Measuring Energy Intensity in Selected Manufacturing Industries in India

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Abstract:

The manufacturing industries are one of the energy intensive industries among other industries in India. Future economic growth significantly depends on the long-term availability of energy in increasing quantities from sources that are dependable, safe and environmentally friendly. Energy intensity is an indicator to show how efficiently energy is used in the economy. This study attempts to measure and analyze energy intensity of seven manufacturing industries of India viz.Paper, aluminium, iron&steel, fertilizer, chemical, glass and cement-at industry level and define energy intensity as the ratio of energy consumption to output. The purpose of this study is to understand the degree of intensity in energy consumption in those industries and observe whether there exists any inter industry variation in energy intensity over those industries. The study shows that seven manufacturing industries under our consideration have been depicting varied energy intensities which are well above the average intensity of the entire aggregate manufacturing industry. Moreover, energy intensity varies across industry over years. Therefore, energy intensity changes over time and varies significantly by types of economic activities.

Key words: Energy, intensity, India, industry, manufacturing.

1. Introduction

India being one of the rapid growing economies in the world has a fast growing energy demand fueled by an ever increasing rate of industrialization and urbanisation.The demand for energy, particularly for commercial energy, has been growing rapidly with the growth of the economy, changes in the demographic structure, rising urbanization, socioeconomic development, and the desire for attaining and sustaining self-reliance in some sectors of the economy. At present, manufacturing accounts for just above one quarter of total energy consumption worldwide but it has also produced a large variety of consumer goods which need yet another form of energy for exploitation. With the growing pace of industrialization, especially in developing countries with 80 per cent of the world's population, energy has been the major concern for sustainable development, environmental protection and a decent standard of living.

Energy intensity is an indicator to show how efficiently energy is used in the economy. The energy intensity of India is over twice that of the matured economies, which are represented by the OECD (Organization of Economic Co-operation and Development) member countries. India's energy intensity is also much higher than the emerging economies. However, since 1999, India's energy intensity has been decreasing and is expected to continue to decrease (GOI, 2001). The indicator of energy–GDP (gross domestic product) elasticity which is the ratio of growth rate of energy to the growth rate GDP captures both the structure of the economy as well as the efficiency. The energy–GDP elasticity during 1953–2001 has been above unity. However, the elasticity for primary commercial energy consumption for 1991–2000 was less than unity (Planning Commission, 2002). This could be attributed to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution. The manufacturing industries are one of the energy intensive industries among other industries in India. Energy is the basic building block for socio-economic development. Future economic growth significantly depends on the long-term availability of energy in increasing quantities from sources that are dependable, safe and environmentally friendly.

In this context, the energy intensity is one of the key factors, which affect the projections of future energy demand for any economy. Energy intensity in Indian industry is among the highest in the world. According to the Govt. of India (GoI) statistics, the manufacturing sector is the largest consumer of commercial energy in India. Energy consumption per unit of production in the manufacturing of steel, aluminum, cement, paper, chemical, fertilizer, glass, etc. is much higher in India, even in comparison with some developing countries.

Against this backdrop, this study attempts to measure and analyze energy intensity at industry level and define energy intensity as the ratio of energy consumption to output. The purpose of this study is to understand the degree of intensity in energy consumption in those industries and observe whether there exists any inter industry variation in energy intensity over those industries.

2. Brief description about the industries under consideration of our study:

Cement industry:

The cement industry in India, second largest in the world, is highly energy-intensive and the main source of energy is coal. The expenditure on energy in some of the units is sometimes as high as 50% of the total manufacturing cost. The contribution of the other fuel types –namely oil, gas or other alternative waste fuels are negligible. The specific energy consumption for the latest plants is as low as 670 kcal/kg of clinker. For the older dry process plants, it can go up to 900 kcal /kg of clinker. Percentage share of energy input in industry's total input is around 28% on an average over our study period of 25 years. The most coal intensive sector is cement with total coal intensity of 3- 4 '000 mtoe/ crore Rs of output (thousand million ton of oil equivalent per Rs crore of output). Total energy intensity in cement industry shows gradual increase with average total intensity of 3.72('000 mtoe/Rs crores).

