LBNL-XXXX

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

India Energy Outlook: End Use Demand in India to 2020

Stephane de la Rue du Can, Michael McNeil, and Jayant Sathaye

Environmental Energy
Technologies Division

January 2009

This work was supported by the United States Agency for International Development (USAID) under the U.S. Department of Energy Contract No. DE-AC02-05CH11231.

Please direct correspondence to Stephane de la Rue du Can at sadelarueducan@lbl.gov and Michael McNeil at mamcneil@lbl.gov

Preface

The past decade has seen the development of many scenarios describing long-term patterns of future greenhouse gas (GHG) emissions. Each new approach adds additional insights to our understanding of overall future energy trends. In most of these models, however, a description of sectoral activity variables is missing. End-use sector-level results for buildings, industry or transportation or analysis of adoption of particular technologies and policies are not provided in global energy modeling efforts.

All major analyses of long-term impacts of greenhouse gas emissions to date rely on scenarios of energy supply and demand. The underlying drivers of all such major scenarios are macro socioeconomic variables (GDP, population) combined with storylines describing the context of economic and social development. Unfortunately, these scenarios do not provide more detail than the sector level (i.e., buildings, industry and transportation). This is to say that the scenarios are developed without reference to the saturation, efficiency, or usage of air conditioners, for example. For energy analysts and policymakers, this is a serious omission, calling into question the very meaning of the scenarios. Energy consumption is driven by the diffusion of various types of equipment; the performance, saturation, and utilization of the equipment has a profound effect on energy demand. Policy analysts wishing to assess the impacts of efficiency or other mitigation policies require more detailed description of drivers and end use breakdown.

Based on these considerations and EETD's extensive expertise in energy demand, the goal of this project is to build a new generation global energy and CO_2 emissions model that will be based on the level of diffusion of end use technologies. The model will address end-use energy demand characteristics including sectoral patterns of energy consumption, trends in saturation and usage of energy-using equipment, technological change including efficiency improvements, and links between urbanization and energy demand.

To this end, LBNL has initiated the Global Energy Demand Collaborative (GEDC) to develop of a new generation of models. The ultimate goal of the GEDC is a complete modeling system that covers the entire world (by region or country), and covers all economic sectors at the end use level. In the short and medium term, the core GEDC team has performed a series of studies such as: country studies, sector studies, or methodology reports. The first of these reports include:

- Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions (Price et al., 2006; de la Rue du Can and Price, 2007)
- Forecasting Building End Use Consumption in Developing Countries (McNeil M. et al, 2008)
- Energy Use in China: Sectoral Trends and Future Outlook (Zhou et al., 2007)
- COBRA-Energy (Wagner and Sathaye, 2005)

The present report draws upon the expertise developed over many years in the Laboratory's International Energy Studies Group in order to present as complete and detailed picture as possible of the components and trends in energy consumption in India.

Executive Summary

Integrated economic models have been used to project both baseline and mitigation greenhouse gas emissions scenarios at the country and the global level. Results of these scenarios are typically presented at the sectoral level such as industry, transport, and buildings without further disaggregation. Recently, a keen interest has emerged on constructing bottom up scenarios where technical energy saving potentials can be displayed in detail (IEA, 2006b; IPCC, 2007; McKinsey, 2007). Analysts interested in particular technologies and policies, require detailed information to understand specific mitigation options in relation to business-as-usual trends. However, the limit of information available for developing countries often poses a problem. In this report, we have focus on analyzing energy use in India in greater detail. Results shown for the residential and transport sectors are taken from a previous report (de la Rue du Can, 2008). A complete picture of energy use with disaggregated levels is drawn to understand how energy is used in India and to offer the possibility to put in perspective the different sources of end use energy consumption. For each sector, drivers of energy and technology are indentified. Trends are then analyzed and used to project future growth. Results of this report provide valuable inputs to the elaboration of realistic energy efficiency scenarios.

1- India 2005 Energy Demand

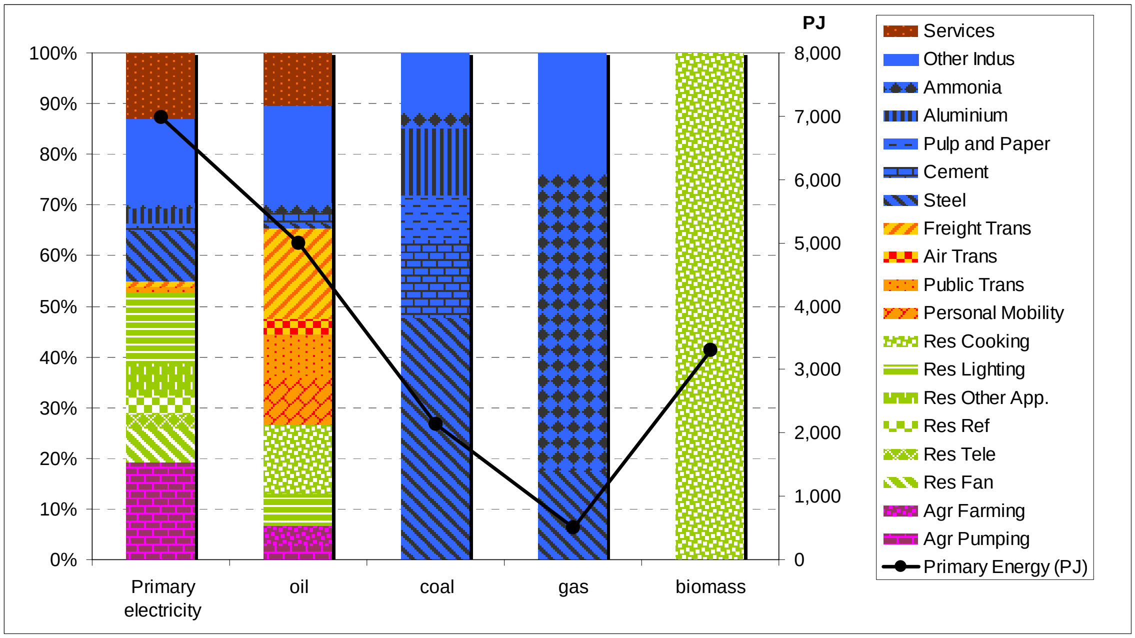
Energy demand in India by fuel and end use is shown in Figure ES 1. The main energy products consumed in India are primary electricity, oil, coal, biomass and gas, and are represented by bars. Primary electricity includes electricity consumption plus the upstream energy inputs and losses in transmission and distribution. Total electricity consumption represents 1,654 PJ (472 TWh) in 2005, while primary electricity represents 6,977 PJ, meaning more than 4 unit of primary energy was necessary to deliver 1 unit of electricity energy at the end consumer. Moreover, it is important to keep in mind that in India, electricity is produced for a large share (71%) from coal, hydro power represents 14%, natural gas 8%, and diesel and nuclear each represent 3%. Absolute fuel consumption is shown by the dark black line with the *y* axis on the right size. Primary electricity is by far the largest energy product used in India, followed by oil, while gas remains the lowest energy product in use.

The main contribution of this report is to shed light on the underlying sectoral end use energy consumption in India. In Figure ES 1 each energy product is proportionally divided by the activity that forms its demand.

Electricity has the widest variety of uses, with industry other than energy intensive ones representing 23%, agricultural pumping 18%, residential appliances 18% (among which fan is 6%, television is 3%, and refrigerator is 3%), residential lighting 13% and services 12%. The remaining primary electricity consumption consists in energy intensive industry demand, and small quantity of transport activities (railways mostly).

Oil is mostly used in the transport sector with freight being the largest user (18%), followed by equal shares of public and personal transport (9%) and finally air travel which represents 3% of total oil used in India. Unlike in developed countries, oil remains an important source of energy for cooking in India, through the use of kerosene. Its consumption represents 14% of total oil use. Kerosene is also used as a source of lighting, representing 6% of total oil use. Oil is also used in the agriculture sector for farming (4%) and pumping water (3%). Finally oil is a source of energy for the commercial and industrial sectors, which use it in many cases to run generators in order to supplement shortages of electricity.

Figure ES 1. Energy Consumption Detail in India by Fuel Type in 2005



At the end use level, only industrial activities use coal directly as a source of energy. The largest user is the iron and steel industry representing almost half of the total coal used (48%); then follows the cement industry with 15%, the aluminium industry with 13% and the pulp and paper industry with 9%. Similarly, gas is only used in industrial sub-sectors, with ammonia representing 60%. Biomass is an important source of energy in India for cooking. Due to its highly inefficient conversion to useful energy, the use of biomass represents a large share of total primary energy use at 18%.

2- India 2020 Energy Flow

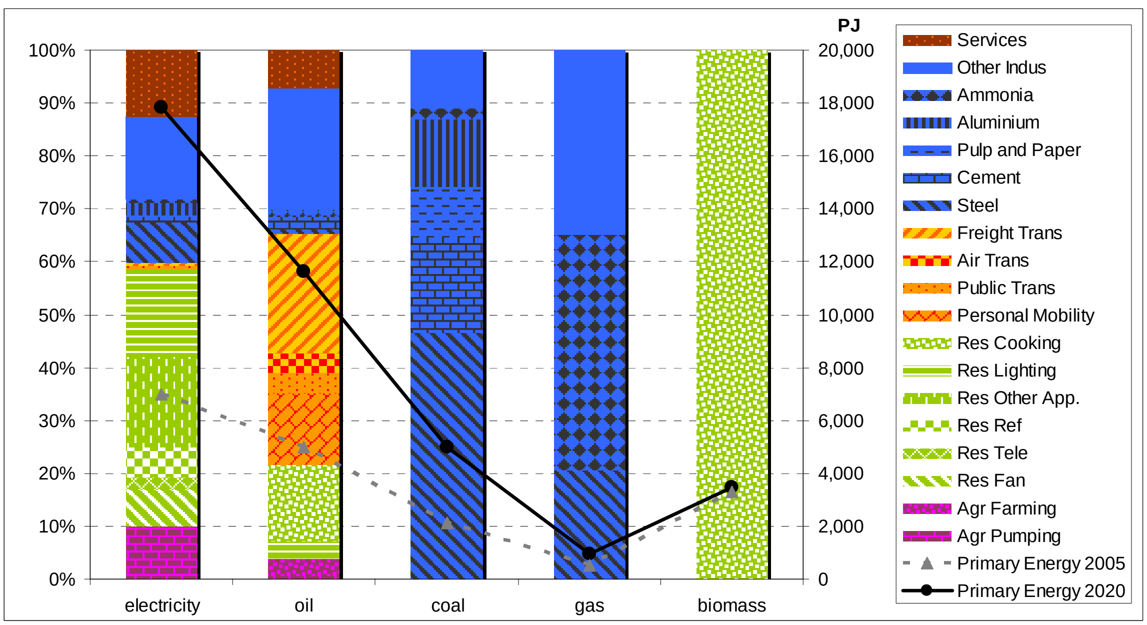
Knowing the current patterns of energy use and assumptions about future trends in economic activity, we constructed an activity driven model to forecast what would be the natural short term evolution of energy use in India for each end use segment by 2020. Through analysis of current patterns of energy use, drivers of energy use were collected at the sub-sector level. For example in the residential sector, we collected data on household size, appliances ownership, etc (confer the report that focuses on residential and transportation sectors, de la Rue du Can, 2008). We then connected trends in activity drivers with evolution of GDP to determine what would be the impact of economic growth on drivers of energy use. We also considered fuel or technology switching in the forecast.

Figure ES 2 shows the resulting projection to 2020 by energy product and end use. The first observation is that the current picture of energy consumption breakdown is not expected to dramatically change as demand for all end uses will grow simultaneously. The same activities that require energy today will continue to consume energy in 2020.

The primary energy requirement is expected to be multiplied by 2.2 over the next 15 years to 38.8 PJ. In the same period, GDP is projected to multiply by 2.8, corresponding to an annul rate of 7%. Hence, the decoupling between energy and GDP growth observed over the last 15 years is expected to continue at the same path. Over the period 1990 to 2005, GDP had multiplied by 2.3 while energy consumption had multiplies by 1.9 only. In our model, energy efficiency improvements were considered in some sectors. For example the primary factor is expected to continue its decline at an annual rate of -0.8% due to the dual effect of increasing input from non-fossil fuel and slight decrease in transmission and distribution loses, to reach a rate of 3.7. The industry and transport energy intensity are also projected to continue their decline due to small technology improvements, as it has been observed in the past.

Industry and residential sectors remain the largest sources of primary energy use. However, the fastest growth is from the transport sector at a rate of 6.4%, followed by the industrial and commercial sectors with rates of 5.8% and 5.3% respectively. Growth in the residential sector is also strong at 5.2%, with opposite forces between significant decrease of biomass and considerable increase of primary electricity consumption.

Figure ES 2. Projected Energy Consumption in India by Fuel Type in 2020



Primary electricity consumption is expected to grow the fastest at 6.4% annually over the period 2005 to 2020, driven by increased appliance ownership in the residential sector and increase in equipment penetration and floor space development in the commercial sector. Oil will remain the second most used fuel in use in the final sectors throughout this period, reaching 11.6 EJ in 2020. The transport sector represents the largest user of oil with a share of 43% of total oil consumption. The residential sector represents about 18% of oil use for the need of LPG and kerosene for cooking and lighting. Biomass energy consumption will decrease slightly at an annual rate of 0.4% over the same period, while natural gas will continue to increase at a rate of 5.3%, lower than in the previous period of 7.3%. Coal consumption will continue to increase at a faster rate than during the period 1990 to 2005, driven by the growth from industrial activities.

Table of Contents

List of Figures and Tables

Figures

Tables

Annexes

List of Abbreviations and Acronyms

AAGR	Average Annual Growth Rate
ASI	Annual Survey of Industries
BEE	Bureau of Energy Efficiency
CEA	Central Electricity Authority
CSO	Central Statistical Organization
CPPRI	Central Pulp and Paper Research Institute
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IBEF	India Brand Equity Foundation
IAI	International Aluminium Institute
IEA	International Energy Agency
IIS	Indian Institute of Science
IISI	International Iron and Steel Institute
LCV	Light Commercial Vehicles
LBNL	Lawrence Berkeley National Laboratory
LEAP	Long-range Energy Alternative Planning System
M&HCV	Medium and Heavy Commercial Vehicles
MNES	Ministry of New and Renewable Energy
MOC	Ministry of Coal
MOCI	Ministry of Commerce & Industry
MoCP	Ministry of Chemical and Petrochemical
MOG	Ministry of Petroleum and Natural Gas
MOP	Ministry of Power
MOSPI	Ministry of Statistics and Programme Implementation
MOR	Ministry of Railways
MPV	Multipurpose Vehicle
MOSSI	Ministry of Small Scale Industries
MUV	Multi-Utility Vehicle
NSSO	National Sample Survey Organization
PCRA	Petroleum Conservation Research Association
SEI	Stockholm Environment Institute
SIAM	Society of Indian Automobile Manufacturers
SRES	Special Report on Emissions Scenarios
SSI	Small Scale Industries
T&D	Transmission and Distribution
UEC	Unit Energy Consumption

1. Introduction

This study of sectoral energy sector in India is part of a larger effort at LBNL to provide sector, country and ultimately global analysis of energy use patterns at the level of sub-sectors and end uses. There are two motivations for this effort. First, as the negative environmental impacts (both local and global) of energy consumption become more urgent, there is a need to evaluate current and future sources of energy-related effects at a greater level of accuracy and detail. Secondly, a disaggregated analysis is highly desirable in order to guide mitigation efforts, including policies towards increased efficiency.

LBNL has a long history in the investigation of energy use patterns in developing countries, particularly in China. By now, the dramatic increase in energy consumption in China accompanying that country's phenomenal economic performance in the past two decades has become a somewhat alarming reference point for the negative environmental consequences associated with rapid growth in developing countries. Chinese energy consumption growth in all sectors, following changing lifestyle patterns as well as booming industrial production. In economic terms, India seems poised to be the next emerging giant, in both economic and energetic terms. We hope that this paper will constitute one of the first in a series of steps shedding light on some of the details of recent trends in order to inform the development of effective policies to address the negative impacts of energy demand growth.

To date, there have been a variety of studies covering multiple sub-sectors and use patterns, but none which attempts to integrate all available data into a comprehensive picture of the Indian economy. This report therefore fills an important gap, and we hope that it will provide a useful basis for forecasts of future sector growth and effective mitigation strategies.

This report looks at energy used at the end-use level over the period 1990 to 2005 and develops a baseline scenario to 2020.

End-use sector-level information regarding adoption of particular technologies was used as a key input in the bottom-up modeling approach. Results for the residential and transport sectors are taken from a previous report that focused on end-use level analysis of historical and projected energy consumption in these sectors (de la Rue du Can, 2009). This report summarizes results from this previous study and adds detailed analysis for the agriculture, industry, and service sectors. The following section (Section 2) describes the methodology developed for this study. Section 3 gives a comprehensive accounting of how energy is consumed today. For each sector, patterns of energy use at the end use level is analysed in details and recent trends of main drivers are described. Drawing from the information collected and analysed in Section 3, a baseline scenario of energy use to 2020 is constructed and explained in Section 4.

2. Methodology and Data

2.1 End Use Model

Statistics that describe energy consumption can be analyzed under two main approaches. The first approach typically consists in analyzing fuel consumption statistics from national sources and constitutes a top down approach. A second approach consists in gathering information on detailed activity variables that drive energy consumption, such as car ownership, refrigerator saturation, steel production and surveys to assess energy used at the end-use level. Data on energy use are then combined with data describing activities to form intensity of energy use. Activity is measured in physical terms (tonnes of steel or number of passenger-kilometers) or to a consumption unit (e.g. per vehicle or dwelling) (Schipper, 1997 and 2001; IEA, 2004). This approach corresponds to a bottom up analysis of end-use energy services. Our interest in this report was to use this second approach when it was possible and gather data at the end use level to compare with top down data.

The bottom-up approach was also used to articulate and project the underlying drivers of energy consumption in different sectors. The accounting and scenario-based modeling platform called LEAP (Long-range Energy Alternative Planning System) was used to generate a baseline energy consumption scenario. LEAP is a scenario-based software tool for integrated energy-environment and greenhouse gas mitigation analysis developed by the Stockholm Environment Institute (SEI, 2006).

The construction of a baseline scenario follows one storyline. Subsequent analyses can then interpret alternative scenarios where activity forecast stay identical but energy intensity improves with the introduction of new technologies or improved energy management encouraged by policies. The scope of this report is the development of a baseline scenario and it is our intention to develop alternative scenarios in subsequent reports.

The following sections describe the decomposition of energy use between drivers and end use energy intensity. For each sector, an equation summarizes the decomposition. Furthermore, Annex 5 to Annex 9 illustrate each equation with historical data (1990 to 2005) and projections (2005 to 2020). Residential and Transport sector were analyzed in a separate report: de la Rue du Can et al., 2008.

2.1.1 Agriculture

Production of food grains was used as the main driver of activity in the agricultural sector and aspects of agricultural practices were used to estimate how energy intensity is susceptible to evolve over time. Energy consumption in the agricultural sector was decomposed into energy use for pumping water per hectare of cultivated land irrigated and energy use for powering farm machinery per hectare of cultivated land. Equation 1 shows the decomposition used:

$$\textbf{Equation 1.}\ E_{Agr} = \sum_k IL \times Pu_k \times IPu_k + L \times Fa_k \times IFa_k$$

where:

k	=	fuel type
IL	=	irrigated arable land
Pu_k	=	number of pumps per irrigated arable land hectare by fuel type (electric or diesel pump) in number per hectare
IPu_k	=	average intensity of energy use per pump type k
L	=	arable land in hectare
Fa_k	=	number of farm tractors per arable land hectare by fuel type in number per hectare
IFa_k	=	average intensity of energy use per tractors type k

The main drivers of agricultural energy use are agricultural production, the quantity of land used and the penetration of material in use, such as pumping set and agricultural machinery. A projection of future production of food grain was based on the Indian government plans and expert estimates and then used to project future irrigated land and machinery penetration.

2.1.2 Commercial Buildings

Energy use in the commercial buildings sector was based on building types and energy use per square meter of floor space.

$$\textbf{Equation 2:}\ E_{CB} = \sum_k^{OPTION} \left(FS_{2005} \times EI_{2005,k} + \sum_s^{OPTION} FS_{new,s} \times EI_{new,k,s} \right)$$

where:

k	=	fuel type
s	=	building Type (Retail, Hotel, Private Office, Government Office, Other)
FS_{2005}	=	total remaining 2005 stock service floor area in m^2
FS_{new}	=	annual new construction of service floor area in building type s in m^2
$EI_{2005\ k}$	=	intensity of energy use per fuel type k of building 2005 stock
$EInew_{k,s}$	=	intensity of energy use per fuel type of new construction of building types

Estimation of existing floor space in use in the commercial floor space was performed based on data available from the economic census (MOSPI, 2008b). Projections of additional floor space were based on extrapolation of construction rates for each building types.

2.1.3 Industry

The industry sector was divided into five energy-intensive industries: iron and steel, aluminum, cement, paper, and ammonia and a category gathering all other industries. Energy demand was decomposed as energy use for the production of physical material in each energy intensive industry and the energy intensities necessary to the production. Hence, physical energy intensities in terms of energy use per tonne (or other unit) of industrial product produced for each industrial sector were used. For the other category, the energy consumption was analyzed using the total value added in the industry sector. Equation 3 summarizes the industry sector decomposition.

Equation 3. $$E_{IN} = \sum_{k}^{OPTION} \left(\sum_{c}^{OPTION} Q_c \times EI_{k,c} + G\ RI_k \right)$$

Where:

k	=	fuel type
c	=	commodity type
Q_c	=	quantity of energy-intensive commodity c produced,
EI_c	=	average intensity for producing energy-intensive industrial commodity c in GJ/metric tonne (or other physical unit),
G	=	Industrial value added GDP, and
$RI_{,k}$	=	average intensity for non energy-intensive industries.

2.2 Primary Energy

National and international statistics generally show energy use in the end use sectors in final energy terms. However final energy does not account for the full energy consumption. One should keep in mind that electricity production requires on average three times its final energy content (de la Rue du Can and Price, 2008). Through out this report energy consumption is displayed using two different accounting methodologies: primary and final energy consumption. Final energy consumption represents the direct amount of energy consumed by end users while primary energy consumption includes final consumption plus the energy that was necessary to produce and deliver electricity. When primary energy consumption in the end use sector is shown, primary electricity is calculated to include all energy use from the electric sector.

