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Shonali Pachauri

An Energy Analysis of Household Consumption

Changing Patterns of Direct and Indirect Use in India

Springer

AN ENERGY ANALYSIS OF HOUSEHOLD CONSUMPTION

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The level of presentation is for graduate students in natural, social and engineering sciences as well as policy and decision-makers around the world in government, industry and civil society.

An Energy Analysis of Household Consumption

Changing Patters of Direct and Indirect Use in India

By

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Springer

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Preface

The book presents a novel socio-economic approach to analysing the energy system and energy consumption in India from a household perspective. In doing so, it views households as the ultimate end-consumers and estimates and analyses the direct and indirect energy requirements of household consumption, both at an aggregate national level as well as at a disaggregate household level. In addition, the work incorporates two crucial aspects often ignored by many energy studies that are characteristic of most developing countries, namely the importance of non-commercial sources of biomass energy in the energy systems of these countries, and the enormous diversity and inequity in the patterns of energy access and use across households with different lifestyles and levels of well being.

This work was initiated as part of my Ph.D. thesis at the Centre for Energy Policy and Economics (CEPE) at the Swiss Federal Institute of Technology in Zürich (ETHZ). The thesis was completed at the end of 2002. Therefore, by the time the idea of the book was conceived, two years later, as part of the Alliance for Global Sustainability (AGS) Bookseries, much of the empirical analysis was already dated. A major challenge in preparing the book, thus, lay in assembling and analysing new data in order to update the work. Some delays were unavoidable, as I was limited by the schedule for release of the new data. Other delays were of my own making. A change of jobs, from ETHZ to the International Institute of Applied Systems Analysis (IIASA), during the course of re-writing the manuscript, led to further delays.

With an expansion of my own professional interests and research over the course of the last few years, the focus and scope of the book also broadened. In addition to updating the information and analysis, I also made major revisions to the organisation and contents of some of the chapters. Some of the original chapters from the thesis were merged and a completely new chapter analysing the links between energy and well being was added.

As a consequence of all these revisions and modifications, I hope that the book provides a broader understanding of the links between energy and development. Developing countries, like India, face a dual challenge of ensuring adequate energy supplies for their rapidly developing economies and addressing the basic needs and growing aspirations of their people, while curbing the adverse environmental impacts associated with an increased reliance on fossil energy. It is hoped that the analysis and assessments introduced in this book will be of assistance in solving some of the real problems associated with meeting this challenge and will provide a foundation for furthering research in this area. The material in this book is intended to inform academics, researchers, policymakers and practitioners as well as those interested in energy analysis and development policy. In particular, I hope that the book will assist in providing an impetus to efforts aimed at integrating energy and social policies in developing countries.

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I am grateful to the Department of Statistics, Government of India for the supply of much of the data used for analysis. In particular, I thank the National Sample Survey Organisation (NSSO) for providing the unit level household survey data and the Central Statistical Organisation (CSO) for supplying the input-output data.

Finally, I would like to express special appreciation and thanks to my parents for providing me with an example of excellence and outstanding achievement in their respective areas of research. They have always encouraged me to aim high. Words cannot express my deep gratitude and appreciation for their understanding, endless patience and encouragement whenever I have needed it most. I also convey my heartfelt thanks to my loving siblings for their unstinting support and absolute confidence in me. Thanks also to other close family members and good friends who supported me throughout the writing of this book. In particular, thanks to my brother and to Preeta for their last proofing and editing of the text. And finally, a very special word of thanks to my mother for taking time out of her own busy schedule to painstakingly edit the entire manuscript.

Chapter 1: Introduction

"The significance of energy for development appears to be the greatest in those countries that have the lowest aggregate levels of energy consumption and where energy use is inefficient."

(UNDP and WEC 2000)

Energy use is crucial to human survival and development. Improvements in lifestyles have historically been associated with increases in energy consumption and the access to appropriate energy services has always been seen as a necessary precondition for development. While the developed or post-industrialised nations have seen some decoupling of energy and gross domestic product (GDP) growth in recent years at high levels of per capita energy use, recent trends reveal that energy consumption in India, and other fast growing developing countries, is increasing rapidly (IEA 2006). The growing share of developing countries like India in global energy use and greenhouse gas emissions serves as the backdrop to this work. The overall purpose is to increase insight into the underlying causes of the growing energy use in India by adopting a household perspective. The household perspective is adopted in order to shed light on the complex relationships between energy use, household consumption, lifestyles and development.

1.1 Background and Significance

The emphasis of much of the energy literature, both in the developed and developing countries, has conventionally been on energy supply and production. This supply-oriented paradigm has encouraged developing countries to follow policies that focus solely on the growth of energy supply to guarantee further economic growth. However, given the present global concern regarding serious environmental, social and macroeconomic problems associated with the more traditional approaches to energy, a number of recent publications have highlighted the need for a reorientation of thinking towards a new focus on energy services rather than on energy supply (UNDP 2000; UNDP and WEC 2000). This new focus also highlights the need to shift the emphasis from looking not only at the demand for energy directly, but rather the demand for products and services that use energy or require energy for their delivery.

Alternative approaches to studying energy services have evolved in the last few decades, one of which assumes that all production in an economy takes place to ultimately satisfy final consumption. Thus, all production in an economy can be projected on to the end-users or the ultimate consumers. All economic activity can then be expressed in terms of energy by using the concept of embodied or grey energy (Spreng 1994). Thus, all household consumption of goods and services is expressed in terms of the energy required to domestically produce that specific good or service. In this way, total energy use in an economy is allocated to final consumption. One can then examine energy use from the perspective of individual consumers or households as they form the main consumption sector of the economy. This approach, however, does not include the energy embodied in capital formation and, exports/ imports, though the latter are still relatively small but growing for the case of large developing economies like India.

Studies that follow such a household perspective on energy consumption do exist for developed countries. Examples of such research include those examining the total (direct and indirect/embodied) energy requirements of households in the USA (Herendeen et al. 1981), in New Zealand (Peet et al. 1985) and Switzerland (Ospelt et al. 1996). A series of publications by researchers at the University of Groningen and University of Utrecht have studied household metabolic flows in the Netherlands (Noorman and Uiterkamp 1998; Vringer and Blok 1995, 2000). A more recent publication in this field that links consumption to environmental pollution reports results from an European study for Germany, France and Netherlands on “Consumer Lifestyles and Pollutant Emissions.” (Weber and Perrels 2000). The existing literature provides important insights for understanding energy use in these countries. However, little analysis of this kind has been conducted in developing countries and this is, clearly, a major lacuna (see Pachauri 2002). In addition, studies that compare trends in developing countries with those of developed countries are few and far between (see Lenzen et al. 2006). Research undertaken, as part of this study, should broaden and deepen the foundation for understanding the links between energy use, overall level of development, and well being of the people of India.

Methodologies and techniques for determining total household energy requirements already exist and have been developed as part of research efforts in various developed countries under the umbrella of energy analysis or energy accounting. Chapter 3 of the book will discuss in detail some of the literature that develops these methodologies. However, what is important to point out here is that the methodologies developed in the past have thus far only been applied in post-industrial or developed countries and have omitted aspects related to non-commercial biomass[1] energy use. The special significance of this study therefore lies in the fact that methods that were developed and have so far been applied in only industrialised countries have been tested and adapted for the first time for India. The key modification has been to include non-commercial energy (which comprised about 33% of primary energy consumption in 1999-00), and to cover a broad spectrum of low and high income households in rural and urban areas covering the entire geographical region of the country.

There are at least two main reasons for the study to focus on India. First, it provides a good example of a rapidly developing economy whose share in total global energy use and greenhouse gas emissions is increasing. It is still a low-income country undergoing a process of economic development. Yet, it has experienced a rapid rate of economic growth over the last decade and a half. An increasing level of urbanisation, industrialisation and modernisation has accompanied the rapid economic growth of the last years and this has also meant rapidly changing lifestyles and patterns of energy use for its population. As in other developing countries, energy services still constitute a sizeable share of total household expenditures in India. Average direct energy consumption per capita is low when compared to developed countries and even when compared to average global figures. However, the demand for energy using services in the household sector has increased considerably in the last couple of decades and is likely to expand rapidly in the years ahead. The household sector as a whole is responsible for a substantial part of the energy consumption in India. In 1999-00, over 40% of total commercial and non-commercial Indian energy consumption was demanded directly by households. By also taking into account the indirect or embodied energy use of goods and services consumed by households the share of this sector in total energy consumption increases to about 70%. The remainder of total Indian energy use is made

[1] While, some traditional biomass is commercially bought and sold in markets, particularly in urban areas, for the purpose of this book, all traditional biomass use is referred to as non-commercial.

up of the energy requirements of public sector consumption, gross investments and net imports.

Another more pragmatic factor that makes India an attractive case study is the availability of statistical data on energy consumption, different aspects of household consumption, and the production structure of the economy. India has a stronger statistical tradition than most poor countries. While there is no one co-ordinated agency that publishes energy statistics in India, annual statistical data are published by the various governmental ministries and departments dealing with different commercial energy sources. The Food and Agricultural Organisation (FAO) also publishes data on non-commercial energy use in India. A consistent set of four input-output tables for the Indian economy providing monetary flows between 115 producing sectors is also available for the period spanning 1983-84 to 1998-99. In addition to these sources of national macro level data, the National Sample Survey Organisation (NSSO) set up in 1950 by the department of statistics, conducts periodic nationwide surveys on various facets of household expenditure for a large representative sample of households covering the entire geographical area of India. Detailed micro-level household data on consumer expenditures and socio-economic characteristics for the years 1983, 1989-90, 1993-94 and 1999-00 from the large quinquennial rounds of the NSSO has been used for this research as it provides a rich source of information for analysis. The data allows for a distinction to be made in the energy use patterns of different household groups, both rural and urban, and those belonging to different income groups and geographical regions. This makes it possible to detect the influence of expenditure patterns and other individual socio-economic and demographic variables relating to private households on direct and indirect energy use.

1.2 Context and Motivation

The work presented in this book may be viewed within the context of certain developments that have occurred within the energy field in recent years. First, it is well recognised that large increases in energy use are expected in the next few decades in developing countries as incomes rise and people aspire to better standards of living. While this is even warranted, especially in the case of those who still have little or no access to commercial energy and eke out a living at a bare subsistence level, the increasing concerns relating to the negative local, regional, and global impacts associated with the use of energy can no longer be ignored (Holdren and Smith 2000).

It is well recognised that the challenge for the future lies in meeting the growing energy needs of developing countries in an efficient and sustainable way. A first step to meeting this challenge is to understand current energy needs and patterns of energy use in these rapidly developing economies. Of importance also, is an assessment of whether developing countries are following lifestyles and the patterns of energy use of developed countries, or whether it is possible and worthwhile for these countries to attempt to leapfrog to more sustainable energy futures. Available data to answer these questions are scarce. The report “Energy Demand, Life Style Changes & Technology” of the World Energy Council (WEC 1995), provides information on changes over long time periods by assuming, at a macro-level, trends that go from rural to urban, from less affluence to more affluence, and from less industry and services to more industry, and especially, more services. The report by the The Energy and Resources Institute, titled “Green India 2047,” also examines at a macro-level, trends in economic, social, environmental and resource use indicators for the five decades since India’s independence in 1947 (TERI 1998).

It is also important to bear in mind that most existing literature and energy studies for India have adopted a sectoral approach to analysing energy supply and demand. In other words, production of energy has been perceived to be a necessary requirement to supply the different end-use sectors in the economy, such as households, industry, transport, commerce, and agriculture. Energy modelling exercises for India have tended to adopt a top-down approach to study past trends and forecast future energy/electricity demand or supply within the country. Additionally, most existing studies adopt a macro approach, with very little literature using micro level data.

One of the important early examples of such a top-down approach to energy modelling for India is the long-run macro model developed by the Planning Commission for the purpose of infrastructural planning and development in India (Sengupta 1993). Researchers at the Indira Gandhi Institute of Developmental Research have been involved more recently in using input-output analysis to calculate the carbon dioxide emissions from energy consumption for different groups of households for the year 1989-90 (Parikh et al. 1997; Murthy et al. 1997a, 1997b). A more recent paper carries out a decomposition of commercial primary and final energy consumption and carbon emissions for broad sectors in India between 1970 and 1995 (Nag and Parikh 2000). Since energy use is a major source of green house gas (GHG) emissions, recent studies have looked at options for reducing emissions through energy substitution options in India. Parikh and Gokarn (1990) have examined the energy flow in the Indian economy considering a 60 sector input-output model. They argue that it would be more expensive for India to save energy from coal (which is now advocated at international levels) than from oil.

Long term modelling of energy emissions in India is a recent phenomenon. The AIM-End-use macro model (Shukla 1996), has been set up for a forty years horizon from 1995 to 2035. The focus of the model is the analysis of end-use demand sectors. The objective of the exercise is minimisation of discounted energy system costs at end-use sub-sector levels over the next forty years. It is developed for six different end-use sectors: 1) industry, 2) transport, 3) agriculture, 4) urban residential, 5) rural residential, and 6) commercial & services.

The bottom-up MARKAL model, originally developed for Canada by Berger et al. (1992), has also been adopted for India (Shukla and Kanudia 1997; Pandey (1998). Rana and Shukla (2001), while using the Edmonds-Reilly-Barnes model (ERB) model, worked with one reference scenario and a few mitigation scenarios wherein imposition of carbon taxes at various levels were varied. The PEW Center on Global Climate Change has developed six scenarios in its study of the electric power sector of India (Chandler et al. 1999). Another set of scenarios analysed in one of the emissions studies using the Asia-Pacific Integrated (AIM) Enduse and Market Allocation (MARKAL) model by Garg et al. (2001) uses an integrated modelling framework that includes a bottom-up and top-down energy and economy model to provide insights into the implications of mitigation commitments on energy and technology mix, energy costs, mitigation costs and competitiveness of Indian industries. The model integrates the top-down AIM-End-use model with the bottom-up MARKAL model. A stochastic Indian MARKAL model has also been developed by Loulou, et al. (1997) to reflect long-term uncertainties in technology and fuel substitution within the Indian context. Another study (Ghosh, 2000) explores the implications of specific intervention scenarios on the long-term technology strategy for power sector. More recently, Shukla (2006) and colleagues have employed an integrated modelling framework for India to construct emissions scenarios for the country spanning the period of the 21st century. The integrated modelling framework comprises of three types of models: (i) national level top-down macro-economic models exclusive or embedded within global models, (ii) national level bottom-up energy system models, and (iii) local level bottom-up models. The models are soft-linked through exchange of various parameters.

This brief overview of some of the major energy studies for India reiterates the fact that most studies on India's energy use changes have been at the macro level and very little has been done to study the problem from a more micro perspective. Most micro-studies have been more anecdotal in nature or in the form of case studies for small regions. While efforts seem to be evolving in the right direction, in terms of following the global trend towards more integrated modelling frameworks, energy modelling work in India has still some way to go to incorporate more micro level information and differentiation that is of a socio-economic or demographic nature. The incorporation of micro approaches to studying energy is essential to understanding equity issues and also to enable an analysis across different heterogeneous household groups by incorporating a wide variety of household characteristics within the analysis (Hawdon 1992).

In addition, the focus of past research for India has been to a large extent on the energy use of particular sectors with most studies being done for the industrial sector (Jha et al. 1991; Murty 1986; Roy 1992). An evaluation of direct and indirect energy requirements of different forms of household expenditure provides an alternative perspective to studying energy use in India. Viewing households as the ultimate end-users also provides additional insights to the linkages between the evolution of energy use and the development process of an economy. Since development is a process that is closely linked with households and individuals and since many development phenomena are experienced at the household level e.g. changes in where people live or how they live, etc, examining energy use of an economy at the household level allows for making the connection between energy and development more explicit.

1.3 Objectives and Purpose

The purpose of this study is to explore patterns and trends in energy use in India over the period 1983-84 to 1998-99, the years for which a consistent set of input-output data is available, and to assess factors that were primarily responsible for the change in energy use over this period. In addition, the study uses micro level data from household surveys to analyse the differing patterns of energy use across households and the relationship between energy, lifestyles and well being. The intent of the study is to provide a key to understanding factors affecting energy use within the country by adopting a household perspective.

Some of the key questions that will be addressed in the chapters that follow are:

1. Can methods of energy analysis and techniques used to determine direct and indirect energy use of households, developed and applied, thus far only in developed countries, be applied in the context of a large developing country such as India?
2. What modifications and adaptations to such methodologies, if any, are needed to suit the Indian data and situation?
3. What characteristics of energy use within the country emerge from the analysis? Do the results of such analysis provide an accurate picture of the existing energy use system in India?
4. What is the relationship between energy access and use and well being? What is the extent of inequality and poverty in energy access and use in India and what trends, if any, are visible in reduction of inequalities?

This study differs from earlier research on energy use in India in some important respects. First, to the best of our knowledge, it is the first of its kind to analyse non-commercial biomass energy consumption, as well as commercial energy consumption, at both an aggregate and disaggregate level. As is the case for many developing countries, non-commercial energy sources in India still remain the primary source of energy for most rural and poor households and thus a crucial component of the nation's energy system. Second, unlike most previous studies which adopt a sectoral approach to studying energy in India, this study analyses energy use from a household perspective and accounts for both direct and indirect energy use. This approach enables one to capture not only the direct energy use implications of individual household consumption decisions but also the indirect impacts by tracing the intersectoral linkages within the various productive sectors of the economy. Finally, the analysis is carried out at both a macro and a micro level, which allows one to place it within the wider context of changing economic conditions and lifestyles of the population and to link energy use changes with the overall development of the country.

1.4 Current Approaches and Future Perspectives to Energy Studies

The complexity of issues involved in the area of energy, environment and sustainable development has resulted in the need for comprehensive studies and models to inform policy makers and planners. A large body of literature on different approaches to energy modelling studies already exists. However, most modelling studies and approaches have originated from the developed world and therefore pertain mainly to developed country situations. These provide a good starting point for any modelling effort, but their relevance for developing countries is limited, as they do not take into account their specific characteristics. As has been discussed by Pandey (2002), developing countries differ significantly from developed countries in terms of characteristics like existence of large scale inequity and poverty, dominance of traditional life-styles and markets in rural areas, transition of populations from traditional to modern markets, existence of multiple social and economic barriers to capital flow and technological diffusion, and radical nature of policy changes being currently witnessed in energy industries.

The most basic methodological distinction made among most energy models differentiates between top-down and bottom-up models. The former is based on the economic paradigm whereas the latter has a tradition in the engineering discipline. The analysis carried out in this study is empirical in nature, but does not fit within the traditional categorisation of either top-down or bottom-up modelling. The study, as such, does not develop or employ any single model or modelling technique for the analysis carried out. In fact, it makes use of a number of different methodologies, which could be said to fall within both the bottom-up and top-down dichotomy of approaches. The input-output energy analysis model employed in this study is a convenient tool for calculating the consequences of household consumption with regard to energy. It combines some of the advantages of both model types and also helps build a bridge between the two model types.

Arguments for and against adopting one or the other modelling approaches abound in the energy literature (see for e.g. Grubb et al. 1993; Krause 1996; Nordhaus and Boyer 1999). However, the particular approach taken finally depends on the purpose of the research and the available data. The strength of the top-down approach lies in its foundation in historical data, which is based upon aggregate human behaviour in the past. Unfortunately, such data are rarely available at the disaggregated level that would allow one to detect trends as new technologies emerge and consumer preferences change. At the aggregate level, the analysis undertaken in this study examines input-output data for four separate years spanning a period of more than a decade and a half. In order to understand the evolution of total and indirect energy requirements of households, corresponding to different consumption categories, an analysis to decompose the computed total household energy requirements, into structural, activity, intensity and population growth effects is carried out at the national level. In this way, for the period of the study, the influence on energy use of the factors reflecting the growth of expenditure volumes, changes in technology as reflected by changes in total energy intensities of producing sectors, and consumer preferences as reflected in the changes in the structure of private household consumption expenditures, and population growth are analysed.

In contrast to the top-down, the bottom-up method explicitly takes into account improvements in efficiency and technological changes, utilisation rates, inter-fuel substitution, etc. However, the approach demands a high level of detailed data on each end-use. In addition, the method has been criticised on grounds that it does not take into account behavioural responses of consumers. It does not give regard to variations in consumption patterns due to demographic, socio-economic or cultural factors and thus may lead to mechanical forecasting of future demands. In this study, the analysis undertaken at the disaggregate level corresponds with a bottom-up approach. However, the approach is not a purely engineering one in the traditional sense of bottom-up modelling and is similar to the household metabolism approach (Noorman and Uiterkamp 1998). As a result of employing this approach, all consumption components (direct and indirect i.e. energy embodied in all other goods and services consumed) are incorporated rather than the direct energy use of particular energy end-use appliances or services. Therefore, the basis to the bottom-up calculations for clubbing energy use and users in this study differs from that of traditional bottom-up models. Energy use, in this study is clubbed according to consumption categories and different household socio-economic groups. In other words, the "activity" level is described in terms of various disaggregate consumption categories such as food, clothing, education, etc. To some extent, using household consumption expenditures instead of housing stock, as a basis for the bottom-up analysis, is better suited to the Indian situation since heating energy use is very low for India and appliance penetration is also very limited. In the final analysis, however, the approach taken was to some extent also dictated by the availability of data.

Rather than employing an engineering approach to understanding the variation in energy use across households, as is usually done in most bottom-up models, the study adopts a more socio-economic approach and relies on statistical analysis to determine factors affecting variations in total energy requirements across households. The advantage of undertaking the analysis in this way is that it allows one to capture the affect of various socio-economic and non-technical variables on the energy requirements of households. In addition, examining energy use from a micro perspective allows one to capture the rich heterogeneity of the composition, behaviour and lifestyles of households. Another major benefit of employing this method of analysis is that it allows for capturing distributional effects that are not captured by other conventional top-down or bottom-up approaches to energy modelling, as these get reflected in shifts in the number of groups and composition of different household groups. Equity effects, as reflected in the variations in energy requirements and access of different household groups and improvements or deterioration in the relative well being of the worst off sections of society, can also be better examined through this approach.

1.5 Organisation of the Book

The book presents analyses done both at an aggregate and disaggregate level. Chapter 2 provides a general overview and introduction to energy consumption in India. Trends in the sectoral consumption of different energy carriers in India over the last couple of decades are presented in this chapter. In addition, the chapter discusses briefly some of the major social and environmental consequences of energy use and policy, regulation and pricing within the energy sector in India.

Chapters 3 and 4 form the aggregate component of the book. In Chap. 3, the general methodology for energy analysis and method used for calculating total sectoral primary energy intensities for India are discussed. Macro data (from the National Income Accounts) in the form of input-output tables for the economy for the years 1983-84, 1989-90, 1993-94 and 1998-99 are used along with energy flow data to calculate the energy intensities for the different productive sectors. In Chap. 4, macro data on total and average private final consumption expenditures of households are combined with the calculated energy intensities to determine total primary energy requirements of households for the same time period. In addition, this chapter includes a decomposition of changes into technical, structural, and economic components of total household energy requirements as well as each category of indirect energy requirements over the period 1983-84 to 1998-99.

At the micro-level, household budget data are used to determine direct and indirect energy use for different categories of households (rural/urban, different income classes, geographic location, etc), and for different categories of household expenditure. Chapters 5 and 6 present results pertaining to cross-sectional variations in household energy requirements at the disaggregate household level. In Chap. 5, the composition of energy requirements across households as well as factors effecting the variation in energy requirements for different groups of households are examined. Analyses of the trends in energy access and use and the relationships between these with different indicators of well being are presented in Chap. 6.

Finally, in Chap. 7, key findings of the research are summarised and main conclusions of the study are presented. The limitations of the research are discussed and a perspective on potential areas for future research is also presented.

Chapter 2: An Overview of Energy Consumption in India

2.1 Lifestyles, Energy and Development over the Last Half-Century

India has experienced and is expected to continue experiencing accelerating growth and substantive changes in the scope, scale and form in which human and economic activity is arranged and performed within its boundaries. This, in turn, will impact on the types and ways in which energy is accessed, transformed and used. The country's current population of over one billion people is spread over an area of 329 million hectares (3.29 million square kilometres). In terms of geographical area it is the seventh largest country in the world. It is also the second most populous country and is projected by the UN to be the most populous by 2030 (UN 1990). The country exhibits wide variations in climate, topology and geography and also has wide economic, social, ethnic, religious and cultural differences amongst its inhabitants. This heterogeneity accounts for differences in habits, attitudes and lifestyles and also manifests itself in varying levels and patterns of energy use throughout the country.

An examination of the history of energy use in India over the last half a century reveals enormous changes and provides a reflection of how the economy and society have developed. At the time of independence, in 1947, India was a largely poor agrarian economy and its inhabitants had low per capita incomes and consumption levels. The majority of the population lived in rural areas and relied primarily on traditional non-mechanised sources of energy such as human and animal power, and non-commercial biomass like wood, crop wastes, and animal dung to meet their energy needs. Over the last half-century, the country has undergone many changes in agricultural practices and rural agrarian lifestyles. However, even today, the agricultural sector in India is characterised by the co-existence of a subsistence traditional sector, engaged in non-mechanised agriculture, i.e. a small-scale pre-technical system of rain-fed farming using human and animal labour to supply power and producing grains largely for self consumption; alongside a modern commercial sector that is engaged in large scale agriculture, with large plots of land cultivated; multiple cropping; intensified input use; mechanised systems; and producing cash crops on a large scale for the Indian market and for export. While traditional subsistence agriculture was a ‘way of life’ for most farmers in the past, it is now slowly becoming obsolete and uneconomic and has started to give way more to modern commercial agriculture.

These emerging changes and the erosion of the traditional agrarian way of life have important implications for the patterns of energy use in both rural and urban areas. Fragmentation of land holdings over generations and the erosion of the traditional subsistence agricultural system have resulted in unemployment and underemployment and a need by these segments of the population to search for alternative means of livelihood. Many have become migrant rural labourers. Some of the rural poor move to urban slums that often have no or poor provision of any kind of infrastructure. Whereas earlier, these populations, in many cases, at least had access to non-commercial biofuels that they could collect from nature, they are now often forced to buy energy from the market and often pay high monetary prices for scarce biomass resources that are still burnt in inefficient and polluting ways, and have high social, health and environmental costs for the users.

Major changes have been simultaneously occurring in the industrial and commercial sectors of the economy. Before independence, the industrial and commerce sectors in India were largely unorganised and arranged in informal small-scale household enterprises. During the early years after independence, the government gave a big thrust to the development of basic infrastructure and heavy and capital goods industries through the public sector in order for the country to achieve self-sufficiency in the production of steel, cement, fertilizers, metals, heavy machinery and other such highly energy intensive basic goods. Over the last couple of decades, there has been a further shift away from heavy and basic industries, to more manufactured goods, consumer goods and service industries. This in turn, has had consequences for the energy intensity of the economy and the indirect energy use in households. The process of industrialisation and expansion of the modern sector has also resulted in a basic transformation of the social fabric of the society including the ways in which labour is organised, social groupings are formed and economic arrangements made (Lewis 1955). This in turn has had and continues to have consequences for the rate of urbanisation and patterns and levels of energy use within the country.

Increasing urbanisation, mechanisation and industrialisation has also meant that there has been a tremendous surge in the need for transportation. Poor urban planning and a lack of investment in public transportation have resulted in more and more people, especially in urban areas, opting for personal modes of transport and subsequently, a huge increase in the energy needs for transport. In general, there has also been a trend towards more road, as opposed to rail transport, both of people and freight. This has been because the Indian railway system has not been able to keep pace with the growth of the economy, in general, and of certain regions in particular. The enormous growth in road transport and more personalised/ private modes of transport is resulting in a rapid increase in the demand for diesel oil and motor gasoline in the country.

Accelerating economic growth, both on account of changes within the agricultural and industrial sectors of the country, particularly over the last two decades, has resulted in increasing per capita income levels. Total national income, over the last five decades, has been growing at an average rate of about 4 % per annum. While per capita income in 1980 prices just about doubled from Indian Rupees (Rs.) 1194 in 1950 to Rs. 2419 in 1990, during 1992-02, India's per capita income grew by 46%, a significant rise from the 36.5% growth rate observed during 1982-92. This accelerating growth in incomes has been accompanied by rapidly changing lifestyles, increasing availability and access to material goods and services and the ability to afford them and increasing energy use (non-commercial also, but particularly, commercial) for the country as a whole (see Fig. 2.1). In addition to the rising real per capita incomes, population growth, urbanisation, and other demographic changes have also fuelled the increased energy use.

The structure and pattern of growth of the economy and industrial sector, in particular, have led to an accelerated growth of commercial energy consumption within the country. In 1950, agriculture and allied activities accounted for about 59% of total Indian GDP while industry accounted for only 13% and services for 28%. By 2001, the share of agriculture and allied activities had declined to 27%, while that of industry had risen to 25% and services to 48% (see Table 2.1). However, in terms of employment, agriculture still remains the dominant activity employing about 60% of the total work force, and most of the rural work force even today. The urban population has increased from 78.9 million in 1961 to 285.4 million in

2001, i.e. approximately 30% of the total population of the country (GoI 2001), yet the vast majority of people still reside in rural areas. Thus, while the country has taken large strides towards industrialising and modernising its economy over the last five decades, it still continues to remain largely rural and agrarian. The Indian economy is also still characterised by a fair deal of dualism. The formal market economy co-exists alongside a large informal sector or unorganised economy. However, historical trends and recent developments indicate large shifts in the pattern of employment from agriculture to industry and services, from informal to formal, and from rural to urban. These traditional to modern transitional dynamics are likely to continue in the future and these changes will clearly have significant implications for future energy use.

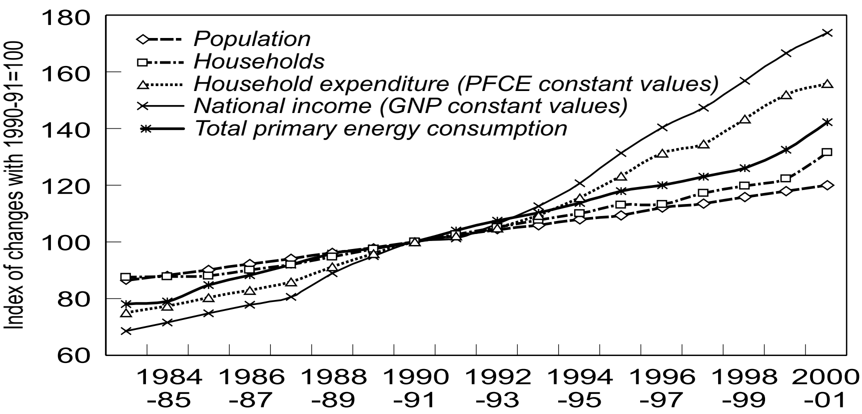

Fig. 2.1. Trends in population and the economy

Table 2.1. Changes in the structure of the economy and the population

Year	Share of sectors in total GDP				% of Population	
	Agriculture	Industry	Transport, trade & communication	Services	Rural	Urban
1950-51	59	13	12	16	82.7	17.3
1960-61	55	17	14	15	82.0	18.0
1970-71	48	20	16	17	80.1	19.9
1980-81	42	22	18	18	76.7	23.3
1990-91	35	24	19	22	74.3	25.7
2000-01	27	25	22	26	72.1	27.9

Source: (1) National Accounts, CSO (2000); (2) Census of India, GoI (2001)

Economic indicators point to significant improvements in the development level of India over the last decades. However, human development indicators reveal that about one-third of its population still lives below the poverty line. With a gross national product (GNP) per capita of US$440 in 1999, India continues to have the highest concentration of poverty of any country. There is also evidence of substantial disparities between rural and urban areas. A recent survey carried out for rural areas in India reports that only 25% of villages have access to tap water and only 43% have an electric connection for domestic lighting. In addition, a majority of rural areas do not have provision for primary health care services and only 41% of villages surveyed across India have a middle school within the village (NCAER 1999). Thus, much still needs to be done to expand the provision of basic public services and infrastructure within the country, particularly, in rural and remote areas. Increasing access through the provision of such basic services to deprived and underdeveloped regions also requires large amounts of materials, capital and energy and will have an impact on the level of well being and possibilities for undertaking productive economic activities in the future by those living in these regions. The existing disparities also underscore the need for analysis that goes beyond macro aggregate assessments and that allows for a disaggregated and contextualised investigation and projection of trends.

This brief look at key developments within the country that have an impact on lifestyles and consequently on the energy consumption amongst its inhabitants, should help the reader understand the context within which many of the energy use changes and trends that are presented in this chapter and analysed in other chapters of the book, are taking place. The basic premise of the analysis presented in the following chapters is that the pattern of household energy consumption (direct and indirect) represents a stage of well being as well as a stage of economic development and these vary significantly across different groups of households. An analysis of these patterns can therefore provide a snapshot of the way people live, the extent of development of the society and economy as a whole and the energy and sustainability implications thereof. The next section provides a brief introduction to some of the important energy terminology that will be used throughout the rest of the book. The following sections will present some broad trends in energy consumption for the nation, some international comparisons and an overview of aggregate direct energy consumption in the household sector in India.

2.2 A Short Digression on Energy Terms

Energy consumption can be measured at various levels of the energy supply chain. As the choice of the level influences the explanatory power of the measure, we make a slight digression to define these terms. This section draws heavily from Spreng (1994).

1. Primary energy is the energy contained in energy carriers sold by firms or division of firms of the energy extraction sector: coal sold by coal mining firms, crude oil sold by oil extracting companies or wood sold by logging firms. In addition, wood and other biomass collected directly by consumers from the environment before being transported, stored and dried, or subjected to any kind of transformation process can also be termed primary energy.
2. Secondary energy designates energy from all sources of energy that results from transformation of primary sources. In other words, it refers to energy produced from materials which have undergone transformation from other energy products, e.g., energy of petroleum products obtained from crude oil or of electricity generated in thermal power stations.
3. Final or end-use energy is the energy sold to final consumers who are not part of the energy industry, i.e. those that buy energy for their own use and not for sale to a third party (be it in the same form or not). Kerosene in a 10-litre canister, electricity at 220 volts supplied to the electricity counter of a residence and collected wood, ready to use, are examples of energy at the end-use level.
4. What consumers are looking for is not so much fuel or electricity, but rather heat supplied to a room or to a cooking pot or the mechanical energy applied to air for air circulation or to water to be lifted to a tank. They do not only have to acquire end-use energy but also equipment, such as heaters, stoves, pumps and lamps that transform end-use energy into heat, mechanical drive and light at the desired location and time. This latter energy is called useful energy.
5. But finally, the direct demand is on energy services: a cooked meal, a well-lit reading corner, being transported from A to B, a cool room, a hot shower etc. The problem for the analyst is that these so-called energy services cannot be measured in energy units; they require many other things than energy carriers. Also, there is no way of distinguishing energy services from other services and products. All products

and services take some energy to produce i.e. contain some embodied energy and are, therefore, energy services in some sense.

Additionally, one can distinguish between two types of energy flows that are necessary for the provision of any energy or non-energy good or service:

- Direct energy, i.e. purchased energy at the point of end-use, (commercial and non-commercial) and;
- Indirect energy, i.e. the energy it takes to produce goods, services and equipment (stoves, lamps, heaters, insulated walls, etc.) necessary for the provision of energy services. Indirect energy is sometimes also referred to as embodied or grey energy.

Finally, we also distinguish between whether the energy consumed is bought in a market place or not i.e.

- commercial energy, which refers to all energy that is bought and sold in a market and includes all fossil energy and electricity; and
- non-commercial energy, which refers to energy that is not bought commercially in a market place. For the purposes of simplicity, all biomass energy, whether bought commercially or collected freely from nature, will be referred to as non-commercial in this book.

2.3 Trends in Energy Consumption in India

2.3.1 Primary Energy Consumption

India ranks sixth in the world in terms of energy demand, accounting for 5% of total world primary commercial and non-commercial energy demand in 2003. Primary energy demand has grown almost four-fold at an annual rate of 3.6% over the last three decades. It is projected that growth rates of 6% to 7% per year for the commercial energy sector (9% for the power sector) are likely to persist in the future. Compared to the rest of the world, India has experienced faster rates of growth in energy consumption over the last few decades and its share in global commercial energy has risen from 1.4% in 1965 to 3.5% in 2001. This trend is likely to continue in the future as well. Despite this rapid growth in commercial energy consumption over the last decades, a large part of India's population still does not have access to it. In per capita terms, therefore, primary energy consumption in India remains well below the world average and far below that of the developed world. Non-commercial primary energy demand has increased at a much slower pace but remains the main source of energy for most rural and poor households.

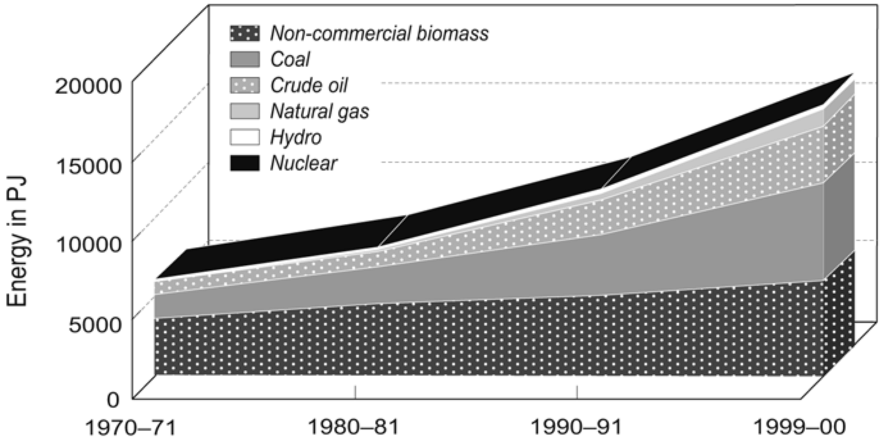

Fig. 2.2. Consumption of primary sources of energy in India

The share of commercial energy in total primary energy consumption has increased substantially over the last decades. While in 1970-71, non-commercial energy comprised about 60% of total primary energy, its share declined to about 33% by 1999-2000 (see Figs. 2.2 and 2.3 for an overview of primary energy consumption in India). In terms of the contribution of commercial fuels to total consumption, coal remains the main commercial energy source in the economy, particularly, in the industry sector. Oil and petroleum products supply more than 98% of the transportation demand. Although the share of natural gas in total primary energy is still very small, it has been increasing very rapidly. The relative share of oil has also increased over the period from 1970-71 to 1999-00 while that of coal has declined.

India is a net importer of energy, with about 22 % of primary energy needs being met through imports mainly in the form of crude oil, and natural gas and to a lesser extent from high quality coal for the steel industry. In fact, imports of crude oil and refined petroleum products are on the rise and these make up the single largest commodity group in India's import bill.

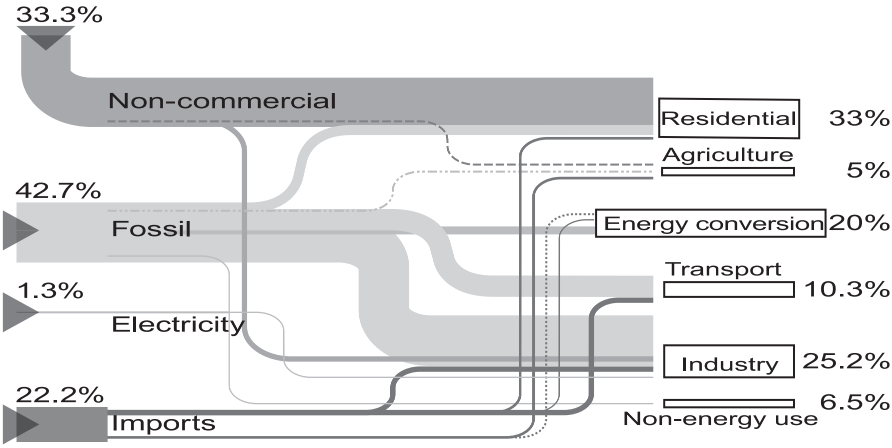

Fig. 2.3. Overview of primary energy consumption in 1999/00

2.3.2 Final Energy Consumption

A look at Table 2.2, which gives the break-up of energy consumption by different sectors and vectors in the economy, reveals several important characteristics of energy consumption in India.

There is an important divergence in the shares of the different sectors of the economy in total final energy consumption depending on whether one considers only commercial or both commercial and non-commercial sources of energy in India. If one considers only commercial sources of energy, then the industrial and transport sectors figure as the largest consumers of final energy in the country. However, when both commercial and non-commercial energy sources are taken into account, then it is apparent that the residential sector is the largest consumer of final energy in the country. The importance of non-commercial energy in the total energy mix of the country therefore persists and is even more evident when one considers that almost 85% of total energy consumed by the residential sector in 1999-00 was non-commercial. Within the other sectors of the economy, fossil fuels and electricity provide the bulk of the energy needs.

Table 2.2. Overview of final energy consumption in India in 1999-00

(in PJ)	Fossil Fuels	Electricity	Commercial	Non-commercial	Total
Industry	3587	440	4027	1095	5122
Transport	1851	28	1879	.	1879
Agriculture	47	392	439	210	649
Residential	633	241	874	4756	5630
Non-specified	191	64	254	.	254
Non-Energy Use	551	.	551	.	551
Total	6859	1165	8023	6061	14084
Shares of sectors for different energy vectors & for total energy					
	Fossil Fuels (%)	Electricity (%)	Commercial (%)	Non-commercial (%)	Total (%)
Industry	52.3	37.8	50.2	18.1	36.4
Transport	27.0	2.4	23.4	.	13.3
Agriculture	0.7	33.7	5.5	3.5	4.6
Residential	9.2	20.7	10.9	78.5	40.0
Non-specified	2.8	5.5	3.2	.	1.8
Non-Energy Use	8.0	.	6.9	.	3.9
Total	100.0	100.0	100.0	100.0	100.0
Shares of energy vectors in different sectors & all sectors taken together					
	Fossil Fuels (%)	Electricity (%)	Commercial (%)	Non-commercial (%)	Total (%)
Industry	70.0	8.6	78.6	21.4	100.0
Transport	98.5	1.5	100.0	.	100.0
Agriculture	7.3	60.4	67.7	32.3	100.0
Residential	11.2	4.3	15.5	84.5	100.0
Non-specified	75.0	25.0	100.0	.	100.0
Non-energy Use	100.0	.	100.0	.	100.0
Total	48.7	8.3	57.0	43.0	100.0

Source: (1) Commercial energy balance (TEDDY 2003); (2) Non-commercial energy data for 1995-96 from Regional Wood Energy Data Base (FAO 1997)

One of the key trends visible in the Indian energy sector is the rapid increase in power or electricity consumption, particularly over the past two to three decades. This has in fact been the fastest growing end-use vector in the country. The annual average rate of growth for this period is almost 8% per annum and, varies across the years from 2.5 to 12% per annum. If one looks at the mix of electricity generation for utilities, over the years there has been a clear movement in favour of fossil-based generation as can be seen from Fig. 2.4. This trend is to some extent a result of the abundant coal reserves within the country and policies at the national level that have fallen short in giving hydropower the degree of support it initially favoured (GoI 1991). In recent years, gas-based thermal power is becoming an increasingly important source of electricity generation.

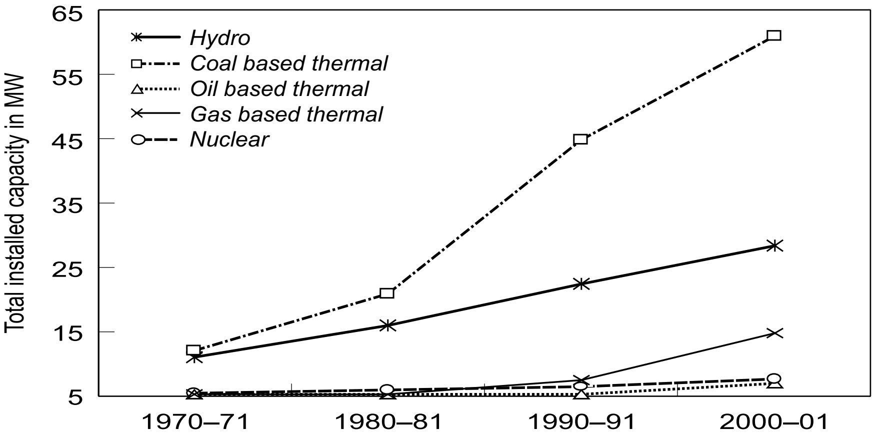

Fig. 2.4. Installed generating capacity mix for electric utilities

2.4 Some International Comparisons of Energy Use

The preceding sections highlight the growth in energy consumption and shifting pattern of consumption in India over the last few decades. Despite the significant increase and rapidly growing energy use, per capita energy consumption and carbon emissions remain significantly less than that of many developed countries and even below the world average. The use of energy between different areas of the world remains very uneven. On average, a person in an OECD country uses more than six times as much energy as a person in India. But the difference in the amount of energy used is not the whole story. There is also an essential difference in the way energy is used. Industrialised countries support high living standards by providing food, water and energy through systems that depend on high inputs of energy, capital and materials. Meanwhile for many people in developing countries energy and materials are desperately needed to take them beyond a level of basic subsistence.

However, the rate of growth of energy use in India has been faster compared to most developed countries, over the last couple of decades. Figure 2.5 gives a comparative picture of the growth in primary energy consumption (inclusive of non-commercial energy), relative to the year 1980 for the countries depicted. Clearly, India is far ahead of the others in terms of experiencing the fastest rate of growth during the period 1980-2000. This seems reasonable, given the fact that it is a developing country and has been experiencing fairly rapid economic growth, industrialisation, urbanisation and population growth during this period. On the other hand, all of the other countries except China are developed nations that are experiencing more stabilised rates of growth for primary energy consumption, in part because of low population increase and also because they have already experienced the phase of rapid growth of energy consumption that accompanies industrialisation and this is levelling out now. In terms of a direct comparison of the annual average rate of growth for the period 1980-2000, Fig. 2.5 shown below clearly reveals the pattern across countries.

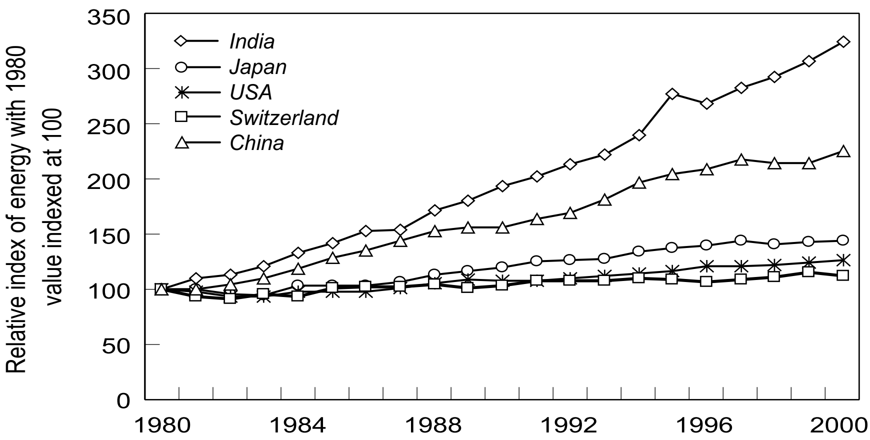

Fig. 2.5. Relative trend in primary energy consumption across nations

It is important, however, to look at the above figures in conjunction with the absolute values of total primary commercial energy consumption in these countries. For the year 2000, primary energy consumption in USA was about 104.5 EJ, in Japan was 23.2 EJ, in China 41.1 EJ, in India was 14.2 EJ and in Switzerland it was approximately 1.4 EJ. Figure 2.6 depicts the share of primary energy consumption for these countries in total world consumption for the year 2000. The figure gives a clear comparative picture of primary energy consumption in the four countries for that year. The US has the largest, by far, almost eight times as much as India and more than four times as much as Japan. There are however, limitations in using primary energy data for international comparisons between such diverse countries as energy systems, energy efficiencies and energy needs vary tremendously between them. Thus for instance, in India, there is very little energy needed for heating because of its warm tropical climate. This is very different to the situation in most OECD countries where heating energy needs are significant. On the other hand, differences in climate and geography across these regions also suggests that energy needs for air cooling/ conditioning are likely to increase significantly in India with rising incomes. In addition, for developing countries like India that still consume large amounts of non-commercial energy often with very low conversion efficiencies, international comparisons with nations using predominantly commercial fuels is not suitable in all cases. Such variations make it essential, therefore to look at energy use in relation to the specific needs, activities, lifestyles and situations existing in a particular country or region.

