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**THE DEMAND FOR ENERGY IN THE
NEPALESE MANUFACTURING ESTABLISHMENT**

**Kamal Banskota
and
Bikash Sharma**

ADPI Series No. 2

September 1993

International Centre for Integrated Mountain Development

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**Dr. Kamal Banskota was a Resource Economist and Mr. Bikash Sharma
an Agricultural Economist at the time of writing this paper at ICIMOD.**

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Preface

This discussion paper was produced as one of the background papers for the preparation of an integrated economic and environmental development plan for the Bagmati Zone. The main purpose of the paper was to develop a better understanding of the energy supply and demand structure, and it provides an in depth analysis of this aspect for the manufacturing sector. Understanding these linkages is very important, not only because of the role of manufacturing in the future development of the region, but also for the purpose of being better prepared to cope with the problems of a rapidly escalating demand for energy. Some energy inputs face inelastic supply, while others have significant environmental problems, and still others involve huge amounts of foreign exchange. The use of pricing policy to reflect the real domestic costs of these resources is essential if energy use is to be efficient as well as non-limiting for the development of manufacturing in the region. In view of the data constraints for the region, the analysis was undertaken on a national level and the broad conclusions arrived at are also valid for the Bagmati Zone.

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1. Introduction

An adequate supply of inexpensive energy is vital for economic development. As a country's economy grows and begins to modernise, the demand for energy will also increase at an accelerated rate. This demand for energy will be more pronounced in the modern or non-agricultural sector than in the traditional sector. Within the last decade or so the modern sector has grown at a faster rate than the agricultural sector. Consequently, the energy demand of the manufacturing sector has also increased (WECS 1989). This study is concerned with the manufacturing sector only.

Nepal's population is growing rapidly and the need to generate more employment opportunities to absorb the increasing population has become a serious concern. Traditionally, the agricultural sector absorbed the increasing population, but the sluggish growth in this sector has resulted in an overall decline in labour productivity. The manufacturing sector in Nepal is very small compared to the agricultural sector. Currently, the manufacturing sector's contribution to total real GDP is improving, but it remains below 40 per cent and employs less than 12 per cent of the total population. This sector has a potential for growth and for the generation of income and employment, as well as the potential to contribute a larger share to the total GDP. The large-scale migration from rural to urban areas provides an indication that the agricultural sector is no longer able to continue absorbing the growing population. Annually, a large number of rural people migrate to urban areas in search of jobs, but employment opportunities have not grown rapidly enough to absorb the new entrants to the urban labour markets.

The development rhetoric of today is environmentally-friendly economic growth. The increasing concern over environmental degradation has added another dimension to the economic growth process (Banskota et al. 1990). It has been realised that growth accompanied by lack of environmental concern is unsustainable since the resource base of a nation gradually degrades over time and development becomes unsustainable (WCED 1987). Non-renewable energy sources that are used by the manufacturing sector constitute a major factor that has caused concern about the process of economic growth, since these types of non-renewable energy also pollute the environment. In the case of Nepal, the situation is even more serious as a large number of industries continue to use wood - a renewable energy source. This has resulted in deforestation which has already reached alarming proportions in Nepal. Water resources can be tapped to generate non-polluting hydropower, but the sluggish development in hydropower generation does not make this a reliable energy source for the manufacturing sector. Hence, for some time to come, the energy types that will be consumed by the manufacturing sector will continue to be a mix of various energy types.

This study is divided into eight sections. The second section describes the problems and objectives of the study. The third section briefly highlights the overall energy consumption pattern in Nepal based on time series data. The fourth section presents the methodology used in this study, consisting of the translog cost function, in order to understand the relationship between the different energy types needed by the manufacturing sector. The fifth section presents the data construction and parameter estimation technique of the translog cost function. The sixth section provides a more detailed discussion of the energy consumption pattern of the manufacturing sector based on 1986/87 census data to estimate the translog cost function. The seventh section is devoted to a discussion of the results generated by the translog cost function. Policy implications are discussed in the last section.

2. Statement of the Problem and Objectives of the Study

Problem

The potential for growth in the manufacturing sector is enormous. It can provide gainful employment to a large number of people in Nepal. This growth in the manufacturing sector will however depend on easy access to raw materials, markets, other inputs, capital, energy, and many other requirements, including a set of conducive policies. The present study focusses on the energy input by the manufacturing sector.

Currently, little is known about the economics of the manufacturing sector. As the role of the manufacturing sector increases, generating more income, employment and exports will be generated, and the structural changes that are likely to take place can be influenced by appropriate policies. Moreover, the resource base is scarce, therefore, appropriate investment policies should be encouraged and inappropriate ones discouraged.

To understand the economics of the manufacturing sector, the production structure or technological features of this sector should be understood. From an economic point of view, a production technology is summarised by the production function or its dual, the cost function. A production function or a cost function that does not *a priori* restrict the technology and which also allows the possibility of testing the validity of different kinds of restrictions is desirable.

Knowledge of the technology of the production structure enhances understanding of factor demand and its relation to changes in relative prices, degree of factor substitution among inputs, economies of scale, technical change biases of factor use, as well as other types of information that can be valuable in policy formulation.

As the role of the manufacturing sector increases, the demand for energy inputs will also increase. Currently, the manufacturing sector consumes three broad classes of energy inputs, namely, solid fuel (wood and coal), liquid fuel (diesel, kerosene, petrol), and electricity. Except for wood and electricity, all other energy inputs are imported by means of convertible currency. Increased energy consumption also has negative environmental implications.

Wood continues to be used by many industries in Nepal. Given the large-scale deforestation and related problems in Nepal, the continued use of this energy type does not appear to be rational from a long-term perspective. Electricity is among the major energy types consumed presently in Nepal. The manufacturing sector of Nepal can be electricity-based, given the fact that Nepal has the potential to develop this non-polluting energy. Currently, however, many industries continue to use other types of energy than electricity for various reasons.

Objectives of the Study

The purpose of this study is to understand the demand for energy in the Nepalese manufacturing establishment. This investigation was carried out by utilising the translog cost function described below. Energy is assumed to be a separable input from labour, capital, and materials in the manufacturing sector. This assumption means that we hold output and other variable inputs constant along a given isoquant and evaluate the role of different types of energy. Thus, we develop an energy sub-model for the manufacturing sector. This sub-model permits examination of the relationship between the different types of energy consumed by the manufacturing sector.

The specific objectives are as follows:

- to estimate the manufacturing sector's energy demand;
- to evaluate the relationships between different types of energy;
- to understand the implications of energy demand on growth of the manufacturing sector and employment generation; and
- to examine policy implications.

3. Energy Consumption Pattern

Overall Consumption Trend

Before discussing the energy demand in the manufacturing sector, this section provides a brief discussion of the overall energy consumption pattern in Nepal. The annual per capita consumption of energy in Nepal is one of the lowest in the world. The total consumption of energy in 1990/91 was estimated to be 9,147 thousand tonnes of coal equivalent (TCE) of which about 95 per cent was derived from traditional sources (fuelwood, agricultural residue, dung) and the remaining five per cent from commercial sources, namely petroleum products, coal, and electricity. The overall consumption trend of both traditional and commercial energy during the period 1979/80-1990/91 is presented in Table 1 and (Figure 1) along with the annual average growth rates of both types of energy.

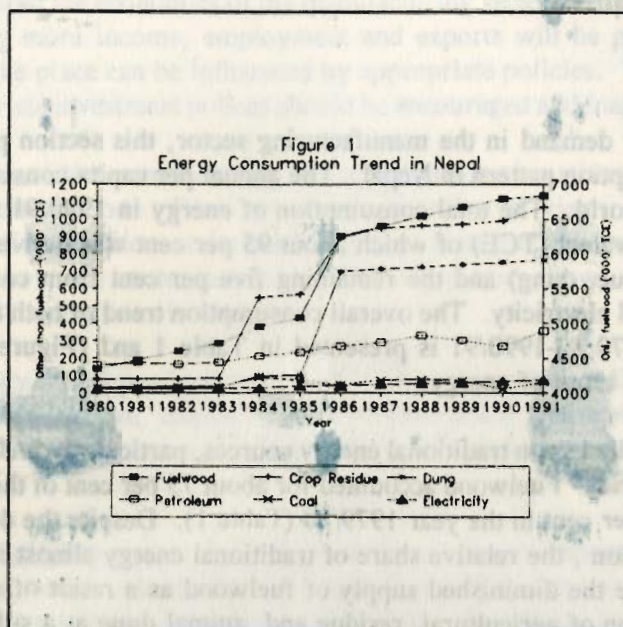
The country is heavily dependent upon traditional energy sources, particularly fuelwood which comes mostly from the forest and private lands. Fuelwood accounted for about 75 per cent of the total energy consumption in 1990/91 compared to 93 per cent in the year 1979/80 (Table 1). Despite the declining share of fuelwood in the total energy consumption, the relative share of traditional energy almost remained stagnant over the past decade. This is because the diminished supply of fuelwood as a result of dwindling forest resources forced increasing consumption of agricultural residue and animal dung as a substitute cooking fuel. The average annual growth rates of agricultural residue and dung consumption during the period 1980-1991 were 27 and 35 per cent respectively, compared to 4.2 per cent annual growth of fuelwood consumption over the same period (Table 1). The current trend of redirecting agricultural waste and dung from use in agricultural fields to use as a cooking fuel will have long-term detrimental effects on soil fertility and productivity. The loss in agricultural production through this substitution and deforestation is still unknown.

