

**Economics of Electricity Consumption:
A Literature Review**

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Economics of Electricity Consumption: A Literature Review

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Abstract

Electricity consumption is determined by the use of electronic gadgets, income level of family members, choice of connection and size of the houses. In India, the energy use is at disaggregate level. Electricity is necessary in various types of activities and in each it takes a different character. There is a strong two-way relationship between economic development and energy consumption. The dynamics of growth in one sector with more residential electricity brings realistic potential for efficiency. The increasing availability and usefulness of electricity set the limit to its requirements in a region and the actual level of its consumption at any given time depends on a number of socio-economic factors which are usually not taken into account in making estimates of future requirements. In India, the growth in demand has exceeded the growth in generation capacity as a result the country is facing acute energy and peak shortages. The studies also discuss possible pricing options to bring about more efficient use of limited generated capacity as well as addressing the issue of equity. Some studies also tried to estimate the final demand which is price sensitive for both residential and industrial consumers. This study attempted to bring out literature reviews covering Studies on Electricity Economics; Studies on Household Electricity Consumption; and Studies on Managing Electricity Consumption.

Keywords: Electricity, consumption, India, climate change, pricing, peak load, household, economics.

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INTRODUCTION

Electricity consumption is imperative for measuring the standard of living of the people. It is determined by the use of electronic gadgets, income level of family members, choice of connection and size of the houses. The available studies on economics of electricity consumption deals with the demand for and supply of electricity level. The studies focus on how to reduce the consumption and wastages in all sectors as well as optimizing the existing resources to improve its generation. An attempt is made in this chapter to review the available studies on the aspects like Studies on Electricity Economics; Studies on Household Electricity Consumption; and Studies on Managing Electricity Consumption.

Studies on Electricity Economics

According to Stephane de la Rue du Can, Michael McNeil, and Jayant Sathaye (2009) in India the complete picture of energy use with disaggregated levels is drawn to understand how energy is used in India and to offer the possibility to put in perspective the different sources of end use energy consumption. For each sector, drivers of energy and technology are identified. Trends are then analyzed and used to project future growth. Results of this report provide valuable inputs to the elaboration of realistic energy efficiency scenarios.

Caldwell, Stephen (2008) analysed that the global climate change has become a topic of increasing importance to political leaders, policymakers, and the general public. Roughly one third of US greenhouse gas (GHG) emissions come from electricity generation. Improved energy efficiency in electricity end-uses offers the promise of reductions in GHG emissions and other benefits. Market failures have prompted federal and state governments to intervene to promote energy efficiency. One of the largest interventions has been in the form of demand-side management (DSM) programs run by electric utilities, state agencies, and third parties. Given policymakers considerations of further investments in energy efficiency through expanded DSM and other programs to help mitigate climate change, it is important to evaluate how effective DSM expenditures have been in improving energy efficiency. This study analyzes a state-level panel data set to estimate the effect of DSM expenditures on state-level electricity efficiency controlling for relevant factors and employing a Fisher Ideal index measure of efficiency that distinguishes changes in electricity usage due to changes in electricity efficiency from those due to changes in economic activity.

Santoshkumar Sahu (2008) is of the view that it has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally compassionate energy sources, and on the other hand, the level of economic development has been observed to be depended on the energy demand. Energy intensity is an indicator to shows how efficiently energy is used in the economy.

Virginie E.Letschert, Michael A. McNeil (2007) have studied that India seems to be on track to experience rapid long-term economic expansion. With this growth will surely come continued massive growth in energy demand. This paper explores the dynamics of that demand

growth for one sector – residential electricity – and the realistic potential for coping with it through efficiency. This paper forecasts ownership growth of each product using econometric modeling. The research takes advantage of an analytical framework developed by LBNL (BUENAS) which integrates end use technology parameters into demand forecasting and stock accounting to produce detailed efficiency scenarios, which allows for a technologically realistic assessment of efficiency opportunities specifically in the Indian context.

