Energy Consumption to Sustain Environment in Perspective: Power Scenario in India

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Abstract

Agenda 21 of chapter 9, Earth Summit stipulate protection of atmosphere by promoting sustainable energy efficiency and consumption. Consumption of earth's resources especially, primary energy resources need be service directed to sustain environment and conservation .Coal is primary energy resource to derive electricity that account for major degradation of environment. This paper analyzes trend of energy consumption of different categories of consumers in India to identify the real entity that attribute to rapid demand growth as well as responsible for convergence of demand during peak hours, but unproductive in terms of deriving economical benefit out of it, ultimately focusing on Residential and Commercial categories of consumers. Energy requirement and Peak Demand in India has grown to 45% and 42% respectively. The assessment of relationship between growth of demand and the variables reveals the trend of consumption interlinked with pattern of growth of variables. The paper attempts to highlight the concept of conventional notion in economics to sustain equilibrium of supply and demand by differentiating consumer base, utilization of price - Demand variation concept, application of advanced technology in metering and generation mix along with educating consumers on utilization of electricity efficiently.

Keywords: *Demand, Consumption, environment, energy, Technology*

1. Introduction

Resources in Nature that are finite in availability and polluting the environment after its transformation to ultimate utilization for human benefit considered in two definite aspects[1], the utilization of such finite resources is out of common ownership and the remedial action to encounter degradation of environment is responsibility of each individual. However, the economic pursuit based on self-interest would not lead to what is best for society as a whole. The pattern of energy utilization at the consumer's discretion is driving force for Rate of Energy resource utilization. One of the options is to develop a system for efficient consumption of energy. Unless the end use mechanism of energy utilization is service directed, there is possibility in ever-growing demand of capacity addition by the process of transforming primary energy resources to meet end use energy requirement. Also, according to Holdren and Enrlich mathematical model, I = PCT, where I is Environmental impact is consumption per head and T is impact per unit of consumption [1]. So, there is necessity to identify some mechanism that will effect efficient consumption of electricity derived from finite resources i.e., fossil fuels to sustain environment The different strategies adopting advanced technology have effect on consumers to change their consumption behavior. In reality, we observe that energy consumption in residential and commercial sector (i.e., service sector) attribute to peaking demand that is unproductive, does not contribute to GDP growth. Therefore, in this sense, electricity is not for use as common commodity. There are options to control Energy usage through Demand side management or introducing Dynamic pricing with advanced technology that will enable Utilities to transfer part of the price variation due to peaking demand during a day to consumers and a 'pushing 'effect on consumers to limit use of unnecessary inefficient appliances. The Generation mix is other option. .This paper attempts to utilize concept of Economics on changing mode of energy consumption covering economic stratum of consumers' base and discusses justification of generation mix for reducing fossil fuel utilization. The studies endeavour to analyze the present power scenario in India, focusing on consumption pattern of different categories of consumers, the peaking energy shortage relevant to AT&C losses and revenue return, finally modeling a demand and pricing relation to determine its effect on efficient energy consumption by the consumers. The section 2 highlight the present pattern of consumption, losses and financial status in power scenario in India that need study, followed by research methodology, economics in pricing and demand with a mathematical model identifying real entity in growth of demand ,correlating the variables attributing to demand growth in section 5. Next section 6 discusses about recommendations and suggestion, subsequently concluded in section 7.

