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GIS Mapping Analysis of Energy Consumption Patterns in Nepal

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Abstract

This paper is an attempt to use computerized GIS tool to visual portray of consumption of the main energy sources – firewood, electricity, kerosene and LPG at district level for the whole country into four levels. A series of tables have also been constructed to depict the average levels of consumption of those energy sources at regional levels. The consumption patterns are that the firewood consumption has dominated over all the energy sources, followed by kerosene, electricity and LPG. The firewood energy source is the largest and available throughout the country. This can be explained by the extensive forest coverage across the country, which is largest in the mountain districts. The consumption patterns of electricity and LPG are more or less the same for the ecological regions; with highest in the Tarai, while the mountain being the lowest. The country has huge water reserviour for generating hydro electricity, but its consumption shares nearly two and half less of the firewood, or half of the kerosene. The other two energy sources - kerosene and LPG are to be imported.

Due to lack of time series data on household level energy consumptions, HDI has been taken to predict the energy consumptions in the future. It shows that the household proportion in consuming firewood will be decreased, signifying lessening burden on forest resource. On the other hand, the household consumption of hydro electricity will be increased, which will mean to increasing utilization of locally available water sources and reducing a huge amount of transportation cost incurred for distribution of kerosene and LPG particularly in the remote hill and mountain districts. But however, increasing projected consumption of LPG would require foreign currencies in the future.

Introduction – energy and development

Energy is a fundamental aspect of development. It is used for different purposes like cooking food, lighting, heating, milling grains, plowing fields, transporting goods and people, irrigating fields, cold storage or refrigeration, communication, etc. Energy programme in the rural areas particularly in the poor developing countries has become a means of poverty alleviation (WEC 1999). However, demand and consumption of energy are growing rapidly across the world due to rising social and economic developments and want for comfort life.

Energy is basically derived from natural resources. There are two extreme views of assessing natural resources prospects. One view is that the stock of resources is a finite supply, which is rapidly being depleted by large and increasing demands resulting from uncontrolled population growth and increasing aspirations. This thus will lead to exhaust the resources rapidly. On the other hand, the technological view concedes that although the stock of resources is ultimately finite, the bounds of possibility within these limits are so extensive that the exhaustion of resources is not a practical problem. Technology may deplete some re-sources, but it also has a capacity for creating others, and as a result all problems can be solved if technical progress is maintained and economic and social constraints can be overcome (Pradhan and Pradhan 2007).

Though Nepal is one of the richest countries in terms of per capita natural resources, it is the least energy consuming country. The energy sources of Nepal can broadly be classified into three types such as traditional (biomass), commercial (conventional) and alternate (renewable) energy. The biomass energy source includes firewood, animal dung, crop by-products and residues, etc, which are available within the country. The commercial energy comprises coal, electricity and petroleum products, of which hydro electricity is by far the largest potential, whereas petroleum products and coal are supplied entirely through imports. Biogas, micro-hydro, solar thermal, solar photo voltaic, and wind energy are termed as alternate or renewable energy sources. Other forms of new and renewable energy technologies include geothermal, hydrogen energy, fuel cell etc. Upon careful utilisation, these energies can be viable options for Nepal.

In Nepal, the biomass energy source contributes the largest, with 87.7 per cent to the total energy supply, whereas the share of alternate energy supply is negligible with mere 0.5 per cent (WECS 2006). Other sources such as fossil fuels share 10 per cent and electricity shares only 1.8 per cent. In urban areas, imported fossil fuels account around 90 per cent of the total energy use. Access to electricity is only about 39 per cent of the country population, mostly in urban areas and nearly 20 per cent of rural population has access to electricity (CBS 2002). Records indicate that there is a gradual shift from traditional source to commercial source in the consumption pattern**.** However, if the energy consumption from the commercial sources other than hydropower continues to rise, foreign currency to be spent for procuring coal and petroleum will increase. Commercial energy consumption is crucial factor in the process of economic abundance and societal development, whereas development of domestic sources of energy appears to be positive for the developing countries (Upadhaya 1979).

One basic feature of household energy consumptions is their unequal distribution pattern among the districts throughout the country. Some districts possess varieties of favourable geographical factors, energy resources, infrastructure, and enthusiastic entrepreneurs while others contain only a few of them. Size of population or demand itself may be a prime factor determining the amount of energy consumption. Here, an attempt is made to assess the energy consumption patterns by using Geographical Information System (GIS) mapping technique at both spatial (district) and temporal (trend) levels.

