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Energy Demand Forecasting for a District in Tamilnadu, India - An Analytical Approach

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Abstract – *A realistic and reliable estimation of future energy demand of a district is an important step in energy planning, both at the micro and at the macro levels. A number of analytical and mathematical models are available for making the estimation at the macro level. However, due to lack of adequate data, these models have to be simplified so as to arrive at a reliable figure for micro models. In this paper, an attempt has been made to predict the future energy demand of a district in India based on the past trends and the socio-economic parameters such as GDP, population growth and per capita income, both at the local and national levels. The future energy demand pattern fuel-wise is analyzed. This paper also discusses the steps needed to meet the anticipated future energy demand.*

Keywords – Energy demand, forecast, GDP, sustainability.

1. INTRODUCTION

Energy input is vital to the growth and development of the economy, and the energy consumption is an important controlling factor in determining overall development of a region/district/state. Analyzing the present trends of energy consumption using appropriate analytical models, it is possible to predict the future trends in energy demand. In this paper, the present energy consumption in Coimbatore, a fairly organized district in the State of Tamil Nadu in India has been considered. This district has shown an all round growth in the areas of agriculture, industry, education, health, transportation and infrastructure facilities. In fact, Coimbatore is considered as the Manchester (United Kingdom) of South India due to the existence of a large number of textile mills, and it has the biggest garment cluster, which has an export potential of US $ 638.84 million.

The central theme of the integrated energy plan would be to prepare an area based decentralized energy plans to meet energy needs for subsistence and development of alternate energy sources. Centralized energy planning exercises cannot pay attention to the variations in socioeconomic and ecological factors of a region which influence success of any intervention. Decentralized energy planning is in the interest of efficient utilization of resources. The regional planning mechanism takes into account the various energy available and demand in a region. This implies that the assessment of the demand and supply and the intervention in the energy system which may appear desirable due to such exercises must be at a similar geographic scale. In this regard, the district is accepted as the appropriate planning level. Energy planning at the district level also gains added importance in view of the resource constraints existing both at the macro and micro levels. Based on this objective, a district level energy demand forecasting has been attempted in this paper. Forecasting has been done to evaluate the future energy demand for the district. These projections, along with energy supply constraints, can lead to the identification of appropriate planning and policy measures to achieve and maintain the desired growth rate at the district level.

Sector-wise/product-wise econometric demand models generated by regression method fitted with ordinary least squares estimation has been made for studying the demand of commercial energy in the State of Kerala [1]. Similarly, another study has been made to study equilibrium relationship between total petroleum products consumption in India and economic growth for the periods 1970-1971 and 2001-2002 using co-integration and error correction modeling approaches [2]. In another study, a conceptual framework for analyzing the energy consumption at domestic sector through decision support system has been developed [3].

However, most of the models are available only for macro-level estimates. In a district, energy consumption is mainly dependent on the standard of living and also on the infrastructure facilities available in that district. A different mode of analysis is needed for estimating the demand at the district level. These macro level models have to be modified and future projection has to be made based on local factors such as per capita income, population growth, crop pattern and animal population.

At present, there are no major district level models. District planning is based on national growth rate and priorities. However, this has led to disparities among the districts. In order to achieve a uniform growth rate in all districts, it is necessary to develop district level planning models which can be later integrated to achieve a national level model.

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The objective is to estimate the future fuel and energy requirements for the period 2006-2015. This helps to identify the demand and supply gap for various fuels and energy in the near future so as to develop appropriate planning strategies by the district authorities.

In this paper, efforts are made to establish the trends of the various fuel and energy consumption in the district of Coimbatore for the period 1991-2005. Based on the established trends, the future fuel and energy demand for the period 2006-2015 have been made. Based on the projections and supply constraints, suitable policy measures have been identified to meet the ever-growing demand of energy. The policy measures suggested include adoption of energy efficient technologies and application of energy conservation techniques.

