Draft Report

Fiscal & Monetary Policy aspects under Framework for Energy Efficient Economic Development (FEED) Mechanism of National Mission for Enhanced Energy Efficiency (NMEEE)

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May 2012

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New Delhi

Preface

This study was sponsored by the Bureau of Energy Efficiency (BEE). The study was carried out under the supervision of Prof. Ramprasad Sengupta. The other member of the team is Dr. Manish Gupta.

The members of the Governing Body of the National Institute of Public Finance and Policy are in no way responsible for the opinions expressed in this report. The authors alone are responsible for the views expressed here.

M. Govinda Rao
Director

Acknowledgement

The Study on Fiscal & Monetary Policy aspects under FEED Mechanism of NMEEE was taken up at the request of the Bureau of Energy Efficiency, Ministry of Power, Government of India. We are grateful to Dr. Ajay Mathur, Director General, Bureau of Energy Efficiency, for taking keen interest in the study. The study team is grateful to Dr. M. Govinda Rao, Director NIPFP for his active interest and support. Discussions with him at various stages of the study were extremely helpful. We would also like to thank Mr. Somit Dasgupta, Adviser, Power & Energy Division, Planning Commission, for his help on the Power Sector part of the report. Discussions with him were very useful in understanding the power sector in India. The authors would like to acknowledge discussions with Dr. Kavita Rao which were very useful. Thanks are also due to Ms. Chetana Choudhury for providing excellent research assistance. Annual Survey of Industries (ASI) data provided by the Ministry of Statistics and Programme Implementation (MoSPI), without which this study could not be completed, is gratefully acknowledged.

Contents

Preface
Acknowledgements

1.	**Introduction**	1-12
	1.1 The Energy Scenario in India	3
	1.2 Trends in Energy Intensity: Time series Analysis	7
2.	**Energy Efficiency Policies: International Experience**	13-38
3.	**Benchmark Analysis**	39-87
	3.1 Unit Level Benchmark Analysis: Energy Consuming Industries	41
	3.2 Benchmark Analysis for the Power Sector	81
4.	**Econometric Model for Inter-input and Inter-fuel Substitution and Derived Demand for Energy for Non-Energy Industry**	88-127
	4.1 The Model	89
	4.1.1 Demand for aggregate inputs: Factor input model	91
	4.1.2 Fuel Model: Demand for fuels	95
	4.2 Data and variables	98
	4.3 Results	100
	4.3.1 Fuel Model	100
	4.3.2 Factor Input Model	104
	4.3.2.1 Cost share trends	106
	4.3.2.2 Productivity tends and technical change	108
	4.3.3 Patterns of Input Substitution	110
5.	**Economic Viability of Energy Conservation in Electricity Generation Industry**	128-139
6.	**Policy Recommendations and Conclusion**	140-148
References		149-153
Appendix		154-157
Appendix 1: Scope and Coverage of Annual Survey of Industries		154
Appendix 2: Tables		155

List of Tables

1.1 Commercial energy consumption in India, by sector (%)
1.2 Share of Select Industries in Total Industry Energy Consumption, Total Output and Gross Value Added in 2007-08 (%)
2.1 Some Financial Initiatives in EU countries
2.2 Energy Efficiency Policy Matrix
3.1a Energy Savings Potential - Textile Industry (2007-08)
3.1b Electricity Savings Potential - Textile Industry (2007-08)
3.1c Group Specific Energy Savings Potential - Textile Industry (2007-08)
3.1d Energy Savings Potential - Textile Industry (2007-08)
3.1e Electricity Savings Potential - Textile Industry (2007-08)
3.1f Group Specific Energy Savings Potential - Textile Industry (2007-08)
3.2a Energy Savings Potential - Paper & Pulp Industry (2007-08)
3.2b Electricity Savings Potential - Paper & Pulp Industry (2007-08)
3.2c Group Specific Energy Savings Potential - Paper & Pulp Industry (2007-08)
3.2d Energy Savings Potential - Paper & Pulp Industry (2007-08)
3.2e Electricity Savings Potential - Paper & Pulp Industry (2007-08)
3.2f Group Specific Energy Savings Potential - Paper & Pulp Industry (2007-08)
3.3a Energy Savings Potential - Fertiliser Industry (2007-08)
3.3b Electricity Savings Potential - Fertiliser Industry (2007-08)
3.3c Group Specific Energy Savings Potential - Fertiliser Industry (2007-08)
3.3d Energy Savings Potential - Fertiliser Industry (2007-08)
3.3e Electricity Savings Potential - Fertiliser Industry (2007-08)
3.3f Group Specific Energy Savings Potential - Fertiliser Industry (2007-08)
3.4a Energy Savings Potential - Chlor-Alkali Industry (2007-08)
3.4b Electricity Savings Potential - Chlor-Alkali Industry (2007-08)
3.4c Group Specific Energy Savings Potential - Chlor-Alkali Industry (2007-08)
3.4d Energy Savings Potential - Chlor-Alkali Industry (2007-08)
3.4e Electricity Savings Potential - Chlor-Alkali Industry (2007-08)
3.4f Group Specific Energy Savings Potential - Chlor-Alkali Industry (2007-08)
3.5a Energy Savings Potential - Cement Industry (2007-08)
3.5b Electricity Savings Potential - Cement Industry (2007-08)
3.5c Group Specific Energy Savings Potential - Cement Industry (2007-08)
3.5d Energy Savings Potential - Cement Industry (2007-08)
3.5e Electricity Savings Potential - Cement Industry (2007-08)
3.5f Group Specific Energy Savings Potential - Cement Industry (2007-08)
3.6a Energy Savings Potential - Iron & Steel Industry (2007-08)

3.6b Electricity Savings Potential - Iron & Steel Industry (2007-08)
3.6c Group Specific Energy Savings Potential - Iron & Steel Industry (2007-08)
3.6d Energy Savings Potential - Iron & Steel Industry (2007-08)
3.6e Electricity Savings Potential - Iron & Steel Industry (2007-08)
3.6f Group Specific Energy Savings Potential - Iron & Steel Industry (2007-08)
3.7a Energy Savings Potential - Aluminium Industry (2007-08)
3.7b Electricity Savings Potential - Aluminium Industry (2007-08)
3.7c Group Specific Energy Savings Potential - Aluminium Industry (2007-08)
3.7d Energy Savings Potential - Aluminium Industry (2007-08)
3.7e Electricity Savings Potential - Aluminium Industry (2007-08)
3.7f Group Specific Energy Savings Potential - Aluminium Industry (2007-08)
3.8 Energy Savings Potential in Select Industries in India– 2007-08
3.9 Energy Savings Potential in Power Sector based of Station Heat Rate (2009-10)
3.10 Energy Savings Potential based on Auxiliary Power Consumption (2009-10)
3.11 Energy Savings Potential based on Secondary Fuel Oil Consumption (2009-10)
3.12 Energy Savings Potential in Coal Based Power Plants in India – 2009-10 (%)
3.13 Overall Energy Savings Potential in Coal Based Power Plants in India – 2009-10 (%)
4.1 Parameter Estimates of the Fuel Model
4.2 Total Own and Cross Price Elasticities (Fuel Model)
4.3 Inter-Fuel Relationship
4.4 Parameter Estimates of the Factor Model
4.5 Factor Input Cost shares - Average for the period 1991-92 to 2008-09
4.6 Technical Change Bias
4.7 Technical change in Indian Industries (1991-92 to 2008-09)
4.8 Own and Cross Price Elasticities – Factor Model
4.9 Inter-factor relationship
4.10 Percentage change in derived demand for Energy and consequent changes in other factor inputs for a 10 percent increase in energy price
4.11 Required percentage change in energy price and consequent changes in factor input requirement for a target 10 percent decline in energy consumption for select industries
4.12 Percentage change in derived demand for Capital and consequent changes in other inputs for a 10 percent Increase in the price of capital
4.13 Percentage change in price of capital for a 10 percent decrease in energy demand
4.14 Percentage change in derived demand for labour and consequent changes in other inputs for a 10 percent increase in price of labour
4.15 Percentage change in price of labour for a 10 percent decrease in energy demand
4.16 Percentage change in derived demand for Material input and consequent

changes in other inputs for a 10 percent increase in material prices
4.17 Percentage change in price of material for a 10 percent decrease in energy demand
4.18 Percentage changes in prices of factor inputs required for inducing a 10 percent decrease in energy demand
4.19 Percentage change in derived demand for Electricity and consequent changes in other energy inputs for a 10 percent increase in electricity prices
4.20 Required percentage change in Electricity prices for a target 10 percent decline in Electricity consumption
4.21 Percentage change in derived demand for Coal and consequent changes in other energy inputs for a 10 percent increase in Coal prices
4.22 Required percentage change in Coal prices for a target 10 percent decline in Coal consumption
4.23 Percentage change in derived demand for Oil and consequent changes in other energy inputs for a 10 percent increase in Oil prices
4.24 Required percentage change in Oil prices for a target 10 percent reduction in oil consumption
4.25 Percent change in aggregate Energy demand due to a 10 percent increase in the price of different fuels
4.26 For targeted 10 percent conservation of aggregate energy the required percentage changes in the price of different fuels
5.1 Economic Viability Analysis of Investment for Energy Conservation: Some Scenarios
5.2 Economically viable capital investment

List of Figures

1.1 Energy Consumption in 2007-08 (%)
1.2 Energy Intensity of Indian manufacturing Sector and Real Energy Price [1982-83 to 2008-09]
1.3 Energy Intensity in Select Industries (1991-92 to 2008-09)
1.4 Real Price of Energy (at 1993-94 prices)
4.1 Fuel Cost shares - Average for 1991-92 to 2008-09
4.2 Factor Input Cost Shares (%)

Chapter 1 Introduction

India is faced with the challenge of sustaining its rapid economic growth while dealing with the threat of global climate change. India's development agenda focuses on the need for rapid economic growth as an essential precondition for eradicating poverty and improving standards of living and reducing climate change related vulnerability of the people. The National Action Plan on Climate change (NAPCC) released in 2008 recognises this need to maintain a high growth rate for raising the living standards of the vast majority of its people since higher income and higher level of infrastructural development can only reduce the vulnerability of the people to the adverse impacts of climate change. However, the environmental sustainability of growth process would require that the adverse impact of the economic growth on the ecosystems should be minimized by combining growth with sustained rise of the efficiency of use of natural resources including efficiency of energy resources.

One of the strategies or missions of the National Action Plan on Climate Change is the National Mission for Enhanced Energy Efficiency (MNEEE) whose objective is to promote innovative policy and regulatory regimes, financing mechanisms, and business models, which not only create, but also sustain, markets for energy efficiency in the different spheres of economic activities in a transparent manner. Framework for Energy Efficient Economic Development (FEEED) is one of the initiatives spelt out in the mechanism of National Mission for Enhanced Energy Efficiency (NMEE) to promote energy efficiency in the country. FEEED seeks to develop fiscal instruments to promote energy efficiency in the country.

Energy is a fundamental requirement for individual households and is also an essential service input (energy service) used in all kinds of production activities of goods and services. Growing population and expanding scale of economy as resulting from high growth puts pressure on the ecosystem to provide increasing supplies of primary energy resources required for providing final energy for use by the non-energy end use sectors and also for absorbing the increasing volumes of wastes or pollution generated. As all energy supplies have to be ultimately drawn from the nature, we mean here by primary energy supplies, all energy resources as drawn from the nature before any conversion or transformation – like coal, crude oil, natural gas, hydro-resource in storage, uranium, wind, solar light energy, etc. The final energy supply would comprise only of flows of energy in such converted or refined forms so that these are directly usable for the non-energy sectors, for example, petroleum products, electricity, coal washed or unwashed as available for direct energy use, etc. The rise in resource efficiency would require the lowering of energy requirement per unit of level of operation of an economic activity or its output, as well as rise in the supply efficiency of final energy through the minimization of losses of conversion of energy resources into the final form, and its subsequent losses in transportation and distribution. These would in turn require energy saving technical changes both in the end use sector of energy as well as in the energy supplying industry.

In this context, the study sponsored by the Bureau of Energy Efficiency (BEE) seeks to investigate and suggest ways for facilitating the objective of enhancing energy efficiency in the country. The Terms of Reference (ToR) for the study are as given below:

1. Suggest appropriate formulations of the fiscal framework for proving fiscal and monetary incentives for promotion of energy-efficient products and development of new equipment under the existing and emerging taxation regime (including that of the new Direct Tax regime).
2. Suggest measures that the government can take to promote energy efficiency through its financial policies. These measures should be consistent with the basic tenets of the new taxation regime.

3. Explore the possibility of including carbon finances, particularly for international protocols, in the same manner as is available for the Montreal Protocol under the direct tax laws.
4. Conduct a survey of the financial incentives provided by way of amendments in fiscal and financial policy in other countries to promote Energy Efficiency and development of Energy Efficient equipment.

This study on energy efficiency, however, confines its scope to the efficiency of use (end-use) and supply of commercial energy. It is the combustible biomass and wastes which constitute a significant share of total primary energy supply (the share being 27.2 percent in 2007) which are mostly not traded through the market and collected mostly by households. These are therefore, called non-commercial energy. The database for this part of energy supply is not as strong as it is for the commercial energy resources. Besides, the biomass is carbon neutral due to the possible recycling of carbon dioxide arising from its combustion through the photosynthetic process. It is the primary commercial energy resource which is accordingly considered to be responsible for most of the energy related environmental pressure accounting for climate change. This is the rationale of the choice of scope of types of energy supply to be confined to the domain of commercial energy for the present study.

1.1 The Energy Scenario in India

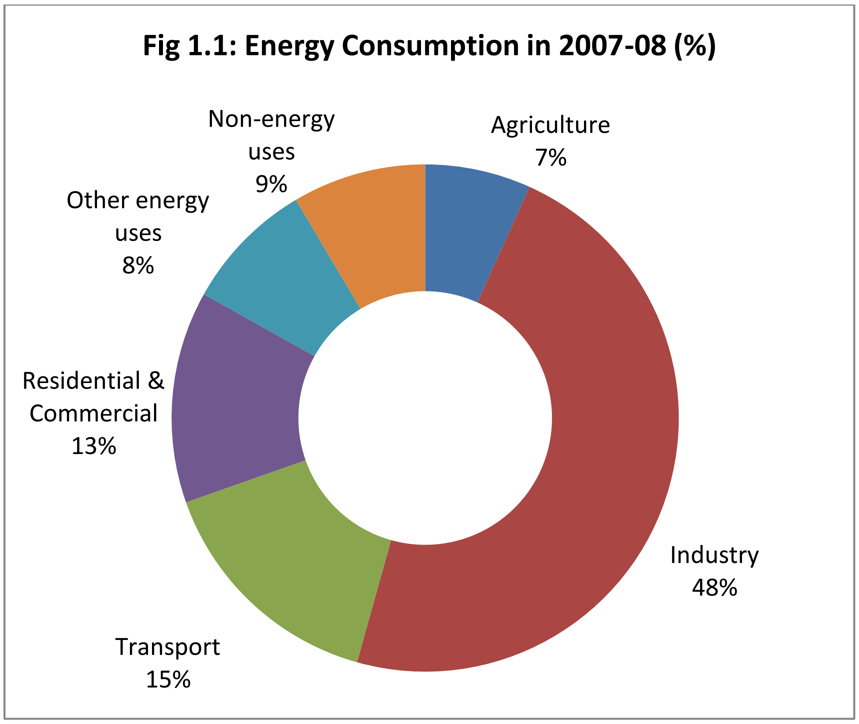
The total primary energy supply in India was 621 million tonnes of oil equivalent (mtoe) in 2008, while the final energy supply in the same year was 412.67 mtoe. Out of these total supplies, the supply of primary commercial energy and that of final commercial energy supply have been 457.4 mtoe and 250.3 mtoe respectively in 2008. In per capita terms, in India the primary energy consumption (including non-commercial energy) has been 529 kilogram of oil equivalent (kgoe) in 2008 while the per capita energy consumption in low income, middle income and high income countries have been 413 kgoe, 1242 kgoe and 5321 kgoe respectively (World Bank 2010) in the same year. Thus we see that the per capita consumption of energy is much lower in India as compared to other middle income and high income countries of the world. This signifies that to provide support of energy security to high economic growth and to meet the lifetime modern clean commercial energy needs of all the citizens as are the present goals of India's energy policy, there will be substantive rise in both the total and the per capita commercial energy requirements of India under a frozen technology scenario. The consideration of environmental sustainability would therefore warrant the moderation of such rise in per capita energy use by reducing the commercial energy intensity of GDP. This study would therefore try to ascertain the scope of commercial energy saving potential in the final energy using sectors and also that of minimization of losses in energy conversion and supply.

The trend and sectoral pattern of commercial energy consumption in India is illustrated in table 1.1, while figure 1.1 shows the sectoral shares of final energy consumption in 2007-08. From table 1.1 we see that industrial sector is the major consumer of energy in the country accounting for about 48 percent of the commercial energy consumed in the country in 2007-08. Although the share of industrial sector in the total commercial energy consumption has declined over the years, it is still the largest consumer of commercial energy in the country. The second most important sector in terms of such energy consumption is the transport sector accounting for 15.27 about percent of the total consumption in 2007-08 followed by the residential and the commercial sector. Agricultural sector accounted for 6.75 percent of the total commercial energy consumption in the country in 2007-08. With increased mechanisation, use of irrigation, etc., the share of agricultural sector in the consumption of commercial energy has increased from 2.33 percent in 1980-81 to 6.75 percent in 2007-08.

Table 1.1: Commercial energy consumption in India, by sector (%)

Sector	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2007-08
Agriculture	*2.33*	*2.59*	*3.92*	*5.27*	*7.93*	*6.97*	*6.75*
Industry	*53.71*	*53.02*	*50.36*	*48.65*	*40.40*	*44.41*	*47.58*
Transport	*25.33*	*23.38*	*22.42*	*23.35*	*17.48*	*16.85*	*15.27*
Residential & Commercial	*8.15*	*9.59*	*10.09*	*9.60*	*12.58*	*15.05*	*13.51*
Other energy uses	*2.77*	*2.91*	*3.12*	*4.27*	*6.99*	*8.63*	*8.37*
Non-energy uses	*7.71*	*8.51*	*10.09*	*8.85*	*14.61*	*8.08*	*8.52*
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Source: Tata Energy Data Directory and Yearbook 2010.



Source: Tata Energy Data Directory and Yearbook 2010

In the present report, we focus on the Industrial sector only in view of its dominant share in the consumption of commercial energy in the country. Within the industrial sector, the prime focus of the study is on eight industrial sectors - seven of them belonging to the non-energy sectors i.e., iron and steel, fertiliser, pulp and paper, aluminum, cement, chlor-alkali and textile - and one sector being an energy supplying industry, viz., the power generation sector. These industrial sectors are the largest industrial consumers of energy in the country and are the designate consumers (DCs) as per Energy Conservation Act 2001. (*Section 14 (e) of the Act empowers the Central Government to notify energy intensive industries, as listed out in the Schedule to the Act, as Designated Consumers (DCs). The Ministry of Power (MoP) has notified industrial units and other establishments consuming energy more than the threshold in 9 industrial sectors namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron & Steel, Aluminum and Railways in March, 2007 as Designate Consumers*)[1].We are not considering here the analysis of the railways because of the very different nature of the problems of energy efficiency and the methodology that would be involved and of the large dimension of the concerned exercises.

The Power sector is different from the other seven industrial sectors as it is an energy-supply industry while the other seven industries are energy-consuming industries and the issue of energy efficiency is different in these two sectors. In case of power sector the focus is primarily on the efficient conversion of primary energy into electrical energy. So the efficiency for this sector is to be analysed with reference to the conversion of coal, gas etc. (i.e., primary energy) into electricity (i.e., final energy) and its transportation and distribution. In the other seven industries the focus is on efficient utilization (or consumption) of energy (final energy). Therefore, the treatment of the power sector would be methodologically different from that of other seven industrial sectors.

The remaining seven industries/industrial sectors (i.e., iron and steel, fertiliser, pulp and paper, aluminum, cement, chlor-alkali, and textile) which were identified as Designate consumers account for 52.48 percent of the total energy consumption (in rupee terms) by all the industries considered in the Annual Survey of Industries in the year 2007-08. These industries account for 58.05 percent of the total electricity consumption, 46.49 percent, and 48.62 percent of the final energy and primary energy

[1] As Railways was outside the scope of the present study we concentrated on the remaining eight sectors which are the designate consumers.

consumption respectively (refer to table 1.2) by the entire industrial sector. Though, the share of energy consumption of these industries is high, their contribution to the total Gross Value added and Value of Total Output of all the industries is somewhat low at 27.63 percent and 22.38 percent respectively. Despite their relatively lower contribution to the industrial sectors' output and gross value added these industries account for more than 50 percent of the total energy consumption of the industrial sector and are therefore important for any study like the present one.

Table 1.2: Share of Select Industries in Total Industry Energy Consumption, Total Output and Gross Value Added in 2007-08 (%)

Industries	**Final Energy**	**Primary Energy**	**Electricity**	**Total Energy**	**Output**	**Gross Value Added**
Textiles	9.56	10.76	10.22	9.76	4.82	4.26
Paper & Pulp	2.30	2.23	3.16	2.83	0.95	1.04
Fertiliser	7.15	5.13	3.49	5.51	1.84	1.56
Chlor-Alkali	1.14	1.01	1.04	1.11	0.30	0.38
Cement	4.24	5.00	7.66	8.86	1.95	4.52
Iron & Steel	20.49	22.83	25.59	22.51	11.66	14.63
Aluminium	1.62	1.66	6.88	1.90	0.86	1.24
Total	***46.49***	***48.62***	***58.05***	***52.48***	***22.38***	***27.63***

Note: Though the energy consumption in the table is represented in terms of percentage of total energy consumed by the industries, the basic data pertaining to Final Energy and Primary energy is in kilogram of oil equivalent (*kgoe*) unit; for Electricity it is in Kilowatt-hour (*kwh*), and in case of total energy it is in monetary units i.e., in rupees.

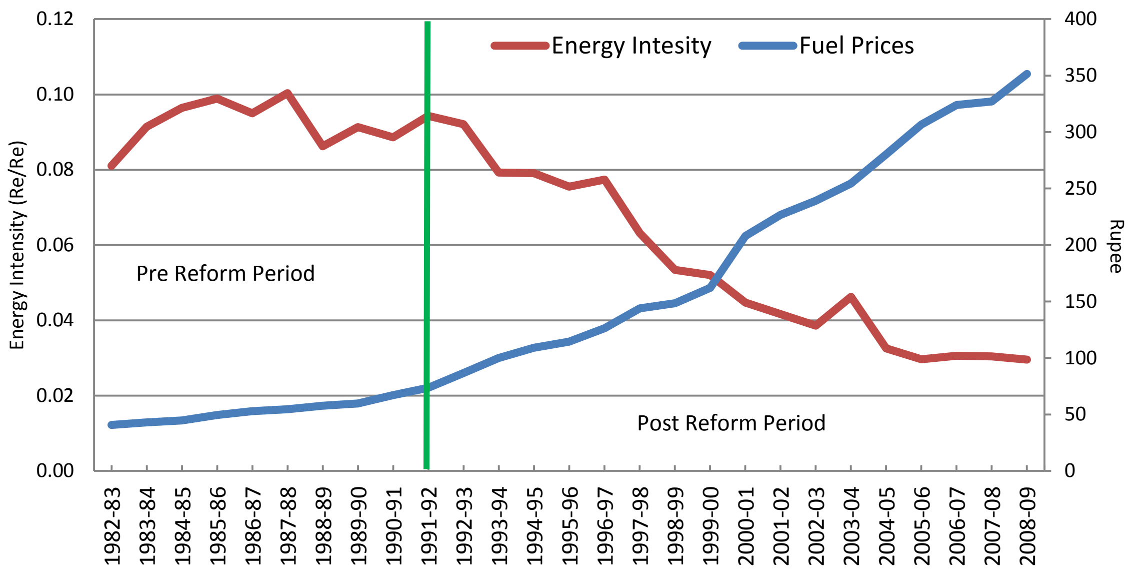
Source: Author's calculation based on Unit level ASI data

1.2 Trends in Energy Intensity: Time series Analysis

The first step towards identifying energy efficiency trends is to calculate the overall energy intensity, a general indicator of energy end-use. Energy intensity is defined here as the energy (commercial energy) consumed (in monetary units, i.e., in Rs.) to produce one unit of output (also expressed in monetary units, Re). The trends in energy intensity in Indian organized manufacturing sector during the period 1982-83 to

2008-09 calculated using the Annual Survey of Industries data is shown in figure 1.2. The energy intensity is calculated by taking the fuel consumption and output figures at constant prices (1993-94 prices) by using appropriate deflators for the two series. The energy intensity of the organized manufacturing sector witnessed a decline during the period 1982-83 and 2008-09. The rate of decline was to the tune of 6.72 percent per annum. However, if we decompose the entire period between 1982-83 to 2007-08 into two sub periods a)the pre-reforms period (1982-83 to 1991-92) and b) the post reforms period (1992-93 to 2008-09), we see that the rate of decline in energy intensity in the post reform period was much higher at 13.25 percent per annum.

Fig 1.2 Energy Intensity of Indian manufacturing Sector and Real Energy Price [1982-83 to 2008-09]



Note: Energy prices are in real terms (at 1993-94 prices) and are measured on the right axis while Energy intensity is represented on the left axis.

Figure 1.3 shows the trends in energy intensity in some of the major energy consuming industries considered in the study for the period 1991-92 to 2008-09. The energy intensity is measured in energy (final energy) consumed (in oil equivalent units) to produce one unit of output (in monetary units). The energy intensity registered a decline for each of the industries during this period. The rate of annual decline was highest for fertilizer industry followed by all manufacturing sector taken as a whole. Among the industries considered in the study the rate of annual decline in energy intensity was the least in textile industry during the period 1991-92 and 2008-09.

Fig 1.3: Energy Intensity in Select Industries (1991-92 to 2008-09)

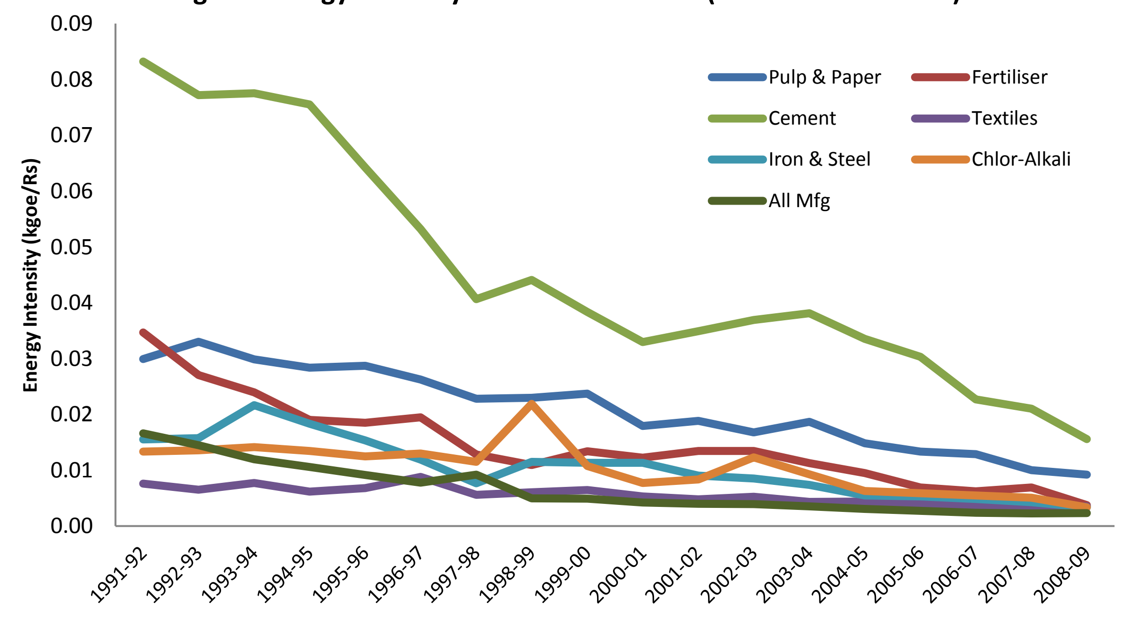
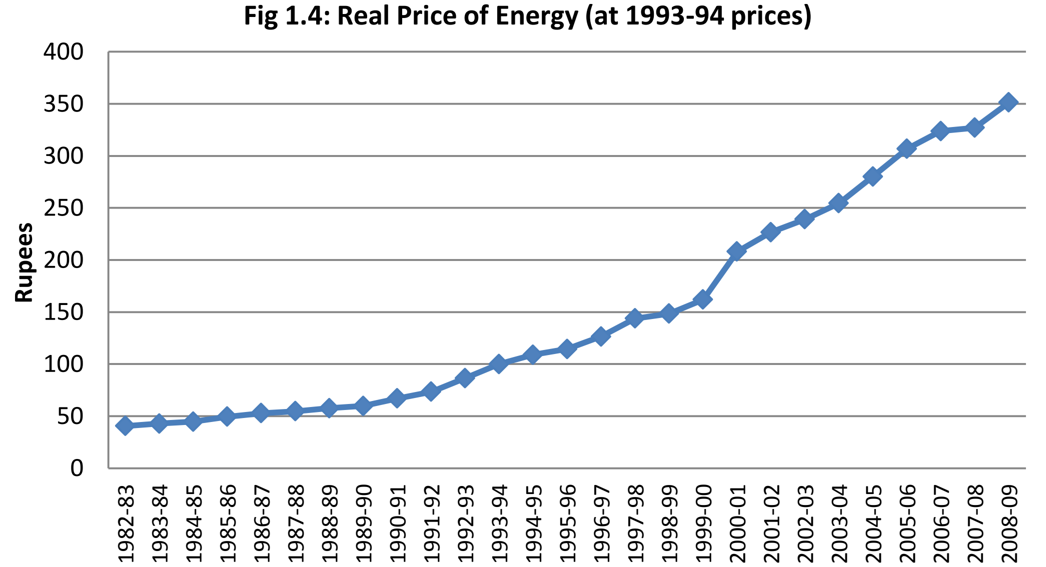


Fig 1.4: Real Price of Energy (at 1993-94 prices)



However, if one considers the movement of real energy prices faced by the manufacturing sector during the same period (i.e., between 1982-83 and 2008-09), one can see a sharp rise in real energy prices[2] (fig 1.4). The energy prices in real terms increased at an annual rate of 3.40 percent between 1982-83 and 2008-09. The annual increase in energy prices at 4.71 percent was higher in the post reform period.

In order to understand the impact of increasing energy prices on the energy intensity of the manufacturing sector we set up the following regression model:

$$\ln(Energy\ intensity) = \alpha + \beta_1 \ln(real\ energy\ price) + \beta_2 time + \beta_3 (time)^2 \quad \text{(I)}$$

where, α is the constant term, *ln* is the natural logarithm term, energy intensity is the dependent variable while real price of energy and time are the independent variables. In order to introduce non-linearity squared term of the time variable is also used.

The result of the regression analysis is given below[3]

Dependent variable: ln(Energy intensity)		
α	*5.346 ****	
β_1	*-0.883 **** *(0.2796)*	*N = 27*
β_2	*0.087 **** *(0 .0255)*	*R^2 = 0.9537*
β_3	*- 0.002 **** *(0.0004)*	*DW statistic: 1.8878*

Note: 1. Figures in parenthesis are the standard error values
2. *** represent significance at 1 percent level

Substituting the estimated values of parameters in equation (I), the regression equation can be written as:

---

[2] Energy prices are at 1993-94 prices

[3] In in the initial regression results the DW statistic was low so the model was re-estimated by applying the Prais-Winsten AR(1) regression. The DW statistic reported is the transformed value.

ln(Energy intensity) =	*5.346*	*- 0.883 ln(real energy price)* *(0.2796)*	*+ 0.087 time* *(0 .0255)*	*- 0.002* $(time)^2$ *(0.0004)*
R2 = 0.9537	*N = 27*	*DW statistic: 1.8878*		

(Figures in parenthesis are the standard error values)

The results show a significant negative effect of energy prices on energy intensity in the manufacturing sector in India. The price elasticity of demand for energy is about 0.883. An increase in real energy prices has resulted in a decrease in the energy intensity.

A key question is what explains the rate of change in energy intensity. Energy per unit of output may be falling (i.e., output per unit of energy rising) in the industrial sector as a result of changes in factor prices (e.g., because of the rising trend of energy prices) inducing the substitution of energy by other inputs for a given technology. Energy per unit of output may also be declining because of energy-saving technical progress. The extent to which rising energy prices are responsible for a decrease in energy intensity (or an increase in energy efficiency) or energy savings technical change resulting in a decrease in energy intensity needs to be further probed. For that purpose we have used a more advanced econometric model which is discussed in chapter 4.

The study is organized as follows:

Chapter 2 looks at some of the policies adopted by countries worldwide to promote energy efficiency. Though there are number of measures that have been adopted by countries worldwide like awareness/information campaigns for different user-groups; labeling schemes for appliances, vehicles, residential properties; energy audit of commercial, residential and public places; tax incentives; subsidies; soft loans and other monetary and financial incentives, recognition awards etc., the focus of the study is primarily on the fiscal and monetary policies adopted by governments at the national, sub-national in various countries.

In chapter 3 we do a benchmark analysis of the seven major energy consuming industries in India and estimate the energy savings potential in these seven industries. The analysis is for the year 2007-08. Benchmarking is a useful tool for understanding energy consumption patterns in industrial sectors and for designing policies for improving energy efficiency. We also do a benchmark analysis for the Power Sector in India where the focus is on the coal fired thermal plants. Being an energy supply industry the energy savings potential in the conversion of primary energy to electrical energy has been worked out.