Nigel Isaacs (2007) study focus of New Zealand's recent energy debate has been on electricity. Electricity is a very important fuel, but it is not the only fuel. 'Energy' and 'fuel' are different – fuel transports energy, but needs to be transformed to be useful. For example, the burning of coal (fuel) releases heat (energy). Uniquely, electricity is both fuel and energy – it can be transformed into heat or used directly (e.g. for a computer). 'Energy' can be thought of in terms of what it does – the 'end-uses'. To boil water, heat to reach 100°C is needed; to cook a cake needs heat over 100°C; Heat can be provided by a wide range of fuels – natural gas, electricity, LPG, wood, coal, oil, geothermal or even the sun. Electricity can be generated from an even wider range of sources e.g. from fuels used in a thermal power station, falling water etc.

According to S. Padmanaban and Ashok Sarkar (2006) The Indian power sector has more than tripled its installed capacity, from 30,000 MW in 1981 to over 100,000 MW in 2001. Despite this growth in supply, its power systems are struggling to overcome chronic power shortages and poor power quality. With demand exceeding supply, severe peak (around 18%) and energy (around 10%) shortages continue to plague the sector. Shortages are exacerbated by inefficiencies in power generation, distribution and end-use systems. The inefficiencies in the end-use systems is due to irrational tariffs, technological obsolescence of industrial processes and equipment, lack of awareness, nascent energy services (ESCO) industry, and inadequate policy drivers (such as energy efficiency standards and labeling system, financial incentives) in India.

V.S. Mahajan, S.K. Agnikstri, (2002) have articulated that demand for energy has been growing over time with the increase of development efforts in various sectors of our economic activities during the last five decades. The rate of consumption of power resources is considered as an index of economic growth in different sectors of national economy. But the conventional energy sources may not last for an indefinite period and there are indications of depletion of reserves of quality coal and petroleum. It is important to develop the existing and available forms of energy resources than to go for higher and much costlier forms. This was clearly analysed by the above study.

V.P Gupta (2000) analysed the patterns of conventional and non-conventional energy in India. The study identifies the reasons for the enlarging energy deficits in India and suggests measures to reduce the widening gap between demand and supply of energy generation, distribution, consumption and losses has been made with respect to India. The study examines in detail the consumption and production of commercial sources of energy, namely, electricity, coal, oil and gas in India. The study also examines the growth of rural electrification in India and its inadequacies.

Dulasi Birundha Varadarajan (1993) opined that energy is capacity to do work or to transfer heat. In ordinary speech we refer to physical work or mental work to describe a variety of activities

that we think of as energetic. Energy means physical ability to perform a work and when a work is done a body is moved by a force. Naturally, there is use of some form of energy in the work that is performed. Energy has been a key factor in the supply of food and also physical comforts necessary for the existence of mankind. The most useful forms of energy for practical purposes are heat, sound and light. Energy has also mechanized, electrical, magnetic, chemical and gravitational forms. The books find out the issues such as energy development, Energy conservations, Energy cost and Prices, importance of energy planning and also analyses the international issues on energy management.

T.K.Moulik, B.H.Dholakia, R.H.Dholakia, K.V.Ramani, P.R.Shukla (1991) are of the opinion that although the links between energy demand and economic growth are becoming increasingly complex, there is hardly any doubt of the existence of a close relationship between the level of economic development and energy consumption. Energy input is at the heart of modern economic development process and makes direct or indirect contributions towards the development and growth of all sectors of the economy. In the planning process energy demand is estimated not as a key factor, but merely as a requirement for meeting the demand for a given set of targets. Because of a large energy supply and demand gap, it is important to examine India's development in relation to energy input.

D.D.Guru Qamar Ahsan (1987) study deals with the current issues related to the problems of energy in the context of technology changes. It examines the relationship between energy and economic development in the historical perspective indicating the factors responsible for switching between different sources of energy. It takes up the questions of demand for energy in the future years and discusses in detail about the existing and possible supply of different forms of energy both conventional and non-conventional. A special feature of the book is the analysis of the different aspects of the energy policy as discussed in the international forms and as also in the plan documents in India and other developing countries.

A.K.Sah' (1987) has analysed that the dawn of independence brought in the relation that development of the power sector would be synonymous with the development of the country. Massive multipurpose hydro-electric projects like the Bhakra-Nangal, Hirukund Dam, Chambal and Domodar Valley development were taken up in the early years of national planning. With the nationalization of coal sector, new coal resources were investigated and exploited which ushered in an era of massive thermal power generation though in a modest way. The study analyses the over all power development of Indian economy, and deals with the aspects which will encourage the improvement in optimum utilization of power.