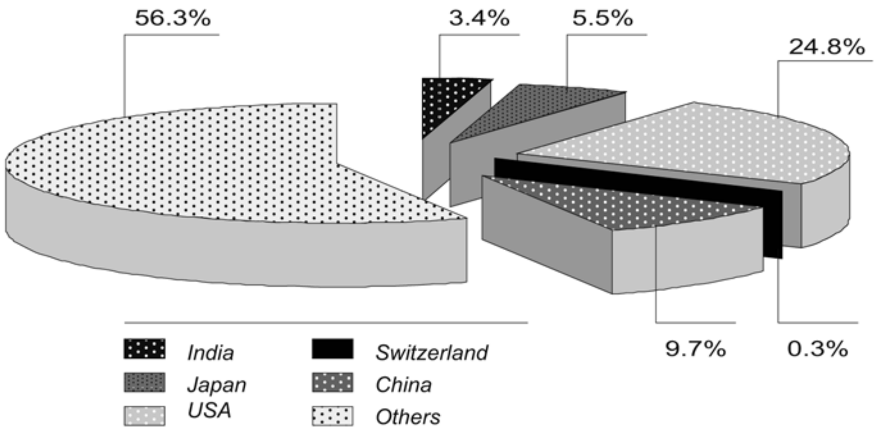

Fig. 2.6. Share in total world primary energy consumption in 2000

2.5 Household Energy Use

Given the vastness and heterogeneity of India, it seems futile to talk in terms of averages. There is no one India but several Indias that co-exist simultaneously and are characterised by a multiplicity of ethnic, lingual, economic, social, cultural and religious groups. Although dramatic changes in residential energy use in developing countries is well documented at the national aggregate level, little if any information exists on the nature of energy use within individual households or groups of households. Later chapters in this book will aim to shed greater light on these issues. Yet, we begin here by reviewing trends based on aggregate statistics of residential energy use within the country.

Households consume energy, both, directly in the form of fuels and electricity and indirectly through the purchase of non-energy goods and services. Consumption by households in developing countries presents two key issues for development. On the one hand, increasing consumption of certain basic goods and services through improving access is vital to development and improving the quality of life of the poorest. On the other hand, consumption transforms energy and materials, reduces their future usability and results in pollution and therefore imposes a large cost which makes it vital to find ways of increasing the efficiency of use of these resources and curbing wasteful consumption. The characteristics of households and their lifestyles have a major impact on the type and volume of their consumption. At the aggregate national level, some of the lifestyle factors or key physical drivers other than income growth and urbanisation, which contribute to changing household energy use, include the change in the number of households (population growth and changes in the average size of households), area and character of dwelling areas, appliance penetration and utilisation rates and changing patterns of fuel choice in households. Combining information regarding such lifestyle changes at the level of an individual or household or for groups of similar households (lifestyle groups) with information regarding the structural and technical changes occurring in the economy as reflected by changes in energy efficiencies and intensities of producing sectors, makes it possible to trace through the energy implications of such changes.

The issue of lifestyles, individual or household behaviours and energy consumption are inextricably linked and assume greater importance in the context of a rapidly developing society like India’s because the impact of changing technologies, economic situations and policies depend fundamentally on these lifestyle factors. Thus, for instance the success or failure of the introduction of a new improved cooking stove in a certain rural region will depend not only on its accessibility, affordability and efficiency and maintenance, but also on whether the stove design and functionality is well tailored to the local culture, tastes and cooking habits or behaviours related to food preparation of the people in that region. In addition, the pace of lifestyle changes is much more rapid in a developing country as compared to an already developed one, and therefore the direction of these changes, and the policies, programs and practices that are adopted today have crucial implications on the future trajectory of energy use within the country. In particular, the pace at which households join the formal market economic system is also a strong determinant of the rate of commercial energy growth in the country.

Direct energy use in households, especially for cooking, comprises a large proportion of the total energy use in India and also contributes significantly to problems of environmental pollution. In particular, the burning of biomass energy, such as wood and dung, in polluting and inefficient stoves, results in indoor air pollution and is a major health hazard. Despite a major shift away from the use of biomass fuels towards commercial fossil fuels and electricity over the last couple of decades, particularly in urban areas, many poor and rural households still rely on wood and other solid biomass fuels as their primary source of cooking energy. Increasing the access of the poor and rural population to cleaner and more efficient energy sources and energy end-using devices has been a policy objective for many years. Such a goal is desirable from an environmental, social, health and efficiency viewpoint.

Both the pattern and the quantum of energy use have changed in households over time with increasing incomes, urbanisation and changing lifestyles. While the rest of the book will provide an in-depth analysis of household energy use, both from an aggregate national and disaggregate household perspective, this section serves only to provide a brief overview of some of the major changes that one can observe in the nature and pattern of direct household energy consumption at the aggregate national level over the last decades. The objective of the following chapters will be to try and analyse the several transitions that are occurring simultaneously within the country in direct and indirect household energy use.

With a view to understanding what behaviours and choices are most likely to influence the likely outcome of different policies and programs and changes within the economy, and the possible direction of future energy use in the country, the following sections will provide a brief overview of the shifting importance (share) of direct energy consumption of the household sector in total energy consumption of the economy, changing patterns of use of different energy types within the household sector, and to what purposes and in what manner energy is commonly used in Indian households.

2.5.1 Trends in Direct Energy Consumption by the Household Sector

As was mentioned in Sect. 2.3 energy consumption in the residential sector represents the largest sector for energy consumption and accounts for almost 40% of the total final energy consumption (commercial and non-commercial) in the country. Looking at data solely on commercial energy use, understates the importance of the residential sector, because biomass still remains the primary source of energy for many rural and poor households. Growth in the consumption of energy, particularly commercial energy, in the residential sector has been enormous over the last few decades and has been related with both growth in the economy and population of the country. However, this growth is not completely understood as it is often in part a shift from non-commercial to commercial energy. In the first three decades following independence, population growth and demographic changes accounted for most energy consumption growth. Over the last couple of decades, increasing access to electricity and a switch to more efficient energy types has offset, to some extent, the impact of population growth on energy consumption. However, more rapid economic development and higher disposal incomes and savings for consumers, have contributed to a change in lifestyles and behaviour on the part of households and led to a faster growth in energy consumption. To date, however, traditional or non-commercial fuels represent the main source of energy for this sector. Table 2.3 below shows the change in the importance of different energy types within the domestic or household sector over the years.

Energy use in the residential sector grew on average by 4% per annum since the time of independence. However, the rate of growth has varied over the decades for different fuels. In particular, there has been a large increase in the use of cleaner commercial fuels, particularly LPG, and electricity in the household sector after 1990. At the same time though, the use of non-commercial fuelwood has also been growing but at a slower rate. This has meant that there has been a shift in the pattern of energy consumption over time. The pattern varies significantly also across rural and urban areas of the country and by socio-economic class. In particular, urban households tend to have wider access to commercial energy forms and tend to switch to the use of these at a lower income range as compared to rural households, which tend to continue depending on biofuels that can be locally collected and are often not paid for in cash.

Table 2.3. Direct energy consumption in the residential sector

Energy carrier in PJ	1970	1980	1990	2000	Growth per annum (%)
Biomass	3091	3866	4351	4955	1.6
Coal/Charcoal	86	59	21	22	-4.4
Kerosene	117	142	282	390	4.1
Liquefied Petroleum Gas (LPG)	-	14	79	227	15.1
Electricity	14	33	115	272	10.4
Others	235	198	150	141	-1.7
Total	3542	4311	4999	6007	1.8

Source: CMIE (2005); TEDDY (2003); Reddy (2003); PC (1999); FAO (1997).

Electricity consumption has risen very rapidly in the household sector and has been growing faster than GDP over the last couple of decades. This follows the trend in most other rapidly developing countries where too, electricity growth tends to grow at a faster rate than GDP growth. Yet, average per capita electricity consumption in India is only one-sixth of the world average and there are many households in India that still have no access to electricity. Official statistics state that 87% of all villages in India are electrified. However, data from the Census of India reveal that the number of households actually using electricity is still very low, and particularly so in rural areas, where it was about only 43% in 2001. Figure 2.7 below provides a snap shot of the rate of electrification within the country over the last couple of decades. Electrification and electricity growth is likely to continue its rapid growth in the future too, both as a result of increased mechanisation, automation and ease of use as well as increased access to electricity for those who currently lack access.

The rate of electricity consumption has been growing rapidly particularly in the last couple of decades also in part due to the wider penetration of electrical appliances and equipment, particularly among urban households (see Table 2.4).

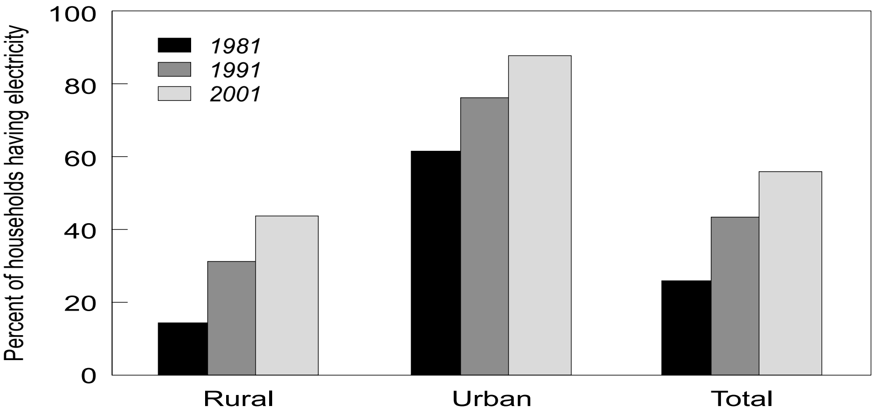

Fig. 2.7. Electrification across rural and urban areas

Table 2.4. Penetration of Consumer Durables (per '000 households)

	1985-86			1995-96			Decadal change (in%)		
	Urban	Rural	India	Urban	Rural	India	Urban	Rural	India
Electric iron	190	30	73	371	83	164	96	179	126
Ceiling fan	552	85	210	814	191	367	48	125	75
Table fan	202	63	101	291	131	176	44	108	75
Mixer/grinder	109	6	34	301	31	108	177	412	219
Refrigerator	88	3	26	252	20	86	185	518	229
TV B&W	151	10	48	456	155	240	202	1513	404
TV colour	40	1	12	212	26	79	424	1931	547
VCR	5	0	1	47	2	15	883	-	1039
Cassette player	136	27	56	466	173	256	243	549	357
Wash machine	14	0	4	109	5	35	684	-	742

Source: Modified from Natarajan (1998).

2.5.2 Direct Energy Services in the Household Sector

The main energy services demanded directly by households in India are for cooking, lighting and appliances and water heating. Space heating is required in only a few parts of the country and is seasonal in these areas. In general, the energy needs for cooking still comprise the bulk of the total direct energy requirements of households in India.

2.5.2.1 Cooking

Cooking is the activity that accounts for the highest amount of direct energy needs of households in India. The use of different fuels for cooking as one of the most important end-uses accounts for about 35% to 45% of the total energy if all energy carriers are considered. In developed countries cooking consumes less than 10% of total national fuel consumption. Nevertheless, only 10% of the commercial energy that is electricity and fossil fuels is consumed in India's household sector. The main commercial energy carriers for residential use are Superior Kerosene Oil (SKO) and Liquefied Petroleum Gas (LPG). Together, these two products have a 5.2% share of the energy consumed in households. The bulk of energy consumption in households consists of biomass (non-commercial) fuels such as firewood (59%), dung (20%) and agricultural residues (14%) normally collected by the users themselves. (TERI 1993).

2.5.2.2 Lighting

Most Indian households use either electricity or kerosene for lighting in India. Additionally, poorer households also use candles and homemade wick lamps dipped in kerosene or other oils. Electric light is vastly superior in quality to the other sources commonly in use. However, access to electricity is limited and therefore for a large proportion of households this is still not an available and in some cases affordable option. There is a large disparity across rural and urban areas in the access to electricity. Access varies tremendously across different states within the country as well. In rural areas, even households that are electrified are often still dependent on kerosene as a back-up fuel for meeting their lighting needs. The use of kerosene for lighting, however, has adverse impacts for the people dependent on this fuel due to its low luminosity and smoke emissions from the inefficient kerosene lighting devices.

Kerosene has traditionally been supplied through the public distribution system (PDS) in India, though since 1993, parallel marketing through private agencies has also been allowed. However, there are still problems regarding access to even kerosene in some areas and to certain populations because of suboptimal policies regarding the allocation and pricing of this fuel. The future rate of electrification will have an impact on the rate at which households shift away from the use of kerosene to the use of more efficient electric lighting. In addition, there are government policies and incentives and some local initiatives to promote the use of renewable technologies like solar lanterns for lighting in rural and remote areas of the country. The diffusion of such renewable and more efficient lighting technologies will also have implications for the future lighting energy needs of the country.

2.5.2.3 Transport

The energy needs for transportation services have increased dramatically over the last few decades and in fact, this sector accounts for the largest share in consumption of petroleum products in the country. There have also been important changes and modal shifts in the types of transport services used – both in terms of forms (roads vs. railways) and ownership (private vs. public). Growing disposable incomes coupled with the poor provision of public transportation have resulted in a greater tendency towards personalised modes of transport and road as opposed to railways. This has consequently led to a large surge in the ownership of private vehicles. Changes in vehicle ownership patterns are taking place as well from non-motorised (bicycles and rickshaws) to motorised and more personalised modes, such as scooters and particularly cars. In rural areas, non-motorised forms of transport - pedestrians, bicycles, rickshaws and animal drawn vehicles remain more important than in urban areas, but with growing provision of road infrastructure, the situation is changing rapidly in rural areas too.

2.5.2.4 Others (Heating, Warm Water, Appliances, etc.)

The energy needs for these services remains a very small fraction of total household direct energy needs in India currently. In part, this is due to the climate and geography of the country. With generally warm temperatures throughout the country and year, heating energy needs are limited to few mountainous regions and months of the year.

Growing disposal incomes and increasing electrification is resulting in a rising demand for electrical appliances and equipment, including water heaters and air conditioning and cooling equipment. Table 2.4 provides data on the growth in penetration of certain durable household electronic equipment and appliances and trends suggest that the share of energy demand on account of these services is likely to rise significantly in the future.

2.5.3 Social and Environmental Implications of the Direct Energy Use Patterns of Households

The lack of access to clean forms of energy and the negative externalities associated with energy consumption tend to perpetuate the poverty cycle of poor households in developing countries like India. This is because the poor often lack access and are unable to afford cleaner and higher quality fuels and electricity and therefore are more dependent on poor quality and inefficiently burning biofuels like wood and dung. These fuels often have to be collected by women and children and involve a high opportunity cost for these persons as they often have to trudge long distances to find and collect sufficient amounts of fuelwood. Women and children also tend to face the heaviest burden in terms of the health costs of using these fuels because they are involved most in the task of cooking and spend more time indoors and are therefore exposed more to the indoor air pollution associated with the inefficient combustion of biofuels. There is now strong evidence to support a link between indoor air pollution and health, particularly respiratory disease, including acute respiratory infections, chronic obstructive lung disease and lung cancer. There is also increasing evidence to suggest links with cataracts, tuberculosis, asthma and possibly low birth weight, perinatal mortality and heart disease (Bruce et al. 2000).

There are other environmental externalities associated with direct energy consumption by households, especially with regard to energy needs for transport and resultant air pollution. Of course, the demand by households for electricity, which drives growth in electricity generation, also means that the environmental problems associated with extracting coal, drilling oil and gas, and the transportation of these fuels, as well as the externalities associated with electricity generation itself, can also be attributed to households. Indirectly, the household sector is also responsible for the pollution resulting from industries, other than power generation as it is households that ultimately demand the products of these sectors.

Energy poverty is the biggest social concern related to energy use in India. This has to do with the lack of secure sources of supply and access to adequate quantities and qualities of energy and the lack of affordability for certain segments of the population. In general, social factors associated with household energy use patterns are largely related to the inequity in access and consumption of different types of energy across different households. Rural households in India have fewer energy choices than urban ones and richer households have more choices as compared to poorer ones. In rural areas, choices are constrained by lack of access to more commercial fuels and markets for energy using equipments and appliances. Often, the choice of fuel is determined more by local availability and transaction and opportunity costs involved in gathering the fuel (mostly wood, dung and other biofuels) rather than by household budget constraints, prices and costs. In contrast to rural households, urban households have a wider choice and greater accessibility to modern commercial fuels, electricity, and energy using end-use equipment and appliances and therefore greater potential for choosing cleaner and more efficient forms of energy. While there is little in terms of hard data and quantitative indicators of the degree of inequity across regions and different household groups, past literature does point to the differences across rural and urban households and different income groups. In addition, such differences also serve as one of the driving forces for migration to urban areas and the concomitant problems associated with urban slums, overcrowding and poverty.

2.6 Policy, Regulation and Pricing in the Energy Sector in India

After independence, the commercial energy sector was put under the purview of the government and government owned public companies to ensure a regular supply and in recognition of the public services nature of energy and its importance for development and improving individual well being. After 1991, however, the government has undertaken several reforms to deregulate and liberalise the energy sector in a bid to encourage private investments in the sector and increase competition and efficiency of the sector. There has been focus in the policy arena on reforms to ensure more cost-reflective energy pricing as well. This too has traditionally been government regulated through an administered pricing regime and has often involved large subsidies to some sectors, especially to the household and agricultural sectors, on equity grounds. However, recent studies and results discussed in later chapters of this book show that most of these subsidies have been misdirected with wealthier and better of sections of the population that have better access and consume larger quantities of energy often benefiting the most from the subsidies[1]. In other words, the subsidies benefit the richer groups rather than the weaker segments of society who they are targeted at. In addition, the subsidies have had a high economic

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[1] For a discussion of the inefficiencies in targeting of kerosene and LPG subsidies in India see Gangopadhyay et al. (2005).

cost and have led to distortions and inefficiencies in the use of different commercial energy forms and are the cause of most of the public sector power companies being in the red today and facing high financial losses.

This section will not aim to provide a detailed overview of energy reforms or the organisation of the energy sector in India. There are several excellent references that do so (TERI 2001, 2003; PC 2006). However, what will follow is a discussion of some of the key regulatory and policy issues that impact on the access and affordability of reliable energy to private households in India.

In particular, there are two main objectives that need to be fulfilled in order to ensure access to clean, reliable and affordable energy for all. The first is to extend the distribution of energy and electricity and to ensure uninterrupted and quality supply to all areas and households in India. The second is to ensure affordability of energy for all. Typically households in rural areas, even when connected to the grid, only have electricity for a few hours of the day. In urban areas as well, electricity shortages and load shedding are common place particular in the hot season. Eventually policies that eliminate subsidies are desirable to ensure efficiency and financial viability of the sector, but for the short-term, a better targeting of the current subsidies, so that the benefits accrue to those who really need them the most, is needed.

Efforts to expand access to electricity include those aimed at either extending the grid to unconnected areas or putting in place incentives and institutions aimed at encouraging decentralised energy solutions. Several efforts were made in the form of national programs for rural electrification and to promote renewable energy technologies in the past. However, providing access to modern energy services in rural areas remains a challenge even today. Recently, the Government of India (GoI) has set out for itself, Mission 2012, which aims for 'Power for All' by 2012- and states that:

1. rural (village) electrification should be completed by the end of the 10th Plan, i.e., by the year 2007;
2. access to all households should be provided by the end of the 11th Plan, i.e., by the year 2012; and
3. at least one unit of electricity per day is provided to all households below the official Poverty Line.

To this end the government has several rural electrification programs in operation under the Ministry of Power and the Ministry of Non-Renewable Energy Sources. The government policies aimed at liberalising the electricity sector and opening up electricity generation and distribution to private parties are also aimed at adding generation capacity within the country. Reforms have been initiated in a number of states within the country. However, efforts at creating a competitive market are still nascent and the regulatory framework to enable this still needs to be put in place in many states.

Unfortunately, the initial focus of the reforms program was to increase capacity and private participation in generation. Improving electricity access was not recognised explicitly as an objective of the early regulatory reforms and distributional reforms were not addressed till the late 1990s. Some recent literature has attempted to analyse the effect of the reforms on the poor. A paper by Sihag et al. (2004) looks at the impact of reforms on the poor in the Philippines and for three Indian States. They conclude that electricity reforms have tended to neglect the poor in India. They state that this is due to the fact that the Indian reforms, unlike those carried out in the Philippines, do not explicitly spell out the provisions for the extension of electricity services to the poor and stress on the need for mechanisms for subsidising marginalised consumers. Clearly, there is call for recognising this lacuna and to have legislative and policy support and incentives to meet these social objectives. In addition, much still needs to be done to improve the transmission and distribution (T&D) losses in this sector as well and to ensure uninterrupted and higher quality of supply. A revision of the current Electricity Act to address this issue more fully is clearly needed.

Cross-subsidisation across sectors continues in the electricity sector, with the average electricity tariffs being generally below the costs of power generation and supply. Electricity is supplied at subsidised rates to domestic and agricultural users while industrial and commercial users pay higher tariffs (see Table 2.5). This has tended to encourage inefficient use by domestic and agricultural users. In particular, the share of electricity consumed by the agricultural sector has increased tremendously, due to the expanding rural electrification programme within the country, as well as the fact that consumers in this category are generally charged a very low flat rate (based on their connected load per horse power of pump-set) irrespective of the hours of use. A study for the state of Gujarat (Bose and Shukla 2001) shows that most agricultural and residential consumers, other than those in the lowest income strata, are willing to pay substantially more for their electricity supply, especially if the reliability of supply is improved. The findings of the study have been used as a guideline in the proposed adjustment of tariffs by the state electricity board of Gujarat. Similar efforts at rationalising tariffs in other states will be required in order to generate funding for further expansion and modernization of electricity generation facilities within the country. Policies aimed at rationalising tariffs, even raising tariffs for the poor in some cases, could be beneficial when combined with strategies aimed at subsidising access.

Table 2.5. Consumer category-wise average electricity tariffs in Paisa/kWh

	1996-97	1997-98	1998-99	1999-2000
Cost of supply	215.6	239.7	263.1	305.1
Average tariff	165.3	180.3	186.8	207.0
Average agricultural tariff	21.2	20.2	21.0	22.6
Average domestic tariff	105.7	136.2	139.1	160.7
Average commercial tariff	239.1	293.6	330.2	369.9
Average Industry tariff	275.5	312.7	322.8	342.0
Average traction tariff	346.8	382.2	410.3	415.3

Source: GoI (2001).

Within the petroleum sector too, the government now allows private sector investment in exploration as well as refining activities. Though traditionally it followed an Administered Pricing Regime (APM), it passed a resolution in 1997 to gradually dismantle this regime as well as the distribution controls originally regulated by the state. The government continues to subsidise most petroleum products for residential users. The fuels that are consumed within the domestic sector are largely kerosene and LPG for cooking and lighting and diesel, motor spirit and gasoline for transport. Kerosene has been historically supplied at a subsidised rate to households through the Public Distribution System (PDS). However, one of the first steps put in place by the APM was to allow parallel marketing of LPG and kerosene by the private sector. The government also provides subsidies on freight transport costs for distribution of petroleum products to far-flung spots. The kerosene subsidy has led to large-scale diversion of the fuel for adulteration with diesel or for sale on the black market. In general, the subsidies have also often been appropriated by the richer segments of the population, rather than the poorest towards which they are targeted, as mentioned above.

The most pressing challenges within the energy policy arena in India that have a direct bearing on the residential sector or private households therefore, are the development of appropriate institutions, legislation, regulations, tariff reforms and incentive mechanisms to ensure and encourage the supply of reliable and quality energy services to poor, rural and remote areas.

Chapter 3: Energy Analysis and Energy Intensities for India

This chapter gives a general introduction to energy analysis. At the outset, a brief description of the theory of energy analysis and the techniques used are discussed. Following that, the application of the input-output technique of energy analysis to calculate energy intensities for India is presented. Results of this analysis are presented and trends in energy intensities of sectors in India examined for the period from 1983-84 to 1998-99. Finally, an assessment is also carried out of the likely accuracy of the results obtained, by accounting for some of the possible sources of uncertainties.

3.1 Introduction to Energy Analysis

The practice of calculating the energy content of goods and services or processes was termed energy analysis by the International Federation of Institutes of Advanced Studies (IFIAS) at a special workshop convened in August 1974. The official definition of energy analysis agreed upon by them was, "the determination of the energy sequestered in the process of making a good or service within the framework of an agreed set of conventions or applying the information so obtained" (Roberts 1975). The field of energy analysis received a particular fillip after the energy crises of the early 1970s when rising energy prices and a growing awareness of the negative environmental impacts of energy use caused increasing interest in conserving scarce energy resources. A number of researchers grappling with the problem of conserving energy turned to energy analysis as a means to furnish greater information on the total energy used in a particular productive or consumptive process and identifying where reductions on energy requirements of total processes could be made. Since then energy analysis has been used as a methodological tool in a number of different studies[1].

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[1] Some of the early studies include that by Chapman to calculate the energy costs of aluminum (Chapman 1974); Leach's study that focused on the energy needed

3.2 Energy Analysis Methods in Practice

Two different methodologies have been developed to calculate the total energy requirements of different items and processes. One that developed out of the engineering profession was termed process analysis. The other had its origins in economics and is referred to as input-output energy analysis. A combination of the two techniques, termed hybrid analysis, has also been applied (Bullard et al. 1978). It combines the advantages of process analysis and the input-output technique. This section provides an overview of the methods of process analysis and hybrid energy analysis, while the next discusses input-output energy analysis in greater detail, along with how the method was adapted for calculating energy intensities in the Indian case. For a more detailed description and exposition on the techniques used in energy analysis refer to Spreng (1988) and Wilting (1996).

Process analysis uses a description in physical terms of the process in the life cycle of a product. It asks the question what goods and services were required to produce the target product. It then distinguishes between the energy and non-energy inputs required and further examines each non-energy input to determine the energy and non-energy inputs required for its production. This process continues, tracing through each stage of the production process, to finally tally all the energy inputs used in each successive stage of production to obtain the total energy required to produce the target product. The first energy input is called the direct energy requirement and the subsequent rounds of energy inputs comprise the indirect energy requirement. A very detailed description of the energy flows associated with the production process of the target product is thus arrived at. This methodology can provide very accurate results but requires extensive data and tends to be very laborious.

Hybrid analysis, as the name suggests, combines some stages of the process analysis technique with input-output energy analysis. The first few stages, in fact, are the same as those in process analysis. However, rather than tracing back through all the stages of production, as in process analysis, hybrid analysis only traces back the most important energy and material inputs required to produce the target product. It then uses input-output energy analysis to determine the total energy required for the material inputs used in the production of the target product. In this way, it minimizes some of the data and computational needs associated with process analysis.

for food production (Leach 1976); Hannon's on the energy requirements of beverage containers (Hannon 1971); among others.

3.3 Input-Output Energy Analysis

Input-output energy analysis is a specific area of application of economic input-output analysis in which attention is concentrated on the primary energy requirements of production and consumption in an economy. Nobel laureate Wassily Leontief developed the technique of input-output analysis during the 1930s and 1940s. He used the framework of an input-output matrix to describe the transactions between all sectors in an economy in financial terms, the basic form consisting of a system of linear equations describing the distribution of each industry's product throughout the economy. Since then, input-output analysis has become one of the most widely applied methods in economics and has been extended to deal with a number of different application areas (Leontief 1986).

Bullard, Herendeen, Hannon and colleagues at the University of Illinois did much of the pioneering work in input-output energy analysis in the early 1970s (Bullard and Herendeen 1975). By recognizing the interdependence of all sectors in the economy, they traced the flows of primary energy into and out of all the producing sectors to calculate the total primary energy, direct and indirect, demanded. Their early work also helped to focus on the question of how to deal with non-uniform prices for energy among different sectors of the economy. Their solution to this problem consisted of using physical energy flows data instead of converting financial data in the input-output tables by using energy tariffs. The input-output table has in this way been modified with transactions in the non-energy sectors being represented in standard monetary units whereas, those for the energy sectors given in physical units, and thus doing away entirely with the problem of energy prices.

The technique basically combines data on the primary energy use of every sector in physical units with traditional information on inter-industry monetary flows contained within the input-output transactions table of an economy. Its purpose is to calculate the total energy required, direct and indirect, to produce one financial unit of product of each sector in the economy, also referred to as the energy intensity of the sector. Since data available from the input-output tables are more aggregated than data obtained from process studies, input-output energy analysis is less accurate than process analysis. However, this technique is a lot less tedious than process analysis and can provide quite accurate results for average national energy intensities of homogeneous sectors. Care however, needs to be taken in applying correct sector definitions and ensuring that sector outputs are as homogeneous as possible. Clearly, the more disaggregated the input-output tables, the more accurate the results are likely to be.

3.4 Theory of Input-Output Energy Analysis

As mentioned above input-output energy analysis is based on the same general framework that is used in standard economic input-output analysis. This section will describe the general principles of input-output energy analysis and the methodology used for calculating energy intensities of commodity sectors. The section draws heavily on chapter 6 of Miller and Blair (1985).

The basic assumption of input-output energy analysis is referred to as the energy conservation condition and it basically implies that for all sectors energy inputs and energy output are in balance. In other words, the sum of energy (of each type) consumed by the inter-industry sectors plus that consumed by total final demand must equal the total amount of energy consumed by the economy. If, we denote *ei* as the inter-industry energy flows in physical units and *Ey* as energy consumed by final demand, then total energy consumption in the economy is *F* where:

$$F = ei + Ey \tag{3.1}$$

The equation for energy balance within the economy can then be represented by:

$$\sum_i e_i X_{ij} + E_y = e_j X_j \tag{3.2}$$

Where:
ei is the embodied energy intensity per unit of Xj or the total direct and indirect energy needed to produce unit of product j
Xij is the intermediate transaction from sector i to j
Ey is the direct primary energy use for final demand
ej is embodied energy intensity per unit of Xj
Xj is total output of sector j

In standard matrix notation where bold typeface is used for matrix denotation, we have

$$\mathbf{eAX} + \mathbf{E} = \mathbf{eX} \tag{3.3}$$

A refers to the technology matrix and has as its elements Aij that is the ratio Xij/Xj or the fraction of total output of sector j that is derived from inputs from sector i.

Assuming there are n sectors in the economy then the above energy balance equations implies a set of n equations in n unknowns and can be solved for the matrix **e** of total energy intensities. For a multi-fuel economy the analysis can be repeated for each type of energy i.e. coal, oil, etc. and the total primary energy intensities can be calculated.

Since for all sectors energy inputs and energy output are in balance, it follows that direct primary energy use for final demand is proportional to total sectoral production so that

$$\mathbf{E} = \mathbf{dX} \tag{3.4}$$

Where **d** is the matrix of direct energy intensities.
Substituting Equation 3.3 into Equation 3.4 and solving for **e** gives:

$$\mathbf{e} = \mathbf{d}\,(\mathbf{I} - \mathbf{A})^{-1} \tag{3.5}$$

The total energy intensity vector therefore is the matrix product of the direct energy intensity vector **d** and the Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1}$, where **I** is the identity matrix. The vectors **d** and **e** represent direct and total energy intensities respectively with their elements having the units' physical energy per monetary unit of output for all non-energy sectors and will be dimensionless for all energy sectors. They provide the link between monetary values of sectoral output and the energy requirements in physical units of that output.

3.5 Data Requirements of Input-Output Energy Analysis for India

Most countries undertake input-output surveys at intervals of about five years in order to collect vast amounts of data on economic activity carried out in a particular country over a given time period, normally one year. In India too, the department of statistic's Central Statistical Organisation (CSO) has the responsibility for preparing the economy-wide input-output transactions tables after every five years in accordance with the basic principles laid down in the United Nations System of National Accounts. The first input-output tables for India were prepared for the year 1968-69, however since then the coverage and composition of the tables have been revised and the level of sectoral aggregation modified over the years. The scheme of sector classification has however, remained the same since 1983-84. With the recent publication of the tables for 1998-99, consistent tables for four years have become available at the 115 sector classification level. The Commodity by Commodity tables for 1989-90, 1993-94 and 1998-99, (CSO 1997, CSO 2000, CSO 2005) and the Commodity by Industry Absorption Matrix for 1983-84[2] (CSO 1990) form the basis of the analysis carried out to determine average sectoral energy intensities for India over this period.

In addition to input-output data, the calculation of energy intensities also requires data on energy transactions in the economy in physical units. This is not a trivial requirement as energy data in India are published by a number of different departmental bodies and are available mostly in a highly aggregated form. In addition, energy data are at times not directly compatible with the structure of the United Nations Systems of National Accounts, which is the one used for the input-output tables. For this reason a number of assumptions and modifications had to be made in order to allocate energy flows to the appropriate input-output sectors. More regarding these modifications will be discussed in a later section of the chapter.

Energy data from various official sources were used such as the ministerial publications - Coal Statistics (GoI various), Petroleum and Natural Gas Statistics (GoI various), Power Statistics (CSO various), various issues on “Energy” by CMIE (CMIE 1996, CMIE 2000, CMIE 2002, CMIE 2005), various issues of Electricity Statistics by CEA (CEA various), and The Energy and Resources Institute’s energy database (TERI 1999, 2003). For non-commercial energy flows, data estimates from the Regional Wood Energy Development Programme in Asia (RWEDP) of the FAO (FAO 1997) was relied upon primarily but was cross-checked with other published estimates as well, such as Ravindranath and Hall (1995) and the Planning Commission (PC 1999).

Finally, price indices were also used in order to correct for price changes and to exclude differences in the time series of energy intensities resulting from these changes. The source for the Wholesale Price Index (WPI) series by sectors and sub-sectors and the Consumer Price Index (CPI) is also from the department of statistics (GoI various), which publishes these data annually.

[2] Commodity X Commodity tables for 1983-84 at the 115 sector classification level were not available. Previous calculation of intensities for this year calculated at the more aggregated sector level using Commodity X Commodity tables and the Absorption Matrix, found the values to be fairly close. Therefore, the Absorption Matrix was used instead for the energy intensity calculations for this year.

3.6 Methodology for Calculating Sectoral Energy Intensities

Starting out with the 115-sector classification input-output transaction tables for India, a number of modifications were made before direct and total energy intensities were determined using Equation 3.5. The following section describes the steps that were taken in order to compute the energy intensities.

In the first stage of the analysis, the 115 sector input-output tables were aggregated to a 99x99 table. The reason why such an aggregation was carried out was two-fold. On the one hand, energy data was available only at a very aggregate level. Therefore, various assumptions had to be made in allocating energy flows to the various commodity sectors in the input-output tables. For certain sectors, such as mining, iron and steel, heavy engineering & machinery, and other transport equipment, preliminary calculations done at the 115 sector level revealed implausible fluctuations in energy intensities over the studied period. This was due to the fact that the procedure for allocating energy from a more aggregate sector (based on the classification of sectors in the energy statistics) to sub-sectors of the sector (following the classification in the input-output tables) only provides accurate results under the assumption that the sub-sectors that comprise the sector have similar energy intensities. However, for the sub-sectors that comprise the industries mentioned above direct energy use is widely varying as the processes involved in these industries are quite disparate and therefore the assumptions used to allocate energy flows to these sectors resulted in implausible results. Therefore, sub-sectors comprising these particular sectors where aggregated.

The second reason for aggregating the sectors of these industries was that since none of the products produced by these industries were consumed as final demand by the household sector directly, energy intensities of these sectors only have an indirect bearing on the calculation of total household energy requirements and would not make much of a difference to the next stage of the analysis. Therefore, it was decided to aggregate the sectors that comprised the above-mentioned industries, thus effectively transforming the 115x115 matrix to a 99x99 matrix. Appendix 3A, at the end of this chapter, provides information on the composition of the sectors in the new sector classification.

The next modification to the input-output tables consisted of adding an additional row and column to represent the non-commercial energy sector, which was originally not included in the official tables. This effectively made the tables into a 100-sector classification. Non-commercial energy still comprises a very large share of direct household energy use in developing countries like India, and therefore it was felt that it was crucial to include its use in a study that aimed to analyse total energy requirements of households. The method of allocation of non-commercial energy flows to different producing sectors included in the input-output tables is discussed in Appendix 3B.

Of the total 100 sectors used for the analysis, five were energy sectors, coal and lignite, crude petroleum and natural gas, petroleum products, electricity, and non-commercial energy. In order to convert the standard monetary input-output tables to hybrid tables, values for the commercial energy rows in the input-output tables were changed from monetary to physical units using the various sources of data mentioned above. Where the physical flows of energy required a further level of disaggregation than was available in the published energy data, monetary flow values in the input-output tables along with energy price data were used to make proportional allocations. The ratio of monetary flows to physical flows of energy were also determined and cross-checked with published data on energy prices for different sectors, wherever available, and appropriate corrections were made. For a detailed description of how this was carried out refer to Appendix 3B.

Following the modifications carried out on the input-output tables described above, direct and total energy intensities were calculated for the years 1983-84, 1989-90, 1993-94 and 1998-99 by main energy carriers for each of the 100 sectors. Direct energy intensities for each energy carrier for all sectors were calculated as the physical energy flows into the sector per Rupee output according to Equation 3.4. Total (direct and indirect) energy intensities for each energy carrier were calculated with the aid of the Leontief inverse matrices whose elements represent direct and indirect requirements per Rupee output for each sector, using the relationship described in Equation 3.5. Finally, the physical units method as described in Wilting (1996), was used to calculate direct primary and total primary energy intensities by adding coal and lignite intensity, crude oil and natural gas intensity, the ratio of electricity from primary sources (i.e. hydro and nuclear) times total electricity intensity and non-commercial energy intensity for each sector.

The energy intensities were consequently deflated to constant 1993-94 prices using sectoral wholesale price indices in order to make the values for different years comparable. For the service sectors the overall consumer price index for urban non-manual employees was used to deflate the intensity figures[3].

3.6.1 Treatment of Exports and Imports

Imports are normally excluded from final demand in the input-output tables and therefore not included in the total output used as the bases for calculating the Leontief inverse matrix used to estimate energy intensities. There are, however, many reasons for including imports especially in the case of countries that have large imports as excluding them would result in an error in estimation of energy intensities. For the case of India, though, the monetary value of imports varied between 5-8% of final demand in the period from 1983-84 to 1998-99, with the remaining demand being met out of domestic output. The commodity composition of imports during that period reveals that imports of direct energy, especially crude petroleum, natural gas, and petroleum products, contributed a very large share of total imports. Most of the energy imports in India are of primary energy, though in recent years the imports of refined petroleum products are on the rise. In the analysis done here, while imported petroleum products are included, the energy requirements of refining imported petroleum products have not been included. Thus, imports of energy were included in the input-output energy analysis. However, imports of non-energy sectors were ignored in calculating energy intensities, as these are still relatively small in India. Energy embodied in exports is automatically included in the analysis since these are part of domestic production.

3.6.2 Treatment of Capital Goods and Investment

In the input-output tables, investments are not part of the intermediate matrix but belong to final demand. Therefore, ordinarily the capital and investments required for the production of consumer goods or for individual sectors of the economy are not included in the calculation of energy intensities by input-output energy analysis. Since investments or capital goods have a lifetime of over one year, the ideal way to deal with them is by using dynamic input-output analysis that takes into account annual depreciations in their stocks. However, there is a great deal of uncertainty regard-

[3] For the service sectors it was assumed that the salary and wages comprised a large share of total value added and in addition that movement in salary and wages followed the trend in the consumer price index for urban non-manual employees.

ing which depreciation rates should be used. While the contribution of capital to energy intensities is not likely to be insignificant for India, because of scarcity of sufficient data on the energy flows associated with capital investments and uncertainties with regard to the correct methodological treatment of capital and depreciation rates to be employed, these were neglected while calculating energy intensities in this study.

3.6.3 Other Drawbacks of Using Input-Output Analysis

In addition to some of the more contentious and more difficult aspects mentioned above such as the treatment of imports and capital goods in input-output energy analysis, the method has certain inherent weaknesses of its own which are a result of the kind of data and computational methods employed in such analysis. The most serious of these shortcomings has to do with the aggregate nature of the data used and the fact that sector outputs are assumed to be homogeneous. This results in joint products of the same sector being treated identically when, in fact, often a single sector may produce a range of products, some of which are more energy intensive than others. However, in the aggregate, the results are likely to be fairly accurate when using commodity by commodity tables. And given the ease of computation, input-output energy analysis provides an attractive method of calculating total energy requirements of a broad range of commodity sectors of the economy.

3.7 Results

This section presents the results of the calculations done to determine energy intensities of economic sectors in India for the years 1983-84, 1989-90, 1993-94 and 1998-99. The calculations are based on the input-output energy analysis method described above. In addition, trends in energy intensities over this period are also examined.

3.7.1 Most Energy-Intensive Sectors

The most energy intensive sectors in terms of total primary energy intensity, as defined in Sect. 3.6 above, are the energy sectors themselves. Table 3C-1 at the end of the chapter presents direct and total primary energy intensities of each of the 100 sectors for the four years calculated using input-output energy analysis. The ten most energy intensive non-energy sectors in India (i.e. other than the energy sectors) in terms of their total primary energy intensity belong mostly to the primary and basic industries groups. As can be seen from the Table 3.1, the most energy intensive non-energy sectors in 1983-84 were cement, fertilisers, coal tar products, structural clay products and iron & steel. By 1993-94, paper, paper products & newsprint, replaced the coal tar sector as being one of the top five most energy intensive commodity sectors. In 1998-99, these sectors continued to be the most energy intensive. Among the other commodity sectors, those in the textile and chemical category were also among the most energy intensive. Figure 3.1 also presents an index of changes in energy intensities for some of the most energy intensive sectors over the period from 1983-84 to 1998-99. Energy intensities for each of these highly intensive basic sectors declined over the whole period, however in the case of the sectors iron & steel and clay the decline was more steady whereas for the sectors fertilizers and paper, paper products & newsprint, intensities first increased for some of the in between years but then declined ultimately. When examining total energy intensities by different energy carriers the ranking of different sectors is seen to be quite different. Tables 3C-2 to 3C-5 included at the end of the chapter, present total energy intensities by energy type for the four years. These tables also show the changing pattern of demand for different forms of energy within the economy. More regarding the changes in energy intensities during this period are discussed in Sect. 3.7.5 of the chapter.

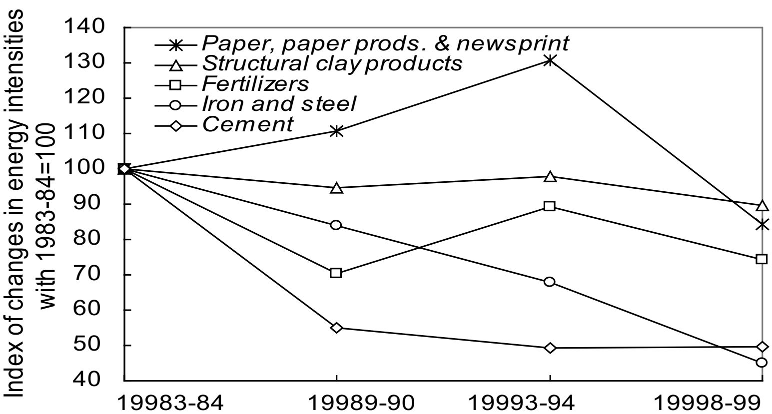

Fig. 3.1. Changes in energy intensities for most energy intensive sectors

Table 3.1. Most energy intensive non-energy sectors

		19983-84			19989-90			19993-94			19998-99
Rank	Sector	MJ/Rs.[93-94]	Rank	Sector	MJ/Rs.[93-94]	Rank	Sector	MJ/Rs.[93-94]	Rank	Sector	MJ/Rs.[93-94]
1	Cement	9.8	1	Structural clay products	6.8	1	Fertilizers	7.7	1	Structural clay products	6.4
2	Fertilizers	8.6	2	Paper, paper prods. & newsprint	6.1	2	Paper, paper prods. & newsprint	7.2	2	Fertilizers	6.4
3	Coal tar products	8.6	3	Fertilizers	6.1	3	Structural clay products	7.0	3	Cement	4.9
4	Structural clay products	7.2	4	Cement	5.4	4	Cement	4.9	4	Paper, paper prods. & newsprint	4.7
5	Iron and steel	5.8	5	Iron and steel	4.9	5	Iron and steel	3.9	5	Wheat	3.0
6	Organic heavy chemicals	5.7	6	Organic heavy chemicals	3.1	6	Inorganic heavy chemicals	3.4	6	Hydrogenated oil	3.0
7	Paper, paper prods. & newsprint	5.5	7	Inorganic heavy chemicals	3.0	7	Water supply	3.3	7	Water supply	2.8
8	Other non-metallic mineral prods.	5.0	8	Coal tar products	3.0	8	Hydrogenated oil	3.2	8	Inorganic heavy chemicals	2.8
9	Hotels and restaurants	3.5	9	Hotels and restaurants	2.8	9	Wheat	3.0	9	Iron and steel	2.6
10	Railway transport services	3.4	10	Other non-metallic mineral prods.	2.8	10	Organic heavy chemicals	2.7	10	Tea and coffee processing	2.3

3.7.2 Upstream and Downstream Sectors of the Production Chain

In general, sectors that are upstream in the production chain have higher energy intensities than the downstream sectors. In other words, sectors that are at the beginning of the production chain such as agriculture, paper, basic metals, basic chemicals, etc. have higher energy intensities than those that are mostly downstream processing industries such as food processing, metal products, printing and publishing and so on. This is an outcome of the fact that while production in most upstream sectors is energy and material intensive, production in downstream sectors, which are largely involved in the further processing of materials, probably require less energy and are more labour-intensive. There is also a correlation between the energy intensities of sectors in the same production chain. In particular, for sectors with relatively high inputs from one sector, the indirect energy intensity is strongly correlated with the energy intensity of that sector. For sectors lying towards the end of the production chains, there is less correlation with the energy intensities of succeeding sectors because these sectors receive their inputs from many different sectors.

3.7.3 Contribution of Direct Energy Intensity to the Total

The contribution of direct energy intensity to the total differs widely across sectors. In the case of less than ten sectors, primarily some of the most intensive such as petroleum products, coal tar products, structural clay products, cement, and electricity, the contribution of direct energy inputs to the total energy intensity was more than 60% for each of the studied years. In most machine/ engineering industries and some manufacturing sectors, the percentage of direct to total energy intensity was very low, less than 8% in most cases for all years. Clearly, for these sectors the contribution of indirect energy inputs to total energy intensity was relatively high, often as large as ten times the direct inputs. From an energy conservation perspective, this highlights the importance of determining total energy intensities as lowering direct energy use alone may not be the most effective strategy for reducing total energy use. Reductions in indirect energy use through the substitution of production factors and reducing materials use are especially important for sectors near the end of production chains.

