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ENERGY DEMAND AND FUEL SUBSTITUTION MODEL FOR URBAN DOMESTIC SECTOR (For Electricity Planning): The Case of Nepal

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ABSTRACT

The Domestic Sector is the major consumer of energy in most developing countries which is also true for many developed countries. Household cooking, which is a very vital and essential end-use activity in domestic sector, consumes a major portion of the total energy consumed in this sector. The potential for fuel substitution is also very high for household cooking energy use in domestic sector, specially in urban areas where commercial energy has usually a major share in the total energy consumption.

In this study, an analytical model has been developed for energy demand projections and fuel substitution studies for urban domestic sector. The model can be used to update the electric load forecast and consequently the electricity generation expansion plan.

The model has been applied to make energy demand projections and fuel substitution studies for urban household cooking in Nepal.

The results reveal that the potential for substituting kerosene oil with electricity in urban cooking is very high in Nepal. The change in the electric load forecast for Integrated Nepal power System due to kerosene oil substitution is very significant. The availability of vast hydropower potential makes this substitution possible.

The total cost of supplying energy for urban household cooking in Nepal has been calculated for the different scenarios considered. The economic viability of substitution of imported kerosene oil with indigenous hydroelectricity depends on the price of kerosene oil vis-a-vis the cost of developing hydroelectricity.

INTRODUCTION

Complex energy model development in many developing countries has been constrained by a number of factors which include:

i. Lack of reliable and sufficient primary and/or secondary data,

ii. Lack of well established energy/economic relationships,

iii. Lack of reliable energy demand forecasting techniques,

iv. Lack of reliable data on energy pricing impacts, (i.e. income and price clasticities)

v. Lack of clear and consistent energy policies,

vi. Unavailability and/or underdevelopment of indigenous energy resources which result in large import of fuels, particularly petroleum products, and causes fuel supply uncertainty.

vii. Qualified and sufficient technical manpower resources.

The domestic sector is the major consumer of energy in most developing countries which is also true for many developed countries. Household cooking, which is a very vital and essential end-use activity in domestic sector consumes a major portion of the total energy consumed in this sector. Also, there exists a very high potential for fuel substitution in domestic sector, specially in urban areas where commercial energy has a major share in the total energy consumption.

In this study, an analytical model has been developed for energy demand projections and fuel substitution studies for urban domestic sector.

The model has been applied to make energy demand projections and fuel substitution studies for urban household cooking in Nepal, which imports all of its petroleum products requirements, and where the domestic sector relies heavily on petroleum products as far as the supply of commercial energy is concerned. Even though Nepal has one of the largest hydropower potential in the world (total hydropower potential is estimated at 83,000 MW), imported kerosene oil consumed in urban household cooking accounts for more than 86 per cent of the total commercial energy consumed for this purpose.

This heavy reliance of Nepal's urban domestic sector on imported kerosene oil for meeting household cooking energy requirements is causing the following problems at present:

- increased dependency on imported petroleum products
- considerable drainage on scarce foreign currency reserves of the country
- increasing trade deficit
- fuel uncertainty in domestic sector

MODEL FORMULATION

Special Features of the Model

The following are some of the special features of the model developed in this study:

1. The energy demand projections are made on the basis of per capita energy consumption and urban population.

2. Disaggregation of total urban population has been done on the basis of physiographic regions and the size of urban communities. A number of domestic household sector energy use surveys conducted in Nepal[8] have shown that there is a wide variation in per capita energy consumption in different physiographic regions urban community sizes in Nepal.

3. Different values of per capita energy consumption have been used for each physiographic region and community size.

4. Potential for fuel substitution can be studied by varying percentage share of fuels in the total per capita energy requirement.

5. Impacts of improving the efficiency of end-use devices on energy demand can also be studied with the present model.

6. Energy demand projections can be carried out with the help of the present model for each end-use activity within the urban domestic household sector or for the whole sector depending upon the purpose of the study and the availability of data.

7. The model incorporates a separate electric load forecast updating module and a Generation Expansion Plan updating module.

Structure of the Model

The present model consists of six basic modules namely the Demographic module, the Energy demand module, the electric load forecast updating module, Generation Expansion Plan updating module, electricity supply cost module, and energy cost module. The Energy Demand Module is further decomposed into two sub-modules.

The general structure of the model is shown in Figure 2.1. Population and population growth rate, physiographic variation, sizes of urban communities, efficiencies of end-use devices, and percentage share of energy types in the total per capita energy requirement are considered to be the determinants of urban energy demand.

