Causality between Electricity Supply and Economic Growth in India: An Empirical Investigation

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CERTIFICATE

I hereby certify that the work which is being presented in this thesis entitled "**Causality between Electricity Supply and Economic Growth in India: An Empirical Investigation**" in partial fulfillment of the requirements for award of the Degree of Masters of Philosophy in Economics, submitted in School of Management and Social Sciences, Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr Naresh Chandra Sahu lecturer ,School of Management and Social Sciences.

The matter presented in this thesis has not been submitted for the award of any degree of this or any other University.

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(Geetu Gupta)

CONTENTS

Appendix

List of Tables

List of Figures

List of Map

Abbreviations

BEE	**Bureau of Energy Efficiency**
BMS	**Building Management System**
CFL	**Compact Fluorescent Lamp**
ECBC	**Energy Conservation Building codes**
EI	**Energy Intensity**
EIKC	**Electricity Intensity Kuznet Curve**
EKC	**Environment Kuznet Curve**
FEM	**Fixed Effect Model**
REM	**Random Effect Model**
GCC	**Gulf Co -operation Council**
GDP	**Gross Domestic Product**
GLS	**Generalized Least Square**
GNP	**Gross National Product**
IEU	**Intensity of Energy Use**
NSDP	**Net State Domestic Product**
NTPC	**National Thermal Power Corporation**
OECD	**Organisation for Economic Co-operation and Development**
PCI	**Per Capita Income**
PPP	**Public Private Partnership**
RBI	**Reserve Bank of India**
SEB	**State Electricity Board**
WTO	**World Trade Organisation**

Abstract

Electricity plays a crucial role in the economy of a country ,especially when the economy of a country is in its developing phase like India .In this study , an attempt has been made to investigate the causality between electricity supply and economic growth in India taking data from 1960-61 to 2006-07 . In order to find out the causal relationship, Granger causality model has been adopted to find whether there is bi-directional or unidirectional causality running from electricity consumption to economic growth or vice-versa.

The direction of causation between electricity consumption and economic growth has significant implications. If, for example, there is a unidirectional causality running from economic growth to electricity consumption, it may imply that energy policies may be implemented with little adverse or no effects on economic growth. On the other hand, if unidirectional causality runs from electricity consumption to income, reducing electricity consumption could lead to fall income or vice versa and if there is 'no causality' in either direction, the co-called 'neutrality hypothesis' would imply that energy policies which do not affect economic growth. However , our results suggest that there exists a unidirectional relationship between electricity supply and economic growth in which electricity act as a catalyst for the further expansion of the economy . In this study , we have incorporated the idea of the existence of a hypothetical environmental Kuznet[1] curve for electricity intensity . Our results reveal that there exists Electricity Intensity Kuznet curve in India during 1960-61 to 2006-07 period. The shape of this curve shows an inverted U-shape like Environmental Kuznet Curve (EKC).

In addition, we have also tried to find out the relationship between electricity supply and economic growth in the major states of India by adopting panel regression model.

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[1] There is wide range of literature which examines the impact of economic growth on environment, popularly known as environmental kuznets curve (Grossman and Krueger, 1993; Selden and Song, 1996).

For this analysis ,the data for post- reform period from 1990 to 2004 have been used to find the relationship between electricity & growth. While adopting panel regression model across different states of India , it is established that inverse relationship between electricity supply and growth in the backward states, which in turn reduce the intensity, whereas the results are reverse in case of foreword states except Delhi for which the reasons are discussed in this study .

The entire study has been classified in four chapters. Chapter- 1 illustrates the significance of electricity in human life. It also sheds light on changes in the structure of power sector in India .In chapter-2 , the existing literature between electricity supply and economic growth has been thoroughly reviewed.Chapter-3 delineates the set of objectives of the study .In addition , it also discusses different methods which are adopted to accomplish our objective. Last but not the least, the estimated ,results and findings of the study have been discussed in detail in chapter-4 .

Chapter 1: INTRODUCTION

1.0 Introduction

This chapter discusses the significance of electricity in daily life , various sources of electricity generation , power sector scenario, various reforms that are taken to improve the performance of state electricity boards and various measures taken to better utilization of these resources.

1.1 Significance of Electricity

Throughout history, human beings have been relying on different types of energy to move on in their daily lives. In fact , the industrial revolution that underpins today `s global economy was all about replacing muscle power with mechanical power which uses electricity both for commercial and non-commercial purposes to carry out various activities which are meant to achieve growth respectively.

Electricity is a secondary energy source which means that we get it from the conversion of other sources of energy ,like coal, natural gas ,oil, nuclear power and other natural sources which are called primary sources .The energy sources we use to make electricity can be renewable and non-renewable but electricity itself is neither renewable nor non-renewable .It is a high quality energy carrier and basic part of nature .So before electricity generation began over 100 years ago at that time houses were lit with lamps, food was cooled in iceboxes and rooms were warmed by wood- burning.

Historically , humanity's use of energy has been marked by four broad trends from developing to developed one these are as follows :

- Rising consumption and transition from traditional sources of energy (e.g. wood, dung, agricultural residuals) to commercial form of energy (e.g. electricity).
- Steady improvement in the power and efficiency of energy technologies.
- A tendency toward fuel diversification and de-carbonization especially for electricity production.
- Improved technology helps in pollution control and lower emissions.

Electricity radically changed the standard of living and way of life of mankind like the way people spent their leisure time through movies, radio and television, access to reliable year- round refrigeration and air conditioning facility during summer , various developments in the field of medical sciences such as X-rays, diagnostic scanning etc which provide cure for various human diseases .So electricity is such an integral part of daily living that it is difficult to imagine a time when it did not exist, a time when there were no lights, no computers and no appliances, a time when everyday tasks like laundry , cooking and vacuuming were not so easy without machines run by electricity. The growing importance of electricity brings number of electrical appliances, improvement in their applications and substitution of fossil fuels.

In present modern era, the importance of electricity is growing in every sphere due to its importance in the same way as conventional currency which is manmade and has no intrinsic use . Rather its usefulness derives from it being an intermediary for matching supply with use while avoiding the need for direct barter .However unlike money this is a currency that you can not put in the tank for a rainy day ,natural gas can be stored in underground caverns during the summer for use in winter. Liquid fuels can be stored in tanks until you need them and coal and uranium can be stockpiled .But electricity has to be used as it is made or to put it the right way round, it has to be made in exactly the quantity it is being used and exactly the moment it is being used (Carr,2007).

Electricity is one of the major inputs for the economic growth and development of a country . The world has become increasingly dependent on electrical appliances and equipment which leads to rise in energy consumption rapidly. In case of developing countries , like India there exists a two- fold challenge in the 21 sty century :(1)To meet the needs of billions of people who still lack access to basic facilities and to provide them modern energy services .(2) On the other hand participating in a global transition to clean ,low-carbon energy systems . In the layout of global warming and climate change both these challenges demands urgent attention. In this regard the study of relationship between electricity consumption and economic growth arises from the need to understand the complex link between both these variables. Electricity plays a vital role in an economy on both demand and supply side. On demand side, energy is one of the products a consumer decides to buy to maximize his or her utility. On supply side, energy is a key factor of production in increasing economic growth and living standards. Overall, energy such as electricity has been indispensable for each and every person of the world.

1.2 Sources of Electric Power

There are different sources of electricity supply in India these are hydro ,thermal , nuclear ,wind and solar.

❖ **Hydro power**

Hydro Power is another source of renewable energy that converts the potential energy or kinetic energy of water into mechanical energy in the form of watermills, textile machines etc., or as electrical energy (i.e. hydroelectricity generation).There are various types –

- ❖ Hydroelectricity
- ❖ Tidal Energy

- Wave Energy
- Waterwheels

- **Thermal power**

Thermal power which is generated by coal and oil has always been the major source of electric power in India. In 1950-51 installed capacity of thermal power was 1150Mw and gradually the share of thermal power had increased from 67% to 71% .The sources used in thermal power generation plants are non-renewable and exhaustible resources.

- **Nuclear power**

Nuclear power is of recent origin and its supply accounts for only 2% of the total installed capacity of electricity .This source has the potential to supply large amount of electricity ,however attempts are made to set up nuclear power stations in Tamil Nadu ,Rajasthan and nuclear deal with USA.

- **Wind Power**

Wind power is the conversion of wind energy into a useful form, such as electricity, using wind turbines. Wind power is generally converted to the form of electricity; large-scale wind farms are connected to electrical grids to supply energy. Individual turbines can provide electricity to isolated locations. In windmills, wind energy may be also used directly as mechanical energy for pumping water or grinding grain. Wind energy is available freely, is renewable and clean and produces no greenhouse gas emissions.

- **Solar Power**

Solar energy is the utilization of the radiant energy from the Sun. Earth receives 174 PW of incoming solar radiation at the upper atmosphere, of which, around 30% is reflected back to space while the rest is absorbed by the atmosphere, oceans and land. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850 zettajoules (ZJ) per year.

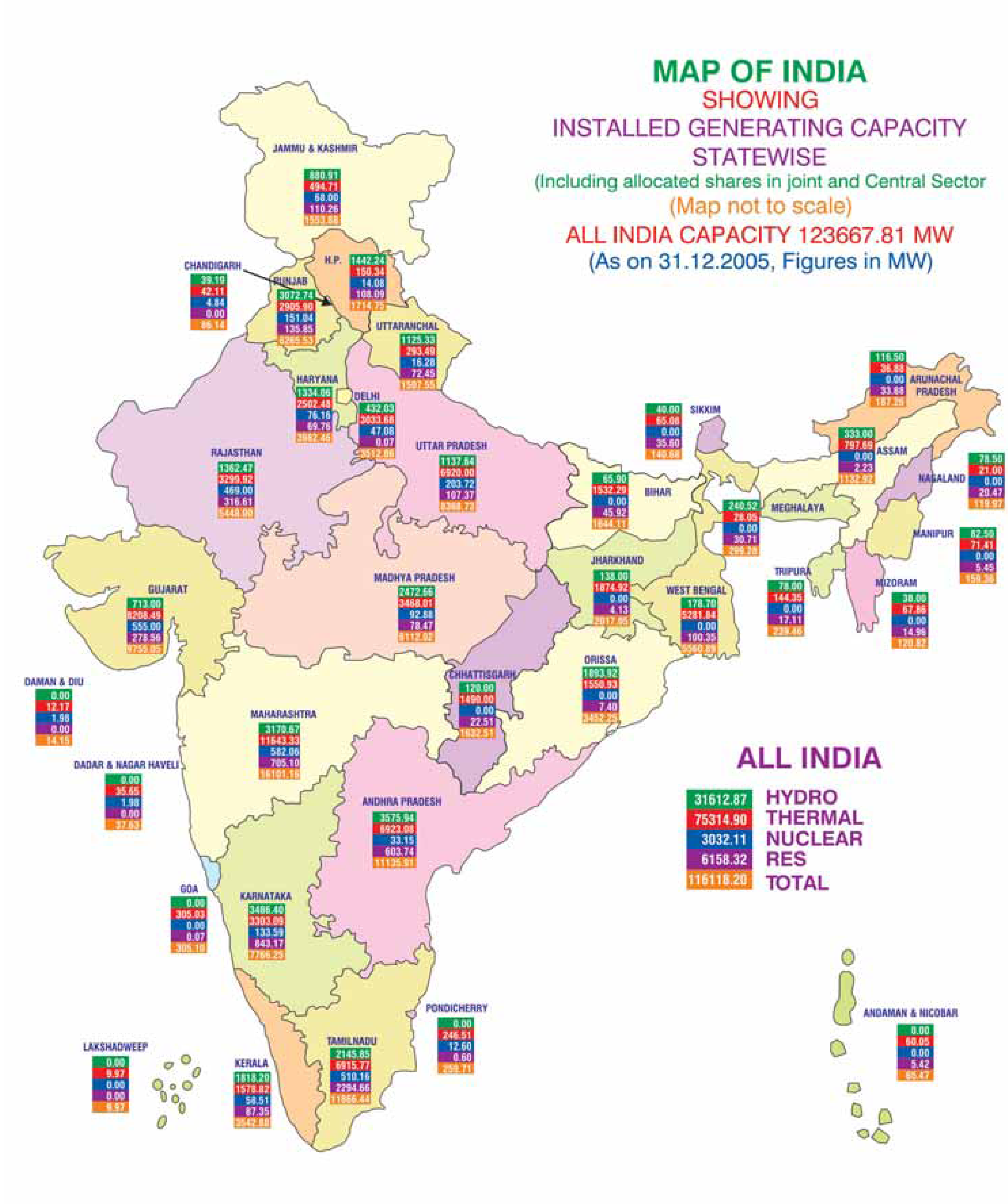
❖ Photovoltaic

The other, and more recent technology to assimilate solar energy is the solar photovoltaic. This technology uses a silicon or other semiconductor material based "solar cell" which is a device that can actively convert light energy emitted from the sun to electricity. This electricity can then be used directly or stored in a battery for later use. The magnitude of the electric current generated depends on the intensity of the solar radiation, exposed area of the solar cell, the type of material used in fabricating the solar cell, and ambient temperature. Solar cells are connected in series and parallel combinations to form modules that provide the required power.