3.7.4 Energy Intensity of Total Production

The primary energy intensity (direct plus indirect) of total economy wide output, that is for all commodity sectors of the economy declined from 1.29 MJ/Rs.$^{93-94}$ to 1.05 MJ/Rs.$^{93-94}$between 1983-84 and 1989-90, and declined further to 0.92 MJ/Rs.$^{93-94}$ by 1993-94 and then to 0.85 MJ/Rs.$^{93-94}$ in 1998-99[4]. There is a need to be cautious in interpreting this change in energy intensities as the observed changes could be a result of a number of different factors. Changes in levels of energy efficiency, changes in types and quality of sectoral output and changes in the structure of the economy and fuel mix all have a bearing on the values of energy intensities. As mentioned earlier, corrections for the changes in prices have been carried out by the use of sectoral price indices to express all intensities in constant prices. However, the effect of changes in quality and type of output and other factors effecting energy intensities have not been investigated as this would require a detailed study at the sectoral level which is not within the scope of this research.

The direct primary energy intensity of total production showed a similar pattern of decrease during this period. It declined from 0.34 MJ/Rs.$^{93-94}$ in 1983-84 to 0.27 MJ/Rs.$^{93-94}$ in 1989-90, 0.23 MJ/Rs.$^{93-94}$ in 1993-94 and further to 0.16 MJ/Rs.$^{93-94}$ in 1998-99. The ratio between direct and total energy intensity of total production also declined correspondingly during this period further strengthening the argument for examining total direct and indirect, energy requirements of industrial processes for purposes of formulating appropriate energy policies.

3.7.5 Trends in Energy Intensities

The development in energy intensities for the 100 commodity sectors during the period 1983-84 to 1998-99 can be observed from Tables 3C-2 to 3C-5. In addition, Table 3C-6 shows the percentage average annual changes in energy intensities over the base period for each of the sub-periods and over the entire decade for all 100 sectors. Positive values indicate that energy intensity increased during the period whereas negative values mean there was a decrease. Many of the commodity sectors experienced a decline in total primary energy intensity during this period. For most of the food and agricultural sectors, however, the energy intensities increased during the entire time period. This is explained by the rapid

[4] All monetary quantities are expressed in constant 1993-94 Indian rupees (Rs.) One $(US) was equivalent to Rs. 31.36 for that year.

mechanisation and intensification of agriculture and fast rate of growth of electricity consumption particularly, for irrigation purposes during this period. In fact, annual average electricity growth rate in the agricultural sector was over 11% between 1970 and 1999, the highest among all sectors in India. If one looks further into the data for numbers of irrigation pump-sets energised (electric pump-sets only), it is apparent that there has been a tenfold increase between 1970 and 1999.

It is difficult to evaluate the degree of accuracy of the reported data on energy used in the agricultural sector. It is possible that some of the observed growth in electricity use in the agricultural and household (direct) sectors may be a result of better reporting and accounting over the years. It is a known fact that transmission and distribution losses in electricity supply are very large in India. The Planning Commission estimates that these losses are as high as 20% or more of total electricity generated and a significant proportion of these losses are attributed to pilferage, especially by the household and agricultural sectors where proper metering is often lacking (GoI 1999). The rapidly rising electricity use in the agricultural sector is also likely, in part, to be a result of the very low, subsidised electricity tariffs for agricultural users.

Trends in the energy intensities of the manufacturing sectors reflect to some extent structural shifts within the economy during this period. The government initiated a number of reforms during the decade of the 1990's to increase industrial efficiency and productivity. Thus, while a majority of sectors experienced an increase in energy intensity over the first sub-period from 1983-84 to 1989-90, subsequently more sectors showed a decline in energy intensity. However, several of the primary agricultural and food sectors experienced an increase in energy intensity of more than 50% during the entire period. There were also several sectors including cement, non-metallic minerals and miscellaneous manufacturing sectors along with several of the services sectors, which experienced a decrease of greater than 50% in their primary energy intensities during this period. For many sectors, the general shift from coal and lignite and non-commercial energy use to greater oil, gas and electricity use during this period are responsible, in part, for the observed decreases in primary energy intensities. In particular, both technological and structural changes and fuel shifts such as the overall shift from non-commercial to commercial energy sources throughout the economy lead to large changes in energy intensities for certain sectors during this period.

By observing the changes in the energy intensities of the different energy carriers during this period, additional information can be ascertained on the fuel substitution that has occurred within different sectors. Non-commercial energy intensity declined continuously for most sectors other than some of the primary agricultural sectors and small-scale traditional industries during this period. In contrast, electricity intensities of most sectors experienced an increase over the decade 1983-84 to 1993-94 but there was a downturn in the electricity intensities of many of the manufacturing sectors during the second half of the 1990s. In general, coal and lignite intensity declined for most sectors over the entire period whereas crude oil and gas intensity rose, except for a slight dip during the period between 1989-90 to 1993-94 when the country faced an oil import crises.

3.7.6 Uncertainties in Energy Intensities

To get some idea of the consistency and reliability of the energy intensity estimates calculated using the input-output energy analysis technique, it is important to discuss some of the uncertainties associated with the technique and its application. As mentioned earlier, by construction, the technique has some limitations as it uses aggregated data on economic transactions of sectors and hence only provides results for the average energy intensities of sectors. In cases where single economic sectors produce a number of different products, the outcomes of energy intensity estimates are valid only for the average product of the sector. In addition, it does not allow for distinguishing between different companies in a given sector, some of which may be more efficient then others or between different qualities of outputs produced by the same sector. Generally, the technique also tends to exclude all non-commercial transactions within the economy as only the monetised part of the economy is recorded within the input-output transactions tables. Including non-commercial energy was an attempt to incorporate the non-formal or unorganised sector of the economy into the analysis for India. Non-commercial (biomass) energy use is crucial from a household and development perspective, especially for a large developing country like India, where it still comprises about 85% of direct energy use of households. Energy inputs associated with animal and human labour, which probably comprise an equally important part of the unorganised, or non-monetised sector, could not, however, be included due to lack of data.

Apart from the methodological limitations and related uncertainties mentioned above, uncertainties related to the outcome of the method basically arise from uncertainties in the elements of the technological matrix and in the direct energy use of the production sectors or in terms of Equation 3.5 uncertainties related to the elements of matrix **A** and **d**. In order to investigate the effect of such uncertainties on energy intensity values, an uncertainty analysis was carried out for the year 1998-99. Following the method described in Bullard and Sebald (1977), the effect on total primary energy intensities of extreme uncertainties related to an upper limit positive deviation of 10% and lower limit negative deviation of 10% in all elements of the technology matrix and the direct energy intensity matrix were calculated. A maximum deviation of 10% was considered suitable for this analysis, as yearly variation in the energy intensities calculated for most sectors was less than this.

In general, the relative deviations in total energy intensities are higher than the original deviations in the elements of the **A** and **d** matrices and the absolute value of negative deviations are smaller than those of positive deviations (Bullard and Sebald 1977 concluded the same). Deviations of a positive or negative 10% in the values of elements in the **A** and **d** matrices results in a greater than 10% deviation in the values of the total energy intensities due to a leverage effect, as even a small perturbation in the value of a direct energy coefficient could cause a simultaneous change in several elements of the $\mathbf{(I\text{-}A)^{-1}}$ matrix.

Table 3.2. Number of sectors showing different ranges of deviations in energy intensity for a maximum 10% positive and negative deviation in the elements of technology and direct energy coefficients matrix for the year 1998-99

		Number of sectors
Positive deviations		
	< 10%	4
	10% to 20%	5
	20% to 30%	22
	30% to 40%	54
	40% to 50%	15
Negative deviations		
	< 7%	4
	7% to 14%	3
	14% to 21%	12
	21% to 28%	52
	28% to 35%	29

Results of the calculations revealed that the maximum positive deviations in the values of energy intensities was less than 40% for the majority of sectors, with the highest deviation being 50% more than the original value. The maximum negative deviations were less than 30% for the majority of sectors, with the highest negative deviation being 35% below the original value (see Table 3.2). While these deviations appear to be fairly large it must be remembered that they refer to the upper and lower bounds of uncertainties in energy intensities and would occur only in the most unfavourable case, that is one in which all elements of the **A** and **d** matrices have a maximum positive or maximum negative deviation of 10%. Also the maximum deviations in energy intensities for most sectors fall within the range observed in other studies (Bullard and Sebald 1977). In reality, such an extreme case is highly unlikely and therefore, actual deviations are likely to be much lower.

3.8 Comparison with Energy Intensities from Previous Studies

An estimation of energy intensities using the input-output energy analysis technique at the 100-sector disaggregated level and incorporating non-commercial energy has not been done for India before. It is therefore difficult to make comparisons of energy intensities of sectors calculated in this study with those of other studies. Differences in methodologies used, levels of disaggregation, and time frames of the studies also limit the usefulness of such a comparison. Any attempt to do so is thus not made. However, a discussion of related literature in this area for India is provided below.

Relatively few efforts have been made to study sectoral energy intensities in the Indian context. The first published study related to this field was undertaken in the early 1980s to calculate total energy intensities for nineteen broad sector groupings based on the 1978-79 input-output tables by Rao et al. (1981). It is interesting to note that the most energy intensive sectors according to their calculations for 1978-79 were cement followed by iron and steel, fertiliser, coal, non-ferrous metals, and transport, which is similar to the ordering of sectors found in this study for the most comparable year 1983-84. Another study calculated energy multipliers rather than intensities for 15 broad sectors using the 1883-84 and 1989-90 input-output tables of India (Roy and Mukhopadhyay 1998). Findings from this study also found the energy sectors to have the highest values of primary energy multipliers, followed by the basic metal industry, infrastructure sectors, and manufacturing sectors. A study by Tiwari calculated direct and total energy intensities for 35 aggregated sectors based on the 1983-84 and 1989-90 input-output tables (Tiwari 2000). This study used more aggregated transactions tables as the bases for the calculations and a slightly different methodology that did not include non-commercial energy. Thus, comparing the values of energy intensities from that study with those of this study is meaningless. However, a comparison can be carried out for trends in intensities during the period 1983-84 to 1989-90. Tiwari's findings related to the trends in energy intensities correspond to those of this study. In particular, the study notes a decline in overall coal and lignite intensity and an increase in electricity intensity. In addition, it reports an increase in energy intensities of the paper and paper products, non-ferrous metals, and woollen textiles sectors but a decrease for cement, iron and steel, and fertiliser sectors. More recent studies on estimating energy intensities for India from Mukhopadhyay and Chakraborty (1999, 2005) also estimate direct and total intensities for India. Their later study estimates intensities for the same years as is done in this research but at the level of 47 aggregated sectors using input-output tables. While they report results separately for coal, oil and gas and electricity intensities, they do not estimate intensities of petroleum product use and also do not include non-commercial energy in their analyses. Their estimates of intensities are similar to those presented here for many sectors, and some of the trends they report also match those observed in the analyses presented in this study.

A comparison with values of energy intensities in other countries is also not very meaningful as differences in prices of goods and services, technologies of production, in levels of sector aggregations, and the product mix of the sector-outputs limit the usefulness of such a comparison. Most studies that have been carried out so far also relate largely to industrially advanced countries[5] where levels of development for comparable time periods are vastly different and so make comparisons even less significant. It is probably more appropriate to compare results from this study for India with those of developed countries done ten or twenty years earlier. However, energy intensities determined in such studies reflect the effects of the oil crises of the 1970s, which prompted these countries to implement a host of energy conservation measures. Such a comparison is therefore, not included here. It is interesting however, to cite a comparison of energy requirements for the production of three commodities from the UNDP/WEC study (Jochem 2000). These specific energy requirements are computed for well-defined products per weight. It is clear from Table 3.3 that despite improvements in the energy intensity of certain sectors in India during the

[5] Some of the studies that have calculated total energy intensities of goods and services by input-output analysis include those by Denton (1975) for Germany, for the USA by Bullard and Herendeen (1975) and Wright (1974), for Canada by Bush (1981), for the UK by Pick and Becker (1975), for Japan by Han and Lakshmanan (1995), for Taiwan by Wu and Chen (1989), and for New Zealand by Peet (1985).

study period, there is a significant potential for further improvements in energy efficiency by adopting more efficient technologies.

Table 3.3. Specific energy use in selected basic products industries and countries in the mid-1990s

Country	Steel	Cement	Pulp and Paper
	GJ/Tonne	GJ/Tonne	GJ/Tonne
India	40	8	47
USA	25	4	41
Japan	18	5	-
Sweden	21	6	32

Source: Jochem (2000)

3.9 Discussion and Conclusions

In this chapter, the methodology for calculating energy intensities using the input-output energy analysis method at the 100 sector classification level and incorporating non-commercial energy use for India is presented. Values and changes in energy intensities were studied for the period 1983-84 to 1998-99. Over this period, an improvement in the energy intensities of some sectors did occur though most food and agricultural sectors experienced an increase in energy intensities. In particular, there seems to have been a downward trend in energy intensities after 1990 for more sectors, particularly for many of the traditional heavy engineering and basic goods sectors. Many of these sectors experienced an increase in intensities in the period 1983-84 to 1989-90 but showed a decline during 1889-90 to 1998-99. This points to some improvement in energy efficiencies for certain sectors. Possible explanations for this progress are the general trend of substitution of coal and lignite and non-commercial energy by electricity, oil and gas. Further research is needed at the sectoral level and sub-sectoral level, however, to determine the exact influences that have lead to a decline in energy intensities for certain sectors. However a comparison of energy intensities from this study with those of studies done for western countries still shows that there is significant potential for further reductions in energy intensities through increased efficiencies and the adoption of advanced technologies.

The trends in intensity changes observed in India seem to follow the general historical trend of initially increasing sectoral energy intensities and then decreasing intensities evident in most currently industrialised or

OECD nations (see Bernardini and Galli 1993 for energy intensity changes over time in UK, USA and Italy). These trends accompany important structural changes that take place during the process of industrialisation with replacement of animated labour (draft animals and human) and inefficient non-commercial biomass energy sources with more machines and commercial fossil fuels in the initial phases of the process. The later stages of industrialisation are characterised by technical efficiency improvements in industrial processes and shifts to more efficient fuels and electricity. Structural elements in the development process also include changes in the share of different activities in economic production with a greater role for the manufacturing sector initially and a subsequent shift to a larger role for the service sectors.

Results relating to the direct and total primary energy intensities of sectors presented in this chapter stress the importance of taking into account indirect energy requirements of sectors, as in the case of most sectors these comprise a significant part of total intensities. Hence, looking at direct energy intensities alone would present a very different picture than one that includes total energy requirements of production processes. From the policy perspective therefore, both direct and indirect requirements need to be considered.

While, it is difficult to determine the exact degree of accuracy of the estimates obtained from the calculations presented here, an uncertainty analysis determining deviations in energy intensities as a result of a maximum positive or negative uncertainty of 10% in the elements of the transactions matrix and direct energy requirements of all productive sectors for the year 1998-99 revealed that the resultant maximum deviations in energy intensities for most sectors fall within the range observed in previous studies. Clearly, the availability of more detailed energy data for India at a more disaggregated level should make it possible to carry out similar calculations with even more accurate results in future studies.

Appendix 3A: Sector Classification for Input-Output Energy Analysis

Sector No.	Description of Sectors for the IOEA	Sector No. in Published Tables	Sector Description in Published 115 Sector Classification Tables
1	Paddy	1	Paddy
2	Wheat	2	Wheat
3	Jower	3	Jower
4	Bajra	4	Bajra
5	Maize	5	Maize
6	Gram	6	Gram
7	Pulses	7	Pulses
8	Sugarcane	8	Sugarcane
9	Groundnut	9	Groundnut
10	Jute	10	Jute
11	Cotton	11	Cotton
12	Tea	12	Tea
13	Coffee	13	Coffee
14	Rubber	14	Rubber
15	Coconut	15	Coconut
16	Tobacco	16	Tobacco
17	Other Crops	17	Other Crops
18	Milk And Milk Products	18	Milk And Milk Products
19	Animal Services (Agriculture)	19	Animal Services (Agriculture)
20	Other Livestock Products	20	Other Livestock Products
21	Forestry And Logging	21	Forestry And Logging
22	Fishing	22	Fishing
23	Coal & Lignite	23	Coal & Lignite
24	Crude Petroleum, Natural Gas	24	Crude Petroleum, Natural Gas
25	Iron Ore	25	Iron Ore
26	Other Minerals	26, 27, 28, 29, 30, 31, 32	Manganese Ore, Bauxite, Copper Ore, Other Metallic Minerals, Lime Stone, Mica, Other Non-metallic Minerals
27	Sugar	33	Sugar
28	Khandsari, Boora	34	Khandsari, Boora

Sector No.	Description of Sectors for the IOEA	Sector No. in Published Tables	Sector Description in Published 115 Sector Classification Tables
29	Hydrogenated Oil (Vanaspati)	35	Hydrogenated Oil (Vanaspati)
30	Edible Oil Other Than Vanaspati	36	Edible Oil Other Than Vanaspati
31	Tea and Coffee Processing	37	Tea and Coffee Processing
32	Miscellaneous Food Products	38	Miscellaneous Food Products
33	Beverages	39	Beverages
34	Tobacco Products	40	Tobacco Products
35	Khadi, Cotton Textile in Handlooms	41	Khadi, Cotton Textile in Handlooms
36	Cotton Textiles	42	Cotton Textiles
37	Woollen Textile	43	Woollen Textile
38	Silk Textiles	44	Silk Textiles
39	Art Silk, Synthetic Fibre Textiles	45	Art Silk, Synthetic Fibre Textiles
40	Jute, Hemp, Mesta Textiles	46	Jute, Hemp, Mesta Textiles
41	Carpet Weaving	47	Carpet Weaving
42	Ready Made Garments	48	Ready Made Garments
43	Miscellaneous Textile Products	49	Miscellaneous Textile Products
44	Furniture & Fixtures	50	Furniture & Fixtures
45	Wood And Wood Products	51	Wood And Wood Products
46	Paper, Paper Products & Newsprint	52	Paper, Paper Products & Newsprint
47	Printing Publishing And Allied Activities	53	Printing Publishing And Allied Activities
48	Leather Footwear	54	Leather Footwear
49	Leather & Leather Products	55	Leather & Leather Products
50	Rubber Products	56	Rubber Products
51	Plastic Products	57	Plastic Products
52	Petroleum Products	58	Petroleum Products
53	Coal Tar Products	59	Coal Tar Products
54	Inorganic Heavy Chemicals	60	Inorganic Heavy Chemicals
55	Organic Heavy Chemi-	61	Organic Heavy Chemicals

Sector No.	Description of Sectors for the IOEA	Sector No. in Published Tables	Sector Description in Published 115 Sector Classification Tables
	cals		
56	Fertilizers	62	Fertilizers
57	Pesticides	63	Pesticides
58	Paints, Varnishes & Lacquers	64	Paints, Varnishes & Lacquers
59	Drugs And Medicines	65	Drugs And Medicines
60	Soaps, Cosmetics & Glycerine	66	Soaps, Cosmetics & Glycerine
61	Synthetic Fibres, Resin	67	Synthetic Fibres, Resin
62	Other Chemicals	68	Other Chemicals
63	Structural Clay Products	69	Structural Clay Products
64	Cement	70	Cement
65	Other Non-Metallic Mineral Products	71	Other Non-Metallic Mineral Products
66	Iron & Steel	72, 73, 74	Iron & Steel Ferro Alloys, Iron & Steel Casting and Foraging, Iron & Steel Foundries
67	Non-Ferrous Basic Metals	75	Non-Ferrous Basic Metals
68	Hand Tools, Hardware	76	Hand Tools, Hardware
69	Miscellaneous Metal Products	77	Miscellaneous Metal Products
70	Industrial & Electrical Machinery	78, 79, 80, 81, 84, 85, 89	Tractors & Other Agricultural Implements, Industrial Machinery for Food & Textile, Industrial Machinery (other), Machine Tools, Electrical Industrial Machinery, Electrical Cables, Wires, Other Electrical Machinery
71	Office Computing & Accounting	82	Office Computing & Accounting
72	Other-Non-Electrical Machinery	83	Other-Non-Electrical Machinery
73	Batteries	86	Batteries
74	Electrical Appliances	87	Electrical Appliances
75	Communication Equipment	88	Communication Equipment

Sector No.	Description of Sectors for the IOEA	Sector No. in Published Tables	Sector Description in Published 115 Sector Classification Tables
76	Electronic Equipment Incl. Televisions	90	Electronic Equipment Incl. Televisions
77	Other Transport Equipment	91, 92, 96	Ships & Boats, Railway Equipment, Other Transport Equipment
78	Motor Vehicles	93	Motor Vehicles
79	Motor Cycle And Scooter	94	Motor Cycle And Scooter
80	Bicycles, Cycle-Rickshaw	95	Bicycles, Cycle-Rickshaw
81	Watches And Clocks	97	Watches And Clocks
82	Miscellaneous Manufacturing	98	Miscellaneous Manufacturing
83	Construction	99	Construction
84	Electricity	100	Electricity
85	Gas	101	Gas
86	Water Supply	102	Water Supply
87	Railway Transport Service	103	Railway Transport Service
88	Other Transport Service	104	Other Transport Service
89	Storage And Warehousing	105	Storage And Warehousing
90	Communication	106	Communication
91	Trade	107	Trade
92	Hotels & Restaurants	108	Hotels & Restaurants
93	Banking	109	Banking
94	Insurance	110	Insurance
95	Ownership Of Dwellings	111	Ownership Of Dwellings
96	Education & Research	112	Education & Research
97	Medical And Health	113	Medical And Health
98	Other Services	114	Other Services
99	Public Administration & Defence	115	Public Administration & Defence
100	Non-commercial energy	Newly created sector	

Appendix 3B: Technical Note on Creating a Hybrid I-O Matrix

This note describes the various steps taken to calculate direct and total energy intensities for India using input-output data by directly incorporating the energy usage patterns for each activity/sector in physical terms into the input-output tables of the economy. The exercise was performed on the 100 sector input-output transactions matrix of the Indian economy, constructed from those published by the Central Statistical Organisation, Department of Statistics, Ministry of Planning, Government of India for the years 1983-84, 1989-90, 1993-94 and 1998-99 (CSO 1990, CSO 1997, CSO 2000, CSO 2005). The exercise used sectoral energy transactions (in value terms) reported in the matrices as the starting point, and then converted these values into physical quantities of energy used. These physical quantities replaced the original values of energy transactions in the 100-sector matrix, and the modified transactions matrix was used to compute a technology coefficient matrix, which was used as the basis of the input-output energy analysis. The following describes in detail the transformation of sectoral energy value transactions into physical quantities.

The original matrices provided information on fossil-fuel usage by each of the sectors in terms of the Rupee values (current prices) of coal and lignite (Sector 23), crude petroleum and natural gas (Sector 24), petroleum products (Sector 52), electricity (Sector 84) and gas (Sector 85) used by each sector during each of the accounting years 1983-84, 1989-90, 1993-94 and 1998-99. The coal classification included all varieties of coal, including coking coal. The petroleum products classification is, again, an aggregated one, inclusive of all refinery products.

(1) Coal and Lignite.

Data on the sectoral consumption of various types of coal and lignite was limited. The data for some sectors was available from various official sources (GoI various). To start with, for these sectors for which physical data was available, the physical quantities of coal were allotted to the respective sectors. These sectors were those that were the largest consumers of coal such as the electricity sector, iron and steel, etc. In the next step, an average price of coal was estimated for each of the years by dividing monetary flow values in the input-output tables by the available physical flow data for these large consuming sectors. Finally, monetary flow values for all the other sectors in the input-output tables were divided by this calculated average price to arrive at the physical coal energy flows for these other smaller consuming sectors.

Lignite production data provided information on the total lignite produced and consumed within the country. In addition, the CEA General Reviews provided data on the physical quantity of lignite consumed by the electricity sector, which was approximately 65% of the total (CEA various). The remaining quantity of lignite was assigned to the manufacturing sector as a share of total coal consumption of each sector.

(2) Crude Petroleum and Natural Gas.

Crude petroleum and natural gas flows were almost entirely shown as an input into the petroleum products activity, as was to be expected, with some small values feeding into several other sectors. These flows were interpreted as the amount of natural gas being directly consumed by these sectors. For some sectors (large consumers such as fertilisers and electricity sector) data on the physical quantities of natural gas consumed for the different years was available. For the other sectors for which physical flows were not available physical quantities of natural gas use were allotted in proportion to the monetary or value flows from the relevant sectors.

(3) Petroleum Products.

The conversion exercise for petroleum products involved an additional step. A distinction had to be made between categories of distillates (light, middle and heavy). The demand for fuels by the production activities (intermediate demand) in the system was taken to consist of furnace oil (FO), LSHS (both heavy distillates) and HSD and LDO (middle distillates) and LPG and Naphtha (light distillates). The final demand component for petroleum products was assumed to consist of LDO (middle), motor spirit and kerosene (light distillates).

For all production sectors the following procedure was used. The document Indian Petroleum and Natural Gas Statistics (P&NGS) (GoI various) provided some idea of the usage patterns of refinery products by some of the production sectors. In addition, the CMIE and CSO publications also provided some data on the physical consumption of selected petroleum products by different sectors (CMIE 2000, 2005). The prices of various distillates were also obtained from the same sources. The value of petroleum product usage provided by the input-output matrix was decomposed into HSD and FO components, using the value distributions obtained from the P&NG Statistics. Since this value decomposition was not available for all sectors separately, some judgments about usage patterns were necessary. The final result was, therefore, a combination of P&NGS distributions applied to as many sectors as possible and own judgments for the rest of the sectors. The rupee value for different petroleum products thus obtained were converted to physical units (tonnes) using the price information described above.

For the final demand components of petroleum products, as well as for imports, the value shares provided in the P&NG Statistics was used to convert the matrix information on aggregate values into product-wise values, and then to physical quantities, using price information from the same source.

(4) Electricity.

Data on electricity consumption by different end-use sectors was culled out from the CMIE and CSO publications, CEA publications and TEDDY (CMIE 2000, 2005, CSO various, CEA various, TERI 1999, 2003). As data for electricity use for each of the 115 sectors was not available, price data was also made use of to convert the value data to physical quantities. In general, quantity data was used wherever available, and for sectors where the disaggregated physical consumption data was not available, assumptions were made such that price of electricity for similar industries/sectors (HT/LT) was taken to be the same. Wherever, possible cross-checks were also carried out between calculated prices (monetary value/physical value) and published data on prices for electricity for different sectors.

(5) Gas.

Gas here refers only to Gobar Gas/Biogas (LPG is included in the Petroleum, Products sector and Natural Gas in the Crude Petroleum and Natural Gas sector) and is very small in value; hence values in this sector were not converted from monetary to physical terms.

Creating a New Non-Commercial Energy Use Sector and Allocating Non-Commercial Energy Flows to the Different End-Use Sectors

For data on the non-commercial energy use by broad sector groupings (industry, services and households) for different years we used the Regional

Wood Energy Development Programme database of the Food and Agricultural Organisation (FAO). The data was crosschecked with other sources of published data on non-commercial energy use in India (Ravindranath and Hall 1995; Natarajan 1985; PC 1999). A further disaggregation to end sectors was done in proportion to total Rupee value of expense on coal and lignite of each sector. In addition, assumptions regarding which sectors are the prime users of non-commercial energy were made based on data on the consumption pattern of wood fuels in industries (FAO 1997).

Appendix 3C: Detailed Results Tables

Table 3C-1. Direct and total primary energy intensities in MJ per constant Rupees

	All in MJ/Rs. 93-94	Direct				Total			
		1983-84	1989-90	1993-94	1998-99	1983-84	1989-90	1993-94	1998-99
1	Paddy	0.06	0.03	0.03	0.04	0.94	1.24	1.41	1.91
2	Wheat	0.28	0.25	0.10	0.08	2.29	2.71	2.97	3.02
3	Jowar	0.00	0.00	0.01	0.00	0.61	0.57	0.58	1.00
4	Bajra	0.01	0.01	0.02	0.02	0.71	0.58	0.92	1.40
5	Maize	0.01	0.02	0.04	0.04	0.76	0.78	1.26	1.90
6	Gram	0.01	0.01	0.01	0.02	0.27	0.51	0.53	0.74
7	Pulses	0.01	0.01	0.02	0.02	0.43	0.73	0.89	1.45
8	Sugarcane	0.01	0.01	0.02	0.02	0.61	0.70	0.66	1.06
9	Groundnut	0.00	0.00	0.01	0.01	0.37	0.44	0.74	0.82
10	Jute	0.00	0.00	0.00	0.00	0.18	0.28	0.17	0.42
11	Cotton	0.02	0.01	0.03	0.02	1.10	0.84	0.88	1.96
12	Tea	0.00	0.00	0.00	0.00	0.16	0.17	0.15	0.38
13	Coffee	0.00	0.00	0.00	0.00	0.41	0.24	0.17	0.16
14	Rubber	0.00	0.00	0.00	0.00	0.52	1.01	0.31	0.36
15	Coconut	0.00	0.00	0.00	0.00	0.11	0.13	0.35	0.89
16	Tobacco	0.00	0.00	0.01	0.01	0.38	0.85	0.58	0.87
17	Other crops	0.03	0.01	0.01	0.01	0.29	0.76	0.62	0.70
18	Milk and milk products	0.04	0.06	0.05	0.00	0.18	0.26	0.20	0.12
19	Animal services (agricultural)	0.00	0.00	0.00	0.00	0.35	0.79	0.66	0.73
20	Other livestock products	0.00	0.00	0.00	0.00	0.37	0.29	0.25	0.29
21	Forestry and logging	0.00	0.00	0.00	0.00	0.16	0.14	0.14	0.18
22	Fishing	0.00	0.00	0.00	0.00	0.07	0.17	0.21	0.33
23	**Coal and lignite**	**0.03**	**0.02**	**0.02**	**0.01**	**1.05**	**1.05**	**1.05**	**1.02**
24	**Crude petroleum, natural gas**	**0.01**	**0.02**	**0.03**	**0.01**	**1.02**	**1.03**	**1.04**	**1.03**
25	Iron ore	0.07	0.20	0.02	0.00	0.86	1.22	1.01	1.00
26	Other minerals	0.06	0.03	0.02	0.00	0.76	0.45	0.41	0.41
27	Sugar	0.15	0.31	0.26	0.00	0.66	1.00	0.91	0.76
28	Khandsari, boora	0.55	0.47	0.09	0.00	1.10	1.57	0.96	0.86
29	Hydrogenated oil (vanaspati)	1.12	0.41	1.58	1.75	2.32	1.26	3.20	2.96

	All in MJ/Rs. 93-94	Direct				Total			
		1983-84	1989-90	1993-94	1998-99	1983-84	1989-90	1993-94	1998-99
30	Edible oils other than vanaspati	0.07	0.21	0.17	0.14	0.50	0.95	0.91	0.84
31	Tea and coffee processing	0.84	1.40	1.06	1.48	1.43	2.03	1.85	2.29
32	Miscellaneous food products	0.85	0.49	0.30	0.26	1.80	1.47	1.12	1.31
33	Beverages	0.62	0.97	0.64	1.03	1.58	2.20	1.66	1.99
34	Tobacco products	0.20	0.10	0.08	0.06	0.67	0.90	0.85	0.89
35	Khadi cotton textiles	0.45	0.11	0.03	0.02	1.52	1.18	0.83	1.57
36	Cotton textiles	1.12	0.85	0.51	0.56	2.77	2.29	1.84	2.29
37	Woollen textiles	1.27	0.59	1.09	0.98	2.68	1.88	2.21	2.21
38	Silk textiles	0.28	0.16	0.23	0.23	1.16	0.87	1.03	1.02
39	Art silk, synthetic fibre textiles	0.66	0.43	0.54	0.21	3.25	2.03	1.88	1.57
40	Jute, hemp, mesta textiles	0.55	0.87	1.00	0.44	1.33	2.04	2.26	1.61
41	Carpet weaving	0.47	0.08	0.30	0.36	1.26	0.76	1.13	1.24
42	Readymade garments	0.73	0.04	0.01	0.01	2.18	1.16	1.05	1.18
43	Miscellaneous textile products	0.17	0.07	0.06	0.05	1.19	1.25	1.13	1.27
44	Furniture and fixtures-wooden	0.11	0.01	0.00	0.00	0.34	0.44	0.43	0.43
45	Wood and wood products	0.10	0.12	0.12	0.14	0.34	0.42	0.64	0.70
46	Paper, paper prods. & newsprint	3.30	3.25	4.72	2.82	5.53	6.13	7.24	4.67
47	Printing and publishing	0.05	0.01	0.01	0.00	1.65	1.75	2.25	1.25
48	Leather footwear	0.20	0.10	0.05	0.05	0.90	1.35	0.85	0.63
49	Leather and leather products	0.17	0.14	0.14	0.11	1.03	1.13	0.88	0.76
50	Rubber products	0.36	1.16	0.82	0.20	1.97	2.75	2.12	1.10
51	Plastic products	0.08	0.08	0.07	0.02	1.87	2.15	1.38	1.12
52	**Petroleum products**	**0.90**	**0.98**	**0.87**	**1.48**	**0.99**	**1.07**	**0.99**	**1.68**
53	Coal tar products	4.96	1.89	0.37	0.58	8.63	3.00	1.12	1.09
54	Inorganic heavy chemicals	0.62	1.42	1.45	1.01	2.50	3.03	3.37	2.76
55	Organic heavy chemicals	0.72	0.90	0.57	0.34	5.73	3.11	2.68	2.08
56	Fertilizers	2.65	2.60	3.28	2.10	8.65	6.09	7.72	6.41
57	Pesticides	0.02	0.08	0.10	0.08	1.35	2.41	2.19	1.45
58	Paints, varnishes and	0.11	0.26	0.38	0.24	1.21	1.84	1.83	1.30

	All in MJ/Rs. 93-94	Direct				Total			
		1983-84	1989-90	1993-94	1998-99	1983-84	1989-90	1993-94	1998-99
	lacquers								
59	Drugs and medicines	0.09	0.09	0.11	0.06	1.98	1.65	1.48	1.34
60	Soaps, cosmetics & glycerine	0.37	0.68	0.29	0.09	1.78	2.65	1.76	1.30
61	Synthetic fibres, resin	0.49	0.50	0.62	0.77	2.20	1.96	1.95	1.79
62	Other chemicals	0.48	0.92	0.65	0.25	1.59	2.37	2.00	1.33
63	Structural clay products	5.54	4.64	5.99	5.50	7.17	6.80	7.01	6.43
64	Cement	6.28	3.35	2.93	2.65	9.84	5.40	4.85	4.89
65	Other non-metallic mineral prods.	1.72	1.02	0.83	1.19	5.03	2.81	2.37	2.14
66	Iron and steel	2.50	1.97	1.56	1.12	5.80	4.87	3.94	2.61
67	Non-ferrous basic metals	0.37	0.48	0.32	0.29	2.84	2.69	2.23	1.93
68	Hand tools, hardware	0.30	0.03	0.05	0.01	1.68	1.94	1.48	0.96
69	Miscellaneous metal products	0.18	0.33	0.25	0.11	2.42	2.38	2.12	1.31
70	Industrial and electrical machinery	0.07	0.06	0.07	0.03	2.30	1.61	1.60	1.31
71	Office computing machines	0.05	0.02	0.02	0.00	1.58	1.32	0.86	0.77
72	Other non-electrical machinery	0.04	0.07	0.07	0.04	2.04	1.77	1.47	1.21
73	Batteries	0.07	0.02	0.07	0.02	1.65	0.13	1.45	1.31
74	Electrical appliances	0.12	0.02	0.04	0.01	2.13	0.42	1.43	1.00
75	Communication equipments	0.02	0.02	0.03	0.00	1.12	1.20	1.22	0.90
76	Electronic equipments (incl.TV)	0.01	0.01	0.01	0.00	1.44	1.12	1.21	0.87
77	Other transport equipments	0.06	0.11	0.10	0.02	1.09	1.33	1.51	1.26
78	Motor vehicles	0.02	0.02	0.05	0.03	2.59	1.30	1.42	1.21
79	Motor cycles and scooters	0.09	0.01	0.03	0.01	1.57	1.31	0.93	0.91
80	Bicycles, cycle-rickshaw	0.30	0.01	0.02	0.01	2.96	1.38	1.20	1.24
81	Watches and clocks	0.49	0.02	0.03	0.00	2.38	0.93	1.45	1.05
82	Miscellaneous manufacturing	0.84	0.06	0.10	0.01	3.18	1.26	1.30	1.19
83	Construction	0.01	0.00	0.01	0.00	1.89	1.49	1.35	1.19
84	**Electricity**	**3.13**	**3.39**	**2.81**	**3.44**	**4.48**	**3.89**	**4.35**	**5.40**
85	Gas	0.00	0.00	0.00	0.00	0.03	0.09	0.14	0.12

	All in MJ/Rs. 93-94	Direct				Total			
		1983-84	1989-90	1993-94	1998-99	1983-84	1989-90	1993-94	1998-99
86	Water supply	0.18	0.12	0.18	0.11	3.17	2.64	3.31	2.84
87	Railway transport services	1.84	0.71	0.23	0.05	3.37	2.04	1.45	1.50
88	Other transport services	0.05	0.01	0.03	0.00	2.09	2.11	1.67	1.73
89	Storage and warehousing	0.08	0.05	0.05	0.05	1.49	1.13	1.13	1.40
90	Communication	0.01	0.00	0.02	0.01	0.45	0.45	0.31	0.29
91	Trade	0.01	0.01	0.01	0.00	0.46	0.51	0.35	0.37
92	Hotels and restaurants	2.69	2.07	1.56	0.63	3.48	2.81	2.21	1.68
93	Banking	0.01	0.01	0.01	0.00	0.36	0.36	0.20	0.26
94	Insurance	0.00	0.01	0.01	0.01	0.40	0.38	0.43	0.59
95	Ownership of dwellings	0.00	0.00	0.00	0.00	0.20	0.23	0.07	0.08
96	Education and research	0.00	0.00	0.01	0.00	0.35	0.19	0.15	0.15
97	Medical and health	0.00	0.00	0.00	0.00	0.88	0.80	0.73	0.67
98	Other services	0.01	0.02	0.02	0.01	0.23	0.92	0.73	0.74
99	Public administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	**Non-commercial energy**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
	TOTAL	0.34	0.27	0.23	0.16	1.23	1.02	0.92	0.75

Note: Figures in bold are dimensionless.

Table 3C-2. Energy Intensities by energy carrier in 1983-84 Coal & lignite (1), Crude petroleum, natural gas (2), Petroleum products (3), Electricity (4), Non-commercial (5). All in MJ per Rupees 93-94

	Sector	(1)	(2)	(3)	(4)	(5)
1	Paddy	0.46	0.40	0.35	0.08	0.05
2	Wheat	1.31	0.68	0.59	0.30	0.20
3	Jowar	0.28	0.30	0.26	0.03	0.03
4	Bajra	0.33	0.35	0.31	0.05	0.02
5	Maize	0.39	0.33	0.29	0.07	0.02
6	Gram	0.17	0.07	0.07	0.04	0.01
7	Pulses	0.23	0.16	0.14	0.04	0.02
8	Sugarcane	0.31	0.27	0.23	0.06	0.01
9	Groundnut	0.16	0.20	0.17	0.02	0.01
10	Jute	0.08	0.10	0.09	0.01	0.01
11	Cotton	0.54	0.50	0.43	0.10	0.03
12	Tea	0.06	0.09	0.08	0.01	0.00
13	Coffee	0.25	0.11	0.12	0.03	0.04

	Sector	(1)	(2)	(3)	(4)	(5)
14	Rubber	0.21	0.29	0.25	0.02	0.01
15	Coconut	0.05	0.05	0.05	0.01	0.01
16	Tobacco	0.16	0.20	0.17	0.02	0.01
17	Other crops	0.14	0.12	0.10	0.02	0.02
18	Milk and milk products	0.06	0.05	0.04	0.01	0.07
19	Animal services (agricultural)	0.16	0.15	0.14	0.03	0.03
20	Other livestock products	0.18	0.14	0.13	0.03	0.04
21	Forestry and logging	0.06	0.08	0.08	0.01	0.02
22	Fishing	0.03	0.03	0.03	0.00	0.01
23	**Coal & lignite**	**1.05**	**0.01**	**0.01**	**0.00**	**0.00**
24	**Crude petroleum, natural gas**	**0.00**	**1.02**	**0.00**	**0.00**	**0.00**
25	Iron ore	0.44	0.34	0.35	0.12	0.04
26	Other minerals	0.40	0.28	0.29	0.10	0.04
27	Sugar	0.30	0.22	0.21	0.05	0.12
28	Khandsari, boora	0.50	0.20	0.18	0.07	0.38
29	Hydrogenated oil (vanaspati)	1.08	0.31	0.31	0.11	0.89
30	Edible oils other than vanaspati	0.23	0.18	0.17	0.04	0.07
31	Tea and coffee processing	0.52	0.22	0.17	0.04	0.68
32	Miscellaneous food products	0.78	0.26	0.24	0.09	0.72
33	Beverages	0.98	0.27	0.27	0.07	0.31
34	Tobacco products	0.29	0.11	0.11	0.03	0.26
35	Khadi cotton textiles	0.64	0.23	0.23	0.08	0.63
36	Cotton textiles	1.22	0.48	0.47	0.20	1.00
37	Woollen textiles	1.13	0.37	0.38	0.13	1.13
38	Silk textiles	0.52	0.30	0.31	0.09	0.31
39	Art silk, synthetic fibre textiles	1.86	0.53	0.52	0.42	0.71
40	Jute, hemp, mesta textiles	0.58	0.26	0.27	0.09	0.46
41	Carpet weaving	0.51	0.19	0.20	0.06	0.54
42	Readymade garments	0.99	0.31	0.31	0.15	0.83
43	Miscellaneous textile products	0.54	0.27	0.28	0.09	0.35
44	Furniture and fixtures-wooden	0.15	0.08	0.09	0.02	0.10
45	Wood and wood products	0.15	0.10	0.10	0.02	0.08
46	Paper, paper prods. & newsprint	2.05	0.33	0.33	0.19	3.09
47	Printing and publishing	0.68	0.18	0.18	0.09	0.76
48	Leather footwear	0.40	0.22	0.22	0.06	0.26
49	Leather and leather products	0.47	0.32	0.33	0.07	0.22
50	Rubber products	1.01	0.46	0.46	0.18	0.45
51	Plastic products	1.16	0.49	0.49	0.27	0.13
52	Petroleum products	0.01	0.97	1.06	0.00	0.00
53	Coal tar products	7.46	0.98	1.02	0.33	0.08

	Sector	(1)	(2)	(3)	(4)	(5)
54	Inorganic heavy chemicals	1.80	0.57	0.58	0.24	0.05
55	Organic heavy chemicals	2.87	2.33	2.46	0.59	0.33
56	Fertilizers	3.26	5.16	4.32	0.35	0.10
57	Pesticides	0.78	0.40	0.41	0.13	0.12
58	Paints, varnishes and lacquers	0.70	0.39	0.41	0.11	0.09
59	Drugs and medicines	1.05	0.64	0.63	0.18	0.23
60	Soaps, cosmetics & glycerine	0.81	0.42	0.44	0.10	0.52
61	Synthetic fibres, resin	1.25	0.59	0.62	0.13	0.33
62	Other chemicals	0.75	0.30	0.30	0.12	0.50
63	Structural clay products	0.91	1.18	1.28	0.05	5.06
64	Cement	8.59	0.90	0.91	0.57	0.15
65	Other non-metallic mineral prods.	3.24	1.63	1.69	0.18	0.10
66	Iron and steel	4.71	0.97	1.01	0.22	0.05
67	Non-ferrous basic metals	1.51	1.20	1.25	0.30	0.03
68	Hand tools, hardware	1.28	0.35	0.37	0.07	0.02
69	Miscellaneous metal products	1.80	0.52	0.55	0.16	0.04
70	Industrial and electrical machinery	1.61	0.58	0.60	0.17	0.06
71	Office computing machines	1.07	0.43	0.45	0.10	0.05
72	Other non-electrical machinery	1.49	0.47	0.49	0.11	0.04
73	Batteries	0.92	0.55	0.58	0.15	0.12
74	Electrical appliances	1.26	0.66	0.68	0.15	0.16
75	Communication equipments	0.70	0.31	0.32	0.09	0.07
76	Electronic equipments	0.91	0.40	0.42	0.11	0.09
77	Other transport equipments	0.76	0.29	0.30	0.07	0.02
78	Motor vehicles	1.82	0.64	0.67	0.15	0.09
79	Motor cycles and scooters	0.97	0.51	0.53	0.11	0.06
80	Bicycles, cycle-rickshaw	2.12	0.70	0.74	0.15	0.09
81	Watches and clocks	1.63	0.61	0.64	0.17	0.08
82	Miscellaneous manufacturing	1.74	0.66	0.68	0.17	0.72
83	Construction	1.25	0.36	0.38	0.10	0.24
84	**Electricity**	**3.57**	**0.51**	**0.41**	**1.12**	**0.01**
85	Gas	0.02	0.02	0.02	0.00	0.00
86	Water supply	2.34	0.54	0.50	0.68	0.06
87	Railway transport services	2.64	0.62	0.66	0.13	0.06
88	Other transport services	0.34	1.68	1.83	0.05	0.06
89	Storage and warehousing	0.93	0.43	0.44	0.27	0.03
90	Communication	0.20	0.15	0.16	0.03	0.08
91	Trade	0.18	0.22	0.24	0.03	0.04
92	Hotels and restaurants	1.47	0.28	0.28	0.08	1.71
93	Banking	0.17	0.10	0.11	0.03	0.07

	Sector	(1)	(2)	(3)	(4)	(5)
94	Insurance	0.18	0.08	0.08	0.03	0.13
95	Ownership of dwellings	0.13	0.04	0.04	0.01	0.03
96	Education and research	0.14	0.07	0.08	0.02	0.12
97	Medical and health	0.43	0.33	0.34	0.08	0.09
98	Other services	0.12	0.06	0.06	0.02	0.05
99	Public administration	0.00	0.00	0.00	0.00	0.00
100	**Non-commercial energy**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Note: Figures in bold are dimensionless.