In the case of India, the factor that converts final electricity consumption to primary energy is relatively high and was equal to 4.2 in 2005 (Table 1). Hence, consuming one unit of energy from electricity is equal to consuming more than four units of energy at the source of generation. Two reasons explain this large primary energy conversion factor: first electricity distribution and transmission (T&D) technical and commercial losses are substantial, representing 31% of electricity production in 2004 (CEA, 2006) and second electricity is generated for a large part (82%) with the use of fuel combustion with low efficiency (26% for coal, 28% for oil and 41% for gas). Indian T&D losses are among the highest in the world. Only about 50% of the electricity in India is billed on the basis of metered consumption. Balance between metered accounts and total net electricity is met by including the consumption from un-metered agricultural customers and transmission and distribution losses. T&D losses include technical loses and commercial loses that are theft of electricity. However, the primary electricity factor calculated in this report excludes commercial losses from the residential sector as it is based on residential survey data rather than metered consumption. . Hence the T&D calculated for 2005 are in the order of 20% of the electricity generated, a lower rate than the 31% estimated by the Central Electricity Authority of India (CEA, 2006).

In this report, the ‘‘direct equivalent’’ accounting method is used similar to the methodology used in the *Special Report on Emissions Scenarios* (SRES) (Nakicenovic et al., 2000; de la Rue du Can and Price, 2008). This method accounts for the primary energy of the non fossil-fuel energy at the level of secondary energy with an efficiency of 100%. For example, the primary energy equivalence of electricity generated from hydro or nuclear power plants is set equal to their respective gross electricity output.

Table 1. Electricity Primary Factor (PJ)

	1990	2005
Fuel input	**2,709**	**6,969**
coal	*2,191*	*5,919*
gas	*126*	*412*
oil	*112*	*210*
nuclear	*22*	*63*
hydro	*258*	*365*
Energy output	**952**	**2,249**
Own Uses	81	157
Transmission and distribution losses	204	439
Electricity delivered	**682**	**1,654**
Primary factor	3.97	4.22

Note: Based on the IPCC methodology accounting 100% for all non fossil fuel (Nuclear, Hydro and Renewables) (de la Rue du Can and Price, 2008)

2.3 Data Issues

2.3.1 Source

Reliable and accurate data are critical to good analysis supporting policy and business. India’s official data does provide information on supply side. Energy data collection is carried out mainly through individual fuel-based energy administrations: the Ministry of Petroleum and Natural Gas collects and processes data on oil and petroleum products (MOG, 2006); the Central Electricity Authority is mandated by the Ministry of Power to handle electricity data (CEA, 2006); the Ministry of Coal monitors coal information (MOC, 2006); the Ministry of Non-Conventional Energy Sources surveys data on renewable energy production; the Ministry of Statistics and Programme Implementation published a condensed version of statics related to energy production and consumption (MOSPI, 2007a). However, data are mostly related to the supply side; consumption statistics are not available for all sectors, notably the commercial sector. TERI (TERI, 2006), an independent Indian energy research group, publishes information on sectors and individual enterprises in greater detail than national Ministries. The Bureau of Energy Efficiency (BEE, 2007) is a statutory body under Ministry of Power whose mission is to institutionalize energy conservation throughout the economy of India. The BEE website provides valuable information on energy conservation schemes and industry performance.

The Central Statistical Organization (CSO) in the Ministry of Statistics & Programme Implementation in the Government of India (MOSPI) is the nodal agency for coordination of statistical activities and maintenance of statistical standards with the Central Ministries and Departments (Swaraj Kumar Nath, 2005). MOSPI also conducts detailed surveys on household energy consumption.

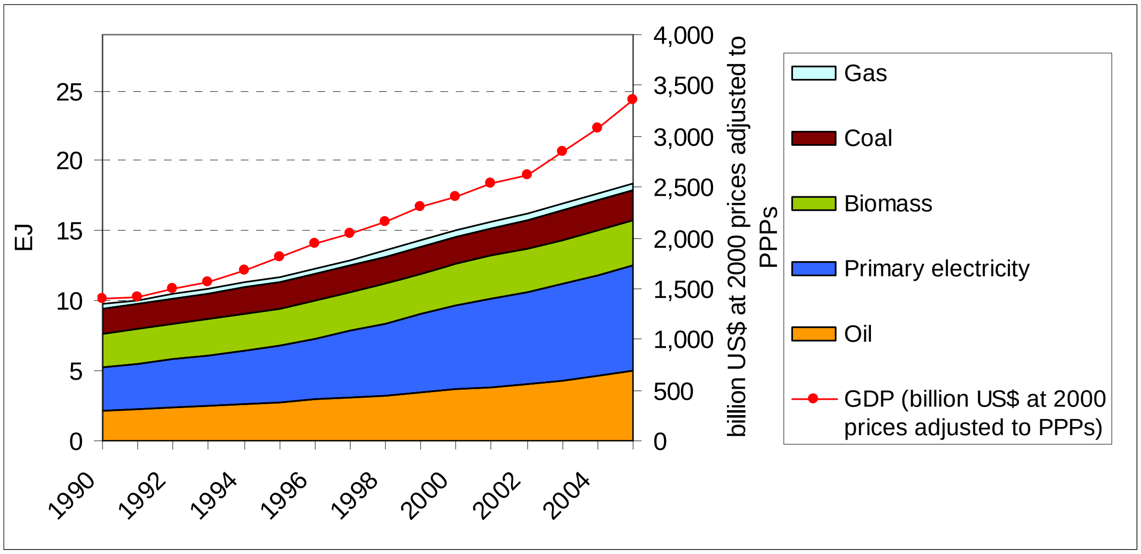
2.3.2 Top Down and Bottom Up data Comparison

A comprehensive report on India's sectoral energy use is a challenging task. Energy is available through various types of products; it is often transformed to more refined products, and it is finally consumed to operate a multitude of activities. Energy is a necessary input to any type of activity in the economy. Accounting for the chain of energy flow requires a thoughtful analysis. Of the different forms of energy used in an economy, biomass energy consumption is certainly the most difficult to quantify. The consumption of biomass by households in rural areas doesn't usually go through commercial distribution networks, but is collected from neighboring wooded areas. Fuel adulteration is another issue making national statistics not fully representative of the true energy consumption of the transport consumption. Even electricity consumption, which is generally accurately monitored, is hard to identify in India, due to theft through either circumventing or tampering with meters to avoid registration or due to non-metering of agricultural and other customers. Through this report, a section for each sector explains adjustment or assessment of consumption level based on a bottom up approach.

3. Energy Use in India

Overall trends in total primary energy consumption show a decoupling of the energy consumption with increasing GDP. Over the period 1990 to 2005, GDP multiplied by 2.3 while energy consumption multiplied by 1.8. Figure 1 shows the trend in total primary energy consumption over that period and the growth in GDP. However, little can be said from this level of data on the cause of energy intensity reduction.

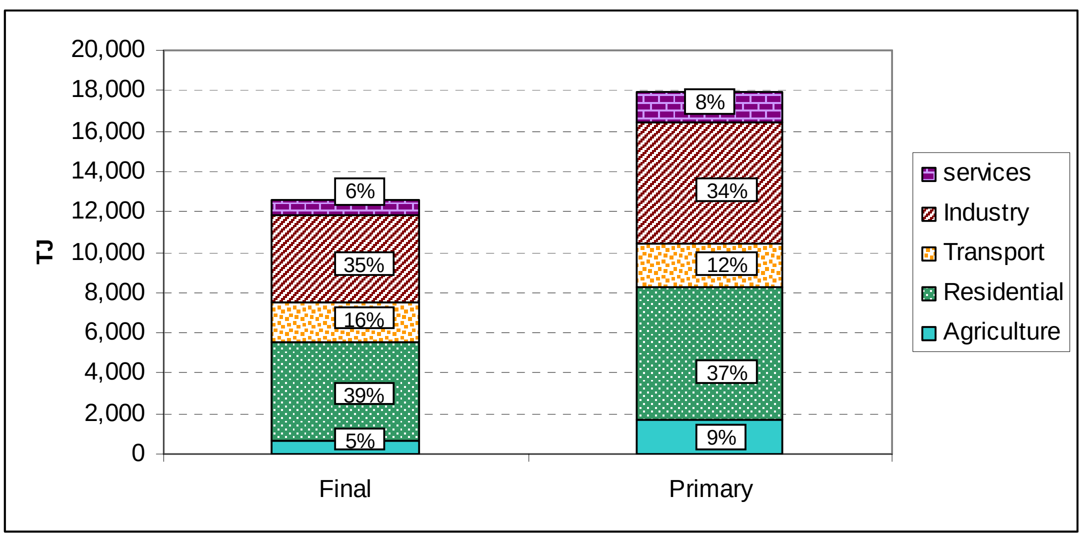
Figure 1. India Primary Energy Supply by fuel type



Note: energy use for electricity generation is included in primary electricity

Figure 2 shows the primary energy use by sector in 2005. The industry and residential sectors are the largest energy users, but use significantly different fuel types. The residential sector is characterized by a large share of biomass energy use representing 50% of primary energy use, followed with primary electricity[1] representing 35%. Conversely, little biomass is used in the industry sector and primary electricity represents the largest source of energy use with a share of 42%, followed by coal representing 32%. Natural gas only represents 8% in the industry sector and less than 1% in the residential sector. Energy used for transport represents 11%, with oil representing 90% of the energy use in this sector. The agriculture sector represents 9% of total primary energy use, with primary electricity representing 80% and finally the commercial sector represents 8% with primary electricity representing 63% and oil consumption representing the rest.

Figure 2. Final and Primary Energy (including biomass) by Sector



[1] Primary electricity is equal to the electricity consumed directly and the indirect energy use that was necessary to produce the electricity.

India's economy encompasses traditional farming and small scale enterprises, as well as highly modern industries and high-tech software companies. Since the early 1990s, government controls have been reduced on foreign trade and investment, and privatization of domestic output has proceeded gradually. The economy has been growing at an average rate of 6.0% annually over the last 15 years (1990-2005) and 6.9% over the last 5 years (2000-2005).

The composition of India's economy consists to a large degree of the service sector. As shown in Table 2, the service sector accounts for more than half of India's GDP, with 54% in 2005-06 (MOSPI, 2007b) and is also the most rapidly growing sector, with an annual average growth rate of 8.5% over the period 2000 to 2005. This sector and the industrial sector have gained at the expense of the agricultural sector during the last 5 year period.

Table 2. Gross Domestic Product by Economic Activity, 2005-06

	GDP (billion 1999 US$)	Share of GDP	AAGR 2000-05
Agriculture, Forestry & Fishing	**118.95**	**20%**	**2.8%**
Industry	**158.64**	**26%**	**7.3%**
Mining & quarrying	12.57	2%	4.9%
Manufacturing	91.50	17%	6.7%
Elect. Gas & Water supply	13.33	2%	5.1%
Construction	41.24	5%	10.4%
Services	**327.34**	**54%**	**8.5%**
Trade (Wholesale and Retail), Hotels & Restaurant	94.05	16%	8.7%
Transport, Storage & Communication	63.95	10%	13.2%
Financing, Insurance, Real Estate & Business services	83.27	13%	8.1%
Community, Social & Personal Services	86.07	13%	5.8%

Source: MOSPI, 2007b. Note: AAGR: Average Annual Growth Rate

The large share of the service sector's share in GDP is uncommon for a country still at an early stage of development. The share of the unorganized sector in the overall economy represents more than half the Net Domestic Product (59%) and constitutes about 93% of the total workforce of the country (NSSO, 2001c, see

Annex 1). The unorganized sector in the Indian national account statistics includes enterprises whose activities are not tracked by a regulated data collection system but assessed through occasional surveys.

The industrial sector has grown rapidly throughout the 1990s, at an annual average rate of 5.9% and has even accelerated during the last 5 years (2000- 2005) reaching an average rate of 7.3% (MOSPI, 2007b). Agriculture's share in India's GDP was 20% in 2005-06 having declined in previous years, marking a structural shift in the composition of GDP. Agriculture's share in India's GDP was equal to 25% in 1999-00. This sector has increased at an average annual rate of 2.3% during the last 5 years.

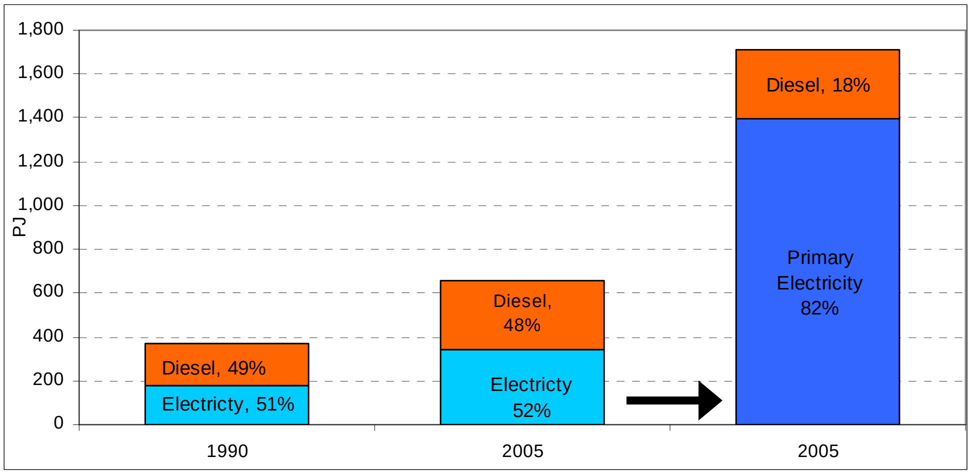
3.1 The Agriculture Sector

Agriculture is a key sector in India that employs two-thirds of the country's work force and continues to be a significant contributor to the GDP, 20% in 2005 (MOSPI, 2007b). Even though agriculture's share in total GDP has decreased over time compared to industry and services, agricultural value added is still increasing. Its growth rate was 2.8% over the last 5 years (2000-2005). After the independence in 1947, India's government put in place several policy and program initiatives to encourage the extension of cultivated area. This period was followed by the "green revolution", from 1965 to 1975, during which cultivated area continued to expand but at a much slower pace while productivity increased greatly. This has allowed India to pass from a food-deficient status to one of the world's leading agricultural nations. Indian arable land surface is the second largest in the world, after the US, representing 20% of the world's arable land (FAO, 2007a). Food grain[2] production has increased rapidly since 1950, at a rate of 2.7% annually to reach 208 Mt in 2005 (MOA, 2006). India is the second largest wheat and rice producer after China, with 68 Mt and 132 Mt respectively. Rice accounts for 44% of the total food-grain production and wheat accounts for about 36% (MOSPI, 2006).

Agricultural practices in India are still at a low level of mechanization. Sales of tractors have increased rapidly over the past decades however. The largest need of energy services is for water pumping for irrigation and to some extent power for farm machinery such as threshers and tractors. Final energy consumption in the agricultural sector was 659 PJ in 2005 (Figure 3), representing 5% of total final energy consumption. Energy consumption increased rapidly after the introduction of policies encouraging food grain production. The figure also shows energy use in primary energy terms for the year 2005. Primary electricity represents a considerably larger share of energy use than final electricity, of 82%. Electricity is a major input to the agricultural activity in India. It accounts for more than half of the final energy consumption in the sector and accounts for 22% of all final electricity consumed in India in 2004 (CEA, 2006). In rural areas, pump sets are installed to provide irrigation facilities for agriculture. As of March 2008, 15.4 million pump set had been installed (CEA, 2008).

[2] Foodgrains include Cereals and Pulses and represents 66% of total cropped area.

Figure 3. Energy Consumption in the Agriculture Sector (PJ)

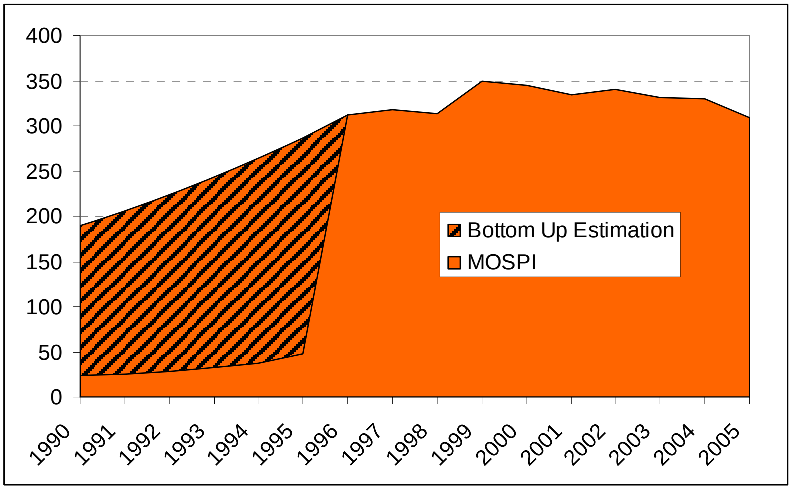


3.1.1 Data Adjustment

Electricity consumption from farmers is un-metered and billing is instead based on the water pump's horsepower rating. Hence, the exact consumption by the agriculture sector is unknown. Meters are increasingly installed on the transformers serving mainly these customers to allow better estimation of sales to agriculture. In this report, electricity consumption is based on a bottom up approach and compared with official estimates.

Data on electricity consumption are available from the Centrally Electricity Authority (CEA, 2006) and show an increase of agricultural electricity consumption of 9% annually over the period 1971 to 2004. The second major fuel used is high speed diesel oil, for which (HSDO) consumption and data are available from the Ministry of Implementation and Program Implementation (MOSPI, 2006). However, a large discontinuity in the time series is observed in 1996. Therefore, diesel consumption for the period 1990 to 1996 was estimated based on the activity data collected at the end use level. Figure 4 shows HSDO consumption between 1990 and 2005 with adjustment of data based on the bottom up estimations.

Figure 4. HSDO Diesel Consumption



3.1.2 End Use Analyses

3.1.2.1 Irrigation

India has a large variety of climatic regions, ranging from tropical monsoon in the south to temperate and cold in the north and from dry in the west to humid subtropical in the east. Having only one rainy season a year in much of the country generally permits a single annual harvest. However, the green revolution introduced the practice of double cropping, encouraged by massive public investments in public irrigation. The percentage of land irrigated increased from 17% of total gross crop area in the 1950s to 48% in 2003 (NSSO, 2005a). The green revolution also encouraged use of high yielding varieties of two staple cereals (rice and wheat), and the use of fertilizer and pesticides.

Irrigation is an energy intensive process as it requires uploading and moving around water. Two different types of irrigation exist in India - surface water irrigation that provides water from canals and tanks and ground water irrigation that provides water from wells. Canals and tube wells represent the largest irrigation system with 34% and 32% of total irrigated land respectively, wells 28%, and tanks 6% (MOA, 2004). The use of privately owned tube wells increased drastically since 1947, from about 1000 in 1947 to about 20 million today (Kelkar, 2006). In terms of fuel use, the vast majority of pumps use electricity. There are reportedly more than 15 million electric and 6 million diesel irrigation pump sets in operation (Purohit, 2006). Pumps operated with electricity are generally preferred, due to convenience of use and the low subsidized price of electricity. The capacity of pump sets with electric motors is typically 3.7 kW, and it is 5.2 kW for diesel engines (Singh G., 1999). Operating hours are highly variable and difficult to monitor, hence we used an estimation of operating hours of 1,600 hours a year (McNeil, 2005). Using capacity and hours of use, we estimated electricity consumption (Table 3), which corresponds very closely to the total electricity use reported by the CEA (0.3% difference).

Table 3. Electric and Diesel Pump Characteristics and Estimates for 2004

	Electric Pump	Diesel Pump	Solar Pump
Pu_k[3]: Pump Energy Intensity (PJ/unit)	21.3	23.9	10
Energy Consumption (estimates)	88,800 GWh (319 PJ)	120 PJ	19 GWh (0.07PJ)
Number Installed (Million)	15.00	6.0	0.007
UEC (kWh/unit) (estimates)	5,904	6,638	2674
Capacity (kW)	3.7	5.2	3.3
Operating hours (h/year)	1,600	1,276	798

It is expected that the share of electric pumps will increase with increasing electrification level. By assuming that the number of operating hours of diesel pump is 20% less due to higher price of diesel, we found that approximately 44% of diesel consumption was used for irrigation. This hypothesis is consistent with another analysis (Singh G., 2006) that estimates the share of diesel consumed for pumping to be around 40%. Table 3 summarizes the characteristics and estimations made to represent energy consumption at the equipment level. The ministry of New and Renewable Energy (MNRE, 2008) has

[3] Ref to Equation 1 and Annex 5

been implementing a program on solar photovoltaic water pumping systems since 1993-94. About 7,000 pump set were installed with a capacity averaging 2 HP (3 kW). This represents an estimated total energy consumption of 19 GWh (0.07PJ), i.e. 0.02% of energy used for pumping.

3.1.2.2 Farm machinery

Farm machinery, specifically tractors, is by far the greatest consumer of fuel in field operations. The mechanization of farming has increased rapidly in India. The number of tractors increased from 0.1 million in 1971 to 2.7 million in 2004 while the number of draft animals has slightly declined, from 78 million to 71 millions (FAOa, 2007; Singh G., 1999). The concentration of tractors is 15.8 per thousand hectared (Table 4). However, a majority of farmer households are still reporting using animal power for plowing (53%) and about 47% used diesel tractors. Among those using non-human energy for harvesting, 59% used diesel-powered machines (NSSO, 2005a). India has produced tractors locally since 1961. In 2000, sales of tractors represented 254,825 units (IASRI, 2007) and have more than tripled since 1986. The most popular tractors range from 15 to 30kW, which correspond to relatively small tractors. Table 4 summarizes some of the characteristics and estimations that were made to calculate the energy intensity for farm machineries.

