Demand for commercial energy in the state of Kerala, India: an econometric analysis with medium-range projections

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Abstract

Rapid growth in the demand for commercial energy in Kerala, a state in India, posed serious development constraints in the recent past. The crucial issue of managing this demand will be of great importance in formulating the future development policy of the state. This study analyses the requirement of three major forms of commercial energy in the state of Kerala (viz. electricity, petroleum products and coal). Sectorwise/productwise econometric demand models are generated using regression method. The primary regression models consisting of statistically significant key energy indicators have been fitted with ordinary least-squares (OLS) estimation. Models wherever required have been subsequently refined in the second stage computations by employing Cochrane-Orcutt transformation algorithm to remove the effects of auto-correlation. The accuracy of the models have been checked using standard statistical techniques and validated against the past data by testing for 'expost' forecast accuracy. Employing the models, medium-range projections of demand of the state for commercial energy till the year 2020 have been made. The policy implications and related key issues have been addressed. The study identifies the urgent need for special attention in evolving effective energy policies to alleviate an 'energy famine' in the near future.

Keywords: Commercial energy; Energy forecasting; Energy modelling

1. Introduction

Kerala is the southernmost state of India, with a population of about 31.84 million. Although the state has achieved remarkable development in the areas of education, literacy and health care, paradoxically, the growth of industrial and energy sectors were not comparable with many other parts of the country. The severe constraints faced by the state in developing industrial and energy infrastructure indicate the under-lying techno-economic as well as policy issues. Energy being the key determinant of economic activities and a prerequisite for social development, its availability, demand and pattern of consumption plays an important role in the total development of the state. Regarding commercial energy availability, the position of the state is rather uncomfortable. The electric power sector, facing serious techno-economic as well as environmental constraints, is operating under severe stress. Until recently, the state utility had to resort to frequent load shedding and power cuts due to restricted availability. The consumption of petroleum products has also overwhelmingly increased over the years. The issue of managing this ever-increasing energy demand in an effective manner is one of the most crucial issues facing the planners and policy makers.

This paper analyses the demand for three major forms of commercial energy being used in the state (viz. electricity, petroleum products and coal) with the aid of mathematical models and estimates the energy requirement till the year 2020. The study also attempts to examine the likely changes in the structure of demand and critically examines its policy implications in the development scenario of the state.
2. Selection of energy model

Owing to numerous uncertainties involved, the exercise of demand modelling is inherently complex. Particularly in the case of energy, the issue is more vicious because of the restrictions imposed to curtail the demand and a number of stochastic elements influencing the consumption. The simplest approach for energy demand modelling is Time-Series trend analysis selecting time as a single independent variable (Bargur and Mandel, 1981). Electricity demand models based on the intensity of consumption have been developed to analyse the demand patterns (Furtado and Suslick, 1993; Harry, 1998). Regression models have been effectively employed for forecasting the consumption of various commodities like electricity, coal and petroleum products (Sharma et al., 2000; Rao and Parikh, 1996; Farahbalhsh et al., 1998). Modern computational techniques using genetic algorithm and artificial neural network also have been recently adapted to frame demand models (Chaturvedi et al., 1995). However, many of these methods require complex computational efforts and the accuracy is seriously restricted by prior subjective prejudices (Spyros et al., 1978).

Econometric models that correlate the energy demand with other macro-economic variables have been proved to be very effective in analysing the energy-consumption pattern of developing countries (Rao and Parikh, 1996; Ramaprasad Sengupta, 1993). This approach is conceptually more attractive for medium-term forecasts, as it relates the demand in physical terms to some socio-economic determinants and hence is useful for developmental planning and policy making. In this work, the functions representing the demand for various types of commercial energy are developed as econometric models. The models developed are mostly in log-linear form employing the ordinary least-squares (OLS) regression. In a few cases, significant explanatory variables could not be located. In such cases, non-linear trend extrapolation has been carried out selecting suitable growth functions.

3. System data

The model is based on time-series data for various parameters during the period from 1970 to 1998. About 20 explanatory variables have been examined to evaluate their level of influence on the energy demand. The data for economic variables like state domestic product (SDP) and its sectoral components, per capita income, index of industrial production (IIP), etc. have been considered at constant (1980-81) prices (State Planning Board, Kerala). Demographic indicators like population and urbanisation index have been adopted from the Government of India publications (Government of India, 1991). Energy-related data like consumption, number of consumers, tariff, etc. have been obtained from the power statistics published by the Kerala State Electricity Board and the special issues of Centre for Monitoring Indian Economy (CMIE) on energy (KSEB, 1998; CMIE, 1994). Summary statistics of key influencing variables appearing in the models are showed in Table 1.