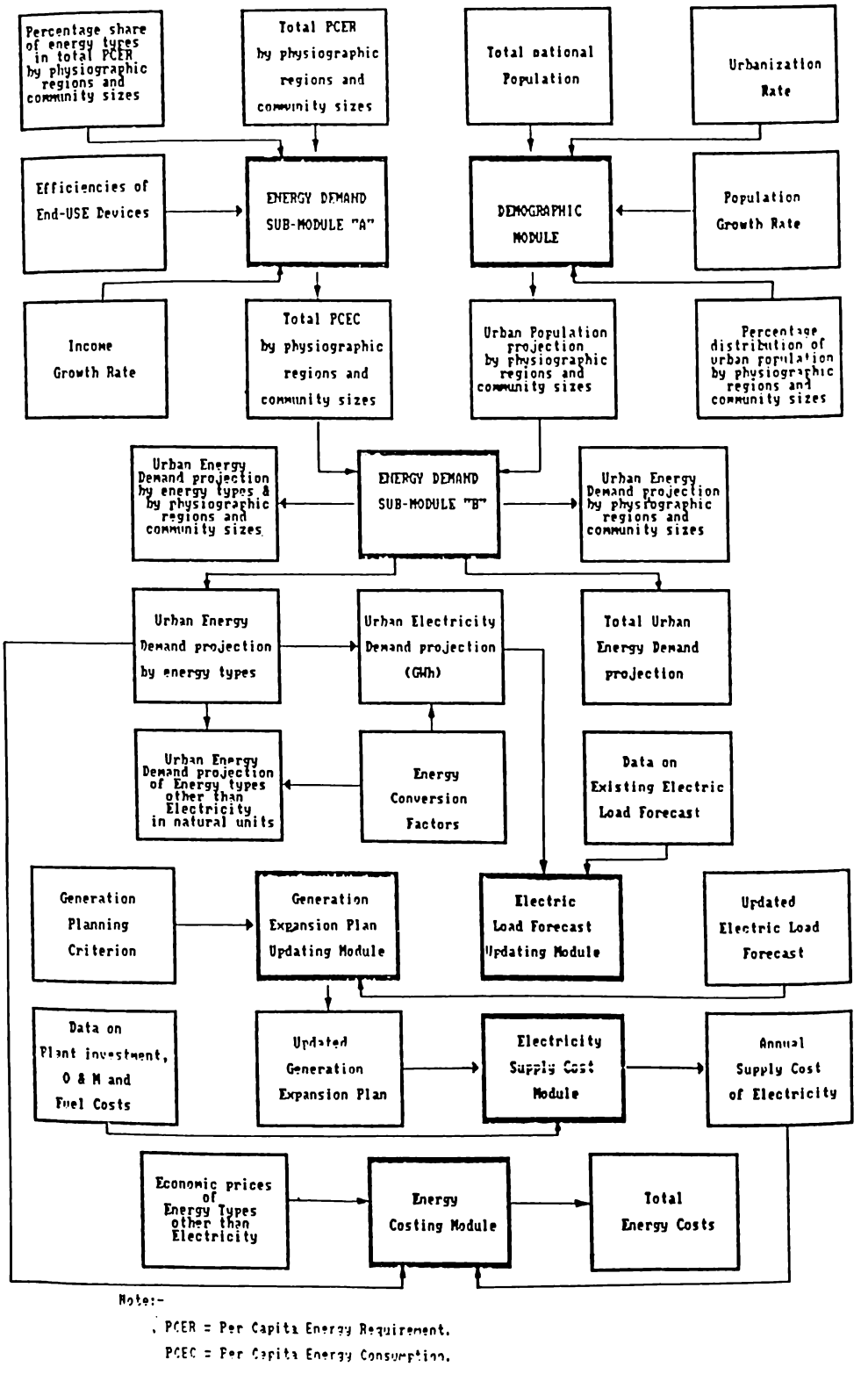

Figure 3.1. General Structure of the Model

Mathematical Formulation of the Model

The Demographic Module

$$TPOP^t = TPOP^{t-1} * (1 + PGR^t)$$

$$UPOP^t = TPOP^t * UR^t$$

$$UPOP_i^t = P_i^t * UPOP^t$$

$$UPT_{ij}^t = P_{ij}^t * UPOP_i^t$$

Where,

$TPOP^t$		Total national population in year t.
$TPOP^{t-1}$	:	Total national population in year t-1.
PGR^t	:	Population growth rate (p.u.) in year t.
$UPOP^t$	:	Urban Population in year t.
UR^t	:	Urbanization Ratio in year t.
$UPOP_i^t$	:	Population of physiographic region i in year t
P_i^t	:	Percentage share of physiographic region i in Urban Population in year t
$UPOP_{ij}^t$	:	Population of community size j of physiographic region i in year t
P_{ij}^t	:	Percentage share of community size j in the population of physiographic i in year t

The Energy Demand Sub-module A

$$PER_{ij}^t = PER_{ij}^{t-1} * (1 + IG_{ij}^t)$$

$$PER_{ijk}^t = P_{ijk}^t * PEFF_{ij}^t$$

$$PEC_{ijk}^t = PER_{ijk}^t / EFF_k$$

Where,

PER_{ij}^t	Total per capita energy requirement of community size j of physiographic region i in year t
IG_{ij}^t	Income growth rate for community size j of physiographic region i in year t
PER_{ijk}^t	Per capita requirement of fuel type k of community size j of physiographic region i in year t
P_{ijk}^t	Percentage share of fuel type k in the total per capita energy requirement of community size j of physiographic region i in year t
PEC_{ijk}^t	Per capita consumption of fuel type k of community size j of physiographic region i in year t
EFF_k	End-use efficiency of fuel type k

The Energy Demand Sub-module B

$$ED_{ijk}^t = PEC_{ijk}^t * UPOP_{ij}^t$$

$$ED_{ij}^t = \Sigma ED_{ijk}^t$$

$$ED_k^t = \Sigma ED_{ik}^t$$

Where,

ED_{ijk}^t	:	Demand of fuel type k of community size j of physiographic region i in year t
ED_{ik}^t	:	Demand of fuel type k of physiographic region i in year t
ED_k^t	:	Total Demand of fuel type k in year t
TED^t	:	Total energy demand of Urban Population in year t

Electric Load Forecast Updating Module

$$ADE^t = DE^t_{SC} - DE^t_{BC}$$

$$UDE^t = DE^t_{ELF} + ADE^t$$

$$UEGR^t = UDE^t / (1\text{-}LRt)$$

$$UPDE^t = UEGR^t / (8.760 * LF^t)$$

Where,

ADE^t Additional demand of electricity (GWh) resulting from fuel substitution year t.

DE^t_{SC} : Demand of Electricity (GWh) from fuel substitution Scenario Case in year t.

DE^t_{BC} : Demand of electricity (GWh) from Base Year Trend Case in year t.

UDE^t : Updated demand of electricity (GWh) in year t.

DE^t_{ELF} Electricity demand (GWh) from existing electric load forecast in year t.

$UEGR^t$: Updated electricity generation requirement (GWh) in year t.

$UPDE^t$: Updated Peak Demand of Electricity (MW) in year t.

LR^t : System Loss Ratio in year t.

LF^t : System Load Factor in year t.

Generation Expansion Plan Updating Module

$$TIC^t > 1.2 * PD^t$$

Where,

TIC^t : Total installed capacity of the electric power system in year t.

PD^t : Peak Demand on the system in year t.

A system reserve margin of at lead 20 percent of the peak demand has been maintained in preparing the Generation Explansion Plan.

Electricity Supply Cost Module

Annual supply cost of electricity is calculated from the following equation.

$$ASCE_t = \frac{TAC_t}{AEG_t}$$

Where,

$ASCE_t$	Annual supply cost of electricity in year t.
TAC_t	Total annual cost in year t.
AEG_t	Total electricity generation in year t.

Total annual cost is given by,

$$TAC_t \quad IC_t + OMC_t + FC_t$$

Where,

IC_t	:	Total investment cost in year t.
OMC_t	:	Total operation and maintenance cost in year t.
FC_t		Total fuel cost in year t.

The annual investment cost is obtained by adding all the annuitized plant development and construction cost and is given by,

$$IC_t = \sum_{R=1}^{n_t} \left[(DCCkt * \frac{i(1+i)^N}{(1+i)N - 1} \right]$$

Where,

DCC_k^t	:	Development and construction cost of plant K in year t.
n_t	:	Number of plants in year t.
i	:	Annual interest rate.
N	:	Life of plant.

The annual supply cost of electricity has been calculated in $/KWh as well as in $/GJ.

Energy Cost Module

The total annual cost of energy for urban household cooking is calculated from,

$$TEC^t = \Sigma\ TED_k^t * EC_k^t$$

Where,

TEC^t : Total energy cost in year t.

TED_k^t : Total Demand of energy type k in year t

EC_k^t : Economic cost of fuel type k in year t.

DISCUSSION OF RESULTS

Base Case

The base case utilizes the fiscal year 1987/88 as the base year and simulation is done for a period of 23 years, or up to the year 2010/11. The base case assumes the following:

1. Distribution of urban population among the different physiographic regions and community sizes will remain unchanged from the base year pattern.

2. Constant price GDP growth rate is used to capture the effect of income growth rate.

3. Same income growth rate has been applied to all physiographic regions and community size:

4. The percentage shares of various energy types in the total per capita energy requirement for cooking in different physiographic regions and community sizes will remain unchanged from the base year pattern.

5. Urban population is disaggregated into two physiographic regions (Hills, Terai) and three community sizes (Small, Medium, Large)

6. Only three types of commercial energy sources namely: kerosene oil, electricity and LP Gas presently being used in urban household cooking are considered.

Results of base case simulation are given in Tables 3.1 and 3.2 and Figure 3.1.