❖ Biomass/Biofuels

Plants use photosynthesis to grow and produce biomass. Also known as biomatter, biomass can be used directly as fuel or to produce liquid biofuel. Agriculturally produced biomass fuels, such as biodiesel, ethanol and bagasse (often a by-product of sugar cane cultivation) can be burned in internal combustion engines or boilers. Typically biofuel is burned to release its stored chemical energy. Research into more efficient methods of converting biofuels and other fuels into electricity utilizing fuel cells is an area of very active work.

Map 1 :Different Sources of Power Generation in India



Source : *Ministry of Power*

The above map of India shows the installed generating capacity of electricity across different states in which three main sources of generation of electric power have been shown.

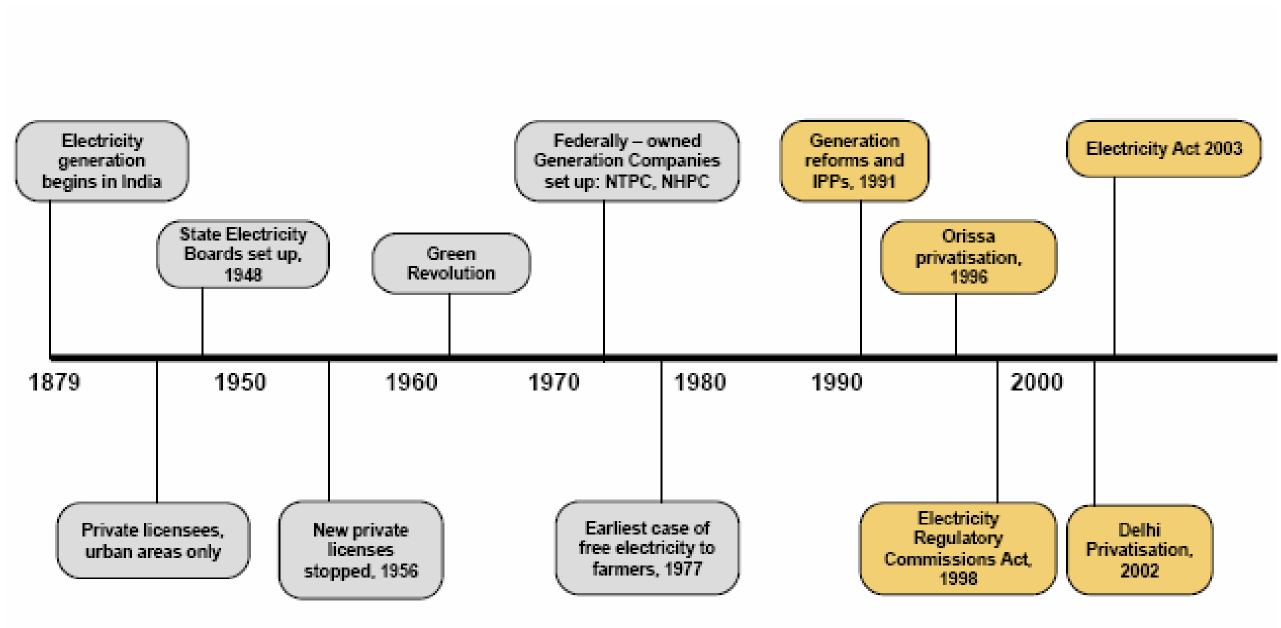
The major source of electricity generation in India is thermal power ,because country possess large coal deposits . Hydro electric power is another major renewable resource used in electricity generation. In 1950-51 installed capacity of hydro power was 560MW. It has increased to 34700MW in 2006-07 but in relative terms it had declined from 33% to 26%.This was because of the greater growth of thermal power since 1951. Nuclear energy is a source accounts for only 2% of the total installed capacity of electricity .

1.3 Power Sector in India

The electricity generation begins in India in 1879.The power industry was in the private sector at the time of independence (1947) and the total commissioned capacity of the power generation in the country was about 1350M.W. There was no power industry in the rural India.

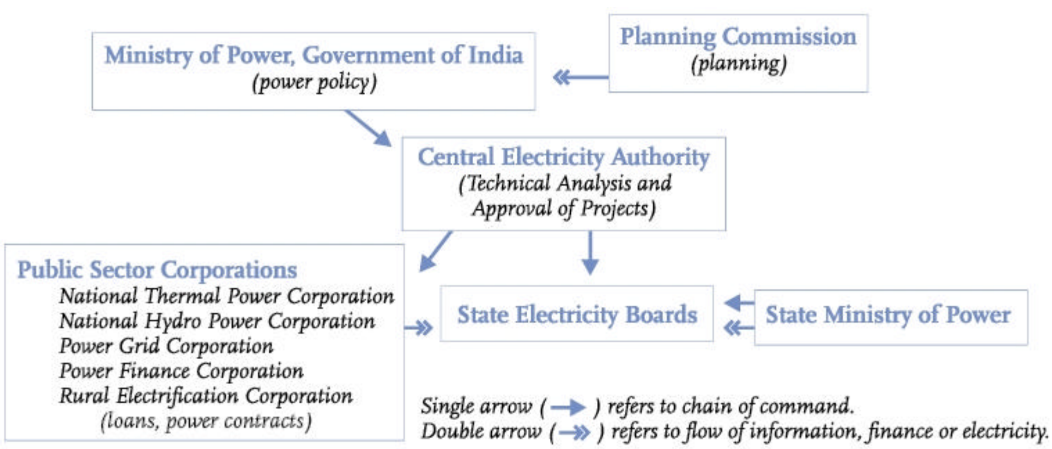
In 1948, the very next year of the independence, the Electricity Supply Act 1948 came into existence which modified the 1910 Act, barring a few licensees in some urban areas, e.g. The Tata Power Company Ltd in Mumbai, Calcutta Electric Supply Corporation Limited (CESC) in Calcutta, Bombay Suburban Electric Supply Company (BSES) in Mumbai, Ahmedabad Electricity Company (AECO) in Ahmedabad, etc the entire power sector is mostly owned by State Governments and is largely managed by vertically integrated electricity business through State Electricity Boards (SEBs) . Figure 1.1 presents the various reforms taken in power sector over the decade .

Fig 1.1 A Timeline of Reforms



Source : *Sen ,2009*

Fig 1.2 Structure of Electricity Sector Before (1991)



Source: *Tongia,2003*

Significantly, SEBs were financed through state government loans and were run as extensions to state energy ministries. As a result, SEBs were “indebted in perpetuity,” and were forced to continue in a relationship of financial and administrative dependence to energy ministries. Nonetheless, SEBs were the backbone of the electricity infrastructure, and by 1991 controlled 70 % of electricity generation and almost all distribution (World Bank, 1991).

Under the Indian constitution, the electricity sector is a “concurrent” subject, allowing both the central and state governments some authority in the sector. SEBs are under the control of state governments, which also controlled the critical tariff-setting function. The central government was responsible for electricity policy, long-term planning, technical analysis, and project approvals through the Power Ministry, Planning Commission, and Central Electricity Authority.(see fig 1.2).

1.4 Reforms in Electricity Sector

Over the period of operations, the sector developed various inefficiencies restructuring therefore was felt necessary. Accordingly, the power generation was opened up in 1991 followed by transmission in 1998. Electricity Regulatory Commissions Act was enacted in 1998 for establishing regulatory commissions in various States. Recently the Electricity Act 2003 has been notified by government of India in June 2003. The objective of this act is to accelerate the power sector reforms. A chronology of various reforms undertaken in power sector are shown in the appendix 3.

In power sector reforms the Orissa was the first state of India adopted World Bank Reform Model in 1996 and as a result Orissa Electricity Reform Act passed . Up till now about 13 state electricity boards have been dismantled. In addition to Orissa the other states are Haryana, Andhra Pradesh, Karnataka, Gujarat, Uttar Pradesh, Uttranchal, Rajasthan, Madhya Pradesh, Delhi, Assam and Maharashtra. and West Bengal.

The State Electricity Boards are still existing in states of Bihar, Jharkhand, Meghalaya, Chhatisgarh, Tamilnadu, Kerala, Himachal Pradesh and Punjab.
Among the dismantled State Electricity Board all except Assam and Maharashtra have been dismantled by enacting state Act, for dismantling. A Central Electricity Act was enacted in 2003. This act 2003 is the clear manifestation of what the Government of India intends to do in the power sector. The various consolidated measures shown in fig.1.3 are explained as follows

❖ **Regulator** : The Central Electricity Regulatory Commission (CERC) along with State Electricity Regulatory Commissions (SERC) have been established .Therefore the establishment of an independent regulator for each state.

❖ **Unbundling** : The power sector reform process, emphasizing the unbundling, tariff rationalization and corporatisation of generation, transmission and distribution.

Fig 1.3 Various Consolidated Measures in Power Sector

Source: Sen, 2009

❖ **Tariff Rationalization** :Setting tariff according to cost of supply and correcting distortions.

❖ **Open Access** :Allowing open access to the transmission sector for private sector.

❖ **Competition in Distribution** : The experience of privatization of distribution sector in the State of Orissa has been far from satisfactory. This is due to the lack of independently verifiable base-line data before privatization. So improvement in other models to improve the efficiency in distribution process.

❖ **Captive Generation** : The complete de-licensing of captive generation.

In India, to achieve the objective of providing access to electricity at lower carbon emissions, a legislation namely "Energy Conservation Act, 2001" has been enacted. The Act provides the much-needed legal framework and institutional arrangement for embarking on an energy efficiency drive.

Under the provisions of the Act, Bureau of Energy Efficiency has been established with effect from 1 March 2002 by merging erstwhile Energy Management Centre of Ministry of Power. The Bureau would be responsible for implementation of policy programmes and coordination of implementation of energy conservation activities.

1.5 Important Features of the Energy Conservation Act

Standards and Labeling

The main provision of EC act on Standards and Labeling are:

❖ Evolve minimum energy consumption and performance standards for notified equipment and appliances.

❖ Prohibit manufacture, sale and import of such equipment, which does not conform to the standards.

- Introduce a mandatory labeling scheme for notified equipment appliances to enable consumers to make informed choices .
- Disseminate information on the benefits to consumers .

Designated Consumers

- Schedule to the Act provides list of designated consumers which covered basically energy intensive industries, Railways, Port Trust, Transport Sector, Power Stations, Transmission and Distribution Companies and Commercial buildings or establishments.
- The designated consumer to get an energy audit conducted by an accredited energy auditor .
- Energy managers with prescribed qualification are required to be appointed or designated by the designated consumers.
- Designated consumers would comply with norms and standards of energy consumption as prescribed by the central government.

