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Energy Consumption Pattern in different Agro-Climatic Zones in Rural Habitations of Western Himalayan Region, India

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Abstract

The present work was conducted to study the energy consumption pattern in different climatic zones (Sub mountain low hill sub tropical, Mid hill sub Humid, High hills wet temperate and High hills dry temperate zone) of rural habitations of Himachal Pradesh, India. Households were sleeted on the basis of multistage random sampling in the selected areas. A pretested questionnaire was prepared and used for conducting primary survey. It was revealed from the study the 90-100% households in the study area used fuelwood as primary energy source, which was followed by LPG and agricultural waste. Electricity was also being used as a source of energy but mainly for lighting. It was found that with the increase in the altitude the per capita per day energy consumption increased in case of fuelwood but the trend was reverse in case of electricity. The fuel consumption varied with the family size, income and land holdings.

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Introduction

Energy is fundamental need to achieve the unified economic, social and environmental aims of sustainable human development. India's energy sector has grown tremendously in recent years. Further economic and population growth, allied to structural trends such as urbanization and industrialization, point to continued rapid expansion in demand for energy. It is found that the share of energy consumption in India and China has also been on the rise due to very fast growth rate. India has grown from being world's seventh largest energy consumer in 2000 to the fourth largest within a decade. Biomass represents between 50 to 90% of primary energy consumption in developing countries and 12 to 15% of global primary energy

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consumption. Three-quarters of the global biomass used for the energy is consumed in developing countries, where 77% of the world's population lives, mainly in rural areas and in poor urban zones for cooking, water heating, space heating etc. The most frequently used fuelwood technology remains the open fire/ traditional mud stove/three stone fire for cooking. Wood is identified as the major source of energy in rural India. Four out of every five rural and one out of every five urban households primarily depend on direct burning of solid biomass fuel like fuelwood, crop residue and cattle dung. At a same time a huge quantity of agro residues are produced in the developing countries and are being as a fuel too. Energy is the basic requirement and a vital input for different processes like cooking, heating, lightening, agriculture, industry etc. In rural areas, the energy sources are highly dependent on locally available biomass resources. The rural energy fuels mainly include fuelwood, crop residues and animal dung. Most of the fuelwood used in rural household is collected from several sources such as common lands, protected/reserved areas, panchayat land, revenue wastelands and owned land. The fuelwood is often collected by women and children. It is burnt in traditional as well as in some cases improved cookstoves. With better economic condition now a day's people are shifting towards more conventional and cleaner fuels such as LPG and electricity for home usage. According to Rao[1] and Pachauri[2] the inertia of the household energy preference and consumption pattern are due to some factors such as economic condition.

Household energy consumption depends on economic status, climate condition and energy resources availability, household size, nature of the occupation, education of family members and high frequency of cooking in a particular area. Economic status of household may create differences in choices and amount of consumption of energy resource. The family income has direct correlation with the preferences towards costly and efficient energy resources, such as LPG, electricity etc. If the price of energy rises, the economic burden of household energy consumption will increase, and consequently, the consumption will decrease. Furthermore, climatic condition of selected agro-climatic zones is another important factor that has an impact on household energy consumption via the energy demand for heating and cooling. In summer, the areas with hot weather have great demand for refrigerating, air conditioning, while in winter; the regions with cold weather have heavy demand for space heating.