2 Need Importance of Study

Coal is primary energy resource that is cost competitive to derive electricity compared to other resources. Emission from coal based thermal power plants accounts for 70% of total emission of co2 into atmosphere. In India, coal based thermal power plants shares 53.5 % of total installed capacity comprising all Primary energy resources. According to World Bank source, present level of co2 emission per capita is1.1MT in India. Therefore, co2 emission from thermal plant contributes to 0.7 MT of total emissions. India stands at sixth position in the ranking of co2 emission among the countries in the world. The energy requirement and peak demand during 2005-2006 has increased by 42% and 45% respectively over last eight years. To meet the growing demand, perspective planning envisages addition of 62000 MW of coal based thermal power plant during 11th and 12th plan period. Peak Demand and Energy shortage during 2011-12 is indicative of shortcomings in power scenario. (TABLE –I) Thus, consumption level of different types of consumers needs analysis to identify the category of consumers responsible for growth of demand during peak hrs or annual growth of demand. TABLE-2 & 3 shows, pattern of Electricity Consumption during 2000-01 to 2005-06 of significant interest due to percentage share of residential consumption is high out of total consumption, almost keeping in pace with industrial consumption. Over all AT&C losses in India [3] in past years shows declining trend where consumer end metering almost reached cent percent of target of APDRP,but still present status in India indicate loss of above 34 % in some areas of states if the AT&C losses is analyzed for district wise all the states in detail. The data reveal that after implementation of APDRP, there is considerable gap between Cost of power supply and average revenue realized implying utilities have to satisfy energy consumption pattern (Table 3) of consumers with financial constraint. Therefore, this study is important that is focused on management of distribution in order to address this issue.

Table 1Peak Demand and Peak Energy status in 2011-12India

	Energy deficit (%)	Peak demand deficit (%)
Northern zone	-7.7	-9.6
Western Zone	-13.4	-13.9
Southern Zone	-13.3	-15.2
Eastern Zone	-6.8	-5.8
North Eastern Zone	-11.2	-10.5
All India	-11.1	-12.1

Source:CEA

Table 2 Share of Consumption among Major categories of Consumer in India

Category	Share of total consumption (%)
Residential & commercial	32.36
Industrial	34.19
Agricultural	24.53

Source:MOSPI

Table 3Growth of sectoral energy consumption (GWH)

Category	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Residential	23.89	24.71	24.54	24.86	24.77	24.89
Commercial	7.12	7.49	7.49	7.84	10.25	8.37
Industrial	33.79	31.72	33.85	34.51	44.94	35.9

Source:MOSPI

Table 4 Percentage AT&C losses, and GAP in cost of supply and revenue realizations

Year	AT &C losses (%)	Gap between Cost of power supply and Average revenue realized		
		Cost of power supply(Paise/Kwh)	Average Revenue realized (Paise/Kwh)	Gap(profit+ or losses -)
2003-04	34.78	239	203	-36
2004-05	34.33	254	209	-45
2005-06	33.02	260	221	-39
2006-07	30.62	276	227	-49
2007-08	29.45	293	239	-54
2008-09	27.74	341	262	-79

[In Table – 4 all India statistics related to AT&C losses [3] and impact on average revenue realized with respect to cost of supply that correspond to all states in India where APDRP target has been nearly achieved.]

Category wise energy consumption during past 6 years indicate increasing trend in growth of demand in Residential and Commercial sector, next to industrial consumption.

Over all AT&C losses in India [3] in past years shows declining trend where consumer end metering almost reached cent percent of target of APDRP,but still present status in India indicate loss of above 34 % in some areas of states if the AT&C losses is analyzed for district wise all the states in detail. The data reveal that in of APDRP implementation, there is considerable gap between Cost of power supply and average revenue realized implying utilities have to satisfy energy consumption pattern (Table 3) of consumers with financial constraint. 11 cables α = 45.9 kV peak β = 5.08 Confidence Intervals 95%

3 Statement of Problem

supply and revenue realized in utilities that implies utilities are running at losses.

4 Objectives

The study aims to develop strategies to evolve management principle in power sector operation to achieve minimization of environmental degradation, to achieve energy supply service directed for maximum use in productive purpose and to reduce AT & C losses at a level for optimum energy utilization and increasing revenue realization with matching cost of power supply.

5 Research Methodologies

The methodology of this study logically unfold different concepts on correlating indicators, developing mathematical model of economics on energy pricing to demand variation that determine necessity of emerging technology to control energy consumption and consumer's base differentiation to understand energy consumption among different stratum of income groups.