Table 4. Tractors Characteristics in 2004

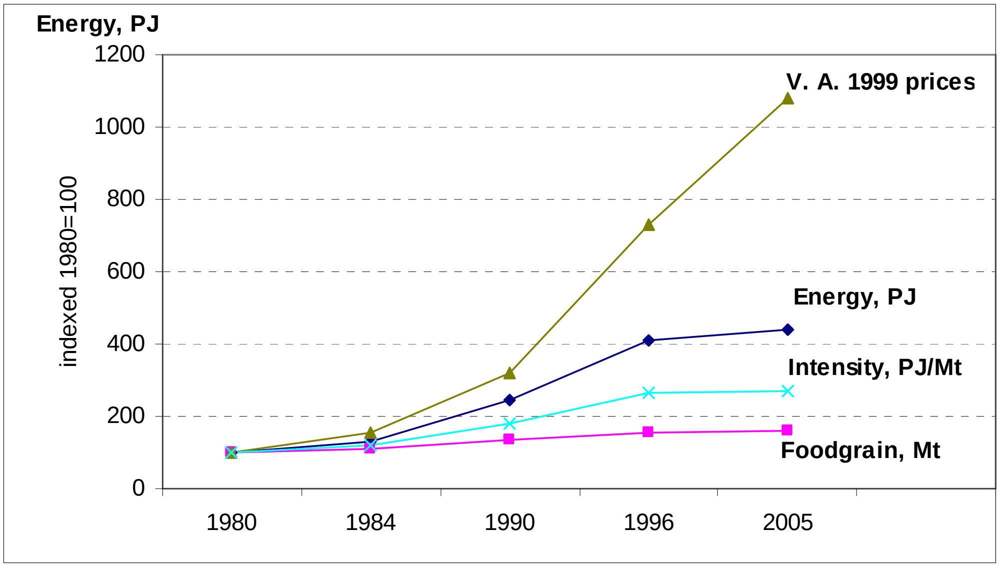
Tractors (Million)	2.7
Diffusion (tractor/kha)	15.8
Intensity (GJ/unit)	66
Intensity (kWh/unit)	18,426
Capacity (kW)	23
operating hours (h/year)	801

3.1.3 Drivers

Historically, energy consumption increased tremendously during the green revolution. The marginal energy requirement to produce an additional tonne of food grains was much higher than the existing requirement. Hence, from 1980 to 2000, energy consumption in the agricultural sector climbed at an average of 7.7% while food grains produced increased only at an average of 2.2%. However, value added from the agriculture sector increased rapidly, at an average rate of 12% per year (Figure 5). Since 2000, food grains production continued to increase but at a slower pace (1.9%), and energy demand has declined by 0.5% over the last 4 years (2000-2004).

Figure 5. Trends in Food Grains Production, Agricultural Value Added and Energy Consumption

(Foodgrains in Mt, Intensity defined as energy use per tonne of foodgrain produced in MJ/t, Energy in PJ and Value Added (VA) at 1999 prices)



Source: MOSPI 2007a, 2007b; MOA, 2008.
Note: Consumption of diesel was back calculated before 1996 because of a major break in the series.

Production of food grains in India is the main driver of energy consumption in the agricultural sector. However, aspects of agricultural practices also play a significant role in the energy consumption requirement. First, the limit in land resource and rainfall imply that additional production needs to be met with increasing yield and increasing irrigation rather than expansion of arable land. Second, India does not yet have a fully mechanized agriculture as developed countries do. Human and animal labors still constitute major production factors (Singh G, 2006; Singh J. 2006; Srivastava, 2006). Continuous mechanization will increase the demand for energy. Table 5 shows some characteristics in two different countries, China and the US, that have similar arable land surface but different practices and energy consumption, as well as different levels of economic development.

Table 5. Agricultural Characteristics Country Comparison, 2004

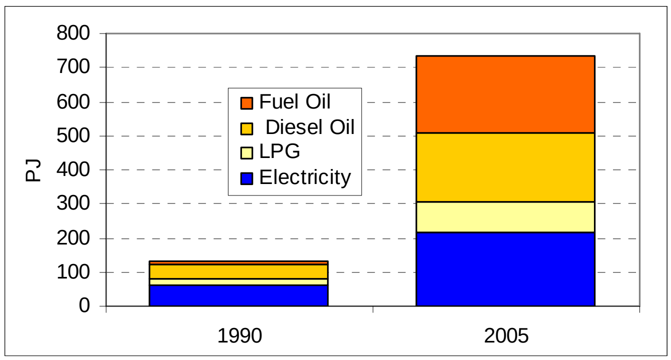
	China	India	USA
Country area (Mha)	956	328	963
Arable land(Mha)	141	160	174
Total area equipped for irrigation (Mha)	54	54	22
Cereal Production (Mt)	413	233	389
Total Energy (PJ)	1,806	609	861
Electricity (% of total energy)	16%	52%	17%
Intensity Energy per food grain, MJ/t	4.5	2.9	2.9

Source: FAO, 2007; NBSC, 2007

3.2 The Service Sector

The service sector[4] covers a wide range of activities from the most sophisticated in the field of information and communication technology to simple services such as repair and small retail shops. This sector also tends to include a large share of the unorganized sector. Even though the service sector in India represents the largest share of GDP (54%), the energy consumption in this sector represents a very small share (6%) of the total final energy consumption in India and 8% of primary energy use. Final energy use in the service sector was equal to 736 PJ in 2005 (Figure 6), about 6 times less than the industrial sector. However, energy consumption is growing very rapidly, at an annual average rate of 12% over the period 1990 to 2005. A large share of fuel and diesel oil is used in on-site generators to provide electricity during grid electricity shortages.

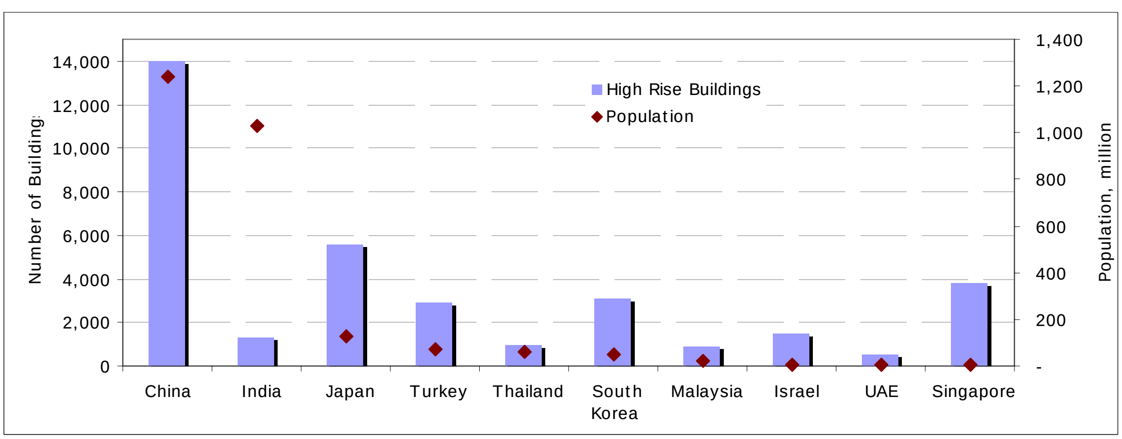
Figure 6. Energy Consumption in the Service Sector



Source: CEA, 2006; MOSPI, 2008a.

Figure 7 shows some statistics on the number of high-rise buildings in the most active Asian cities collected by Emporis (2007). India has relatively few high-rise buildings compared to its number of inhabitants, which leads one to believe in high growth potential in building construction with continuing economic development.

Figure 7. High Rise Buildings and Population in the Most Active Asian Cities



Source: Emporis, 2007; Note: High-rise buildings are those taller than 20 m (68 feet)

[4] Wholesale trade; retail trade; restaurants & hotels; transport & storage; post & telecommunication; financial intermediation; real estate, renting & business services; public administration & defense, compulsory social security; education; health and social work; and other community, social & personal services.

3.2.1 Data source

Little information is available on how energy is consumed in the service sector in India. In *Energy Statistics* (MOSPI, 2008, a). quantities of fuel oil and diesel oil use are reported under the categaory "Miscealleneous Services". No further detail could be obtained to determine what the exact uses of these fuels are. Hence, we have considered this consumption as part of the service sector but future work will determine with more certitude the end-use consumption of these fuels.

Concerning activity, the Government of India conducts on occasional economic census that provides a comprehensive count of all entrepreneurial units in India. The last economic census was conducted in 2005 and covers all the establishments in non-agricultural activities. Table 6 shows the main results from the economic census concerning the service sector. About 35 million enterprises are engaged in non-agricultural activities, which is 30% higher than in the last census conducted in 1998. Establishments engaged in service activities represented 73% of the total non-agricultural enterprises. About 4.8 million enterprises (17%) did not have any premises for carrying out their activity. Retail trade represents by far the largest number of service enterprises, with a share of 40% of all establishments. It is also important to note that the service sector in India comprises a large number of household enterprises for which no complete and regular sets of accounts are available.

Table 6. Number of Enterprises and Employment by Economic Activity

	Own account Enterprises			Establishments		Total	
	Number	With premises	Employee/ enterprise	Number	Employee/ establishment	Number	Total Employment.
Wholesale trade	470	316	1.2	382	4.03	852	2,105
Retail trade	10,566	8,252	1.2	4,387	2.84	14,953	25,139
Restaurants & hotels	832	725	1.4	660	3.97	1,492	3,784
Transport & Storage	1,088	188	1.1	425	4.09	1,513	2,935
Post & telecommunication	429	413	1.1	268	3.77	697	1,484
Financial intermediation	100	63	1.5	193	7.75	292	1,642
Real estate, renting , business services	539	422	1.2	476	4.48	1,015	2,780
Public adm. & defense; compulsory social security	45	41	1.6	528	10.94	573	5,852
Education	199	159	1.4	1,242	5.80	1,441	7,484
Health and social work	311	307	1.2	469	4.85	780	2,650
Other community, social & personal services	1,554	1,251	1.3	1,072	2.73	2,626	4,947
Other	888	134	1.8	878	4.41	1,766	5,470
Total	17,020	12,272		10,982		28,001	66,271

Source: MOSPI, 2008b, "*Economic Census, 2005*".

Note: Own account Enterprise (OAE) is an enterprise normally run by members of the household without hiring any worker on a fairly regular basis. Establishment is an enterprise run by employing at least one hired worker on a fairly regular basis.

3.2.2 Main Activity Sectors

The national account statistics report that about 57% of the service sector falls into the unorganized sector (MOSPI, 2007b). The unorganized sector refers to enterprises whose activities or collection of data are not regulated under any legal provision.
Table **7** shows the share of each service activity in total service value added as well as the share of the unorganized sector.

The service sector is the largest contributor to India's economy, representing 54% of GDP in 2005, and is also the most rapidly growing economic sector, with 8.5% over the period 2000-2005. Within the service sector, retail trade and community, social and personal services are by far the largest contributors to the service sector value added each having a similar share of 26%. However, it is the sector of communications which shows the highest growth with a staggering average annual growth of 23.5% over the period 2000-2005. Transport by other means, banking & insurance, and retail trade sectors all have higher growth than the overall sector average.

Table 7. Share of the Unorganized Segment in each Service Sub-Sector (As share of net domestic product, 2004-05)

	Share of Services Value Added, 2005	Share of unorganized Segment	AAGR 2000-2005
Total Services	100%	57%	8.5%
Retail trade	26%	82%	8.7%
Hotels & restaurants	2%	70%	8.0%
Railways	2%	0%	6.5%
Transport by other means	10%	81%	9.5%
Storage	0%	46%	3.2%
Communication	7%	43%	23.5%
Banking & insurance	11%	11%	9.0%
Real estate, & business services	14%	71%	7.4%
Community, social & personal services	26%	46%	5.8%

Source: MOSPI, National Accounts Statistics 2007b.

3.2.2.1 Retail Space

During the 2005 economic census, there were about 15 millions retail outlets, 55% of which were own account enterprises, run by household members without hiring any worker on a fairly regular basis. The retail sector in India is witnessing a radical transformation. Small stores and street markets are being replaced by larger and more organized structures, such as shopping centers. This sector is expected to continue to grow rapidly over the next 15 years, driven by the increasing share of the middle class population and its disposable income. Since 2006 the government has allowed direct foreign investment in retailing, with 51% participation (Deutsche Bank, 2006). Shopping centers have only been built in the last few years, starting in the major cities. There are currently around 100 shopping centers in India (Deutshe Bank, 2006) and about 220 new ones are under construction (Ernst & Young, 2006). In term of energy use, shopping centers use a large quantity of energy to cool and light the commercial space.

3.2.2.2 Office Space

In the past few years, software and call-center companies have underpinned demand for commercial property in India. The entire country has a little more than 6.5 million m^2, of A-grade office space, less than Shanghai and Beijing put together (International Herald Tribune, 2006). Grade A Office consists of buildings with central air conditioning and 100% power backup. The demand for this type of offices has increased fast, with around 4.3 million m^2 in 2006 and is expected to grow to 5.2 million m^2 in 2007 (Deutshe Bank, 2006).

3.2.2.3 Hotel

The number of foreign visitors in the country in 2006 was around 4.4 million resulting in international tourism receipts of US$ 7.2 billion (Ministry of Tourism, 2006). With continued business and tourism interest, the hotel industry is expected to show growth rates in excess of 8% per annum. Total numbers of rooms are estimated to be around 109,000 in 2006 and have increased at an average of 3% over the period 2002 to 2006 (FHRAI, 2007). Among the different category of hotels, five-star deluxe grew rapidly, at a rate of 6% over the same period. HVS, a global consulting group focusing on hotel and leisure industries, is tracking new supply of rooms closely each year, and estimates that about 22,400 rooms are being developed or planed to be developed in the near future (HVS, 2006). The biggest growth in proposed supply is being witnessed in the two information technology cities of Hyderabad and Bangalore, with 5 and 4 times the current supply respectively.

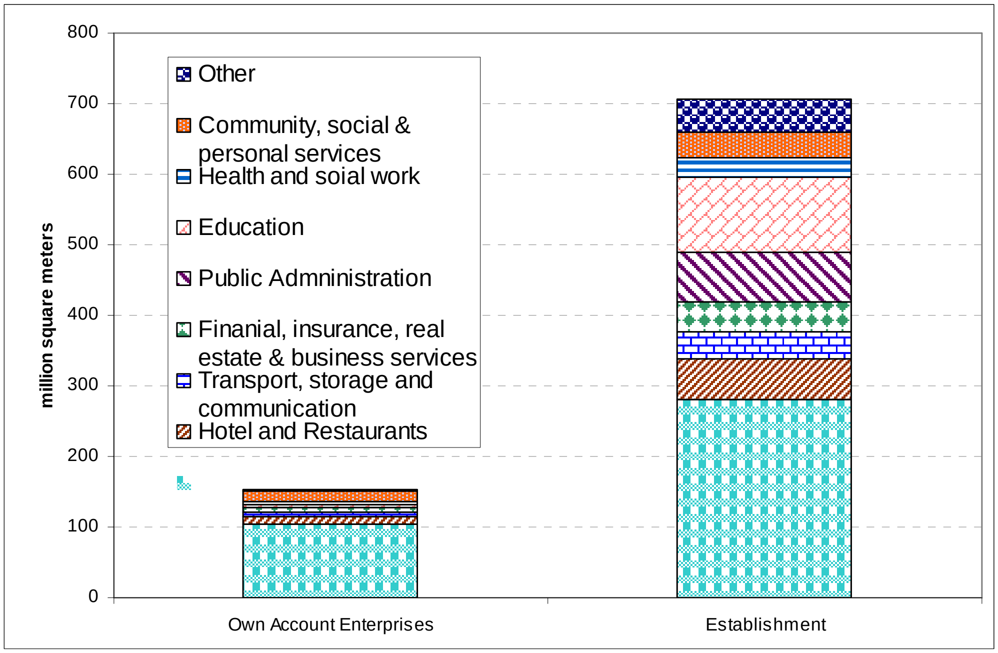
3.2.2.4 Drivers of Energy use in the Service sector

Consumers do not demand energy per se, but the services that energy provides. In the commercial sector, the key energy services are lighting, office equipment and cooling. The energy intensity of usage differs across service and building types. For example, in the US, health care facilities require about 6 times more energy per square foot than warehouses (U.S. DOE, 2006). Therefore, service sector energy consumption patterns depend upon numerous factors, including the type of activity, regional climate (Annex 4), and equipment stock.

Data on the number of enterprises by economic activity, the type of ownership and employment (Table 6) were used to estimate the total floor space used in the service sector as in 2005. Figure 8 shows the estimates of the building stock in 2005 per building type. In order to estimate total floor space used, we used estimates of floor space per employee, by building and ownership type based on expert judgments (see

Annex 2).

Figure 8. Estimates of Floor Space by Economic Activity (2005)



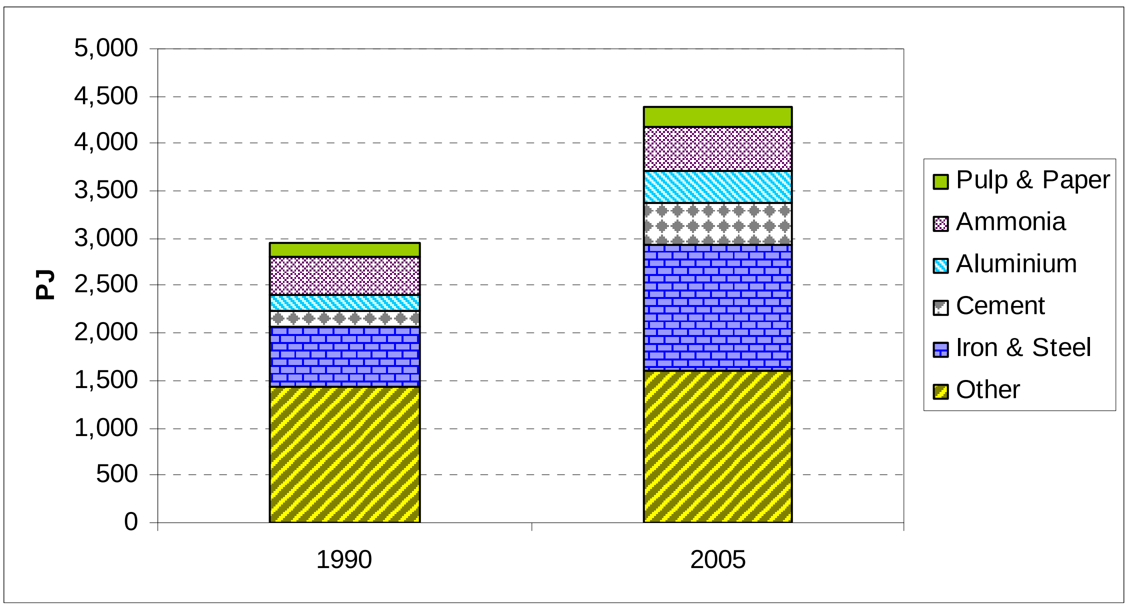
In 2005, the service sector was composed of about 28 million enterprises, of which 60% were own account enterprises. Of these, about 27% did not have any premises. The resulting total space used in the service sector in India in 2005 was estimated to be 860 million m^2. By far, the large use of floor space is used for retail and wholesale activities, as well as for public administration, community, social & personal services. Figure 8 shows the results of floor space by building types.

With total electricity consumption in 2005 of 216 PJ, the average floor electricity intensity is equal to 251 MJ/m^2 (69 kWh/m^2). This is low compared to developed countries. In the US, the average electricity intensity is equal to 634 MJ/m^2 (176 kWh/m^2) in 2003. If the diesel and fuel oil consumption are included, the total average energy intensity is equal to 856 MJ/m^2 (237 kWh/m^2). In the US, total average energy intensity is equal to 1,252 MJ/m^2 in 2004 (US DOE, 2006) but includes a relative large share of fuel used for space heating. If only the South region is considered, the intensity is equal to 941 MJ/m^2 (U.S. EIA, 2003). However, another major difference between the two regions is the use of back up generators that are often used in India to supplement shortages of electricity from the grid.

3.3 The Industry Sector

The industry sector in India consumed 4,525 PJ in 2005, including energy use in captive power plants, representing the second largest share of final energy consumption (36%) after the residential sector. In terms of primary energy, the share of the industrial sector is also 36%. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials, and manufacture finished products. The industrial sector can be broadly defined as consisting of energy-intensive industries (e.g. iron and steel, chemicals, petroleum refining, cement, aluminium, pulp and paper) and light industries (e.g. food processing, textiles, wood products, printing and publishing, and metal processing). The energy intensive industries represented 63% of the total energy consumed in the sector in 2005 (Figure 9). Modern industry has advanced fairly rapidly since India's independence in 1947, and the industrial sector contributed 26% of the GDP in 2005 (MOSPI, 2007b). Industrial value added grew at an annual average rate of 5.6% in the 1990s and 7.0% during the last 5 years (2000 to 2005). Total industrial primary energy consumption increased at a slower rate of 3% over the period 1994-2004, reflecting a decoupling in the relation of value added – energy consumption. This trend can be observed since the mid-1980s. Energy use in the intensive industry increased sharply between 1990 and 2005 while that in the rest of the industry remained virtually unchanged (Figure 9).

Figure 9. Industrial Final Energy Use by Sub-sector

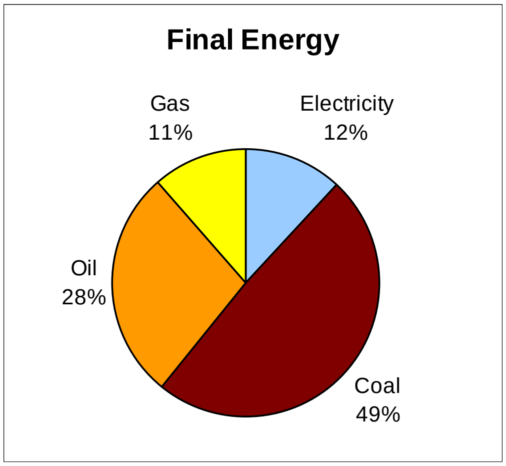


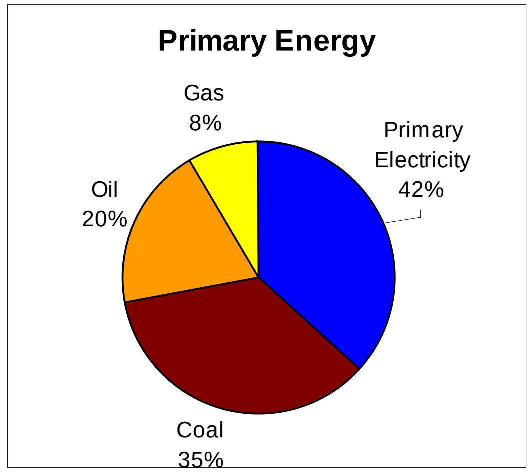
3.3.1 Data Source and Adjustment

3.3.1.1 Source

The primary source of energy data was the Ministry of Statistics and Programme Implementation (MOSPI, 2007a). Detail by sectors were also gathered from several Ministries such as MOG (2006), MOC (2006), CEA (2007), and TERI (TERI, 2006). Data for each energy intensive industry were compiled individually. For some industries, such as aluminium, data at the plant level were gathered from company's annual reports. For cement and ammonia, a previous LBNL study was used (Sathaye et al, 2005). No biomass use is reported in India's national statistics for this sector, and according to the last survey on small scale industries (MOSSI, 2004) the percentage of small scale industries (SSI) that used biomass was less than 3%. Figure 10 shows the fuel share for final and primary energy consumption in industry in 2004 according to LBNL compilation of data. As shown in Figure 10, coal represents the largest energy product consumed in industry (48%). The remaining energy consumed comprises of petroleum products with a share of 28%, electricity (13%), and natural gas (11%). When primary energy for electricity bought from the grid is accounted in the total, primary electricity accounts for 42%, while the share of coal accounts for 35%.