Energy Conservation Building Codes

- The BEE would prepare guidelines for Energy Conservation Building codes (ECBC).
- Energy audit of specific designated commercial building consumers would also be prescribed .

Bureau of Energy Efficiency (BEE)

The mission of Bureau of Energy Efficiency is to institutionalize energy efficiency services, enable delivery mechanisms in the country and provide leadership to energy efficiency in all sectors of economy. The primary objective would be to reduce energy intensity in the Indian Economy .List of designated agency to coordinate , regulate and enforce the provisions of act are given in appendix.

In this study , we have made an attempt to unravel the relationship between electricity supply and economic growth of Indian economy .In order to carry out this exercise , we have reviewed the existing literature in the next chapter pertaining to the above mentioned study.

Chapter 2 : LITERATURE REVIEW

2.0 Introduction

In this chapter, various previous studies on causal relationship between electricity consumption and economic growth are reviewed in three separate sections and separate section for studies pertaining to energy intensities.

2.1 Review of Existing Literature

The relationship between energy consumption and economic growth is well established in the literature, yet the direction of causation of this relationship remains controversial whether economic growth leads to energy consumption or that energy consumption is the engine of economic growth. In various studies ,empirically it has been tried to find out the direction of causality between energy consumption and economic activities for the developing as well as for the developed countries employing different methodologies ,however results are mixed. In this chapter we have divide the studies into following sections:

- Studies in which causal relationship exist .
- Studies in which no causal relationship exist.
- Studies in which unidirectional relationship exist.
- Studies related to energy intensity.

2.2 Existence of Causal Relationship

In a study, Atle (2004) presented a comprehensive analysis of causality between energy consumption and economic growth for the period (1960-2002). In this paper Johansen procedure is used. To illustrate the methodology empirical illustration looking at for nine different countries . The results emphasized close relationship between energy use and economic growth.

Another study in which Lee and Chang ,(2005) found that different directions of causality exist between G.D.P. and energy consumption. stability between energy consumption and G.D.P. for the period (1954-2003) in Taiwan. The unit root test and co-integration test were used while allowing structural breaks.

Chontanawat,Hunt and Pierse(2006) tested for causality between energy and G.D.P. using a consistent data set and methodology for 30 OECD and 78 Non-OECD countries. The data source for all countries comes from the I.E.A.(2002) energy statistics data for OECD for the period 1960 to 2000 and Non-OECD (1971-2000) causality from aggregate energy consumption to GDP and GDP to energy consumption is found to be more prevalent in the developed OECD Countries compared to the developing Non OECD Countries.

In a similar study Squalli and Wilson (2006) presented the electricity consumption-income hypothesis for 6 member countries of G.C.C.(Bahrain, Kuwait, Oman, K.S.A. and U.A.E.) The paper uses the bounds test procedure suggested by Pesaran et al (2001) to test for a long –run relationship . The non-causality approach suggested by Toda and Yamamto(1995) to test causality. The data used in this study are yearly and range between 1980-2003. This paper finds evidence of a long-run relationship between electricity consumption and economic growth for all G.C.C. It also finds support for the efficacy of energy conservation measures in 5 of the 6 countries except Qatar.

An empirical time series analysis of energy consumption in Cyprus Zachariadis (2006) computed the first econometric analysis of energy consumption using annual data from 1960-2004.The dynamic interaction between the energy form and appropriate income , price variables through time series analysis. The time series analysis techniques such as unit root test and co-integration test, vector error correction models, Granger causality tests and impulse response functions. Autoregressive distributed lag models were also employed. Results from co-integrated tests and V.E.C. models show that a long- run equilibrium relationship between energy, income and price exists for most energy uses. Granger causality test indicate that electricity prices can be treated as purely exogeneous. Granger cause electricity use and there is bidirectional causality between most energy forms or economic activity.

In a discussion paper, Zachariadis (2006) provides an overview of methodological and theoretical aspects and discuss the appropriateness of drawing policy conclusions on the exploration of causal relationship between energy and economy .Various methodological issues arising from the number and type of variables or the test methods used are outlined. The paper underlines the importance of using multivariate models which accommodate several mechanisms and causality channels and provide a better representation of real world interaction between energy use and economic growth.

Chang (2007) described a set of explicit functional relationship that link energy and the economy using data for 16 O.E.C.D. countries from 1980-2001. The methodology used are period-by –period regression, pooled regression, cross-sectional tests. Results shows that energy price is a macro economic instrument that offers tradeoff between energy efficiency and economic well being.

A wavelet analysis Cifter and Ozun (2007) proposed it as a semi-parametric model for detecting multi-scale causality between electricity consumption and growth in emerging economies from 1968 to 2002 found that in the short run there is feedback relationship between G.N.P. and energy consumption. In the long run G.N.P. leads to energy consumption. The magnitude of the wavelet correlation changes based on time –scales for G.N.P. and energy consumption and indicate that V.A. and E.C. are fundamentally different in long run.

On the basis of his study Henderson (2007) found structural change in the Koreas electricity consumption during 1991-2007 period. The vector auto regression and vector error correction models are used to estimate the relationship between electricity consumption by sector and economic activity .The results show that there exists a strong relationship between the electricity consumption and industrial production over our sample period.

Erbaykal(2008) investigated energy consumption ,economic growth relation disaggregates using oil and electricity consumption for 1970-2003 period in Turkey. Bounds test approach by Pesaran et al (2001) for co-integration was employed. Co-integration results show that in short run both oil consumption and electricity consumption has positive and statistically significant effect on economic growth. However in long run oil consumption has positive effect on economic growth while electricity consumption has negative effect. In long run the electricity and oil consumption coefficients are statistically insignificant. We can infer both electricity and oil has short run effect on economic growth.

The paper examined the stationary of energy consumption per capita for a panel of 13 pacific islands countries over the period 1980-2005. Mishra ,Sharma and Smyth(2008) used the panel stationary test developed by Carrion-i-Silvestre et al (2005). The conclusion from the study indicates that energy consumption per capita in approximately 60% of countries is stationary and that energy consumption per capita for the panel as a whole is stationary. The study offered several suggestions for modeling energy consumption and policy making in the pacific islands.

Applied panel data techniques Nondo and Kahsai (2009) to investigate the long -run relationship between energy consumption and GDP for a panel of 19 African countries based on annual data for the period 1980-2005. The results show that GDP and energy consumption move together in the long run. The paper also estimated long-run relationship and test for causality using panel-based error correction model. The results indicate that long-run and short run causality is unidirectional , running from energy consumption to GDP.

A panel co-integration technique examined the causal relationship for12AsiandevelopingBangladesh,India,Indonesia,Malaysia,Myanmar,Nepal,Pakistan,China,Philippines,SriLanka,Thailand,Vietnam and data taken for the purpose of analysis are annual time series data for the period 1971-2005.The results show evidence of bi-directional causality between electricity consumption and GDP in this panel Asian group .The relationship described that limiting energy use would hamper economic growth in these countries.

2.3 Non-Existence of Causal Relationship

The relationship between electricity consumption and economic growth in case of industries of Iran. Ghaderi , et al (2006) examined in which Granger test devised in the E-views software package used for the period 1980-2001.The estimation results inferred that causal relationship does not exist between the value added and electricity consumption .So supportive policies to increase electricity consumption is inefficient in economic growth in Iran.

Jobert and Karanfil (2007) provides in their paper a brief summary of economic development .It analyze in detail energy consumption in Turkey for 1960- 2003 period using Granger causality , unit root test- D.F., Phillips-Perron, Johansen , vector auto regression representation with two non-stationary and un co-integrated variables. The results find no evidence of long run relationship in which energy and income appear to be neutral with respect to each other. The analysis also shows strong evidence of instantaneous causality between these variables.

With a view to examine ,the long- run sustainability between real G.D.P. and disaggregate energy consumption. Hu and Lin used A.D.F. and K.P.S.S. tests, co-integration test proposed by Hansen and Seo(2002) , V.A.R. and E.C.M. All the data used in this study are quarterly observation of variables .The period range from 1982:1-2006:3. The results of this study confirm that the null hypothesis of linear co-integration between G.D.P. and disaggregate energy consumption would be rejected in favour of a two-regime threshold co-integration model.

To explore the relationship between energy use and economic growth Zachariadis made an attempt to explore the relationship between energy use and economic growth for five countries .These countries are Germany ,Japan ,France ,U.K. and U.S. in which different methods based on a vector error correction model. A test based on an autoregressive distributed lag model.The Toda-Yamamoto test cover the period 1960-2004.Results of the three methods were in agreement for the U.S. but inferred large disparity for all other countries.In case of U.S. neutrality relationship between total energy and G.D.P. exists.

In Malaysia Yusof and Abdul applies the co-integration theory to examine the causal relationship between electricity consumption and economic growth during 1980-2006.The result stated that there exists a co-integration relationship between the income growth and economic impact of electricity consumption .The results described that economic growth has no causality effect on total electricity consumption and vice-versa. The implications of the study suggest that an energy conservation policy regarding electricity consumption would not lead to any adverse side-effects on economic growth.

2.4 Existence of Unidirectional Causality

The multivariate co-integration analysis, Stern(1998) analyzed the causal relationship of GDP and energy use in the USA in the post -war period. Which shows that energy is significant in explaining GDP .Further there exists co-integration relationship in GDP ,capital , labour and energy. These results support the previous results of Stern (1993) regarding Granger causality between energy and GDP.

On the basis of his study, Aqueel and Butt (2001) looked at the causal relationship in Pakistan .The study used co-integration and Hsiao version of Granger causality for the period 1955 to 1996. The results inferred that economic growth causes total energy consumption. Further, investigation indicates that electricity consumption leads to economic growth without feedback. It causes employment directly.

In another study, Morimoto and Hope (2001) examined the impact of electricity supply on economic growth in Sri Lanka using Granger causality. They found that electricity supply have a significant impact on a change in real G.D.P. taken1984 to1997 period for their study.

In an article ,Stern (2003) presented the relationship between energy and economic growth. In which the principal finding is that energy used per unit of economic output has declined due to shift from direct use of fossil fuels to higher quality fuels especially electricity. The results strengthen Sterns previous conclusions that energy is a limiting factor in economic growth. This article provides picture that there is a strong link between energy Use , economic growth and pollution.

Altinay and Karagol (2005) in Turkey for the period 1950-2000 in which different methodology employed to test :- Granger non-causality,Dolado-Lutkepohl test using the V.A.R. in levels standard Granger causality test using the detrended data. Tests have yielded a strong evidence for unidirectional causality running from the electricity consumption to income. The supply of electricity is vitally important to meet the growing electricity consumption in Turkey.

An attempt has been made to unfold the linkage between energy consumption and GDP used co-integration analysis in the research paper by Lise and Mont Fort (2005) for Turkey with annual data over the period 1970-2003.The results indicate unidirectional causality running from GDP to energy consumption .It implies energy saving would not harm economic growth.

The research paper presented by Ho and Siu in 2006 report the following findings for the period(1966-2002) in which a one-way causal exists from electricity consumption to real G.D.P. A significant adjustment process occurs when equilibrium is interrupted. There exists possible structural change in the relationship between electricity consumption and economic activities in (1990) in Hong-Kong. The method used are unit root test, co-integration and Granger causality(V.E.C.M. Model).

In a study ,Jiahai ,Jing and et al (2006) used the co-integration theory to examine the causal relationship between electricity consumption and real GDP during 1978-2004.The results indicate that real GDP and electricity consumption for china are co-integrated and there exist unidirectional Granger causality running from electricity consumption to real GDP but not vice-versa.

Another Paper ,computed both linear and non linear causality between electricity consumption and economic growth in Spain(2007) . The Ciarreta, A. and Zarrage ,A. taken the period from (1971-2005) in which they found unidirectional linear causality running from GDP to electricity consumption. They find no evidence of non linear Granger causality between the series in either direction. The Toda and Yamamoto and Dolado and Lutkepohl and linear Granger causality test in a V.A.R. for the differenced series.