5.1Identifying correlation between Demand and variables

Energy Consumption per capita [2] in residential sector and commercial sector is strongly correlated (r=0.99) to growth of HH [4] as shown in Table-5.Similarly, the trend of variables growth of energy consumption and growth of per capita income has been indicated in Table – 6.It is observed that these variables is highly correlated (correlation coefficient r = 0.9776).Therefore, Energy consumption varies directly with growth of HH and growth of income per capita in the country. The pattern of income level of consumers is in transition keeping in pace with gross national income. Energy consumption per capita [6] increases with per capita income. It implies that Energy consumption in HH will rise with growth in income, the middle and higher income level HH utilizes more energy intensive appliances in the changed life style. There is marked transitions of HH from lower to middle and Middle and higher income level. Therefore, electricity utilization in the horizon

Energy consumption pattern determine corresponding economic growth in a country because of strong correlation between these two indicators of economic development. The present power scenario indicate 57% of total generation is fossil fuel based that has impact on environmental degradation, secondly, there is increasing trend of energy consumption in residential sector because changing life style with more economic growth. So, this pattern of energy consumption is unproductive compared to productive utilization in industrial sector. Next major issue is AT &c losses that gap between cost of power

year will have rising trend. The statistics shows, though AT&C losses declining with improvement of overall
to some extent, but the change in peaking shortage are erratic. That implies the necessity to adopt a suitable mechanism to reduce consumption during peak period.

Table 5: Growth of HH and electricity consumption

Item	1991	2001	2011	Correlation coefficient =r
Growth of House hold (million)	152	193.6	330	0.8640
Energy Consumption residential& commercial sector (MU)	60346	79694	169326	

Source MOSPI[5] &Census India

5.2. Efficacy of Price and Demand Concept

Above analysis on energy consumption pattern deserve developing methodology that could enforce a mechanism of efficient consumption to sustain environment.

The mathematical model of price –Demand variation for peak and off-peak dynamic pricing as follows

$$Y = X + XL$$

Y =supply of energy, X = energy requirement and XL = energy lost.

$$\text{Then, } CY - Cx = Cxl \quad (1)$$

CY = cost of power supply, expenses incurred for fuel, labors and capital invested.

Py.Cy – px.Cx = pxl.Xl,

Where Py = price per unit of electricity for supply,

Px = Price of selling electricity/unit

If N = nos of consumers,

$$Py\,.Cy - NpxCx = pxl.Xl \ldots \quad (2)$$

If Total quantity of electricity = X, then X = x+xl

Equation (2) rewritten as,

$$P.X - Np.cx = p.(X-x) \quad \ldots \qquad (3)$$

$$P.X - p.(X-x) = N.p.cx;\; X(P-p) + px = N.pcx$$

$$X = \frac{Np.cx - p \ldots}{(P-p)} \qquad (4)$$

$$\text{Or, } X = \frac{pNcx - p.x}{(P-p)} = A.N.cx - q,$$

Where q is loss factor that depends on metering deficiencies, theft and billing inefficiency .This factor will increase or decrease according to improvements of technology.

$$\text{Or } X = \begin{vmatrix} A1 & A2. \\ A3 & A4. \end{vmatrix} \begin{vmatrix} cx1 - cx2 \\ cx3 - cx4 \end{vmatrix} * q \quad . \qquad (5)$$

Where matrix [A], is a coefficient, that determine varying prices
If Q denote Energy input, replacing X

Table – 6 Income and energy consumption relation

	2004-05	2005-06	2006-07			
Per capita income @current prices	23222	25788	31198			
Energy consumption per capita	612	631	672			

	2007-08	2008-09	2009-10	Correlation coefficient=r				
Per capita income @current prices	33283	40605	46492	0.9776				
Energy consumption per capita	717	734	779					