Table 1: Traditional and Commercial Energy Consumption Pattern in Nepal
'000 tonnes of coal equivalent (TCE)

Energy Types	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Growth
Traditional													
Wood	4341	4476	4596	4718	4946	5075	6248	6393	6544	6667	6786	6834	4.21
Residue	77	79	81	83	550	565	893	944	961	967	989	1067	27.00
Dung	29	30	31	32	95	98	696	710	725	737	748	761	34.59
Total	4447	4585	4708	4833	5591	5738	7837	8047	8230	8371	8523	8662	6.25
Share	95.51	95.30	95.48	95.27	94.47	94.48	95.69	95.13	94.73	95.13	96.01	94.70	-0.08
Commercial													
Petroleum	158	174	165	177	211	230	268	288	330	301	266	355	7.64
Coal	31	32	35	36	86	69	46	74	76	70	21	58	5.86
Electricity	20	20	23	27	30	36	39	50	52	58	67	72	12.35
Total	209	226	223	240	327	335	353	412	458	429	354	485	7.95
Share	4.49	4.70	4.52	4.73	5.53	5.52	4.31	4.87	5.27	4.88	3.99	5.30	1.53
Grand Total	4656	4811	4931	5073	5918	6073	8190	8459	8688	8800	8877	9147	6.33

Source: Economic Survey 1991 (Ministry of Finance, HMG)

Note: Growth rates were estimated using a semilog function.



The country's lack of modern infrastructure, low manufacturing and commercial potential, and, above all, the low level of industrialisation explain why the commercial consumption is very low. The commercial energy consumption, however, has been growing at a faster rate (8.0% per annum) than traditional energy consumption (6.2%) over the past decades. According to data presented in Table 1, commercial energy consumption is well below energy provided by dung and crop residues.

Petroleum products, coal, and electricity are the three major forms of commercial energy used in the country and they accounted for 73.2 per cent, 12.0 per cent, and 15 per cent respectively of the total commercial energy consumption in the year 1990/91. Table 1 indicates that the average growth rate of electricity consumption is relatively higher (12.3%) than that of petroleum fuel (7.6%) and coal (5.8%).

All the petroleum products and coal consumed in Nepal are imported. Over 85 per cent of the commercial energy used in 1990/91 was imported and the remaining 15 per cent came from domestic sources (i.e., electricity). The total import of POL products increased from 75,019 MT in 1979/80 to 231,847 MT in 1990/91. Diesel was dominant among imported POL products followed by kerosene and petrol. The share of diesel in total POL products increased from 29 per cent in 1979/80 to over 45 per cent in 1990/91.

A large share of the country's foreign exchange earnings from export is spent annually on the import of POL products. For example, the value of POL product import increased from Rs 193.9 million in 1979/80 to Rs 3,025.6 million in 1991. In other words, the value of import of POL fuel as a percentage of merchandise export almost doubled during this period from 21.8 per cent to 40 per cent, and this financial burden is expected to increase over time with growth in the overall economy. It is evident from the table that the share of POL products in the total commercial energy consumption slightly declined from 76 in 1980 to 73 per cent in 1991, whereas the share of electricity was increasing. In other words, the consumption of electricity was growing at a faster rate (12.35%) than petroleum fuel (7.64%) and coal (5.8%). The consumption of electricity in 1991 was 72 thousand TCE compared to 20 thousand TCE in 1980. Rapid urbanisation has led to further increase in the demand for electricity.

Sectoral Consumption of Energy. Table 2 presents the sectoral consumption pattern of both traditional and commercial energy during the 1981-1989 period. The total consumption of energy in 1989 was estimated to be 6,006 thousand tonnes of oil equivalent (TOE) of which about 95 per cent was consumed by the domestic sector and the rest by other sectors like industry (1.8%), commerce (0.9%), transport (1.78%), and agriculture (0.2%). Over ninety per cent of the total energy use in the domestic sector was accounted

for by traditional sources and its share almost remained stagnant over the period. The average annual growth rate of energy consumption in this sector was 7.4 per cent during the 1981-1989 period. Energy consumption in the commercial sector registered the highest growth rate (15.7%), followed by the agricultural sector (12.7%), and industry (9.3%). The lowest growth rate was recorded in the transport sector (5.2%). The relative share of traditional energy was steadily declining in the commercial sector at an annual rate of eight per cent, whereas the opposite prevailed in the industrial sector. Transport and agricultural sectors consumed only commercial energy. Further details of the sectoral energy consumption pattern by type of energy and annual growth rates are presented in Table 3.

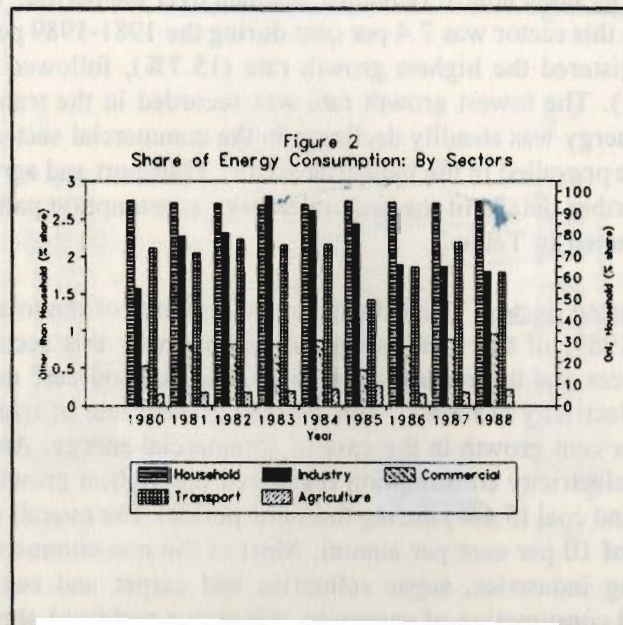
Energy Use in the Manufacturing Sector. The industrial sector's share of the total energy consumption was less than two per cent. In 1989, of the total energy consumption by this sector, about 50 per cent was derived from traditional sources and the remaining from commercial sources, namely, petroleum products (8.3%), coal (27.7%), and electricity (13.8%). The average growth rate of traditional energy is about 12 per cent compared to nine per cent growth in the case of commercial energy. Among the different types of commercial energy sources, electricity consumption registered the highest growth rate (17%), followed by petroleum products (8.6%), and coal (5.6%) during the same period. The overall energy consumption in this sector is growing at the rate of 10 per cent per annum. Most of the non-commercial fuel was consumed by bricks and tile manufacturing industries, sugar refineries and carpet and rug industries. The share of fuelwood and coal in the total consumption of energy by this sector remained almost stagnant at 41 per cent since 1980 (see Figure 2).

Table 2: Share of Energy Consumption by Sectors and by Major Sources of Energy in %

Sectors	1981	1982	1983	1984	1985	1986	1987	1988	1989	Growth
Domestic:										
Traditional	98.81	98.90	98.84	98.77	98.67	98.81	98.72	98.70	98.78	-0.00
Commercial	1.19	1.10	1.16	1.23	1.33	1.19	1.28	1.30	1.22	0.39
Total	95.64	94.73	94.47	94.04	94.14	95.40	95.30	94.86	95.24	-0.05
Industry:										
Traditional	41.51	56.96	55.56	40.87	43.64	56.93	45.87	46.85	50.00	2.35
Commercial	58.49	43.04	44.44	59.13	56.36	43.07	54.13	53.15	50.00	-1.94
Total	1.57	2.26	2.31	2.80	2.61	2.43	1.89	1.87	1.80	1.69
Commercial:										
Traditional	50.00	67.86	65.52	58.82	56.76	48.15	26.09	24.53	25.86	-7.91
Commercial	50.00	32.14	34.48	41.18	43.24	51.85	73.91	75.47	74.14	5.05
Total	0.53	0.80	0.83	0.83	0.88	0.48	0.80	0.89	0.97	7.69
Transport:										
Commercial	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Total	2.11	2.03	2.22	2.14	2.16	1.42	1.85	2.19	1.78	-2.07
Agriculture:										
Commercial	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Total	0.15	0.17	0.17	0.19	0.21	0.27	0.16	0.19	0.22	4.84
All Total:										
Traditional	95.42	95.52	95.19	94.51	94.52	95.88	95.16	94.72	95.22	-0.03
Commercial	4.58	4.48	4.81	5.49	5.48	4.12	4.84	5.28	4.78	0.54
Quantities ('000 TCE)										
All Total:										
Traditional	3217	3335	3338	3883	3987	5400	5492	5617	5719	7.46
Commercial	154	156	169	226	231	232	279	313	287	8.07
Grand Total	3371	3491	3507	4109	4218	5632	5771	5930	6006	7.49

Source: Water and Energy Commission 1989

Note: Within each sector the traditional and commercial shares are based on total sectoral consumption. The total share within a sector is the share of the sector's energy consumption relative to all Nepal.