Aluminium industry:

The aluminium manufacturing process is energy intensive. The energy required for producing alumina from bauxite (based on the US study of 1995) amounts to 3.76 kWh / kg (kilowatt hours per kilogram) of alumina. This works out to be 7.27kwh / kg of aluminium produced, assuming 1.93 kg of alumina consumption for producing 1 kg of aluminium. The industry consists of five primary producers- Hindalco Industries, Indian Aluminium co, Bharat Aluminium co, National Aluminium co, Madras Aluminium co. The primary producers have strong presence in the sheet business and are enlarging their role in foil segment. The specific energy consumption of aluminium industries for various years is given in table 3. Average energy-output ratio is estimated to be 0.25 over our study period of 25 years(Table-3.3).The energy intensity in aluminium industry is estimated to be 0.4602 ('000 mtoe/Rs crores) with observed gradual decline in intensity. The energy requirement in various forms in various production processes in aluminium industry in India is very high in comparison to best practices.

Glass Industry:

This industry is highly energy-intensive because it found from our calculation over a period of 25 years, 1979-80 to 2003-04 that the consumption of energy occupies 33% in total input requirements in Glass industry. The share of energy costs in the value of output was on an average 19.5%.Coal and petroleum are the two main sources of energy required in production plants. A gradual increase in year-wise total intensity is observed and average total intensity in glass sector is estimated to be 1.11 **(**'000 mtoe/Rs crores).

Fertilizer Industry:

India ranks third in the world in terms of production and consumption of fertilizers. Energy consumed per unit of output is 14.17% over our study period (shown in table-3.3). Main ingredients of energy are coal and petroleum. Of the four types of fertilizers- nitrogen, phosphate, potash, and complex- the production of nitrogenous fertilizers is highly energy-intensive. The basic chemical that is used to produce nitrogenous fertilizer is ammonia. Natural gas, naphtha, fuel oil and coal are used as feedstock for ammonia production. Thus, production of ammonia itself involves almost 80% of the energy consumption in the manufacturing process of a variety of final fertilizer products. The average total intensity of energy in fertilizer sector is calculated to be 0.89.

Paper Industry:

The Indian paper industry is the 15th largest in the world and is highly energy intensive. This industry is the sixth largest energy consumer in the country and accounts for 7% of the country's coal and about 35% of the electrical energy requirements. The percentage share of energy costs in the total output (energy intensity) is about 13.5%. Coal and electricity are the two major energy sources used in paper production. Other fuels such as LSHS, furnace oil etc. are used to fire boilers. LDO (light diesel oil) and HSD (high speed diesel) are also used for captive power generation in diesel generators sets in plants. Steam and electricity consumption per tonne of paper is about 11-15 tonnes and 1500-1700 kWh, respectively in Indian mills. The specific energy consumption of the Indian paper industry ranges from 31 GJ (gigajoules) to 51 GJ (gigajoules) per tonne of product which is roughly double the norms compared to North American and Scandinavian units. From our estimate, it is found that average total intensity is 1.53('000 mtoe/Rs crores) reflecting also a gradual increase in year-wise total intensity.

Iron and Steel Industry:

India is the eighth largest crude steel producing country in the world .The iron and steel sector is the largest consumer of energy in the industrial sector. Energy constitutes sometimes 30-35% of the cost of production of the iron and steel industry. Coking and non-coking coal and electricity are the main energy sources. Percentage share of energy input in industry's total output is around 12% on an average over the period of 25 years. The main ingredient of energy in steel sector is coal. Average total energy intensity is found to be 1.09('000 mtoe/Rs crores).

Chemical Industry:

This industry is one of the energy intensive industries in India. Petroleum is the major source of energy used in chemical sector. Percentage share of energy input in total output cost appears to be around 11%. Total energy intensity varies from 0.50 to 0.77 with average intensity of 0.53('000 mtoe/Rs crores).