Table 3.1 Energy Demand Projections for Urban Household Cooking
Urban-Total
Base Case Scenario

Unit : ,000 GJ

	Fiscal Year	Kerosene Oil	Electricity	LP Gas	Total
0	1987/1988	611.908	29.285	106.573	847.774
1	1988/1989	655.187	30.858	112.252	898.274
2	1989/1990	836.458	33.789	122.922	1003.170
3	1990/1991	1038.936	37.522	136.505	1213.963
4	1991/1992	1185.388	42.048	152.068	1380.384
5	1992/1993	1305.303	47.097	171.338	1523.738
6	1993/1994	1461.382	52.729	191.825	1705.936
7	1994/1995	1635.419	59.008	214.670	1909.097
8	1995/1996	1828.431	66.009	240.136	2135.576
9	1996/1997	2051.503	74.021	268.286	2394.810
10	1997/1998	2209.873	82.978	301.862	2604.510
11	1998/1999	2578.845	92.980	336.257	3008.182
12	1999/2000	2888.868	104.155	376.812	3368.733
13	2000/2001	3220.781	116.211	422.770	3759.772
14	2001/2002	3609.857	130.242	473.814	4213.713
15	2002/2003	4044.402	145.928	530.880	4721.210
16	2003/2004	4530.353	163.462	594.867	5288.682
17	2004/2005	5073.453	183.058	665.956	5922.466
18	2005/2006	5680.324	204.955	745.815	6630.884
19	2006/2007	6356.350	229.419	834.015	7422.384
20	2007/2008	7115.760	256.748	934.035	8306.543
21	2008/2009	7961.727	287.271	1045.079	9294.078
22	2009/2010	8906.474	321.350	1169.009	10396.922
23	2010/2011	9961.390	359.422	1307.560	11628.373

Table 3.2 Energy Demand Projections for Urban Household Cooking
Urban-Total
Base Case Scenario

Units : ,000 natural units

	Fiscal Year	Kerosene Oil (Kl)	Electricity (MWh)	LP Gas (Ton)
0	1987/1988	22.387	8.137	2.188
1	1988/1989	23.558	8.571	2.282
2	1989/1990	25.798	9.386	2.498
3	1990/1991	28.648	10.423	2.774
4	1991/1992	32.104	11.680	3.108
5	1992/1993	35.058	13.083	3.462
6	1993/1994	40.258	14.647	3.898
7	1994/1995	45.053	16.391	4.383
8	1995/1996	50.388	18.336	4.881
9	1996/1997	56.515	20.561	5.473
10	1997/1998	63.352	23.048	6.135
11	1998/1999	70.980	25.828	6.875
12	1999/2000	79.522	28.932	7.701
13	2000/2001	88.727	32.281	8.593
14	2001/2002	99.440	36.178	9.630
15	2002/2003	111.418	40.538	10.790
16	2003/2004	124.803	45.406	12.087
17	2004/2005	139.764	50.849	13.536
18	2005/2006	156.483	56.932	15.155
19	2006/2007	175.181	63.728	16.964
20	2007/2008	196.026	71.319	18.984
21	2008/2009	219.331	79.798	21.241
22	2009/2010	245.357	89.268	23.762
23	2010/2011	274.418	99.840	26.576

Table 3.3 Energy Demand Projections for Urban Household Cooking
Urban-Total
Low Scenario

Unit : ,000 GJ

	Fiscal Year	Kerosene Oil	Electricity	LP Gas	Total
0	1987/1988	611.908	29.285	106.573	847.774
1	1988/1989	655.167	30.858	112.252	898.274
2	1989/1990	938.459	33.768	122.922	1093.170
3	1990/1991	1039.938	37.522	136.505	1213.963
4	1991/1992	1165.368	42.048	152.968	1360.384
5	1992/1993	1305.303	47.097	171.338	1523.739
6	1993/1994	1461.382	52.729	191.825	1705.936
7	1994/1995	1635.419	59.008	214.870	1908.087
8	1995/1996	1829.431	66.009	240.138	2135.578
9	1996/1997	1848.352	266.863	269.286	2382.501
10	1997/1998	2068.705	299.145	301.862	2670.712
11	1998/1999	2318.251	335.213	338.257	2992.721
12	1999/2000	2597.888	375.502	378.912	3352.413
13	2000/2001	2908.712	418.965	422.770	3740.447
14	2001/2002	2526.780	1148.185	473.814	4148.739
15	2002/2003	2831.081	1286.450	530.880	4648.410
16	2003/2004	3171.247	1441.022	594.667	5206.936
17	2004/2005	3551.417	1613.772	665.956	5831.144
18	2005/2006	3976.227	1808.806	745.815	6528.848
19	2006/2007	3178.175	3217.844	834.815	7231.833
20	2007/2008	3557.880	3601.155	934.035	8093.070
21	2008/2009	3980.864	4029.283	1045.078	9055.228
22	2009/2010	4453.237	4507.402	1169.089	10129.728
23	2010/2011	4980.695	5041.278	1307.560	11329.531

Table 3.4 Updated Electricity Load Forecast Low Scenario

	Fiscal Year	Electricity Demand(GWh)	Loss Ratio(%)	Generation (GWh)	Load Factor(%)	Peak Load(MW)
0	1987/1988	442	27.60	611	49.47	141
1	1988/1989	482	26.50	656	49.90	150
2	1989/1990	510	26.20	691	49.30	160
3	1990/1991	556	24.80	739	49.90	169
4	1991/1992	617	23.00	811	50.00	185
5	1992/1993	684	23.10	889	49.80	204
6	1993/1994	750	22.40	977	50.00	223
7	1994/1995	841	21.50	1071	49.90	245
8	1995/1996	932	20.80	1177	49.90	269
9	1996/1997	1089	20.70	1385	50.00	312
10	1997/1998	1107	20.40	1504	50.00	343
11	1998/1999	1323	20.20	1658	50.10	378
12	1999/2000	1482	20.00	1820	50.00	417
13	2000/2001	1618	19.80	2015	50.00	460
14	2001/2002	1941	19.70	2417	50.20	550
15	2002/2003	2212	19.60	2027	50.40	595
16	2003/2004	2290	19.50	2850	50.60	644
17	2004/2005	2501	19.40	3104	50.80	697
18	2005/2006	2723	19.30	3374	51.00	755
19	2006/2007	3208	19.20	4070	51.20	910
20	2007/2008	3580	19.10	4447	51.40	988
21	2008/2009	3920	19.00	4850	51.60	1073
22	2009/2010	4201	18.90	5201	51.80	1160
23	2010/2011	4687	18.80	5772	52.00	1267

Table 3.5 Energy Demand Projections for Urban Household Cooking
Urban-Total
Scenario Medium

Unit : .000 GJ

	Fiscal Year	Kerosene Oil	Electricity	LP Gas	Total
0	1987/1988	811.808	28.295	106.573	947.774
1	1988/1989	855.187	30.856	112.252	998.274
2	1989/1990	936.458	33.789	122.922	1093.170
3	1990/1991	1039.938	37.522	136.505	1213.903
4	1991/1992	1165.303	42.048	152.909	1360.304
5	1992/1993	1305.303	47.097	171.338	1523.738
6	1993/1994	1461.302	52.728	191.825	1705.936
7	1994/1995	1635.419	59.008	214.670	1909.097
8	1995/1996	1829.431	66.009	240.136	2135.576
9	1996/1997	1848.352	266.863	269.286	2382.501
10	1997/1998	2069.705	290.145	301.862	2670.712
11	1998/1999	2318.251	335.213	338.257	2992.721
12	1999/2000	2597.000	375.502	378.812	3352.413
13	2000/2001	2908.712	416.965	422.770	3748.447
14	2001/2002	2105.794	1467.473	473.814	4127.081
15	2002/2003	2428.041	1668.823	530.880	4624.144
16	2003/2004	2718.212	1080.875	594.867	5178.754
17	2004/2005	3044.072	2000.678	665.956	5800.704
18	2005/2006	3408.104	2340.757	745.815	6494.586
19	2006/2007	1807.505	4413.213	834.615	7155.333
20	2007/2008	2134.720	4838.918	934.035	8007.001
21	2008/2009	2388.518	5528.088	1045.079	8850.085
22	2009/2010	2671.842	6101.619	1169.009	10022.850
23	2010/2011	2988.417	6814.017	1307.580	11208.085

