x_i denote average population (POP), monthly average income (INC), average school going children (CHIL), monthly average temperature (T) and monthly average rainfall (RAIN).

The underlying idea with this analysis was to know the combined effect of all the independent variables in explaining the variation on the dependent variable. The predictive power of the multiple regression analysis was evaluated with the help of co-efficient of multiple determination, R^2. Further significance of the partial co-efficient (b's) was tested by using the formula (Chandel, 1984) as presented in Appendix III.

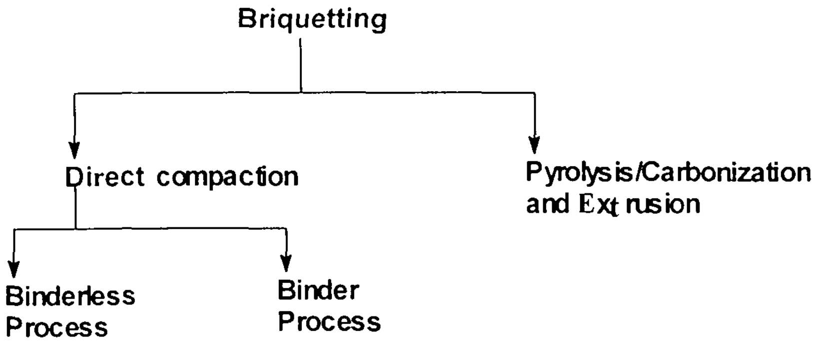
The SPSS computer package was used to establish the model from the data set collected from the sampled households.

4.8 Fuel Briquettes from Agricultural Residues

Though the production of agricultural residues as well as dung are in huge quantity in rural areas, the use of these wastes are very limited because of non-availability of proper and efficient devices. Moreover, traditional stove is not suitable to burn loose biomass. So, there is a need to provide quality fuels from agricultural residues and appropriate devices for burning these fuels in rural areas. Densification of biomass in the form of briquettes produces solid fuel which burns as well as coal, leaves less ash content, emits less or no smoke and is easy to handle, store and transport. Fuel briquettes can easily replace B and C grade coal. Though the thermal efficiency of directly burnt wastes is about 100 per cent while briquetted fuels give only 70 per cent, the efficiency of utilization is very low in the former due to unsteady flame.

4.8.1 Process of Briquetting

Utilization of biomass as fuel in its original form is not simple and straight forward due to its very low bulk density that is responsible for low rate of heat release per unit volume and requires high transportation and storage cost. Briquetting of biomass is done to increase its bulk density. The different briquetting processes are :



4.8.1.1 Direct Compaction

There are two technologies for manufacture of direct compaction briquetted fuel.

i) Binderless Process or Technology

The biomass is semi-fluidized through application of high pressure (117.7 to 196.2 MN/m^2) at which it gets heated to temperature about 180°C and the lignin begins to flow and acts as binder. The semi-fluidized biomass is densified through a power operated briquetting machine. The equipment cost of such briquetting units range from Rs. 3 lakhs to Rs. 20 lakhs depending on the capacity. So, this technology is not suitable for rural areas.

ii) Binder Process or Technology

This technology require additional binders such as animal dung, molasses, glue cement, wood tar, corn or wheat starch, ligna-sulphonate, and sodium silicate.

4.8.2 Limitations of Fuel Briquettes

The raw material for briquetting has generally high moisture content. So, pre-treatment (drying, sorting of uncombustible substances etc.) is required for effective and efficient utilization of agricultural residues.

4.8.3 Briquetting Time

Briquetting time is defined as the time required to produce a briquette. It is measured from the instant of filling the mixture into the die, till the compression of mixture followed by removal of the briquette from the die.

4.8.4 Durability Test

A briquette with high durability is desirable as it will withstand handling, transportation, and storing without falling apart. There is, however, a limit to its bond strength. If the residues are too strongly bonded, it may be difficult for the briquette to continue burning.

A simple durability test was carried out to determine the handling characteristics of the briquette. In this test the dry briquette was first weighed (Wo). The briquette was then allowed to drop freely from a height of 1 m above the ground. The weight was determined after one fall. The briquette was redropped few times. The percentage of weight loss was determined as,

% of weight loss = $(W_o - W_n/W_o) \times 100$

Where, W_n = Weight after 'n' falls

The procedure was repeated until the briquettes were broken into pieces or the weight loss reaches 10 per cent. A graph was plotted with the number of tests as abscissa and percentage loss in weight as ordinate.

4.9 Determination of Calorific Value of the Fuel Briquette

The calorific value of fuel briquette so produced was determined in a Bomb calorimeter in the laboratory of Mechanical Engineering Department, Jorhat Engineering College, Jorhat, Assam.

4.9.1 Determination of Water Equivalent of Bomb Calorimeter

A fuel of known calorific value was burnt for finding out water equivalent of bomb calorimeter. The fuel used for this purpose was benzoic acid (calorific value = 26.483 MJ/kg) and nepthaline (calorific value = 40.563 MJ/kg). The fuel taken should be such that the temperature rise of water is limited to 3°C to minimize the radiation losses.

4.9.2 Procedure to Find Calorific Value

The procedure adopted for finding out calorific value using bomb calorimeter was as stated below :

i) The weight of crucible and the weight of fuel sample were taken.

ii) The crucible with the sample fuel was weighed.

iii) A piece of firing wire was connected tightly across the terminals of the bomb.

iv) A known weight of cotton was tied to the firing wire and the ends of the cotton were arranged so that they touched the sample.

v) 1 ml of distilled water was put in the bomb. The bomb was assembled and was charged slowly with oxygen to a pressure of 3.0 x 10^6 N/m^2 without displacing the original air.

vi) Sufficient water was put in the calorimeter vessel to cover the upper surface of the bomb cap. The temperature of water was kept at 2.5°C lower than that of the water jacket.

vii) The calorimeter vessel was transferred to the water jacket. The bomb was lowered into the calorimeter vessel and the bomb was checked for gas tightness.

viii) The apparatus was started up and kept the stirrer and the circulation arrangement in continuous operation throughout the determination. A constant rate of stirring was used. The temperature on the Backman thermometer was observed in equal duration (1 minute)

ix) After 6 minutes of stirring the calorimeter was bombed with the help of the fuse wire The temperature rise was observed for 13 minutes with same time interval (1 minute). The rise of temperature was rapid to a maximum limit of temperature in this period. The temperature again began to fall after reaching a maximum value. Again the temperature drop was observed for 5 minutes in the thermometer with the same time interval (1 minute).

x) The bomb was removed from the calorimeter vessel, released the pressure and dismantled the bomb interior. The test was discarded if unburnt sample or sooty deposits were found.

Based on the principle of bomb calorimeter i.e. heat given by the fuel due to combustion + heat given by the combustion of fuse wire = heat absorbed by the water and calorimeter, the calorific value of fuel briquette was found out. The mathematical expression followed was (Kothandaraman, 1981).

$$m_f \times H.C.V. + m_{wf} \times C.V. = (m_w + m_c)\theta$$

$$\therefore \quad H.C.V. = \frac{(m_w + m_c)\theta - m_{wf} \times C.V.}{m_f}$$

Where, m_f = mass of fuel briquette

H.C.V. = higher calorific value of fuel

m_{wf} = mass of fuse wire

C.V. = calorific value of fuse wire (1.403 MJ/kg)

m_w = mass of water in calorimeter

m_c = water equivalent of calorimeter

θ = uncorrected temperature rise

Water equivalent of bomb calorimeter was found out as given in Appendix IV. This value of water equivalent of calorimeter was later used to find out higher calorific value of fuel briquette made from the mixture of paddy straw and cow dung. Here values measured are :

m_w = mass of water

m_{wf} = mass of fuse wire

θ = uncorrected temperature rise of fuel briquette

m_f = mass of fuel

Thus higher calorific value of fuel briquette was calculated (Appendix IV).

4.10 Briquetting Device

The hydraulic press briquetting device was constructed for producing fuel briquettes under high pressure. It is a simple device operated by a hydraulic jack that is used to lift cars or other automobiles to change wheels. Complete assembled view of the device is presented in Chapter VI. The jack was placed on a wooden base and the ram was fitted upside down on a wooden plate. The whole assembly was supported on the base plates with the help of 4 steel rods. The plate on the jack acted as a platform. As the jack lifted, the ram started compressing the raw material. After exerting sufficient pressure, the clamps were loosened and the briquette thus formed was taken out from the split die and left to dry in the sunlight.

4.11 Design of a Modified Stove

A need was felt for a modified cook stove to burn fuel briquettes from agricultural residues. The idea of modification was taken from the wood burning stove recommended by the Indonesian Dian Desa Field Work Centre and the Intermediate

Technology Development Group at Reading (U.K.). The detail views are presented in Chapter VI.

The stepwise procedures used in engineering design were followed in the modified stove. The stove was made of M.S. Sheet of 3 mm thick and permits simultaneous cooking in two pans. The characteristic of the stove were defined as :

Length of the stove body (mm)

Width of the stove body (mm)

Height of the stove body (mm)

Inner cross sectional area of the chimney (mm^2)

Diametre of the first pot opening (mm)

Diametre of the second pot opening (mm)

Area of the fuel feeding opening (mm^2)

The calculations of the designed stove was based on proximate analysis (Appendix IV) of paddy straw briquette. The most important part of the stove design is the design of the chimney on which performance and efficiency of the stove mainly depend. For this purpose, amount of exhaust gases produced during the process of combustion were found out using proximate analysis [ASTM a,b,c,d, 1977] of fuel briquettes. The discharge rate of exhaust gas (Q) was found out as given by Kothandaraman (1981).

$$Q = 22.40\left(\frac{T_{exh}}{T_{NTP}}\right) x\, W_{exh}$$

Where, W_{exh} = total mass of products of exhaust gas in kg/mole

T_{exh} = exhaust product temperature

T_{NTP} = Normal temperature 273 k

So, the rate of exhaust gas discharge was found out. Hence, height of the chimney (H) was determined using the formula (Kothandaraman, 1981) as :

$$H = \frac{V^2}{2g}\left[\frac{T_g}{T_a} - 1\right]$$

Where, V = velocity of the gas

Tg = temperature of the flame

Ta = atmospheric temperature

g = gravitational accelaration

The calculated height ultimately helped in determining the diametre of the chimney (D) using formula (Kothandaraman, 1981) as :

$$D = \sqrt{\frac{4Q}{\pi V K}}$$

Where, K is a constant and its standard value is 0.6

Taking into consideration the dimensions of the stove parts, the stove was fabricated by using 3 mm M.S. Sheet. The chimney was made by using M.S. sheet of 1 mm thickness. An angle iron frame was made to support the whole stove.

4.11.1 Efficiency Test of the Stove

The efficiency of the stove is independent of the material cooked or heated in the pot (Sielcken and Nieuwvelt, 1980-81). If the material is a liquid, the heat transferred to it (sensible or latent) can be determined. On the otherhand, if an empty pot is placed on the stove, there will be continuous mass transfer (hot air inside the pot going out and cold air replacing it). It is difficult to find out the actual heat transfer to the pot. But the energy gained by the pot and its content in both the cases is identical for equal fuel burning rates. Efficiency of bio-fuel stoves can be evaluated by water heating methods [Krishna Prasad, 1981]. The overall efficiency or thermal efficiency of the stove is defined as the ratio of the amount of heat absorbed by water in the pots and the amount of sensible heat supplied by the fuel. The formula suggested by Krishna Prasad (1981), Geller and Dutt (1982) and Joseph and Shahnahan (1980) was used to calculate the overall efficiency ($\eta_{overall}$) of the stove :

$$\eta_{overall} = \frac{\sum_{i=1}^{n} m_{wi} c_{pi} (T_b - T_i) + m_{we} L}{m_f \times C.V.}$$

Where, m_{wi} = initial weight of water in the vessels in litres

m_{we} = weight of water evaporated in litres

m_f = weight of fuel briquettes burnt in kg

C_{pi} = specific heat of water at atmospheric pressure

L = latent heat of evaporation in KJ/kg

C.V. = calorific value of fuel briquette in MJ/kg

T_b = boiling temperature of water in °C

T_z = initial temperature of water in °C

Summation is over the different pots.

The testing procedure has been presented in detail in Chapter VI.

4.11.2 Comparison with Traditional Stove

Although overall efficiency range of traditional stove (5 to 10%) [Annon, 1986] used in rural North-East is known, the performance analysis of traditional stove and modified stove was done by changing the fuel depths. Same water evaporation method was repeated for varying fuel depths. Because fuel feeding rate (determined by depth of fuel over the grate) is one of the important parameter which effects stove performance. The overall efficiency was calculated using the standard water evaporation test formula as mentioned in Section 4.10.1. Amount of fuel used at that particular time was recorded. As suggested by Kandapal *et al* (1995), fuel-feeding rate was converted into kg/s and multiplied with calorific value of fuel to get actual power input for that particular test. Later, power output of the stove was found out (power input x overall efficiency). The test was repeated changing the fuel-feeding rate. The performances of the traditional stove and the modified stove have been presented in the form of a plot as given in Chapter VI.

CHAPTER V

Analysis and Findings

CHAPTER – V

ANALYSIS AND FINDINGS

5.1 Introduction

According to the methodology narrated in chapter – IV, the data collected from the villages under study were analysed. Besides, the data related to household energy consumption pattern in some selected semi-urban and urban areas of Jorhat district were also analysed. These analyses revealed certain pattern regarding sources of rural energy, energy consumption in rural, semi-urban and urban domestic sectors, and thus threw some light on the overall domestic energy consumption scenario. The detail analyses of the data and the inferences drawn are presented in the following sections :

5.2 Village Profile

Table 5.1 presents the profiles of the twelve villages covered by the study across two Rural Development Blocks of Jorhat district of Assam. Out of these twelve villages, Gariabhanga (G), Khongia (K) Kathalbari (KA) and Birina (BI) represent upper caste population; 8 No. Spur (8 NO), Na-Jankhona (NJ), Kheremora (KH) and Kondar (KO) represent schedule caste population; Upper Deorigaon (UP), Nam-Deorigaon (NAM), Chowdung gaon (CNG) and Bahek (BH) represent schedule tribe (plain) population. Average family size is highest in Upper Deorigaon (16) and lowest being in Kondor (6). Total area cultivation of rice is highest in Nam-Deorigaon (490 ha). But 8 No. Spur is endowed with more cultivating land (1.06 ha/capita). The animal density in Bahek is the highest (3.1 animals/ha). The least animal density being in 8 No. Spur (0.85 animals/ha).

Table – 5.1
Features of Twelve Villages

Sl No	Description	Villages in Dhekargarah block							Villages in Baghsung block				
		G	K	8 No	NJ	UP	NAM	CNG	BH	KHE	KO	KA	BI
1	Population	288	256	256	416	512	480	224	256	192	224	224	256
2	Sex-ratio (M F)	58 42	54 46	57 43	56 44	52 48	52 48	52 48	54 46	52 48	52 48	47 43	58 42
3	Average family size	9	8	8	13	16	15	7	8	6	7	7	8
4	Operational land holdings												
	Total cases	32	32	32	32	32	32	32	32	32	32	32	32
	% of households Large farmers (>2ha)	17	20	26	21	21	19	11	10	20	15	16	19
	Small farmers (>1ha <2ha)	32	30	30	29	35	35	36	40	32	42	40	39
	Marginal farmers (upto 1ha)	43	45	37	43	39	40	47	40	42	40	35	34
	Landless (< 1ha)	8	5	7	7	5	6	6	10	6	3	9	8
5	Land utilization pattern (ha)												
	Total land owned	71	183	275	27	215	501	25	33	35	37	46	52
	Net area of cultivation												
	Khariff crops	67	176	271	22	211	490	23	31	33	36	41	49
	Rabi crops	–	–	–	–	4	11	–	0 4	0 2	–	–	0 6
6	Types of crops	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy	Paddy
		–	–	–	–	Mus-tard	Mus-tard	–	Mus-tard	Mus-tard	–	–	Gram
		–	–	–	–	Pea Gram	Pea Gram	–	–	–	–	–	–
7	Livestock population	122	162	235	53	325	679	72	102	68	112	73	122
	Bullock	76	101	153	33	202	423	45	63	42	69	45	76
	Milch cow	30	41	60	13	80	167	18	26	17	28	18	31
	Calves	16	20	22	7	43	89	9	13	9	15	10	15

[a] M : F Male : Female

Source : Survey data by author

Out of those twelve villages, Gariabhonga, Khongia, 8No. Spur, Na-Jankhona, Upper-Deorigaon, Nam-Deorigaon and Kheremora are un-electrified villages. In agriculture, rice is the commonly grown crop in Kharif season in the twelve villages. Intercropping is done only in Upper-Deorigaon, Nam-Deorigaon, Bahek, Kheremora and

Birina in Rabi season. Mustard, pea, grams are grown during Rabi season. The farmers do not use modern agricultural implements in any of the twelve villages. Instead, they use traditional implements in farming. Moreover, no irrigation facility is available in any of the twelve villages. Heavy rainfall during rainy season helps the farmer in rice cultivation.

5.2.1 Cropping Pattern and Productivity

The area and yield of various crops grown in the twelve villages for the Kharif and Rabi seasons are presented in Table 5.2. It is seen that productivity of mustard, gram and pea in the villages are very low compared to the rice production in those villages.

Table – 5.2
Area and Yield of Rice and Rabi Crops in the Twelve Villages

Village	Khariff crops		Rabi crops					
	Area of cropping in hectares	Production in tones/yr	Area of cropping in hectares			Production in tones/yr		
	Rice (Oriza satival)[a]		Mustard (Brassica juncea)[b]	Gram (Cicer arietinum)[c]	Pea (Pisum sativam)[d]	Mustard	Gram	Pea
G	67 (94 4)	219	–	–	–	–	–	–
K	17 6 (96 1)	574	–	–	–	–	–	–
8 No	271 (98 5)	883	–	–	–	–	–	–
NJ	22 (81 5)	71	–	–	–	–	–	–
UP	211 (98 1)	686	2 5 (1 16)	0 5 (0 23)	1 00 (0 47)	3 0	0 5	0 45
NAM	490 (97 8)	1598	6 0 (1 2)	2 0 (0 40)	3 0 (0 60)	3 5	0 75	6 70
CNG	23 (92 0)	117	–	–	–	–	–	–
BH	31 (93 9)	158	0 4 (1 2)	–	–	1 02	–	–
KHE	33 (94 3)	168	0 2 (0 5)	–	–	0 36	–	–
KO	36 (97 3)	183	–	–	–	–	–	–
KA	41 (89 1)	209	–	–	–	–	–	–
BI	49 (94 2)	250	0 6 (1 15)	–	–	1 8	–	–

Note : a, b, c, d are botanical names Source : Survey data by author

Figures within parentheses indicate percentage of the total area

5.3 Energy Profiles

As the production of mustard, gram and pea are very less in comparison to rice production; available energy (untapped) from rice residues only has been estimated. The data collected for production of rice residue and yield of cattle dung in the twelve villages were analysed in the following sections.

5.3.1 Rice Residues

The villagers do not prefer paddy straw for thatching, as a special type of grass is found in abundance on the riverside. A minor quantity of rice husk and straw is used as fodder. The rural mass do not use rice residues as fuel due to easy availability of fuel wood. Some households use straw to initiate fire in the traditional stove. Table 5.3

Table – 5.3
Rice and Residues Production in the Twelve Villages

Village	Rice produced (tonnes/yr)	Rice husk[a] (tonnes/yr)	Straw[b] (Post harvest) tonnes/yr	Straw (left over) tonnes/yr	Use of rice residues (tonnes/yr)	
					Husk as fodder	Straw as fodder
G	219	88	146	467	–	0 05
K	574	230	382	1225	–	0 02
8 No	883	353	588	1885	–	–
NJ	71	28	49	153	–	–
UP	686	274	457	1468	–	0 04
NAM	1598	639	1064	3410	–	0 05
CNG	117	45	78	160	0 02	–
BH	158	63	106	216	–	–
KH	168	67	113	229	–	0 03
KO	183	73	123	250	–	–
KA	209	84	140	285	0.02	–
BI	250	100	168	341	0 04	0 2

Source : Survey data by author

a Husk : Grain = 0.4 : 1.00

b A head load of paddy bundle (locally called 'Dangori') produces 10kg straw.

c 1 hectare of land produces 6958.8 kg of left over straw.

summarizes total rice production and residue production after deducting non-fuel applications such as fodder, building material etc. in the twelve villages The production of rice and residues is highest in Nam-Deorigaon (1598 tonnes/yr) and lowest in Na-Jankhona (71 tonnes/yr)

5.3.2 Cow-dung

Table 5.4 shows daily average wet dung production in the twelve villages. Average dung output per day per bullock is estimated to be 6.42 kg and that of milch cow and calves are found to be 4.8 kg and 2.2 kg respectively. Hence average dung output per animal is found to be 4.5 kg in the twelve villages. A part of dung produced is

Table – 5.4
Daily Production of Dung by Various Animals and Its Uses

Village	Number of animals			Daily production of wet dung (kg)			Total production of wet dung (kg)	Use of dung as manure (kg)	Surplus dung (kg)
	Bullock	Milch cow	Calves	Bullock	Milch cow	Calves			
G	76	30	16	487 92	144 0	35 2	667 12	390 00	277 12
K	101	41	20	648 42	196 8	44 0	889 22	157 50	731 72
8 No	153	60	22	982 26	288 0	48 4	1318 66	948 80	369 72
NJ	33	13	7	211 86	62 4	15 4	289 66	141 65	148 01
UP	202	80	43	1296 84	384 0	94 6	1775 44	820 68	954 76
NAM	423	167	89	2715 66	801 6	195 8	3713 06	2015 60	1697 46
CNG	45	18	9	302 40	86 4	19 8	408 60	131 08	277 52
BH	63	26	13	423 40	124 8	28 6	576 80	209 86	366 94
KH	42	17	9	282 24	81 6	19 8	383 64	116 52	267 12
KO	69	28	15	464 70	134 4	33 0	632 10	304 28	327 82
KA	45	18	10	302 40	86 4	22 0	410 80	130 60	280 20
BI	76	31	15	487 92	148 8	33 0	669 72	342 13	327 59

Source : Survey data by author

mainly used for manuring the fields and sometimes as clay materials. Available surplus dung is highest in Nam-Deorigaon (1679 kg/day) and lowest in Na-Jankhona (148.01 kg/day). Conversion of different physical units into energy is shown in Table 5 5

Table – 5.5
Conversion of Physical Units into Energy

Energy source	Gross calorific value[a] (MJ/kg)
Fuel wood with 20% moisture content	15 0
Rice husk	14 3
Rice straw	13 4
Cattle dung	9 0
Commercial fuel Kerosene	44 0

[a] Ref Ravindranath *et al*, (1995)

Table 5 6 summarizes available energy from rice residues and dung lying untapped after deducting the quantity used in different applications It may be observed that yearly per capita available energy from rice residues and dung is maximum in Nam-Deorigaon (155 55 GJ/Capita/yr) followed by minimum in Na-Jankhona (8 57 GJ/Capita/yr) Conversion of different physical units into energy is shown in Table 5 6

Table – 5.6
Available Energy from Rice Residues and Dung in the Twelve Villages

Village	Rice husk (GJ/yr)	Rice straw (Post harvest) (GJ/yr)	Rice straw (left over) (GJ/yr)	Dung (GJ/yr)	Available energy (GJ/yr)	Available energy GJ/ Capita/yr
G	1258 40	1956 40	6257 80	910 64	10,383 24	36 05
K	3289 00	5118 80	16415 00	2404 69	27 227 47	106 36
8 No	5047 90	7879 20	25245 60	1215 00	39,387 70	153 86
NJ	400 40	656 60	2,023 40	486 22	3,566 62	8 57
UP	3918 20	6123 80	19617 60	2136 48	31,796 08	62 10
NAM	9137 70	14257 60	45694 00	5576 16	74,665 46	155 55
CNG	643 50	1045 20	2144 00	911 65	4744 35	21 18
BN	900 90	1420 40	2894 40	1205 40	6421 10	25 08
KH	958 10	1514 20	3068 60	877 49	6418 39	33 43
KO	1043 90	1648 20	3350 00	1074 85	7116 95	30 41
KA	1201 20	1876 00	3819 00	920 46	7816 66	33 40
BI	1430 00	2251 20	4569 40	1076 13	9326 73	36 43

Source Survey data by author

5.3.3 Fuel Wood

During this study, no quantitative data were collected for the area from which the villagers gather fuel wood. However, it was observed that the northern side of all the six villages of Dhekargara block does not have forest as they border the river Brahmaputra on that side. A dense forest cover surrounds the southern and western sides of Upper-Deorigaon and Nam-Deorigaon. It provides plenty of fuel wood in those two villages. In the other ten villages. the villagers collect twigs, fallen branches, bushes, logs, bamboo etc. from the riverside, forests, fields and own farms.

Table 5.7 shows the mode of supply of fuel wood via gathering from surrounding environment. Assessments by the people as to the availability of fuel wood are also included in Table 5.7. In the well-wooded area of the survey, there is no lack of fuel wood. 84.4 per cent of the respondents reported that they collect fuel wood from nearby forests or fields. Other 15.6 per cent collect from their own farms or homestead gardens. 48.9 per cent of the respondents have a feeling of sufficiency of fuel wood for the present and in the near future. 39.7 per cent of the respondents are assured of present sufficiency; but uncertain about the near future. The rest 11.4 per cent feel that present availability of fuel wood is barely sufficient.

Table – 5.7
Sources Availability and Future Predictions of Fuel Wood
(A = % of respondents, D = amount of wood in kg/day)

Sector size	Size	Source			Availability		
		Market	Collected	Ownfarms	S	U	B
Rural domestic 100 % of wood using households	A	0	84 4	15.6	48.9	39.7	11.4
	D	0	5081	1402	–	–	–

S Sufficient now and in the near future

U Sufficient now but uncertain in the near future B Barely sufficient

5.4 Rural Domestic Energy Consumption Pattern

Energy consumption in rural domestic sector is mainly for three end uses : cooking and water heating (combined), space heating, and space lighting. Though a variety of energy sources are available, only fuel wood in the form of twigs. branches, bushes, bamboo etc. is used for domestic energy consumption in cooking, water heating and space heating.

5.4.1 Cooking and Water Heating (Combined) and Space Heating

Table 5.8 presents yearly per capita energy consumption for cooking and water heating (cobined) and space heating in summer and winter months across the twelve villages. The estimation figures presented in Table 5.8 has been done using the conversion figures from Table 5.5. The following observations can be made from Table 5.8.

- The yearly per capita electricity consumption in the electrified villages is very low.