4. Methodology

For the purpose of analyses, the electrical energy demand has been categorised under four major sub-sectors viz., residential, services, industries, and miscellaneous. For detailed analysis, the industrial sector has been further classified into medium and large industries (HT and EHT consumers) and small industries (LT consumers). Under miscellaneous sector, four subsectors viz., public lighting, water works, agriculture and licensees have been included. This categorisation is generally in line with the subdivisions made by Central Electricity Authority (CEA) of India for conducting

Table 1
Summary statistics of key influencing variables appearing in the model

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of cases</th>
<th>Mean</th>
<th>Median</th>
<th>Std. error of mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of residential electricity consumers</td>
<td>28</td>
<td>1784.663</td>
<td>1609725</td>
<td>211198</td>
<td>386195</td>
<td>3 959741</td>
<td>1117.556</td>
<td>1.25E+12</td>
</tr>
<tr>
<td>SDP (primary) (million rupees)</td>
<td>28</td>
<td>17018.6</td>
<td>15361.3</td>
<td>662.5</td>
<td>13 190.0</td>
<td>25 658.3</td>
<td>3505.9</td>
<td>1.2E + 07</td>
</tr>
<tr>
<td>SDP (secondary) (million rupees)</td>
<td>28</td>
<td>10216.0</td>
<td>9261.2</td>
<td>756.7</td>
<td>5316.5</td>
<td>18 482.0</td>
<td>4004.4</td>
<td>1.60E + 07</td>
</tr>
<tr>
<td>SDP (tertiary) (million rupees)</td>
<td>28</td>
<td>19872.2</td>
<td>14927.3</td>
<td>1318.1</td>
<td>9872.2</td>
<td>33 397.6</td>
<td>6975.0</td>
<td>4.87E + 07</td>
</tr>
<tr>
<td>SDP (total) (million rupees)</td>
<td>28</td>
<td>44 669.0</td>
<td>38 620.3</td>
<td>2687.0</td>
<td>30028.1</td>
<td>77 583.1</td>
<td>14218.4</td>
<td>2.02E + 08</td>
</tr>
<tr>
<td>Per capita income (rupees)</td>
<td>28</td>
<td>1635</td>
<td>1465</td>
<td>62.68</td>
<td>1377</td>
<td>2442</td>
<td>331.67</td>
<td>110006</td>
</tr>
<tr>
<td>Population (million)</td>
<td>28</td>
<td>25.55</td>
<td>26.22</td>
<td>1.00</td>
<td>3.23</td>
<td>31.41</td>
<td>5.31</td>
<td>2.82E + 07</td>
</tr>
<tr>
<td>Urbanisation index</td>
<td>28</td>
<td>21.80</td>
<td>20.69</td>
<td>0.94</td>
<td>16.11</td>
<td>30.90</td>
<td>4.98</td>
<td>24.84</td>
</tr>
<tr>
<td>Index of industrial production</td>
<td>28</td>
<td>131.01</td>
<td>95.06</td>
<td>14.34</td>
<td>58.50</td>
<td>268.40</td>
<td>75.88</td>
<td>5757</td>
</tr>
<tr>
<td>Wholesale price index of petrol</td>
<td>28</td>
<td>502.14</td>
<td>524.05</td>
<td>44.13</td>
<td>100</td>
<td>825.60</td>
<td>233.52</td>
<td>54 431</td>
</tr>
</tbody>
</table>
national power surveys. In the case of petroleum products, product-specific analysis has been carried out. Major distillates used in the state like petrol, kerosene, HSD, LPG, light diesel oil, LSHS, Naphtha, and furnace oil have been included in this study.

In order to select the relevant independent variables, stepwise regression has been carried out using SPSS package (SPSS, 1996). The final demand functions contain only those variables that have a maximum level of statistical significance and are capable of revealing the structural characteristics of the demand. The primary models have been developed in log-linear functional form.

On developing the models, it has been found that the coefficients are significant, the standard errors of coefficients are very low and the $R^2$ values depict good model explanation. However, the Durbin-Watson (DW) statistics indicated the possibilities of positive auto-correlation of residuals in certain cases. As the models are developed for forecasting purpose, it is essential to eliminate the effects of auto-correlation for better forecasting accuracy. Hence, the primary regression equations are refitted taking the auto-correlation into consideration in a second-stage correction by applying Cochrane-Orcutt algorithm (Chatterjee and Price, 1991).

5. The models developed

The final modified models developed for consumption of electricity, petroleum products and coal along with their model features and statistics are discussed below.

5.1. Electricity

The electricity supply system of the state is owned by a single, Government-owned utility company viz., Kerala State Electricity Board (KSEB). Started in 1940 with a single 5MW hydel plant, this system grew substantially to an installed capacity of 2391 MW (as on 31-3-2000). Out of this, 16 hydel stations account for about 1795 MW (75%) of the capacity and balance from thermal plants and a small wind farm of 2.475 MW. There are eight categories of consumers, which the KSEB serves. They are domestic (residential), commercial (including service sector), LT industries, HT industries, water works, public lighting, agriculture and a few licensees. The number of consumers, which was 28,000 in 1951, grew substantially and as on 31-3-2000 it has reached 6 million. The major consuming sector of electricity in the state (as on 31-03-2000) is the residential sector (46.22%). The consumption of electricity by large industries (EHT&HT consumers) and small industries (LT) sectors has been severely constrained by the periodical power cuts and load shedding imposed in the state. Consequently, their share of consumption has been decreasing over the years and as on 31-03-2000, large industries and small industries sector consumed about 28.85% and 6.35%, respectively, of the total energy generated annually. However, the prominence of service sector in the state is fast increasing and this sector consumed about 9% of the total energy during 1999-2000. All other sectors put together consumed only about 9.5%. The per capita electricity consumption of the state during 1999-2000 is provisionally estimated to be about 300.6 kWh.