GIS Mapping Methodology

In Nepal, the use of energy sources such as electricity and kerosene is primarily for lighting and that of firewood, biogas, and liquid petroleum gas (LPG) is for cooking. Micro hydro, kerosene, bio-gas and solar home system are used for both lighting and cooking. Hydro electricity and

petroleum products such as petrol and diesel are used for manufacturing industries and transports and communication. Following methodological steps have been adopted for GIS mapping of the energy consumption pattern.

i. Consumption of different types of energy by households available at district level for 2001 was collected. This data for other following years was not available.

ii. Due to lack of time series data on energy consumption at district level, an indirect method such as Human Development Index (HDI) at district level has been adopted for its forecasting. It is adopted, as the United Nations (UN) has indicated that there is a close relationship between human well-being and energy consumption and therefore HDI is considered as a major indicator for consumption of energy.[1] So, first the district level HDI has been forecasted taking the HDI figures of 1996 and 2001 by using the formula $y = a+bx$ and then the forecasted figures being adjusted assuming the National HDI of 0.742 (i.e. ASEAN HDI value) for 2030. The coefficient for 2001 between HDI and district level households energy consumption was obtained and based on the coefficients and HDI forecasted figures, the household energy consumption data has been forecasted for the years 2005, 2015, and 2030. Regression has been computed for HDI paired separately with each type: (i) firewood, (ii) electricity, (iii) kerosene, and (iv) LPG.

iii. The paired data outputs between HDI and each individual of four energy types at district level have been plotted by using GIS for different years such as 2005, 2015 and 2030. Five classes of the output data have been obtained in most cases, provided by the automatic classification method of GIS ArcView Programme. In few cases, classification was done manually.

iv. The values are computed into percentage. Five classes for each of the paired variables (HDI versus each of individual energy consumption sources), the GIS generated thematic maps at district level are indicated with graduated grayscale tone shading; with lighter tone indicating less energy consumption and darker tone for higher energy consumption. A series of tables are also generated to support interpretation of the levels of energy consumption.

v. Interpretation of energy consumption pattern is made at district, ecological regions and development regions. The existing consumption pattern of energy sources is based on 2001 census data. Mean value of energy consumption at the national level is taken as reference value. Interpretation is also made at ecological region and development region. There are 75 districts, three ecological regions (mountain, hill and Tarai) from north to south and five development regions (eastern, central, western, mid-western, and far-western) from east to west.

[1]In a correlation analysis of electricity use versus human well-being, the UN indicates that HDI reaches a maximum value when electricity consumption is about 4,000 kWh per person per year, which is well below the consumption levels for most developed countries, but well above the level for developing countries. It also indicates that the use of commercial or traditional fuels is a distinguishable feature for its place in the HDI ranking. Highest HDI countries use commercial energy, while lowest HDI countries consume traditional fuels.

Results and Interpretation

Energy Consumption Patterns

Firewood

On average, 77 per cent households are dependent on firewood for cooking (Table 1). Figure 1 depicts that 43 districts with over 80 per cent firewood consumption represent mostly the hill and mountains of the eastern and the far-western regions. Three Tarai districts, viz. Bardiya, Kailali and Kanchanpur have over 80 per cent of firewood consumption. Only in Kathmandu district, households with 20 per cent and below have used firewood for cooking. By ecological region, the mountain has the largest consumption of firewood with 92.6 percent, whereas the Tarai has the lowest with 56.76 per cent (Table 1). By development region, the consumption pattern of firewood increases from the central towards both western regions and eastern region, with the far-western region being the highest (92.32%).

Electricity

Figure 2 shows that four districts – Kathmandu, Bhaktapur, Lalitpur and Manang – have highest electricity consumption with above 80 per cent, whereas 26 districts including mostly the hill and mountain districts of the eastern, mid- and far-western regions have the lowest with below 20 per cent. Compared to 31.60 per cent national average, only 34 districts, most of which lie in the western and central regions have above this value. The average consumption pattern of electricity as depicted in Table 1 is constantly increased from the Mountain to the Tarai region. In case of development regions, there is a wide gap in average electricity consumption; with the central region being the highest (46.94%), followed by the western development region (41.78%) and the far western region is being the least with 18.44 per cent (Table 2).