Various studies on energy consumption pattern have been conducted in Himachal Pradesh, revealed that fuelwood is the most preferred fuel and used in the state.[3,4,5] The total energy requirement of rural people in the state was met out by fuelwood, which contribute 52% of total energy mix in the region. The fuelwood is being provided in the snow bound areas by the state government on subsidized rates particularly during winters, which is transported from lower belt of the state.[6] According to the study conducted by Aggarwal (2011)[7] in mid hills of Himachal Pradesh 95.2% households were using fuelwood. The total annual consumption of fuelwood in Junga, Salogra and Nohradhar worked out to be 0.116 million tones. A study was conducted by Ritica *et. al.* (2014)[8] in Solan block (Mid Hills area of Himachal Pradesh) revealed that 93.3% of total households depend on fuel wood. Out of the total energy consumed in the high altitude and snow bound area of Lahaul & Spiti district of Himachal Pradesh, fuelwood consumption was highest followed by electricity, dung cakes, LPG and kerosene. The annual use of fuel wood was worked out to be 905.2 tonnes.[9] The energy consumption pattern in mid hills areas of Solan district revealed that fuelwood consumption contributed highest (80.43%) proportion of total energy mix followed by electricity (11.55%), kerosene (2.87%), dung cake (2.79%), and LPG (2.31%).[10] Vikas *et. al.* (2016)[11] in their study in low hills of Kangra district reported that 88.9% of total households used fuel wood to meet out their energy requirements. The fuelwood consumption increased with increase in altitude was reported by Yash Pal *et. al.* (2015)[12] in their study in mid hills of Mandi district in Himachal Pradesh. The daily per capita fuelwood consumption was 4.47kg.

As discussed above, there is still a lack of research on agro-climatic zone wise differences of household energy consumption preferences, pattern and factors causing such differences. This paper thereby uses the agro-climatic zone wise energy consumption data of Himachal Pradesh thereby exploring the zonal differences in household energy consumption and adds climate condition as an explanatory and

supplementary factor to the other factors mentioned in previous studies.

Material and Methods

The study was carried in four districts of Himachal Pradesh which covered Sub mountain low hill sub tropical, mid hill sub humid and high hill temperate wet and dry zones of the state. The districts selected were Hamirpur, Kullu, Shimla and Kinnaur (Fig 1.). Three seasons (summer, winter and monsoon) have been considered to analyze the fuelwood consumption for cooking and heating purposes.

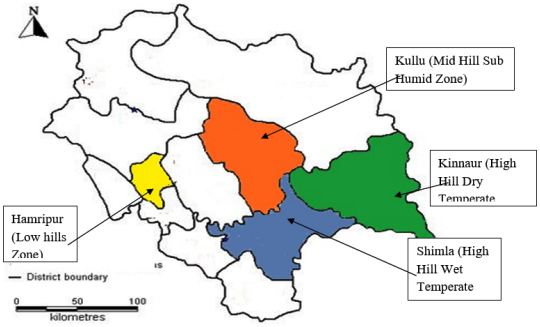

Fig. 1: Map showing the selected study areas

Table 1. Categorization of households on the basis of land holding, income and family size

The households were categorized on the basis of land holding		
Marginal	:	< 1 hectare
Small	:	1 to ≤ 2 hectare
Semi medium	:	2 to ≤ 4 hectare
Medium	:	> 4 hectare
The households were categorized on the basis of monthly income		
Very low income	:	< Rs. 5000
Low income	:	Rs. 5,000 to Rs. 10,000
Middle income	:	Rs. 10,000 to Rs. 15,000
High middle income	:	Rs. 15,000 to Rs. 20,000
High income	:	>Rs. 20,000
The households were categorized on the basis of family size		
Small	:	< 4 members
Medium	:	4 to 6 members
Large	:	7 to 8 members
Very large	:	>8 members

A pre structured questionnaire schedule was used to gather information on energy consumption pattern of rural households and their fuel preferences. Multistage simple random sampling was employed to select the households in the selected districts. The series of selection was from districts to blocks, from blocks to panchayats, from panchayats to villages and then different selected households. In every district three blocks were selected and in every block three panchayats. In every panchayat a cluster of villages was selected and in each cluster households were selected randomly. Statistical method used to draw the inferences was through averages and percentages. In total 180 households were selected in all agro-climatic zones for the present study. Thereafter, the selected respondents were classified into different categories on the basis of APL & BPL, land holding, family income and family size as per norms fixed by the Agriculture Census Department (Table 1).