The statistics of models developed for sectoral demand of electricity are listed in Table 2.

5.1.1. Residential sector

This sector indicated a rapid consumption growth during the period of observation with a demand of 80.71 Million Units (MU) in 1970 to 3776 MU in 1997. The model developed for the residential sector of the state is

<table>
<thead>
<tr>
<th>Sector</th>
<th>$R^2$</th>
<th>Durbin-Watson</th>
<th>$F^*$ statistics</th>
<th>$f$ Statistics</th>
<th>Variance inflation factor</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential sector</td>
<td>0.99</td>
<td>1.82</td>
<td>2180</td>
<td>19</td>
<td>1.87</td>
<td>0.0028</td>
</tr>
<tr>
<td>Service sector</td>
<td>0.99</td>
<td>1.88</td>
<td>576</td>
<td>6.3</td>
<td>9.83</td>
<td>0.0005</td>
</tr>
<tr>
<td>Medium and large industries</td>
<td>0.90</td>
<td>1.70</td>
<td>213</td>
<td>4.0</td>
<td>3.09</td>
<td>0.0005</td>
</tr>
<tr>
<td>Small industries</td>
<td>0.92</td>
<td>1.82</td>
<td>131</td>
<td>2.1</td>
<td>3.09</td>
<td>0.0029</td>
</tr>
<tr>
<td>Other miscellaneous sector</td>
<td>0.95</td>
<td>1.72</td>
<td>218</td>
<td>11.9</td>
<td>2.49</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Note: $f$ statistics, variance inflation factor and significance levels are expressed in respective orders as the variables appear in the model. All variables are significant at 95% level of confidence.
of the following functional form
\[
\ln(ER_i = Pi) = 1.41818 + 0.272731 \ln(Q_i = Pi) + 1.33666 \ln(N_i = N_i) ;
\]
where ER, P, Q and N are, respectively, energy demand, population, state domestic product (at 1980-81 prices) and the number of electrified residential dwellings. The subscripts 'i' and 'b', respectively, represent the values corresponding to the ith year and that of the base year (1970-71). 'ln' is the natural logarithm to the base, 'e'.

5.1.2. Service sector
During the past two decades, the electrical energy demand in the service sector indicated a rapid increase from 65.6 MU in 1970 to 652 MU in 1997. The final model developed for this sector after removing the auto-correlation error is of the form
\[
\ln(ES_i) = 0.9885353 + 5.744798 \ln(P_i) + 0.698549 \ln(U_i) + 0.56422 \ln(C_i) ;
\]
where ES, U and C are, respectively, energy demand in service sector, urbanisation index and per capita income.

5.1.3. Industrial sector
While domestic and service sectors indicated a steep growth in the consumption of electrical energy, the demand growth in different industrial sectors was relatively slow. As mentioned earlier, the analysis of these sectors have been carried out under two subheads viz., medium and large industries (HT and EHT consumers) and small industries (LT consumers).

5.1.4. Medium and large industries
During the period of study, the consumption of this sector indicated an average annual compounded growth rate of about 8%. The model finalised for this sector after effecting correction for auto-correlation error is given below.
\[
\ln(EHT_i) = 0.396916 + 0.520412 \ln(QS_i) + 0.168424 \ln(IIP_i) ;
\]
where QS and IIP represent the share of SDP of secondary sector and index of industrial production, respectively.

5.1.5. Small-scale industries
The demand of energy in this sector indicated a steady average annual growth rate of about 6% in the past. The demand model
\[
\ln(ELT_i) = - 6.813731 + 0.258348 \ln(QS_i) + 0.893710 \ln(QTOT_i) ;
\]
where ELT and QTOT represent the energy demand of the small industries and the aggregate of the shares of secondary and tertiary sectors in SDP, respectively.

5.1.6. Other miscellaneous sectors
The electricity demand under other sectors like public lighting, water pumping stations, agriculture and private licensees is consolidated and categorised under 'miscellaneous sector'. The demand model finalised for this sector is of the form
\[
\ln(EMISQ) = - 4.408 + 0.358 \ln(QP_i) + 1.937 \ln(C_i) ;
\]
where EMISC and QP are the energy demand of miscellaneous sector and the share of primary sector in SDP, respectively.

5.2. Petroleum products
The consumption pattern of commercial energy forms other than electricity has also undergone changes in the state over time. The gross consumption of petroleum products has shown an annual compounded growth rate of 5.4% during the past 30 years. The rapid development in transport and household sectors of the state must be the prime reason for the increased consumption of petroleum products. This increased consumption did not make any direct impacts on the economy of the state, but it implied the incurrence of additional expenditure for purchase of fuel and reduced share for planned expenditure in the developmental activities. This also brought in new vicious issues in transportation planning, development of roads and highways and also pollution-related problems.