Table 3.6 Updated Electricity Load Forecast Scenario Medium

	Fiscal Year	Electricity Demand(GWh)	Loss Ratio(%)	Generation (GWh)	Load Factor(%)	Peak Load(MW)
0	1987/1988	442	27.88	611	49.47	141
1	1988/1989	482	28.50	658	49.80	150
2	1989/1990	510	26.20	691	48.30	100
2	1990/1991	556	24.00	738	49.80	169
4	1991/1992	617	23.90	811	50.00	185
5	1992/1993	664	23.10	888	49.80	204
6	1993/1994	758	22.40	977	50.00	223
7	1994/1995	841	21.50	1071	49.00	245
8	1995/1996	932	20.80	1177	48.90	269
9	1996/1997	1083	20.70	1365	50.00	312
10	1997/1998	1107	20.40	1504	50.00	343
11	1998/1999	1323	20.20	1658	50.10	378
12	1999/2000	1462	20.00	1828	50.00	417
13	2000/2001	1616	19.80	2015	50.00	460
14	2001/2002	2035	19.70	2534	50.20	576
15	2002/2003	2217	19.80	2758	50.40	625
16	2003/2004	2417	19.50	3003	50.00	677
17	2004/2005	2634	19.40	3268	50.00	734
18	2005/2006	2871	19.30	3558	51.00	798
19	2006/2007	3628	19.20	4400	51.20	1001
20	2007/2008	3970	19.10	4907	51.40	1000
21	2008/2009	4344	19.00	5363	51.60	1187
22	2009/2010	4758	18.90	5864	51.80	1292
23	2010/2011	5207	18.80	6412	52.00	1408

Table 3.7 Energy Demand Projections for Urban Household Cooking
Urban-Total
Scenario Medium

Unit : ,000 GJ

	Fiscal Year	Kerosene Oil	Electricity	LP Gas	Total
0	1987/1988	811.908	20.285	106.573	947.774
1	1988/1989	855.187	30.856	112.252	998.274
2	1989/1990	938.459	33.769	122.822	1093.170
3	1990/1991	1039.830	37.522	136.505	1213.863
4	1991/1992	1165.306	42.048	152.068	1360.384
5	1992/1993	1305.303	47.087	171.338	1523.739
6	1993/1994	1401.362	52.729	191.825	1705.936
7	1994/1995	1635.419	59.008	214.670	1909.097
8	1995/1996	1829.431	66.009	240.136	2135.576
9	1996/1997	1538.627	556.124	269.266	2364.037
10	1997/1998	1724.754	623.389	301.862	2650.015
11	1998/1999	1932.709	698.502	338.257	2969.528
12	1999/2000	2164.990	782.522	378.812	3326.433
13	2000/2001	2425.503	873.097	422.770	3711.400
14	2001/2002	2004.829	3820.781	473.614	4105.424
15	2002/2003	2072.201	2048.787	530.890	4509.878
16	2003/2004	2265.177	2282.728	584.807	5152.572
17	2004/2005	2530.728	2567.581	665.956	5770.263
18	2005/2006	2040.162	2874.707	745.015	6460.484
19	2006/2007	1569.587	4712.058	834.615	7136.258
20	2007/2008	1778.940	5273.350	934.035	7986.333
21	2008/2009	1000.432	5900.209	1045.070	8835.800
22	2009/2010	2226.618	6600.423	1168.008	9886.130
23	2010/2011	2490.348	7382.203	1307.560	11180.110

Table 3.8 Updated Electricity LOad Forecast
Scenario High

	Fiscal Year	Electricity Demand(GWh)	Loss Ratio(%)	Generation (GWh)	Load Factor(%)	Peak Load(MW)
0	1987/1988	442	27.00	611	40.47	141
1	1988/1989	482	26.50	656	40.00	150
2	1989/1990	510	20.20	691	40.30	160
3	1990/1991	556	24.00	738	40.00	169
4	1991/1992	617	23.00	811	50.00	185
5	1992/1993	664	23.10	888	40.80	204
6	1993/1994	750	22.40	977	50.00	223
7	1994/1995	841	21.50	1071	40.80	245
8	1995/1996	932	20.80	1177	40.00	269
9	1996/1997	1163	20.70	1466	50.00	335
10	1997/1998	1287	20.40	1617	50.00	369
11	1998/1999	1424	20.20	1785	50.10	407
12	1999/2000	1578	20.00	1009	50.00	450
13	2000/2001	1742	19.80	2172	50.00	496
14	2001/2002	2120	19.70	2652	50.20	603
15	2002/2003	2323	19.60	2888	50.40	654
16	2003/2004	2535	19.50	3150	50.00	711
17	2004/2005	2700	19.40	3432	50.00	771
18	2005/2006	3020	19.30	3742	51.00	838
19	2006/2007	3711	19.20	4593	51.20	1024
20	2007/2008	4063	19.10	5022	51.40	1116
21	2008/2009	4440	19.00	5482	51.60	1215
22	2009/2010	4872	18.90	6008	51.80	1324
23	2010/2011	5337	18.80	6572	52.00	1443

Table 3.9 Total Cost of Energy for Urban Household Cooking

	Year	Total Annual Cost (In Current NRS)			
		Base Case	Low Scenario	Medium Scenario	High Scenario
0	1987/1988	8190078	8190078	8190078	8190078
1	1988/1989	9034818	9034818	9034818	9034818
2	1989/1990	10383430	10383430	10383430	10383430
3	1990/1991	12081097	12081097	12081097	12081097
4	1991/1992	14005613	14005613	14005613	14005613
5	1992/1993	16650778	16650778	16650778	16650778
6	1993/1994	18294228	18294228	18294228	18294228
7	1994/1995	22004905	22004905	22004905	22004905
8	1995/1996	26461824	26461824	26461824	26461824
9	1996/1997	30753040	32528718	32528718	32528718
10	1997/1998	35432210	37268641	37268641	37268641
11	1998/1999	40785908	42840844	42840844	42840844
12	1999/2000	46903752	48007814	48007814	48007814
13	2000/2001	53055719	55860306	55860306	55860306
14	2001/2002	62040337	74078309	77173000	81121830
15	2002/2003	72103193	82147318	84732009	88180157
16	2003/2004	82870841	91281997	93234140	95043903
17	2004/2005	95102282	1.0E+08	1.0E+08	1.1E+08
18	2005/2006	1.1E+08	1.1E+08	1.1E+08	1.2E+08
19	2006/2007	1.3E+08	1.3E+08	1.3E+08	1.3E+08
20	2007/2008	1.5E+08	1.6E+08	1.6E+08	1.6E+08
21	2008/2009	1.7E+08	1.7E+08	1.7E+08	1.8E+08
22	2009/2010	1.9E+08	1.0E+08	1.0E+08	1.9E+08
23	2010/2011	2.2E+08	2.1E+08	2.0E+08	2.0E+08

Table 3.10 Generation Expansion Plan Nepal Electricity Authority

	YEAR	PLANT TYPE	CAPACITY ADDITION			
			BASE CASE	LOW SCENARIO	MEDIUM SCENARIO	HIGH SCENARIO
0	1987/1988					
1	1988/1989					
2	1989/1990					
3	1990/1991					
4	1991/1992					
5	1992/1993					
6	1993/1994					
7	1994/1995	Diesel	30MW	30MW	30MW	30MW
8	1995/1996					
9	1996/1997	hydro	30MW	50MW	50MW	80MW
10	1997/1998	hydro	40MW	40MW	40MW	40MW
11	1998/1999	hydro	40MW	40MW	40MW	50MW
12	1999/2000	hydro	45MW	45MW	45MW	50MW
13	2000/2001	hydro	50MW	50MW	50MW	50MW
14	2001/2002	hydro	300MW	425MW	465MW	475MW
15	2002/2003					
16	2003/2004					
17	2004/2005	hydro		10MW	10MW	10MW
18	2005/2006	hydro		10MW	10MW	10MW
19	2006/2007	hydro		100MW	125MW	150MW
20	2007/2008	hydro	300MW	440MW	500MW	500MW
21	2008/2009					
22	2009/2010					
23	2010/2011					