Figure 10. Final and Primary Energy Consumption in the Industry Sector, 2005





Note: includes feedstock

3.3.1.2 India Industry Characteristics

About 33% of the industrial value added is attributed to small enterprises with less than 10 people, for which no data are consistently collected. Manufacturing activities are classified into two sectors 'registered' and 'unregistered'. The registered sector represents 66% of total manufacturing value added in 2003-04 and includes all factories employing 10 or more workers using power and those employing 20 or more workers but not using power (CSO, 2007). The unregistered sector consists of the remaining manufacturing units. The main source of data pertaining to the registered sector is the Annual Survey of Industries (ASI), while the data on unregistered sector are collected mainly through periodic sample surveys conducted by NSSO through the economic census and also censuses conducted by the ministry of SSI.

3.3.2 Energy Intensive Industry

For the energy intensive industry we constructed a set of physical energy intensity indicators describing energy use per tonne of industrial product. Theses indicators show the level of technology advancement in term of energy efficiency. Data on activity variable such as tonne of material produced were taken from the UN Commodities database (UN, 2005).

Recent trends show a steady decline of energy per unit of tonne produced in the industrial sector since the mid 1990's.

Table 8 shows estimates of specific energy consumption for three energy intensive industries in India and compares it with some key countries. However, opportunities to reduce energy intensity still exist. While selected modern Indian units often display very high efficiency that approaches world best practice levels, the average intensity lags world best levels.

Table 8. Final Energy Intensity (GJ per Tonne)

	India 1990	India 2005	EU 15 2002	Japan 2004	China 2001	US 2002
Crude Steel	42	28.3	17.8	23.3	25.6	20.1
Cement	3.61	3.06	3.7	4.3	6.0	5.8
Ammonia	55	43	35.5	-	41.7	37.1

An exact comparison between countries specific energy consumption would need to be adjusted for the country specific product and technology mix. For example, the recycling rate for steel scrap exceeds 60% in the US and 50% in the EU, which explains the lower energy requirement. In India the recycling rate for steel scrap is in the order of 5%.

3.3.2.1 Steel

The iron and steel sector is divided in two segments, the integrated steel plants (ISP) representing more than 60% of the finshed steel produced abnd numerous medium sized and small companies. India produced 5% of the world steel production and ranks at the 6th position in 2006 (IISI, 2007a). Production is growing very rapidly, by an annual average of 7% over the last 5 years.

Specific final energy consumption in India has decreased considerably over the last 20 years. While in the 1980s final energy consumption had been on average 45 GJ/tcs (excluding energy used for coke making), in the early 1990s it had already declined to around 35 GJ/tcs (Schumacher and Sathaye, 1998) and has since further decreased to an estimated 28.3 GJ/t in 2005 based on data collected at the plant level and estimations. (Table 9).

The Indian steel industry is slowly shifting from the Blast Furnace (BF) - Oxygen Blown Converters (OBC) route to Direct Reduction (DR) - Electric Furnace (EAF) route. Production of sponge iron (through DR) has grown very rapidly over the last 15 years, from 0.6 Mt in 1990 to 16.9 Mt in 2006, representing 35% of production in 2006. India is the largest worldwide producer of sponge iron.

Table 9. Production of finished Steel in 2006 and Estimated Specific Energy Consumption (SEC)

	Production (Mt)	SEC (GJ/t)
ISP (Oxygen route)	25.4	32.0
ISP DRI nat gas-EAF	5.8	19.0
ISP DRI coal-EAF	4.1	21.4
Smaller DRI coal	13.0	31.2
Smaller Scrap-EF	3.5	3.5
Smaller BF-OBC	0.7	35.9
Total	52.5	28.3

Source: MOS, 2008 and own estimates

In India, coal represents the bulk of the energy use in the iron and steel production, with a share of 77%. Even though India is able to satisfy most of its country's coal demand through domestic production, less than 5% of its reserve is coking coal used by the steel industry. As a result, the steel industry imports around 70% of coking coal annually.

More recently, three large plants have been producing sponge iron with gas based DR. Electricity is an important input of the EAF/Induction furnaces process and is sometimes produced on site with coal or furnace oil steam turbine or small generators during power outages.

The ratio of iron to crude steel is 96% (IISI, 2007b) indicating that most of the steel produced is based on iron and very little is based on recycled material.

Steelmaking is followed by casting and shaping. Ingot casting is the classical process and is rapidly being replaced by more energy efficient, continuous casting processes (Kim and Worrell, 2002). The degree of penetration of continuous casting processes increased from 12 % in 1990 to 66% in 2005 (IISI, 2007b). Even if opportunities to save energy in this sector remain, the penetration of more energy efficient technology has considerably reduced the energy consumption from this sector over the last 15 years.

3.3.2.2 Cement

India is the second largest producer of cement in the world, after China. In 2005, India produced 134 million metric tonnes (Mt) of cement, with 6% of world production (USGS, 2007). The Indian cement industry is comprised of 125 large cement plants and 300 mini-cement plants, with installed capacities of 148.28 and 11.10 million metric tonnes, respectively (MOCI, 2004). Cement plants have mostly changed from the wet process (94% in 1960) to the energy efficient dry process (93% in 2003) (Sathaye et al, 2005). About 56% of the cement produced in India is Ordinary Portland Cement (OPC), 31% is Pozzolana Cement (PPC), 12% is Portland Blast Furnace Slag Cement (PBFS), and the remaining 1% are special cements (Kumar, 2003). Blended cements, where energy use and associated emissions are reduced because a portion of the clinker is replaced by other materials such as fly ash or blast furnace slag, are only a very small portion of the Indian cement production (Sathaye et al, 2005). In 1995, the Indian cement industry produced about 68 million metric tonnes of cement and consumed approximately 243 PJ of final energy. In 2005, cement production almost doubled to 134 million metric tonnes but, due to increases in energy efficiency, annual final energy consumption only increased to approximately 336 PJ of final energy. Though the best of the industry matches quite well with world standards in terms of energy, the average performance of the Indian industry is still lagging behind.

3.3.2.3 Pulp and Paper

The Indian pulp and paper industry is the sixth largest energy user in the Indian industrial sector, accounting for 3% of industrial energy use in 2004. Energy use per tonne of paperboard production has decreased considerably over the last 15 years (

Table 8). The Indian paper industry is composed of a mix of large and small paper mills, having capacities ranging from 1 to 200 kt/year, with an average of 11.5 kt/yr (Jain, 2005). There are, at present, about 666 units engaged in the manufacture of paper and paperboards and newsprint in India (CPPRI, 2005). However, about a third of the paper mills, particularly small mills, have low capacity utilization around 65% (Bhati et al, 2006). Paper made from wood represents only 36%, agricultural residues 28% and waste paper 35%. The use of wood-based technology is gradually on the decline because of raw material availability constraints. Under the existing forest policy, the paper industry cannot use wood from any of the national reserves. The share of waste paper (secondary fiber) based technology, which is less energy intensive, has increased considerably over the last 10 years. Production of recovery paper increased 8% on average (1995-2005) and imports of recovery paper 20% (FAO, 2007).

On a per capita basis, average annual per capita paper consumption is only 4.5 kg in India, compared with 42 kg in China, 55 kg in the world as a whole, and around 185-190 kg in Australia and New Zealand (Bhati et al, 2006). An inference from India's low per capita consumption is that enormous scope exists for the consumption to rise in India in the future.

3.3.2.4 Fertilizer

India is the second largest producer of fertilizer in the world, after China, with 10.8 Mt of ammonia production in 2005 (USGS, 2007). Production has grown rapidly over the period 1980 to 2000, at an average rate of 7% annually, but has leveled off since, with a rate of 1.3% over the last 5 years. Presently, there are 65 large-sized fertilizer plants in India (Sathaye, 2005). Urea accounts for 83% of the nitrogenous fertilizer consumption in India. Fertilizers have helped transform the agriculture sector in India - from being dependent on food grain imports before independence (1947), India is now self sufficient. Fertilizer is one of the remaining sectors that are still regulated by the government. The Retention Pricing Scheme (RPS) was established to provide fertilizers to farmers at an affordable price. Subsidies vary across plants, depending on the age of the plant, technology used, energy consumed and the feedstock utilized. The policy has nurtured inefficiency and allowed high-cost naphtha and fuel oil based plants to stay competitive and to prosper. The government is aware of this bias and has announced a new policy to move toward price decontrol where domestic industry will have to compete with each other and with imports. The feedstock mix used for ammonia-urea production has changed over the past few decades. The shift towards the use of natural gas as feedstock is an improvement in terms of energy efficiency as its conversion into nitrogenous fertilizer is considerably less energy intensive than for other types of feedstocks (Sathaye, 2005). The Indian fertilizer sector is still characterized, however, by a high share of non-natural-gas-based units (50%). Worldwide, the share of natural gas in ammonia-urea production capacity is approximately 83% (GOI, 2003) compared to only 50% in India.

3.3.2.5 Aluminium

Aluminum production is the most energy intensive consumer on a per-weight basis and is the largest electric energy consumer of all industries. The aluminium industry is highly concentrated, with two plants out of a total of five accounting for the 80% of total production. India's share in world aluminium capacity represents about 3%. Reducing alumina to aluminum by means of electrolysis is the most energy intensive step in aluminum production. This process requires an uninterrupted supply of power. The two biggest plants have specific electrical energy consumption in the smelting process of about 15,000 kWh/t aluminium, compared to the world best practice of 13,000 kWh/t (IAI, 2001). The main weak point of this sector is that all aluminum producers in India own captive power plants that produce electricity from coal with a very low efficiency rate of around 20%.

Aluminium production from recycled material requires only 5% of the energy as compared with primary production. Recycled metal already satisfies around a third of world demand for aluminium and it is an ever growing proportion of total aluminium production. In India, secondary aluminium production is still a low percentage of total production compared to developed countries. This is in part due to the fact that the demand is growing much more rapidly than the recycling potential.

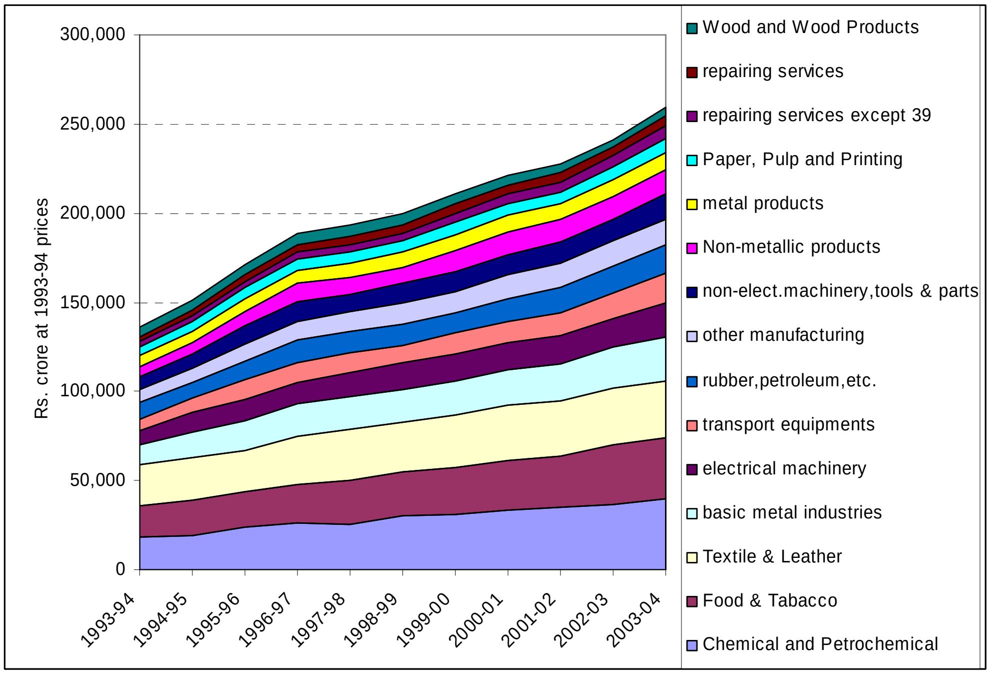
3.3.2.6 Petrochemicals and Chemicals

India ranks twelfth in the world for production of chemicals by volume (IBEF, 2006), while contributing to about 8% of industrial value added (MOSPI, 2007b). The Indian chemicals industry comprises both small and large-scale units. While the fiscal concessions granted to the small sector in mid-eighties led to the establishment of a large number of units in the small scale industries (SSI) sector, the industry is currently in the midst of major restructuring and consolidation (MoCP, 2005). Within industry categories, energy use varies and is closely tied to product configurations and whether fuels are used as a raw material (feedstock). For instance, the production of chlor-alkali does not require hydrocarbon feedstocks but is a very energy intensive process that requires an uninterrupted supply of power for electrolysis. Production of chlor-alkali increased 6.7% over the period 1998-2004. Organic chemicals and petrochemicals, on the other hand, rely on energy inputs as raw materials. The production of organic chemicals in India during the year 2003-04 was 1.4 Mt, while the production of major petrochemicals was 7 Mt. In India, the main sources of feedstock and fuel for petrochemicals are natural gas and naphtha. There are five naphtha and three gas-based cracker complexes in the country with a combined capacity of 2.5 million tonne per annum (MoCP, 2006). Over the period 1998-2004, the production of organic chemicals and polymers increased 4.5% and 13.6% respectively. Chemicals and petrochemicals production is expected to continue to grow fast. For example, the per capita consumption is 4.2 kg which is much lower than the world average of about 24 kg. At present, about 10% of domestic production is exported (MoCP, 2005).

3.3.3 Other Industry

The other industries represent 38% of total manufacturing value added in 2003, a decrease of 3% since 1993. Food & tobacco and textile & leather sectors are the largest contributors representing 13% and 12% respectively in 2003 (MOSPI, 2007b) (Figure 11).

Figure 11. Domestic Production from Manufacturing – Registered and Unregistered Sectors



Average annual growth has been positive for all industrial sub sectors and increased from 10% in transport equipment and electrical machineries sector to 3% for pulp and paper. India has established its role in the high value-added sectors of the "new economy" sectors of information technology (IT), computer hardware and computer software. The manufacturing value added energy intensity of other industry, measured in constant Rs crore, decreased at an annual average rate of almost 5% over the period 1993-2003.

In the last small scale industries census survey (MOSSI, 2004), SSI covering manufacturing, assembling and processing activities comprised 4.2 million units of which 3.3 million units were in the unregistered sector. The primary energy source used is 76% electricity, 11% oil, 6% coal, and traditional energy. A survey conducted by the Indian Institute of Science in the State of Karnataka (IIS, 2006) shows that the likely energy savings potential in SSI that could be achieved through shift of units belonging to low and medium efficiency groups to high efficiency group represented 32% of the total energy consumed. Motive power and process heat through furnaces, kilns, ovens, etc are the two major end uses of energy in SSI and the sector is generally characterized by a lack of awareness of scheme for enhancing energy efficiency.

3.3.4 Drivers

The main driver of energy use in the industrial sector is the level of activity in each industry. The quantity of tonnes of commodities produced over the period 1990-2004 has increased rapidly (Table 10).

Table 10. Commodities Production from Energy Intensive Industries (kt)

	1990	1994	1999	2004	AAGR 90-04
Crude Steel	14,963	19,282	24,300	32,625	6%
Cement	46,170	63,461	100,230	133,570	8%
Pulp & Paper	4,095	4,955	6,643	8,637	5%
Aluminium	428	479	614	874	5%
Ammonia	7,176	7,503	10,376	10,717	3%

Industrial energy use depends on technology and resource availability, but also on the structure of the industrial sector. The share of energy-intensive industry in the total output is a key determinant of the level of energy use. The industrial subsectors constituting the production of raw material is particularly energy intensive.

4. Future outlook for Energy Use in India

4.1 Macro Activity and Structural Change

Population and GDP are two fundamental activity drivers that influence energy demand from all the sectors. Between 1990 and 2005, India population increased at an annual average growth rate of 1.9% and GDP grew at an average rate of 6.0% (WB, 2005). Urbanization rate remains low at 29% (2004) but is expected to increase rapidly. Population and urbanization rate forecast were based on the United Nations projections for India (UN, 2007a) which estimate a population growth rate of 1.3% and an urbanization level of 35% by 2020 (UN, 2007b). We assume a 7% increase in GDP with continuous increase of service and industry share at the expense of the agriculture sector (Table 11).

Table 11. GDP Projection Assumptions

	1990	2005	2020	AAGR 1990-2005	AAGR 2005-2020
Total	**244**	**585**	**1618**	6.0%	**7.0%**
Agriculture, value added (constant 2000 US$)	78	112	151	2.5%	2.0%
Industry, value added (constant 2000 US$)	64	156	461	6.1%	7.5%
Services, etc., value added (constant 2000 US$)	101	317	1006	7.9%	8.0%
Share					
Agriculture		19%	9%		
Industry		27%	28%		
Services		54%	62%		

4.1.1 Primary Electricity Factor

Reduction of 1% of T&D losses is estimated to generate savings of over Rs.700 to Rs.800 crores ($17, 5 to 20 Million[5]) and reduction of 10% will save energy equivalent to an additional capacity of 10,000-12,000 MW (MOP, 2007). Realizing the loss for the

[5] Exchange rate of $1=40 INR, 1 July 4, 2007.

country that commercial loss represents, the Indian government has made one of its priorities to reduce them. In 2003, the Electricity Act was enacted, that set stringent penalties for power theft among other reforms directed to promote competition and protecting consumers' interests. Primary electricity factor were forecast to decline at an annual rate of 0.9% during the period 2005 to 2020 to account for the new policy in place and also in conjunction with recent trend that shows an annual rate of decline of -2.3% over the period 2000 to 2005.

Table 12. Primary Electricity Factor Forecast

	1990	2005	2020	AAGR 00-05	AAGR 05-20
Fuel input	**2,709**	**6,969**	**19,842**	**6.5%**	**7.2%**
Coal	*2,191*	*5,919*	*15,947*	*6.8%*	*6.8%*
gas	*126*	*412*	*1,400*	*8.2%*	*8.5%*
oil	*112*	*210*	*703*	*4.3%*	*8.4%*
nuclear	*22*	*63*	*697*	*7.3%*	*17.4%*
hydro	*258*	*365*	*1,094*	*2.3%*	*7.6%*
Energy output	**952**	**2,249**	**7,159**	**5.9%**	**8.0%**
Own Uses	81	157	501	4.5%	8.0%
Transmission and distribution loses	204	439	1,289	5.2%	7.4%
Electricity delivered	**682**	**1,652**	**5,369**	**6.1%**	**8.2%**
Primary factor	3.97	4.22	3.72	0.4%	-0.9%

4.2 The Agriculture Sector

4.2.1 Drivers and Intensity of Agricultural Energy Use

About 49% of the land in India is used for agricultural purposes, representing 160 Mha (FAO, 2007). The arable land has remained constant over the last 20 years (1983-2003). However the productivity has increased considerably, by more than 60%, as a result of increasing use of fertilizer and development of irrigation systems, allowing the production of food grains to grow at a similar rate. However, per capita intake of food grains has increased only by 6% over the entire period 1980 to 2003, from 410 grams per day to 436. This is due to the continuous increase in population growth, which augmented at a rate of 1.9% annually over the same period. Indian authorities are concerned about food security and support growth of food grains production to meet the population needs.

Agriculture remains a key sector in India, in which modernization is seen as enhancing more rapid economic development. The 11th Five Year Plan (2007-2012) envisages 4.1% growth in agriculture value added with the purpose of achieving an overall 10% economic growth (Planning Commission, 2007). In terms of food grains, the estimated production is about 297 Mt in 2020, representing an annual growth of 2.3% from 2004, compared to 2% from 1980 to 2004 (Planning Commission, 2007). The projected production growth is planned to be met with improved resource efficiency and increase in yield. The task force on agriculture advocates further technology dissemination among small farmers. India has a large number of small farms with land holding of less than 2 hectares, representing 80% of total agricultural land. The plan's target is ambitious and will require strong efforts from farmers and public authorities. Targets set are not always readily met but ensure a strong motivation. In this report, we projected food grain production based on historical trends. We assumed a growth rate of 1.8% to reach 274Mt of food grains production in 2020, with most of this increase coming from improved mechanization and surface irrigation extension.

Energy consumed in the agriculture sector is in large part attributable to pumping for irrigation. Since the cultivated area cannot be increased, the increased production will be only possible by increasing productivity factors and cropping intensity. Increasing cropping intensity requires principally bringing water to crop fields which normally receive water only once a year. Increasing productivity factors implicate further diffusion of modernized and mechanized tools. Srivastava (2006) shows that Indian States with higher forms of mechanization have higher productivity level. In both cases, energy consumption for pumping and for more mechanized tools will need to increase.

We projected energy consumption based on the diffusion of farm equipment as well as equipment unit energy consumption. In order to project irrigated land we used a linear regression of historical food production over irrigated land area for the last 15 years (see Annex 3). We assumed that the quantity of electric pump sets will increase from 16 to 23 million by 2020 while diesel pumps will decrease from 6 to 3 million due to a preference for electric pumps and higher electrification level.

Furthermore, we assume that annual sales of tractors continue to grow but rapidly reach a peak over the next 5 years and decline to attain a level of 5.1 millions tractors sold in 2020, which represents a diffusion of approximately 36 tractors per thousand hectares. This is higher than the US which has approximately 27 tractors per thousand hectares but it is lower than France which has approximately 69 tractors per thousand hectares (Table 13). Agriculture in the US is very different than in India due a very high concentration of land ownership. The average farm size is 195 ha while it is 39 ha in France and only 1 ha in India (Pawlak, 2002, NSSO, 2005a). In India, like in France, machinery tractors are often used in common between farmers. The practice of farm machinery custom hiring in India is developing among small marginal and small farms that cannot enjoy the benefits of mechanization through individual ownership (Sharma, 2006). In the US, very large scale farming has also allowed the diffusion of more powerful tractors. Tractors with capacity over 132 kW are common in the US.