Source: *CEA & PIB*

Then, Energy input

$$Q = f(p, x) = p/P\text{-}p.NCx - p.x$$

$$Q = p/P\text{-}p.N.Cx - q$$

Let t be the shortage cost, included in the selling price, then the relation in eq. (5) will be transformed to eq. (6). The electricity-selling price will be determined for the peak and off –peak demand period, according to economic stratum of the consumers based on their ability to meet expenditure towards electricity purchase. Where, $pt^* = \sum pi1t + pi2t + \ldots + pint$

$$Q = \frac{pt^*.N.c - q}{P - pt^*}$$

The price variation in selling and supply of power for different values is in matrix form. If X or electricity supply increases, then P, cost of supply will increase, for increase in demand Cx .where P, cost of energy for supply will include the generation plus the additional energy purchase from grid to meet the requirement. Therefore, there will be several variation of sale and supply price, and then X will decrease. If p varies with variation of P i.e., sale price and advanced technology in metering is adopted, then q will decrease and the variation of X will vary directly with second part of the equation (6)

5.3 Concept of Consumers Base Differentiation

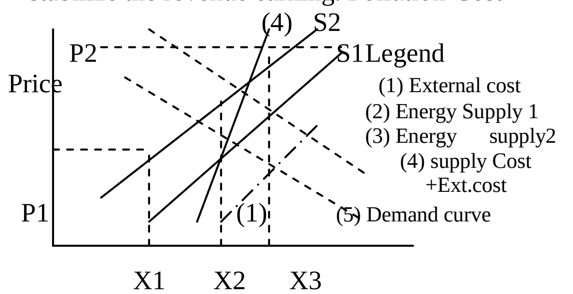
The tariff is applicable to all consumers irrespective of their purchasing power capacity, but there exist considerable difference in utilization of appliances in consumer bases. The High level income group consumers utilizes high energy intensive end use devices ,here the consumer sovereignty persists as they meet their requirement at their discretion as they can afford to pay more. The spiraling effect of consumption attribute to convergence of demand during peak period. The logical effect is to enforce the sliding scale of tariff. The differentiation of consumer bases for peak demand pricing may be possible by identifying the connected load of the consumers. The consumers having energy intensive appliances may be categorized in high energy consuming group while the consumers having only lighting and fan load will be classified as low energy consuming group. The future action of such metering program after base year needs a strategy to link the ownership of high-energy consuming appliances for determining their consumer status in grouping. Their purchase of appliances in the market will link to unique consumer no. of utility. The utility can ascertain each of the consumer's ownership of energy intensive appliances; accordingly, the consumers will be categorized in dynamic pricing system. There is necessity for differentiation in selling price according to ownership of high energy intensive appliances Air conditioner, Refrigerator, Washing machine and micro wave oven, and water pump. According to the statistics available with FICCI, the middle and high-income level group utilizes high-energy intensive appliances. Therefore, the peak demand metering for these group of people will have impact on the following aspects:-

a. Majority of consumers in middle-income group will resort to option of purchasing minimum electricity to maintain basic requirements during peak hours, curtailing unnecessary use of electrical devices.
b. While for the consumers in the high-income group, price variation with demand is inelastic, higher price during the peak period will have no effect.

In the case of (a), the energy saving will be effect, and for case, (b) the shortage cost realized from the consumers may be carried to environment friendly project. The price per unit of electricity may be determined based on generation cost plus the cost of import of energy during peak hours. Discussion in next section covers the application of this concept

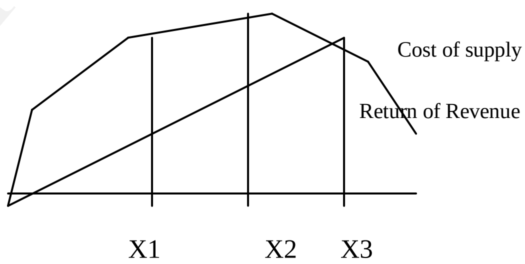
5.4. Price-Demand Variation Concept in Electricity Industry