Table 3C-3. Energy Intensities by energy carrier in 1989-90 Coal & lignite (1), Crude petroleum, natural gas (2), Petroleum products (3), Electricity (4), Non-commercial (5). All in MJ per Rupees $^{93\text{-}94}$

	Sector	(1)	(2)	(3)	(4)	(5)
1	Paddy	0.66	0.51	0.27	0.15	0.03
2	Wheat	1.70	0.72	0.39	0.44	0.17
3	Jowar	0.23	0.31	0.17	0.04	0.02
4	Bajra	0.31	0.23	0.15	0.07	0.02
5	Maize	0.46	0.27	0.15	0.11	0.02
6	Gram	0.29	0.19	0.11	0.07	0.01
7	Pulses	0.38	0.30	0.17	0.08	0.03
8	Sugarcane	0.34	0.32	0.16	0.08	0.01
9	Groundnut	0.18	0.24	0.13	0.03	0.01
10	Jute	0.10	0.17	0.08	0.01	0.01
11	Cotton	0.39	0.40	0.22	0.08	0.03
12	Tea	0.06	0.11	0.05	0.01	0.01
13	Coffee	0.13	0.08	0.07	0.02	0.02
14	Rubber	0.35	0.61	0.30	0.05	0.03
15	Coconut	0.06	0.05	0.04	0.01	0.01
16	Tobacco	0.33	0.48	0.24	0.06	0.03
17	Other crops	0.35	0.37	0.19	0.07	0.02
18	Milk and milk products	0.09	0.09	0.05	0.02	0.07
19	Animal services(agricultural)	0.35	0.38	0.23	0.07	0.04
20	Other livestock products	0.14	0.13	0.08	0.03	0.02
21	Forestry and logging	0.06	0.05	0.05	0.01	0.03
22	Fishing	0.07	0.08	0.08	0.01	0.02
23	**Coal and lignite**	**1.04**	**0.01**	**0.01**	**0.01**	**0.00**
24	**Crude petroleum, natural gas**	**0.00**	**1.03**	**0.00**	**0.00**	**0.00**
25	Iron ore	0.65	0.37	0.34	0.16	0.16
26	Other minerals	0.18	0.23	0.23	0.04	0.03
27	Sugar	0.43	0.29	0.18	0.08	0.26

	Sector	(1)	(2)	(3)	(4)	(5)
28	Khandsari, boora	0.70	0.45	0.35	0.14	0.38
29	Hydrogenated oil(vanaspati)	0.53	0.34	0.22	0.09	0.37
30	Edible oils other than vanaspati	0.42	0.31	0.19	0.08	0.20
31	Tea and coffee processing	0.57	0.27	0.17	0.04	1.19
32	Miscellaneous food products	0.53	0.39	0.30	0.08	0.53
33	Beverages	1.15	0.34	0.26	0.13	0.67
34	Tobacco products	0.37	0.26	0.20	0.06	0.25
35	Khadi, cotton textiles(handlooms)	0.54	0.33	0.29	0.11	0.28
36	Cotton textiles	1.03	0.43	0.35	0.18	0.78
37	Woollen textiles	0.81	0.35	0.31	0.13	0.67
38	Silk textiles	0.37	0.28	0.25	0.07	0.20
39	Art silk, synthetic fibre textiles	0.98	0.40	0.33	0.16	0.59
40	Jute, hemp, mesta textiles	0.77	0.36	0.31	0.16	0.86
41	Carpet weaving	0.33	0.20	0.18	0.05	0.21
42	Readymade garments	0.54	0.30	0.26	0.09	0.30
43	Miscellaneous textile products	0.58	0.33	0.27	0.10	0.31
44	Furniture and fixtures-wooden	0.20	0.19	0.19	0.04	0.04
45	Wood and wood products	0.18	0.12	0.11	0.03	0.12
46	Paper, paper prods. & newsprint	2.10	0.36	0.32	0.26	3.60
47	Printing and publishing	0.67	0.21	0.20	0.09	0.84
48	Leather footwear	0.64	0.44	0.40	0.14	0.24
49	Leather and leather products	0.55	0.31	0.28	0.09	0.24
50	Rubber products	1.12	0.44	0.36	0.17	1.14
51	Plastic products	1.36	0.48	0.36	0.25	0.24
52	**Petroleum products**	**0.01**	**1.06**	**1.06**	**0.00**	**0.00**
53	Coal tar products	2.55	0.39	0.38	0.09	0.04
54	Inorganic heavy chemicals	2.47	0.38	0.32	0.19	0.13
55	Organic heavy chemicals	2.15	0.68	0.60	0.22	0.22
56	Fertilizers	1.86	4.04	1.81	0.25	0.12
57	Pesticides	1.36	0.70	0.62	0.29	0.28
58	Paints, varnishes and lacquers	1.17	0.42	0.38	0.13	0.22
59	Drugs and medicines	0.91	0.38	0.34	0.15	0.32
60	Soaps, cosmetics & glycerine	1.12	0.51	0.47	0.12	0.98
61	Synthetic fibres, resin	1.10	0.51	0.31	0.10	0.33
62	Other chemicals	1.00	0.38	0.30	0.16	0.94
63	Structural clay products	1.51	1.62	1.61	0.08	3.65
64	Cement	4.68	0.53	0.48	0.34	0.10
65	Other non-metallic mineral prods.	2.04	0.65	0.63	0.15	0.09
66	Iron and steel	3.96	0.78	0.72	0.26	0.06
67	Non-ferrous basic metals	1.87	0.68	0.62	0.29	0.06

	Sector	(1)	(2)	(3)	(4)	(5)
68	Hand tools, hardware	1.30	0.54	0.51	0.12	0.06
69	Miscellaneous metal products	1.83	0.44	0.39	0.18	0.06
70	Industrial and electrical machinery	1.12	0.38	0.34	0.15	0.07
71	Office computing machines	0.92	0.32	0.28	0.11	0.06
72	Other non-electrical machinery	1.25	0.42	0.38	0.13	0.07
73	Batteries	0.07	0.05	0.04	0.02	0.00
74	Electrical appliances	0.27	0.12	0.10	0.05	0.02
75	Communication equipments	0.72	0.35	0.31	0.09	0.11
76	Electronic equipments(incl.TV)	0.68	0.30	0.28	0.10	0.11
77	Other transport equipments	0.96	0.28	0.25	0.14	0.06
78	Motor vehicles	0.83	0.32	0.30	0.10	0.12
79	Motor cycles and scooters	0.82	0.36	0.33	0.10	0.10
80	Bicycles, cycle-rickshaw	0.87	0.39	0.36	0.10	0.10
81	Watches and clocks	0.56	0.28	0.26	0.11	0.05
82	Miscellaneous manufacturing	0.77	0.33	0.30	0.12	0.12
83	Construction	0.96	0.33	0.30	0.09	0.18
84	**Electricity**	**3.19**	**0.38**	**0.25**	**1.12**	**0.02**
85	Gas	0.04	0.04	0.03	0.01	0.01
86	Water supply	2.04	0.39	0.31	0.57	0.06
87	Railway transport services	1.38	0.58	0.56	0.14	0.04
88	Other transport services	0.27	1.75	1.74	0.05	0.07
89	Storage and warehousing	0.80	0.25	0.22	0.22	0.03
90	Communication	0.20	0.16	0.15	0.03	0.09
91	Trade	0.20	0.23	0.23	0.04	0.07
92	Hotels and restaurants	1.02	0.24	0.17	0.09	1.52
93	Banking	0.19	0.10	0.10	0.04	0.06
94	Insurance	0.15	0.16	0.16	0.03	0.06
95	Ownership of dwellings	0.15	0.05	0.05	0.01	0.03
96	Education and research	0.08	0.06	0.06	0.01	0.04
97	Medical and health	0.41	0.25	0.23	0.07	0.13
98	Other services	0.54	0.22	0.19	0.08	0.14
99	Public administration	0.00	0.00	0.00	0.00	0.00
100	**Non-commercial energy**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Note: Figures in bold are dimensionless.

Table 3C-4. Energy Intensities by energy carrier in 1993-94 Coal & lignite (1), Crude petroleum, natural gas (2), Petroleum products (3), Electricity (4), Non-commercial (5). All in MJ per Rupees $^{93\text{-}94}$

	Sector	(1)	(2)	(3)	(4)	(5)
1	Paddy	0.75	0.57	0.33	0.20	0.03
2	Wheat	1.94	0.85	0.46	0.56	0.04
3	Jowar	0.21	0.33	0.23	0.05	0.02
4	Bajra	0.48	0.39	0.27	0.13	0.02
5	Maize	0.75	0.43	0.26	0.21	0.02
6	Gram	0.29	0.21	0.13	0.08	0.01
7	Pulses	0.49	0.33	0.22	0.13	0.03
8	Sugarcane	0.38	0.23	0.13	0.11	0.01
9	Groundnut	0.29	0.42	0.25	0.06	0.02
10	Jute	0.05	0.10	0.07	0.01	0.01
11	Cotton	0.51	0.32	0.19	0.14	0.02
12	Tea	0.05	0.10	0.06	0.01	0.01
13	Coffee	0.07	0.08	0.07	0.01	0.02
14	Rubber	0.11	0.18	0.10	0.02	0.01
15	Coconut	0.11	0.22	0.12	0.02	0.01
16	Tobacco	0.27	0.28	0.16	0.06	0.01
17	Other crops	0.30	0.28	0.16	0.07	0.02
18	Milk and milk products	0.07	0.07	0.05	0.02	0.06
19	Animal services(agricultural)	0.29	0.31	0.22	0.07	0.04
20	Other livestock products	0.12	0.11	0.08	0.03	0.02
21	Forestry and logging	0.06	0.06	0.06	0.01	0.02
22	Fishing	0.08	0.10	0.10	0.01	0.02
23	**Coal and lignite**	**1.03**	**0.01**	**0.01**	**0.01**	**0.00**
24	**Crude petroleum, natural gas**	**0.00**	**1.03**	**0.00**	**0.00**	**0.00**
25	Iron ore	0.48	0.44	0.44	0.13	0.06
26	Other minerals	0.20	0.16	0.15	0.05	0.04
27	Sugar	0.42	0.24	0.17	0.09	0.22
28	Khandsari, boora	0.41	0.41	0.36	0.10	0.10
29	Hydrogenated oil(vanaspati)	1.43	0.43	0.32	0.28	1.27
30	Edible oils other than vanaspati	0.36	0.33	0.23	0.07	0.20
31	Tea and coffee processing	0.50	0.50	0.41	0.04	0.83
32	Miscellaneous food products	0.45	0.35	0.28	0.09	0.30
33	Beverages	0.84	0.27	0.24	0.09	0.52
34	Tobacco products	0.31	0.21	0.18	0.05	0.32
35	Khadi, cotton textiles(handlooms)	0.43	0.24	0.21	0.10	0.14

	Sector	(1)	(2)	(3)	(4)	(5)
36	Cotton textiles	0.90	0.44	0.37	0.20	0.45
37	Woollen textiles	0.85	0.37	0.34	0.13	0.96
38	Silk textiles	0.45	0.28	0.26	0.09	0.28
39	Art silk, synthetic fibre textiles	0.86	0.35	0.29	0.15	0.63
40	Jute, hemp, mesta textiles	0.97	0.46	0.44	0.19	0.78
41	Carpet weaving	0.47	0.25	0.23	0.09	0.38
42	Readymade garments	0.47	0.31	0.29	0.10	0.24
43	Miscellaneous textile products	0.52	0.33	0.28	0.11	0.25
44	Furniture and fixtures-wooden	0.21	0.16	0.15	0.04	0.06
45	Wood and wood products	0.28	0.17	0.17	0.06	0.17
46	Paper, paper prods. & newsprint	1.60	0.37	0.31	0.22	5.21
47	Printing and publishing	0.61	0.29	0.26	0.10	1.33
48	Leather footwear	0.42	0.25	0.23	0.09	0.16
49	Leather and leather products	0.40	0.25	0.23	0.07	0.21
50	Rubber products	0.92	0.40	0.29	0.15	0.76
51	Plastic products	0.77	0.38	0.24	0.13	0.19
52	**Petroleum products**	**0.01**	**0.98**	**1.06**	**0.00**	**0.00**
53	Coal tar products	0.75	0.28	0.27	0.09	0.07
54	Inorganic heavy chemicals	2.31	0.90	0.35	0.17	0.12
55	Organic heavy chemicals	1.74	0.61	0.49	0.28	0.26
56	Fertilizers	2.29	5.22	2.48	0.32	0.12
57	Pesticides	1.16	0.71	0.55	0.22	0.26
58	Paints, varnishes and lacquers	1.06	0.54	0.38	0.14	0.20
59	Drugs and medicines	0.71	0.41	0.33	0.13	0.32
60	Soaps, cosmetics & glycerine	0.73	0.44	0.37	0.10	0.56
61	Synthetic fibres, resin	1.10	0.56	0.30	0.10	0.26
62	Other chemicals	0.86	0.39	0.29	0.14	0.71
63	Structural clay products	1.33	0.45	0.45	0.10	5.21
64	Cement	4.15	0.52	0.47	0.36	0.09
65	Other non-metallic mineral prods.	1.65	0.61	0.61	0.15	0.06
66	Iron and steel	3.30	0.53	0.50	0.21	0.06
67	Non-ferrous basic metals	1.59	0.49	0.44	0.29	0.07
68	Hand tools, hardware	1.03	0.35	0.33	0.11	0.06
69	Miscellaneous metal products	1.65	0.36	0.32	0.19	0.06
70	Industrial and electrical machinery	1.12	0.36	0.31	0.17	0.08
71	Office computing machines	0.50	0.25	0.21	0.09	0.09
72	Other non-electrical machinery	1.07	0.32	0.29	0.12	0.06
73	Batteries	0.88	0.40	0.31	0.14	0.13
74	Electrical appliances	0.94	0.39	0.34	0.14	0.07
75	Communication equipments	0.76	0.33	0.29	0.09	0.11

	Sector	(1)	(2)	(3)	(4)	(5)
76	Electronic equipments(incl.TV)	0.77	0.30	0.27	0.11	0.11
77	Other transport equipments	1.13	0.28	0.25	0.14	0.06
78	Motor vehicles	0.98	0.32	0.29	0.14	0.09
79	Motor cycles and scooters	0.55	0.27	0.25	0.08	0.09
80	Bicycles, cycle-rickshaw	0.69	0.38	0.37	0.09	0.11
81	Watches and clocks	0.94	0.36	0.33	0.19	0.10
82	Miscellaneous manufacturing	0.80	0.32	0.25	0.14	0.14
83	Construction	0.86	0.26	0.25	0.10	0.20
84	**Electricity**	**3.59**	**0.44**	**0.22**	**1.13**	**0.03**
85	Gas	0.06	0.07	0.07	0.01	0.01
86	Water supply	2.64	0.40	0.25	0.80	0.06
87	Railway transport services	0.87	0.50	0.50	0.16	0.04
88	Other transport services	0.25	1.31	1.39	0.05	0.10
89	Storage and warehousing	0.81	0.21	0.17	0.24	0.06
90	Communication	0.18	0.09	0.08	0.05	0.02
91	Trade	0.16	0.10	0.09	0.03	0.08
92	Hotels and restaurants	0.64	0.25	0.20	0.08	1.31
93	Banking	0.13	0.04	0.03	0.03	0.03
94	Insurance	0.21	0.14	0.13	0.06	0.06
95	Ownership of dwellings	0.05	0.01	0.01	0.01	0.01
96	Education and research	0.07	0.05	0.05	0.01	0.03
97	Medical and health	0.33	0.26	0.24	0.07	0.12
98	Other services	0.40	0.18	0.15	0.06	0.13
99	Public administration	0.00	0.00	0.00	0.00	0.00
100	**Non-commercial energy**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Note: Figures in bold are dimensionless.

Table 3C-5. Energy Intensities by energy carrier in 1998-99 Coal & lignite (1), Crude petroleum, natural gas (2), Petroleum products (3), Electricity (4), Non-commercial (5). All in MJ per Rupees $^{93\text{-}94}$

	Sector	(1)	(2)	(3)	(4)	(5)
1	Paddy	1.01	0.83	0.36	0.29	0.01
2	Wheat	1.74	1.16	0.51	0.51	0.02
3	Jowar	0.25	0.73	0.36	0.06	0.01
4	Bajra	0.46	0.91	0.46	0.12	0.01
5	Maize	0.87	0.97	0.42	0.24	0.01
6	Gram	0.35	0.35	0.16	0.10	0.01
7	Pulses	0.59	0.81	0.36	0.16	0.02
8	Sugarcane	0.52	0.50	0.21	0.15	0.01

	Sector	(1)	(2)	(3)	(4)	(5)
9	Groundnut	0.26	0.54	0.24	0.06	0.01
10	Jute	0.10	0.31	0.13	0.02	0.01
11	Cotton	0.61	1.30	0.72	0.17	0.01
12	Tea	0.08	0.29	0.12	0.01	0.00
13	Coffee	0.07	0.08	0.04	0.01	0.01
14	Rubber	0.09	0.26	0.11	0.02	0.01
15	Coconut	0.19	0.68	0.28	0.03	0.01
16	Tobacco	0.23	0.63	0.33	0.06	0.01
17	Other crops	0.27	0.41	0.18	0.07	0.01
18	Milk and milk products	0.05	0.07	0.03	0.01	0.01
19	Animal services(agricultural)	0.28	0.42	0.20	0.07	0.02
20	Other livestock products	0.12	0.16	0.08	0.03	0.01
21	Forestry and logging	0.05	0.12	0.08	0.01	0.01
22	Fishing	0.07	0.25	0.16	0.01	0.01
23	**Coal and lignite**	**1.02**	**0.01**	**0.00**	**0.00**	**0.00**
24	**Crude petroleum, natural gas**	**0.00**	**1.03**	**0.01**	**0.00**	**0.00**
25	Iron ore	0.22	0.75	0.49	0.05	0.02
26	Other minerals	0.13	0.26	0.17	0.03	0.01
27	Sugar	0.38	0.34	0.16	0.10	0.02
28	Khandsari, boora	0.37	0.44	0.23	0.10	0.02
29	Hydrogenated oil(vanaspati)	1.27	0.47	0.24	0.17	1.19
30	Edible oils other than vanaspati	0.34	0.35	0.17	0.07	0.13
31	Tea and coffee processing	0.82	0.59	0.27	0.05	0.88
32	Miscellaneous food products	0.51	0.51	0.28	0.11	0.27
33	Beverages	0.75	0.31	0.17	0.08	0.91
34	Tobacco products	0.30	0.30	0.18	0.05	0.27
35	Khadi, cotton textiles(handlooms)	0.63	0.76	0.46	0.15	0.16
36	Cotton textiles	0.99	0.82	0.48	0.22	0.43
37	Woollen textiles	0.80	0.62	0.39	0.10	0.76
38	Silk textiles	0.34	0.45	0.29	0.05	0.22
39	Art silk, synthetic fibre textiles	0.82	0.47	0.27	0.17	0.24
40	Jute, hemp, mesta textiles	0.69	0.56	0.33	0.15	0.32
41	Carpet weaving	0.44	0.40	0.25	0.06	0.38
42	Readymade garments	0.48	0.54	0.32	0.10	0.14
43	Miscellaneous textile products	0.57	0.49	0.29	0.11	0.18
44	Furniture and fixtures-wooden	0.19	0.19	0.12	0.03	0.05
45	Wood and wood products	0.34	0.22	0.13	0.07	0.13
46	Paper, paper prods. & newsprint	1.13	0.37	0.20	0.17	3.14
47	Printing and publishing	0.37	0.20	0.12	0.06	0.66
48	Leather footwear	0.29	0.24	0.15	0.05	0.09

	Sector	(1)	(2)	(3)	(4)	(5)
49	Leather and leather products	0.34	0.27	0.16	0.05	0.13
50	Rubber products	0.70	0.32	0.18	0.08	0.07
51	Plastic products	0.71	0.30	0.17	0.10	0.09
52	**Petroleum products**	**0.02**	**1.66**	**1.10**	**0.00**	**0.00**
53	Coal tar products	0.83	0.23	0.14	0.06	0.02
54	Inorganic heavy chemicals	1.51	1.13	0.51	0.15	0.07
55	Organic heavy chemicals	0.98	0.96	0.58	0.14	0.11
56	Fertilizers	1.28	5.05	2.00	0.21	0.04
57	Pesticides	0.69	0.63	0.33	0.11	0.11
58	Paints, varnishes and lacquers	0.75	0.45	0.26	0.08	0.09
59	Drugs and medicines	0.61	0.46	0.27	0.10	0.24
60	Soaps, cosmetics & glycerine	0.62	0.47	0.26	0.08	0.20
61	Synthetic fibres, resin	1.26	0.40	0.23	0.08	0.11
62	Other chemicals	0.78	0.39	0.21	0.11	0.14
63	Structural clay products	2.00	0.44	0.28	0.09	3.96
64	Cement	3.85	0.91	0.54	0.36	0.04
65	Other non-metallic mineral prods.	1.79	0.30	0.17	0.13	0.03
66	Iron and steel	2.18	0.37	0.21	0.18	0.02
67	Non-ferrous basic metals	1.41	0.44	0.23	0.27	0.03
68	Hand tools, hardware	0.63	0.29	0.17	0.08	0.03
69	Miscellaneous metal products	0.98	0.28	0.16	0.12	0.03
70	Industrial and electrical machinery	0.89	0.34	0.20	0.15	0.04
71	Office computing machines	0.46	0.25	0.15	0.08	0.05
72	Other non-electrical machinery	0.84	0.33	0.20	0.10	0.03
73	Batteries	0.80	0.42	0.24	0.14	0.05
74	Electrical appliances	0.60	0.35	0.21	0.09	0.02
75	Communication equipments	0.56	0.27	0.16	0.07	0.05
76	Electronic equipments(incl.TV)	0.54	0.26	0.15	0.08	0.05
77	Other transport equipments	0.89	0.31	0.18	0.12	0.03
78	Motor vehicles	0.80	0.35	0.21	0.13	0.04
79	Motor cycles and scooters	0.53	0.31	0.19	0.09	0.04
80	Bicycles, cycle-rickshaw	0.69	0.48	0.29	0.11	0.05
81	Watches and clocks	0.58	0.40	0.25	0.09	0.05
82	Miscellaneous manufacturing	0.81	0.31	0.17	0.14	0.05
83	Construction	0.73	0.32	0.19	0.09	0.12
84	**Electricity**	**4.32**	**0.85**	**0.31**	**1.02**	**0.02**
85	Gas	0.04	0.07	0.04	0.01	0.00
86	Water supply	2.16	0.50	0.21	0.64	0.05
87	Railway transport services	0.71	0.72	0.45	0.18	0.03
88	Other transport services	0.24	1.42	0.94	0.05	0.06

	Sector	(1)	(2)	(3)	(4)	(5)
89	Storage and warehousing	0.95	0.32	0.16	0.28	0.07
90	Communication	0.17	0.09	0.05	0.04	0.02
91	Trade	0.14	0.20	0.13	0.03	0.02
92	Hotels and restaurants	0.47	0.54	0.30	0.11	0.65
93	Banking	0.14	0.07	0.04	0.04	0.04
94	Insurance	0.26	0.22	0.13	0.07	0.09
95	Ownership of dwellings	0.05	0.02	0.01	0.01	0.01
96	Education and research	0.05	0.08	0.05	0.01	0.02
97	Medical and health	0.32	0.25	0.14	0.06	0.09
98	Other services	0.40	0.23	0.13	0.07	0.09
99	Public administration	0.00	0.00	0.00	0.00	0.00
100	**Non-commercial energy**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**

Note: Figures in bold are dimensionless.

Table 3C-6. Percentage average annual changes in total primary energy intensities for sub-periods and the period 1983-84 to 1998-99

	Sector	84-90	90-94	94-99	84-99
1	Paddy	4.8	3.1	6.4	4.9
2	Wheat	2.8	2.3	0.4	1.9
3	Jowar	-1.1	0.4	11.6	3.4
4	Bajra	-3.3	12.3	8.8	4.6
5	Maize	0.3	12.9	8.5	6.3
6	Gram	11.4	1.1	6.7	7.0
7	Pulses	9.4	5.0	10.4	8.5
8	Sugarcane	2.4	-1.7	10.1	3.7
9	Groundnut	3.0	13.9	2.2	5.5
10	Jute	7.3	-12.4	20.6	5.7
11	Cotton	-4.2	1.1	17.3	3.9
12	Tea	1.3	-3.3	20.0	5.9
13	Coffee	-8.4	-8.1	-1.4	-6.0
14	Rubber	11.9	-25.5	3.2	-2.3
15	Coconut	3.5	27.8	20.8	15.3
16	Tobacco	14.6	-9.1	8.5	5.8
17	Other crops	17.6	-5.0	2.4	6.1
18	Milk and milk products	6.2	-5.9	-9.1	-2.4
19	Animal services(agricultural)	14.6	-4.4	2.0	5.0
20	Other livestock products	-3.7	-3.8	3.1	-1.5
21	Forestry and logging	-2.6	0.6	5.1	0.8
22	Fishing	15.1	5.4	9.8	10.7

	Sector	84-90	90-94	94-99	84-99
23	Coal and lignite	0.0	-0.2	-0.4	-0.2
24	Crude petroleum, natural gas	0.2	0.2	-0.2	0.1
25	Iron ore	6.0	-4.7	-0.2	1.0
26	Other minerals	-8.3	-2.6	0.0	-4.1
27	Sugar	7.2	-2.5	-3.4	1.0
28	Khandsari, boora	6.2	-11.7	-2.2	-1.6
29	Hydrogenated oil(vanaspati)	-9.7	26.2	-1.5	1.6
30	Edible oils other than vanaspati	11.4	-1.3	-1.5	3.5
31	Tea and coffee processing	6.0	-2.4	4.5	3.2
32	Miscellaneous food products	-3.3	-6.5	3.1	-2.1
33	Beverages	5.6	-6.8	3.6	1.5
34	Tobacco products	5.0	-1.3	0.8	1.9
35	Khadi, cotton textiles(handlooms)	-4.1	-8.4	13.6	0.2
36	Cotton textiles	-3.2	-5.3	4.5	-1.3
37	Woollen textiles	-5.8	4.2	0.0	-1.3
38	Silk textiles	-4.7	4.4	-0.3	-0.9
39	Art silk, synthetic fibre textiles	-7.6	-1.8	-3.5	-4.7
40	Jute, hemp, mesta textiles	7.4	2.6	-6.6	1.3
41	Carpet weaving	-8.1	10.5	1.8	-0.1
42	Readymade garments	-10.0	-2.5	2.4	-4.0
43	Miscellaneous textile products	0.7	-2.4	2.3	0.4
44	Furniture and fixtures-wooden	4.3	-0.7	0.0	1.5
45	Wood and wood products	3.7	11.1	1.9	5.0
46	Paper, paper prods. & newsprint	1.7	4.3	-8.4	-1.1
47	Printing and publishing	1.0	6.5	-11.2	-1.9
48	Leather footwear	7.0	-10.9	-5.7	-2.3
49	Leather and leather products	1.6	-6.1	-2.8	-2.0
50	Rubber products	5.7	-6.3	-12.4	-3.8
51	Plastic products	2.4	-10.5	-4.0	-3.3
52	Petroleum products	1.3	-1.9	11.2	3.6
53	Coal tar products	-16.2	-21.9	-0.5	-12.9
54	Inorganic heavy chemicals	3.3	2.7	-3.9	0.7
55	Organic heavy chemicals	-9.7	-3.7	-4.9	-6.5
56	Fertilizers	-5.7	6.1	-3.6	-2.0
57	Pesticides	10.2	-2.4	-7.9	0.5
58	Paints, varnishes and lacquers	7.2	-0.1	-6.6	0.5
59	Drugs and medicines	-3.0	-2.7	-2.0	-2.6
60	Soaps, cosmetics & glycerine	6.8	-9.8	-5.8	-2.1
61	Synthetic fibres, resin	-1.9	-0.1	-1.8	-1.4
62	Other chemicals	6.8	-4.1	-7.8	-1.2

	Sector	84-90	90-94	94-99	84-99
63	Structural clay products	-0.9	0.8	-1.7	-0.7
64	Cement	-9.5	-2.6	0.1	-4.6
65	Other non-metallic mineral prods.	-9.2	-4.3	-2.0	-5.5
66	Iron and steel	-2.9	-5.2	-7.9	-5.2
67	Non-ferrous basic metals	-0.9	-4.6	-2.8	-2.5
68	Hand tools, hardware	2.4	-6.6	-8.2	-3.7
69	Miscellaneous metal products	-0.3	-2.8	-9.2	-4.0
70	Industrial and electrical machinery	-5.8	-0.1	-4.0	-3.7
71	Office computing machines	-2.9	-10.3	-2.1	-4.7
72	Other non-electrical machinery	-2.3	-4.5	-3.9	-3.4
73	Batteries	-34.7	83.5	-2.1	-1.5
74	Electrical appliances	-23.7	35.8	-7.0	-4.9
75	Communication equipments	1.2	0.3	-5.9	-1.5
76	Electronic equipments(incl.TV)	-4.1	1.9	-6.4	-3.3
77	Other transport equipments	3.4	3.2	-3.6	0.9
78	Motor vehicles	-10.9	2.3	-3.2	-4.9
79	Motor cycles and scooters	-3.0	-8.3	-0.3	-3.6
80	Bicycles, cycle-rickshaw	-11.9	-3.4	0.7	-5.6
81	Watches and clocks	-14.5	11.8	-6.2	-5.3
82	Miscellaneous manufacturing	-14.3	0.9	-1.8	-6.4
83	Construction	-3.8	-2.5	-2.6	-3.1
84	Electricity	-2.3	2.8	4.4	1.3
85	Gas	17.6	11.4	-3.7	8.4
86	Water supply	-3.0	5.8	-3.1	-0.7
87	Railway transport services	-8.1	-8.1	0.7	-5.3
88	Other transport services	0.1	-5.6	0.7	-1.2
89	Storage and warehousing	-4.5	0.0	4.3	-0.4
90	Communication	0.0	-9.1	-1.2	-2.9
91	Trade	1.9	-9.1	1.4	-1.3
92	Hotels and restaurants	-3.5	-5.8	-5.4	-4.8
93	Banking	0.0	-13.2	5.0	-2.1
94	Insurance	-0.7	3.0	6.6	2.6
95	Ownership of dwellings	2.5	-24.8	1.7	-5.9
96	Education and research	-9.5	-6.1	0.4	-5.4
97	Medical and health	-1.5	-2.3	-1.9	-1.8
98	Other services	26.1	-5.6	0.3	8.1
99	Public administration	0.0	0.0	0.0	0.0
100	Non-commercial energy	0.0	0.0	0.0	0.0

Chapter 4: Total and Average Household Energy Requirements

The chapter begins with an introduction to the concept of energy requirements of households and related literature on this topic. A discussion of the methodology used for calculating total household energy requirements for India using national level data on private final consumption expenditures, and the calculated primary energy intensities of producing sectors that were presented in the last chapter, follows. After briefly introducing some of the terminology and the data sources used for the analysis, results relating to total, direct and indirect energy requirements per capita, and for total energy requirements of all households in India are presented. In Sect. 4.4, the relative importance of the main drivers of the observed changes in household energy requirements over the study period are determined using a decomposition analysis for changes in both the total as well as in each of the major categories of indirect energy requirement. Finally, some comparisons of the results of this study are made with previous studies.

4.1 Overview of Literature on Household Energy Requirements

Changes in technology, income levels, and lifestyles are bringing about major changes in total household energy requirements in the country. Incomes and spending patterns clearly have a strong bearing on both direct and indirect energy consumption. The embodied or indirect energy requirements of goods and services consumed are also affected by changes in energy intensities of the producing sectors. Household spending, in fact, ultimately determines to a large extent total energy use in the economy. Therefore, by using data on household consumption expenditures along with information on the energy intensities of the consumed goods and services, it is possible to find out more about the use of primary energy in a country. Households are directly responsible for about 40% of total final energy consumption of the nation. Yet, the results of this study indicate that total (direct and indirect) primary energy use of Indian households accounts for over 70% of total primary energy use in the country. The remainder comprises government use, energy content of investments and net imports. While net imports of energy are included in the analysis, imports of other goods and services are not, as these are still relatively small for India.

A number of studies have been carried out in developed countries to analyse total direct and indirect energy requirements in households. Studies specifically examining total (direct and indirect) energy requirements of households using input-output analysis have been done for the USA (Herendeen et al. 1981), for Norway (Herendeen 1978), New Zealand (Peet 1985), Finland (Nurmela 1993), and Switzerland (Ospelt et al. 1996; Duerrenberger et al. 2001). Studies extending the analysis to calculate total carbon emissions associated with household consumption have been conducted in the UK (Gay and Proops 1995), in Australia (Common and Salma 1992; Lenzen 1998) and in other countries. A series of publications by researchers at the University of Groningen and the University of Utrecht have examined household metabolic flows in the Netherlands (Noorman and Uiterkamp 1998; Vringer 2005; Vringer et al. 1995a, 1995b, 1995c, 2000; Biesot and Noorman 1999; Wilting 1996, 1998; Karla et al. 1995; Van der Wal and Moll 2001). Other studies that have examined the energy and emissions flows embodied in household consumption include Wier (1998), Wier et al. (2001), Wilting et al. (1999), Jacobsen (2000), Munksgaard et al. (2000a, 2000b), and Lenzen (2001). More recent publications in this field that link consumption and lifestyles to environmental pollution include a European study covering several different countries (Weber et al. 2000; Moll et al. 2005).

Literature in this field, for developing countries in general and Asian countries in particular, is very limited. A recent study by Park and Heo (2004) examines the direct and indirect household energy requirements in Korea over a period of two decades. Researchers at the Indira Gandhi Institute of Developmental Research have used input-output analysis to calculate the carbon dioxide emissions from energy consumption for different groups of Indian households for the year 1989-90 (Parikh et al. 1990, 1994, 1997). Pachauri and Spreng (2002) have carried out a similar analysis on direct and indirect energy requirements of households for the decade 19983-84 to 1993-94. However, to the best of the author's knowledge, the present study is the first attempt at examining changes in total energy requirements over the period from 1983-84 to 1998-99, including non-commercial energy of different household consumption categories in a developing country using input-output analysis at the disaggregated 100 sector level.

4.2 Methods and Data

Energy requirements of household consumption are calculated making use of the estimated energy intensities of commodity sectors and data on total private final consumption expenditures. Data on private final consumption expenditures derived from the input-output tables for the years 1983-84, 1989-90, 1993-94 and 1998-99 have been converted to constant 1993-94 values using the consumer price index data published by the department of statistics (GoI various). For the purpose of this study, direct energy requirement of households is defined as the total primary energy required and energy content of the energy carriers consumed directly by households (e.g., kerosene, electricity, etc.). Indirect energy requirement of households is defined as the total primary energy required for producing all other goods and services that are consumed by households. Total energy requirements of households comprise the sum of direct and indirect energy requirements. Energy intensities of products are defined as the total primary energy inputs required for producing a single rupee output of the product and are estimated using the method described in Chap. 3. In the same way, energy intensity of a group of products or of all household expenditures is also computed in this chapter.

Total energy requirements of households are calculated according to the following formula:

$$E = \sum_i I_i S_i \tag{4.1}$$

Where E refers to total household energy requirements, I_i energy intensity of consumption category i, and S_i expenditure on consumption category i.

4.3 Results

In this section, results related to total household energy requirements and total energy intensity of household consumption, the ratio between direct and indirect energy requirements and the changes in energy requirements per main consumption category are discussed. Before presenting the results related to household energy requirements, a brief description of general trends in household expenditures are presented.

4.3.1 General Trends in Household Expenditures

Household expenditure per capita during the period 1983-84 to 1998-99 grew by a factor of 1.8 at an average rate of about 3.8% per year. The rate of change accelerated during the decade of the 1990's. The average annual growth rate of private expenditures per capita was 2.3% per year between 1983-84 and 1989-90 but increased to 4.9% per year between 1989-90 and 1998-99. Expenditure on direct energy consumption of households varied between 2.1 and 2.3% of total household expenditure during the whole period. The items of household expenditure that showed the highest growth rate during this period were electricity followed by expenditures on transport and medical care and hygiene. The slowest growing expenditures were those on food and per capita expenditures on clothing and footwear even declined marginally over this period. In general, there was a shift in the composition of household expenditures from basic items such as food and clothing towards services (education, medical and others) and transport equipment and services over this period.

4.3.2 Total Household Energy Requirements

Total household energy requirements grew from 8019 PJ in 1983-84 to 13640 PJ in 1998-99 at an average rate of 3.6% per year. Figure 4.1 shows the increase in total household energy requirements broken down by direct commercial, direct non-commercial and indirect energy requirements (for more detailed results see Table 4B-1 at the end of the chapter). As in the case of official energy statistics, a very large but declining proportion of direct non-commercial to direct commercial energy use is observed. However, the analysis also reveals that the ratio of indirect energy requirements to the total rose over this period. These findings are consistent with past patterns observed in most industrialised countries.

The average per capita total energy requirements of private consumption increased from 10.9 GJ in 1983-84 to 13.9 GJ in 1998-99 exhibiting an average annual rate of increase of about 1.6%. During the same period, the level of direct energy requirements per capita increased only marginally at an average rate of 0.2% per annum largely as a result of the substitution of non-commercial by more efficient commercial energy. However, indirect per capita energy requirements grew at a rate of 3.2% per year. There is more discussion regarding the changes in direct and indirect energy in Sect. 4.4.

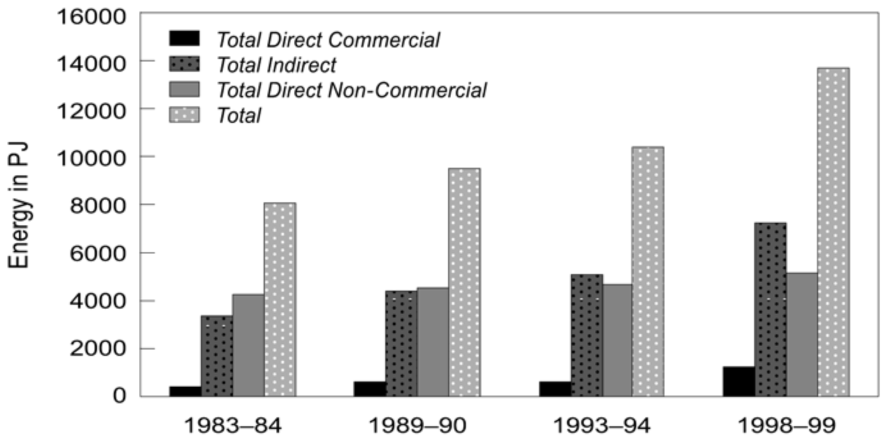

Fig. 4.1. Total primary direct and indirect energy requirements of household consumption

4.3.3 Direct Energy Requirements

While per capita total direct energy requirements increased only marginally for Indian households, as mentioned in Sect. 4.3.2, total direct final energy use households increased by 29% during the period 1983-84 to 1998-99. Total direct primary energy use of households, which is defined as direct final energy use multiplied by the energy intensity of the energy sectors or energy requirements of energy, increased at a higher rate of 38%, during the same period. In fact, there was an overall increase in direct primary energy requirement for all energy carriers other than coal and lignite during this period. The most rapid increase was observed in the case of electricity.

The trends in per capita direct primary energy requirement broken down by different energy carriers clearly show that while non-commercial energy use still dominates direct household energy requirements its use in per capita terms declined continuously over the study period. In contrast, the use of petroleum products increased during the same period. Direct consumption of coal in private households remained small and is decreasing (see Fig. 4.2). Among all direct energy carriers, the use of electricity grew the fastest between 1983-84 and 1998-99 in the household sector. This large increase in electricity use is primarily a result of greater accessibility for households to electricity grids, higher incomes and the faster penetration of electrical and electronic equipment in households.

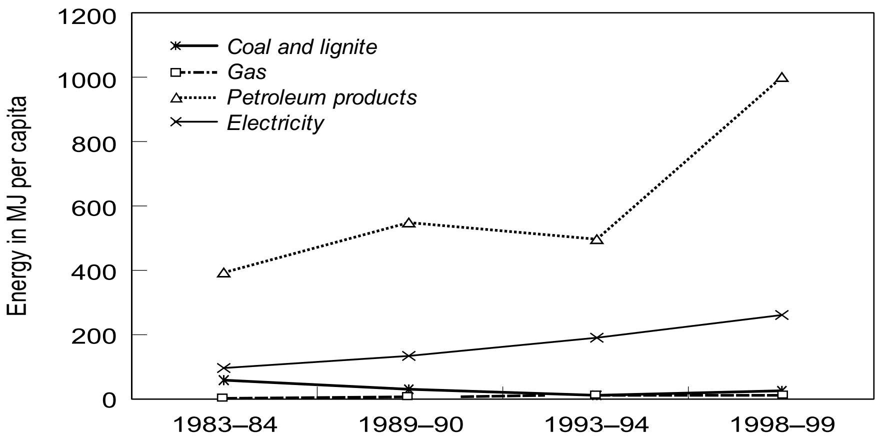

Fig. 4.2. Direct primary commercial household energy requirements

These shifts in the energy carriers also have an impact on total direct primary energy requirements as the energy contents and efficiency of different fuels vary by a wide range. Thus, while direct commercial energy use increased at an average rate of almost 6% per annum during the study period, it was offset by a decrease of 0.7% per annum in per capita non-commercial energy consumption. These trends suggest that households are progressing up the "energy ladder", a phenomenon well documented by other researchers wherein households move to more sophisticated fuels and energy applications with increases in levels of income and urbanisation (Leach 1988, 1992; Leach and Gowen 1987; Barnes and Qian 1992; Sathaye and Tyler 1991; Smith et al. 1994; Reddy and Reddy 1994; Kulkarni et al. 1994). More recent research on energy transitions in developing countries point towards other factors including tastes and customs affecting choice of fuels and less clear cut shifts with more households stacking rather than switching fuels (Davis 1998; Masera et al. 2000; Barnett 2000). More regarding some of these changes are presented in Chap. 6.

4.3.4 Indirect Energy Requirements

In 1983-84 indirect primary energy requirements comprised about 42% of total household energy requirements but this share increased to about 53% by 1998-99. A breakdown of per capita indirect energy requirements of households by the main consumption categories shows an increasing trend for most categories during this period. An exception is observed in the case of the 'clothing and footwear' category (see Table 4.1). Also, in the case of the 'housing and household effects' category indirect energy requirements first increased and then decreased during the latter part of the period. Indirect energy requirements for the category 'food, beverages and tobacco' accounted for the largest proportion of total indirect energy requirements and also showed the largest absolute increase in energy requirements over the period. This can be explained in part by the very rapid rate of mechanisation and growth of direct energy use in the agricultural sector during this period. Energy requirements of the 'transport and communications' group also showed a large increase during this period. The latter also experienced the fastest rate of increase resulting in an increase in the share of indirect primary energy requirements for this category (see Fig. 4.3). Further discussion regarding these changes in total and indirect energy requirements for different consumption categories over the study period are presented in a later section of the chapter.

Table 4.1. Indirect primary energy requirements of households per capita by main consumption categories in MJ

		1983-84	1989-90	1993-94	1998-99
1	Food, beverages & tobacco	1742	2225	2734	3722
2	Clothing & footwear	920	811	630	667
3	Housing & household effects	347	450	327	313
4	Medical care & hygiene	199	362	409	526
5	Education & recreation	544	473	488	576
6	Transport & communication	638	683	816	1200
7	Other services	178	264	243	338
	TOTAL	4566	5268	5647	7343

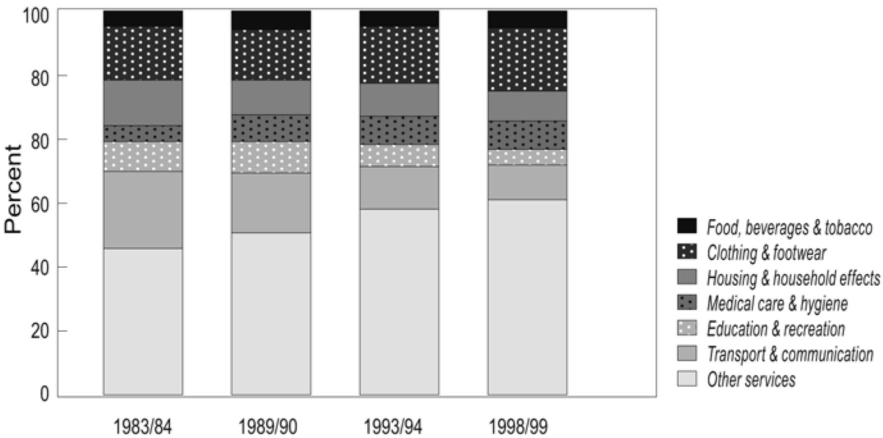

Fig. 4.3. Share of each consumption category in the average total indirect energy requirements per capita of households

4.3.5 Energy Intensities of Household Consumption

Energy requirements, in absolute terms, for households in India were presented above. In the following section, the energy intensity of household consumption or in other terms energy requirements relative to household expenditures, are presented. The energy intensity of total household consumption may be defined as:

$$CI_{total} = \frac{E}{\sum S_i} \tag{4.2}$$

Where CI_{total} is the energy intensity of total consumption, E is total household energy requirements and ΣS_i total household expenditure. Similarly, energy intensity of indirect household consumption can be calculated as the ratio of indirect energy requirements to household consumption on indirect goods and services (i.e. household expenditure other than expenditure on direct energy requirements).

Total energy intensity of household consumption declined between 1983-84 and 1998-99 from 2.5 MJ/Rs.$_{93\text{-}94}$ to 1.8 MJ/Rs.$_{93\text{-}94}$. However, the rate of decrease between 1983-84 and 1989-90 was about 1.5% per year, whereas between 1989-90 and 1993-94 it was 5.0% per year and subsequently, between 1993-94 and 1998-99 it was only 0.5% per year. Over the entire time period it declined at an annual average rate of about 2.2% per year. This change in total energy intensity of consumption can be explained in part by changes in the ratio of direct to indirect energy. Typically, energy intensities of direct commercial energy carriers are a factor ten higher that of other consumption categories. Therefore, the decline in ratio of direct to indirect energy had an important effect on total energy intensity of household consumption.

From 1983-84 to 1998-99, the indirect energy intensity of household consumption followed a similar path showing only a slight decline of about 0.6% on average per year. Figure 4.4 shows energy intensities of some indirect consumption categories and total indirect energy intensity. The changes observed in the figure can be ascribed to changes in the expenditure patterns of households and changes in energy intensities of the producing sectors. For example, there was a relative decrease in household expenditure in the category 'food, beverages & tobacco', and 'clothing & footwear', both of which are fairly energy intensive. This, in part, was the cause of a reduction in the total indirect energy intensity of consumption during this decade. In the case of 'food, beverages & tobacco', the relative decrease in expenditure was offset by the increase in productive energy intensities of most sectors comprising this category.

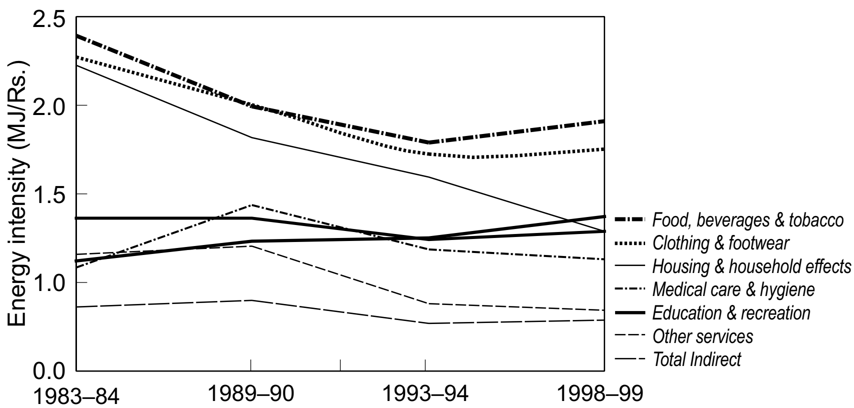

Fig. 4.4. Energy intensities for indirect consumption categories and the total indirect energy intensity of household consumption

4.4 Decomposition Analysis

To understand the evolution in total and indirect energy requirements of households during the period 1983-84 to 1998-99, total changes that occurred were decomposed into four component factors (1) change in the composition of the household shopping basket or structure of consumption; (2) change in the productive energy intensities of goods and services consumed; (3) change in per capita levels of energy-using activities or the per capita consumption expenditures on each item; and (4) change in total population.

$$E = \sum_i \frac{S_i}{\Sigma S_i} * \frac{E_i}{S_i} * \frac{\Sigma S_i}{P} * P \quad (4.3)$$

Where,

E refers to total household energy requirements,

S_i refers to the share of expenditure on item i in total spending,

P refers to total population

For total household energy requirement and for each indirect consumption category, changes in activity, structure, intensity, and population size were measured. The change in energy use that would have occurred in response to each factor if the other three had remained constant at the base year values was then calculated. In this way, the contribution to energy use made by changes in the shares of household expenditure (structure), primary energy intensity of each item (intensity), per capita household expenditures (activity), and population size were disaggregated. The objective was to understand the relative importance of these different factors.

