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Determination of Energy requirement for cooking in Rural Household of Orissa, India

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ABSTRACT

In rural areas, domestic cooking fuels emphasize the predominance of wood, animal residues, and bio-mass etc. These are also in short supply, because of quantum of energy input, those are locally available at zero-cost and manner of their use. This research study aims at determining actual fuel energy requirement to meet the cooking need of rural household in Orissa. The work was carried out in three steps; Data collection for determining the common food items of rural household, observation for determining energy requirement for cooking in field condition, and experiment for determining actual energy requirement in controlled laboratory condition. Households from both coastal and hilly region were selected for such purpose. The results revealed that available energy i.e. energy input per day was more in comparison to actual energy requirement for cooking common food items. The available energy expenditure was influenced significantly by family size and farm size, but useful energy expenditure was influenced by only family size. Size of landholdings, and types of location had a significant effect on determination of cooking energy efficiency. In the study coastal area household had a higher efficiency than hill households. Standardization of cooking for a standard meal in different Chula design and different pot design in controlled condition revealed that very less energy input was required for cooking in comparison to energy input measured in village condition. The efficiency was maximum 17.484% in improved Chula and 13.704% in traditional wooden Chula, against actual requirement cooking efficiency was found 3.25%, where loose bio-mass was used as fuel. (Maximum 5.305 MJ was required for cooking of a standard meal). Hence it indicate the wastage of energy during cooking in village condition against the actual requirement.

Key words: Cooking energy, Common food items,Available energy, Useful energy, fuel efficiency

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INTRODUCTION

In India share of fossil energy is 79.85 %(2015-16)[1]in electricity sector.In rural India, fire wood and chips was used in 2009-10 as principal source of energy for cooking by more than three-quarters (76.3%)of house hold, lpg by 11.5%and dung cake by 6.3%. About 1.6% of house hold did not have any arrangement for cooking. The consumption also vary according to economic level, occupational and social group(data asper NSS 66th [2]**.** The rural settlement are wood and cow dung as major sourceof fuel,eventhoughstrawand other loose bio-mass are abundantly available at zero prices,because of its bulky nature, and high moisture content,very low thermal efficiency and wide scale air pollution. The conversion efficiency is as low as 40%. Though bio-mass is available at a low price or at a zero price, people have to spend considerable time and energy to procure them. Under such situation, there is a need for improving energy management at individual household level and conserve them. In the rural area, women are the ultimate dispenser and users of energy. They are over-burdened at home and agricultural field. Within a family, collection of house-hold items like food, fuel, fodder and water are left to woman. The maximum impact of deforestation is felt on rural women, irrespective of their income, family size and landholding. But the felt needs, perceived by them, are shortage of income and food rather than energy. It is therefore necessary to educate them and involve them in energy related matters, concerning housekeeping's. George J. [3] studied,the major source of energy were firewood, shrubs and crop residues, dung cake etc. The average annual household energy consumption varied from 24.2 GJ to 24.6 GJ. The useful energy consumption increased as the income level increased. This research study aimed at determining actual energy requirement for preparation of a standard mealby a rural family. Dendukuri. G., (1981-89)[4] studied that in semi-arid regions, more than 75 % of total household energy consumption (24-53 GJ per year) was from non-commercial fuel sources viz. firewood, crop residues and animal dung. Percapita energy use for cooking ranges from 4.4 to 8.8 GJ per year in millet eating areas and was more than twice the energy consumption levels of 2 to 4 GJ in the rice eating areas. Although the biomass productivity was lower in the former areas, the annual fuel saving was estimated to be 0.3 to 0.5 tonnes of firewood per household because of the use of improved chulhas.This research study aimed at determining actual energy requirement for preparation of a standard meal by a rural family.

MATERIAL AND METHODS

The research wok was carried out in three different stages

Data collection –To know the common food items of rural household,which serve as the basis for determination of cooking energy,data collection was done through survey method.295 samples from different categories of farming household according to landholdings(50%from each categories) were selected randomly from four villages of two blocks,where blocks were selected randomly from hilly and costal districts of Orissa to bring homogeneous in nature. Common food items considered in the study as the number of food items which are consumed more than four times in a week.

Field Experiment-To determine the available energy required for preparation of common food items,a detail study was done among selected 48 families (12nos from each districtsFig.1)Selection was done on the basis of land holdings and family size.Measurement of input of fuels was done starting from the cooking procedure, along with the weight of food ingredients, cooking style, temperature of the cooking foods was recorded in every 5 minutes time intervals. Energy supplied and fuel energy required were calculated by using following formulae.The available fuel energy required for cooking was determined.

Supplied energy (Available energy)= Quantity of fuel (kg) x Fuel calorific value (MJ/kg)

Fuel (Heat) energy required (**useful energy**) = $m \triangle Cp \quad T\ t$

Where m = Weight of the food cooked (kg)

Cp = Specific heat of the food

$\triangle$T= Temperature difference

t = Time duration (sec)

Lab Experiment Under Controlled Condition

Standardization of cooking method indicating the actual energy requirement for common food item in the rural area for a standard family size i.e. family consisting of 5-6 adult members, where 2 primary school children are considered as one member.