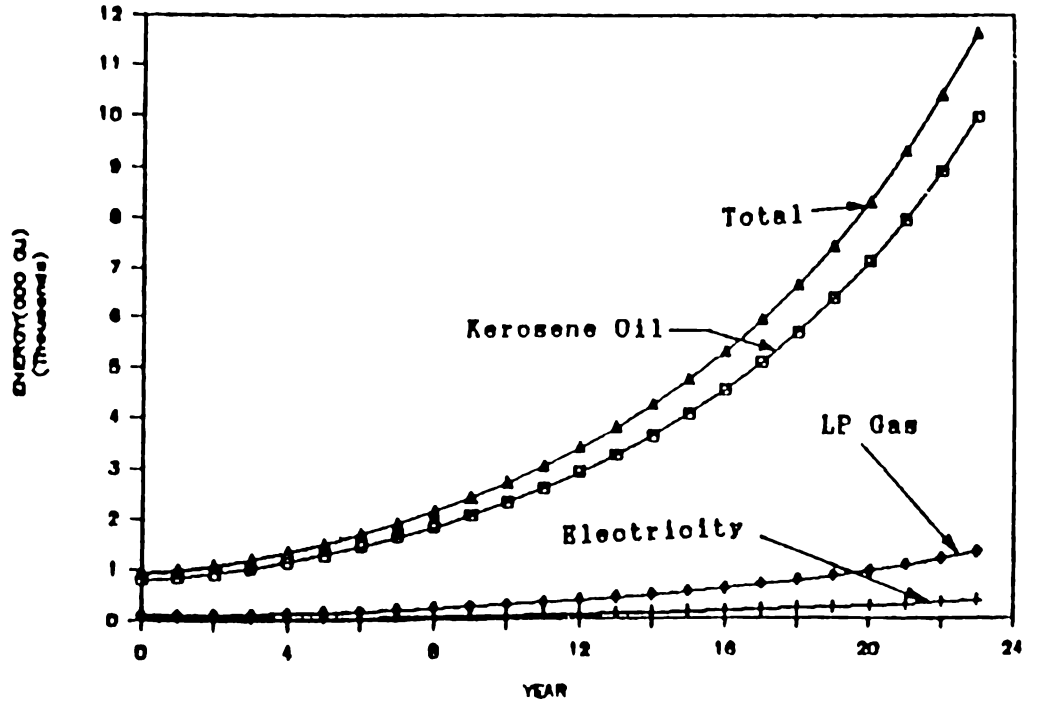

Figure 3.1 Energy Demand Projections
Base Case Scenario

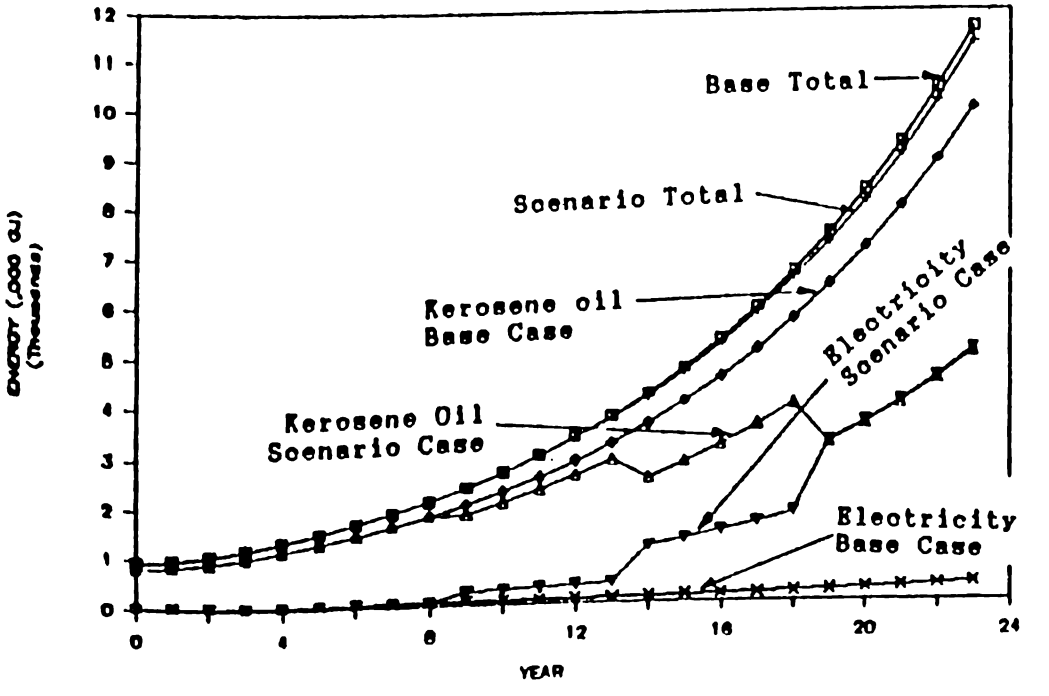

Figure 3.2 Energy Demand Projections
Base Case vs. Low Scenario

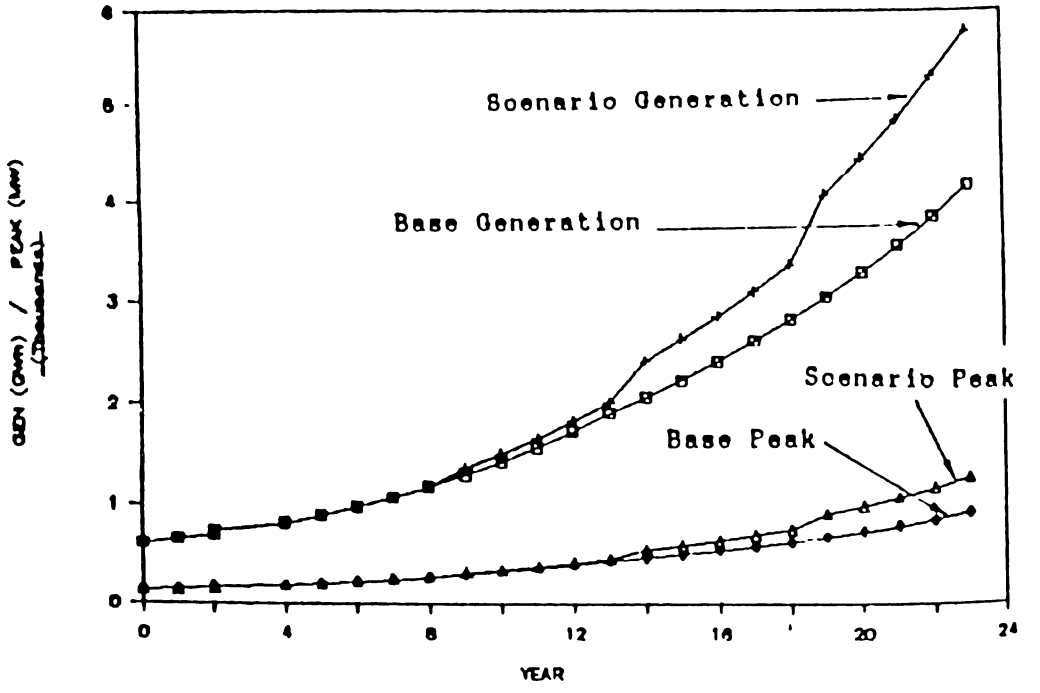

Figure 3.3 Electricity Load Forecast