4. The Translog Cost Function

A production function defines the physical relationship between output(s) and input(s). Consider Q as output and capital (K), labour (L), energy (E), and material (M) as aggregate inputs entering the production process then:

$$Q = f(K, L, E, M). \quad (1)$$

It is likely that producers allocate their outlays first to major groups of inputs such as labour, material, and energy. Once this decision is made and each major input budget has been allocated, the decision to purchase individual inputs within each broad group of inputs may be the second step. For example, once the energy budget has been established, producers may then decide on the amounts of wood, coal, diesel, or electricity to be purchased. In the jargon of economics, such a process implies that inputs are weakly separable. Separability of inputs means that inputs in the production function can be partitioned into subgroups so that some form of independence exists among inputs in each subgroup. As a result, inputs purchased can be written as a function of group expenditure and prices. Weak separability in inputs exists if input use in one subgroup is related to input use in another group in a fixed manner. Stated differently in terms of economic theory, weak separability implies that the marginal rate of technical substitution between two inputs in a subgroup is weakly independent of input use in another subgroup. Other forms of separability can also exist among subgroup of inputs. Global separability implies no dependence among inputs in a subgroup (case of Cobb-Douglas function). Strong separability implies that only some inputs in each subgroup will exhibit relationship among inputs in other subgroups. It is only when weak separability among a subgroups of inputs exists does subgroups aggregates exist. Since our interest in this exercise is to understand the relationship between different energy types used in the manufacturing sector, we assume that energy input is weakly separable from other inputs in the Nepalese manufacturing sector.

Since labour and material inputs are the other two inputs assumed to be used in the manufacturing sector, at least in the case of energy input, it is assumed that energy is weakly separable from materials and labour. Therefore given an aggregate production function (Eq. 1) and assuming energy to be weakly separable from labour and material aggregates, it is possible to write the production function as in Equation 2.

$$Q = f\{E(E_w, E_c, E_d, E_e), L, K, M\} \quad (2)$$

Table 3: Energy Consumption Pattern by Type of Energy and Sector
(^{'000 TCE})

	1981	1982	1983	1984	1985	1986	1987	1988	1989	Growth
Domestic										
Traditional Fuel:										
Wood	3110	3193	3196	3365	3455	4220	4319	4419	4500	4.73
Residue	55	56	57	384	394	620	631	643	652	36.22
Dung	21	22	21	7	69	469	480	490	498	48.55
Petroleum: LPG	0.26	0.4	0.52	0.55	2	1	1.3	1.3	2	29.05
Kerosene	31	28	28	38	40	49	53	56	52	6.68
Total Traditional	3186	3271	3274	3816	3918	5309	5430	5552	5650	7.42
Total Petroleum	31.26	28.4	28.52	38.55	42	50	54.3	57.3	54	7.07
Total Commercial	38.26	36.4	38.52	47.55	53	64	70.3	73.3	70	7.84
Total	3255.5	3335.8	3341	3902.1	4013	5423	5554.6	5682.6	5774	7.43
Industrial Sector										
Fuelwood	22	45	45	47	48	72	44	46	48	10.24
Residue						6	6	6		
Diesel	3	3	2	2	3	10	4	4	4	3.66
Fueloil	2	2	3	3	5	7	7	5	4	9.05
Kerosene						1	1	1		
Coal	22	24	24	56	46	30	33	35	30	3.95
Electricity	4	5	7	7	8	12	14	14	15	17.97
Total Traditional	22	45	45	47	48	78	50	52	54	11.88
Total Petroleum	5	5	5	5	8	17	12	10	9	7.62
Total Commercial	31	34	36	68	62	59	59	59	54	7.18
Total	53	79	81	115	110	137	109	111	108	9.31
Commercial Sector										
Fuelwood	9	19	19	20	21	13	12	13	15	6.59
Kerosene	2	1	2	2	2	3	6	13	16	29.68
LPG					1	1	1	1	1	
Diesel	3	3	2	2	3	1	2	2	-4.94	
Fueloil	2	2	3	3	5	7	7	5	4	9.05
Total Petroleum	7	6	7	7	11	11	15	21	23	16.03
Coal	1	1	3	1	1	17	17	17		
Electricity	2	2	2	4	4	2	2	2	3	5.20
Total Commercial	9	9	10	14	16	1434	40	43	21.59	
Total	18	28	29	34	37	27	46	53	58	15.75
Transport sector										
HSDO	47	43	49	55	58	45	70	88	72	5.48
Motor Spirit	9	11	12	13	14	16	16	18	16	7.46
ATF	14	16	16	19	18	18	20	23	18	3.19
Total Petroleum	70	70	77	87	90	79	106	129	106	5.32
Electricity										
Coal	1	1	1	1	1	1	1	1	1	0.00
Total Commercial	71	71	78	88	91	80	107	130	107	5.26
Agriculture										
Petroleum	5	5	5	6	7	14	7	8	7	4.30
Electricity	1	1	2	2	1	2	3	6		
Total	5	6	6	8	9	15	9	11	13	12.69

Source: Water and Energy Commission 1989

Notes: LPG, HSDO, and ATF are liquified petroleum gas, high speed diesel oil, and aircraft turbine fuel respectively.

What Equation 2 says is that the production function is characterised by an aggregator energy function $E(E_w, E_d, E_c, E_k, E_e)$ and aggregate labour (L), capital (K), and materials (M) respectively. The aggregator energy function $E(.)$ is assumed to consist of wood (w), diesel (d), coal (c), kerosene (k), and electricity (e). It is also possible to define each input in terms of its sub-inputs. For example, the labour input can be assumed to consist of skilled, semi-skilled, and unskilled labour and a similar aggregator function for labour can be defined. Since our interest in the present exercise is only to model the energy demand originating in the manufacturing sector, labour, capital, and material inputs are treated as single aggregate inputs.

Energy Sub-model

Presuming a weak separability of energy inputs in the Nepalese manufacturing sector, the energy demand can be modelled in two stages. If it is assumed that factor prices and output levels are exogenously determined, then the production function (Eq. 1) implies that duality between production and cost exists and, hence, Equation 1 can be written in terms of a cost function as in Equation 3.

$$C = g(P_K, P_L, P^E, P_M, Q). \quad (3)$$

The cost function (Equation 3) represents the minimum cost required to produce the output level Q given labour, capital, energy, and material prices (P_K, P_L, P^E, P_M) respectively. In this study the cost function corresponding to Equation 3 is represented by the translog second-order approximation or simply the translog cost function. The translog cost single output, multi-input cost function developed by Christensen, Jorgenson, and Lau (1973) can be written as:

$$\ln C = \alpha_0 + \sum \alpha_i (\ln P_i) + \alpha_q (\ln Q) + \alpha_f (\ln \text{FIX}) + \frac{1}{2} \sum_i \sum_j \alpha_{ij} (\ln P_i \ln P_j) + \frac{1}{2} \sum_i \alpha_{iq} (\ln P_i \ln Q) + \sum_i \alpha_{if} (\ln P_i \ln \text{FIX}). \quad (4)$$

The α 's are the parameters of the cost function with Q as output and FIX as fixed input (discussed below). The neoclassical production theory states that a production structure must be well behaved. For the cost function, this implies the following:

- 1) the cost function must be a strictly positive function for positive input prices and positive output levels;
- 2) the cost function is a smooth non-decreasing function in input prices;
- 3) the cost function is positively and linearly homogeneous in input prices, (when all prices double, the cost also doubles);
- 4) the cost function is concave in input prices; and
- 5) the cost function is a continuous function of prices given that the first and second partial derivatives exist.