2. Background behind measuring energy intensity of those industries in India under consideration of our study:

India ranks sixth in the total energy consumption and needs to accelerate the development of the sector to meet its growth aspirations. The country, though rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy has very small hydro-carbon reserves (0.4 % of the world's reserve).India, like many other developing countries is a net importer of energy, more than 25percent of primary energy needs being met through imports mainly in form of crude oil and natural gas. The rising oil import bill has been the focus of serious concerns it has placed on scarce foreign exchange resources and also responsible for energy supply shortages. The sub-optimal consumption of commercial energy adversely affects the productive sectors, which in turn affects economic growth.

The use of energy from commercial sources (fossil fuels and electricity generation) in India has increased ten folds in sixty years since independence in 1947, and the total energy consumption from commercial sources was around 200 million tones of oil equivalent (mtoe)for the year 1998/99. The industrial sector consumes half of the total commercial energy available in India, 70% of which in energy intensive industries in India. An analysis of the share of commercial energy use by different sectors indicate that the industry is the most dominant sector, accounting for more than half of the total commercial energy use in the country (TERI. 2000c). If the pattern of energy production is noticed, coal and oil accounts for 54 percent and 34 percent respectively with natural gas, hydro and nuclear contributing to the balance. In the power generation front, nearly 62 percent of power generation is from coal fired thermal power plants and 70 percent of coal produced every year in India has been used for thermal generation.

On the consumption front, the industrial sector in India is a major energy user accounting for about 52 percent of commercial energy consumption. Per capita energy consumption in India is one of the lowest in the world. But, energy intensity, which is energy consumption per unit of GDP, is one of the highest in comparison to other developed and developing countries. The increased energy intensity in Indian industry is partly due to investments in basic and energy intensive industries due to emphasis laid in the past development plans on achieving self reliance. It is 3.7 times that of Japan, 1.55 times that of United States, 1.47 times that of Asia, and 1.5 times that of the world average. Thus there is a huge scope for energy conservation in the country.

In view of scarce energy resources in India, it is necessary to examine the import dependence of fuel supply. The data of fuel consumption, production within the country and the imports each year in detail is set out in Table-1.

[Insert Table-1 here]

The above table shows that the import dependence has increased in the decade of the 1980s and 1990s and this is due to the increased imports of oil products. The increase in oil import dependency has generated a phenomenal growth from a low 23 per cent in 1980-81 to 86 per cent in 2005-06. At present, no single source or mix of sources is at hand to meet the specifications. Although India is rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy, its hydrocarbon reserve is really small (0.4 per cent of world.s reserve). Current reserve-to-production ratio for coal, oil and natural gas are 235, 23 and 35 years respectively. India, like many other developing countries, is a net importer of energy, 20 per cent of primary energy needs being met through imports mainly in the form of crude oil and natural gas. The rising oil import bill has been the focus of serious concern due to the pressure it placed on scarce foreign exchange resources and also, because it is largely responsible for energy supply shortages. The suboptimal consumption of commercial energy adversely affects the productive sectors,which in turn hamper economic growth.

From the above analysis, it is quite evident that India still is an importer of energy, particularly of oil. An increase in reliance on oil import, due to increase in demand will put severe pressure on foreign exchange reserves. Moreover, energy costs enter into the cost structure of all productive sectors of economy as universal input.

The quadrupling of oil prices and subsequent rise of coal and electricity cost during 90s and thereafter accompanied by gradual withdrawal of fuel subsidy by India Government had a profound, permanent impact on the Indian economy. The initial impact was an explosion in the prices of most of the goods and services. The large increase in the prices of energy during those periods permanently reduced economic capacity or the potential output of Indian economy. The productivity of existing capital and labour resources was sharply reduced.

From the viewpoint of environment, the concentration of carbon dioxide (CO2) in the atmosphere has been increasing over the last two decades at the average rate of about 0.5 percent per year. In October 1989, the CO2 concentration level in the atmosphere (Mauna Loa Observatory) was 350.1 ppm (parts per million), and in December 2009, it had risen to 387.3 ppm. Some recent studies have indicated that inconceivable catastrophic changes in the environment will take place if the global temperatures increase by more than 2° C (3.6° F). A warming of 2° C (3.6° F) corresponds to a carbon dioxide (CO2) concentration of about 450 ppm in the atmosphere. CO2 concentration, as noted above, has already crossed 380 ppm and it has been rising on average 2-3 ppm each year. Thus, the critical value will be reached in approximately 20 to 30 years from now. Hence, the serious adverse effect that the current rate of increase in CO2 concentration, if maintained, can have on the global environment in course of time is a very important issue today.