Details of district wise altitudinal gradients for survey and primary data collection are presented in Fig 2. Coal equivalent values of various fuels are given in Table 2.

Results and Discussion

The data presented in Table 3 revealed that in the low hills of Himachal Pradesh, fuelwood was the main source of energy followed by LPG, electricity and kerosene oil. The fuelwood consumption was higher in the families below poverty line as compared to the above poverty line with the average values 31.7 and 27.6 Kg/day. In case of monthly income it was found that maximum 29.4 Kg/day consumption was recorded in the families with very low income

Table 2: Coal equivalent values of various fuels

Fuel	Fuel Coal Equivalent (kg per unit)
Electricity	0.70
Kerosene	6.00
LPG	1.19
Fuelwood	0.82
Dung cake	0.30

followed by low, middle, high middle and very high income with the respective values of 24.2, 23.7, 22.3 and 21.4 Kg/day. The families owning medium land holding used the maximum (27.2 Kg/day) fuelwood as compared to semi medium (26.3 Kg/day), small (24.7 Kg/day) and marginal (21.7Kg) land holders. It was also seen that as the family size increased the fuelwood consumption also increased. The family with a very large family size used the maximum (23.4Kg/day) fuelwood and the value decreased with large (23.6Kg/day), medium (21.7 Kg/day) to small family (20.6Kg/day). The season wise analysis revealed that the fuelwood consumption was more in the winter followed by rainy and summer season in all the classes. The fuelwood consumption was followed by the use of LPG. In the low hills it was found in the range of 4.24 to 6.57 cylinders per year. It was observed that the LPG consumption was 4.2 in BPL and 6.7 cylinders per year in APL families. The LPG consumption followed a decreasing trend of high income (6.9) > high middle (6.5) > middle (6.1) > low (5.3) > very low (5.1) income families. Similar results were also reported by Kumar11. The consumption was found highest (6.7 cylinders/ year) with the people with marginal and lowest (6.0 cylinders/year) in the medium land holdings. The use of kerosene oil was minimal in low hills but its use was higher in BPL as compared to APL families.

The analysis of data (Table 4) revealed that in the mid hills of Himachal Pradesh also, fuelwood was the main source of energy. The fuelwood consumption was higher in the families below poverty line as compared to the above poverty line with the average values 43.6 and 39.7 Kg/day. In case of monthly income it was found that maximum consumption was recorded in the families with very low income followed by low, middle, high middle and very high income

Table 3: Energy consumption pattern in selected households of low hill zone

Particulars	Fuelwood (Kg/day)			LPG Cylinder/ (month)	Kerosene (litre/day)	Electricity (Rs/month)
	Winters	Summers	Rainy			
APL	27.6	3.4	12.3	6.7	1.57	516.6
BPL	31.7	4.9	14.2	4.2	3.41	409.4
Overall average monthly income						
Very Low	29.4	4.6	12.9	5.1	2.63	413.5
Low	24.2	4.3	12.2	5.3	2.52	450.2
Middle	23.7	4.1	11.7	6.1	2.30	493.6
High Middle	22.3	3.7	10.6	6.5	1.75	512.6
High Income	21.4	3.3	9.1	6.9	1.49	525.0
Overall average land holding (ha)						
Marginal	21.7	3.1	9.7	6.7	2.34	429.7
Small	24.7	3.9	10.1	6.3	1.78	483.4
Semi medium	26.3	4.3	10.4	6.1	1.63	572.3
Medium	27.2	4.6	11.1	6.0	1.42	617.5
Overall average family size (No.)						
Small	20.6	2.7	10.6	5.0	1.78	415.3
Medium	21.7	3.9	11.3	5.4	2.12	473.2
Large	23.3	4.3	14.2	6.4	2.61	516.1
Very Large	24.9	4.8	15.9	6.7	3.31	549.5