2. METHODOLOGY

The year-wise consumption of all the fuels and energy was collected from different sources (both at supply and at user points) and based on suitable conversion factors, the energy consumption has been converted into comparable energy units and analyzed. Appropriate assumptions for selected domestic fuels have been made based on the survey figures [4]. These are suitably modified to suit the present conditions. The present energy consumption especially in the rural areas is based on the census - survey conducted periodically. This census survey takes care of the socio-economic factors like family income, expenditure, literacy rate etc. Per capita energy/fuel consumption is based on these values and these figures are provided in the National Sample Surveys (NSS) [5]. Petrol, Liquefied Petroleum Gas (LPG) and diesel consumption data available with state oil companies have been collected. Kerosene consumption data was taken from the public distribution system records and coal consumption data was collected from sales depots and industry associations. However, in the case of non-commercial fuels like firewood and agro-waste, economic factors and per capita consumption figures available in NSS were used to estimate the total consumption. The Government of India conducts a National Sample Survey periodically in order to assess the economic factors like per capita income, per capita expenditure and fuel consumption in rural and urban households as well as in other sectors of the economy. Based on this survey and population break up, the per capita energy consumption is indicated in the survey. This per capita fuel/energy consumption is used for estimating the total consumption in the concerned period. Thus indirectly, the socio- economic factors are considered to arrive at the consumption figures. National level data has been referred from the reports of Center for Monitoring Indian Economy [6]. In the case of renewable energy demand, since no trend analysis is available, an average growth rate equal to national planned growth rate is assumed for estimation.

All these projections were summed up individually and collectively to evaluate the consumption trend and trend equations have been established for each fuel source. In order to make easy and reliable comparisons, all fuels and energy consumed were converted to the same energy units.

The present energy consumption trend has been analyzed and regressed to get the future demand trend. From the projected future trend, inferences have been made for considering appropriate policy measures to effect necessary changes, so that continuous growth and sustainable development are achieved. The socio-economic factors considered in the paper are given in Table 1. The estimation and evaluation procedure adopted in this work is shown in Figure 1.

3. PAST AND CURRENT ENERGY AND FUEL USE PATTERNS

The various fuels considered are firewood, cow dung, agro-waste, kerosene, LPG, biogas, coal, diesel, petrol and fuel oil apart from energy such as electricity, solar and wind. The yearly consumption of energy/fuel from sources for the period 1991-2005 in the district is given in Table 2.

Table 1. Socio-economic factors.

Fuel/Energy types	Years considered	Socio-economic parameters
Electricity Coal Kerosene LPG Diesel Petrol Fuel oil	1991-2005	Per capita income, population growth, sectoral growth rate
Firewood	1991-2005	Per capita consumption, urban/rural households, rural/urban population ratio
Cow dung	1991-2005	Animal population and growth rate
Agro-waste	1991-2005	Crop pattern, land use pattern
Biogas	1995-2005	Human and animal population in rural areas
Solar	2002-2005	Plan growth rate for the renewable sector
Wind	2001-2005	

From Table 2, it is observed that total energy consumption in the district has grown by a Compound Annual Growth Rate (CAGR) of 2.66% for the period 1991-2005.

In the fossil fuel use, LPG has shown a CAGR of 7.78%. This is due to the fact that LPG has substituted firewood and kerosene in both urban and rural households. Kerosene has shown a CAGR of 1.44% due to its use by the people at lower income level and its subsidized supply. Petrol consumption has gone up by a CAGR of 6.54% due to the increased use of personal transport such as four wheelers and two wheelers. Diesel fuel has shown a CAGR rate of 2.59%. This growth is due to increase in public transportation. Fuel oil has shown a CAGR of 3.83%. This can be due to large number of industries such as textile mills, foundries using this fuel for heating purposes. The use of coal has shown a CAGR of only 0.66%. This can be due to switching from coal based systems to either oil or electricity based systems.