When the above conditions are satisfied by a cost function, it is said to be well behaved. Translating the above conditions to application means the following set of requirements need to be imposed on the cost function.

- i) **Adding up condition:** sum of input costs must equal total cost.
- ii) **Cournot's aggregation:** producers can reallocate their input expenditures when input prices change but cannot violate the adding up condition.
- iii) **Engel's aggregation:** for a given budget allocation, expenditure will not violate the adding up condition.
- iv) **Symmetry:** the symmetry condition implies that the cross second order partial derivative is equal.

The above conditions can be readily translated in the context of the translog cost function and requires some *a priori* restrictions on the parameters of the cost function (Equation 5). The restrictions are defined in Eq 6 as follows:

$$\Sigma \alpha_i = 1; \Sigma_i \alpha_{ij} = \Sigma_j \alpha_{ji} = 0; \Sigma_i \Sigma_j \alpha_{ij} = 0; \alpha_{ij} = \alpha_{ji}; \Sigma_i \alpha_{iq} = 0; \Sigma_i \alpha_{iq} = 0. \quad (5)$$

It is worth summarising some essential merits of this function in relation to the more common Cobb-Douglas and the CES functions. The translog function is a member of the family of the so-called flexible function forms. What this means is that these flexible functional forms have enough parameters which allow the determination of many economic characteristics of the production structure under investigation. The elasticities of substitution are not *a priori* restricted and can be estimated for each sample observation. Also, economies of scale are not restricted *a priori* and can be evaluated from the estimated parameters of the function. In other words, the flexible functional forms are unrestricted and different production structures such as the homogeneous production structure or the Cobb Douglas structure can be tested for using these flexible functional forms.

The duality principal or Shepherd's lemma, is crucial to the estimation of production attributes from well-behaved cost functions. The factor demand equations (in terms of factor input cost share) can be derived from this lemma and it can be written as follows for the translog cost function (Equation 6):

$$\delta \ln C / \delta \ln P_i = (P_i * W_i) / C = \alpha_i + \Sigma_j \alpha_{ij} (\ln P_j) + \alpha_{iq} (\ln Q) + \alpha_{if} (FIX). \quad (6)$$

where W_i stands for the quantity of i-the input factor. The term $(P_i * W_i) / C = S_i$ gives i-the factor's input budget share. For the translog cost function, the Allen-Uzawa partial elasticities of substitution and price elasticities of demand are given by Eq. 7.

Substitution elasticities

$$\begin{aligned} \sigma_{ii} &= \{S_{ii} - S_i + \alpha_{ii}\} / S_{ii} \\ \sigma_{ij} &= \{S_i * S_j + \alpha_{ij}\} / (S_i * S_j) \end{aligned} \quad (7)$$

Price elasticities

$$\begin{aligned} \epsilon_{ii} &= \sigma_{ii} * S_i \\ \epsilon_{ij} &= \sigma_{ij} = \{S_i * S_j + \alpha_{ij}\} \text{ for all } i, j \text{ and } i \text{ not equal to } j \end{aligned}$$

The Demand for Energy Inputs

We will now discuss the derivation of the energy sub-model. The manufacturing sector can choose among a number of energy types, namely, wood (W), diesel (D), coal (C), kerosene (K), and electricity (E). Imposing weak separability in energy as discussed above, the sub-translog cost function for the energy sub-model can be derived as follows:

$$\ln C_e = \beta_0 + \Sigma \beta_i (\ln R_i) + \frac{1}{2} \Sigma_i \Sigma_j \beta_{ij} (\ln R_i * \ln R_j). \quad (8)$$

where

C_e is the energy cost borne by the firm. The R 's here represent the unit price of each energy type (wood, diesel, coal, kerosene, and electricity). The share equations derived above for the manufacturing sector can

also be derived for the energy cost function as well as the substitution and factor demand elasticities. All the restrictions (Eqs 5) are also imposed on the energy sub-model.

5. Data and Estimation Technique

Data

The data sets used in this study are all from the 1986-7 Census of Manufacturing published by the Central Bureau of Statistics. Six different types of energy are consumed by the manufacturing sector, namely, wood, diesel, coal, kerosene, and electricity. The cost of each type of energy borne by the firm and quantity of each energy type consumed are also available. The cost divided by quantity gives the unit price of each energy type.

The census gives information on about 51 establishments or industries. However, information on all these industries is not complete. We have included a total of 38 industries in our analysis. Energy costs per firm have been used in our analysis. Where some firms did not report using some energy types, the average price has been used, i.e., the independent variables (prices) are non-zero across all observations. For such firms, the dependent variable (energy shares) will nevertheless be zero reflecting non-consumption of a particular type of energy.

It is also important to point out that the data set used is a cross-sectional sample. Cross-sectional data characterise a long-run situation in which producers have been able to select their plant size and the technology within the context of resource constraints faced by them. In the short run, new firms enter industries that have excess profit and some that have suffered losses have quit the industry. As a result, cross-sectional data are characterised to depict a long-run equilibrium situation.

Estimation

Ordinary least square (OLS) cannot be applied to estimate the system. This is because budget share equations imply that their sum must equal one and as a result, the sum of the error terms should equal zero. The model contains a system of equations and should therefore be treated as such. An efficient approach to estimate the parameters of the model is to utilise the technique known as the seemingly unrelated regression equations. Therefore, for the purposes of stochastic estimation, additive disturbance terms are appended to each of the four equations in the multivariate system. The disturbance term captures errors caused by firms failing to behave in a cost-minimising manner. The estimation procedure employed is Zellner's iterative technique (Kmenta and Gilbert 1968). This iterative estimation gives results that are equivalent to the maximum likelihood parameters and are invariant to the equation deleted from the dual system. The disturbance terms in the cost function and the cost-share equations are assumed to be normally distributed, contemporaneously correlated for individual firms, but uncorrelated across firms.

Furthermore, because of the homogeneity constraint, only $n-1$ cost-share equations are linearly independent. Thus, one cost-share equation must be deleted from the system to avoid problems associated with linear dependency. The full dual system includes the translog cost equation and four cost-share energy equations which are estimated as a simultaneous system. The other restrictions implied in Equation (5) also need to be imposed. The SHAZAM econometric package has been used for estimation.

6. Characteristics of Energy Consumption by the Manufacturing Sector

This section will discuss the characteristics of energy consumption by 38 establishments on the basis of census data. The results reported are per establishment. An establishment consists of many firms.

Mean Energy Prices and Energy Budget Shares

Table 4 below presents the mean values of each energy price and energy type budget share, based on 38 manufacturing establishments, as reported in CME 1986-87.

The average unit price of energy borne by firms in the manufacturing establishment are presented in Table 4. The energy price standard deviations reported in Table 4 indicate that unit energy prices do vary across different industries. Under assumptions of perfect competition, prices across industries are expected to be the same. However, the variability can arise due to various factors. The variability, however, must be of a nature that prices are not influenced by internal decisions of the industry (i.e., price elasticity of demand for factors must be perfectly inelastic to individual firms). Price variability in perfectly competitive factor markets is caused by localised markets for relatively immobile factors, institutional factors, variable transportation distances, and non-homogeneous factors of production. To the extent that these influences are beyond the control of the firm, input prices are exogenous. Thus, all industries are price takers in the factor markets and hence the variability observed in the prices is not surprising.

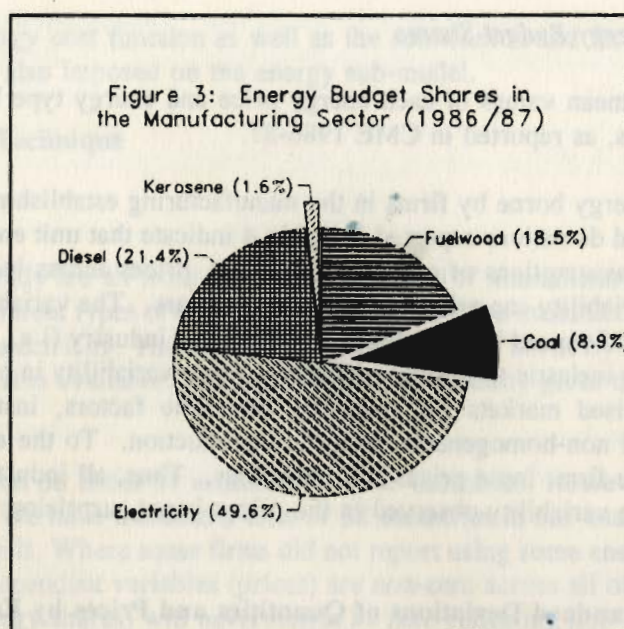
Table 4: Means and Standard Deviations of Quantities and Prices by Energy Types (1986/87)