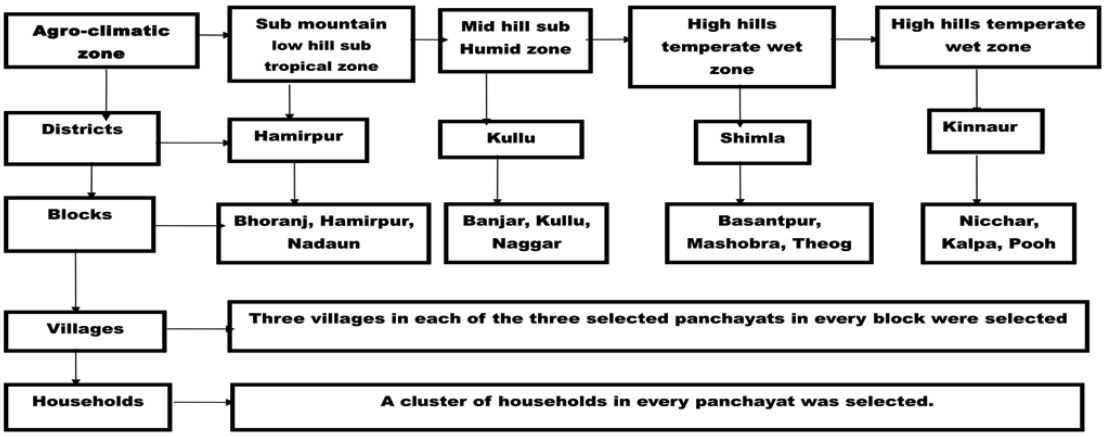

Fig. 2: Details of district wise altitudinal gradients for survey and primary data collection

Table 4: Energy consumption pattern in selected households of mid hill sub humid zone

Particulars	Fuelwood (Kg/day)			LPG Cylinder/ (month)	Kerosene (litre/day)	Electricity (Units/month)
	Winters	Summers	Rainy			
APL	39.7	6.4	19.7	6.8	0.56	413.0
BPL	43.6	8.7	24.6	4.2	1.34	322.9
Overall average monthly income						
Very Low	42.7	11.0	28.3	4.7	1.63	315.9
Low	39.6	10.3	27.4	5.3	1.42	375.0
Middle	36.7	9.8	26.7	5.6	1.29	393.9
High Middle	35.4	9.5	26.1	6.2	1.01	416.9
High Income	31.6	8.7	25.3	6.7	0.78	429.4
Overall average land holding (ha)						
Marginal	37.6	7.3	21.4	5.2	1.27	306.9
Small	39.4	8.7	23.8	6.4	1.04	329.1
Semi medium	40.2	8.1	24.9	6.9	0.93	400.1
Medium	43.7	11.3	26.7	7.6	0.87	427.8
Overall average family size (No.)						
Small	33.7	5.6	23.1	4.9	1.29	336.5
Medium	34.2	7.2	23.8	5.5	1.11	354.9
Large	36.8	7.8	25.3	5.9	0.75	409.8
Very Large	39.2	8.4	27.6	6.8	0.54	425.1

with the respective values of 42.7, 39.6, 36.7, 35.4 and 31.6 Kg/day. The families owning medium land holding used the maximum (43.7 Kg/day) fuelwood as compared to semi medium (39.4), small (40.21 Kg/day) and marginal (37.6 Kg/day) land holders. It was also seen that as the family size increased the fuelwood consumption also increased. The family with a very large family size used the maximum (39.2Kg/day) fuelwood and the value decreased with large (36.8Kg/day), medium (34.2 Kg/day) to small family (33.7Kg/day). The season wise analysis revealed that the fuelwood consumption was more in the winter followed by rainy and summer season in all the classes. The fuelwood consumption was followed by the use of LPG. In the low hills it was found in the range of 4.24 to 7.9 cylinders per year. It was observed that the LPG consumption was 4.24 in BPL and 6.81 cylinders per year in APL families. The LPG consumption followed a decreasing trend of high income (6.7) > high middle (6.21) > middle (5.65) > low (5.32) > very low (4.70) income families. The consumption was found highest (6.9 cylinders/ year) with the people with medium and lowest (5.20 cylinders/year) in the marginal land holdings. The use of kerosene oil was in the range 0.56 to 0.1.63 litres/day in mid hills and its use was higher in BPL as compared to APL families. The electricity was mainly used for lighting and cooling purpose but only in very few cases it was used for cooking. The electricity bill in the low hills was in the range of Rs 409 to 617 per month.