In chapter 4 we use an econometric model for inter-input and inter-fuel substitution for the non-energy industries to study the behavioural response of industries to changes in factor prices. The estimates of the model are extremely important from the point of view of designing both fiscal and financial policy instruments for promoting energy efficiency in the Indian manufacturing sector. In chapter 5, the focus is on the energy supply sector, i.e., the coal fired thermal power plants. In this chapter we look at the economic viability of energy conservation in the power sector and suggest measures which will enhance energy efficiency in the energy supply industry. Finally, chapter 6 concludes by giving various fiscal and monetary measures as recommended by the study for enhancing energy efficiency in the country.

Chapter 2 Energy Efficiency Policies: International Experience

According to World Energy Council, energy efficiency encompasses all changes that result in a reduction in the energy used for a given energy service (heating, lighting, etc.) or level of activity. This does not necessarily imply introduction of a new technology (like changing the fuel mix or switching to a new fuel), but a better management or organization of the existing one (for example using a more efficient heating system). In a report by the International Energy Agency, by 2030, the Reference Scenario (which assumes no change in government policies) world primary energy demand is expected to be a dramatic 40 percent higher than in 2007.[4] With an increase in the magnitude of demand and high amount of unreliability over the availability and the prices of the sources of energy, most of the nations have recognized the importance of energy efficiency. Many countries have adopted, or are working towards framing their national policies in this direction. National Mission on Enhanced Energy Efficiency, India; US Energy Efficiency Trade Mission; UK Energy Efficiency Action Plan, 2007; EU Energy Efficiency Policy; Industrial Energy Efficiency Policy, China; Renewable Energy and Energy Efficiency Policy, Brazil etc. are all some of the many steps initiated by countries to achieve efficient energy consumption.

Given the emphasis on mitigating the effects of global warming and climate change, nations have realized that the most cost effective way to achieve the required reduction in GHG emissions is through energy-efficiency. To this effect, nations have initiated programmes at the national as well as sub-national levels, to induce energy efficiency. Though there are number of measures that have been adopted by different countries like awareness/information campaigns for different user-groups; labeling schemes for appliances, vehicles, residential properties; energy audit of commercial,

[4] World Energy Outlook 2009 Fact Sheet, Why is our current energy pathway unsustainable? Available at http://www.worldenergyoutlook.org/docs/weo2009/fact_sheets_WEO_2009.pdf

residential and public places; tax incentives; subsidies; soft loans and other monetary and financial incentives, recognition awards etc., we list various financial and fiscal measures adopted by different countries to promote energy efficiency. In the process we look at the policies of the European Union and its member countries, United States of America, Japan, Australia, Canada, South Africa, Brazil, Russia, and China.

European Union and Member Countries

EU has initiated a number of policy measures to achieve energy efficiency. These include creating awareness through information dissemination, minimum efficiency standards (for products, commercial and residential buildings), promotion (knowledge about inefficient consumption, its consequences, and the possible solutions), and fiscal and financial incentives (tax exemptions, rebates, etc.). Besides various programmes being implemented at the level of EU, individual member states have also adopted an array of fiscal and financial measures to induce energy efficiency.

Subsidies for promoting energy efficiency

Austria*: Subsidies targeting the commercial sector*

For renovation, the Austrian government provides subsidies to commercial establishments based on energy criteria. Buy linking subsidy to energy consumption, an automatic incentive mechanism is built. This subsidy is for the building envelope and windows of the buildings constructed before 1990. A subsidy of 30% of total energy related investment cost is provided where energy consumption indicator is upto a maximum of 50 kWh/m^2a and a subsidy of 20% when energy consumption indicator is between 50 und 70 kWh/m^2a

Czech Republic*: The Green Light for Savings Programme*

It provides support for heating installations which utilizes renewable energy and also for investment in energy savings in reconstructions and new buildings. The programme supports investment in quality insulation of family houses and non-panel multiple-dwelling houses, the replacement of environment unfriendly heating for low-emission biomass-fired boilers and efficient heat pumps, installations of these sources in new low-energy buildings, as well as construction of new houses in the passive energy standard. The subsidy is granted for equipment installed in residential houses, and has recently been extended to panel buildings.

Finland

Finland[5] offers 15-20 percent subsidies for conventional energy saving investments for companies who have joined the voluntary Energy Conservation Agreements with the Government. Companies and other organizations subscribing to this agreement resolve to carry out energy audits in their properties and production plants, draw up energy conservation plans, and implement cost-effective conservation measures[6]. Higher subsidies, to the tune of 20-25 percent are awarded to ESCO investment projects.

Energy Tax

Energy taxes are simply taxes on energy. Their purpose is to increase the price of energy so as to reduce its consumption or cut down on wasteful consumption of energy. In March 2010, the EU announced a nation-wide carbon tax. Under the current regulation, the tax is to be paid on the consumption i.e., on the quantity of fuel consumed. In future it is proposed to levy taxes on the basis of CO_2 and energy content of the fuel. Therefore, fuels having a high CO_2 content and/or low energy content will be taxed heavily.

[5]Energy Audit in Finland and International review of Energy Audit; Available at: http://www.google.co.in/#hl=en&xhr=t&q=energy+audits+in+finland&cp=24&pf=p&sclient=psy&site=&source=hp&aq=f&aqi=&aql=&oq=energy+audits+in+finland&pbx=1&fp=65c7f4c4fed002cb

[6] Energy Conservation Agreements and Energy Audits; Available at: http://www.unep.org/GC/GCSS-IX/Documents/FINLAND-energyaudit.pdf

Netherlands: *Regulatory Energy Tax (RET)*[7]

RET was introduced in 1996 on the use of natural gas and electricity. The RET was imposed especially on small consumers with a view to stimulate additional conservation of energy and to avoid risks associated with imposing a tax on big industrial houses, which would have bearing on their international competitiveness. The tax was expected to generate extra energy conservation through the price impact on the demand side. Natural gas, electricity, mineral oil products which can be used as substitutes for gas by households or small commercial establishments were also taxed (home heating oil, light fuel oil, non-transport applications of LPG/butane/propane). The rate of the energy tax which came into force in 1996 was taken from the first draft EU-directive for a CO_2/energy tax in the European Union which provided for step-by-step increases up to an ultimate rate equal to $10 per barrel oil equivalent. The tax was introduced in three stages in order to limit potentially undesirable economic impacts. At its 1998 level the tax has raised the gas price by 20 to 25 percent for smaller consumers.

Other Financial Incentives: There are several other financial incentives, in addition to subsidies, offered to member states to achieve energy efficiency. Such measures are complementary to many of the existing ones and help in increase the effectiveness of the existing measures. In Finland, companies which have signed the energy conservation agreement can get higher rates of subsidies for energy audits. UK, Denmark and Sweden have established a climate change levy to reduce energy use by the industry and public sector. Those committing to emission reductions or improved energy efficiency targets would have to pay the climate change levy at a lower rate. These other measures for energy efficiency are summarised in table 2.1.

[7] The Netherlands Tax on Energy;
http://www.wind-works.org/FeedLaws/Netherlands/NLEnergytax2004.pdf

Table2.1: Some Financial incentives in EU countries

Country	Name of the Programme	Incentive Detail	Date of launch of programme
Belgium	Tax deduction for energy saving Investments	**Tax relief:** 15.5% of investment cost deductible	1983-ongoing
France	Amortisation Law for Energy Saving Equipment	**Accelerated Depreciation:** 100% write off in the first year of Purchase	1991-ongoing
Ireland	Accelerated Capital Cost Allowance Scheme	**Accelerated Depreciation :** 100% write-off in the first year of Purchase	Oct 2008- Dec 2012
Netherlands	Energy investment Allowance (EIA)	**Tax relief :** 44% of investment cost deductible from profits	1997 - ongoing
UK	Enhanced Capital Cost Allowance Scheme	**Accelerated Depreciation:** 100% write-off in first year of purchase	2001 - ongoing

Source: Energy Efficiency Unit, IEA

Besides these there are various voluntary arrangements/agreements that are in place in many countries of the European Union. Many of them are linked with the threat of future regulations or energy/greenhouse gas emissions taxes as a motivation for participation in these voluntary arrangements (e.g. AERES Negotiated Agreements in France) or are implemented in conjunction with an existing energy/GHG emissions tax policy or with strict regulations (e.g. Denmark's Agreements on Industrial Energy Efficiency (Danish Energy Authority, 2002); Ireland's new Negotiated Energy Agreements Pilot Project (Brabazon et al., 2003); United Kingdom's Climate Change Levy and Agreements (DEFRA, 2004))

United States of America

Drawing flak due to its non-signatory status on Kyoto Protocol, USA has been under immense pressure to introduce energy efficient policies. Consequently, there have been various programs and measures that have been introduced at the national level, as well as by individual states, to make energy consumption more efficient. US have used a wide variety of instruments like Awareness campaigns (e.g. Best Practices Programme, National Action Plan for Energy Efficiency etc.), Labeling (Appliances, Buildings), Energy Audits (residential only by Austin City), and programmes (like The

Energy Independence and Security Act 2007) for improving energy efficiency. It has also put in place various fiscal and financial Incentives for promoting energy efficiency. These are

Energy Efficiency and Conservation Block Grant Program: Funds are provided under this programme, in the form of grants, to entities in implementing strategies that will improve energy efficiency in transportation, building, and other appropriate sectors, and reduce fossil fuel emissions and total energy use in an environmentally sustainable manner. Eligible entities include cities, counties, states and Indian tribes. Activities eligible for use of grant funds include:

i. Strategic planning: developing and implementing energy efficiency and conservation plans, including technical consultant services as required
ii. Information sharing and developing public education programmes
iii. Developing building codes, auditing and inspection services
iv. Installing renewable energy technologies
v. Implementing technologies to reduce, capture, and use methane and other GHGs from landfills or similar sources
vi. Establishing financial incentive programmes, and providing grants to organisations to perform energy efficiency retrofits
vii. Developing and implementing programmes to conserve energy used in transportation (e.g., flex time by employees, satellite work centres, promotion of zoning requirements that promote energy efficient development, transportation infrastructure: bike lanes/pathways, pedestrian walkways, and synchronised traffic signals)

Self-Generation Incentive Program - California: California's Self-Generation Incentive Program provides a financial incentive to customers that install new, qualifying self-generation equipment installed to meet all or a portion of the electric energy needs of a facility. The program provides incentive funding to renewable and non-renewable self-generation units up to 1 MW in size. The state's Self-Generation Incentive Program, which was set to expire at the end of 2004, was extended in 2003 through the end of 2007. The new legislation, Assembly Bill 1685, also sets emissions standards and requires a minimum conversion efficiency of 60% for any fossil-fuel distributed generation that seeks to qualify for the incentive payment. Combined heat and power projects can earn credits against the emission standards based on how much heat they recover.

Energy-Efficient Federal Motor Vehicle Fleet Programme: By the provisions of The American Recovery and Reinvestment Act of 2009, funds are made available for capital expenditures and necessary expenses of acquiring motor vehicles with higher fuel economy, including hybrid vehicles, electric vehicles, and commercially-available, plug-in hybrid vehicles. This falls under the Government Procurement Programme, where a financial aid is given in procuring more energy efficient equipment.

New Energy Efficient Home Credit: The Energy Policy Act of 2005 allows tax credits to be taken by home builders for new homes which meet the International Energy Conservation Code (IECC) energy efficiency standards. Site-built homes qualify for a US$ 2,000 credit if they are awarded the certificate to reduce heating and cooling energy consumption by 50 % relative to the IECC standard and also meet the minimum efficiency standards of Department of Energy.

Energy Savings Performance Contracts (ESPCs): Energy Savings Performance Contracts (ESPCs) were authorised by Congress to encourage federal agencies to become more energy-efficient and reduce energy use and costs through private investments. Under ESPCs, a private sector Energy Service Company (ESCO) is contracted to design, purchase, and install the necessary equipment and processes to increase energy efficiency at the facility. Federal agencies then pay the ESCO a share of the cost savings from the efficiency improvements over the life of the contract. Contractors receive a predetermined share of the cost savings and are only paid on the basis of actual savings achieved and additional savings go to the Federal government.

Energy Efficient Mortgages: Energy Efficient Mortgages (EEMs) can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through Federal Housing Authority (FHA) or Veterans Affairs (VA) programs. This allows borrowers, who might otherwise be denied loans, to pursue energy efficient improvements by securing lenders against loan default and providing them with confidence in lending to customers whom they would usually deny. The FHA and VA EEM programs allow lenders to add up to 100% of energy efficiency improvements to an existing mortgage loan with certain restrictions.

Tax incentives

Energy Improvement and Extension Act 2008: The Act extends energy efficiency tax deductions for commercial buildings till 2013 and revived similar deductions for home improvements installed in 2009, adding a new US$ 300 tax credit for energy-efficient biomass fuel stoves. It also extends tax credits for builders of new energy-efficient homes through 2009 and increased tax credits for manufacturers of energy-efficient appliances. The act creates a new tax credit of up to US$ 7,500 for plug-in hybrid vehicles, expected to go on sale in 2010, while providing tax exemptions for idle reduction technologies and advanced insulation installed in trucks. Electric charging stations are also to be covered by a 30% tax credit through to 2010. To facilitate financing, the bill authorised US$ 800 million in Qualified Energy Conservation Bonds, which will be issued by state and local governments. The bonds can be applied to a wide range of energy efficiency projects, research and demonstration projects, and even renewable energy projects. The Act also aims for a more complete use and benefit of the tax credits. To this end it includes a provision to increase the income limits for the Alternative Minimum Tax. It also allows unused tax credits to be carried over to the following year.

Japan

Japan features amongst the most energy efficient nations. It has a long history of taking measures on energy efficiency, dating back to almost 30 years. Over this period of thirty years, Japan has seen considerable improvement in energy efficiency. Technology is Japan's one of the biggest strengths in preserving energy. A glance into a typical Japanese household shows energy-efficient home appliances, from refrigerators that buzz if the door is left open too long, to machines that change hydrogen into electrical energy in order to heat water etc. Such products have higher price tags, but use energy more efficiently, and bring down utility costs. In Japan regulations in energy efficiency are largely based on the Rational Use of Energy Act.

Rational use of Energy Act: This act was passed in 1979, and since then, five amendments have been made to it. The Act was enacted primarily to ensure energy conservation in the industrial sector. The 1979 Act set standards for prevention of heat loss and recovery and utilisation of waste heat in industrial processes and established quantitative goals for energy efficiency improvements in individual factories. Over the years, the Act has evolved to include many new provisions and also to extend its scope. Post its last revision in 2008, Act covers all sectors: Energy management in manufacturing, commercial and transportation sectors; energy efficiency standards for vehicles and appliances (Top Runner Program); energy efficiency standards for houses and buildings.

National Policy Direction on Energy Conservation, 2007: This sets the future agenda for Japan's Energy Efficiency Policy. The new thrust areas were identified as tightening regulations, increasing support measures, and improving information and dissemination.

Fuel Efficiency Standards for Heavy Duty Vehicles: Japan introduced the fuel-efficiency target standard values for heavy duty vehicles in 2006 as a part of measures to reduce fuel consumption and to address global warming. The new fuel efficiency standards for heavy duty vehicles using light oil as fuel were established for freight and passenger vehicles (passengers over 11 persons) of a gross weight of over 3.5 ton. Japan also introduced tax incentives for vehicles that meet both fuel economy and low emission standards. It is possible to have 1-2 percent reduction in the acquisition tax of new vehicles if the standards have been met.

Fiscal and Financial Incentives

Eco-Points Scheme for Green Home Appliances: This scheme has been put into regulatory framework to promote environmentally friendly home appliances products. Consumers can obtain eco-points on purchase of green home appliances like air-conditioners, refrigerators, TVs, etc. The points so earned can be exchanged for a number of items. This scheme, integrated with the labeling scheme (Uniform Energy Saving Labeling Program) is applied such that the product for the eco-points scheme should have four-star efficiency rating in national labeling scheme.

Preferential Tax Scheme For vehicle Weight Tax and Vehicle Acquisition Tax: Japan introduced a new preferential tax system for environmentally friendly vehicles, in 2010. This preferential tax scheme applies to the vehicle weight tax and vehicle acquisition tax. The types of environmental friendly vehicles eligible under this scheme are: Electric vehicles (including fuel cell vehicles); Natural gas vehicles; Plug-in hybrid vehicles; Hybrid vehicles; Diesel cars which conform to the 2009 Car Emissions Regulation; Trucks, buses and other types of vehicles weighing between 2.5-3.5 tonne, which conform to the 2015 Fuel Efficiency Standard; and Vehicles recognized as fuel efficient and with low gas emissions.

Tax incentives for Energy Efficient Houses & Buildings: The government promotes energy efficient houses and buildings by providing special financial or tax incentives. These are:

- Low interest loan programme for energy conservation renovation of buildings. Targeted for energy conservation renovation projects for existing buildings using Energy Service Companies. Funds to be provided to execute these projects by a way of leasing or an Energy Service Provider (ESP).
- Low interest loan programme for plans for environmentally-friendly buildings; these are provided for specific measures taken in the planning phase, such as energy conservation measures, roof-top greening projects, etc.
- Tax Scheme for Promoting Investment in the Reform of the Energy Demand-Supply Structure: This scheme is available for businesses that acquire specified energy conservation equipment. It provides special depreciation rate applied for 30% of the acquisition cost (small scale businesses are provided with the option of a 7% tax deduction of acquisition cost). Since 2006, highly-efficient equipment and systems used in the residential and commercial sectors, such as highly efficient air conditioning systems, high insulation windows facilities, and light-emitting diodes, are covered by this scheme.
- The Japan Housing Finance Agency (JHF) allows for lower interest rates and preferential loans to be provided for energy efficient houses. The JHF provided extra loan for houses meeting energy saving performance. For energy performance, all the houses for which the loan was requested had to meet at least the 1980 thermal insulation standard. On top of that, an extra loan was provided for those meeting the 1992 or 1999 standards. Reduced interest rates are provided to house for those meeting the 1999 standards.

Subsidies for Energy Efficient Hot Water and Air Conditioning Systems: Since 2002, the Japanese government has been providing specific financial or tax incentives for the diffusion of energy-efficient hot water supply systems. Subsidies are provided for the purchase of state-of-the-art hot water systems. The subsidy covers the price difference between the efficient and conventional water-heating systems. Subsidies are also provided to encourage the uptake of highly efficient air conditioning systems using heat pump technologies in commercial buildings.

Low Interest Loans for Building Equipment Installation: Low interest loans are available for manufacturers, building owners and other business operators. Based on the Energy Conservation and Recycling Assistance Law. The law is designed to support business operators voluntarily implementing projects to promote the rationalization of the use of energy and natural resources. The kinds of projects eligible are (a) Installation or improvement of equipment that can contribute to the rational use of energy in factories or other business sites; (b) Use of building materials, or installation or improvement of equipment that can contribute to the rational use of energy at the time of building construction; and (c) conduct R&D on the manufacturing technology of industrial products that can contribute to the rational use of energy. Approved projects receive a subsidy on interest rates, and can also receive bonds issued by the New Energy and Industrial Technology Development Organisation (NEDO).

Subsidies for Environmentally-Friendly Community Energy Projects: This policy began in 1993. In order to fully utilize surplus energy, including waste heat dispersed over a region, this project aimed to establish an effective district energy utilization system. Subsidies were provided to those who invested in and installed large-scale co-generation district heating and cooling systems in which thermal energies of low to high temperatures were fully utilized in combination at all stages for various applications (including power generation without wasted energy) in accordance with regional characteristics.

Low Interest Loans for Cogeneration System Installation: Low interest loans are available for installing cogeneration systems. This applies to the equipment that generates over 50kW output and has over 60% in primary energy use efficiency.

Financial and Tax Incentives for Industry: Various financial and fiscal incentives have been put in place to encourage energy conservation and efficiency in industry since the mid-1970s. A special depreciation system to promote equipment facilitating the rational use of energy resources was established in 1975. Government provided low-interest loans for financing introduction of energy conservation and efficiency systems in industry. From 1990s onwards, direct financial assistance measures were implemented to develop and introduce state-of-the-art energy-efficient equipment. Furthermore, a tax incentive scheme (Tax Scheme for Promoting Investment in the Reform of the Energy Demand-Supply Structure) has been provided for businesses investing in specified energy conservation and efficient equipment, providing a special depreciation rate of 30% of the acquisition cost. For small businesses, the special depreciation rate is coupled with a 7% tax deduction of the acquisition cost. Since 2006, preferential tax rates have applied to systems used in the commercial and residential sectors, such as highly-efficient air conditioning systems, high insulation windows, LEDs, etc.

Green Taxation and Subsidies for Automobiles: The Japanese government introduced in April 2001 a broad taxation scheme which reduces the automobile acquisition tax, the tax on low-polluting vehicles (methanol, hybrid, compressed natural gas, and electric, including fuel cells) and on certain fuel-efficient and low-emissions vehicles. It also increased the tax on old polluting vehicles to promote development and social acceptance of environmentally sound vehicles. In 2003, the taxation was revised to focus on more fuel-efficient and lower-emission vehicles and to cover LPG cars. In addition to the above taxation measures, a series of subsidies for environmental friendly cars, such as hybrid vehicles, etc. have been introduced. Tax rates were further reduced in 2006 on vehicles that promote energy efficiency.

Energy Bank - Fund for Energy efficiency and CO_2 Reduction: The Development Bank of

Japan (DBJ), a government-affiliated financial institution, and Japan Smart Energy Co., a Japanese accounting firm specialised in environmental issues, have jointly established Energy Bank. The bank is first fund of its kind in Japan, to invest in the installations of appliances that reduce CO_2 and/or induce Energy Efficiency. The bank aims to invest US$ 120 million worth of energy-efficient facilities in its first three years. Energy Bank provides energy-saving facilities and supplies energy to customers, receiving a service charge based on the customer's energy consumption. This scheme allows customers to install energy-saving facilities without making an initial investment.

Australia

Coal and natural gas, along with oil based products, are currently the primary sources of Australian energy usage, despite the fact that the coal industry produces approximately 38% of Australia's total greenhouse gas emissions.[8] Since coal mining and natural gas industries contribute substantially to the revenues to the government, Federal energy policies continue to provide subsidies for fossil fuel use and production. Australia initiated its efforts towards energy efficiency as late as around December 2004, when it adopted National Framework on Energy Efficiency.

Fiscal and Financial Incentives

Green Loans Program: The programme provides free assessment of energy efficiency for households and provides them with loans to implement the alternatives the sustainability report may suggest. The programme ended in February 2011.

South Africa

Given its rich natural endowment, energy efficiency measures have largely been

[8] Energy Policy of Australia; Available at: http://en.wikipedia.org/wiki/Energy_policy_of_Australia

absent from the energy policy of South Africa[9]. With historically low electricity prices, there has been little incentive for the consumer to save. In fact, the electricity prices are among the lowest in the world.[10] Nonetheless, need for energy efficiency measures has been felt in South Africa as well with the outcome that some measures have been put in place to induce energy efficiency in the South African economy.

Fiscal and Financial Incentives

Energy Efficient Motor Programme: Eskom[11] launched an Energy Efficient Motors Programme in mid-2007. The programme promotes replacement of old, inefficient motors with new, highly-efficient motors, through subsidising the purchase cost. Efficient motor suppliers registered with Eskom are directly paid the subsidy, resulting in an immediate discount on the purchase price for the consumer. The subsidy aims to smooth out the price difference between standard and high-efficiency motors.

Canada

Canada is one of the largest energy producers in the world. It also imports energy products. It is both an importer and exporter of coal and petroleum because its major coal and oil fields are located in Western Canada, far removed from its main population and many of its oil refineries cannot handle the types of oil produced in Canada. Canada has high energy intensity on account of its geographical location. Being a cold country, energy consumption is very high in winters. Canada has adopted several policy initiatives to reduce it energy intensity.

Fiscal and Financial Incentives

[9] Draft Energy Efficiency Strategy of Republic of South Africa, Department of Minerals and Energy, 2004 Available at: http://unfccc.int/files/meetings/seminar/application/pdf/sem_sup2_south_africa.pdf

[10] South Africa's Energy Story; http://www.pikeresearch.com/blog/south-africa's-energy-efficiency-story

[11] Eskom is an electricity generating company in Africa, owned wholly by the South African government. Eskom generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa.

Accelerated Capital Cost Allowance: The accelerated Capital Cost Allowance (CCA) allows investors an accelerated write-off of certain equipment used to produce energy in a more efficient way or to produce energy from alternative renewable sources. A 50% accelerated CCA is provided for eligible equipment that generated either (1) heat for use in an industrial process or (2) electricity by using a renewable energy source (e.g. wind, solar, small hydro), waste fuel (e.g. landfill gas, manure, wood waste) or (3) making efficient use of fossil fuels (e.g. high efficiency cogeneration systems). The provision is available for assets acquired between 2005 and 2012. For assets acquired before 2005, accelerated CCA is provided at 30-percent. The eligibility criteria for these classes are generally the same except that cogeneration systems that use fossil fuels must meet a higher efficiency standard. Assets acquired during the next seven years in district energy systems using high-efficiency cogeneration and biogas production systems will be eligible for the new 50-percent CCA rate.

Manufacturing Investment Tax Credit - Manitoba: The Government of Manitoba broadened the Manufacturing Investment Tax Credit (MITC) to encourage businesses to invest in energy efficient equipment or environmentally friendly sources. This programme targets new manufacturing plants and equipment purchased for first-time use in manufacturing or processing in Manitoba. Qualified investments must be made after March 1992 and before July 2006. The amount deductible against Manitoba income tax will be the lesser of the 10% investment tax credit or the Manitoba Corporate Income Tax otherwise payable. Unused investment credits can be carried forward up to 10 years, or carried back up to 3 years. This credit was made partially refundable in the 2005 Budget. The 2008 Manitoba Budget increased the refundable portion to 70% of earned credits for qualified property acquired on or after January 2008.

Canadian Renewable Conservation Expenses (CRCE): Canadian Renewable Conservation Expenses (CRCE) is a category of fully deductible expenditures associated with the start-up of renewable energy and energy conservation projects for which at least 50% of the capital costs of the property. These expenditures may be deducted in full in the year incurred or can be carried forward indefinitely for deduction in later years. The CRCE expenditures are also eligible for flow-through share treatment. That is, the corporation may renounce the CRCE expenditures that it has incurred to a person who acquires flow-through shares from the corporation. This allows shareholders to claim deductions as if they had incurred the expenditures directly. This is particularly helpful to corporations that are not yet profitable. Budget 2010 amended the definition of "principal-business corporation" under CRCE to clarify that flow-through share eligibility extends to corporations the principal business of which is one, or any combination, of: (a) producing fuel; (b)generating energy; or (c) distributing energy. This measure will apply in respect of taxation years ending after 2004.

ECOEnergy Retrofit- Homes: The ecoENERGY Retrofit - Homes encourages the existing low-rise housing sector in Canada to become more energy efficient, reduce emissions produced through energy use and contribute to clean air, water and energy and a healthy environment for Canadians. ecoENERGY Retrofit - Homes will provide property owners with the information they need to make good home energy retrofit decisions and will reward energy and water saving measures with a grant. Grants are provided to homeowners of low-rise residential properties who improve the energy performance of dwellings. This includes owner-occupied as well as rental units. Housing on First Nations territories and band-owned lands, social housing and housing cooperatives also qualify.

Green Municipal Funds: The Government of Canada doubled its funding (from CAD125 million to CAD 250 million) of the Green Municipal Enabling Fund (GMEF) and the Green Municipal Investment Fund (GMIF) aimed at stimulating investment in innovative municipal infrastructure projects and environmental practices for Canadian municipal governments and their public and private-sector partners. The Government of Canada established two complementary funds to stimulate investment in innovative municipal infrastructure projects and environmental practices by Canadian municipal governments and their public and private-sector partners. There are two funds: the Green Municipal Enabling Fund (GMEF) with CAD 25 million; and the Green Municipal Investment Fund (GMIF) with CAD100 million. The GMEF provides grants for cost-shared feasibility studies to improve the quality of air, water and soil through greater energy efficiency, the sustainable use of renewable and non-renewable resources and more efficient water, waste and waste water management. Through GMIF, a municipal government can borrow at preferred interest rates of 1.5 per cent below the Bank of Canada bond rate. Partners are also eligible for loans at attractive rates.

Commercial Buildings Incentive Program: The Commercial Building Incentive Program (CBIP), established in April 1998, provides financial incentives to builders and developers to incorporate energy-efficient technologies and practices into the design and construction of new commercial, institutional and multi-unit residential buildings. To qualify for the incentive, buildings must be at least 25% more efficient than buildings that meet the requirements of the Model National Energy Code for Buildings (MNECB). CBIP provides a one-time grant equal to twice the difference in estimated annual energy costs between an approved CBIP design and an MNECB design, up to a maximum of CAD $80,000. The Commercial Building Incentive Programme was expanded in 1999 to include multi-unit residential buildings.

Energy Retrofit Assistance for Implementation Projects: The EnerGuide for Existing Buildings provides Energy Retrofit Assistance (ERA-I) funding for retrofit implementation projects, offering grants for costs related to management, materials, labour, monitoring and tracking, staff training, awareness and for other retrofit implementation projects in buildings. Measures for efficient lighting, the building envelope, motors, controls, heating, ventilating, air conditioning and other energy-saving projects may be eligible for grants. Grant beneficiaries can receive up to $7.50 per gigajoule (1 GJ = 277.8 equivalent kilowatt hours) of annual energy savings or up to 25 percent of eligible costs, whichever amount is less to a maximum of $250,000.

Commercial Building Incentive Program: The program offers a financial incentive of up to $60,000 for new commercial and institutional buildings that are designed to be at least 25% more energy-efficient than a building designed to the requirement of the Model National Energy Code for Buildings. The incentive is intended to help offset the incremental design costs associated with designing energy efficient buildings.

Brazil

Brazil is the 10th largest consumer of energy in the world[12]. Around the beginning of the 2000s, Brazil saw its energy sector undergo fundamental changes. The market was liberalized, energy subsidies were reduced, competition in the energy market was increased, etc. While the thrust of the earlier energy policies was on structural changes of the energy sector, the current policies focused more on improvement of energy efficiency, in both residential as well as industrial sectors. With a view to promoting energy efficiency in all the sectors, the government of Brazil has undertaken various initiatives.

National Electrical Energy Conservation Program (PROCEL)

This policy initiative is directed at minimizing the waste from the production and consumption electrical energy. The various measures include: consumption labeling to inform consumers to influence purchasing decisions and induce manufacturers to make efficient products; energy audits to assess energy use and efficiency; supporting R&D of efficient technologies/products; replacing incandescent lamps in public lighting with mercury vapor and high pressure sodium vapor lamps that consume 75% less energy; promoting efficient lighting and appliances in government and residential buildings; actions to reduce electricity demand during peak hours; PROCEL also helps utilities

[12] Energy Policy of Brazil, Available at: http://en.wikipedia.org/wiki/Energy_policy_of_Brazil

obtain low-interest financing for major energy efficiency projects from a revolving loan fund within the electric sector.[13] PROCEL helps in financing, getting tax incentives, and other measures to encourage more local production of efficient, high-quality lighting products and components.

Public Benefit Funds: Public benefit funds (PBFs) are a pool of resources typically created by levying a small fee or surcharge on customers' electricity rates, which can then be used by states to invest in clean energy supply[14]. Brazil is one of the very few countries to have introduced PBF's (US, UK, Ireland, Brazil and Netherlands being the only countries using PBFs to finance energy efficiency programmes)[15.] These PBF's create a sufficient pool of resources for the state of Brazil to invest in measures promoting energy efficiency[16]. This fund also provides means to invest in renewable energy for Brazil. (This is also called the wire-charge mechanism). The ratio in which this fund is to be used has been subject to constant changes over-time. In 2007, the Brazilian congress passed a law which reinstates the energy efficiency allocation to 50 percent of the total revenues generated through the wire-charge, half of which must be spent on energy efficiency measures targeted at low-income households.

Russia

Russia features among the top five consumers of primary energy in the world. It also has one of the highest energy intensity in the world. Many efforts have been initiated to reduce energy intensity and consequently, energy consumption. Through its

[13] World Resources Institute, Special Projects: http://projects.wri.org/sd-pams-database/brazil/national-electrical-energy-conservation-program-procel

[14] http://www.epa.gov/chp/state-policy/funds.html

[15] The Regulatory Assistance Project, International Experience with Public Benefits Funds: A Focus on Renewable Energy and Energy Efficiency; Available at:
http://www.raponline.org/docs/CRS_PBFInternationalExperience.pdf

[16] Case Study, Brazil's Public Benefit Wire-Charge Mechanism: Fueling Energy Conservation: http://electricitygovernance.wri.org/files/egi/Case%20Study%20Brazil's%20wire-change%20mechanism.pdf

various legislatives, the government aims to reduce its energy intensity by 40% as compared to the 2008 level. Besides steps at the national and the state levels, steps have been initiated at district as well as city levels. For example, as a part of the legislation, states are required to develop and implement regional energy efficiency programs; hold information campaigns; coordinate and supervise activities and sustain achieved results in local public buildings and utilities; supervise installation of metering devices; maintain local information system on energy efficiency in buildings (including energy audit results, energy passports, energy efficiency measures and savings reports, etc.). The following section gives details about various steps.

Fiscal and Financial incentives: In June 2010, the Russian President proposed to exempt energy efficient equipment from property tax for a period of three years. This move is aimed at stimulating the demand for energy efficient technology. Besides this, the following tax incentives are in place[17]:

- From January, 2009 businesses are allowed to use accelerated depreciation on new equipment. Assets with a lifetime between 3 to 20 years can be depreciated for a third of its value in the tax period when it was acquired (in 2008 the threshold was 10%).
- The amount of interest that can be deducted from taxable income has been increased nearly one-half, to 19% for the Rouble loans (against 13.2% in 2008) and to 22% for loans nominated in the foreign currency (in 2008 - 15%).
- The income tax rate has been cut to 20% instead of 24% the previous year.
- Also the threshold to use the simplified system of taxation has been lowered. Now companies with annual revenues up to 57 million Roubles (USD$1.7 million), almost twice as much as before, can benefit from the system.