It is also observed that the electricity use has shown an increasing CAGR of 4.68%. This is primarily due to large scale industrialization, public lighting needs, commercial establishments' expansion and increased agricultural requirements. In the case of fuels like firewood, the consumption shows a decreasing CAGR of 0.67% due to deforestation, fuel switching and large scale urbanization. Agro-waste has shown an increasing CAGR of 1.75% due to increased land use and improved yield. Cow dung has been used as domestic household fuel in rural areas and has shown an increasing CAGR of 1.74% due to increase in animal population.

In case of renewable energy, biogas has been in use only from the year 1995 due to large scale installation of biogas plants in rural areas. The other energy such as wind and solar are being used recently from 2001. A growth rate of 10% is assumed [7], [8] for these two types of energy based on the national growth rate and capital subsidy available.

The total number of districts in India is 626. The proportion of energy consumption of the district under study when compared to country is very low and already this district is considered to be fairly well developed and as such there will not be any drastic change in energy scenario except to continue the present trend. Further, there are many districts which are not developed like the one under the present study. Under these circumstances it is assumed that district will have the same trend as observed in the past. Also, energy supply is controlled and some times get restricted due to dependency of supplies from other regions. Therefore, linear regression is assumed. Further, the forecast is only for a short term. However, for LPG and petrol non-linear trend has been assumed based on the present consumption trend.