Supply curve S1 (fig. 1) represent marginal private cost of producing electricity. This cost represent utilities expenditure on all priced input (i.e. labours, capital, and raw materials).However, in the process of production of electricity, the Utility is polluting the environment by emission of co2 at no cost, i.e that is externalities as shown line 1. However, this is not possible in reality, If x3 is the demand of electricity say, at peak period, then the cost of supply is P2, because of import of power from grid to meet excess demand, the supply curve will shift to S2. When demand increases to x3, price p increases, as cost of supply increases, the demand will fall due to dynamic pricing to x2; thus, restoring x to equilibrium level[7]. Therefore differentiation of price according to economy stratum will in effect achieve to reduce demand in energy utilization of low and middle-income group consumers during peak period, whereas, sliding price scale will stabilize the revenue earning. Pollution Cost



Electricity x kWh

Figure 1: variation of cost and price of electricity with externalities



Electricity (x) kWh

Figure 2: Rate of Return with variation of price

determination based on co2 emission per unit of electricity generated may be included in sliding price scale. The revenue realization on the part of excess electricity utilization shift to environment friendly projects or towards the cost of pollution free production technology.X2 is equilibrium point when cost of supply of electricity = cost of production, But, in reality, such situation is not expected.

6 Recommendations and Suggestion

It is necessary to eliminate the human processing of energy usage data at the distribution end by employing IT enabled technology of metering, straight through processing of energy consumption data; technology of remote metering would feed real data to utility's desk. Transaction processes from data capture by electronic meter through confirmation and settlement need automation to avoid risk of losses.

The selling risk in electricity industry is more when the utility experiences high demand at fixed cost and the rising cost of supply. Utility's total operating cost will vary with production of additional Kwh during time of the day and season. During Peak Demand period, the Utility would have to import or purchase energy at extra cost to meet the shortage over and above its own capacity of generation. To meet the shortage cost the utility must charge the consumers to reduce the gap of average cost of supply and average return of Revenue. Since Peak demand is high in the load profile due to convergence of Demand of Residential and commercial category of consumers, the pricing of energy cost need be sliding with energy usage. The advanced technology required to materialize the concept discussed in section 3.2

6.1 Application of Technology

Dynamic pricing of Electricity is possible by introducing advanced Metering technology in Distribution system. Installation of Electronic meter is required at the HH and commercial premises that will record time of day energy consumption.

More advanced technology of automated meter reading with wide communication network based supply by generation mix of grid power and Bio power (fig3). Thus, the two-fold effect of generation mix will reduce fossil fuel consumption and GHG emission, 1 kWh of electricity from Bio power system will curtail 0.79 – 0.81 kg-co2 GHG generated from coal based power plants. Maximum reliability in supply of electricity from bio power is possible .Bio mass may be used directly by burning biomass fuel in boiler providing energy in the range of 20 – 50 MW. With efficiency of over 40% [8] or biomass may be mixed with coal to burn in existing coal-fired boiler to reduce co2 emission. Generation of electricity from Biomass is useful to maintain supply when the electricity supply from the grid fails to meet the meet the demand, especially experienced in rural industrialized villages. MNES facilitate large and small entrepreneurs to build biogas farm. Further, better market value fetched for residue free agro-product.[10]More organized effort in this direction necessary to use urban and rural waste that is nearly 44 Million tons and 500 Mt respectively. There is available advance technology in biogas and anaerobic digestion, bio gas purification to use in power generation. The technologies provide scope for utilizing feed stock of different types of easily available waste products in HH.Local bodies should be involved to provide land near the dumping sites .Indigenous technology will be cost effective with provision of cost subsidy by MNES [11].Electricity generation from bio gas plants is possible at the

infrastructure is required for transmitting Household data to utility's desk by AMR technology, using radio frequency transmitter set at each meter of HH. Alternatively, using power – line – carrier technology enabled electricity grid. Existing meters can be upgraded and new connections with electronic meters for time of day metering is necessary.