The data presented in Table 5 revealed that in the high wet temperate zone of Himachal Pradesh, fuelwood was the main source of energy. The fuelwood consumption was higher in the families below poverty line as compared to the above poverty line. In case of monthly income it was found that

Table 5: Energy consumption pattern in selected households of high hill wet temperate zone

Particulars	Fuelwood (Kg/day)			LPG Cylinder/ month)	Kerosene (litre/day)	Electricity (Units/month)
	Winters	Summers	Rainy			
APL	39.7	12.3	28.2	6.6	1.3	293.7
BPL	43.6	17.3	31.7	5.2	2.1	175.8
Overall average monthly income						
Very Low	41.3	17.1	25.4	5.5	1.67	198.6
Low	42.7	16.5	27.6	6.2	1.43	215.4
Middle	38.7	15.4	29.8	6.3	1.23	276.4
High Middle	36.5	14.3	30.3	6.6	1.16	291.2
High Income	33.4	14.0	31.7	7.1	1.07	313.6
Overall average land holding (ha)						
Marginal	36.7	13.6	26.5	6.2	1.21	265.4
Small	39.3	14.3	28.4	6.4	1.14	288.3
Semi medium	41.4	15.1	29.3	6.6	1.05	308.5
Medium	47.6	17.5	31.7	6.9	0.97	325.0
Overall average family size (No.)						
Small	37.4	12.7	29.6	5.7	1.13	186.3
Medium	43.2	14.3	32.3	5.9	1.43	212.6
Large	40.7	15.9	31.7	6.7	2.04	255.4
Very Large	44.6	16.6	34.8	6.9	2.11	279.5

maximum 41.3 Kg/day consumption was recorded in the families with very low income followed by low, middle, high middle and very high income with the respective values of 42.7, 38.7, 36.6 and 33.4 Kg/day. The families owning medium land holding used the maximum (47.5Kg/day) fuelwood as compared to semi medium (41.4 Kg/day), small (39.3 Kg/day) and marginal (36.7Kg/day) land holders. It was also seen that the family with a very large family size used the maximum (44.6Kg/day) fuelwood and the value decreased with large (43.2Kg/day), medium (40.7Kg/day) to small family (37.4Kg/day). The season wise analysis revealed that the fuelwood consumption was more in the winter followed by rainy and summer season in all the classes. In the winters the fuelwood consumption was in the range 33.4 to 44.7 Kg/day while in summers and rainy season the range decreased to 12.3 to 17.5 and 25.3 to 34.8Kg/day. The fuelwood consumption was followed by the use of LPG. In the low hills it was found in the range of 5.21 to 6.9 cylinders per year. It was observed that the LPG consumption was 5.2 in BPL and 6.6 cylinders per year in APL families. The number of cylinders followed a decreasing trend of high income (6.7) > high middle (6.3) > middle (6.2) > low (6.0) > very low (5.5) income families. The consumption was found highest (6.57 cylinders/year) with the people with marginal and lowest (6.03 cylinders/year) in the medium land holdings. The use of kerosene oil was minimal in low hills but its use was higher in BPL as compared to APL families.