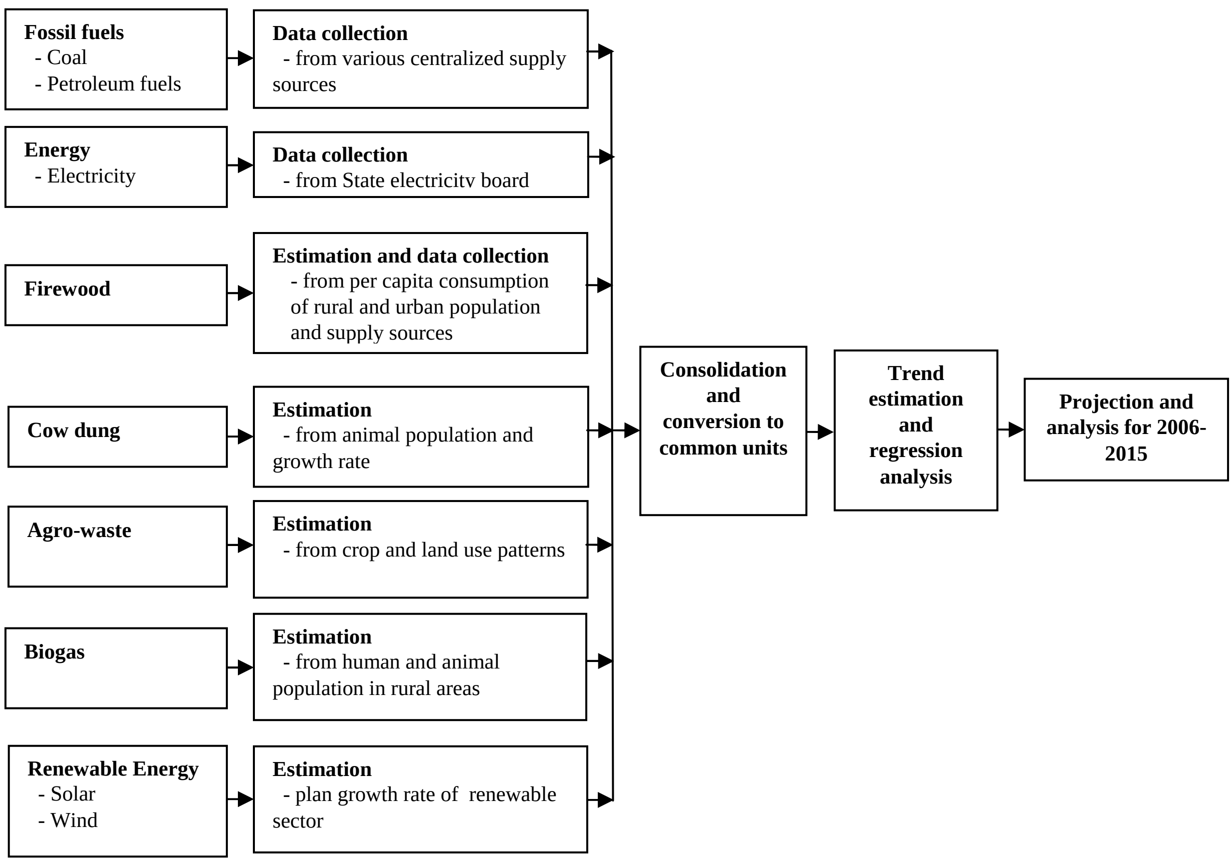

Fig. 1. Flowchart for the estimation methodology. (Source: District Planning Authority)

Table 2. Annual consumption of different energy/fuel in the district.

Fuel/Energy \ Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Electricity (PJ)	7.52	8.14	8.73	9.85	11.32	11.66	12.09	12.26	12.42	12.60	12.77	12.97	13.40	13.84	14.27
Firewood (PJ)	10.75	10.58	10.46	10.32	10.31	10.31	10.14	10.08	10.06	10.10	10.15	9.96	9.90	9.84	9.78
Cow dung (PJ)	2.81	2.87	2.93	3.00	3.06	3.12	3.18	3.22	3.27	3.32	3.37	3.42	3.47	3.52	3.58
Agro-waste (PJ)	8.69	8.89	9.08	9.28	9.48	9.67	9.86	10.00	10.14	10.29	10.43	10.58	10.75	10.91	11.08
Kerosene (PJ)	1.98	2.04	2.11	2.15	2.18	2.25	2.29	2.31	2.32	2.33	2.32	2.34	2.37	2.39	2.42
LPG (PJ)	1.92	1.96	2.00	2.06	2.14	2.22	2.33	2.71	3.29	4.25	4.74	4.59	4.89	5.19	5.48
Biogas (PJ)	NA	NA	NA	NA	3.66×10^{-2}	3.74×10^{-2}	3.82×10^{-2}	3.89×10^{-2}	3.97×10^{-2}	4.05×10^{-2}	4.13×10^{-2}	4.21×10^{-2}	4.29×10^{-2}	4.38×10^{-2}	4.47×10^{-2}
Coal (PJ)	5.10	5.15	5.22	5.26	5.31	5.36	5.39	5.40	5.41	5.42	5.43	5.50	5.53	5.56	5.59
Diesel (PJ)	13.87	14.37	14.85	15.29	15.73	16.07	16.38	17.02	17.64	18.12	18.39	18.60	19.01	19.42	19.83
Petrol (PJ)	1.99	2.10	2.20	2.32	2.51	2.67	2.68	3.02	3.41	3.83	4.23	4.16	4.38	4.61	4.83
Fuel oil (PJ)	1.76	1.80	1.88	1.91	1.95	1.98	2.06	2.14	2.23	2.32	2.41	2.71	2.80	2.89	2.98
Wind energy (PJ)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.07	1.17	1.29	1.42	1.56
Solar energy (PJ)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.55×10^{-3}	1.71×10^{-3}	1.88×10^{-3}	2.07×10^{-3}
Total (PJ)	56.39	57.90	59.46	61.44	64.03	65.35	66.44	68.20	70.23	72.62	75.35	76.04	77.83	79.64	81.45

4. RESULTS AND DISCUSSIONS

The demand for the fuel and energy has been projected based on the regression equations arrived at by using present trends, and the regression equations. The regression equation is primarily a time series regression with X axis representing the time scale while the Y axis refers to consumption of energy/fuel in PJ

The regression equations along with R^2 values are given in Table 3. The value of x is taken as 1 for the year 1991 and so on. The value of y refers to the energy and fuel consumption in PJ.