Sachchidananda Janaki Prakashan (1983) in his study noted the electricity is an invaluable input for social change in any society. This study seeks to bring out the changes taking place in the quality of life among people in tribal areas in Bihar. It also throws light on the pre-requisites for the acceptance of the electricity by the people, the difficulties in getting connections and the irregular supply of electricity in the interior areas. An attempt has been made to explore the positive changes in the Socio-economic life of the people in qualitative terms. The author also makes a number of suggestions for better planning, implementation and utilization of electrification in tribal areas.

P.P. Pillai (1981) is of the view that the electricity is the most important common form of commercial energy in our country. In India with frequent and unprecedented increase in oil prices since 1973-74 and with the serious power shortages in most of the states, the need and urgency for scientific long-range planning in the electricity sector is now well recognised. No doubt, power development and distribution policy, whether at the national or State level, needs to be evolved and established primarily on the basis of existing and anticipated future demand for and supply of electricity. Kerala is one of the few states in India where the cost of electricity production is one of the lowest and where the electricity system is purely hydro. It is a state where the percapita electricity consumption, however is one of the lowest in the country. Kerala's power sector thus exhibits some unique characteristics which deserve to be studied.

Yet another study is made to examine the factors influencing sector wise growth of electricity use in India since 1951. Electricity is necessary in various types of activities and in each it takes a different character. The increasing availability and usefulness of electricity set the outer limit to its requirements in a region; the actual level of its consumption at any given time depends on a number of Socio-economic factors which are usually not taken into account in making estimates of future requirements. The usual methods for estimation are either an extrapolation of past trends with some allowance for new technical possibilities or a derivation of its requirements of existing rates from the expected rates of growth of activities using electricity. This study was undertaken to bring out the various factors which had influenced electricity demand in India in the recent past. In the last part of the study, an attempt has been made to analyse the trends of growing electricity intensity in India (Nirmala Banerjee (1979).

K.Venkataraman (1972) opined that the growth of national income and the economic development of any country have invariably been marked by an increase in the power consumed by the population. In the initial stages of economic development, lack of power may constitute an important obstacle to speedy development. The broad analysis of the study of power development in India, explains the overall picture of the various aspects that helps in power development. A great deal of discussion on the pricing of electricity in India has taken place. The charging of differential rates for different classes of consumption like Domestic, industry and agriculture also carries with it many implications and effects. The imposition of a tax on electricity by some states has also added another dimension to the problem of rate fixing. Another dimension to the financial aspects of power development is added by the fact the power generating machinery has so far required a good deal of foreign exchange. Aid has been received from various countries for power stations in India and the terms of such aid, the countries of origin and the agencies of aid have necessarily varied.

Studies of Household Electricity Consumption

The main purpose of this study is to explore the role of economic and non-economic factors in the determination of household's demand for electricity in the district of Peshawar. Primary data was collected for this purpose from 200 households of City Rural Division during November-December 2009. Multinomial logistic model was used to derive estimates. The study concluded that income, number of rooms, price of electricity, weather and education are important determinants of household demand for electricity in district Peshawar. However, the study suggested that a provincial level study in this regard will be more helpful for government in

understanding the real pattern of domestic demand for electricity (Naeem Ur Rehman Khattak (2010)).

Léa Cristina Lucas de Souza, Alinne Prado de Oliveira (2008) in their paper analyzed the electrical energy consumption of households as a function of urban variables, by modelling the urban thermal environment with Artificial Neural Networks (ANN). The study area was a residential neighbourhood. Urban features of reference points were determined by the following characteristics: urban heat island, sky view factor, and users' income level. For each of these reference points, urban air temperatures at the pedestrian level were collected with data-loggers. At the same time, rural temperatures made available by the city meteorological station site were registered. In addition, the user's profiles were identified by means of a questionnaire applied to the households. Their electrical energy consumption data were also collected from the power supply company. The results show that low values of sky view factor and high urban heat islands, when observed in high income zones, are associated with the largest electrical energy consumption patterns.