The product-specific models derived for each petroleum product are discussed below. The model statistics are shown in Table 3.

5.2.1. Petrol
Petrol has been used in Kerala mainly as fuel for motor cars and bikes for personal transport. During the last few years, there has been a rapid increase in the growth rate of consumption of petrol (about 2.5% annually). This is mainly due to the popularisation of small cars and a good number of two wheelers all over India. The log-linear model finalised for the demand of petrol is
\[
\ln(PETROL_i) = -59.141 - 0.0967 \ln(WPI_i) + 3.770 \ln(P_i) ;
\]
where WPI is the wholesale price index of petrol and P is the population.

5.2.2. High-speed diesel (HSD)
HSD is the most consumed petroleum product in the state, which amounts to 40^5% of the total petroleum consumption, the transport sector being the major consumer. The model finalised for this product is
\[
\ln(DIESEL_i) = -2.624 + 1.880 \ln(U_i) + 0.268 \ln(QS_i) ;
\]
Table 3
Statistics of various models for petroleum products

<table>
<thead>
<tr>
<th>Product</th>
<th>$R^2$</th>
<th>Durbin-Watson</th>
<th>‘$F$’ statistics</th>
<th>‘$t$’ Statistics</th>
<th>Variance inflation factor</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>0.97</td>
<td>1.08</td>
<td>403</td>
<td>-1.7</td>
<td>1.54</td>
<td>0.0009</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.97</td>
<td>1.26</td>
<td>426</td>
<td>1.5</td>
<td>1.49</td>
<td>0.0080</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.98</td>
<td>1.32</td>
<td>774</td>
<td>6.1</td>
<td>1.49</td>
<td>0.0033</td>
</tr>
<tr>
<td>LPG</td>
<td>0.95</td>
<td>1.39</td>
<td>485</td>
<td>1.7</td>
<td>1.25</td>
<td>0.0108</td>
</tr>
</tbody>
</table>

Note: ‘$f$’ statistics, variance inflation factor and significance levels are expressed in respective orders as the variables appear in the model. All variables are significant at 95% level of confidence.

Table 4
Model functions identified for other petroleum products

<table>
<thead>
<tr>
<th>Product</th>
<th>Non-linear regression function</th>
<th>Type of model</th>
<th>$R^2$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>$Y = a + b \cos(c t + d)$</td>
<td>Sinusoidal fit</td>
<td>0.89</td>
</tr>
<tr>
<td>Light diesel oil</td>
<td>$Y = a + b \cos(c t + d)$</td>
<td>Sinusoidal fit</td>
<td>0.80</td>
</tr>
<tr>
<td>Furnace oil</td>
<td>$Y = a \ln \left( \frac{C}{t} \right)$</td>
<td>Heat capacity model</td>
<td>0.79</td>
</tr>
<tr>
<td>LSHS</td>
<td>$Y = a e^{-bt} + c e^{-dt}$</td>
<td>Logistic model</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Note: $a$, $b$, $c$ and $d$ are regression coefficients of each model and $t$ is the time period in years.

where $U$ and $QS$ represent the urbanisation index and the share of state domestic product of secondary sector, respectively.

5.2.3. Kerosene
Kerosene is mainly used in the domestic sector of Kerala for lighting and cooking. Due to the rapid rate of electrification achieved by the state, with 100% villages and about 60% dwellings electrified, the use of kerosene for lighting purposes has been diminishing. Further, due to the recent market liberalisation in allowing the distribution of liquified petroleum gas (LPG) through private outlets, the prominence of kerosene as a cooking fuel in urban areas is also reduced. The model finalised for kerosene is

$$\ln(\text{KEROSENE}) = 3.494 + 2.383 \ln(\text{C/}t) - 0.767 \ln(\text{Q}),$$

where $U$ and $C$ represent the urbanisation index and per capita income, respectively.

5.2.4. Liquified petroleum gas (LPG)
LPG is the chief commercial cooking fuel of the state. Until 1998, the distribution of LPG was limited and administered through the outlets of the government-owned petroleum companies with substantial subsidy to the consumers. Due to the recently liberalised policy of Government of India, permission was granted to private refiners, bottling plants and retailers to produce and market LPG without subsidy. Consequently, though at a higher price, the consumption of LPG has grown at a very rapid pace during the recent past. The model finalised for LPG is

$$\ln(\text{LPG}) = -19.134 + 7.187 \ln(\text{U})$$

The single explanatory variable identified is the urbanisation index.

5.2.5. Other petroleum products
The consumption of light diesel oil, Naphtha, furnace oil and low-sulphur heavy-stack (LSHS) is not considerable in the state. Significant explanatory regression variables could not be captured for these products during regression analysis. Hence, non-linear trend extrapolation of the consumption data for the past 20 years has been carried out. The models for these products along with relevant statistics are displayed in Table 4.