A standard meal was prepared 3 times in the existing traditional chulha and in the energy efficient chulha (Harsha chulha) with varying vessel shapes i.e. flat bottom and round bottom.

The cooking method was standardized keeping in view all the parameters for conservation of fuel and eliminating the points of wastage. Following fuel saving practices were taken care of in the controlled cooking method.

Pre cooking Method

a) Soaking of cereal grains and pulses

b) Size reduction by cutting , grinding, pounding

Cooking Method

a) Using shallow vessels which cover the flame

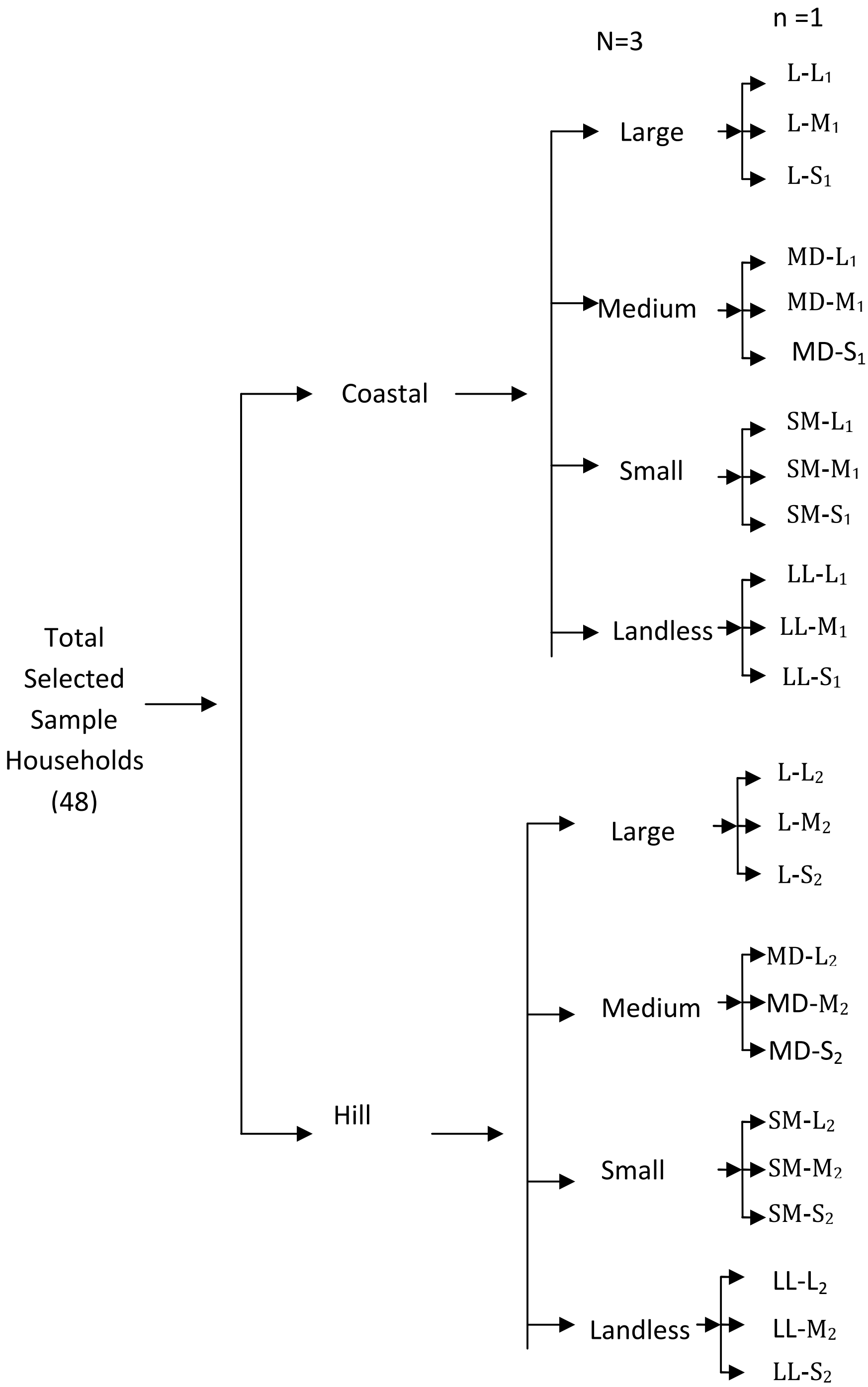
b) Covering the cooking utensils with a lid

c) Using just enough water
d) Lowering flame once boiling point is reached
e) Using aluminium vessels for better heat transfer

Fuel use Methods

a) Cutting logs into shorter and thinner pieces
b) Using dry fuels

Fig.1 Selection of Households for Field Experiments



(L = Large family (above 10); MD = Medium Family (6 to10); SM = Small family (up to 5))

RESULTS AND DISCUSSION

Profile of farm women (respondents) revealed that majority of selected village women were in the age group of 25 to 40 years of age and low education.