Energy Type	Mean	Standard Deviation	Minimum	Maximum	Coefficient of Variation (%)
Wood price (Rs/kg)	0.49	0.11	0.29	0.93	22.45
Coal price (Rs/kg)	1.71	0.56	1.43	2.61	45.88
Electricity price (Rs/Kwhr)	1.03	0.16	0.75	1.40	15.53
Kerosene price (Rs/lit)	5.83	0.75	0.00	8.32	12.86
Diesel price (Rs/lit)	7.34	1.23	0.00	9.85	16.76
Wood quantity ('00'kg)	15695	30105	0.00	13061	191.81
Coal quantity ('00'kg)	2934	8566	0.00	48361	291.95
Electricity ('000'kwhr)	3004	5606	5.00	31907	186.62
Kerosene (Lit)	4583	5683	0.00	20919	124.00
Diesel (Lit) 171221	273245	0.00	103970	159.59	

Source: Census of Manufacturing, Central Bureau of Statistics, 1986/87

The coefficient of variation of unit energy prices reported in Table 4 indicates that coal prices, followed by wood prices, show the greatest variation. The remaining three energy prices vary to a lesser extent. The greater variation in the wood price relative to the other energy types may be indicative of segmented wood markets across industries, and this results in large price variations. The observed variation in coal price reflects the differences in the quality of coal that is imported into the country among other conditions.

Table 5 (Figure 3) provides the mean energy budget and budget shares per establishment. An average establishment spent about Rs 5,354,000 per year on energy in 1986/87. It must be noted that each establishment has many firms and the results reported in the tables are per establishment or industry and not per firm. However, the large standard deviation associated with the total energy expenditure implies that substantial variability exists across the industries regarding their energy budgets. Electricity is by far the chief energy source. The average electricity bill was found to be almost half the total energy bill. The relatively (in relation to the mean) small standard deviation also indicates that variability in the electricity bill was far less than observed for the total energy bill. Electricity is relatively the most efficient type of energy among the five types considered, in terms of cost per B.T.U., and it is also a non-polluting energy type.



Following electricity, diesel accounted for nearly half the remaining energy bill after subtracting the electricity bill. The mean budget share for diesel was found to be about 21 per cent. The variability in diesel shares across the industries was greater than that observed for electricity. Wood is the third most important source of energy in the manufacturing sector of Nepal with an average budget share of about 19 per cent. Variations in wood budget shares across industries were more pronounced than in the case of other two energy types already discussed. Coal ranked fourth and kerosene ranked fifth in importance.

Diesel, kerosene, and coal are imported energy types which require foreign exchange. These imported energy types accounted for about 30 per cent of the energy bill. It is quite possible that in the future these imported types of energy will be replaced by electricity, which will not only save foreign exchange but also generate income and employment as well as abate environmental pollution. The relatively huge budget share of wood energy also has grave consequences for the environment as deforestation has already become a serious problem in Nepal.

Table 5: Mean Energy Cost and Energy Type Shares for the Manufacturing Establishment of Nepal (1986/87)

	Mean	Standard Deviation	Minimum	Maximum
Total Energy Budget ('000'Rs)	5354.3	7430.5	41	38124
Wood share	0.185	0.253	0	0.878
Coal share	0.089	0.163	0	0.552
Electricity share	0.496	0.297	0	1.000
Kerosene share	0.015	0.028	0	0.105
Diesel share	0.214	0.212	0	0.666

Source: Census of Manufacturing, Central Bureau of Statistics, 1986/87

Structure of Energy Input Across NSIC Groups

The 1986/87 Manufacturing Census provides a detailed breakdown of input and output of different types of industries classified according to the Nepal Industrial Standard Classification (NISC). The number of

industrial establishments and their percentage distribution by type of industrial grouping are reported in Table 6. For the purpose of analyses, a further aggregation of the industries is conducted on the basis of the NISC. Out of a total of 2,714 establishments, about one-third of the industries are food and food processing industries. Wood and wood products account for the second largest number of establishments (23.3 %), followed by chemical and mineral products (Table 6).

Average Price of Energy

Establishment or industry specific prices of energy have been computed and are provided in Table 7. The average price of wood borne by the firm varies from Rs 0.44 per kg for chemical and mineral-based industries to Rs 0.61/kg for textile, with an average price of Rs 0.50/kg for the industry as a whole. The variation in wood price is found to be minimal for each group of industries as indicated by their respective standard deviation. The average price of coal borne by metal and capital-based industries was relatively higher compared to the other industrial groups. There was less variation in electricity price across the industries. It is interesting to note that, although the average price of kerosene faced by the chemical/mineral and metal based industries was found to be relatively higher compared to the other industrial groups, the price variation within the former group (chemical & metal-based industries) was minimal, relative to the latter. A similar pattern can be observed in regard to the diesel price. It should be noted that the variation in diesel price among food and beverage industries is much more pronounced compared to the chemical and metal/capital based industries as indicated by their standard deviation.

Energy Input Utilisation Pattern

Table 7 shows the average quantity of different types of energy input used by type of industries along with their standard deviations. A close examination of the table reveals a wide variation in the composition of energy utilisation by type of industries. Wood was by far the most important energy input for the carpet and rug industries. The annual wood consumption of these industries in 1986/87 amounted to 64,642 quintals. The beverage industry ranked second in terms of wood consumption although variation in wood use by this industry was much larger than in other types of industry. The large volume of wood required by these industries, especially the carpet industry (mostly located in the Kathmandu Valley), has a grave impact on the environment. Chemical and mineral based industries were the major users of coal and electricity whereas kerosene was mostly used by the beverage industry. Wood and metal based industries consumed a larger volume of diesel compared to the other industries. The details are provided in Table 7. Electricity use across industries was also varied. The paper, chemical, and rubber industries were the prime users and the smallest users were the beverage and tobacco industries.

Budget Share

The energy budget shares by group of industries are given in Table 8. As discussed earlier, the carpet industry relies heavily on wood which is the major source of energy input. About 86 per cent of the total energy cost of this industry was accounted for by wood alone. The contribution of wood to total energy cost was also found to be the highest (60%) for beverage industries. Electricity ranked first in terms of total energy cost for food processing, wood, textiles, and chemical and mineral-based industries. The share of kerosene in total energy cost was generally less than two per cent for the entire establishment. Similarly, coal was found to be the second major source of energy for metal and capital goods' industries, accounting for about 19 per cent of the total energy cost. It should be noted that the last column of the preceding table also provides an idea of the energy intensity of the industries considered. The cost of energy incurred on producing Rs 1 worth of output was also calculated. The beverage and tobacco industries incur the highest energy cost to produce output worth Rs 1. The wood and wood product industries required energy worth Rs 0.20 to produce output worth Rs 1. The carpet and rug industries were in the third position. The remaining industries required less than Rs 0.10 of energy to produce output worth Rs 1. Clearly, the beverage and tobacco, wood and wood product, and the carpet and rug industries are the most energy-intensive industries in the manufacturing establishment of Nepal. An interesting feature of the most energy

intensive industries is that the beverage and tobacco and the carpet and rug industries are the most wood-energy intensive industries. The demand for output of these industries is growing, therefore, the demand for wood will also continue to grow and this has grave implications for the environment as deforestation will be accelerated.¹

Table 6: Average Price of Energy Input by Type of Energy and Industry
Nepal Manufacturing Sector (1986/87)

Industry Classification		Wood Rs/kg	Electricity Coal Rs/kg	Kerosene Rs/kWhr	Diesel Rs/lit	Rs/lit
Food and food processing (NSIC 3112-3122)	Mean	0.453	1.563	0.964	5.373	6.902
	Std	0.100	0.408	0.068	0.352	2.318
Beverages and tobacco (NSIC 3131-3134)	Mean	0.459	1.581	1.002	4.925	4.771
	Std	0.062	0.217	0.002	3.564	3.374
Textiles, apparel & footwear (NSIC 3211-3216, 322-324)	Mean	0.607	1.754	1.034	5.577	7.266
	Std	0.156	0.352	0.191	0.417	0.451
Carpets and rugs (NSIC 3214)	Mean	0.527	1.428	1.044	6.179	8.064
Wood and wood products (NSIC 3311, 3319, 332)	Mean	0.450	1.555	1.036	6.294	7.335
	Std	0.050	0.179	0.113	0.464	1.891
Paper, chemical, and rubber (NSIC 34, 35, 36)	Mean	0.445	1.712	1.016	5.835	8.123
	Std	0.100	0.347	0.028	0.415	0.906
Basic metals and fabricated (NSIC 371, 381)	Mean	0.468	2.031	1.075	6.562	7.311
	Std	0.054	0.310	0.152	0.528	0.989

Source: Census of Manufacturing, Central Bureau of Statistics, 1986/87

Note: There is only one industry under the carpets and rugs category.