5.3. Coal
Though the demand is not significant, the requirement of coal has also increased in the past. Coal finds only a limited application in the industrial sector of Kerala and as a cooking fuel in some parts of the state. Coal is not mined in the state and has to be transported from the neighbouring states like Tamilnadu and Andhra Pradesh. As significant influencing variables could not be identified even for the demand of coal, the demand model is finalised by selecting a suitable non-linear model viz., MMF model for trend extrapolation of the past data. The model details and statistics are given below.

$$\text{COAL} = \delta a b \left( \frac{c d}{t} \right) b = \delta b \left( \frac{c d}{t} \right).$$
where \( t \) is the time period in years and \( a, b, c \) and \( d \) are regression coefficients. The \( R^2 \) value is 0.90.

6. Analysis of model accuracy

In order to ascertain the accuracy of the above models, the following procedures have been adopted.

(i) The coefficient of determination \( (R^2 \text{ values}) \) associated with all models has been evaluated, which are also indicated along with the statistics of each model. The \( R^2 \) values depict ‘good’ model fits.

(ii) The plots comparing the actual consumption with the model estimation have been verified. The plots illustrate acceptable levels of accuracy of these models. Two sample plots relevant to electricity consumption in residential and service sectors are illustrated in Figs. 1 and 2.

(iii) To further ensure the effectiveness of these models in forecasting, the validity of these models has been tested for an ‘expost’ test period (1996-98). For this purpose, the models are redeveloped excluding the data for the expost test period. The models developed with restricted data sets are then employed to forecast the demand for the test period. The percentages of forecast errors are found to be in the range of 3-6%. The results depict a satisfactory performance of the models.

7. Projection of explanatory variables

The models developed in this work have been utilised for obtaining the forecast of demand of commercial energy until 2020. The summary of significant explanatory variables in various models is given in Table 5. Although for detailed analysis different scenarios representing various conditions of socio-economic growth have been selected and results examined, the forecast results corresponding to the most plausible scenario, viz., business as usual (BAU) scenario, have been presented here. This scenario is based on the normal trend of explanatory variables. This corresponds to the continuation of the economic conditions and other determining factors without any change in the trend. The most-fit functions explaining the trend of growth of the explanatory variables have been identified with the help of the software ‘Curve Expert’ by searching through about 50 standard model families (Curve expert, 1993). The non-linear functions selected to represent the BAU growth of these variables are given in Table 6.

8. Results and analysis of demand forecast

8.1. Electrical energy

The summary of forecast results and the estimated demand of electrical energy for various sectors for selected years are illustrated in Table 7. Projections indicate that by the end of 2020 the energy consumption in the residential sector will be about 15,454 MU, which is four times the present demand. The demand grows at a rate of about 8% during the initial years of forecast period and at about 6% during the later years and finally, reaches a growth rate of about 5%. Regarding the service sector, during the period of study, this sector indicated a rapid growth in the consumption at an annual compounded rate of 15%. It can be observed that under the conditions of normal economic growth estimations, the electricity demand of this sector by 2020 will be eight to nine times the present consumption. Although the above growth rates reflect the sign of development that the state may achieve in this sector, the great responsibility placed on the State Electricity
Table 5
Summary of significant explanatory variables occurring in various models

<table>
<thead>
<tr>
<th>Sector</th>
<th>SDP primary</th>
<th>SDP secondary</th>
<th>SDP tertiary</th>
<th>SDP total</th>
<th>Per capita income</th>
<th>Population</th>
<th>Urbanisation index</th>
<th>Index of industrial production</th>
<th>Price index</th>
<th>Number of consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
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<td>Service</td>
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<td>Medium and large industries</td>
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<tr>
<td>Small industries</td>
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<td>Miscellaneous</td>
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<tr>
<td>Petroleum products</td>
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<tr>
<td>Petrol</td>
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<tr>
<td>Diesel</td>
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<tr>
<td>Kerosene</td>
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<tr>
<td>LPG</td>
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</tbody>
</table>

Table 6
Functions identified for extrapolation of explanatory variables

<table>
<thead>
<tr>
<th>Energy indicator</th>
<th>Non-linear regression function</th>
<th>Type of model</th>
<th>R² value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of electrified residential dwellings</td>
<td>N = a(b + c t) + d(b + t)²</td>
<td>MMF model</td>
<td>0.99</td>
</tr>
<tr>
<td>Population</td>
<td>P = (a + b t)² + c t³</td>
<td>Gompertz model</td>
<td>0.99</td>
</tr>
<tr>
<td>SDP total</td>
<td>Q = a(b + c t) + d(b + t)²</td>
<td>MMF model</td>
<td>0.99</td>
</tr>
<tr>
<td>SDP primary</td>
<td>QP = a + b t + c t²</td>
<td>Quadratic model</td>
<td>0.98</td>
</tr>
<tr>
<td>SDP secondary</td>
<td>QS = a + b t + c t²</td>
<td>Quadratic model</td>
<td>0.99</td>
</tr>
<tr>
<td>SDP secondary + tertiary</td>
<td>QTOT = (a(b + c t) + d(b + t)²</td>
<td>MMF model</td>
<td>0.91</td>
</tr>
<tr>
<td>Index of industrial production</td>
<td>IIP = a - b t</td>
<td>Weibull model</td>
<td>0.95</td>
</tr>
<tr>
<td>Urbanisation index</td>
<td>U = (a c + c t²)(b + f t³)</td>
<td>MMF model</td>
<td>0.99</td>
</tr>
<tr>
<td>WPI of petrol</td>
<td>WPI = a + b t + c t²</td>
<td>Quadratic model</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Note: a, b, c and d are regression coefficients of each model and t is the time period in years.