If CO2 emissions are halved by 2050 compared to the 1990 level, global warming can be stabilized below two degrees. This may be contrasted with the growth that has actually taken place in CO2 emissions since 1990. Between 1991 and 2008, CO2 emissions have grown from 21.6 billion tones to 31.5 billion tones, an increase by about 46 percent. The annual growth rate of emissions at the global level in the 1990s was about one percent per year, while that in period 2000 to 2008 was about more than 3 percent per year. The CO2 emissions from India and China have been growing faster than the growth rate at the global level. The CO2 emissions from China increased by about 150 percent between 1990 and 2006. China's share in global CO2 emissions increased significantly in this period and reached 21.5 percent in 2006. The CO2 emissions from India grew by about 125 percent between 1990 and 2008. The share of India in global CO2 emissions has increased over time, and it was about 5 percent in 2008. It may be mentioned in this connection that the CO2 emissions from India are expected to grow three to five times by 2031 as the economy expands and population increases (Government of India, 2009).From 1.4 billion tones in 2008, the emission level is projected to increase to somewhere in the range of 4 to 7.3 billion tones in 2031. In spite of this increase in emissions, India's share in cumulative CO2 emissions will remain relatively low. While China's share in cumulative CO2 emissions in the period 1990 to 2030 is expected to be about 16 percent approaching the shares of US (25 percent) and EU (18 percent), India's share in cumulative emissions during 1990-2030 is projected at 4 percent. In the United Nations Climate Change Summit in Copenhagen, held December 2009, the United States has agreed to cut its greenhouse gas emissions by roughly 17 percent by 2020, as compared to the 2005 levels. This is a major change from the trends in the past. The U.S. had not ratified the Kyoto Protocol, a regime that would have obliged it to reduce its emissions by a fixed percentage below 1990 levels. The U.S. has, in fact, increased its carbon dioxide emissions by 20 percent between 1990 and 2007.China, which had a growth rate of CO2 emissions of about 10 percent per annum and has recently taken over the US as the leading country in CO2 emissions, has declared that it would bring down the carbon intensity of its economy by 40 to 45 percent below the 2005 level by 2025. India has similarly announced a unilateral climate mitigation measure to reduce its carbon intensity level by 20 to 25 percent over the next 11 years. Of the various measures that could be taken for reducing carbon intensity, measures directed at improving energy use efficiency obviously occupy a very important place. There is a proposal to specify optimum energy use norms for various industries to be coupled with a system of trading in energy efficiency certificates. This is likely to be introduced soon and, if successfully administered, is expected to save about 10,000 MW energy every year. In the context of the government's emission intensity reduction plan for the nonagricultural sector by 20-25 percent in the course of next 11 years, a study of energy intensity of Indian manufacturing firms, especially what factors determine energy intensity, assumes considerable significance.3 The paper makes an attempt in that direction.

Industry is the major energy consumer utilizing about 50% of the total commercial energy use in India. The seven key industries – namely aluminium,cement,fertilizers, pulp& paper, chemicals ,fertilizer and steel - consumes about 65% of the total energy use in India. The energy intensity in some of these industries is reported to be higher than the industries in developed countries. One of the main reasons for higher energy use is the presence of obsolete and energy inefficient processes in some of these sectors. The seven industries under review occupy an important place in India's strategy of planned economic development where industrialization was considered the engine of growth for the rest of the economy. Iron and steel has always been considered essential to the development of all other industries. Aluminum is an essential input to the power sector, which is a priority sector in the Indian economy. As a versatile non-ferrous metal it has diverse applications beyond the power sector. Its importance is heightened by the fact that the country does not have an adequate resource base for copper while there are abundant reserves of bauxite ore which is the raw material for the manufacture of aluminum. Cement is a major input to construction and therefore its production along with iron and steel is considered an important index of development. The fertilizer sector has played a critical role in the success of India's green revolution, which has ensured much desired self-sufficiency in food. At present, India has a large and diversified fertilizer sector which ranks fourth in the world in terms of production. The paper industry apart from its widespread use in packaging is vital to the country's literacy, education and social development plans. On the basis of its perceived importance, the Indian government made the development of the iron and steel industry the exclusive responsibility of the state. The remaining four industries were open to private investment, but it was considered essential that the state regulate them. Looking back at the development experience of the last 50 years, one can see the important role these industries have played. Apart from providing the critically needed capital and intermediate goods for other industries, they have been a source of both direct and indirect employment for a large part of the population. At the same time, the development of these industries has become a source of concern because they consume a disproportionately large share of energy in the manufacturing sector, and as a result are a major source of greenhouse gas emissions. Additionally, they have been identified as major sources of local pollution.