[17] Tax incentives for energy efficiency; http://www.russianlawonline.com/content/tax-incentives-energy-efficiency

China

China surpassed USA to become the largest consumer of primary energy in 2009. Its status as one of the fastest growing economy and also as the most populated economy implies that its energy consumption would continue to grow rapidly. As a result pressure on China to reduce its energy consumption is immense. China had adopted many policies for addressing this issue of improving energy efficiency and energy conservation in different sectors. From 1970-2001, China was able to significantly limit energy demand growth through aggressive energy efficiency programs. Energy use per unit of gross domestic product (GDP) declined by approximately 5% per year during this period. However, the period 2002-2005 saw energy use per unit of GDP increase an average of 3.8% per year. To stem this out-of-control growth in energy demand, in November 2005 the Chinese government enunciated a mandatory goal of 20% reduction of energy intensity between 2006 and 2010. The National People's Congress passed legislation identifying the National Reform and Development Commission as the lead agency to design and carry out programs in support of this goal. These policies and programs, created after almost a decade of decline of the energy efficiency policy apparatus, have had considerable impact. Although initial efforts have not been sufficient to meet the annual declines required to reach the ambitious 20% energy intensity target, the latest reports indicate that China may now be on track to meet this goal.[18] The following are some of the programmes that have been initiated in China to improve energy intensity in the country.

Labeling/ Efficiency Standards

National Building Energy Standard was passed in August 2008. It requires a 50% reduction of building's total operation load based on a building's energy consumption during 1980s, calculated using average consumption by building type within a designated climate zone. The regulation covers residential, commercial and public

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[18]Overview of Current Energy Efficiency Policies in China, Nan Zhou, Mark D. Levine, and Lynn Price, *Energy* Policy, Volume 38: Issue 11. November 2010

buildings, including those used for education and sanitation purposes. For the non-complying parties, there is a monetary penalty.

Vehicle fuel economy standards: The National Development and Reform Commission established mandatory fuel efficiency standards for passenger cars in 2004. The standards classify each vehicle into one of the sixteen vehicle categories, established on the basis of vehicle weight. Standard values are set for each category. In addition, there are different standard values for manual transmissions and automatic transmissions. Manufacturers are required to get the vehicle type they want to market certified to comply with the standards.

Aluminum Industry Permitting Standards: Standards are issued for bauxite mines, alumina refineries, primary aluminium smelting operations, secondary aluminium and aluminium process plants. The standards cover a range of elements, such as scale of production, minimum size of plants and furnaces, technology to be implemented, resource use, as well as water and energy consumption.

Fiscal and Financial Incentives

Efficient Light bulb Subsidy Programme: The move is directed at increasing and promoting the use of energy efficient technology. The subsidy is indirect. Efficient energy products are available to the consumers at a cheaper price and the manufacturers are reimbursed by the government. An individual customer pays half the price agreed by the government and the manufacturer while businesses pay just 30% of that price. The products are selected on the basis of their efficiency. The government has already named thirteen companies, which have been asked to produce first batch of light bulbs.

Hong-Kong tax incentives for environmentally friendly commercial vehicles: This applies to heavy duty and light duty commercial diesel vehicles meeting Euro-V emission standards for vehicles. Under this scheme, incentive is in the form of reduction in their First Registration Tax.

The rates of reduction of the FRT for different vehicle classes are as follows:

- 100% for taxis, light buses, non-franchised buses and special purpose vehicles;
- 50% for goods vehicles (except van-type goods vehicles up to 1.9 tonnes permitted gross vehicle weight); and
- 30% for van-type goods vehicles up to 1.9 tonnes permitted gross vehicle weight.

The waivers range from 3.7% of the vehicle's market value for taxis to 35% for vans. The tax concessions are subject to caps ranging from HK$ 8500 to HK$ 78000 depending on the type of vehicle[19].

Vehicle Excise Tax Rates: Excise tax rates for vehicles have been proportional to the size of car engines since 1994. The rate for cars with engines 1.0L or less was set at 3%, for engines over 4.0L it was 8%, and for engines in between the rate was 5%. As of April 2006, the range of excise tax rates for vehicles was broadened to 3-20%. Rates for small cars with engines between 1.0 and 1.5L decreased to 3%, for engines from 1.5 to 2.0L they remained at 5%, while for engines between 2.0 to 4.0 the rate increased to between 9% and 15%. For engines over 4.0L, the rate nearly doubled from 8% to 20%. On September 2008, the excise tax rate for engines 1.0L or less further decreased to 1%, while for engines from 3.0 to 4.0L it increased to 25%. The rate for cars with engines over 4.0L increased to 40%.

Retirement of Inefficient Plants: The National Development and Reform Commission (NDRC), under this directive, starting early 2007 issues orders to retire small and inefficient plants in various industrial sub-sectors. In the power sector as of August 2007, a total of 50GW of small, inefficient power plants were required by 2010, (comprising approximately 40GW of coal-fire and 10GW of oil-fired plants) to shut

[19] Energy Efficiency Policies and Measures; Available at http://www.iea.org/textbase/pm/?mode=pm&id=4192&action=detail

down. The government also provides compensations to speed up the process. All coal-fired power plants of less than 50MW capacity, and those with capacity between 50 and 100MW that have been in operation for over 20 years will be required to close by 2010. Generators with unit coal consumption 10% or more above the provincial average or 15% above the national average are also targeted for closure.

In the cement sector, all plants with an annual capacity under 200 000 tonnes were to be closed by the end of 2008, and 250 million tonnes (Mt) of outdated and inefficient capacity to be retired by 2010.

In the steel sector, outdated and inefficient pig iron capacity is to be reduced by 100 Mt and steel capacity by 55 Mt, both by 2010. In addition, all blast furnaces below 300 m3 must be closed by 2010. Steel-making furnaces with less than 20 tonne capacity and blast furnaces below 100m3 were to be closed by 2007[20].

'Top 1000 industrial Energy Conservation' Programme: This is a voluntary programme under which China aims to reduce the energy consumption of its 1000 largest industrial consumers. These include industries from the following sectors: energy production, textile, iron and steel, chemical industry, construction materials, coals, petroleum and petrochemical industries, non-ferrous metals and paper industry. The programme sets five-year goals. Government at different levels is expected to provide the participating industries with incentives. These incentives may include, for example, an inclusion in the Energy Efficient List, which also makes them fit for receiving tax incentives.

Table 2.2 provides a matrix of the different measures both fiscal/financial and otherwise which have been adopted by various countries worldwide.

[20] Energy Efficiency Policies & Measures
http://www.iea.org/textbase/pm/?mode=pm&id=4306&action=detail

Table 2.2: Energy Efficiency Policy Matrix

Country	Awareness program	Labeling		Energy Audit of Buildings			Tradable Permits	Financial Incentives	Fiscal Incentives
		Appliances	Vehicles	Govt	Comm	Res			
EU-27	Y	Y	Y	Y	Y	Y	Y	Y	Y
Austria	Y	Y	Y	Y	Y	Y	Y	Y	Y
Belgium	Y	Y	Y	Y			Y	Y	Y
Bulgaria	Y	Y		Y	Y	Y	Y	Y	Y
Cyprus	Y	Y	Y	Y	Y	Y	Y	Y	Y
Czech Republic	Y	Y		Y	Y	Y	Y	Y	
Denmark	Y	Y	Y	Y	Y	Y	Y	Y	Y
Estonia	Y						Y	Y	Y
Finland	Y						Y	Y	Y
France	Y						Y	Y	Y
Greece	Y						Y	Y	
Hungary	Y						Y	Y	Y
Ireland	Y						Y	Y	Y
Italy	Y						Y	Y	Y
Latvia	Y						Y	Y	
Lithuania	Y						Y		
Luxembourg	Y						Y	Y	Y
Netherlands	Y						Y	Y	Y
Poland	Y						Y	Y	
Portugal	Y						Y	Y	Y
Romania	Y					Y	Y	Y	
Slovenia	Y						Y	Y	
Spain	Y		Y				Y	Y	Y
Sweden	Y						Y	Y	Y
UK	Y		Y				Y	Y	Y
Germany	Y						Y	Y	
Slovakia	Y						Y	Y	
US	Y	Y	Y			Y	Y	Y	Y
Japan	Y	Y							
Canada	Y	Y							
Australia	Y	Y							
South Africa	Y	N	Y						
China	Y	Y							
Brazil	Y	Y							
Russia	Y	N							

Note: Y refers to presence of some measure; N refers no measure; Blank cells indicate no-information; Govt: government; Comm: commercial; Res: residential

Chapter 3 Benchmark Analysis

As a first step, we do a benchmark analysis of the above-mentioned industries. Benchmarking can be a useful tool for understanding energy consumption patterns in industrial sectors and for designing policies for improving energy efficiency. Energy benchmarking for an industry is a process in which the energy performance of an individual plant or an entire sector comprising of similar plants is compared against a common metric which represents a 'standard' or an 'optimal' performance. It may also entail comparing energy performance of a number of plants against each other.

As benchmarking is used for comparison across a number of plants or sectors, it should have an important characteristic. As it is applied to plants or sectors of different sizes and outputs, the metric used should be irrespective of plant size. This is accomplished by using the concept of energy intensity, which measures energy use per unit of output.

Industrial benchmarking has been used in a number of contexts, for example

a) In evaluating an entire industrial sector, such as iron and steel, aluminum, cement, etc. This evaluation can be used to answer the following questions: How well is the sector performing compared to how it would have performed if it were using the best available technologies? How well is it performing as compared to the same sector in other countries of the world? Has the sector's performance improved over time vis-a-vis the best practices? The answers to these questions depend not just on the state-of-the-art performance in the sector, but also the adoption and diffusion of efficient technology throughout the sector;

b) For comparing individual plants within a sector, a benchmark-type indicator is calculated for all the facilities within a sector so that they can be compared on even terms. This evaluation can answer the following questions: What is the state of the art performance in the sector? How does a particular plant compare against the state-of-the-art plant? How does it compare against the majority of other plants in the sector? In developing benchmarks at the level of individual plants, the issue of proprietary data becomes important. Individual companies may be reluctant to disclose information about their production processes, particularly if they fear that such data will be released to their competitors. It is important, therefore, to develop benchmark indicator which is general enough not to reveal any proprietary information relating to individual plants and that a credible system is established that encourages plants to trust the process; and

c) The other context for industrial energy benchmarking that has been seen widely in application in recent years is the case of large companies to set themselves energy efficiency goals by using benchmarks. Companies use this approach to set targets for reducing energy use by certain percentages over given periods. In such cases as the benchmarking is done internally the companies need not divulge any proprietary information.

For the present study the only available data source for carrying out a benchmarking analysis is the Unit level data on Industries of the Annual Survey of Industries (ASI) provided by the Ministry of Statistics and Programme Implementation (MoSPI).[21] We have used the 2007-08 unit level data for developing an industry level benchmark for our energy efficiency analysis. There are certain limitations of the ASI data which delimit the scope of application of benchmark analysis discussed above. The ASI data does not provide information of the technology used by different units nor does it gives names of the different units. As the identity of different units within an industry is not disclosed one cannot use time series data for analysing the performance of different units over time, although one can gauge the trend of performance of the different industries vis-a-vis the bench mark.

[21] See Appendix 1 for the scope and coverage of Annual Survey of Industries (ASI).

We also do a benchmark analysis for the Power Sector where the focus is on the coal fired thermal plants. Being an energy supply industry the energy savings potential in the conversion of primary energy to electrical energy has been worked out. The data for such an exercise is based on the both plant level and unit level information for central sector, state sector and some private sector plants provided in the various publications of the Central Electricity Authority (CEA).

3.1 Unit Level Benchmark Analysis: Energy Consuming Industries

The motive behind such an exercise is to get an idea regarding the energy savings potential that exists in each of the seven industries considered in the study. We have used Unit level Annual Survey of Industries data for the year 2007-08 for this analysis.

For any given industry, the Annual Survey of Industries provides unit level information. These units vary in size consuming varying quantities of energy. Comparing energy intensity of a small unit within an industry with that of large unit may not be meaningful because of the returns to scale issue (i.e., scale of operation). In order to overcome the problem of comparing units which are not similar we have classified or grouped the different units within an industry into different groups based on a number of criteria so that within each group the units are more or less of similar nature. There are a number of ways in which the units can be classified or grouped. In the present study we have classified units on the basis of

a) share of total energy (final energy measured in oil equivalent units) consumption,
b) share in electricity consumption (electricity consumption measured in Kwh), and
c) total output measured in monetary terms i.e., in rupees

Energy savings potential is then calculated for each group within a given industry.

In order to calculate the energy savings potential of an industry the different units within the industry are first grouped on the basis of different criteria as discussed above. Having classified the units in an industry into different groups, units within a group are ranked in order of their energy intensities. Energy intensity of an industrial unit is defined as the total energy consumed or used for every generating one unit of the output. Here we measure the output in rupee (i.e., in monetary) terms. Thus energy intensity is defined as energy consumed for generating Re. 1 worth of the output. For measuring energy consumption we have used two measures. These are

1) Energy (final energy) consumption is measured in oil equivalent units (i.e., in kgoe units). Annual Survey of Industries provides data on coal and electricity consumption both in values terms and in their respective physical units, tonnes for coal and kilowatt-hour (kwh) for electricity. Data on consumption of petroleum products, however, is provided only in value terms. We have used Indian Petroleum and Natural Gas Statistics to get data on prices of different petroleum products. Using the price data and the information provided by the Bureau of Energy Efficiency (BEE) on the ratio in which different petroleum products are consumed by different industries we calculate consumption of different petroleum products in physical units. For each of the fuel the consumption figures are in their respective units. For example coal is in tonnes, electricity in kwh, LDO, HSD are in litres etc. These fuel consumption figures then converted from their respective units to a common oil equivalent unit to get the total fuel consumption in oil equivalent terms. The energy intensity thus calculated measures energy use (in kgoe) per rupee of output.
2) Alternatively we have used electricity consumption (measured in kilo-watt hours i.e., Kwh) by industrial units as a measure of energy consumption. Data on electricity consumption is provided by the Annual Survey of Industries both in values terms and physical units i.e., in kilowatt-hour (kwh). Energy intensity thus calculated measures electricity used (in Kwh) per rupee of output.

We have used the two measures of energy intensity as defined above depending upon the way in which the units are grouped as shown below.

	Unit of energy intensity	Definition of Energy Intensity
1	**Classification based on Share of total energy consumption**	
	c) Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
2	**Classification based on Share of total electricity consumption**	
	d) Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$
3	**Classification based on Value of Output**	
	a) Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
	b) Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$

Having arranged the units within a group in order of their energy intensities, we select 10 percent of the units that have the ***lowest*** energy intensity and average energy intensity of these units is calculated. This average energy intensity of the top 10 percent energy ***efficient*** units (i.e., the mean of the first decile of the energy intensity distribution within a group) is taken as the benchmark to which all the units within the group having energy intensity higher than the average were to achieve within a given period. Energy consumption of all units having intensity higher than the benchmark is worked out using the benchmark energy intensity and the overall energy consumption of the group is obtained. For a group the difference between the actual energy consumption and the modified energy consumption worked using the benchmark intensity gives the energy savings potential of that group. Similarly, energy savings potential for different groups within the industry is calculated. Aggregating the energy savings potential of different groups gives the energy savings potential of the industry.

Similar exercise is repeated by taking the ***lowest*** 25 percent units as per energy intensity criteria within a group and taking their average intensity (i.e., the mean of the first quartile of the energy intensity distribution) as the benchmark and energy savings potential for the group is calculated. In a similar manner the energy savings potential is calculated for each of the groups within the industry and aggregating the savings potential of all the groups within a industry we get the energy savings potential for the concerned industry as a whole.

We repeat the above exercise by taking the average intensity of units having energy intensity lower than the median energy intensity of the group (i.e., mean of the median of the energy intensity distribution) as the benchmark. Energy savings potential of each of the group within the industry and also for the entire industry is calculated on the basis of median energy efficiency basis.

Table 3.1a shows the overall energy savings potential in the textile industry and the share of different groups in the energy savings potential of the textile industry. The different units in the textiles industry are classified/grouped on the basis of their share in total energy consumption of the textile industry. Based on the share in energy consumption we have grouped the units in the textile industry into 5 broad groups. These broad groups are i) units whose Share of Energy consumption < 0.025 percent, b) units having energy consumption share greater than 0.025 percent but less than 0.05 percent, c) units having energy consumption share greater than 0.05 percent but less than 0.1 percent, d) units having energy consumption share between 0.1 and 0.5 percent, and e) units having energy consumption share greater than 0.5 percent but less than 5 percent. The table also shows the share of different groups in total output and energy consumed by the textile industry. The energy savings potential of the different groups varies between a lower limit of 4.38 percent to a high of 21.87 percent. The energy savings potential for the textile industry as a whole is obtained by aggregating the energy savings potential of each of the group. The energy savings potential for the textile industry for 2007-08 thus obtained ranges between a low of 45.59 percent and a high of 70.68 percent.

Tables 3.2a, 3.3a, 3.4a, 3.5a, 3.6a and 3.7a are similar to table 3.1a. They show the energy savings potential for paper &pulp, fertiliser, chlor-alkali, cement, iron &steel and aluminium industries respectively. The energy savings potential ranges between 62.52 percent and 79.14 percent for paper & pulp industry, 39.78 percent and 59.20 percent for fertilizer industry, 36.91 percent and 55.75 percent in chlor-alkali industry, 30.16 and 50.00 percent in cement industry, 50.65 percent and 66.46 percent in iron & steel industry and 40.28 and 53.85 percent in aluminium industry.

Table 3.1b depicts the electricity savings potential in the textile industry. Here the units are classified based on their share in total electricity consumption in the textile industry. The units are classified into 5 groups depending upon their share in textile industry's electricity consumption and the electricity savings potential in the textile industry ranges between 45.83 percent and 72.48 percent. Tables 3.2b, 3.3b, 3.4b, 3.5b, 3.6b and 3.7b are counterparts of table 3.1b and show energy savings potential for paper & pulp, fertiliser, chlor-alkali, cement, iron & steel and aluminium industries respectively. The electricity savings potential in these industries varies between 42.66 percent and 68.43 percent for paper & pulp industry, 26.13 percent and 37.70 percent for fertilizer industry, 39.53 percent and 49.12 percent in chlor-alkali industry, 22.67 and 40.02 percent in cement industry, 52.07 percent and 72.94 percent in iron & steel industry and 8.59 and 10.49 percent in aluminium industry.

Unlike tables 3.1a and 3.1b which show the energy savings potential for textile industry as a whole, table 3.1c illustrates the energy (and also electricity) savings potential within different groups. Table 3.1c also show for each group the share in output and energy (and electricity) consumed by the 10 percent, 25 percent and median units that have the lowest energy intensity within the group. The corresponding tables for the other industries considered in the study namely paper &pulp, fertiliser, chlor-alkali, cement, iron &steel and aluminium, are tables 3.2c, 3.3c, 3.4c, 3.5c, 3.6c, 3.7c respectively.

Tables 3.1d and 3.1e are similar to tables 3.1a and 3.1b with the exception that in the later set of tables the units in the textile industry were grouped on the basis of value of output. The energy savings potential for the textile industry ranges between 53.25 and 86.88 percent while the electricity savings potential varies between 53.63 and 88.23 percent. Tables 3.2d, 3.3d, 3.4d, 3.5d, 3.6d and 3.7d show energy savings potential for paper & pulp, fertiliser, chlor-alkali, cement, iron &steel and aluminium industries respectively. The energy savings potential ranges between 68.96 percent and 93.66 percent for paper & pulp industry, 77.02 percent and 93.65 percent for fertilizer industry, 66.20 percent and 88.32 percent in chlor-alkali industry, 59.37 and 83.85 percent in cement industry, 63.36 percent and 91.20 percent in iron & steel industry and 43.43 and 58.52 percent in aluminium industry. Tables 3.2e, 3.3e, 3.4e, 3.5e, 3.6e and 3.7e show electricity savings potential for paper & pulp which ranges between 65.28 –92.44 percent, fertilizer (between 78.14–89.50 percent), chlor-alkali (between 87.15–95.19 percent), cement (between 39.98 –73.59 percent), iron & steel (between 73.45–91.71 percent) and aluminium (between 8.68 - 11.14 percent) industries respectively.

Table 3.1f is analogous to table 3.1c with the exception that the classification is on the basis of value of output. The corresponding tables for paper &pulp, fertiliser, chlor-alkali, cement, iron &steel and aluminium industries are 3.2f, 3.3f, 3.4f, 3.5f, 3.6f, 3.7f respectively.

Table 3.1a: Energy Savings Potential - Textile Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.025 percent	30.130	23.852	21.865	19.413	16.251
0.025 percent < Share of Energy consumption < 0.05 percent	14.437	15.216	10.440	8.581	6.903
0.05 percent < Share of Energy consumption < 0.1 percent	14.237	14.638	9.279	7.850	5.877
0.1 percent < Share of Energy consumption < 0.5 percent	29.292	32.545	21.247	16.392	12.179
0.5 percent < Share of Energy consumption < 5.0 percent	11.903	13.749	7.844	6.289	4.382
Overall Industry	**100.000**	**100.000**	**70.675**	**58.526**	**45.592**

Table 3.1b: Electricity Savings Potential - Textile Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			Share in industry Electricity consumption (%)	least Electricity intensive 10% units	least Electricity intensive 25% units
Share of Electricity consumption < 0.025 percent	30.523	20.262	18.628	16.283	13.096
0.025 percent < Share of Electricity consumption < 0.05 percent	11.151	11.906	8.494	6.670	5.556
0.05 percent < Share of Electricity consumption < 0.1 percent	16.181	17.568	11.761	9.370	7.574
0.1 percent < Share of Electricity consumption < 0.5 percent	27.522	34.486	21.867	16.993	12.495
0.5 percent < Share of Electricity consumption < 5.0 percent	14.623	15.779	11.732	8.971	7.104
Overall Industry	**100.000**	**100.000**	**72.482**	**58.288**	**45.825**

Table 3.1c: Group Specific Energy Savings Potential - Textile Industry (2007-08)

Classification based on Share in total energy consumption		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.025 percent	Energy Saving potential (%)	91.67	81.39	68.13	91.94	80.37	64.63
	Share in fuel consumption (%)	2.29	10.98	30.57	1.78	10.31	31.72
	Share in total output (%)	25.32	50.23	72.95	20.84	45.51	71.82
0.025 percent < Share of Energy consumption < 0.05 percent	Energy Saving potential (%)	68.61	56.40	45.36	71.34	56.03	46.67
	Share in fuel consumption (%)	11.87	28.86	50.66	9.62	29.89	53.25
	Share in total output (%)	35.24	58.43	77.36	31.57	59.49	79.79
0.05 percent < Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	63.39	53.62	40.15	66.94	53.34	43.11
	Share in fuel consumption (%)	10.33	22.13	47.37	10.42	27.59	51.48
	Share in total output (%)	27.24	44.35	69.43	29.54	53.53	74.88
0.1 percent < Share of Energy consumption < 0.5 percent	Energy Saving potential (%)	65.28	50.37	37.42	63.41	49.28	36.23
	Share in fuel consumption (%)	9.32	26.05	50.87	7.87	23.31	50.14
	Share in total output (%)	25.33	47.69	71.26	20.89	42.93	69.67
0.5 percent < Share of Energy consumption < 5.0 percent	Energy Saving potential (%)	57.05	45.74	31.87	74.35	56.86	45.03
	Share in fuel consumption (%)	9.42	22.79	54.91	6.30	21.17	40.34
	Share in total output (%)	21.83	39.72	72.04	23.90	43.72	62.90

Table 3.1d: Energy Savings Potential - Textile Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.806	1.746	1.698	1.581	1.365
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	9.321	14.268	13.196	12.044	9.812
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	42.158	41.407	35.850	29.675	19.309
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	39.716	36.720	30.810	25.674	19.308
Value of output >Rs. 100000 lakhs	7.998	5.859	5.321	3.910	3.459
Overall Industry	**100.000**	**100.000**	**86.876**	**72.885**	**53.253**

Table 3.1e: Electricity Savings Potential - Textile Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.782	1.229	1.181	1.106	0.961
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	9.173	11.225	10.346	9.334	7.397
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	42.185	42.477	38.164	32.217	21.587
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	39.752	37.638	32.955	25.868	19.002
Value of output >Rs. 100000 lakhs	8.107	7.431	5.587	5.238	4.681
Overall Industry	**100.000**	**100.000**	**88.233**	**73.764**	**53.629**

Table 3.1f: Group Specific Energy Savings Potential - Textile Industry (2007-08)

Classification based on Value of Total Output		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	97.30	90.59	78.22	96.11	90.00	78.23
	Share in fuel consumption (%)	0.23	2.08	12.72	0.38	2.48	12.75
	Share in total output (%)	8.14	20.77	46.23	9.54	23.21	50.32
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	92.48	84.41	68.76	92.17	83.16	65.90
	Share in fuel consumption (%)	0.85	4.95	16.64	0.84	5.52	20.31
	Share in total output (%)	11.00	29.75	51.10	10.50	30.66	55.97
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	86.58	71.67	46.63	89.85	75.85	50.82
	Share in fuel consumption (%)	2.82	12.54	35.38	1.98	10.28	32.19
	Share in total output (%)	19.81	39.37	63.99	18.42	37.81	62.98
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	83.91	69.92	52.58	87.56	68.73	50.49
	Share in fuel consumption (%)	2.34	10.04	30.28	1.47	10.47	32.76
	Share in total output (%)	13.96	31.15	55.60	11.56	31.02	56.84
Value of output > 100000 lakhs	Energy Saving potential (%)	90.82	66.74	59.05	75.19	70.49	63.00
	Share in fuel consumption (%)	1.59	13.66	23.68	6.13	13.38	23.74
	Share in total output (%)	17.28	35.68	49.77	24.69	43.10	57.18

Table 3.2a: Energy Savings Potential - Paper & Pulp Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	Energy Saving potential as share in total industry energy consumption (%) Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.1 percent	16.819	8.007	7.514	7.086	6.218
0.1 percent < Share of Energy consumption < 0.5 percent	27.841	26.944	23.402	20.086	18.656
0.5 percent < Share of Energy consumption < 1.0 percent	18.389	15.258	11.910	10.904	9.141
Share of Energy Consumption > 1.0 percent	36.951	49.791	36.315	33.701	28.502
Overall Industry	**100.000**	**100.000**	**79.141**	**71.777**	**62.516**

Table 3.2b: Electricity Savings Potential - Paper & Pulp Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	Electricity Saving potential as share in total industry electricity consumption (%) Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.1 percent	27.063	13.381	12.813	11.992	9.827
0.1 percent < Share of Electricity consumption < 0.5 percent	20.239	14.821	11.710	9.895	7.694
0.5 percent < Share of Electricity consumption < 1.0 percent	17.967	15.634	12.336	8.251	7.928
Share of Electricity Consumption > 1.0 percent	34.731	56.164	31.570	25.280	17.206
Overall Industry	**100.000**	**100.000**	**68.429**	**55.417**	**42.655**

Table 3.2c: Group Specific Energy Savings Potential - Paper & Pulp Industry (2007-08)

Classification based on Share in total energy consumption		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	93.85	88.51	77.66	95.76	89.62	73.44
	Share in fuel consumption (%)	1.59	5.97	21.12	0.45	2.90	27.95
	Share in total output (%)	25.07	45.14	69.05	10.35	25.96	68.25
0.1 percent < Share of Energy consumption < 0.5 percent	Energy Saving potential (%)	86.85	74.55	69.24	79.01	66.76	51.91
	Share in fuel consumption (%)	4.49	17.14	31.78	6.65	16.68	37.48
	Share in total output (%)	31.93	55.44	69.49	28.66	43.91	64.13
0.5 percent < Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	78.05	71.46	59.91	78.90	52.78	50.71
	Share in fuel consumption (%)	7.31	16.71	37.29	6.09	29.11	72.52
	Share in total output (%)	32.50	53.14	73.29	26.49	51.10	85.82
Share of Energy Consumption > 1.0 percent	Energy Saving potential (%)	72.93	67.68	57.24	56.21	45.01	30.64
	Share in fuel consumption (%)	6.42	15.68	31.21	3.98	10.81	44.74
	Share in total output (%)	23.67	46.18	61.06	8.99	19.23	61.72

Table 3.2d: Energy Savings Potential - Paper & Pulp Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.342	0.399	0.364	0.324	0.282
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	6.985	7.797	7.626	7.373	6.641
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	31.603	36.856	35.063	29.494	22.755
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	61.070	54.949	50.613	46.393	39.285
Overall Industry	**100.000**	**100.000**	**93.666**	**83.584**	**68.963**

Table 3.2e: Electricity Savings Potential - Paper & Pulp Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.364	0.334	0.317	0.291	0.243
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	7.315	5.821	5.696	5.632	5.189
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	29.905	20.931	18.900	15.631	11.301
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	62.416	72.914	67.531	62.987	48.541
Overall Industry	**100.000**	**100.000**	**92.444**	**84.541**	**65.275**

Table 3.2f: Group Specific Energy Savings Potential - Paper & Pulp Industry (2007-08)

Paper & Pulp Industry (Classification based on Value of Total Output)		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	91.44	81.29	70.69	95.00	87.22	72.87
	Share in fuel consumption (%)	0.56	4.87	25.30	0.47	3.69	22.15
	Share in total output (%)	6.45	24.97	60.71	9.23	26.85	59.97
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	97.81	94.56	85.18	97.86	96.76	89.15
	Share in fuel consumption (%)	0.28	1.64	10.91	0.40	0.92	5.43
	Share in total output (%)	12.39	27.88	51.80	17.91	26.56	45.33
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	95.14	80.02	61.74	90.29	74.68	53.99
	Share in fuel consumption (%)	0.65	7.65	22.47	0.87	9.72	29.37
	Share in total output (%)	12.91	34.22	55.20	8.81	35.44	59.58
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	92.11	84.43	71.49	92.62	86.38	66.57
	Share in fuel consumption (%)	0.68	4.34	19.52	1.01	3.04	23.85
	Share in total output (%)	8.52	26.58	59.31	13.27	20.82	48.26

Table 3.3a: Energy Savings Potential - Fertiliser Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.1 percent	5.750	1.100	1.020	0.875	0.623
0.1 percent < Share of Energy consumption < 1.0 percent	31.741	4.170	2.574	2.143	1.552
1.0 percent < Share of Energy consumption < 5.0 percent	41.589	40.278	28.819	24.622	18.689
5.0 percent < Share of Energy consumption < 10.0 percent	20.920	54.451	26.787	21.279	17.906
Share of Energy Consumption > 10.0 percent	--	--	--	--	--
Overall Industry	**100.000**	**100.000**	**59.200**	**48.920**	**38.769**

Table 3.3b: Electricity Savings Potential - Fertiliser Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.1 percent	6.728	1.648	1.520	1.316	1.205
0.1 percent < Share of Electricity consumption < 1.0 percent	32.774	7.879	4.678	3.987	2.985
1.0 percent < Share of Electricity consumption < 5.0 percent	42.609	34.263	24.076	20.061	14.517
5.0 percent < Share of Electricity consumption < 10.0 percent	10.396	13.086	3.950	3.950	3.950
Share of Electricity Consumption > 10.0 percent	7.493	43.125	3.471	3.471	3.471
Overall Industry	**100.000**	**100.000**	**37.696**	**32.786**	**26.128**

Table 3.3c: Group Specific Energy Savings Potential - Fertiliser Industry (2007-08)

Classification based on Share in total energy consumption		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	92.69	79.56	56.60	92.24	79.87	73.13
	Share in fuel consumption (%)	0.53	4.45	28.22	0.53	7.66	17.69
	Share in total output (%)	7.19	20.68	57.60	6.72	36.44	53.52
0.1 percent <Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	61.73	51.38	37.21	59.38	50.60	37.89
	Share in fuel consumption (%)	4.21	21.45	47.18	4.76	15.96	53.52
	Share in total output (%)	11.00	41.45	65.60	11.65	31.58	78.27
1.0 percent < Share of Energy consumption < 5.0 percent	Energy Saving potential (%)	71.55	61.13	46.40	70.27	58.55	42.37
	Share in fuel consumption (%)	6.84	16.49	41.02	6.54	16.38	42.93
	Share in total output (%)	23.67	39.31	65.15	22.01	36.60	65.51
5.0 percent < Share of Energy consumption < 10.0 percent	Energy Saving potential (%)	49.19	39.08	32.88	30.18	30.18	30.18
	Share in fuel consumption (%)	9.57	21.11	37.48	45.31	45.31	45.31
	Share in total output (%)	18.84	33.36	52.86	64.91	64.91	64.91
Share of Energy Consumption > 10.0 percent	Energy Saving potential (%)	--	--	--	8.05	8.05	8.05
	Share in fuel consumption (%)	--	--	--	35.63	35.63	35.63
	Share in total output (%)	--	--	--	38.74	38.74	38.74

Table 3.3d: Energy Savings Potential - Fertiliser Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	Energy Saving potential as share in total industry energy consumption (%)		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.096	0.048	0.045	0.042	0.039
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.633	0.241	0.224	0.196	0.153
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	3.374	0.663	0.592	0.528	0.448
Rs.10000 lakhs < Value of output <Rs.100000 lakhs	14.432	17.853	15.937	14.047	8.800
Value of output >Rs.100000 lakhs	80.465	81.196	76.850	73.973	67.576
Overall Industry	**100.000**	**100.000**	**93.648**	**88.787**	**77.016**

Table 3.3e: Electricity Savings Potential - Fertiliser Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	Electricity Saving potential as share in total industry electricity consumption (%)		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.094	0.066	0.061	0.057	0.052
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.611	0.365	0.350	0.330	0.270
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	3.355	1.146	1.033	0.941	0.854
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	14.439	13.266	12.465	11.065	9.943
Value of output >Rs. 100000 lakhs	80.502	85.157	75.589	72.332	67.017
Overall Industry	**100.000**	**100.000**	**89.497**	**84.726**	**78.137**

Table 3.3f: Group Specific Energy Savings Potential - Fertiliser Industry (2007-08)