Table 7
Future demand for electricity

<table>
<thead>
<tr>
<th>Sector</th>
<th>Demand in 1997-98 (MU)</th>
<th>Estimated demand (MU) in the year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2005-06</td>
</tr>
<tr>
<td>Residential</td>
<td>3776</td>
<td>6461</td>
</tr>
<tr>
<td>Service</td>
<td>652</td>
<td>2748</td>
</tr>
<tr>
<td>Medium and large industries</td>
<td>2000</td>
<td>3795</td>
</tr>
<tr>
<td>Small industries</td>
<td>514</td>
<td>937</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>761</td>
<td>1196</td>
</tr>
<tr>
<td>Total</td>
<td>7703</td>
<td>15137</td>
</tr>
</tbody>
</table>

Board to meet this enormous demand is a crucial aspect to be considered in future planning. Regarding the energy demand assessed for medium- and large-industries sector, the results indicate that by 2020, the consumption of this sector will be about 5000 MU under the conditions of moderate economic growth. However, the demand of electricity by 2020 for small industries will be comparatively low, about 1700 MU only. The demand of electrical energy by 2020 estimated for other miscellaneous sectors of the state is about 1860 MU. The total requirement for electrical energy of the state by 2020 is assessed to be about 33,000 MU, which is almost four times the present demand.

8.2. Petroleum products

The summary of the forecast results and the estimated demand for various petroleum products for the state for selected years are illustrated in Table 8. It is estimated that the rate of growth of demand will be much faster in
The coming decades and will be as high as 3% annually. This is obviously due to the rapidly expanding automobile population in India and consequential increase in the number of petrol vehicles in the state. The consumption of diesel also assumes a moderate growth rate in future, about 2.32%. This is mainly due to the increasing rate of urbanisation of the state and the enhanced demand for public transportation and cargo movement. It can be observed that the demand for kerosene is almost saturated and is not likely to increase considerably in the future, whereas the demand for LPG rapidly increases. This increase in demand of LPG is attributable to the recent liberalisation policy and the changing life style of the urban population. The study revealed that the rate of growth of demand for other petroleum products shall remain without much significant change even in the future.

8.3. Coal

Regarding the consumption of coal, the forecast shows that in future even coal will continue to remain as a 'less'-used commercial energy source in the state. The level of consumption of coal may continue without much change up to 2020 and it will not be an important component in the commercial energy mix of the state during this period.

9. Total mix of commercial energy

The assessment of requirement for commercial energy for the state, to be met from electrical energy, petroleum products and coal, during the next two decades is illustrated in Table 9. It can be seen that during 1997-98, electricity constituted about 38% of the total commercial energy consumption of the state. The results show that this share increases and by 2020, about 56% of the commercial energy requirement will have to be met by electrical energy. At the same time, the share of petroleum products, which constituted about 58% during 1997-98, gradually reduces and by 2020 this will be around 42% only. The reason for this structural shift in consumption is mainly attributable to the easiness in conversion of electrical energy and also due to the low electricity tariff prevailing in the state. The rapid urbanisation and change in the standard of living of the population may also be attributed to this structural transition.

9.1. Policy implications

The likely shift in the consumption of energy, in future, from petroleum products to electricity is a crucial factor having a direct impact on the energy policy of the state. The state is already striving hard to meet the ever growing electric-energy demand within its available limited resources. A changing pattern in the consumption of commercial energy demanding more share from electricity sector will vest much more challenges on the single state-owned electric utility company. The Kerala State Electricity Board. Substantial investment in the energy sector for new generating stations and capacity additions will become imperative to meet the energy demand. This will call for a future planning strategy with a predominant thrust on the energy development.