The above discussion on energy issues led me to conduct the measurement of energy intensity of these industries to see how intensely these industries consume different types of energy in their production process.

3. Measurement of energy Intensity:

3.1. Description of data and measurement of variables:

The present study is based on industry-level time series data taken from several issues of Annual Survey of Industries, National Accounts Statistics, *CMIE* and economic survey, statistical abstracts (several issues), *RBI* bulletin on currency and finance, handbook of statistics on Indian economy, whole sale price in India prepared by the Index no of office of Economic Advisor, Ministry of Industry etc covering a period of 25 years commencing from 1979-80 to 2003-04. Selection of time period is largely guided by availability of data.[1]

As far as the data relating to energy sectors are concerned , we made use of the data published by the Centre for Electricity Authority (CEA) for electricity, Petroleum and Natural Gas Statistics (several issues) published by the Ministry of oil and natural gas for crude oil ,petroleum product and natural gas. While for the coal, we relied on the Coal India Dictionary besides different reports of central statistical organization (CSO), New Delhi, and Centre for Monitoring Indian Economy (CMIE), Annual Survey of Industries (ASI) etc.

Coal input to different sectors was divided by coal prices to convert rupee value of coal input into physical units (tons). The petroleum demand by production activities in the system consists of Furnace oil (FO), LSHS (both heavy distillates),HSD and LDO(middle distillates).Indian Petroleum and Natural Gas Statistics(1983-84,1989-90, 2003-04,2004-05) provided some idea about the usage pattern of refinery products for some production sectors. Similarly, volume of electricity consumption was taken into consideration. Energy consumed by different sectors in different forms and in different physical units is then converted into mtoe (million ton of oil equivalent) by applying some recent common conversion factors. Million ton of oil equivalent (MTOE) is the method of assessing work of calorific value of different sources of energy in terms of one ton oil. The following table shows the conversion procedure of different energy units into mtoe.

[Insert Table-2 here]

It is assumed that due to non availability of detailed data about the average calorific content of various grades of coal, the same average calorific value of coal is used in converting coal tonnage into mtoe units.

3.1. Model for assessing energy intensity of the industries taken up for the present study:

We define energy intensive industries to include those which are characterized by high energy to output ratios. These industries, therefore, account for a large share of total energy consumption in the manufacturing sector relative to their share in output. Energy intensity is often used as a measure of the efficiency with energy resources is being used. Typically constructed as the ratio of energy input to output, energy intensity provides a single, simple, easy to compute, summary measure of the efficiency with which energy is utilized. As is well known and widely noted, trends in energy intensity many not reflect underlying trends in technical efficiencies, but instead may reflect such factors as changes in the structure of industry. A decrease in energy intensity may reflect the fact that producers on an average are becoming more efficient at producing finished good. Energy efficiency is normally measured as the ratio of energy consumption to output (for example, Farla et al (1998), Han et al (2007), Young (2007), which is also used to measure energy intensity.

The concept of industrial energy intensity denotes the amount of energy required to produce one unit of output**.** Two basic approaches are in use to express industrial energy intensity − per unit of physical product and per unit of economic output. When output is measured in physical units, an estimate of physical energy intensity is obtained (e.g., PJ/tonne). Economic energy intensity, on the other hand, is calculated using monetary value of output measures (e.g., PJ/Rs.billion).