Table : 1 Food Consumption Pattern of Sample Households

Area →	% of Households					
	HILL		COASTAL		TOTAL	
Frequency of use /week → Food Item ↓	0-3	4 & above	0-3	4 & above	0-3	4 & above
RICE	0.000	100.000	0.000	100.000	0.000	100.000
DAL/DALMA	30.769	69.231	16.832	83.168	26.014	73.986
VEGETABLE	0.000	100.000	0.990	99.010	0.338	99.662
FISH	73.333	26.667	70.297	29.703	72.297	27.703
CHAPATI	97.949	2.051	97.030	2.970	97.635	2.365
FRY	23.077	76.923	54.455	45.545	33.784	66.216
TRADITIONAL CAKE	100.000	0.000	100.000	0.000	100.000	0.000
MEAT	100.000	0.000	100.000	0.000	100.000	0.000
MILK	74.359	25.641	50.495	49.505	66.216	33.784
MILK PRODUCT	99.487	0.513	98.020	1.980	98.986	1.014

As the villages were paddy cultivated areas, all most all the respondents were rice eater. Hence the data on chapatti consumption was less than 3 times in a week for maximum families. Some family members were taking chapati during breakfast with tea. As frequently consumed items, those were taken more than four times in a week were taken as common foods. Hence for the data rice, dal / dalma, mixed vegetable curry, a fry (vegetable fry or fry of greens) were listed as common food items.

Common Food Items

Table :2 Identified Common Food Items In Rural Households (%)

Area → Food Item ↓	HILL	COASTAL	IN GENERAL
RICE	100.000	100.000	100.000
DAL/DALMA	69.231	83.168	73.986
GETABLE CURRY	100.000	99.010	99.662
FRY ITEM	76.923	45.545	66.216

Table:2 shows the common food items in rural households. All the sample families were rice- eater. Apart from rice all the families of hilly and 99 % families of coastal consumed vegetable curry with the rice. About 73.98 % families of rural area choose dal / dalma (combination of dal and varities of vegetables)as the common food items

FIELD EXPERIMENTS

Common food items (as explained in the methodology) served as the basis for comparing the energy requirement for cooking among various categories of households.

Determination of Available Energy

Table : 3 Available Energy For Preparation of Common Food Items In Rural Areas (in MJ / Household / Day)

CATEGORY OF FARMERS → / FARM FAMILY SIZE ↓ (no. of members)	LANDLESS	SMALL (< 2.5 acres)	MEDIUM (2.5 acres ≤ X < 5)	LARGE (≥ 5 acres)
SMALL (1 - 5)	76.577 *62.641*	72.999 *92.905*	77.054 *90.924*	78.330 *109.967*
MEDIUM (6 – 10)	84.445 *79.440*	90.574 *95.142*	94.384 *103.871*	98.560 *98.464*
LARGE (> 10)	89.769 *112.446*	104.178 *118.516*	97.753 *116.608*	106.719 *131.954*

1st Row of each cell represents data from Coastal Areas
2nd Row of each cell represents Data from Hilly Areas

The available energy i.e., fuel energy supplied presented in the **Table 3.** The energy consumption or energy supplied per day was more for hill area family than coastal family. It might be the reason that the fuel availability was more in that region or the housewives were not aware about fuel saving practices. When the available fuel energy among four different landholding categories of both the areas were compared, no trend was seen; but the energy input increased slowly, as the farm-size increased, except few categories. But the available fuels from various sources, described on survey did not have any impact on amount of available energy used. The housewives were consuming fuels according to their requirements. Their percapita per day energy expenditure varied from minimum 72.999 MJ (SM-S_1) to maximum 131.954 MJ (L-L_2).

The data indicate that, in hilly as well as coastal area, among all the categories, the fuel energy supplies increased as the number of family members increased. Only one exception was noticed among L-L_2. Though the energy supply was 109.967 MJ / day in L-S_2 and 131.954 MJ / day in L-L_2 but only 98.464 MJ / day was recorded in the family having members 6-10 numbers. The awareness regarding fuel saving practices might be the reason for this.

Hence available energy or energy expenditure was influenced by family size-wise, farm size-wise, and location wise.

Useful Fuel Energy

Table : 4 Useful Fuel Energy Required For Common Food Preparation In rural Areas (MJ / Household / Day)

CATEGORY OF FARMERS → / FARM FAMILY SIZE ↓ (no. of members)	LANDLESS	MARGINAL (< 2.5 acres)	SMALL (2.5 acres ≤ X < 5)	LARGE (≥ 5 acres)
SMALL (1 - 5)	1.542 *1.501*	1.739 *1.544*	1.791 *1.46*	1.702 *1.725*
MEDIUM (6 – 10)	2.052 *1.702*	2.006 *2.186*	2.096 *1.893*	2.134 *1.993*
LARGE (> 10)	2.921 *2.595*	2.64 *2.785*	2.797 *2.941*	2.852 *3.271*

- 1st Row of each cell represents data from Coastal Areas
- 2nd Row of each cell represents Data from Hilly Areas

Table -4 states the useful energy for preparation of common food items in the same selected households.No significant difference was found in the useful energy requirement among the families of various categories of landholdings in both hill and coastal region. In coastal area, minimum energy requirement was recorded for LL-S1 (1.542 MJ) and maximum 2.921 MJ was recorded for LL-L_1. It might be because, the actual fuel requirement increases, when more amount of raw materials were cooked in the same environment.

In hill area, the minimum data recorded was 1.46 MJ for MD-S_2 and maximum 3.271 MJ for L-L_2. No particular trend was marked among the families of various landholdings. But the actual energy expenditure was more as the family members increased irrespective of their land size. Hence useful energy varied according to family size.