- The yearly per capita domestic energy consumption in the form of fuel wood is highest in Upper-Deorigaon (12.63 GJ) and lowest in 8 No. Spur (7.44 GJ)

- The consumption of domestic energy is not uniform throughout the year. The domestic energy consumption in cooking, water heating, and space heating is found to be more in winter than in summer in the entire twelve villages. In descending order 42, 40, 27.9, 25.5, 24.8, 24.8, 22.8, 22.6, 22.2, 22.1. 21.5 and 20.6 per cent more domestic energies are found to be consumed in winter than in summer in the villages such as Upper-Deorigaon, Nam-Deorigaon, Na-Jankhona, Bahek, 8 No. Spur, Kheremora, Kathalbari, Khongia, Chowdung gaon. Birina, Gariabhonga and Kondar, respectively (Sarmah *et al.*, 2002).

Table – 5.8
Consumption of Domestic Energy in GJ/yr for Cooking and Water Heating (Combined), Space Heating and Space Lighting

Village	Non-commercial				Commercial		Gross Consumption
	Cooking and water heating (fuel wood)		Space heating in winter (fuel wood)	Total Fuel wood consumption	Space lighting (Kerosene)	Space lighting (electricity)	
	Summer	Winter					
G	1404 93 (4 88)	1488 86 (5 17)	218 83 (0 76)	3112 62 (10 83)	43 25 (0 15)	–	3155 87 (10 96)
K	1157 03 (4 52)	1192 99 (4 66)	224 37 (0 88)	2574 40 (10 06)	33 40 (0 13)	–	2607 79 (10 19)
8No	846 42 (3 31)	947 121 (3 70)	110 12 (0 43)	1903 66 (7 44)	17 18 (0 067)	–	1920 841 (7 503)
NJ	1567 74 (3 77)	1783 39 (4 29)	221 54 (0 533)	3572 67 (8 59)	115 89 (0 28)	–	3688 56 (8 87)
UP	2672 64 (5 22)	2965 35 (5 79)	830 10 (1 62)	6468 09 (12 63)	30 09 (0 059)	–	6498 24 (12 69)
NAM	2504 00 (5 21)	2627 10 (5 47)	872 58 (1 82)	6003 60 (12 51)	17 56 (0 0366)	–	6021 16 (12 54)
CNG	1089 42 (4 86)	1180 78 (5 27)	150 75 (0 672)	2420 93 (10 81)	13 66 (0 061)	5 10 (0 023)	2439 69 (10 89)
BH	1332 05 (5 203)	1458 32 (5 70)	211 57 (0 83)	3002 26 (11 76)	32 05 (0 143)	10 23 (0 04)	3044 54 (11 89)
KH	744 61 (3 88)	824 00 (4 29)	106 05 (0 552)	1674 69 (8 72)	52 08 (0 203)	–	1726 77 (8 99)
KO	880 69 (3 76)	933 15 (3 99)	127 33 (0 544)	1951 17 (8 34)	30 04 (0 156)	12 04 (0 051)	1993 25 (8 52)
KA	905 35 (3 87)	985 33 (4 22)	123 72 (0 53)	2014 40 (8 61)	32 30 (0 138)	12 89 (0 056)	2059 59 (8 80)
BI	1189 40 (4 65)	1279 94 (5 00)	173 76 (0 68)	2643 10 (10 32)	21 14 (0 083)	12 73 (0 053)	2676 97 (10 46)

Note Figures within parentheses indicate per capita energy consumption

The reasons for consuming more energy in winter are such as the need for space heating, a change in food intake, more time needed to boil water due to low pressure and low temperature, the need for more hot water in bathing as well. The people of Upper-Deorigaon, Nam-Deorigaon, Chowdung gaon and Bahek have a habit of three meals (cooked rice) a day while the people of other eight villages have a habit of taking two meals a day. Tea is the common beverage in all the twelve villages. Moreover, the people of Upper-Deorigaon, Nam-Deorigaon, Chowdung gaon and Bahek are regular drinkers of a home made liquor Called "Apong" which is made from cooked rice (Sarmah *et al*, 2002).

Table 5.9 shows per capita gross and useful energy consumption for cooking, water heating, and space heating. It is important to note that the actual operational efficiency of the traditional stove is much lower which leads to greater conversion losses. For this reason, the per capita useful energy consumption has a wide difference from the

Table – 5.9
Per Capita Gross and Useful Energy Consumption in Cooking, Water Heating and Space Heating in the Twelve Villages.

Total	Unit	Cooking and water heating (Combined) and Space heating (fuel wood)											
		G	K	8 No	NJ	UP	NAM	CNG	BH	KH	KO	KA	BI
Gross	GJ/Capita/yr	10 83	10 06	7 44	8 59	12 63	12 51	10 81	11 73	8 72	8 34	8 01	10 32
Useful*	GJ/capita/yr	1 30	1 11	0 67	0 86	2 40	2 38	1 08	1 99	1 13	0 917	0.72	1 24

* Useful energy refers to the amount consumed net of conversion losses.

per capita gross energy consumption. The per capita useful energy consumption in cooking, water heating and space heating in the eight villages is above the minimum requirements estimated by the Advisory Board on Energy [ABE, 1985] i.e., 0.9475 GJ/capita/yr useful energy in India (Gariabhonga : 1.3 GJ/yr; Khongia : 1.1 GJ/yr; Upper-Deorigaon : 2.4 GJ/yr; Nam-Deorigaon : 2.38 GJ/yr; Chowdung gaon : 1.08 GJ/yr; Bahek : 1.99 GJ/yr; Kheremora : 1.13 GJ/yr and Birina : 1.24 GJ/yr). On the other hand in 8 No.

Spur, Na-Jankhona, Kondar and Kathalbari, the per capita useful energy consumption level in cooking, water heating and space heating is lower (0.67 GJ/yr, 0.86 GJ/yr, 0.917 GJ/yr and 0.72 GJ/yr, respectively) than the minimum requirement. It has been found that easy and free availability of fuel wood leads to excessive energy consumption. Also, differences in cooking habits, meals and family size may lead to excessive energy consumption.

Figure 5.1 presents the pattern of domestic energy consumption for three different categories of society.

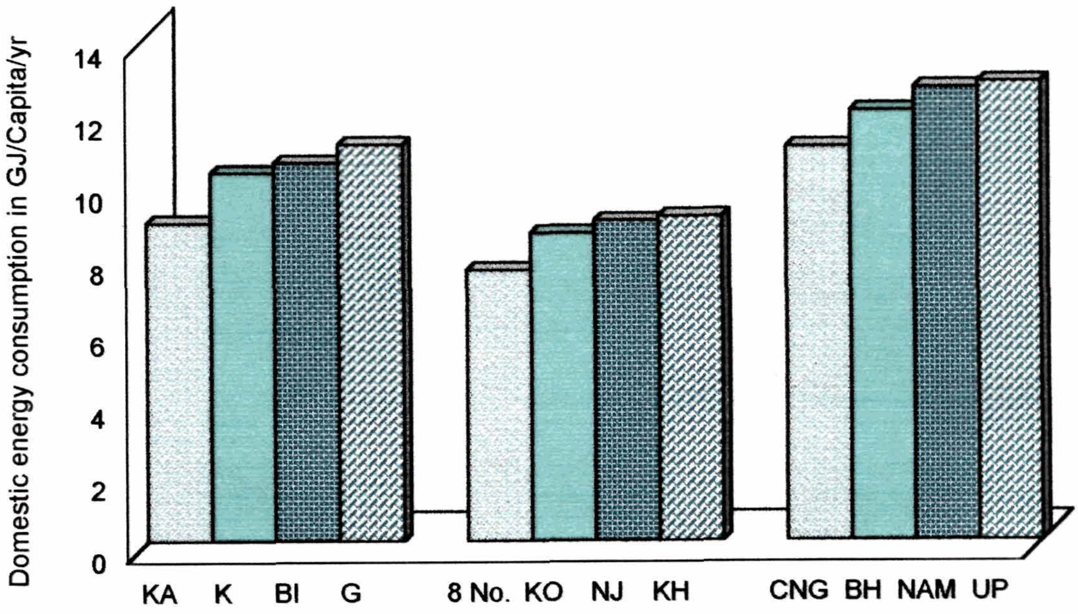


Fig. 5.1 Pattern of Per Capita domestic energy consumption in the Villages of Different Categories

5.4.2 Space Lighting

The requirement for domestic lighting in Gariabhonga, Khongia, 8 No. Spur, Na-Jankhona, Upper-Deorigaon, Nam-Deorigaon and Kheremora is met by kerosene. Kerosene and electricity both are used in Chowdung gaon, Bahek, Kondar, Kathalbari and Birina. As the electricity failure is major and regular feature (average 8 hours per day and mostly at night), kerosene is the only alternative fuel for space lighting in those five electrified villages. Wick lamps and hurricanes are found to be the lighting appliances. Fig. 5.2 shows kerosene consumption in ltr/hr for different types of lamps used in the sampled villages.

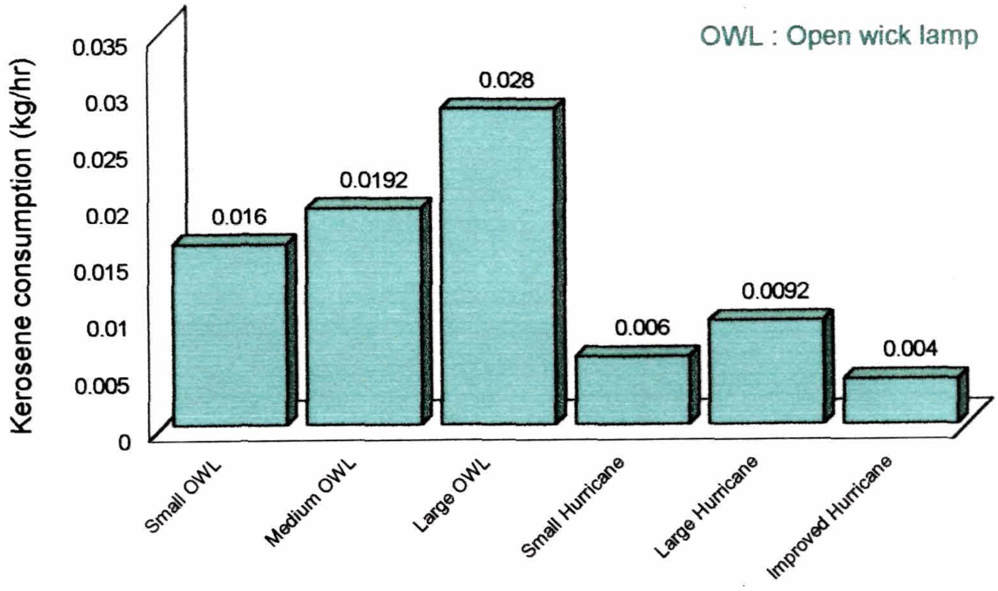


Fig. 5.2 Kerosene Consumption for Different Wick and Hurricane Lamps

The rural people use waste cloth fibre as wick in the wick lamps. Based on the size of the family limited quantity of kerosene is available through Public Distribution System. The seasonal variation of kerosene and electricity consumption is insignificant in the villages. Because kerosene and electricity are used for lighting purposes only. Variation of yearly per capita kerosene consumption in domestic lighting is maximum in Na-Jankhona (0.28 GJ) and minimum consumption of kerosene is in Nam-Deorigaon (0.0366 GJ/capita/yr). The yearly consumption of kerosene in lighting for the un-electrified households in all the twelve villages is much lower than all India average of 1.028 GJ/capita/yr as estimated by National Council of Applied Economic Research [NCAER, 1985]. The yearly per capita variation of energy consumption in space lighting in the twelve villages may be due to differences in (a) availability of kerosene and electricity, (b) sleeping habits, (c) number of school-going children.

5.4.3 Fuel wood Collection Activities

Table 5.10 presents fuel wood collection activities in the rural areas Majority (68.8%) of the respondents go out far away from their residence for fuel wood collection. 7.8 per cent of the respondents cover very far distance and 14.3 per cent collect fuel wood

Table – 5.10
Firewood Collection Activities in the Sampled Villages

	N	%
A Distance covered in collection		
Total	384	100 0
Very far from home	30	7 8
Far from home	264	68 8
Near home	55	14 3
No response	35	9 1
B Hours spent in collection		
Total	384	100 0
Whole day	65	17 0
> 4 hours	99	25 8
2 to 4 hours	146	38 0
1 to 2 hours	58	15 0
No response	16	4 2
C Frequency of collection		
Total	3	100 0
Daily	195	50 8
Weekly	164	42 7
Monthly	6	1 6
No response	19	4 9
D Specific problems cited		
Total	384	100 0
Excessive time required	234	61 0
Restriction of forestry	12	3 1
Other	44	11 5
Encounter no problem	44	11 5
No response	50	12 9

Source : Survey data by author

N number of respondents.

from the nearby forests or fields. 38 per cent of respondents spend 2 to 4 hours of the day; 25.8 per cent spend more than 4 hours; 17 per cent of them take whole day and 15 per cent spend 1 to 2 hours time in fuel wood collection. 50.8 per cent of the respondents are dependent on daily collection; 42.7 per cent and 1.6 per cent gather fuel wood on weekly and monthly basis, respectively. Majority (61%) informed that excessive time is spent in fuel wood collection. Only 3.1 per cent face problem in collection due to the restriction imposed by the Forest Department. Other 11.5 per cent do not face any problem in fuelwood collection.

5.5 Comparison of Rural Domestic Energy Consumption with Semi-Urban and Urban Domestic Sectors

The data regarding domestic energy consumption, domestic fuel technology, hours spent in cooking in semi-urban and urban domestic sectors were analysed as per the methodology adopted in Chapter IV. This comparison was done to analyse the impact of domestic fuel on the health of rural women.

5.5.1 Energy Consumption in Rural Domestic Sector

Table 5.11 presents per capita per year domestic energy consumption in rural, semi-urban and urban sectors of Jorhat district. 100 per cent of rural households rely on fuel wood as their cooking fuel and kerosene as their lighting fuel. Although, few of the villages are connected by electrical network, the position of electricity is not at all favourable in the rural sector (average 8 to 9 hours failure per day, mostly at night). Fuel woods in the form of twigs, fallen branches, bushes, bamboo and other low quality fuels are used in cooking. The annual energy consumption in the form of fuel wood for cooking was estimated at 36040 GJ/yr and per capita per year consumption to be 10.001 GJ. The annual energy consumption in the form of kerosene was found to be 973.04 GJ and per capita per year consumption was estimated at 0.270 GJ. Wick lamps and hurricanes are found to be the lighting appliances in the rural sector. The electricity consumption in the electrified villages was estimated at 10.452 GJ/yr and per capita per year consumption was found to be 0.0029 GJ.

Table – 5.11
Comparison of Domestic Energy Consumption in Rural, Semi-Urban and Urban Sectors of Jorhat District

Item	Rural	Semi urban	Urban
Distance from the town	> 10 km	> 5 km	0-5 km
Population	3604	1640	1350
Use of kerosene	973 08 GJ/yr (0 270 GJ/capita/yr)	565 80 GJ/yr (0 345 GJ/capita/yr)	448 20 GJ/yr (0 332 GJ/capita/yr)
Use of fuel wood	36040 00 GJ/yr (10 001 GJ/capita/yr)	1118 48 GJ/yr (0 682 GJ/capita/yr)	NIL
Use of LPG	NIL	2399 32 GJ/yr (1 463 GJ/capita/yr)	2569 05 GJ/yr (1 903 GJ/capita/yr)
Use of electricity	10 45 GJ/yr (0 0029 GJ/capita/yr)	455 92 GJ/yr (0 278 GJ/capita/yr)	841 05 GJ/yr (0 623 GJ/capita/yr)

5.5.2 Energy Consumption in Semi-Urban Domestic Sector

In semi-urban sector, the annual fuel wood consumption in cooking has been estimated at 1118.48 GJ and per capita per year consumption has been 0.682 GJ. 15 per cent of the semi-urban people use fuel wood as their cooking fuel. Also, some households keep fuel wood as one of the alternatives for cooking when there is a shortage of LPG supply or delay in LPG collection due to transportation problem. The people of this sector purchase fuel wood from the market supplied by rural mass or directly from the rural people.

Majority of the semi-urban people prefer LPG as cooking fuel and they collect LPG cylinders from the local agencies or from the central town agencies. The annual LPG consumption in this sector was found to be 2399.22 GJ and per capita per year consumption has been estimated at 1.463 GJ.

The semi-urban areas in the district surveyed are mostly electrified. Thus, electricity is the main lighting source there. Electricity is also used to run T.V. People do keep kerosene in stock (procured from public distribution system) as lighting alternative during major and regular electricity failure (average 6 hr/day) in this sector. The annual kerosene consumption has been estimated at 565.80 GJ and per capita per year consumption at 0.345 GJ. The annual electricity consumption is around 455.92 GJ and per capita per year consumption is 0.278 GJ.

5.5.3 Energy Consumption in Urban Domestic Sector

In general, the urban people do not use fuel wood for cooking. Instead, they use LPG as their prime cooking fuel. In some urban households kerosene stoves are used for water heating purposes. They gather LPG cylinders from the central agencies. Home delivery of LPG cylinders is also available there. The annual LPG consumption has been found to be 2569.05 GJ and per capita per year consumption has been found to be 1.903 GJ in the sampled households.

This sector is totally electrified. Electricity is the main lighting component there. Besides lighting, electrical appliances like oven, heater, press, grinder, T.V. etc. are used in urban households.Duration of electricity failure varies everyday. Therefore, based on the data and information collected, an allowance of average 2 hours electricity failure per day has been considered. Annual electricity consumption has been estimated at 841.05 GJ and per capita annual consumption was found to be 0.623 GJ. The kerosene consumption was found to be 448.20 GJ/year and per capita per year consumption was estimated at 0.332 GJ.

Fig. 5.3 depicts the consumption of domestic energy using different fuels in GJ/capita/yr in three different sectors.

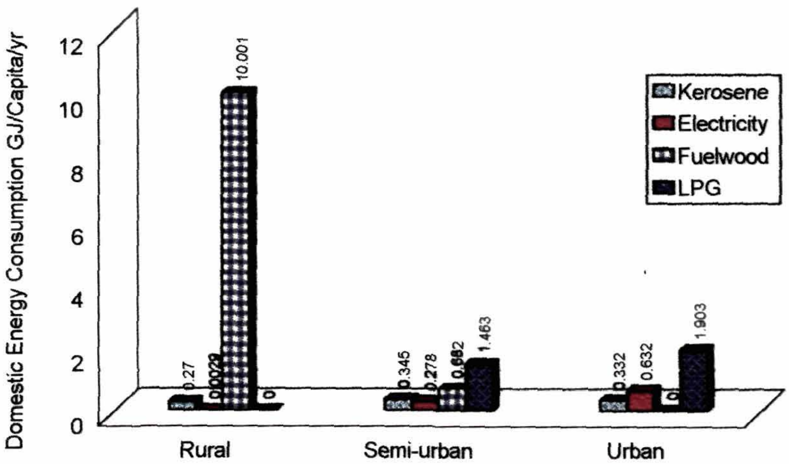


Fig. 5.3 Comparison of Domestic Energy Consumption in the Three Sectors

5.5.4 Test of Variations

The major hypothesis to be tested in the study is to find out significant variations, if any, of fuel consumption in between and within the treatment i.e., sectors. To test the hypothesis, analysis of variance (ANOVA) i.e. F-test was employed. Table 5.12 depicts one-way ANOVA analysis on domestic energy consumption in selected rural, semi-urban and urban sectors of Jorhat district.

Table – 5.12
One-way ANOVA Analysis on Domestic Energy Consumption in Rural, Semi-urban and Urban Sectors

Types of fuel	Source of variation	Sum of square	Degree of freedom	Mean square	Calculated 'F'	Table value of 'F'	Acceptance / Rejection of hypothesis	Level of significance
Fuel wood	BT	7134.71	2	2218.15	6.99	4.74	Rejected	0.05
	WT	2218.15	7	316.88				
Kerosene	BT	101.25	2	50.63	67.11	6.70	Rejected	0.01
	WT	9.72	13	0.75				
LPG	BT	49.26	2	24.63	6.57	4.46	Rejected	0.05
	WT	29.99	8	3.75				
Electricity	BT	14.39	2	7.20	8.95	8.02	Rejected	0.01
	WT	7.34	9	0.82				

BT Between treatment WT Within treatment

The calculated F-values in case of all the fuels are higher than the table values of F, which are 4.74 and 4.46 for fuel wood and LPG, respectively, at 5 per cent level of significance. On the other hand, table values of F are 6.70 and 8.02 for kerosene and electricity, respectively, at 1 per cent level of significance. Hence, the null hypothesis is rejected. This means that the consumption of domestic energy has high significant variations in between and within the sectors.

Fuel wood consumption has a significant variation among the three sectors. It clearly indicates that with development, determined by the availability of infrastructural facilities, the use of fuel wood goes down in the semi-urban sector and is nil in the urban sector.

LPG consumption has also a significant variation among the sectors indicating that with increasing infrastructural facilities, the use of LPG goes up in urban sector first, then in semi-urban sector and the rural sector do not at all use LPG in cooking.

The variation in the use of kerosene is found to be highly significant in between and within the sectors, where F-ratio is estimated as 67.71. It reveals that with the increase in distance from infrastructural facilities, there is an adverse condition in electricity position. Electricity is available mostly in urban sector. As most of the rural sector is completely un-electrified, use of kerosene is must for domestic lighting there. Hence, the variation in the use of electricity among three sectors is estimated to be significant with F-ratio 8.95 (Sarmah *et al.*, 2000).

5.6 Impact of Domestic Fuels on Rural Women

An analysis on impact of domestic fuels on rural women has been presented by comparing the domestic energy consumption in semi-urban and urban sectors. The semi-urban people use fuel wood, kerosene and LPG as cooking fuels. Electricity and kerosene are used as lighting energy source. The urban people use LPG and kerosene as cooking fuels. Electricity and kerosene are used for lighting. The rural people completely rely on fuel wood for cooking and on kerosene for lighting purposes as the position of electricity are very poor in rural areas. The following factors were analysed to study the health condition of the women in relation to use of fuel for cooking.

5.6.1 Income Level and Use of Fuels

All the households were divided into four groups based on income levels as presented in Table 5.13. Majority of the households are in low and lower medium income groups in rural sector. Only fuel wood is preferred as cooking fuels by all groups. In semi-urban sector, majority of the households are in upper-medium and higher income groups. Only 22.2 per cent of low-income group and 6.4 per cent of lower medium income group use fuel wood in cooking. Majority of the urban households are in higher income group. They do not at all use fuel wood in cooking. Availability of infrastructural facilities and better income status are two main factors for their liking to clean fuels.

Table – 5.13
Types of Cooking Fuels and Income Group

Sector	Annual income (Rs)		No of HH[1] in the range	Number of HH[1] using particular types of cooking fuels					
	Group	Range		FW[2]	Ag res[3]	Dung	Kerosene	LPG	Electricity
Rural	Low	<6000	202	202 (100%)	-	-	-	-	-
	Lower-medium	6000-18000	133	133 (100%)	-	-	-	-	-
	Upper-medium	18000-24000	45	45 (100%)	-	-	-	-	-
	Higher	>24000	4	4 (100%)	-	-	-	-	-
	Total		384	384 (100%)	-	-	-	-	-
Semi-urban	Low	<6000	25	18 (72%)	-	-	7 (28%)	-	-
	Lower-medium	6000-18000	31	12 (39%)	-	-	10 (32 3%)	9 (29%)	-
	Upper-medium	18000-24000	74	-	-	-	9 (12 16%)	65 (88%)	-
	Higher	>24000	75	-	-	-	15 (20%)	60 (80%)	-
	Total		205	30 (15%)	-	-	41 (20%)	134 (65%)	-
Urban	Low	<6000	-	-	-	-	-	-	-
	Lower-medium	6000-18000	45	-	-	-	5 (11%)	40 (89%)	-
	Upper-medium	18000-24000	70	-	-	-	5 (7%)	65 (93%)	-
	Higher	>24000	110	-	-	-	2 (1 8%)	105 (95%)	3 (2 7%)
	Total		225	-	-	-	12 (5 3%)	210 (93%)	3 (1 3%)

Note : HH[1] Households   FW[2] Fuel wood   Ag.res[3] Agricultural residues

5.6.2 Combustion Technology and Practice

In semi-urban and urban households, cooking is done in separate kitchen inside the house by 95 per cent of families. Table 5.14 shows percentage of households using different types of stoves for domestic use. Only 15 per cent of semi-urban households use fuel wood for cooking in improved stove. 20 per cent of semi-urban households and 6 per cent of urban households use kerosene stove in cooking and water heating. Other 65 per cent of semi-urban households and 94 per cent of urban households use LPG stoves for cooking. Smoke escapes through open windows and doors. So, the indoor air pollution is absent in semi-urban and urban sectors.

Table – 5.14
Percentage of Households Using Different Types of Stoves

Sector	3-brick wood	Home-made mud	Improved	Kerosene	LPG	Total
Rural domestic	12	88	0	0	0	100
Semi-urban domestic	0	0	15	20	65	100
Urban domestic	0	0	0	6	94	100

Source : Survey data by author

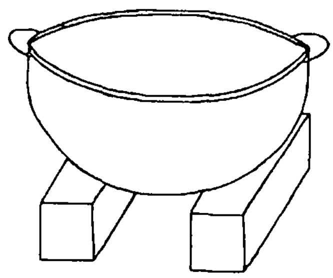


Fig. 5.4 3-brick Stove

Findings reveal that 100 per cent of rural households use fuel wood for cooking, water heating and space heating (in winter). 12 per cent of rural households use 3-brick stove (Fig. 5.4) for burning fuel wood. Other 88 per cent of rural households use traditional stove, which is made of mud with a fuel feeding port as shown in Fig. 5.5. It is a versatile stove without any chimney where vessels of varying dimensions can be used.

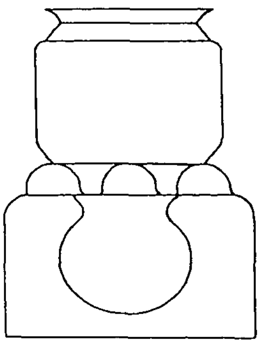


Fig. 5.5 Traditional Mud Stove

The efficiency of this traditional stove ranges from 8-10 per cent [Anonymous, 1986]. No variations in this mode are observed in the selected rural households. The kitchens of the rural households are also improperly ventilated. Absence of chimney in the traditional stove and improper ventilation in the kitchen together with fuel wood burning in efficient traditional stove causes excessive smoke. In turn it causes indoor air pollution. It may be one of the major causes of observed health problems of rural women.