¹ The growing demand for food and beverage industries is indicated by the fact that Nepal is considered to be self-sufficient in the production of alcoholic beverages and the tobacco industry has been experiencing a boom.

**Table 7: Average Quantity of Energy Consumption by Type of Energy and Industry
Nepal Manufacturing Sector (1986/87)**

Industry Classification	Wood Quintals	Coal Quintals	Electricity 000' kWhr	Kerosene Litres	Diesel Litres
Food and food processing (NSIC 3112-3122)	15527 26998	704 2319	2176 3248	3821 5775	180226 80731
Beverages and tobacco (NSIC 3131-3134)	46363 59639	899 1271	268 190	6959 5628	127069 177272
Textiles, apparel & footwear (NSIC 3211-3216, 322-423)	4624 7304	555 790	2804 4492	4433 6100	66855 122126
Carpets and rugs (NSIC 3214)	64642	0	412	1942	
Wood and wood products (NSIC 3311, 3319, 332)	11815 16709	201 284	1496 1281	2525 1803	270345 353320
Paper, chemical, and rubber (NSIC 34, 35, 36)	13585 27846	10983 15957	6489 9723	5078 3739	160780 91757
Basic metals and fabricated (NSIC 371, 381)	857 989	783 1549	2315 2918	5758 8758	272472 443304

Source: Census of Manufacturing, Central Bureau of Statistics, 1986/87

Note: There is only one industry under the carpets and rugs' category.
The means are contained in the first line and standard deviation in the second line
for each industry group.

Table 8: Average Budget Shares of Energy Input by Type of Energy and Industry
Nepal Manufacturing Sector (1986/87)

Industry Classification	Total Cost (Rs'000)	Energy Budget Shares					Energy Cost to Produce Rs 1 Worth of Output
		Wood	Coal	Electricity	Kerosene	Diesel	
Food and food processing (NSIC 3112-3122)	4347	0.18	0.03	0.45	0.01	0.26	0.09
	5233	0.21	0.07	0.32	0.03	0.22	0.08
Beverages and tobacco (NSIC 3131-3134)	3154	0.59	0.12	0.14	0.02	0.12	0.22
	3499	0.24	0.17	0.08	0.03	0.15	0.13
Textiles, apparel & footwear (NSIC 3211-3216,322-324)	3540	0.20	0.08	0.62	0.01	0.09	0.08
	5469	0.23	0.18	0.22	0.02	0.06	0.10
Carpets and rugs (NSIC 3214)	3959	0.86	0	0.11	0.003	0.03	0.18
Wood and wood products (NSIC 3311, 3319, 332)	3443	0.07	0.02	0.56	0.02	0.33	0.20
	3603	0.10	0.03	0.17	0.01	0.12	0.05
Paper, chemical, and rubber (NSIC 34, 35, 36)	9899	0.07	0.15	0.51	0.02	0.25	0.10
	11542	0.10	0.22	0.30	0.04	0.26	0.06
Basic metals and fabricated (NSIC 371, 381)	4605	0.01	0.19	0.64	0.02	0.15	0.13
	6029	0.01	0.16	0.15	0.02	0.14	0.07

Source: Census of Manufacturing, Central Bureau of Statistics, 1986/87

Note: There is only one industry under the carpets and rugs' category. The means are contained in the first line and standard deviation in the second line for each industry group.

7 Energy Demand in the Manufacturing Establishment

Parameter Estimates

The maximum likelihood estimates of the energy sub-model are presented in Table 9. Out of the 27 different parameters of the energy sub-model, only 20 are independent. The remaining parameters can be derived as residuals from the restrictions defined in Equation 6. The t-ratios of the estimated parameters indicate that 12 coefficients are significant at the five or 10 per cent level. For a cross-sectional sample, the number of parameters (45%) that are significant is not surprising. In developed countries where data quality is far better than the data available for the manufacturing sector of Nepal, a similar percentage of parameters have been found to be significant.

The parameters of the equations reported in Table 9 do not have useful meaning in themselves but are used in deriving the elasticities of substitution and price elasticities discussed above. The large value of the intercept term in the equation indicates that substantial scope exists to improve the energy sub-model by

introducing other variables. Large values of the intercept occur when the explanatory variables are not able to fully capture the observed variations in the dependent variable, i.e., energy cost or energy cost shares.

**Table 9: Coefficient Estimate of the Homogeneous Translog Cost Function
Nepalese Manufacturing Sector (1986/87): Energy Sub-model**

Parameters	Coefficient	T-Ratio	Parameter	Coefficient	T-Ratio
α_0	9.1951	24.4200*	α_{DK}	-0.00115	1.6873**
α_W	0.9620	5.3000*	α_{CC}	0.2586	1.8650**
α_D	0.0309	0.1400	α_{CE}	-0.2744	1.9500**
α_C	0.0003	0.0160	α_{CK}	0.06154	2.9204*
α_E	0.0356	0.1390	α_{CK}	0.06154	2.9204*
α_K	-0.0287	1.5490	α_{EE}	0.0729	0.2620
α_{WW}	0.2514	1.8140**	α_{EK}	-0.00679	0.3017
α_{WD}	-0.1909	2.0390*	α_{KK}	-0.01032	0.0861
α_{WC}	0.0102	0.1090	DW	-0.3011	4.3400*
α_{WE}	-0.0274	0.1630	DE	0.2460	2.4290*
α_{WK}	-0.0433	2.6860*	DC	-0.0471	0.7500
α_{DD}	0.0124	0.1040	DD	0.0988	1.1670
α_{DC}	-0.0561	0.6030	DK	1.0034	0.5795
α_{DE}	0.2357	1.6740**			

Note: * and ** denote significance at the five and 10 per cent levels respectively. Also note that W, D, C, E and K refer to wood, diesel, coal, electricity and kerosene. Note that for the translog model when share equations are jointly estimated with the cost function, the degree of freedom equals the number of equations (5) multiplied by the number of observations (38), minus the number of independent coefficients estimated (19). The last four terms refer to dummy variables associated with each energy type. The dummy variable used was industries that had electric motors. Industries that had electric motors that were larger than 1,000 hp were assigned a value of 1 and zero otherwise. The introduction of this dummy variable in the model significantly improved the results.

Comparative Static Results

Own and Cross Price Elasticities. According to economic theory, own-price elasticities are expected to have a negative sign, indicating that the demand for the factor input will fall (increase) when its own price increases (decreases). In Table 10, the own (diagonal elements) and cross-(off diagonal elements) price elasticities corresponding to each energy input are presented. The results indicate that the own price elasticity of demand for wood and coal in the Nepalese manufacturing industry is positive, i.e., increase in price of wood and coal increases demand for these energy inputs. Cases of positive own price elasticities do occur. If prices are increasing rapidly due to say speculative motives, then this can result in tendencies to buy the commodity even when its prices increase. Also, in some industries, if wood is the only source of energy and output demand of this industry is growing, then it is likely that the industry will continue to buy the factor input even when its price increases. This may be the case with the carpet and rug industries, where demand (export) has been increasing and wood is the main energy source, which also has little substitution (examined below).

In Nepal, many of the firms within an industry may not have been able to modernise, thus wiping out the scope for substitution between energy types. Reliance on the existing technology thus forces such firms to purchase these fuels even when the prices are increasing, especially when the demand for output of such industries is also increasing. In the carpet and rug industries, dyeing requires extensive wood fuel and since alternative technology is not adopted, demand for wood fuel increases when its price increases, given that the export demand for carpets has been increasing. Similar arguments can be made for the tea industry as well, where the chief source of energy is wood fuel. The own-price elasticity of demand for the other energy

types have the expected negative sign. A 10 per cent increase in the price of diesel, electricity, and kerosene caused the demand for these energy inputs to decrease by 7.28, 4.9, and 16.9 per cent respectively. Clearly, demand for electricity was the most inelastic, followed by diesel and kerosene.

The cross-price elasticities also presented interesting results. A 10 per cent increase in the price of diesel caused wood demand to decrease by about eight per cent when all other energy input prices held constant. Since a given firm has the option to substitute between energy types, either coal, electricity, or kerosene is likely to be substituted when the price of diesel increases and if permitted by the firm's technology. Based on the results presented in Table 10, diesel and electricity appear to have had the greatest impacts (substitution and complementarity) when their prices increased.