Abosedra,Dah and Ghosh(2008) studied the relationship between electricity consumption and economic growth for Lebanon ,using monthly data covering the period 1995 to 2005.Empirical results of the study confirm the absence of a long-term equilibrium relationship whereas the existence of unidirectional causality running from electricity consumption to economic growth when examined in a bivariate vector autoregression framework with change in temperature and relative humidity as exogenous variables.

In a study, Chebbi and Boujelbene (2008) investigated the co-integration and causality link between energy consumption and agricultural and non-agricultural outputs. In this A.D.F and KPSS(KwiatKowsKiet al 1992), Johansen, V.E.C.M. methods are used for 1971-2003 period in Tunisia. Empirical results suggest that there is only unidirectional causality running from agricultural and non- agricultural sectors to energy consumption. This unidirectional causality signifies a less energy dependent economy.

Chombo(2008) computed the direction and dynamics of the interrelationship between electricity infrastructure and real GDP in the Mexican economy during 1937-2007.To test the direction and dynamics of such causality ,a battery of parametric tests and non-parametric methodologies are applied.To test ,causality the paper used Granger causality based on an error correction model ,as well as on the methodology proposed by Dolado-Lutkepohl (1996) of an unrestricted VAR model .The results suggest that economic growth in Mexico preceded the expansion of the electricity infrastructure in most of the sample, except during short periods ,particularly in recent years ,when there had been a switch in the lead-lag structure.

In Nepal ,Dhungel(2008) used co-integration and Granger causality test to determine the relationship between energy consumption and economic growth during 1980-2004.A unidirectional causality running from per capita electricity consumption is found .This suggests that per capita energy consumption is the stimulating input for enhancing economic growth in Nepal.

Omotor (2008) studied the causal relationship between energy consumption disaggregated into coal ,electricity and oil consumption and economic growth in Nigeria. The annual data from 1970-2005 described the unidirectional relationship exist in which energy consumption leads to economic growth. The results derived from the application of Hsiaos Granger causality version. The findings suggest that energy growth policies should be adopted and enhanced to amplify the economic growth of Nigeria.

Thure Traber (2008) studied relationship between electricity and economic growth using Granger causality. Electricity demand is likely to increase as long as we experience economic growth.

Bohm mentioned the bivariate relationship between energy and GDP for the 15 biggest global consumers between 1978 and 2005. The research paper used panel co-integration analysis and results show a very heterogeneous picture.Energy saving policies could be harmful to countries like Belgium,Cyprus,the Czech Republic,Denmark,Greece,Luxemburg,Malta and Slovakia.European Union is very energy dependent as a whole.Unidirectional causality from economic growth to energy use can be established for Canada,Japan,Saudia Arabia and South Africa. The neutrality hypothesis hold for Korea .

An attempt made by Rafiq to analyze the relationship in six developing countries these are (China,India,Indonesia,Malaysia,Philippines,Thailand) in which multivariate co-integration analysis used.The paper used annual data from 1965-2006 for all selected countries. The empirical results show a uni-directional causality running from energy consumption to income for China for both short and long run. In India the results are opposite i.e. short -run unidirectional causality from output to energy consumption is found .However there is no evidence of long-run causality between the variables .In Philippines there exists a long-run uni-directional causality from energy consumption to output. While for Thailand bi-directional causality exists between energy consumption and income in the short run and for Malaysia and Indonesia the results revealed neutrality of energy in both short and long run. These findings have important policy implications for the concerned countries. The results indicate that India may initiate energy conservation measures ,China and Thailand may adopt a balanced combination of alternative policies.

In a developing country like India ,Narayanan and Tupe measured the relationship between economic growth and total energy consumption during 1971-2004 period used Johansen test , vector error correction model and dynamic error correction model. The results shows that population causes energy consumption and energy consumed for domestic purpose promotes economic growth in India .Bilateral causality between capital formation and energy consumption and unidirectional relationship between electricity tariff and energy consumption is observed.

Fatai, Oxley and Scrimgeour examined the relationship between energy consumption and GDP in New Zealand and Australia .The data base comprise annual data 1960-99 for total energy consumption. All data were transformed to natural logarithms .In this application of the standard Granger causality method and Toda and Yamamoto(1995) approach were used. Unidirectional relationship found from real GDP to aggregate final energy consumption in New Zealand and Australia .In case of four Asian countries considered India, Indonesia ,Thailand and Philippines unidirectional link from energy to GDP was established for India and Indonesia. Also results in this study found bidirectional link for Thailand and Philippines.

2.5 Energy Intensity Studies

Currie(1996) measured the relationship between energy consumption and GDP (gross domestic product) in Fiji during1981-1990. During this period energy intensity declined by 1.9Tj per F $m of GDP. The petroleum and electricity intensities indicate that the economy become less dependent on imported petroleum products for its energy requirements and more dependent on electricity for energy consumption during 1980’s.

Reddy(1998) examined the pattern of energy consumption and growth in Fiji. The work of Sheerin (1992) used and decomposition of the components of the commercial sector energy demand have been done. The period taken are different for different fuel types for the purpose of study. The results revealed that Fijis energy dependency over the last two decades and if efforts are not made either to increase conservation and efficiency of energy use it will impose significant impact on import bill.

Vaden(2002) employed a unique data set of approximately 2500 large and medium enterprises in China for the year 1997-1999 to identify the factors driving the fall in total energy use and energy intensity. The results indicate that energy prices and research and development activities are important contributors to the decline in firm- level energy intensity according to Divisia calculations. Further the paper also found that changes in the share of output by region ,ownership type and industry contribute to decline in measured energy intensity.

An empirical investigation presented on energy intensity evolution for both developing and developed countries in which Martin and Cerda (2003) test the hypothesis of a de-linking between economic growth and energy use. The paper applied phase-diagrams in which the intensity of use of the year t-1 are represented and check the validity of continuous relationship or possibility of the existence of a step-wise behavior, which can be seen at lower time-scale ,similar to the idea of "punctuated equilibrium" for the evolution of systems at larger time- scales. The data set covered the time period from 1960 and 1999 for OECD countries and from 1971-1999 for non-OECD countries .The variable energy intensity measured as total primary energy supply(TPES) per thousand 1995 $ GDP measured in purchasing power parity (PPP)i.e.TPES/GDP.In this countries with different income groups are taken. The results contradict the idea of the existence of a hypothetical environmental Kuznet curve for energy intensity

.The three cases of study more or less follow a pattern compatible with EKC i.e. UK is decreasing its intensity and both Turkey and Brazil are increasing its energy intensity. Low income countries like India and South Africa should not lower their energy intensity while Spain would decrease its energy intensity but this is not the case .So the evolution of energy intensity cannot be explained just by the process of economic growth rather various internal causes in each country explain behavior.

Study on Asia energy security issues, in which special emphasis on China and India. According to this study Gupta and Jaswal (2006) India witnessed a decline in its energy intensity between 1990 and 2003 ,reducing at the rate of 1.1% on an average annual basis due to relatively higher growth in the service sector and better energy management in the industrial sector. However on the other hand China is the highly energy intensive country at the same time the Chinese economy has undergone a significant decline in energy intensity ,falling at an average of 5.5% primarily attributed to multifaceted energy conservation efforts in comparison with India `s decline of 1.1%.

Applying the IEU technique in his study, Chima(2007) computed the intensity of energy use in USA covered the period 1949-2003.In this paper to understand the nature of interaction between energy consumption and GDP and to analyze intensity of energy use (IEU) (Amount of energy required to produce a unit of income) methods are used. The results show that energy consumption is very sensitive to energy prices ,which in turn impacts the GDP and the IEU has declined in the USA for the covered in study .The Kuznets environmental curve used in developing a model which depict downward sloping segment for the IEU. The result indicated that energy conservation policies are desirable.

In India ,Ray and Reddy (2007) calculated the energy intensity in the manufacturing sector during 1992-2002 .The study indicates that recent

decline in energy intensity in the manufacturing sector was mainly due to fuel substitution away from coal in some of the sectors ,especially cement.
So decomposition analysis found that most of the intensity reductions are driven purely by structural effect rather than energy intensity.

The estimated trends for China computed in the study of Sheehan and Sun (2007) which shows rapid growth in energy intensive industries after entry to WTO in 2001. China has reverted to the normal developing economy case of an elasticity of over one, based on a simple projection model ,conclude that China's energy use and carbon dioxide emissions from fuel combustion are likely to grow by more than 6% p.a. over 2005-30. The study suggested a sustained policy process involving use of the full range of instruments could reduce China energy use and carbon dioxide emission by 35-40% by 2030.The study found low elasticity of energy use with respect to GDP over 1980-2001,conclude that low elasticity was primarily due to technological upgrading and energy conservation ,stimulated by energy rationing in a command economy with limited energy supplies and high initial usage levels ,but increasing relative price become important during 1990's.

The above described studies clearly state that a relationship exists between electricity consumption and economic growth. But there are no clear trends in the literature , depending on the methodology used, country and time period studied so different results are available . In case of energy intensity studies result shows differences in intensities of developed and developing countries . From the above review, it is clear that there has been no empirical study to look into the relationship between electricity supply and economic growth in India. Therefore in this study attempt has been made to unravel the existing relationship between the above two variables.

In the next chapter, the objectives of the study are explained. Further, the different methods of our study have been discussed in detail to achieve the stipulated set of objectives.

Chapter 3 : OBJECTIVES AND RESEARCH METHODOLOGY

3.0 Introduction

In this chapter , we have stated our objectives of study and discussed in detail about methodology specifications which are used to achieve objectives of our study. The major methods used in this study are such as stationary tests, Granger causality and panel regression model.

3.1 Objectives

In the last chapter, we have thoroughly reviewed the existing literature . It is evident that there has been no empirical study conducted to unravel the causal relationship between electricity supply and economic growth in India . Therefore in this study , an attempt has been made to study the above mentioned relationship to formulate a sustainable policy relating to electricity use in India. In this regard we have stipulated the following objectives for our study .These are as follows:

- ✓ To investigate the causal relationship between electricity production and G.D.P.
- ✓ To examine the trend and pattern of electricity supply across different states.
- ✓ To unravel the relevance of Kuznet Curve in case of electricity and growth.

3.2 Data and Variable Description

In order to achieve the above stated objectives the following research methods have been adopted . The entire methodology of study has been been divided into two sections. These are as follows:

- ❖ Stationarity test and Engel Granger Causality test .
- ❖ Panel Regression Analysis.

To estimate the relationship between electricity consumption and GDP for India yearly data on electricity consumption and GDP from 1960 to 2006.The data were collected from the centre for monitoring Indian economy, economic survey and Reserve bank of India in printed as well as online database. Electricity consumption was measured in kilowatt per hour, it consists of both utility and non-utility i.e. gross electricity consumption are taken into account . GDP is measured at constant price and denominated in millions.

3.3 Stationarity Test and Causality Test

According to Engle and Granger (1987), a linear combination of two or more non stationary series (with the same order of integration) may be stationary. If such as stationary linear combination exist, the series are considered to be co integrated and long run equilibrium relationships exist. A series is said to be non stationary if it has non constant mean, variance, and auto covariance over time. If a non stationary series has to be differenced d times to become stationary, then it said to be integrated of order d i.e. I(d).

When both series are integrated of the same order, we can proceed to examine for the presence of co -integration. The Johansen Maximum like hood procedures are used for the test (Johansen and Juselius,1990).Traditionally to test for the causal relationship between two variables, the standard Granger (1969) test had been employed in the relevant literature.

