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REVIEW ARTICLE

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Review of Energy Usage Patterns in India

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Energy has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be dependent on the energy demand (EIA, 2006). Energy intensity is an indicator to shows how efficiently energy is used in the economy. The energy intensity of India is over twice then that of the matured economies, which are represented by the OECD (Organization of Economic Co-operation and Development) member countries. India's energy intensity is also much higher than the emerging economies. However, since 1999, India's energy intensity has been decreasing and is expected to continue to decrease (GOI, 2001).

The indicator of energy–GDP (gross domestic product) elasticity, that is, the ratio of growth rate of energy to the growth rate GDP, captures both the structure of the economy as well as the efficiency. The energy–GDP elasticity during 1953–2001 has been above unity. However, the elasticity for primary commercial energy consumption for 1991–2000 was less than unity (Planning Commission, 2002). This could be attributed to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution. The energy sector in India has been receiving high priority in the planning process. The total outlay on energy in the Tenth Five-year Plan has been projected to be 4.03 trillion rupees at 2001/02 prices, which is 26.7% of the total outlay. An increase of 84.2% is projected over the Ninth Five-year Plan in terms of the total plan outlay on energy sector. The Government of India in the mid-term review of the Tenth Plan recognized the fact that under-performance of the energy sector can be a major constraint in delivering a growth rate of 8% GDP during the plan period. It has, therefore, called for acceleration of the reforms process and adoption of an integrated energy policy. In the recent years, the government has rightly recognized the energy security concerns of the nation and more importance is being placed on energy independence. On the eve of the 59th Independence Day (on 14 August 2005), the President of India emphasized that energy independence has to be the nation's first and highest priority, and India must be determined to achieve this within the next 25 years. The objective of the study is to examine the trend of total primary energy consumption of India from 1980 to 2005. From different research findings, it is prominent that the total primary energy consumption of the country may be a determinant of GDP.

Hence here we have tried to find out the relationship between the total primary energy consumption and GDP from 1980 to 2005. We have tried to find out the relationship between different indicators such as Per capita energy consumption, Production of energy resources, Population with the total energy consumption, and checked whether there is a relationship between them and can they be partially determined by the other variables indicated in the literature.

Energy is crucial for the socio economic development of a country. The energy sector is a part of the economy as well as it itself consist of parts such as energy supply and energy demand interacting with each other. Energy is required for all the economic activities. The economic development is mainly dependent on the energy system of the country. In India, a variety of sources of energy are in use. Like firewood, agricultural waste, animal dung and human power are the traditional sources of energy which still continue to meet the bulk of energy requirements in rural India. These traditional fuels are gradually getting replaced by commercial fuels such as coal, petroleum, natural gas and electricity (Tiwari, 2000). Post oil crisis shifted the focus of energy planners towards renewable resources and energy conservation. However, a major cause of climatic change and air pollution in India is consumption of fossil fuels.

Micro level planning is analogous to the Gandhian concept of decentralization. However, from the beginning, Indian planners took recourse to centralized planning, and macro level policies were formulated at the center. There was no focus on local problems or situations in tiny villages which form the basic elements of any planning movement

(Ramachandra, 2009). As a result, one of the primary objectives of planning, i.e., rural uplift has not been fulfilled. Locally available, scarce energy resources are not used scientifically, the existing local technologies have lost their value, and the level of dispossession and impoverishment has increased many folds since independence. Despite strong centralized efforts straddling over four decades, the countryside has experienced severe economic slump and unbridled poverty and unemployment. The disparities between the existing socioeconomic divisions have widened, leading to a dangerous degree of social split in the country (Pachauri and Spreng, 2002). The critical situation can only be circumvented by ensuring rational use of resources at the micro level, and by carefully weighing the implications of various alternative policy decisions.