Classification based on Value of Total Output		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	93.24	88.15	80.69	92.19	86.22	78.35
	Share in fuel consumption (%)	1.13	4.44	8.93	0.41	4.36	10.74
	Share in total output (%)	16.53	34.27	46.16	5.25	29.93	45.62
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	93.16	81.52	63.62	95.79	90.40	74.07
	Share in fuel consumption (%)	0.95	6.98	32.09	0.59	2.23	22.18
	Share in total output (%)	13.38	34.05	67.66	13.57	21.32	58.58
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	89.32	79.66	67.58	90.09	82.14	74.54
	Share in fuel consumption (%)	0.60	2.61	19.04	0.73	3.12	8.32
	Share in total output (%)	5.55	12.50	41.90	7.27	16.87	29.10
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	89.27	78.68	49.29	93.96	83.41	74.95
	Share in fuel consumption (%)	0.33	2.71	21.21	0.64	7.06	15.22
	Share in total output (%)	3.11	12.47	38.47	10.54	36.83	50.40
Value of output > 100000 lakhs	Energy Saving potential (%)	94.65	91.11	83.23	88.77	84.94	78.70
	Share in fuel consumption (%)	0.63	2.42	10.97	0.77	4.37	12.20
	Share in total output (%)	11.74	25.88	55.97	6.80	28.27	51.44

Table 3.4a: Energy Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.1 percent	16.737	4.726	4.444	3.910	3.545
0.1 percent < Share of Energy consumption < 1.0 percent	20.470	10.238	7.192	6.330	4.887
1.0 percent < Share of Energy consumption < 10.0 percent	38.919	55.010	44.072	34.709	28.430
Share of Energy Consumption > 10.0 percent	23.874	30.027	0.044	0.044	0.044
Overall Industry	**100.000**	**100.000**	**55.751**	**44.992**	**36.906**

Table 3.4b: Electricity Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.1 percent	19.071	2.653	2.335	2.217	2.109
0.1 percent < Share of Electricity consumption < 1.0 percent	31.369	11.911	9.976	9.496	8.687
1.0 percent < Share of Electricity consumption < 10.0 percent	35.159	34.827	29.185	28.464	22.319
Share of Electricity Consumption > 10.0 percent	14.400	50.609	7.621	7.621	6.414
Overall Industry	**100.000**	**100.000**	**49.117**	**47.798**	**39.529**

Table 3.4c: Group Specific Energy Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Share in total energy consumption		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	94.04	82.73	75.01	88.01	83.57	79.51
	Share in fuel consumption (%)	0.25	8.70	22.25	2.39	7.97	18.22
	Share in total output (%)	4.12	47.43	72.06	19.51	45.66	65.53
0.1 percent < Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	70.25	61.83	47.74	83.75	79.72	72.93
	Share in fuel consumption (%)	4.78	17.47	45.89	6.18	12.37	25.10
	Share in total output (%)	15.97	43.37	73.93	36.46	55.75	73.34
1.0 percent < Share of Energy consumption < 10.0 percent	Energy Saving potential (%)	80.12	63.10	51.68	83.80	81.73	64.09
	Share in fuel consumption (%)	3.53	16.30	38.41	7.61	10.56	46.13
	Share in total output (%)	17.56	40.27	70.58	46.97	52.53	86.37
Share of Energy Consumption > 10.0 percent	Energy Saving potential (%)	0.15	0.15	0.15	15.06	15.06	12.67
	Share in fuel consumption (%)	31.06	31.06	31.06	26.71	26.71	57.26
	Share in total output (%)	31.10	31.10	31.10	31.45	31.45	64.76

Table 3.4d: Energy Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.357	0.171	0.164	0.139	0.139
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	9.940	5.468	5.253	4.888	4.520
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	22.749	23.075	22.098	21.379	17.676
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	66.954	71.286	60.803	57.749	43.784
Overall Industry	**100.000**	**100.000**	**88.318**	**84.155**	**66.119**

Table 3.4e: Electricity Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.359	0.059	0.055	0.050	0.050
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	9.717	2.695	2.464	2.395	2.265
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	22.707	16.734	16.331	15.859	14.445
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	67.218	80.512	76.270	75.563	70.394
Overall Industry	**100.000**	**100.000**	**95.119**	**93.868**	**87.153**

Table 3.4f: Group Specific Energy Savings Potential - Chlor-Alkali Industry (2007-08)

Classification based on Value of Total Output		**Unit of energy intensity: Kgoe/Re**			**Unit of energy intensity: Kwh/Re**		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	95.75	81.08	81.07	91.82	84.19	83.63
	Share in fuel consumption (%)	0.74	10.58	31.97	0.59	3.57	23.43
	Share in total output (%)	16.85	48.37	83.60	7.04	21.83	62.02
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	96.06	89.39	82.66	91.45	88.89	84.04
	Share in fuel consumption (%)	0.19	2.79	13.08	1.12	3.20	7.47
	Share in total output (%)	4.73	24.94	53.10	12.86	27.89	41.06
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	95.77	92.65	76.60	97.59	94.77	86.32
	Share in fuel consumption (%)	0.65	3.00	12.33	0.37	2.48	7.60
	Share in total output (%)	15.28	36.75	58.37	15.05	40.82	59.07
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	85.30	81.01	61.42	94.73	93.85	87.43
	Share in fuel consumption (%)	0.92	2.98	16.14	0.91	1.47	8.53
	Share in total output (%)	6.27	15.46	37.66	17.02	23.28	56.99

Table 3.5a: Energy Savings Potential - Cement Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.1 percent	4.698	2.836	2.551	2.473	2.093
0.1 percent < Share of Energy consumption < 0.5 percent	29.636	16.563	12.598	10.044	8.227
0.5 percent < Share of Energy consumption < 1.0 percent	19.457	15.982	11.124	9.064	7.540
1.0 percent < Share of Energy consumption < 10.0 percent	46.209	64.619	23.722	16.452	12.301
Overall Industry	**100.000**	**100.000**	**49.995**	**38.033**	**30.160**

Table 3.5b: Electricity Savings Potential - Cement Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.1 percent	7.089	2.486	2.292	1.991	1.709
0.1 percent < Share of Electricity consumption < 0.5 percent	17.776	11.671	6.407	6.019	4.982
0.5 percent < Share of Electricity consumption < 1.0 percent	12.347	14.452	5.387	4.808	3.994
1.0 percent < Share of Electricity consumption < 10.0 percent	62.788	71.391	25.943	17.311	11.987
Overall Industry	**100.000**	**100.000**	**40.029**	**30.129**	**22.672**

Table 3.5c: Group Specific Energy Savings Potential - Cement Industry (2007-08)

Classification based on Share in total energy consumption		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	89.94	87.19	73.80	92.23	80.09	68.77
	Share in fuel consumption (%)	5.36	9.19	30.88	0.49	15.00	34.22
	Share in total output (%)	50.28	61.35	82.21	6.18	65.61	82.69
0.1 percent < Share of Energy consumption < 0.5 percent	Energy Saving potential (%)	76.06	60.64	49.67	54.89	51.57	42.69
	Share in fuel consumption (%)	8.49	29.64	55.36	15.42	27.37	48.92
	Share in total output (%)	33.25	64.08	86.29	33.88	54.80	78.92
0.5 percent < Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	69.60	56.72	47.18	37.27	33.27	27.63
	Share in fuel consumption (%)	10.16	30.04	52.28	10.03	26.90	48.39
	Share in total output (%)	31.83	61.29	78.83	15.96	39.88	63.99
1.0 percent < Share of Energy consumption < 10.0 percent	Energy Saving potential (%)	36.71	25.46	19.04	36.34	24.25	16.79
	Share in fuel consumption (%)	5.43	21.92	59.23	8.09	24.43	60.08
	Share in total output (%)	8.53	29.01	69.13	12.59	31.56	68.40

Table 3.5d: Energy Savings Potential - Cement Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	Energy Saving potential as share in total industry energy consumption (%) — Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.236	0.466	0.429	0.384	0.315
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.292	1.405	1.361	1.282	0.999
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	4.137	7.923	7.685	7.286	5.072
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	78.430	78.781	64.532	56.615	44.433
Value of output >Rs. 100000 lakhs	15.905	11.424	9.844	9.202	8.554
Overall Industry	**100.000**	**100.000**	**83.851**	**74.769**	**59.374**

Table 3.5e: Electricity Savings Potential - Cement Industry (2007-08)

Cement Industry (Classification based on Value of Total Output)	Share in output of the industry (%)	Share in industry Electricity consumptio n (%)	Electricity Saving potential as share in total industry electricity consumption (%) — Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.225	0.272	0.251	0.214	0.169
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.222	0.797	0.777	0.752	0.609
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	3.968	5.343	5.150	4.694	3.606
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	78.637	79.076	62.598	56.166	32.699
Value of output >Rs. 100000 lakhs	15.947	14.512	4.813	3.961	2.897
Overall Industry	**100.000**	**100.000**	**73.590**	**65.786**	**39.981**

Table 3.5f: Group Specific Energy Savings Potential - Cement Industry (2007-08)

Classification based on Value of Total Output		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	92.01	82.41	67.64	92.31	78.67	62.28
	Share in fuel consumption (%)	0.91	5.17	18.53	0.34	6.37	24.91
	Share in total output (%)	11.13	27.51	54.98	4.34	28.32	60.61
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	96.86	91.26	71.08	97.50	94.28	76.36
	Share in fuel consumption (%)	0.51	2.77	20.56	0.39	1.71	17.07
	Share in total output (%)	16.05	28.18	63.48	14.94	27.04	63.18
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	96.99	91.96	64.01	96.39	87.85	67.49
	Share in fuel consumption (%)	0.30	1.30	17.64	0.28	2.27	14.18
	Share in total output (%)	9.56	15.21	44.21	7.50	17.56	41.35
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	81.91	71.86	56.40	79.16	71.03	41.35
	Share in fuel consumption (%)	2.87	8.92	21.98	2.70	6.23	25.75
	Share in total output (%)	15.27	29.78	46.89	12.57	20.70	42.82
Value of output > 100000 lakhs	Energy Saving potential (%)	86.17	80.54	74.88	33.17	27.29	19.96
	Share in fuel consumption (%)	2.52	8.21	14.40	14.18	24.50	39.65
	Share in total output (%)	18.18	39.63	51.40	21.21	32.98	47.44

Table 3.6a: Energy Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.025 percent	21.433	13.643	12.574	11.272	9.811
0.025 percent < Share of Energy consumption < 0.1 percent	17.803	19.567	15.312	13.540	11.255
0.1 percent < Share of Energy consumption < 0.5 percent	22.871	17.397	13.776	11.611	9.868
0.5 percent < Share of Energy consumption < 1.0 percent	5.897	6.770	4.046	3.045	2.475
1.0 percent < Share of Energy consumption < 10.0 percent	31.996	42.622	20.756	20.156	17.245
Overall Industry	**100.000**	**100.000**	**66.463**	**59.624**	**50.653**

Table 3.6b: Electricity Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.025 percent	24.426	11.620	10.618	9.113	8.134
0.025 percent < Share of Electricity consumption < 0.1 percent	16.430	20.029	17.147	15.283	13.198
0.1 percent < Share of Electricity consumption < 0.5 percent	22.204	18.788	14.581	12.798	10.522
0.5 percent < Share of Electricity consumption < 1.0 percent	3.195	5.881	3.253	3.041	2.586
1.0 percent < Share of Electricity consumption < 10.0 percent	33.744	43.681	27.345	26.578	17.633
Overall Industry	**100.000**	**100.000**	**72.944**	**66.813**	**52.073**

Table 3.6c: Group Specific Energy Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Share in total energy consumption		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.025 percent	Energy Saving potential (%)	92.17	82.62	71.91	91.38	78.42	70.00
	Share in fuel consumption (%)	1.95	8.85	28.21	1.78	12.36	31.55
	Share in total output (%)	22.95	44.16	69.06	19.22	50.28	76.90
0.025 percent < Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	78.25	69.20	57.52	85.61	76.30	65.89
	Share in fuel consumption (%)	6.73	15.63	43.20	5.74	15.32	43.71
	Share in total output (%)	29.83	45.47	74.01	35.89	54.64	76.58
0.1 percent < Share of Energy consumption < 0.5 percent	Energy Saving potential (%)	79.19	66.74	56.72	77.61	68.12	56.01
	Share in fuel consumption (%)	10.90	28.82	50.46	9.70	24.53	51.62
	Share in total output (%)	45.22	68.12	84.58	40.35	65.02	86.99
0.5 percent < Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	59.75	44.97	36.55	55.32	51.71	43.96
	Share in fuel consumption (%)	6.71	27.78	50.64	12.51	28.12	50.62
	Share in total output (%)	16.66	47.78	71.67	28.00	56.00	78.57
1.0 percent < Share of Energy consumption < 10.0 percent	Energy Saving potential (%)	48.70	47.29	40.46	62.60	60.85	40.37
	Share in fuel consumption (%)	10.66	16.68	45.13	9.16	13.69	54.21
	Share in total output (%)	20.71	31.45	71.80	24.48	34.34	77.48

Table 3.6d: Energy Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	Energy Saving potential as share in total industry energy consumption (%)		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.063	0.091	0.086	0.080	0.068
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.403	1.776	1.641	1.509	1.311
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	19.597	23.971	21.674	19.532	15.843
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	26.669	24.378	23.231	20.687	17.052
Rs.100000 lakhs < Value of output <Rs. 1000000 lakhs	32.675	31.894	28.891	26.444	21.439
Value of output >Rs. 1000000 lakhs	19.594	17.889	15.676	15.676	7.651
Overall Industry	**100.000**	**100.000**	**91.199**	**83.927**	**63.363**

Table 3.6e: Electricity Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.061	0.090	0.086	0.082	0.071
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	1.405	1.755	1.695	1.551	1.360
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	19.616	24.812	23.025	21.295	19.240
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	26.341	25.517	24.462	23.107	21.008
Rs.100000 lakhs < Value of output <Rs. 1000000 lakhs	32.868	32.196	29.094	26.496	22.733
Value of output >Rs. 1000000 lakhs	19.709	15.630	13.343	13.343	9.035
Overall Industry	**100.000**	**100.000**	**91.706**	**85.874**	**73.446**

Table 3.6f: Group Specific Energy Savings Potential - Iron & Steel Industry (2007-08)

Classification based on Value of Total Output		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	94.04	86.93	74.04	95.49	91.39	78.53
	Share in fuel consumption (%)	0.84	4.68	15.47	0.92	3.36	13.84
	Share in total output (%)	13.74	33.04	57.90	19.64	35.08	57.36
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	92.39	84.93	73.78	96.58	88.38	77.49
	Share in fuel consumption (%)	0.63	4.18	18.84	0.20	2.67	15.42
	Share in total output (%)	8.13	26.48	57.58	5.89	21.86	55.48
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	90.41	81.48	66.09	92.80	85.83	77.54
	Share in fuel consumption (%)	1.04	5.00	20.98	0.65	4.40	13.62
	Share in total output (%)	10.64	25.50	53.01	8.86	29.54	53.64
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	95.30	84.86	69.95	95.87	90.55	82.33
	Share in fuel consumption (%)	0.55	5.29	18.54	0.63	3.30	11.88
	Share in total output (%)	11.37	31.97	54.41	14.54	32.01	56.70
Rs.100000 lakhs < Value of output <Rs. 1000000 lakhs	Energy Saving potential (%)	90.59	82.91	67.22	90.37	82.30	70.61
	Share in fuel consumption (%)	1.42	4.24	16.47	0.90	3.84	13.16
	Share in total output (%)	14.41	23.00	44.29	9.06	20.76	40.73
Value of output >Rs. 1000000 lakhs	Energy Saving potential (%)	87.63	87.63	42.77	85.37	85.37	57.80
	Share in fuel consumption (%)	2.08	2.08	43.15	2.46	2.46	28.06
	Share in total output (%)	16.83	16.83	65.08	16.83	16.83	58.73

Table 3.7a: Energy Savings Potential - Aluminium Industry (2007-08)

Classification based on Share in total energy consumption	Share in output of the industry (%)	Share in industry fuel consumption (%)	Energy Saving potential as share in total industry energy consumption (%) Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Share of Energy consumption < 0.1 percent	12.211	5.551	4.885	4.610	3.429
0.1 percent < Share of Energy consumption < 1.0 percent	35.053	13.646	9.700	8.302	5.660
1.0 percent < Share of Energy consumption < 10.0 percent	9.284	7.827	3.362	3.362	2.379
Share of Energy Consumption > 10.0 percent	43.452	72.976	35.907	35.907	28.809
Overall Industry	**100.000**	**100.000**	**53.853**	**52.181**	**40.276**

Table 3.7b: Electricity Savings Potential - Aluminium Industry (2007-08)

Classification based on Share in total electricity consumption	Share in output of the industry (%)	Share in industry Electricity consumption (%)	Electricity Saving potential as share in total industry electricity consumption (%) Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Share of Electricity consumption < 0.1 percent	38.000	2.627	2.433	2.360	1.578
0.1 percent < Share of Electricity consumption < 1.0 percent	17.355	1.698	0.957	0.940	0.799
1.0 percent < Share of Electricity consumption < 10.0 percent	--	--	--	--	--
Share of Electricity Consumption > 10.0 percent	44.645	95.675	7.101	6.213	6.213
Overall Industry	**100.000**	**100.000**	**10.492**	**9.512**	**8.590**

Table 3.7c: Group Specific Energy Savings Potential - Aluminium Industry (2007-08)

Classification based on Share in total energy consumption		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Share of Energy consumption < 0.1 percent	Energy Saving potential (%)	88.01	83.05	61.77	92.64	89.82	60.07
	Share in fuel consumption (%)	2.26	4.60	40.46	3.24	5.73	35.37
	Share in total output (%)	18.14	25.26	74.09	39.78	47.23	75.03
0.1 percent < Share of Energy consumption < 1.0 percent	Energy Saving potential (%)	71.08	60.84	41.48	56.37	55.36	47.04
	Share in fuel consumption (%)	12.36	27.60	46.35	7.41	13.61	33.79
	Share in total output (%)	39.47	60.06	77.32	16.98	30.35	59.47
1.0 percent < Share of Energy consumption < 10.0 percent	Energy Saving potential (%)	42.95	42.95	30.39	-	-	-
	Share in fuel consumption (%)	17.89	17.89	52.06	-	-	-
	Share in total output (%)	31.35	31.35	69.10	-	-	-
Share of Energy Consumption > 10.0 percent	Energy Saving potential (%)	49.20	49.20	39.48	7.42	6.49	6.49
	Share in fuel consumption (%)	20.48	20.48	59.80	45.18	56.33	56.33
	Share in total output (%)	40.33	40.33	89.12	48.80	59.67	59.67

Table 3.7d: Energy Savings Potential - Aluminium Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry fuel consumption (%)	**Energy Saving potential as share in total industry energy consumption (%)**		
			Unit of energy intensity: Kgoe/Re		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Value of output <Rs. 100 lakhs	0.365	0.241	0.197	0.174	0.131
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	3.493	2.944	2.653	2.433	2.044
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	14.123	7.764	7.094	5.438	4.450
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	38.567	16.076	12.667	11.370	7.997
Value of output >Rs. 100000 lakhs	43.452	72.976	35.907	35.907	28.809
Overall Industry	**100.000**	**100.000**	**58.517**	**55.321**	**43.432**

Table 3.7e: Electricity Savings Potential - Aluminium Industry (2007-08)

Classification based on Value of Total Output	Share in output of the industry (%)	Share in industry Electricity consumption (%)	**Electricity Saving potential as share in total industry electricity consumption (%)**		
			Unit of energy intensity: Kwh/Re		
			least Electricity intensive 10% units	least Electricity intensive 25% units	Median Electricity intensive units
Value of output <Rs. 100 lakhs	0.375	0.064	0.054	0.050	0.036
Rs. 100 lakhs < Value of output <Rs. 1000 lakhs	3.214	0.501	0.480	0.452	0.379
Rs. 1000 lakhs < Value of output <Rs. 10000 lakhs	13.305	1.138	1.043	0.987	0.798
Rs.10000 lakhs < Value of output <Rs. 100000 lakhs	38.461	2.622	2.462	2.109	1.258
Value of output >Rs. 100000 lakhs	44.645	95.675	7.101	7.101	6.213
Overall Industry	**100.000**	**100.000**	**11.141**	**10.698**	**8.684**

Table 3.7f: Group Specific Energy Savings Potential - Aluminium Industry (2007-08)

Classification based on Value of Total Output		Unit of energy intensity: Kgoe/Re			Unit of energy intensity: Kwh/Re		
		Top 10% units	Top 25% units	Median units	Top 10% units	Top 25% units	Median units
Value of output < 100 lakhs	Energy Saving potential (%)	81.72	72.44	54.60	84.26	77.42	55.35
	Share in fuel consumption (%)	2.02	7.94	31.65	2.64	6.26	40.02
	Share in total output (%)	10.92	27.71	58.29	16.64	26.14	68.81
100 < Value of output < 1000 lakhs	Energy Saving potential (%)	90.11	82.64	69.45	95.87	90.26	75.73
	Share in fuel consumption (%)	0.33	2.25	15.18	0.53	2.75	15.93
	Share in total output (%)	3.35	12.73	45.24	12.36	26.18	54.44
1000 < Value of output < 10000 lakhs	Energy Saving potential (%)	91.36	70.04	57.32	91.68	86.69	70.14
	Share in fuel consumption (%)	0.91	9.65	31.39	0.43	4.74	14.79
	Share in total output (%)	10.30	29.69	65.18	5.21	34.47	51.68
10000 < Value of output < 100000 lakhs	Energy Saving potential (%)	78.80	70.73	49.75	93.90	80.44	47.97
	Share in fuel consumption (%)	6.01	13.64	28.84	1.85	10.98	34.61
	Share in total output (%)	28.22	42.08	59.88	29.13	43.96	68.12
Value of output > 100000 lakhs	Energy Saving potential (%)	49.20	49.20	39.48	7.42	7.42	6.49
	Share in fuel consumption (%)	20.48	20.48	59.80	45.18	45.18	56.33
	Share in total output (%)	40.33	40.33	89.12	48.80	48.80	59.67

The energy savings potential in each of the seven industries considered in the study calculated using the unit level Annual Survey of Industries (ASI) data for the year 2007-08 as discussed above in details summarized in table 3.8.

Table 3.8 Energy Savings Potential in Select Industries in India– 2007-08

Classification Based on	Unit of energy intensity	least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
1. Textile Industry				
a) Share in total energy consumption	Kgoe/Re	70.675	58.526	45.592
b) Share in total electricity consumption	Kwh/Re	72.482	58.288	45.825
c) Value of Total Output	Kgoe/Re	86.876	72.885	53.253
d) Value of Total Output	Kwh/Re	88.233	73.764	53.629
2. Paper & Pulp Industry - 2007-08 (%)				
a) Share in total energy consumption	Kgoe/Re	79.141	71.777	62.516
b) Share in total electricity consumption	Kwh/Re	68.429	55.417	42.655
c) Value of Total Output	Kgoe/Re	93.666	83.584	68.963
d) Value of Total Output	Kwh/Re	92.444	84.541	65.275
3. Iron & Steel Industry				
a) Share in total energy consumption	Kgoe/Re	66.463	59.624	50.653
b) Share in total electricity consumption	Kwh/Re	72.944	66.813	52.073
c) Value of Total Output	Kgoe/Re	91.199	83.927	63.363
d) Value of Total Output	Kwh/Re	91.706	85.874	73.446
4. Fertiliser Industry				
a) Share in total energy consumption	Kgoe/Re	59.200	48.920	38.769
b) Share in total electricity consumption	Kwh/Re	37.696	32.786	26.128
c) Value of Total Output	Kgoe/Re	93.648	88.787	77.016
d) Value of Total Output	Kwh/Re	89.497	84.726	78.137
5. Chlor-Alkali Industry				
a) Share in total energy consumption	Kgoe/Re	55.751	44.992	36.906
b) Share in total electricity consumption	Kwh/Re	49.117	47.798	39.529
c) Value of Total Output	Kgoe/Re	88.318	84.155	66.119
d) Value of Total Output	Kwh/Re	95.119	93.868	87.153
6. Cement Industry				
a) Share in total energy consumption	Kgoe/Re	49.995	38.033	30.16
b) Share in total electricity consumption	Kwh/Re	40.029	30.129	22.672
c) Value of Total Output	Kgoe/Re	83.851	74.769	59.374
d) Value of Total Output	Kwh/Re	73.59	65.786	39.981
7. Aluminium Industry				
a) Share in total energy consumption	Kgoe/Re	53.853	52.181	40.276
b) Share in total electricity consumption	Kwh/Re	10.492	9.512	8.59
c) Value of Total Output	Kgoe/Re	58.517	55.321	43.432
d) Value of Total Output	Kwh/Re	11.141	10.698	8.684

It should however, be noted that the extent to which the derived energy savings potential which can be achieved in reality is a difficult question. Attaining the level of intensity of the best performing unit may not be technologically feasible or economically efficient or viable for all the units within an industry as this may involve considerable investments raising the unit costs at the given current prices and interest rates. Nonetheless, efforts must be made to improve energy intensity of all units within the industry so that improvement in the overall energy intensity of the industry can be achieved. It is important to ask what would be the cost as well as the energy savings for adopting more energy-efficient technologies. Will the gains from improving energy savings outweigh costs of steps taken for improvement in energy intensity? What fiscal and monetary measures need to be adopted that would incentivize energy efficiency both in the short and long run and the energy savings that these improvements would result in.

3.2 Benchmark Analysis for the Power Sector

The energy savings potential in the power sector is in the conversion of primary energy (i.e., coal, oil, gas etc.) into final energy (i.e., into electricity). Unlike in the previous section where the industrial units were the end users of energy, the power sector is the supplier of energy in the form of electrical energy. Energy efficiency in the power sector would imply efficiency in the conversion of primary energy into final energy. In the present study we focus only on the coal fired power plants in the country. The power plants considered in the study comprises of plants in the central sector, state sector and private sector. The data for this analysis is collected and collated from the various published documents of the Central Electricity Authority (CEA). In order to calculate the energy savings potential of the power sector in India we use three important parameters. These are

a) station heat rate measured in kcal/Kwh,
b) auxiliary consumption expressed as percentage of gross generation and
c) specific secondary fuel oil consumption measure in ml/Kwh.

a) ***Heat rate***: The heat rate of a coal fired thermal power plant is a measure of how efficiently it converts the energy (chemical) contained in the fuel (i.e., coal/lignite) into electrical energy. This conversion is accomplished though a number of steps and in each of these steps some amount of energy is lost or goes waste. Thus, the heat rate of a power plant is defined as the amount of chemical energy required to produce one unit of electrical energy. If a power plant converted 100 percent of the chemical energy in the fuel into electricity, the plant would have a heat rate of 860kcal/kWh. Chemical energy is usually measured in kilocalories (kcal) while the electrical energy is measured in kilowatt-hours (kWh). The unit of heat rate is normally kcal/kWh. Thus, heat rate is the thermal energy contained in the fuels used, in kilo calories, required to generate 1 kwh of electricity. The lower the heat rate, higher will be the efficiency of the power plant and vice versa.

In order to calculate the energy savings potential in the coal fired thermal power sector, all the power plants are first grouped on the basis of their average unit size (measured in MW)[22]. We define the average unit size of a plant as the total installed capacity of the plant divided by the number of units in commercial operation. Based on the available data the power plants considered are grouped in to six broad groups on the basis of the average unit size. The groups are i) average unit size between 40-90 MW, ii) average unit size between 105-130 MW, iii) average unit size between 140-175 MW, iv) average unit size 210 MW, v) average unit size 250 MW, and vi) average unit size between 290-500 MW.[23]The data on the station heat rate is available for the period 2005-06 to 2009-10. Within each group the plants are arranged or ranked on the basis of their best performance i.e., attaining the lowest heat rate value between 2005-06 and 2009-10. The plants are ranked on the basis of lowest heat rate achieved during the

[22] Average unit size of a power plant is the total installed capacity of the plant divided by the number of units in operation.

[23]The classification of plants into different groups based on average unit size remains same for the three parameters i.e., heat rate, auxiliary consumption and specific secondary fuel oil consumption used though the number of plants in each of the groups have changed depending upon the availability of data for each of the parameters

period for which data is available. For a group after having arranged the plants in order of their best heat rate performance, we select 10 percent of the plants that have the ***lowest*** heat rate in the group and their average heat rate is calculated. This average heat rate of the top 10 percent ***efficient*** plants (i.e., the mean of the first decile of the heat rate distribution within a group) is taken as the benchmark which all the plants within the group having heat rate higher than the benchmark were required to achieve within a given period. The total energy used by all plants having heat rate higher than the benchmark rate was therefore, worked out using the benchmark heat rate and the overall energy consumption of the group is obtained by adding to it the actual energy consumption of the plants with heat rate lower than the benchmark. For a group the difference between the actual energy consumption and the modified energy consumption worked out using the benchmark heat rate gives the energy savings potential of that group. Similarly, energy savings potential for all groups within the sector is calculated and the savings potential of the sector is obtained by aggregating the savings potential of all the groups.

Table3.9: Energy Savings Potential in the Power Sector based of Station Heat Rate (2009-10)

Classification based on Average Unit Size	Share in total power generation (2009-10) (%)	Share in total Energy (mn kcal) consumed (%)	Overall Power Sector Savings potential		
			Station Heat rate (kcal/kwh)		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Average Unit Size 40-90 MW	5.22	6.33	0.97	0.81	0.58
Average Unit Size 105-130 MW	4.39	4.93	0.97	0.70	0.45
Average Unit Size 140-175 MW	12.14	13.35	1.50	1.27	1.02
Average Unit Size 210 MW	34.61	34.80	3.87	3.28	2.52
Average Unit Size 250 MW	6.03	5.67	0.36	0.35	0.28
Average Unit Size 290-500 MW	37.61	34.91	0.99	0.79	0.64
Total	***100.00***	***100.00***	***8.67***	***7.20***	***5.48***

Similar exercise is repeated by taking 25 percent of the plants that have the lowest heat rate in the group and also by taking plants having heat rates lower than the median heat rate in the group. The energy savings potential thus obtained using the heat rate criteria is depicted in table 3.9. The coal fired thermal power plants are classified into 6 groups on the basis of average unit size of the plant. The energy savings potential varies between a low of 5.48 percent of the total input energy (in calorific units) used in the generation of electric energy to a high of 8.67 percent.

b) ***Auxiliary Consumption***: A power plant consists of several pumps, motors, crushers, grinders and other equipment besides boiler, turbine and generator which are the main equipment. These are collectively known as power plant auxiliaries. These Auxiliaries themselves consume power in the process of generating power. Auxiliary power consumption is the energy (electrical energy) consumed by the power plant in the process of generating electrical energy and is expressed as electricity consumed as a percent of its gross generation. Higher the auxiliary consumption lower will be the availability of electric energy to other consumers.

Table 3.10: Energy Savings Potential based on Auxiliary Power Consumption (2009-10)

Classification based on Average Unit Size	Share in total power generation (2009-10) (%)	Share in auxiliary power (MU) consumed (%)	Overall Power Sector Savings potential Auxiliary Consumption (as % of gross generation)		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Average Unit Size 40-90 MW	9.42	10.86	1.67	1.30	0.80
Average Unit Size 105-130 MW	4.50	5.18	0.75	0.62	0.35
Average Unit Size 140-175 MW	11.90	13.68	2.09	1.33	0.82
Average Unit Size 210 MW	34.08	35.57	5.70	4.51	3.02
Average Unit Size 250 MW	5.34	5.65	0.72	0.63	0.52
Average Unit Size 290-500 MW	34.76	29.06	5.53	5.19	3.78
Total	***100.00***	***100.00***	***16.47***	***13.58***	***9.28***

For calculating the energy savings potential on the basis of reduction in auxiliary consumption we use the same methodology as discussed above for heat rate to obtain the energy savings potential for the power sector. We use plant-wise data on auxiliary consumption for the period 2002-03 to 2009-10 to derive energy savings potential by the power plants' operational improvement (i.e., reduction) in auxiliary consumption. We use similar benchmarking method of savings potential estimate based on merit ordering of the plants within a group as per the efficiency in auxiliary consumption. The savings potential thus obtained ranges between a low of 9.28 percent of the auxiliary power consumed to a high of 16.47 percent (refer table 3.10).

c) ***Specific secondary fuel oil consumption***: In the coal fired thermal power plants fuel oil is used as a secondary fuel for the ignition of the boiler unit i.e., for start-up process and also for the stabilization of flame. For obtaining the secondary fuel savings potential of the power sector the methodology used is similar to the one used for heat rate. We use plant-wise data on specific secondary fuel oil consumption (SFOC) for the period 2006-07 to 2009-10 to derive secondary fuel oil savings potential. We use similar benchmarking method of savings potential estimate based on merit ordering of the plants within a group as per the efficiency in secondary fuel oil consumption. The savings potential for SFOC obtained ranges between a low of 63.30 percent to a high of 80.84percent (table 3.11).

Table 3.11: Energy Savings Potential based on Secondary Fuel Oil Consumption (2009-10)

Classification based on Average Unit Size	Share in total power generation (2009-10) (%)	Share in secondary oil (mn ml) consumed (%)	Overall Power Sector Savings potential		
			Specific Oil Consumption (ml/kwh)		
			least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
Average Unit Size 40-90 MW	3.90	9.59	8.25	7.62	6.33
Average Unit Size 105-130 MW	3.94	8.67	6.98	6.17	4.67
Average Unit Size 140-175 MW	15.08	28.74	23.41	21.47	17.42
Average Unit Size 210 MW	38.44	37.78	30.57	28.09	25.08
Average Unit Size 250 MW	6.23	2.62	1.82	1.82	1.44
Average Unit Size 290-500 MW	32.40	12.59	9.81	9.41	8.36
Total	***100.00***	***100.00***	***80.84***	***74.59***	***63.30***

The energy savings potential in the power sector based on the three parameters namely, heat rate, auxiliary consumption and specific secondary fuel oil consumption as discussed above is summarized in table 3.12.