5.6.3 Hours Spent by Women in Cooking

Table 5.15 shows number of hours spent in cooking by women respondents and percentage of cases in rural, semi-urban, and urban domestic sectors. The variation of number of hours required for cooking in rural domestic sector may be due to the differences in domestic fuel technology. Simultaneous cooking is not possible in the traditional stove. Also percent heat utilization in this type of stove is very low. The gap maintained between the bottom of cooking vessel and the flame leads to less heat transfer rate. For this reason also, the number of hours spent by rural households in cooking is more than that of semi-urban and urban households.. More number of hours spent in cooking lead to more hours of exposure to smoky environment. In comparison to this, majority of the women stated that 1 to 2 hours cooking time (63% from semi-urban nd 65% from urban households) are needed per day. The commercial and clean fuel like LPG mainly dominates the semi-urban and urban sectors. The excessive exposure to smoke resulting from the inefficient burning may be the major cause of observed health problems of the rural women.

Table – 5.15
Hours Spent in Cooking by Women Respondents

Hours spent in cooking per day	Number of women			% of cases		
	R	SU	U	R	SU	U
Total (N)	658	305	325	100	100	100
> 5 hours	0	0	0	0	0	0
4 to 5 hours	359	0	0	55	0	0
3 to 4 hours	197	0	0	30	0	0
2 to 3 hours	40	92	98	6	30	30
1 to 2 hours	28	192	211	4	63	65
No response	34	21	16	5	7	5

N Number of women respondents

R Rural SU Semi-urban U Urban

5.6.4 Health Problems

The main health problems of rural women caused by inefficient burning of fuel wood in traditional stove are analysed and determined in consultation with the medical authority of the Rural Development Block. Figure 5.6 presents observed health conditions of rural women. Lack of technology in traditional stove leads to emissions of CO, CO_2, NO_x, hydrocarbons (HC_s) and particulate matters [De Koning *et al.*, 1985] from fuel wood combustion. For these reasons the users may be affected by chronic lung diseases, heart problems, diseases of respiratory tract, child diseases and increased infant mortality. 15.6 per cent of the respondents reported about problem of chest pain. 18.4 per cent of wheezing, 18.6 per cent from giving birth to underweight babies, 40.6 per cent from dry cough, 80 per cent from running nose and 91 per cent stated symptoms of eye irritation. The rural women respondents stated that blowing of air to keep fuel wood burning is a tiring exercise.

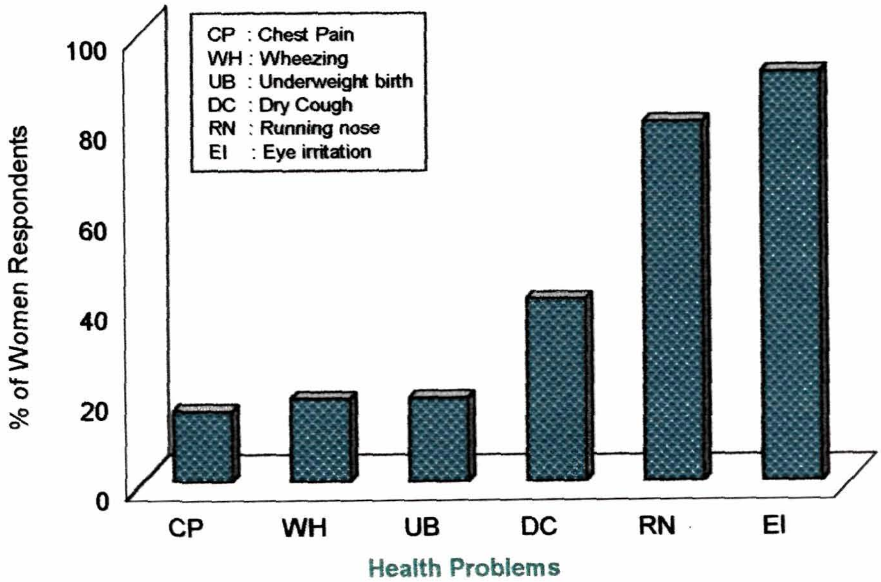


Fig. 5.6 Health Disorders Among Rural Women Due to Fuel Wood Burning

Table 5.16 shows ANOVA analysis of diseases among rural women due to smoke exposure to number of cooking hours. The analysis was employed through F-test to test the null hypothesis i.e. there is no significant variation of the degree of diseases among rural women due to smoke exposure and number of cooking hours. As per Table 5.15, four groups were taken according to the number of hours taken for cooking. The F-ratio is calculated as 4.95 which is higher than the critical table value of F = 4.07 at 1 per cent level of significance. Hence, the null hypothesis is rejected which means that the degree of diseases among rural women due to smoke exposure has a high significant variation to number of cooking hours.

Table – 5.16
ANOVA Analysis of Diseases Among Rural Women Due to Smoke Exposure to Number of Cooking Hours

Source of variation	Sum of square	Degree of freedom	Mean square	Calculated 'F'	Table value of 'V'	Acceptance/Rejection of hy pothesis	Level of significance
Between groups	406.8	3	102 9	4 95	4.07	Rejected	0 01*
Within groups	1476.72	71	20.8				

* 1% level of significance

5.7 Modelling of Rural Domestic Energy Consumption

An attempt has been made to develop a model to represent the rural domestic energy consumption scenario by taking into account the various parameters of rural domestic energy consumption. The data on domestic energy consumption in cooking and water heating (combined) in summer including pre-monsoon, cooking and water heating (combined) and space heating in winter including post-monsoon, domestic energy consumption in lighting over a year, average population, monthly average income, number of school-going children and weather sensitive parameters such as monthly average rainfall and monthly average temperatures were used for estimating the regression co-efficient in equation as stated in Chapter IV.

Since there is a drastic variation in domestic energy consumption rate with the variation of climatic condition over the year, a season-wise regression analysis has been attempted. Model results for domestic energy consumption in cooking and water heating in summer including pre-monsoon, cooking, water heating and space heating in winter including post-monsoon, energy consumption in space lighting over the year are analysed in the following sections.

5.7.1 Summer Season Including Pre-monsoon

A perusal of 'r' (correlation coefficient) value in Table 5.17 reveals that the variables included under the study display their association with rural domestic energy consumption in cooking and water heating in summer (including pre-monsoon). It is evident from Table 5.17 that average population is positively and significantly correlated (r = 0.863) which means that rural domestic energy consumption in cooking and water heating increases with increasing population. The positive and significant correlation of monthly average income (0.854) suggests for higher rate of energy consumption in cooking and water heating with increase income. Increasing income leads to increasing standard of living. Monthly average temperature is negatively and significantly correlated (r = -0.317). It may suggest low rate of energy consumption in cooking and water heating on warm days as less time is required to boil in comparatively high temperature and pressure. Monthly average rainfall and rural domestic energy consumption in cooking and water heating are found to have a negative and significant correlation (r = -0.309). It can be concluded from such relationship that the fuel wood collection is affected by heavy rainfall in summer and high percentage of moisture content in fuel wood signifies less energy consumption in summer.

Table – 5.17
Correlation Co-efficient Between Variables Under Study for Summer Season

Sl. No.	Predictor variables	Correlation co-efficients 'r'	Critical value of 'r'
1.	Average population, X_1	0.863*	0.463
2.	Monthly average in come, X_2	0.854*	0.463
3.	Monthly average temperature, X_3	-0.317**	-0.306
4.	Monthly average rainfall, X_4	-0.309**	-0.306

* At .01 level of significance ** At .10 level of significance

It is evident from Table 5.18 that out of four regression co-efficients of four independent variables, average population is significant at 0.1 per cent level of probability and monthly average income is significant at 5 per cent level of probability. Monthly average temperature and monthly average rainfall are significant at 1 per cent level of probability. It may be noted that for the summer season (including pre-monsoon), there are 30 observations over a period of 5 years (1995-1999).

Table – 5.18
Regression Co-efficient Showing Prediction Potentialities of Variables Under Study for Summer Season (including premonsoon)

Predictor variables	Constant (a)	Regression Coefficients (b)	Standard error of co-efficients	t-value	R^2
Average population, X_1		0 0377	0 00984	3 8318*	
Monthly average income, X_2		0.03927	0 01647	2 384***	
Monthly average temperature, X_3	498 52	-3.5408	0 9996	-3 542**	0 9029
Monthly average rainfall, X_4		-0 0301	0 01232	-2 443**	

* At .001 level of significance ** At .01 level of significance

*** At .05 level of significance

Thus the null hypothesis that individual slope coefficients are zero is rejected (i.e. there is no linear relationship among the variables). The value of co-efficient of multiple determinations R^2 is 0.9029. It indicates that 90.29 per cent variation in rural domestic energy consumption in cooking and water heating (combined) during summer season can be explained by average population, monthly average income, monthly average temperature, and monthly average rainfall. The significant t-values further indicate that one unit change in these four attributes (four predictor variables) would effect 3.8338, 2.384, 3.542 and 2.443 units change in the domestic energy consumption in summer.

Table 5.19 shows ANOVA analysis for consumption of rural domestic energy consumption in cooking and water heating during summer season (including pre-monsoon). Analysis of variance i.e. F-test was employed to test the hypothesis for finding out significant variations of predictor variables. The computed F-ratio = 121.965 is very much greater than critical Table value of F = 4.64 for degrees of freedom (3,26) at 1 per cent level of significance. It can be assured that the rural domestic energy consumption has an effect on selected predictor variables. Thus on the basis of t-statistics, F-ratio and co-efficient of multiple determination R^2-values, the model result is found to be adequate. Therefore, these four attributes could be termed as good contributors or good predictors to rural domestic energy consumption for summer season.

Table – 5.19
Results of Analysis of Variance for Summer Season

Source of variance	Sum of square	Degree of freedom	Mean square	Calculated 'F'	Table value of 'F'	Level of significance
Model	1276.132	3	425 377			
				121-965	4.64	0 01
Error	90.69	26	3 488			

A plot of observed vs predicted rural domestic energy consumption in cooking and water heating in summer (including pre-monsoon) is shown in Figure 5.7. It may be shown that the points in the plot are clustering around a straight line which shows adequacy of the model.

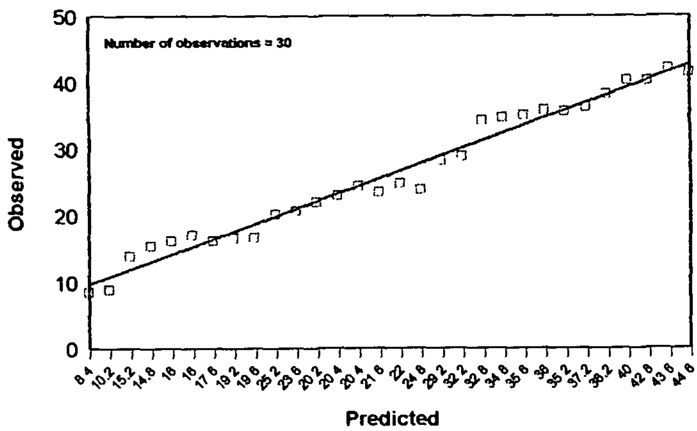


Fig. 5.7 Observed Vs Predicted Rural Domestic Energy Consumption in Cooking and Water Heating (combined) in Summer (including premonsoon)

5.7.2 Winter Season Including Post-monsoon

Table 5.20 shows that the correlation of average population with energy consumption is positive and significant (r = 0.883). This means that rural domestic energy consumption in cooking and water heating (combined) and space heating during winter increases with increase in population. The monthly average income is positively and significantly correlated (r = 0.951). It suggests more consumption of energy (due to more number of cooking items) with increase in income level. The negative and significant correlation of monthly average temperature (r = -0.486) claims for increasing rural domestic energy in cooking and water heating (combined) and space heating as more energy is consumed due to low pressure and low temperature during winter season. More time needed for cooking and water heating is also another reason of more energy consumption in winter. Also, extra arrangement for space heating in winter increases more fuel consumption. Monthly average rainfall and monthly average rural domestic energy consumption in cooking and water heating (combined) and space heating during winter season are found to have a very weak negative correlation and not significant. It can be concluded from such relationships that rural domestic energy consumption during winter season is independent of monthly average rainfall.

Table – 5.20
Correlation Co-efficients Between Variables Under Study for Winter Season Including Post-monsoon

Sl. No.	Predictor variables	Correlation co-efficient 'r'	Critical value of 'r'
1.	Average population, X_1	0.883*	0.463
2.	Monthly average income, X_2	0.951*	0.463
3.	Monthly average temperature, X_3	-0.485**	0.361
4.	Monthly average rainfall, X_4	-0.060^{NS}	0.306

* At 0.01 level of significance

** At 0.1 level of significance

^{NS} Non-significant

It is evident from Table 5.21 that regression co-efficient of average population and monthly average income are significant at 1 per cent level of probability and that of monthly average temperature is significant at 10 per cent level of probability. As the relationship of monthly average rainfall was found to be weak and not significant in winter, it is excluded from the model. For the winter season (including post-monsoon), there are 30 observations over a period of 5 years (1995-99).

Table – 5.21
Regression Co-efficients Showing Prediction Potentialities of Variables for Winter Season (including post-monsoon)

Predictor variables	Constant (a)	Regression coefficient (b)	Standard error of coefficient	t-value	R^2
Average population, X_1		0 206715	0 06884	3 003*	
Monthly average income, X_2		0 4040	0 11444	3 531*	
Monthly average temperature, X_3	646 088	-5 10402	2 3979	-2 129*	0 9163
Monthly average rainfall, X_4		-0 3230	0 2864	-1 128^{NS}	

* At 0.01 level of significance

** At 0.1 level of significance

^{NS} Non-significant

Thus the null hypothesis that there is no linear relationship among the variables is rejected. The value of co-efficient of multiple determination, $R^2 = 0.9163$ suggests that 91.63 per cent of total variation in rural domestic energy consumption in cooking and water heating (combined) and space heating during winter can be explained by average population, monthly average income and monthly average temperature alone. The significant t-values further indicate that one unit change in these three attributes (average population, monthly average income and monthly average temperature) would effect 3.003, 3.531 and 2.129 units change in rural domestic energy consumption in winter. So, they are termed as good contributors or good predictors to rural domestic energy consumption in winter.

Table 5.22 shows analysis of variance to test the hypothesis for finding out significant variations among the variables. The computed F-ratio = 78.299 is much greater than critical value of F = 5.49 for degree of freedom (2, 27) at 1 per cent level of significance. This indicates that the variation of predictor variables has an effect on rural domestic energy consumption in winter. Thus, on the basis of t-statistics, F-ratio and co-efficient of multiple determination, R^2 values, the model is found to be adequate. The plot of observed vs predicted values of rural domestic energy consumption in cooking, water heating and space heating shows all the points approximately along a straight line as depicted in Figure 5.8. This indicates the suitability of the model co-efficients as presented in Table 5.21.

Table 5.22
Results of Analysis of Variance for Winter Season

Source of variance	Sum of square	Degrees of freedom	Mean square	Calculated 'F'	Table value of 'F'	Level of significance
Model	2386 232	2	1193.116			
				78.299	5.49	0 01
Error	411.430	27	15.238			

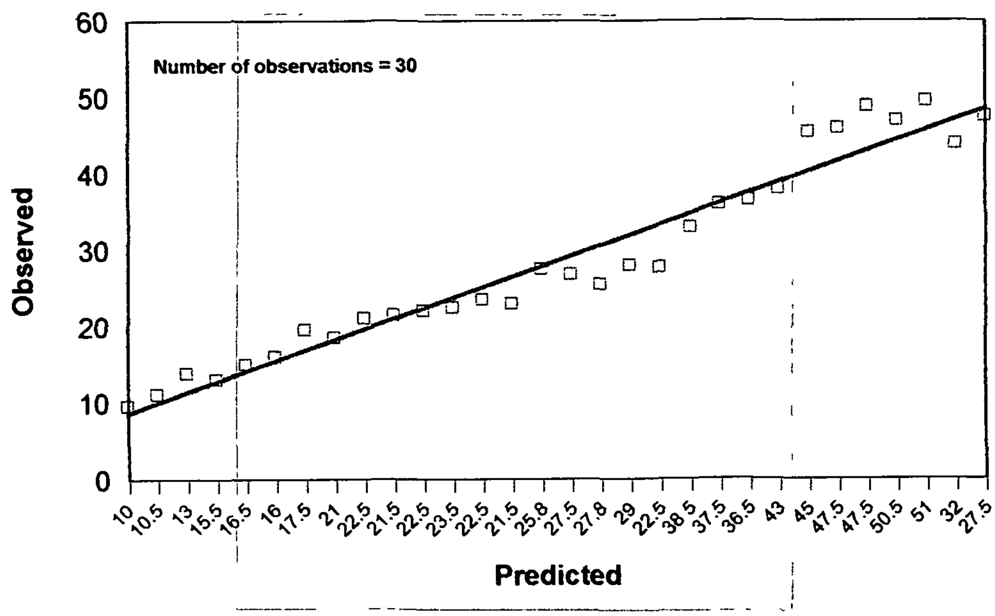


Fig. 5.8 Observed vs Predicted Rural Domestic Energy Consumption in Cooking and Water Heating (combined) and Space Heating in Winter (including postmonsoon)

5.7.3 Rural Domestic Energy Consumption in Space Lighting Over the Year

It is evident from Table 5.23 that average population is positively and significantly correlated (r = 0.922) with rural domestic energy consumption in space lighting. It suggests for increasing rate of rural domestic energy consumption in space lighting with increasing population. Monthly average income and rural domestic energy consumption in space lighting are positively and significantly correlated (r = 0.986) as higher income level demands for higher rate of energy consumption in lighting more rooms as compared to lower income level people. The positive and significant correlation (r = 0.992) means that the rural household energy consumption in space lighting increases according to the number of school going children. More hours of lighting is required during study hours at night. Monthly average temperature and monthly average rainfall are found to have non-significant correlation. It suggests that temperature and rainfall both do not affect domestic energy consumption in space lighting.

Table – 5.23
Correlation Co-efficients Between Variables for Space Lighting Over the Year

Sl. No.	Predictor variables	Correlation co-efficient 'r'	Critical value of 'r'
1.	Average population, X_1	0.922*	0.331
2.	Monthly average income, X_2	0.986*	0.331
3.	Average school going children X_3	0.992*	0.331
4	Monthly average temperature, X_4	0.040	NS
5.	Monthly average rainfall, X_5	0.003	NS

* At 0.01 level of significance

NS Non-significant

It is evident from Table 5.24 that regression co-efficient of average population is significant at 1 per cent level of probability, that of monthly average income is significant at 0.1 per cent level of probability. The regression co-efficient of average school going children is significant at 5 per cent level of probability. As the relationships of monthly average temperature and monthly average rainfall are found to be non-significant, they are excluded from the model. For space lighting, there are 60 observations over a period of 5-years (1995-99).

Table 5.24
Regression Co-efficients Showing Prediction Potentialities of Variables for Space Lighting Over the Year

Predictor variables	Constant (a)	Regression coefficient (b)	Standard error of coefficient	t-value	R^2
Average population, X_1		0.00045531	0.000151	3.014**	
Monthly average income, X_2		0.0031613	0.0003892	8.123*	
Average school going children, X_3	3.5524	0.02364	0.010352	2.2832***	0.9756
Monthly average temperature, X_4		0.00021	0.00013	0.1615^{NS}	
Monthly average rainfall, X_5		0.000162	0.00421	0.0385^{NS}	

* At .001 level of Significance   ** At .01 level of Significance

*** At .05 level of Significance   NS : Non-significant

Thus the null hypothesis that there is no linear relationship among the variables, is rejected. The co-efficient of multiple determination $R^2 = 0.9756$ suggests that 97.56 per cent of total variation of rural domestic energy consumption in space lighting can be explained by average population, monthly average income and average school-going children alone. The significant t-values further indicate that one unit change in these three attributes would affect 3.014, 8.123 and 2.2832 units change in rural domestic energy consumption in space lighting. So, they can be termed as good contributor or good predictor to rural domestic energy consumption in space lighting.

Table 5.25 shows analysis of variance to test the hypothesis for finding out significant variations among the variables. The computed F-ratio = 94.745 is much greater than critical value of F = 4.98 for degrees of freedom (2, 57) at 1 per cent level of significance. It indicates that the variation of predictor variables has an effect on rural domestic energy consumption in space lighting over the year. Thus, on the basis of t-statistics, F-ratio and co-efficient of multiple determination, R^2 value, the model is found to be adequate. The plot of observed vs predicted rural domestic energy consumption in space lighting shows all points clustering around a straight line as presented in Fig. 5.9. This indicates suitability of the model co-efficients obtained in Table 5.24.

Table – 5.25
Results of Analysis of Variance for Space Lighting Over the Year

Source of variance	Sum of square	Degrees of freedom	Mean square	Calculated 'F'	Table value of 'F'	Level of significance
Model	204.27	2	102.135			
				94 745	4 998	0 01
Error	61 50	57	1 078			

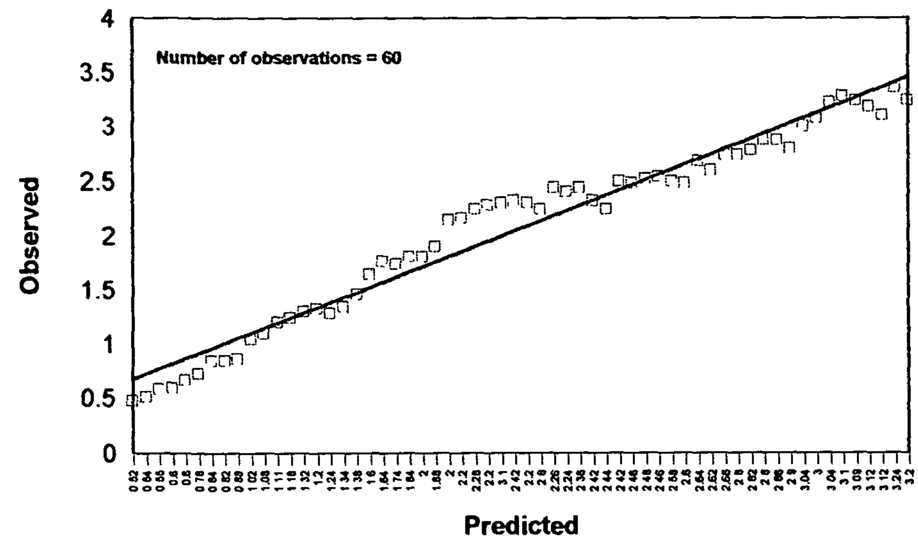


Fig. 5.9 Observed vs Predicted Rural Domestic Energy Consumption in Space Lighting Over the Year

From the above discussions it can be concluded that the linear multiple regression model can account for most of the variations in rural domestic energy consumption in cooking and water heating during summer (including pre-monsoon) season; in cooking, water heating and space heating during winter (including postmonsoon) season and in space lighting over the year. Based on the results in Tables 5.18, 5.21 and 5.24 the following model equations are obtained :

1. For cooking and water heating (combined) during summer (including pre-monsoon) season :

   $$\mathbf{Y = 498.52 + 0.0377\ (POP) + 0.03927\ (INC) - 3.5408\ (T) - 0.0301\ (RAIN)}$$

2. For cooking and water heating (combined) and space heating during winter (including post-monsoon) season :

   $$\mathbf{Y = 646.088 + 0.2067\ (POP) + 0.404\ (INC) - 5.104\ (T)}$$

3. For space lighting over the year

   $$\mathbf{Y = 3.5524 + 0.0004551\ (POP) + 0.003161\ (INC) + 0.02364\ (CHIL)}$$

The above models are proposed for rural domestic energy consumption in Jorhat district of Assam. They may describe data set of same pattern with identical conditions, but may not describe the data set of different geographical and environmental conditions.

5.8 Conclusion

From the above discussions, a vast source of untapped energy is available in the study area. A wide variation in domestic energy consumption between rural, semi-urban and urban sectors of Jorhat district of Assam has been observed. The diseases among rural women due to smoke exposure were found to be significant. The season-wise linear multiple regression model fits were found to be adequate on the basis of t-statistics, F-ratio and co-efficient of multiple determination, R^2 values.

CHAPTER VI

Efficiency Evaluation of a Modified Stove

CHAPTER – VI

EFFICIENCY EVALUATION OF A MODIFIED STOVE

6.1 Introduction

The study on the quantity of agricultural residues and livestock wastes in the sampled villages reveal that production of rice residues and dung are in huge quantity, but their uses are very limited because of easy availability of fuel wood. The rapid depletion of forest fuel as well as mode of storing and wasting of rice residues and dung in present form is hazardous to the environment, to the community and a loss to the national economy. So, there is a need to provide quality fuels from agricultural residues. Briquettes from agricultural wastes can provide economically transportable fuels in rural areas. But the traditional stove in the present form is not suitable for burning loose biomass and fuel briquettes. So, there is a need for designing a modified stove for using fuel briquettes from agricultural residues.

6.2 Briquette Preparation

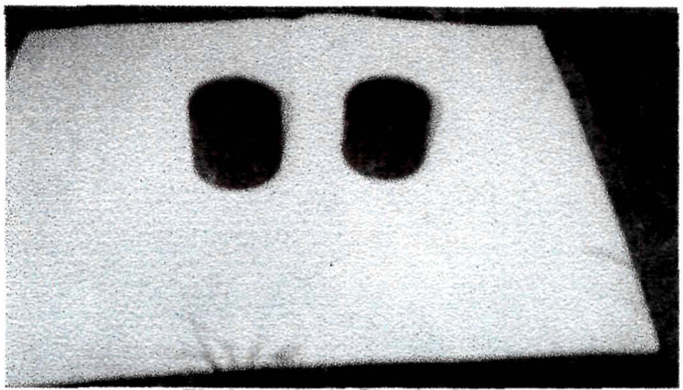
The briquetting devices used to form briquettes are of two types such as :

i) Simple cylindrical die

ii) Hydraulic press briquetting device

i) Simple Cylindrical Die

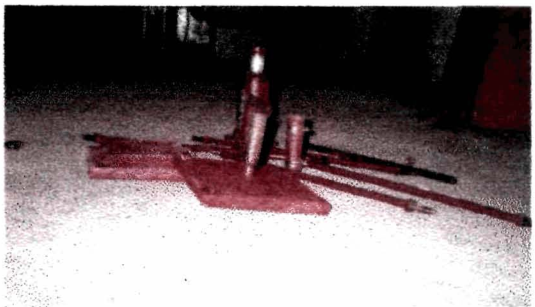
This is a simple die made of 5.08 cm diameter Galvanized iron (G.I.)[1] pipe as shown in Photograph 1. The rice straw was chopped to a length of 1 cm with a simple cutter and mixed with cow-dung to a proportion 1:1. The mixture was then pressed in the die to form a briquette. An adult can exert an average force of 98.1 N through hands. So, a force of 98.1 N was directly applied on the die while producing a briquette using this simple die. Size of the briquette is 5 cm. The average time taken to produce a briquette by a single person following this method was around 6 minutes.