M. Adetunji Babatunde, M. Isa Shuaibu (2007) examined the residential demand for electricity in Nigeria as a function of real gross domestic product per capita, and the price of electricity, the price of substitute and population between 1970 and 2006. The study makes use of the bounds testing approach to co-integration within an autoregressive distributed framework, suggested by Pesaran et al. In the long run, the income, the price of substitute and population emerges as the main determinant of electricity demand in Nigeria, while electricity price is insignificant. The relationship among variables is more stable and significant.

Power-generating capacity in India has increased steadily over the years, and so has the demand for power. However, the growth in demand has exceeded the growth in generation capacity, as a result of which the country is facing acute energy and peak shortages. Over the years, the focus has primarily been on implementing supply-side measures, such as capacity addition, reduction of transmission and distribution losses, and so on. Supply-side measures, though extremely important, require large investments and are spread over long periods of time. It is, therefore, important to adopt a multi-pronged strategy that not only focuses on the supply side but also incorporates improvements in efficiency at the demand side. Demand-side measures like promotion of energy-efficient appliances and load management are much faster to implement and are cost-effective options in narrowing the gap between supply and quantity demanded. Besides providing quick and viable options, such measures also reliably mitigate the risk of global climate change and environmental degradation associated with electricity production and use. This publication, by way of a case study, demonstrates the energy-saving potential of basic demand-side management measures and the associated savings that can accrue to households and utilities by adopting them (Manisha Jain, Vikas Gaba, Leena Srivastava (2007)).

A. Mc Neil, Virginie E. Letschert (2006) studied the increase in the rate of appliance ownership with rising incomes is a major driver of the growth of residential electricity consumption in developing countries. Macroeconomic parameters such as GDP growth, while useful in forecasting residential electricity use, may fail to take into account the determinants of appliance use at the household level, such as total market penetration of primary appliances among certain classes, subsequent ordering and climate dependency of secondary products, the dynamics

of economic growth and income distribution, urbanization and rural electrification. A detailed, multi-country investigation of the relationship between household income and appliance ownership is therefore valuable for predicting future residential energy consumption, as well as evaluating strategies for mitigation of its environmental impacts.

Runa Nesbakken (1998) tried to test the stability of the results of a model which focus on the relationship between the choice of heating equipment and the residential energy consumption. The results for the income and energy price variables are of special interest. Stability in the time dimension is tested by applying the model on micro data for each of the years 1993, 1994 and 1995. The parameter estimates are stable within a 95 per cent confidence interval. The results for two different income groups in the pooled data set are also subject to stability testing. The energy price sensitivity in residential energy consumption is found to be higher for high-income households than for low-income households.

The residential energy sector in developing countries has become the focus of increasing concern and attention. This is partly because of its great size within national energy budget, but also because, in poorer third world countries, the social and economic costs of supplying it with energy are high and are rising rapidly. Data from 15 country assessment by the United Nations Development Programme and the World Bank show that household account for 30-95% of total energy use, compared to 25-30% for industrialized countries. In low-income sub-Saharan Africa the proportions range from more than 50% to 95% (Gerald A. Leach (1988)).

Studies on Managing Electricity Consumption

Adrian Carter, Roland Craigwell and Winston Moore (2009) paper estimates a model of residential electricity demand to project the impact of proposed tariff changes on a representative sample of 130 Barbadian households. The results from the demand function suggest that the price elasticities of demand for particular appliances varied significantly, with households that utilize solar water heating being more price elastic than households that use air conditioning and electric water heating. The income effects were, however, statistically insignificant as they may have been captured by choices of appliances rather than utilisation. The income elasticity for households with solar water heating was found to be negative, probably reflecting the substitution impact arising from the use of solar power to provide water heating. The database also allowed the authors to breakdown price and income elasticities by individual households and these results suggest that middle-income households tend to be more prices sensitive, indicating that these households may be more able to reduce their usage of discretionary appliances than low-income households. Changes in consumption will however be more noticeable within upper consumption and upper income households.

Andreas V. Stokke, Gerard L. Doorman, Torgeir Ericson (2009) have analysed the demand response from residential electricity consumers to a demand charge grid tariff. The tariff charges the maximum hourly peak consumption in each of the winter months December, January and February thus giving incentives to reduce peak consumption. We use hourly electricity consumption data from 443 households, as well as data on their network and power prices, the local temperature, wind speed and hours of daylight. The panel data set is analysed with a fixed effects regression model. The estimates indicate a demand reduction between 0.07 and 0.27 kWh/h

in response to the tariff. This is on average a 5 percent reduction, with a maximum reduction of 9 percent in hour 8. The consumers did not receive any information on their continuous consumption or any reminders when the tariff was in effect. It is likely that the consumption reductions would have been even higher with more information to the consumers.