Table 1: Average household consumption of energy sources by ecological region, 2001

Ecological region	Firewood	Electricity	Kerosene	LPG
Mountain	92.60	21.97	54.42	3.21
Hill	81.08	32.13	62.75	15.82
Tarai	56.76	38.28	59.95	19.68
Nepal	77.05	31.60	60.22	14.16

Table 2: Average household consumption of energy sources by development region, 2001

Development region	Firewood	Electricity	Kerosene	LPG
Eastern	79.00	24.26	73.79	9.68
Central	64.07	46.94	51.44	23.51
Western	72.46	41.78	56.20	17.69
Mid western	87.15	17.05	55.04	8.52
Far western	92.32	18.44	70.45	5.51

Kerosene

National average consumption of kerosene is nearly double that of electricity. Compared to electricity, kerosene consumption pattern is reverse at district level.

Table 3: Projected consumption of electricity and kerosene by ecological region

Ecological region	Electricity			Kerosene		
	2005	2015	2030	2005	2015	2030
Mountain	29.1	35.4	51.6	70.9	64.6	48.4
Hill	43.4	52.7	71.0	56.6	47.3	29.0
Tarai	40.6	47.3	63.7	59.5	52.7	36.3
Nepal	39.6	47.6	64.9	60.4	52.4	35.1

Those hill and mountain districts of mid- and far-western regions with lowest electricity consumption have the highest kerosene consumption with over 80 per cent (Fig. 3), whereas Kathmandu, Bhaktapur, Lalitpur and Manang have the lowest consumption of kerosene (<20%). In the latter case, the households may have other options than to use kerosene for lighting. Figure 3 also shows that 43 districts with over 60 per cent households have used kerosene for lighting. Yet, the hill region has, on average, the highest consumption of kerosene, whereas the mountain region has the lowest, which may be due to difficulty of terrain and lack of roads for transporting kerosene from the supply centres.

Table 4: Projected consumption of electricity and kerosene pattern by development region

Development region	Electricity			Kerosene		
	2005	2015	2030	2005	2015	2030
Eastern	42.4	51.9	68.9	57.6	48.1	31.1
Central	49.4	53.6	68.1	50.6	46.4	31.9
Western	49.9	61.0	83.6	50.1	39.0	16.4
Mid western	23.0	30.3	46.1	77.0	69.7	53.9
Far western	23.3	32.3	49.2	76.7	67.7	50.8

LPG

Unlike other three energy sources, LPG consumption pattern is quite different. Average LPG consumption is the lowest, among the energy sources. The average consumption of LPG by households is 14.16 per cent, which is half of the electricity average consumption and far below than other two energy sources. There are seven districts comprising five of central region and two of western region have highest with over 40 per cent LPG consumption. Twenty-three districts have households consumed LPG with over 15 per cent; most of which represent the central, western and some of the eastern regions. Most of the hill and mountain districts of the far- and mid-western and eastern regions have consumed LPG with 5 per cent and below. This pattern is basically related to the lack of road link with the supply centres (Fig. 4). Like electricity, the mountain has the lowest consumption of LPG and it increases constantly from the hill to the Tarai. Likewise, its consumption pattern also decreases from the central region towards both western regions and eastern region (Table 1). The western region occupies second position in terms of consumption of both LPG and electricity.

Table 5: Projected consumption of firewood and LPG pattern by ecological region

Ecological region	LPG			Firewood		
	2005	2015	2030	2005	2015	2030
Mountain	10.1	17.0	29.2	81.2	72.0	58.5
Hill	19.8	27.8	41.9	68.1	57.4	42.5
Tarai	17.6	24.6	36.7	55.4	41.5	32.0
Nepal	17.2	24.7	37.8	67.5	56.3	43.1

Projected Energy Consumption Patterns

The consumptions of the four energy sources have been projected for three years, viz. 2005, 2015 and 2030 and their average values are computed by ecological and development regions (Tables 3, 4, 5 & 6). The estimated results as shown in Fig.5 show that the electricity consumption

households will be increased by 16 per cent between 2005 and 2015 to 42 per cent by 2030. By the year 2030, an average of 60 per cent households will be using electricity. The projected consumption pattern of electricity will be increased at 8 per cent from 2005 to 2015 and at 14.3 per cent by 2030. This ratio will be much higher for the hill than that for the Tarai and the mountain (Table 3). Likewise, as shown in Table 5, there are increased ratios of projected LPG consumption by 7.5 per cent between 2005 and 2015 and by 13.1 per cent from 2015 to 2030. The ratios of consumption of LPG will be increased with higher percentage in the mountain districts than other two ecological regions. These ratios will be about three times from 2005 to 2030 in the mid- and far-western regions, while two times and less in other development regions (Table 6).