Base Case vs. Low

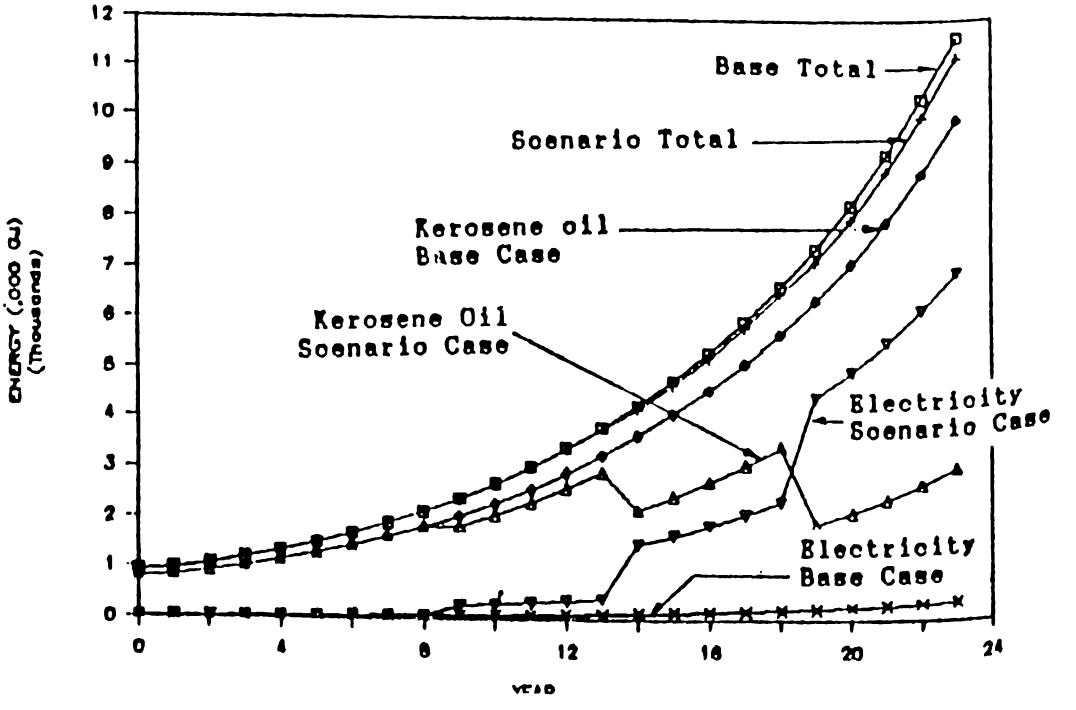

Figure 3.4 Energy Demand Projections
Base Case vs. Medium Scenario

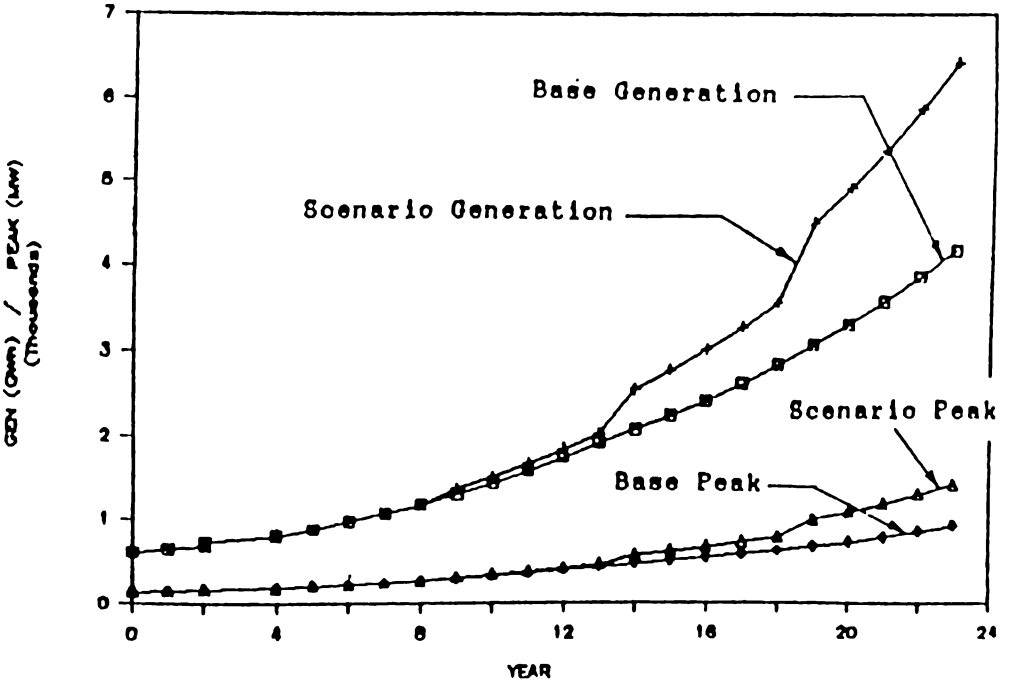

Figure 3.5 Energy Demand Projections
Base Case vs. Scenario

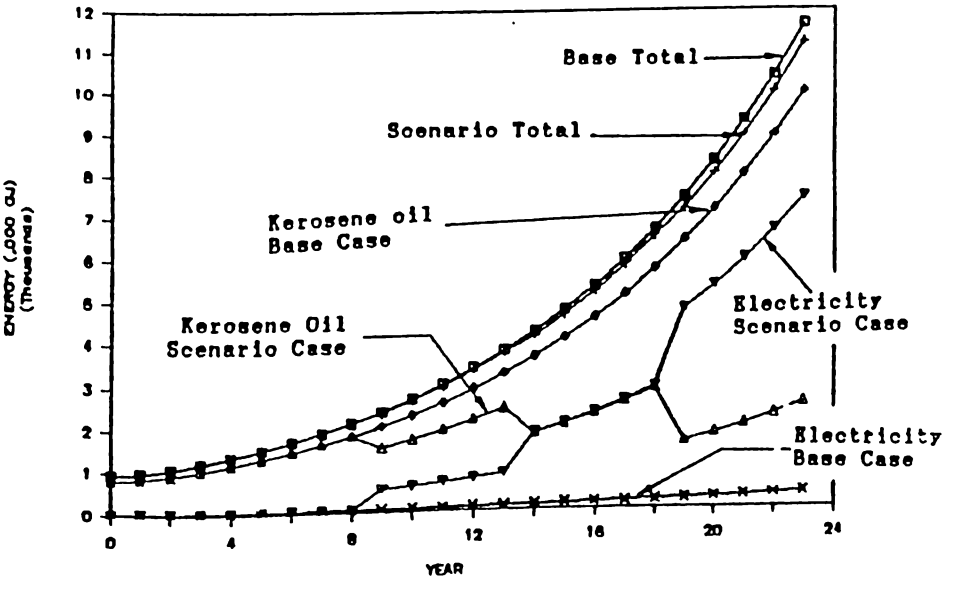