Micro level planning takes into account the essential needs of the local people and arrives at policies for judicious utilization of the locally available resources. A successful micro level plan relies upon several planning tools, such as system analysis, operations research, statistics, and socioeconomic evaluation (Azadeh and Faiz, 2011). For the present investigation, district-level real-life data were collected from a carefully selected representative sample of the target population. A step wise regression model was employed, and various energy-related interactions within the rural system were incorporated. Since prolific utilization of available energy resources is one of the prime aims of development, the objective of the model was to make out the optimized way of utilizing the per capita energy. The quantitative impact of several possible changes in the rural domestic system has been investigated by this approach, and forecasts of future energy scenarios for the rural domestic segment of the state were made (Malik et al, 1994). In order to increase the awareness and importance about the growing energy use and micro level planning in India, especially in a state like Kerala, a domestic perspective is adopted. The domestic sector perspective is adopted because it will show an insight into the complex relationships.

Since 2005, India has witnessed an average annual GDP growth rate of 8.5%. India's impressive growth is accompanied by a complex story of increasing aggregate energy demand and growing need for increasing energy inclusion. Millions of households in India still lack access to reliable electricity and clean cooking fuels. According to the International Energy Association (2009) approximately 36% of India's population – over 400 million Indians – lack access to electricity1. Furthermore, nearly 70% of Indians over 725 million individuals – rely on biomass as their primary cooking fuel.

Against this backdrop, India is witnessing an upsurge in activity for the development of new renewable energy technologies, products, and services to meet the rising energy demands of poor households at the "Base of the Pyramid" (BoP).

The combination of the need to sustainably eliminate energy poverty and the emergence of new and exciting energy technologies and business models in India has attracted the interest of multinational corporations, multilateral development donor organizations, foundations, and social venture investors alike. This increased interest is evidenced by the announcement of the Global Cook stoves Alliance in 2010, the Shell Foundation's investment of $25 million to develop commercially viable improved cook stoves, the Government of India's launch of a new Improved Cook stoves Mission, and the proliferation of social enterprises and traditional companies that seek to provide clean energy products and services to BoP consumer segments since 2007. While increased interest in developing innovative policies and business models to enhance energy inclusion is exciting, entrepreneurs, investors, and policy makers face significant challenges related to technology development, marketing and distribution, and policy and incentive design. Underlying each of these specific challenges, too little is currently known about the target market for clean energy products and services. Access to robust, accessible data about the energy consumption and expenditure patterns of BoP consumer segments are in short supply.

Fortunately, in India the National Sample Survey (NSS) Consumer Expenditure Survey compiles household level data from across the country. While these data are well known to academics and policy professionals, they are relatively underutilized by entrepreneurs and impact investors. The data presented in the Energy Atlas are drawn from the 61st round of NSS 2004-2005 Consumer Expenditure Survey, which covers over 124,000 households across the entire geographical area of India. As part of its broad-based data on household consumption, the NSS data contain detailed information on household-level consumption and expenditure patterns on fuel and light, including quantities of fuel used, the value of the fuels consumed and amount households spend per month on each fuel type6. The Energy Atlas focuses specifically on the NSS cooking and lighting fuel consumption and expenditure data to paint a more refined picture of household-level energy consumption dynamics at both the national and state level.

Aggregate data on economic activity, fuel use patterns and bulk fuel usage are commonly used to provide a useful national-level snapshot of household energy use and consumption dynamics. While these aggregate data may be insightful when used for the purpose of country or regional comparison, they mask the substantial variation across states, locales (urban rural), and income segments.

Disaggregated data can yield substantial insight to improve product design, service delivery, marketing and communication, as well as policy design and

implementation. For example, 65% of households across India report using electricity as their primary lighting source. However, when disaggregated into urban and rural populations, the data reveal that 92% of urban and 55% of rural households use electricity as their primary lighting source. Similarly, a close examination of the state level NSS data for Bihar and Punjab highlights the extreme inter-state variability. The Energy Atlas reveals that while 96% of rural households in Punjab report using electricity as their primary lighting source, only 10% of rural households in Bihar report doing so. Disaggregated data reveals a large potential market opportunity for providing alternative lighting and energy solutions to the nearly 12.7 million households in rural Bihar that would otherwise be masked by the commonly cited all-India figures.