Table 6: Projected consumption of LPG and firewood by development region

Development region	LPG			Firewood		
	2005	2015	2030	2005	2015	2030
Eastern	21.2	28.2	40.0	62.0	51.3	37.5
Central	19.7	27.2	40.1	58.5	44.6	34.1
Western	24.1	33.9	51.0	60.8	48.8	32.5
Mid western	7.4	14.1	25.4	81.9	73.2	61.1
Far western	8.6	14.4	26.4	84.4	74.9	61.1

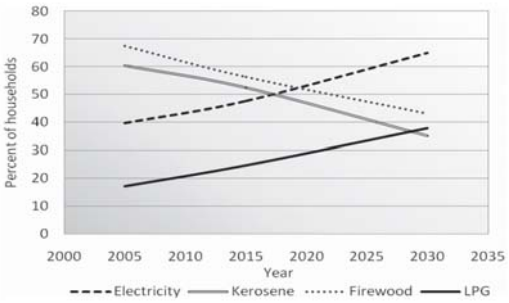

Figure 5: Trends of project consumption of energy sources, Nepal

The increase in projected consumption of hydro electricity and LPG means to decrease in consumption of other two energy sources, such as firewood, and kerosene. However, the patterns of consumption of those two energy sources will differentially decrease by ecological region and development region. Figures 6 – 17 depict estimated consumption patterns of all four types of energy sources for the country. For instance, the ratios of the consumption of kerosene will be decreased at 8.0 percent between 2005 and 2015 and then with 14.3 percent between 2015 and 2030. The decrease in consumption of kerosene ratios will be drastic in the case of mountain districts than in other two ecological regions. Similar decreasing pattern will occur among the development region, but not with a distinct feature. In terms of number of districts, there will be nine districts using kerosene with over 60 percent in 2030, decreased from 27 districts in 2015. Likewise, the number of districts in consuming firewood will be reduced from 34 in 2015 to 15 in 2030. Fourteen and 33 districts in the years 2015 and 2030 will have less than 40 percent households using firewood.

Conclusions

The computerized GIS tool has been used to visual portray of consumption levels of each of the four main energy sources – firewood, electricity, kerosene and LPG at district level into four categories for the whole country through a series of thematic maps, while a series of tables

have been constructed to depict their average levels at ecological and development regions. Both techniques are found suitable to vividly depict the consumption patterns of the energy sources.

The consumption patterns are that the overall country's consumption level of firewood in 2001 was 77.05 per cent, followed by kerosene and electricity with 60.22 and 31.6 per cent respectively. The consumption level of LPG was the lowest with 14.16 per cent. The consumption patterns of electricity and LPG are more or less the same for the ecological regions; with highest in the Tarai, while the mountain being the lowest. The firewood energy source is the largest and available throughout the country. This can be explained by the extensive forest coverage with slightly over 38 per cent across the country. Ironically, the hydro electricity based on locally available water source, being the largest natural reserviour shares only 31.6 per cent, nearly two and half less of the firewood, or half of the kerosene. The other two energy sources - kerosene and LPG are to be imported.

In absence of time series data on household level energy consumptions of those four main energy sources, their predictions for three different years - 2005, 2015, and 2030 at district level have been made taking HDI, based on the finding of close relationship between the energy consumption level and human well-being.

The projected values of those energy sources are that there will be a decreasing trend of household proportion in consuming firewood, which signifies lessening burden on forest resource and improving HDI. This also means that larger number of households across the county will use other alternative or renewable energy sources. Likewise, increasing in household consumption of hydro electricity means rising HDI ratios, as well as increasing utilization of locally available water resource, which significantly will help to decrease the burden of foreign currencies that would be required for import of energy sources like kerosene. Here, increasing hydro electricity means to provide electricity through developing micro hydro projects, which will reduce a huge amount of transportation cost incurred for distribution of kerosene, particularly in the remote hill and mountain districts. But however, increasing projected consumption of LPG would require foreign currencies in the future, and internally within the country, if roads are not constructed, the cost for transporting LPG to the remote areas would be much higher. The projected consumption patterns of the energy sources may however be affected by the internal movements of people resulted from the provision of facilities and infrastructure in few selected places or districts.