Fig:2Comparison of Available and Useful Energy (in Coastal Areas)

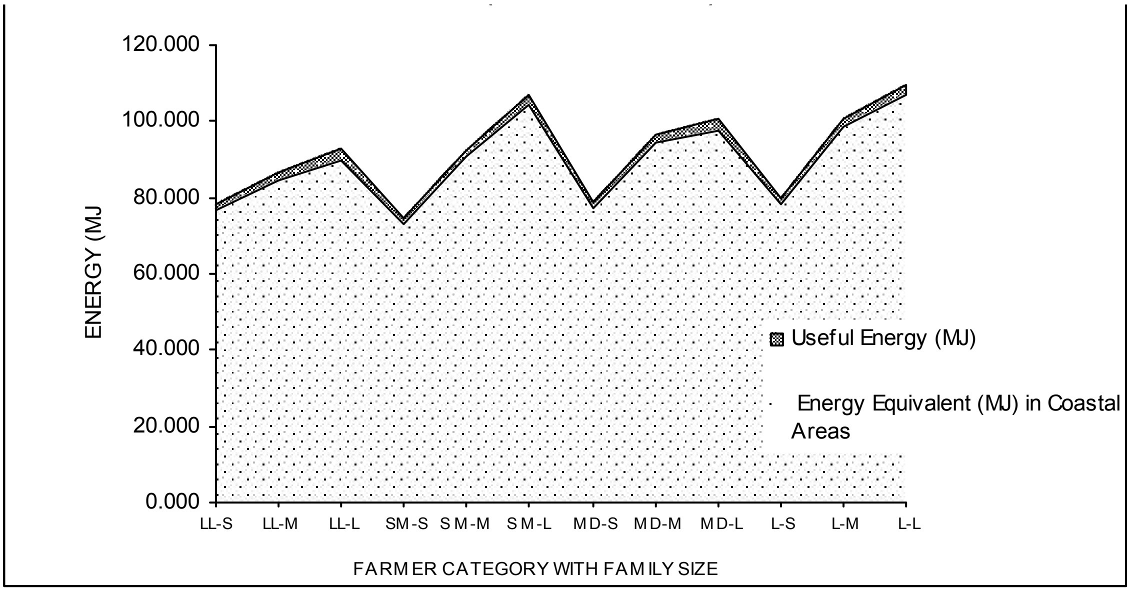


Fig:3 Comparison of Available and Useful Energy (in Hilly Areas)

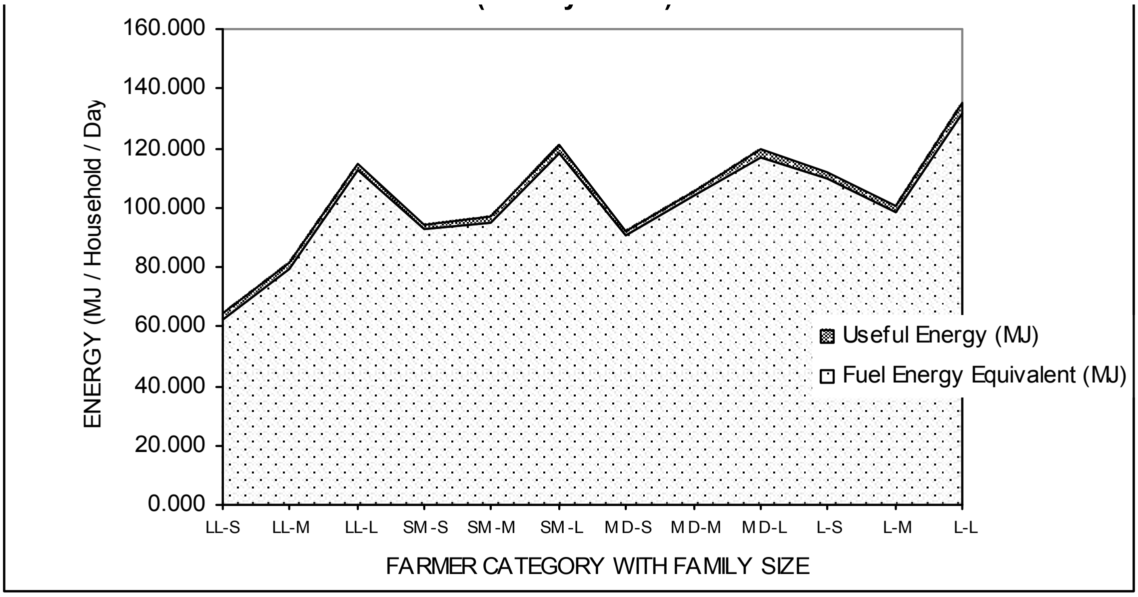


Fig: 2 and Fig: 3 compare the proportion of utilized energy to available energy and show the maximum wastage might be due to chulha design, pot design, fuel types, raw materials and awareness of fuel saving practices