A simple average divisia decomposition method[1] was used to disaggregate the total changes in household energy requirements into the component effects due to changes in structure, intensity, activity, and population, using Equation 4.4 below.

[1] For literature on the divisia decomposition methods and the application of this method see Ang (2004), Ang and Zhang (2000), Ang and Choi (1997). For more on the general drawbacks of decomposition methods see Muller (2006a, 2006b).

$$LN\left(\frac{E_T}{E_0}\right) = \tag{4.4}$$

$$\sum_i w_i^* LN\left(\frac{P_T}{P_0}\right) + \sum_i w_i^* LN\left(\frac{A_T}{A_0}\right) + \sum_i w_i^* LN\left(\frac{S_{iT}}{S_{i0}}\right) + \sum w_i^* LN\left(\frac{I_{iT}}{I_{i0}}\right)$$

Where, the subscripts T and 0 refer to the terminal and initial time period and the subscript i refers to the i^{th} item of consumption and LN is the natural logarithm of the term.

A refers to total household spending or expenditure, that is ΣS_i

I_i is total primary energy intensity of each item of consumption E_i/S_i, and

$$w_i^* = \frac{1}{2}\left(w_{iT} + w_{i0}\right) \tag{4.5}$$

Where w_i is the share of household energy on account of item i in total household energy requirements.

Thus,

$$w_{i0} = \frac{E_{i0}}{E_0} = \frac{P_0 A_0 S_{i0} I_{i0}}{E_0}$$

At the first level, an analysis was carried out to disaggregate changes in the overall total household energy requirements which increased throughout this period. Figure 4.5[2] shows the changes in total energy requirements resulting from changes in each of the component factors, keeping the values of the other factors unchanged. As can be seen from the figure, the results vary across each of the sub-periods considered. While the changes on account of growth in population and total household spending were positive in each of the sub-periods, changes on account of shifting structures of consumption were negative for the periods 1983-90 and 1990-94. Intensity changes also had a negative effect during the sub-period 1990-94. However, it is clear from this analysis that in Indian households increases in activity levels or volume of consumption spending was the main driver of increases in energy requirements during the period between 1983-84 and 1998-99.

[2] The sum of all effects may not add up to the actual change due to a residual term in the decomposition.

Overall, a 76% increase in real per capita household expenditure over the entire period translated into a 27% increase in per capita total energy requirements, implying an energy elasticity of household spending of about 0.83 over this period.

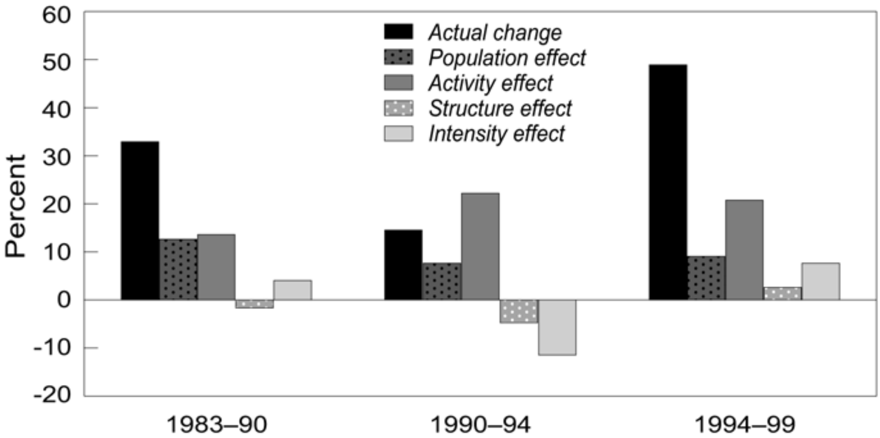

Fig. 4.5. Decomposition of changes in total household energy requirements by structure, activity, intensity and population effects

A similar disaggregation was carried out to examine changes in indirect energy requirements per capita for each of the major consumption categories over the entire period from 1983-84 to 1998-99. The results of that analysis can be seen in Fig. 4.6. In general, for most of the categories, other than ‘clothing and footwear’, structural changes were responsible for a slight decrease or had almost no effect in changing indirect energy requirements. Changes in energy intensity also led to a decrease in energy use for all categories except ‘food, beverages and tobacco’ where it contributed to a large increase and the ‘medical and hygiene’ category where it contributed to a smaller increase. Changes in activity levels exerted an upward pull on energy use for each category except in the case of ‘clothing and footwear’ where per capita expenditures declined marginally over the entire period. In general, the activity effect or volume change had the largest contribution to the total increase in indirect energy requirements in most of the indirect consumption categories.

Findings from the disaggregation of indirect energy use for each of the consumption categories reflect in some ways those for total energy use, the big exceptions being for the categories ‘food, beverages and tobacco’ and ‘clothing and footwear’. The food category comprised about half of all indirect energy requirements of Indian households in 1998-99 and also experienced the largest increase over the period 1983-99 because energy intensity for most of the agricultural and food sectors increased significantly during this period. Thus, the combined effect of increasing expenditures on food and rising energy intensities in this sector led to a large increase in energy requirements for this consumption category. In fact, the combination of direct energy needs for cooking and the indirect energy requirements of the 'food, beverages and tobacco' consumption category constituted about 60-70% of total household energy needs during this period.

'Clothing and footwear' was another category that exhibited changes contrary to the average during this decade. This was the only category for which per capita indirect energy requirements decreased consistently over the entire period. Interestingly, this was the only category for which real per capita expenditure levels declined. To better understand this trend, physical textile consumption data for India was examined for this period. Data from the World Apparel Fibre Consumption Survey of FAO (FAO various) shows that for the decade studied, per capita availability of fibres increased only marginally. In addition, important structural changes took place within this sector during this period with a larger increase in the consumption of natural fibres during the late 1980s, but with a decrease in the same during the early to mid-1990s, and a larger increase in the consumption in man-made fibres during this period. Greater durability of man-made fibres might, in part, be responsible for the almost constant per capita expenditures for this category during the study period.

For the category 'housing and household effects' indirect energy requirements also showed a slight decline over the entire period. However, in this case, indirect energy requirements increased over the period from 1983 to 1990 and decreased thereafter largely as a result of a sharp decline in the energy intensities for some of the items in this category. In particular, the energy intensity of production for the commodity sector 'other non-metallic mineral products' decreased to a large extent over the 1990s. This sector which comprises products such as bricks, glass, etc. made largely within the informal sector using traditional techniques has experienced some degree of modernisation and big shifts in fuel use from non-commercial and coal to more efficient energy sources over this period.

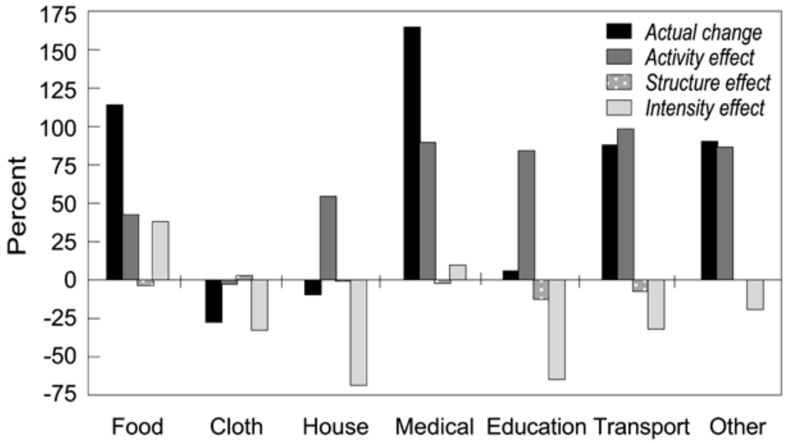

Fig. 4.6. Decomposition of changes in categories of indirect energy requirements per capita by structure, activity and intensity effects

4.5 Comparison with Previous Studies

As this is the first such study carried out for India and is also the first to include non-commercial energy use, it is difficult to compare the results obtained from this analysis with other studies. In Sect. 4.1 above, literature on similar studies carried out in various western industrialised nations was presented. Total per capita household energy requirements in most of those studies for comparable time periods are a factor 7 to 10 times higher than the values for India determined in this study. These differences in energy requirements arise from differences in direct and indirect energy use both of which are larger in industrialised countries.

Rather than comparing actual numerical quantities of energy requirements for Indian households with those of other countries, it is interesting to compare some of the trends in household energy requirements between countries. Studies conducted in the Netherlands show indirect energy requirements to comprise more than 50% of total household energy requirements (Vringer et al. 1995a, 1995b). In India, this share was about 42% in 1983-84 but increased rapidly over the study period and exceeded 50% by 1998-99. Within the indirect energy category, the share of basic commodities like food, clothing and housing, was lower in the Netherlands in 1990 (Vringer et al. 1995a) as compared to the share of these basic commodities determined in this study. This seems reasonable given the vast differences

in living standards between the two countries. The only anomalous trend is the rising share of indirect primary energy requirements for food, beverages and tobacco in India. However, the trends for other basic commodities show that the share of these in total household energy requirements, both for India and the Netherlands, is declining. Similarly, the share of transport and communication is rising for both countries.
Regarding changes in household energy requirements over time, Wilting's study on the decomposition of changes in total indirect energy requirements of Dutch households between 1969 and 1988 also shows that growth in the volume of household consumption was the most important factor responsible for the increase observed during this period. The study also showed that the intensity effect led to a decrease and the effect of changes in the structure of consumption were negligible for the Netherlands (Wilting 1996).

A fairly large body of literature also exists on decomposition of changes in direct energy use by different factors in different sectors. Lee Schipper and other researchers at the Lawrence Berkeley Laboratory have carried out an analysis of this kind for many different countries (Schipper 1989; Schipper and Ketoff 1985; Shipper and Tyler 1990). To understand factors influencing changes in energy use over time, these studies distinguish between activities, intensities and structures and factorise either total direct energy use or direct energy use of different end-use sectors according to these three main factors. For instance, Shipper and Tyler (1990) conclude that changes in activity levels and structures have been the main drivers of change in energy use in all sectors in Norway.

It is difficult to directly compare results of this study with those of other Indian studies as most tend to exclude non-commercial energy use. There are no studies to date that look at total direct and indirect energy requirements of Indian households. Therefore, only some results from recent studies that assess changes in total national energy consumption in India are discussed. A recent paper using decomposition analysis for total commercial primary and final energy consumption and carbon emissions for India between 1970 and 1995 reached a similar conclusion regarding the importance of changes in activity levels in driving the increase in energy use and carbon emissions during this period (Nag and Parikh 2000). Nag and Parikh conclude that "India is likely to become more and more important as a global energy consumer and therefore autonomous technical change will not be enough to attain the desired level of efficiency and emissions reduction". Mukhopadhyay and Chakraborty (1999) have carried out a structural decomposition analysis of energy consumption changes in India between 1973-74 and 1991-92. Their analysis also indicates that shifts in final demand levels were the most important driver of increase in total commercial energy consumption during the period between 1973-74 and 1993-94. More recently, Mukhopadhyay (2002) used an input-output structural decomposition analysis approach to determine the sources of change in CO2, SO2 and NOx emissions between the periods 1991-92 and 1996-97. Results of the study indicate that both structural and volume factors played a dominant role in increasing demand and hence emissions and the electricity and petroleum products sectors in particular have contributed to large extent to direct and indirect emissions for this period.

4.6 Discussion and Conclusions

During the period 1983-84 to 1998-99, the total population of India increased by about 29% contributing in part to the increase in total household energy requirement. Total household energy consumption (direct and indirect) however, increased by about 70% indicating that other factors including changes in volume of consumption per capita, the pattern or structure of consumption and energy intensities of goods and services contributed to the total change.

The share of indirect energy requirement to the total also increased during this period. This shows the importance of undertaking such analysis, and the importance of focusing on not only direct energy use, but also on indirect energy embodied in goods and services consumed by households. Options for curbing the future growth of fossil energy use within sustainable limits in India could include those that involve changes in the structure of household consumption and therefore indirect energy needs, along with those increasing the efficiency of direct energy use.

While food is a basic necessity and its consumption must increase given the increasing population numbers and widespread poverty in India, the results of this study indicate that large energy savings can be realised by increasing the efficiency of energy use, both in the food producing and manufacturing sectors, as well as in food preparation. Appropriate energy pricing policies that encourage energy conservation, especially for agricultural users, policies that encourage the adoption of newer more energy efficient technologies in upstream sectors that provide inputs to the agricultural sectors (for e.g., fertilisers and pesticides) and policies that encourage the use of more sophisticated direct fuels and appliances for cooking, could go a long way in improving efficiency in this sector.

The results of the decomposition analysis of changes in total and indirect energy requirements of households during this period indicate that the main driver of energy increase was the rise in the volume of consumption. This suggests that further increases in income levels of households will lead to further increase in household consumption and hence energy requirements in India. Decreases in energy intensities of producing sectors only partly compensated for the growth in the volume of consumption during the decade studied. However, there is considerable scope for further improvements in energy intensities in the future.

The results of the decomposition analysis also indicate that changes in the structure of consumption could have significant impacts on total household energy requirements. Results for the indirect energy category ‘clothing and footwear’ showed that a change in the structure of consumption towards less energy-intensive items of apparel led to an actual decrease in total indirect energy requirement for this category. Significant differences in energy intensities within and among household consumption categories also suggest that possibilities of influencing consumption patterns towards less intensive consumption categories could influence the rate of growth of total household energy requirements in the future.

The results for all households and for the average per capita household energy requirement in India are presented in this chapter. However, given the high degree of heterogeneity in living conditions and consumption levels across different groups of households and urban/rural areas in India, it is important to examine the variations in patterns across different categories of households and the implications of these differences for total household energy requirements. The next two chapters will address these issues.

Appendix 4A: Goods and Services Included in the Consumption Categories

Food, beverages & tobacco:

Paddy, Wheat, Jower, Bajra, Maize, Gram, Pulses, Sugarcane, Groundnut, Jute, Cotton, Tea, Coffee, Rubber, Coconut, Tobacco, Other Crops, Milk And Milk Products, Animal Services (Agriculture), Other Livestock Products, Forestry And Logging, Fishing, Sugar, Khandsari & Boora, Hydrogenated Oil, Edible Oil other than Vanaspati, Tea & Coffee Processing, Miscellaneous Food Products, Beverages, Tobacco Products

Clothing & footwear:

Khadi, Cotton Textile in Handlooms, Cotton Textiles, Woollen Textiles, Silk Textiles, Art Silk, Synthetic Fibre Textiles, Jute, Hemp, Mesta Textiles, Carpet Weaving, Ready Made Garments, Miscellaneous Textile Products, Leather Footwear

Housing & household effects:

Furniture & Fixtures, Wood & Wood Products Except Furniture, Leather & Leather Products Except Footwear, Rubber Products, Plastic Products, Other Chemicals, Structural Clay Products, Other Non-Metallic Mineral, Miscellaneous Metal Products, Office Computing and Accounting, Other-Non-Electrical Machinery, Batteries, Electrical Appliances, Other Electrical Machinery, Watches & Clocks, Miscellaneous Manufacturing, Ownership Of Dwellings

Medical care & hygiene:

Soaps, Cosmetics & Glycerine, Water Supply, Medical & Health Services, Other Services

Transport & communication:

Communication Equipment, Ships & Boats, Rail Equipment, Motor Vehicles, Motor Cycle & Scooter, Bicycles, Cycle-Rikshaw, Other Transport Equipment, Railway Transport Service, Other Transport Service, Communication

Education & recreation:

Paper, Paper Products & Newspapers, Printing Publishing And Allied Activities, Electronic Equipment Incl. Television, Hotels & Restaurants, Education & Research

Other services:

Trade, Banking, Insurance

Appendix 4B: Detailed Results Tables

Table 4B-1. Household expenditures in constant 1993-94 prices and household primary energy requirements - expenditures in 1983-84 (1), primary energy requirements in 1983-84 (2), expenditures in 1989-90 (3), primary energy requirements in 1989-90 (4), expenditures in 1993-94 (5), primary energy requirements in 1993-94 (6), expenditures in 1998-99 (7), primary energy requirements in 1998-99 (8)

	Commodity	(1) Rs. 10^9	(2) PJ	(3) Rs. 10^9	(4) PJ	(5) Rs. 10^9	(6) PJ	(7) Rs. 10^9	(8) PJ
1	Paddy	302.3	283.2	342.5	425.7	390.7	549.7	371.9	712.0
2	Wheat	157.7	361.6	161.3	437.4	212.4	630.6	242.9	734.8
3	Jowar	39.5	24.1	37.9	21.6	32.6	18.8	33.5	33.6
4	Bajra	22.4	15.9	16.7	9.7	14.1	13.0	19.6	27.5
5	Maize	26.1	20.0	25.3	19.7	24.5	31.0	29.3	55.7
6	Gram	20.8	5.5	24.3	12.3	31.7	16.8	32.8	24.1
7	Pulses	58.2	24.7	73.5	53.5	73.4	65.1	70.8	102.8
8	Sugarcane	36.9	22.5	60.6	42.5	76.4	50.1	85.1	90.2
9	Groundnut	5.7	2.1	13.5	5.9	15.2	11.3	17.2	14.1
10	Jute	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Cotton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Coffee	0.0	0.0	0.0	0.0	7.2	1.2	8.7	1.4
14	Rubber	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	Coconut	23.2	2.4	22.9	3.0	31.5	10.9	19.2	17.1
16	Tobacco	0.5	0.2	0.5	0.4	0.3	0.2	0.7	0.6
17	Other crops	239.5	68.9	281.9	214.1	529.3	327.5	606.9	423.8
18	Milk and milk products	221.2	39.4	321.6	82.1	370.0	73.9	450.4	55.7
19	Animal services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	Other livestock products	82.3	30.2	128.1	37.6	169.2	42.5	174.4	51.0
21	Forestry and logging	53.0	8.6	87.9	12.2	73.3	10.4	85.1	15.5
22	Fishing	24.6	1.8	60.1	10.0	77.2	15.9	98.9	32.6
23	Coal and lignite	1.1	41.2	1.7	25.0	1.8	8.2	3.2	21.9
24	Crude petroleum,	0.0	0.6	0.0	1.6	0.3	7.6	0.0	7.7

	Commodity	(1) Rs. 10^9	(2) PJ	(3) Rs. 10^9	(4) PJ	(5) Rs. 10^9	(6) PJ	(7) Rs. 10^9	(8) PJ
	natural gas								
25	Iron ore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	Other minerals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	Sugar	54.5	35.9	81.2	81.3	87.8	79.5	76.8	58.5
28	Khandsari, boora	0.5	0.6	1.1	1.8	8.8	8.4	8.2	7.1
29	Hydrogenated oil (vanaspati)	20.6	47.7	25.4	32.1	18.0	57.6	27.1	80.3
30	Edible oils other than vanaspati	87.0	43.4	52.8	50.3	67.2	60.9	201.8	169.3
31	Tea and coffee processing	23.4	33.5	29.4	59.7	31.5	58.1	37.8	86.7
32	Miscellaneous food products	86.7	155.7	108.5	159.3	187.5	210.8	484.2	635.2
33	Beverages	14.0	22.3	14.9	32.8	29.2	48.5	69.6	138.1
34	Tobacco products	42.0	28.2	52.5	47.3	73.3	62.6	102.7	91.4
35	Khadi, cotton textiles	41.3	62.9	26.3	31.1	25.3	21.1	21.4	33.7
36	Cotton textiles	97.7	271.0	142.9	326.7	134.4	246.7	152.7	349.2
37	Woollen textiles	8.5	22.8	10.8	20.2	15.9	35.2	12.7	28.0
38	Silk textiles	10.8	12.6	6.5	5.6	7.4	7.7	6.1	6.2
39	Art silk, synthetic fibre textiles	64.7	210.0	93.5	189.4	96.7	181.8	84.2	132.5
40	Jute, hemp, mesta textiles	0.0	0.0	0.7	1.3	0.5	1.2	0.8	1.2
41	Carpet weaving	2.3	2.9	5.5	4.2	1.9	2.1	3.0	3.7
42	Readymade garments	24.6	53.8	14.8	17.2	20.5	21.5	35.6	42.1
43	Miscellaneous textile products	23.2	27.8	47.9	59.7	27.8	31.4	37.8	47.9
44	Furniture and fixtures-wooden	2.0	0.7	2.4	1.1	10.1	4.4	26.3	11.3
45	Wood and wood products	0.0	0.0	0.3	0.1	2.1	1.4	5.9	4.1
46	Paper, paper prods. & newsprint	2.8	15.6	1.7	10.5	9.1	65.8	15.2	71.1
47	Printing and publishing	13.8	22.7	23.3	40.8	37.1	83.6	47.6	59.3
48	Leather footwear	12.6	11.4	14.2	19.1	20.5	17.5	17.8	11.3
49	Leather and leather	1.3	1.3	1.8	2.0	3.9	3.4	6.6	5.1

	Commodity	(1) Rs. 10^9	(2) PJ	(3) Rs. 10^9	(4) PJ	(5) Rs. 10^9	(6) PJ	(7) Rs. 10^9	(8) PJ
	products								
50	Rubber products	8.5	16.8	12.3	33.8	5.7	12.1	8.6	9.4
51	Plastic products	2.6	4.9	5.8	12.4	17.7	24.4	30.2	34.0
52	Petroleum products	50.6	286.9	57.9	455.6	65.9	446.1	98.3	982.1
53	Coal tar products	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
54	Inorganic heavy chemicals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	Organic heavy chemicals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	Fertilizers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	Pesticides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	Paints, varnishes and lacquers	0.0	0.0	0.0	0.0	0.0	0.0	2.7	3.5
59	Drugs and medi-cines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60	Soaps, cosmetics & glycerine	31.7	56.5	38.2	101.2	46.1	80.9	69.4	90.5
61	Synthetic fibres, resin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	Other chemicals	10.2	16.2	17.5	41.4	20.8	41.7	27.2	36.3
63	Structural clay products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
64	Cement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65	Other non-metallic mineral prods.	14.9	75.1	21.1	59.3	11.3	26.7	6.4	13.6
66	Iron and steel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	Non-ferrous basic metals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	Hand tools, hard-ware	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69	Miscellaneous metal products	16.8	40.6	52.4	124.5	45.6	96.8	45.1	59.1
70	Industrial and elec-trical machinery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	Office computing machines	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1
72	Other non-electrical machin-ery	2.1	4.2	6.9	12.3	5.1	7.5	6.3	7.6

	Commodity	(1) Rs. 10^9	(2) PJ	(3) Rs. 10^9	(4) PJ	(5) Rs. 10^9	(6) PJ	(7) Rs. 10^9	(8) PJ
73	Batteries	3.0	5.0	4.6	0.6	4.6	6.7	5.2	6.7
74	Electrical appliances	2.2	4.6	4.9	2.1	2.4	3.5	3.3	3.3
75	Communication equipments	1.1	1.2	1.8	2.2	3.3	4.0	3.6	3.2
76	Electronic equipments(incl.TV)	7.7	11.1	27.1	30.4	14.4	17.4	20.6	17.9
77	Other transport equipments	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	Motor vehicles	3.1	8.0	9.6	12.5	12.7	18.0	18.8	22.8
79	Motor cycles and scooters	8.5	13.3	17.6	23.1	25.0	23.1	18.0	16.4
80	Bicycles, cycle-rickshaw	4.3	12.7	14.0	19.3	8.1	9.8	6.4	7.9
81	Watches and clocks	3.0	7.2	7.4	6.9	4.4	6.4	3.7	3.9
82	Miscellaneous manufacturing	9.7	30.8	10.9	13.6	18.2	23.7	59.1	70.3
83	Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
84	Electricity	14.3	70.1	25.3	112.1	39.5	170.3	60.1	257.4
85	Gas	3.3	0.1	9.6	0.9	7.9	1.1	9.3	1.1
86	Water supply	3.4	10.9	4.5	12.0	2.6	8.5	8.3	23.7
87	Railway transport services	37.0	124.6	34.3	69.8	46.3	67.1	43.3	64.8
88	Other transport services	144.7	302.7	204.7	431.8	360.5	602.9	602.9	1045.7
89	Storage and warehousing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	Communication	12.6	5.7	21.9	9.8	24.7	7.6	64.7	18.7
91	Trade	263.4	120.6	398.5	204.7	581.5	203.8	691.0	259.0
92	Hotels and restaurants	93.6	326.2	105.4	296.6	112.9	249.9	225.0	377.4
93	Banking	26.1	9.3	40.1	14.4	58.2	11.8	199.2	51.8
94	Insurance	1.7	0.7	2.3	0.9	5.6	2.4	37.1	21.7
95	Ownership of dwellings	234.1	47.2	276.0	64.5	464.2	34.7	479.2	39.1
96	Education and research	67.5	23.5	83.1	15.8	146.8	21.8	269.1	40.8
97	Medical and health	63.0	55.4	80.3	64.5	103.1	75.4	329.3	219.1

	Commodity	(1) Rs. 10^9	(2) PJ	(3) Rs. 10^9	(4) PJ	(5) Rs. 10^9	(6) PJ	(7) Rs. 10^9	(8) PJ
98	Other services	102.0	23.3	135.1	124.0	278.5	202.8	249.7	184.3
99	Public administration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	Non-commercial energy	0.0	4267.7	0.0	4516.7	0.0	4689.2	0.0	5151.1
	TOTAL	3196.1	8018.6	4149.2	9497.8	5591.3	10393.8	7533.9	13639.6

Chapter 5: Disaggregate Household Energy Requirements

5.1 Introduction

In the previous chapter, results were presented on total and average per capita household energy requirements calculated from data on private consumption expenditures contained in the national input-output tables prepared by the CSO and total primary energy intensities calculated for the period from 1983-84 to 1998-99. These totals and averages, however, mask big differences in the patterns and amounts of energy used among households. In this chapter, results of household energy requirements calculations using consumer expenditure survey data for households from the National Sample Survey (NSS) and the appropriate productive energy intensities presented in Chap. 3 are discussed. Variations in total energy requirements across different types of households emanating from differences in consumption patterns are discussed and factors affecting such variations examined. A comparison of the results from the household level analysis using National Sample Survey Organisation (NSSO) data with those of private expenditure data from the National Accounts Statistics data of the CSO, which were used for the analysis presented in the last chapter is also carried out, and discussed in Sect. 5.3.2 of this chapter.

5.2 Methods, Data Sources, and Data Preparation

Basic consumption data on detailed item-wise expenditures from the National Sample Survey Round 55 for the year 1999-00 are made use of to determine detailed energy requirements of households at a disaggregate level (NSSO 2002). The expenditure data are multiplied with appropriate productive energy intensities calculated for the Indian economy for the year 1998-99 to determine the energy requirements of consumption.

5.2.1 An Introduction to the Household Expenditure Survey Data

The starting point for this analysis is the data on household consumption expenditure from the NSSO. The NSSO was set up in 1950 in India, by the department of statistics, in order to conduct periodic nationwide surveys on various facets of the economy. It conducts enquiries in the form of rounds usually of one year and sometimes of six months duration using an interview method and schedule approach of data recording. The household consumer expenditure schedule was canvassed quinquennially for the early years of the survey, but since 1986-87, an annual series of smaller-scale consumer expenditure surveys have been launched. At present, the NSS rounds reach the entire area of the country, involving separate and comprehensive coverage of rural and urban areas, with the exception of some very interior areas, and the disputed regions of the State of Jammu and Kashmir.

For each NSS round the household expenditure survey data is collected from a nation-wide probability sample of households by the interview method. The sampling design is stratified and includes two or more independent and interpenetrating sub samples. Weights for each individual household observation are provided for the sub-sample and with the combined sample estimate. The sample of households is drawn based on a two-stage stratified random sampling procedure. The first stage units are the census villages and urban blocks and the second stage comprises the households in these villages and urban blocks. The first stage units are selected circular systematically with probability proportional to the population and the villages and urban blocks are selected in the form of two or more independent sub samples. In the second stage, the households are arranged by means of livelihood (main occupation), and area of landholding in rural areas and monthly per-capita consumption expenditure in urban areas. The samples are selected circular systematically with a random start. In order to get adequate number of sample households from the affluent section of the society, the NSS 1993-94 survey, for the first time, stratified the households into affluent and others, based on the assets holding and monthly consumption expenditure. In the 1999-00 survey this practise was continued and from each selected village or block, 12 households were selected for the consumer expenditure survey.

Household consumption as included in the survey includes consumption of goods and services acquired through (a) purchases in the market, (b) receipts in exchange of goods and services, (c) subsistence production, and (d) transfer receipts such as gifts and loans. The annual series of consumer expenditure surveys, up to the 49th round, used a uniform reference period of ‘last 30 days’ for all items of consumption. In the bigger surveys of the quinquennial series, an additional reference period of ‘last 365 days’ was used for some items of consumption particularly, clothing, footwear and durable goods but most results were tabulated using the ‘last 30 days’ data. This practice, which is at variance with that in most other parts of the world where people are asked about their consumption over the previous seven days, had been criticised for some time now. Some small studies in the 1990s showed that people tend to have a poor memory. People’s daily food consumption computed from the 30-day question turns out to be close to 20 % less than that computed from the 7-day question (Visaria 2000). During the 51st to 54th rounds, one-half of the sample households were surveyed through schedule type I, which had a reference period of 30 days for all items. In the other half of the sample, a schedule (schedule type 2) with different reference periods for different items was tried out on an experimental basis. The experiments with alternative reference periods, carried out in some rounds of the NSS, have shown overall higher consumption estimates by the one-week recall, but also larger sampling errors of these estimates.

During 55th round of NSS, information on consumption of food, pan, tobacco & intoxicants was collected independently for two different reference periods of 7 days and 30 days from the same households. However, the field staff was instructed to collect independently the data with ‘30 days’ reference period before the data for the previous week i.e. ‘7 days’ in consumer expenditure schedule (Sch.1.0).

Another important feature of this round was that information in respect of consumption of clothing, footwear, durable goods, education and medical (institutional) services was collected only for one reference period of ‘last 365 days’. In some of the quinquennial rounds, information on these items was collected for two different reference periods – last 30 days and last 365 days - from the same households. The results of 50th or other earlier quinquennial rounds were, however, based on a reference period of 30 days only for all the items.

The departure in Round 55 from the earlier practise regarding the use of a 30-day recall-period for all expenditure items covered by the NSS survey resulted in several issues concerning the comparability of this round with previous rounds of the survey. The interested reader may refer to Datt, Ravallion and Kozel (2003); Deaton (2001, 2003a, 2003b, 2003c); Deaton and Drèze (2002); Sen (2000); Sundaram and Tendulkar (2001, 2003) and Visaria (2000) for a detailed discussion of the main issues and consequences of the non-comparability. In particular, the analysis conducted in these papers showed that expenditure on food was significantly higher for the shortened recall period and the opposite result was found for most durables with the lengthened recall period. This resulted in a net effect of a larger estimate of household consumer expenditure and a correspondingly lower estimate of poverty incidence for that year.

For the purpose of the analyses carried out in this study, data pertaining to the 30-day recall on all food items, fuel and light and miscellaneous goods and services have been utilised, and for all other items of consumption data pertaining to the 365-day recall has been used in order to keep the analysis consistent with that from previous rounds of the survey. All household expenses have then been extrapolated to the whole year, so that all results presented here are in terms of annual values per capita.

To minimise recall errors, a very detailed item classification is adopted to collect information, including 190 items of food and beverages, 25 items of clothing and footwear, 20 items of educational and medicinal expenses, 66 items of durable goods, and about 111 other miscellaneous goods and services items. In addition, data on a host of other socio-economic variables is collected through the survey.

5.2.2 Reliability of NSS Estimates of Household Consumption Expenditure

The nature and the reliability of estimates from the NSS have been reported on from time to time by several economists and statisticians on the basis of available external data mainly from the National Accounts Statistics (NAS) published by the Central Statistical Organisation (CSO), which are indirect estimates following a commodity flow method. A detailed study on reliability of available estimates of private consumption expenditure was made by Minhas et al. (1986); Minhas (1988); Minhas and Kansal (1990); Sundaram and Tendulkar (2001); NSSO (2005) with the purpose of identifying factors that may be responsible for differences in the two sets of estimates and for determining the shortcomings in the two databases.

The causative differences in the two sets of estimates based on detailed item-wise comparisons brought out the fact that easy and straightforward comparisons cannot be made. Though some of the differences between the two sets of data can be reconciled by making appropriate adjustments in the relevant factors some other appeared to be irreconcilable as they were an integral part of the respective estimation procedures adopted by the two agencies. Some of the more important causes for differences in the estimation procedures from the two data sources on household expenditure, i.e. NSSO and CSO, are discussed in greater detail in Sect. 5.2.5.

5.2.3 Data Modifications

For the purpose of this study, the basic source of household data was the raw data tape from the household consumer expenditure survey for 1999-2000 (NSSO, 2002). The survey covered a representative sample consisting of a total of 120,310 households of which 71,386 were in rural and 48,924 in urban areas of the country, the weighted information representing a total population of 928.15 million. The data on the raw data tape were highly disaggregated and followed the detailed item classification described above. It was therefore, necessary to aggregate the data into 55 broad consumption categories[1] that were conformable to the calculated sector energy intensities for the year 1998-99 from the input-output data. Most of the results are presented in a further aggregated form for a classification based on 12 broad consumption categories (see Table 5.1).

Table 5.1. Correspondence between the 55-level and the 12-level classification of consumption categories

S. No.	12-level sector	55-level sector
1	Food, Beverages & Tobacco	1-18
2	Clothing & Footwear	34-35
3	Education & Recreation	36 and 44
4	Medical care & Hygiene	37-38 and 45-46
5	Transport	41 and 52
6	Other Services	39-40 and 43

[1] A list of all the consumption categories at the 55-level are included in the appendix in Table 5B-1.

S. No.	12-level sector	55-level sector
7	Housing & HH effects	42 and 47-51 and 53-55
8	Non-commercial energy[2]	20 and 22 and 27
9	Electricity	21
10	Coal	19 and 24
11	Petroleum Products	23 and 26 and 28-29 and 31-33
12	Gas	25 and 30

5.2.4 Method for Matching Expenditure Items from the Household Survey with Productive Sector Energy Intensities

For many of the 55 broad consumption categories from the household survey data, matching with energy intensities from the input-output data sectoral classification was easily handled, as they both followed a fairly similar scheme of classification. The energy intensities of a few consumption categories had to however, be recalculated because they differed from the input-output data sector classification. In some other cases, energy intensities of certain sub-categories were assumed to have the same energy intensity of the broader category. Thus, for example the consumption categories 'fresh fruits' and 'fresh vegetables' from the household survey were both assumed to have the same energy intensity as the sector 'other crops' from the input-output tables. Table 5B-1 at the end of this chapter shows the energy intensities of each of the 55 broad consumption categories.

Physical data on the direct consumption of fuels from the household survey was used to calculate direct primary energy requirements of households. The survey included volume data on the consumption of 15 different direct fuel types, of which data on the consumption of match sticks and candles had to be discarded, as there appeared to be high errors associated with the data for these categories. Physical data for the other fuels and electricity were recorded in a number of different physical units, e.g. kWh for electricity, kg for firewood, etc. Thus, the first step was to convert the fuel quantities to uniform physical energy units of mega joules (MJ). The

[2] Data on non-commercial energy refers largely to fuelwood. While the survey records information regarding the burning of dung for cooking, quantitative data on the amount of dung used is not included. To overcome this gap in the data, modifications to the survey data were made to estimate the amount of dung used. See Appendix 5A for a detailed description of the modifications.

conversion factors used in order to do so are included in Table 5B-2 at the end of the chapter. Next, physical energy intensities for direct fuels from the input-output tables in MJ_{in}/ MJ_{out} were multiplied with the household fuel consumption quantities in MJ, to arrive at the primary energy requirements of direct fuels.

Data on the consumption of petroleum, diesel and other auto fuels were only recorded in terms of rupee expenditures on these items and not in physical volume terms in the household survey. Therefore, these data were first converted to physical terms by dividing expenditures on these items by the appropriate average all-India fuel prices for that year. In the next step, the methodology described in the previous paragraph was used to convert these final energy use figures to primary terms.

As mentioned earlier, the method adopted to convert all other non-direct energy purchases from rupee terms to their energy equivalents simply involved multiplying the expenditure on each of the items listed, with its corresponding energy intensity. The commodities were then grouped into a previously chosen set of categories (see Table 5.1) and their energy requirements totalled. For the sake of consistency and compatibility with other studies, all household data were divided by the number of household members to arrive at per capita figures, and all monthly figures were converted into annual figures.

5.2.5 A Comparison of Private Final Consumption Expenditure Estimates from the CSO and the NSS Data

To examine the comparability of data from the NSS household consumption expenditure surveys and the private final consumption expenditure figures from CSO input-output data, the expenditures in rupees per main consumption category for both sources are shown in Table 5.2. There are large differences between the same categories for the two separate sources of data. This makes a direct comparison between the two data sources difficult. It is clear that NSS data are subject to both sampling and non-sampling errors, but given the large sample size of these surveys these errors should be small. Clearly then there must be other reasons that are responsible for the large differences in the aggregate and per capita estimates of private household consumption from the survey and official sources. A few studies in the past have tried to carry out a systematic comparison between the expenditure data for certain years from the two different sources. Some of the main factors responsible for the observed differences as reported in these studies (Minhas 1988; Mukherjee 1986; Sundaram and Tendulkar 2001; NSSO 2005) are discussed briefly below.

- The NSS figures and official estimates from the CSO are based on completely independent data. The former depends on individual consumer responses, while the latter is based on output and sales estimates implicit in official national income statistics.
- There is a time lag between the official estimates that are based primarily on production data and the survey estimates that refer, by and large, to the time point of actual consumption. Current consumption by households is unlikely to have been concurrently produced by the production sector and most likely refer to production in the previous year.
- Large differences in the data from the two sources also arise on account of the fact that official national estimates also include the final consumption of private non-profit and charitable institutions, and populations residing in institutional households such as orphanages, prisons, hospitals, etc., as well as financial intermediation whereas the NSS estimates include final consumption of private households only.
- A major problem of comparability arises because, while official national estimates include, both the actual rent paid and the imputed rent receivable from owner occupied houses, the survey estimates include largely the former. This accounts for a large share of the divergence in expenditure estimates between the two data sources.
- While the estimates of private expenditures on food seem fairly well matched between the two data sources, there is a mismatch here too in terms of the classification schemes used by the two agencies for certain sub-items within the food category, such as expenditures on food given to domestic servants.
- It is difficult to compare coverage for the category education, as the official CSO estimates include institutional expenditure on education, which is not included by the NSS.
- The NSS estimates for certain non-food items such as clothing, footwear, and durable goods might be under-estimated, as households do not buy these in a regular fashion. Therefore, estimates based on recall of household consumption could lead to large sampling errors for these categories.

Despite these large differences in estimates of private household consumption from the NSS and the official CSO sources of data, for the purpose of comparison of consumption patterns across a cross-section of different households, the survey data do provide a considerable amount of invaluable information. There is also evidence that most of the underestimation that occurs in the NSS consumption data is in the consumption of the very rich, so that unadjusted NSS figures are still accurate in measuring consumption for the majority of the population.

Table 5.2. Private expenditure data from the CSO compared with household consumer expenditure data from the NSS - (1) CSO data for 1998-99 in current Rs. (2) NSS data for 1999-00 in current Rs. (3) NSS data as a percent of CSO data

S. No.	Group	(1)	(2)	(3)
INDIRECT				
1	Food, beverages & tobacco	5169.4	3980.4	77
2	Clothing & footwear	573.0	435.4	76
3	Housing & household effects	1102.9	679.9	62
4	Medical care & hygiene	1011.8	526.4	52
5	Education & recreation	889.8	207.7	23
6	Transport & communication	1167.1	230.2	20
7	Other services	1428.4	418.5	29
DIRECT				
8	Coal and lignite	5.0	6.1	122
9	Gas	14.3	0.7	5
10	Petroleum products	151.8	226.3	149
11	Electricity	92.5	148.1	160
12	Non-commercial energy	-	220.2	-
TOTAL		11605.8	7079.8	61

The most recent official assessment of differences between the NSS and national accounts estimates of consumption expenditure was carried out in 2005 by an Expert Group constituted by the Ministry of Statistics and Programme Implementation (NSSO 2005). A previous comparison was carried out in 1993 by an official Expert Group constituted by the Planning Commission (PC 1993). They recommended that poverty ratios and other such estimates be calculated exclusively from the NSS consumption data without any adjustment for the discrepancy between these and the CSO data. More recent analysis of the national accounts data after revisions to certain categories of consumption expenditure has revealed serious problems with the accuracy of the national accounts measures of consumption. Kulshreshtra and Kar (2002) and Sundaram and Tendulkar (2003), show that the national accounts estimate for consumption of fruits and vegetables in 1993–94 in nominal rupees more than doubled between the 1998 and 1999 versions of the national accounts. The estimate for clothing fell by about a half, and that for rent, fuel, and power rose by more than 40 %. Even with some cancelling out of the pluses and minuses, total consumption was revised upwards by 14 %. These revisions reflect changes in data collection practices

Thus, after taking into consideration all of these factors and the recommendations and conclusions arrived at by previous studies, for the purpose of this study the above mentioned differences are kept in mind but no explicit adjustments to correct for these are carried out. Section 5.3.2 will discuss some of these discrepancies in more detail. However in what follows, results pertaining to total household energy requirements using the survey data are presented with a view to gaining insights into the pattern of energy requirements of consumption across households.

5.3 Variations in Household Energy Requirements across Households

In this section, results relating to the per capita total household energy requirements for the average Indian household are presented based on the methodology described above. Next, a discussion of the main factors or variables influencing total energy requirements follows. Results examining the relationships between energy requirements and important household and dwelling characteristics are presented.

5.3.1 All-India Average Per Capita Total Household Energy Requirements

The average total household energy requirements per capita provide a good starting point for the discussions and results presented in the following sections. For the year 1999-00, average total household energy requirements per capita were 10,130 MJ[3], implying an overall per capita en-

[3] The estimate using data from the CSO Input-Output Tables from 1998-99 in current Rupees for total household energy requirements per capita is 14,080 MJ, which is almost 40% higher than the NSSO estimates. This corresponds to the dif-

ergy intensity of household expenditure of about 1.4 MJ/Rs. Figure 5.1 presents a breakdown of the per capita energy requirements of household consumption for the average Indian. Energy requirements are about equally divided between direct and indirect needs, with direct energy constituting about 46% of the total and indirect energy the remaining 54%. Indirect energy requirements for food comprise more than one third, and non-commercial energy use just under one third (29%) of the total household energy requirements. The remaining third is about equally made up of other indirect energy needs (other than food) and direct commercial energy needs. In terms of energy intensities of household expenditure, the direct energy items have the highest intensities.

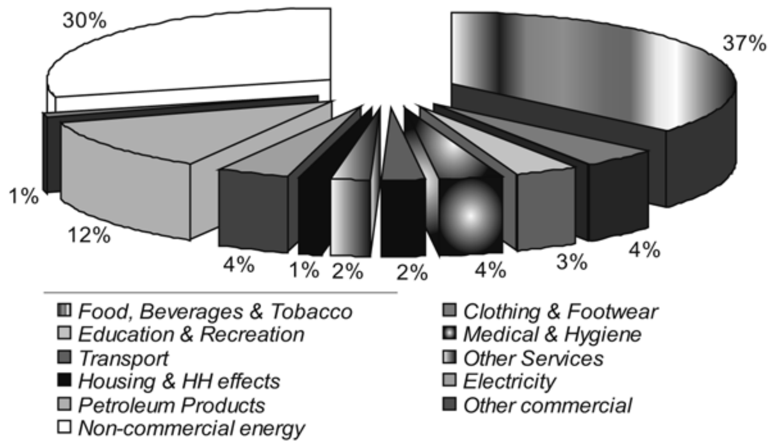

Fig. 5.1. Pattern of per capita total household energy requirements for the average Indian in 1999-00 from calculations based on NSS data

In Fig. 5.2 total and direct per capita household energy requirements are plotted against per capita household expenditures. As may be seen, the slopes of the curves for direct and total energy requirements differ, with total energy requirements rising faster with increases in expenditures than direct energy requirements. At the same time the data show a steady decrease in the average per capita energy intensity of consumption expenditure from the lowest to the highest household expenditures. This suggests that household expenditures for the lowest income groups in the

ference one observes in consumption expenditure across the two data sources that was discussed in Sect. 5.2.5.

country are focused on more energy intensive goods and services as compared to those of the highest income groups. This is, in part, also a result of the fact that the lower income groups are more dependent on non-commercial energy sources that are more inefficient. The ratio of direct to total energy requirements also steadily declines from the lowest to highest household expenditure levels. It appears, therefore, that increases in expenditure, are accompanied by increases in direct and indirect energy use but expenditure tends to shift from the direct use of energy towards increased indirect forms of consumption.

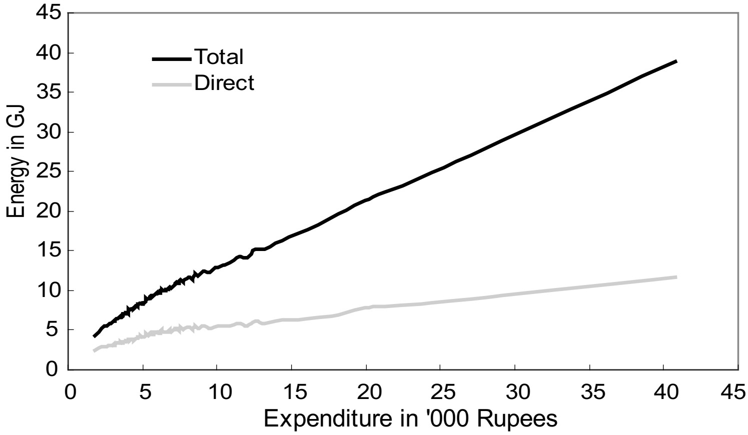

Fig. 5.2. Energy – expenditure relationship for Indian households in 1999-00

The findings for per capita total energy requirements for India are similar to those reported for per household energy requirements in Australia and New Zealand (Peet 1985; Lenzen 1998). However, results for per capita energy requirements for developed countries like New Zealand show a more constant trend over the entire range of household expenditures. Only in the case of indirect energy requirements does one see a rising trend in per capita requirements with increasing expenditure levels (e.g. in the case of Netherlands (Vringer 1995, 2005). These differences also reflect, to a great extent, the difference in the level of development between India and OECD countries. More regarding the relationship between expenditure levels and energy requirements is discussed in a later section of the chapter.

5.3.2 Comparison with Results from the Input-Output Model

As mentioned in Sect. 5.2.5 above, large differences exist between the household expenditure estimates from the NSS rounds and those from the CSO input-output tables. Corresponding differences in the energy requirements of household consumption are also observable and therefore a comparison of the actual magnitudes of household energy requirements estimated using the two different data sources is not presented here. Instead, a comparison between the patterns of total household energy requirements per capita for the average household from the two different sources, along with the energy intensities of household consumption for broad consumption categories are presented in this section.