Energy intensity can be measured following various alternative methodologies.

A review of literature suggests that there are various alternative measures of energy intensity.

1. Energy -output ratio

2. Energy-value added ratio

3. Energy- capital ratio.

The practical use of energy-capital ratio as a measure of energy intensity gives rise to certain problems which arises from the problems related to the measurement of capital itself in the production process.

Misunderstanding around the use of energy-value added ratio comes from the theoretical contradiction between the very concept of value added approach and the definition of energy input. While former is defined as the total value added by the capital and labour excluding the contribution of other intermediate products, the latter 'energy input'- is an intermediate good in itself. From their empirical findings, Berndt and Wood (1975) call in question the reliability of factor demand studies based on value added specification as they invalidate the conventional value added specification of technology.

In this section, an attempt has been made to study the energy intensities of different sectors at an aggregate level which represents a set of measurable coefficients of the energy requirement for the formation of a unit of produced goods or services. Energy intensity is a prerequisite numerical exercise for the discussion on structural change in energy demand evaluation of a particular industry or area. Our energy intensity analysis covers the period from 1996-97 to 2004-05 which will definitely provide an insight into the both short-term as well as long term responses.

Iron and steel, cement, aluminium, fertilizers, paper and pulp, chemical, glass are some of the energy intensive industries in India. This section focuses on these seven industries regarding energy consumption vis-à-vis energy intensity.

In our study, energy intensity is defined as energy consumption in physical units of 'j'th industry per crore rupees of value added in that industry.

$E_{jkt} =$ Energy consumed in physical units in time't' by sector 'j' for energy type 'k'.

$P_{jt} =$ 'j'th industry's value added.

Energy intensity (of energy type 'k') of 'j'th industry is given by

$e_{jkt} = E_{jkt} / P_{jt}$

[Energy intensity for non-energy sector = '000 mtoe /crore Rs. where 'mtoe / Rs' is the mtoe(million ton of oil equivalent) required to produce one unit of output measured in value term , this coefficient is the measure of direct energy intensity].

3.2. Energy- input ratio

This ratio indicates the share of energy cost in total input or intermediate consumption. The terms "total input" and "intermediate consumption" are often interchanged, even though there is a difference in the way of data collection and the compilation methods employed. Input is often used in industrial statistics which covers the cost of all goods and services purchased by an establishment during a reference period and can, in the broadest sense, be classified into: i) materials and supplies; ii) energy; iii) industrial and non-industrial services. Input may not include the cost of some additional services purchased at the enterprise level, which are adjusted in the process of compilation of the production accounts for estimation of GDP and other macroeconomic variables. In this paper, reference is made to input for which data are available from the annual industrial surveys.

The energy input ratio is calculated as relation of energy cost to total input of manufacturing activities.

$e_j^{\,m} = x_j / C_j^{\,m}$

Where $e_j^{\,m}$ = energy input ratio

$x_j =$ cost of energy

$C_j^{\,m}$ = total input

Suffix *j* stands for a manufacturing sector.

Using the industrial survey method, energy cost comprises the cost of fuel and electricity. Actual consumption of fuel is derived from the purchase of fuel during a given year at purchasers' prices and change in stock. The value of electricity consumed by an industrial establishment is calculated as the difference between the value of electricity purchased and sales to a third party of its own generation. Electricity generated for self consumption is included in the electricity balance of an enterprise but not in production costs. Omission of this item may underestimate energy costs at the firm level, but at the sector level its share is quite negligible.

Alternatively, we also make use of energy-output ratio in estimating energy intensity for seven Indian manufacturing industries-Cement, Glass, Paper and paper products, Fertilizer, Aluminium, Iron and Steel and chemical- under consideration of our study. Therefore, the present study also examines energy-output ratio towards evaluation of energy intensity for individual manufacturing industry.

4. Results showing measurement of energy intensity:

The following two tables (3 & 4 below) depict the result of coal, electricity and petroleum intensity as well as total intensity of seven Indian manufacturing industries under our consideration over a period of 1996-97 to 2004-05.