Table 13. India, US and France Farm Machinery Intensity

	India (2004)	India 2020	US (2004)	France (2004)
Tractors (Millions)	2.8	5.1	4.8	1.3
Tractors/’000ha	19.8	35.8	27.3	68.5
Energy Intensity (MJ/ha)	1.1	2.4	4.1	6.0

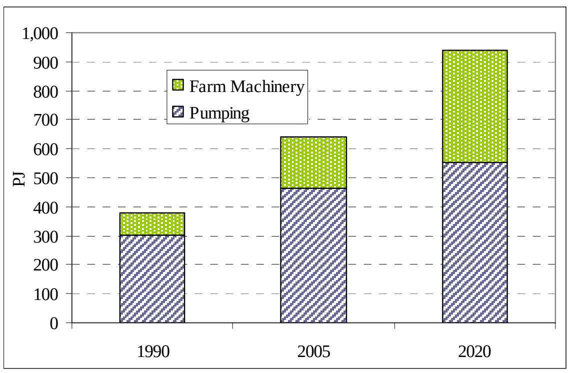
Note: Energy intensity for the US and France estimated as total agriculture oil consumed divided by hectare.

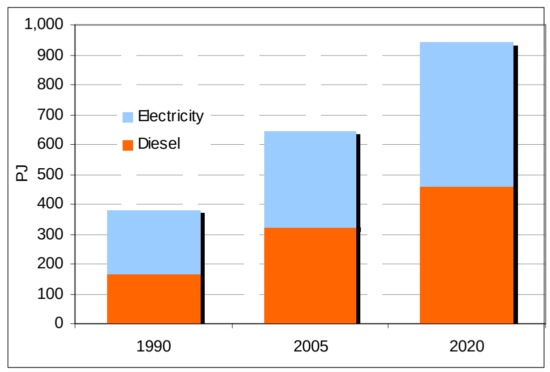
Our projection assumed increased sales of tractors with higher capacity over time to reach an average of 25 kW in 2020. We also assumed that tractors in use will have slightly longer operating hours as demand for their use will rise with increasing custom hiring and economic activity, from an estimate of 785 h/year to 900h/year. The resulting energy intensity annual growth rate is equal to 5.6%. Some of the major results from our projections for farm machineries are presented in Table 13 and compared with US and France.

4.2.2 Baseline Energy Projection in the Agricultural Sector

The resulting projections of energy consumption in the agriculture sector for pumping and farm machinery are shown in Figure 12. The largest growth is expected to result from increasing mechanization. Energy use in farm machinery will represent 41% in 2020 compared to 28% in 2005. Total energy consumption in 2020 in the agriculture sector in India is estimated to grow at a rate of 2.4% annually and reach 940 PJ, with electricity still representing the largest share of 51% and diesel consumption 49%. The figure also shows back casting of energy consumption by end use and by fuel since 1990.

Figure 12. Projected Final Energy Consumption in the Agriculture Sector by End-Uses and by Fuel (PJ)





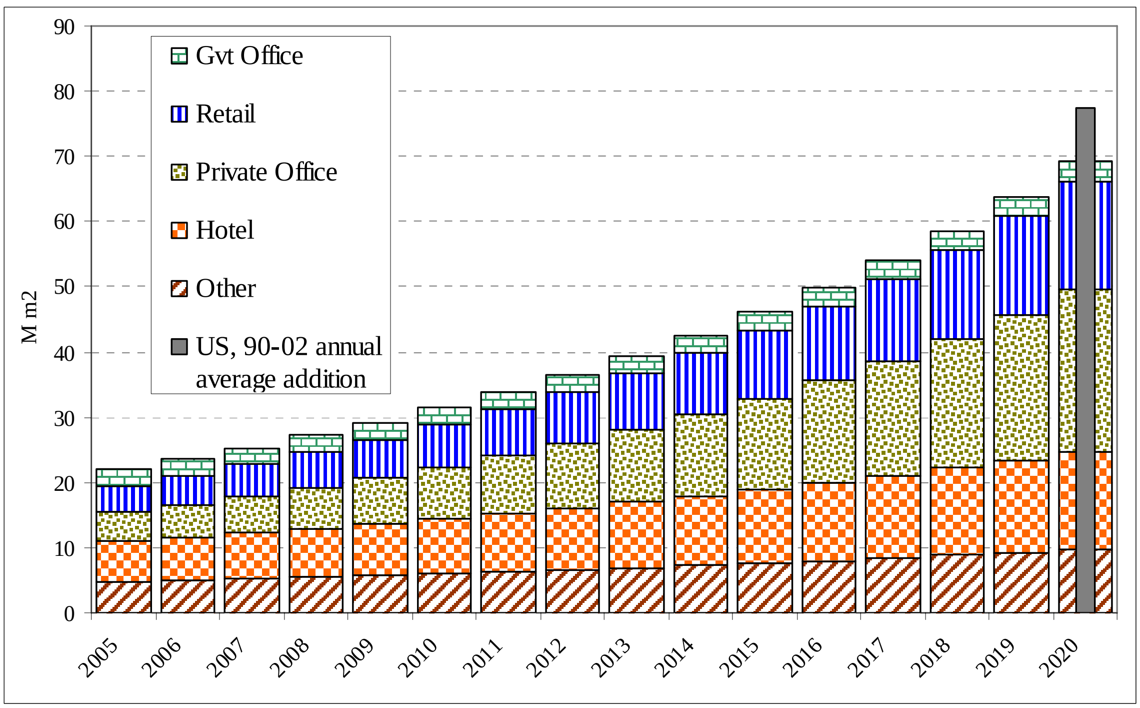
4.3 The Service Sector

4.3.1 Drivers of Service Energy consumption

In this report, service value added is expected to continue increasing rapidly, at an annual rate of 8% over the period 2005 to 2020. Final energy use per US dollar in power purchasing parity exchange rate is about 0.3 while it is about 1 in average for the IEA countries (IEA, 2007) and 1.1 in China. However, this indicator needs to be used carefully as different sectors of activity can have similar total energy consumption but produce very different level of value added and vice versa. The key driver to service energy consumption is the total amount of floor space used. According to the Construction Industry Development Council (CIDC), in 2004-05 residential construction accounted for 19 million m^2 and commercial construction 22 million m^2. For 2005-06 a 10% increase from the previous year is expected (Mathur, 2006). Most new commercial construction is air-conditioned. For comparison, China has been adding an average of 416 million m^2 per year of commercial floor space per year over the period 1990 to 2003 (Zhou et al, 2007), while the US, which has a more mature service sector, has been adding 77 million m^2 annually during the same period (US Buildings Energy Data Book).

Over the next 15 years, we project that new construction of commercial floor space will continue to increase at a faster rate. The additional yearly service floor space is projected to increase at an average rate of 7.3% per year over the next 15 years. Hence, additional commercial floor space will equal 652 million m^2 over the next 15 years. This rate of additional floor space varies by economic activity. We project that the highest growth will be for office space (AAGR: 12%). Additional retail floor space will also increase fast (AAGR: 10%), but part of this growth will come as a replacement of older small commercial space. Figure 13 shows projections per building type of new construction in square meters and compares the 2020 total annual Indian addition with the average annual addition in the US over the period 1990-2002. Average annual floor space added in the US over the period 1990-2002 is equal to 77 million square meters. India annual addition is about 4 times less today and is projected to be close to the US average level in 2020.

Figure 13. Additional Annual Service Floor Space Projection (Mm^2/yr)



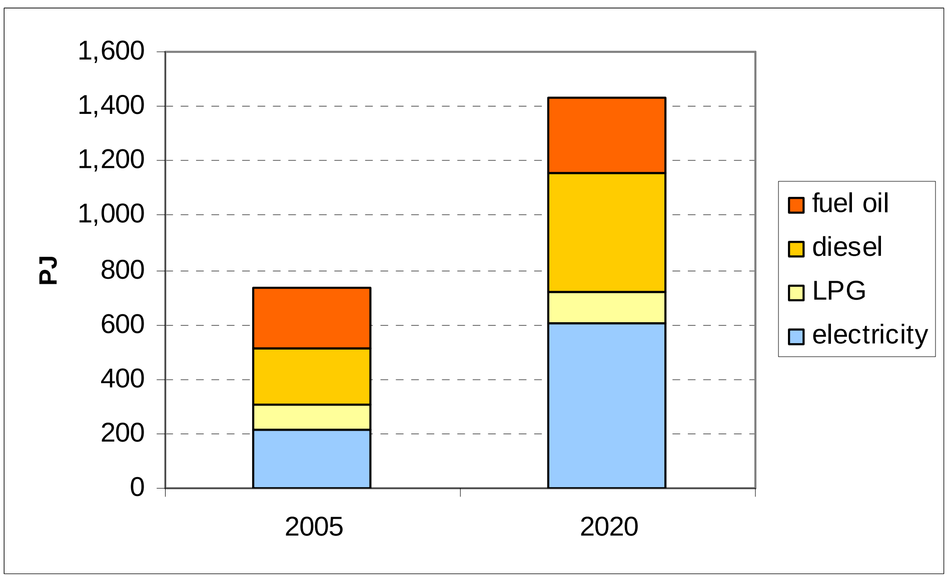
4.3.2 Commercial Energy Intensities

India has developed its first energy conservation building code (ECBC) modeled after the ANSI/ASHRAE/IESNA Standard 90.1 for Energy Efficiency in Buildings in 2006 (BEE, 2006). The code will be mandatory for commercial buildings or building complexes that have a connected load of 500 kW or greater or a contract demand of 600 kVA or greater when enforced, probably in 2010. The code is also applicable to all buildings with a conditioned floor area of 1,000 m^2 or greater. Implementation of the ECBC will enable energy efficiency practices and technologies to be introduced in the building envelope, lighting, HVAC, service water heating and electric power distribution within the building facilities. Programs to coordinate the tracking and reporting of ECBC enforcement are yet to be determined. Analysis done during the development of ECBC indicated that energy savings from 27% to 40% could be achieved in an ECBC compliant building.

Projection of energy consumption in the commercial sector was estimated accordingly to the energy consumed by old buildings and consumption from new construction. Electricity consumption from the 2005 stock was estimated to augment by 7% annually due to the penetration of new equipment while estimation of energy intensity of new construction was spilt by building type and based on developed country estimates corrected for space heating. Annex 7 shows the energy intensity estimations. We assumed that about 20% of the new construction electricity demand will be met by diesel generators with an efficiency of 25%. The resulting total energy used for commercial buildings is 1,433 PJ in 2020, with an annual growth rate of 4.6%.

4.3.3 Energy Projection in the Commercial Sector

Figure 14. 2020 Service Sector Energy Projection (PJ)



Energy consumption is expected to grow very rapidly for two main reasons. First, the average energy consumption per square meter of existing commercial buildings is currently relatively low due to a slow penetration of modern equipment. Second, construction of new buildings accommodating the service sector is expected to increase very rapidly.

4.4 The Industry Sector

4.4.1 Drivers Industry Energy consumption

Drivers of energy use in industry are based on the quantity of material produced. In order to forecast steel, cement, aluminum, paper, and ammonia production, we looked at the ratio of quantity consumed per capita and compared it with world averages and developed countries, represented herein by OECD countries. Per capita material production in India is still very low compared to world averages and even lower compared to developed countries.

Per capita consumption of steel in India remained among the lowest in the world, increasing from 5 kg in 1950 to only 27 kg in 2002, against a world average of 135 kg. Table 14 summarizes per capita material production in India for the major energy intensive industries and compares it with world averages and OECD countries average. India's cement industry has grown significantly over the past three decades, with production increasing at an average rate of 7% per year over the last 10 years. Cement consumption per capita at about 107 kg per capita is still low compared to the world average of about 343 kg/capita. The per capita consumption of aluminum in India in 2002 is only 0.6 kg compared to 25 kg in USA, 19 kg in Japan and 24 kg in Europe (EEA, 2006). Per capita paper production in India is also very low at about 4 kg per capita compared to the world average of 53 and 573 kg for North America (Canada and US). Per capita ammonia production is the closest to the world average, with 10 kg per capita, relatively close to world average of 19 kg/ca. This is largely due to an emphasis on food security during the Green Revolution.

Table 14. Per Capita Material Production Compared to Regional Rates (kg/capita)

		Steel	Aluminium	Cement	Paper	Ammonia
World Average, 2002	kg/capita	135	4	343	53	19
OECD, 2002	kg/capita	414	13	515	377	27
India, 2002	kg/capita	27	0.6	107	4	10
India Forecast, 2020	kg/capita	85	2	329	6	13
India Total	kt	110,000	2,208	424,337	21,656	16,928
Historical, AAGR 1990-2004	%	6.5%	5.2%	7.9%	5.5%	2.9%
Projection, AAGR 2005-2020	%	7.3%	6.0%	7.4%	6.0%	2.9%

Projection of material production is based on consideration of historical growth and industry's own projections. For example, the national steel committee projects a production of 110 Mt of steel by 2019-2020 (National Steel Committee, 2005), which was taken by our model as a reasonable estimate. Generally, we assumed that India's energy intensive industry will continue a growth similar to that in the last decades, with a slight intensification of growth for steel and aluminum. Table 14 shows AAGR for the historical period 1990 to 2004 and for the projected period 2004 to 2020. The table shows the resulting per capita production for each material in 2020. The per capita production remains lower than world average in each case. In this baseline scenario, projections are mostly based on growth from domestic demand rather than exports.

4.4.2 Industry Sub-sector Intensities

Table 15. India Industry Energy Intensities (GJ/t)

	1990	2005	2020	Best Practices
Crude Steel	42	29	27	17.8
Aluminium	399	365	344	144*
Cement	3.6	3.1	2.9	1.9**
Pulp Paper	35	24	23	17***
Ammonia	55	43	40	28

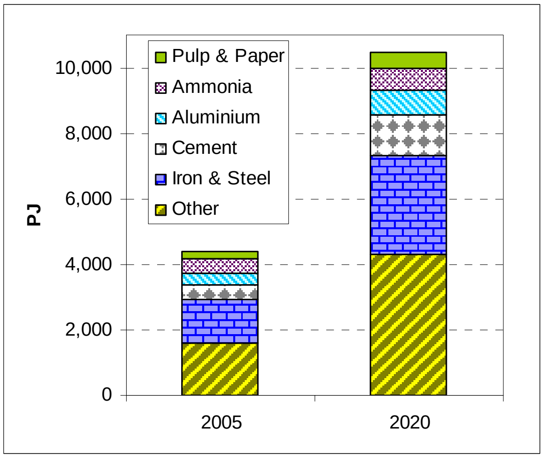
Source: Best paractices data are based on Worrell et al, 2007
*Here primary electricity is calculated as india intensity include own use generation, an electricity conversion efficiency of 33% was used for best practices. ** Blast Furnace Slag Cement Plant, *** Wood based Paper Mill

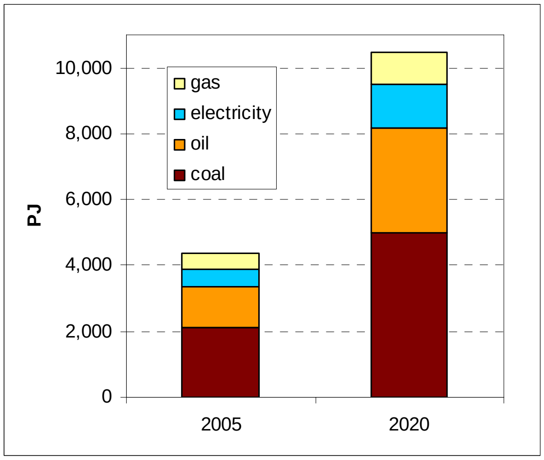
Table 15 shows energy intensities in the energy intensive industries in India in 1990, 2005 and 2020. Energy intensity is projected to decrease at annual rate of 0.4% from 2005 to 2020, at a much slower rate than during the period from 1990 to 2005. The main reasons are that even if the potentials remains large, the cost of implementing measures and technology to save energy is generally higher. Table 15 shows world best practices energy intensity per industry type to have an order of magnitude of the potential to save energy if best practices were in used. However, these numbers have to be handled with care as they are based on feedstocks that are not always available in all locations and at competitive prices.

4.4.3 Baseline Energy Projection in the Industry Sector

Final energy consumption in the industry sector is projected to increase at a rate of 6.0% over the period 2005 to 2020, faster than during the previous period, 1990 to 2005 where it increased at an average rate of 2.7% annually. Energy use in the production of iron and steel will remain the largest contributor to energy demand in the industry sector (Figure 15). The highest growth is projected to be in the cement industry with an average annual growth rate of 7.0% over the period 2005 to 2020, followed by pulp and paper production, with a AAGR of 6.2%. Energy demand for ammonia represents the lowest growth with 2.6% annually. Finally, energy demand for the light energy intensive industry is expected to grow fast, with an AAGR of 6.8%. In terms of fuel consumption, coal remains the dominant fuel, explained partly by a large consumption of this fuel by iron and steel and cement industries.

Figure 15. Final Energy Projection in the Industry Sector

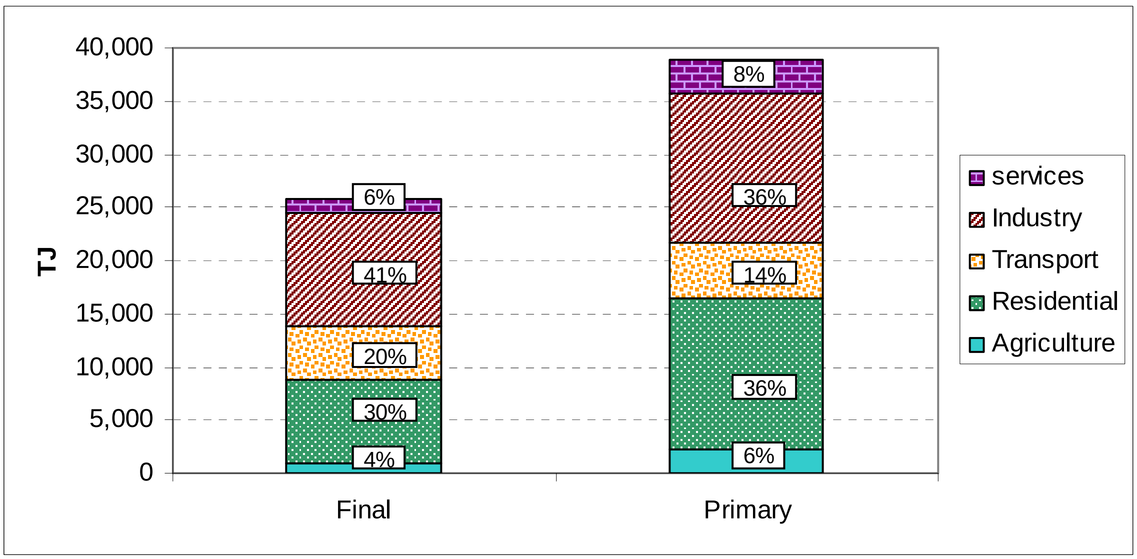




4.5 Summary Results

Results from the residential and transport sectors are taken from a previous report (de la Rue du Can, 2008). Under the baseline scenario, India's final energy consumption by 2020 is projected to be multiplied by 2.1 to reach 25.8 EJ and primary energy to be multiplied by 2.2 to reach 39.8 EJ (Figure 16). Industry and residential sectors remain the largest source of primary energy use. However, the fastest growth is from the transport sector with a rate of 6.4%, followed by the industrial and commercial sectors with rates of 5.8% and 5.3% respectively. Growth in the residential sector is also strong at 5.2%, with opposite force between significant decrease of biomass and considerable increase of primary electricity consumption.

Figure 16. Primary Energy Consumption by Sector

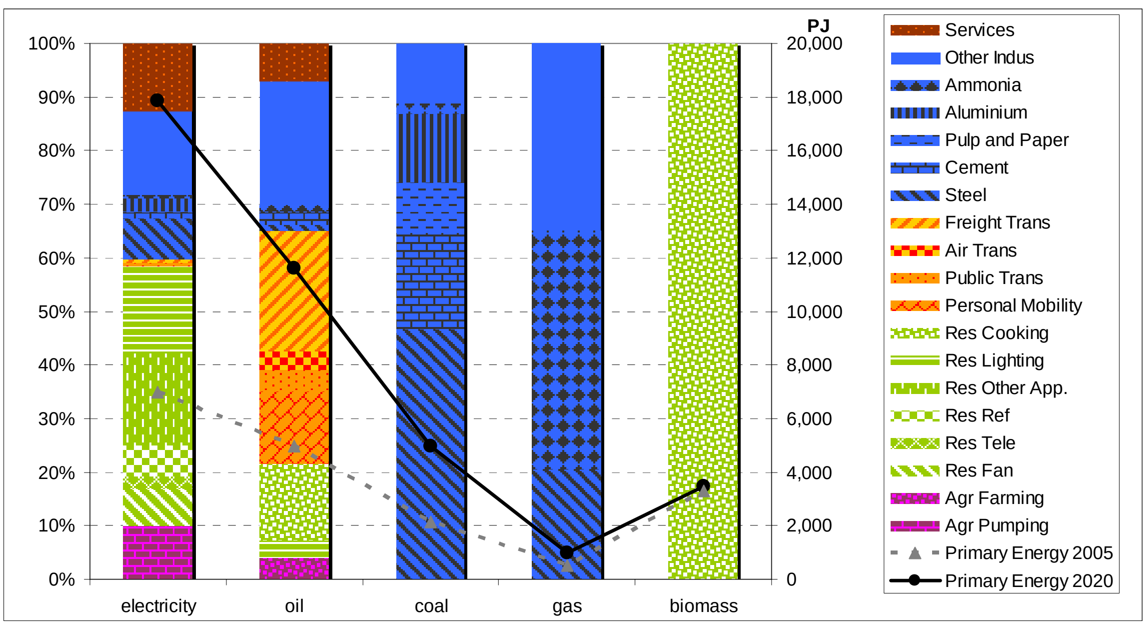


In 2020, the production of electricity is estimated to be accompanied with a conversion factor of 3.8, including distribution losses. This represents an amelioration compared to

2005, where the primary factor of electricity was 4.2. In term of generation mix from utilities, coal remains the main input to electricity production with a share of 59%, compared to 70% in 2005. Both hydro and nuclear increases significantly, to a share of 16% compared to 13% in 2005 for hydro, and a share of 8% compared to 3% for nuclear. Electricity production from natural gas increases slightly to a share of 11% compared to 10%. The rest is met with unchanged share of diesel (4%) and wind (1%). These shares are based on estimates for the 12th plan capacity additions (CEA, 2007). Hence, the primary electricity conversion is improved by the increase of non fossil fuel inputs[6] and by a slight reduction in T&D loses rate, reaching 3.7 in 2020 compared to 4.2 in 2005.