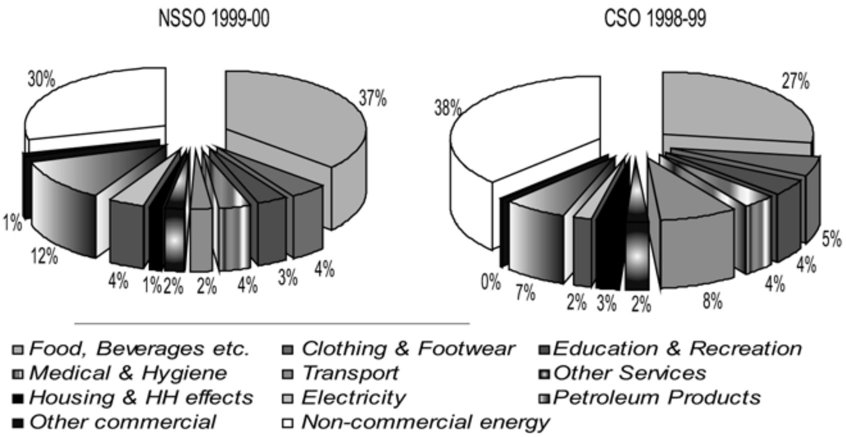

Fig. 5.3. Pattern of total per capita household energy requirements compared for NSS and CSO data

Figure 5.3 above provides a break-up of total household energy requirements per capita from the two different data sources. It is clear that the share of energy requirements for food in the total is larger when computed using the NSS data than when CSO data are used. This might, in part, be a result of the fact that expenditures on data on more energy intensive food items are larger in the NSS data as compared to the CSO data, even though total food expenditure is larger in the CSO dataset. The share of non-commercial energy use in total household energy requirements from the NSS data is in contrast lower than the corresponding share in the CSO data. This could possibly be because the estimates of household non-commercial energy use from the household surveys tend to underestimate total non-commercial energy use. Most of such energy is collected by women and children of the household, rather than being bought in a market, and therefore tends to be underreported in surveys despite efforts to include a section on home-grown (non-marketed) volume of non-commercial energy consumption in surveys. However, since most survey respondents are male heads of the family, it is often the case that they do not even know the true volume of non-commercial energy consumed by the household.

The share of housing and household effects in the results using CSO data is 2.6%, whereas it is only 1.3% of the total in the NSS data. This discrepancy arises largely on account of the way rent of dwellings is dealt with in the two data sources. As mentioned earlier, imputed rent of all owner occupied dwellings is included in the CSO data but imputed rents are included only for urban households in the case for the NSS data.

Another large difference arises in the case of the share of transport and communication energy requirements in total household energy requirements from the two different data sources. NSS data do not cover consumption of communication services adequately and this might be responsible for part of that difference. However, a very large difference still exists in the case of transport energy requirements, which is difficult to explain. According to Minhas who studied the differences in consumption expenditures from the two sources for the year 1977-78, estimates of expenditure on transport and communication services are particularly, at wide variance in part because of the methodology by which the data on this item is distributed among the household, commercial, and government sectors within CSO national accounts (Minhas 1988). The more recent study by NSSO (2005) also finds a large discrepancy in the estimates for transport services and equipment from the two data sources.

Examining differences in the energy intensities of consumption for the broad consumption categories, Table 5.3 provides the figures for calculated energy intensities based on the two data sources. The overall energy intensity of household expenditure from NSS data is slightly higher at 1.4 MJ/Rs. as compared to that from CSO data, in which case it is 1.2 MJ/Rs. If non-commercial energy use is excluded, then the intensities work out to be 0.8 MJ/Rs. and 1.1 MJ/Rs. from the CSO and NSS data, respectively. The ranges of intensities of consumption estimated from the two data sources while of similar magnitude vary significantly in value for many of the consumption categories. However, these differences can in most cases can be explained by the different factors resulting in divergences in the expenditure data from the two sources as discussed above in this section and presented in Sect. 5.2.5.

Table 5.3. Energy intensities of household consumption in MJ/current Rs. estimated from (1) CSO 1998-99 and (2) NSS 1999-00 data

S. No.	Group	(1)	(2)
INDIRECT			
1	Food, beverages & tobacco	0.742	0.929
2	Clothing & footwear	1.225	1.027
3	Housing & household effects	0.331	0.188
4	Medical care & hygiene	0.513	0.738
5	Education & recreation	0.698	1.666
6	Transport & communication	1.008	0.999
7	Other services	0.230	0.594
DIRECT			
8	Petroleum products	6.585	5.355
9	Electricity	2.830	2.860
10	Other commercial energy	1.617	11.623
11	Non-commercial energy	-	13.318
	TOTAL	1.213	1.431
	TOTAL excluding non-commercial energy	0.762	1.049

5.3.3 Factors Affecting Total Household Energy Requirements

In the following section, per capita total household energy requirements will be considered in relation to some important household characteristics and variables in order to understand how these variables affect the quantum and pattern of household consumption and energy use. Variables that have an impact on total household energy requirements can be grouped in various ways. In what follows, they are grouped under the heads of economic variables, demographic variables, geographic variables, household dwelling attributes, and infrastructural variables.

5.3.3.1 Economic Variables

Total monetary expenditure of households is the most important economic variable influencing total household energy requirements. Since the survey does not include any data on household incomes, total household expenditure is used as a proxy for this, and the two terms are at times used interchangeably in what follows[4]. The overall relationship between energy requirements and household expenditures was discussed in Sect. 5.3.1 above. In this section, the focus is on comparing the pattern of energy requirements for different deciles and expenditure groups. In order to study the variation in pattern of energy requirements with household expenditure levels, the sample household data are divided into deciles according to their level of total per capita expenditure and an additional differentiation is also made between rural and urban households belonging to these expenditure deciles. A further grouping of households by expenditure into Bottom (30% of the population), Middle (50% of the population) and Top (20% of the population) segments is also carried out.

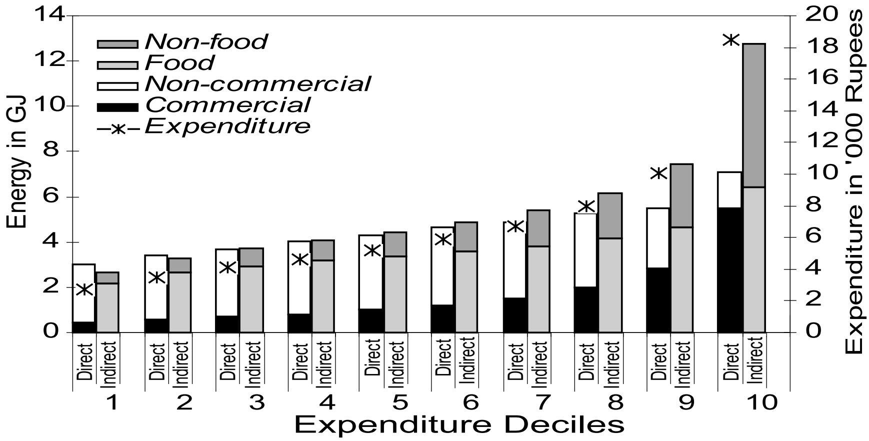

Fig. 5.4. Per capita direct and indirect household energy requirements for each per capita expenditure decile

[4] Literature from other studies (see for instance Vringer 2005, Jiang and O'Neill 2004) has shown that the relationship between energy and expenditure and that between energy and income is not always consistent because savings rates differ significantly with income and expenditure. However, in many instances, household expenditure is considered to better reflect long-term income, than estimates of income itself, particularly those from surveys that often do not capture real income.

The relationship between all the main categories of household energy requirements and monetary expenditures is positive with higher expenditures getting clearly translated into higher energy requirements. This relationship is shown in Fig. 5.4, which shows the average direct and indirect components of energy requirements per capita for each per capita expenditure decile. While both direct and indirect energy requirements increase with household expenditure levels, the rate of increase of direct energy use is much slower. On the other hand, indirect energy requirements increase more directly with household expenditures with the share of indirect to direct also rising significantly from 0.9 for the lowest decile to 1.8 for the highest. In particular, the indirect energy requirements for non-food items increase steeply for the top expenditure deciles.

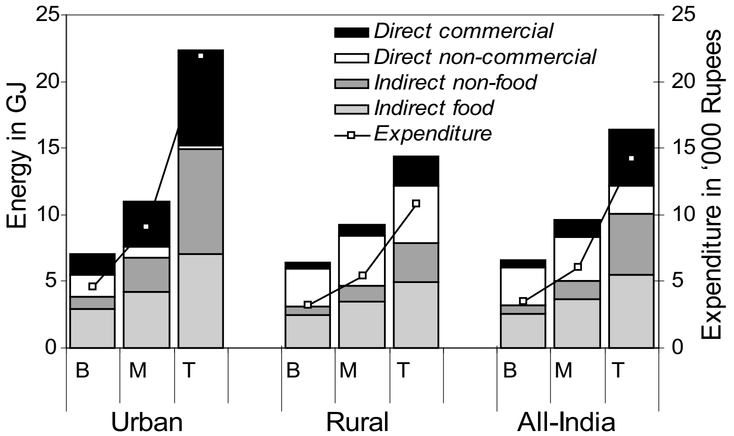

Fig. 5.5. Details of average per capita total household energy requirements for bottom (B), middle (M), and top (T), urban (U), rural (R), and all-India (A) expenditure groups

Table 5.4 and Fig. 5.5 provide information on the pattern of total household energy requirements per capita for the three main expenditure segments for the average rural, urban and all-India resident. Energy requirements, both direct and indirect, rise consistently from the bottom to the top expenditure segments for rural and urban households. While total energy requirements per capita are higher among urban households of each expenditure segment compared to that of rural households, a closer examination of the break-up of the total for these different groups reveals interesting differences in the pattern of energy requirements. Differences in the amount of indirect food energy requirements among expenditure segments across rural and urban households are relatively small. However, for each expenditure segment, the indirect non-food energy requirements of urban households are on average at least twice as much as that of rural households. For all three expenditure segments, per capita energy intensities for food consumption are significantly higher in rural households as compared to urban households. This is due to differences in the share of different items within the food category across segments. Clearly, this implies that within the food category, rural households spend their money on more energy intensive items of expenditure than urban households. They also spend a larger share of their budget on food items than urban households with the same total household expenditure. More regarding differences in the pattern of food energy requirements is discussed in Sect. 5.3.5 of the chapter.

An examination of most categories of non-food energy requirements shows that urban households in all expenditure segments, in general, have higher non-food indirect energy requirements per capita than their rural counterparts. The energy intensities of consumption for most non-food categories are quite similar across rural and urban households in the same expenditure segment. However, the energy intensity of consumption for the category housing and household effects is significantly higher for rural households as compared to urban households for each of the three expenditure segments. This is because the survey includes information on rent (imputed or actual) for urban households only.

The largest variation in the pattern of household energy requirements across different total expenditure classes is for the categories of direct energy use. Direct commercial energy requirements of urban residents are, on average, between two and three times that of rural residents for the corresponding total per capita household expenditure levels. On the other hand, non-commercial energy needs of rural households are much higher than that of their urban counterparts. In general, the results indicate the highest energy intensities for the categories of direct energy consumption and the energy intensities of consumption for all direct energy categories are higher in rural as compared to urban households. These differences in patterns of direct energy use are discussed in greater detail in Sect. 5.3.4.

Table 5.4. Average energy intensities of household consumption for (1) Bottom-Rural, (2) Middle-Rural, (3) Top-Rural, (4) Bottom-Urban, (5) Middle-Urban, (6) Top-Urban households in MJ/Rs.

S. No.	Group	(1)	(2)	(3)	(4)	(5)	(6)
INDIRECT							
1	Food, Beverages & Tobacco	1.32	0.82	0.49	0.99	0.59	0.33
2	Clothing & Footwear	1.05	1.04	1.01	1.03	1.02	1.01
3	Housing & Household Effects	0.76	0.71	0.66	0.09	0.10	0.13
4	Medical Care & Hygiene	0.76	0.74	0.71	0.77	0.76	0.74
5	Education & Recreation	1.72	1.70	1.70	1.68	1.66	1.62
6	Transport	1.01	1.02	1.00	1.02	1.02	0.97
7	Other Services	0.66	0.65	0.60	0.62	0.58	0.52
DIRECT							
8	Coal & coal products	18.52	14.04	12.22	13.81	10.78	8.84
9	Petroleum Products	8.49	7.68	4.89	7.99	5.67	3.58
10	Electricity	3.54	3.12	2.90	2.85	2.68	2.51
11	Non-commercial Energy	14.46	13.65	12.73	10.66	10.04	9.86
TOTAL		2.19	1.66	1.21	1.39	0.96	0.73

In general, energy intensities of consumption are seen to decrease with increase in expenditure levels across rural and urban households, so that households in the bottom segment have higher intensities over all expenditure categories than those in the middle and top segments. The differences in energy intensities across bottom, middle and top expenditure segments are particularly marked for the categories of direct energy consumption in both urban and rural households. The energy intensities of consumption for most indirect energy categories, other than food, are more constant across expenditure segments. Some of the decrease in intensities with increasing expenditure can be explained also by the decline in the proportion of direct energy expenditure in the total as expenditure rises. The same argument is also responsible for the significant decrease in the intensities of food expenditures from bottom to top expenditure segments in both rural and urban households.

5.3.3.2 Geographic Variables

A distinction on geographic lines between households can be made based on the broad geographic area they live in, that is, whether residing in rural or urban regions, between households residing in different states or administrative areas of the country, or regions of the nation, and between households residing in different urban town sizes. In the following, differences in household energy requirements across rural and urban areas and States of India will be discussed.

Nature of the rural-urban divide

Data on household consumption in the NSS is reported separately for rural and urban[5] areas of the country, largely because there are significant differences in the lifestyles of households residing in these broad geographical areas. Some of these differences have already been presented in the previous sections and it is clear that there are significant differences between rural and urban residents in terms of their household energy requirements as well. Figure 5.6 shows the break up of total household energy requirements per capita for an average rural and urban household. On an average, urban energy requirements per capita are 27% higher than those of rural residents. This is largely a result of higher incomes and therefore higher per capita expenditure in urban areas than in rural areas. According to the survey data, an average urban citizen spent twice as much on household consumption than a rural citizen in 1999-00. To get a clearer picture of the difference between urban and rural areas, the Rural-Urban Disparity Ratio (RUDR), a concept used by Murthy et al. (1997), is calculated for each of the main consumption categories. It basically refers to the ratio of energy requirements of the average urban person to that of the average rural person. These ratios are presented in Table 5.5. Larger differences in the per capita energy requirements across rural and urban households are evident, especially in the case of primary energy requirements for most commercial energy forms. As expected, non-commercial energy is the only category where rural energy requirements are higher than urban requirements. In the indirect energy category, large discrepancies are evident in the energy requirements of most items of household consumption especially, education and recreation, housing and household effects and transport between rural and urban areas.

[5] The official definition of urban areas is based on number of criteria including "(a) the population of the place should be greater than 5000; (b) a density of not less than 400 persons per square km.; (c) three-fourths of the male workers are engaged in non-agricultural pursuits." (GoI 2001).

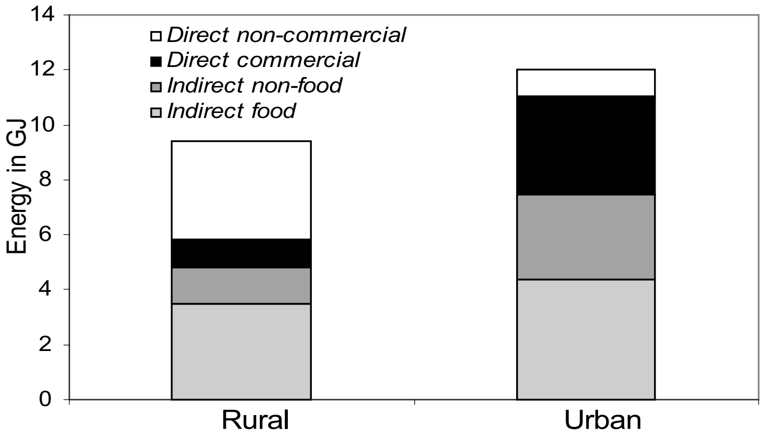

Fig. 5.6. Per capita total household energy requirements for the average rural and urban resident

In addition to examining the differences in the quantum of energy requirements between rural and urban persons, it is also interesting to look at the different demand patterns between these two areas. The share of food energy needs in total household energy requirements for the average rural and urban household are almost the same. However, for most other indirect energy categories, the share in urban areas is at least a percentage point higher than in rural areas. For the case of indirect energy requirements of education and recreation, housing and household effects and transport, the share is significantly higher in urban areas. Large differences are apparent in the case of direct energy needs as well. Here, widely differing patterns of use are visible with rural households still relying almost only on non-commercial energy sources, whereas the share of commercial sources of energy is much higher in urban households. It is also clear that largely as a result of this difference in the patterns of use of direct energy types, rural households are more energy intensive on an average than urban households (see Table 5.5). This is a pattern that has also been observed in studies done for other countries e.g. Australia (Lenzen 1998) and Norway (Herendeen 1978).

Table 5.5. Details of per capita household energy requirements in rural and urban areas (1) percentage to total - Rural, (2) percentage to total - Urban, (3) energy intensity of consumption - Rural, (4) energy intensity of consumption - Urban, (5) RUDR

S. No.	Group	(1)	(2)	(3)	(4)	(5)
INDIRECT		51.13	62.20	0.94	0.71	1.55
1	Food, Beverages & Tobacco	36.85	36.46	0.96	0.86	1.26
2	Clothing & Footwear	4.15	5.15	1.03	1.02	1.58
3	Housing & household effects	0.85	2.23	0.68	0.11	3.34
4	Medical care & Hygiene	3.43	4.65	0.73	0.75	1.73
5	Education & Recreation	2.09	6.60	1.70	1.64	4.02
6	Transport	1.73	3.58	1.01	0.99	2.64
7	Other Services	2.02	3.53	0.63	0.55	2.23
DIRECT		48.87	37.80	10.00	4.69	0.99
8	Coal	0.54	1.33	14.25	11.78	3.16
9	Petroleum Products	7.98	21.55	6.25	4.76	3.44
10	Electricity	2.36	6.94	3.06	2.62	3.75
11	Non-commercial energy	37.99	7.97	13.60	10.33	0.27
	TOTAL	100.00	100.00	1.69	1.05	1.28

The differences in the patterns and quantum of per capita household energy requirements between rural and urban areas when examined for the equivalent expenditure groups reveal the biggest differences to be in the items of direct energy requirements (Fig. 5.7). For the same expenditure levels, rural households on average have higher per capita energy requirements for food items than urban ones but urban households on average have higher per capita energy requirements for other non-food items of indirect energy consumption. As far as direct energy requirements for the equivalent expenditure group are concerned, rural households have higher non-commercial energy consumption, whereas urban households have much higher direct commercial energy consumption.

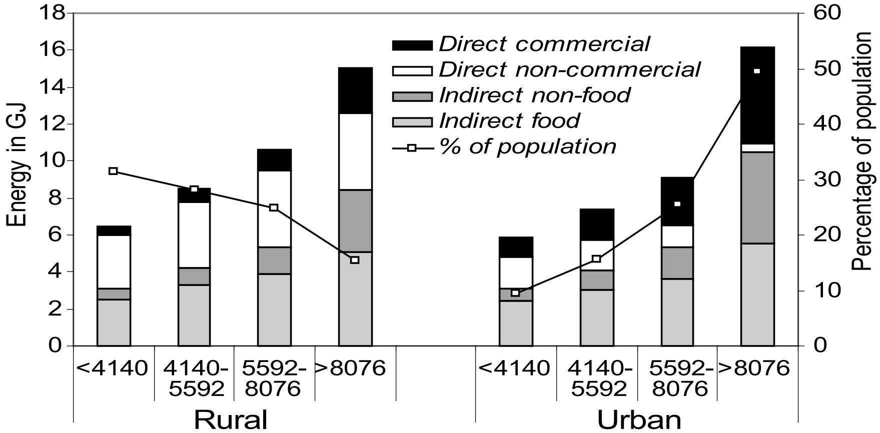

Fig. 5.7. Per capita total household energy requirements for the rural and urban expenditure groups

Differences among major states

India is subdivided into administrative units known as states and union territories. In 1999, the country was divided into 32 states and union territories. Results pertaining to 16 of the major states[6] (defined as those that had a sample population not less than 1% of the total sample population size) are described. Based on the sample data, the total population of these 16 States comprised 95% of the total population of the country for that year.

It is interesting to note that the pattern of total household energy requirements per capita for different states reflects, to a great degree, the general level of development of these states. Figure 5.8 shows the break-up of average household energy requirements for the major states. In terms of total per capita incomes, the ordering of the states does not exactly follow their order based on their average per capita total household energy requirements. This confirms the suggestion that there are factors other than income that affect the level of development of a region and the level of energy requirements of its population. A number of studies that examine inter-state differences and experiences in reducing poverty levels (e.g. Ravallian and Datt 1995; Harriss 2000) have been undertaken for India. Many of these studies tend to divide states into low, middle and high in-

[6] See Table 5B-3 at the end of the chapter for a list of the major states and the state codes used.

come states. Table 5.6 below provides such a break up by income levels and per capita energy requirement levels for the 16 major states of India. It shows that the correspondence between average income levels and average per capita energy requirements is not direct. A number of different factors are responsible for this difference, including differences in the levels of education, levels of poverty, rural-urban differences, and a host of other socio-economic and geographic factors, which are not dealt with in detail here. However, it is interesting to highlight that when looking at the break up of total energy requirements, by state, the states that have the highest per capita income levels have on average the highest proportion of non-food indirect energy requirements, and proportionally lower food energy requirements than the low income states. Additionally, higher per capita income states tend to use a higher proportion of commercial energy rather than non-commercial energy. This too might be responsible, in part, for some states with relatively higher income levels having relatively lower per capita energy requirements, as there are large differences in the efficiencies of fuel use between commercial and non-commercial forms.

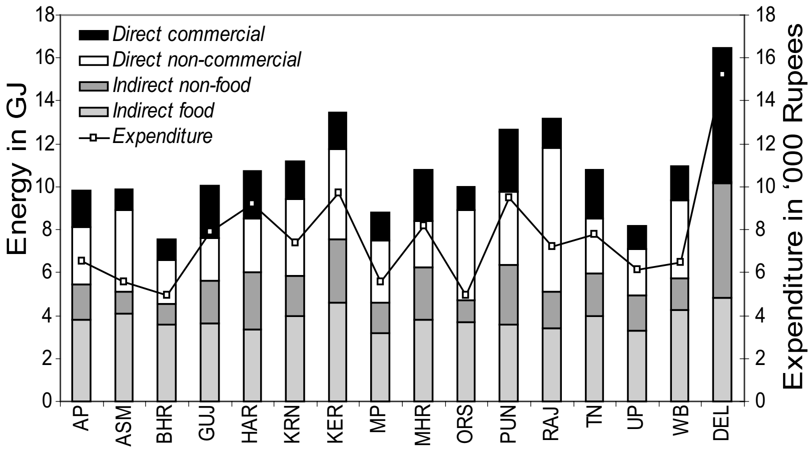

Fig. 5.8. Patterns of total per capita energy requirements in major states of India

Data for the state of Delhi have been included in the results presented here as it represents a very large and rapidly growing metropolitan area and reflects the lifestyles of those living in such areas. The total household energy requirement per capita is one of the highest of all states in Delhi. There is also a relatively much higher share of non-food indirect energy and commercial requirements as compared to non-commercial direct energy use on average for residents of Delhi. These results appear to validate findings from other studies that show a high degree of positive correlation between city size and direct energy requirements (e.g. see Kulkarni et al. 1994; Sathaye and Meyers 1985 for a more detailed description of the relationship between size of urban town and energy demand).

Table 5.6. Categorisation of major states based on their development level as reflected by per capita income and energy requirement levels

	Low	Middle	High
Per capita income categories*	RAJ, BHR, UP, MP, ORS, ASM	AP, KRT, KER, TN, WB	GUJ, MHR, PUN, HAR, DEL
Per capita total household energy requirements	AP, ASM, BHR, MP, ORS, UP	GUJ, HAR, MHR, TN, WB	KRN, KER, PUN, RAJ, DEL,

Source: *Per capita income categories as described in Harris (2000).

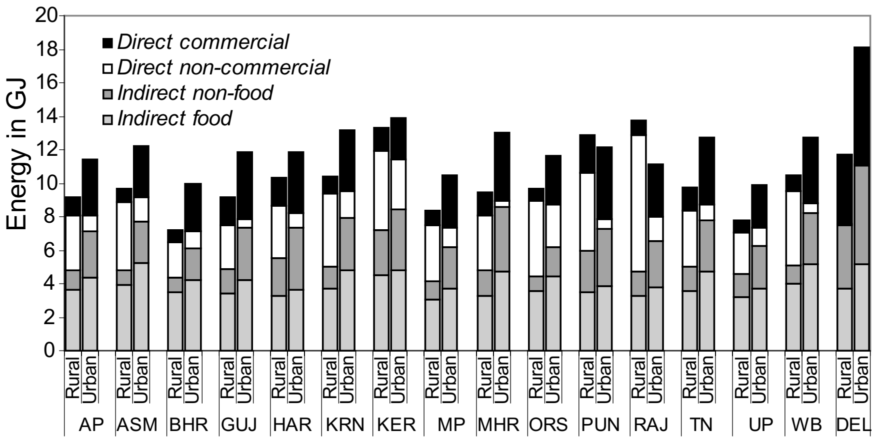

Fig. 5.9. Average rural and urban energy requirements by state

Rural-urban differences vary widely across different states. As may be seen in Fig. 5.9, in general, more developed states like Kerala (KER) exhibit the least differential in energy requirements between rural and urban areas. This is to be expected, as it is a well established fact that Kerala is one of the most socially progressive and equitable states in India. The really backward states of India like Bihar (BHR), Uttar Pradesh (UP) and Madhya Pradesh (MP) show relatively larger disparities between rural and urban average energy requirements. In the case of some states, like Punjab, the relatively equal average per capita total energy requirements across rural and urban households, mask large variations in the pattern of energy requirements particularly, differences in the amount of commercial and non-commercial direct energy requirements.

5.3.3.3 Demographic Variables

The key demographic variable that has the largest influence on the energy requirements of households is the household size. In addition, however, there are many other demographic variables such as level of education, age of the head of the household, sex of the head of the household, employment type, etc. that affect the pattern and level of energy requirements of different households. In what follows we discuss the relationship between a few of the more important demographic variables and energy requirements.

Household size

In general, total energy requirements are lower for persons living in larger households. However, in the case of urban households, the average per capita direct energy requirements increase from single person households to those with two residents. This is probably because most persons classified as single persons in urban areas belong to the poorest homeless category. In all other cases, however, an increase in the size of the household reduces total per capita household energy requirements. On average, the addition of one member to the household reduces total per capita household energy requirements by about 0.9 GJ per year. The biggest difference in total per capita household energy requirements is evident between the average single member households and couples or households with two members, the difference being 2.2 GJ. From Fig. 5.10 it is also clear that household size has an inverse relationship with per capita monetary expenditures. People residing in larger households have lower per capita total expenditures on average, which is also in part responsible for their lower per capita total energy requirements. In general, one observes significant economies of scale in household consumption, both in terms of direct and indirect energy.

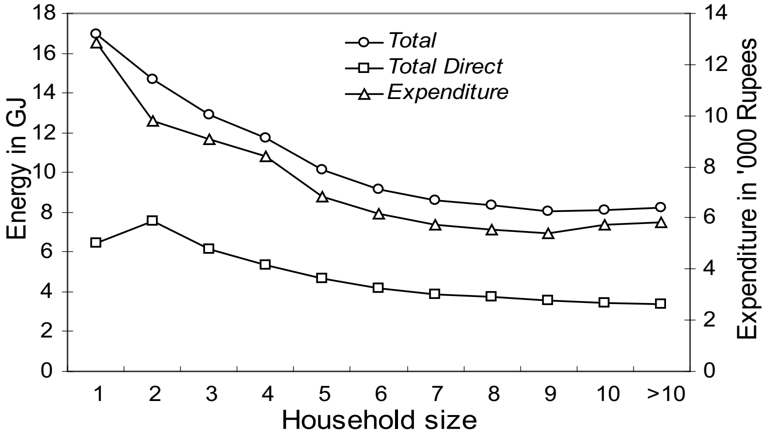

Fig. 5.10. Per capita direct and total energy requirements for different household sizes

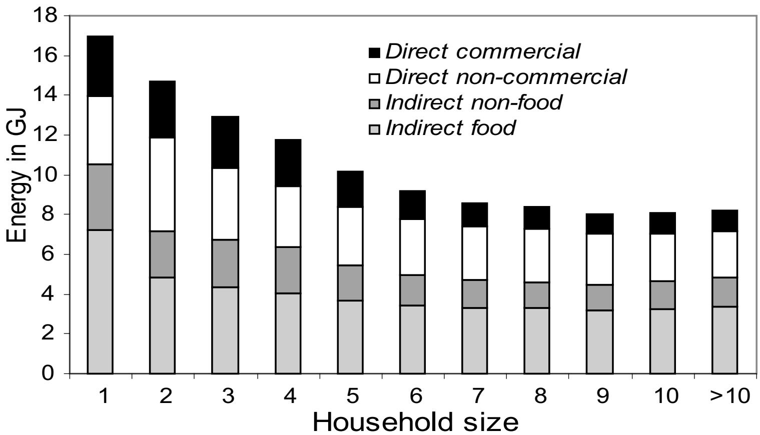

Fig. 5.11. Pattern of per capita total household energy requirements for inhabitants living in different size households

The energy intensity of household consumption for different household size groups does not show any definite trend and no such trend is visible in Fig. 5.11 in the break-up in total household energy requirements for these different groups. This seems to suggest that people in larger households buy the same range of commodities and services as people in smaller households, but only in smaller proportions. Or in other words, the average per capita household spending and energy requirement pattern does not change in any structural way with a variation in household size.

Sex of the head of the household

The majority of households are male headed, in India but the sample data reveal that females head about 7% and, on average, members of these households have a higher total energy requirement than those of male headed households (see Fig. 5.12). This may also be due to the fact that on average female headed households are smaller, in terms of the total number of household members, than male headed households. In terms of the pattern of energy requirements, no big differences between male and female headed households are observed. The largest divergence between female and male headed households is in terms of direct non-commercial energy requirements and the indirect food energy requirements, both of which are higher in female headed households.

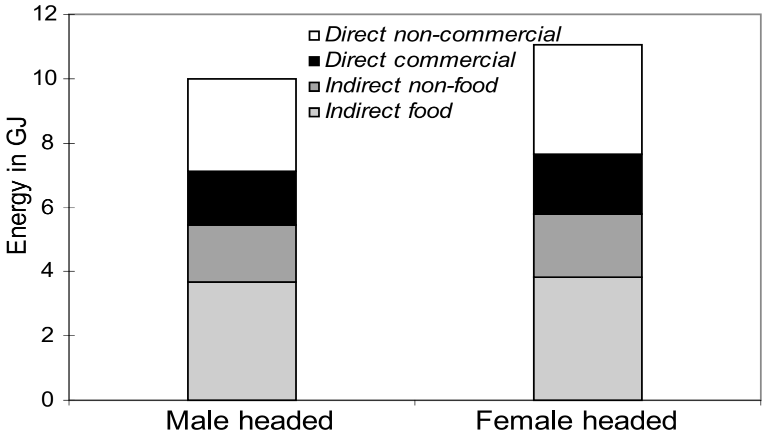

Fig. 5.12. Pattern of per capita household energy requirements for male and female headed households

Employment of the head of the household

The survey data distinguish between a number of different employment types for the head of the household, three types in particular are described here – those where the head of the household is self-employed or engaged in some kind of household enterprise, those that are salaried employees, those that work as casual labour and finally those that are self-employed in agriculture. Households falling in these categories make-up about almost 90% of the total population, and hence comprise the most important employment categories. As seen from Fig. 5.13, households where the head is a salaried employee enjoy the highest level of energy requirements. Next follow those that are self-employed in non-agricultural enterprises, whereas those that work as labourers have the lowest energy requirements. In addition, members of salaried households tend to use a much higher proportion of direct commercial energy than the other types of households. This is also due to the fact that salaried households live in urban areas. Households that are engaged in agricultural activities, on the other hand live in rural areas and have a higher non-commercial energy use, compared to other households.

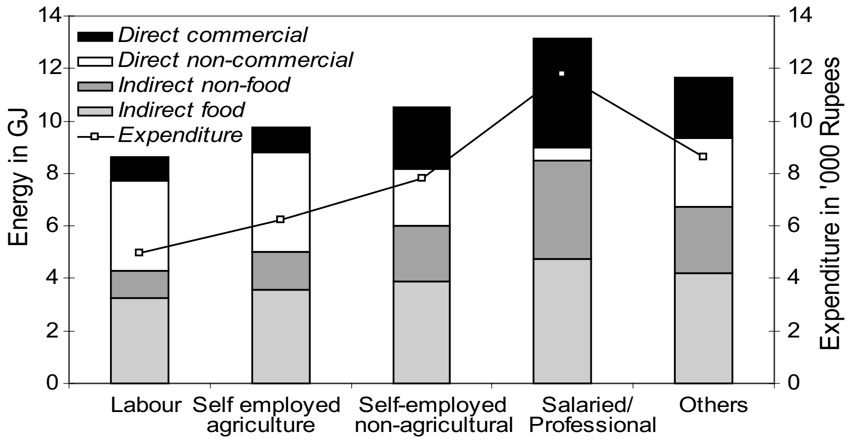

Fig. 5.13. Per capita energy requirements for different employment categories of the head of the household

Age and education of the head of the household

The age of the head of the household provides an indication of the stage in the family life cycle of the household and is another demographic variable that could influence the pattern of energy requirements. Figure 5.14 shows the differences in average per capita energy requirements across different categories of age of the head of the household. The total per capita energy requirements of households appear on average to be lower for very young households (<35 years) but then steadily rises to peak for households in the 45-50 age bracket. There is a slight dip in the total for the subsequent age group, but thereafter the total appears to be fairly constant for those households headed by persons between the ages 56-80. There is a sharp increase for the last age category, but since less than 1% of the total population falls within this category, it is difficult to say how reliable this trend may be. The trend is the same when one looks at per capita expenditures across age groups and appears to be consistent with the expected development of productivity by age, which peaks for persons in the middle age group.

Differences in the pattern of household energy requirements across different age categories are not that evident. No clear trends are apparent other than a slightly rising share for the average non-commercial direct energy requirements per capita with age.

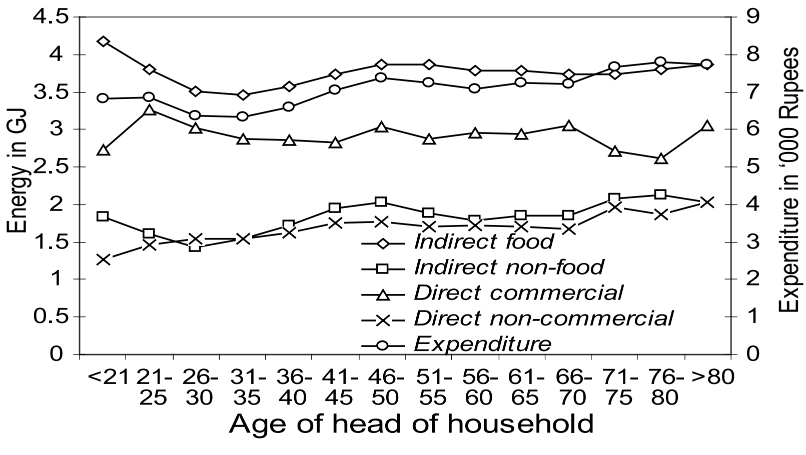

Fig. 5.14. Per capita energy requirements for different age categories of the head of the household

One might expect the education of the head of the household to also have an influence on total energy requirements per capita and Fig. 5.15 shows that the average expenditure and energy requirements are higher for those households with higher level of education of the head. What is of particular interest are the widely divergent patterns of energy requirements across households with differing education levels of the head. Households where the head is more educated use significantly more and an increasing share of commercial direct energy in contrast to diminishing non-commercial direct energy. In addition, the share of indirect non-food energy requirements rises significantly for the more educated households. Both these trends suggest the greater integration of more educated households in the market economy so that their higher incomes are translated in increased consumption of more efficient modern forms of direct energy and higher purchases of non-food items of indirect consumption.

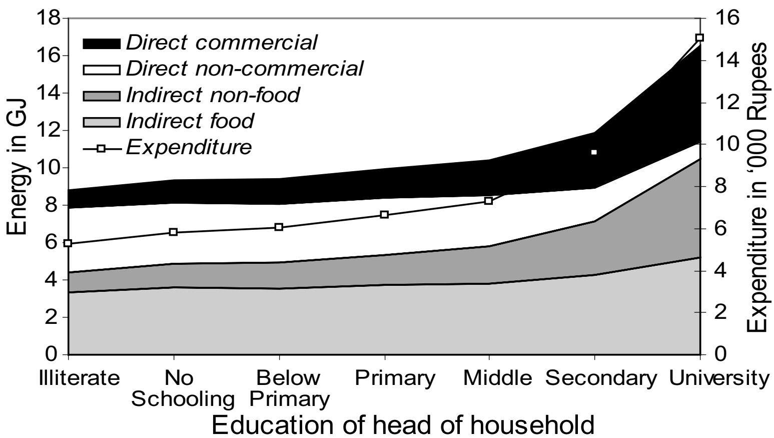

Fig. 5.15. Per capita energy requirements for different education categories of the head of the household

5.3.3.4 Household Amenities

Household amenities includes built infrastructure such as roads, electric power lines and water systems, or in other words, the basic installations and facilities on which the continuance and growth of the community depends. The idea behind examining such infrastructural variables is to gain an understanding of how access to better or more developed markets and infrastructure affects total household energy requirements. Two variables pertaining to household amenities and access to energy sources, in particular, are examined in this section, in relation to total household energy requirements per capita – the main source of cooking energy used by the household and the main source of lighting energy used by the household.

Table 5.7. Total per capita energy requirements for households with different household amenities

		Average household size	Average per capita expenditure	Average per capita total energy	Average per capita direct energy	% of total population
		numbers	in Rs.	in GJ	in GJ	in %
Source of cooking energy	Coke/coal	5.6	7268	14.4	4.1	3%
	Fuelwood	6.3	5503	11.9	5.0	63%
	LPG	5.9	12817	18.4	5.3	16%
	Dung	7.2	5764	9.1	2.2	10%
	Kerosene	5.1	8426	13.1	3.8	6%
	Others	6.3	5817	9.3	2.0	3%
Source of lighting energy	Kerosene	6.3	4943	10.7	4.2	40%
	Electricity	6.1	8290	14.2	4.9	59%
	Others	6.4	6502	12.3	4.7	1%

Table 5.7 shows that households using Liquid Petroleum Gas (LPG) have on average higher per capita expenditures and total household energy requirements per capita as compared to all other households. Kerosene users follow LPG users in terms of total household energy requirements; while fuelwood and dung users, or in other words those households that use non-commercial energy sources for cooking have on average lower per capita expenditures and energy requirements. Looking at the data for the difference between households using different energy sources for lighting, it is evident that households are about equally divided between kerosene users and electricity users and electricity users on average have higher energy requirements and expenditures per capita. Thus, expenditure levels and energy requirements seem to be strongly related with the type of fuel used by households. This is a theme that is further explored in the next chapter, which discusses results related to direct energy requirements and indirect food energy requirements of households in more detail.

5.4 Regression Analysis of Cross-sectional Variations

The previous sections examined several factors that determine variation in total per capita energy requirements across different household groups using survey data from 1999-00. The analysis, presented graphically, is suggestive of several key factors that affect variations in energy requirements. However, the influence of individual variables was not isolated and the extent to which they influenced energy requirements was not quantified. The graphical analysis can also be supplemented by statistical results that quantify some of these relationships. In order to do so, an empirical regression analysis was undertaken to determine the extent to which different variables are responsible, individually and jointly, for variation in per capita total energy requirements in India for the year 1993-94 by Pachauri (2004). The analysis provides estimates of the expenditure and household size elasticity of total per capita energy requirements and other coefficients for variables that affect per capita household energy requirements. Sample survey data for the year 1993-94 was chosen to undertake this analysis as this was the most recent year of survey data with a large enough sample, devoid of any controversy regarding the sampling period, and that included questions regarding the dwelling size and other dwelling characteristics. Data regarding the latter were not elicited in the 1999-00 household consumer expenditure survey.

In what follows, key results from the study by Pachauri (2004) are highlighted however, for details regarding the data and methodology, the reader is referred to the paper. Estimation results for the parameter estimates are reproduced in Table 6.1. The largest coefficients in the model are for the economic variable – per capita expenditure. The expenditure elasticity estimate calculated is in the range of previous household studies for the US (Herendeen and Tanaka 1976; Herendeen et al. 1981), Norway (Herendeen 1978), Netherlands (Vringer and Blok 1995), Australia (Lenzen 1998) and Denmark (Wier et al. 2000). The expenditure elasticity estimated for India from Pachauri's (2004) analysis is 0.68, implying that a one percent increase in per capita expenditure would result in a 0.68% higher per capita energy requirement. The results for India lie at the lower end of the scale as expenditure elasticities from the other studies are in the range of 0.72-0.9. This is possibly due to the fact that expenditure elasticity calculated for India is with respect to, both commercial and non-commercial, total energy whereas that estimated in developed countries does not take into account non-commercial energy. Expenditures on non-commercial energy are often made in kind so are very low or even zero.

Thus, it could be expected that non-commercial energy use is less dependent on expenditure than commercial energy use. Non-commercial energy is also used much less efficiently than commercial energy and thus provides less service per unit of physical energy consumed. The household size elasticities from the different studies quoted above appear to be lower than that for India, which is estimated at -0.53.

Table 5.8. Parameter estimates from the multivariate regression analysis

Variable	Parameter estimates (t-ratio in paren-	Exponential Coefficients for dummy
(Constant)	4.421*** (167.800)	
Total per capita monthly expenditure in Rupees	0.676*** (361.002)	
Regional Dummy variable for persons living in a Central State	-0.162*** (-53.479)	0.850
Regional Dummy variable for per-sons living in a Northern State	-0.033*** (-8.216)	0.967
Regional Dummy variable for persons living in a Western State	-0.095*** (-29.007)	0.909
Regional Dummy variable for persons living in a Southern State	-0.018*** (-6.333)	0.982
Dummy variable for urban households	-0.126*** -56.395	0.881
Total area of the household in square feet	0.028*** (23.574)	
Dummy variable for those living in a single-unit house	0.058*** (22.558)	1.060
Age of the head of the household	0.093*** (30.22)	
Household size	-0.530*** (-75.058)	
Dummy variable for households where the head is illiterate	0.019*** 9.59	1.019
Dummy variable for non-vegetarians	0.030*** (13.423)	1.030

Source: Reproduced from Pachauri (2004).

The regression analysis also shows that several other variables such as geographic dummy variables[7], level of urbanization, age of the head of the household and literacy of the head of the household have a significant effect on total per capita energy requirements. Household dwelling area exhibits a positive effect on total household energy requirements and the coefficient for the dummy variable for type of household dwelling (single-unit versus flats/chawls) is also positive implying that compared to those who live in flats or chawls, those in single-unit or independent housing units have 6% higher per capita energy requirements. Finally, the variable representing food preferences (non-vegetarian versus vegetarian) is also significant and positive, which implies that vegetarians have (3%) lower per capita energy requirements than non-vegetarians. This result seems intuitive given the relatively high energy intensity of meat consumption and is similar to that reported from most other studies on food energy requirements (Carlsson-Kanyama 1999; Kramer et al. 1998).

5.5 Discussion and Conclusions

Several interesting trends regarding the energy requirements of household consumption in India are presented in this chapter. A number of factors such as broad geographical location, income levels, household size, employment, gender, and infrastructural and dwelling characteristics of the household are shown to have a bearing on the per capita quantum and pattern of energy requirements of consumption. These findings could be of relevance to policy-makers, planners, producers and traders, as they provide important insights into likely future requirements. While results in the previous chapter indicated that improvements in the energy efficiencies of productive sectors could have an important impact on slowing the increase in total or per capita household energy requirements, trends in this chapter highlight the importance of structural and lifestyle changes in arresting the future increase in energy needs of the country.

Future increases in income levels of individuals and other demographic changes such as a move to smaller household sizes, are likely to lead to large increases in future energy requirements. To some extent these increases are warranted to improve lifestyles, especially of people who are still living in abject poverty. However, these results also reveal the scale

[7] States included in each of the regions for which dummy variables are created in the model are listed in Table 5B-3 in the chapter appendix.

and diversity of India. Though the majority of the population still belongs to the middle class, with low average income levels and relatively low per capita energy requirements, the country has a small but very fast growing upper class, whose lifestyles tend to emulate those of the rich in the western world. In fact, transitions in lifestyles and consumption patterns observed in the developed world at much higher income levels are taking place at relatively lower income levels in developing countries like India. At the same time, some trends also give rise to more optimism, such as the still low per capita energy requirements of meat, a reflection of Indian cultural and religious beliefs.

In the face of growing carbon emissions in India, predicting future growth of energy requirements for households becomes an interesting issue. Increases in per capita expenditures are expected to continue. However, to what extent and in what direction the structure of expenditures will change and energy intensities of consumed goods and services vary is yet an open question.

Appendix 5A: Corrections to NSS Data for Underestimation of Dung Use

In northern states of India, particularly, Uttar Pradesh, Haryana, Punjab, Himachal Pradesh and Bihar, there are many rural households that depend on cattle dung, particularly in certain seasons of the year, for all or part of there cooking energy needs. Data from the NSSO however, does not include any information on the quantity of dung used. Information is collected only on whether the household uses dung or not, but no information on the amount of dung used is recorded. This leads to a problem of underestimation of the energy consumption of such households. In general, one observes a declining trend in the number of dung users in India over time and as income levels increase. Estimates of dung use from the literature vary significantly across sources, space and time. An early national level study for the year 1978-79, shows the proportion of households using dung cakes as 21 % on average for rural areas and 4 % on average for urban areas (Natarajan 1985). Data from the latest quinquennial round of the NSSO for the year 1999-00 shows the percentage of households using dung cakes as 47 % in rural areas and 10 % in urban areas, when one looks at responses to the question regarding whether the household incurred any expenditure (in money or time) on dung. However, if one analyses the responses to the question pertaining to the main source of cooking energy used by the household, then the percentage of rural households using dung as their main source of cooking energy in 1999-00 is only 3 %, whereas among urban households less than 1 % claim to use dung as their main source of cooking fuel. Estimates regarding the amount of dung energy used by different households are even less forthcoming. Ravindranath and Hall (1995) list estimates from different village level studies from different regions of the country. Dung use as a percentage of total energy use varies from about 11 to 65 % depending on the specific village. Estimates in Joshi et al. (1992) provide mean estimates of dung used by different agro-climatic regions of the country. The estimates they provide vary from between 0.01 kg/capita/day (0.137 MJ/capita/day in primary energy terms[8] or 0.015 MJ/capita/day in useful energy terms[9]) to 1.29 kg/capita/day (17.7

[8] Assuming an energy conversion factor for dung cakes of 1tonne = 13.7 GJ (Ravindranath and Hall 1995, pp. 15). The factor used in this work is 1 tonne = 10.0 GJ as stated in Sengupta (1993).

[9] Assuming an efficiency of 11.1% for a traditional dung stove (Ravindranath and Hall 1995, pp. 30).