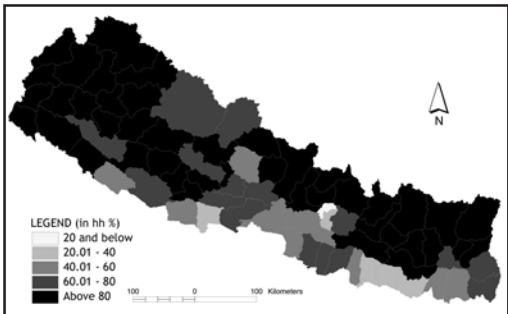

Fig 1 Households using firewood, 2001

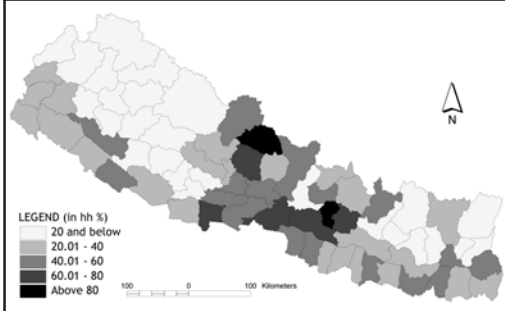

Fig 2 Households using electricity, 2001

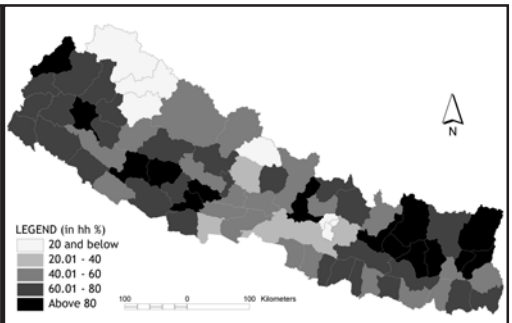

Fig 3 Households using kerosene, 2001

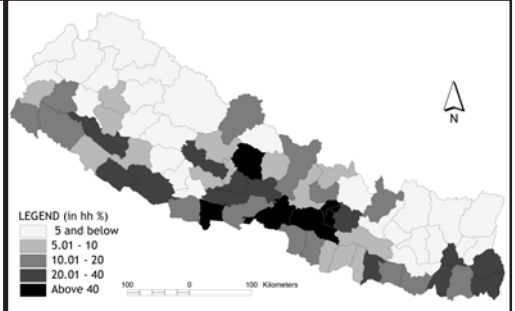

Fig 4 Households using LPG, 2001

Electricity consumption projected pattern pattern

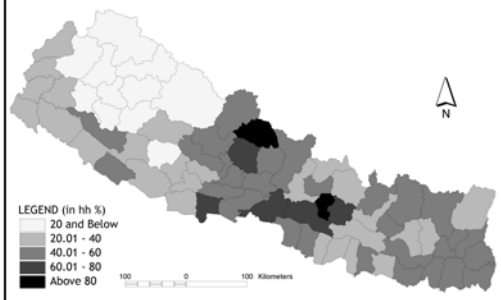

Fig 6 Households using electricity, 2005

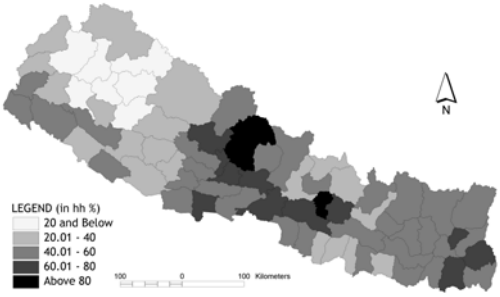

Fig 7 Households using electricity, 2015

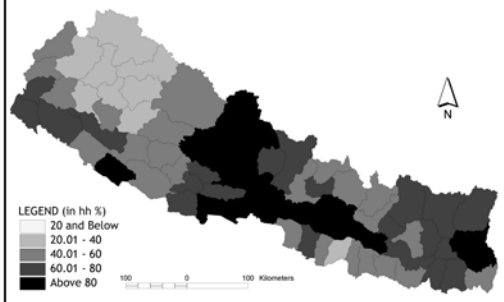

Fig 8 Households using electricity, 2030

Kerosene consumption projected

Fig 9 Households using kerosene, 2005

Fig 10 Households using kerosene, 2015

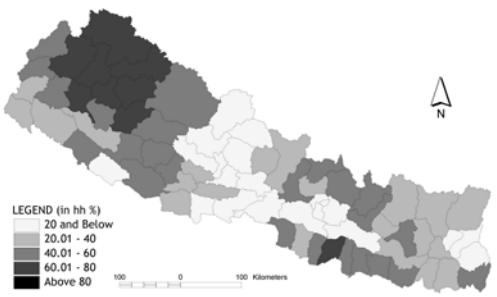

Fig 11 Households using kerosene, 2030

Firewood consumption projected pattern **LPG consumption projected pattern**

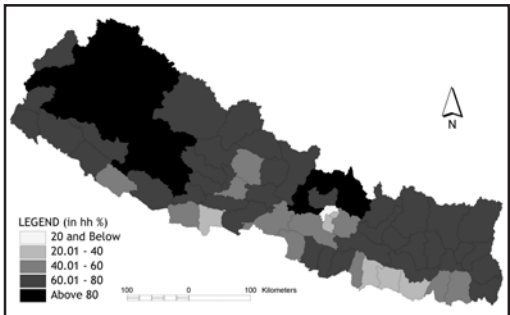

Fig 12 Households using firewood, 2005

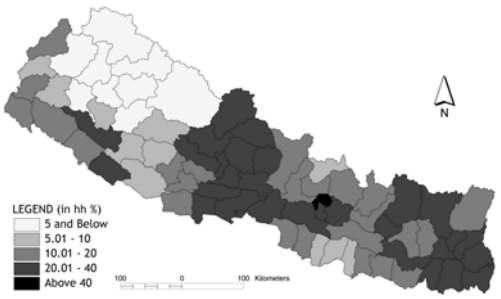

Fig 15 Households using LPG, 2005

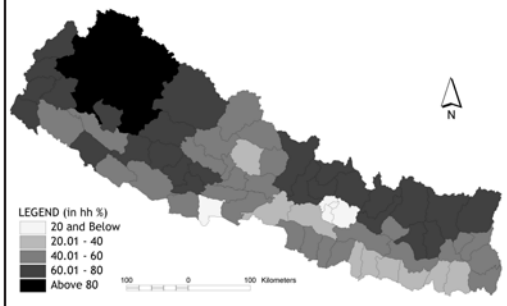

Fig 13 Households using firewood, 2015