Figure 3.6 Energy Demand Projections
Base Case vs. Scenario

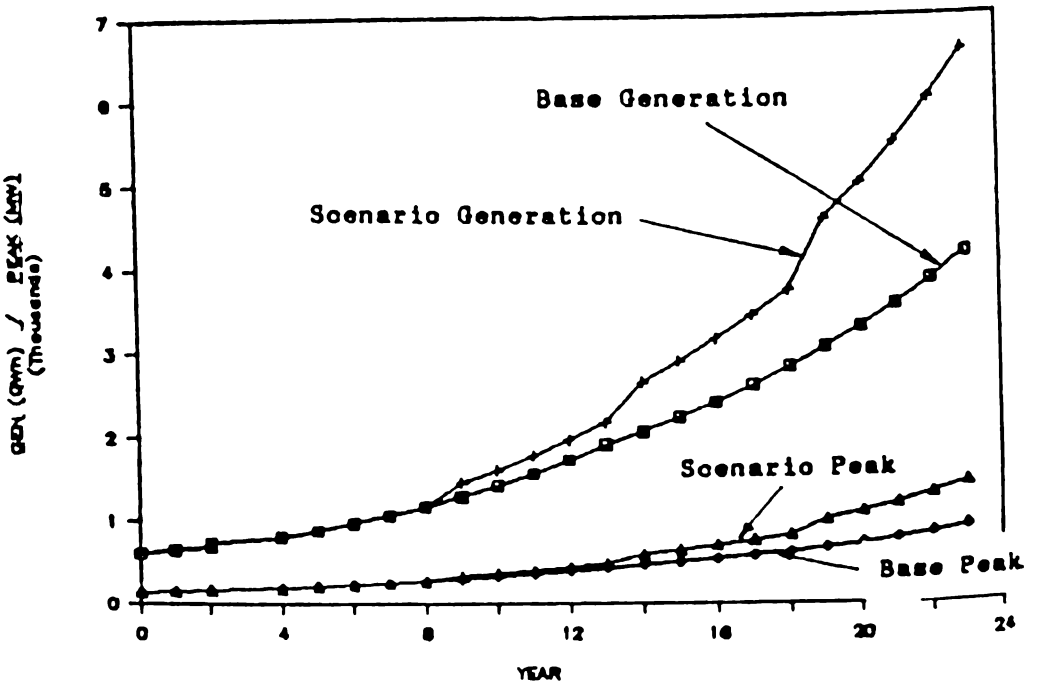

Figure 3.7 Electricity Load Forecast
Base Case vs. High

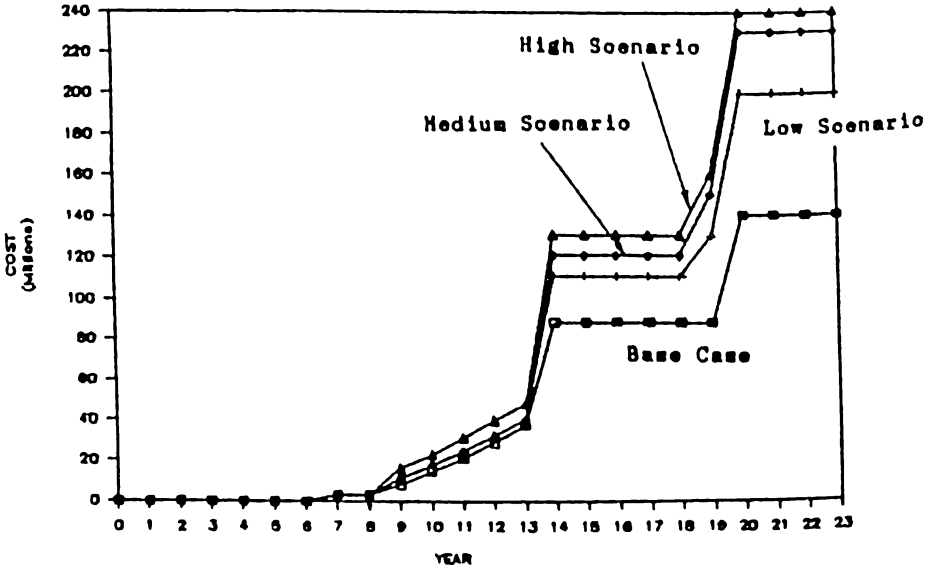

Figure 3.8 Investment Cost For Electricity
Generation (Current US $)