Primary electricity consumption is expected to grow the fastest at 6.4% annually over the period 2005 to 2020, driven by increased appliance ownership in the residential sector and increase in equipment penetration and floor space development in the commercial sector. Oil will remain the second most fuel in use in the final sectors throughout this period, reaching 11.6 EJ in 2020. The transport sector represents the largest user of oil with a share of 43% of total oil consumption. The residential sector represents about 18% of oil use for the need of LPG and kerosene for cooking and lighting. Biomass energy consumption will decrease slightly at an annual rate of 0.4% over the same period, while natural gas will continue to increase at a rate of 5.3%, lower than in the previous period of 7.3%. Coal consumption will continue to increase at a faster rate than during the period 1990 to 2005, driven by the growth from industrial activities.

Figure 17. Primary Energy Projection by Fuel and by End Uses



[6] In this report, the ''direct equivalent'' accounting method is used, which accounts for the primary energy of the non fossil-fuel energy at the level of secondary energy with an efficiency of 100% (cf Section2.2)

5. Conclusion

The analysis presented in this report significantly advances, we believe, the understanding of sources of energy demand in India, and the accuracy in predicting their trajectory over the next decade. In doing so, we have presented a consistent and robust framework for national and sector level demand forecasting, which relies on separating the drivers of energy demand, and the intensity of its use in meeting that demand. We believe this to be a critical step in developing a comprehensive strategy of national energy demand management – the need for which is becoming ever more urgent for large developing countries like India.

The analysis as performed in this way reveals several interesting features of energy use in India. Electricity consumption is expected to increase fast, driven by the demand of the residential and commercial sectors that add to the already increasing demand from the industry sector. Per household residential electricity consumption will likely quadruple in the 20 years between 2000 and 2020. In fact, primary electricity use will increase more rapidly than any other major fuel – even more than oil, in spite of the fact that transport is the most rapidly growing sector. The growth in electricity demand implies that chronic outages are to be expected unless drastic improvements are made both to the efficiency of the power infrastructure and to electric end uses and industrial processes. In the transport sector, the rapid growth in personal vehicle sales indicates strong energy growth in that area. However, our analysis indicates that in total energy terms, oil product consumption will remain comparable in the residential sector (in the form of kerosene), and in heavy industry. In addition, oil consumption used for freight transport will continue to outpace passenger transport. Even though the industry sector has experienced tremendous improvements in energy intensity per tonne of material produced, energy use from this sector is expected to continue to grow fast. The main reason is a strong activity projection in this industry sector driven by the demand for infrastructure development.

The intent of this report was to use as wide an array of available data at the highest level of detail possible. Undoubtedly, some already available sources were overlooked. In general, however, the authors feel that the greatest gaps in data availability arise from a lack of accurate statistics, more specifically for the transport sector. In this way, we hope to highlight areas where the greatest gains could be made through more thorough unearthing of data sources or, if necessary, completing the surveys and statistical analysis necessary to generate new data sources. For example, the sector with the least knowledge is the service sector, where data on floor space needs to be collected and surveys on energy use need to be conducted. We also found that the transport sector lacks consistent data reporting from a national source, specifically on the stock of vehicles in use and fuel economy of vehicles. Finally, only a few data points were found to describe the unit energy consumption by appliance type and little is known on their typical life time and hour of use. Future data collection on these issues will allow refining the first energy use breakdown matrix developed in this report for India.

Ultimately, the value of an analysis such as presented in this report will be measured by its use in subsequent research into energy demand in India. In particular, the analytical framework presented in detail here is designed with an eye toward development of detailed, realistic and robust energy efficiency scenarios for India. Such scenarios can be made by applying best practice technology options at the level of endues, equipment or process, thus ensuring that global improvements are underpinned by achievable bottom-up policy and market interventions. The construction of such scenarios would go beyond an evaluation of savings potentials, providing the analytical elements for a comprehensive energy strategy, or roadmap.

Reference

Basu N., Chaudhuri B. and Roy P. K. ; "*Energy management in Indian Aluminum Industries*", Energy engineering (Energy eng.) ISSN 0199-8595. 2005, vol. 102, no6, pp. 7-25.

Bhati U.N. and Raghbendra Jha, 2006. "*Emerging opportunities for Australia in India's paper and paperboard market*". http://sres-associated.anu.edu.au/marketreport/EOA.pdf

Bureau of Energy Efficiency (BEE), 2006. "*The Energy Conservation Building Code* "2006, US Agency for International Development (USAID) and International Institute for Energy Conservation (IIEC), Bureau of Energy Efficiency, 2006. http://www.usaid.gov/in/Pdfs/Energy_Cons_Bldg.pdf

Bureau of Energy Efficiency (BEE), 2007. Website: www.bee-india.nic.in

Central Electricity Authority (CEA), 2006. "*All India Electricity Statistics, General Review 2006, (Contain data for the year 2004-05)*". Government of India, Ministry of Power, Central Electricity Authority, New Delhi, March 2006. www.cea.nic.in

Central Electricity Authority (CEA), 2007. "*Working Group on Power for 11th Plan*". Government of India, Ministry of Power, Central Electricity Authority, New Delhi, 2008. http://cea.nic.in/planning/WG%2021.3.07%20pdf/03%20Contents.pdf

Central Electricity Authority (CEA), 2008. "*Progress report of Pumpset Energisation as on 31-03-2008*". Government of India, Ministry of Power, Central Electricity Authority, New Delhi, 2008. http://www.cea.nic.in/god/dpd/pumpset_energisation.pdf

Central Pulp and Paper Research Institute (CPPRI). 2005a. "*Statistics of the Indian Paper Industry: Directory of Indian Paper Indu*stry". Volume II. Saharanpur, India.

de la Rue du Can Stephane, Virginie Letschert, Michael McNeil, Nan Zhou, and Jayant Sathaye, "Residential and Transport Energy Use in India: Past Trend and Future Outlook",LBNL forthcoming.

de la Rue du Can S. and L. Price, 2008 "Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions", Energy Policy 36 (2008) 1386–1403.

Deutsche Bank Research, 2006. "*Building up India: Outlook for India's real estate*", DB Research, India Special, Current Issues, May 8, 2006.

DTZ, 2007. "*Commercial Real Estate, Norwegian Wood (This Bird Has Flown), India 2007*", 2007. www.dtz.com

European Aluminium Association (EEA), 2006, "Sustainability of the European aluminium industry 2006"

Ernst & Young, 2006. "*The Great Indian Retail Story", Markets & Retail Industry"*. 2006, www.ey.com/india

Emporis, 2007. "*Most Active Asian cities", Building Statistics on the Most Active Continents, Countries and cities*". August 2007. www.emporis.com

Federation of Hotel & Restaurant Associations of India (FHRAI) "*Ninth annual edition of the Indian Hotel Industry Survey*", Federation of Hotel & Restaurant Associations of India (FHRAI) in cooperation with HVS International 2007

Federation of Indian Chambers of Commerce and Industry (FICCI), 2005. "*The Service report"*, http://www.ficci.com/surveys/service-report.pdf

Food and Agriculture Organization of the United Nations (FAO) 2007a. *Forestat database*, FAOSTAT Statistics Division 2007, http://www.fao.org/waicent/portal/statistics_en.asp

FAO, 2007b. *Resource Statististics Database*. FAOSTAT, FAO Statistics Division, 24 April 2007 http://faostat.fao.org

Government of India, 2003. Department of Fertilizers, Gokak Committee, "*Report of the Committee on Efficient Energy Levels etc. for Urea units*", May 2003.

HVS, "*Hotels in India: Trends and Opportunities*". HVS International, 2006 Edition, New Delhi office, 2006.

Indian agricultural Statistics Research Institute (IASRI), 2007. "*Agricultural Research databook 2007*". Director, Indian Agricultural Statistics Research Institute, Pusa, New Delhi -110012 http://www.iasri.res.in/agridata/HOME.HTML

India Brand Equity Foundation (IBEF), 2006. "*Chemicals"*. Davos 2006, India Brand Equity Foundation www.ibef.org

International Aluminium Institute, IAI, 2001. "*The Aluminium industry's sustainable development report*", New Zealand House, www.world-aluminium.org. Associations and Int. Org/UNEP Report dated 20.11.01 CPC and EE&LCI/LCA.

International Energy Agency, 2004. "*Oil Crises & Climate Challenges - 30 Years of Energy Use in IEA Countries*", IEA/OECD, Paris, France.

International Energy Agency, 2006a. "*World Energy Outlook*", IEA/OECD, Paris, France.

International Energy Agency, 2006b. "*Energy Technology Perspectives: Scenarios and Strategies to 2050*", IEA/OECD, Paris, France.

International Energy Agency, 2007a. "*Energy Balances of Non-OECD Countries 2004-2005*", IEA/OECD, Paris, France.

International Energy Agency, 2007b. "*Energy Use in the New Millenium*", IEA/OECD, Paris, France.

International Hearld Tribune, January 12, 2006 "*Missed India's software boom? Try real estate*" By Andy Mukherjee Bloomberg News

Indian Institute of Science (IIS), 2006 "*Energy Utilisation in Karnataka: Part-III Small Scale Industries Sector?*" Indian Institute of Science, State of Karnataka. http://ces.iisc.ernet.in/energy/paper/part3/utilisation3.html

International Iron and Steel Institute, IISI, 2007a. "*Steel statistic archive 2006*". IISI: Brussels, Belgium, www.worldsteel.org

International Iron and Steel Institute, IISI, 2007b. Steel Statistical Yearbook, 2006. IISI: Brussels, Belgium

IPCC Working Group III Contribution to the Fourth Assessment Report, Climate Change 2007: Mitigation of Climate Change (Geneva: WHO and UNEP IPCC, 2007), www.ipcc.ch

Jain R. K., Singh K. and Kulkarni A.G., 2005. "*The Indian Paper Industry: Towards Sustainability*", PPI March 2005.

Kim Y. and Worrell E., 2002. "*International comparison of CO2 emission trends in the iron and steel industry*" Energy Policy 30 (2002) 827–838

Kelkar U., 2006 "*Designing Policies that can Adapt to a World of Uncertainty, Change and Surprise: Adaptive Policymaking for Agriculture and Water Resources in the Face of Climate Change*." "Chapter 3: Indian agriculture: growth, sustainability, and vulnerability" November 2006, IISD–TERI–IDRC Adaptive Policies Project. http://www.iisd.org/pdf/2006/climate_designing_policies.pdf

Mathur Ajay, "*Current Status of Energy Efficiency Building Codes in India*", DG BEE, presentation to India –IEA Joint Workshop on Energy Efficiency in Buildings & Building Codes, 4-5 October 2006

McKinsey Global Institute, "Curbing Global Energy Demand Growth: The Energy Productivity Opportunity", 2007, http://www.mckinsey.com/

McNeil M. A., V. E. Letschert, and S. de la Rue du Can, "*Global Potential of Energy Efficiency Standards and Labeling Programs*", LBNL draft report, March 2008.

McNeil M. A., Iyer M., Meyers S., Letschert V. E. and McMahon J. E. (2008). "*Potential benefits from improved energy efficiency of key electrical products: The case of India*". Energy Policy (In Press) LBNL- 58254.

Ministry of Agriculture (MOA), 2004. “*Agricultural Statistics at a Glance*”, Departments viz. Department of Agriculture and Cooperation, August 2004. IFFCO, New Delhi - 110 019, http://agricoop.nic.in/

Ministry of Agriculture (MOA), “*Agricultural Statistics at a Glance*”, Departments viz. Department of Agriculture and Cooperation, 2006.August 2006. IFFCO, New Delhi - 110 019, http://dacnet.nic.in/eands/agStat06-07.htm

Ministry of Chemical and Petrochemical (MoCP), 2005. “*Annual Report 2005-05*”. http://www.chemicals.nic.in/AnnRep0506.pdf

Ministry of Coal (MOC), 2006. “*Coal Directory of India*”Govenement of India.

Ministry of Commerce & Industry (MOCI), “*Profile of Industries Under the Jurisdiction of DIPP: Cement Industry*”. Department of Industrial Policy and Promotion, 2004. http://dipp.nic.in/industry/cement.htm

Ministry of New and Renewable Energy (MNES), 2008. “*Annual Report 2007-08*”. Government of India. http://mnes.nic.in/annualreport/2007_2008_English/index.htm

Ministry of Oil and Gas (MOG), 2006. “*Indian basic Petroleum & Natural Gas Statistics*”. Govenement of India.

Ministry of Power (MOP), 2007. “*Report of for Eleventh Plan (2007-12)*” Volume – II” Main Report. The Working Group on Power Working Group on Power for 11th Plan. Government of India. Ministry of Power, New Delhi, February 2007

Ministry of Tourism, 2007. “*Annual Report 2006-2007*”. Government of India, 2007. http://www.tourism.gov.in/AnnualReport2006-07.pdf

Ministry of Small Scale Industries and Agro & Rural Industries (MoSSI) 2004. “*Final Results*”, Third All India Census of Small Scale Industries, 2001-2002, www.smallindustryindia.com

Ministry of Statistics and Programme Implementation (MOSPI), India, 2006. “*Statistical Abstract India 2004*”. New Delhi, web: www.mospi.nic.in/

Ministry of Statistics and Programme Implementation (MOSPI), India, 2007a, “*Energy Statistics, 2005-06*”, New Delhi, web: www.mospi.nic.in/

Ministry of Statistics and Programme Implementation (MOSPI), India, 2007b, “*National Account Statistics 2007*”, New Delhi, web: www.mospi.nic.in/

Ministry of Statistics and Programme Implementation (MOSPI), India, 2007c, “*Statistical Pocket Book India*”, combined Issue 2006-2007, 45th edition, Central Statistical Organisation, http://mospi.nic.in/rept%20_%20pubn/ftest.asp?rept_id=siu04_2006&type=NSSO

Ministry of Statistics and Programme Implementation (MOSPI), India, 2008a, "*Energy Statistics, 2006-07*", New Delhi, web: www.mospi.nic.in/

Ministry of Statistics and Programme Implementation (MOSPI), India, 2008b. "*Economic Census* 2005". New Delhi, web: www.mospi.nic.in/

Ministry of Steel (MOS) 2008. "*Annual Report 2007-08*". http://steel.nic.in/

Misra Neha, Ruchika Chawla, Leena Srivastava, and R K Pachauri, "*Petroleum pricing in India: balancing efficiency and equity*", 2005, the Energy and Resources Institute (TERI), New Delhi.

Nakicenovic , N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grubler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N., Zhou, D., 2000. "*Special Report on Emissions Scenarios*": Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, London.

National Bureau of Statistics of China (NBSC), 2007. "*China Statistical Yearbook - 2006*". http://www.stats.gov.cn/

National Council of Applied Economic Research (NCAER), 2005. "*Comprehensiv Study to Assess the Genuine Demand and Requirement of SKO*", New Delhi.

National Sample Survey Organisation (NSSO), 1998. "*Travel and Use of Mass Media and Financial Services by Indian Households*". Ministry of Statistics & Programme Implementation, Government of India, NSS 54th Round, Report No. 450.

National Sample Survey Organisation (NSSO), 2001c, "*Informal Sector in India, 1999-2000*", Salient Features. NSSO 55th round (July 1999 - June 2000) National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India, May 2001, Report No. 459.

National Sample Survey Organisation (NSSO), 2005a, "*Situation Assessment Survey of Farmers: Some Aspects of Farming*", 2003, Ministry of Statistics & Programme Implementation, Government of India, NSS 59th Round (January–December 2003), July 2005, Report No. 496: (59/33/3)

National Steel Committee, 2005. "*National Steel Policy – 2005*", Ministry of Steel, Governement of India. http://steel.nic.in/nspolicy2005.pdf

Pawlak, J., G. Pellizzi and M. Fiala. "*On the Development of Agricultural Mechanization to Ensure a Long-Term World Food Supply*". Agricultural Engineering International: the CIGR Journal of Scientific Reaseach and Development. Invited Overview Paper. Vol. IV. June, 2002

Pellegrino Joan L., "*Energy and Environmental Profile of the U.S. Chemical Industry*", May 2000, Incorporated Energetic, Columbia, Maryland, U.S. Department of Energy Office of Industrial Technologies.
http://www.eere.energy.gov/industry/chemicals/pdfs/profile_chap1.pdf

Planning Commission, "*Recommendations of working group on agricultural extension for formulation of eleventh five-year plan*", 12th January, 2007, http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_agrext.pdf

Purohit P., and Michaelowa A. 2006, "*CDM potential of SPV pumps in India*", Renewable and Sustainable Energy Reviews, Received 21 March 2006; accepted 24 May 2006

Price Lynn, Stephane de la Rue du Can, Jonathan Sinton, Ernst Worrell, Zhou Nan, Jayant Sathaye and Mark Levine. "*Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions*". July 2006. LBNL-56144

Sathaye J, L. Price, S.de la Rue du Can, and D. Fridley, 2005. "*Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India*". LBNL-57293.

Sharma, A. 2006. ' *A Cross-country Analyses of Trends in Agricultural Labour Force* ', paper presented at 5th IWMI-Tata Annual Partners' Meet at IRMA, Anand, Gujarat.

Schipper L, Des Rosiers J-P, Justus D, Cornell R, Sullivan S. 1997. "*The Link Between Energy and Human Activity*". IEA. Paris: OECD

Schipper L., Unander F., Murtishaw S., and Ting M., 2001. "*Indicators of Energy Use and Carbon Emissions : Explaining the Energy Economy Link*". Annual Review of Energy and the Environment, Vol. 26: 49-81

Stockholm Environment Institute (SEI). (2006) Long-range Energy Alternatives Planning System. Software version 26. Stockholm Environment Institute: Boston.

Shukla O. P., Rai U.N. and Subramanyam S. V., 2004. "*Biopulping and Biobleaching: An Energy and envioronment Saving Technology for Indian Pulp and Paper Industry*" Newsletter of ISEB India, Vol. 10 No. 2 - April 2004, http://isebindia.com/01_04/04-04-3.html

Singh G., 1999. "*Empowering farmers through animal traction in India*", published in: Kaumbutho P G, Pearson R A and Simalenga T E (eds), 2000. Empowering Farmers with Animal Traction. Proceedings of the workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 20-24 September 1999, Mpumalanga, South Africa. 344p. ISBN 0-907146-10-4. http://www.atnesa.org

Singh G. 2006 "*Agricultural Machinery Industry in India (Manufacturing, Marketing and Mechanization promotion)*", Status of Farm Mechanization in India, Department of Agriculture and Cooperation (DOAC), 2006. http://agricoop.nic.in/Farm%20Mech.%20PDF/contents.htm

Singh Joginder, "*Scope, Progress and Constraints of Farm Mechanization in India*" Status of Farm Mechanization in India, Department of Agriculture and Cooperation (DOAC), 2006. http://agricoop.nic.in/Farm%20Mech.%20PDF/05024-03.pdf

Singh, Inderjeet and Axel Michaelowa "*Indian Urban Building Sector: CDM Potential through Engergy Efficiency in Electricity Consumption*", HWWA Discussion Paper 289, Hamburgisches Welt-Wirtschafts-Archiv (HWWA),Hamburg Institute of International Economics, 2004, ISSN 1616-4814.

Srivastava N. S. L. "*Farm Power Sources, their Availabitiies and Future Requirements to Sustain Agricultural Production*", Status of Farm Mechanization in India, http://agricoop.nic.in/Farm%20Mech.%20PDF/contents.htm

Swaraj Kumar Nath, 2005, "*Industrial Statistics of India: Status and Issues*", Expert Group Meeting on Industrial Statistics, Department of Economic and Social Affairs, statistics Division, United Nation, New York, 19-23 September 2005, ESA/STAT/AC.105/7. http://unstats.un.org/unsd/industry/meetings/eg2005/AC105-7.PDF

TERI. The Green Revolution. http://edugreen.teri.res.in/explore/bio/green.htm

The Energy and Ressource Institute (TERI), 2002, "*TEDDY: TERI's energy data directory and yearbook 2002–2003*". New Delhi: Tata Energy Research Institute, 2002. www.teriin.org

The Energy and Ressource Institute (TERI), 2006. "*TEDDY: TERI's energy data directory and yearbook 2004/05*", New Delhi: Tata Energy Research Institute, 2006. www.teriin.org

United Nations (UN), Population Division of the Department of Economic and Social Affairs, 2007a. "*World Population Prospects: The 2006 Revision*" http://esa.un.org/unpp, Friday, April 20, 2007; 8:00:16 PM.

United Nations (UN), Population Division of the Department of Economic and Social Affairs, 2007b. "*World Urbanization Prospects: The 2005 Revision*", http://esa.un.org/unpp, Friday, April 20, 2007; 8:00:16 PM.

United Nations (UN), 2007c. "*Commodity Production Statistics*". United Nations CDrom.

U. S. Energy Information Administration, "*Commercial Building Energy Consumption Survey*" (CBECS), 2003.

U.S. DOE, 2006, "*Buildings Energy Data Book 2006*", September 2006. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) http://buildingsdatabook.eren.doe.gov/

United States Geological Survey, 2007. "*Mineral Commodity Summary: Nitrogen*". http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/

World Bank, 2002. "*India's Transport Sector: The Challenges Ahead*", Volume 1: Main Report, May 2002, The World Bank Group.

World Bank, 2005. World Development Indicators (WDI), CDroom. www.worldbank.org/data

World Bank, 2008. World Development Indicators (WDI), CDroom. www.worldbank.org/data

Worrell Ernst, Lynn Price, Maarten Neelis, Christina Galitsky, Zhou Nan. "World Best Practice Energy Intensity Values for Selected Industrial Sectors", February 2008, LBNL-62806 Rev. 2

Zhou Nan, Michael A. McNeil, David Fridley, Jiang Lin, Lynn Price, Stephane de la Rue du Can, Jayant Sathaye, and Mark Levine, 2007a. "*Energy Use in China: Sectoral Trends and Future Outlook*". January 2007. LBNL-61904

Zhou Nan, Michael McNeil, Stephane de la Rue du Can and Jayant Sathaye, June 2007b "*What do India's transport energy data tell us? A Bottom-up Assessment of Energy Demand in India Transportation Sector*" ECEEE June 2007.