The analysis of data in Table 6 revealed that in the high hills dry temperate zone of Himachal Pradesh also, fuelwood consumption was highest as compared to other agro climatic zone. The fuelwood consumption was higher in the families below poverty line as compared to the above poverty line with the average values 74.7 and 69.1 Kg/day. The consumption reduced to 27.4 and 21.6 Kg/day in summers and 43.6 and 39.7 Kg/day during rainy season in BPL and APL families respectively. In case of monthly income it was found that maximum consumption was recorded in the families with very low income followed by low, middle, high middle and very high income with the respective values of 71.2, 65.8, 63.5, 59.4 and 55.7Kg/day. The families owning medium land holding used the maximum (66.4Kg/day) fuelwood as compared to semi medium (61.7), small (59.0Kg/day) and marginal (56.4Kg/day) land holders. It was also seen that as the family size increased the fuelwood consumption also increased. The family with a very large family size used the maximum (66.9Kg/day) fuelwood and the value decreased with large (63.0Kg/day), medium (59.4 Kg/day) to small family (56.6Kg/day). The season wise analysis revealed that the fuelwood consumption was more in the winter followed by rainy and summer season in all the classes. The fuelwood consumption was followed by the use of LPG. In the low hills it was found in the range of 4.24 to 7.9 cylinders per year. It was observed that the LPG consumption was 4.3 in BPL and 9.5 cylinders per year in APL families. The LPG consumption followed a decreasing trend of high income (8.7) > high middle (8.3) > middle (7.6) > low (7.1) > very low (6.4) income families. The consumption was found highest (8.6 cylinders/year) with the people having medium and lowest (6.7 cylinders/year) in the marginal land holdings. The use of kerosene oil was in the range 0.93 to 1.91 litres/day in high hills dry temperate zone and the consumption was higher in BPL as compared to APL families. The kerosene oil consumption was also reported by Tenzin9 for lighting purposes.

Overall it was observed that the consumption of fuelwood was found to increase with the increase in altitude. The consumption was in the range of 2.7-29.4 Kg/day in the low hills of Himachal Pradesh and it increased to 5.6- 43.7 Kg/day in Mid Hills, 12.3- 47.6 Kg/day in High Hill Wet Temperate zone and was in the highest range (17.4-74.7Kg/day) in the Dry temperate zone. The LPG consumption was also found to be highest in the dry temperate zone and lowest in the low hills.

The study revealed that fuelwood was the main source of energy followed by LPG, electricity and kerosene oil5. It was found that with the increase in the altitude the daily energy consumption per capita in kg of coal equivalent increased in case of fuelwood. It was lowest (7.1 kg coal equivalent) in the low hills zone and decreased through mid hills (13.9 kg coal equivalent), wet temperate (14.81 kg coal equivalent) and was highest (16.15 kg coal equivalent) in the dry temperate zone. This might be attributed to prolonged and colder conditions in temperate areas as compared to low hills. The study is in line with the findings of Lin,[13] according to them

the consumption of fuelwood is related to the climatic conditions of the area. The total consumption of energy sources per capita was 10.88, 16.45, 19.05 and 18.88 kg of coal equivalent in low, mid hills, dry and wet temperate zones respectively which included mainly fuelwood followed by LPG and kerosene oil. The study was in accordance with the findings of Joon11 who also studied that complete conversion to cleaner fuels has not taken place yet even in households that has been using LPG for many years. According to them, there was more availability and utilization of solid biomass fuels as energy resources in domestic sector as compared to the commercial fuels. The fuelwood consumption was found highest in the winters followed by rainy and summer season in all the agro climatic zones. It was also revealed from the study that with the increase in income the energy consumption in terms of electricity and LPG increased as compared to fuelwood consumption. This may be due to the fact that people with higher income shifts towards cleaner energy as the lifestyle changes.[14] Electricity was mainly used for lighting and cooling purposes. The highest consumption was found in the low hills and it decreased in the temperate areas. This may be attributed to the climatic conditions and availability of electricity. As in temperate areas due to snowfall the electricity lines are disrupted and also in low hills electricity is also used to cooling purposes. Also in all the agro climatic zones the consumption of electricity increased as the income of the families increased. The results were in line with findings of Anantharam[15] who also studied that with rising income, a growing share of household energy is used for lighting and electric appliances, and a decreasing share for cooking.