Uwe Dulleck and Sylvia Kaufmann (2003) empirically studied the effectiveness of a customer information program to decrease energy demand by increasing efficient electricity use. This demand side management (DSM) program aims at reducing the lack of information on the customers' side that is documented in related literature. The Irish DSM program which is particularly well suited to investigate this issue as strategic behavior is ruled out in this setting for both customers and suppliers. On the customers' side because information programs allow only for a limited substitution of own effort. The study found that providing customers with information reduced overall electricity demand by roughly 7%, as well as reducing demand fluctuations over the year. Further, we find that the DSM program had a larger impact upon long run demand, with consumers' short run demand behavior not being changed significantly.

P.V. Srinivasan B.Sudhakara Reddy (1996) estimated the price elasticities of demand for electricity in the domestic and industrial Sector in India, and assess the potential role of pricing in managing demand. It also discusses several possible pricing options that can bring about more efficient use of limited generated capacity, as well as addressing the issue of equity. The study estimates the final demand to be reasonably sensitive to price changes among both residential and industrial consumers.

H.Stuart Burness and H.Patrick (1991) deals with the issues concerning time-use (TOU) pricing with continuous and interdependent demand are examined in a context where increasing marginal costs of production, as opposed to capacity constraints, provide the major incentives for flattening the load curve. The analysis develops the underlying consumer preferences sufficient to insure a continuously varying load curve and generalizes previous considerations of the peak load pricing problems by simultaneously. Continues and interdependent demand in determining optional prices discrimination is revealed, which is tempered as substitution across pricing periods allows limited international arbitrage. The profit incentive leads as price-regulated firm, *ceteris paribus*, to choose a peak pricing longer than the social optimum.

Mohan muna singhe, Shyam Rungta (1984) have opined that the rapid increase in energy prices have clearly indicated that the era of cheap and abundant, especially oil is over. The critical dependence of modern economies on energy in various forms, especially electricity, underlines the need for efficient use of scarce energy resources. At a more general level, the achievement of economic development requires that the intricate link between energy and the different sectors of an economy, as well as the interactions among the various forms of energy, carefully examined within a disaggregate but integrated frame work. The application of rational economic analysis, particularly to the costing and pricing of electricity will improve the efficiency of investment decisions in the electric power sector and discourage wasteful consumption of electricity. The average annual growth rate of electricity consumption in DMCs is more than twice the rate of developed countries. In the past, convenience and relatively low price of electricity in most developing countries have helped to promote electricity use.

Robert W. Gilmer and Richard S. Mack (1983) made a critical input to planning by electric utilities is the cost to their customers of power outages. This paper assesses the cost of electrical outages to households, using customers of the Tennessee Valley Authority as an example. Unlike the industrial or commercial sectors where a loss of electric service disrupts a flow of goods and services, the residential sector has no measure of its output that is routinely valued by the market. This necessitates indirect methods to measure losses due to power outages - and perhaps explains the relative neglect of this sector in past studies.

The Electric power industry expanded rapidly during the first two-third of the twentieth century. Increased Industrial productivity and changed living standards were taken for granted almost as quickly as they were achieved. New pressures began converging. Existing technology had been pressed nearer to its physical and engineering limits, technological innovation, which had played an important role in reducing the unit costs of electric power, had reached a plateau. The study also discussed about the history of laws which structure the regulation of the industry. The study shows the possibilities for improving licensing procedures, rate regulation, and pooling arrangements by better use of existing authority (Edward Berlin Charles J. Cicchetti William J. Gillen (1974)).

CONCLUSION

The literature on economics of electricity consumption based on the studies of the eminent scholars tried to isolate the process and determinant of factors which creates necessity for electricity. The views and findings of scholars differ not only on the basis of variables but also the dependencies of other factors which is responsible for production and consumption. The points raised by the scholars like the dependency of variables on time which are region specific and individual specific. This has been done by making micro level studies based on field Surveys to understand the direction and quantum of household electricity consumption in different situations.

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