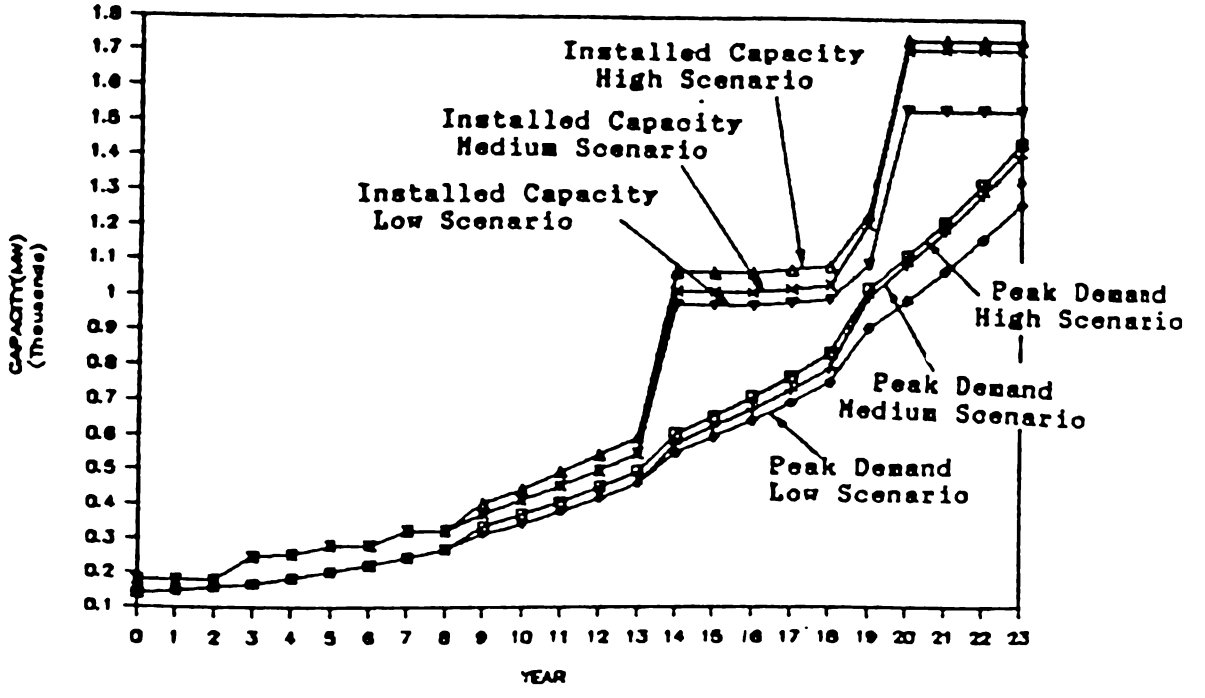

Figure 3.9 Electricity Generation PLanning
Low, Medium, and High Scenario

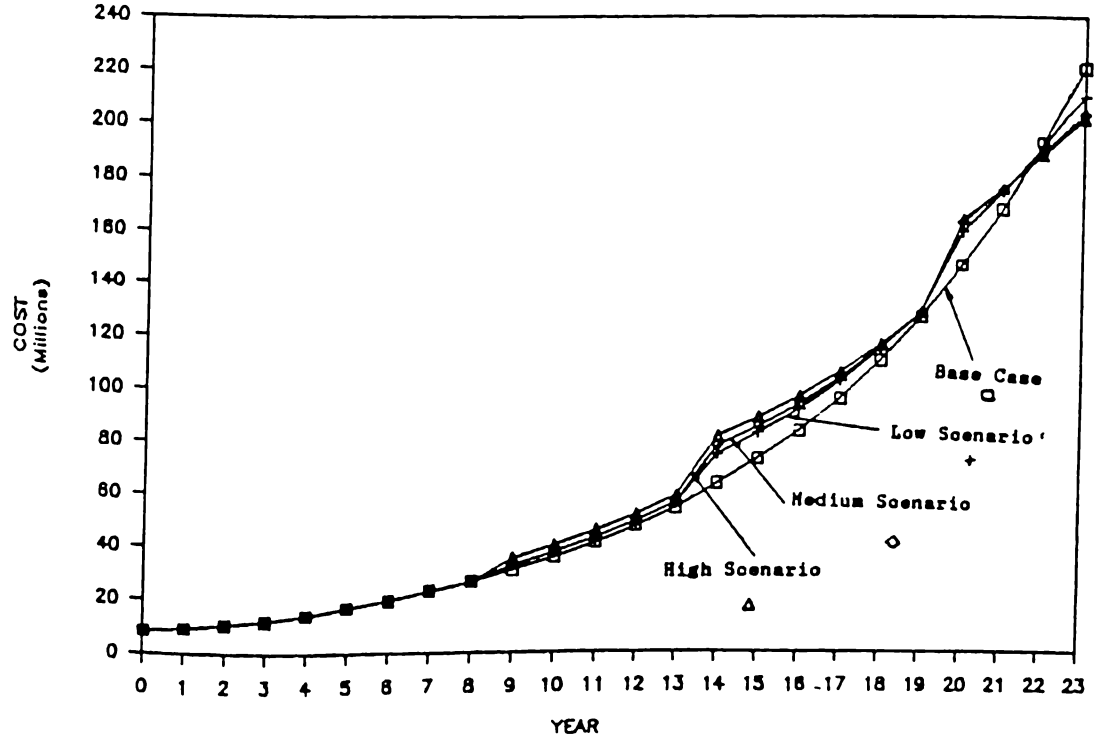

Figure 3.10 Total Energy Cost For Urban Household Cooking
(Current US $)

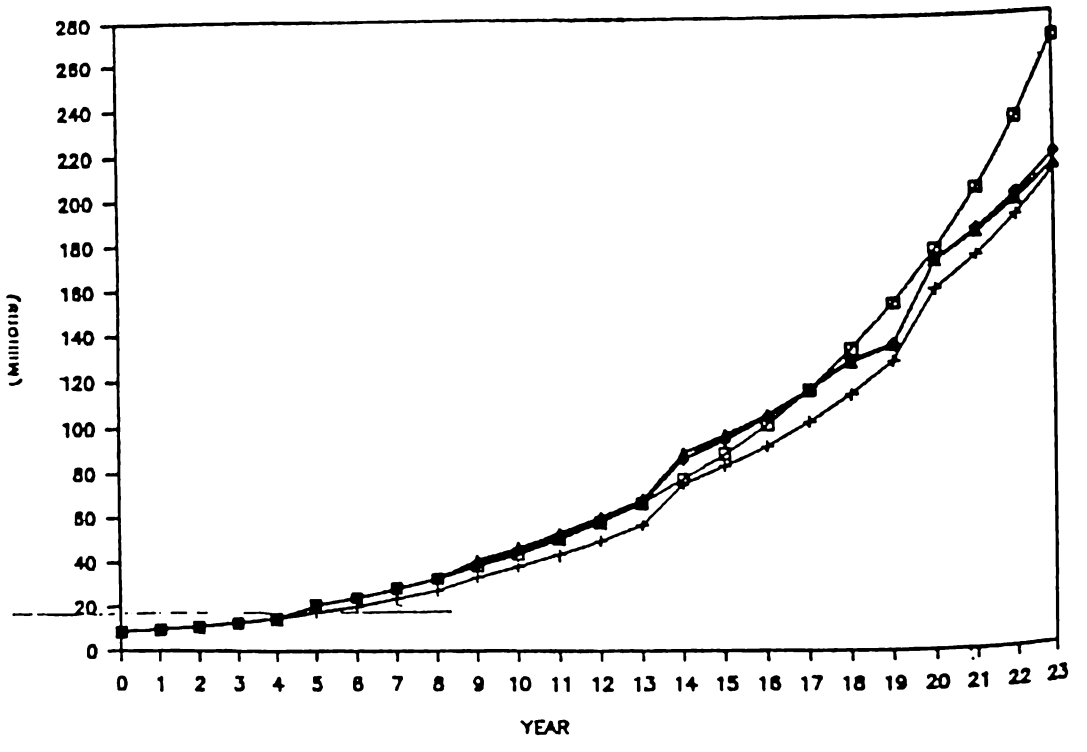

Figure 3.11 Total Energy Cost For Urban Household Cooking
(Current US $)
Case - Price of Kerosene Oil Increase by 25% in 1992/93

Scenario Cases

Substitution of kerosene oil with electricity in urban cooking is considered for low, medium and high scenarios. In the low scenario, the share of kerosene oil in total per capita energy requirement is reduced to 90%, 70% and 50% of the based year value in 1996/97, 2001/02, and 2006/07. In the medium and high scenarios, the share of kerosene oil is reduced to 90%, 60%, 30% and 75%, 50%, 25% respectively in 1996/97, 2001/02, and 2006/07.

Results of scenario case simulation are given in Tables 3.3 to 3.8 and Figures 3.2 to 3.7.

Energy Cost Considerations

The results of considering energy cost are given in Table 3.9, 3.10 and Figures 3.8 to 311.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The model developed in this study is believed to be a significant contribution to the field of energy modeling in general and to energy planning and policy making in Nepal in particular.

One of the most important features of the model, as far as Nepal is concerned, is the disaggregation of urban population into distinct physiographic regions and urban community sizes.

The model allows different cases like changing the percentage share of different fuels in the total per capita energy requirement, efficiencies of end-use devices, population growth rate, income growth rate, and percentage distribution of urban population to be studied.

The accuracy of the computer simulation program and the dependability of the simulation results has been validated by comparing the model results with the results estimated from an actual survey for the base year.

The results of the simulation provide the following conclusions:

1. It has reinforced the fact that the cooking activity in urban domestic household sector is a major consumer of commercial energy in Nepal. The base case scenario shows that the total commercial energy demand for urban cooking in the year 2010/11 will be almost equal to the total commercial energy consumption in the whole of Nepal in 1987/88.

2. There exists a very high potential for substituting kerosene oil with electricity in urban cooking.

3. Substitution of kerosene oil with electricity in urban cooking results in a significant increase in the total electricity generation requirement and the peak demand on the Integrated Nepal Power System. Under the scenario considered the peak demand increases by more than 58 percent of the latest Nepal Electricity Authority laod forecast for 2010/11. This will require the addition of a major hydroelectric power plant of about 500 MW installed capacity.

Recommendations

The following are recommendations for future work:

1. The computer simulation program developed can be modified to include more than three fuel types.

2. When reliable data become available, the model can be updated to incorporate the effects of fuel price, fuel availability, and changes in household behavior due to fuel switching.

3. Economics of substituting kerosene oil with electricity in urban cooking in Nepal should be studied in terms of fuel prices, prices and availability of end-use devices, and fuel supply.

4. Cost of additional electricity generation requirement and peak demand resulting from substitution of kerosene oil with electricity in urban cooking should be studied further using more accurate data. Possible increase in the price of kerosene oil in the coming years and the cost of storage facilities for the large volume of kerosene oil should be considered in the costing.

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