Photograph 1. Simple dies

ii) Hydraulic Press Briquetting Device

The device is also very simple and it was constructed in the workshop of Jorhat Engineering College following the methods as stated in the Chapter IV. The device with various parts before assembling is shown in Photograph 2 and overall assembled view is shown in Photograph 3. The time required to produce a briquette of size 6 cm. was estimated to be around 4.5 minutes.



Photograph 2. Briquetting device before assembling

Table 6.1 presents different components required in hydraulic press briquetting device.

Photograph 3. Assembled view of the briquetting device

[1] G.I. Galvanized iron

Table – 6.1
Component, Materials and Dimensions of Briquetting Device

Component	Material	Dimension	
Ram	Mild steel	Dia. = 4.75 cm	Length = 9.5 cm
Die	G.I. pipe	Dia. = 5.08 cm	Length = 15.0 cm
Support bars	Mild steel	Dia. = 1.70 cm	Length = 46.8 cm
Clamp for split dies	Stainless steel		
Base and upper support bars	Wood	Length = 30 cm	Breadth = 28 .0 cm
Base plate for jack	Wood	Length = 23 cm	Breadth = 21.5 cm

The detailed drawing of different components of the device is presented in Fig. 6.1.

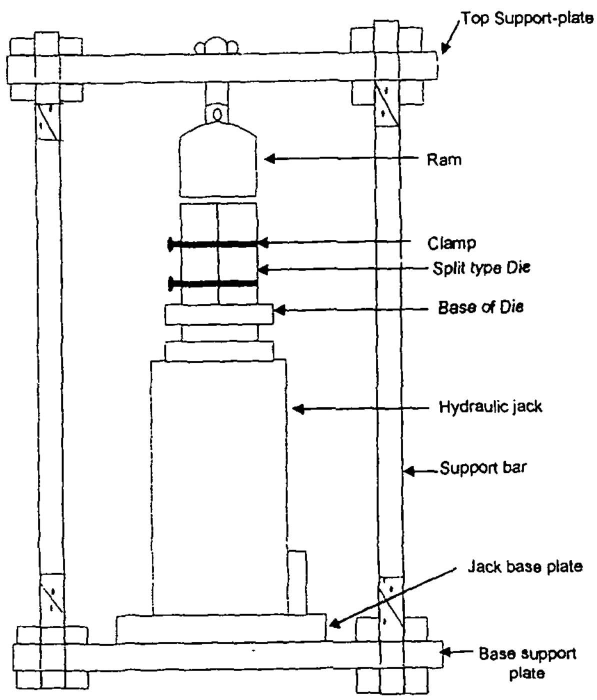


Fig. 6.1 Hydraulic Press Briquetting Device

Average force exerted by an adult is 98.1 N through hands. Therefore, 98.1 N was directly applied on the lever end. This force caused the jack to lift up. The pressure exerted by the piston on the mixture of chopped straw and cowdung (1:1) in the die was measured by a pressure gauge and found to be 978.91 N/m^2. This pressure was sufficient for the production of a briquette with desired durability as given in Section 6.4.

6.3 Drying of Briquettes

The briquettes formed by both the devices were left for sun drying. Segal *et al.* (1987) suggested that open sun drying is a most simple, economic and effective process for rural applications. The flow chart used for preparation of briquettes by compaction process is shown in Fig. 6.2.

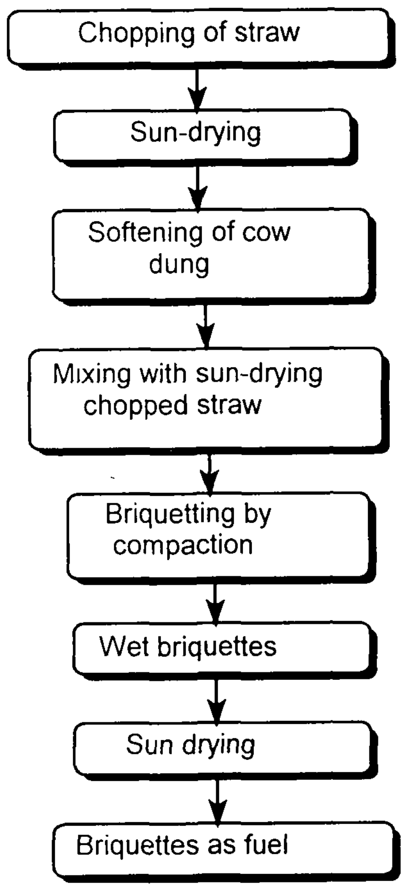
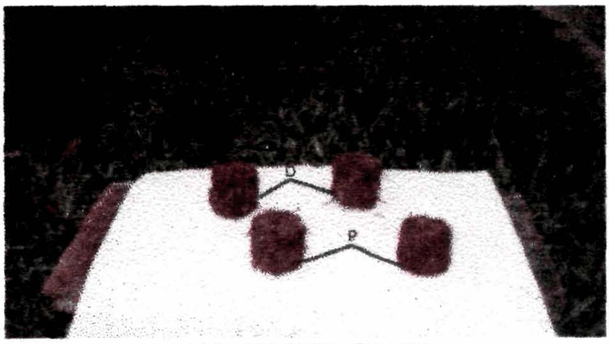


Fig. 6.2. Flow Chart for Preparation of Fuel Briquettes

Photograph 4 shows the samples of briquettes formed. The two samples marked 'D' were produced with the help of simple G.I. die and the other two samples marked 'P' were produced by the hydraulic press device. The calorific value of briquette was measured with the help of Bomb Calorimeter following he methods as presented in Chapter IV.



Photograph 4. Samples of briquettes

6.4 Durability Test

A simple durability test was carried out to determine the handling characteristics of the briquettes using the procedure as presented in Chapter IV. The procedure was repeated until the percentage weight loss reached 10 as presented in Table 6.2.

Table 6.2. Results of Durability Test

Composition	No. of falls (n)	Weight before fall (gm)	Weight after fall (gm)	Percentage weight loss (%)
1 : 1 (Hand Die) A	1	28.0	26.8	4.29
	2	26.8	25.0	6.71
	3	25.0	23.2	7.20
	4	23.2	21.0	9.48
	5	21.0	18.4	12.38
1 : 1 (Hydraulic Die) B	1	32.0	31.6	1.25
	2	31.6	30.0	1.90
	3	30.0	29.3	2.33
	4	29.3	28.1	4.10
	5	28.1	26.2	6.76
	6	26.2	24.0	8.40
	7	24.0	21.9	8.75
	8	21.9	19.9	9.13
	9	19.9	14.5	12.06

Fig. 6.3 Shows the variation of the percentage weight loss with the number of falls (n) for the two briquette samples.

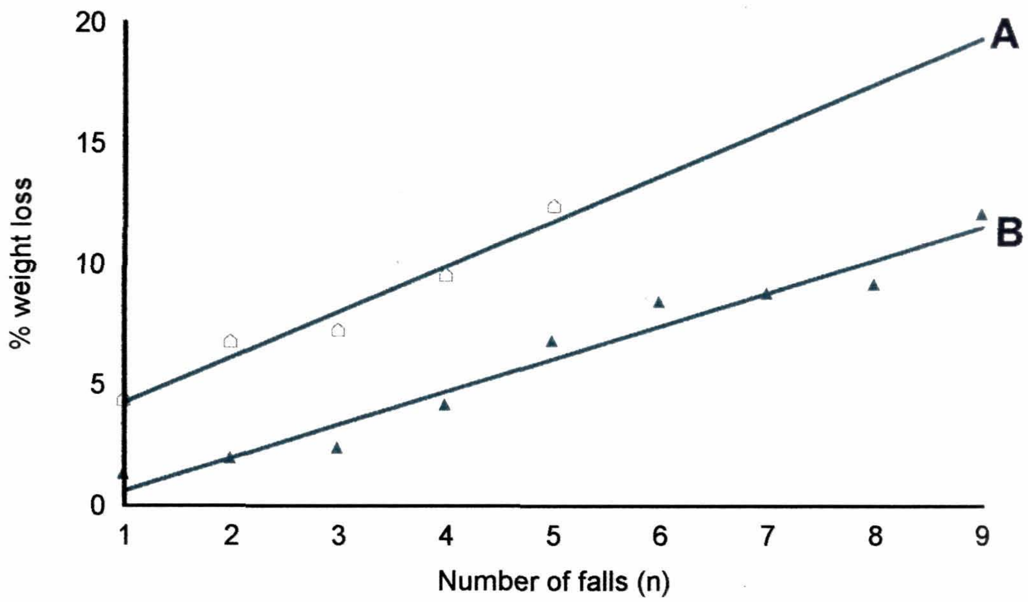


Fig. 6.3 Durability Test

The figure shows that briquette B is more durable than briquette A. Briquette A showed the highest weight loss for a given number of falls i.e. least durable.

6.5 Design and Description of the Modified Stove

The idea of the modified stove was based on the mud stove recommended by the Indonesian Technology Development Group at Reading (U.K.). Fig. 6.4 shows the top view and front view of the stove from which idea of modified stove was taken. This stove does not have grate and chimney. Dimensions are changed in the modified stove to provide chimney and grate. The modified stove is a metallic stove instead of mud.

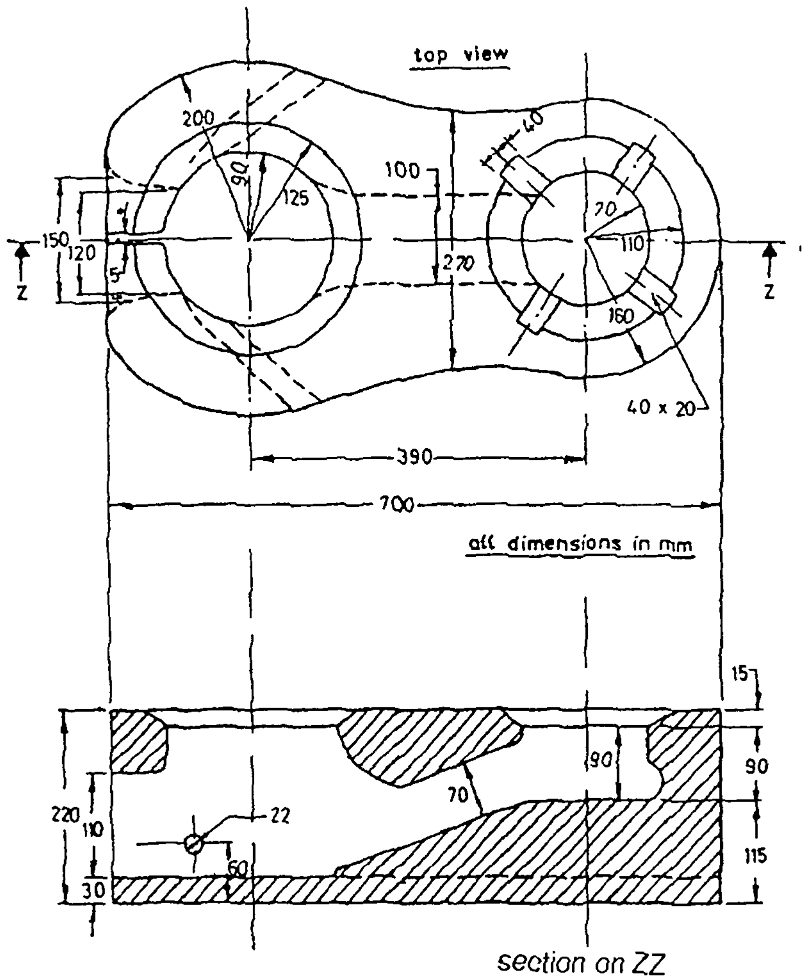


Fig. 6.4 The Mud Stove

The three views of the modified stove model are shown in Fig. 6.5 the stove is made of M-S[1] sheet of 3mm thick and permits simultaneous cooking in two pans. A supporting stand is also provided for user's advantage.

[1] M-S : Mild steel

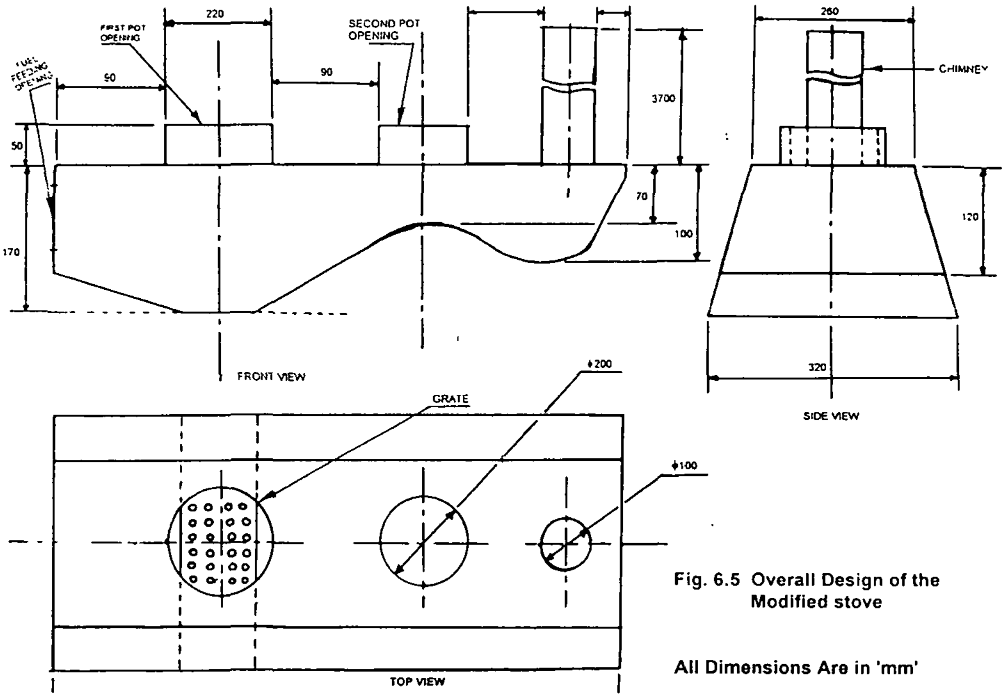


Fig. 6.5. Three Views of The Modified Stove

The stove has a chimney and it is constructed on the basis of proper draught analysis as stated in Chapter-IV and is presented in Table 6.3. Although the chimney is made of sheet metal, it can be made of other cheaper materials like asbestos, fire-clay. The major benefit of providing a chimney in the new stove is that the smoke is released outside the cooking place. The stove does not contain a damper, but a grate is provided. Reducers are also provided for using smaller size pots. Photograph 5, 6 and 7 show the different views of the fabricated stove model.

Table – 6.3
Draught Analysis and Chimney Dimensions

Exhaust product temperature Texh (K)	Normal temperature T_{NTP} (K)	Total mass of exhaust gas products Wexh (kg/mole)	Velocity of the exhaust gas, V (m/s)	Temperature of the flame Tg (k)	Atmosphoic temperature Ta (K)	Gravitational accelaration g(m/s)^2	Exhaust gasdischarge, Q (m^3/S)	Diameter of the chimney D (m)	Height of the chimney H (m)
423	273	0.076	10	723	303	9.81	0.044	10×10^{-2}	3.7

Photograph 5. Top view

Photograph 6. Side view

Photograph 7. Assembled view

6.6 Cost of the Modified Stove

The cost of the various parts of the stove including labour charges (as per market value during 1998) are presented in Table 6.4.

Table – 6.4
Estimation of Cost of the Stove

Sl No	Particulars	Material used	Dimension in mm^2	Cost per sq m (Rs)
1	Side plates (2 nos)	M-S Sheet	2x(770 x 220)	50 82
2	Upper and lower plates	M-S Sheet	2x(770 x 254)	57 75
3	Pan ring for larger size opening	M-S Sheet	700 x 50	5 25
4	Pan ring for smaller size opening	M-S Sheet	650 x 50	4 90
5	Chimney	M-S Sheet	3700 x 320	168 00
6	Labour charges	-	-	200 00

Total materials required = 19133 cm^2 = 1 9133 m^2 Total cost = Rs 486 72

So the cost of the modified stove is around Rs 487 00 However, the cost can be minimized by using some cheaper materials like asbestos, fire-clay etc for the construction of chimney Production in mass scale will bring down the cost further

6.7 Specifications of the Modified Stove

Considering the design concept stated above, the specification for the modified stove has been determined as presented below

Length of the stove body	=	770 mm
Width of the stove body	=	254 mm
Height of the stove body	=	220 mm
Inner cross sectional area of the chimney	=	7850 mm^2
Height of the chimney	=	3700 mm
Diameter of the first pot opening	=	220 mm
Diameter of the second pot opening	=	200 mm
Pot openings with reducers	=	2 numbers
Area of the fuel feeding opening (provided In the extreme left hand side)	=	18064 mm^2
Damper	=	Nil
Supporting stand	=	made of angle iron

6.8 Experimental Work

Fabrication work was done in the workshop of General Engineering Section, Regional Research Laboratory, Jorhat. The efficiency of the stove was calculated with the help of standard water boiling test as stated in Chapter-IV in the laboratory of the Mechanical Engineering Department, Jorhat Engineering College. Two aluminum vessels of 250 mm and 235 mm diameters with lids were used for the test. The stove is lit and water of known quantity was placed in the two vessels. The volume of water evaporated was found out by the difference in weight of vessel contents before and after the test.

6.8.1 Testing Procedure

i) The fuel briquettes were weighed.

ii) Vessels 1 and 2 were filled with 2 litres of water each.

iii) Initial temperature was recorded as 30°C.

iv) Initial fire was made with cotton waste soaked in a little kerosene.

v) Water in vessel 1 was allowed to boil on the main opening over the grate keeping vessel 2 on the second opening and the boiling time was recorded.

vi) As soon as the water of vessel 1 reached boiling point, it was interchanged with vessel 2. Vessel 2 was heated to boil and boiling time was recorded.

vii) The vessels were removed and the fire was extinguished by sprinkling cold water.

viii) On the completion of the test, unburnt briquettes were weighed, the final temperature of water was recorded and the amount of water evaporated was measured. The difference between initial weight of briquettes and the weight of unburnt briquettes was the actual weight of fuel burnt during the test.

6.8.2 Testing Report

The testing report of modified stove is presented in the form of Table 6.5.

Table – 6.5
Testing Report

Sl No.	Particulars	Values
01	Bottom diameter of the two aluminium vessels in mm	250 and 235
02	Initial weight of water (m_{wi}) in two vessels in ltrs.	2.0 and 2.0
03	Weight of water evaporated (m_{we}) from the two vessels in ltrs.	0.3 and 0.25
04	Weight of fuel briquettes fed (m_f) in kg	1.3
05	Weight of unburnt briquettes in kg	0.297
06	Weight of briquettes burnt in kg (m_f)	1.003
07	Calorific value of briquetted fuel in MJ/kg (measured in Bomb calorimeter)	10.125
08	Specific heat of water at 50°C under atmospheric pressure (Cp) in KJ/kg/°C	4.180
09	Temperature of boiling water (T_b) in °C	100
10	Initial temperature of water (T_i) in °C	30
11	Latent heat of evaporation of water (L) in KJ/kg (taken from steam tables)	2.2594×10^3

6.8.3 Efficiency

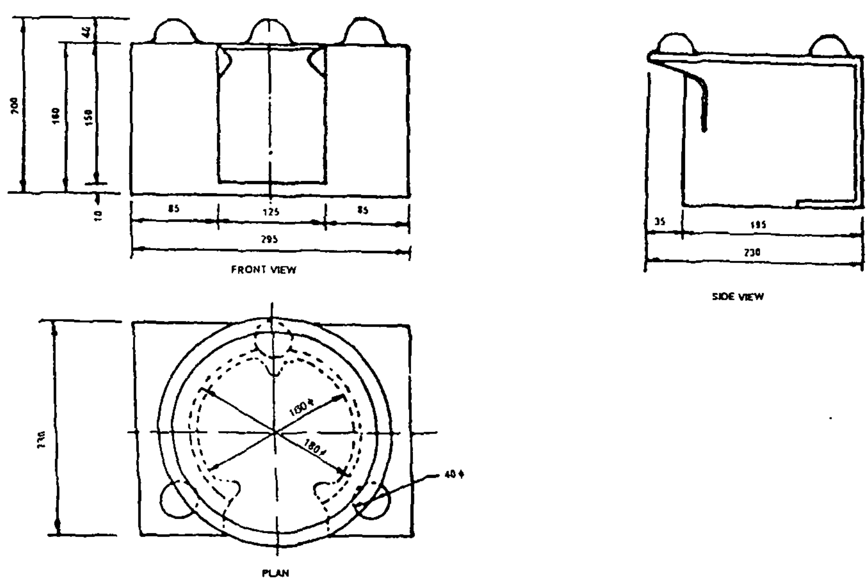
The overall efficiency or thermal efficiency of the stove is the ratio of the amount of heat absorbed by water in the pots and the amount of sensible heat supplied by the fuel. As suggested by Krishnaprasad (1981), Geller and Dutt (1982), Joseph and Shahnahan (1980) the overall efficiency (η_{verall}) of the stove was calculated with the help of following formula :

$$\eta_{overall} = \frac{\sum_{i=1}^{n} m_{wi} c_{pi} (T_b - T_i) + m_{we} L}{m_f \times C.V.}$$

Where summation is over the different pots. The nomenclature of each term was already given in Table 6.5. The maximum overall efficiency calculated by using the above formula was found to be 19.84 per cent [Sarmah *et al.*, 2000]. The overall efficiency of a traditional stove in rural North East of India does not exceed 10 per cent [Annon., 1986]. So, a fairly 9.84 per cent increase in efficiency is possible from the proposed design of the stove using rice-straw briquettes as the fuel.

6.9 Traditional Stove

Fig. 6.6 shows the three views of the traditional stove. It is made of mud with single fuel feeding opening. The fuel wood insertion opening is of dimensions 120 mm x 140 mm and fuel w ood can be inserted to a length of 190 mm. Three mounts of 40 mm on the top permits vessel placement.



All Dimensions are in mm

Fig. 6.6 Three Views of Traditional Stave

The thermal performance of the traditional stove was measured by the standard water boiling and evaporation test procedure as stated in Chapter IV. The detail results of the thermal performances of traditional and modified stoves by varying the fuel feeding rates are presented in Tables 6.6 and 6.7.

Table – 6.6
Thermal Performance of Traditional Stove

Fuel wood* feedıng rate (kg/S)	Power ınput (KW)	Thermal effıcıency (%)	Power output (KW)
2 78 x 10^{-4}	4 17	5 20	0 216
3 02 x 10^{-4}	4 53	7 77	0 352
3 47 x 10^{-4}	5 21	8 25	0 430
3 80 x 10^{-4}	5 70	9 46	0 539
4 17 x 10^{-4}	6 26	10 01	0 632
4 87 x 10^{-4}	7 31	9 31	0 980
5 55 x 10^{-4}	8 33	8 34	0 694
5 84 x 10^{-4}	8 76	8 01	0 702

Fuel wood wıth 20 per cent moısture content

Table – 6.7
Thermal Performance of Modified Stove

Fuel wood* feedıng rate (kg/S)	Power ınput (KW)	Thermal effıcıency (%)	Power output (KW)
2 08 x 10^{-4}	2 11	18 02	0 380
2 78 x 10^{-4}	2 82	19 24	0 542
3 47 x 10^{4}	3 51	19 84	0 697
3 89 x 10^{-4}	3 94	18 71	0 737
4 17 x 10^{-4}	4 22	18.48	0 780
4 86 x 10^{-4}	4 92	18 12	0 892
5 01 x 10^{-4}	5 07	18 00	0 913

* Brıquettes of paddy straw and cowdung.

By changing the depth of fuel bed, the varıation of fuel feeding rates was obtained. Correspondıng boiling time was recorded for different fuel feeding rates. The depth of fuel bed is one of the important parameters which affects the thermal efficiency of the stoves (De–Lepelerie *et al* , 1981, Swamınathan *et al* , 1985).

It may be noted from Table 6.6 that when the traditional stove is filled with fuel wood at the rate of 4.17 x 10^{-4} kg/s, the thermal efficiency is improved to a maximum of 10.01 per cent. After this, any further insertion of fuel wood reduces the thermal efficiency of traditional stove. But when the modified stove is filled with fuel briquettes at the rate of 3.47 x 10^{-4} kg/s, the thermal efficiency obtained is maximum at 19.84 per cent. The thermal efficiency starts decreasing for any further insertion of fuel briquettes. So, it is clear that modified stove should be filled with fuel briquettes at the rate of 3.47 x 10^{-4} kg/s for deriving maximum efficiency. The power output of traditional stove at a feeding rate of 4.17 x 10^{-4} kg/s was found to be 0.632 KW, while in case of modified stove the power output was found to be 0.697 KW at a feeding rate of 3.47 x 10^{-4} kg/s. The thermal performance of the modified stoves using briquettes is presented in Fig. 6.7. Fig. 6.8 presents the thermal performance of the traditional stove using fuel wood.