Table 10: Energy Demand Elasticities by Energy Types in the Nepalese Manufacturing Sector

	Wood	Diesel	Coal	Electricity	Kerosene
Wood	0.542	-0.816	0.034	0.644	-0.219
Diesel	-0.705	-0.728	0.349	1.596	0.009
Coal	0.071	0.837	1.981	-2.572	0.703
Electricity	0.241	0.689	-0.464	-0.490	0.001
Kerosene	-2.774	0.136	4.295	0.032	-1.691

The own and cross-price effects also were estimated for different industries based on the NSIC. The results are presented in Table 11. It can be observed from Table 11 that the own price and cross-price demand elasticities were very different across the seven groups of industries. Own-price elasticities varied considerably across the industries. The own-price elasticity of wood, though positive in all the seven groups, varied considerably with the basic metals and fabricated group, registering the highest value, and the beverages' industry, registering the lowest value. The own-price demand elasticity for diesel across all the industries was almost the same (ranges from .53 to .777²) except for the paper, chemical, and rubber industries, where the value was found to be relatively more elastic (1.263).

The own-price demand elasticity for coal also exhibited considerable variation with the value ranging from 0 (carpet and rug industries) to 10.57 (wood and wood products' industry). Notice that the carpets and rugs' industries did not use coal as an energy input according to the Census data.

Change in electricity demand due to changes in its own price also had the same narrow range as that of diesel. The own-price demand elasticity of electricity ranges from .22 (carpet and rug industries) to .36 (food and food processing industries). Furthermore, the own-price demand elasticity for electricity is the most inelastic, indicating that the industries did not cut back their demand in the same proportion as price increased. This has implications for the electricity pricing policy for the industrial sector.

Kerosene's own-price demand elasticity also exhibited variations across the industries with a minimum value of 1.41 (beverages industry) and a maximum value of 4.44 (carpet and rug industries). The demand for kerosene energy was clearly very elastic and its value greater than that of diesel. With the exception of chemical-based industries (1.26), own price demand elasticity of diesel for other industries ranged from 0.5 to 0.7.

² We have not written the sign of the elasticities, but it is implied in the argument.

Table 11: Energy Demand Own-and Cross-price Elasticities for Different Types of Industries Classified by NSIC

Industry	Wood	Diesel	Coal	Electricity	Kerosene
Food and Food Processing (NSIC 3112-3122)					
Wood	0.521	-0.737	0.090	0.342	-0.21
Diesel	-0.506	-0.680	-0.168	1.345	0.008
Coal	0.470	-1.272	6.166	-7.078	1.709
Electricity	0.132	0.758	-0.526	-0.363	-0.001
Kerosene	-3.233	0.184	4.899	-0.049	-1.803
Beverages (NSIC 3131-3134)					
Wood	0.017	-0.206	0.140	0.098	-0.049
Diesel	-1.047	-0.777	-0.359	2.168	0.130
Coal	0.675	0.133	1.226	-2.087	0.524
Electricity	0.403	0.079	-1.772	-0.352	-0.023
Kerosene	-1.217	0.630	2.693	-0.139	-1.407
Textiles, Apparel and Leather (NSIC 3211-3216, 322, 323, 324)					
Wood	0.474	-0.879	0.137	0.480	-0.212
Diesel	-1.901	-0.773	-0.532	3.209	-0.004
Coal	0.317	-0.570	2.130	-2.647	0.733
Electricity	0.153	0.472	-0.363	-0.263	-0.003
Kerosene	-5.018	-0.048	7.496	-0.199	-2.234
Carpets and Rugs (NSIC 3214)					
Wood	0.152	-0.194	0.000	0.077	-0.047
Diesel	-5.958	-0.529	0.000	8.527	-0.038
Coal	0.000	0.000	0.000	0.000	0.000
Electricity	0.609	2.190	0.000	-0.222	-0.059
Kerosene	-13.573	-0.355	0.000	-2.154	-4.437
Wood and Wood Products (NSIC 3311, 3319, 332)					
Wood	2.535	-2.298	3.584	0.180	-0.581
Diesel	-0.503	-0.631	-0.147	1.268	0.012
Coal	11.617	-2.173	10.567	-11.692	2.763
Electricity	0.023	0.755	-0.470	-0.312	0.003
Kerosene	-2.721	0.258	3.993	0.120	-1.650
Paper, Chemical, Rubber, Plastic and Mineral (NSIC 34, 35, 36)					
Wood	2.886	-2.646	4.085	0.089	-0.639
Diesel	-0.683	-1.263	-0.066	2.031	0.012
Coal	1.740	-0.108	0.828	-1.271	0.418
Electricity	0.012	1.024	-0.388	-0.350	0.006
Kerosene	-2.466	0.156	3.360	0.152	-1.518
Basic Metal and Fabricated (NSIC 371, 381)					
Wood	34.921	27.118	37.129	-3.279	-6.168
Diesel	-1.234	-0.766	-0.178	2.168	0.010
Coal	1.394	-0.147	0.573	-0.836	0.347
Electricity	-0.036	0.525	-0.245	-0.250	0.007
Kerosene	-2.496	0.087	3.744	0.243	-1.579

The cross-price elasticities are also reported in Table 11. Reading across the rows of the table indicates the change in the demand of (row) energy input when the price of the (column) energy input changed. The results can be interpreted in a manner similar to that already described for the whole industry above.

Energy Substitution in the Nepalese Manufacturing Sector

The estimated parameters of the translog function can be used to derive the Allen-Uzawa partial elasticities of substitution and complementarity between pairs of energy inputs. The substitution-complementarity relationship between the energy inputs is presented in Table 12 for the entire manufacturing establishment. Positive values of these elasticities imply substitution relationship and negative values imply complementarity relationships.

**Table 12: Elasticities of Substitution and Complementarity between Energy Types
Nepalese Manufacturing Sector**

	Wood	Diesel	Coal	Electricity
Diesel	-3.807	--	--	--
Coal	0.385	3.904	--	--
Electricity	1.298	3.216	-5.182	--
Kerosene	-14.974	0.633	48.020	0.065

Diesel and wood, kerosene and wood, and electricity and coal were found to be complements, given the negative signs of the elasticities between these pairs of inputs. Electricity was found to be a substitute for all types of energy except coal. Kerosene was also found to be a substitute for diesel, coal, and electricity. The results indicate that energy types exhibit substitution and complementarity relationships in the manufacturing sector of Nepal. These relationships arise due to changes in relative energy prices. Based on the census data, many industries used more than one energy type in their production process. It might be the case that different energy types were used at different stages of production. Thus, the observed complementarity relationship between wood and diesel energy inputs could be an indication that such industries cut back (increase) energy consumption when either one of the energy prices decreased (increased). Since production involves different activities that require the use of different types of energy, energy curtailment (due to price change) at one stage will also lead to curtailment of the other type of energy at the following stage of production. Complementarity relationships between energy inputs in different industrial groups might reflect different stages of production before the final output was produced. Greater substitution between energy types indicates a more flexible production technology, since the industry had the ability to substitute cheaper fuels for the ones whose prices had increased.

The results for the industrial different group are reported in Table 13. Based on these results, it can be stated that a good deal of substitution takes place between energy types in the manufacturing sector. Also some pairs of inputs display a complementarity relationship. Wood is a substitute for electricity and coal, but is a complement to kerosene and diesel. Diesel is a substitute for all other energy types. Kerosene is a substitute for diesel, coal, and electricity but is a complement to the other two energy types. Coal is a substitute for all energy types except electricity.