Granger Causality :

Let's start by defining Granger's concept of causality.
'Granger -Causality ' implies causality in the prediction (forecast) sense rather than in a structural sense. It starts with the premise that ' the future cannot cause the past '; if event X occurs after event Y, then X cannot cause Y .X is said

to be Granger cause Y if Y can be predicted with greater accuracy by using past values of X .Consider the following equation:

$$\mathbf{Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \beta_1 X_{t-1} + \beta_2 X_{t-2} + u_t}$$

If $\beta_1 = \beta_2 = 0$, X does not Granger cause Y. If, on the other hand, any of the β coefficients is non-zero, the X does Granger cause Y. The null hypothesis that $\beta_1 = \beta_2 = 0$ can be tested by using the standard F-test of joint significance. Note that it has been taken two period lags in the above equation. In practice, the choice of the lag is arbitrary. Varying the lag length may lead to different result. As a practical guide, one can include as many as are necessary to ensure non-auto correlated residuals.

To estimate our Granger causality, we have made stationary test of the variables concerned by using Augmented Dickey-Fuller test. If the variables don't have unit root problem then Granger can be estimated.ty method found mixed results about the causality between electricity and growth. In our paper the test of stationarity of the time series of the above mentioned variables are systematically done in order to rule out the likely spurious results.

In time series analysis to check whether or not the variables under consideration are stationary. Tests for stationarity are well known in the literature as Augmented Dicker Fuller(ADF) test to test the existence of unit roots in a time series. The estimating equation for unit root tests for a series Yt for example, can be written as the Augmented Dickey Fuller (ADF) and Phillips -Perron (PP) tests are used for this purpose.

The ADF regression equations are

$$\Delta X_t = \alpha_1 + (p-1)X_{t-1} + \sum_{i=1}^{m} \gamma_j \Delta X_{t-j} + u_t \qquad \text{--------------- (1)}$$

Where X_t is a variable, u_t is the white noise, Δ is difference operator and m indicates the number of differenced terms used. The additional lagged terms include ensuring the errors are uncorrelated. It is the presence of these differenced terms that distinguishes the augmented Dickey Fuller test from the ordinary Fuller test. However the ADF test are unable to discriminate well between non-stationary series with a high degree of auto regression.

The ADF and PP tests are known to have low power against the alternative hypothesis that the series is stationary (or TS) with a large autoregressive root. (See, e.g., DeJong, et al, J. of Econometrics, 1992.) In consequence the Phillips – Perron (PP) test (Phillips and Perron, 1988) is applied. The PP test has an advantage over the ADF test as it gives robust estimates when the series has spurious correlation and time dependent heteroscedasticity. . If the two variables are not co-integrated then the best approach is to find out the causality between variables by using standard Granger test, which only establishes short run relationship. In practice, however, a number of econometrics packages can be used to perform these tests which also give the critical values of the ADF statistic.

3.4 Panel Data Regression Model

The use of panel data models is a powerful research instrument, because it combines the cross-sectional data with time-series data, and provides results that could not be estimated and studied if we use only time-series or cross-section data In particular, in this method the same cross-sectional units (e.g. individuals, families, firms, cities, states) are observed over time. The panel data has advantages over both cross-section or time series analysis which are as follows:

- ❖ In panel data there is bound to be heterogeneity in different units like firms, state and country .This technique take such heterogeneity explicitly into account.

- Panel data give more informative data , more viability ,more efficiency and more degree of freedom by combining time series of cross- section observations.
- This method can minimize the bias that might result if we aggregate individuals or firms into broad aggregates.
- The panel data increase the sample size considerably.
- Panel data enable us to study more complicated behavioral model.
- Panel data are better suited to study the dynamics of change.

In case of panel if the cross-sectional unit has the same number of time series observations then panel data is balanced panel in this study balanced panel is used. The data set covers the period from 1990-2004 in order to found the relationship between electricity consumption and economic growth in which 21 cross -section are used while in case of relationship between energy intensity and per capita income 20 cross- section are used .So in this study we have 15 year time period we have 315 and 300 observations respectively .In panel there are two prominent types of estimation are fixed effect model (FEM) and random effect model (REM).

3.5 Model Specification

In random effect model it is assumed that the intercept of an individual unit is a random drawing from a much larger population with a constant mean value. This method is economical in degree of freedom, as we do not have to estimate N cross-sectional intercepts. In this method we have to estimate the mean value and its variance .Although fixed effect or LSDV modeling straight forward to apply can be expensive in terms of degree of freedom if we have several cross -sectional units. So “If the dummy variables do in fact represent a lack of knowledge about the (true) model, why not express this ignorance through the disturbance term

u_{it}?", This is precisely the approach suggested by the proponents of random effect model over fixed effect model .

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + u_{it} \quad \text{-------------------(3.1)}$$

$$\text{if } \beta_{1i} = \beta_1 + \varepsilon_i \quad \text{i=1,2, ------,N------(3.2)}$$

$$\varepsilon_i - \text{random error term with zero mean and var of } \sigma_\varepsilon^2$$

$$\text{then}$$

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + \varepsilon_i + u_{it} \quad \text{or}$$

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + w_{it} \quad \text{------------------- (3.3)}$$

The basic idea is to start with (3.1) in this equation β_{li} as random variable with a mean value of β_l (no subscript i here) and in equation 3.2 the intercept value for an individual state can be expressed .The individual differences in the intercept values of each state are reflected in the error term ε_i .
Substituting (3.2) into (3.1) we obtain (3.3) where

$$w_{it} = \varepsilon_i + u_{it} \quad \text{------------------------(3.4)}$$

The composite error term w_{it} consists of two components
ε_i which is the cross -section or error component.
u_{it} which is the combined time-series and cross-section error component.
The usual assumptions made by random effect model are that

$$\varepsilon_i \sim N(0,\sigma^2_\varepsilon)$$

$$u_{it} \sim N(0, \sigma^2_u) \quad \text{----------------------(3.5)}$$

$$E(\varepsilon_i u_{it})=0 \quad E(\varepsilon_i \varepsilon_j)=0 \quad (i \neq j)$$

$$E(u_{it} u_{is})=E(u_{it} u_{jt}) =E(u_{it} u_{js})=0 \quad (i \neq j \; ; \; t \neq s).$$

The individual error component are not correlated with each other and are not auto correlated across both cross-section and time series units. For estimation purpose we have taken the variables in log linear form.

As a result of the assumptions stated in (3.5) it follows that

$$E(w_{it})=0 \quad \text{------------(3.6)}$$

$$\text{var}(w_{it})= \sigma^2_{\varepsilon} + \sigma^2_{u} \quad \text{---------------(3.7)}$$

Equation (3.7) shows that the error term w_{it} is homoscedastic . However the error terms of a given cross-sectional unit at two different points in time are correlated. The correlation coefficient , corr (w_{it}, w_{is}) = $\sigma^2_{\varepsilon} / \sigma^2_{\varepsilon} + \sigma^2_{u}$.

There are two special features of the correlation coefficient first ,for any given cross-sectional unit, the value of the correlation between error terms at two different times remains the same no matter how far the two time periods second feature the correlation structure remains the same for all cross- sectional units . The important implication of this feature is that if we do not take this correlation structure into account and estimate by OLS ,the resulting estimators will be inefficient . The most appropriate method is the method of generalized least squares (GLS) .

3.6 Description of Data and Variables

In this study, we have taken gross domestic product (GDP) and electricity supply to calculate causal relationship between electricity supply and economic growth. For this we have used secondary data collection method, taken the data from the economic survey and centre of monitoring Indian economy.

In panel estimation, we have taken net state domestic product (NSDP) for different states of India, the data was collected from handbook of statistics on Indian economy, Reserve Bank of India (RBI). Data on different states electricity generation have been taken from centre of monitoring Indian economy. In this study, the electricity generation data has been taken as dependent variable on NSDP.

With a view to find out the causal relationship between electricity supply and growth, the above mentioned regression techniques have been estimated by using both time series and panel data set series for Indian economy . The estimated results have been analyzed and discussed in the next chapter.

Chapter 4: RESULTS AND DISCUSSIONS

4.0 Introduction

Owing to our stipulated objectives we have estimated different regression models to find out and establish a relationship between electricity supply and economic growth in India .Therefore the entire estimation of different regression models have been carried out by E –Views statistical package. The estimation of our models has been made in three steps. These are as follows :

- Stationarity and causality Test .
- Panel Regression Model.

4.1 Stationary and Causality Results

Before carrying out causality test , we have tried to find out whether GDP and electricity supply have unit root problem .To carry out causality test it is prerequisite to know that the variables are free from unit root problem. To test stationarity of the two variables two model such as ADF and PP have been estimated.

Table 4.1 Results of the ADF and PP unit root tests

Variable	Augmented-Dickey Fuller (ADF)		Phillips- Perron (PP)	
	Level	First-Difference	Level	First-Difference
GDP	5.466546	1.429690	12.82172	0.394277
ELEC	4.482458	-0.151530	10.06908	-0.121736

Note: All values are significant at 1% level .

From the above table, it is clear that these two time series variable have no unit root problem .Now, we can estimate Granger -Engel causality model .

Table 4.2 Estimated Granger-Engel Causality Model

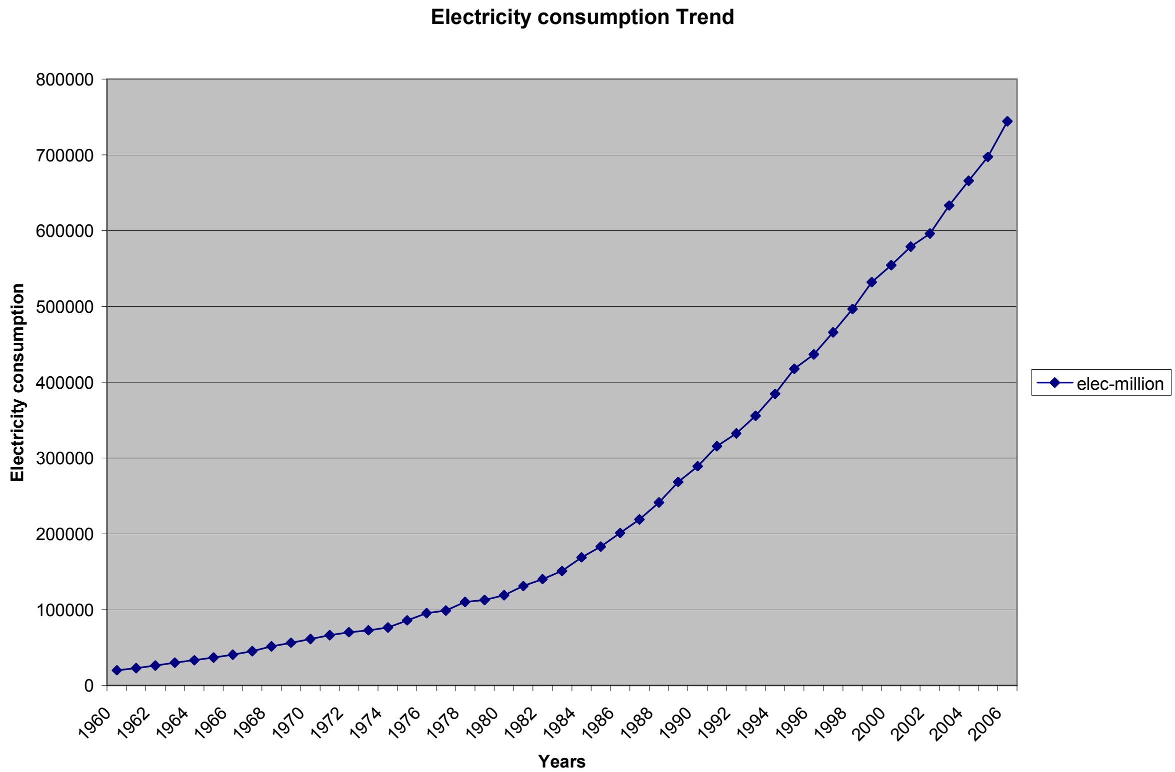
Null hypothesis	F-statistic	p-value	Decision
GDP doesn’t Granger cause ELEC	0.10604(1)	0.74628(1)	Do not Reject
ELEC doesn’t Granger cause GDP	6.59454(1)	0.01379(1)	Reject*

*Note: * indicates the rejection of the null hypothesis at 5% significant level. Figures in the parentheses are number of lags.*

Perusal of the above table reveals that null hypothesis is rejected and alternative hypothesis is accepted .The rejection of null hypothesis indicates that electricity does not Granger cause GDP .So alternative hypothesis that electricity Granger cause GDP holds true in this study. It is apparent from the above that there is evidence of a unidirectional Granger causality running from electricity consumption to GDP ,whereas there is no evidence of Granger causality running in other direction.