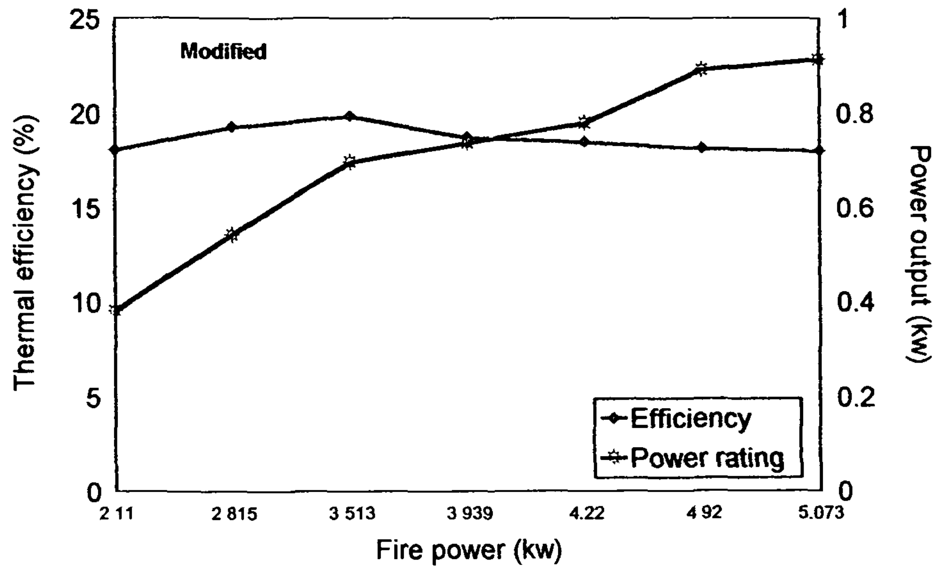


Fig. 6.7 Thermal Performance of Modified Stove Using Briquette

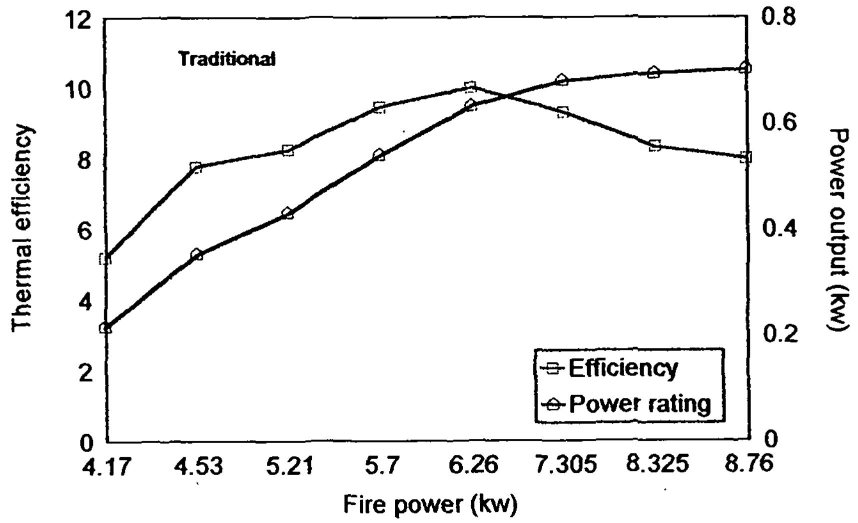


Fig. 6.8 Thermal Performance of Traditional Stove Using Fuel wood

It is clear from the figures that increasing the fire power i.e., fuel input the power output increases. The thermal efficiency increases in the beginning with increase in power input, reaches a maximum value and then falls.

6.10 Conclusion

On the basis of the foregoing discussions the following conclusions may be drawn.

Agricultural residues could be used in modified stove with proper technology for increasing energy efficiency. Rice residues which are available in huge quantities in rural areas, finds limited use and go to waste due to easy availability of fuel wood. One of the means by which these wastes could be utilized to generate energy is by briquetting them and using them in domestic purposes in rural areas. The technologies for manufacture of briquetted fuels from agricultural residues need to be perfected for reliable performance. Another point worth considering is that the traditional stoves presently being used for burning fuel wood operate at very low efficiency. It becomes important to limit the fuel wood sizes to reduce loss of energy. The stove designs are to be improved and modified further for using fuel wood chips and fuel briquettes to minimize the fuel consumption as well as the smoke problem.

CHAPTER VII

Integrated Rural Energy Management

CHAPTER VII

INTEGRATED RURAL ENERGY MANAGEMENT

7.1 Introduction

It is needless to say that the domestic sector, particularly household cooking, consumes by far the largest amount of energy. The domestic energy system in rural India is predominantly based on bio-fuels that are mostly collected, and on energy conversion devices that are made locally. The fast depleting biomass resource base is a strain on the energy systems, further exacerbated by the inability of the people to shift to commercial fuels because of low purchasing power [Joshi, 1993]. Moreover, in most of the rural areas in Assam, huge amount of agricultural residues and cow dung go waste due to easy accessibility to and availability of fuel wood. It is generally seen that the rural people burn low quality fuel wood in inefficient traditional stove for cooking. Time spent by rural women in cooking with poor quality fuel wood, inefficient cooking devices, extent of exposure to pollutants, wastage of energy in agricultural residues and dung demand for Integrated Rural Energy Management in rural Assam, vis-à-vis in India.

7.2 Various Forms of Rural Energy

Figure 7.1 shows a taxonomy of energy sources. The main sources of renewable energy are hydro-power, solar energy, wind energy, ocean energy, animal energy, biomass energy etc. Except biomass energy and animate energy, the technical use of all other energies are not economically feasible for rural people whose per capita income is very low.

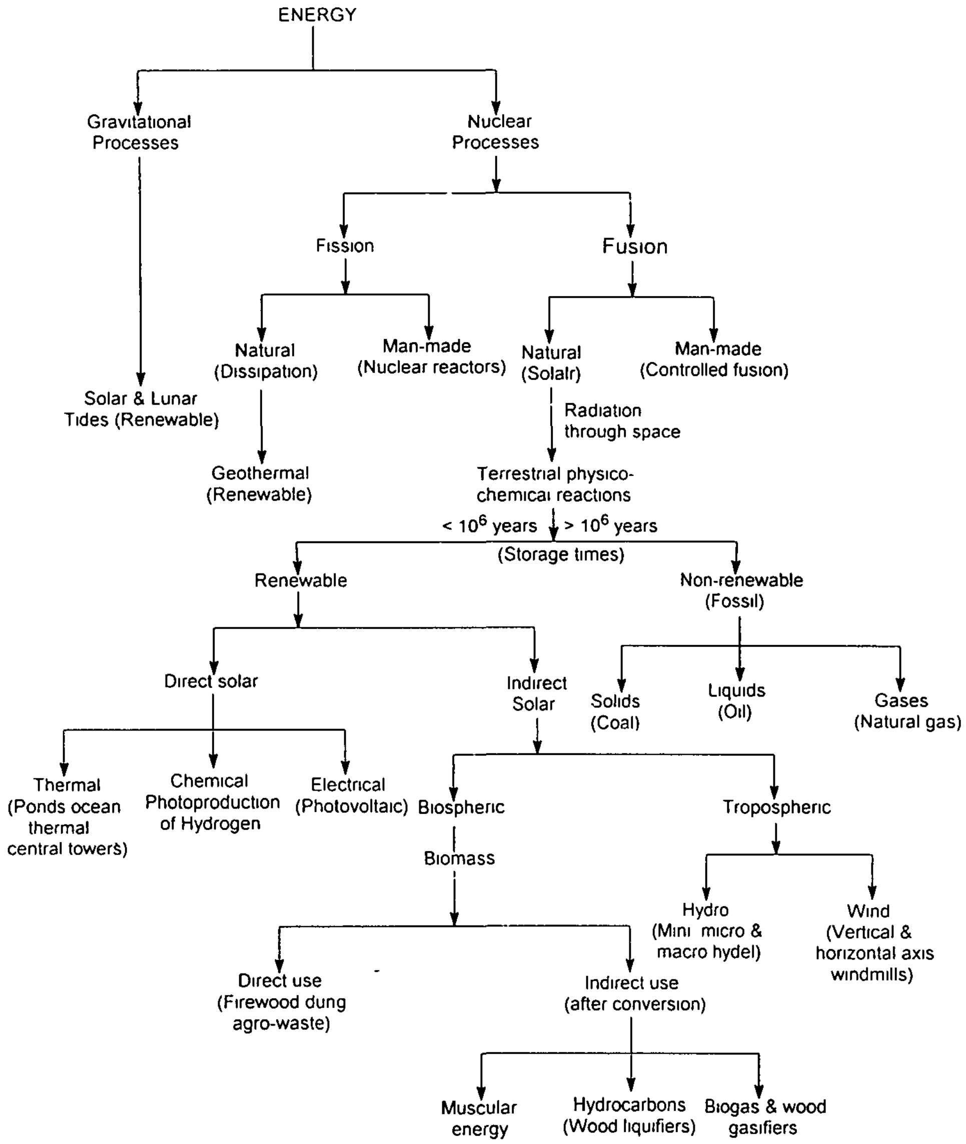


Fig. 7.1 Taxonomy of Energy Sources

7.2.1 Non-commercial Energy

As a result of poor status of consumption of commercial energy in the rural areas the study has been centered around direct use of biomass. A brief review of various energy alternatives will be helpful for arriving at a broad policy framework for their popularization in the rural areas of Assam.

A. Biomass Energy

The different biomass energy sources available in rural Assam are discussed below :

- **Fuel wood**

Fuel wood is the most important fuel for over 90 per cent of rural households in Assam. It accounts for more than one-third of energy used in rural areas. A rural household mainly depends on fuel wood (twigs, branches, bushes etc.) collected from forests, fields, roadside etc. The quality as well as quantity of fuel wood used in a rural household depends on availability and several other factors such as household's capacity to buy or gather the fuel wood. Severe shortage of fuel wood has already afflicted many areas. The natural rate of regeneration rarely matches the rate at which wood resources are being consumed. The rural population would not be able to cook their food by 2010 if the rate of depletion of fuel wood continues at the present rate.

- **Cow-dung**.

The total cattle population of Assam in 1992 was estimated to be 7.31 million (Table 3.7). Average dung output per cattle was found to be 4.5 kg/day. The rural people of Assam do not use cow dung as domestic fuel. So, a huge quantity of dung go waste in rural Assam after deducting non-fuel uses such as manure, building material etc. The dung of sheep and goat is not used in rural Assam and go waste. The rate of production of dung of sheep and goat is low. It can not be made into cakes easily due to the lower moisture content. But such dung can be used as feed stock for biogas production. The available cattle dung (after deducting non-fuel uses) can be used as binder for briquetting agricultural residues and for biogas production. The briquetted fuel can be stored in heaps for use in rainy season. Thus, theoretically all the available dung could be used for energy purposes.

- **Agricultural Residues**

Rice is the major crop of Assam. A huge quantity of rice residues (husk and straw) goes waste in rural areas due to lack of awareness of rural people about the proper utilization of those as domestic fuels. Available energy can be tapped from these vast sources after deducting non-fuel uses such as fodder, thatching etc. The use of available energy from rice residues with proper technology will minimize the wastage. It will also help in conserving energy.

Jute is one of the tropical cash-crop in rural areas of some of the districts such as Nagaon, Sonitpur, Lakhimpur, Goalpara etc. Jute cultivation is done mainly for the fibre from the bark of this tropical plant. The cultivators use jute stalk as domestic fuel without proper assessment of its energy value. So, possible heat content from jute stalk can be assessed and quantified for using as domestic fuel.

Sugarcane cultivation is done in some rural areas of Assam. Sugarcane bagasse after extraction of juice is another important waste for fuel purposes. It has a high heating value (19 MJ/kg). Untapped energy from this waste can be assessed for using as domestic fuel alternatives.

Moreover, the Rabi crops such as pea, grams, mustard are seen in vast cultivable land in some selected areas. The wastes of these crops have also energy potential to a great extent. The energy value of such type of crops should be properly assessed and quantified for better utilization as domestic fuels.

B. Solar Energy

It is the source of energy driven by thermonuclear fusion reactions deep in sun's core. Earth receives 170 trillion kilowatts of radiation from the sun-light days of sunshine. It is equal to all the available sources of energy in the world put together. A world population of 10 billion with a total power input need per person would require 10 kw of energy. It is thus apparent that if irradiance of only 1% of Earth's surface could be converted into useful energy with 10% efficiency, solar energy could fulfil needs of entire population [Satsangi, 1988]. This enormous solar energy resource may be converted into other form of energy through thermal or photovoltaic conversion routes. The solar thermal route uses radiation in the form of heat that in turn may be converted into mechanical, electrical and chemical energy. Solar thermal devices like solar cookers, solar water/air heaters, solar dryers have been developed.

An important advantage of solar energy is that it does not cause any pollution. Moreover, it is available at free of cost. A big limitation of solar energy is that it is location specific. It is not available in sufficient amount all the time in the State like Assam. The availability and intensity of solar energy gets reduced during rainy season and during winter months. Also, solar energy conversion technology is not economically feasible for rural population of Assam.

C. Wind Energy

Moving air is called wind. The wind has energy. The energy possessed by wind is due to its high speed. It does not cause any pollution and it is available free of cost. Wind energy may be converted into mechanical and electrical energies. Now-a-days wind energy is being used to generate electricity with modern technology. Wind energy may be useful in remote areas, helping to save fossil fuels. It delivers quantity of energy which is free from pollution and environmental degradation. A major limitation of wind energy is that it is not available all the time at places like Assam. Also, wind energy conversion technology is not at all economic.

7.2.2 Commercial Energy Consumption

The rural people of Assam have to depend to a large extent on non-commercial sources of energy as the status of commercial energy consumption is very poor. The use of LPG in cooking in rural areas of Assam is very limited due to low economic status of rural population. Most of the rural households are un-electrified or availability of electricity is very poor in rural Assam. So, the people have to depend on commercial fuel such as kerosene for space lighting.

7.3 Rural Energy Front

The basic features of rural energy scene of Assam are :

- low energy intensity
- high domestic energy consumption
- heavy dependence on non-commercial energy
- fuel collection through individual efforts at zero or non-zero private cost
- rapid environmental degradation
- deterioration of health

The existing energy situation in rural Assam is, therefore, a part of the vicious circle of low energy input, low productivity and poverty. Even this low energy input is mostly for such non-productive activities as cooking for sheer survival. In productive activities such as entrepreneurship, agriculture, energy input is negligible.

To bring desirable change in the current mode of energy utilization in the rural areas, proper technological intervention is vital. The scope of meeting the rural energy demand through commercial sources is limited by their low availability and also the low purchasing power of rural masses. In view of this grin reality, adoption of vigorous rural energy programme based primarily on the use of locally available sources and conservation of energy, is of crucial importance.

7.4 Rural Energy Conservation, Audit and Plan

Rural energy conservation can be defined as the substitution of rural energy with capital, labour, material and time. This definition also covers the substitution of scarce type of rural energy sources with abundant type of energy sources.

The energy must be conserved for the future by all possible means. This energy saved is the money earned which could be used in other productive means. It is, therefore, imperative that rural energy which is in a critical status, be utilized efficiently. The areas, where rural energy is wastefully used or rural energy sources go waste are to be identified and corrective measures are searched for adoption. This could be done by Energy Audit. Rural energy audit is a technical survey of rural energy consumption pattern and an attempt is made thereby to balance the total energy input correlating with supply and availability. As a result, the areas where rural energy is wastefully used and improvements are felt are identified and corrective measures are recommended for adoption on short term/long term basis to improve the rural energy efficiency.

Rural energy conservation is the rural energy demand management that aims at increasing the efficiency of use. A rural energy audit helps to understand more about the ways different rural energy sources are used. The rural energy audit would give a positive orientation to the reduction of rural energy cost preventing maintenance and quality control programmes. These are vital for energy utility activities. Rural energy audit is one of the concepts used in energy management. It involves methodological examination and comprehensive review of energy use in rural areas. So, energy audit can be treated as starting of the energy management plan. Rural energy audit broadly covers the following questions :

i) How much energy is consumed in rural areas ?
ii) Where is the rural energy consumed ?
iii) How efficiently is the rural energy consumed ?
iv) Can there be improvements in energy use ?

The rural energy audits result in energy conservation proposals. Such an audit programme will help in formulating proper rural energy management plan for availability and reliability of rural energy sources, appropriate rural energy mix, energy conservation technologies. The action plan towards the achievement of energy conservation through energy audit may be drawn up in three phases : (a) Short Term Plan : This plan should aim at avoiding rural energy wastages and minimizing non-essential energy users and improving the system efficiency through improved maintenance programme, (b) Medium Term Plan : This plan should aim at achieving efficiency improvement through modifications of existing equipments, and (c) Long Term Plan : This plan should aim to achieve economy through latest energy saving techniques and innovations.

7.5 Socio-economic Feasibility

Technically, biomass energy has the potential to meet the energy needs of rural Assam. Technical feasibility is only one of several factors required to promote rural energy strategies. The current pattern of rural domestic energy consumption was shown to be non-sustainable, since it leads to environmental degradation, wastage, social inequality and financial problems. Alternative approaches, on the other hand, may lead to reclamation of degraded lands, promotion of biodiversity, reduction of indoor air pollution, change of food habits. Bio-energy based systems are always sustainable and equitable, with rural women benefiting the most. Use of appropriate technology in solving the rural energy problem may bring a significant change in socio-cultural and socio-economic status of rural areas. Appropriate technologies may demand a higher level of innovative abilities in rural Assam by :

- the use of locally available resources,
- the use of rural energy to the extent possible,
- their suitability for local maintainability
- the use of local skill
- the maximum use of semi-skilled labour
- the generation of local employment
- encouraging self-reliance and self-employment

But the technology to be appropriate for rural poor has to be cost-effective and user-friendly.

7.6 Thrust Areas of Appropriate Technology

The thrust areas of utilization of appropriate technology for using untapped energy sources in rural Assam are – biogas technology, wood chipping, energy plantation, modified improved stoves, briquetting of agricultural residues. solar dryer etc.

- **Biogas Technology**

Recycling of animal and agricultural/plant wastes through biogas plants to produce fuel gas and good quality manure is an important source of energy for the rural community. The available biomass in the form of agricultural or plant wastes and animal dung (may be cow-dung, poultry excreta, pig excreta etc.) can be fed to a biogas plant to produce fuel gas that can be used for cooking and lighting in domestic sector of rural areas. The residual slurry after fermentation can be used for composting or dried in the sun for use as manure in the agricultural sector which contains a good deal of micro-nutrient elements essential for plant growth.

- **Briquetting of Agricultural Residues**

The agricultural residues and cow-dung which go waste can be used for briquetting. As the biomass briquettes serve as 'B' grade coal (MNES, 1998-99), those can be used as solid fuel for cooking in rural domestic sector. Both mechanical and manual processes can be used for production in briquettes with less skill.

- **Wood Chipping**

The traditional stoves presently being used for burning fuel wood operate at low efficiency. Moreover, the size of fuel wood used in traditional stove is not uniform in rural areas. The whole length of fuel wood is not required to cook a particular meal. So, the rest portion of fuel wood is wasted by burning for no reasons due to lack of awareness of rural people about energy conservation. It becomes important to limit the fuel wood sizes to reduce loss of energy. Wood chipping can be done in rural areas with less effort and skill.

- **Modified/Improved Stoves**

The traditional stoves are not suitable for burning briquetted fuel and wood chips. Proper technology can be used to construct modified or improved stoves for using briquetted fuel and wood chips. The stoves can be made of metal, mud, brick for burning those fuels. Local people can be employed to make stoves at a cheaper rate.

- **Energy Plantation**

The plantation of quick-growing and high calorific value yielding trees on waste lands is commonly referred to as energy plantation. In this scheme, fast growing trees are planted in short rotation, followed by regular thinning/replanting to ensure continued fuel wood supply. Energy plantation generates overall prosperity by increasing opportunities for rural employment, providing ample feed and fodder for animals, improving soil structure and fertility, ameliorating the environment, increasing the production of crops and fuel wood, and generally economic utilization of the available land.

- **Solar Energy Utilization**

As discussed earlier, use of solar energy technology is not economically viable for the rural poor. Also, intensity of solar radiation decreases during rainy season and winter months in Assam. So, direct application of solar energy can be used in rural areas through solar dryers. Solar drying can speed up drying process, and eliminate wastages and contamination. Solar dryers can be used to dry agricultural products such as paddy, turmeric, chilli, tobacco etc. Solar power through thermal route is even more expensive and complicated.

7.7 Three Dimensions for Rural Energy Planning

On the basis of above discussions, Rural Energy Planning may be taken up incorporating three mutually dependent dimensions as presented in Fig. 7.2.

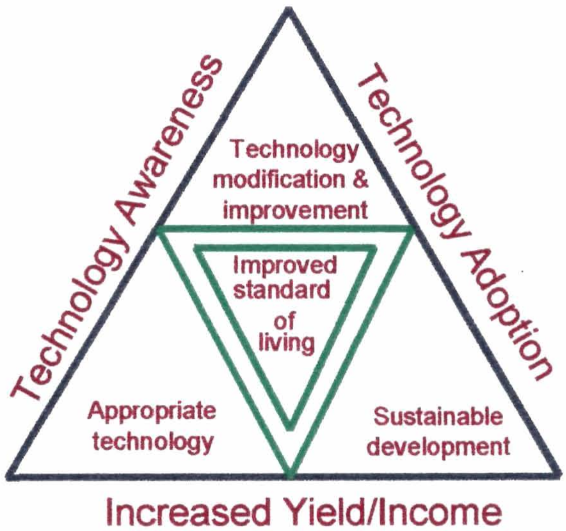


Fig. 7.2. Three Dimensions for Rural Energy Planning

The successful implementation of rural energy programme may be possible by using three dimensions such as :

- Technology awareness
- Technology adoption
- Increased yield/income

Need-based efficient rural energy management is possible through the generation of technology awareness among rural people. Technology awareness is the only key to have better understanding regarding benefits and application of appropriate technology.

Technology awareness motivate rural people to adopt new technology This is a positive effect of technology awareness generation. As a result of technology adoption, innovations diffuse in the form of technology modification and improvement.

The rural energy programme may lead to the growth of village industries for building biogas plants, making improved stoves and briquetting of loose biomass by local artisans, thereby generating the employment opportunities of the rural poor.

7.8 Role of Non-Government Organisations

Non-Government Organisations (NGO) play or shall have to play a catalytic and pivotal role to bring about desirable changes in the rural development. This UN term – 'NGO' encompasses all types of voluntary organizations. In India, a voluntary organization or an NGO is registered as a society of trust and acquires its legal status as such under Societies Registration Act or Indian Trust Act. They are found to be engaged in diverse fields of livelihood including farming, environment, health and sanitation, arts and culture, language and literature, education/adult education/non-formal education, relief and management of natural disasters, care of disabled, spastics, orphanages. old age homes. gender equity, mental health, alcohol/drug deaddiction, human rights, wild life, consumer protection, AIDS control, religious and spiritual development etc. The Government of India has laid much emphasis in strengthening and involving NGOs in the eighth and ninth five year plans. NGOs may mean organizations such as Krishak Mandals, Panchayats, Mahila Samities/Mandals, Youth Clubs/Yuvak Dal, Cultural Organisations, Rural Libraries, Sports Club etc. With the emerging importance of NGOs, as agents of change in their respective areas, the NGOs can be engaged for implementation of successful integrated rural energy programme (IREP) in rural Assam.

7.9 Consumer Education and Biomass Energy Awareness

Rural energy programme attempts to improve quality of life of rural poor. Education contributes to such an effort by improving the well being of people in two ways, directly as a source of personal gratification, and indirectly as an important method to increase income and occupational status. At present, villages of Assam do not provide a rosy picture due to poverty, underemployment, poor schooling, poor housing, unhealthy conditions and poor status of energy consumption. The potential of education is a successful instrument for development.

Consumer education in integrated rural energy programme need to be effectively organized not only by the government machinery but also by NGOs in co-ordination with the Panchayats and IREP Cells. Generation of awareness and dissemination of information through consumer education play an important role in promoting new devices based on biomass energy technology.

In general, consumer education may help to achieve the goals such as :

- Creating awareness about the realities regarding present energy situation and also about the potentialities which can be explored by rural individual
- Creating awareness to take up collective efforts regarding benefits and application of improved technology
- Developing people's capabilities to critically analyse social reality, to identify cause of their poverty, to .give expression to the feeling of exploitation and deprivation
- Helping people to discover their cultural identity
- Bring about attitudinal changes conducive to development through social change
- Providing relevant knowledge and skills required for economic growth and for improving quality of life
- Motivating people for planning and implementing integrated rural energy programme, and

- Creating an environment conducive to people's participation in the planning for development and in the implementation of the plan.

A powerful educational programme can play a significant role in motivating the rural masses for adoption of appropriate technology.

7.10 Rural Health

The declining health of rural mass particularly rural women due to low quality biofuel burning in inefficient stoves is a great concern for the state such as Assam. Greater emphasis should be given to educate the rural people about health measures and better nutritions. All members of the rural family have to be educated and informed about the ill effect of present rural energy system on health. The rural people particularly the rural women have to understand the good-effect of adoption of improved/appropriate technology in domestic energy system. This education to the rural women can be given through Mahila Mandals which are independent voluntary organizations of local women.

Rural people would be obliged to pay more attention on improving their knowledge, skill and adoption behaviour. Adoption behaviour and knowledge would create a climate congenial to entrepreneurship development based on appropriate technology. Broadly speaking, achievement of rural consumer would be linked directly with increased yield and income. All these factors may lead the rural system to sustainable development with significant improvement in living standard.

7.11 Options In Cooking

Table 7.1 presents the intention of the people surveyed to change to a different type of fuel. Only 22 per cent of rural households opted for fuel wood use in improved stove and rest showed interest in traditional stove. This indicates that accessibility to fuel wood, lack of awareness on clean fuel, efficient technology. new and renewable energy technology make the rural people to opt for food cooked in traditional stove. In contrast, 94.1 per cent of semi-urban and 100 per cent of urban households preferred LPG because of its cleanliness and convenience. Other 11.2 per cent and 2.4 per cent from semi-urban households and 5.3 per cent and 18.2 per cent of urban households opted for kerosene and electricity as alternative fuels when there is a shortage of LPG supply.

Table – 7.1
Future Energy Options in Cooking

Future energy options preferred	Number of households		
	Rural	Semi-urban	Urban
LPG	-	193 (94.1%)	205 (100%)
Kerosene	-	23 (11.2%)	12 (5.37%)
Fuel wood in improved stove	77 (20%)	-	-
Biogas	-	-	-
Briquetted biomass	-	-	-
Electricity	-	5 (2.4%)	41 (18 9%)
None of these	-	-	-

Figures within parenthesis indicate percentage.

7.12 Scale and Scope of Rural Energy Management Planning

The objectives of rural energy planning and interventions have primarily concentrated on conserving environment, demonstrating renewable energy technologies (appropriate technologies), improving quality of life through economic development. Fig. 7.3 shows the dimensions of integrated rural energy management planning in changing domestic energy consumption scenario of rural Assam.