The regression has been carried out for all the fuel/energy independently. Since it is considered fuel wise, the total consumption has been taken care of in the estimation. Substitution effects have also been taken care of in the individual fuels as some fuels have exhibited an exponential trend and some fuels have shown a negative trend. Thus an increase in one indicates the substitution of the other fuel due to decreased availability and modernization. For example, LPG and petrol have shown a higher than average trend while firewood shows a negative trend. The growth rate of each fuel widely differs indicating that their utilization is either increased or decreased.

Also, it is observed that the majority of the fuel/energy has shown a linear trend whereas petrol and LPG have shown an exponential trend. This is due to the fact that LPG has substituted firewood and kerosene in rural and urban households to a large extent. Also, LPG supply was available in large quantity due to increased bottling and processing capabilities. The reason for change in trend in petrol is due to higher rate of increase in vehicle population. Increased availability of finance led to this sudden increase.

The demand projections for the fuels like firewood, cow dung and agro-waste have been based on economic factors like anticipated rural-urban population ratio, animal population and land use pattern. The supply constraints like the agricultural land available were also considered.

The demand projection for various fuels and energy is shown in Table 4.

The demand projection has been evaluated with respect to the availability of different fuels and energy. For example, the availability of petrol, diesel and kerosene has to be considered keeping in view large imports required and their increasing prices in the international market.

Table 3. Regression equations.

Fuel/Energy	Regression equation	R^2
Electricity	$y_1 = 0.4421x + 8.0523$	0.90
Firewood	$y_2 = -0.0586x + 10.651$	0.92
Cow dung	$y_3 = 0.0539x + 2.7776$	0.99
Agro-waste	$y_4 = 0.1671x + 8.6059$	0.99
Kerosene	$y_5 = 0.028x + 2.0287$	0.90
LPG	$y_6 = 1.5062\, e^{0.0888x}$	0.93
Biogas	$y_7 = 0.0008x + 0.0357$	0.99
Coal	$y_8 = 0.0317x + 5.1212$	0.96
Diesel	$y_9 = 0.4265x + 13.56$	0.99
Petrol	$y_{10} = 1.8014\, e^{0.0687x}$	0.98
Fuel oil	$y_{11} = 0.0897x + 1.5376$	0.94

Table 4. Demand projection for period 2006 – 2015.

Fuel/Energy \ Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Electricity (PJ)	15.13	15.57	16.01	16.45	16.89	17.34	17.78	18.22	18.66	19.10
Firewood (PJ)	9.71	9.65	9.60	9.54	9.48	9.42	9.36	9.30	9.24	9.19
Cow dung (PJ)	3.64	3.69	3.75	3.80	3.86	3.91	3.96	4.02	4.07	4.13
Agro-waste (PJ)	11.28	11.44	11.61	11.78	11.95	12.11	12.28	12.45	12.61	12.78
Kerosene (PJ)	2.48	2.50	2.53	2.56	2.59	2.62	2.64	2.67	2.70	2.73
LPG (PJ)	6.24	6.82	7.45	8.14	8.90	9.72	10.62	11.61	12.69	13.87
Biogas (PJ)	4.56×10^{-2}	4.65×10^{-2}	4.74×10^{-2}	4.84×10^{-2}	4.93×10^{-2}	5.03×10^{-2}	5.13×10^{-2}	5.23×10^{-2}	5.34×10^{-2}	5.45×10^{-2}
Coal (PJ)	5.63	5.66	5.69	5.72	5.76	5.79	5.82	5.85	5.88	5.91
Diesel (PJ)	20.38	20.81	21.24	21.66	22.09	22.52	22.94	23.37	23.80	24.22
Petrol	5.41	5.79	6.20	6.64	7.12	7.62	8.17	8.75	9.37	10.03
Fuel oil (PJ)	2.97	3.06	3.15	3.24	3.33	3.42	3.51	3.60	3.69	3.78
Wind energy (PJ)	1.67	1.79	1.92	2.04	2.16	2.29	2.41	2.53	2.66	2.78
Solar energy (PJ)	2.4×10^{-3}	2.6×10^{-3}	2.8×10^{-3}	3.0×10^{-3}	3.2×10^{-3}	3.4×10^{-3}	3.6×10^{-3}	3.8×10^{-3}	4.0×10^{-3}	4.2×10^{-3}
Total (PJ)	84.59	86.83	89.20	91.62	94.18	96.81	99.54	102.43	105.43	108.58