Table 3.12: Energy Savings Potential in Coal Based Power Plants in India – 2009-10 (%)

Classification based on Average Unit Size	least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
a) Station Heat rate (kcal/kwh)	8.67	7.20	5.48
b) Auxiliary Consumption (as % of gross generation)	16.47	13.58	9.28
c) Specific Oil Consumption (ml/kwh)	80.84	74.59	63.30

Savings in the auxiliary consumption would imply that for a given level of generation lesser amount of power is consumed by the plant and electricity available for other users is more. Combining this savings in electricity with the savings potential in the heat rate would give the overall savings potential (measured in calorie terms) per unit (i.e., kwh) of electricity generated. The combined savings potential is illustrated in table 3.13. Combining the savings in the auxiliary consumption with that of specific secondary fuel oil consumption would give the overall savings that can be achieved in the consumption of secondary fuel. The possible savings potential is shown in table 3.13 which shows the broad range of the savings potential that exists. The actual potential, however, would depend on the quality of coal, type of technology and various other factors. Attaining the level of efficiency of the best performing unit may not be technologically feasible or economically viable for all the units within an industry as this may involve considerable investments raising unit costs at the given current prices and interest rates. Nonetheless, efforts must be made to improve the energy efficiency all units within the sector thereby leading to the improvement of the sector's energy efficiency over a period of time.

Table 3.13: Overall Energy Savings Potential in Coal Based Power Plants in India – 2009-10 (%)

Classification based on Average Unit Size	least Energy intensive 10% units	least Energy intensive 25% units	Median Energy intensive units
i) Station Heat rate (kcal/kwh)	9.43	7.84	5.97
ii) Specific Oil Consumption (ml/kwh)	86.55	79.97	68.00

Chapter 4 Econometric Model for Inter-input and Inter-fuel Substitution and Derived Demand for Energy

Demand for inputs by industry is essentially a derived demand. A firm's demand for inputs is derived from its output. Since firms prefer to choose input quantities which minimize their total cost of producing a given level of output, the derived demand for inputs depend upon the substitution possibilities among inputs allowed by the technology, and the relative prices of all the inputs. The estimates of derived demand functions for inputs including energy are important from the point of view of formulating policies for realizing various objective of the economy.

We estimate the demand functions for energy and non-energy inputs in the Indian manufacturing sector using a methodology similar to that used by Fuss (1977) and Pindyck (1979). Information relating to substitution possibilities between different energy inputs and between energy and non-energy inputs is particularly important in an environment of increasing global energy prices and growing concern for global climate change. For example, if energy and capital are substitutes, *ceteris paribus,* an increase in the price of energy would increase the demand for capital goods. However, if energy and capital are complementary, other things remaining the same, higher energy prices will dampen the demand for energy and capital goods. However, if the substitution possibilities between energy and non-energy inputs like capital, labour etc. are very limited, a rise in price of energy may change the composition of industrial output in favour of less energy intensive products. These estimates are extremely important from the point of view of designing both fiscal and financial policy instruments for promoting energy efficiency in the Indian manufacturing sector.

4.1 The Model

We assume that there exists in the Indian manufacturing sector a production function of the form

$Y = f(K, L, E_e, E_c, E_o, M, t)$ (1)

where,

Y represents the total output

L represents labour input

K is the capital input

E_i is the i^{th} energy input (i = electricity (e), coal (c) and oil (o))

M represents all other intermediate material inputs and

t is the time variable

Inclusion of the time variable (t) as an argument in the production function represented by equation (1) means that the production relationship is assumed to change over time.

We make some assumptions about the production functions for the analysis. We assume that the production function $f(.,.)$ is twice differentiable and embodies constant returns to scale. It is assumed that the production function is weakly separable in the major categories of capital, labour, material and energy[24]. This assumption implies that the marginal rate of substitution between individual fuels are independent of the quantities of capital, labour and material inputs. We further assume that capital, labour, material and energy aggregates are homothetic in their components. In particular it is assumed that the energy aggregate is homothetic in its electricity, oil and coal inputs. The last two assumptions are together referred to as homothetic separability assumption (see Pincyck, 1979).

[24] See Fuss (1977) and Pindyck (1979)

Using the two assumption of homothetic separability the production function represented by equation (1) can be reformulated as

$$Y = F[K, L, E(E_e, E_c, E_o), M, t] \quad (2)$$

where, E is a homothetic function of the three fuels electricity (e), coal (c), and oil (o).

If factor prices and output levels are exogenously determined, the theory of duality between the cost and production implies that, given the cost minimizing behavior, production characteristics implied by equation (2) can be uniquely represented by a cost function which is also weakly separable. The cost function will be of the following form

$$C = g[P_E(P_{Ee}, P_{Ec}, P_{Eo}), P_L, P_K, P_M, t, Y) \quad (3)$$

where, C is the total cost, P_L is the price of labour, P_K is price of capital, P_M price of material inputs. P_{Ei} is the price of the i^{th} fuel. P_E is the aggregate price of energy input. It is a function that aggregates the prices of the individual fuels. The aggregator function is homothetic and does not include the total quantity of energy as one of its arguments.

Homogeneity of degree one of the production function then implies the existence of a dual unit cost function giving output price as a function of input prices. Equation (3) can be written as

$$C = Y.G[P_L, P_K, P_M, P_E(P_{Ee}, P_{Ec}, P_{Eo}), t] \quad (4)$$

or

$$c = G[P_L, P_K, P_M, P_E(P_{Ee}, P_{Ec}, P_{Eo}), t] \quad (5)$$

where, c is the unit cost (i.e., c = C/Y)

The unit cost function represented by equation (5) then can be characterized and estimated in stages. In the first step we represent the price of energy, which is the unit cost of energy to a producer choosing fuel inputs which would minimize the total cost of energy, by a homothetic translog cost function with constant returns to scale.

Estimation of the share equations implied by this cost function gives the own and cross partial price elasticities for the three fuels considered in the study, and the cost function itself provides an instrumental variable for the price of aggregate energy. In the next step we represent the cost of industrial output by a non-homothetic translog cost function. Estimation of the share equations implied by this cost function gives us price elasticity of demand and elasticity of factor substitution among the four inputs capital, labor, material and energy (see Pindyck, 1979 and Fuss, 1977 for a detailed discussion).

4.1.1 Demand for Aggregate Inputs: Factor Input Model

We adopt a translog functional form for the unit cost function. The dual unit cost function (or the output price function) can be written as

$$\ln(c) = \ln(a_0) + \sum_i a_i lnp_i + a_t t + \frac{1}{2}\sum_i \sum_j b_{ij} lnp_i lnp_j + \sum_i b_{it} lnp_i t + \frac{1}{2} b_{tt} t^2 \quad (6)$$

where, *i , j = K , L , E , M* and $b_{ij} = b_{ji}$.

For the cost function to be well behaved over the price range covered in the sample, it must satisfy the following conditions:

a) ***Monotonicity***: The function must be monotonically increasing function of input prices, i.e.,

$$\frac{\partial \ln(c)}{\partial lnp_i} \geq 0 \quad i = K, L, E, M \quad (7)$$

b) ***Linear homogeneity in input prices***: If all input prices go up by k-times, the unit cost will also go up by k-times. This implies restriction on the coefficients of the cost functions as

$$\sum_i a_i = 1 ; \quad \sum_i b_{ij} = \sum_j b_{ji} = 0 , \ i \neq j; \quad \sum_i b_{it} = 0 \quad (8)$$

c) ***Concavity***: The cost function has to be concave in input prices. This requires the Hessian Matrix (H) to be negative semi definitive where H is defined as

$$H = \left[\frac{\partial^2 C}{\partial p_i \partial p_j}\right] \quad (9)$$

Symmetry of share elasticities and biases of productivity growth imply further restrictions: $b_{ij} = b_{ji}$, $i \neq j$ and $b_{it} = b_{ti}$ (10)

The factor share equations can be derived from the unit cost function. We make use of Shephard's lemma which implies $\frac{\partial C}{\partial p_i} = x_i$ (11)

Since C = cY

We can write equation (11) as $\frac{\partial c}{\partial p_i} = \frac{x_i}{Y}$ (12)

Now consider

$$\frac{\partial \ln(c)}{\partial \ln(p_i)} = \left(\frac{p_i}{c}\right)\left(\frac{\partial c}{\partial p_i}\right)$$

Substituting $\frac{\partial c}{\partial p_i} = \frac{x_i}{Y}$ from equation (12), the above equation can be written as

$$\frac{\partial \ln(c)}{\partial \ln(p_i)} = \left(\frac{p_i}{c}\right)\left(\frac{x_i}{Y}\right) = \frac{p_i x_i}{cY} = \frac{p_i x_i}{C} = S_i \ ; \quad i = K, L, E, M \quad (13)$$

Factor intensity of output is the product of factor cost share multiplied by the ratio of the concerned factor's price to the unit cost or price of the output under the condition of constant returns to scale in competitive equilibrium. The value shares of capital, labour, energy and intermediate materials (S_i) are derivatives of the cost function represented by equation (6). The factor price elasticities and can be estimated using the following econometric model of share equations. The input demand function in the form of cost shares, takes the form

$$S_i = a_i + \sum_j b_{ij} lnp_j + b_{tt}t + \epsilon_i \ ; \ \forall\, i \quad (14)$$

where, ϵ_i is the error term.

The time variable t in the production function represents the way in which the output is affected by the time or the unit cost or price of sectoral output is affected by the autonomous trend of technical progress. The rate of technical change is defined as[25]

$v_t = -\frac{\partial \ln(c)}{\partial t}$, assuming all prices to remain unchanged (15)

The rate of technical change for each sector can be expressed as the negative of the rate growth of unit cost or price of sectoral output with respect to time as defined in equation (15), holding input prices constant:

$-v_t = a_t + \sum_i b_{it} lnp_i + b_{tt}t + \mu_t$ (16)

where, μ_t is the error term.

In this model, rates of productivity growth and the value shares of inputs are endogenously determined. Since value shares sum to unity, the random disturbances in the four value share equations for labour, capital, energy and intermediate materials are not independently distributed. However, from the cross equation restrictions, we observe that any three of the value share equations, along with the technological change equation, together yield estimates for all parameters. Since the value shares sum to unity, the sum of the disturbances across is zero at all observations. Hence, to avoid singularity of the covariance matrix any one of the four share equations can be dropped, i.e., three share equations can be estimated and the fourth one can be derived as a balance equation making the sum of all shares to be unity. We, therefore, drop the capital share equation to avoid singularity. The remaining three equations (for labour, energy and intermediate material inputs) are jointly estimated along with the technical change equation (16), subject to symmetry and homogeneity restrictions, represented by equations (10) and (8), imposed on the parameters. Estimates were obtained using the iterative Zellner-efficient estimation procedure. This estimation procedure is equivalent to full information maximum likelihood estimation (Pindyck, 1978).[26]

[25] This is based on Hogan and Jorgenson (1991) and Sanstad et al (2006)

[26] We assume no heteroscedasticty or autocorrelation within equations

The substitutability of inputs is captured by the Allen-Uzawa partial elasticities of substitution (AES). From the parameter estimates of the above model we can derive AES (σ_{ij}) using the following relations

$$\sigma_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j}, \quad i,j = K,L,E,M, \quad i \neq j \quad and$$

$$\sigma_{ii} = \frac{b_{ii} + S_i^2 - S_i}{S_i^2}, \quad i,j = K,L,E,M, \quad i = j \qquad (17)$$

The Allen-Uzawa partial elasticities of substitution (AES) can further be used to derive the own and cross price elasticities of factor demand as follows:

$$\eta_{ij} = S_j \sigma_{ij}, \quad \forall\, i \neq j, \quad i,j = K,L,E,M \quad and$$

$$\eta_{ii} = S_i \sigma_{ii}, \quad \forall\, i \qquad (18)$$

The parameters of the model can be interpreted as follows:

a_i can be interpreted as average value shares of capital, labor, energy and intermediate materials inputs for the corresponding sector;

a_t is the average of the negative of rates of (sectoral) technological change or pure productivity improvement;

b_{it} has a two-fold interpretation. It represents the change in share of the i^{th} input over time when relative factor prices are held constant i.e., it is the impact of technology trends on input shares, or the factor price bias. Under the assumptions of the model, it also displays the impact on the trend in total factor productivity with changing input prices. In the case of energy share, a positive value of the parameter b_{et} would mean a greater pressure on the expansion of output with rising energy prices, due to greater energy use. Alternatively, if energy price rises, the trend in total factor productivity will decline. If higher energy prices retard productivity growth, then future output (and aggregate consumption) may be reduced indirectly as a result of energy conservation attained through policies that increase energy prices;

b_{tt} can be interpreted as constant rates of change or acceleration of the negative of the rates of technical change. If the estimated value is positive, the rate of technical change is decreasing. And if negative, the rate is increasing;

b_{ij} is interpreted as constant share elasticity with respect to the price of inputs. Along with the Allen Elasticities of Substitution (AES) and price elasticities, these parameters can yield short and medium run policy implications. They describe the implications of patterns of substitution among the four inputs for the relative distribution of the value of output among the inputs. Positive share elasticities imply that value shares increase with price.

4.1.2 Fuel Model: Demand for Fuels

Consider the unit cost function as give in equation (5)

$c = G[P_L , P_K , P_M , P_E(P_{Ee} , P_{Ec} , P_{Eo}), t]$

where, P_E is the aggregator price index of the energy input comprising of three fuels electricity, coal and oil. The aggregator function is homothetic and does not include the total quantity of energy as one of its arguments. Linear homogeneity in $P_E(P_{Ee} , P_{Ec} , P_{Eo})$ implies that the cost share of the three fuels are independent of the total expenditure on aggregate energy.

As mentioned earlier the unit cost function represented by equation (5) is estimated in two stages. First, energy cost is minimised in the choice of fuels (i.e., the inter-fuel model). Second, the total cost is minimized in the choice of factor inputs - labour, capital, material and energy (i.e., the inter-factor model). The inter-fuel model provides estimates of price of aggregate energy input ($\hat{P}_E$) which is used as an instrumental variable for the price of energy in the estimation of the inter-factor model (which is represented as a non-homothetic translog model as discussed earlier).

We adopt a homothetic translog functional form so the aggregate energy price function can be represented as

$$lnP_E = \gamma_0 + \sum_{i=1}^{n} \gamma_i lnP_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} lnP_i \, lnP_j \quad (19)$$

where, *i , j =Electricity, Coal, Oil* and $\gamma_{ij} = \gamma_{ji}$.

Using Shephard's lemma the fuel share equations can be derived from aggregate energy function as

$$\mathrm{S_{Fuel}} = \gamma_\mathrm{i} + \sum_{\mathrm{i=1}}^{\mathrm{n}} \gamma_{\mathrm{ij}} \mathrm{lnP_j} \quad (20)$$

The fuel share equations given by equations (20) are estimated subject to the parametric restrictions

$$\sum_i \gamma_\mathrm{i} = 1, \ \gamma_{ij} = \gamma_{ji} \ , \ \text{and} \sum_i \gamma_{ij} = \sum_j \gamma_{ji} \quad (21)$$

Just as in case of factor model, in the fuel model also since the value shares sum to unity, the sum of the disturbances across is zero at all observations. Hence, to avoid singularity of the covariance matrix any one of the three share equations can be dropped and two share equations can be estimated while the third one can be derived as a balance equation making the sum of all shares to be unity. We therefore, drop the share equation for the fuel input coal to avoid singularity. The remaining two equations for electricity and oil are jointly estimated subject to the parametric restrictions specified by equation (21). Estimates were obtained using the iterative Zellner-efficient estimation procedure.

The substitutability of the different fuel inputs is captured by the Allen-Uzawa partial elasticities of substitution (AES). From the parameter estimates of the above model (i.e., equation 20) we can derive AES (σ_{ij}) using the following relations

$$\sigma_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j} \ , \quad i,j = Electricity, Coal, Oil \quad i \neq j \quad and$$

$$\sigma_{ii} = \frac{b_{ii} + S_i^2 - S_i}{S_i^2} \ , \quad i,j = Electricity, Coal, Oil, \quad i = j \quad (22)$$

The Allen-Uzawa partial elasticities of substitution (AES) can further be used to derive the own and cross price elasticities of demand as follows:

$$\eta_{ij} = S_j \sigma_{ij} \ , \ \forall \, i \neq j \text{ and}$$
$$\eta_{ii} = S_i \sigma_{ii} \ , \ \forall \, i \qquad (23)$$

However, these price elasticities are partial price elasticities when applied to fuels; i.e., they account only for substitution between fuels, under the constraint that the total quantity of energy consumed remains constant. However, the expenditures on energy will not remain constant. In fact, if the price of a particular fuel increases, its demand will decrease for two reasons, a) inter-fuel substitution resulting from changing relative fuel prices, and b) a decreased use of all energy resulting from an increase in the aggregate price of energy. The total own price elasticity for each fuel accounts for both inter-fuel substitution and the effect of a change in the price of the fuel on total consumption of energy.[27] Thus, the total own and cross price elasticity of demand for each of the fuel is given by

$$\eta_{ii}^{*} = \eta_{ii} + \eta_{EE} S_i$$
$$\eta_{ij}^{*} = \eta_{ij} + \eta_{EE} S_j \qquad (24)$$

Following the two-stage approach suggested in Pindyck (1979), we first estimate the homothetic translog fuel cost share equation (20) under the assumption of constant returns to scale. The resulting parameter estimates yield partial own and cross-price elasticities of different fuel inputs. The parameters estimates of equation (20) are then used to compute the estimated fuel cost ($\hat{P}_E$) using equation (19). The estimate value of the parameter γ_0 in the equation (19) is obtained under the assumption that for each of the industry under consideration P_E = 1 in 1991-92 and relative price index is calculated for all the years separately for the different industries. This estimated fuel cost (or the unit price of aggregate energy $\hat{P}_E$) is used as an instrumental variable for the aggregate

[27] For a detailed discussion and derivation procedure see Pindyck (1979)

price of energy (P_E) while deriving estimates for the factor cost function given by equation (14).

4.2 Data and Variables

The econometric analysis is carried out for the seven industries which as mentioned earlier are the large energy consuming industries in the country. These industries are iron & steel, cement, fertilizer, paper & pulp, aluminium, chlor-alkali, and textiles. In addition to the seven large energy consuming industries, analysis has also been carried out by taking the entire ASI manufacturing sector as a single category representing the organized manufacturing sector as a whole. For any econometric study results will be statistically more meaningful, the larger is the time period of the study. The period of study for the econometric analysis in the present study is eighteen years covering the period from 1991-92 to 2008-09, the latest year till which the information is available.[28] It should be noted that the initial year of the study which is 1991-92, is significant, as India embarked on the path of economic reforms in 1991-92. The period of coverage of the study is thus the post economic reforms period during which the Indian economy had undergone considerable changes.

For the econometric analysis we use the Annual Survey of Industries' data, both unit level and time series, provided by the Ministry of Statistics and Programme Implementation (MoSPI) for information relating to the cost of production, value of output, cost of different inputs considered. The factor shares have been obtained by dividing the annual cost of the factor by the total cost of production.

[28] For aluminium and chlor-alkali industries the analysis as for the period 1991-92 to 2007-08 as the data for 2008-09 was not available in the form required for the study.

The price of the factor input labour (P_L) required for the econometric model is calculated as the ratio of wages and salaries including employers' contribution to total number of persons engaged as given by the ASI data.

The price of capital (P_K) is calculated as $P_K = [(\alpha*r)+\{(1-\alpha)*(r+d)\}]$ where, P_K is the price of capital, $\alpha = \left(\frac{working\ capital}{working\ capital+fixed\ capital}\right)$, r is the rate of interest paid and is calculated as the ratio of total interest paid to outstanding loan, d is the rate of depreciation and is the ratio of total depreciation to fixed capital. The data on working capital, fixed capital, depreciation, outstanding loans, interest paid is from the ASI.

The price of material inputs (P_M) is calculated using the input-output tables for the year 2003-04 and the wholesale prices indices (at 1993-94 prices) of different inputs used in the production of that commodity. From the input-output tables we get for the concerned industry the shares of different non-energy intermediate inputs that are consumed by the industry and using these shares as weights and the wholesale price indices of the non-energy intermediate inputs as prices we get the price of the intermediate materials as the weighted average of wholesale price indices of different non-energy material inputs consumed by the industry. The price so calculated is the price of intermediate materials.

The ASI data provides information on the consumption of coal and electricity in both physical units and in monetary units. Consumption of both coal and electricity were converted from their respective unit to oil equivalent by using fuel specific conversion factor. For electricity the conversion to oil equivalent units is in final energy terms. Dividing coal and electricity consumption in oil equivalent terms by the value of these two fuels consumed gives their prices per oil equivalent unit of consumption. The information relating to consumption of different petroleum products is not adequate in ASI. For some earlier years consumption of different petroleum products are given in both monetary units as well as in physical units. In the later years however, ASI only provides information for the consumption of petroleum products as a group by different industries only in monetary terms. We used the information provided by the Bureau of Energy Efficiency (BEE) on physical consumption of different petroleum products to derive for each industry the ratio in which the different petroleum products are consumed by different industries. We used these ratios along with the price information given in the Indian Petroleum and Natural Gas Statistics to get the prices of different petroleum products consumed by industries. Dividing monetary value of consumption of different fuels by their prices one gets the fuel consumption in physical units. As the consumption of fuels is in different units they are converted into common oil equivalent units using fuel specific conversion factors.

4.3 Results

4.3.1 Fuel Model

The parameter estimates of the fuel model are given in table 4.1. Majority of the parameter estimates are statistically significant.[29] Conventional goodness of fit is checked through R^2. For fuel share equations except for few cases R^2 values, all R^2 values are high ranging between 0.517 and 0.784. It is negative for the oil share equation in case of cement industry.

Table 4.1: Parameter Estimates of the Fuel Model

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
γ_e	0.4230	***	0.4494	***	0.3204	***	0.5737	***
γ_o	0.1212	***	0.2091	***	0.5398	***	0.2092	***
γ_c	0.4558	***	0.3415	***	0.1398	***	0.2172	***
γ_{ee}	0.1771	***	0.0574		0.2008	***	0.0663	*
γ_{eo}	-0.0715	***	-0.0727	***	-0.2468	***	-0.0292	
γ_{ec}	-0.1056	***	0.0153		0.0460		-0.0371	
γ_{oe}	-0.0715	***	-0.0727	***	-0.2468	***	-0.0292	

[29] 60 out of 88 parameter estimates were significant either at 1, 5, or 10 percent level

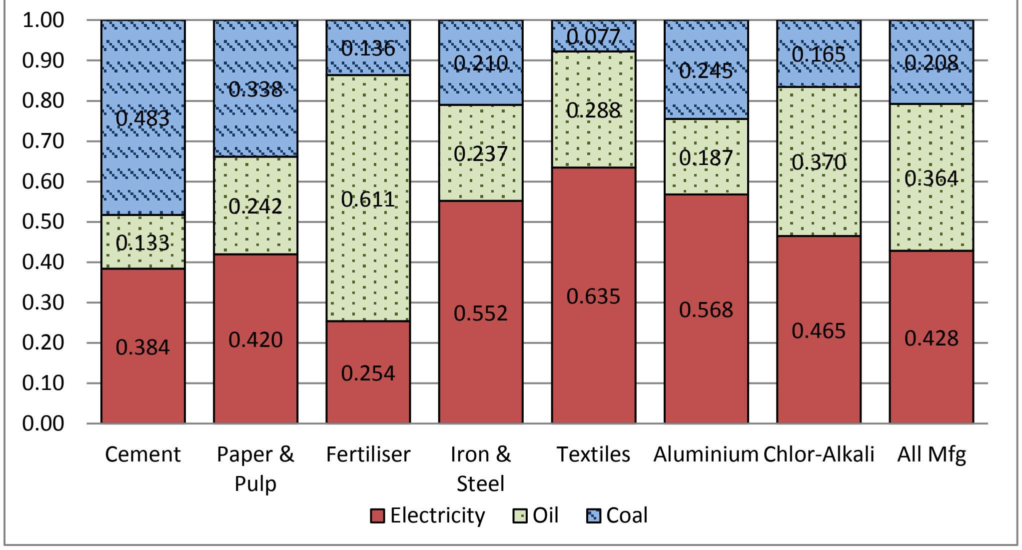
	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
γ_{oo}	0.0109		0.0822	***	0.2648	***	0.0524	**
γ_{oc}	0.0605	**	-0.0095		-0.0180		-0.0232	
γ_{ce}	-0.1056	***	0.0153		0.0460		-0.0371	
γ_{cc}	0.0451		-0.0058		-0.0279		0.0603	
$R^2_{electricity}$	0.7824		0.5728		0.7839		0.1481	
R^2_{oil}	-0.4161		0.5749		0.7689		0.2847	

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
γ_{e}	0.6721	***	0.6084	***	0.5871	***	0.3378	***
γ_{o}	0.2682	***	0.1652	***	0.2465	***	0.3582	***
γ_{c}	0.0597	***	0.2263	***	0.1665	***	0.3040	***
γ_{ee}	0.1130	***	0.1118	***	0.1836	***	0.2888	***
γ_{eo}	-0.0601	**	-0.0533	***	-0.1413	***	-0.0541	
γ_{ec}	-0.0530	***	-0.0584	*	-0.0424		-0.2347	***
γ_{oe}	-0.0601	**	-0.0533	***	-0.1413	***	-0.0541	
γ_{oo}	0.0321		0.0366	***	0.1388	***	0.0625	*
γ_{oc}	0.0280	***	0.0168		0.0025		-0.0084	
γ_{ce}	-0.0530	***	-0.0584	*	-0.0424		-0.2347	***
γ_{cc}	0.0250		0.0417		0.0399		0.2432	***
$R^2_{electricity}$	0.2148		0.3808		0.7484		0.7334	
R^2_{oil}	0.0445		0.5167		0.5199		0.1542	

Note: The parameter estimates are obtained with coal equation dropped.
e = electricity; o = oil; c = coal
***, **, * represent level of significance at 1, 5 and 10 percent respectively.

Having estimated the parameters of the fuel model we calculate the Allen-Uzawa partial elasticities of substitution (σ_{ij}) and using these also calculate the partial own and cross price elasticities of demand between different fuels (η_{ii}, and η_{ij}) at the mean values of the shares of different fuels in respective industries. The estimates of Allen Uzawa partial elasticities of substitution and partial own and cross price elasticities of demand are reported in the Appendix. Fuel cost shares for different industries averaged over the period of study i.e., 1991-92 to 2008-09 is shown in figure 4.1. We see that in almost all the concerned industries, electricity (i.e., electricity purchased from the grid) is the dominant energy input with the exception of cement and fertilizer industries where the share of coal and oil respectively is the highest.

Fig 4.1 Fuel Cost shares - Average for 1991-92 to 2008-09



The estimates of total own and cross price elasticities of demand for different fuels derived from partial price elasticities on the basis of equation (24) and calculated at the mean values of the shares of different fuels in respective industries are shown in table 4.2. A typical elasticity notation like η^*_{ec} would denote the total price elasticity of demand for electricity input due to rise in coal prices. Positive cross price elasticity indicates substitutability among fuels, while negative value would imply complementarity.

Table 4.3 shows the relationship between the different energy inputs (i.e., different fuels) based on the estimates of total price elasticities. From the table we see that in case of chlor-alkali industry and for the overall manufacturing sector the three fuels electricity, coal and oil are complements with each other. In other words a rise in the price of one fuel would lead to a decrease in demand for the other. However, in iron and steel industry all the three fuels are substitutes implying that an increase in price of one would result in an increased demand for the other fuel and vice-versa.

Table 4.2: Total Own and Cross Price Elasticities (Fuel Model)

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
η*ee	-0.6013	***	-0.6958	***	-0.1472	**	-0.4927	***
η*ec	-0.3535	***	0.1715	***	0.2139	***	0.0802	*
η*eo	-0.2078	***	-0.0765	***	-0.8268	***	0.1135	**
η*ce	-0.2811	***	0.2127	***	0.3989	***	0.2109	**
η*cc	-0.9851	***	-0.8821	***	-1.1727	***	-0.5657	***
η*co	0.1037	***	0.0686	***	0.0138		0.0559	
η*oe	-0.5989	***	-0.1325	***	-0.3433	***	0.2642	**
η*oc	0.3759	***	0.0957	***	0.0031	**	0.0495	
η*oo	-0.9396	***	-0.5640	***	-0.4198	***	-0.6127	***

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
η*ee	-0.4934	***	-0.8929	***	-0.7116	***	-0.3202	***
η*ec	-0.0435	***	-0.1415		-0.1289	**	-0.5454	***
η*eo	0.0545		-0.1233		-0.3883	***	-0.1216	***
η*ce	-0.3586	***	-0.3280		-0.3631	**	-1.1244	***
η*cc	-0.6357	***	-0.8686	***	-0.7963	***	0.1730	***
η*co	0.5118	***	0.0390		-0.0694		-0.0359	
η*oe	0.1201		-0.3756		-0.4884	***	-0.1431	***
η*oc	0.1369	***	0.0512		-0.0310		-0.0205	
η*oo	-0.7394	***	-0.8333	***	-0.7094	***	-0.8236	***

Note: ***, **, * represent level of significance at 1, 5 and 10 percent respectively;
All elasticities are calculated at the mean of each fuel's share in total energy
e = electricity; o = oil; c = coal

Table 4.3: Inter-Fuel Relationship

Industry	Electricity-Coal	Electricity-Oil	Oil-Coal
Cement	C	C	S
Paper & Pulp	S	C	S
Fertiliser	S	C	S
Iron & Steel	S	S	S
Textiles	C	S	S
Aluminium	C	C	S
Chlor-Alkali	C	C	C
All Mfg	C	C	C

Note: C = complements; S = Substitutes.
The relationship between fuels is based on total price elasticities

4.3.2 Factor Input Model

The estimates of the parameters of the factor model are illustrated in table 4.4. A large number of the parameter estimates are statistically significant either at 1 percent, 5 percent or 10 percent level.[30] Goodness of fit is checked through R^2 for input share equations. The R^2 values are high for all but seven cases ranging between 0.539 and 0.962. The technological change equation represented by equation (16) however, has very low R^2 values.