The forecast results derived from the simulation of demand models provided estimates as well as the product mix of future demand of various forms of commercial energy. But the complex and stochastic nature of the energy system makes this issue highly non-susceptible for a microscopic regional level analysis to suggest a 'better' or 'optimal' fuel mix of commercial energy for the state. A microscopic state-level analysis to study the feasibility of inter-fuel substitution (like substitution of oil by power for transport sector, etc.) may not be easy. This is because numerous boundary conditions of environment management and socio-economic factors are to be essentially overviewed in a national scenario before suggesting any optimal commercial fuel mix for a particular state. However, a lucid perception on the plausible future energy mix of the state is highly beneficial and imperative to the extent that this will help to refine the quality of current decisions on energy development and related issues and also help to evolve long-run energy planning strategies more effectively. A review of implications of the observed trend in commercial energy consumption as
Table 9
Future commercial energy mix (Unit: Million tons of oil equivalent)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>1.76</td>
<td>3.33</td>
<td>4.43</td>
<td>5.71</td>
<td>7.15</td>
</tr>
<tr>
<td></td>
<td>(37.8%)</td>
<td>(46.3%)</td>
<td>(49.7%)</td>
<td>(52.9%)</td>
<td>(56%)</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>2.70</td>
<td>3.64</td>
<td>4.25</td>
<td>4.85</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>(57.9%)</td>
<td>(50.6%)</td>
<td>(47.7%)</td>
<td>(44.9%)</td>
<td>(42.1%)</td>
</tr>
<tr>
<td>Coal</td>
<td>0.203</td>
<td>0.2</td>
<td>0.23</td>
<td>0.23</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>(4.35%)</td>
<td>(3.06%)</td>
<td>(2.58%)</td>
<td>(2.13%)</td>
<td>(1.89%)</td>
</tr>
<tr>
<td>Total</td>
<td>4.66</td>
<td>7.19</td>
<td>8.91</td>
<td>10.79</td>
<td>12.76</td>
</tr>
</tbody>
</table>

well as suggestions of certain policy frameworks on a state-level basis are attempted in the ensuing section of this study.

10. Review of policy and recommendations

The major issues of concern which are related to the future energy sector of Kerala, that could be revealed as a result of this study are:

- Increasing demand growth of electricity and also the conspicuous structural shift in consumption from petroleum products to electricity (which, if left unattended, may lead to a continuing inability to provide 'quality' power and ultimately to a stage of energy poverty).
- Enormous capacity additions that would be required in the electricity sector to bridge the supply demand gap (which will be confronted by resource constraints).
- Likely increase of environmental impacts and degradation due to substantial capacity additions in the power sector and also the expanding requirement for petroleum products.

Obviously, the above situation will pose serious challenges to the performance of the future power sector of Kerala. A set of co-ordinated and effectively implemented policy options are highly imperative to stride over these constraints in future.

10.1. 'Vigorous' energy planning: a priority imperative

The sensitivity of energy demand with respect to economic growth of the state has been revealed in this study. It was observed that the energy demand of most of the electricity consuming sectors is sensitive to SDP or its sectoral components. The strong energy-economy coupling identified in this work demands that energy planning should form an integral part of the state planning process, in contrast to the present practice. Given the crucial link between the energy sector and economic growth, energy cannot be isolated from the overall development strategy and fiscal imperatives of the state. The study emphasises that not only the energy planning should be in close co-ordination with the economic planning, but also the economic targets of the state in different time frame should be set consistent with the demand and availability of energy permitted within the financial resources.

The principal concern of energy planning of the state adopted in the past has been mainly based on political and social factors, and not developmental ones. The deficiency of such a planning in all spheres and its impacts on the development of the state have been brought out in certain studies, and energy sector also is not an exemption (George, 1994). A new, development-focussed outlook and planning culture is unavoidable in the future. An integrated long-term energy plan, with futuristic outlook, set in full consistency with the targeted future economic growth and embedded in the core planning process of the state is of utmost importance in Kerala context.

10.2. Rational tariff: a powerful tool

The analysis performed in this study showed that electricity demand in all sectors is not sensitive to its present prices. The average selling price of electricity in Kerala does not even cover its production cost. The social commitments and political compulsions of the Governmental machinery resulted in setting heavily underpriced/subsidised non-scientific electricity tariffs. It is estimated that the Kerala State Electricity Board in 1997-98 suffered losses to the tune of 3960 million rupees due to subsidised pricing in agriculture and domestic sectors alone (KSEB, 1998). Subsidising the price of energy is a measure that invites inefficiency. Low and irrational prices set for electricity give rise to excessive demand and by undermining the revenue base, it reduces the ability of the utility even to provide and maintain energy supplies. The low energy tariff of Kerala extended for industrial consumers is also totally non-scientific and irrational. Demand analysis performed in this study revealed that the growth rate of energy consumption in industrial sector is low. The slow down of industrial dynamism experienced in Kerala teaches that 'cheap power' is not the one and only
prerequisite for industrial development. Except a few 'energy intensive' electro-chemical and process industries, that are now the biggest beneficiaries of the defective tariff structure of the state, the low price for electricity could not attract industries to Kerala considerably.

The Government policy of offering low-cost energy to new small-scale industries also has suffered a setback. A few heavily energy consuming industries, (in their pretext of small-scale operation) consumes a major portion of this subsidised energy, while offering low employment potential and value additions within the state. Studies conducted in this area after the evaluation of specific fuel consumption of such industries revealed that the performance of these industrial units in Kerala proved that subsidising energy cost for energy intensive industries could mean nothing but subsidising energy inefficiency (Menon, 1998).