[Insert Table-3 here]

In table 3, average total energy intensity is computed by taking combined average of coal, electricity and petroleum intensity in each sector taken up for our study. It has been found out that aggregate manufacturing displays an average total intensity of 0.3863 ('000 mtoe/ Rs crore).The industries considered for our study – cement, iron&steel, fertilizer, aluminium, chemical, paper&pulp and glass sectors – are treated as energy intensive because average total intensity in those industries are considerably higher in comparison with that of aggregate manufacturing sectors. Moreover, there exists inter industry variations in energy consumption in these industries. It shows that cement industry's total intensity is 3.7161being highest whereas least intensity is noticed in aluminium industry. Out of three types of energy intensity comprising total energy intensity, coal intensity, electricity intensity and petroleum intensity are the highest in cement,aluminium and iron industries respectively.

Alternatively, the step towards identifying energy intensity trends is to calculate overall energy intensity, a general indicator of energy end-use. Energy intensity is defined here as the amount of energy (in Rs) used to produce a unit of output by accumulating different inputs (in monetary units, Rs.). This is simply obtained by dividing deflated energy consumption by deflated inputs. Energy intensity values in Indian industries based on inputs utilized over the period (1979-80 to 2003-04) are provided in Table 4.

[Insert Table-4 here]

From our analysis of energy-output ratio(table-4), it has been noticed that all the seven industries taken into our consideration have greater energy intensity in comparison with energy intensity of aggregate manufacturing sector. In this measurement also, energy intensity in cement industry is the highest and least energy intensed industry is chemical. Inter-industry variations among different industry groups are also noticed over years.

[Insert Figure-1 here]

Cement industry is the most energy intensive showing intensity of around 28 percent and others are ranked accordingly and chemical is the least energy-intensive. Therefore, there is no difficulty in considering those industries having comparatively greater intensity as energy intensive industries.

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5.Conclusion:

The study shows that seven manufacturing industries under our consideration have been depicting varied energy intensities which are well above the average intensity of the entire aggregate manufacturing industry. Moreover, energy intensity varies across industry over years. Therefore, energy intensity changes over time and varies significantly by types of economic activities. Statistics provide an accurate measurement for such variations, which is instrumental to the correct assessment of efficiency in energy use. This paper has been prepared on the basis of limited data from a small sample only. For a more comprehensive analysis, aimed to discover the economic and technological efficiency of energy use, data collection should be extended to a larger sample of countries.

The seven key industries under consideration of our study- namely cement, iron&steel, chemical, aluminium, paper&pulp, glass and fertilizer- consumes about 65% of the total energy use in India. The energy intensity in some of those industries is reported to be higher than the industries in developed countries. One of the main reasons for higher energy use is the presence of obsolete and energy inefficient processes in some of these sectors. Therefore, measures have to be initiated for modernizing the obsolete plants within the industries that will surely be the productivity enhancing mechanism. Immediate initiatives have to be taken for drawing up energy consumption norms for various kinds of fuel using equipment. In the absence of energy consumption norms for various energy intensive industries in India, these industries have adopted their own benchmarks. The common practice is to compare their performance with the best specific energy consumption figure in that particular sector/region or their own best figure achieved in the recent past. This attempt may not be adequate. The plants within those industries should also set their long-term goals and year-wise targets may be framed to achieve these goals. Few plants in India have achieved specific energy consumption figures which are very close to the best in the world, despite all the constraints. All plants should carefully plan out a roadmap leading to similar objective which will help them to be least cost producer of their product and become competitive globally. The strategies should be to introduced to use alternative fuel like CN.G, Natural gas and bio gas fuel instead of oil to cover up the extra strain arising due to severe oil price hike.

From managerial viewpoint, demonstration of top management's participation in energy management and encouragement to the employees for the same is very important to the shop floor workers. All energy intensive industries should have a dedicated energy management cell with a full time ‘Energy Manager’ who will be responsible for supervision of its operations. The energy management cell should provide essential structure and formalize the process of energy conservation thereby enhancing its efficacy with full support from top management.