Annexes

Annex 1. Percentage Share of Unorganised Segment in Net Domestic Product by Industry in 1993-94 and 1999-00

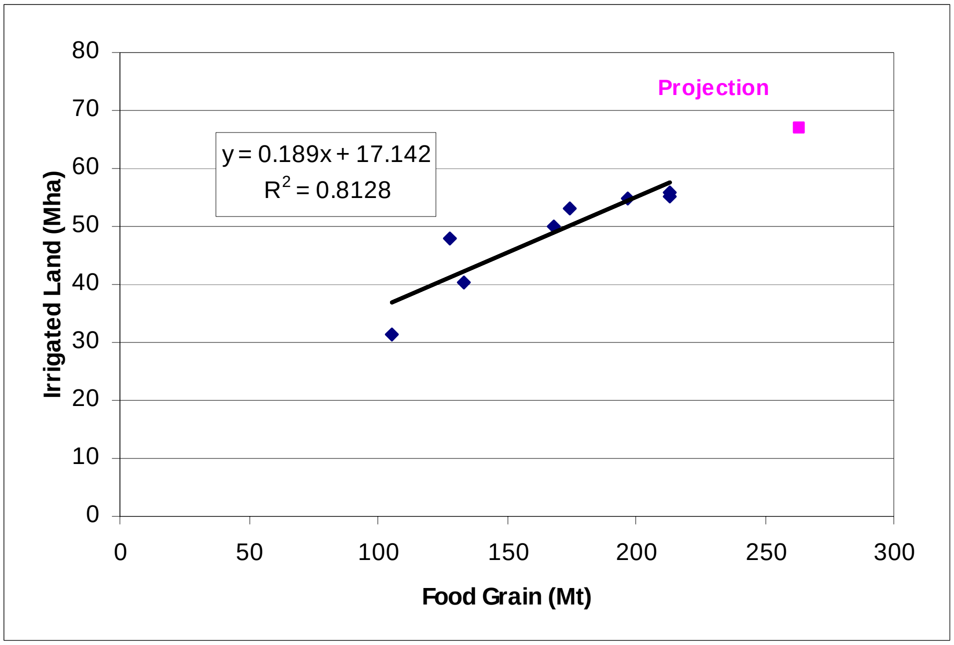
	Industry	% Share in respective industry		% Share in total NDP	
		1993-94	1999-2000	1993-94	1999-2000
1.	Agriculture	96.5	96.9	31.75	26.84
2.	Mining & quarrying	7.3	8.4	0.15	0.17
3.	Manufacturing	36.6	39.2	5.45	5.21
4.	Electricity, gas & water supply	7.2	6.2	0.09	0.08
5.	Construction	51.1	58.2	2.86	3.72
6.1	Trade	89.7	81.9	11.75	12.45
6.2	Hotels & Restaurants	71.9	58.8	0.58	0.59
7.1	Railways	0	0	0	0
7.2	Transport by other means	68.9	77.4	2.27	3.17
7.3	Storage	58.9	50.4	0.59	0.50
7.4	Communication	8.1	8.6	0.09	0.11
8.1	Banking & insurance	6.8	9.5	0.39	0.68
8.2	Real estate, ownership of dwelling & business services	94.2	81.4	5.46	4.40
9.1	Public administration & defence	0	0	0	0
9.2	Other services	34.3	29.6	2.37	2.49
10	NDP at Factor cost	63.1	59.2	63.1	59.2

Source: NSSO, 2001

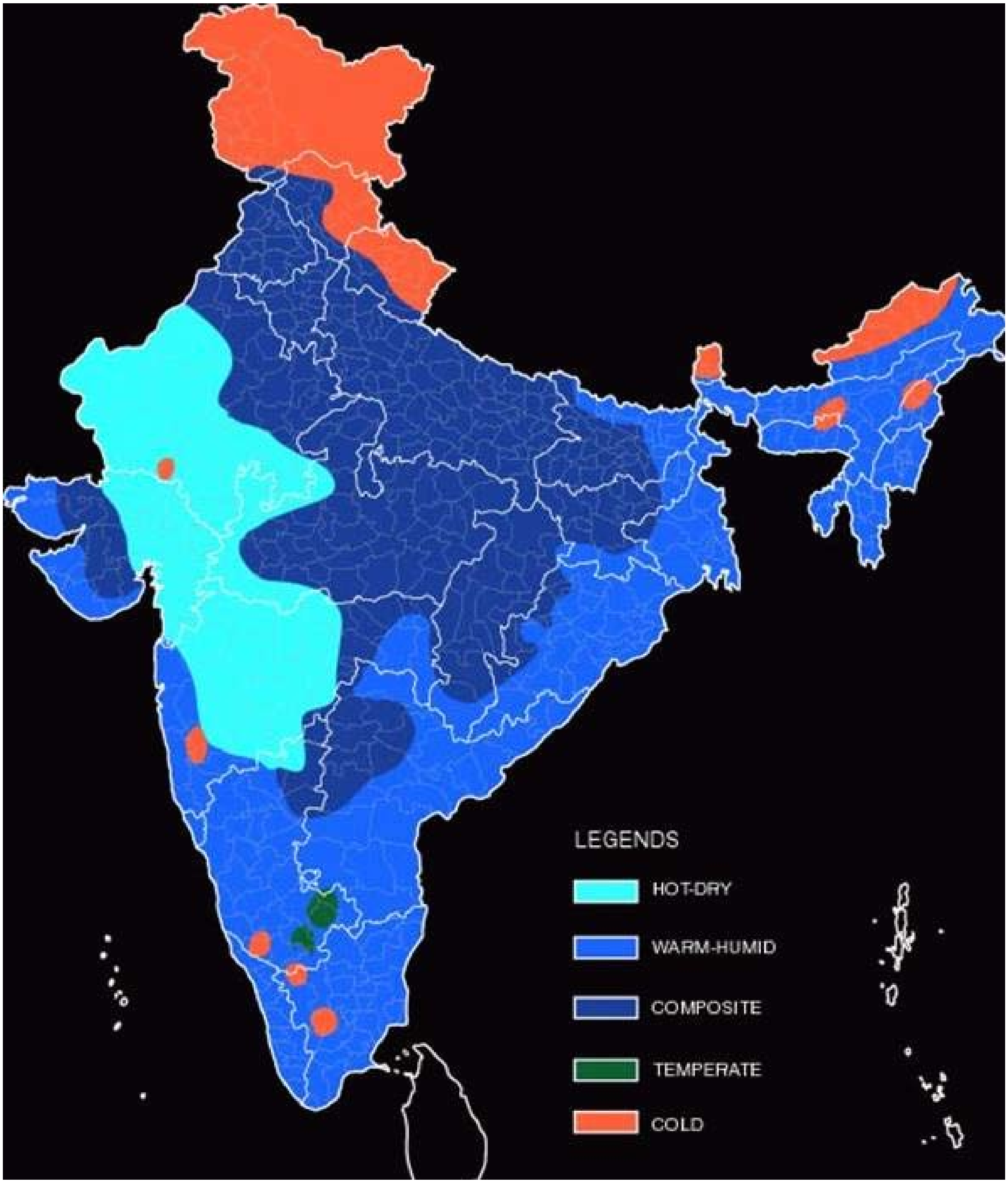
Annex 2. Floor Space per Employee Estimates
(sq. m./employee)

	Own account Enterprises	Establishments
Wholesale trade	15	20
Retail trade	10	20
Restaurants & Hotels	10	22
Transport & Storage	10	15
Post & telecommunication	10	12
Financial intermediation	10	12
Real Estate, Renting & Business services	10	12
Public administration and defense; compulsory social security	10	12
Education	15	15
Health and social work	10	12
Other Community, social & personal services	10	12
Other	10	12

Annex 3. Irrigated Land Projection



Annex 4. India Climatic Zones



Source: BEE, 2006

Annex 5. Agriculture Sector Energy Use and Projections

Sector	Variable Type	Name		Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
AGRICULTURE		AGRICULTURE			378	482	576	659	750	844	940		
Agriculture	driver	*FG*		Mt	168.38	181.79	195.19	208.6	227.03	245.46	264	1.4%	1.6%
Agriculture	driver	*L*		Mha	143	142	142	140.88	141	142	142	-0.1%	0.1%
Agriculture	driver	IL		Mha	48	50	53	55	59	63	67	0.9%	1.3%
Agriculture	driver	Pu_k	k=elec	unit/ha	0.144	0.187	0.229	0.272	0.294	0.315	0.336	4.3%	1.4%
Agriculture	intensity	IPu_k	k=elec	GJ/unit	30.5	27.4	24.3	21.3	21.3	21.3	21.3	-2.4%	0.0%
Agriculture	driver	Pu_k	k=diesel	unit/ha	0.097	0.101	0.105	0.109	0.088	0.066	0.04	0.8%	-5.8%
Agriculture	intensity	IPu_k	k=diesel	GJ/unit	20.0	21.3	22.6	23.9	23.9	23.9	23.9	1.2%	0.0%
Agriculture	driver	Fa_k	k=diesel	unit/ha	0.0074	0.0115	0.0156	0.0197	0.0251	0.0304	0.0358	6.7%	4.1%
Agriculture	intensity	IFa_k	k=diesel	GJ/unit	70	70	71	71	73	75	77	0.1%	0.5%
Agriculture	Total Energy			PJ	378	482	576	659	750	844	940	3.8%	2.4%
Agriculture	Energy Pumping			PJ	304	366	420	462	492	522	551	2.8%	1.2%
Agriculture	Energy Farming			PJ	74	115	156	197	258	322	389	6.7%	4.6%
Agriculture	Electricity			PJ	211	258	295	319	369	422	479	2.8%	2.8%
Agriculture	Diesel			PJ	168	224	281	341	382	422	461	4.8%	2.0%

Annex 6. Residential Sector Energy Use and Projections

Sector		Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
RESIDENTIAL				PJ	2,897	3,288	4,030	4,854	5,825	6,861	7,864		
Residential	driver		population	k pers	860,195	954,282	1,046,235	1,134,403	1,220,182	1,302,535	1,379,198	1.9%	1.3%
Residential	driver		urbanization rate	%	25.5%	26.6%	27.7%	28.7%	30.1%	31.9%	34.3%	0.8%	1.2%
Residential	driver	*Pm*	m=rural	k pers	640,845	700,443	756,428	808,829	852,907	887,026	906,133	1.7%	0.8%
Residential	driver	*Pm*	m=urban	k pers	219,350	253,839	289,807	325,574	367,275	415,509	473,065	2.7%	2.5%
Residential	driver	*Fm*	m=rural	pers/hh	5.57	5.38	5.19	4.91	4.80	4.77	4.75	-0.8%	-0.2%
Residential	driver	*Fm*	m=urban	pers/hh	5.30	4.94	4.60	4.31	4.05	3.85	3.70	-1.4%	-1.0%
Residential	driver	*Em*	m=rural	%	36.7%	39.9%	46.2%	53.7%	65.0%	76.3%	86.0%	2.6%	3.2%
Residential	driver	*Em*	m=urban	%	82.8%	85.8%	90.0%	93.4%	96.6%	98.4%	99.3%	0.8%	0.4%
Residential	driver	*Sm,j*	m=rural, j=refrigerator	%	1%	1%	2%	4%	8%	16%	27%	14.6%	13.6%
Residential	driver	*Sm,j*	m=rural, j=Air Conditioner	%	0%	0%	0%	0%	0%	0%	1%	6.0%	10.4%
Residential	driver	*Sm,j*	m=rural, j=Air Cooler	%	1%	1%	2%	3%	6%	10%	17%	9.3%	11.8%
Residential	driver	*Sm,j*	m=rural, j=washing Machine	%	0%	0%	0%	1%	2%	3%	7%	11.0%	15.5%
Residential	driver	*Sm,j*	m=rural, j=fan	%	20%	25%	37%	54%	81%	117%	161%	7.0%	7.6%
Residential	driver	*Sm,j*	m=rural, j=television	%	9%	11%	16%	22%	32%	43%	56%	6.2%	6.3%
Residential	driver	*Sm,j*	m=rural, j=water heating	%	0%	0%	1%	1%	2%	4%	8%	10.3%	14.5%
Residential	driver	*Sm,j*	m=rural, j=other	%	37%	40%	46%	54%	65%	76%	86%	2.6%	3.2%
Residential	driver	*Sm,j*	m=urban, j=refrigerator	%	16%	19%	27%	35%	46%	57%	69%	5.6%	4.6%
Residential	driver	*Sm,j*	m=urban, j=Air Conditioner	%	1%	1%	1%	3%	5%	9%	15%	10.5%	12.6%
Residential	driver	*Sm,j*	m=urban, j=Air Cooler	%	10%	11%	14%	17%	21%	26%	33%	3.4%	4.8%
Residential	driver	*Sm,j*	m=urban, j=wash. Machine	%	3%	5%	7%	12%	18%	27%	38%	8.7%	8.2%
Residential	driver	*Sm,j*	m=urban, j=fan	%	103%	116%	140%	166%	196%	228%	259%	3.2%	3.0%
Residential	driver	*Sm,j*	m=urban, j=television	%	51%	54%	59%	64%	70%	75%	80%	1.6%	1.5%
Residential	driver	*Sm,j*	m=urban, j=water heating	%	3%	4%	6%	9%	14%	21%	31%	7.6%	8.4%
Residential	driver	*Sm,j*	m=urban, j=other	%	83%	86%	90%	93%	97%	98%	99%	0.8%	0.4%
Residential	intensity	*UECj*	m=rural, j=refrigerator	kWh/unit	459	477	483	497	512	528	550	0.5%	0.7%
Residential	intensity	*UECj*	m=rural, j=Air Conditioner	kWh/unit	2,160	2,160	2,160	2,329	2,657	3,038	3,426	0.5%	2.6%
Residential	intensity	*UECj*	m=rural, j=Air Cooler	kWh/unit	298	298	298	298	298	298	298	0.0%	0.0%
Residential	intensity	*UECj*	m=rural, j=wash. Machine	kWh/unit	190	190	190	190	190	190	190	0.0%	0.0%
Residential	intensity	*UECj*	m=rural, j=fan	kWh/unit	145	145	145	145	145	145	145	0.0%	0.0%

Sector		Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
Residential	intensity	*UECj*	m=rural, j=television	kWh/unit	150	150	150	150	150	150	150	0.0%	0.0%
Residential	intensity	*UECj*	m=rural, j=water heating	kWh/unit	624	623	620	400	612	607	603	-2.9%	2.8%
Residential	intensity	*UECj*	m=rural, j=other	kWh/unit	-	-	-	89	164	238	298		8.4%
Residential	intensity	*UECj*	m=urban, j=refrigerator	kWh/unit	484	478	469	502	517	531	554	0.2%	0.7%
Residential	intensity	*UECj*	m=urban, j=Air Conditionner	kWh/unit	2,160	2,160	2,160	2,298	2,596	2,973	3,385	0.4%	2.6%
Residential	intensity	*UECj*	m=urban, j=Air Cooler	kWh/unit	298	298	298	298	298	298	298	0.0%	0.0%
Residential	intensity	*UECj*	m=urban, j=wash.Machine	kWh/unit	190	190	190	190	190	190	190	0.0%	0.0%
Residential	intensity	*UECj*	m=urban, j=fan	kWh/unit	145	145	145	145	145	145	145	0.0%	0.0%
Residential	intensity	*UECj*	m=urban, j=television	kWh/unit	150	150	150	150	150	150	150	0.0%	0.0%
Residential	intensity	*UECj*	m=urban, j=water heating	kWh/unit	620	623	624	400	612	607	602	-2.9%	2.8%
Residential	intensity	*UECj*	m=urban, j=other	kWh/unit	-	-	-	74	149	223	298		9.7%
Residential	driver	*Li,m*	i=fluorescent, m=rural	bulb/hh	1.2	1.3	1.5	1.8	2.1	2.5	3.0	2.6%	3.6%
Residential	driver	*Li,m*	i=fluorescent, m=urban	bulb/hh	1.6	1.8	2.1	2.5	3.0	3.6	4.4	3.0%	3.9%
Residential	driver	*Li,m*	i=incandescent, m=rural	bulb/hh	1.5	1.7	2.1	2.6	3.2	4.0	4.9	3.7%	4.4%
Residential	driver	*Li,m*	i=incandescent, m=urban	bulb/hh	2.3	2.6	3.2	4.0	5.0	6.2	7.8	3.9%	4.5%
Residential	power	*Cai,m*	i=fluorescent, m=rural	Watt	40	40	40	40	40	40	40	0.0%	0.0%
Residential	power	*Cai,m*	i=fluorescent, m=urban	Watt	40	40	40	40	40	40	40	0.0%	0.0%
Residential	power	*Cai,m*	i=incandescent, m=rural	Watt	60	60	60	60	60	60	60	0.0%	0.0%
Residential	power	*Cai,m*	i=incandescent, m=urban	Watt	60	60	60	60	60	60	60	0.0%	0.0%
Residential	usage	*Hi,m*	i=fluorescent, m=rural	hours	4	4	4	4	4	4	4	0.0%	0.0%
Residential	usage	*Hi,m*	i=fluorescent, m=urban	hours	4	4	4	4	4	4	4	0.0%	0.0%
Residential	usage	*Hi,m*	i=incandescent, m=rural	hours	4	4	4	4	4	4	4	0.0%	0.0%
Residential	usage	*Hi,m*	i=incandescent, m=urban	Hours	4	4	4	4	4	4	4	0.0%	0.0%
Residential	useful	*LKi,m*	i=kerosene, m=rural	MJ/ca/mth	8.3	10.2	19.6	24.7	29.0	31.7	28.5	7.5%	1.0%
Residential	useful	*LKi,m*	i=kerosene, m=urban	MJ/ca/mth	14.4	17.0	16.7	16.5	15.9	14.4	12.6	0.9%	-1.8%
Residential	final	*CWm,k*	m=rural, k=LPG	MJ/ca/mth	2.1	2.4	3.6	9.3	20.2	35.6	54.3	10.3%	12.4%
Residential	final	*CWm,k*	m=rural, k=wood	MJ/ca/mth	280.7	285.2	307.3	323.0	332.5	330.1	310.9	0.9%	-0.3%
Residential	final	*CWm,k*	m=rural, k=Kerosene	MJ/ca/mth	6.5	6.6	7.1	8.8	10.3	11.0	9.7	2.0%	0.6%
Residential	final	*CWm,k*	m=rural, k=biogas	MJ/ca/mth	0.3	0.6	0.7	0.8	0.9	0.9	0.9		
Residential	final	*CWm,k*	m=urban, k=LPG	MJ/ca/mth	30.27	44.63	80.52	101.77	123.12	141.83	157.72	8.4%	3.0%
Residential	final	*CWm,k*	m=urban, k=wood	MJ/ca/mth	97.44	85.29	54.92	42.38	31.60	23.32	17.05	-5.4%	-5.9%
Residential	final	*CWm,k*	m=urban, k=Kerosene	MJ/ca/mth	34.31	32.60	30.91	29.93	26.51	21.60	16.38	-0.9%	-3.9%

Sector	Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
Residential	rural appliance	k=electricity	PJ	20	27	52	117	224	381	585	12.4%	11.3%
Residential	rural lighting	k=electricity	PJ	30	38	66	104	166	250	357	8.7%	8.5%
Residential	rural lighting	k=kerosene	PJ	64	86	178	239	297	338	310	9.2%	1.7%
Residential	rural cooking	k=LPG	PJ	17	20	33	91	207	379	590	12.0%	13.3%
Residential	rural cooking	k=wood	PJ	2,159	2,397	2,790	3,135	3,403	3,514	3,380	2.5%	0.5%
Residential	rural cooking	k=kerosene	PJ	50	56	64	86	105	118	105	3.6%	1.4%
Residential	rural cooking	k=biogas	PJ	2	5	6	8	9	10	10		1.5%
Residential	urban appliance	k=electricity	PJ	55	68	123	204	352	579	941	9.2%	10.7%
Residential	urban lighting	k=electricity	PJ	36	45	83	126	192	289	429	8.8%	8.5%
Residential	urban lighting	k=kerosene	PJ	38	52	58	64	70	72	72	3.6%	0.7%
Residential	urban cooking	k=LPG	PJ	80	136	280	398	543	707	895	11.3%	5.6%
Residential	urban cooking	k=wood	PJ	256	260	191	166	139	116	97	-2.9%	-3.5%
Residential	urban cooking	k=kerosene	PJ	90	99	107	117	117	108	93	1.7%	-1.5%
Residential	Energy	Eres	PJ	2,897	3,288	4,030	4,854	5,825	6,861	7,864	3.5%	3.3%

Mth: month
Wash. Machine: Washing Machine
Source: de la Rue du Can, 2008

Annex 7. Commercial Sector Energy Use and Projections

Sector	Variable Type	Name	edgh	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
COMMERCIAL				PJ	131	200	363	736	883	1,025	1,195		
Coomerical	driver	*FSstock*	-	m^2	-	-	-	860	851	843	834		-0.2%
Commercial	driver	$FSnew_s$	s=retail	m^2/yr				4.0	6.4	10.4	16.7		10.0%
Commercial	driver	$FSnew_s$	s=private office	m^2/yr				4.5	8.0	14.0	24.7		12.0%
Commercial	driver	$FSnew_s$	s=gov office	m^2/yr				2.5	2.6	2.8	2.9		1.0%
Commercial	driver	$FSnew_s$	s=hotel	m^2/yr				6.3	8.4	11.3	15.1		6.0%
Commercial	driver	$FSnew_s$	s=other	m^2/yr				4.7	6.0	7.6	9.7		5.0%
Commercial	intensity	$EIstock_k$	k=electricity	MJ/m^2	-	-	-	251	291	409	573		7.0%
Commercial	intensity	$EIstock_k$	k=LPG	MJ/m^2	-	-	-	107	124	127	130		0.5%
Commercial	intensity	$EIstock_k$	k=diesel	MJ/m^2	-	-	-	235	273	316	367		3.0%
Commercial	intensity	$EIstock_k$	k=fuel oil	MJ/m^2	-	-	-	262	304	320	336		1.0%
Commercial	intensity	$EInew_{k,i}$	k=electricity, s=retail	MJ/m^2				600	600	600	600		0.0%
Commercial	intensity	$EInew_{k,i}$	k=electricity, s=private office	MJ/m^2				800	800	800	800		0.0%
Commercial	intensity	$EInew_{k,i}$	k=electricity, s=gov office	MJ/m^2				400	400	400	400		0.0%
Commercial	intensity	$EInew_{k,i}$	k=electricity, s=hotel	MJ/m^2				1000	1000	1000	1000		0.0%
Commercial	intensity	$EInew_{k,i}$	k=electricity, s=other	MJ/m^2				400	400	400	400		0.0%
Commercial	stock			Mm^2				860	988	1,041	1,130		1.8%
Commercial	energy		k=electricity	PJ	59	87	119	216	307	431	608	9.0%	7.1%
Commercial	energy		k=LPG	PJ	23	38	73	92	105	107	108	9.6%	1.1%
Commercial	energy		k=diesel	PJ	41	59	141	203	291	353	436	11.2%	5.2%
Commercial	energy		k=fuel oil	PJ	8	16	30	226	259	270	280	25.0%	1.5%
Commercial	energy		total	PJ	131	200	363	736	962	1,160	1,433	12.2%	4.5%