**Table 13 : Substitution and Complementarity Relationship between Energy Inputs
Nepalese Processing Sector (1986/1987)**

Industry	Wood	Diesel	Coal	Electricity
Food and Food Manufacturing (NSIC 3112-3122)				
Diesel	-2.683	--	--	
Coal	2.491	-4.629	--	
Electricity	0.702	2.759	-14.514	
Kerosene	-17.139	0.669	135.071	-0.100
Beverages (NSIC 3131-3134)				
Diesel	-1.769			
Coal	1.140	1.140	--	
Electricity	0.680	0.680	-14.414	
Kerosene	-2.056	5.410	21.906	-0.959
Textiles, Apparel, and Leather (NSIC 3211-3216, 322, 323, 324)				
Diesel	-9.661			
Coal	1.610	-6.260	--	
Electricity	0.775	5.185	-4.276	
Kerosene	-25.495	-0.522	88.265	-0.321
Carpets and Rugs (NSIC 3214)				
Diesel	-6.928	--		
Coal	0.000	0.000		
Electricity	0.708	78.228	0.000	
Kerosene	-15.783	-12.690	0.000	-19.765
Wood and Wood Products (NSIC 3311, 3319, 332)				
Diesel	-6.925	--		
Coal	160.017	-6.548	--	--
Electricity	0.323	2.274	-20.969	--
Kerosene	-37.479	0.776	178.247	0.214
Paper, Chemical, Rubber, Plastic, and Minerals (NSIC 34, 35, 36)				
Diesel	-10.382	--	--	--
Coal	26.437	-0.425	--	--
Electricity	0.176	4.019	-2.514	
Kerosene	-37.479	0.612	21.746	0.300
Basic Metal and Fabricated (NSIC 371, 381)				
Diesel	-176.317	--	--	--
Coal	199.085	-0.956	--	
Electricity	-5.162	3.413	-1.316	--
Kerosene	-356.556	0.568	20.074	0.382

8. Energy Use and Policy Implications

The results on price and substitution elasticities estimated provide insight into energy pricing policy. To recapitulate, it has been found that the demand for electricity, diesel, and kerosene is inelastic, with the demand for electricity being the most inelastic, followed by diesel. This was found to hold true for the entire manufacturing establishment as well as across the seven groups. The implication of this result is that, for small changes in electricity demand, firms are not likely to increase or decrease their demand for electricity, thus implying the demand for electricity to be relatively stable among the different energy sources. This has implications for the energy pricing policy. Given the inelastic nature of the demand, for large changes in electricity prices the manufacturing sector is not likely to curtail demand proportionately. Therefore, raising electricity prices (relative) as a means to generate revenue will not be an effective policy, at least in the short run. At the same time, providing subsidies by lowering the electricity price will also not encourage the manufacturing sector to consume more electricity. In the short run, the demand for electricity is conditioned by the firm size and the technology used and hence, small changes in electricity price are not likely to influence the demand for electricity in the manufacturing establishment. The same argument can be put forth in the case of diesel, although the demand for diesel is likely to be relatively more responsive to price changes than electricity demand. The possibility of raising the relative price of electricity, diesel, and kerosene to discourage consumption cannot be totally ruled out in the short run, given that the own-price elasticities of these energy types are all negative. However, the scope to discourage or encourage consumption through pricing policy is fairly limited in the short run.

On the basis of results, it appears that policies aimed at influencing electricity demand have to also rely on non-price actions as well. In the short run, raising the energy price is likely to result in an increase in production costs, given the size and technology of the firm. This cost will ultimately be passed on to consumers. The gains or loss in social welfare have to be judged from more of a macro-perspective. Electricity is domestically produced and discouraging its consumption through pricing policy implies that the manufacturing sector is likely to substitute electricity with other energy types. The substitution elasticities estimated indicate that large substitution possibilities exist between most energy types in the manufacturing sector. Many industries use more than one energy type in the Nepalese manufacturing sector, perhaps at different stages of production. Making electricity relatively more expensive than the other energy types can bring significant changes in the energy mix consumed by this sector, given the state of the technology which characterises this sector.

For example, the results show that the demand for diesel is more highly sensitive to changes in the electricity price rather than to its own price change. Given the strong substitution relationship between these energy types, there is ample scope for reducing (increasing) diesel consumption through removal of tax (subsidy) on the electricity price. Similarly, kerosene demand is highly influenced by coal prices. Such knowledge of cross-price relations are vital for devising successful energy pricing policies. If the policy is to gradually reduce the financial burden of importing diesel and kerosene (by the manufacturing sector), the manipulation in the price of their substitute (electricity) is more effective than mere manipulation of their own prices.

The shares of diesel and kerosene together account for about 22 per cent of the energy budget share of the manufacturing sector. The drain on foreign exchange is already substantial (40 per cent of the export earnings are spent on importing petroleum products as a whole). Continued reliance on these imported energy inputs, therefore, implies that more foreign exchange will have to be diverted for their importation. Energy input is a variable cost for the manufacturing sector. For industries that export their products and earn foreign exchange, greater reliance on the imported energy inputs will be at the cost of plant modernisation, and this also requires foreign exchange. Already many industries in Nepal use technology that is old and cannot invest in modernisation. This has grave consequences for the domestic export industries because they cannot compete in the export markets while product quality and prices suffer as a result of decay, obsolescence, and lack of new capital investments, thereby reducing efficiency in this sector. The implications, however, are not confined to the manufacturing sector alone. Since all sectors of the

economy compete for foreign exchange, if more foreign exchange is diverted to the importation of petroleum products, less foreign currency is available for other sectors of the economy.

The implications of exchange rate depreciation also has implications for the growth and efficiency of the manufacturing sector as well as the whole economy. Exchange rate depreciation implies more diversion of domestic resources to the importation of petroleum products, leading to similar implications as discussed above. In addition, exchange rate depreciation is also likely to raise the domestic price of the products manufactured by the industries and will have direct impact on the relative prices of consumable items. Of course, over-valued domestic currency results in inefficient use of foreign exchange and has to be discouraged. The recent policy towards a more relaxed exchange rate regime made by HMG is a step in the right direction and will over time ease the problem of 'over-valued' domestic currency.

It was also found that fuelwood and coal have positive own-price elasticities and reasons have already been forwarded as to why such might be the case at least in the case of fuelwood. In terms of quantities consumed (expressed in tonnes of coal equivalent), fuelwood continues to be the energy type most consumed by the manufacturing sector. Some industries, such as the carpet, rug, sugar refinery, and beverage are heavy users of fuelwood. Continued use of fuelwood has a direct impact on the rate of deforestation; and this is already a serious environmental problem in Nepal.

It should be pointed out that electricity is domestically produced and its demand is also the most inelastic in the manufacturing sector. Increasingly, more industries in Nepal are beginning to rely on electricity as the main source of energy. The continuous shortage and unreliable supply of electricity can be a major constraint input in the growth of the manufacturing sector. Household consumption of electricity is also increasing in the country and households compete with the manufacturing sector in terms of electricity consumption. Nepal's potential for electricity generation is enormous (second in the world after Brazil) but the ever-escalating production cost has added to the skepticism regarding whether Nepal has a comparative advantage in electrical energy production. Other countries in the world are known to produce electricity at a much cheaper rate than Nepal. Since the technology used to generate electricity is borrowed from the developed countries, it is surprising why costs in Nepal exceed costs in these countries, even after discounting the transport cost, exchange rate differences, and other costs.

If electricity production lags behind industrial growth, and as investors have to rely increasingly on imported energy sources, the growth of this industry will be seriously jeopardised as foreign currency for energy imports, a variable input, will have to compete strongly with foreign currency for capital investments in this sector, as well as in the rest of the economy. Furthermore, new production of electricity has a gestation period that is fairly long. Output growth as well as modernisation can therefore be retarded, and this will have an impact on the efficiency of the domestic industries. Within such a context, the scope for employment generation by the manufacturing sector will also be limited, especially in urban areas, where in the future the bulk of new employment opportunities will have to be generated by the manufacturing sector. Therefore, policies that encourage the production and use of more electricity have to be given top priority. This energy source is non-polluting as well. Since the potential to generate electricity within Nepal is enormous, not only will industries have a more assured supply of energy from domestic sources, but income, employment, and foreign currency impacts can also be significant and positive.

The present energy demand analysis based on econometric techniques is the first of its kind to be carried out for the Nepalese manufacturing sector. Therefore, the results from this study need to be cautiously used. Many questions need to be better explored in order to understand more precisely the demand for energy in the manufacturing sector. Most of the manufacturing establishments appear to use more than one fuel. This could be the result of shortage or unreliability in supply of the desired fuel. Therefore, shortage can lead to captive power generation. Backup systems involve higher unit investment costs because they lack economies of scale and generally consume more expensive types of energy. Over capitalisation will result in inefficient use of scarce resources, especially convertible currency, if such backup systems have to be imported from third countries. Unreliable supply or supply shortages will encourage the continued reliance

on fuelwood among some industries, and this can lead to further deforestation. Clearly, the extent of unfulfilled demand needs to be assessed for a more reliable formulation of a long-run energy policy.

Finally, the present study's focus has been on estimating the energy demand of the manufacturing sector. Relative energy prices have been used to explain energy demand. Pricing policy is an important tool for demand management, especially in the medium and long terms. Once a firm's technology has been decided, the ability of firms to respond to relative energy prices in the short run is limited. Pricing policy is one aspect of energy policy. Other aspects of energy policy would require detailed examination of investment policies, exchange rate policies, policies concerned with power generation, and other factors. The present study is thus fairly limited to provide concrete guidelines on energy policy.

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Director General: Dr. E.F. Tacke

International Centre for Integrated Mountain Development

G.P.O Box 3226, Kathmandu, Nepal

Telex : 2439 ICIMOD NP

Cable : ICIMOD NEPAL

Telephone : (977-1) 525313

Fax : (977-1) 524509