Fig:4Comparison of Energy Input Among Various Family Size of Sample House Holds

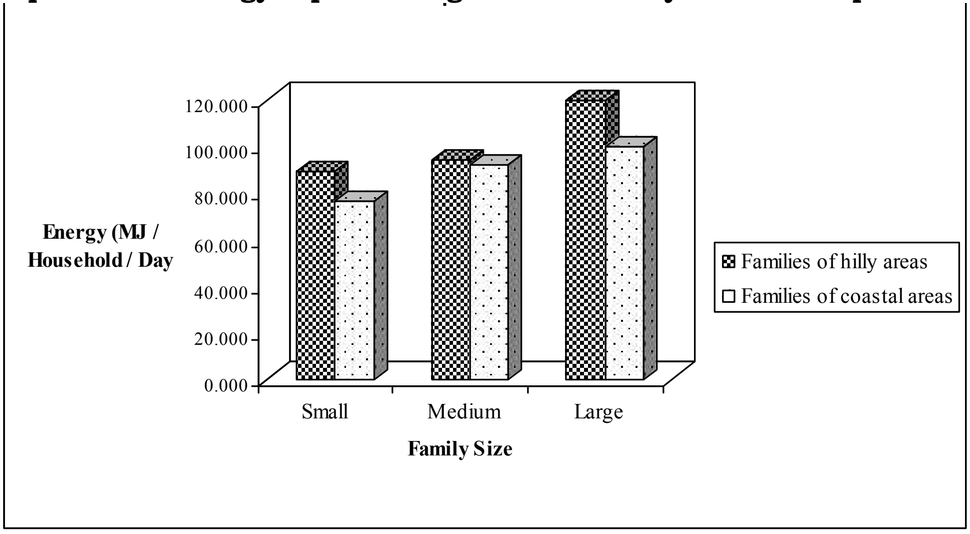


Fig 5: Trend of Change in available Energy Consumption with family size

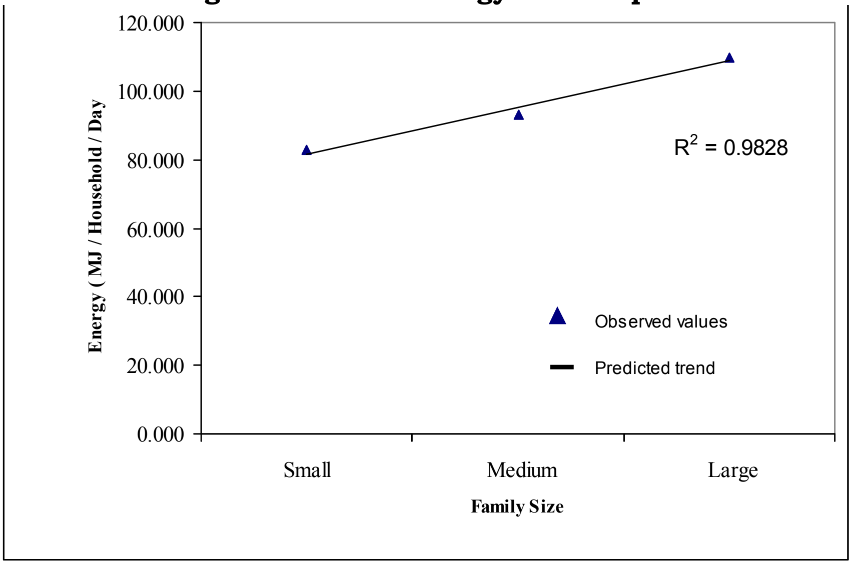


Fig: 4 to 5 compare how the available energy varies significantly because of the impact of family size and land holding size.