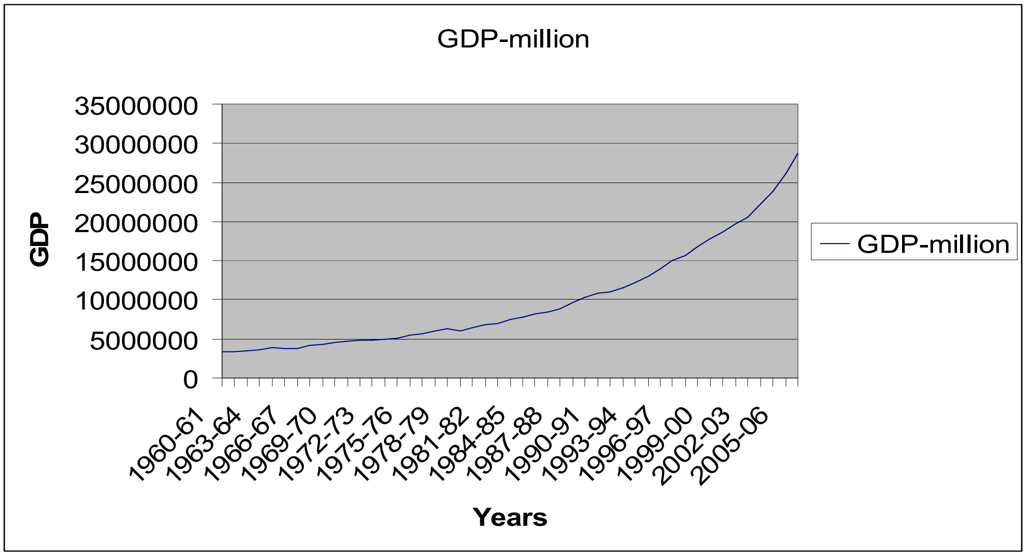
Our results indicate that use of electricity is growing fast and it’s faster than the consumption of primary energy .Electricity emerged as a high quality energy carrier and its capability is to serve practically any energy service whether light, appliances, motion, electronics and heat from a single system. Technology innovation in electricity use is a cornerstone of global economic progress. Extremely reliable delivery of high quality “digital-grade” power is needed by a growing number of critical end-uses ,India one of fastest growing economy used approximately 70% of this form of energy to accelerate it` s economic growth.

Fig 4.1 Electricity Consumption Trend in India (1960-2006)



The above graph shows that electricity consumption in India increases over the years ,during this period electricity reached at various such places where it is not available earlier, so it generates further demand .Over the years there is increase in economic activities as well as expansion of information technology sector in the economy , which accelerate the demand of electricity manifold.

Fig 4.2 Economic Growth in India (1960-2006)



The above graph shows the trend of GDP from 1960-61 to 2005-06 in India .It shows that income of the country has upward trend and indicates that it has increased over the years . In India , the major sector which helps in economic growth is service sector in which electricity is the basic input. So the above graph supports the rising trend over the period.

4.2 Results of Panel Regression between Electricity Supply and Growth

The estimated results for electricity supply are reported in Table 4.3. There is a positive relationship which has been found out between electricity generation and economic growth the coefficient 0.316995 is enough to support the relationship. Also the co-efficient R^2 is 0.97 implies that 97% of the variations in the dependent variable i.e., energy will be explained i.e. due to variations in the independent variable i.e. net state domestic product (NSDP).

Table 4.3 Panel regression estimates for Electricity

Model	$\ln E_{it} = \beta_1 + \beta_2 \ln NDP_{2it} + w_{it}$
Method	**Random Effects (GLS)**
Dependent Variable	**LnE**
LNNDP *	0.316995(9.234627)
Andhra Pradesh	1.377081
Arunachal Pradesh	-3.432888
Assam	-1.346413
Bihar	-0.954288
Delhi	-0.634211
Gujarat	1.544256
Haryana	0.496644
Himachal Pradesh	-0.784738
Jammu & Kashmir	-1.433166
Karnataka	1.057482
Kerala	0.186863
Madhya Pradesh	1.061031
Maharashtra	1.853379
Meghalaya	-1.328746
Orissa	0.400347
Punjab	1.271533
Rajasthan	0.718605
Sikkim	-3.252699
Tamil nadu	1.231927
Uttar Pradesh	1.105728
WestBengal	0.862271
R^2	0.978449
DW statistic	0.409744
Observations	315

Note: *Values in parentheses are the t-statistics. The reported t-statistics are White-heteroscedasticity consistent t-statistics. They are robust to heteroscedasticity within each cross-section, but do not account for the possibility of contemporaneous correlation across cross-sections. The random effects are reported for each cross-section. * indicates significant at 1% level.*

The random effects for each of the states that are reported in the results table demonstrates that some states having positive relationship towards economic activities and electricity generation ,results indicate that as economic activities in these states increases electricity consumption also increases and have large random effects for example Andhra Pradesh, Gujarat ,Haryana, Karnataka ,Kerala , Madhya Pradesh ,Maharashtra ,Orissa, Punjab ,Rajasthan, Tamil nadu ,Uttar Pradesh and West Bengal .The states which shows negative relationship are backward (laggard) states like Arunachal Pradesh , Assam ,Bihar , Jammu and Kashmir , Megahalaya and Sikkim .

However, there exists two exceptions are there i.e. ,Delhi and Himachal Pradesh .In these two major states there exists negative relationship between electricity and economic growth. The presence of negative relationship can be possible due to the following reasons .

Delhi: In 1996 the apex court ordered the closure of major polluting and hazardous industries from Delhi and their relocation in the neighbouring states more than 1300 major polluting industries were closed down in Delhi .Industries numbering more than 90,000 operating in non-performing areas in Delhi had also been asked to close down their operations and shift them to conforming areas.
Also the Delhi Vidhyut Board own generation installed capacity is 664 MW but availability is only around 400 MW. More than 80% of Delhi's power needs are met by purchases from NTPC and other sources. The first Gas Turbine Unit of 104MW capacity of Pragati Power Project (PPP) has started functioning from 20.2.2002. The project would commence running to its full capacity of 330 MW by the end of November, 2002.

Himachal Pradesh : H.P. has a vast hydel potential , out of the total hydel potential only 3942.07 MW (mega watt) has been harnessed so far, out of which only 326.80 MW is under the control of H.P. as bulk of the potential has been exploited by the central government and other agencies .In case of State domestic product H.P. is predominantly dependent upon agriculture and in the absence of strong industrial base , any fluctuations in the agricultural and horticultural production cause significant change in economic growth. During

2001-02 about 22% of state income has been contributed by agricultural sector alone (Ecosurvey,2003).

In case of India the results revealed that economic growth has been intrinsically coupled to electricity use. The major sector which contributes to higher gross domestic product and as a result higher economic growth of the country is service sector or information technology sector for which the electricity is the basic input , as this sector is growing rapidly it is necessary to ensure reliable power supply for the sustained industrial growth and other developments .But in case of electricity supply there exists frequent power cuts i.e. uninterrupted supply of power is not very much evident. In different part of country the electricity generation shortage occur due to different reasons. In north-east states , there exists vast potential of hydel power generation but it suffered because of poor hydel storage and in other parts of nation the generation comes to halt due to various vagaries in coal quality and supply which in turn impede economic growth of the country.

4.3 Electricity Intensity and NSDP

The concept of the intensity of energy use (IEU) predicts that the amount of energy consumed in an economy depends on two relationships. The first that the intensity of energy use, or energy intensity ─ defined as the amount of energy, measured in physical units, that the economy consumes per unit of net state domestic product (NSDP), measured in constant terms is a function of its level of economic development as indicated by income per capita (NSDP/P), where P is the population. In order to examined the electricity -NSDP relationship in India intensity of energy use method are used.

The estimated results which describe the relationship between electricity intensity and per capita income are reported in table 4.4.

Table 4.4 Panel Regression Estimates for Electricity Intensity

Model	$\ln EI_{it} = \beta_1 + \beta_2 \ln PCI_{2it} + w_{it}$
Method	**Random Effects (GLS)**
Dependent Variable	**LnEI**
LNPCI *	-0.491904 (-21.22234)
Andhra Pradesh	0.530237
Arunachal Pradesh	-1.364187
Assam	-1.408862
Bihar	-1.610171
Delhi	-0.423799
Gujarat	0.956242
Haryana	0.490366
Himachal Pradesh	0.063314
Jammu & Kashmir	-0.825956
Karnataka	0.459210
Kerala	-0.124871
Madhya Pradesh	0.412128
Maharashtra	0.799067
Meghalaya	0.241123
Orissa	0.145017
Punjab	1.139526
Rajasthan	0.162554
Tamil nadu	0.487715
Uttar Pradesh	-0.142709
WestBengal	0.014058
R^2	0.870744
DW statistic	0.678279
Observations	300

Note: *Values in parentheses are the t-statistics. The reported t-statistics are White-heteroscedasticity consistent t-statistics. They are robust to heteroscedasticity within each cross-section, but do not account for the possibility of contemporaneous correlation across cross-sections. The random effects are reported for each cross-section. * indicates significant at 1% level.*

The results indicate lower intensity of electricity use in India .In this study random effects of different states are reported. The states which shows negative results are backward states like Arunachal Pradesh , Assam ,Bihar and Jammu and Kashmir in these states lack of development activities leads to less consumption of electricity so intensity is lower in these states not due to efficient use of electricity but due to lack of availability and demand. In case of Uttar Pradesh which is fourth largest state in the country with a population of nearly 166 million ,total 97,122 villages out of which 18,042 are still un - electrified, leaving almost 80% of the population in the dark .So intensity is lower due to non-availability of electricity to large section of population.

Delhi and Kerala also shows lower electricity intensity in case of Delhi the initiatives have been taken to lower electricity intensity such as Delhi Metro Rail Corporation is the biggest consumer of electricity in the state of Delhi. Its traction system is completely electricity driven. In addition to traction, electricity is required for signaling, communication, Air-conditioning and lighting etc.

- **Energy Efficient Air-Conditioning System**

The air conditioning of the underground stations is controlled through Building Management System (BMS) having the features of running the system in automatic logic control, open/closed loop, enthalpy and timetable control to ensure the air-conditioning system is optimally utilized. The air conditioning system of stations is kept off during the non-summer period .Starting / closing timings of the chillers are reviewed regularly according to temperature and peak traffic hours. In the morning hours the Air-conditioning systems of the stations are started in open mode to drive out the stale air and take in the low temperature air from the atmosphere and run in Closed mode to re circulate the air with 10% fresh air. The chillers are run on auto logic mode depending upon the enthalpy of load and time table control through BMS. More number of chillers are run to cater the load (more energy efficient mode) rather than running the less numbers of chillers at full load.

❖ Energy Efficient Auxiliary System at Stations

Though, the air conditioning in any system consumes the major part of electricity, the other auxiliary measures cannot be neglected. Delhi Metro has considered various aspects during the designing of auxiliary system at stations. Such as selection of various equipments like lifts, Escalators, energy efficient lighting sources with automatic timers. While constructing the building provision of natural light with minimum heat trapping inside the station has been made to maintain the temperature inside the air-conditioned building. Energy conservation measures to save energy in lighting of the stations CFL`s(compact fluorescent lamps) are 13 % more efficient due to electronic ballast. Apart of this Electronic ballast have been provided, which saves 6w energy/tube.