Table 5. Availability of agro and solid wastes in Coimbatore district.

Biomass/Agro residue availability	Availability in Coimbatore district (million tonnes)	Power generation potential (MW)
Firewood	4.2	--
Agricultural wastes	1.56	60.0*
Animal and poultry wastes	2.73	80.0*
Solid waste	0.274	5.0
Total power generation potential		145.0

** Collection efficiency = 20% (assumed)*

Therefore, alternate strategies have to be considered to limit the use of these fuels at the optimum level. Strategies such as adoption of energy conservation techniques, use of energy efficient technologies and substitution of petroleum fuel systems with alternate fuel and energy systems like fuel cell, electric vehicle systems, Compressed Natural Gas (CNG) systems etc. [9] have to be applied. National policies alone can influence substitution effects in the local scenario and as such it is difficult to bring it into the local level model.

As far as coal supply is concerned, there is no constraint in view of the large supply available within the country. LPG will be available for some more years due to the discovery of new gas fields.

The demand for electricity in this district will be about 610 MW for the year 2015. Regarding electricity supply, there is a restriction due to huge investment requirement for large sized power stations and also due to high transmission losses and pollution load. Measures such as the use of renewable energy based power plants including solar, wind and biogas plants and solid waste power plants, gas based generating stations, nuclear power plants, mini hydro power systems are some of the other power generation systems which need greater attention and development. The urban solid waste is becoming a source for energy generation. A special mention must be made of the use of biogas especially in industrial clusters. Gasifiers can be installed in these industrial clusters, where considerable quantity of biomass like coconut shell and agro-waste are available. The availability of these fuels is given in Table 5.

The use of solid wastes in this district for electricity generation is another area where immediate development is needed. It is possible to meet the demand of industrial clusters and integrated rural village/tiny industries by these decentralized sources. Considering the low calorific value of agro-wastes, firewood and animal wastes and the low end use efficiency of burning equipments like stoves, it is worthwhile to consider the use of biogas. Both wet processes and dry gasifiers can be used to generate biogas. The potential for the use of this appears to be high in the coming decade. The availability of firewood is low in the district. Energy plantations will also provide the basic fuel source for biogas systems leading to sustainable development and environmental protection, since the use of biofuels is environmental friendly and zero polluting. Wasteland can be identified to develop these energy plantations. Already, efforts are on in this direction.

5. CONCLUSION

The demand projections have indicated a need for controlling the demand of various types of energy/fuel and also for developing alternate strategies to avoid fuel/energy shortages and increasing prices. Further, future fuel and energy demand can be reduced by effectively implementing the energy conservation measures, adopting energy efficient technologies and fuel substitution to a great extent in the district. Therefore, considerable attention has to be given in order to make the district self-sufficient in meeting the energy demand and balancing supply and demand on sustainable basis. This will pave the way for continuous growth in the region leading to a better standard of living and also improved environment conditions by reduced Green house gases (GHG) emissions.

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NOMENCLATURE

CAGR	Compound Annual Growth Rate
CNG	Compressed Natural Gas
GDP	Gross Domestic Product
GHG	Green House Gases
LPG	Liquefied Petroleum Gas
NSS	National Sample Surveys
p.a.	per annum
PJ	Peta Joule (10^{15} J)
R^2	Regression coefficient
x	Year for which the demand was forecasted
y	Energy demand in x^{th} year

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