Table 4.4: Parameter Estimates of the Factor Model

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
a_l	0.0372	***	0.0651	***	0.0448	***	0.0377	***
a_e	0.2630	***	0.1619	***	0.1141	***	0.0863	***
a_m	0.5123	***	0.5980	***	0.6532	***	0.6567	***
a_k	0.1876	***	0.1751	***	0.1880	***	0.2193	***
b_{ll}	0.0334	***	0.0313		0.0290	***	0.0413	***
b_{le}	0.0110	*	0.0089	**	-0.0064		0.0167	**
b_{lm}	-0.0285	***	-0.0349	**	-0.0171	***	-0.0453	***
b_{lt}	-0.0027	***	-0.0013	***	-0.0035	***	-0.0027	***
b_{el}	0.0110	*	0.0089		-0.0064		0.0167	**
b_{ee}	-0.0964	***	0.0370	***	0.0144		0.0613	***
b_{em}	0.2252	***	-0.0283	*	-0.0075		-0.0565	***
b_{et}	-0.0173	***	-0.0017	***	0.0028		0.0010	
b_{ml}	-0.0285	***	-0.0349	***	-0.0171	***	-0.0453	***
b_{me}	0.2252	***	-0.0283	*	-0.0075		-0.0565	***
b_{mm}	-0.1354	***	0.1071	***	0.0614		0.1514	***
b_{mt}	0.0089	***	0.0008		0.0035		0.0012	
a_t	-0.0878		-0.1521	*	-0.1071		-0.0629	
b_{tl}	-0.0027	***	-0.0013	***	-0.0035	***	-0.0027	***
b_{te}	-0.0173	***	-0.0017	***	0.0028		0.0010	
b_{tm}	0.0089	***	0.0008		0.0035		0.0012	
b_{tk}	0.0111	***	0.0022		-0.0028		0.0005	
b_{tt}	-0.0034		0.0092		0.0006		-0.0059	
b_{kl}	-0.0159	***	-0.0053		-0.0054	*	-0.0127	***
b_{ke}	-0.1398	***	-0.0175	***	-0.0005		-0.0215	***
b_{km}	-0.0613	**	-0.0438		-0.0369	*	-0.0497	***
b_{kk}	0.2169	***	0.0666	*	0.0428	***	0.0839	***
R^2_{Labour}	0.7789		0.5394		0.6448		0.7763	

[30] 133 out of 208 parameter estimates are significant

	Cement	Paper & Pulp	Fertiliser	Iron & Steel
R^2_{Energy}	0.7000	0.8243	0.0204	0.6563
$R^2_{Material}$	0.8746	0.4251	0.6217	0.7579
R^2_{time}	0.0350	0.0840	0.0018	0.0520

	Textiles	Aluminium	Chlor-Alkali	All Mfg
a_l	0.0974 ***	0.0424 ***	0.0562 ***	0.0700 ***
a_e	0.0802 ***	0.2084 ***	0.1440 ***	0.0771 ***
a_m	0.6991 ***	0.5761 ***	0.6231 ***	0.7017 ***
a_k	0.1232 ***	0.1731 ***	0.1766 ***	0.1512 ***
b_{ll}	0.0275 ***	0.0353 **	0.0448 ***	0.0540 ***
b_{le}	0.0212 ***	0.0308	-0.0212 *	0.0105 ***
b_{lm}	-0.0400 ***	-0.0706 ***	-0.0162	-0.0434 ***
b_{lt}	-0.0028 ***	0.0002	-0.0039 ***	-0.0033 ***
b_{el}	0.0212 ***	0.0308	-0.0212 *	0.0105 ***
b_{ee}	0.0373 ***	-0.0479	-0.0582	-0.0032
b_{em}	-0.0413 ***	0.0239	0.0403	0.0274 ***
b_{et}	-0.0002	-0.0104 *	0.0004	-0.0048 ***
b_{ml}	-0.0400 ***	-0.0706 ***	-0.0162	-0.0434 ***
b_{me}	-0.0413 ***	0.0239	0.0403	0.0274 ***
b_{mm}	0.0899 ***	0.1357	0.0079	0.0228
b_{mt}	0.0020	0.0075	0.0035	0.0124 ***
a_t	-0.1238 ***	0.3268	1.2149	-0.1176 ***
b_{tl}	-0.0028 ***	0.0002	-0.0039 ***	-0.0033 ***
b_{te}	-0.0002	-0.0104 *	0.0004	-0.0048 ***
b_{tm}	0.0020	0.0075	0.0035	0.0124 ***
b_{tk}	0.0010	0.0027	0.0000	-0.0043 ***
b_{tt}	0.0039	0.0074	-0.0327	-0.0019
b_{kl}	-0.0086	0.0044	-0.0074	-0.0211 ***
b_{ke}	-0.0172 **	-0.0069	0.0391	-0.0348 ***
b_{km}	-0.0086	-0.0890 **	-0.0320 *	-0.0069
b_{kk}	0.0345	0.0916 ***	0.0003	0.0627 ***
R^2_{Labour}	0.8764	0.6116	0.4920	0.9624
R^2_{Energy}	0.7086	0.4855	0.0930	0.8324
$R^2_{Material}$	0.4375	0.3776	0.1686	0.9520
R^2_{time}	0.0658	0.0007	0.0015	0.0076

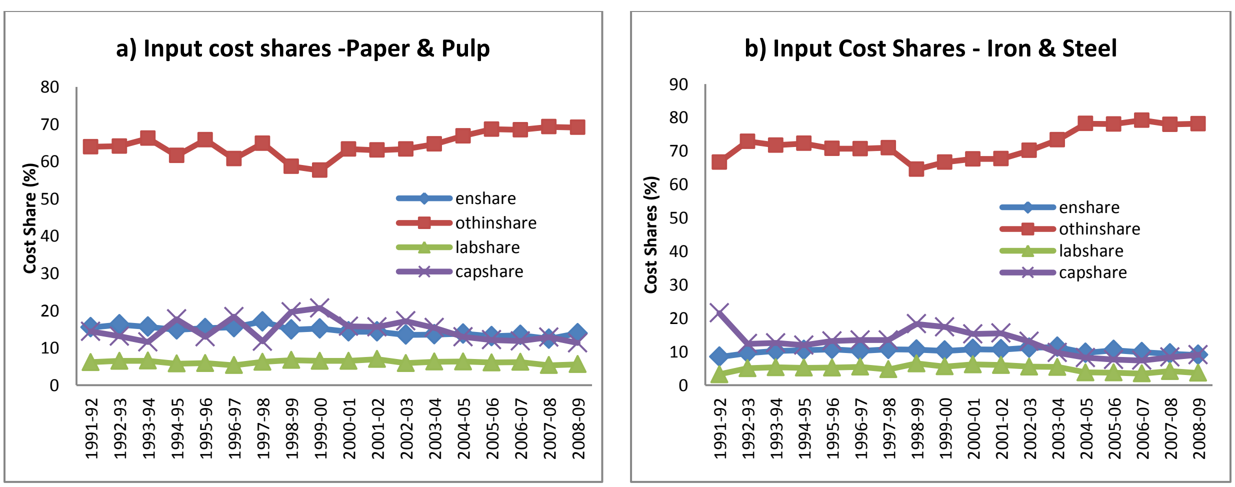
Note: The parameter estimates are obtained with capital equation dropped.
l = labour; k = capital, m = intermediate material input; e = energy; t = time
***, **, * represent level of significance at 1, 5 and 10 percent respectively

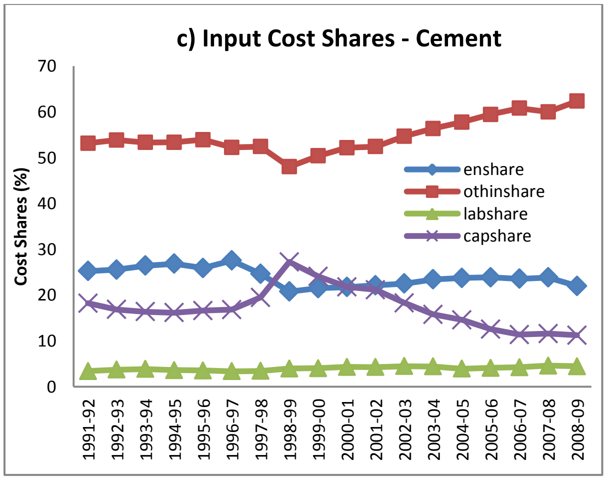
4.3.2.1 Cost Share Trends

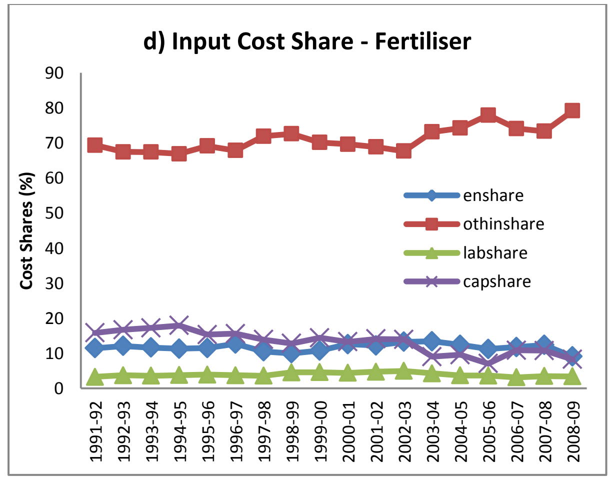
Despite changing temporal patterns, intermediate material shares have consistently dominated over the other three inputs' share viz., energy, labor and capital in the concerned industries (refer fig 4.2(a-h) and table 4.5). Intermediate material cost share dominates over the cost share of the other three inputs in all industries during the whole period under consideration. The share of labour input cost in the total cost has been the lowest for all industries. The capital cost share has exceeded the energy cost share for all industries except cement, aluminium and chlor-alkali industries.

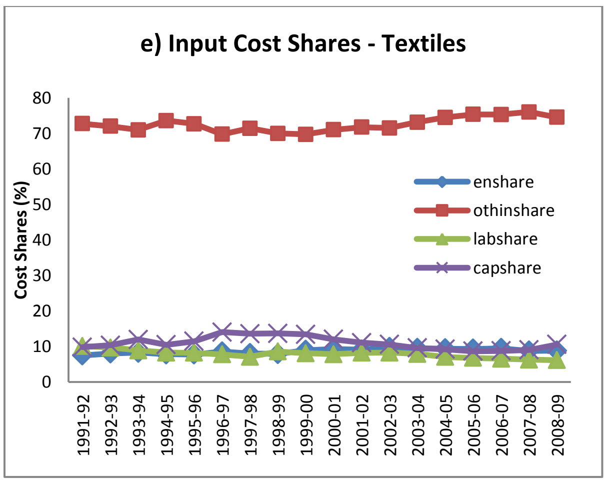
From the estimated values of the parameter a_i (see table 4.4) one can infer that the intermediate material input prices has the largest effect on the aggregate cost (or sectoral price) while the price of labour input has the least effect on the cost shares for the industries considered in the study.

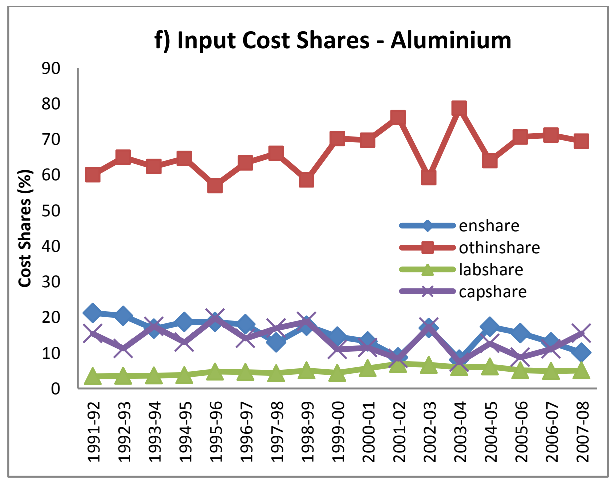
Fig 4.2 (a-h): Factor Input Cost Shares (%)

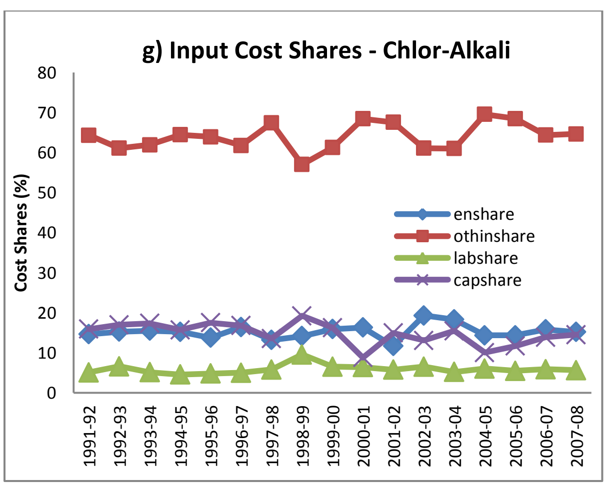



c) Input Cost Shares - Cement
Cost Shares (%)
enshare
othinshare
labshare
capshare


d) Input Cost Share - Fertiliser
Cost Shares (%)
enshare
othinshare
labshare
capshare


e) Input Cost Shares - Textiles
Cost Shares (%)
enshare
othinshare
labshare
capshare


f) Input Cost Shares - Aluminium
Cost Shares (%)
enshare
othinshare
labshare
capshare


g) Input Cost Shares - Chlor-Alkali
Cost Shares (%)
enshare
othinshare
labshare
capshare

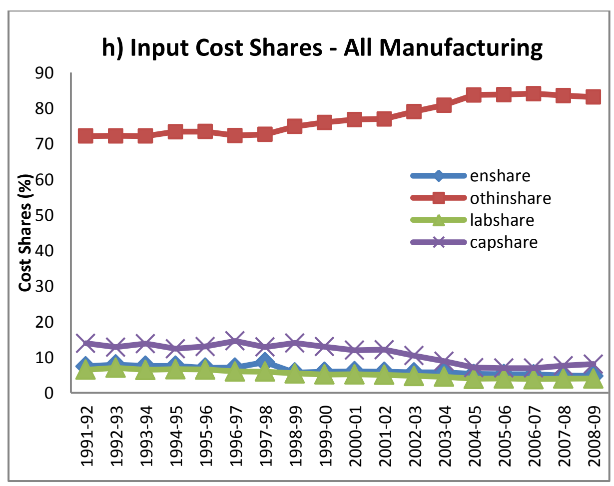

h) Input Cost Shares - All Manufacturing
Cost Shares (%)
enshare
othinshare
labshare
capshare

Table 4.5: Factor Input Cost shares - Average for the period 1991-92 to 2008-09

Inputs	Cement	Paper & Pulp	Fertiliser	Iron & Steel	Textiles	Aluminium	Chlor-Alkali	All Mfg
Energy	0.240	0.146	0.117	0.102	0.086	0.154	0.153	0.063
Materials	0.548	0.644	0.712	0.721	0.725	0.662	0.640	0.773
Labour	0.040	0.062	0.039	0.049	0.078	0.049	0.059	0.053
Capital	0.172	0.148	0.132	0.127	0.110	0.135	0.148	0.111

Note: For aluminium and chlor-alkali industries the average is over the period 1991-92 to 2007-08

4.3.2.2 Productivity Trends and Technical change

The factor saving bias of technical change is represented by the parameter b_{it} in our model (see table 4.4). For the period under consideration i.e., 1991-92 to 2008-09, the negative value of the parameter shows energy savings bias for all industries except fertilizer, iron and steel and chlor-alkali (table 4.6). For all these industries b_{et} the technical bias parameter for energy was negative and statistically significant in most cases. However, in case of the three industries where the parameter is positive the estimates are not found to be statistically significant at all. The negative value of coefficient indicating energy saving bias in the technical change implies that, with constant relative input prices, the value shares of energy are to decrease over time as per the model estimate. In other words the energy savings rises due to technological change as induced by rises in prices of energy. If productivity growth due to technical change is considered as an indicator for welfare gain, our findings show that an energy price increase would cause such energy saving technical change that there will be a rise in the estimate of overall factor productivity and thereby welfare gain. The technical change has been found to be labour saving for all industries except aluminium and capital saving for fertilizer, chlor-alkali and all manufacturing sector. Such technical change taking place over time has had material using bias in all industries considered in the present study (table 4.6).

Table 4.6: Technical Change Bias

Inputs	Cement	Paper & Pulp	Fertiliser	Iron & Steel	Textiles	Aluminium	Chlor-Alkali	All Mfg
Energy	*Saving*	*Saving*	*Using*	*Using*	*Saving*	*Saving*	*Using*	*Saving*
Materials	*Using*	*Using*	*Using*	*Using*	*Using*	*Using*	*Using*	*Using*
Labour	*Saving*	*Saving*	*Saving*	*Saving*	*Saving*	*Using*	*Saving*	*Saving*
Capital	*Using*	*Using*	*Saving*	*Using*	*Using*	*Using*	*Saving*	*Saving*

Note: Factor Saving bias if b_{it} is negative; Factor Using bias if b_{it} is positive

The annual rate of acceleration of technical change is represented by the parameter b_{tt} (table 4.4). The value of b_{tt} was negative for cement, iron and steel, chlor-alkali and all manufacturing sector. This means that for these four industries the annual rate of growth of productivity due to pure technical change is positive. However, for the remaining industries namely, paper and pulp, fertilizer, textiles and aluminium the purely autonomous technical change is negative with adverse effect on total factor productivity. However, it should be noted that for none of the industries the parameter b_{tt} has been found to be statistically significant.

As seen from fig 1.2 the energy intensity registered a decline for the industries considered in the study during the period 1991-92 to 2008-09. A key question is what explains the rates of change in energy intensity. Did the energy intensity declined due to changes on factor prices (i.e., due to rise in energy prices), or was it the result of energy savings technical progress? In order to answer these questions we define autonomous efficiency trend for the i^{th} factor as

$$\tau_{it} = \frac{\partial ln\left(\frac{x_i}{Y}\right)}{\partial t} \qquad (25)$$

and relate it to two familiar measures of technical change, namely,

(i) θ_{it} = i^{th} factor price bias, defined as $\frac{\partial S_{it}}{\partial t}$, and

(ii) v_t = rate of sectoral productivity, defined as $-\frac{\partial \ln c(p,t)}{\partial t}$

Using the methodology suggested by Jorgenson and Hogan (1990) and Sanstad et al (2006) we can express changes in sectoral productivity into two change – price neutral technical change ($\frac{\theta_{it}}{s_{it}}$) and factor price induced technical change (τ_{it}) as

$$v_t = \frac{\theta_{it}}{s_{it}} + \tau_{it} \qquad (26)$$

Table 4.7 shows the estimates of these changes derived from the parameter estimates of the factor model discussed earlier. We see that the changes in factor productivity is mainly price induced (i.e., energy price induced) and the results are also in all cases significant statistically. The impact of changes which are price neutral can be in either direction and are not that important. These are significant only for some industries.

Table 4.7: Technical Change in Select Industries in India (1991-92 to 2008-09)

Industry	Productivity	Price Neutral		Price Induced	
Cement	0.1242	-0.0723	***	0.1965	***
Paper & Pulp	0.0659	-0.0118	***	0.0777	***
Fertiliser	0.1049	0.0238		0.0812	**
Iron & Steel	0.1223	0.0095		0.1128	***
Textiles	0.0880	-0.0021		0.0901	***
Aluminium	-0.3952	-0.0675	*	-0.3277	***
Chlor-Alkali	-0.9188	0.0026		-0.9214	***
All Mfg	0.1265	-0.0754	***	0.2019	***

4.3.3 Patterns of Input Substitution

Having derived the parameter estimates of the factor model, Allen-Uzawa partial elasticities of factor substitution (AES) are calculated using equation (17). The AES are reported in Appendix. The AES and the parameter estimates of the factor model are now used to derive estimates of price elasticities using equation (18). All elasticities are calculated at the mean of each factor share. Positivity of cross price elasticity estimates indicates substitutability among the inputs, while negative value indicates complementarity. A typical elasticity notation like η_{ke} would denote the price elasticity of demand for capital input due to a change or variation in the price of the aggregate energy input. These elasticities are partial price elasticities. Table 4.8 shows the estimates of price elasticities. From the table one can see, as expected, the own price elasticity estimates are all negative with the exception of own price elasticity of capital input in the cement industry and that of labour in all manufacturing sector. The price elasticities are in most cases inelastic. The own price elasticity of aggregate energy is not only negative in all the concerned industries but is also statistically significant except in case of iron and steel industry where although negative, it is not significant.

Table 4.8: Own and Cross Price Elasticities – Factor Model

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
η_{ll}	-0.1238		-0.4315	***	-0.2251	***	-0.1147	
η_{lk}	-0.2250	*	0.0618		-0.0067		-0.1299	**
η_{le}	0.5140	***	0.2899	***	-0.0464		0.4403	***
η_{lm}	-0.1653		0.0798		0.2782	*	-0.1957	*
η_{kl}	-0.0521	*	0.0259		-0.0020		-0.0504	**
η_{kk}	0.4314	*	-0.4010	*	-0.5434	***	-0.2131	**
η_{ke}	-0.5717	***	0.0273		0.1136		-0.0669	
η_{km}	0.1925		0.3477		0.4318	***	0.3304	***
η_{el}	0.0856	***	0.1228	***	-0.0156		0.2124	***
η_{ek}	-0.4111	***	0.0275		0.1278		-0.0831	
η_{ee}	-1.1626	***	-0.6008	***	-0.7600	***	-0.2989	
η_{em}	1.4880	***	0.4505	***	0.6479	**	0.1697	
η_{ml}	-0.0120		0.0077		0.0154	*	-0.0134	*
η_{mk}	0.0605		0.0796		0.0799	***	0.0583	***
η_{me}	0.6504	***	0.1021	***	0.1066	**	0.0241	
η_{mm}	-0.6989	***	-0.1894	***	-0.2019	***	-0.0690	***

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
η_{ll}	-0.5717	***	-0.2331		-0.1807		0.0748	
η_{lk}	-0.0004		0.2248	*	0.0228		-0.2883	***
η_{le}	0.3567	***	0.7800	*	-0.2073		0.2620	***
η_{lm}	0.2154	**	-0.7718	*	0.3652	*	-0.0486	
η_{kl}	-0.0003		0.0819	*	0.0091		-0.1367	***
η_{kk}	-0.5765	**	-0.1875		-0.8502	***	-0.3254	**

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
η_{ke}	-0.0699		0.1024		0.4171	***	-0.2491	***
η_{km}	0.6467	***	0.0033		0.4240	*	0.7112	***
η_{el}	0.3237	***	0.2500	*	-0.0800		0.2193	***
η_{ek}	-0.0888		0.0901		0.4045	***	-0.4396	***
η_{ee}	-0.4824	***	-1.1577	**	-1.2288	***	-0.9872	***
η_{em}	0.2475	*	0.8177		0.9043	**	1.2075	***
η_{ml}	0.0233	**	-0.0574	*	0.0336	*	-0.0033	
η_{mk}	0.0979	***	0.0007		0.0980	*	0.1025	***
η_{me}	0.0295	*	0.1899		0.2156	**	0.0986	***
η_{mm}	-0.1508	***	-0.1331		-0.3472	***	-0.1978	***

Note: 1) ***, **, * represent level of significance at 1, 5 and 10 percent respectively;
2) All elasticities are calculated at the mean of each factor share.
3) l = labour; e = energy; k = capital; m = intermediate material input
4) Positive cross price elasticity estimates indicate substitutability among inputs while negative estimates indicate complementarity.

The cross-price elasticity estimates reveal that a) capital and intermediate material inputs are substitutes in all the industries considered in the present study, b) energy and intermediate materials inputs are also substitutes in all the industries, c) labor and energy inputs are substitutes in all except fertilizer and chlor-alkali industries, d) capital and labour are substitutes only in paper and pulp, aluminium and chlor-alkali industries. Table 4.9 shows the inter-factor relationship in different industries based on the estimates of cross price elasticities.

Table 4.9: Inter-factor relationship

	Capital - Labour	Capital - Energy	Capital - Material	Labour - Energy	Labour - Material	Energy - Material
Cement	C	C	S	S	C	S
Paper & Pulp	S	S	S	S	S	S
Fertiliser	C	S	S	C	S	S
Iron & Steel	C	C	S	S	C	S
Textiles	C	C	S	S	S	S
Aluminium	S	S	S	S	C	S
Chlor-Alkali	S	S	S	C	S	S
All Mfg	C	C	S	S	C	S

Note: C = complements; S = Substitutes.

Negative own price elasticity estimates for energy input (i.e., η_{ee}) have far reaching implications as far as carbon-di-oxide (CO_2) emissions are concerned. The estimate of the parameter b_{ee} is positive in paper and pulp, fertilizer, iron and steel and textile industries (refer table 4.4). The positive estimates of b_{ee} for these four industries indicate that with rising energy prices the cost share of energy would increase. This coupled with negative own price elasticity of energy input η_{ee} in these industries indicate that although the share of energy cost in the total cost will increase due to an increase in the price of energy, there would be reduction in energy consumption in physical terms. This implies that energy price increase would reduce carbon emissions depending on the quantity of reduction in carbonous energy use in these four industries. However, for the remaining industries namely, cement, aluminium, chlor-alkali and all manufacturing for which b_{ee} is negative, the energy cost share would decrease with an increase in energy prices. For these industries as the own price elasticity of energy also is negative, any increase in energy price will not only result in a decline in energy consumption in physical terms but the share of aggregate energy cost in the total cost will also fall. Thus energy price rise would not only reduce energy consumption in physical terms thereby reducing the associated carbon emission, the energy bill in the total cost of the industry will also register a decline.

As mentioned earlier, these estimates of own and cross price elasticities calculated from the industries' derived demand for different factor inputs can be used to analyse the behaviour of industries, their response to changes in factor prices and so on. These responses are important from the point of view of designing policies to meet the various economic objectives of the country. We use these estimates of own and cross price elasticities obtained for different industries considered in the study to examine their response to changes in factor prices and suggest plausible policy measures for achieving the desired goal of energy conservation envisaged in the National Mission for Enhanced Energy Efficiency (NMEEE) under the National Action Plan on Climate Change (NAPCC).

To begin with we look at the impact of a 10 percent increase in price of aggregate energy on the demand for aggregate energy and also its impact on the demand for other factor inputs namely, capital, labour and materials. The results are reported in refer table 4.10. We see that an increase in energy prices by 10 percent will result in a reduction in demand for energy input in all the industries considered in the study and this effect is statistically significant in all industries except iron and steel where the effect though not significant is in the right direction. Thus, energy price rise would result in energy conservation in these industries. The impact of a rise in energy prices on the demand for capital, however, is ambiguous. In some industries the demand for capital would increase due to a rise in price of energy while in others it is expected to decline and the results are statistically significant in only three industries namely, cement, chlor-alkali and all manufacturing. In cement and all manufacturing sector capital requirement would decline with an increase in energy prices i.e., energy and capital inputs are complements while in chlor-alkali they are substitutes as more of capital would be required with the rise in energy prices. Increase in energy prices would result in more of labour being demanded in most industries and in all the cases the results are found to be statistically significant.[31] However, in case of intermediate material inputs, their demand is expected to increase with an increase in energy prices and the results are significant in six out of eight industries considered. Hence based on these results one can say that an increase in energy prices results in decrease in energy requirement, intermediate material input and labour requirement would also decline but its impact on capital input demand is somewhat ambiguous. Thus, any policy which increases the price of aggregate energy input in these industries would result in the conservation of energy.

[31] However, in industries (fertilizer and chlor-alkali) where the demand for labour registers a decline the results are not statistically significant.

However, if one were to target energy conservation of say 10 percent, the change in price of energy input required to achieve the targeted reduction in aggregate energy consumption is shown in table 4.11. For a 10 percent targeted energy conservation the energy prices has to increase and the required increase in the concerned industries would be in the range of 8.14 to 33.46 percent (see table 4.11). For all manufacturing sector the required increase would be around 10.13 percent if energy conservation of 10 percent is to be achieved as can be seen from table 4.11.

Table 4.10: Percentage change in derived demand for Energy and consequent changes in other factor inputs for a 10 percent increase in energy price

Industries	Percent change in Energy demand		Percent change in Capital requirement		Percent change in Labour requirement		Percent change in Material requirement	
Cement	-11.626	***	-5.717	***	5.140	***	6.504	***
Paper & Pulp	-6.008	***	0.273		2.899	***	1.021	***
Fertiliser	-7.600	***	1.136		-0.464		1.066	**
Iron & Steel	-2.989		-0.669		4.403	***	0.241	
Textiles	-4.824	***	-0.699		3.567	***	0.295	*
Aluminium	-11.577	**	1.024		7.800	*	1.899	
Chlor-Alkali	-12.288	***	4.171	***	-2.073		2.156	**
All Manufacturing	-9.872	***	-2.491	***	2.620	***	0.986	***

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.11: Required percentage change in energy price and consequent changes in factor input requirement for a target 10 percent decline in energy consumption for select industries

Industries	Required percentage change in Energy Price	Percentage change in Capital requirement	Percentage change in Labour requirement	Percentage change in Material requirement
Cement	8.602	-4.918	4.422	5.595
Paper & Pulp	16.644	0.454	4.825	1.700
Fertiliser	13.157	1.495	-0.611	1.402
Iron & Steel	33.456	-2.238	14.731	0.806
Textiles	20.728	-1.449	7.394	0.612
Aluminium	8.638	0.884	6.738	1.640
Chlor-Alkali	8.138	3.394	-1.687	1.754
All Manufacturing	10.129	-2.523	2.654	0.999

Note: Positive values indicate increase while Negative values indicate decrease

We now look at the likely impact the changes in prices of different factor inputs would have on their own demand and also on the demand for other inputs. Since the focus of the present study is on energy conservation our analysis is restricted to analysing the impact of changes in prices of different factor inputs on the demand for energy, although, results relating to the requirement of other inputs due to changes in factor prices are also reported. Table 4.12 shows the percentage change in the derived demand for capital input and consequent changes in other factor inputs for a 10 percent Increase in the price of capital. A rise in price of capital, as can be seen from the table, is associated with a fall in demand for capital in all industries except cement industry where more capital would demanded as its price increases. These results are found to be statistically significant in all industries except aluminium industry. The impact of a rise in capital input price on the demand for energy is found to be somewhat ambiguous. The impact is statistically significant only for three industries namely, chlor-alkali, cement, and all manufacturing. In chlor-alkali industry more energy will be required as the price of capital increase while in cement and all manufacturing sector capital input price increase will be associated with a reduced demand for aggregate energy. Thus, if one were to conserve energy, price of capital should increase in cement and all manufacturing sector, while it should fall in chlor-alkali.

Table 4.12: Percentage change in derived demand for Capital and consequent changes in other inputs for a 10 percent Increase in the price of capital

Industries	Percent change in Capital requirement		Percent change in Energy demand		Percent change in Labour requirement		Percent change in Material requirement	
Cement	4.314	*	-4.111	***	-2.250	*	0.605	
Paper & Pulp	-4.010	*	0.275		0.618		0.796	
Fertiliser	-5.434	***	1.278		-0.067		0.799	***
Iron & Steel	-2.131	**	-0.831		-1.299	**	0.583	***
Textiles	-5.765	**	-0.888		-0.004		0.979	***
Aluminium	-1.875		0.901		2.248	*	0.007	
Chlor-Alkali	-8.502	***	4.045	***	0.228		0.980	*
All Manufacturing	-3.254	**	-4.396	***	-2.883	***	1.025	***

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.13, derived from table 4.12, shows the percentage change in price of capital required to achieve a target 10 percent reduction in energy demand in each of the industries considered. For the three industries for which the results are statistically significant we see that targeted 10 percent energy conservation would require the price of capital input to increase by about 24.32 percent for cement industry and by about 22.75 percent for all manufacturing sector and a decline of 24.72 percent for chlor-alkali industry. For the other industries also the results are somewhat ambiguous. Thus we see that there is no clear cut policy prescription for achieving conservation through capital input price route. Changing prices of capital may lead to reduced energy consumption in some industries but in others the result would be totally opposite. Thus, providing incentive to industries by means of lowered interest rate policy which would reduce the cost of capital servicing to improve energy efficiency may not result in energy conservation. Providing financial policy incentives which would lower the cost of accessing capital from the market or any such incentive to some industries and providing no incentives to others is bound to complicate things and is therefore not a desirable policy option.

Table 4.13: Percentage change in price of capital for a 10 percent decrease in energy demand

Industries	Change in Price of Capital		Industries	Change in Price of Capital	
Cement	24.32	***	Textiles	112.64	
Paper & Pulp	-362.99		Aluminium	-111.05	
Fertiliser	-78.27		Chlor-Alkali	-24.72	***
Iron & Steel	120.29		All Manufacturing	22.75	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

The impact on the demand for the different factor inputs of a 10 percent increase in the real wage rate i.e., 10 percent increase in the price of labour input is shown in table 4.14. From the table we see that a rise in price of labour would result in a lower demand for labour in all industries except all manufacturing sector where the demand for labour will increase but this result is not found to be statistically significant.

The results in table 4.14 indicate that the increase in wage rate is likely to lead to an increase in demand for energy input in six out of eight industries considered and the results are also statistically significant. In industries where energy requirement is expected to decline due to a rise in labour prices are fertilizer and chlor-alkali. However, these results are not significant. Thus one can conclude that demand for aggregate input would increase due to a rise in the real wage rate. This result is corroborated by table 4.15 which shows the price behavior of labour input for a targeted 10 percent energy conservation. If a reduction in energy consumption has to be achieved the price of labour or the real wage rate should decline. The reduction in wage rate required in different industries, associated with 10 percent energy conservation, is in the range of 30.89 to 116.78 percent and in case of all manufacturing sector the required reduction in wage rate is 45.59 percent. This is clearly not a politically acceptable policy measure. Reduction in wages is simply not possible. Thus conserving energy via changes (reduction) in real wage rate is not an acceptable solution and is, therefore, ruled out.

Table 4.14: Percentage change in derived demand for Labour and consequent changes in other inputs for a 10 percent increase in price of labour

Industries	Percent change in Labour requirement		Percent change in Energy demand		Percent change in Capital requirement		Percent change in Material requirement	
Cement	-1.238		0.856	***	-0.521	*	-0.120	
Paper & Pulp	-4.315	***	1.228	***	0.259		0.077	
Fertiliser	-2.251	***	-0.156		-0.020		0.154	*
Iron & Steel	-1.147		2.124	***	-0.504	**	-0.134	*
Textiles	-5.717	***	3.237	***	-0.003		0.233	**
Aluminium	-2.331		2.500	*	0.819	*	-0.574	*
Chlor-Alkali	-1.807		-0.800		0.091		0.336	*
All Manufacturing	0.748		2.193	***	-1.367	***	-0.033	

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.15: Percentage change in price of labour for a 10 percent decrease in energy demand

Industries	Change in Price of Labour		Industries	Change in Price of Labour	
Cement	-116.78	***	Textiles	-30.89	***
Paper & Pulp	-81.45	***	Aluminium	-40.00	*
Fertiliser	640.54		Chlor-Alkali	124.94	
Iron & Steel	-47.08	***	All Manufacturing	-45.59	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

A 10 percent increase in intermediate material input prices will be associated with decrease in material input demand in the industries considered in the study and the results are significant in most cases, with the exception of aluminium (refer table 4.16). The increase in prices of material inputs will be accompanied by a reduction in demand for energy inputs in all the industries and the results are significant in most cases. In industries where the results are not significant, the direction of change is in the desired direction. Hence if energy use has to be restricted i.e., if the goal is to conserve energy the prices of intermediate material inputs have to be reined if not reduced. In other words a policy of general deflation which would lower material input prices will give the desired outcome.

Table 4.16: Percentage change in derived demand for Material input and consequent changes in other inputs for a 10 percent increase in material prices

Industries	Percent change in Material requirement		Percent change in Energy demand		Percent change in Capital requirement		Percent change in Labour requirement	
Cement	-6.989	***	14.880	***	1.925		-1.653	
Paper & Pulp	-1.894	***	4.505	***	3.477		0.798	
Fertiliser	-2.019	***	6.479	**	4.318	***	2.782	*
Iron & Steel	-0.690	***	1.697		3.304	***	-1.957	*
Textiles	-1.508	***	2.475	*	6.467	***	2.154	**
Aluminium	-1.331		8.177		0.033		-7.718	*
Chlor-Alkali	-3.472	***	9.043	**	4.240	*	3.652	*
All Manufacturing	-1.978	***	12.075	***	7.112	***	-0.486	

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.17 show the changes in material prices required if aggregate energy use has to be conserved by 10 percent. In order to achieve the desired objective material prices have to be reduced and degree of reduction ranges between 6.72 and 40.40 percent in the concerned industries. The way we have define the intermediate material input, it includes all non-energy intermediate inputs that goes into the production process and is calculated using the input-output table for India for 2003-04. Reduction in material prices would mean that overall prices in the economy has to be reduced which is not possible given that in an open economy the behavior of world commodity prices greatly influence the movement of domestic prices and is therefore beyond the control of any government. Thus conserving energy use through regulating material prices is not a feasible outcome.