It is quite natural that the state-owned utility facing heavy loss could neither focus on capital-intensive future additions, nor supply 'quality' power. Hence, formulation and implementation of a rational and comprehensive energy pricing structure, avoiding underpricing, by letting the price reflect the real cost, and also encompassing a future development-oriented vision will aid a better overall efficiency in all spheres of energy sector and hence, assume, great priority in Kerala context.

10.3. Efficiency improvement measures: a long-delayed action

Like many other states in India, the energy transaction in Kerala is also a paradigm of inefficiency at all operational spheres. T&D losses ranging between 20% and 30% is a sink into which major portions of the power sector investments disappear. Bringing this down to reasonable and achievable levels is, therefore, of great priority among the measures to bridge the supply demand gap of electricity. Further, as the end-users of electricity are only concerned about the services that electricity can provide and not about the quantum of energy consumed, energy efficiency improvement measures are very much valuable to bring the demand and supply of electricity closer to balance. But a number of technical, cost and institutional barriers constrain the efficient use of electricity in Kerala. The concept of appliance-efficiency is yet to be popularised effectively among the domestic, commercial and agricultural consumers in the state. Energy-efficient equipments duly supplemented with technology upgradation, modernisation and renovations would be necessary to achieve desired results among industrial consumers.

A mechanism to explore short-term and long-term possibilities of energy conservation, efficiency improvement measures and demand side management techniques and to effectively implement them in a phased manner should form an essential part of future energy-management programme of the state. New policy initiatives, minimum energy-efficiency standards, regulations, taxation rules, etc. are also yet to be set in Kerala to promote the end-use efficiency. Therefore, it is highly imperative to formulate a comprehensive package of measures for raising the efficiency in all spheres of electricity use within a closely co-ordinated framework and effective Government support and stimulation, in order to achieve a 1:1 match between the supply and demand of electricity in future.

10.4. Institutional changes

Performance of SEBs in India is characterised by heavy financial losses, uneconomic tariffs, capital crisis and poor quality of supply (Stephen C. Little Child, 1999). The present performance of Kerala power sector also is not an exemption. Energy planning and efficiency improvement measures will be effective only in an efficient institutional structure. Hence, implementation of financial and institutional reforms of fundamental and radical nature to make the institutional structure of the Kerala power sector efficient and effective is unavoidable.

10.5. Forethought on fuel-mix and timely implementation of projects

Early decisions on an optimal fuel-mix for the future power projects, duly taking into account the commercial energy availability, calls for special attention. An early planning (for implementation of the schemes for establishing new power stations in a phased manner) has to be chalked out well in advance. Feasibility studies for tapping small hydel potential as well as renewables for power generation also have to be initiated immediately. Definite programmes to ensure firm linkage of coal from other states or by import have to be identified. Necessary techno-economic and environmental clearances for future schemes also have to be processed and obtained in advance. To avoid time and cost over-runs (that was experienced while realising most of the power projects in the past), project implementation can be vested with a special task team and closely monitored. In short, lucid perceptions on the optimal fuel mix for generation expansion in Kerala, on rational considerations and realisation of the same through efficient project implementation programmes are of great importance.

10.6. Vision for a sustainable development

Experiences of developed countries show that during the course of development, new and serious environmental hazards are also bound to creep in, that are hard
to manage. A simplistic idea that energy conservation and the enhanced use of renewables alone will provide adequate additional energy to meet future demand and thereby solve the ecological and environmental issues is unrealistic. Substantial capacity additions through hydel and thermal generation will be an 'essential evil' to bridge the supply demand gap. Hence, new and improved technology options to minimise emission hazards and environmental impacts will have to be adopted while implementing new power projects.

Massive deforestation that occurred in Kerala mainly during the implementation of hydel projects in the past poses a serious concern. A positive precautionary strategy which assumes that it is not advisable to run down environmental assets and impair ecosystems is essential during the course of planning and implementing further major hydel projects in the state. While selecting the location for future hydel projects, the environmental impacts should be subjected to 'true' and careful evaluation. Since a lot of disruption has already been caused to the eco-system of Kerala while implementing hydel projects as well as due to deforestation in connection with various activities, abundant precautions and extreme care are imperative to minimise further destruction to the precious, complex and unique ecosystem of the state. Transparent and continuing energy dialogues at all levels of the society will be needed to provide the planners with outlook and awareness in this perspective. Therefore, it is essential to develop a futuristic vision in the energy sector based on sustainable development for the greater benefit of all and to ensure that the available resources are consumed in most rational, cost-effective and productive manner.

11. Conclusion

The consumption of commercial energy has been rapidly increasing in the state of Kerala, which aggravated the present energy crisis. In this study, econometric models have been developed, which explain the demand of three major forms of commercial energy viz., electricity, petroleum products and coal, in terms of major socio-economic determinants. The developed models have been refined and validated to ensure consistency. The models have been employed for forecasting the future energy requirement until 2020. The requirement of future energy as well as the structure and pattern of consumption have been examined. The policy implications of the forecast results have been critically analysed. The results identify the basis on which energy planning can be carried out and emphasise the need for evolving effective strategies.

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References