MJ/capita/day or 1.97 MJ/capita/day). This range of dung use is similar to that reported from the selected village case studies cited in Ravindranath and Hall (1995) as well. Estimates of per capita useful energy consumption for rural households from the NSSO for the year 1999-00 are 2.24 MJ/capita/day. This suggests that dung use ranges from less than 1 % to 88 % of total useful energy consumption of rural households.

Using estimates from Joshi et al. (1992) for quantity of dung use in different agro-climatic regions, with data from the NSSO on percent of persons reporting dung use from Round 55 of the survey covering the year 1999-00, estimates are made to correct for the underestimation of dung consumption. Mean estimates of average daily consumption per state from Joshi et al. (1992) were used to calculate the amount of dung used by those households that report positive dung consumption in the NSSO survey. The analysis redone in this manner using primary energy estimates suggests that rural estimates per capita are on the average underreported by between 14-15% if one ignores dung use. Therefore, a correction for this factor is necessary in order to accurately estimate biomass fuel use by households.

Appendix 5B: Appendix Tables

Table 5B-1. Energy intensities in 1999-00 of the 55 household consumption items in MJ/Rs.

S. No.	Group	Intensity
1	Cereals	1.69
2	Gram	0.50
3	Cereal substitutes	0.98
4	Pulses and pulse products.	0.95
5	Milk and milk products.	0.09
6	Edible oils	0.93
7	Meat, eggs and fish	0.19
8	Vegetables	0.45
9	Fresh fruits	0.45
10	Dry fruits	0.94
11	Sugar	0.60
12	Salt	0.45
13	Spices	0.45
14	Beverages	1.23
15	Processed foods	0.94
16	Pan	0.45
17	Tobacco	0.57
18	Intoxicants	1.26
19	Coke	**1.05**
20	Firewood & chips	**1.00**
21	Electricity	**1.14**
22	Dung cake	**1.00**
23	Kerosene	**1.66**
24	Coal	**1.05**
25	Coal gas	**1.05**
26	LPG	**1.05**
27	Charcoal	**1.02**
28	Other oil	**1.66**
29	Methylated spirit	**1.66**
30	Gas	0.07
31	Other fuel & light	**1.66**
32	Diesel	**1.66**

33	Petrol	**1.66**
34	Clothing	1.66
35	Footwear	1.11
36	Amusement	0.52
37	Personal care items	0.47
38	Toilet articles	0.97
39	Sundry articles	0.91
40	Consumer services	0.91
41	Conveyance (excl. Fuels)	0.47
42	Rent	1.04
43	Consumer taxes & cesses	0.05
44	Educational expenses	2.02
45	Medical expenses -medicines	0.83
46	Medical expenses -services	0.43
47	Furniture & fixtures	0.27
48	Goods for recreation	0.82
49	Jewellery & ornaments	0.97
50	Household utensils	1.08
51	Cooking & household Appliances	0.92
52	Personal transport equipment	0.87
53	Therapeutic appliances	0.97
54	Other personal goods	0.86
55	Residential bldg, land & other durables	0.76

Note: Figures in bold are in MJ/MJ

Table 5B-2. Major states and state codes

S.No.	State	Code
1	Andhra Pradesh	AP
2	Assam	ASM
3	Bihar	BHR
4	Gujarat	GUJ
5	Harayana	HAR
6	Karnataka	KRT
7	Kerala	KER
8	Madhya Pradesh	MP

S.No.	State	Code
9	Maharashtra	MHR
10	Orissa	ORS
11	Punjab	PUN
12	Rajasthan	RAJ
13	Tamil Nadu	TN
14	Uttar Pradesh	UP
15	West Bengal	WB
16	Delhi	DEL

Table 5B-3. State codes and regions

North East	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, West Bengal	ARP, ASM, MPR, MEG, MIZ, NAG, ORS, SIK, TRI, WB
South	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Andaman & Nicobar Islands, Lakshwadeep, Pondicherrry	AP, KRT, KER, TN, A&N, LKS, PON
West	Goa, Gujarat, Maharashtra, Rajasthan, Dadra & Nagar Haveli, Daman &Diu	GOA, GUJ, MHR, RAJ, D&N, DIU
North	Harayana, Himachel Pradesh, Jammu & Kashmir, Punjab, Chandigarh, Delhi	HAR, HP, J&K, PUN, CHD, DEL
Central	Bihar, Madhya Pradesh, Uttar Pradesh	BHR, MP, UP

Chapter 6: Energy Requirements and Well Being

6.1 Introduction

Previous chapters of the book have focused on how to combine aggregate input-output data and energy flows to calculate energy intensities of broad sectors and use these calculated intensities in conjunction with micro-level disaggregate household survey data to analyse variations in direct and indirect energy use patters across different types of households. Households were distinguished in terms of their location (rural/urban, different states), economic status, demographic characteristics, educational and employment status, and different attributes of the dwelling area they live in. This chapter focuses, more specifically, on linkages between energy and well being at the household level. Well being is defined broadly in terms of economic status, socio-economic, and health parameters. In particular, variations in patterns of direct energy requirements and indirect energy requirements of food items, across different groups of households are examined. The two dimensions of direct energy use that are examined are access to different sources and actual use. Access to clean and efficient direct energy sources at the household level is assessed in relation to location and expenditure levels and trends in terms of the patterns of direct energy consumed are examined. Patterns of food consumption are seen through the lens of indirect energy requirements of food consumption in households. These indicators, in turn, are looked at in relation to monetary measures of well being and poverty such as per capita expenditures, sufficiency in terms of adequate nutrition or caloric content of food consumed, and other measures of human development and well being such as health and education.

Energy use and human well being are inextricably linked and the kinds of energy services people consume have concrete and tangible consequences for their quality of life. Some of these linkages have been touched upon in Chap. 2. While Sect. 2.5.2 discussed some of the negative environmental and social implications of energy use, in this chapter, an area of research, that has so far received relatively little attention in the literature, on how energy access and use are related to several different dimensions of human well being is examined.

6.2 Direct Energy Use

In the previous chapters, results on direct energy use were discussed in terms of primary energy, so that they were comparable with the estimates for indirect energy use. However, in this chapter, results are presented in terms of direct final energy use of households. The previous chapter highlighted the large variations in the use of different types of fuels, both in terms of quantum and pattern, across rural and urban households as well as the variations across households with different levels of household expenditure or income. In what follows, the percentage of total population dependent on different fuels and electricity will be examined in order to understand the nature and direction of energy transitions taking place within households and the implications of these changing patterns of direct energy use for the total per capita direct energy use and total aggregate direct use. In addition, the relationship of direct energy use with monetary and other indicators of well being is examined.

6.2.1 Changing Patterns of Direct Energy Use: 1983-2000

In Chap. 5, cross-sectional variations in direct and indirect energy requirements for households were presented using NSS data from Round 55 of the household consumer expenditure survey. Round 55, which was conducted in 1999-00, is the most recent quinquennial round in which information was collected from a very large sample of households representing the entire area of the country. In what follows, data from the previous quinquennial rounds of the expenditure survey from Round 50 (1993-94) (NSSO 2000), Round 43 (1987-88) (NSSO 1990) and Round 38 (1983) (NSSO 1985) are also used in order to examine the trends in access and consumption of direct energy by households over this time period. While data from the later quinquennial rounds of the survey included information on household energy consumption of petrol and diesel fuels for transportation as well, Round 38 does not include this information and therefore in what follows, results pertaining mostly to the direct energy consumption for cooking and lighting purposes alone, are presented.

Figure 6.1 shows trends in direct energy use for cooking and lighting across the different NSS rounds for rural and urban areas. As can be seen from the figure, there was an increase in absolute terms in the use of all direct fuels and electricity, except for coal/coke during the period from 1983 to 2000. In rural areas, non-commercial biomass energy provided the bulk of direct energy used by households in 1983 (91%) and this share declined only slightly to 85% by 2000. In urban areas, the shifts and transitions in energy use are starker. In 1983, just over 60% of total direct energy needs of urban households were met from biomass sources but by 2000 the share of biomass in direct energy consumption had dropped to under 30%. Simultaneously, the share of LPG in total direct energy consumption for urban households increased from under 0.5% to 22% over the same time period and the share of electricity increased from 7% to 28%.

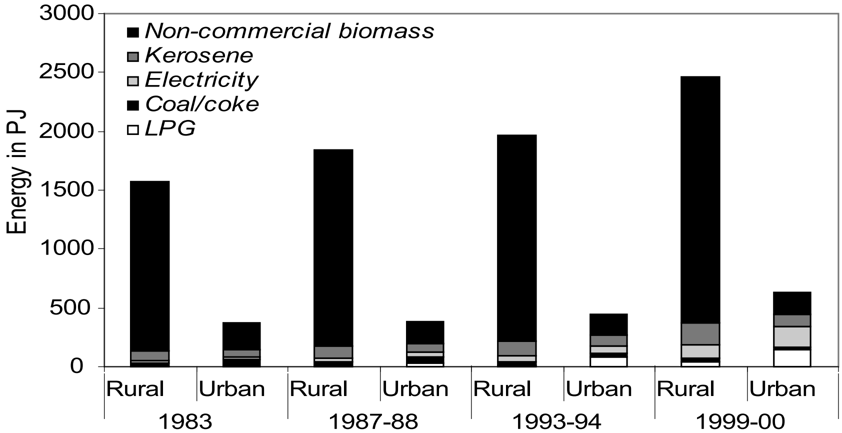

Fig. 6.1. Aggregate trends in direct final household energy use in rural and urban areas

The period from 1983 to 2000 witnessed an increase in total population from approximately 734 to 983 million with increasing levels of urbanization. Thus, in order to take these changes in to account, Fig. 6.2 presents final direct energy use in rural and urban areas in per capita terms for the same time period. The shifts in shares of different fuels and electricity in total direct energy consumption are more clearly evident from this graph. The total average per capita final direct energy use in rural areas is higher than that in urban areas, for all years, because of the much higher levels of non-commercial biomass energy used in rural areas. As can be seen in the figure, about 85% of total direct final energy use in rural areas is still met by non-commercial biomass energy sources. The remaining 15% is comprised largely of kerosene and electricity, though in volume terms the use of these commercial fuels is still very low in rural areas. In urban areas, in contrast, non-commercial fuel use in 2000 was only about 40% of total direct energy use. Commercial energy forms, such as kerosene, LPG and electricity are now more widely distributed and also consumed in larger amounts by urban households. As a result of the changing patterns of energy consumption, urban direct final energy use per capita decreased between 1983 and 1993-94, largely on account of non-commercial biomass energy being substituted by more efficient commercial energy forms. Between 1993-94 and 1999-00, direct energy use per capita in urban households increased due to the very rapid growth of electricity and LPG use during this period. It should be noted that there are significant regional variations across states of India in the pattern of direct energy use as well. Some of these changes have already been discussed in the previous chapter. Further analyses of regional differences in direct energy use are presented in Sect. 6.2.3.

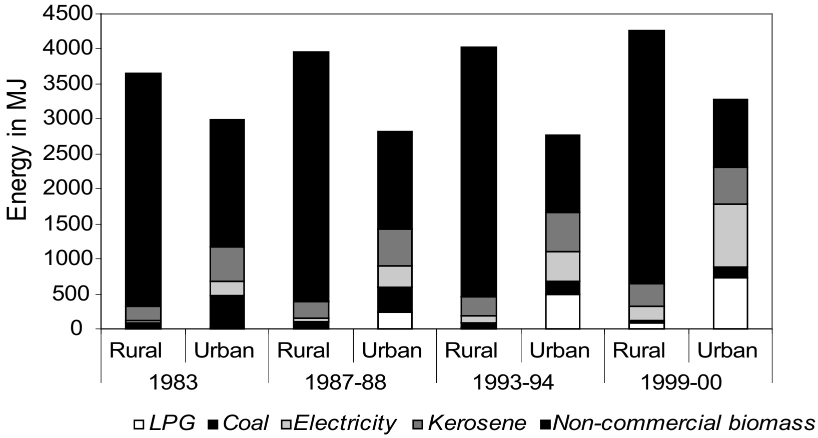

Fig. 6.2. Pattern of direct final energy use for the average rural and urban resident

Some authors have argued that to compare non-commercial and commercial energy types in primary or final energy terms, might imply an inordinately dominant share for non-commercial energy as such energy forms are used in a highly inefficient manner. This implies that, in principle, these non-commercial biomass energy types could be replaced by much smaller quantities of fossil fuels. It is, therefore, important to take into account the average end-use efficiencies while summing across different energy carriers used for cooking by households. In addition, while relating energy use with well being, there is greater value in looking at the services that the energy provides rather than the actual primary or final amounts of energy used. The problem for the analyst is that these so-called energy services can not often be measured in energy units alone. They also require more than the direct energy of the energy carriers themselves for their delivery. Thus, there is no way of distinguishing energy services from other services and products. In the absence of the possibility of directly measuring energy services, a promising approximation is to measure consumption at the level of useful energy.

As a general exercise, data on direct energy use in the household surveys was converted to end-use or useful energy terms for the year 1999-00 by using the appropriate average energy efficiencies for the different cooking and lighting fuels and electricity[1]. The pattern of direct energy use in useful energy terms was then analysed in order to compare it to that of direct final energy use described above.

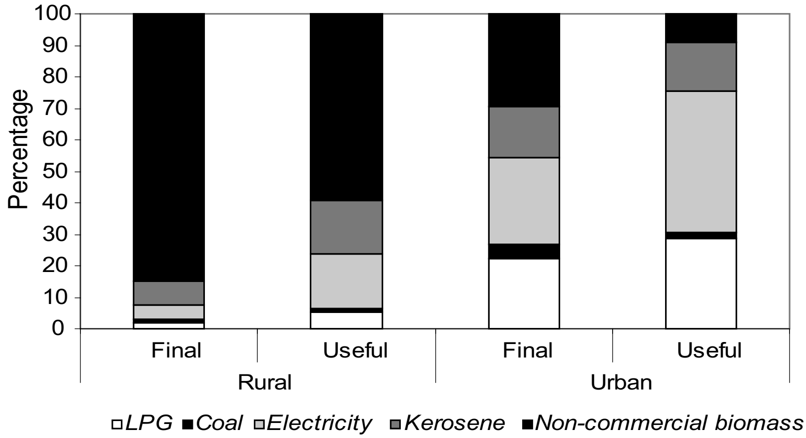

Fig. 6.3. Pattern of use of direct end-use and useful energy in rural and urban areas

[1] This is of course a simplification as the efficiencies of end-use technologies used by households could vary significantly (e.g. an efficient wood stove maybe up to three times as efficient as a traditional wood stove). See appendix table 6A-1 for values of the average efficiencies assumed.

Figure 6.3 shows a comparison of the share of different energy types in total end-use or useful energy and final energy use of households for the year 1999-00. The share of more modern and efficient fuels like kerosene, LPG and electricity is much larger for both the rural and urban samples, when end-use energy is considered as compared to final energy. In fact, the share of non-commercial energy is less than 9% for the urban sample when the efficiencies of the different energy types are taken into account, whereas it is about 30% when one considers total final energy use. These end-use statistics are important especially when assessing household energy demand as well as to understand energy services demanded by households. Improving the end-use efficiency of fuels is an important way forward for meeting the conflicting objectives of increasing the quality of life of people while reducing adverse environmental impacts associated with energy production and use.

Trends regarding shifts in the use of different direct energy types over the period of 1983 to 2000 can also be analysed by examining the percentage of users of different fuels and electricity over time. Table 6.1 shows the usage of different energy types by rural and urban households over this period. The fact that the columns don't sum to 100% provides evidence of the fact that most households use multiple fuels. Major changes are evident in the usage of different energy types across rural and urban households over this period. The percentage of LPG users increased from 9% to 47% in urban areas. However, in rural households, the uptake of LPG has been much slower and even in 2000 only 6% of the rural population used this fuel. Electricity usage has also changed dramatically over this period. Whereas 15% of the rural population and 58% of the urban population was using electricity in 1983, by the year 1999-2000, 47% of the rural and 84% of the urban population were doing so. Kerosene usage is very widely prevalent. While the share of population using this fuel has not changed over time in rural areas, its share declined from 92% to 75% in urban households over this period. The share of non-commercial energy users (both wood and dung) in rural areas also did not change during this period. However, in urban areas, the percentage of the population using non-commercial biomass energy forms decreased significantly between 1983 and 2000.

Results and analysis relating to the percentage of persons having access to different energy types and using different combinations of direct energy are discussed in Pachauri et al. (2004) and Pachauri and Spreng (2004). Their analysis based on the NSSO household survey data shows that in

1999-00, most households used multiple fuels and about a third of the population used three or more fuels. A combination of kerosene and fuelwood or kerosene, fuelwood and electricity is used by the largest proportion of the population. In urban areas however, the proportion of population using a combination of LPG and electricity has risen significantly, particularly during the decade of the 1990s. Such trends regarding multiple fuel use have been reported from other countries undergoing a process of energy transition, as well. Results from a multi-country study on urban energy transition by Barnes et al. 2005 reports similar trends, as also work by Heltberg (2004) on fuel switching in eight developing nations.

Table 6.1. Percentage of users of different energy types by rural and urban populations

	1983		1987-88		1993-94		1999-00	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
LPG	0	9	1	20	2	33	6	47
Coal/coke	3	21	3	14	2	8	2	5
Electricity	15	58	24	67	36	77	47	84
Kerosene	95	92	96	88	95	83	96	75
Fuelwood	86	61	89	50	88	42	88	35
Dung	53	27	56	24	53	18	52	12

6.2.2 Cross-sectional Variations in Direct Energy Use

In order to analyse the relationship between the pattern of direct energy use and household expenditure, the population in rural and urban areas has been divided into deciles of per capita expenditure using survey data from Round 55 for the year 1999-00. Data on the consumption of direct fuels for transportation such as diesel and petrol are also included in the results presented in this section. Looking at the variation in pattern and quantity of direct final energy use with levels of household expenditure, there are distinct differences in the types of energy used across different expenditure decile groups[2] in 1999-00. These differences are clearly more striking in

[2] The stylized progression from non-commercial to commercial fuel types and from less modern to more modern and efficient energy types and end-uses with increases in income and urbanization has been termed the energy ladder phe-

urban areas of the country than in rural areas where income levels are lower on average and modern fuels are not so accessible. However, overall, given an equally easy access to modern fuels, income or total expenditure is the main driving force for switching to more modern forms of energy. Convenience of these more modern fuels makes them attractive to households and, therefore, once they become affordable these fuels are adopted. The trend towards the adoption of more modern fuels with higher incomes is seen more clearly from Figs. 6.4 and 6.5. Figure 6.4 shows per capita direct commercial and non-commercial energy use by expenditure deciles for urban and rural households. The graph makes it evident that non-commercial energy use tends to increase with increase in income up to a certain level, but beyond this level, it declines even with further increases in income. However, the use of commercial energy continues to consistently rise with increases in total expenditure levels.

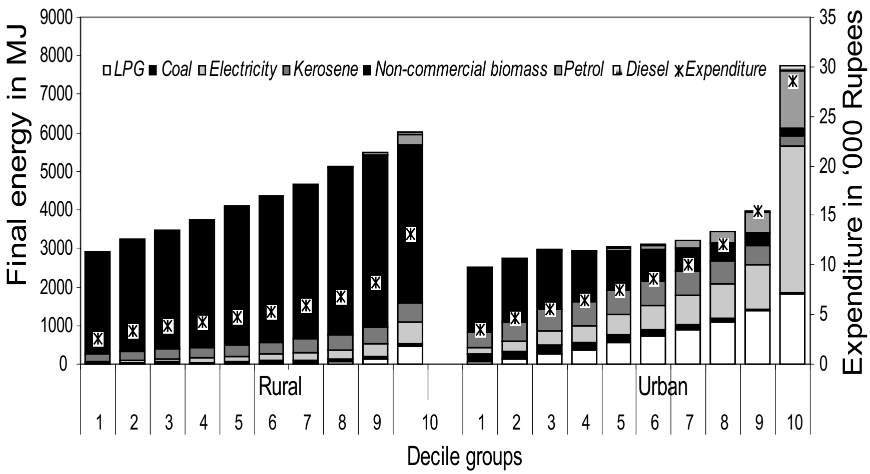

Fig. 6.4. Direct final energy use per capita by per capita expenditure deciles in rural and urban households

An analysis of the relationship between energy use and expenditure for urban households, for whom the lack of access to commercial energies is less of an issue, reveals that the use of most commercial energy types is

nomenon. For literature on this topic refer to Leach and Gowen (1987); Leach (1992); Sathaye and Tyler (1991); Smith et al. (1994); Reddy and Reddy (1994); Barnes and Qian (1992).

negligible at very low income levels (see Fig. 6.5). Above a per capita household expenditure level of about Rs. 7500 per year, however, the share of LPG and electricity in direct energy consumption exceeds half. Kerosene is used in even low income households. The use of kerosene peaks at a certain expenditure level, beyond which other fuels like LPG are substituted for it. Thus, beyond a certain income level, kerosene use declines with further increases in income. On the other hand, the use of all other forms of commercial energy like LPG, diesel, petrol and electricity are seen to increase continuously with increases in expenditure levels. Electricity consumption, in particular increases rapidly with rise in expenditure. For an econometric analysis of factors affecting variations in electricity demand across urban households in India see Filippini and Pachauri (2002).

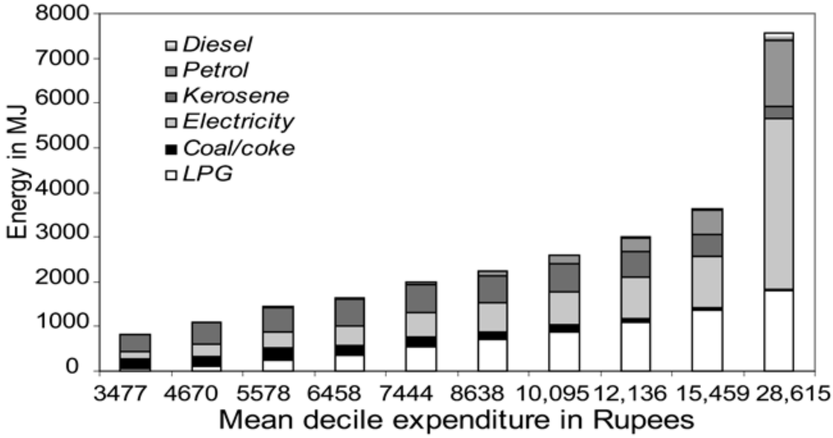

Fig. 6.5. Direct commercial energy use per capita by per capita urban expenditure deciles

Transitions in energy use with increasing income levels are also evident from Figs. 6.6 and 6.7 which show the relationship between the percentage of users of each fuel and the total per capita expenditure levels for rural and urban populations. It is evident that the switch in fuels is much faster in urban areas. That is to say, that at the same level of expenditure, a much larger proportion of the urban population uses more modern fuel types as compared to the proportion of rural population. For instance, among the urban population with a per capita expenditure level of above Rs. 10,000, over 90% use electricity and over 60% use LPG. However, in rural areas, at the equivalent per capita expenditure level, 70% of the population use electricity and only about 20% use LPG. This is again largely a result of easier availability of modern fuels in urban areas and suggests that more widespread availability of modern fuels in rural areas could result in a substantial increase in the users of these fuels in the future.

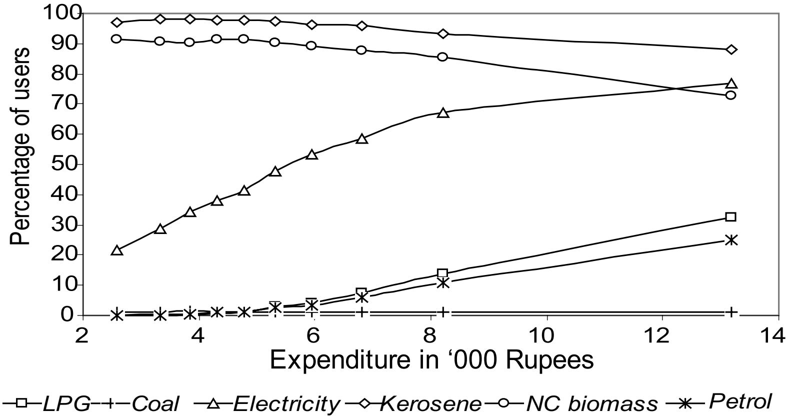

Fig. 6.6. Percent of population using different fuels in rural areas

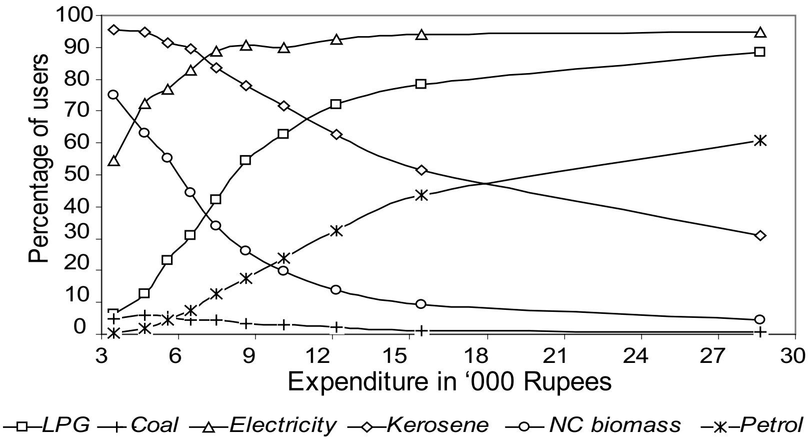

Fig. 6.7. Percent of population using different fuels in urban areas

Inequities in access to energy also get manifested in the inability of the poor to afford modern energy services. Prices when calculated per unit useful energy differ considerably from the average price per unit delivered or final energy because of the widely differing efficiencies of the alternative energies used. In general, those without access to modern energy pay more per unit useful energy than those with access. This is borne out by the results shown in Table 6.2. The table also presents the average share of energy expenses in total household expenditure for the bottom, middle and top rural and urban expenditure groups using the 1999-00 survey data. Energy expenditures constitute a significant fraction of the household budget for most Indian households. In fact, analysis of the expenditure data from the survey shows that poorer households spend a larger fraction of their total household expenditure on energy compared to those in the top expenditure groups. This is despite the fact that many poor households, particularly those living in rural areas, often do not purchase their energy in markets. If complete account is taken of the significant costs involved in the labour time devoted to collecting and utilizing traditional non-commercial energy and the health impacts of indoor air pollution, the budget share for energy of the poorer households would be considerably larger.

Table 6.2. Budget shares for energy for access groups across bottom, middle and top rural and urban households

Expenditure Groups	Access to no LPG & no electricity	Access to electricity but no LPG	Access to electricity &LPG
RURAL			
Bottom	0.08	0.09	0.11
Middle	0.07	0.08	0.09
Top	0.06	0.07	0.07
Price per unit useful energy	0.96	0.54	0.51
URBAN			
Bottom	0.08	0.09	0.10
Middle	0.06	0.08	0.08
Top	0.03	0.06	0.07
Price per unit useful energy	0.69	0.60	0.54

Prices are also important in determining the combination of fuels chosen by households. In fact, for most poor households, in addition to variable energy costs, fixed or capital costs of start-up and connections and for purchasing the equipment and appliances needed to use more efficient energy types, are substantial and act as a real hindrance to the wider adoption of these energy forms. In some cases, it has been shown that more efficient fuels may also be more economical when prices are considered per unit of useful energy, that is, when efficiencies are accounted for (WB, 2003; Reddy, 2003; Gupta & Ravindranath, 1997). However, even in such cases, the adoption of more efficient energy forms is limited as households cannot often afford the high capital costs associated with the use of such fuels.

While income and prices are unarguably important determinants of fuel choice, there are several other socio-demographic and household characteristics that affect choice. Studies in Mexico by Masera et al. (2000) and work by Davis (1998) and Barnett (2000) have shown that social and cultural factors and taste preferences also influence households in their energy choices. A recent study of fuel choices in urban Indian households has shown the importance of factors such as size of the household, age, sex and education of the head of the household and size of the city in which the household is located in decisions regarding the types of energy used (Farsi et. al 2006). All these studies point to the importance of policies other than those related to pricing and subsidies in fostering transitions to cleaner and more efficient types of energy by households. In rural areas, easier, more secure and regular access to modern fuels, electricity and equipments and supplies, could facilitate a transition to these energy types.

6.2.3 Inequalities in Energy Access and Use

The previous section has highlighted differences in the pattern of direct energy use and access across household expenditure deciles. In this section, these inequalities are further explored. Several studies have examined inequalities in income (total expenditure) across households and across time for India (see for instance Deaton & Dreze 2002; Bhalla & Das 2004). Most of these studies have concluded that inequalities in incomes in both urban and rural households have either increased or at best remained more or less constant over the last couple of decades. In particular, most authors have found that inequalities across states have increased in India in the post-reforms period after 1991. Whether such trends are also visible when one examines the distribution of direct final energy use and access over the period 1983 to 2000 will be examined in this section. In what follows, the distribution of total, direct and indirect, primary energy for the year 1999-00 and of direct final energy use in 1983 and 1999-00 for the entire population is examined first. Following this, inequalities in direct energy use and access across major states of India are further explored.

The energy distribution of India for the year 1999-00 is plotted in Fig. 6.8. It is clearly evident from the figure that for the vast majority of Indians, per capita primary energy consumption levels are very low. About two-thirds of the population uses less than 20 GJ of primary energy per capita. This amounts to less than a third of the current global average and is also lower than the amount of 1 kilowatt per capita estimated by Goldemberg (1990) as that needed to meet basic needs. Thus, energy poverty is a persistent reality for a large fraction of the Indian population even today. At the same time, there exists a small but growing segment of the Indian population whose lifestyles and consumption patterns rival those of the developed world. In addition, there is evidence of widening disparities in the energy distribution over time. These trends are particularly worrying given the strong evidence to show that low energy access and consumption are correlated with so many dimensions of poverty. More regarding some of the linkages between energy access and use and various indicators of well being is discussed in Sect. 6.2.4.

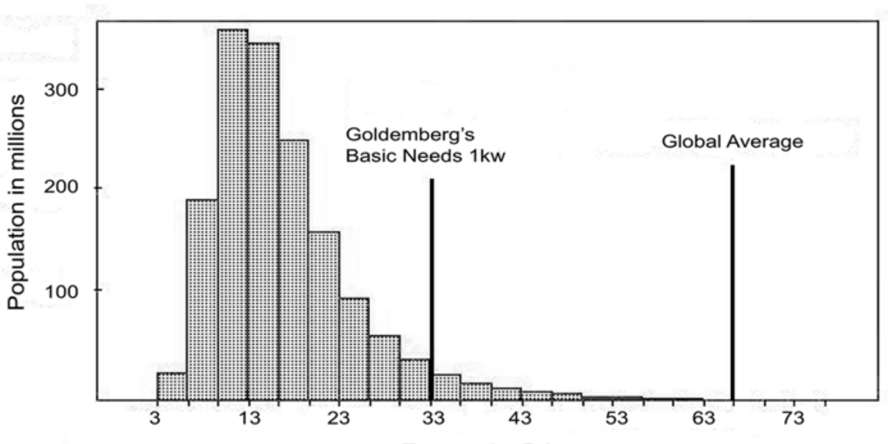

Fig. 6.8. Primary energy distribution for India in 1999-00

The distribution of final direct energy use per capita for the years 1983 and 1999-00 is depicted in Fig. 6.9. The Lorenz curve in this figure plots the percentage of direct energy used by various portions of the population when the population is ordered by their total direct energy use. As can be seen from the graph, there is significant inequality in the use of direct energy, with the bottom 60% of the population using only about 33% of total direct energy and the top 10% of the population consuming as much as 30% of total direct energy in 1983. The inequality in energy use also persists over time with the Lorenz curve for the year 1999-00 more or less identical to that for 1983. A comparison of the Gini coefficients of the distributions for the two years (0.57 and 0.54 respectively) also reveals little change in the level of inequality over this time period.

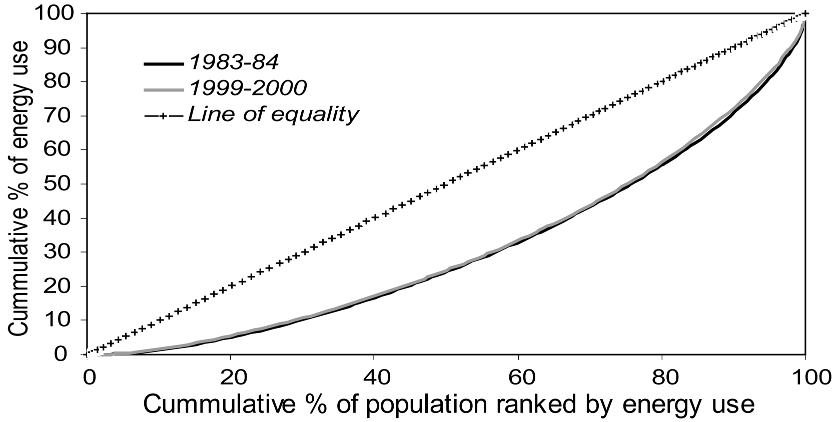

Fig. 6.9. Lorenz curve of per capita direct energy consumption in 1983 and 2000

In order to analyse the inequality in access to electricity across the population between 1983 and 2000, a concentration curve is derived for each year by plotting the cumulative percentage of persons using electricity by various portions of the population with the population ordered by total per capita expenditure. Thus, in Fig. 6.10, in 1983 one observes that the bottom 70% of the population ranked by per capita expenditure accounted for only 40% of those with electricity access. By 1999-00, however, the inequality in electricity access reduced significantly. The concentration curve for 1999-00 shows that the bottom 50% of the population accounted for about 35% of those using electricity and among the bottom 70%, almost 58% were electricity users. This improvement in access to electricity is also reflected in the improved Gini coefficient which was 0.41 in 1983 but almost halved to 0.21 in 1999-00.

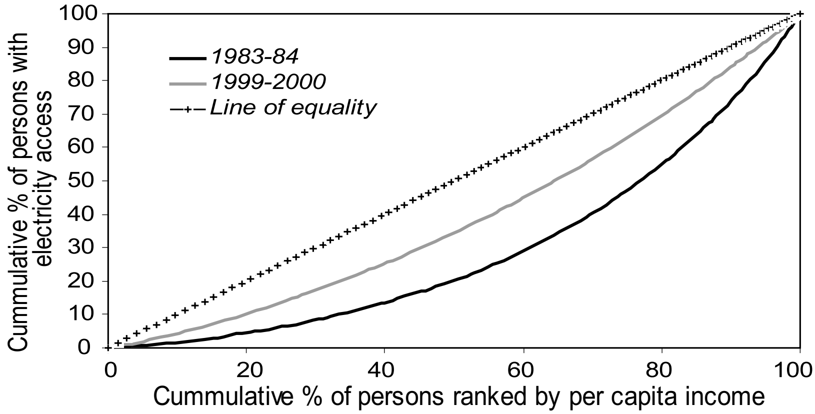

Fig. 6.10. Concentration curve for persons with electricity access in 1983 and 2000

In addition to looking at the inequality in access to electricity, one can also look at the distribution of electricity consumption among those who use electricity. Figure 6.11 shows the Lorenz curves for electricity distribution for the years 1983 and 1999-00. The distribution of electricity use can be observed as highly unequal in both years and appears to have changed little over this time period. The Gini coefficient of electricity distribution was 0.57 in 1983 and improved only marginally to 0.54 by 1999-00. Even in 1999-00, the top 10% of electricity users accounted for as much as 34% of the total electricity consumption, whereas the bottom 60% accounted for only 34% of the total direct household electricity consumption.

The results for inequality in direct energy and electricity use presented above are similar to those reported by other authors who have examined income inequalities. For instance Deaton and Dreze (2002), who analysed per capita consumption expenditure patterns using NSSO data, concluded that there was a marked increase in inequalities in many forms over the decade of the 1990s. In particular, they observed that regional disparities across states of India increased in the 1990s with better off states growing more rapidly than poorer states over this period. An examination of the direct energy use and access patterns across states over the period of 1983-2000 also indicates a similar trend of increasing inequalities.

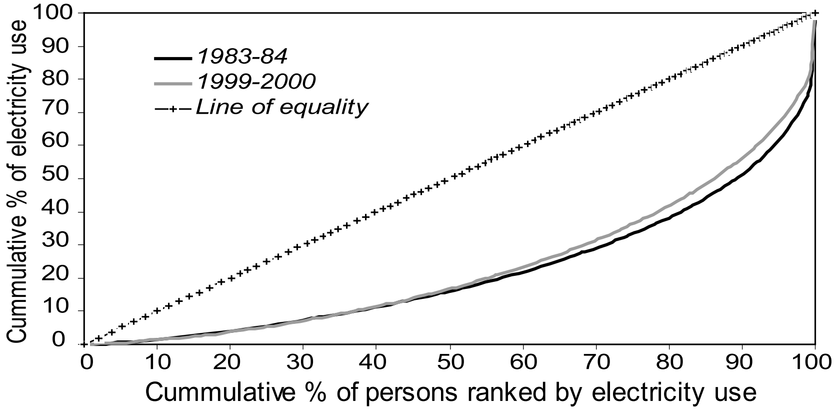

Fig. 6.11. Lorenz curve for per capita direct electricity use in 1983 and 2000

Energy poverty defined as per Pachauri and Spreng (2004) and Pachauri et al. (2004) according to the two dimensions of access and use did decline in most major states of the country between 1983 and 2000. However, the extent of energy poverty reduction differed across states over this period, with better off states generally experiencing a faster reduction in levels of energy poverty than the less well off states. This has generally resulted in greater inequalities between states. Figure 6.12 shows changes in energy poverty levels across states between 1983 and 2000. In all major states[3], the percentage of energy poor persons defined in terms of those lacking access to modern energy (electricity and LPG) and using a quantity of useful energy less than that necessary to cook two meals a day, declined over the entire period from 1983 to 1999-2000, except in the case of Bihar, where the share of energy poor people initially declined between 1983 and 1993-94 but then increased marginally between 1993-94 and 1999-00. In general, the poorer states like Bihar, Orissa and Uttar Pradesh experienced the slowest decline in levels of energy poverty over this period.

[3] For state codes refer to appendix 5A-2 of Chap. 5. Major states are defined as in Chap. 5, Sect. 5.3.3.2.

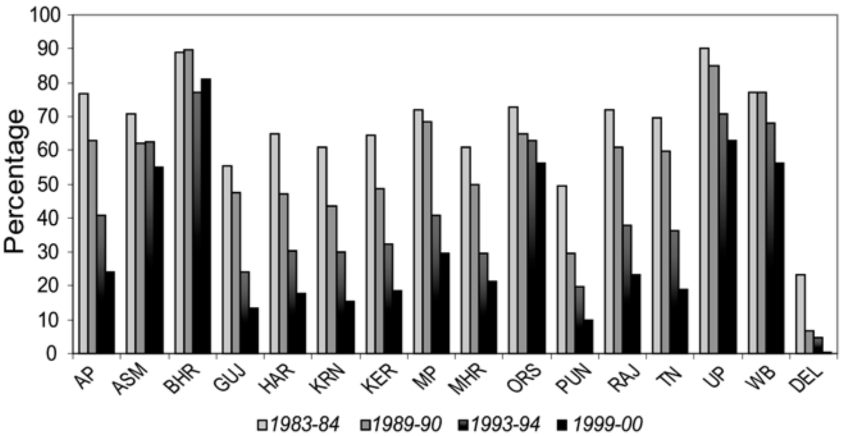

Fig. 6.12. Changes in energy poverty levels for major states between 1983-2000

Figure 6.13 shows changes in the proportion of population with access to electricity and LPG by major states over the period of 1983-2000. Again, one observes, in poor states like Bihar, Orissa and Uttar Pradesh, progress in terms of the rate of increasing electrification and access to LPG has lagged behind other better off states of the country. However, in general, while some of the states with lower levels of access to modern energy have performed better on average in increasing access over the period 1983-00, their initial levels of access were so low that they have still not caught up with the better performing states. Table 6.3 presents the growth rate of the average total useful energy per capita for each of the major states relative to the average for all of India between 1983 and 2000. The evidence from this table indicates that disparities across states in terms of useful energy consumption levels appear to be widening which mirrors the increasing disparities in state domestic products and incomes reported by authors like Deaton and Dreze (2002). Their results also indicate that in addition to disparities across states, there are substantial differences in income levels across rural and urban sectors within states. They conclude, for instance, that in the rural sector, states like Bihar and Orissa experienced extremely high and virtually unchanged levels of poverty during the nineties.

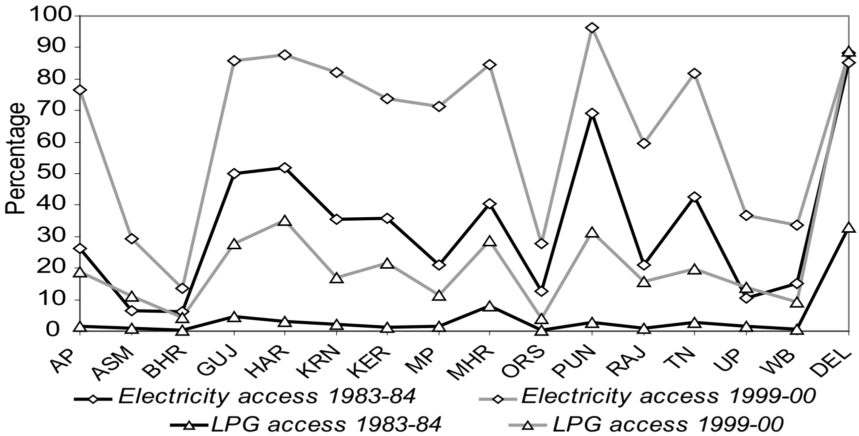

Fig. 6.13. Changes in electricity and LPG access rates in major states between 1983-2000

Table 6.3. State growth rates in total useful energy per capita relative to the all-India growth rate between 1983-2000

	Rural	Urban
	Poor States	
BHR	-0.41	-0.27
ORS	-0.24	-0.03
MP	-0.29	-0.02
RAJ	0.41	-0.02
UP	-0.2	-0.02
	Middle States	
AP	0.07	0.1
KRT	-0.05	-0.01
KER	0.04	0.11
WB	-0.07	-0.07
	Rich States	
GUJ	-0.04	0.03
HAR	0.28	0.11
MHR	-0.01	0.02
PUN	0.32	-0.07
TN	0.18	0.28

6.2.4 Relationship between direct energy access and use and well being indicators

The previous section has highlighted the highly uneven distribution and use of energy and modern energy supplies across India. One can see that despite some progress in terms of increasing access to modern energy for the poorest, a large fraction of the population remains energy poor, that is, they lack access to adequate, affordable, clean and efficient energy supplies. Households are very heterogeneous in terms of their consumption patterns and behaviours. Therefore, when studying the issue of energy use, it is important to examine not only the rate of growth, but also the composition of growth across different sectors and population groups. This necessitate a disaggregate approach to analysing energy use and access.

The importance of energy for improving well being is well recognized and has been the recent subject of renewed focus with the framing of the Millennium Development Goals (MDG). While there is general consensus on the need for integrating development goals with energy planning, the perspectives vary on the most effective ways of doing so. This is, in part, because large gaps still exist in our understanding of the complexity of the energy problem in relationship to development and, in particular, the energy and environmental implications of meeting social challenges of improving well being. Within the international energy community significant progress has been made to understand the techno-economic interactions that drive long-term aggregate energy use and emissions. However, the explicit integration of social and developmental factors and concerns, relevant for policy making in most developing countries, remains largely unexplored. The development community, on the other hand, has focused largely on understanding current conditions and historical development patterns. Little work has been done to integrate energy in development policy or understand the development implications of energy-related programmes and activities.

Past efforts at analysing the links between energy access or use and well being have largely been anecdotal or presented as case studies for small regions. A few early studies such as those by Revelle (1976); Krugman and Goldemberg (1983); Goldemberg et al. (1985, 1987), attempted to estimate an average value for basic energy needs on the basis of engineering calculations. Calculations made by Goldemberg et al. estimated that the requirement of direct primary energy per time unit to satisfy basic needs is about 500 watts[4] per person. This kind of a calculation rests on a number of arbitrary assumptions regarding the type of energy consuming equipment (stove, light bulbs etc.), their sizes, efficiencies and intensity of use. In addition, the approach requires, as a first normative step, defining a set of basic needs. This is a problematic endeavour as basic needs vary with climate, region, period in time, age and sex. More importantly, there is no single level, but a hierarchy of basic needs, which are also normatively defined.

A similar engineering approach for estimating the basic energy needs for cooking, lighting and heating was adopted by planning agencies in India in fixing 'norms' that were then used while forecasting and evaluating energy demand, especially in rural areas. The Advisory Board on Energy in its 1984 report on energy demand modelling for India (ABE 1985) assumed that about 30 watts of useful energy is needed per capita to meet cooking energy needs. Similarly about 1.5 watts of useful energy per capita is required to meet space heating needs and the same amount again, 1.5 watts of useful energy per capita, to meet lighting needs. These values are normative in the sense that they are calculated on the basis of various assumptions regarding what is considered as the basic minimum for meeting human needs. Thus, a total of some 33 watts of useful energy per capita, approximately (1 GJ per capita per year) was assumed by ABE to be required at the household level to meet the three basic direct energy services, cooking, lighting and space heating.

Early work, such as that by Goldemberg et al., also underscored the importance of the link between indices such as the Human Development Index (HDI) and the provision of at least minimum basic energy needs. Cross-national comparisons were made to highlight the fact that nations with per capita energy use below a certain minimum level lagged behind other nations in terms of well being indicators such as the HDI, literacy and per capita GDP. More recent work done in preparation to the build up to the Johannesburg 2002 World Summit on Sustainable Development, has also highlighted the importance of increasing modern energy access as a means of improving well being for the poorest and has affirmed that energy must be made a crucial part of all development and poverty allevia-

[4] A watt is a measure for (physical) power, i.e. energy per unit time. According to Goldemberg (1990), 1000 watts per capita is the power required to satisfy basic human needs: 500 watts directly in the form of fuels and electricity and 500 watts indirectly as a result of consuming other goods and services which are necessary to satisfy basic needs and that require energy inputs for their production.

tion projects and programmes (WEC 1999; WB 2000; UNDP 2000; DFID 2002). As part of the Millennium Development Goals, the UN Commission for Sustainable Development 9th Session (CSD9 2002) also explicitly acknowledged that access to sustainable energy services is an essential element of sustainable development, stating that: "To implement the goal accepted by the international community to halve the proportion of people living on less than US$1 per day by 2015, access to affordable energy services is a prerequisite."