Table 4.17: Percentage change in price of material for a 10 percent decrease in energy demand

Industries	Change in Price of Material		Industries	Change in Price of Material	
Cement	-6.72	***	Textiles	-40.40	*
Paper & Pulp	-22.20	***	Aluminium	-12.23	
Fertiliser	-15.44	**	Chlor-Alkali	-11.06	**
Iron & Steel	-58.94		All Manufacturing	-8.28	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

The above discussion is summarized with the help of table 4.18 which shows the percentage changes in prices of factor inputs required for inducing a 10 percent decrease in energy demand by the industrial sector. Energy conservation in Indian industries can be achieved either by raising the price of aggregate energy input or by tinkering the price of capital input or by lowering the industrial wage rate prevailing in the country or by reducing the prices of material inputs or by a combination of all or some of these. Clearly the latter two options are not possible as any policy measure which results in a cut in labour price i.e., which reduced wage rates will not be accepted. Similarly, reduction in intermediate material input prices in not possible as commodity prices cannot be influenced in a globalised world where India is a price taker. As regards price of capital input is concerned we saw that its impact on aggregate energy consumption is somewhat ambiguous and may not necessarily result in the desired policy outcome. Thus the only option left is raising the price of aggregate energy input and as can be seen from table 4.18, increase in energy prices will give the desired result, i.e., help to conserve or reduce the usage of aggregate energy by the industrial sector. The required increase in energy prices would be in the range of 8.14 to 33.46 percent. For all manufacturing section the required increase in aggregate energy price would be 10.13 percent.

Table 4.18: Percentage changes in prices of factor inputs required for inducing a 10 percent decrease in energy demand

Industries	Energy		Capital		Labour		Material	
Cement	8.602	***	24.32	***	-116.78	***	-6.72	***
Paper & Pulp	16.644	***	-362.99		-81.45	***	-22.20	***
Fertiliser	13.157	***	-78.27		640.54		-15.44	**
Iron & Steel	33.456		120.29		-47.08	***	-58.94	
Textiles	20.728	***	112.64		-30.89	***	-40.40	*
Aluminium	8.638	**	-111.05		-40.00	*	-12.23	
Chlor-Alkali	8.138	***	-24.72	***	124.94		-11.06	**
All Manufacturing	10.129	***	22.75	***	-45.59	***	-8.28	***

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Aggregate energy (final energy) used as an input in the industrial production process, as mentioned earlier, comprises of electricity purchased from the grid by the industry, coal used for energy purposes,[32] and oil and its different distillates used as energy. The demand of aggregate energy input and its price depends upon the demand and prices of the three different fuels. From the above discussions we concluded that any policy measure which results in an increase in the price of aggregate energy input would result in energy conservation. In other words the rise in energy prices would results in the reduction in the demand for energy in industries. What does this mean in terms of demand for different fuels which form the aggregate energy input, their prices

[32] Coal used for non-energy purposes are separated out from those used as energy.

etc., are some of the issues which needs to be addressed for deriving policy conclusions that result in energy conservation.

Table 4.19 shows the change in the demand (derived demand) for electricity by different industries due a 10 percent increase in the price of electricity. Due a rise in electricity prices, the demand for electricity, calculated on the basis of its own price elasticity, is seen to decline in all the industries and the result are also found to be statistically significant. The decline in electricity demand would be in the range of 1.47 and 8.93 percent in these industries. The decline in all manufacturing sector's demand for electricity would be around 3.20 percent. The impact of the rise in electricity prices on the demand for coal and oil would depend upon whether they are substitutes or complements to electricity. For the all manufacturing sector, these two fuels are complement to electricity and their demand would decline with the increase in electricity prices. Coal requirement in the all manufacturing sector will decline by 11.24 percent while the demand for oil would go down by only 1.43 percent.

Table 4.19: Percentage change in derived demand for Electricity and consequent changes in other energy inputs for a 10 percent increase in electricity prices

Industries	Percent change in Electricity demand		Percent change in Coal requirement		Percent change in Oil requirement	
Cement	-6.013	***	-2.811	***	-5.989	***
Paper & Pulp	-6.958	***	2.127	***	-1.325	***
Fertiliser	-1.472	**	3.989	***	-3.433	***
Iron & Steel	-4.927	***	2.109	**	2.642	**
Textiles	-4.934	***	-3.586	***	1.201	
Aluminium	-8.929	***	-3.280		-3.756	
Chlor-Alkali	-7.116	***	-3.631	**	-4.884	***
All Manufacturing	-3.202	***	-11.244	***	-1.431	***

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

For a targeted 10 percent electricity conservation by the industrial sector, the required increase in price of electricity would be in the range of 11.20 to 67.94 percent as can be seen from table 4.20 and for all manufacturing sector the required increase electricity prices to achieve 10 percent conservation in electricity consumption would be around 31.23 percent.

Table 4.20: Required percentage change in Electricity prices for a target 10 percent decline in Electricity consumption

Industries	Change in Electricity Price		Industries	Change in Electricity Price	
Cement	16.631	***	Textiles	20.268	***
Paper & Pulp	14.372	***	Aluminium	11.199	***
Fertiliser	67.939	**	Chlor-Alkali	14.053	***
Iron & Steel	20.298	***	All Manufacturing	31.230	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Change in the industries' derived demand for coal due a 10 percent increase in its price is shown in table 4.21. As coal prices increase there will be a decline in the demand for coal used for energy purposes by the industries. However, one can see that in case of overall manufacturing sector the impact of increased coal prices would be in the opposite direction, i.e., requirement of coal will increase as its prices go up. This is an unusual result which needs further probing. All these results are statistically significant. One of the uses of coal in the industrial sector is to generate electricity (i.e., coal is used for captive generation). Supply side constraints of grid electricity may coincide with the shortage in the supply coal resulting. This would result in an increase in coal prices. As the supply of electricity from the grid is constrained by availability of coal, the dependence of the overall manufacturing sector on the grid electricity will decrease. In order to meet its electricity requirement the overall manufacturing sector will have to fall back upon coal for captive generation resulting in an increase in demand for coal despite an increase in coal prices. The impact of an increase in coal prices of the demand on electricity, however, would depend upon whether the two are substitutes of complements. If coal and electricity are substitutes, increase in coal prices would result in more electricity being purchased from the grid. If they are complements the demand for electricity will decline with the increase in coal prices. We see from table 4.21 an increase in coal prices results in decrease in overall manufacturing sector's demand for grid electricity. This means that coal and grid electricity are complements in case of all manufacturing sector. As regards the impact on oil requirement, we see that higher prices of coal would result in increased demand for oil in six out of eight industries and the results are significant in four of them (i.e., coal and oil are substitutes). In the two industries where the oil requirement declines with increase in coal prices the results are not significant.

Table 4.21: Percentage change in derived demand for Coal and consequent changes in other energy inputs for a 10 percent increase in Coal prices

Industries	Percent change in Coal demand		Percent change in Electricity requirement		Percent change in Oil requirement	
Cement	-9.851	***	-3.535	***	3.759	***
Paper & Pulp	-8.821	***	1.715	***	0.957	***
Fertiliser	-11.727	***	2.139	***	0.031	**
Iron & Steel	-5.657	***	0.802	*	0.495	
Textiles	-6.357	***	-0.435	***	1.369	***
Aluminium	-8.686	***	-1.415		0.512	
Chlor-Alkali	-7.963	***	-1.289	**	-0.310	
All Manufacturing	1.730	***	-5.454	***	-0.205	

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.22: Required percentage change in Coal prices for a target 10 percent decline in Coal consumption

Industries	Change in Coal Price		Industries	Change in Coal Price	
Cement	10.151	***	Textiles	15.731	***
Paper & Pulp	11.337	***	Aluminium	11.512	***
Fertiliser	8.527	***	Chlor-Alkali	12.558	***
Iron & Steel	17.678	***	All Manufacturing	-57.792	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

If one were to target a 10 percent reduction in coal consumption, the associated price increase given in table 4.22 would be in the range of 5.66 to 11.73 percent. In case of all manufacturing sector, however, conservation in coal consumption would require coal prices to decrease by about 57.79 percent (refer table 4.22).

Just as in case of electricity and coal, increase in the prices of oil and oil products results in a decline in its demand (table 4.23). The decrease in oil demand by the industries is in the range of 4.20 to 9.40 percent for a 10 percent increase in oil price and all these results are found to be significant. If the objective of the government is to conserve oil consumption in the industrial sector, the prices of oil should increase. The price increase required for a 10 percent reduction in oil consumption would be in the range of 10.64 to 23.82 percent and for the all manufacturing sector the required increase in oil prices would be around 12.14 percent (see table 4.24).

Table 4.23: Percentage change in derived demand for Oil and consequent changes in other energy inputs for a 10 percent increase in Oil prices

Industries	Percent change in Oil demand		Percent change in Electricity requirement		Percent change in Coal requirement	
Cement	-9.396	***	-2.078	***	1.037	***
Paper & Pulp	-5.640	***	-0.765	***	0.686	***
Fertiliser	-4.198	***	-8.268	***	0.138	
Iron & Steel	-6.127	***	1.135	**	0.559	
Textiles	-7.394	***	0.545		5.118	***
Aluminium	-8.333	***	-1.233		0.390	
Chlor-Alkali	-7.094	***	-3.883	***	-0.694	
All Manufacturing	-8.236	***	-1.216	***	-0.359	

Note: Positive values indicate increase while Negative values indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

Table 4.24: Required percentage change in Oil prices for a target 10 percent reduction in Oil consumption

Industries	Change in Oil Price		Industries	Change in Oil Price	
Cement	10.643	***	Textiles	13.524	***
Paper & Pulp	17.730	***	Aluminium	12.000	***
Fertiliser	23.822	***	Chlor-Alkali	14.097	***
Iron & Steel	16.322	***	All Manufacturing	12.141	***

Note: Positive changes indicate increase while negative changes indicate decrease
***; **; and * refers to significance at 1%, 5%, and 10% respectively

So far we had looked at the impact of changes in prices of different fuels on their respective demands and demand for the other fuels. But what is important from the point of view of energy conservation is the impact the changes in prices of different fuels will have on the demand for aggregate energy. If, suppose, the price of electricity changes, not only will its own demand will change, but the demand for the other two fuels namely, coal and oil will also change thereby effecting the demand for the aggregate energy input. It is therefore, important to study the impact on the aggregate energy demand of changes in the prices of various fuels. Will the aggregate demand for energy increase or will it decline? Table 4.25 provides answers to some of these questions. It shows how the demand for aggregate energy input will be affected due to a 10 percent increase in the prices of different fuels. We see that a 10 percent increase in electricity price will result in a decline in aggregate energy demanded in all the concerned industries. The aggregate energy requirement would decline the least in iron and steel industry (around 1 percent reduction in energy demand), the highest decline being observed in the chlor-alkali industry (around 5.23 percent). The all manufacturing sector's demand for energy will decline by around 3.84 percent due to a 10 percent increase in electricity prices.

Table 4.25: Percent change in aggregate Energy demand due to a 10 percent increase in the price of different fuels

Industries	Electricity	Coal	Oil
Cement	-4.0162	-6.8156	-0.7939
Paper & Pulp	-2.2343	-2.1826	-1.5911
Fertiliser	-2.3643	-1.1356	-4.1004
Iron & Steel	-0.9966	-0.2609	-1.7315
Textiles	-3.0992	-0.7718	-0.9536
Aluminium	-4.8081	-4.2089	-2.5600
Chlor-Alkali	-5.2341	-2.4118	-4.6419
All Manufacturing	-3.8365	-2.0916	-3.9443

Note: 1) Calculated on the basis of shares of different fuels prevailing in 2008-09 in the respective industry. However, for aluminium and chlor-alkali the shares are for the year 2007-08.
2) Positive changes indicate increase while negative changes indicate decrease.

Similarly increase in coal and oil prices by 10 percent will also lead to a decline in aggregate energy requirement by all industries. For a 10 percent increase in coal prices the aggregate energy demand would decline in the range of 0.26 percent in case of iron and steel industry to 6.82 percent in cement industry. The energy demand in all manufacturing sector will register a decline of about 2.09 percent. For oil, 10 percent increase in its price would result in a decline in aggregate energy demand in the range of 0.79 (in cement industry) to 4.69 percent (in chlor-alkali industry). In case of all manufacturing sector the decline in aggregate energy demand is expected to be around 3.94 percent (see table 4.25).

Table 4.26: For targeted 10 percent conservation of aggregate energy the required percentage changes in the price of different fuels

Industries	Electricity	Coal	Oil
Cement	24.90	14.67	125.97
Paper & Pulp	44.76	45.82	62.85
Fertiliser	42.30	88.06	24.39
Iron & Steel	100.34	383.30	57.75
Textiles	32.27	129.58	104.87
Aluminium	20.80	23.76	39.06
Chlor-Alkali	19.11	41.46	21.54
All Manufacturing	26.07	47.81	25.35

Note: Positive changes indicate increase while negative changes indicate decrease

For a targeted 10 percent reduction in aggregate energy consumption in each of the industries table 4.26 shows the required percent change in prices of different fuels. Based on the industries' derived demand for energy and different fuels inputs energy conservation will be associated with the rise in energy and fuel prices. For 10 percent energy conservation, the required rise in electricity prices would be in the range of 19.11 to 100.34 percent in different industries. The associated increase in coal prices for the targeted energy conservation would be between 14.67 to 383.30 percent while the increase in oil prices would be in the range of 21.54 to 125.97 percent in different industries.

Chapter 5 Economic Viability of Energy Conservation in Electricity Generation Industry

Energy efficiency in the electricity generation industry which is an energy supply industry, would mean efficiency in the conversion of primary energy into final energy i.e., electricity. From the benchmark analysis of the coal fired thermal power plants carried out in chapter 3 one can see that there exists considerable energy savings potential in the conversion of primary energy (i.e., coal) into final energy (i.e., electricity). From table 3.12 one can see that the energy savings potential on account of improvement in operating heat rate varies between 5.48 - 8.67 percent for the coal fired power plants in India in 2009-10. The savings potential due to improvement in auxiliary consumption varies between 9.28 - 16.47 percent.

Given the savings potential that exists in the power sector in India, how can the power plants be induced to improve their operational efficiency? How much of additional capital would be required for achieving improvement in conversion/operational efficiency? Will such investment be worthwhile? In order to answer these questions we have generated a number of scenarios of upgradation of the system by a combination of different policy instruments using data of a sample of thermal plants of different average unit sizes. The average unit size of the thermal plants considered varies between 175 MW to 500 MW. The improvement in operational efficiency of a power plant is captured by improvements in the operating heat rate and also by improvement in the auxiliary consumption. The data, both operational and financial for such an analysis were taken from the plant specific Tariff orders of the Central and State Regulatory Commission for the year 2008-09. Various scenarios were generated for deriving the conditions on capital cost to make the investment for upgradation of energy efficiency to the benchmark level as economically viable under the assumption of a reasonable rate of return.

In each of these scenarios it is assumed that due to an improvement in the operating heat rate and/or the auxiliary consumption only the energy cost component of the current cost changes while the recurring non-fixed capital cost component of the current cost does not change. The recurring non-fixed capital cost comprises of interest on working capital, operation and maintenance expenses and cost of secondary fuel, while the current cost comprises of energy cost and recurring non-fixed capital cost. It is further assumed that the rate of return on the additional capital is around 12.5 percent and any additional investment would be assured of this level of return to make such an investment worthwhile. It is also assumed that the average gross calorific value of the main or primary fuel i.e., coal and the secondary fuel (LDO, HSD, FO, etc.) consumed by the power plant and their average prices remain unchanged. The various scenarios considered in the study are as

Scenario-1: This scenario assumes an improvement in the operating heat rate of all power plants. For a thermal power plant the operating heat rate should correspond to the 25 percent benchmark heat rate of the group in which it belongs. However, if for a plant, its actual operating heat rate is lower than the benchmark heat rate, it is assumed that the plant continues to operate at its existing operating heat rate.

Scenario-2: This scenario assumes an improvement in both operating heat rate and auxiliary consumption of all power plants. For a plant the operating heat rate and its auxiliary consumption should correspond to the 25 percent benchmark heat rate and auxiliary consumption of the group in which it belongs. However, if for a power plant, its actual operating heat rate is lower than the benchmark heat rate, it is assumed that the plant continues to operate at its existing operating heat rate. Similarly, if its auxiliary consumption is lower than the benchmark level, it continues to maintain its existing auxiliary consumption.

In the above two scenarios it was assumed that the power plants would improve their operating heat rate and auxiliary consumption due to the standards set by the regulatory authority which have to be complied with by investing in additional capital, if necessary. In these scenarios it is also assumed that no financial or monetary incentives is provided by way of providing access to capital at rates lower than the market rates. Such improvement in the operational efficiency by the power plants may be alternatively enforced though tax intervention by the government. Let us assume that the government, in order to improve the operational efficiency of the sector decides to levy a tax on coal. Such a tax would increase the operational cost of power plants thereby forcing them to improve their operational efficiency by reducing their heat rate. Scenarios have been generated to find out the economic viability of such upgradation if a tax is levied on the coal which is the main input in the generation of electricity. These scenarios are

Scenario-1a: The operating heat rate of the power plants should be targeted at the 25 percent benchmark heat rate of the group in which they belongs (this is same as scenario-1) and a tax of 10 percent is imposed by the government on coal.

Scenario-1b: The operating heat rate of the power plants should be targeted at the 25 percent benchmark heat rate of the group in which they belongs (this is same as scenario-1) and a tax of 20 percent is imposed by the government on coal.

Scenario-2a: The operating heat rate and the auxiliary consumption of the power plants should be targeted at the 25 percent benchmark heat rate and auxiliary consumption of the group in which they belongs (this is same as scenario-2) and a tax of 10 percent is imposed by the government on coal.

Scenario-2b: The operating heat rate and the auxiliary consumption of the power plants should be targeted at the 25 percent benchmark heat rate and auxiliary consumption of the group in which they belongs (this is same as scenario-2) and a tax of 20 percent is imposed by the government on coal.

The detailed calculations corresponding to each of these scenarios is shown in table 5.1.

Table 5.1: Economic Viability Analysis of Investment for Energy Conservation: Some Scenarios

	Vindhyachal TPS			Korba	Rihand
	Stage-I	**Stage-II**	**Combined**	**STPS**	**TPS**
Installed Capacity	1000	1260	2260	2100	1000
No. of Units	2	6	8	6	2
Average Unit Size	500	210	282.5	350	500
Capital Cost (Rs. Lakhs)	247716	148337	396053	174805	241311
Operating HR (kcal/kwh)	2425.0	2500.0	2466.8	2464.3	2425.0
Specific Fuel oil (ml/kwh)	2.00	2.00	2.00	2.00	2.00
Aux Consumption	0.0650	0.0900	0.0789	0.0793	0.0750
Avg. GCV(Main fuel) (Kcal/kg-coal, lig)	3528.67	4095.33	3844.60	3289.40	3362.00
Price (Main fuel) (Rs/kg-coal, lig)	1.71	1.09	1.37	0.55	1.15
Avg. GCV (Sec. fuel) (Kcal/ml)	10.00	9.73	9.85	10.22	9.65
Energy Charge (Rs./kwh)	1.1668	0.6614	0.8697	0.4079	0.8195
Energy cost (Rs lakh)	80648	57603	135854	59203	56647
as % of Capital Cost	*32.56*	*38.83*	*34.30*	*33.87*	*23.47*
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
as % of Capital Cost	*7.79*	*12.31*	*9.48*	*15.49*	*5.65*
Current Cost (energy + recurring cost)	99946	75857	173406	86280	70272
Scenario 1: Heat rate targeted at 25% benchmark heat rate and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	1.1246	0.6182	0.8239	0.3868	0.7949
Energy cost (Rs lakh)	77730	53841	128703	56144	54941
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. Lakh)	97029	72095	166255	83221	68566
Saving in current cost due to energy conservation (Rs lakh)	2917	3762	7151	3059	1706
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**23339**	**30096**	**57210**	**24475**	**13648**
As % of capital cost	***9.42***	***20.29***	***14.44***	***14.00***	***5.66***
Scenario 1a: Scenario 1 + 10 % tax on coal					
Energy Charge (Rs./kwh)	1.2370	0.6800	0.9063	0.4255	0.8744
Energy cost (Rs lakh)	94054	65148	155730	67934	66479
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. lakh)	104802	77479	179125	88835	74060
Saving in current cost due to energy conservation (Rs lakh)	3209	4138	7866	3365	1877
Maximum economically viable capital investment at 12.5% rate of return (Rs. Lakh)	**25673**	**33105**	**62931**	**26923**	**15013**
As % of capital cost	**10.36**	**22.32**	**15.89**	**15.40**	**6.22**

	Vindhyachal TPS			Korba STPS	Rihand TPS
	Stage-I	Stage-II	Combined		
Scenario 1b: Scenario 1 + 20 % tax on coal					
Energy Charge (Rs./kwh)	1.3495	0.7419	0.9887	0.4641	0.9538
Energy cost (Rs lakh)	93276	64610	154443	67372	65929
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. lakh)	112575	82863	191996	94449	79554
Savings in current cost due to energy conservation (Rs. Lakh)	3501	4514	8581	3671	2047
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**28007**	**36115**	**68652**	**29370**	**16378**
As % of capital cost	**11.31**	**24.35**	**17.33**	**16.80**	**6.79**
Scenario 2: Heat rate & Auxiliary consumption targeted at 25% benchmark & recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	1.1244	0.6180	0.8237	0.3867	0.7947
Energy cost (Rs lakh)	77721	53822	128670	56129	54929
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. lakh)	97020	72076	166222	83206	68554
Saving in current cost due to energy conservation (Rs lakh)	2926	3782	7184	3074	1718
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**23410**	**30253**	**57471**	**24591**	**13742**
As % of capital cost	***9.45***	***20.39***	***14.51***	***14.07***	***5.69***
Scenario 2a: Scenario 2 + 10 % tax on coal					
Energy Charge (Rs./kwh)	1.2369	0.6798	0.9061	0.4254	0.8742
Energy cost (Rs lakh)	94043	65124	155691	67916	66464
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. lakh)	104792	77458	179089	88819	74047
Saving in current cost due to energy conservation (Rs lakh)	3219	4160	7902	3381	1890
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**25751**	**33278**	**63218**	**27050**	**15117**
As % of capital cost	**10.40**	**22.43**	**15.96**	**15.47**	**6.26**
Scenario 2b: Scenario 2 + 20 % tax on coal					
Energy Charge (Rs./kwh)	1.3493	0.7416	0.9884	0.4640	0.9536
Energy cost (Rs lakh)	93266	64586	154404	67355	65915
Recurring non-fixed capital cost (Rs. lakh)	19299	18254	37552	27077	13625
Current Cost (energy + recurring) (Rs. lakh)	112564	82840	191956	94432	79540
Saving in current cost due to energy conservation (Rs lakh)	3512	4538	8621	3689	2061
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**28092**	**36303**	**68965**	**29509**	**16491**
As % of capital cost	**11.34**	**24.47**	**17.41**	**16.88**	**6.83**

Source: Calculated by authors from Tariff Orders of CERC and SERCs for power plants for 2008-09

Table 5.1: Economic Viability Analysis of Investment for Energy Conservation: Some Scenarios

	Ramg'dam TPS	Talcher STPS	Unchahar TPS		
			Stage-I	Stage-II	Combined
Installed Capacity	2100	2000	420	420	840
No. of Units	6	4	2	2	4
Average Unit Size	350	500	210	210	210
Capital Cost (Rs. Lakhs)	229332	513272	96505	126693	223198
Operating HR (kcal/kwh)	2464.3	2450.0	2500.0	2500.0	2500.0
Specific Fuel oil (ml/kwh)	2.00	2.00	2.00	2.00	2.00
Aux Consumption	0.0793	0.0750	0.0877	0.0900	0.0889
Avg. GCV(Main fuel) (Kcal/kg-coal, lig)	3986.67	3375.00	3519.00	3519.00	3519.00
Price (Main fuel) (Rs/kg-coal, lig)	1.19	0.49	1.34	1.34	1.34
Avg. GCV (Sec. fuel) (Kcal/ml)	10.03	9.88	9.98	9.98	9.98
Energy Charge (Rs./kwh)	0.7318	0.3537	0.9469	0.9469	0.9469
Energy cost (Rs lakh)	106227	48900	27489	27490	54979
as % of Capital Cost	46.32	9.53	28.48	21.70	24.63
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
as % of Capital Cost	12.50	5.18	6.90	5.25	5.96
Current Cost (energy + recurring cost)	134904	75483	34153	34137	68290
Scenario 1: Heat rate targeted at 25% benchmark heat rate and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.6937	0.3351	0.8897	0.8897	0.8897
Energy cost (Rs lakh)	100695	46325	25829	25830	51659
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	129372	72908	32493	32476	64969
Saving in current cost due to energy conservation (Rs lakh)	5532	2576	1660	1660	3321
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**44256**	**20604**	**13283**	**13284**	**26567**
As % of capital cost	***19.30***	***4.01***	***13.76***	***10.48***	***11.90***
Scenario 1a: Scenario 1 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.7631	0.3686	0.9787	0.9787	0.9787
Energy cost (Rs lakh)	121840	56053	31253	31254	62507
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	139442	77540	35075	35059	70135
Saving in current cost due to energy conservation (Rs lakh)	6085	2833	1826	1827	3653
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**48682**	**22665**	**14612**	**14612**	**29224**
As % of capital cost	**21.23**	**4.42**	**15.14**	**11.53**	**13.09**
Scenario 1b: Scenario 1 + 20 % tax on coal					
Energy Charge (Rs./kwh)	0.8325	0.4021	1.0677	1.0677	1.0677

	Ramg'dam TPS	Talcher STPS	Unchahar TPS		
			Stage-I	Stage-II	Combined
Energy cost (Rs lakh)	120833	55590	30995	30995	61990
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	149511	82173	37658	37642	75301
Saving in current cost due to energy conservation (Rs lakh)	6638	3091	1993	1993	3985
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**53108**	**24725**	**15940**	**15940**	**31880**
As % of capital cost	**23.16**	**4.82**	**16.52**	**12.58**	**14.28**
Scenario 2: Heat rate & Auxiliary consumption targeted at 25% benchmark and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.6935	0.3350	0.8896	0.8896	0.8896
Energy cost (Rs lakh)	100669	46315	25825	25825	51650
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	129346	72898	32488	32472	64960
Saving in current cost due to energy conservation (Rs lakh	5558	2586	1665	1665	3330
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**44464**	**20685**	**13317**	**13322**	**26638**
As % of capital cost	***19.39***	***4.03***	***13.80***	***10.51***	***11.93***
Scenario 2a: Scenario 2 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.7629	0.3685	0.9785	0.9785	0.9785
Energy cost (Rs lakh)	121809	56041	31248	31248	62496
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	139413	77529	35071	35054	70125
Saving in current cost due to energy conservation (Rs lakh)	6114	2844	1831	1832	3663
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**48910**	**22753**	**14648**	**14654**	**29302**
As % of capital cost	**21.33**	**4.43**	**15.18**	**11.57**	**13.13**
Scenario 2b: Scenario 2 + 20 % tax on coal					
Energy Charge (Rs./kwh)	0.8322	0.4020	1.0675	1.0675	1.0675
Energy cost (Rs lakh)	120802	55578	30990	30990	61980
Recurring non-fixed capital cost (Rs. lakh)	28678	26583	6664	6647	13310
Current Cost (energy + recurring) (Rs. lakh)	149480	82160	37653	37637	75290
Saving in current cost due to energy conservation (Rs lakh)	6670	3103	1997	1998	3996
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**53356**	**24821**	**15980**	**15986**	**31966**
As % of capital cost	**23.27**	**4.84**	**16.56**	**12.62**	**14.32**

Source: Calculated by authors from Tariff Orders of CERC and SERCs for power plants for 2008-09

Table 5.1: Economic Viability Analysis of Investment for Energy Conservation: Some Scenarios

	Farakka TPS	Korba (DSPM)	Dadri-1 TPS	Kahalgaon TPS	NLC-1 Expansion
Installed Capacity	1600	500	840	840	420
No. of Units	5	2	4	4	2
Average Unit Size	320	250	210	210	210
Capital Cost (Rs. Lakhs)	312997	215596	172374	204056	144959
Operating HR (kcal/kwh)	2468.8	2449.6	2500.0	2500.0	2750.0
Specific Fuel oil (ml/kwh)	2.0	0.31	2.0	2.0	2.0
Aux Consumption	0.0756	0.0781	0.0900	0.0900	0.0950
Avg. GCV(Main fuel) (Kcal/kg-coal, lig)	2701.67	3444.00	3682.61	2698.33	2733.33
Price (Main fuel) (Rs/kg-coal, lig)	0.98	1.04	1.92	1.04	1.41
Avg. GCV (Sec. fuel) (Kcal/ml)	9.6	10.00	9.90	9.91	10.00
Energy Charge (Rs./kwh)	0.8848	0.7403	1.2960	0.9613	1.4106
Energy cost (Rs lakh)	97856	25585	75249	55816	40951
as % of Capital Cost	31.26	11.87	43.65	27.35	28.25
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
as % of Capital Cost	*7.37*	*5.48*	*8.05*	*6.40*	*7.86*
Current Cost (energy + recurring cost)	120933	37394	89119	68875	52347
Scenario 1: Heat rate targeted at 25% benchmark heat rate and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.8376	0.6868	1.2178	0.9033	1.2040
Energy cost (Rs lakh)	92633	23735	70704	52444	34954
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	115710	35544	84574	65504	46350
Saving in current cost due to energy conservation (Rs lakh)	5223	1851	4545	3371	5997
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**41786**	**14805**	**36359**	**26969**	**47977**
As % of capital cost	***13.35***	***6.87***	***21.09***	***13.22***	***33.10***
Scenario 1a: Scenario 1 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.9214	0.7554	1.3395	0.9936	1.3244
Energy cost (Rs lakh)	112085	28719	85551	63458	42294
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	124973	37917	91645	70749	49845
Saving in current cost due to energy conservation (Rs lakh)	5746	2036	4999	3708	6597
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**45965**	**16285**	**39995**	**29666**	**52775**
As % of capital cost	**14.69**	**7.55**	**23.20**	**14.54**	**36.41**
Scenario 1b: Scenario 1 + 20 % tax on coal					
Energy Charge (Rs./kwh)	1.0051	0.8241	1.4613	1.0839	1.4448

	Farakka TPS	Korba (DSPM)	Dadri-1 TPS	Kahalgaon TPS	NLC-1 Expansion
Energy cost (Rs lakh)	111159	28482	84844	62933	41945
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	134237	40291	98715	75993	53341
Saving in current cost due to energy conservation (Rs lakh)	6268	2221	5454	4045	7197
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**50143**	**17765**	**43631**	**32363**	**57572**
As % of capital cost	**16.02**	**8.24**	**25.31**	**15.86**	**39.72**
Scenario 2: Heat rate & Auxiliary consumption targeted at 25% benchmark and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.8374	0.6867	1.2175	0.9031	1.2040
Energy cost (Rs lakh)	92612	23733	70691	52435	34954
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	115690	35542	84561	65495	46350
Saving in current cost due to energy conservation (Rs lakh)	5244	1852	4558	3381	5997
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**41949**	**14816**	**36463**	**27047**	**47977**
As % of capital cost	***13.40***	***6.87***	***21.15***	***13.25***	***33.10***
Scenario 2a: Scenario 2 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.9212	0.7554	1.3393	0.9934	1.3244
Energy cost (Rs lakh)	112061	28717	85536	63446	42294
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	124951	37916	91630	70738	49845
Saving in current cost due to energy conservation (Rs lakh)	5768	2037	5014	3719	6597
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**46144**	**16298**	**40110**	**29751**	**52775**
As % of capital cost	**14.74**	**7.56**	**23.27**	**14.58**	**36.41**
Scenario 2b: Scenario 2 + 20 % tax on coal					
Energy Charge (Rs./kwh)	1.0049	0.8241	1.4610	1.0837	1.4448
Energy cost (Rs lakh)	111135	28480	84829	62922	41945
Recurring non-fixed capital cost (Rs. lakh)	23078	11809	13870	13060	11396
Current Cost (energy + recurring) (Rs. lakh)	134212	40289	98699	75982	53341
Saving in current cost due to energy conservation (Rs lakh)	6292	2222	5469	4057	7197
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**50339**	**17779**	**43756**	**32456**	**57572**
As % of capital cost	**16.08**	**8.25**	**25.38**	**15.91**	**39.72**

Source: Calculated by authors from Tariff Orders of CERC and SERCs for power plants for 2008-09

Table 5.1: Economic Viability Analysis of Investment for Energy Conservation: Some Scenarios

	Bokaro TPS	Mejia TPS	Kolaghat TPS	Bakreshwar TPS	Durgapur TPS
Installed Capacity	630	630	1260	630	350
No. of Units	3	3	6	3	2
Average Unit Size	210	210	210	210	175
Capital Cost (Rs. Lakhs)	55322	158024	129303	88982	19807
Operating HR (kcal/kwh)	2700.0	2500.0	2750.0	2590.0	2820.0
Specific Fuel oil (ml/kwh)	2.00	2.00	2.15	1.70	2.40
Aux Consumption	0.1000	0.0900	0.1010	0.0900	0.1055
Avg. GCV(Main fuel) (Kcal/kg-coal, lig)	4432.00	4150.67	4221.02	4703.83	4867.00
Price (Main fuel) (Rs/kg-coal, lig)	1.18	1.28	1.65	1.70	1.42
Avg. GCV (Sec. fuel) (Kcal/ml)	9.60	9.49	9.20	9.48	9.46
Energy Charge (Rs./kwh)	0.7145	0.7658	1.0664	0.9312	0.8176
Energy cost (Rs lakh)	31112	33348	92873	40551	19779
as % of Capital Cost	56.24	21.10	71.83	45.57	99.86
Recurring non-fixed capital cost (Rs. lakh)	12691	8588	13217	4700	10480
as % of Capital Cost	*22.94*	*5.43*	*10.22*	*5.28*	*52.91*
Current Cost (energy + recurring cost)	43803	41936	106090	45251	30259
Scenario 1: Heat rate targeted at 25% benchmark heat rate and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.6212	0.7196	0.9102	0.8437	0.7451
Energy cost (Rs lakh)	27052	31334	79273	36738	18025
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	39743	39923	92491	41439	28505
Saving in current cost due to energy conservation (Rs lakh)	4060	2013	13600	3813	1754
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**32477**	**16108**	**108799**	**30501**	**14028**
As % of capital cost	***58.70***	***10.19***	***84.14***	***34.28***	***70.83***
Scenario 1a: Scenario 1 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.6834	0.7915	1.0013	0.9280	0.8196
Energy cost (Rs lakh)	32733	37914	95921	44453	21811
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	42448	43056	100418	45113	30308
Saving in current cost due to energy conservation (Rs lakh)	4466	2215	14960	4194	1929
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**35724**	**17719**	**119679**	**33551**	**15431**
As % of capital cost	**64.58**	**11.21**	**92.56**	**37.71**	**77.91**
Scenario 1b: Scenario 1 + 20 % tax on coal					
Energy Charge (Rs./kwh)	0.7455	0.8635	1.0923	1.0124	0.8941

	Bokaro TPS	Mejia TPS	Kolaghat TPS	Bakreshwar TPS	Durgapur TPS
Energy cost (Rs lakh)	32463	37601	95128	44086	21630
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	45154	46189	108345	48786	32111
Saving in current cost due to energy conservation (Rs lakh)	4871	2416	16320	4575	2104
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**38972**	**19329**	**130559**	**36601**	**16834**
As % of capital cost	**70.45**	**12.23**	**100.97**	**41.13**	**84.99**
Scenario 2: Heat rate & Auxiliary consumption targeted at 25% benchmark and Recurring non-fixed capital cost same as before					
Energy Charge (Rs./kwh)	0.6211	0.7194	0.9100	0.8435	0.7449
Energy cost (Rs lakh)	27045	31328	79250	36732	18021
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	39736	39917	92467	41432	28501
Saving in current cost due to energy conservation (Rs lakh)	4067	2019	13623	3819	1758
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**32538**	**16154**	**108986**	**30555**	**14063**
As % of capital cost	***58.82***	***10.22***	***84.29***	***34.34***	***71.00***
Scenario 2a: Scenario 2 + 10 % tax on coal					
Energy Charge (Rs./kwh)	0.6832	0.7914	1.0010	0.9279	0.8194
Energy cost (Rs lakh)	32724	37907	95892	44445	21805
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	42440	43050	100392	45105	30303
Saving in current cost due to energy conservation (Rs lakh)	4474	2221	14986	4201	1934
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**35792**	**17769**	**119884**	**33611**	**15469**
As % of capital cost	**64.70**	**11.24**	**92.72**	**37.77**	**78.10**
Scenario 2b: Scenario 2 + 20 % tax on coal					
Energy Charge (Rs./kwh)	0.7453	0.8633	1.0920	1.0122	0.8939
Energy cost (Rs lakh)	32453	37594	95100	44078	21625
Recurring non-fixed capital cost (Rs. lakh)	43803	41936	106090	45251	30259
Current Cost (energy + recurring) (Rs. lakh)	45144	46182	108317	48778	32105
Saving in current cost due to energy conservation (Rs lakh)	4881	2423	16348	4583	2109
Maximum economically viable capital investment at 12.5% rate of return (Rs lakh)	**39046**	**19385**	**130783**	**36666**	**16876**
As % of capital cost	**70.58**	**12.27**	**101.14**	**41.21**	**85.20**

Source: Calculated by authors from Tariff Orders of CERC and SERCs for power plants for 2008-09

Table 5.2 is generated from table 5.1 and shows only the maximum additional capital investment (expressed as percentage of the current capital cost as reported in the respective plant's tariff orders) which will ensure at least 12.5 percent rate of return or a maximum of 8 years of payback period under each of these scenarios. The table also illustrates the maximum viable capital investment for alternative targets of energy efficiency and the choice of regulatory instruments. If the actual cost of upgradation to the benchmark level of efficiency is less than the maximum capital investment which is economically viable at 12.5 percent normative cost of capital, the target of energy savings of the concerned scenarios is achievable. If the actual additional investment required is found to be exceeding such viability limits, the energy conservation may warrant considering closing down such inefficient plant units.