Annex 8. Industry Sector Energy Use and Projections

Sector	Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
INDUSTRY				**2,959**	**3,460**	**3,765**	**4,380**	**5,817**	**7,742**	**10,486**	**2.6%**	**6.0%**
Industry	Q_c	c=steel	k ton	14,963	20,768	26,920	45,780	62,140	82,677	110,000	7.7%	6.0%
Industry	$EI_{c,k}$	c=steel, k=coal	GJ/t	38.78	33.32	27.87	22.41	21.98	21.54	21.11	-3.6%	-0.4%
Industry	$EI_{c,k}$	c=steel, k=gas	GJ/t	0.00	0.64	1.29	1.93	1.89	1.85	1.82	65.6%	-0.4%
Industry	$EI_{c,k}$	c=steel, k=oil	GJ/t	1.12	1.12	1.13	1.14	1.11	1.09	1.07	0.1%	-0.4%
Industry	$EI_{c,k}$	c=steel, k=electricity	GJ/t	2.00	2.53	3.05	3.58	3.51	3.44	3.37	4.0%	-0.4%
Industry	Q_c	c=cement	k ton	46,170	67,722	99,227	145000	206,934	296,967	424,337	7.9%	7.4%
Industry	$EI_{c,k}$	c=cement, k=coal	GJ/t	2.64	2.50	2.37	2.24	2.19	2.15	2.11	-1.1%	-0.4%
Industry	$EI_{c,k}$	c=cement, k=oil	GJ/t	0.83	0.79	0.75	0.70	0.69	0.68	0.66	-1.1%	-0.4%
Industry	$EI_{c,k}$	c=cement, k=electricity	GJ/t	0.14	0.14	0.13	0.12	0.12	0.12	0.12	-1.1%	-0.4%
Industry	Q_c	c=pulp and paper	k ton	4,095	5,150	6,531	8231	10,505	14,251	21,656	4.8%	6.7%
Industry	$EI_{c,k}$	c=pulp and paper, k=coal	GJ/t	34	30.48	26.88	23	22.83	22.37	21.92	-2.5%	-0.4%
Industry	$EI_{c,k}$	c=pulp and paper, k=electricity	GJ/t	1	0.69	0.70	1	0.69	0.68	0.67	0.3%	-0.4%
Industry	Q_c	c=aluminium	k ton	428	518	644	925	1,192	1,536	2,208	5.3%	6.0%
Industry	$EI_{c,k}$	c=aluminium, k=coal	GJ/t	281.43	307.94	302.81	305.81	299.86	293.91	287.97	0.6%	-0.4%
Industry	$EI_{c,k}$	c=aluminium, k=oil	GJ/t	15.70	1.86	10.05	6.48	6.36	6.23	6.10	-5.7%	-0.4%
Industry	$EI_{c,k}$	c=aluminium, k=electricity	GJ/t	101.83	83.98	67.64	52.62	51.60	50.57	49.55	-4.3%	-0.4%
Industry	Q_c	c=ammonia	k ton	7,176	8,287	10,148	10800	12,220	14,096	16,928	2.8%	3.0%
Industry	$EI_{c,k}$	c=ammonia, k=coal	GJ/t	11.15	9.42	7.70	5.97	5.86	5.74	5.63	-4.1%	-0.4%
Industry	$EI_{c,k}$	c=ammonia, k=oil	GJ/t	13.85	15.77	12.17	8.06	7.90	7.74	7.59	-3.5%	-0.4%
Industry	$EI_{c,k}$	c=ammonia, k=gas	GJ/t	27.83	32.65	29.74	27.14	26.61	26.08	25.56	-0.2%	-0.4%
Industry	$EI_{c,k}$	c=ammonia, k=electricity	GJ/t	2.46	2.58	2.28	1.77	1.74	1.70	1.67	-2.2%	-0.4%
Industry	G	-	M US $	64.3	86.1	111.1	155.7	223.5	320.9	460.69	6.1%	7.5%
Industry	RI_k	k=coal	MJ/US $	10.26	7.38	4.50	1.62	1.48	1.34	1.20	-11.6%	-2.0%
Industry	RI_k	k=gas	MJ/US $	0.89	0.85	0.81	0.77	0.76	0.74	0.73	-1.0%	-0.3%
Industry	RI_k	k=oil	MJ/US $	7.98	7.38	6.78	6.18	6.06	5.94	5.82	-1.7%	-0.4%
Industry	RI_k	k=electricity	MJ/US $	3.27	2.77	2.26	1.75	1.71	1.67	1.63	-4.1%	-0.5%
By Industry Sub-sectors												
Industry		c=steel	PJ	627	781	897	1,330	1,770	2,309	3,010	5.1%	5.6%
Industry		c=cement	PJ	167	232	322	444	621	874	1,224	6.8%	7.0%

Sector	Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
Industry		c=pulp and paper	PJ	142	161	180	197	247	329	489	2.2%	6.2%
Industry		c=aluminium	PJ	171	204	245	338	426	539	759	4.7%	5.5%
Industry		c=ammonia	PJ	397	501	527	464	515	582	685	1.0%	2.6%
Industry		other	PJ	1,441	1,582	1,594	1,607	2,237	3,110	4,320	0.7%	6.8%
By Fuel Type												
Industry		k=electricity	PJ	311	368	417	528	716	967	1,321	3.6%	6.3%
Industry		k=coal	PJ	1,702	1,892	1,934	2,142	2,820	3,701	4,973	1.5%	5.8%
Industry		k=oil	PJ	674	843	987	1,209	1,670	2,315	3,221	4.0%	6.8%
Industry		k=gas	PJ	272	357	426	501	612	760	970	4.2%	4.5%

Annex 9. Transport Sector Energy Use and Projections

Sector	Variable Type	Name		Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
TRANSPORT					**1,056**	**1,199**	**1,446**	**1,964**	**2,716**	**3,830**	**5,119**		
Transport	driver	$V_{t,j,k}$	t=pass, j=two wheelers, k=gasoline	k unit	8,811	15,556	29,690	50,225	56,933	84,914	121,368	12.3%	6.1%
Transport	driver	$K_{t,j}$	t=pass, j=two wheelers	km/yr	9,000	6,750	6,300	6,300	6,300	6,300	6,300	-2.3%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=two wheelers, k=gasoline	km/l	40	48	60	68	73	74	75	3.5%	0.7%
Transport	driver	$V_{t,j,k}$	t=pass, j=pass car, k=gasoline	k unit	956	1,527	3,421	4,788	6,602	12,031	19,728	11.3%	9.9%
Transport	driver	$K_{t,j}$	t=pass, j=pass car	km/yr	9,000	9,000	8,000	8,000	8,000	8,000	7,500	-0.8%	-0.4%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=pass car, k=gasoline	km/l	8.86	9.80	12.00	12.83	13.50	13.80	14.00	2.5%	0.6%
Transport	driver	$V_{t,j,k}$	t=pass, j=pass car, k=diesel	k unit	0.00	25	324	2,175	3,492	9,007	19,728		15.8%
Transport	driver	$K_{t,j}$	t=pass, j=pass car	km/yr	9,000	9,000	8,000	8,000	8,000	8,000	7,500	-0.8%	-0.4%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=pass car, k=diesel	km/l	0.00	0.00	14.00	14.00	14.00	14.00	15.09		0.5%
Transport	driver	$V_{t,j,k}$	t=pass, j=MPV, k=diesel	k unit	152	275	869	1,497	2,133	4,445	8,337	16.5%	12.1%
Transport	driver	$K_{t,j}$	t=pass, j=MPV	km/yr	10,000	9,000	8,000	7,800	7,800	7,800	7,500	-1.6%	-0.3%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=MPV, k=diesel	km/l	6.20	6.86	8.40	8.52	8.73	8.95	9.18	2.1%	0.5%
Transport	driver	$V_{t,j,k}$	t=pass, j=three wheelers, k=gasoline	k unit	591	993	1,730	2,583	3,943	5,927	7,397	10.3%	7.3%
Transport	driver	$K_{t,j}$	t=pass, j=three wheelers	km/yr	35,500	35,500	35,500	35,500	35,500	35,500	35,500	0.0%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=three wheelers, k=gasoline	km/l	16.93	21.31	26.83	32.26	34.00	35.00	37.00	4.4%	0.9%
Transport	driver	$V_{t,j,k}$	t=pass, j=buses, k=diesel	k unit	298	423	559	772	852	941	1,038	6.5%	2.0%
Transport	driver	$K_{t,j}$	t=pass, j=buses	km/yr	65,000	60,000	55,480	55,000	55,000	55,000	52,000	-1.1%	-0.4%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, j=buses, k=diesel	km/l	3.00	3.40	3.57	3.93	4.10	4.30	4.50	1.8%	0.9%
Transport	driver	$V_{t,j,k}$	t=freight, j=heavy truck, k=diesel	k unit	350	525	731	971	1,571	2,372	3,521	7.0%	9.0%
Transport	driver	$K_{t,j}$	t=freight, j=heavy truck	km/yr	60,000	60,000	55,000	55,000	55,000	55,000	55,000	-0.6%	0.0%
Transport	intensity	$V_{t,j,k}$	t=freight, j=heavy truck, k=diesel	km/l	2.70	2.98	3.21	3.51	3.60	3.69	3.78	1.8%	0.5%
Transport	driver	$K_{t,j}$	t=freight, j=light truck	k unit	410	724	846	1,019	1,635	1,991	2,346	6.3%	5.7%
Transport	driver	$V_{t,j,k}$	t=freight, j=light truck, k=diesel	km/yr	25,000	20,000	20,000	20,000	20,000	20,000	15,000	-1.5%	-1.9%
Transport	intensity	$K_{t,j}$	t=freight, j=light truck	km/l	3.26	3.57	4.07	4.42	4.53	4.64	4.76	2.1%	0.5%
Transport	driver	$Q_{t,r}$	t=pass, r=air	M pass-km	15,253	20,856	26,212	40,999	65,849	92,357	128,327	6.8%	7.9%
Transport	driver	$S_{t,r,k}$	t=pass, r=air, k=kerosene	%	100%	100%	100%	100%	100%	100%	100%	0.0%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, r=air,k=kerosene	MJ/pass-km	3.60	3.50	3.50	3.48	3.39	3.39	3.22	-0.2%	-0.5%

Sector	Variable Type	Name		Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
Transport	driver	$Q_{t,r}$	t=freight, r=air	M ton-km	675	642	582	7,262	12,798	17,949	25,175	17.2%	8.6%
Transport	driver	$S_{t,r,k}$	t=freight, r=air, k=kerosene	%	100%	100%	100%	100%	100%	100%	100%	0.0%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=freight, r=air, k=kerosene	MJ/ton-km	18.90	18.02	18.02	17.90	17.46	17.46	16.60	-0.4%	-0.5%
Transport	driver	$Q_{t,r}$	t=pass, r=water	M pass-km	6,364	8,809	9,681	10,009	10,999	12,087	13,282	3.1%	1.9%
Transport	driver	$S_{t,r,k}$	t=pass, r=water, k=diesel	%	100%	100%	100%	100%	100%	100%	100%	0.0%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, r=water, k=diesel	MJ/pass-km	0.37	0.40	0.40	0.37	0.36	0.36	0.34	0.0%	-0.5%
Transport	driver	$Q_{t,r}$	t=freight, r=water	M ton-km	42,689	54,876	77,542	99,157	141,264	201,253	286,717	5.8%	7.3%
Transport	driver	$S_{t,r,k}$	t=freight, r=water, k=diesel	%	100%	100%	100%	100%	100%	100%	100%	0.0%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=freight, r=water, k=diesel	MJ/ton-km	0.30	0.26	0.22	0.20	0.20	0.20	0.19	-2.7%	-0.5%
Transport	driver	$Q_{t,r}$	t=pass, r=rail	M pass-km	306,282	348,385	457,022	517,212	536,018	555,508	575,706	3.6%	0.7%
Transport	driver	$S_{t,r,k}$	t=pass, r=rail, k=coal	%	22%	1%	0%	0%	0%	0%	0%		
Transport	driver	$S_{t,r,k}$	t=pass, r=rail, k=diesel	%	42%	64%	56%	51%	42%	34%	25%	1.2%	-4.6%
Transport	driver	$S_{t,r,k}$	t=pass, r=rail, k=electricity	%	36%	35%	44%	49%	58%	66%	75%	2.1%	2.8%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, r=rail, k=coal	MJ/pass-km	1.20	1.20	0.00	0.00	0.00	0.00	0.00		
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, r=rail, k=diesel	MJ/pass-km	0.24	0.17	0.15	0.15	0.15	0.15	0.14	-3.1%	-0.5%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=pass, r=rail, k=electricity	MJ/pass-km	0.12	0.12	0.10	0.08	0.08	0.08	0.07	-2.7%	-0.5%
Transport	driver	$Q_{t,r}$	t=freight, r=rail	M ton-km	251,476	275,899	315,520	362,973	399,760	440,276	484,899	2.5%	1.9%
Transport	driver	$S_{t,r,k}$	t=freight, r=rail, k=coal	%	2%	0%	0%	0%	0%	0%	0%		
Transport	driver	$S_{t,r,k}$	t=freight, r=rail, k=diesel	%	60%	49%	44%	40%	33%	27%	20%	-2.7%	-4.5%
Transport	driver	$S_{t,r,k}$	t=freight, r=rail, k=electricity	%	38%	51%	56%	60%	67%	73%	80%	3.1%	1.9%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=freight, r=rail, k=coal	MJ/ton-km	3.00	3.60	0.00	0.00	0.00	0.00	0.00		
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=freight, r=rail, k=diesel	MJ/ton-km	0.23	0.18	0.14	0.11	0.11	0.11	0.11	-4.8%	0.0%
Transport	intensity	$EI_{TR\ t,r,j,k}$	t=freight, r=rail, k=electricity	MJ/ton-km	0.11	0.10	0.09	0.08	0.08	0.08	0.08	-2.1%	0.0%
Transport	Motor Gasoline		t=pass, r=road, j=two wheelers	PJ	69	76	108	162	170	251	353	5.9%	5.3%
Transport	Motor Gasoline		t=pass, r=road, j=pass car,	PJ	34	49	79	103	136	242	366	7.8%	8.8%
Transport	Diesel		t=pass, r=road, j=pass car,	PJ			7	45	72	183	358		14.8%
Transport	Diesel		t=pass, r=road, j=MPV	PJ	8	12	29	45	61	124	221	11.8%	11.2%
Transport	Motor Gasoline		t=pass, r=road, j=three wheelers,	PJ	43	57	79	99	143	208	246	5.7%	6.3%

Sector	Variable Type	Name	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
Transport	Diesel	t=pass, r=road, j=bus	PJ	236	272	317	394	417	439	438	3.5%	0.7%
Transport	Diesel	t=freight, r=road, j=heavy truck	PJ	284	386	458	555	876	1,290	1,868	4.6%	8.4%
Transport	Diesel	t=freight, r=road, j=light truck	PJ	115	148	152	168	263	313	270	2.6%	3.2%
Transport	Kerosene	t=pass, r=air	PJ	55	73	92	143	223	313	414	6.6%	7.4%
Transport	Kerosene	t=freight, r=air	PJ	13	12	10	130	223	313	418	16.7%	8.1%
Transport	Diesel	t=pass, r=water	PJ	2	3	4	4	4	4	5	3.1%	1.4%
Transport	Diesel	t=freight, r=water	PJ	13	14	17	20	28	39	53	3.0%	6.8%
Transport	Coal	t=pass, r=rail	PJ	80	4	0	0	0	0	0		
Transport	Coal	t=freight, r=rail	PJ	15	0	0	0	0	0	0		
Transport	Diesel	t=pass, r=rail	PJ	31	38	40	39	33	27	20	1.6%	-4.4%
Transport	Diesel	t=freight, r=rail	PJ	35	25	19	16	15	13	11	-5.1%	-2.6%
Transport	Electricity	t=pass, r=rail	PJ	13	15	20	20	24	29	32	3.0%	3.1%
Transport	Electricity	t=freight, r=rail	PJ	11	14	16	18	21	26	31	3.5%	3.9%

Pass. : passenger

Source: de la Rue du Can, 2009

Annex 10. Total Sector Final Energy Use and Projections

Sector	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
AGRICULTURE	**PJ**	**378**	**482**	**576**	**659**	**750**	**844**	**940**	**3.8%**	**2.4%**
electricity		211	258	295	319	369	422	479	2.8%	2.8%
diesel		168	224	281	341	382	422	461	4.8%	2.0%
RESIDENTIAL	**PJ**	**2,897**	**3,288**	**4,030**	**4,854**	**5,825**	**6,861**	**7,864**	**3.5%**	**3.3%**
electricity		141	177	323	551	935	1,499	2,313	9.5%	10.0%
kerosene		242	292	408	506	589	635	580	5.0%	0.9%
LPG		96	156	313	488	749	1,087	1,485	11.4%	7.7%
wood		2,415	2,657	2,981	3,300	3,542	3,630	3,477	2.1%	0.3%
TRANSPORT	**PJ**	**1,056**	**1,199**	**1,446**	**1,964**	**2,716**	**3,830**	**5,119**	**4.2%**	**6.6%**
electricity		24	29	36	38	46	55	63	3.2%	3.5%
diesel		715	887	1,013	1,242	1,709	2,314	3,023	3.7%	6.1%
motor gasoline		154	194	295	412	515	835	1,202	6.8%	7.4%
kerosene		68	85	102	273	447	626	832	9.7%	7.7%
Coal		95	5	0	0	0	0	0		
INDUSTRY	**PJ**	**2,959**	**3,460**	**3,765**	**4,380**	**5,817**	**7,742**	**10,486**	**2.6%**	**6.0%**
electricity		311	368	417	528	716	967	1,321	3.6%	6.3%
Coal		1,702	1,892	1,934	2,142	2,820	3,701	4,973	1.5%	5.8%
oil		674	843	987	1,209	1,670	2,315	3,221	4.0%	6.8%
gas		272	357	426	501	612	760	970	4.2%	4.5%
COMMERCIAL	**PJ**	**131**	**200**	**363**	**736**	**962**	**1,160**	**1,433**	**12.2%**	**4.5%**
electricity		59	87	119	216	307	431	608	9.0%	7.1%
LPG		23	38	73	92	105	107	108	9.6%	1.1%
diesel		41	59	141	203	291	353	436	11.2%	5.2%
fuel oil		8	16	30	226	259	270	280	25.0%	1.5%

Annex 11. Total Sector Primary Energy Use and Projections

Sector	Unit	1990	1995	2000	2005	2010	2015	2020	AAGR 90-05	AAGR 05-20
PRIMARY ENERGY		9,633	11,525	14,608	17,903	23,296	30,157	38,836	4.2%	5.3%
Primary Factor		3.97	4.16	4.73	4.22	4.05	3.88	3.72	0.4%	-0.8%
AGRICULTURE	**PJ**	**1,004**	**1,296**	**1,674**	**1,685**	**1,875**	**2,061**	**2,242**	**3.5%**	**1.9%**
electricity		837	1,072	1,393	1,345	1,493	1,639	1,781	3.2%	1.9%
diesel		168	224	281	341	382	422	461	4.8%	2.0%
RESIDENTIAL	**PJ**	**3,312**	**3,843**	**5,228**	**6,619**	**8,668**	**11,176**	**14,140**	**4.7%**	**5.2%**
electricity		558	738	1,527	2,324	3,787	5,824	8,598	10.0%	9.1%
kerosene		242	292	408	506	589	635	580	5.0%	0.9%
LPG		96	156	313	488	749	1,087	1,485	11.4%	7.7%
wood		2,415	2,657	2,981	3,300	3,542	3,630	3,477	2.1%	0.3%
TRANSPORT	**PJ**	**1,126**	**1,290**	**1,578**	**2,086**	**2,855**	**3,987**	**5,291**	**4.2%**	**6.4%**
electricity		94	119	168	160	185	212	234	3.6%	2.6%
diesel		715	887	1,013	1,242	1,709	2,314	3,023	3.7%	6.1%
motor gasoline		154	194	295	412	515	835	1,202	6.8%	7.4%
kerosene		68	85	102	273	447	626	832	9.7%	7.7%
Coal		95	5	0	0	0	0	0		
INDUSTRY	**PJ**	**3,883**	**4,623**	**5,322**	**6,081**	**8,000**	**10,530**	**14,077**	**3.0%**	**5.8%**
electricity		1,235	1,531	1,974	2,229	2,899	3,755	4,913	4.0%	5.4%
Coal		1,702	1,892	1,934	2,142	2,820	3,701	4,973	1.5%	5.8%
oil		674	843	987	1,209	1,670	2,315	3,221	4.0%	6.8%
gas		272	357	426	501	612	760	970	4.2%	4.5%
COMMERCIAL	**PJ**	**307**	**473**	**806**	**1,432**	**1,898**	**2,403**	**3,086**	**10.8%**	**5.3%**
electricity		235	360	562	912	1,243	1,674	2,261	9.4%	6.2%
LPG		23	38	73	92	105	107	108	9.6%	1.1%
diesel		41	59	141	203	291	353	436	11.2%	5.2%
fuel oil		8	16	30	226	259	270	280	25.0%	1.5%