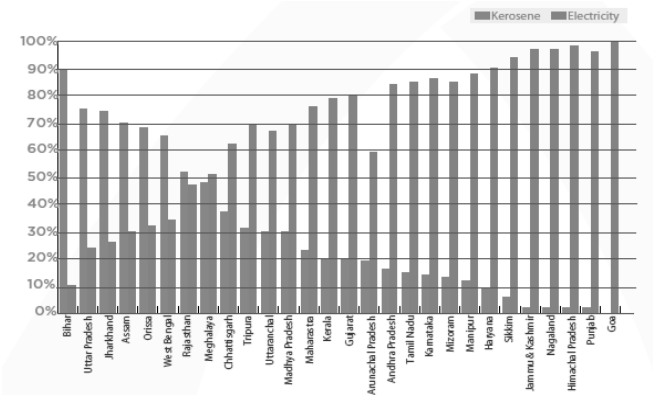

Figure: Percent of Rural of Households Using Each Energy Type as a Primary Lighting Source

Energy Scenario in India

The decade of seventies has witnessed major world oil supply disruptions. During the 1970s the OPEC production was cut down by two and a half per cent causing severe oil supply distortions. From 1975 oil prices remained high but not as high as in 1973-74. But the Iranian revolution in 1979 worsened the situation and oil prices again rose sharply in 1979, generating the second oil shock. From the mid 1980s, there was again a resumption of the growth of demand for refined products. This demand upsurge led to an increase in oil prices from the late 1980s. From July to October 1990, following Iraq's invasion of Kuwait, there was a near doubling of oil prices. However, this 1990 oil price shock had substantially lesser impact on the world economy than the other two oil price shocks (Mukhopadhyay, 2002).

The reason for this diminished effect was the short duration (only 4 months) of the 1990s oil price hike, the substitution of oil, to a large extent, by competing energy sources and an overall recession of economic activities that had already begun before the price hikes. India being an oil importing country witnessed significant changes in the energy consumption pattern due to the oil shocks.

Faced with rising inflation and a balance of payment crisis in mid 1991 the government of India introduced a fairly comprehensive policy reform package comprising currency devaluation, deregulation, de-licensing, privatisation of the public sector. The government of India initiated these policy changes to overcome the critical situation. The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources.

The brief discussion about the commercial energy shows that the country is having potential in some cases but utilization is not up to the desired level. From the oil front, it is apparent that country has to rely on import. Due to the volatility of the international market country's import bill is rising. On the other hand transmission and distribution losses are making the electricity sector critical. The industrial sector in India is a major energy user, accounting for about 65% of the commercial consumption (EIA, 2004). There are wide variations in energy consumption among different units within the same industry using comparable technology.

Years	Energy consumed in agriculture	Energy consumed in industry	Energy consumed in transport	Energy consumed in services
1990-91	4.36	56.01	24.93	14.69
1991-92	4.75	55.89	24.85	14.50
1992-93	4.96	55.69	24.88	14.47
1993-94	5.31	55.43	24.67	14.60
1994-95	5.70	54.74	24.74	14.81
1995-96	5.19	53.53	27.87	13.41
1996-97	5.16	57.14	26.06	11.64
1997-98	5.40	48.01	29.49	17.10
1998-99	4.86	44.04	31.29	19.82
1999-00	4.79	45.69	32.30	17.31
2000-01	3.53	47.26	32.64	17.56
2001-02	3.02	46.52	33.30	17.75
2002-03	3.33	49.52	31.93	15.27
2003-04	3.85	47.05	32.16	17.27

Table: Growth of Energy Consumption in different sectors of the Economy

Table reflects the growth pattern of the energy consumption in different sectors of the economy since the 1990s. Transport sector shows high energy consumption growth through out. Though the industrial sector records high growth in first half of the 1990s but it starts decline from later half of the 1990s.

Energy Consumption in India: India's per capita commercial energy consumption, increased from 9% of global average in 1965 to 19.4% in 2000 (TERI, 2000). In 1998-99, commercial energy consumption in India was estimated at 195.11 MT of oil equivalent,

indicating a 75% growth over a decade. However, India's per capita consumption of commercial energy continues to be much lower than the global average of about 1684 Kg of oil equivalent and is 5-10% that of developed countries like; Japan, France and the USA. In India, commercial energy demand grew at six percent (CMIE, 2001).