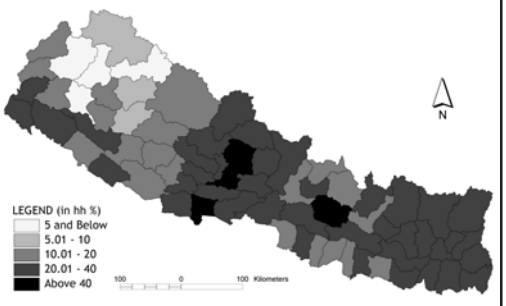

Fig 16 Households using LPG, 2015

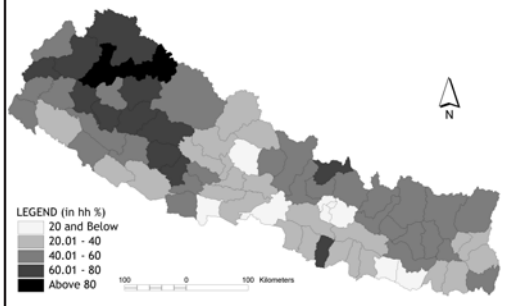

Fig 14 Households using firewood, 2030

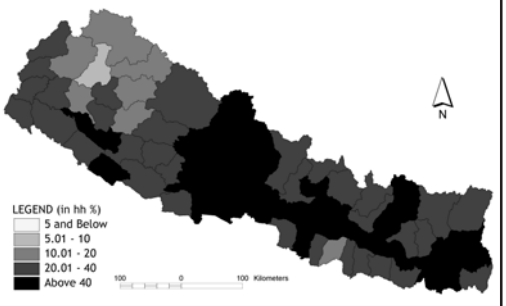

Fig 17 Households using LPG, 2030

References

CBS (2003), *Population Projection for Nepal 2001* - 2021, Kathmandu: Central Bureau of Statistics.

CBS (2002), *Population Census 2001 National Report*. Kathmandu: Central Bureau of Statistics.

Pradhan, Pushkar K and Pradhan, Bandana (2007), *Environment and Natural Resources: Concepts, Methods, Planning & Management.* Kathmandu: Quest Publications.
UNDP (2004), *Nepal Human Development Report 2004*. Kathmandu.

UNDP (2002), *Nepal Human Development Report 2001*: *Poverty Reduction and Governance*. Kathmandu.

Upadhyaya, P (1979), *Energy Consumption and Societal Development: A Cross National Causal Analysis 1960-1970*. Cornel University, USA.

WEC (1999), *The Challenge of Rural Energy Poverty in Developing Countries.* London: World Energy Council (WEC).

WECS (2006), *Energy Synopsis Report-2006*. Kathmandu: Water and Energy Commission Secretariat.