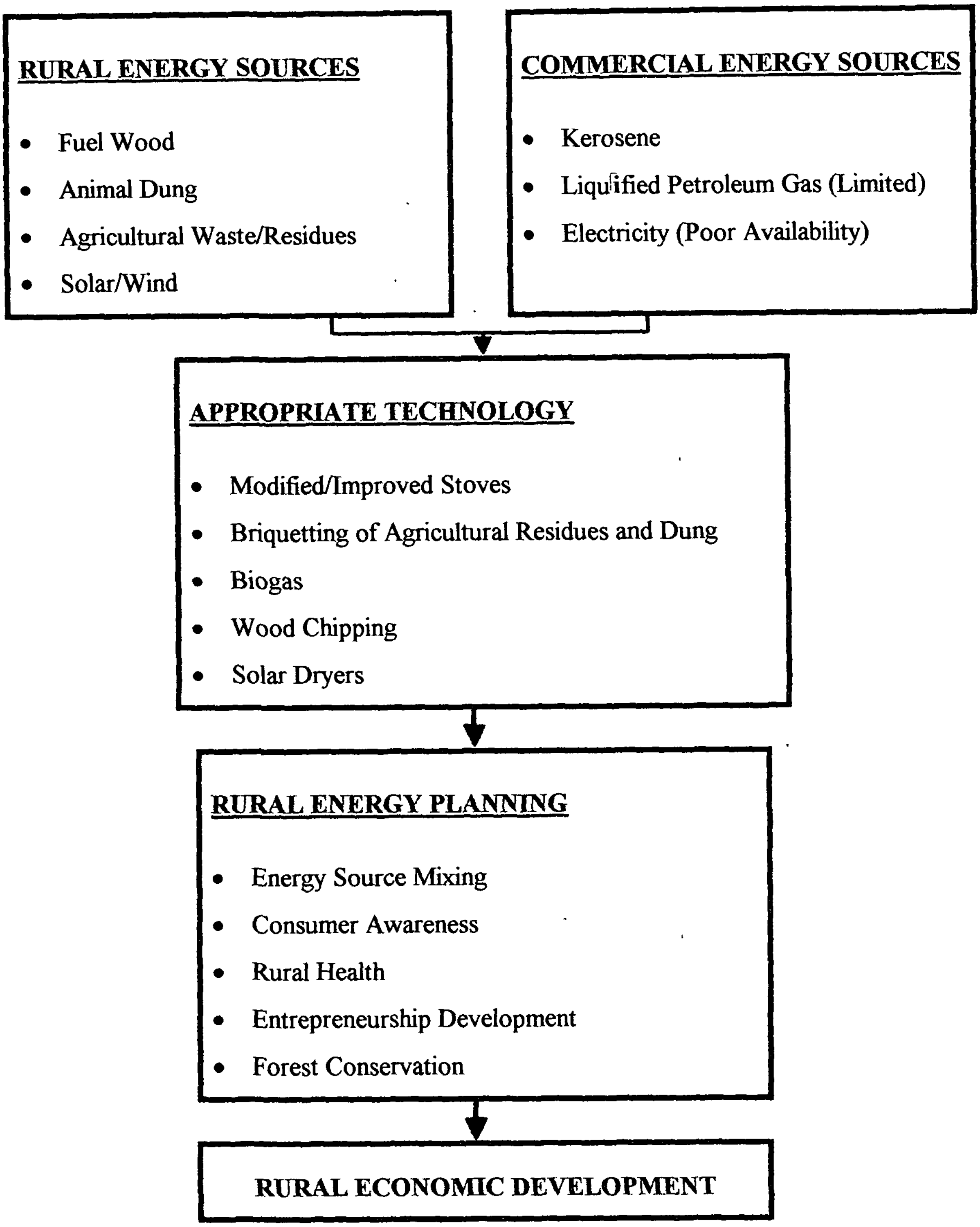


Fig. 7.3 Integrated Rural Energy Management Planning

The 'challenge seems to lie in augmenting the energy supply using local/renewable resources. The interventions to improve quality of life or to conserve environment have to deal with existing energy systems whose cost to the user is negligible. This is true for interventions for supplying cooking fuel and for improving end use efficiency [Joshi, 1993]. Locally available energy sources will have to be taken into account in energy planning to meet future rural energy needs and rural economic development.

Considering the dependence of rural energy system on biofuels, it is the biomass resources that are of primary importance to a rural community. Notwithstanding this, there is little information available on the supply of these fuels. Part of the reason for this is the complexity of the biomass system. Biomass rarely enters the monetary market, making it even more difficult to monitor exchanges and movements. Therefore, it is imperative that proper methodology be devised to assess the biomass availability as a integral part of rural energy planning. While analyzing the biomass situation in the area besides its role as an energy source, its other uses such as fodder, timber, manure etc. need to be examined. The mandate of "integrated energy planning" has more often than not referred to integrating energy sources and technologies rather than integrating the energy plan with the economic development.

If the objective of the intervention is to alter the energy consumption or fuel mix, the demand should be based on existing consumption (commercial and non-commercial) levels and patterns. Keeping in view the heavy pressure on per capita fuel wood use and necessity to proper utilization of available agricultural residues and dung, alternative approaches [Sarmah *et al.*, 2002] with the help of appropriate technology must be carried out most urgently and efficiently. The traditional stove with thermal efficiency ranging from 5-10 per cent is not suitable for burning loose biomass directly. Unused agricultural residues and dung can be used in briquetted form as cooking fuel. Accordingly, biomass briquettes based, efficient, smokeless stoves can be developed to meet the need and demand of fuel wood. Likewise, installation of biogas plants with 50% thermal efficiency will not only help in using available biomass, it will result in saving of fuel wood.

7.13 Conclusion

Rural energy plan should be integrated with the development planning of the area. It should address the rural economic development in an environmentally sustainable manner. Untapped energy sources can be used with the help of appropriate technology to meet the need and demand of fuel wood in rural areas. A powerful educational programme can play a significant role in motivating the rural masses for adoption of appropriate technology. Not only government machinery but also NGOs may help in implementation of successful rural energy programme in Assam.

CHAPTER VIII

Summary and Conclusions

CHAPTER – VIII

SUMMARY AND CONCLUSIONS

The analysis of energy use pattern in rural domestic sector is very important for estimation of future energy requirement in rural areas. Biomass is the dominant source of energy in rural areas. The sources of fuel wood used for cooking in rural areas were analysed. All types of crop residues and dung having potential for use as fuel in rural domestic sectors were analysed. Biomass energy use in the domestic sector is characterized by low efficiency of use, drudgery in gathering and use, emission of smoke in the kitchen, and ultimately lower quality of life. Kerosene is the fuel used by majority of rural households for lighting. It has poor conversion efficiency and poor-quality lighting. The availability of electricity is significantly less in rural areas and most of the rural households are not electrified. There is a need to explore the potential for providing quality fuels and efficient devices to promote development in rural areas. It is also necessary to understand the impact of the current patterns of biomass energy use on environment and health to enable to explore alternative options. With all these views, the present study was conducted with the following objectives.

i) To identify and assess the locally available energy sources in rural areas and to quantify the heat content of different types of bio-fuels.

ii) To analyse the consumption pattern of rural domestic energy with that of semi-urban and urban sectors.

iii) To study the indigenous technology used for energy conversion in rural domestic sectors.

iv) To study the impact of present rural energy system on the health of the rural women.

v) To develop a model to represent the rural domestic energy consumption scenario by taking into account the various parameters.

8.1 Research Methodology

The study was conducted in the Jorhat district of Assam. At the initial stage Jorhat and Titabar sub-divisions of Jorhat district were selected purposively. For subsequent selection a multistage stratified sampling procedure was followed. Blocks were considered as the first stage units, villages as the second stage units and contact households were considered as the ultimate stage units. Two blocks namely Dhekargarah and Baghsung were randomly selected from Jorhat and Titabar sub-divisions, respectively. Six villages from each of the blocks were selected to represent different categories of society and different cultural systems. Eight households were selected from each of the four groups of contact households (large, small, marginal and landless). Thus, from 4 groups of contact households 32 contact households were selected from each village. Ultimately 384 respondents were obtained from 12 villages.

The data were collected through personal interview method. Data were collected from all the households during the agricultural year 1997-1998. The data on area of cropping, production of rice, dung production based on animal population, fuel wood consumption and commercial fuel consumption were collected and converted into energy forms using standard conversion ratio [Ravindranath *et al.*, 1995]. The rural domestic energy consumption in cooking and water heating (combined), space heating and space lighting were estimated [Sarmah *et al.*, 2001].

Also per capita per year gross and useful energy consumption in cooking, water heating, and space heating has been estimated.

To compare rural domestic energy consumption, the semi-urban and urban sectors were identified based on availability of electricity, transportation, civic amenities etc. Data regarding consumption of fuel wood and kerosene per day per household, number of LPG cylinders required per household per month and unit of electricity consumption per month per household were collected from the semi-urban and urban sectors. Later those were converted into energy units using standard conversion relationship [Ravindranath *et al.*, 1995]. For comparison, these fuels were grouped into fuel wood, kerosene, LPG and electricity against the three sectors.

Impact of domestic energy consumption on rural women was analysed by considering types of cooking fuels and income groups, different types of stoves used, hours spent by women in cooking in the three sectors. Analysis of variance (ANOVA) was used to test the diseases among rural women due to smoke exposure.

A modified stove was designed to use briquettes from agricultural residues. The stove was fabricated and tested using standard water boiling method as suggested by Annonymous (1965) and Krishnaprasad (1981). The overall efficiency of the stove was found out using standard formula [Joseph and Shahnan, 1980; Krishnaprasad, 1981; Geller and Dutt, 1982]. Thermal performance of this stove was measured and compared with thermal performance of traditional stove for varying fuel feeding rate.

Seasonwise multiple regression analyses of rural domestic energy consumption in cooking, water heating and space heating and that of space lighting over the year were done. The statistical techniques *viz.*, analysis of variance, F-test, correlation co-efficient, multiple regression and t-test were used to draw inferences.

8.2 Salient Findings

The salient findings are presented below

8.2.1 Village Profile

Total area of cultivation of rice is highest in Nam-Deorigaon (490 ha) but, 8 No Spur has more cultivating land (1 06 ha/capita) The animal density in Bahek is the highest (3 1 animals/ha) and the least being in 8 No Spur (0 85 animals/ha) Rice is the commonly grown crop in the twelve villages Intercropping is done only in Upper-Deorigaon, Nam-Deorigaon, Bahek, Kheremora and Birina during *Rabi* season

8.2.2 Energy Profile

The production of rice and rice residues is highest in Nam-Deorigaon (1598 tonnes/yr) and lowest is in Na-Jankhona (71 tonnes/yr) After deducting non-fuel uses such as manure, clay material etc , available surplus dung is found to be highest in Nam-Deorigaon (1679 46 kg/day) and lowest in Na-Jankhona (148 01 kg/day) It was observed that yearly per capita available energy from rice residues and dung is maximum in Nam-Deorigaon (155 55 GJ/capita/yr) followed by minimum in Na-Jankhona (8 57 GJ/capita/yr) [Sarmah *et al* , 2002]

8.2.3 Rural Domestic Energy Consumption Pattern

The consumption of domestic energy in all the twelve villages is not uniform throughout the year The yearly per capita energy consumption for cooking and water heating (combined) and space heating in Upper-Deorigaon is found to be 42 per cent more in winter than in summer, in Nam-Deorigaon it is estimated at 40 per cent more, in Na-Jankhona it is found to be 27 9 per cent more, in Bahek it is estimated at 25 5 per cent more, 8 No Spur and Kheremora consume 24 8 per cent of more energy in winter than in summer, in Kathalbari, Khongia, Chowdung Gaon, Birina, Gariabhanga and Kondai, the domestic energy consumption in cooking, water-heating and space heating are found to be 22.8, 22.6, 22.2, 22.1, 21.5 and 20.6 per cent more in winter, respectively.

The per capita useful energy consumption has a wide difference from the per capita gross energy consumption. This is because actual operational efficiency of the traditional stove is much lower which leads to greater conversion losses. The per capita useful energy consumption in eight villages namely Gariabhonga, Khangia, Upper-Deorigaon, Nam-Deorigaon, Chowdunggaon, Bahek, Kheramora and Birina is above the minimum requirements estimated by the Advisory Board on Energy i.e. 0.9475 GJ/capita/yr useful energy in India. But the per capita useful energy consumption level is lower in 8 No. Spur, Na-Jankhona, Kondar and Kathalbari in comparison to all India level.

The seasonal variation of kerosene and electricity is insignificant in the twelve villages. Because kerosene and electricity are used for lighting purposes only. Variation of yearly per capita kerosene consumption in domestic lighting is maximum in Na-Jankhona (0.28 GJ/capita/yr) and minimum consumption of kerosene is in Nam-Deorigaon (0.0366 GJ/capita/yr). The yearly consumption of kerosene in lighting for the un-electrified households is much lower than all India average of 1.028 GJ/capita/yr as estimated by the National Council of Applied Economic Research (NCAER).

8.2.4 Comparison of Rural Domestic Energy Consumption With Semi-Urban and Urban Domestic Sectors

The per capita per year energy consumption in the form of fuel wood was estimated at 10.001 GJ in the rural domestic sector. In semi-urban domestic sector the per capita per year fuel wood consumption has been 0.682 GJ. The urban people do not use fuel wood for cooking. The annual energy consumption in the form of kerosene in rural domestic sector were estimated at 0.270 GJ and that in semi-urban and urban sector was found to be 0.345 GJ and 0.332 GJ, respectively [Sarmah *et al*, 2000]. The electricity consumption in rural domestic sector was estimated at 0.0029 GJ/capita/yr and that in semi-urban and urban sector was found to be 0.275 GJ/capita/yr and 0.623 GJ/capita/yr, respectively. The rural people do not use LPG for cooking. The consumption of LPG in semi-urban and urban domestic sectors was estimated at 1.463 GJ/capita/yr and 1.903 GJ/capita/yr, respectively [Sarmah *et al.*, 2000].

The calculated 'F' values for fuel wood and LPG consumption (6.99 and 6.37) are higher than the table values (4.74 and 4.46) at 5 per cent level of significance. On the other hand, the calculated 'F' values for kerosene and electricity consumption (67.77 and 8.95) are higher than the table values (6.70 and 8.02) at 1 per cent level of significance. This means that the consumption of domestic energy has high significant variations in between and within the sectors.

8.2.5 Impact of Domestic Fuel on Rural Women

Majority of the rural households are in low and lower-medium income groups. Only fuel wood is preferred as cooking fuel by all the four groups (low, lower-medium, upper medium and higher). In semi-urban sector, majority of the households are in upper medium and higher income groups. Only 22.2 per cent of low-income group and 6.4 per cent of lower-medium income group use fuel wood in cooking. Majority of the urban households are in higher income group. They do not at all use fuel wood in cooking.

Twelve per cent of rural households use 3-brick stove for burning fuel wood. Other 88 per cent of rural households use traditional stove (chimneyless), which is made of mud with a fuel feeding port. 15 per cent of semi-urban households use improved stove for burning fuel wood during cooking. 20 per cent of semi-urban households and 6 per cent of urban households use kerosene stoves for cooking and water heating. Other 65 per cent of semi-urban households and 94 per cent of urban households use LPG stoves for cooking. So, the indoor air pollution is absent in semi-urban and urban sectors.

Simultaneous cooking is not possible in the traditional stove. Also per cent heat utilization in this type of stove is very low. So, the number of hours spent by rural households is more than that of semi-urban and urban households. More number of hours spent in cooking lead to more hours of exposure to smoky environment. 15.6 per cent of the respondents reported about problem of chest pain, 18.4 per cent wheezing, 18.6 per cent from giving birth to underweight babies, 40.6 per cent from dry cough, 80 per cent from running nose, and 91 per cent stated symptoms of eye-irritation. The degree of diseases among rural women due to smoke exposure during cooking hours was found to be significant at 1 per cent level.

8.2.6 Modelling of Rural Domestic Energy Consumption in Cooking and Water Heating for Summer Season

The average population is positively and significantly correlated (r=0.863) to rural domestic energy consumption. It means that rural domestic energy consumption in cooking and water heating increases with increasing population. Monthly average income and the rural domestic energy is positively and significantly correlated (r=0.854) to energy consumption. Monthly average temperature and monthly average rainfall are negatively and significantly correlated (r=-0.317 and r=-0.309) with rural domestic energy consumption.

Out of the four regression co-efficients of four independent variables, co-efficients of average population and monthly average income, are significant at 0.1 and 5 per cent level of probability, that of monthly average temperature and monthly average rainfall are significant at 1 per cent level of probability respectively. The value of co-efficient of multiple determination is R^2 = 0.9029. F-ratio is found as 121.965 at 1 per cent level of significance.

8.2.7 Rural Domestic Energy Consumption in Cooking, Water Heating and Space Heating for Winter Season

Average population and monthly average income are positively and significantly correlated with rural domestic energy consumption in cooking, water heating and space heating (r = 0.883 and 0.951, respectively) at 1 per cent level of probability. Monthly average temperature is negatively and significantly correlated (r = 0.485) with rural domestic energy consumption in cooking, water heating and space heating at 10 per cent level of probability.

Regression co-efficients of average population and monthly average income are significant at 0.001 level of probability while that of monthly average temperature is significant at 0.01 level of probability. The value of co-efficient of multiple determination is $R^2 = 0.9163$ and F ratio is found as 18.299 at 0.01 level of significance.

8.2.8 Rural Domestic Energy Consumption in Space Lighting Over the Year

Average population, monthly average income and average school going children are positively and significantly correlated (r = 0.922, 0.986 and 0.992, respectively) to domestic energy consumption at 1 per cent level of probability. Monthly average temperature and monthly average rainfall are found to be non-significant.

Regression co-efficients of average population is significant at 0.1 per cent level of significance, that of monthly average income and average school going children are significant at 1 and 5 per cent level of probabilities respectively. The value of co-efficient of multiple determination is $R^2 = 0.9756$ and F-ratio is estimated as 94.745 at 1 per cent level of significance.

8.3 Design of An Improved Stove

The overall efficiency of the designed stove was calculated by using standard water boiling test method and found to be 19.84 per cent [Sarmah *et al.*, 2000] by using briquettes of straw and cowdung at a fuel feeding rate of 3.47×10^{-4} kg/S. The overall efficiency of a traditional stove in rural areas does not exceed 10 per cent [Annonymous 1986]. So, a fairly 9.84 per cent increase in efficiency is possible from the new stove. The power output at fuel feeding rate of 3.47×10^{-4} kg/S was found to be 0.697 kw, while, 10 per cent thermal efficiency was obtained from traditional stove using fuel wood at a fuel-feeding rate of 4.17 x 10^{-4} kg/S. The power output of the traditional stove at this fuel-feeding rate was found to be 0.632 kw.

8.4 Implications

1) It implies from the analysis of 'Energy Profile' in the twelve villages that a huge amount of biomass energy goes waste due to easy availability of fuel wood.

2) There is a need to explore technical potential of bio-energy for using these wastes, which in turn may minimize utilization of fuel wood.

3) The use of modern agricultural implements and technology, irrigation facilities will help to produce more agricultural crops. In turn more production of agricultural residues can be expected.

4) Collection of fuel wood by 84.4 per cent of the respondents from forests or fields implies fast forest degradation i.e. impact on environment.

5) Analysis on consumption of rural domestic energy in cooking, water heating, space heating reveals that consumption of energy is not uniform throughout the year. Extra 20.6 to 42.0 per cent more energy is needed in winter than in summer. It clearly indicates excess fuel wood consumption in winter.

6) There is a wide difference between per capita gross and per capita useful energy consumption for cooking, water heating and space heating. It implies that the actual operational efficiency of the traditional technology is much lower due to greater conversion losses.

7) The per capita useful energy consumption in some villages is above the minimum requirements at national level. It implies that easy and free availability of forest fuel leads to excessive consumption. On the other hand the per capita useful energy

consumption in some villages is much below the minimum requirements at national level. It means poor quality of life.

8) The yearly per capita kerosene consumption in lighting in all the twelve villages is much lower than all India average. It indicates poor conversion efficiency of lighting appliances (wick lamps and hurricanes) used in those villages.

9) Excessive time spent in fuel wood collection implies a major loss of human energy.

10) Comparison of rural domestic energy consumption with that of semi-urban and urban sectors clearly indicates better quality of life of semi-urban and urban people due to the use and availability of cleaner fuel and efficient technology.

11) An analysis of type of cooking fuels and income groups in rural, semi-urban and urban domestic sector shows that better economic status of semi-urban and urban people is also another factor for their liking to cleaner fuels.

12) It was found that the rural women spent more number of hours in cooking compared to semi-urban and urban women due to the difference in domestic fuel technology. It implies that improper technology in traditional stove leads to less heat transfer rate and inefficient combustion.

13) More number of cooking hours spent by rural women lead to more hours of exposure to smoky environment. More hours of exposure to smoke has a implication of inflicting various diseases such as chest pain, wheezing, dry cough, running nose etc.

14) A fairly 9.84 per cent increase in thermal efficiency is possible from the modified stove which implies saving of energy. Also provision of chimney helps in removing the smoke from the cooking place.

15) The significant regression co-efficient of variables implies that those variables are good contributors (good predictors) to rural domestic energy consumption.

8.5 Suggestions for Further Research

1) The research project of this kind may be advocated for long term, comprising all the rural energy sources for fulfilling the utilitarian purpose of energy research. Long-term plan aims to achieve economy through energy saving techniques and innovations. Such type of research helps many types of innovations to be diffused and adopted by creating a positive general attitude to change the rural domestic energy consumption pattern among rural people.

2) The study on Rural Domestic Energy Consumption was limited to block level in Jorhat district only. Suggestions may be forwarded for investigations in district level studies, which in turn will help in state level energy research. Need based items or areas should be included sufficiently looking into the potentialities for improving quality of rural life.

3) In the present study, availability of rural energy is studied only for rice residues. Other crops such as jute, sugar cane, pea, gram, mustard seed etc, are sown in mass scale in some rural areas of different district of the state. Investigations may be made to assess the energy content of those crops and to utilize them as domestic fuel to meet the need and demand of fuel wood.

4) Present study was conducted covering rural domestic energy consumption. It may be suggested to study and analyse the rural energy consumption in agricultural sector also. This sector covers human energy, animal energy, commercial energy such as diesel consumption etc. Diesel use is mainly for running pumps for irrigating cultivating land. Energy content of different wet crops can be assessed while studying for agricultural sector.

5) Investigations may be made on the impact of rural domestic energy consumption in all districts of the State. Domestic combustion technology, type of houses, type of kitchen, work burden of rural women per day etc. are to be analysed. The reasons for

not adopting the quality or efficient technology may be sorted out for a fruitful state level rural energy planning.

6) It may be suggested that "Modelling of Rural Domestic Energy Consumption" may be a separate research project instead of studying it is an objective. The model can be developed using various techniques such as time series, linear programming, econometric etc. The mathematical model linking agriculure and energy may also be developed using those techniques.

7) A study may be conducted to go into the details of rural energy conservation, energy audit and planning. The study should come out with details of short-term plan, medium term plan, and long term plan for proper utilization of rural energy sources in a sustainable manner.

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APPENDICES

REPRINT OF THE PAPERS

Paper - I

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DESIGN OF AN IMPROVED STOVE FOR USING FUEL BRIQUETTES OF AGRICULTURAL WASTES FOR THE RURAL NORTH-EAST INDIA

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ABSTRACT

Most of the rural people in North-East depends on the twigs, branches and firewood collected from the nearby jungles or fields for fuels. Though a huge quantity of agricultural wastes lie in abundance in rural areas, these are not fully utilized by the rural masses as fuel. Also, the mode of storing and wasting environment, the community and to the national economy. A survey of the use of agricultural residues and livestock wastes in several villages under two identified blocks in Jorhat District, Assam was conducted. Also the domestic energy use pattern and consumption pattern was surveyed. Though the production of agricultural residues as well as cowdung are in huge quantity, but their uses are very limited because of non-availability of proper and efficient devices. So, there is a need to provide quality fuels from agricultural residues. Briquettes from agricultural wastes can provide economically transportable fuels for rural sector. But the traditional chullah in present form is not at all suitable for burning fuel briquettes. This paper deals with the design and fabrication of a two pan stove with chimney for rural mass ad the stove as a model was tested with briquettes of rice - straw and rice husk with cowdung as binding material.

Keywords : Agricultural residues, Fuel briquettes, Rural energy, Stove geometry.