Kerala state used the hydro and wind sources of energy to produce electricity. Failure of the monsoons create further shortage of the hydel power production, leading to increased import of thermal power and hence in increased electricity costs, generating financial loss to the State Electricity Board. The state has been trying to exploit the huge potential for generation of hydroelectricity, as it is non polluting and inexpensive .Although all the villages of the state of Kerala have access to electricity and the percentage of households using electricity is an astounding 84 percent.

The results indicate that as per capita income increase there is no increase in electricity consumption so there exists an inverse relationship .Electricity intensity is energy consumption per unit of GDP. In India the various initiatives are taken to achieve objective of providing access to electricity at lower carbon emissions. The results are in line with the steps taken in this direction in which In India separate Ministry for New and Renewable Sources of energy exist which encourage the use of renewable sources of energy like wind ,solar and hydro to produce electricity as a result renewable energy scenario in India shows a growing trend. Also the Ministry of Non-Conventional Energy Sources (MNES) provides financial incentives, such as interest subsidies and capital subsidies. In addition, soft loans are provided through the Indian Renewable Energy Development Agency (IREDA), a public sector company of the Ministry and also through some of the nationalized banks and other financial institutions for identified technologies.

The Government also provides various types of fiscal incentives for the renewable energy sector, which include: 100% depreciation in the first year of the installation of the project; exemption/reduction in excise duty; exemption from the central sales tax; and customs duty concessions on the import of material, components and equipment used in renewable energy projects. But the renewable energy technology at current is not a very efficient one. While certain solar cells are up to 25% efficient in conversion of solar energy to electricity, other devices are not very efficient. If renewable energy is to largely replace conventional sources in the future then ways and means have to be found to make the technology far more efficient and capable of producing more power. Another serious issue is that of external factors, such as the weather, or amount of rainfall. These must also be tackled in the best conceivable way. So far steps are taken in the right direction to reduce electricity intensity.

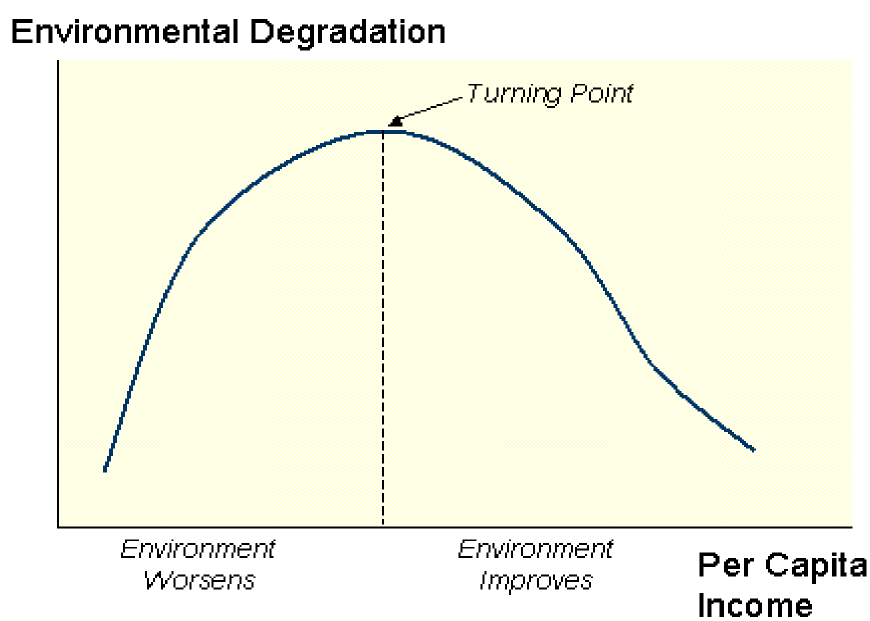
4.4 Intensity of Electricity Use (IEU): Applying The Environmental Kuznets Curve to Electricity Supply

In this study , we have also made an attempt to examine the relevance of Environment Kuznet Curve (EKC) pertaining to electricity supply and growth in India. A brief introduction of EKC is illustrated below.

4.5 Environmental Kuznet Curve

The EKC is named for Simon Kuznets (1955) who hypothesized that income inequality first rises, and then falls as economic growth increases.The environmental Kuznets curve (EKC) is a hypothesized relationship between various indicators of environmental degradation and income per capita. It is held that in the early stages of economic growth, degradation and pollution increases. However, beyond some level of income per capita, the trend reverses so that at high per capita income levels, economic growth leads to better environmental quality. Thus, the EKC implies that the environmental impact indicator is an inverted U-shaped function of income per capita.

Fig 4.3 Environment Kuznet Curve



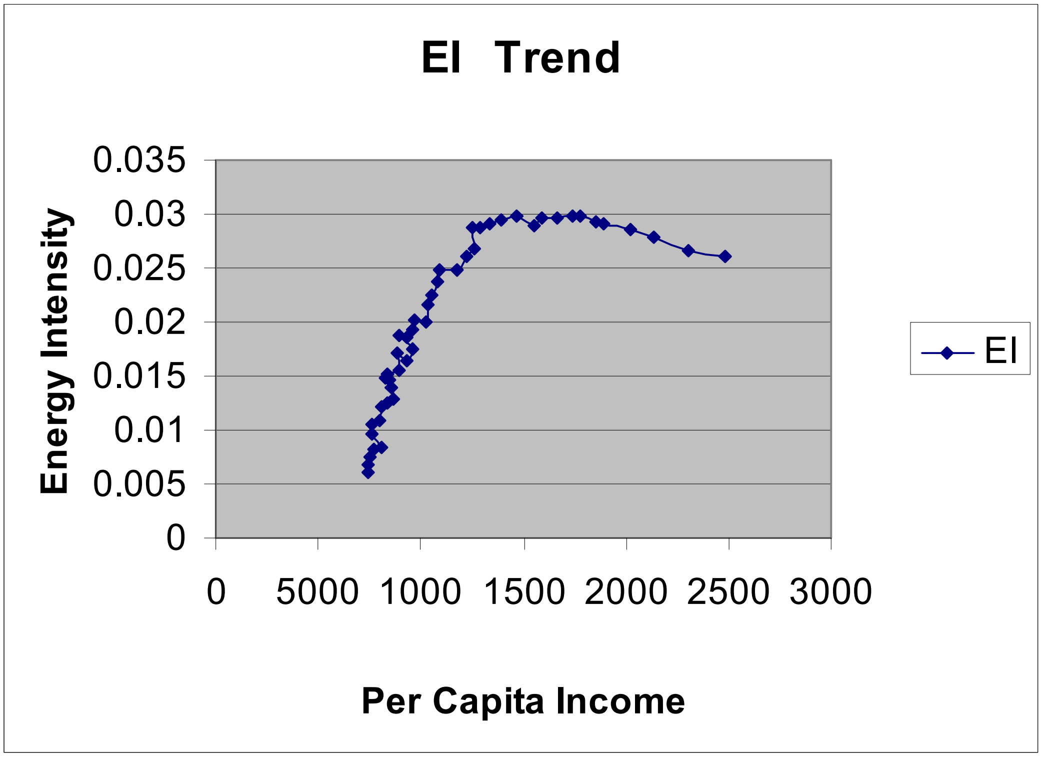
4.6 Intensity of Electricity Use

The concept of the intensity of electricity use (IEU) predicts that the amount of electricity consumed in an economy depends on two relationships. The first assumes that the intensity of electricity use, or electricity intensity ─ defined as the amount of electricity consumed, measured in physical units, that the economy consumes per unit of gross domestic product (GDP), measured in constant terms ─ is a function of its level of economic development as indicated by income per capita (GDP/P), where P is the population. In any given year, this relationship can be represented by equation (1).

$$IEU = f\,(GDP / P) \qquad (1)$$

Empirically, the exact specification or nature of the above equation can be determined, but would vary from one energy source to another. However, the difference between the IEU model and the Kuznets curve is in the vertical (y) axis. The vertical axis in the Kuznets curve represents environmental degradation. In the IEU model, the vertical axis represents electricity intensity, the amount of electricity required to produce a dollar of income (Chima ,2007).

Fig 4.4 Applying the Environmental Kuznet Curve to Electricity Supply



It is apparent from the graph that electricity intensity shows declining trend as per capita income increases and its shape appeared to be inverted U -shape which indicates the existence and relevance of EIKC in case of India .The trend of decreasing electricity intensity are due to number of factors which are as follows :

❖ **Technological innovation :** Technological change influence energy intensity, new technologies can make energy use more efficient for example Compact fluorescents which are on average 80% more efficient than incandescent lamps and have 8 to12 times longer lifetime.

❖ **Energy policies and actions of national, state and local governments:** government energy policies and actions can influence the choice of energy-consuming technologies and subsequently affect energy intensity. For example, building codes instituted in country as mentioned in the Energy Conservation Act 2001 at the national, state, or local levels influenced energy intensity .

4.7 Conclusion

As it is clear , from the above discussion energy in many forms is the engine to progress of mankind and the quantum of power utilized, indicates the scale of development and progress of country .In India we examined the electricity component of energy from 1960-61 to 2006-07 , while applying Granger causality which reveals unidirectional relationship between electricity supply and economic growth, running from electricity consumption to economic growth. Electricity emerged as the basic infrastructural requirement for the growth of industries as well as the overall economy of a country. The power supply scenario in the state during pre-reform period has not been satisfactory. After reforms there has been some improvements from the past .The information revolution would not be possible without a stream of electrons which helps the economy to grow at higher rate .Electricity becomes an integral part of our lives and has a large component of public benefit associated with it. Electricity supply act as a catalyst so measures should be taken to ensure its round the clock availability.

In addition in this study the relationship between electricity supply and economic growth in the major states of India by adopting panel regression model. The data for post- reform period from 1990-2004 have been used . , it is established that inverse relationship between electricity supply and growth in the backward states, which in turn reduce the intensity, whereas the results are reverse in case of foreword states except Delhi for which the reasons are discussed above.

On the other hand , excessive usage of fossil fuels is also very harmful to the environment. Global warming and climate change are very apparent, as polar icecaps melt faster than before and sea levels rise and at this point of time it is necessary to reduce electricity intensity so it is not only imperative that we should reduce our energy usage, but also to replace these sources of energy with cleaner fuels. With the fast depleting fossil fuels, authorities must now look at alternate energy sources – renewable energy sources, which also are clean and environmentally sound. India has taken many steps in this regard and realized this at an early stage our results indicate that there exists Electricity Intensity Kuznet curve during 1960-61 to 2006-07 period .The results support the various initiatives taken by the government in power sector.

4.8 Significance of the Study

The findings of the study would help in removing various electricity related problems and suggest remedial measures to correct them. The study would also address environment related issues and achievement of sustainable development .With regard to energy use the results show Kuznet Curve is relevant in case of Indian electricity sector. This indicates that we can raise income through energy conservation policies, which in turn promote improvements in technology for electricity use plus the ability to substitute amongst various forms of electricity inputs in India. The results of the study provides important information, indicators and direction to policy makers to chalk out future policies related to energy and to achieve sustainable development in Indian economy.

4.9 Policy Implications

Power provides lifeblood in any country for its industrial growth so due care should be taken while formulating policies for this sector .In case of India it is necessary to evolve an integrated energy policy that would provide a coherent framework of policy because energy sources is distributed over a number of different ministries e.g. Petroleum, Coal ,Power ,Water Resources ,Atomic energy and New and Renewable energy each ministry concerned with its own turf, policies are not always consistent, opportunities for inter linkages and synergy are missing and suboptimal solutions are the result. Several other like finance ministry determines tax rates for different fuels and many areas of policies are in hands of state government all these policy matters should be made consistent with the overall energy policy. This integrated energy policy report given by Planning Commission of India supported by our study as a step in right direction if implemented.

Public- Private Partnership (PPP) should be increased in establishing and operating various projects . Private-sector involvement and investment in the power sector are greatly facilitated by establishing a transparent and stable framework and rules governing competition (both on price and access to customers) It will help in reducing the various administrative bottlenecks and inefficiencies.