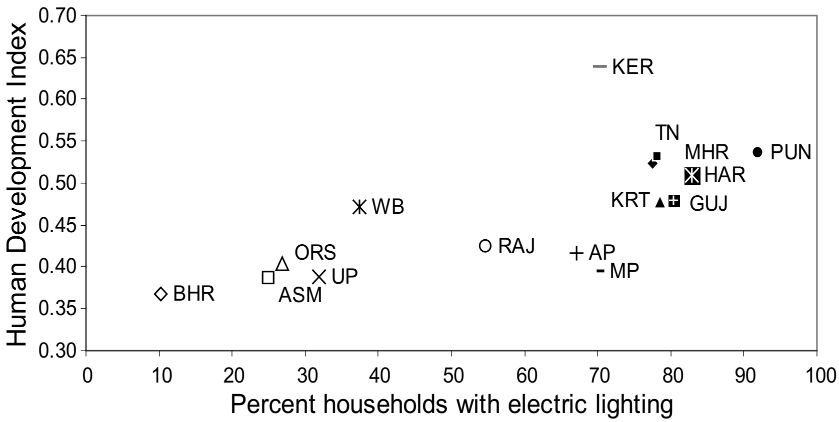

Fig. 6.14. Electricity access and human development across states[5]

Despite this renewed focus of the international community on the importance of provision of basic energy services to the poor to improve their well being, little comprehensive analysis has been done on quantifying these linkages. There are few quantitative studies that analyse these linkages in India. Thus, there is a huge potential for research in this area. Pachauri and Spreng 2004 and Pachauri et al. 2004, have highlighted that differences in access levels to modern energy services are strongly correlated with well being indicators such as literacy, access to tap water, etc. Pachauri 2006 has also shown that differences among states in India in terms of access to modern energy supplies are related to well being indicators such as the HDI. As Fig. 6.14 shows, states where a larger proportion of the population have access to electric lighting, also tend to perform better in terms of their HDI. In addition, states where a lower percentage of

[5]Data for HDI across states sourced from UNDP (2001).

the population is reliant on biomass and other solid fuels, such as coal and charcoal, tend to have lower under-five mortality rates and higher female life expectancy (see Fig. 6.15). Such correlations are expected given the strong body of evidence that exists on the health impacts of indoor air pollution associated with the burning of biomass and solid fuels for cooking.

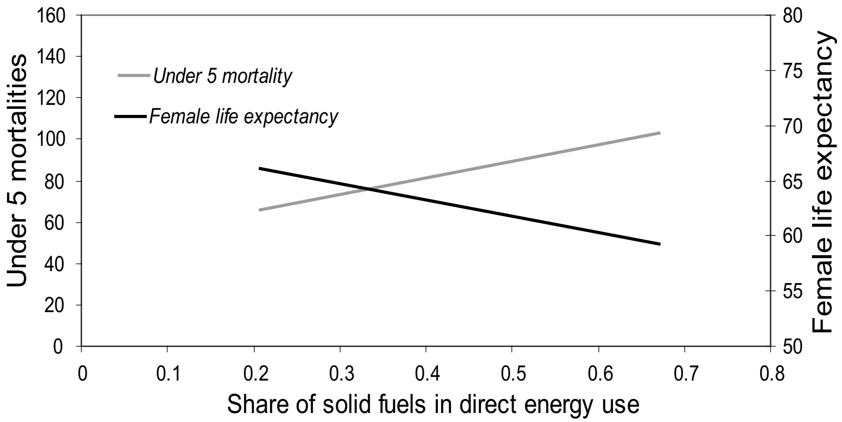

Fig. 6.15. Traditional and solid fuel use and demographic indicators[6]

6.3 Indirect Food Energy Requirements and Well Being

Indirect energy requirements of food consumption comprise the largest category of indirect energy needs of household consumption in India. Food consumption is a particularly interesting subject of investigation as the need for food is basic. However, while it is clear that all humans must satisfy their basic food and nutritional needs, food consumption patterns also express differences in lifestyles, cultures, and levels of affluence. It would, therefore, be interesting to analyse in further detail the pattern of food energy needs across households and across food categories. In what follows, primary energy requirements of food consumption of households is presented in greater detail and variations in the pattern of food consumption analysed, based on detailed household consumption expenditure data from the NSS expenditure survey for 1999-00 and the energy intensities of food

[6] Data for demographic indicators sourced from the Census of India (GoI 2001).

producing sectors calculated using the 1998-99 input-output tables that were presented in Chap. 3.

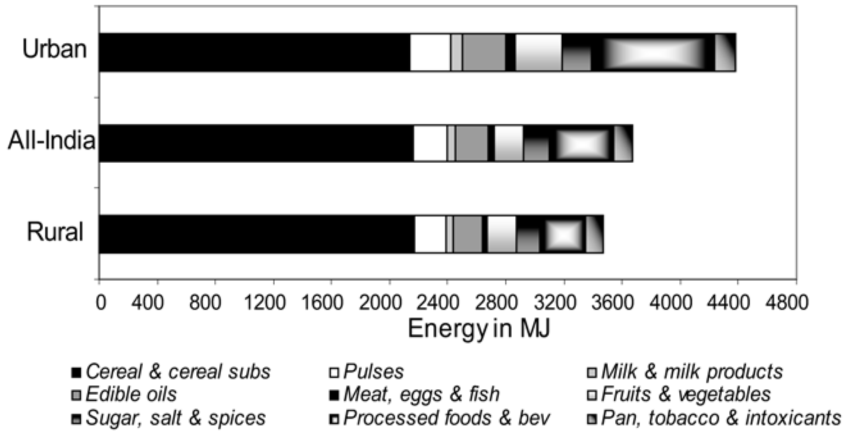

Fig. 6.16. Pattern of food energy requirements for the average rural, urban and Indian

An analysis of the patterns of food energy requirements for the average rural, urban and all-India residents reveals that the energy requirements for food are higher in urban compared to rural areas. This is, in a large part, due to the higher average incomes in urban areas. In addition, at the average level, some differences in the pattern of food energy needs can be distinguished between urban and rural consumers. The energy requirements for consumption of cereal and cereal substitutes dominate food energy needs of individuals in India. On average, urban residents consume more of all food commodities except cereals and cereal substitutes than rural residents (see Fig. 6.16). This probably reflects the more physically active lifestyles of the rural people who are often engaged in agriculture or other labour-intensive activities and, therefore, require more caloric energy intake. Urban, consumers, on the other hand have on average a larger share of processed foods and beverages in their diets than their rural counterparts.

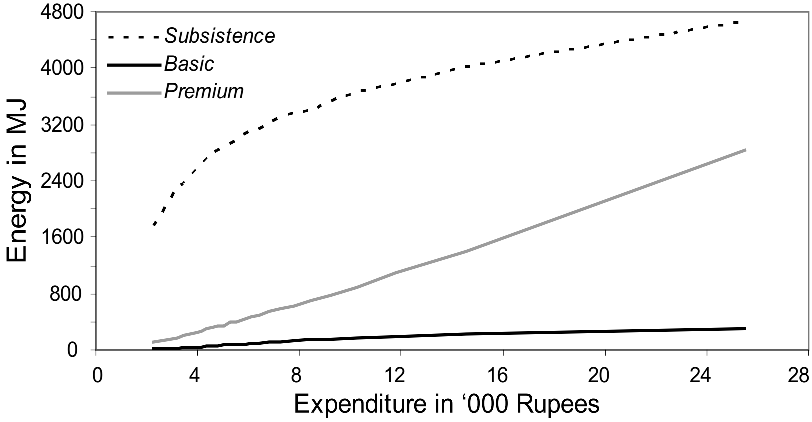

Fig. 6.17. Relationship between food energy requirements and per capita total household expenditures

It is more interesting to examine variations in food energy needs with income or total expenditure levels. While energy requirements of consumption for all food commodities can be seen to increase with income levels, significant differences in the rate of increase can be observed across different food commodity groups (see Fig. 6.17). Three distinct categories of food commodities can are distinguished here. Subsistence foods such as cereals and cereal substitutes, and fruits and vegetables which are needed to satisfy basic nutritional needs comprise the largest share in total food energy requirements. In particular, consumption of cereal and cereal substitutes increases very rapidly at very low income levels and then tends to level off at higher income levels, essentially reflecting satisfaction of basic nutritional needs. The second category refers to basic foods, which are used to supplement a diet comprising of subsistence food items, and include milk and milk products, meat, eggs and fish. The consumption of these food items is zero at very low income levels but increases rapidly with income. In terms of indirect energy, the levels are low compared to that of subsistence items but the share relative to subsistence items increases gradually with increases in income levels. Finally, the third category of food consumption refers to premium goods such as processed foods, beverages and exotic items. Energy requirements for this category can be seen to increase dramatically with increases in income levels. Thus, while the share of processed foods in total food energy needs is negligible at low income levels, its share increases rapidly with rising incomes. It has the highest share after cereals and cereal substitutes in the food budget of high income individuals.

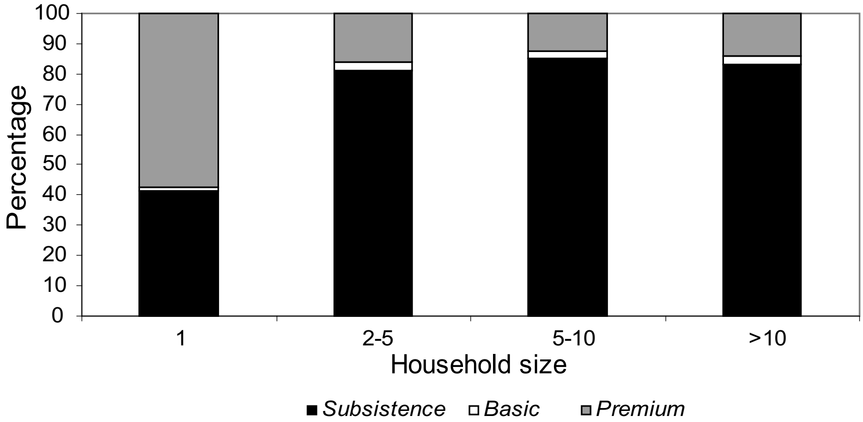

Fig. 6.18. Pattern of food energy requirements by household size

Socio-economic and demographic factors other than income levels also influence the energy requirements of food consumption in Indian households. While all these factors are not discussed in detail here, one of the most important is household size, including total number of children in the household. Per capita food energy requirements are lower for persons living in larger households. This is in part due to lower per capita income levels of those living in larger households. In addition to differences in the quantum, the pattern of food energy requirements also differs markedly from small to large households. As seen from Fig. 6.18, the share of energy requirements for subsistence foods increases with household size. The share of basic foods is quite small and more or less constant across different household sizes, whereas that of premium foods declines substantially from single person households to larger sized households. In particular, single person households tend to spend a very large fraction of their food budget on premium foods, which are faster and easier to prepare. These trends have also been reported in other studies (e.g. Meenakshi and Ray, 1999; Abdulai et al. 1999) that suggest that as family size increases, households tend to spend more on relatively inexpensive subsistence food items to feed the extra mouths and cut costs on basic and premium food items which are relatively more expensive.

It is also important to analyse whether differences in access to direct cooking fuels are related in anyway to differences in the pattern of indirect food energy requirements. Figure 6.19 shows the pattern of indirect food energy requirements on average for households differing in their primary sources of cooking energy. On average households with access to lower quality fuels such as dung and fuelwood, have lower total food energy requirements per capita than those with access to better quality cooking fuels like LPG and kerosene. The pattern of indirect food energy requirements also differs. Households with access to higher quality cooking fuels also consume a larger fraction of basic and premium food items than those who use fuelwood or dung as their primary source of cooking fuel.

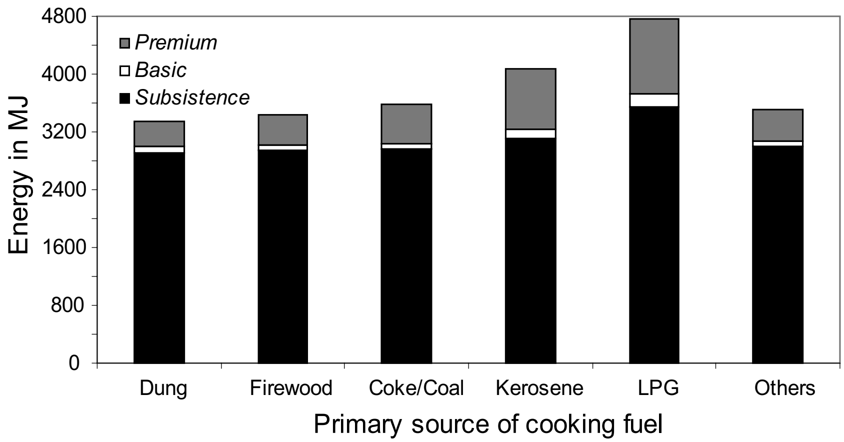

Fig. 6.19. Pattern of indirect food energy requirements among households using different fuels as their primary source of cooking energy

Finally, Fig. 6.20 depicts differences in the average daily calories consumed from food by the average rural and urban resident categorised by their primary source of cooking energy. On average, rural residents have a higher daily calorie intake than urban residents, but the residents of households using inferior cooking fuels like fuelwood and dung as their primary cooking energy have a lower daily calorie intake on average than those that use more efficient fuels such as kerosene and LPG. In both rural and urban areas, the percentage of population that is calorie poor[7] also seems to be correlated with the type of cooking fuels households have access to. Thus, the percentage of calorie poor population is higher among households using dung and fuelwood compared to those using LPG as their primary cooking energy. One might expect that those who use inferior fuels, like dung and fuelwood, expend more energy in the day, as these fuels are often collected by the women and children members of such households rather than being bought in the market. Therefore, this drudgery should in fact be compensated for by a higher calorie intake. However, in reality, on average the members of these households consume fewer calories and a larger proportion of persons residing in such households do not have an adequate dietary intake of calories. While, the evidence does not allow one to conclude that the cause of inadequate nutrition is a lack of access to clean and efficient sources of cooking energy supplies, it is clear that continued reliance on inferior biomass cooking sources has serious implications for the day-to-day life of the majority of poor people.

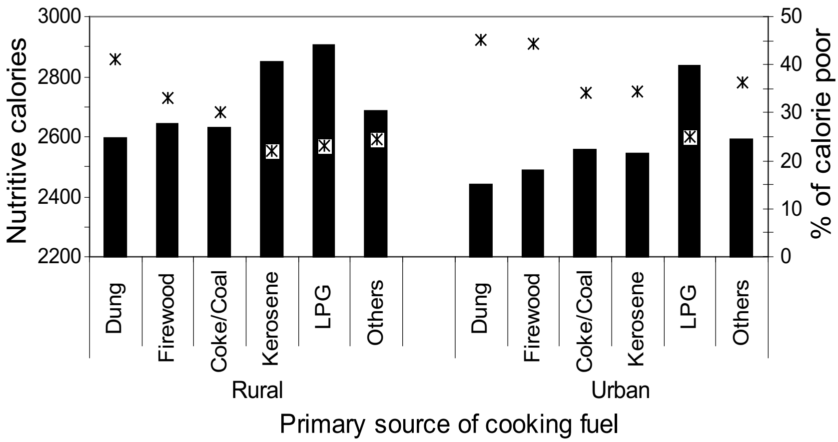

Fig. 6.20. Primary fuel used for cooking and nutritional status in urban and rural areas

[7] A person consuming less than an average of 2200 calories per day is defined as calorie poor (GoI, 1998).

6.4 Discussion and Conclusions

This chapter has attempted to underscore some linkages between energy access and use and various dimensions of development and human well being such as income and economic productivity, health, nutrition and education. Despite significant progress having been made over the last couple of decades in increasing access to electricity and other efficient energy sources, data from the most recent round of the NSS household expenditure schedule for 1999-00 suggests that over 50% of rural households still lack access to electric lighting and over 85% still rely on fuelwood as their main source of cooking energy. Energy poverty is also still pervasive in urban areas where, though a much larger proportion have access to electricity, 35% of the population still relies on fuelwood. This low level of modern energy services for so many poor households clearly has implications for their quality of life and well being. Indicators such as the HDI and literacy are shown to be correlated with level of access to modern energy sources. Previous research by authors like Goldemberg et al. (1995) has also pointed to the fact that low energy consumption though not a cause of poverty is often a good indicator for many of its characteristics, such as poor education and healthcare. Their work on cross-national differences showed that energy consumption below a basic minimum appeared to be highly correlated with higher infant mortality, fertility and illiteracy. Previous work presented in Pachauri et al. 2004 has also indicated that energy poverty in the Indian case, defined in terms of a lack of access to modern energy supplies and adequate quantities of energy, is significantly correlated with other dimensions of poverty such as poor health, illiteracy and lack of adequate nutrition.

The empirical evidence presented in this chapter indicates the importance of including energy poverty within a broader more multidimensional definition of poverty. A lack of access to appropriate types and adequate amounts of energy, a problem that is still faced by a large proportion of the Indian population, is a clear manifestation of the deprivation faced by the poor and contributes to their reduced capabilities and lower standard of living.

Analysis of energy use and access in relation to social and well being indicators, provides a fertile ground for new research. While there has been a renewed interest to study some of these issues in recent years, the body of empirical work for developing countries is still limited. The nature of the issues necessitate a disaggregate bottom-up approach making use of micro-level data wherever possible. This area of research presents several avenues of mutual learning and exchange between energy analysts and modellers and those in the developmental field and holds promise for increasing our understanding of the complex nature of relationships between energy and development.

Appendix 6A: Appendix Tables

Table 6A-1. Average efficiencies assumed for conversion from final to useful energy

Fuel type	Average efficiency
Wood	14%
Kerosene	45%
LPG	60%
Electricity	75%
Dung cake	10%
Charcoal	20%
Coal	20%
Soft coke	19%
Other oil	18%

Chapter 7: Conclusions and Reflections

This concluding chapter discusses the main lessons emerging from the work contained in this book. Key results pertaining to the empirical analysis conducted, together with observations on the methods used are presented. It acknowledges the difficulties of conducting research that transcends some established methodological boundaries and presents the main limitations of the research in this context. While some of the key findings from the analysis presented in previous chapters are revisited and main achievements highlighted in this chapter, it does not present a comprehensive summary of all the results. The chapter is organised in three sections. The first provides some general conclusions from the empirical part of the research. The key findings of applying a household perspective to study energy consumption in the Indian scenario are also discussed and some general reflections and implications of the work are presented. In the second section, the general findings, from the application of the different methods to the Indian data and situation, are highlighted. The main methodological limitations, largely pertaining to data availability and quality, are also discussed. Finally, the last section presents the scope for future research in this field.

7.1 Key Empirical Findings and Their Implications

Important changes have occurred in household energy use in India over the period 1983-84 to 1999-00. Changes in lifestyles, technologies, demographics, and affluence levels have had significant effects on total household energy requirements. The interplay of these factors will also determine future energy needs of India.

Changes in lifestyles, as characterised by the structure of consumption of households, are significant. The results of this study suggest that counteracting trends may be at play. A general shift towards the consumption of more energy-intensive manufactured goods is evident for higher income classes. However, at the same time, there is also a trend towards higher spending on less energy-intensive services. In terms of direct energy use, there is a definite shift from the use of non-commercial energy to more efficient commercial forms of energy. Analyses of patterns of indirect energy requirements of households shows that energy requirements of food items still dominate total indirect energy requirements for poor households (almost 40%), but the share of food energy requirements in the total decreased with increase in levels of income (less than 25% for the top income class). At the same time, the contents of the food basket is also seen to change with increasing income levels with a general shift from cereals and grains to fruits and vegetables and to meat, eggs and processed foods. The proportion of non-food indirect energy requirements is also seen to change with a rise in income. In particular, the share of energy required for manufactures and transport is seen to increase significantly with a rise in levels of total expenditure, especially for urban households. Increased need for mobility and poor public transport infrastructure in most Indian cities has meant that with rising incomes, people opt for personally owned modes of transport. In addition, the better availability, accessibility and visibility of manufactured goods in urban areas has meant that with increasing urbanisation and income levels, there has been a greater degree of penetration of these items in Indian households leading to an increasing share of non-food indirect energy requirements in better-off households.

In addition to changes in patterns of consumption, key demographic changes are also taking place within the country. The study shows that change in household size, levels of urbanisation, literacy rates, and age distribution of the population have important implications for energy use. Despite some progress in recent years in stabilising the rate of growth of population in India, the population of the country is projected to increase from 1.028 billion in 2001 to 1.264 billion in 2016. In addition, according to the Planning Commission's projection (Ramachandran et al. 2000), average household size in 2010 is likely to be 4.86 in contrast to the value of 5.3 estimated by the 2001 census. Analysis presented in Chap. 5 and Chap. 6 indicates that both these trends will exert an upward pull on total household energy requirements. According to the predictions of the United Nations, the degree of urbanisation in India in 2010 will also increase to about 35% (UN, 1990). All other factors remaining the same, the regression model quoted in Chap. 5 predicts a marginally lower per capita energy requirement for urban residents as compared to those living in rural areas. Therefore, an increase in the urbanisation rate should reduce the average per capita total energy requirements other factors remaining the same. However, if the increasing urbanisation is accompanied by rising incomes and greater motorisation, then total household energy requirements can be expected to increase. From the policy perspective, the possibility of increasing employment and income generating activities in rural areas that halt migration to urban towns could have a potentially important effect on total energy requirements as, on average, rural lifestyles have been seen to have lower indirect energy needs than urban ones. At the same time, improving the access to modern and more efficient commercial fuels for rural and poor households could result in substantial direct energy savings for the nation. Encouraging the adoption of alternative renewable sources of energy could also be an important step in this direction. In addition, results presented in Chap. 5 also suggest that improvements in the spread of literacy in the country could also lead to some energy savings. Yet, the expectation is also that as average educational levels and awareness levels improve, this will contribute to a further development of personal lifestyles and aspirations.

Thus, results of the study indicate the important economic, technical, demographic, and lifestyles changes, that have significant impact on energy use. It is certain that household energy requirements will and should increase in India in the future. However, to what extent this increase can be brought about in an efficient, equitable and sustainable way will depend heavily on whether in the future development patterns, policies and institutions will be put in place that can help meet the shared needs and aspirations of its people while still respecting the living systems and natural resources of the country.

In what follows, some of the key trends and insights obtained from the analyses presented in the previous chapters are highlighted and general reflections and implications that have relevance for the future development of India are discussed.

7.1.1 Downturn in Energy Intensities of Sectors

With industrialisation and a first motorisation, economies go through a period with rising energy use per unit of gross domestic product (GDP), then a period of little change of energy intensity at a maximum level, followed by a trend where the energy/GDP ratio is declining due to de-industrialisation and a growing share of the tertiary or service sector in

GDP[1]. The developed countries of today have undergone this development pattern during the last quarter of the nineteenth and first quarter of the twentieth century (UNDP 2000). In the early decades of industrialisation, energy-intensive industries are established and grow. Shifts in the sectoral composition of the economy from less energy-intensive sectors to more energy-intensive sectors leads to an overall increase in the energy/GDP ratio. At the same time, greater mechanisation occurs within sectors as machines take over processes and jobs previously carried out by manual labour, and this leads to increases in the energy intensities of individual sectors as well. As development continues and per capita GDP rises beyond some threshold level, the need for infrastructure declines, technical progress leads to more energy efficient processes, and consumer demand shifts towards less energy-intensive services. These factors lead to a reduction in the energy intensities of individual sectors as well as of total output (WEC, 1993). The Indian economy today is experiencing this historical phase of development. Trends in energy intensities estimated in this study provide indication of the fact that many productive sectors in India appear to have recently passed the apex of high energy intensity.

The results presented in Chap. 3 on trends in the estimated sectoral energy intensities for India for the period 1983-84 to 1998-99 indicate that many of the commodity sectors experienced an increase in energy intensity over the first sub-period of the study from 1983-84 to 1989-90. However, during the second sub-period between 1989-90 and 1998-99, the majority of sectors showed a decline in energy intensity. In all, 15 sectors experienced an increase in energy intensity of more than 50% during the entire decade, these being largely those in the food and agricultural sectors but also the wood products sector. There were also sectors including cement, the miscellaneous manufacturing sector, and the rail transport services sector, which experienced a decrease of greater than 50% in their primary energy intensities. The general trend for many sectors, however, points to a downturn in energy intensities, for the period analysed.

The results of the decomposition analysis of changes in total and indirect energy requirements of households during the decade 1983-84 to 1998-99, which were presented in Chap. 4, indicate that decreases in energy intensities of producing sectors only partly compensated for the growth in volume of consumption during the decade studied. In addition, for most of the categories of household consumption, structural changes

[1] For literature on the relationship between energy and GDP, see for instance Galli (1998); Judson et al. (1999); Medlock and Soligo (2001).

were responsible for a slight decrease in indirect energy requirements. Changes in energy intensity also led to a decrease in energy use for all categories of household consumption items except ‘food, beverages and tobacco’, where it contributed to a large increase, and the ‘medical and hygiene’ category, which showed a smaller increase.

In general, therefore, results from this study indicate that the energy intensities of productive sectors as well energy intensities of different categories of household consumption show a declining trend over the period studied. The overall energy intensity of the Indian economy in terms of the ratio between total primary energy required and the GDP also improved. It declined from 1.29 MJ/Rs.$^{93-94}$ to 1.05 MJ/Rs.$^{93-94}$between 1983-84 and 1989-90, and declined further to 0.92 MJ/Rs.$^{93-94}$ by 1993-94 and then to 0.85 MJ/Rs.$^{93-94}$ in 1998-99. Whether these trends truly reflect long-term improvements of energy efficiency in the various sectors of the Indian economy or just some short-term fluctuations of energy consumption due to variations of stocks or structural fluctuations due to the business cycle, is difficult to determine. In order to answer such questions, one would need to carry out more research analysing the trends in energy intensities and energy consumption indicators at the level of individual sectors and sub-sectors.

Thus, it is important to be cautious in interpreting the decrease in total primary energy intensity evident in the case of many sectors. While it is possible that some of these sectors have in fact become more energy efficient, some of the observed changes are also a result of the general shift from non-commercial to commercial energy sources, and from the use of coal to oil and electricity. Changes in energy intensities are not only resulting from changes in energy efficiency, but also by such factors as changes in prices of products, inflation, temperature, changes in type and quality of the sectoral output and changes in the structure of the economy. What is clear though, by comparing energy intensities from this study with those of other countries, is that there is tremendous scope for further reductions in energy intensities for most productive sectors, as absolute intensity levels for India are far higher than those in developed countries. Therefore, development and transfers of advanced technologies from industrialised countries could go a long way in reducing the future rate of increase in energy requirements in India. In addition to the technical potentials of improving energy efficiency, there is a substantial structural component that is likely to reduce energy intensities in several branches and productive sectors in the future. For instance, a movement up the product quality ladder and a shift into higher value added products, mainly in the chemical, steel, machinery, building materials, and light industry sectors can result in further energy savings within the country.

7.1.2 Increasing Specialisation of Labour and Importance of Market Economy

Results presented in Chap. 4 and Chap. 5 suggest that the indirect component of energy demand has increased in importance as compared to direct energy requirements of households. This, in turn, indicates a greater degree of commercialisation, mechanisation, specialisation and growth of the market economy. While, the Indian economy is still characterised as largely agrarian, it is undergoing a rapid phase of industrialisation, motorisation and commercialisation. This has been accompanied by far reaching changes in lifestyles and livelihood patterns for its population, some of which were alluded to earlier in this chapter. The subsistence nature of the economy, and self-sufficiency of the household, has given way to a more commercially based market exchange economy. Thus, today even rural households consume more and more from the market and less from individual self-production. These changes have two important implications for the growth of the economy and energy use. First, greater monetisation and commercialisation leads to an increasing GDP as more and more services and products that were not paid for in cash earlier (for e.g. food, household labour for cleaning services, etc.) are now paid for and enter the formal monetary economy. Second, these changes also lead to an increase in commercial energy use as more and more activities that were carried out by using human and animal power, in the past, are now carried out through the use of commercial forms of energy.

Labour specialisation and an increasing share of skilled labour force also imply more diversification and growth of the market economy. Increasing specialisation as a result of the division of labour, mechanisation, and skill development has also resulted in productivity gains, i.e., either more output for a given unit of labour or less labour for a given output. In part, such gains have translated into greater wage income, which the worker, as consumer, then spends on an increasing variety of marketed goods and services. In turn, the creation and provision of these goods and services result in further increases in energy use.

General trends that emerged from this work show that indirect energy requirements of households are assuming increasing importance in India, as is already the case in most developed nations. While, one can expect the direct energy consumption of households to increase as well in the next few decades, especially that of commercial energy, it is the indirect energy requirements of the non-energy goods and services that households consume, that are likely to increase at an even faster rate. Therefore, strategies and policies aimed at increasing efficiency of energy use should focus not only on direct energy consumed by households but also their indirect energy use.

Estimates for total energy intensities of productive sectors also point to the fact that while direct energy use is of importance especially for sectors upstream in the production chains, for many downstream sectors, the share of indirect energy use is larger than that of the share of direct energy use. Therefore, total energy requirements and intensities, inclusive of the direct and indirect components should be the focus of future policies on energy conservation and efficiency, rather than direct energy use of sectors alone. In other words, strategies for the more efficient use of non-energy or material inputs need to be explored in addition to those that encourage the more efficient use of direct energy inputs.

7.1.3 Declining Vegetarianism and Increasing Energy Requirements of Food

Despite the general shift towards lower energy intensities for most productive sectors, almost all sectors in the 'food and agricultural' group, experienced large increases in primary energy intensities during the decade studied. This trend is explained in part by the fast rate of growth of electricity use in the agricultural sector during this period, which in fact, was the highest among all sectors in India.

The post-green revolution era has resulted in a much more input-intensive farming system in India. While the performance of the agricultural sector has been impressive in terms of higher farm yields and India gaining self-sufficiency in grain production, greater mechanisation and intensification of agricultural operations has meant a large increase in energy required for food production. Farmers have switched from rain-fed subsistence type farming to more market-oriented commercial agriculture. High-yielding varieties of seeds that require more irrigation and more of other inputs are in widespread use now. This has led to an increase in the direct energy needs for running irrigation pump-sets. Indirect energy use in terms of fertiliser and pesticide application has also increased substantially. Thus, total energy needs for food production, as reflected in the primary energy intensities of the agricultural sectors, have increased over the period analysed.

At the same time, however, in absolute terms, food energy requirements for India are still low compared to those for developed countries. A comparison of food energy needs in India with those of a developed country like Switzerland reveals that average per capita food energy requirements in India are almost one-eighth of those in Switzerland. The study for Switzerland made by Duerrenberger et al. (2001) estimates average per capita energy requirements for feeding, as 28.77 GJ per year and this comprises less than 15% of the total energy requirements of the average Swiss. In contrast, the estimates for 1998-99 from this study reveal the per capita energy requirements for food for the average Indian are 3.72 GJ and yet these comprise about one-third of the total per capita energy requirements.

The food factor, therefore, is of crucial significance in a discussion of total household energy requirements in India. This study shows that food energy requirements comprised the largest component of indirect energy requirements of Indian households. Future growth in population will mean more mouths to feed and therefore improvements in energy efficiency of food cultivation, processing, and transportation will have important implications on future food energy needs. At the same time, improved efficiencies of cooking stoves and household appliances as well as improved cooking practices can also have an important impact on future energy needs. As presented in Chap. 6, three distinct categories of food commodities were distinguished from the analysis carried out in this study. With an increase in income there is a definite shift in favour of “premium foods” such as processed foods and beverages, and “basic foods” such as meat and eggs, as compared to “subsistence foods” like cereals. These trends in the pattern of food consumption point to a likely shift towards more energy intensive items such as meat, milk products, and processed foods. Thus, large increases can be expected in energy needs for “basic” and “premium foods” in the future. Recent trends also indicate an increasing share of the population switching from a vegetarian diet to a non-vegetarian one. If this trend can be halted or reversed in future years, then this could help in lowering the growth in food energy requirements of the country.

7.1.4 Rapid Substitution of Non-Commercial Energy by Commercial Energy

The results of the analyses presented in previous chapters show that households in India have witnessed dramatic increases in the use of commercial energy forms during the period from 1983-84 to 1999-00. While, non-commercial biomass supplied over 90% of household direct primary energy needs in 1983-84, less than 80% of these needs were met from biomass by 1999-00. The direct use of petroleum products by households increased at an average rate of about 4.5% per year over this period, while that of electricity increased by over 10% per year over the same period. The level of increase has been particularly large in the case of urban households. The average data on per capita total household energy requirements show little difference between rural and urban households. However, these averages mask large disparities, which are evident in the pattern of primary energy requirements for most commercial energy forms. In fact, as results in Chap. 6 indicated, urban households in the same income category have on average higher commercial energy requirements than their rural counterparts for every income category. Non-commercial energy is the only form of energy for which rural requirements are on average higher than urban requirements. Higher levels of affluence and urbanisation are the underlying determinants of changing patterns of direct energy use in households. Thus, future trends towards further urbanisation and personal income growth are likely to sustain these trends of rapidly reducing use of non-commercial energy and increasing commercial energy use.

A detailed analysis of changes in energy requirements over time and across households, carried out in this study, indicates that as income and expenditure levels rise, households tend to use more commercial fuels and electricity. Disparities in the use of direct energy are, in part, the result of an energy ladder effect. An increased reliance on modern fuels stems from a preference among consumers for more convenient, efficient, and readily available fuels. Thus, in rural areas, where accessibility to modern fuels is a problem, households still rely heavily on non-commercial energy. However, in urban areas, easy access to modern fuels has resulted in a faster transition to the use of such fuels. Results presented in Chap. 6, also show that at the same level of expenditure, a much larger proportion of the urban population uses more modern fuel types as compared to the proportion of rural population. Thus, for instance, among the top income group, more than 88% use LPG as a cooking fuel in urban areas, whereas in rural areas the corresponding figure is only about 30%.

These trends in household direct energy use patterns hold both positive and negative implications for future energy needs in India. The switch from non-commercial to commercial energy consumption could lead to large efficiency gains, as the end-use efficiencies of modern commercial fuels are higher. In addition, improvements in health, the environment and overall well being can be expected from such a shift taking place. On the other hand, this transition is also resulting in a further surge in commercial energy use. In addition, increase in the penetration of household appliances points to a rapid increase in the use of electricity in Indian households. Meeting these growing energy demands in a sustainable way poses a huge challenge for India.

7.1.5 Rising Income Levels and Increasing Energy Requirements

The income factor is likely to be the prime driver of increasing energy requirements in the future for India. Growth in incomes is leading to an increased demand for energy, particularly electricity end use, and energy-intensive products and services. An increase in the total per capita energy requirements is a consequence. Both the cross-sectional and time trend analyses carried out in this study show the significance of total expenditure (income) levels in increasing household energy requirements. The decomposition analysis, presented in Chap. 4, clearly shows the contribution of changes in structure, intensity, activity, and population size to total change in household energy requirements. It also shows that the activity effect, or in other words, growth in household consumption, dominated the increase in total energy requirements and each category of indirect energy requirements for the period analysed. In addition, in Chap. 5, the results regarding factors affecting cross-sectional variations in total household energy requirements per capita indicate that per capita expenditure levels are the most important explanatory factor.

The growth in income levels and energy requirements for Indian households should be looked at in the context of the absolute levels of energy use. According to the estimates from this study, the average Indian had a total energy requirement of approximately 14 GJ in 1998-99. This is about one-fifth of the global average of 68 GJ (about 2 kilowatt per capita) and slightly less than half that postulated by Goldemberg (1990) as that which could satisfy basic human needs. Thus, energy poverty is still a reality for most of the Indian population. The energy distribution of the population shows that over two-thirds have a total household energy requirement per capita of less than 20 GJ. Only the top few percentages of the population, in fact, consume more than 60 GJ (or 2kW) per year. According to the draft approach paper for the eleventh five year plan (PC 2006), a target growth rate of 8.5% is envisaged for India for the next five years. Assuming the expenditure elasticity of energy requirements estimated by the analysis presented in Chap. 5 remains the same over this period, this growth in income will imply an average growth in per capita primary household energy requirements of over 3% per year till 2012.

While both direct and indirect energy requirements were shown to increase with household expenditure levels for the studied period, the rate of increase of direct energy use was much slower and tended to level off at very high expenditure levels. On the other hand, indirect energy requirements increased more directly with household expenditures. As a consequence, the share of indirect to direct energy also rose significantly with an increase in expenditure level. Clearly, rising income levels will have important implications for household energy requirements in the future.

7.1.6 Persistent energy poverty and growing disparities in energy use

The analysis of distributional and equity issues presented in Chap. 6, point to the fact that while development has resulted in gains, the distribution of these gains has not always been equitable. Several researchers who have studied household poverty and income distribution within India agree that overall levels of poverty declined during the 1980s. However, a great degree of controversy persists over whether or not poverty levels and inequalities have reduced during the 1990s (see Bhalla and Das 2004; Datt et al. 2003).

The analyses presented in Chap. 6 reveal some important facts related to distributional issues. Large rural-urban disparities, disparities among different Indian states and disparities among rich and poor persist. Rural and urban disparities in energy use stem in part from differences in income levels and lifestyles, but disparities in access to energy, infrastructure, supplies and energy related equipments and appliances are also significant and contribute to these differences. While less than 30% of India's population is urban, they account for about 65% of total direct and indirect household energy requirements. Results presented in Chap. 6 indicate, that above a threshold per capita expenditure level of Rs. 10, 000 in 1999-00, among the urban population over 90% used electricity and over 60% used LPG. However, in rural areas, at the equivalent per capita expenditure level, 70% of the population used electricity and only about 20% used LPG. Inequities in access are also reflected in the bigger relative share of household budget spent by the poor on energy services and higher costs per unit useful energy for those without access to modern energy types. These results clearly have implications for energy price or tax policies as such policies will inevitably differentially affect poorer households.

Inequalities in energy access, especially electricity access have declined over the last couple of decades. However, large inequalities in energy and electricity use still persist. While some progress has been made in improving access to modern energy sources, the evidence regarding disparities across regions and states in terms of energy consumption levels indicates further widening which mirrors the increasing disparities in state domestic products and incomes reported by authors like Deaton and Dreze (2002).

These results of persisting energy poverty and widening disparities are particularly worrying given the strong evidence to show that low energy access and consumption are correlated with many other important dimensions of poverty. Clearly, improving the well being of the poorest requires renewed efforts at increasing their access to the basic minimum level of energy services. Whether future development of the country will lead to a reduction in these disparities still remains to be seen. However, efforts to reach the poorest can not be pinned on markets alone and concerted public policy and action is needed to ensure more equitable development. Future research on exploring the impact of changing distributions of income on total household energy requirement in India is also needed to inform such public policy.

7.2 Conclusions and Limitations of the Data and Methods

The special significance of the work presented in the previous chapters is in increasing understanding of energy use patterns in India, especially in the context of socio-economic changes taking place within the country. Methodologically, the novelty of the work lies in the fact that it tests, for the first time, whether some methods developed in industrially advanced countries, of examining energy systems from an alternative household perspective, can be adapted for a developing country like India. The analysis carried out demonstrates that established techniques of energy analysis could be effectively adapted to the Indian context to provide a fruitful methodological framework to study the direct and indirect energy requirements of private household consumption in India. The methods could also be effectively adapted to include non-commercial energy use as well, which still comprises a large part of total energy use in India. An expansion of the methodology to analyse issues of distributions, poverty and the relationship between energy access and use and well being, proved to be essential for gaining additional insights and revealing the complexity of changes within the context of a rapidly developing country such as India. Adopting this alternative household perspective to Indian data provides a good snapshot of the energy system in India, and holds considerable promise for future research in this area. It can also be concluded that the methodological principles and general analysis carried out in this study are not unique to any one country or region and the successful application of these to India suggests that they can be applied to other developing countries as well, assuming that the required date are available.

Two general caveats relating to the data need to be mentioned here. First, the quality of the data was not discernable in all cases. While crosschecks were carried out with different sources of data in many instances, some of the data were still found to be of questionable quality. Therefore, the estimates presented in this study should be interpreted as reflecting the general trends and pattern of energy use in India rather than as exact estimates in all instances. Second, while both the aggregated and disaggregated data used for the different classes of analyses carried out, were quite detailed, the availability of more disaggregate data in the future would make it possible to capture in more detail energy use changes related to specific categories of consumption or production processes.

The methodologies involved in looking at energy systems from the household perspective were applied to Indian data within different areas. The specific conclusions and limitations for each of these areas of application are presented below.

7.2.1 Adaptation and Application of the Input-Output Energy Analysis Method

A major question posed by this work was whether it is feasible to modify and apply the input-output energy analysis model to calculate energy intensities of production sectors in India. This question was addressed by using a combination of monetary input-output transactions data for the economy along with physical energy flow data, including data on non-commercial energy. The input-output method of energy analysis was successfully modified to include non-commercial energy use of sectors and was applied to calculate total primary energy intensities of productive sectors in India. Total primary energy intensities were calculated at the 100-sector disaggregated level for the years 1983-84, 1989-90, 1993-94 and 1998-99. This is the first time that such an exercise has been carried out for India at such a disaggregated level and by incorporating data on non-commercial energy use. The absolute values of calculated intensities could not be compared with those from other Indian studies, but the trends and relative magnitudes of intensities of different sectors from this analysis were similar to those observed in related studies for India (Rao et al. 1981; Roy and Mukhopadhyay 1998; Tiwari 2000).

Some of the main conclusions of the investigation of applying the input-output methodology to Indian data are presented hereunder:

- Despite the fact that data on energy flows to different productive sectors for India are published in an aggregate form, data are available for both commercial and non-commercial energy sources. It was therefore, possible to successfully adapt the input-output energy analysis methodology to calculate total primary energy intensities of productive sectors in India. The published energy data and the input-output data were observed to be more detailed than in the case of many developed countries, making it more amenable for analysis.
- The results of an uncertainty analysis that was carried out by simulating a maximum positive or negative deviation of 10% in all elements of the transactions matrix and direct energy requirements of all productive sectors for the year 1998-99 revealed that the resultant maximum deviations in energy intensities for most sectors, while not insignificant, were quite small and fell within the range observed in other studies (Bullard and Sebald, 1977). The results were acceptable in comparison to the outcome of the analysis of trends in energy intensities over the period of study. The changes in total energy intensities observed over the decade can therefore be accepted with greater confidence.

The limitations to the application of input-output energy analysis to Indian data are discussed below. Most of these pertain to a lack of data or to poor quality of some data. Some relate to methodological constraints.

- While the input-output method allows one to calculate average sectoral productive energy intensities, it does not allow for a distinction to be made between qualities or types of sector outputs (for e.g. high and low quality steel with differing specific energy values). Therefore, although this method provides accurate estimations of the total energy costs per unit of average sector outputs for largely homogenous sectors, process analysis or hybrid analysis could be useful at arriving at more accurate results in cases where the target product is a very minor output of a large and diverse sector (for e.g. soap or toothpaste from the chemical sector). But, the detailed and voluminous data that are required for process or hybrid analysis precluded the application of these techniques in this study.
- Input-output data are published for India at the 115-sector level. An analysis of energy intensities could, therefore, not be carried out at a more disaggregated level. Clearly, the availability of more detailed input-output transactions tables and energy flow data at the 350-sector level, as available for the USA, would result in even more accurate estimation of total energy intensities for India. It should, however, be pointed out that the input-output data published for India were found to be of good quality and the sector definitions quite homogenous. In addition, the degree of disaggregation was found to be much greater than that for most developed countries.
- Theoretically, energy requirements of net imports of all goods and services, and of capital goods and investments should be included in the estimation of total sectoral primary energy intensities. These could not be included in the estimations carried out in this study due to a lack of related energy flow data. The exclusion of net imports should not, in all likelihood, affect estimates of energy intensities for India significantly, because net imports, other than those of crude oil, which were included in the estimation, are negligible. However, the exclusion of energy flows on capital goods would probably have resulted in an underestimation of indirect energy intensities of productive sectors. These data should be incorporated in future research.

7.2.2 Estimation and Analysis of Total Household Energy Requirements

The other research questions of the study were whether or not it was feasible to calculate energy requirements, both direct and indirect, of households in India and analyse the variation in these household energy requirements across time and households. At the aggregate level, multiplying total private final consumption expenditures with appropriate sectoral primary energy intensities resulted in estimates of total household energy requirements for the country. The average per capita household energy requirements could then be calculated by dividing the total by population size. At the disaggregate level, detailed data from a national survey on household budget expenditures were used in conjunction with the calculated primary energy intensities of productive sectors, in order to determine the energy requirements of different consumption categories as well as different types of households. Some of the key methodological conclusions and limitations in this regard are:

- It was feasible to calculate total and average household energy requirements for the years 1983-84, 1989-90, 1993-94 and 1998-99, as well as household energy requirements for many different individual households using household survey data for the corresponding years.
- Large disparities were evident in the total household energy requirements calculated using aggregate, and disaggregate household survey data. Values based on national data are likely to be overestimates whereas those based on survey data, underestimates. The reasons for these disparities stem for the different estimation procedures adopted by the two agencies that collect the data (see Sects. 5.2.2, 5.2.5 and 5.3.2. for a detailed discussion of these differences).
- The household survey data on the consumption of durable goods was not as detailed as that on food, clothing and other expendable goods and services. Since durables have a long life, the purchase of these goods takes place at discrete intervals of time and the survey data does not accurately capture durable ownership. Therefore, the energy requirements associated with the consumption of such goods might have been underestimated in this study. The availability of more detailed data on consumption of durable goods by households should make it possible to arrive at more accurate estimates in the future.
- While an analysis at the per capita level was carried out using household sample budget data, the estimated values for per capita energy requirements refer to average values per household and do not capture intra-household differences in consumption patterns (i.e. differences in consumption between male and female members of the household or children and adult members). The sample data on household expenditures and consumption patterns refer to the totals for the entire household and

do not include data on the distribution among different members of the family and thus did not allow for capturing these differences.

7.3 Future Research

The study is unique in that it is the first of its kind carried out for India or, for that matter, for any other developing country. It has been important for deepening the understanding of factors that influence direct and indirect energy requirements of households in India. It also builds a strong case for the need for including issues of energy access, reliability and affordability in all well being assessments. The preceding sections have highlighted some of the key conclusions of the research. These should be useful to policy makers and planners in assessing the energy implications of alternative development strategies.

The work presented herein has highlighted several new avenues for future research. Analytical approaches are needed that improve our understanding of the complexity of the energy problem in relationship to development. More specifically, analysis is needed that can assist in assessing the energy and environmental implications of meeting the social challenges of improving the well being of vast numbers of poor and reducing inequities in current distributions that most developing countries are faced with. There is need for developing new methodologies, especially for developing countries, that enable more detailed analysis of the interplay of changing lifestyles and infrastructural attributes on household energy requirements. Given the increasing significance of India as a contributor to global energy consumption and environmental pollution, an important area of future research is to extend the analysis done here to determine the environmental impacts (indoor, local and global) of household consumption, both in terms of direct and indirect emissions associated with energy use.

Further work using disaggregate data sources that analyse patterns of energy use, both direct and indirect, in Indian households with a view to gaining a further understanding of how energy use differs between different household groups within the country and the relationship of the patterns of energy use with the overall level of development, is also needed. More work needs to be carried out on developing methodologies that account for compositional changes in the population across different demographic and socio-economic groups and the likely impact of these compositional changes on the value of future macro economic, energy and environmental aggregates. Further research is also needed on what affect distribution (in terms of infrastructural variables and income) has on the pattern of energy use and whether this also has implications for the extent to which different groups are exposed to varying degrees/ types of environmental pollution. Clearly such efforts could also be extended to other developing countries.

The creation of multiple scenarios are widely recognised as a tool for exploring the uncertainties behind potential trends in political, economic, social, demographic and technological developments and related energy and environmental developments. Exploring possible alternative energy use trajectories for India is another area of future work. Greater use of analyses and models to construct future scenarios regarding possible paths of development based on varying assumptions relating to different factors affecting the level and patterns of total energy use in households and the composition of different household groups is needed. These scenarios could act as a planning tool and provide insights into suitable strategies and policies that need to be implemented and adopted in order to influence energy use and development in the future, in a direction that is more sustainable.

Clearly, much more empirical research needs to be done before the energy-development relationship for India can be fully understood. The work presented in this book has made a first significant step in that direction and has improved the methodological and empirical foundation upon which to conduct further research. The book has value to energy planners and policy makers as well. It has identified and assessed a number of important trends and patterns of energy use in the country and factors influencing these trends. It will hopefully contribute to formulation and implementation of more sustainable energy strategies in the future, which help to meet the development goals of India.

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