The study revealed that with the increase in the altitude the daily energy consumption per capita in kg of coal equivalent increased in case of fuelwood.

Table 6: Energy consumption pattern in selected households of high hill dry temperate zone

Particulars	Fuelwood (Kg/day)			LPG Cylinder/ month)	Kerosene (litre/day)	Electricity (Units/month)
	Winters	Summers	Rainy			
APL	69.1	21.6	39.7	9.5	1.53	415.4
BPL	74.7	27.4	43.6	4.3	1.91	375.3
Overall average monthly income						
Very Low	71.2	24.6	41.5	6.4	1.87	313.2
Low	65.8	22.9	39.0	7.1	1.63	326.1
Middle	63.5	20.0	37.5	7.6	1.49	423.4
High Middle	59.4	17.6	33.5	8.3	1.29	493.0
High Income	55.7	15.9	29.1	8.7	1.01	507.4
Overall average land holding (ha)						
Marginal	56.4	17.4	31.6	6.7	1.31	384.3
Small	59.0	19.5	34.8	7.5	1.24	401.2
Semi medium	61.7	21.7	36.7	7.9	1.19	420.3
Medium	66.4	25.8	39.8	8.6	1.06	476.0
Overall average family size (No)						
Small	56.6	19.6	29.5	5.7	0.93	379.6
Medium	59.4	23.0	31.6	6.9	1.16	393.6
Large	63.0	26.4	33.1	7.8	1.19	416.7
Very Large	66.9	29.1	36.3	9.2	1.26	425.0

It was lowest (7.1 kg coal equivalent) in the low hills zone and decreased through mid hills (13.9), wet temperate (14.81) and was highest (16.15) in the dry temperate zone. The people in the study areas still depend upon fuelwood for cooking and heating as evident from the data that the consumption of fuelwood increased with the increase in altitude. The consumption was in the range of 2.7-29.4 Kg/ day in the low hills and it increased to 5.6- 43.7 Kg/ day in Mid Hills, 12.3- 47.6 Kg/day in High Hill Wet Temperate zone and was in the highest range (17.4-74.7Kg/day) in the Dry temperate zone.

The tree felling in the state has been banned and people are getting fuel wood from their own collection. The state government is providing electricity on subsidized rates to the domestic consumers. The LPG and kerosene are also having subsidy and fuelwood is provided to the people in snow bound areas at subsidized rates, which is transported from lower areas.[9] The fuelwood is generally available nearby forest in lower parts of the state free of cost. The state has 250- 300 sunshine hours in the state, which can be utilized for power generation. The high altitude and snow bound areas also have sufficient sunshine to meet out the energy requirement of the people. The LPG is easily available to people in lower area as compared to upper areas in the state due to high transport cost. The change in fuel wood consumption in different agro-climatic zones is mainly due to change in temperature. The fuel wood is easily available in the most part of the state free of cost that is why it is most preferred fuel for cooking and space heating Yash Pal, Tenzine.[9,12] LPG is being used only during summer as such its consumption deceases with increase in altitude. The electricity is mainly used for lighting in most part of the state and kerosene is used for lighting in snow bound areas for lighting provided on subsidized rates.[9]

Conclusions

The study revealed that the fuel wood is most preferred fuel and being used throughout the state for cooking and heating. Traditional mud cookstoves are being used in the state, which has low efficiency and causing emission of carbon thus, needs improvement in efficiency of cookstove. The biogas plant should be encouraged in rural areas for cooking and lighting, which will reduce the fuel wood consumption. The briquetting of loose biomass should be made mandatory as a fuel in rural areas, which will also generate employment for rural population.

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Conflict of interest

We do not have any conflict of interest including any financial, personal or other relationships with other people or organizations that can influence their work

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