Energy Consumption by Sources: Overall Production and Consumption: India is both a major energy producer and consumer. India currently ranks as the world's eleventh greatest energy producer, accounting for about 2.4% of the world's total annual energy production, and as the world's sixth greatest energy consumer, accounting for about 3.3% of the world's total annual energy consumption. Despite its large annual energy production, India is a net energy importer, mostly due to the large imbalance between oil production and consumption. An historical summary of India's Total Primary Energy Production (TEP) and Consumption (TPEC) is shown in Table.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TEP	7.49	8.00	9.48	8.75	9.17	9.37	9.58	9.83	10.23	9.99	10.15
TPEC	9.24	9.97	11.49	11.14	11.76	12.17	12.74	13.50	13.85	13.79	14.03

Table: India's TEP and TPEC, 1993-2003 (in Quads)

Petroleum: India's proved oil reserves are currently estimated (January 2005) at about 5 billion barrels, or about 4.5% of the world total. Most of these reserves lie offshore near Mumbai and onshore in Assam state. However, exploration is still happening, and India's off-shore and on-shore basins may contain as much as 11 billion barrels. India presently ranks as the 25th greatest producer of crude oil, accounting for about 1% of the world's annual crude oil production. About 30% of India's energy needs are met by oil, and more than 60% of that oil is imported. A strong growth in oil demand has resulted in India's annual petroleum consumption increasing by more than 75% from what it was a decade ago. India is currently the world's sixth greatest oil consumer, accounting for about 2.9% of world's total annual petroleum consumption. An historical summary of petroleum production and consumption in India is shown in Table.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Production (total)*	578	651	770	751	780	761	765	770	782	813	815
Production (Crude Oil only)	534	590	703	651	675	661	653	646	642	665	660
Consumption	1,311	1,413	1,575	1,681	1,765	1,844	2,031	2,127	2,184	2,263	2,320

Table: Petroleum Production and Consumption in India, 1993-2003 (in thousands of barrels per day)

Natural Gas: India's natural gas reserves are currently estimated (as of January 2005) at about 29-32 trillion cubic feet (tcf), or about 0.5% of the world total. Most of these reserves lie offshore northwest of Mumbai in the Arabian Sea and onshore in Gujarat state. India does not yet rank in the top 20 of the world's greatest natural gas consumers, but that will soon change. Natural gas has experienced the fastest rate of increase of any fuel in India's primary energy supply; demand is growing at about 4.8% per year and is forecast to rise to 1.2 tcf per year by 2010 and 1.6 tcf per year by 2015. An historical summary of natural gas production and consumption in India is shown in Table.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Production	0.53	0.59	0.63	0.70	0.72	0.76	0.75	0.79	0.85	0.88	0.96
Consumption	0.53	0.59	0.63	0.70	0.72	0.76	0.75	0.79	0.85	0.88	0.96

Table: Dry Natural Gas Production and Consumption in India, 1993-2003 (in tcf) Coal

India's has huge proven coal reserves, estimated (as of January 2005) at more than 90 billion tons, or about 10% of the world's total. Most of these reserves are relatively high ash bituminous coal and are located in Bihar, West Bengal, and Madhya Pradesh states. At the current level of production and consumption, India's coal reserves would last more than two hundred years. India is currently the third-largest coal-producing country in the world (behind China and the United States), and accounts for about 8.5% of the world's annual coal production. India is also currently the third-largest coal consuming country (behind the China and the United States), and accounts for nearly 9% of the world's total annual coal consumption. More than half of India's energy needs are met by coal, and about 70% of India's electricity generation is now fueled by coal. The annual demand for coal has been steadily increasing over the past decade, and is now nearly 50% greater than it was a decade ago. Even though India is able to satisfy most of its country's coal demand through domestic production, less than 5% of its reserves is coking coal used by the steel industry. As a result, India's steel industry imports coking coal, mainly from Australia and New Zealand, to meet about 25% of its annual needs. An historical summary of coal production and consumption in India is shown in Table.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Production	295.56	311.96	323.63	319.93	326.58	337.94	352.60	367.29	389.20	412.95
Bituminous	273.41	289.32	300.40	296.51	304.10	313.69	327.79	341.27	361.24	382.61
Lignite	22.15	22.64	22.23	23.42	22.48	24.25	24.81	26.02	27.96	24.34
Consumption	332.2	358.5	362.9	375.4	406.1	413.6	430.6	430.6	N/A	N/A