Fig: 6 Available Energy Consumption among Different Farmers

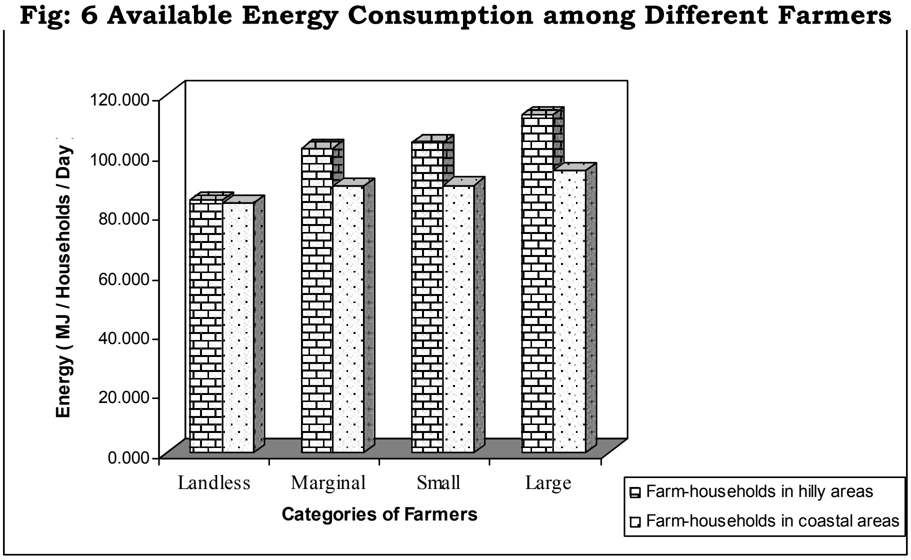


Fig: 7 Trend of change in Available energy consumption with land holding

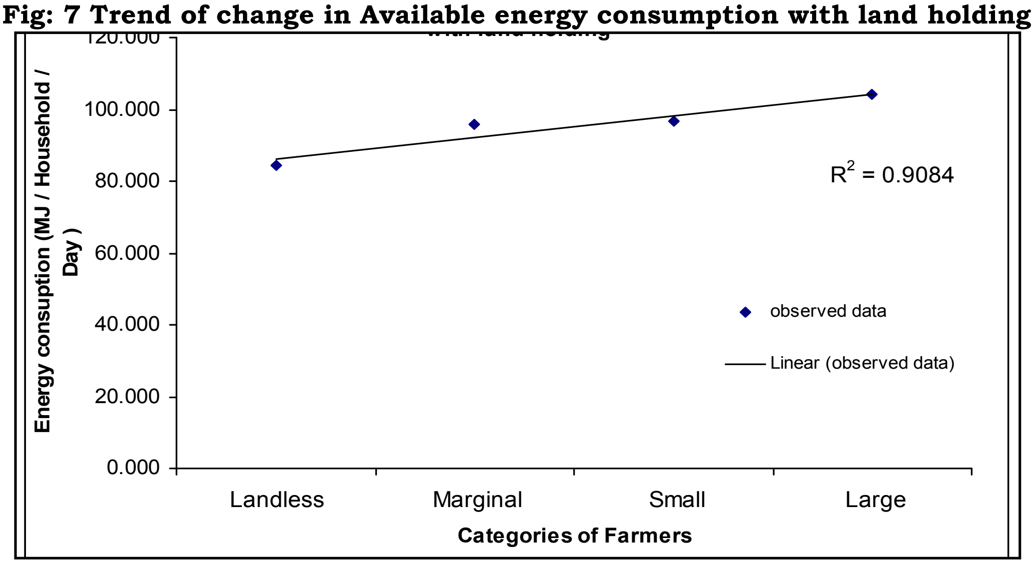


Fig: 8 Changes of Useful Energy in Cooking among Different Farmer Category

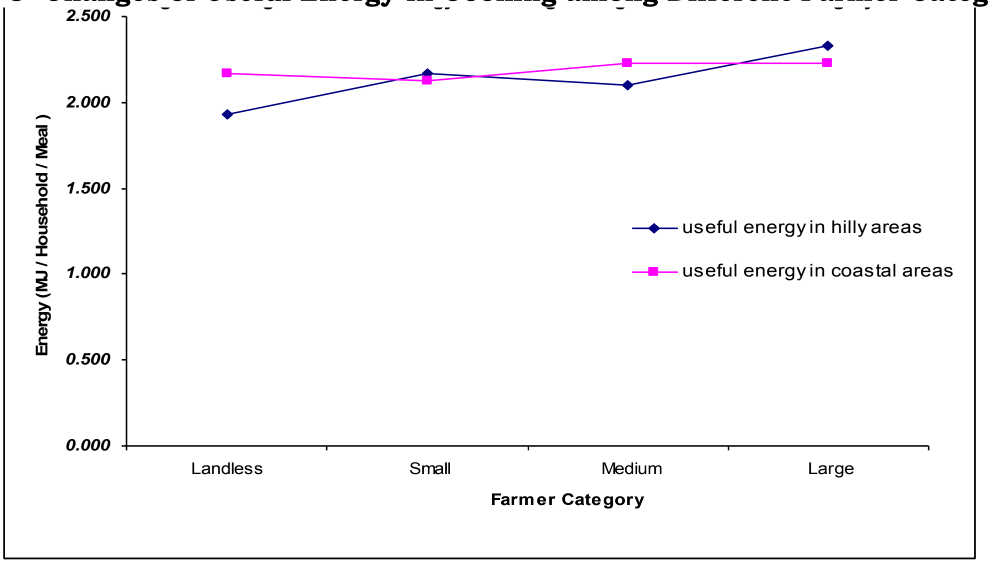
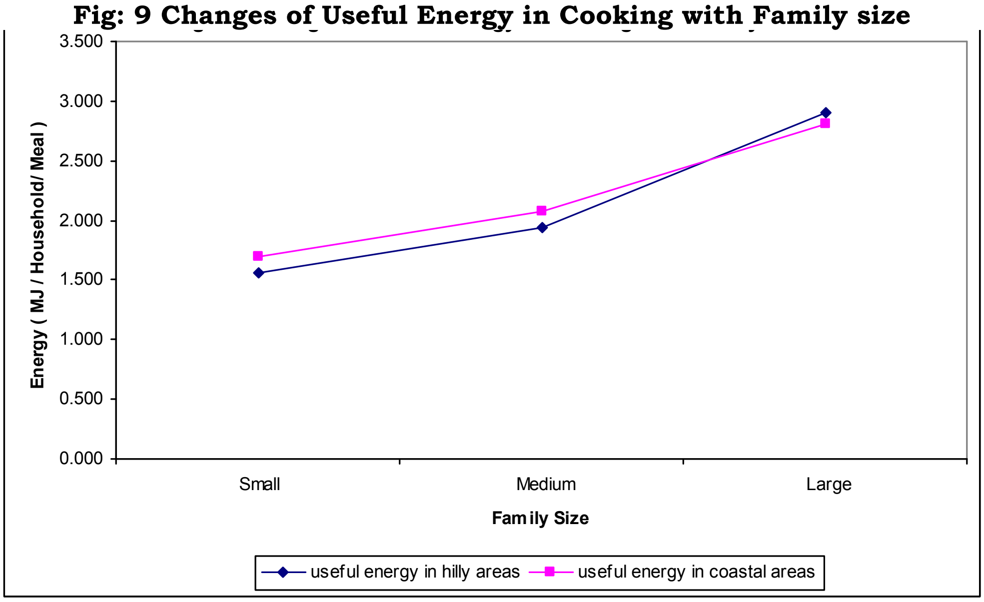