Table 5.2: Economically viable capital investment

Power Plant	Scenario-1	Scenario-1a	Scenario-1b	Scenario-2	Scenario-2a	Scenario-2b
Vindhyachal	14.44	15.89	17.33	14.51	15.96	17.41
Stage-1	9.42	10.36	11.31	9.45	10.40	11.34
Stage-2	20.29	22.32	24.35	20.39	22.43	24.47
Korba STPS	14.00	15.40	16.80	14.07	15.47	16.88
Rihand STPS	5.66	6.22	6.79	5.69	6.26	6.83
Ramagundam	19.30	21.23	23.16	19.39	21.33	23.27
Talcher TPS	4.01	4.42	4.82	4.03	4.43	4.84
Unchahar	11.90	13.09	14.28	11.93	13.13	14.32
Stage-1	13.76	15.14	16.52	13.80	15.18	16.56
Stage-2	10.48	11.53	12.58	10.51	11.57	12.62
Farakka	13.35	14.69	16.02	13.40	14.74	16.08
Korba DSPM	6.87	7.55	8.24	6.87	7.56	8.25
Dadri-1 TPS	21.09	23.20	25.31	21.15	23.27	25.38
Kahalgaon	13.22	14.54	15.86	13.25	14.58	15.91
NLC-1 Expn	33.10	36.41	39.72	33.10	36.41	39.72
Bokaro TPS	58.70	64.58	70.45	58.82	64.70	70.58
Mejia TPS	10.19	11.21	12.23	10.22	11.24	12.27
Kolaghat	84.14	92.56	100.97	84.29	92.72	101.14
Bakreshwar	34.28	37.71	41.13	34.34	37.77	41.21
Durgapur TPS	70.83	77.91	84.99	71.00	78.10	85.20
Min	4.01	4.42	4.82	4.03	4.43	4.84
Max	84.14	92.56	100.97	84.29	92.72	101.14

Source: Authors' calculation

Chapter 6 Policy Recommendations and Conclusion

The Framework for Energy Efficient Economic Development (FEEED) is one of the initiatives under the National Mission for Enhanced Energy Efficiency (NMEEE) under the National Action Plan on Climate Change which seeks to develop fiscal instruments to promote energy efficiency in the country. The present study addresses this issue focusing on the industrial sector in view of its dominant share in the consumption of commercial energy in the country. Within the industrial sector, the prime focus is on the seven large energy consuming industries namely, iron and steel, fertiliser, pulp and paper, aluminum, cement, chlor-alkali and textiles. The study also analyses the energy efficiency of the power sector which is an energy-supply industry. In case of power sector the focus is primarily on efficient conversion of primary energy into electrical energy. So the efficiency for this sector is to be analysed with reference to the conversion of coal (i.e., primary energy) into electricity (i.e., final energy). In the other seven industries the focus is on efficient utilization (or consumption) of final energy by the non-energy industries.

As a first step, benchmark analysis, was carried out in order to derive the energy savings potential that exists in each of these industries. From the analysis one can see that there is enormous scope for energy conservation (savings) in each of the concerned industries including the coal fired power generation sector. Table 3.8 provides the range of energy savings potential that exists within each industry calculated using different measures of energy intensity, while table 3.13 shows the energy savings potential for the power sector in the country. However, the extent to which the energy savings potential can be realized in each of the industries in reality is an altogether different question. Attaining the level of intensity of the best performing unit may not be technologically feasible or economically efficient or viable for all the units within an industry as this may involve considerable investments, raising the unit costs at the given current prices and interest rates. Nonetheless, efforts must be made to improve energy intensity of all units within the industry so that improvement in the overall energy intensity of each of the concerned industries and also of the entire industrial sector can be achieved. As energy savings would lead to an estimate of current account cost savings, any additional investment required to upgrade the energy efficiency at the target benchmark level in an industry would be warranted if such savings of energy cost complies with the requirement of normative rate of return on capital of say at least 12.5 percent or a payback period of maximum 8 years.

In order to achieve energy conservation by improving the energy efficiency of the industrial sector various policy measures, both fiscal and monetary, can be adopted by the government. An econometric model of inter-factor and inter-fuel substitution using data for the period 1991-92 to 2008-09 was developed to study the behavioural response of the seven non-energy industries considered to different policy measures. The results of the model would be useful in the formulation of policies for realizing the various objectives of the economy. From the results of the model one can conclude that energy conservation can be achieved by changing the prices of various factor inputs namely, labour, material, capital and energy used by industries.

If energy conservation has to be achieved through changes in intermediate material input prices then from the model we see that the prices of intermediate material inputs have to decline. In other words a policy of general deflation which would lower material input prices will give the desired outcome. The way the intermediate material input is defined in the model, reduction in material prices would require the overall price level in the economy to decline. This is not possible given that in an open economy the behavior of world commodity prices greatly influences the movement of domestic prices and in a globalised world India is a price taker and therefore cannot influence global commodity prices. Similarly, it is found that energy conservation through changes in labour prices would not be an acceptable policy measure since the results of the model indicate that reduction in energy consumption by the industrial sector would require the price of labour i.e., the real wage rate to fall. A fall in real wages is clearly not a politically acceptable policy option to achieve energy conservation. As regards the impact of changes in the price of capital input on energy conservation is concerned, one finds its outcome to be somewhat ambiguous. In three industries the impact of changes in the price of capital was found to be significant. For two such industries where the results were found to be significant, it is seen that a reduction in energy consumption would require price of capital input to rise, while for the third industry namely, chlor-alkali, energy conservation would require the cost of servicing capital i.e., the price of capital input to decline. Even in industries where the results were not significant a fall in capital input price may not result in energy conservation. Thus achieving reduction in energy consumption through changes in price of capital input may not give the desired results. Providing incentives to industries and pampering them by way of providing access to capital at rates which are lower than the market rates will not thus result in energy conservation. In fact the results of the model indicate that energy conservation in overall manufacturing sector would require the price of capital input to rise. Thus, energy conservation though capital price route will not necessarily give the desired results as capital and energy appears to be complementary rather than substitute. Providing incentives to industries through monetary policy instruments that lower their cost of accessing capital from the market or providing any such incentive to some industries and providing no incentives to others is bound to introduce distortions and therefore is not a desirable policy option.

The only option left is the effect of a change in the price of aggregate energy input on the demand for energy. It can be seen from the results of the model that reduction in energy consumption in the industrial sector can be achieved by raising the price of energy input and the results are also statistically significant for all industries except iron and steel where the result, though not significant, is in the right direction. To achieve energy conservation in the industrial sector, prices of energy would have to rise.

For a target 10 percent reduction in energy consumption the required increase in energy prices would be in the range of 8.14 to 33.46 percent and for all manufacturing sector the required increase in energy prices would be around 10.13 percent. Any economic instrument which raises the price of energy would result in energy conservation by improving the energy efficiency of the industrial sector. A tax on consumption of energy is one such instrument which would yield the desired outcome. This tax can be a specific tax i.e., levied on each unit of energy consumed, alternatively, it can be an *ad valorem* tax levied on the value (or unit price) of energy consumed. Thus, the policy option for the government would be to impose a tax on energy.

Aggregate energy consumption by the industries comprises of consumption of mainly three fuels in the context of the industries considered. These are, electricity which is purchased from the grid, coal which is used as an energy input in industries for captive generation of steam and electricity, and oil and oil products used as energy. Changes in prices of these fuels will affect the price of aggregate energy input. From the model one can see that increase in the price of any one of these fuels results in changes in the demand for all the three fuels due to substitution effects. It would not only result in a decline in the own demand for the fuel by different industries but also in the decline in the aggregate demand for energy. An increase in electricity price (i.e., electricity tariff) not only results in a decrease in the demand for electricity purchased from the grid by the industries, but also reduces their demand for aggregate energy. A 10 percent increase in electricity tariff would result in a decrease in aggregate energy demand by industries in the range of 1.00 to 5.23 percent and for the overall manufacturing sector the decline in the aggregate energy demand would be around 3.84 percent. Similarly, for oil a 10 percent increase in its price lowers its demand by industries and also the demand for aggregate energy. The decline in demand for aggregate energy by industries due to a 10 percent increase in oil prices is in the range of 0.79 to 4.64 percent. The overall manufacturing sector's demand for aggregate energy declines by about 3.94 percent due to a 10 percent increase in the price of oil.

For coal also one can see that an increase in coal prices would result in a decline in its demand by industries with the exception of the overall manufacturing sector. However, the demand for coal by the overall manufacturing sector increases with the increase in the price of coal. One of the uses of coal in the industrial sector is to generate electricity (i.e., coal is used for captive generation). Supply side constraints of grid electricity may coincide with the shortage in the supply of coal resulting in a rise in its price. As the supply of electricity from the grid is often constrained by the availability of coal, the dependence of the overall manufacturing sector on the grid electricity will decrease. Therefore, in order to meet its electricity requirement the overall manufacturing sector will have to fall back upon coal for captive generation resulting in an increase in demand for coal despite an increase in its prices. However, for all industries including overall manufacturing sector, the demand for aggregate energy decreases with the increase in coal prices. The decline in the demand for aggregate energy by the overall manufacturing sector would be around 2.09 percent for a 10 percent increase in coal prices.

Thus, from the above discussion one can conclude that energy conservation in the industrial sector can be achieved by raising the prices of different fuels. A tax, either specific or *ad valorem*, levied by the government on the consumption of different fuels would raise the price of fuels consumed by the industrial sector. This will raise the cost of production of the industrial sector thereby affecting the quantity of inputs including energy inputs consumed. The demand for energy inputs will decline as the industry will be forced to move towards efficient utilization of energy. Thus a tax on fuels by the government would result in energy conservation.

Fuel or Energy Tax in a GST Regime

The system of taxation of goods and services in India has been subjected to considerable reforms since early nineties. These reforms were aimed at the elimination and correction of distortions and inefficiencies prevalent in the Indian tax system. One of the major tax reforms has been in the sphere of indirect taxes, namely, the introduction of a value added tax (VAT). Having adopted the system of Value Added Tax for goods, we are now in the process of moving towards a comprehensive system of value added tax under the name of Goods and Services Tax (GST). The GST will integrate the central and state taxes on goods and services into a comprehensive goods and services tax. At present the Empowered Committee of State Finance Ministers is working towards evolving a common structure of GST which will be acceptable by both the Centre and States.

In near future as GST will be implemented, any new tax proposed should conform to the norms of GST. As discussed, a tax levied by the central government on the consumption of different fuels would have the desired effect of energy conservation provided the user of energy in the production chain cannot pass on the burden to the consumer of the products without facing any rise in the cost of production. However, in a value added tax or goods and services tax regime, producers earn input tax credit on the taxes on different inputs paid by them. The net tax liability of a producer would be the difference between his/her total tax liability and the taxes paid by him/her on the inputs used in the production process. In such a case imposing a tax on fuels (energy) which are used as inputs will not yield desired results as the taxes paid on energy inputs by the producers would be credited back to them and would not therefore, be reflected in their cost of production. In order to overcome this problem it is proposed that the Central Government levy a non-rebatable excise duty on fuels and energy over and above the normal GST. Such an excise duty can be in the form of a specific duty or an *ad* *valorem* duty on the consumption of different fuels. This non-rebatable excise duty should also have a countervailing component for fuel inputs which are imported.

Such non-rebatable excise duty on energy inputs like electricity, coal and oil would work through the production structure and affect the prices of goods that use the energy inputs thereby affecting the competitiveness of the manufacturing units. Units which consume more energy per unit of output will have a relatively higher cost of production as their tax liability on account of higher energy consumption will be higher vis-à-vis units which have relatively lower energy intensity. This would adversely affect the profitability and competitiveness of these units thereby forcing them to either utilise energy efficiently or undergo technological restructuring through modernization for switching to an altogether new and more energy efficient production process.

We see there is considerable scope for energy savings in the industrial sector. Different industries have different energy savings potential. However, the extent to which the savings potential can actually be realized is a different question. It would depend on a number of factors. From the model on inter-fuel and inter-factor substitution we that energy conservation can be achieved by increasing the price of aggregate energy input. A tax in the form of a non-rebatable excise duty on energy inputs namely, electricity purchased from the grid, coal and oil, would lead to a reduction in energy consumption by industries. Energy conservation which can be achieved by levying the non-rebatable excise duty on energy inputs would depend on the behavioural response of each of these industries to changes in prices of energy inputs. From the results of the model we have seen wide variation in the energy savings which can be achieved in different industries through a given, say, 10 percent increase in the prices of energy inputs.

It is seen that there is variation in energy saving potential across industries. In some industries the savings potential is high while in others it is low. The impact of an increase in energy prices on energy conservation is also quite diverse across industries. Is it then possible to tax different industries differently? In order to have differentiated tax incidence among different manufacturing units one can design the proposed non-rebatable excise duty on energy inputs in the form of a progressive tax on energy or on electricity consumption where the tax rate increases with the increase in the taxable base. The base in this case could be the quantum of energy or electricity consumed. Energy or electricity consumption above a certain threshold level can be taxed at a relatively higher rate. Such a tax would increase the tax incidence on units which are large consumers of energy/power consumers without imposing additional liability on the smaller units.

Another way of addressing the issue of assigning differentiated responsibility to different industries is to have a system of tradable permits for industries that are large energy consumers. This system of tradable permits should be in addition to the non-rebatable excise duty imposed on energy inputs. Will such a system of tax and tradable permits result in the desired conservation of energy would depend on how the mechanism of tradable permits is designed and implemented. Will there industry specific permits or single permit system covering all the industries considered. What will be the competitive character of the permit market that would emerge and how it would determine the permit prices? What would be the process of initially allocating permits among different plants or firms? These are some of the many questions which we do not address here, but need to be sorted out before such a system can be recommended to be put in place.

To summarise the above discussion, the study proposes, for energy conservation in the industrial sector, a non-rebatable excise on energy inputs (i.e., on different fuels) consumed by the industries to be levied by the central government over and above the normal GST. It is proposed that such a non-rebatable excise duty should also have a countervailing component for fuel inputs which are imported. The excise duty could either be in the form of a specific duty or an *ad valorem* duty. The excise duty can also be designed in the form of a progressive tax on energy or electricity consumption where energy or electricity consumption above a certain threshold will be taxed at a higher rate. Alternatively, one can combine the proposed excise duty on different fuels with the system of tradable permits implemented for select industries units which are large consumers of energy.

References

Ahmed, E., and N. Stern (2011), "Effective Carbon Taxes and Public Policy Options", in M.G. Rao and M. Rakshit (eds.), Public Economics: Theory and Policy Essays in honour of Amaresh Bagchi, Sage Publications, New Delhi.

Apostolakis, B.E. (1990a), "Interfuel and Energy-Capital Complementarity in Manufacturing Industries", *Applied Energy*, Vol. 35, pp. 83-107.

Apostolakis, B.E. (1990b), "Energy-Capital Substitutability/Complementarity", *Energy Economics*, pp. 48-58.

Arnberg, S. and T.B. Bjorner (2007) "Substitution between energy, capital and labour within industrial companies: A micro panel data analysis", Resource and Energy Economics, Vol. 29, pp. 122-136.

Balachandra, P., D. Ravindranathan and N.H. Ravindranathan (2010), "Energy efficiency in India: Assessing the policy regimes and their impacts", *Energy Policy*, Vol. 38, pp. 6428-6438.

Berndt, Ernst R. and David O. Wood (1975), Technology, Prices, and the Derived Demand for Energy, *The Review of Economics and Statistics*, Vol. 57, No. 3, pp. 259-268.

Binswanger, H.P. (1974a), "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution", *American Journal of Agricultural Economics*, Vol. 56, No. 2, pp. 377-386, May.

Binswanger, H.P. (1974b), "The Measurement of Technical Change Biases with Many Factors of Production", *The American Economic Review*, Vol. 64, No. 6, pp. 964-976, December.

Burkia, A. A. and M.H. Khan (2004), “Effects of allocative inefficiency on resource allocation and energy substitution in Pakistan’s manufacturing”, *Energy Economics*, Vol. 26, pp. 371-388.

Central Electricity Authority (2010), All India Electricity Statistics: General Review 2010, Ministry of Power, Government of India, New Delhi.

Central Electricity Authority (Various years), Review of Performance of Thermal Power Stations, Ministry of Power, Government of India, New Delhi.

Christensen, L.R., D.W. Jorgenson, and L.J. Lau (1973), “Transcendental Logarithmic Production Frontiers”, *The Review of Economics and Statistics*, Vol. 55, No. 1, pp. 28-45.

Cropper, M. and S. Bhattacharya (2010), “Options for Energy Efficiency in India and Barriers to Their Adoption: A Scoping Study”, Resources for Future Discussion Paper (RFF DP 10-20), Washington DC.

Fuss, M.A., (1977), “The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with many Inputs”, *Journal of Econometrics*, Vol. 5, pp. 89-116.

Goldar, B (2010), Energy Intensity of Indian Manufacturing Firms: Effect of Energy Prices, Technology and Firm Characteristics, Institute of Economic Growth, Mimeo, February.

Government of India (2008), Input-Output Tables 2003-04, Ministry of Statistics and Programme Implementation, New Delhi.

Government of India (Various years), Annual Survey of Industries, Ministry of Statistics and Programme Implementation, New Delhi.

Government of India (Various years), Petroleum and natural Gas Statistics, Economic Division, Ministry of Petroleum and Natural Gas, New Delhi.

Griffin, J.M. (1977), “Inter-Fuel Substitution Possibilities: A Translog Application to Inter-country Data”, *International Economic Review*, Vol. 18, No. 3, pp. 755-770.

Halvorsen, R. (1977), “Energy Substitution in U.S. Manufacturing”, *The Review of Economics and Statistics*, Vol. 59, No. 4, pp. 381-388.

Hogan, William W. and Dale Jorgenson (1991), “Productivity Trends and the Cost of Reducing CO2 Emissions,” *The Energy Journal*, 12(1): pp. 67-85.

International Energy Association (2010), Energy Efficiency Governance, IEA, France

Jha, R., M.N. Murty, S. Paul and B.B. Rao (1993), An Analysis of Technical Change, Factor Substitution and Economies of Scale in Manufacturing Industries in India, *Applied Economics*, Vol 25, pp. 1337-1343.

Jorgenson, D.W. and Barbara M. Fraumeni (1981), “Relative Prices and Technical Change,” In E.R. Berndt and B. Fields (eds.), Modeling and Measuring Natural Resources Substitution, MIT Press, Cambridge.

Ma, H., L. Oxley, and J. Gibson (2009), “Substitution possibilities and determinants of energy intensity for China,” *Energy Policy*, Vol. 37, pp. 1793-1804.

Mukherjee, K. (2008), “Energy use efficiency in the Indian manufacturing sector: An interstate analysis”, *Energy Policy*, Vol. 36, pp. 662-672.

Pindyck, R. S. (1979a), World Energy Demand, MIT Press, Cambridge MA.

Pindyck, R.S. (1979b), “Interfuel Substitution and the Industrial Demand for Energy: An International Comparison”, *The Review of Economics and Statistics*, Vol. 61, No. 2, pp. 169-179.

Price, L., C. Galitsky, and J. Sinton (2005), “Tax and Fiscal Policies for Promotion of Industrial Energy Efficiency: A Survey of International Experience”, Ernest Orlando Lawrence Berkeley National Laboratory Berkeley, CA

Roy, J., A. Sanstad, J.A. Sathaye and R. Khaddaria (2006), “Substitution and price elasticity estimates using inter-country pooled data in a translog cost model”, *Energy Economics*, Vol. 28, pp. 706-719.

Roy, J., J. Sathaye, A. Sanstad, P. Mongia, and K. Schumacher (1999), "Productivity trends in India's energy-intensive industries", *Energy Journal*, Vol. 20 No. 3, pp. 33-61.

Roy, Joyashree (1999), A Study on Fuel Substitution and Bias in Technical Change during 1978-79 and 1993-94 in Energy Intensive Manufacturing Industries in India Using Panel Data, Mimeo, National Institute of Public Finance and Policy, New Delhi.

Roy, Joyashree, (1992), Demand for Energy in Indian Industries: A Quantitative Approach, Daya Publishing House, Delhi 110006.

Saha, Anindita Roy (1997), The Economics of Energy Conservation and Industrial Cogeneration of Electricity: Case Studies of Certain Selected Industries in India, Unpublished Ph.D. Thesis submitted to the Jawaharlal Nehru University.

Sankar, U. (2010), Policy Instruments for Achieving Low Carbon and High Economic Growth in India, Monograph, National Institute of Public Finance and Policy, New Delhi.

Sanstad, A.H., J. Roy, and J.A. Sathaye (2006), "Estimating energy-augmenting technological change in developing country industries," *Energy Economics*, Vol. 28, pp. 720–729.

Sengupta, Ramprasad (2010), Prospects and Policies for Low Carbon economic Growth of India, Monograph, National Institute of Public Finance and Policy, New Delhi.

Stern, D.I. (2010), "The Role of Energy in Economic Growth," USAEE-IAEE Working Paper 10-055, November.

UNEP (2006), Improving Energy Efficiency in Industry in Asia: A review of financial mechanisms as part of the Energy Efficiency Guide for Industry in Asia (draft), UNEP.

UNIDO (2008), Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies, UNIDO, Vienna.

Uri, N.D. (1979), "Energy Demand and Inter-fuel Substitution India," *European Economic Review*, Vol 12, pp.181-190.

Williams, M. and P. Laumas (1981), "The Relation between Energy and Non-Energy Inputs in India's Manufacturing Industries", *The Journal of Industrial Economics*, Vol. 30, No. 2, pp. 113-122.

World Bank (2011), World Development Indicators 2010, World Bank, Washington DC.

World Energy Council (2008), Energy Efficiency Policies around the World: Review and Evaluation, WEC, UK.

Zahid, S.N., M. Akbar, and S.A. Jaffry (1992), "Technical Change, Efficiency, and Capital-Labour Substitution in Pakistan's Large Scale Manufacturing Sector," *The Pakistan Development Review*, Vol. 32, No. 2, pp. 165-188.

Appendix

Appendix 1: Scope and Coverage of Annual Survey of Industries

Annual Survey of industries (ASI) covers the entire country except the states of Sikkim, Arunachal Pradesh, Mizoram and the Union Territory of Lakshadweep. It covers all factories registered under Sections 2m(i) and 2m(ii) of the Factories Act, 1948 i.e. those factories employing 10 or more workers using power; and those employing 20 or more workers without using power. The survey also covers bidi and cigar manufacturing establishments registered under the Bidi & Cigar Workers (Conditions of Employment) Act, 1966 with coverage as above. All electricity undertakings engaged in generation, transmission and distribution of electricity registered with the Central Electricity Authority (CEA) were covered under ASI irrespective of their employment size. Certain servicing units and activities like water supply, cold storage, repairing of motor vehicles and other consumer durables like watches etc. are covered under the Survey. Though servicing industries like motion picture production, personal services like laundry services, job dyeing, etc. are covered under the Survey but data are not tabulated, as these industries do not fall under the scope of industrial sector defined by the United Nations. Defence establishments, oil storage and distribution depots, restaurants, hotels, café and computer services and the technical training institutes, etc. are excluded from the purview of the Survey.

From ASI 1998-99, the electricity units registered with the CEA and the departmental units such as railway workshops, RTC workshops, Government Mints, sanitary, water supply, gas storage etc. are not covered, as there are alternative sources of their data compilation for GDP estimates by the Central Statistical Organisation (CSO).

Appendix 2: Tables

Table A1: Allen-Uzawa Elasticities of Substitution (Fuel Model)

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
σ_{ee}	-0.4034	**	-1.0576	***	0.1795		-0.5929	***
σ_{ec}	0.4304	**	1.1079	***	2.3333	*	0.6806	**
σ_{eo}	-0.3971		0.2850	*	-0.5942	***	0.7772	***
σ_{ce}	0.4304	**	1.1079	***	2.3333	*	0.6806	**
σ_{cc}	-0.8778	***	-2.0073	***	-7.8649	***	-2.3919	**
σ_{co}	1.9411	***	0.8838	***	0.7826	***	0.5345	
σ_{oe}	-0.3971		0.2850	*	-0.5942	***	0.7772	***
σ_{oc}	1.9411	***	0.8838	***	0.7826	***	0.5345	
σ_{oo}	-5.8908	***	-1.7276	***	0.0725		-2.2826	***

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
σ_{ee}	-0.2947	***	-0.4135	***	-0.3011	**	0.2397	
σ_{ec}	-0.0824		0.5805	***	0.4481		-1.6380	***
σ_{eo}	0.6715	***	0.4969	***	0.1786		0.6531	***
σ_{ce}	-0.0824		0.5805	***	0.4481		-1.6380	***
σ_{cc}	-7.7663	***	-2.3856	***	-3.5944	**	1.8201	***
σ_{co}	2.2593	***	1.3666	***	1.0411	**	0.8887	***
σ_{oe}	0.6715	***	0.4969	***	0.1786		0.6531	***
σ_{oc}	2.2593	***	1.3666	***	1.0411	**	0.8887	***
σ_{oo}	-2.0845	***	-3.3102	***	-0.6895	***	-1.2759	***

Note: ***, **, * represent level of significance at 1, 5 and 10 percent respectively;
All elasticities are calculated at the mean of each fuel's share in total energy;
e = electricity; o = oil; c = coal

Table A2: Own and Cross Partial Price Elasticities (Fuel Model)

	Cement		Paper & Pulp		Fertiliser		Iron & Steel	
η_{ee}	-0.1549	**	-0.4437	***	0.0455		-0.3275	***
η_{ec}	0.2078	**	0.3747	***	0.3172	*	0.1431	**
η_{eo}	-0.0529		0.0690	*	-0.3627	***	0.1845	***
η_{ce}	0.1653	**	0.4648	***	0.5916	*	0.3760	**
η_{cc}	-0.4238	***	-0.6789	***	-1.0694	***	-0.5028	**
η_{co}	0.2586	***	0.2141	***	0.4778	***	0.1269	
η_{oe}	-0.1525		0.1196	*	-0.1506	***	0.4294	***
η_{oc}	0.9372	***	0.2989	***	0.1064	***	0.1124	
η_{oo}	-0.7847	***	-0.4185	***	0.0442		-0.5417	***

	Textiles		Aluminium		Chlor-Alkali		All Mfg	
η_{ee}	-0.1871	***	-0.2350	***	-0.1400		0.1026	
η_{ec}	-0.0063		0.1423	***	0.0740		-0.3403	***
η_{eo}	0.1934	***	0.0927	***	0.0661		0.2377	***
η_{ce}	-0.0523		0.3299	***	0.2084		-0.7016	***
η_{cc}	-0.5985	***	-0.5848	***	-0.5934	**	0.3781	***
η_{co}	0.6508	***	0.2549	***	0.3850	**	0.3234	***
η_{oe}	0.4263	***	0.2824	***	0.0831		0.2797	***
η_{oc}	0.1741	***	0.3350	***	0.1719	**	0.1846	***
η_{oo}	-0.6005	***	-0.6174	***	-0.2550	***	-0.4643	***

Note: ***, **, * represent level of significance at 1, 5 and 10 percent respectively;
All elasticities are calculated at the mean of each fuel's share in total energy;
e = electricity; o = oil; c = coal

Table A3: Allen-Uzawa Elasticities of Substitution (Factor Model)

	Cement	Paper & Pulp	Fertiliser	Iron & Steel
σ_{ll}	-3.1022	-6.9736 ***	-5.7161 ***	-2.3228
σ_{lk}	-1.3056 *	0.4190	-0.0510	-1.0207 **
σ_{le}	2.1453 ***	1.9840 ***	-0.3965	4.2994 ***
σ_{lm}	-0.3015	0.1238	0.3908 **	-0.2714 *
σ_{kl}	-1.3056 *	0.4190	-0.0510	-1.0207 **
σ_{kk}	2.5035 *	-2.7181 *	-4.1271 ***	-1.6748 **
σ_{ke}	-2.3860 ***	0.1868	0.9702	-0.6533
σ_{km}	0.3511	0.5395	0.6066 ***	0.4583 ***
σ_{el}	2.1453 ***	1.9840 ***	-0.3965	4.2994 ***
σ_{ek}	-2.3860 ***	0.1868	0.9702	-0.6533
σ_{ee}	-4.8519 ***	-4.1118 ***	-6.4908 ***	-2.9187
σ_{em}	2.7146 ***	0.6990 ***	0.9101 **	0.2353
σ_{ml}	-0.3015	0.1238	0.3908 **	-0.2714 *
σ_{mk}	0.3511	0.5395	0.6066 ***	0.4583 ***
σ_{me}	2.7146 ***	0.6990 ***	0.9101 **	0.2353
σ_{mm}	-1.2750 ***	-0.2939 ***	-0.2836 ***	-0.0957 ***

	Textiles	Aluminium	Chlor-Alkali	All Mfg
σ_{ll}	-7.2852 ***	-4.7318	-3.0663	1.4168
σ_{lk}	-0.0034	1.6630 *	0.1540	-2.5892 ***
σ_{le}	4.1251 ***	5.0755 *	-1.3581	4.1532 ***
σ_{lm}	0.2970 **	-1.1660 *	0.5704 *	-0.0629
σ_{kl}	-0.0034	1.6630 *	0.1540	-2.5892 ***
σ_{kk}	-5.2489 **	-1.3874	-5.7424 ***	-2.9221 **
σ_{ke}	-0.8083	0.6662	2.7321 ***	-3.9479 ***
σ_{km}	0.8917 ***	0.0049	0.6622 *	0.9204 ***
σ_{el}	4.1251 ***	5.0755 *	-1.3581	4.1532 ***
σ_{ek}	-0.8083	0.6662	2.7321 ***	-3.9479 ***
σ_{ee}	-5.5792 ***	-7.5331 **	-8.0492 ***	-15.6470 ***
σ_{em}	0.3413 *	1.2353	1.4122 **	1.5626 ***
σ_{ml}	0.2970 **	-1.1660 *	0.5704 *	-0.0629
σ_{mk}	0.8917 ***	0.0049	0.6622 *	0.9204 ***
σ_{me}	0.3413 *	1.2353	1.4122 **	1.5626 ***
σ_{mm}	-0.2079 ***	-0.2011	-0.5422 ***	-0.2559 ***

Note: 1) ***, **, * represent level of significance at 1, 5 and 10 percent respectively;
2) All elasticities are calculated at the mean of each factor share;
3) l = labour; e = energy; k = capital; m = intermediate material input