INTRODUCTION

With the years gone by, the sources of energy that are being used over the years are decreasing rapidly. It has warranted the need for proper use of the existing sources of renewable energy by introduction of some energy efficient devices. Presently over 90% of the domestic energy is being supplied by firewood in rural North-East. A typical rural housewife has to pass most of her time in cooking with low quality bio-fuels For this, she can not spare any time for her own and to look after her children Besides, efficiency of the traditional stoves used in majority of rural households ranges from 5% only (Anonymous, 1986) Inefficient burning of low quality fuelwood causes indoor pollution affecting the health of rural women and their families The inhabitants of the remote villages of North-East, whose per capita income is very low, can not switch over to the other commercial fuels like L P G , electricity etc

The imbalance in production and consumption of bio-fuels without any increase in forest area, and also the present forms and wastages of agricultural residues posing challenges to the national economy the conservation of important resources have become essential for the greater interest of the nation Minimising the deforestation, balancing the eco-system and environment reducing drudgery of rural women, maintainance of hygienic condition in the kitchen are the additional concerns

Though the production of agricultural residues as well as dung are in huge quantity in rural areas, the use of these wastes are very limited because of non-availability of proper and efficient devices So, there is a need to provide quality fuels from agricultural residues and appropriate devices in rural areas Fuel briquettes, from agricultural residues can provide economically transportable fuels in rural sector So, there is a need to design a new stove for using fuel briquettes as the traditional stoves in present forms are not suitable for using briquettes as fuels

MATERIALS AND METHODS

The idea of new stove design is based on the following objectives,

(a) energy conservation

(b) *smokeless*

(c) easy to fabricate

(d) reasonable cost

(e) reduction in cooking time

Three views of the design of the stove model are shown in fig 4 The stove is made of sheet metal of 3 mm thick and permits simultaneous cooking in two pans A supporting stand is also provided (not shown) for user's advantage and it may be helpful during the shifting period in flood affected areas

The stove has a chimney and it is constructed by proper drought analysis Though the chimney is made of sheet metal, it can be made of some other cheaper materials, like asbestos pipe fired clay tubes *etc* One major benefit is found from the chimney that the smoke is released away from the cook and usually outside home The stove does not contain a damper, but a grate is provided with proper calculations Reducers are also provided for using smaller size pots

The rice straw was chopped to a length of 1 cm with a simple cutter and mixed with cowdung to a proportion 1 1 The mixer was then pressed in a simple cylindrical die to from a briquettes which was later allowed to dry in open air Similar method was followed to prepare briquettes from rice husk The average

DESIGN OF AN IMPROVED STOVE FOR USING FUEL BRIQUETTES

Fig 1 Top view of the stove

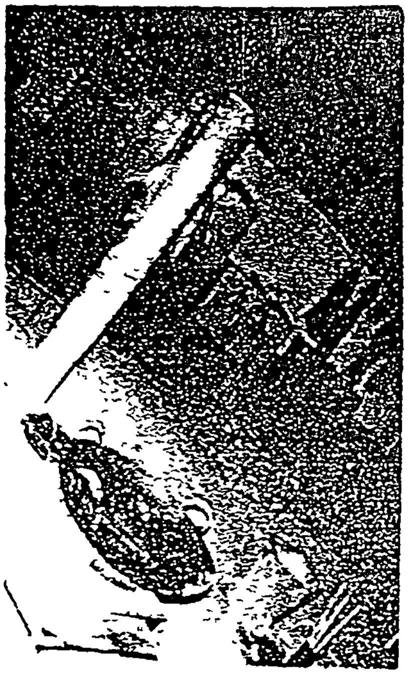

Fig 3 Assembled view of the stove

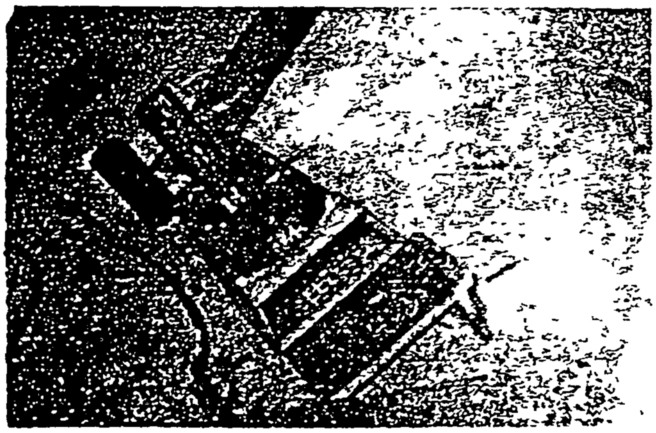

Fig 2 Side view of the stove

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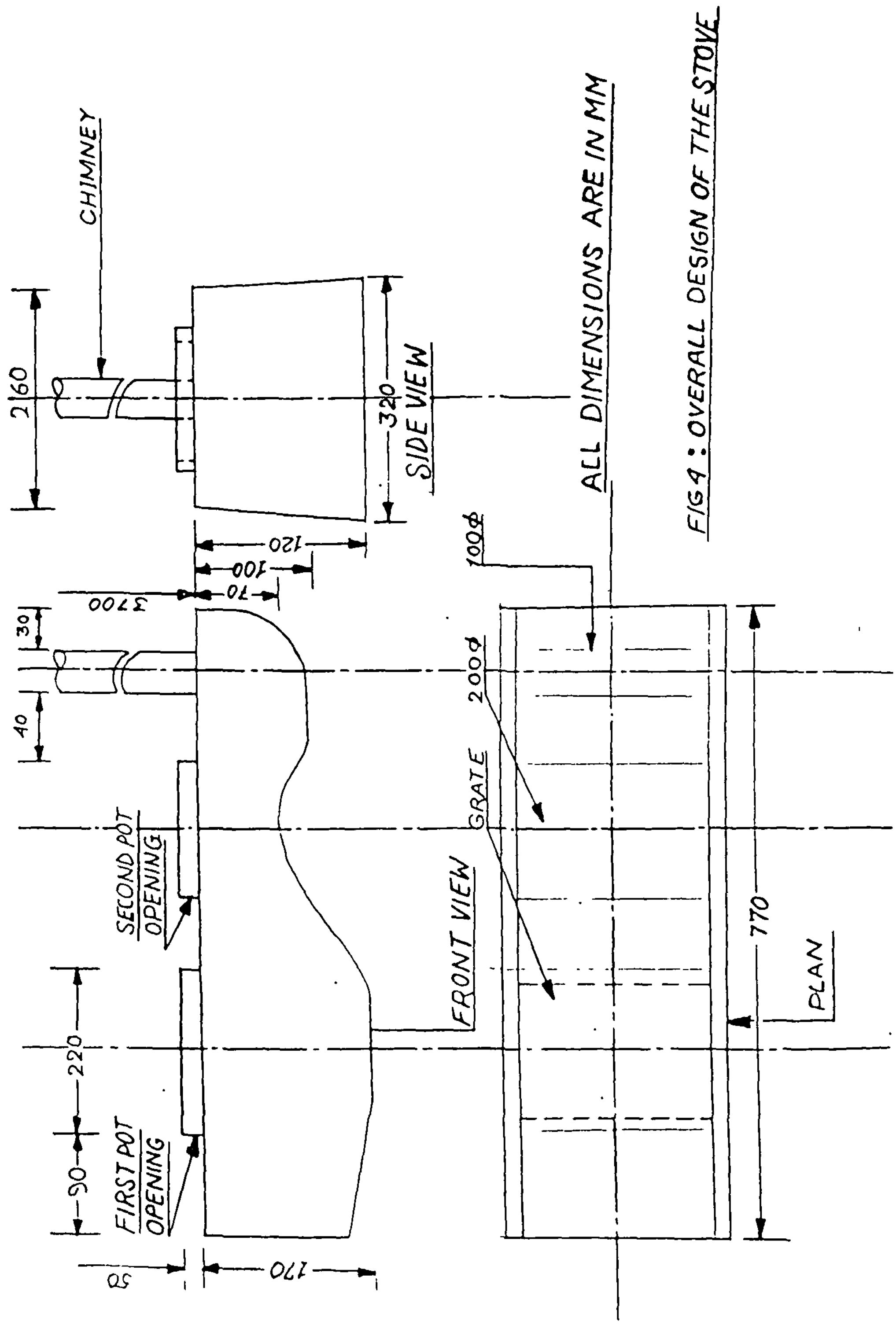

FIG 4 : OVERALL DESIGN OF THE STOVE

time taken by a single person following this simple method was around 6 minutes. The calorific values of the briquettes were measured with the help of Bomb Calorimeter in the laboratory of Mechanical Engineering Department, Jorhat Engineering College.

Table 1. Specification of the stove

Particulars	Values
Length of the stove bod y	770 mm
Width of the stove body	254 mm
Height of the stove body	220 mm
Inner cross sectional area of the chimney	78.5 cm²
Height of chimney	3700 mm
Diameter of the first pot opening	220 mm
Diameter of the second pot opening	200 mm
Pot openings with reducers	2 number
Area of the fuel feeding opening (provided in the extreme left hand side)	180.64 cm²
Damper	Nil
Supporting stand	made of angle iron

Fabrication work was done in the workshop of General Engineering Section, Regional Research Laboratory, Jorhat. The efficiency of the stove was calculated with the help of standard water boiling test in the laboratory of Mechanical Engineering Department, Jorhat Engg. College. Two aluminium vessel of 250 mm and 235 mm diameters with lids were used for the test for two different sizes openings of the stoves (Table 1)

The following testing procedure was followed :

(a) The fuel briquettes were weighed.

(b) Vessel 1 and vessel 2 were filled with 2 litres of water.

(c) Initial water temperature was recorded as 30°C.

(d) Initial fire was made with cotton waste soaked in a little kerosene.

(e) Water in vessel 1 was allowed to boil on the main opening over the grate keeping vessel 2 on the second opening and boiling time was recorded

(f) After reaching boiling point vessels 1 and 2 were switched and vessel 2 was heated to boil and time was recorded

(g) The vessels were removed and the fire was extinguished by sprinkling cold water

(h) At the completion of the test, unburnt briquettes were weighed, the final temperature was recorded and the amount of water evaporated was measured The difference between initial weight of briquettes and the weight of unburnt briquettes was the actual weight of fuel burnt during the test.

RESULTS AND DISCUSSION

The efficiency of the Chullah is independent of the material cooked or heated in the pot (Sielcken and Nieuwvelt 1980,1981). If the material is a liquid, the heat (Sensible or latent) transferred to it can be determined. On the other hand, if an empty pot is placed on the Chullah there will be continuous

Table 2 Performance test report of improve *chulla*

Sl No	Particulars	Value
01	Diameter of the two Al vessels in mm	250 and 235
02	Initial weight of water (mw_i) in two vessels in ltrs	2 0 and 2 0
03	Weight of water evaporated (mw_e) from the two vessels in ltrs	0 3 and 0 25
04	Weight of fuel briquettes fed in Kg	1 3
05	Weight of unburnt briquettes in Kg	0.297
06	Weight of briquettes burnt (m_f) in kg	1 003
07	Calorific value of briquetted fuel in (MJ/Kg (c v) (measured in Bomb Calorimeter)	10 125
08	Specific heat of water at 50°C under atmospheric pressure (Cp) in KJ/Kg °C (taken from the steam tables)	4 180
09	Temperature of boiling water (Tb) in °C	100
10	Initial temperature of water (Ti) in ° C	30
11	Latent heat of evaporation of water (L) in KJ/Kg (taken from steam tables)	2.2594×10^3

mass transfer (hot air inside the pot going out and cold air replacing it) and it is difficult to find out the heat transfer to the pot But the energy gained by the pot and its contents in both the cases is identical for equal fuel burning rates, provided the experiments are conducted on the same stove In the computation of energy losses, the size of the pots come into consideration as the energy loss from the surfaces of the pot and pot cover, EL is estimated from

$$EL = \sum_{i=1} U_{p_i} A_{p_i} (T_i - T_a) \times \tau_i$$

Where, EL = Energy losses, the summation is over 'n' number of pots, U_p is the overall heat transfer co-efficient for pot and cover, A_p is the area of pot and pot cover exposed to the atmosphere when the pot is on the stove, T_i is average temperature of the contents of pot and τ is the cooking time

The overall efficiency of the stove can be determined by finding out the heat transfer to the pot and its contents and the corresponding fuel input Kerosene and electric stoves are tested by transferring the heat output to a pot containing a fixed mass of water placed on the stove (Annon 1965) Therefore efficiency of firewood devices can also be evaluated by water heating methods The overall efficiency of the Chullah is determined by standard water boiling test In this method the Chullah is lit and water of known quantity is placed on it The volume of water evaporated is found out after complete burning of the fuel by the difference in weight of the vessel contents before and after the test This test was recommended by Krishna Prasad (1981)

The overall efficiency is thus the ratio of the amount of heat absorbed by water in the pots and the amount of sensible heat supplied by the fuel.

As suggested by Krishna Prasad (1981), Geller and Dutt (1982); Joseph and Shanahan (1980) the following formula was used to Calculate overall efficiency of the stove -

$$\eta_{Overall} = \frac{\sum_{i=1} m_{w_i} C_{p_i} (T_b - T_i) + m_{w_e} L}{m_f \times C.V.}$$

where, summation was over the different pots. The nomenclature of each term was already given in testing report. The overall efficiency of the proposed stove was calculated using the above formula as 19 84% The overall efficiency of a traditional stove in rural North - East India does not exceed 10% (2) So the overall efficiency of the proposed stove seems to be 9 84% more than that of a traditional Chullah in rural areas

Conclusion

The tests revel that a fairly 9.84% increase in efficiency is possible from the proposed design of stove using rice straw briquettes as fuel The variation of efficiency and fuel consumption and heat conservation can be tested by insulating the stove by utilising proper technology and economics. Easily available and cheapest material like mud may serve this purpose. To reduce cost the chimney can be made of locally available material. The briquettes can be tested by varying the proportion of ingredients As the fuel consumption is sensitive to regulation of heat inpute rate to the stove, a damper may be needed to improve the efficiency. Further research work is needed to optimize the efficiency and to promote the technology.

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Paper - II

International Energy Journal: Vol. 1, No. 1, June 2000

A Study on Domestic Energy Consumption in Rural, Semi-urban, and Urban Sectors of Jorhat District: Assam

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ABSTRACT

The energy consumption pattern of rural, semi-urban and urban domestic sectors of Jorhat district of Assam was examined. Rural sector was so chosen that 100% of the households used fuelwood as cooking fuel and kerosene as space lighting fuel. The per capita fuelwood consumption was found to be 8.531 GJ/year and that of kerosene per capita was found to be 0.270 GJ/year. In semi-urban sector, the households used fuelwood and LPG as cooking fuels with kerosene and electricity as space lighting fuels. The per capita consumption of fuelwood in this sector was found to be 0.682 GJ/year while the kerosene per capita was estimated as 0.278 GJ/year In the urban households, consumption per capita was estimated as: LPG 1.903 GJ/year, kerosene 0 332 GJ/year and electricity 0.623 GJ/year. The urban households used LPG and kerosene as cooking fuels with electricity and kerosene as space fuels

1. INTRODUCTION

Like most developing countries, domestic consumption of fuel has a larger share in the national energy consumption in India. Despite the availability of the commercial sources of energy such as electricity, petroleum, oil, diesel, LPG, coal and introduction of new and renewable sources; the non-commercial and traditional sources of energy namely, fuelwood, dung and agricultural wastes still constitute the main sources of domestic energy in rural India catering to the needs of about 86% of rural households [1]. Of these traditional sources, fuelwood occupies a pre-eminent position catering to 56% of the rural households [2]. Besides, fuelwood also satisfies the energy needs of more than 30% of urban households [3-5].

With varied physical and socio-economic scenarios, the energy situations in India have been diverse in nature which calls for a wide range of solutions [6]. As such, special understanding appears to be a basic approach towards evolving area-specific rural energy strategies [7].

In Assam, which is situated in the north-easthern part of India, majority of the rural people rely primarily on woodfuels collected from nearby forests or fields as cooking fuel and on kerosene as domestic lighting fuel, since electricity is very poor in rural areas Consequent upon the large scale consumption of fuelwood is the rapid depletion of forest resources Though rice is the main crop in Assam, a huge amount of rice residues go to waste due to lack of awareness of rural mass about the proper utilization of these as domestic fuels Six un-electrified villages were sampled on the bank of river Brahmaputra in Jorhat district of Assam purposely to study the domestic energy consumption pattern Total mass do not buy wicks for wick lamps as they buy for hurricane lamps They use waste cloth fiber as wick in lamps as they find it easily available in their houses

The semi-urban people use fuelwood, kerosene and LPG as cooking fuels with kerosene and electricity as lighting fuels. They purchase fuelwoods from the market that come from the rural areas As electricity failure is regular in this area, almost all people have to keep kerosene as alternative for domestic lighting Fuelwood and LPG agencies are from the town agencies Transportation problems are the major problems faced by semi-urban mass in carrying LPG cylinders as no home service arrangements are available

The urban people of Assam mainly use LPG and kerosene for cooking, with kerosene and electricity for lighting purposes Besides lighting, the urban mass uses electricity to run some household electrical appliances They also keep kerosene in stock as alternative energy source for lighting when electricity fails

As not much studies have been conducted in the line of domestic energy consumption in the north eastern part of India, [4, 8] this paper attempts to present an analysis on domestic energy consumption in rural, semi-urban and urban sector of Jorhat district of Assam

2 MATERIALS AND METHODS

The study was based on sample survey A stratified random sampling technique was used for selecting households as sample units The three sectors were identified based on infrastructural facilities like condition of roads, availability of electricity transportation civic amenities like post office, bank co operative society, marketing facilities LPG agencies educational facilities medical facilities etc Based on the existing facilities and distance required to traverse to avail these facilities the three sectors were identified in which 0 5 km represents urban > 5 km represent semi urban and > 10 km represents rural sectors Sample of 458 households were chosen for rural households, 205 for semi urban households and 225 for urban households

The domestic energy consumption and patterns were obtained from every household through a questionnaire The survey data were collected at two levels the sector and the household Table 1 lists the parameters on which information was sought. The data were collected by personal interview Data were collected from all the households (458 households in rural sector, 205 households in semi urban sector and 225 households in urban sector) Approximately 30 min time was taken in filling up the information schedule for each household

The domestic energy demand for two end uses were considered, mainly for cooking and lighting The information on cooking from the questionnaire was on the type of fuel and amount consumed per day per household Data regarding consumption of fuelwood and kerosene per day per household and unit of electricity consumption per month per household were collected from the sampled families Based on the feed back received, the data were modified to standard forms These fuels were grouped into firewood, kerosene, LPG and electricity against the three sectors, i e urban, semi urban and rural

The amount of fuel consumed in one day was multiplied by its calorific value to find the daily energy consumption Calorific values of different types of fuels used in the three sectors were taken from [5, 9] The calorific value of fuelwood with 20% moisture content (air-dried) is 15 MJ/kg and

Table 1 Information Items Covered in the Survey

Sector schedule • Location of the sector • General characteristics - distance from the central town, infrastructural facilities, etc. • Demographic characteristics - population, number of households, etc. • Types of domestic fuels • Types of end uses • Sources of fuels
Household schedule • Domestic energy consumption - consumption of fuelwood (both in summer and winter), kerosene, LPG and electricity for different end uses such as cooking, water-heating, space heating and space lighting • Cooking stove particulars - type of stoves, number of hours spent in cooking • Space lighting particulars - type of appliances, consumption

that of kerosene is 44 MJ/kg. Also calorific value of LPG is 44 MJ/kg (35.2 MJ/m^3). 1 kW-hr of electricity is equivalent to 3.6 MJ.

The energy consumed per day was converted into the annual energy consumption. Extra 40% of the daily fuelwood consumption was added for winter season (November to February) in the calculation of annual consumption rate because most of the rural households keep extra arrangement to burn low quality bio-fuels for warming up. The energy consumption in a household was added to obtain annual energy consumption rate of a sector.

LPG serves as cooking fuel in semi-urban and urban sectors. Data on number of cylinders required in a month per household were obtained and converted into energy. One LPG cylinder for domestic use contains 14.2 kg of fuel and this converts to 624.8 MJ of energy. The consumption of energy per household per month was multiplied by 12 to find the annual energy consumption of LPG in cooking. The energy consumption of households in a sector was added to obtain annual energy consumption rate of a sector.

Kerosene is the second source of energy used for lighting in rural domestic sector. As sampled rural areas were totally un-electrified, 100% of rural households depend on kerosene for space lighting. In semi-urban sector, average electricity failure usually occurs for 6 hours per day and that in urban sector for two hours per day. For this reason, the semi-urban and urban and urban people keep kerosene as alternative for lighting their houses. Some of urban households use kerosene for cooking also. Daily consumption of kerosene per household was obtained in volumetric measurements in the three study sectors and those were converted to weight (1 liter of kerosene = 0.8 kg). The daily consumption of kerosene in kg per household has been multiplied by 365 days to find the annual consumption. Finally, the sum of energy consumption for the three sectors was taken.

Data regarding average unit consumption of electricity in kWh per month in the households of semi-urban and urban sectors were collected. These data collected were converted to MJ (1 kw-hr = 3.6 MJ) and then multiplied by 12 to obtain annual electricity consumption per household. When added for total households, the pattern of annual electricity consumption was obtained for each sector.

3. RESULTS AND DISCUSSIONS

3.1 Rural Domestic Sector

Table 2 shows the data on per capita per year domestic energy consumptions in rural, semi-urban and urban sectors. 100% of rural households rely on fuelwood as their cooking fuel and kerosene as lighting fuel. Fuelwoods in the form of twigs, fallen branches, bamboo and other low quality fuels are used in cooking. The annual energy consumption in the form of fuelwood for cooking was estimated for villages under study to be 50 831.26 GJ and per capita per year consumption to be 8.531 GJ. The annual energy consumption from kerosene was to be 1606.53 GJ and capita per year consumption was estimated as 0.270 GJ. Wick and hurricane lamps were found to be the lighting appliances in the sampled villages. Kerosene is rationed on the basis of size of family. The rural people do not buy wicks for wick lamps as they buy for hurricane lamps. They use waste cloth fiber as wick for the wick lamps.

Table 2. Comparison of Energy Consumption in Domestic Sectors for Rural, Semi-rural and Urban Sectors of Jorhat District, Assam

Sl No	Item	Rural	Semi-urban	Urban
1	Distance from Jorhat town	> 10 km	< 5 km	0 – 5 km
2	Population	5954	1640	1350
3	Use of kerosene	1606 53 GJ/year (0 270 GJ/capita/year)	565 80 GJ/year (0 345 GJ/capita/year)	448 20 GJ/year (0 332 GJ/capita/year)
4	Use of fuelwood	50831 26 GJ/year (8 531 GJ/capita/year)	1118 48 GJ/year (0 682 GJ/capita/year)	Nil
5	Use of LPG	Nil	2399 32 GJ/year (1 463 GJ/capita/year)	2569 05 GJ/year (1 903 GJ/capita/year)
6	Use of electricity	Nil	455 92 GJ/year (0 278 GJ/capita/year)	841 05 GJ/year (0 623 GJ/capita/year)

3.2 Semi-urban Domestic Sector

In semi-urban sector, the annual fuelwood consumption in cooking has been estimated at 1118.48 GJ and per capita per year consumption has been 0.682 GJ. About 35% of semi-urban residents use fuelwood as their cooking fuel with some households keep fuelwood as one of the alternatives for cooking when there is a shortage of LPG supply or delay in LPG collection due to transportation problems. The people of this sector purchase fuelwood from the market supplied from the rural sector or directly from the rural people.

Majority of the people from semi-urban sector prefer LPG as cooking fuel and buy LPG cylinders from local agencies or from central town agencies. They face transportation problem in collecting LPG cylinder from the town. The annual LPG consumption in this sector was found to be 2399.22 GJ and per capita per year consumption was estimated at 1.463 GJ.

sectors. The F-ratio is calculated for different fuels as shown in Table 3. The calculated F-values in case of all the fuels are higher than the table values of F which are 4.74 and 4.46 for fuelwood and LPG respectively at 5% level of significance. On the other hand, table values of F are 6.70 and 8.02 for kerosene and electricity respectively at 1% level of significance. Hence, the null hypothesis is rejected which means that the consumptions of domestic energy have high significant variations in between and within the sectors.

Fire wood has a significant variations among the sectors. It clearly indicates that with development, determined by the availability of infrastructural facilities, the use of firewood goes down in the semi-urban sector and is nil in urban sector.

LPG has also a significant variations among the sectors indicating that with increasing infrastructural facilities, the use of LPG goes up in urban sector first then in semi-urban sector and the rural sector do not at all use LPG in cooking.

The variation in the use of kerosene is found to be highly significant in between and within the sectors, where F-ratio is estimated as 67.71. It reveals that with the increase in distance for infrastructural facilities, there is an adverse condition in electricity position. Electricity is available mostly in urban sector with average two hours of failure per day, in semi-urban sector with average six hours of failure per day for which use of kerosene is another alternative for domestic lighting in those two sectors. As most of the rural sector is completely un-electrified, use of kerosene is a must for domestic lighting. Hence, the variation in the use of electricity among the three sectors is estimated to be significant with F-ratio of 8.95.

Table 3 One Way ANOVA Table with Unequal Sample Size on Domestic Energy Consumption in Rural, Semi-Rural and Urban Sectors of Jorhat-District, Assam

Types of fuel	Source of variation	Sum of square	Degree of freedom	Mean square	Calculated "F"	Table value of "F"	Acceptance/ Rejection of hypothesis	Level of significance
Fuelwood	BT	7134.71	2	2218.15	6.99	4.74	Rejected	0.05
	WT	2218.15	7	316.88				
Kerosene	BT	101.25	2	50.63	67.71	6.70	Rejected	0.01
	WT	9.72	13	0.75				
LPG	BT	49.26	2	24.63	6.57	4.46	Rejected	0.05
	WT	29.99	8	3.75				
Electricity	BT	14.39	2	7.20	8.95	8.02	Rejected	0.01
	WT	7.34	9	0.82				

BT = Between Treatment
WT = Within Treatment

The semi-urban sector is mostly electrified, and thus electricity is the main lighting source. Also electricity is used in some households to run TV. However, the people do keep kerosene in stock (procured from family rationed system) as lighting alternative during major and regular electricity failure (average 6 hours per day) in this sector. The annual kerosene consumption is estimated at 565.80 GJ and per capita per year consumption at 0.345 GJ. The annual electricity consumption is around 455.92 GJ and per capita per year consumption is 0.278 GJ.

3.3 Urban Domestic Sector

In general the urban people do not use fuelwood as cooking fuel. Instead they use LPG as their prime cooking fuel. In some urban households kerosene stoves are used for water heating. They buy LPG cylinders from the agencies. Home delivery of LPG cylinders is available. The annual LPG consumption is around 2569.05 GJ and per capita per year consumption was found to be 1.903 GJ in the sampled households.

This sector is totally electrified. Electricity is the main lighting component. Besides lighting, electrical appliances like oven, heater, press (iron), grinder, TV etc. are used in urban households. Electricity failure varied every day. Therefore based on the data and information collected an allowance of average two hours electricity failure per day has been considered. Annual electricity consumption was estimated at 841.05 GJ and per capita per year consumption was found to be 0.632 GJ. The kerosene consumption was found to be 448.20 GJ/Year and per capita per year consumption was estimated as 0.332 GJ.

Figure 1 shows the bar diagram of domestic energy consumption of different fuels in GJ/Capita/year in three different study sectors.

3.4 Test of Variations

The major hypothesis to be tested in the study is to find significant variations, if any, of fuel consumption in between and within the treatment, i.e. sectors. To test the hypothesis, analysis of variance (ANOVA) e.g. F-test was employed. Table 3 shows one way ANOVA table with unequal sample size on domestic energy consumption in the selected rural, semi-urban and urban sectors of Jorhat district of Assam. The per capita consumption of each type of domestic fuel was taken for three

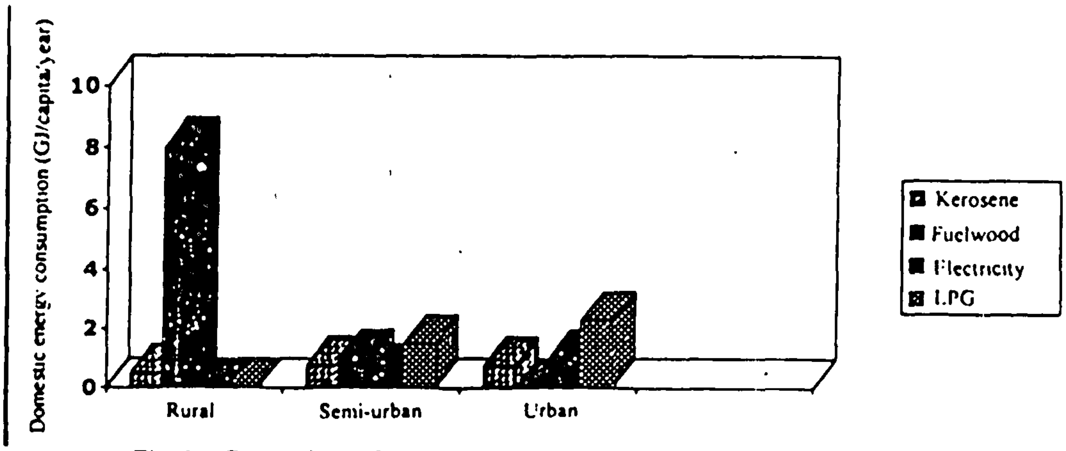

Fig. 1. Comparison of energy consumption in domestic sectors for rural, semi-rural, and urban sectors of Jorhat district, Assam.