Fig: 9 Changes of Useful Energy in Cooking with Family size



Determination of Fuel Efficiency

Table: 5 Efficiency of Fuel Energy (%) for Preparation of Common Food Items in Rural Areas

FARM FAMILY SIZE (no. of members) ↓	CATEGORY OF FARMERS				
	LANDLESS	**SMALL** (< 2.5 acres)	**MEDIUM** (2.5 acres ≤ X < 5)	**LARGE** (≥ 5 acres)	**AVERAGE**
coastal **SMALL** (1 - 5)	2.014	2.382	2.324	2.173	2.223
hill	***2.396***	***1.662***	***1.606***	***1.569***	**1.808**
coastal **MEDIUM** (6 – 10)	2.430	2.215	2.221	2.165	2.258
hill	***2.142***	***2.298***	***1.822***	***2.024***	**2.072**
coastal **LARGE** (> 10)	3.254	2.534	2.861	2.672	2.830
hill	***2.308***	***2.350***	***2.522***	***2.479***	**2.415**
coastal **AVERAGE**	2.566	2.377	2.469	2.337	2.437
hill	**2.282**	**2.103**	**1.983**	**2.024**	**2.098**

(Fuel Efficiency = Useful Energy/ Available Energy X 100 %)

* 1st Row of each cell represents data from Coastal Areas

* 2nd Row of each cell represents Data from Hilly Areas

It has been seen that fuel efficiency was very low, compared to conventional fuel (average thermal efficiency of electricity is 70 % and 50 -60 % in petroleum products; thermal efficiency of wood 0.17 MJ/ kg and other biomass ranging 0.12 – 0.2 MJ/ kg. Thermal efficiency of fuels in inter and intra regional area both showed not much difference. The efficiency varied from 1.56 – 3.25 % among different land size and family size farm in both the regions. All these consequences might be due to

- use of low efficient and voluminous bio fuels
- use of low efficient of traditional chulha
- lack of energy conservation practices

Hence, in coastal areas maximum thermal efficiency (3.254 %) was found among LL-L_1,

Fig 10: Comparison of Fuel efficiency among Various sizes of Farm Families in Hilly and Coastal Villages

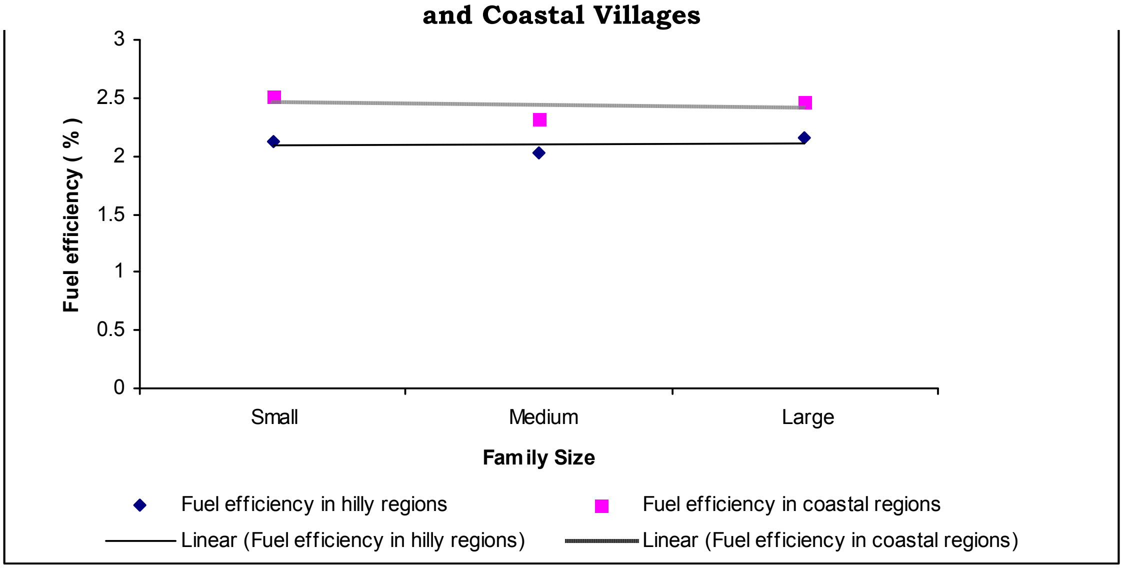
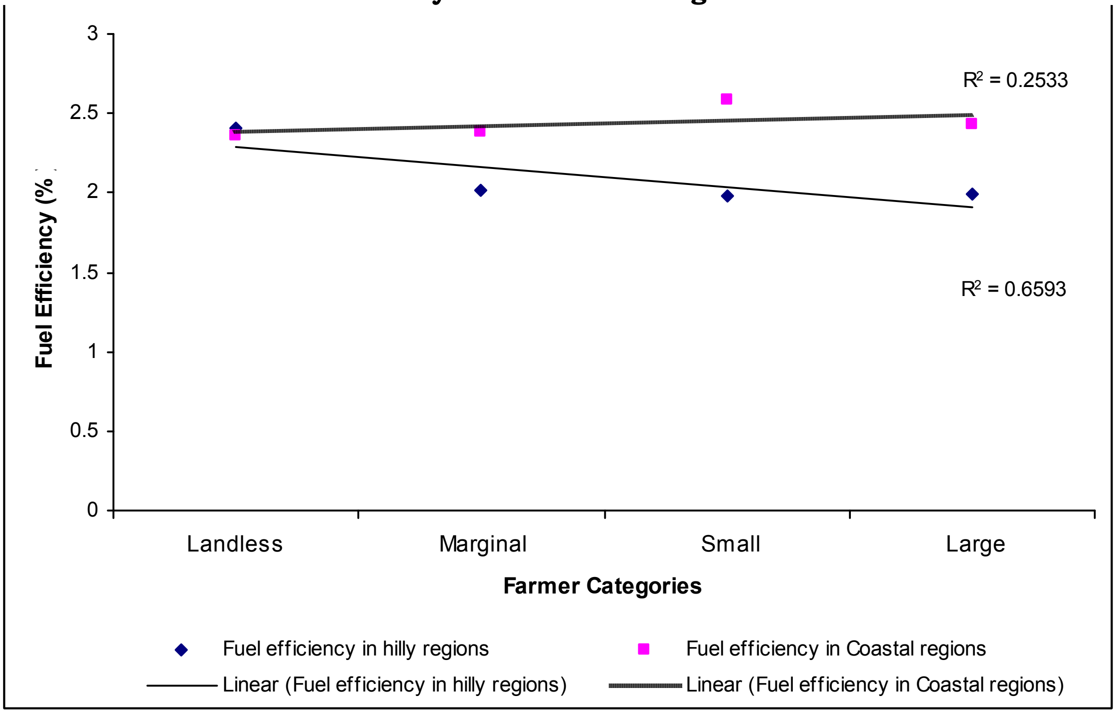