Dynamic pricing will fix the rate on real time pricing depending on the electricity requirement or the price on seasonal change. Utilities will communicate the real time price of electricity to the consumers through internet, media and mobile. It will be necessary to create awareness of consumers about energy consumption pattern of the different end use devices, thus, the consumers will be able to adjust their connected load after ascertaining the real time data from the media or mobile or telephone.The setting up of infrastructure and maintenance of the system will involve large amount of investment.

6.2 Generation Mix

In rural industrialized villages of India, it is possible to minimize electricity consumption out of fossil fuel

installation charge of Rs 20000 -25000/, the pay back period is 6-9 months [12].

Therefore, decentralized generation in rural area where organic waste is abundantly available is possible with the financial assistance from MNES across the country if the state governments policy issues is conducive to exploit renewable energy resources is encouraging. The statistics on power generation capacity is encouraging that is observed small scale size biogas plants generate 0.44 MW out of 0.0042 million m3 per day [10].

When Bio power system exist in the distribution system along with power from Grid, energy requirement will be reduced by X3- X', where x' is energy supplied from Bio power.

Considering, equation (6)

$$Q = \sum \frac{p.t^*.N.C_x}{P-p.t^*} - q$$

$$Q' = \sum \frac{pt^*.N.C_x - x'}{P-pt^*} - q' \quad \dots \quad \dots \quad \dots \qquad (7)$$

Where Q' is energy input, when x' is supplied from Bio power resources. q' is new loss factor

Bio power as renewable energy is considered in view of its several advantages over electricity available from solar and wind power.[8] [9]

(1) Bio power is not varying with seasonal change as experienced for solar and wind power generation.

(2) life cycle cost of bio power is Rs 2.8 -4 .2/kWh compared to solar PV that cost Rs 8.2 – 52/kWh

(3) Bio power generation is conducive to employment generation, this benefit is not available for solar or wind power generation.
(4) Smaller scale bio power generation is possible at Affordable cost, so rural HH can be served in villages

7. Conclusion

In the course of analysis of consumption pattern in the Distribution system, present rate of growth of energy requirement associated with peaking shortages in India is within the focal point of discussion. The associated issue on environmental degradation due to emission of GHG is also in the scope of discussion .One of the major concern in distribution is rising trend of energy consumption. The paper attempts to identify the different variables responsible for growth of energy requirement and peaking shortages. Observations on available statistics indicate that appropriate measures taken on this issue have minor impact on reduction of AT&C losses, but financial constraint persists. Peaking shortage, rate of CO_2 emission, rising growth rate of energy consumption in Residential and commercial category and losses of energy in T&D are other area of concern.

The paper developed a mathematical model to visualize pattern of supply variation with cost and sale of power, indicating possibilities of introducing advanced metering technology in this sector to change the mode of energy consumption from energy as commodity to energy as service directed. It has been observed that share of total energy consumption out of total consumption in Residential and Commercial sector touched 32.36 % next to energy Consumption in Industrial sector, also peaking shortage in majority of states is attributed to energy Consumption in Residential and commercial sector.

Data analysis established strong correlation between Growth of HH and national income. Middle and high-income level group of consumers utilizes energy intensive appliances. The mathematical model of cost of supply and energy demand shows relationship and its variation of selling price of electricity, variation of energy requirement and effect of dynamic pricing. Introducing advanced metering technology for dynamic pricing will have impact on the middle-income level consumers towards saving

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energy consumption .Consequently, reducing energy input; the reduction of GHG will be the ultimate result. In case of High-income level consumers, dynamic pricing will generate revenue to develop a fund for meeting expenditure of environment friendly projects as the price variation is almost inelastic in respect of High-income level consumers, associated requirement is educating consumers about efficient energy consumption . Advanced metering Technology implementation will require substantial investment; that is Capital investment out of public fund; pay back period is short, because of assured return of revenue due to perfect energy accounting process. The paper highlights the importance of managing growing energy consumption out of fossil fuel based resources by Gen mix of Bio power, reducing GHG emission.

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