To reduce electricity consumption , awareness among masses through various methods of media so that consumer purchased efficient product even if it is available at little higher cost because the extra cost will be covered from the reduced bills. On the other side industries producing energy efficient and clean technologies should be rewarded through awards, giving subsidies in initial stages of production as these projects have long gestation period and industries whose activities and products create pollution penalties should be imposed.

More and more potential energy resources should be tapped through the help of advancement in the field of science and technology because technology led growth paves the path for inclusive growth and hence development of the country as a whole. In addition the government can promote energy efficiency and adopt minimum efficiency standards for buildings, appliances and equipment, and vehicles , reform and re-direct energy subsidies, identify the most promising indigenous renewable energy resources and implement policies to promote their sustainable development. Seek developed-country support for the effective transfer of advanced energy technologies, while building the indigenous human and institutional capacity needed to support sustainable energy technologies.

Accelerate the dissemination of clean, efficient and affordable technologies.

4.10 Limitations of the Study

This study, is based on one important form of energy i.e., electricity so the other important non-renewable sources of energy like coal and oil and various renewable sources of energy like wind, solar , geothermal , hydro and tidal are not studied in detail .

In this study, only 21 states are taken and states which are newly formed like Jharkhand, Chhatisgarh and Uttranchal have not been covered. The time period of study only has covered only the post-liberalization era of India and pre-liberalization era has not been addressed in this study.

4.11 Scope for Further Research

A comparative study between pre- reform and post-reform scenario pertaining to electricity sector can be done so as to draw better conclusions. During reforms different states adopted different models so a study can be done to evaluate these models and which model gives best result.

In this study, only one form of energy i.e., electricity has been taken and variables like oil and coal can be added for extensive study in the energy sector of India to get a clear picture.

For a detailed analysis, about the issues of electricity a states level study can be conducted regarding electricity supply, price of electricity and sector-wise consumption in different industries and government policies towards this sector.

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Appendix

Descriptive Statistics

Appendix 1

Statistics	LNEI	LNPCI
Mean	-1.685348	8.935769
Median	-1.526199	9.087151
Standard Deviation	0.856405	0.891979
Skewness	-1.198094	-0.407093
Kurtosis	4.987949	2.174279
Probability	0.0000	0.000224

Appendix 2

Statistics	LNE	LNNDP
Mean	8.405803	10.12729
Median	8.983816	10.51143
Standard Deviation	1.967498	1.570854
Skewness	-0.998003	-1.071883
Kurtosis	3.120340	3.492092
Probability	0.00000	0.00000

Appendix3: Chronology of Electricity Sector Reforms In India

1991	Electricity Laws (Amendment) Act allows private sector participation in generation, with foreign investors allowed 100 percent ownership.
1992-1997	Eight projects given "fast-track" approval status and sovereign guarantees by the central government.
1995	Orissa Electricity Reform Act established the Orissa Electricity Regulatory Commission and provided for unbundling of Orissa State Electricity Board.
1996	World Bank support for Orissa Power Sector Restructuring Project approved.
1996	Chief Ministers' Conference formulated a common minimum action plan for electricity.
1997	World Bank Haryana Power Sector Restructuring Project approved, and Haryana state government passes the Haryana Electricity Reform Act.
1998	Electricity Regulatory Commissions Ordinance Notification provides for establishment of a Central Electricity Regulatory Commission and state-level electricity regulatory commissions.
1999-2001	Andhra Pradesh, Karnataka, and Uttar Pradesh proceed with preparation of Electricity Reform Acts. The World Bank prepares and approves projects supporting reform in each of these states. APDRP has been undertaken during 2000-01.
2000-2002	Draft central government Electricity Bill prepared and introduced in Parliament
2003	The Electricity Bill 2003, notified in June 2003, aims to enhance the scope of power sector reforms .

Appendix 4: Status of Power Sector Reforms in Various States

State	Status
Andhra Pradesh	SERC constituted, functional, two tariff orders issued Reform law enacted, SEB unbundled Distribution privatization strategy being finalized MOU signed with Government of India
Arunachal Pradesh	SERC notified (yet to be constituted)
Assam	Chairperson of SERC appointed; SERC functional MOU signed with Government of India
Bihar	MOU signed with Government of India SERC constituted Members yet to be appointed
Chhatisgarh	MOU with Madhya Pradesh adopted SERC constituted Members yet to be appointed
Delhi	SERC constituted and functional Tariff order issued Reform law enacted DVB unbundled and distribution privatized
Goa	MOU signed with Government of India SERC constituted
Gujarat	SERC constituted and functional Tariff order issued Reform law approved by Government of India and introduced in the Assembly MOU signed with Government of India
Haryana	SERC constituted and functional Two tariff orders issued Reform law enacted, SEB unbundled MOU signed with Government of India
Himachal Pradesh	Single-Member HPSERC constituted Tariff order issued and implemented MOU signed with Government of India
Jammu & Kashmir	Reform bill passed by State Assembly MOU signed with Government of India
Jharkhand	MOU signed with Government of India
Karnataka	SERC constituted, functional, tariff order issued Reform law enacted, SEB unbundled MOU signed with Government of India Distribution privatization in progress, after unbundling into four separate companies, which have started functioning from June 1, 2002
Kerala	State does not envisage unbundling of State Electricity Board. Working of Board to be re-organized into three profit centers. MOU signed with Government of India,SERC constituted

Madhya Pradesh	SERC constituted Tariff order issued Reform law passed by the Assembly and notified SEB functionally unbundled MOU signed with Government of India
Maharashtra	SERC constituted and functional Tariff order issued MOU signed with Government of India
Orissa	SERC functional Four tariff orders issued Reform law enacted; SEB unbundled Distribution privatized MOU signed with Government of India
Punjab	SERC constituted Tariff order issued MOU signed with Government of India
Rajasthan	SERC constituted and functional Tariff order issued Reform law enacted SEB unbundled – one generation, one transmission and three distribution companies created MOU signed with Government of India
Tamil Nadu	SERC constituted MOU signed with Government of India
Uttar Pradesh	SERC constituted and functional Tariff order issued Reform law enacted and SEB unbundled Distribution privatization strategy to be finalized MOU signed with Government of India
Uttaranchal	MOU signed with Government of India SERC constituted
West Bengal	SERC constituted Tariff order issued MOU signed with Government of India
Nagaland	Has expressed willingness to constitute Joint Electricity Regulatory Commission.

Appedix 5 : List of Designated Agency to coordinate, regulate and enforce the provisions of Energy Conservation Act 2001

1. Andaman and Nicobar UT: Electricity Department, UT of Andaman and Nicobar, Port Blair .

2. Andhra Pradesh:Non-Conventional Energy Development Cooperation of Andhra Pradesh Ltd. (NEDCAP).
3. Arunachal Pradesh:Arunachal Pradesh Energy Development Agency (APEDA).

4. Assam: Electricity Department, Government of Assam, Guwahati .

5. Bihar: Bihar Renewable Energy Development Agency (BREDA), Bihar .

6. Chhattisgarh: Chhattisgarh State Renewable Energy Development (CREDA), Raipur .

7. Delhi: Delhi Transco Limited, Delhi .

8. Gujarat: Gujarat Energy Development Agency (GEDA), Gujarat .

9. Haryana: Department of Non-conventional Energy Sources (DNES), Chandigarh .

10. Himachal Pradesh: Director (Enforcement and Energy Audit), Office of the Chief Engineer (Commercial), H.P. State Electricity Board, Shimla .

11. Jharkhand: Chief Engineer-cum-Chief Electrical Inspector, Energy Department, Government of Jharkand, Ranchi .

12. Karnataka: Karnataka Renewal Energy Development Limited (KREDL).

13. Kerala: Energy Management Centre, Kerala, Thiruvananthapuram .

14. Lakshadweep UT: Department of Electricity, Union Territory of Lakshadweep, Kavaratti .

15. Madhya Pradesh: M.P.Urja Vikas Nigam Limited (MPUVNL);

16. Maharashtra: Maharashtra Energy Development Agency (MEDA), Pune .

17. Mizoram: Chief Engineer (Power), Power and Electricity Department, Government of Mizoram, Mizoram .

18. Nagaland: Electrical Inspectorate, Department of Power, Government of Nagaland, Kohima.

19. Orissa: Electricity-cum-Principal Chief Electrical Inspectorate, Bhubaneswar .

20. Pondicherry: ThiruG. Joseph Adrien Auto, Executive Engineer, Division-II, Electricity Department, Pondicherry .

21. Punjab: Punjab Energy Development Agency, Chandigarh .

22. Rajasthan: Rajasthan Renewable Energy Cooperation, Jaipur.

23. Tamil Nadu: Electrical Inspectorate Department, Chennai .

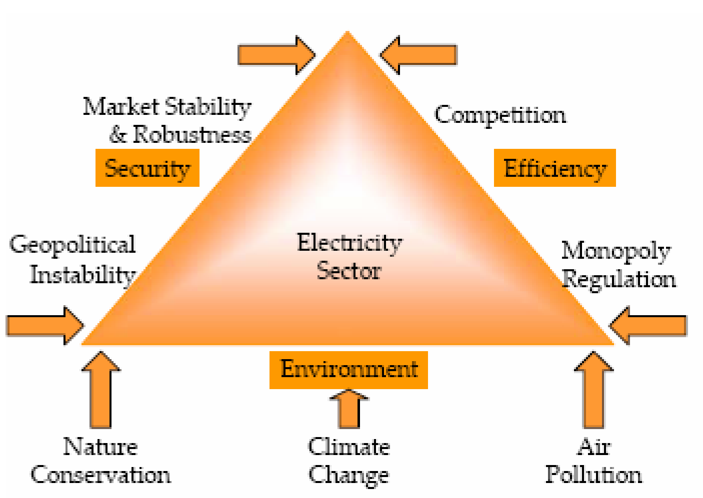
24. Tripura: Department of Power, Tripura, Agartala .

25. Uttaranchal: Electricity Safety Department, Government of Uttaranchal, Haldwani .

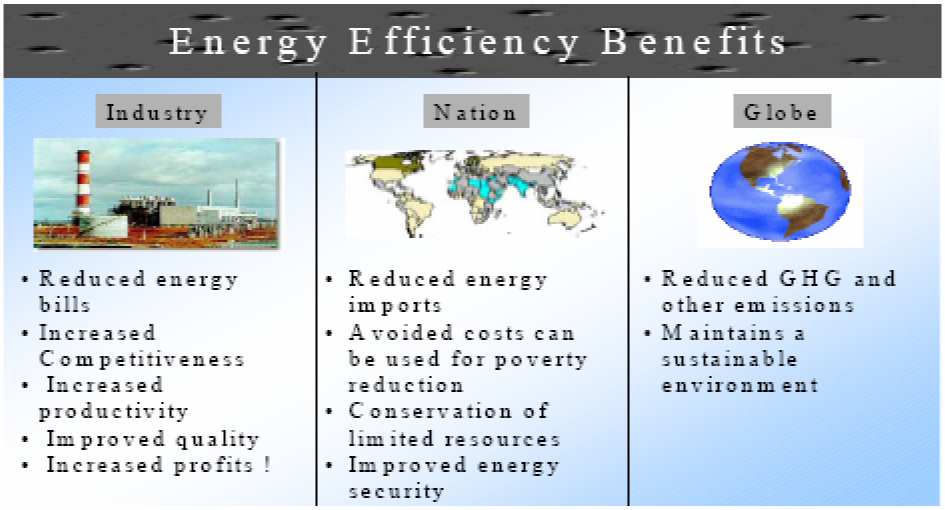
26. Uttar Pradesh: Uttar Pradesh Power Corporation Ltd., Uttar Pradesh .

27. West Bengal: West Bengal State Electricity Board, Kolkata.

Appendix 6: Trade offs Between Potentially Conflicting Goals



Appendix 7: Energy Efficiency Benefits



Appendix 8 : Energy Efficiency Equipments