Fig:11 Comparison of Fuel efficiency among Different Categories of Farm Families in Hilly and Coastal Villages



In **Fig 10 & Fig: 11** showed that linear regression lines of fuel efficiency during cooking among different categories of households that family size and landholdings had no significant impact on efficiency. Higher efficiency was seen in coastal area as compared to hilly areas, which might be due to the fact that

- People of hilly areas were mostly dependent upon wood and twigs, which had greater thermal efficiency than any other loose biomass or agriwaste
- the wet woods / bio-fuels used in wet season in the hilly area require additional heat energy for drying.
- The compactness of thick wood makes the energy regulation difficult unless it was made into thinner pieces.
- Fuels were plentily available in the nearby forest.

LABORATORY EXPERIMENTS IN CONTROLLED CONDITION

Table-6Standardization of Cooking For Common Food Preparation according to Chulha Design & Pot Design (wood as fuel)

CHULAH DESIGN	TRADITIONAL 1-POT CHULAH			HARSHA CHULAH		
POT DESIGN	**AVAILABLE ENERGY (MJ)**	**USEFUL ENERGY (MJ)**	**EFFICIENCY (%)**	**AVAILABLE ENERGY (MJ)**	**USEFUL ENERGY (MJ)**	**EFFICIENCY (%)**
ROUND BOTTOM VESSEL	38.667	5.299	13.704	30.342	5.305	17.484
FLAT BOTTOM VESSEL	42.012	5.164	12.292	32.21	5.114	15.877

The result of the cooking method in changing chulha design and pot design, keeping all other associated variables constant is presented in the **Table 6**.
It was observed that energy efficiency in improved chulha (15.877 % –17.484 %) was more than the traditional chulha (12.292 % – 13.704 %). Cooking on round bottom utensils, it was found to be more energy efficient than flat bottom utensils. It has been observed that maximum 5.305 MJ was required for cooking of a standard meal. Hence a major chunk of

energy was being wasted because of inefficient chulha design or utensil type, low thermal efficient biomass fuel etc

CONCLUSION

- There was a wide gap between the energy input (available energy) and energy utilization (useful energy) and a substantial proportion of energy was being wasted because of inefficient chulha design pot design, use of less efficient bio-fuels. 5.305 MJ of energy was required for cooking of a standard meal (common food) under controlled condition.
- The cooking efficiency for preparation of common food using biomass as fuel was very low i .e maximum upto 3.25 %.. Cooking efficiency was more with round bottom utensils in improved Harsha chulha i.e., 17.484 %,where wood is used as fuel.
- As the rural people are dependent on bio-fuels, smokeless chulha should be popularized to reduce the drudgery of women
- As hill area villagers were dependent on forest for fuels, social foresting should be encouraged in the villages.
- Cow dung not only used as manure, but also increases the fertility of soils. Hence the women folk should be awarded, not to use the cow dung as fuel.
- Technology must be developed to use the fuel in dense form ,having high calorific value.

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