Table: Coal Production and Consumption in India, 1996-2005 (in millions of tons) Electricity

India is presently the sixth-greatest electricity generating country and accounts for about 4% of the world's total annual electricity generation. India is also currently ranked sixth in annual electricity consumption, accounting for about 3.5% of the world's total annual electricity consumption. Overall,

India's need for power is growing at a prodigious rate; annual electricity generation and consumption in India have increased by about 64% in the past decade, and its projected rate of increase for electricity consumption is one of the highest in the world. An historical summary of electricity generation and consumption in India is shown in Table.

Electricity consumption in India has more than doubled in the last decade. The primary energy supply in the country is coal-dominant, with the power sector accounting for about 40 percent of primary energy and 70 percent of coal consumption (CMIE, 2000). The Indian power sector is characterized by large demand-supply gap. Faced with unreliable power supply, many industries have invested in on-site power generation that now accounts for more than 10 percent of total capacity (CMIE, 2000). Five regional grids operate in India, with regional grids connecting state transmission networks within a region.

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Net Generation	441.1	470.7	504.3	529.1	548.0	563.5	556.8	558.33	587.37
Hydroelectric	73.9	82.2	79.9	73.7	73.0	63.5	68.5	73.77	84.50
Nuclear	10.4	10.6	11.4	14.1	18.2	17.8	16.4	17.77	16.84
Geo/Solar/ Wind/Biomass	0.9	1.0	2.3	2.9	3.9	4.1	4.2	n/a	n/a
Conventional Thermal	355.8	376.8	410.7	438.5	453.0	478.2	467.7	466.82	486.03
Net Consumption	411.6	439.0	470.1	493.4	510.9	525.4	519.0	n/a	n/a
Imports	1.6	1.5	1.4	1.5	1.5	1.5	1.4	1.4	1.4
Exports	0.1	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2

Table: Electricity Generation and Consumption in India, 1997-2005 (in billions of kilowatt-hours)

Renewable Energy Sources: Though the present contribution of renewable energy is small, existing capabilities offer the flexibility to respond to emerging environmental and sustainable development needs. Renewable energy technologies (RETs) have a vast potential and have the advantage of being environmentally sustainable. Table gives a detailed estimated potential for RET in India.

Source/System	Approximate Potential
Biogas Plants (In Numbers)	12 million
Improved Cook-stoves (in numbers)	120 million
Biogas Power Plants	17000 MW
Solar Energy	20MW/km^2
Wind energy	45000 MW
Small hydro Power	15000 MW
Ocean energy	5000 MW
Urban and Industrial Wastes	1700 MW

Table: Estimated Potential for RETs in India

Small Hydro Power: Hydro based power generation up to 25 MW capacities, classified as small hydropower, and offers a number of advantages for electricity generation. It has been one of the earliest known renewable energy sources, in existence in the country. Estimates place the small hydro potential in India at 15,000 MW (TERI 2000). Since a large potential of this technology exists in remote hilly areas, development of small hydropower for decentralized power generation leads to rural electrification and local area development. The gestation period of the technology is low and the indigenous manufacturing base is strong.

Solar Technologies: Solar Photovoltaic (SPV) contributes at present around two and a half percent of the power generation based on renewable energy technology in India. Solar photovoltaic systems with an aggregate capacity of 47 MW have been deployed for different applications (GOI, 2001), that includes solar photovoltaic power projects aggregating 1.615 MW for providing voltage support in rural areas and peak load shaving in urban areas. Solar thermal technologies have a very high potential for applications in solar water heating systems for industrial and domestic applications and for solar cooking in the domestic sector. Solar Thermal Power Generation potential in India is about 35 MW per Sq. Km Estimates indicate 800 MW per year potential for solar thermal based power generation in India during the period 2010 to 2015, with worldwide advancements in the parabolic trough technology (TERI, 2000). The technologies for power generation using solar thermal technology are parabolic dish, parabolic trough collectors, central receivers, solar ponds and solar chimneys. Dissemination of SPV technology has been undertaken by a technology-push approach adopted by the government.

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