4. CONCLUSIONS

A wide variation of the types of energy sources used for domestic consumption in rural, semi-urban sectors of Jorhat district of Assam is evident from statistical analysis. Though production of agricultural residues and animal dung are found in abundance in rural areas, these are not used due to availability of free forest fuel and due to lack of technology of using the wastes. So, stress should be given to employ appropriate technology for proper utilization of agricultural wastes and dung minimizing fuelwood use. This might be helpful in checking deforestation and upgrading of environment and quality of rural life. Urban sector depends entirely on commercial fuels. The scope of installing new and renewable technology is more promising due to better level of educational and awareness among urban mass. Hence, there is ample scope for energy conservation through appropriate use of untapped energy sources available in the rural area in the form of agricultural wastes. It is necessary to initiate studies to estimate the domestic energy use in different regions and potential for efficiency improvements to formulate effective energy policy in near future.

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Paper - III

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Energy profiles of rural domestic sector in six un-electrified villages of Jorhat district of Assam

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Abstract

A comparative analysis of the household energy consumption patterns and available biomass energy in six un-electrified villages of the Jorhat district of Assam is presented This empirical study examines how the energy consumption patterns in six villages (Gariabhonga, Khongia 8 No Spur, Na-Jankhona Upper Deorigaon and Nam-Deorigaon), each representing different categories are influenced by the locally available biomass energy resources The study reveals that the total energy consumed in GJ/capita/year for domestic activities ranges from 7 503 to 12 692 Major findings in the domestic sector are (1) fuel wood is preferred for domestic energy consumption, (2) easy availability encourages excessive consumption (3) 21 5 to 42% more energy is consumed in winter than in summer for meeting cooking, water heating and space heating needs, (4) rice residues and dung are present in abundance but go to waste owing to the easy availability of fuel wood, and (5) commercial fuel kerosene is the only alternative for domestic lighting

1. Introduction

Rural households in India depend on locally available biomass resources to meet their domestic energy needs [1,2] These resources consist of wood fuels, agricultural residues and cattle dung Modern fuels like kerosene, diesel and electricity are also used at the village level The quantity of a particular fuel used in a household depends on the availability of that fuel and several other factors that determine the household's ability to buy/gather the fuel The energy consumption pattern varies from region to region and also according to the standard of living [3] Fuel wood

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occupies a pre-eminent position, catering to 56% of rural households [4]. Fuel wood satisfies the energy needs of more than 30% of urban households [5,6].

In Assam, which is situated in the north-eastern part of India, the majority of rural people rely primarily on wood fuels collected from nearby forests or fields for cooking and on kerosene for domestic lighting, since the availability of electricity is very poor in rural areas. Consequently, the large-scale consumption of fuel wood is rapidly depleting the forest resources. Although rice is the main agricultural crop in Assam, a huge amount of rice residue goes to waste as the rural population is unaware how to utilize it properly as a domestic fuel. In order to formulate long-term energy policy, it is important to assess rural domestic energy consumption and the available energy resources [7,8].

As few studies have been conducted on domestic energy consumption in the north-eastern part of India [9,10], this paper attempts to present an analysis of rural household energy consumption patterns and the available energy resources that are lying untapped in six un-electrified villages in the Jorhat district of Assam. Of these six villages, Gariabhonga and Khongia represent the upper caste population, 8 No. Spur and Na-Jankhona represent the schedule caste population, and Upper-Deorigaon and Nam-Deorigaon represent the schedule tribe (plain) population.

2. Materials and methods

A stratified sampling plan was designed to carry out the study in the Dhekargara Rural Development Block, which was identified to represent different categories of society (census 1995). Six villages, namely Gariabhonga, Khongia, 8 No Spur, Na-Jankhona, Upper-Deorigaon and Nam-Deorigaon, were selected in consultation with the Block Development Officer and with officials of the Assam State Electricity Board. In total 508 sample units (households) were selected. The stratification was done primarily on the basis of existing infrastructural facilities, such as availability of electricity, condition of roads, population density, educational facilities, health centres, occupational structure and social hierarchy, etc. Information on domestic energy consumption and available energy sources was collected through a questionnaire with 252 variables. Hence, about 128,000 data points were obtained. Table 1 presents profiles of the six villages in the Jorhat district. The information had to be collected in local units of measures. Later, it was converted into standard units.

Although a variety of energy sources is available, only fuel wood is used for domestic energy consumption in cooking, water heating and space heating. The amount of fuel consumed in one day was multiplied by its calorific value to find the daily energy consumption. Calorific values of different types of fuel were taken from Ref. [6]. The energy consumed per day was converted into annual energy consumption. Fuel wood consumption rates increase during winter. An additional 42% more energy is consumed during winter than in summer. To burn fuel wood for space heating, extra provisions must be kept in rural areas.

Kerosene is the second type of energy used for lighting in rural households. As sampled, the six villages are totally un-electrified and 100% of the rural households depend on kerosene for space lighting. Daily consumption of kerosene was obtained in volumetric measurements, which were later converted into annual consumption.

The available energy sources that are lying untapped in these villages have been estimated.

Table 1
Features of the six un-electrified villages in Jorhat district

Serial no.	Description	G	K	8No.	NJ	UP	Nam
1	Village	Gariabhonga	Khongia	8 No. Spur	Na-Jankhona	Upper-Deorigaon	Nam-Deorigaon
2	Population	450	704	904	195	1200	2505
3	Sex ratio	58:42	54:46	57:43	56:44	52:48	52:48
4	Average family size	9	8	8	13	16	15
5	Operational land holdings						
	Total cases (% of households)	47	84	108	14	72	160
	Large farmers, >20 acres[a]	17	20	26	21	21	19
	Medium farmers, 7–20 acres	32	30	30	29	35	35
	Small farmers, <7 acres	43	45	37	43	39	36
	Landless	10	4	7	7	6	10
6	Land utilization pattern (acres)						
	Total land owned	176	452	678	67	532	1237
7	Net cultivated area						
	Rice (*kharif*)	166	435	669	54	520	1211
	Rabi	-	-	-	-	2	3
8	Type of crops	Paddy	Paddy	Paddy	Paddy	Paddy Mustard Pea Gram	Paddy Mustard Pea Gram

[a] 1 acre=0.405 hectares.

Since rice is the main agricultural crop in rural areas, total residue production has been estimated by using a standard residue to grain ratio [6]. Rice straw production is estimated separately as post harvest and left-over.[1] Later, available energy from rice residues was obtained by deducting non-fuel uses. Available energy from cow dung was estimated after deducting its non-fuel uses such as manure. Hence, all of the physical units were converted into energy units for domestic consumption and availability.

[1] *Straw that is left in the field after harvesting*

3. Results and discussion

3.1. Domestic energy consumption

The energy consumption pattern in rural domestic sector is mainly for three end uses: cooking and water heating, space heating and space lighting.

3.1.1. Cooking and water heating (combined), space heating

Table 2 presents the yearly per capita energy consumption for combined cooking and water heating in summer and winter months in the six villages. It is clear from Table 2 that the consumption of energy is not uniform throughout the year. The yearly per capita energy consumption for cooking and water heating (combined) and space heating in Upper-Deorigaon is found to be 42% more in winter than in summer. In Nam-Deorigaon, it is estimated at 40.6% more; in Na-Jankhona it is found to be 27.9% more; in 8 No. Spur it is estimated as 24.8% more; in Khongia it is estimated as 22.6% more; and in Gariabhonga, 21.5% more energy is found to be consumed in winter than in summer. The reasons for consuming more energy in winter are the need for space heating, a change in food intake, more time needed to boil water due to low pressure and temperature, and the need for more hot water in bathing, etc.

Firewood is the most common domestic energy source in the six villages. Table 2 shows that the yearly per capita energy consumption in cooking, water heating and space heating is greatest in Upper-Deorigaon, then Nam-Deorigaon, Gariabhonga, Khongia and Na-Jankhona, with the minimum consumption in 8 No. Spur. The variation of energy consumption for cooking, water

Table 2
Consumption of domestic energy in GJ/year for cooking and water heating (combined), space heating and space lighting

Village[a]	Cooking and water heating (fuel wood)		Space heating in winter (fuel wood)	Space lighting (kerosene)	Gross consumption
	Summer	Winter			
G	2195.20 (4.88)[b]	2201.35 (4.89)	466.92 (1.04)	67.584 (0.15)	431.054 (10.95)
K	3181.84 (4.52)	3005.73 (4.27)	892.03 (1.27)	91.84 (0.131)	7171.44 (10 19)
8No.	2988.92 (3.31)	3026.71 (3.35)	706.68 (0.782)	60.65 (0.067)	6728.96 (7.50)
NJ	734.88 (3.77)	789.09 (4.05)	150.72 (0.773)	54.28 (0.28)	1728.97 (8.87)
UP	6263.84 (5.22)	6621.80 (5.52)	2273.94 (1.89)	70.54 (0.059)	15,230.13 (12 69)
Nam	13,032.51 (5.20)	13,223.10 (5.28)	5075.67 (2.03)	91.64 (0.0366)	31,422.92 (12 54)

[a] See Table 1 for abbreviations used.
[b] Figures in parentheses represent energy consumption in GJ/capita/year.

heating and space heating may be due to (1) family size, (2) availability of fuel wood and (3) differences in food habits.

Table 1 shows that average family size in Upper-Deorigaon is the highest, with Nam-Deorigaon, Na-Jankhona, Gariabhonga, Khongia and 8 No. Spur following. The domestic energy consumption in cooking, water heating and space heating in Upper-Deorigaon and Nam-Deorigaon is directly related to the average family size. Although Na-Jankhona is third in average family size, it was ranked fifth in domestic energy consumption because Na-Jankhona is an economically and agriculturally backward village. From Table 1 it is clear that Na-Jankhona is endowed with the lowest amount of cultivated land.

It was observed that the northern side of all of the six villages is free from forest as they border the river Brahmaputra on that side. The southern and western sides of Upper-Deorigaon and Nam-

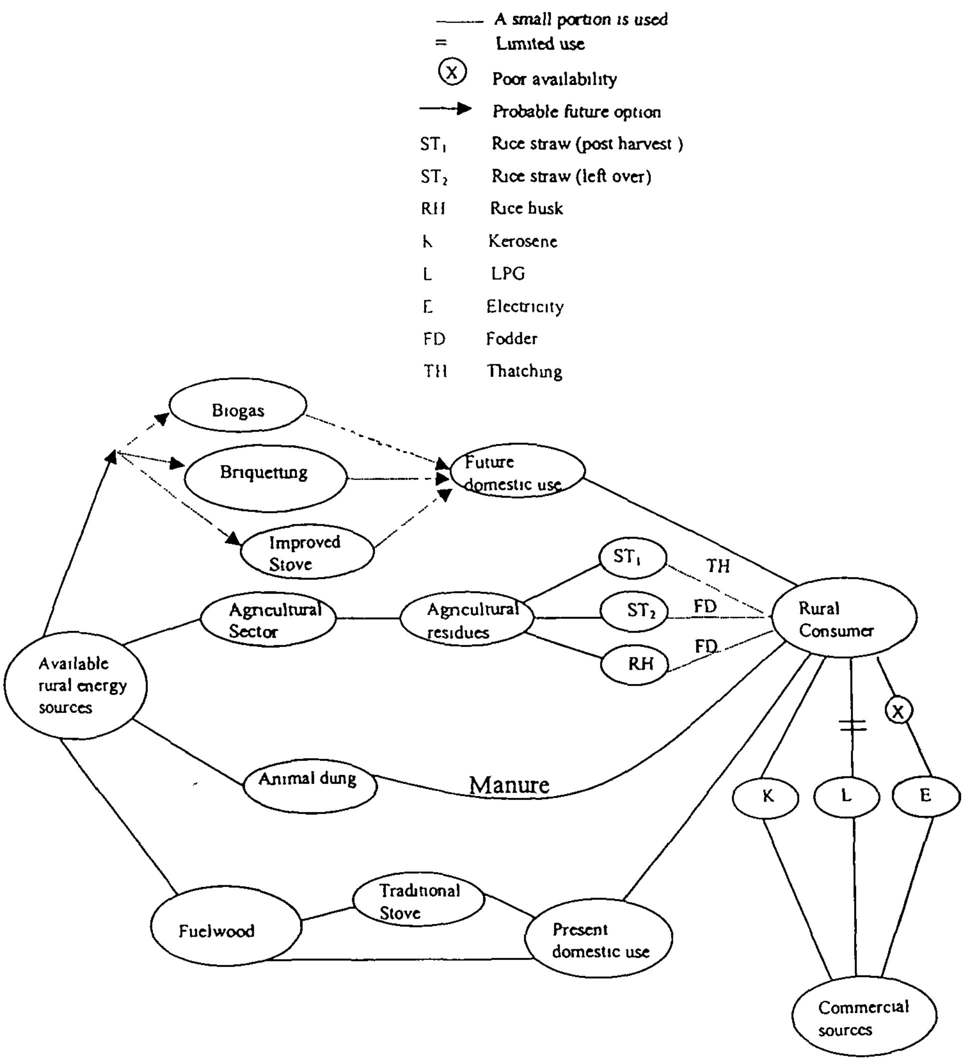

Fig 1 Present and probable future-use scenario of energy valid for rural north-east India

Deorigaon, however, are surrounded by a dense forest cover which provides easy availability of fuel wood and this encourages more domestic energy consumption

The variation of energy consumption in cooking, water heating and space heating is influenced by differences in food habits as well Rice is the chief food in Assam The people of Upper-Deorigaon and Nam-Deorigaon have a habit of taking three meals a day while the people of the other four villages have a habit of taking two meals a day Tea is the common beverage in all six villages Moreover, the people of Upper-Deorigaon and Nam-Deorigaon are regular drinkers of a liquor called '*apong*' that is made from cooked rice

3 1 2 Space lighting

The requirement for domestic lighting in the six villages is met by kerosene Table 2 shows yearly per capita kerosene consumption in the six villages The seasonal variation in consumption of kerosene is insignificant in all six villages Variation in yearly per capita energy consumption of domestic lighting is found to be greatest in Na-Jankhona and then in Garabhonga, Khongia, 8 No Spur and Upper-Deorigaon, with the least consumption in Nan-Deorigaon Yearly per capita variation of kerosene consumption in the six villages may be due to differences in (1) availability of kerosene and (2) the number of school-age children

Kerosene is available in the six villages through a public distribution (rationing) system The main occupation of householders of Na-Jankhona is fish selling in the town They procure extra kerosene from the town in addition to that which is rationed The number of school-age children is greatest in Garabhonga and lowest in Nam-Deorigaon

Table 2 shows that per capita yearly domestic energy consumption is greatest in Upper-Deorigaon and least in 8 No Spur The heavy dependence on fuel wood (of the order of 99%) for meeting domestic energy needs in those villages is clearly indicated

3 2 Availability of biomass resources

Table 3 shows rice and residue production in the six villages Daily production of dung and its use in the six villages is presented in Table 4. Table 5 summarizes available energy from rice residues and dung lying untapped after deducting non-fuel uses such as fodder, building material, manure, etc It may be observed from Table 5 that yearly per capita available energy from rice residues and dung is greatest in 8 No Spur and lowest in Na-Jankhona, because 8 No Spur is endowed with more cultivating land (0 74 acre/capita)

3 3 Alternative approaches

Keeping in mind the heavy pressure on per capita fuel wood use and need to properly utilize available agricultural residues and dung, alternative approaches must be carried out quickly and efficiently The traditional wood stove with thermal efficiency ranging from 5 to 10% is not suitable for burning loose biomass directly. Biomass briquettes made through proper technology can be used as cooking fuel in the domestic sector, however Accordingly, efficient, smokeless, biomass-briquette-burning stoves with 25% thermal efficiency can be developed to meet the need and demand of fuel wood Likewise, installation of biogas plants with 50% thermal efficiency will not only help in using available biomass, but also will result in fuel wood savings However,

Table 3
Rice and residue production in the six villages

Village[a]	Rice produced (tonne/year)	Rice husk[b] (tonne/year)	Straw[c] (post harvest (tonne/year)	Straw[d] (left-over) (tonne/year)	Use of rice residues (tonne/year)			
					Husk as fodder	Straw as fodder	Thatching	Fuel
G	219	88	146	467	-		-	
K	574	230	382	1225	-	-	-	
8No	883	353	588	1884	-	-	-	
NJ	71	28	49	151	-	-	-	
UP	686	274	457	1464		0 5	-	
Nam	1598	639	1064	3410		1 0	-	

[a] See Table 1 for abbreviations used
[b] Husk grain=0 4 1 00
[c] A head load of paddy bundle (locally called *dangori'*) produces 10 kg of straw
[d] 1 acre of land produces 2816 2 kg of left over straw

Table 4
Daily production of dung and its use

Village[a]	Total production of wet dung (kg)	Use of dung as manure (kg/day)
G	667 12	390 00
K	889 22	157 50
8No	1318 66	948 80
NJ	289 66	141 65
UP	1775 44	820 68
Nam	3713 60	2015 60

[a] See Table 1 for abbreviations used

in order to strengthen these programmes, the awareness and participation of the rural population is necessary The present and probable future-use scenarios of energy valid for rural north-east India are presented in Fig 1

4. Conclusions

The large-scale consumption of fuel wood in all of the villages and the wastage of biomass indicate a heavy loss of energy in rural areas There is an urgent need to strengthen briquetting technology, improve stoves and introduce biogas programmes for efficient use of energy sources in rural north-east India

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Table 5
Available energy from rice residues and dung in the six villages in GJ/year

Village[a]	Rice husk	Rice straw (post harvest)	Rice straw (left-over)	Dung	Available energy	Available energy (GJ/capita/year)
G	1258 40	1956 40	6257 80	910 64	10,383 24	23 07
K	3289 00	5118 80	16,415 00	2404 69	27,227 49	38 68
KNo	5047 90	7879 20	25,245 60	1215 00	39,387 70	43 57
NJ	400 40	656 60	2023 40	486 22	3566 62	18 29
UP	3918 20	6123 80	19,617 60	2136 48	31,796 08	26 50
Sam	9137 70	14,257 60	45,694 00	5576 16	74,665 46	29 81

[a] See Table 1 for abbreviations used

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APPENDIX – I

INFORMATION ITEMS COVERED IN THE SURVEY

Village Schedule

Location of the village

General characteristics

i) Distance from the block

ii) Status of irrigation

iii) Status of education facilities – primary school, high school etc.

iv) Primary health center

Demographic characteristics

i) Population

ii) Number of households

Land particulars

i) Cultivable land

ii) Forests

iii) Pastures etc.

iv) Number of households with large farms, small farms, marginal farms and landless

Type of crops sown

Types of animals

Fuel types

Household Schedule

Demographic details

i) Household size

ii) Number of school going children per household

Land particulars

i) Cultivable land

ii) Forests

iii) Homestead gardens

Crop particulars

i) Type of crops

ii) Area of cropping

iii) Yield

Livestock particulars

i) Number of animals

ii) Dung output

Domestic energy consumption

i) Consumption of biomass fuels such as dung, crop residues, fuel wood (twigs, branches, bushes etc)

ii) Consumption of commercial fuels such as kerosene, electricity

iii) Different end uses such as cooking, water heating, space heating and space lighting

(These data were collected for summer and winter months to capture seasonal variations)

iv) Domestic fuel technology

v) Combustion practice

vi) Fuel wood collection activities

a) Distance covered in collection

b) Hours spent in collection

c) Frequency of collection

d) Specific problems cited in collection

APPENDIX – II

Information items for comparison of domestic energy consumption in rural, semi-urban and urban sectors

Distance from the town

Population

Type of fuel used

- i) Fuel wood
- ii) Kerosene
- iii) LPG
- iv) Electricity

Quantity of fuel used/day (LPG, kerosene, fuel wood and electricity)

- i) Fuel wood, kg/day/HH
- ii) Kerosene kg/day/HH
- iii) Number of LPG cylinders/month/HH
- iv) Unit of electricity consumption/months/HH

End use of different fuels

Type of stoves used (3-brick, traditional, kerosene, LPG, improved)

Type of appliances used in domestic lighting

Hours of failure of electricity

Number of households in different income groups

- i) Low < Rs. 6000
- ii) Lower medium Rs. 6000-18000
- iii) Upper medium Rs. 18000-24000
- iv) Higher > Rs. 24000

Hours spent by women in cooking

- i) Whole day
- ii) 4 to 5 hours
- iii) 3 to 4 hours
- iv) 2 to 3 hours
- v) 1 to 2 hours
- vi) No response

APPENDIX – III

Statistical techniques

1. The computing formulae for analysis of variance (ANOVA) are :

$$\text{Total sum of squares, } SS_T = \sum x^2 - \frac{(\sum x)^2}{N}$$

$$\text{Sum of squares between groups, } SS_B = \frac{(\sum x_1)^2}{N_1} + \frac{(\sum x_2)^2}{N_2} + \ldots\ldots + \frac{(\sum x_K)^2}{N_k} - \frac{(\sum x)^2}{N}$$

Sum of squares within groups, $SS_W = SS_T - SS_B$

Degree of freedom between groups, $df_B = k - 1$

Degree of freedom within groups $df_W = N - K$

Mean square between groups $MS_B = \frac{SS_B}{df_B}$

Mean square within groups $MS_W = \frac{SS_W}{df_W}$

Where, k = number of groups, N = total number of observation

$$F - \text{ratio} = \frac{MS_B}{MS_W} \text{ with df} = k - 1, N - k$$

2. Pearson's product moment co-efficient of correlation (r)

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{N}}{\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{N}\right]}$$

Where, r = Co-efficient of correlation between X and Y

X = Independent variables (average population, monthly average income, etc.)

Y = Dependent variable (rural domestic energy consumption)

ΣXY = Sum total of product of X and Y

ΣX_2 = Sum total of squares of X

ΣY_2 = Sum total of squares of Y

N = Number of observations

3. Fisher/s 't' ratio

$$t = \frac{\sqrt{N-2}}{\sqrt{1-r^2}} \text{ with } N-2 \text{: degree of freedom}$$

Where, r = observed correlation co-efficient

N = number of observations

4. 't' test for testing of significance of partial co-efficients

$$t = \frac{bi}{S.E.(bi)} \text{ with } (N-k) \text{ d.f.}$$

Where, bi = partial co-efficient of respective independent variables

i = 1, 2, 3, ..., k

k = number of independent variables

N = number of observations

SE(bi) = standard error of bi

d.f. = degree of freedom

5. Analysis of variance (ANOVA)

APPENDIX – IV

PROXIMATE ANALYSIS OF THE FUEL BRIQUETTES

The moisture content of the fuel briquette was determined by taking 1-2 g of fuel briquette in a crucible and drying it at 105 ± 5°C for 3 hours. The loss in weight represents the moisture content of the fuel. The volatile matter was determined by placing a weighed quantity of powdered fuel in the crucible, covering with a lid, in a furnace at a temperature of 750°C for 6 min and 950°C for 6 min. The loss in weight represent the volatile matter. The ash content was determined by placing a weighed quantity of powdered fuel in a open crucible in a furnace at a temperature of 700°C for 3 hours. The fixed carbon was determined by subtracting the sum of moisture, volatile matter and ash content from 100.

Water equivalent of calorimeter

Weight of crucible	11.55 g
Weight of benzoic acid	0.675 g
Weight of fuse wire	15 mg

Calorimeter reading :

Time interval (min)	Temperature rise (°C)
0	0.10
1	0.105
2	0.11
3	0.12
4	0.125
5	0.13 (t_o)
6	1.4

7	1.5
8	1.76
9	1.89
10	1.96
11	2.0
12	2.3
13	2.35
14	2.25
15	2.1 (t_n)
16	2.06
17	1.98
18	1.96
19	1.945
20	1.923
21	1.88
22	1.875
23	1.85
24	1.83
25	1.515
26	1.79
27	1.76
28	1.745
29	1.73
30	1.715

Uncorrected temperature rise = $t_n - t_o$

For water equivalent = 2.1 – 0.13 = 1.97°C

So, water equivalent of calorimeter

$$m_c = \frac{H.C.V x\ m_f + m_{wf}\ x C.V.}{\theta} - m_w$$

Where, H.C.V. = Higher calorific value of Benzoic acid

= 6325 kcal/kg-°C

m_f = Mass of fuel = 0.675 x10^{-3} kg

m_{wt} = Mass of fuse wire = 15 mg = 15 x 10^{-6} kg

C.V. = Calorific value of fuse wire = 335 kcal/kg=°C

θ = Uncorrected temperature rise = 1.97°C

M_w = Mass of water = 2.009 kg

$$\therefore \ mc = \frac{6325 \text{ x } 0.675 \text{ x} 10^{-3} + 15 \text{ x } 335}{1.97} - 2.009$$

$$= 0.1607 \text{ kg.}$$

Observation of temperature rise for finding out higher calorfic value of fuel briquette :

Time interval (min)	Temperature rise (°C)
0	0.600
1	0.658
2	0.665
3	0.675
4	0.687
5	1 58
6	1 78
7	1.94
8	2.080
9	2.110
10	2.125
12	2.128
13	2.130
14	2.138

15	' 2.09
16	2.08
17	2.068
18	2 05
19	2.03
20	2.01
21	1 998
22	1.988
23	1.97
24	1.969
25	1.957
26	1.932
27	1.90
28	1.88

∴ Uncorrected temperature rise, $(t_n - to)$ $= 2.138 - 0.687$

$= 1.451°C$

∴ Higher calorific value of fuel briquette (Straw + Cowdung)

$$H.C.V = \frac{(m_w + m_c)\,\theta - m_{wf} \times C.V.}{m_f}$$

where, m_w = mass of water = 2.009 kg

m_c = water equivalent of calorimeter = 0.1607 kg

θ = uncorrected temperature rise for = 1.451°C fuel briquette

M_{wf} = mass of fuse wire = 15 mg = 15×10^{-6} kg

m_f = mass of fuel briquette = 1.3 g = 1.3×10^{-3} kg

C.V = calaific value of fuse wire = 335 Kcal/kg°C

[By heat balance, Heat given by the fuel due to combustion + Heat given by the combustion of fuse wire = Heat absei ved by the water and the calorimeter

$m_f \times H\,C\,V + m_{wf} \times C\,V = (m_w + m_c)\, C_{pw} Q$

C_{pw} = Specific heat of water at constant pressure

= 1 kcal/kg-°C]

$$H\,C\,V = \frac{(2\ 009 + 0\ 1607) \times 1\ 451 - 15 \times 10^{6} \times 335}{1\ 3 \times 10^{3}}$$

$= 2417\ 85$ kcal / kg

$= 10\ 125$ MJ / kg