India needs a sustainable energy policy that will not only meet the future energy demand for rapid economic growth but also protect the environment and conserve scarce resources. By making our thermal power sector more efficient, increasing the use of environmental management systems in energy-intensive industries, imposing stringent emission norms industrial sector, expanding the use of renewable energy technologies and introducing the Energy Conservation Bill, 2000 by Government of India, India has already taken major steps in the right direction. Industry associations can play an important role to spread the culture of energy efficiency among its plants on a larger scale. In few selected energy intensive industrial sectors, such as, aluminium, cement, chlor-alkali, fertilizer, pulp & paper, petrochemicals, refinery, and textiles, industry association has set up a 'task force' of selected plants and association from that sector with an objective to promote energy efficiency on a sectoral basis. These forums could be utilized by these plants to showcase successful case studies on energy conservation in their premises, share best practices, keep track of international scenario, technological advances occurring in their field and market conditions etc. These forums can also help in framing energy consumption norms and targets for that particular sector.

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Table 1: Consumption, production and imports of commercial fuels

Sl.	Item	Units	1980-81	1990-91	1995- 96	2000- 01	2005- 06
1	Coal/Lignite consumption	mtoe	58.5	108.2	140.7	169.1	181.9
2	Coal Imports	mtoe	0.2	4.0	9.0	11.0	12
3	Dependency of Coal	%	0.3 %	2.8 %	4.4 %	7.0 %	6.7 %
4	Oil Product Consumption	mt	31	68.2	77.3	98.6	99.2
5	Oil Imports as Crude Products	mt	7	26.1	49.8	83.4	85.7
6	Oil imports Dependency	%	23	38	64	85	86
7	Consumption of Natural Gas (All domestic)	mtoe	0.2	10	16	25	27
8	ElectricityConsumption (All domestic)	mtoe	5.0	6.0	8.0	8.0	9.0
9	Total fuel imports as % of total Consumption in toe terms.		8	16	24	24	31

Source: Compiled from several issues of Coal Bulletin, CMIE, Petroleum & Natural Gas Statistics, and Annual Survey of Industries.

Table-2: Conversion factors for transforming different energy inputs into million ton of oil equivalent (mtoe)

Energy inputs	Present energy unit	Conversion factor

		(into mtoe)
Coal	1 million ton	0.67 million ton of oil equivalent
Electricity	12000 million KWH	0.86 million ton of oil equivalent
Petroleum	1 million ton petroleum	1 million ton of oil equivalent

- **One million =10 ^{6} =10, 00,000**
- **Source: TATA energy Data Dictionary and Year Book.**

Table-3:Energy intensity in selected manufacturing sectors in India ('000 mtoe/Rs crores)

Industry/ Years	Energy intensity	1996-'97	1997-'98	1998-'99	1999-'00	2000-'01	2001-'02	2002-'03	2003-'04	2004-'05	Average of entire time periods
Cement	Coal Intensity ('000 mtoe/Rs crores)	3.5637	2.5509	3.2219	2.6714	2.3289	2.7919	2.9882	3.521	3.8703	3.0565
	Electricity Intensity ('000 mtoe/Rs crores)	0.1803	0.1539	0.1626	0.1362	0.1101	0.1240	0.1356	0.1406	0.1303	0.1415
	Petroleum Intensity ('000 mtoe/Rs crores)	0.1811	0.1865	0.4044	0.6142	0.54157	0.6211	0.7289	0.6562	0.7293	0.5181
	Total Intensity('000 mtoe/Rs crores)	3.9250	2.8914	3.7888	3.4217	2.9806	3.5369	3.8525	4.3178	4.7299	**3.7161**
Iron& Steel	Coal Intensity('000 mtoe/Rs crores)	0.84041	0.35892	0.89744	0.89047	0.86120	0.62374	0.68935	0.84107	0.85108	0.7615
	Electricity Intensity ('000 mtoe/Rs crores)	0.01400	0.08226	0.10703	0.10574	0.09549	0.11442	0.13950	0.14257	0.17148	0.1081
	Petroleum Intensity ('000 mtoe/Rs crores)	0.00726	0.34373	0.19160	0.18174	0.24464	0.19494	0.17552	0.25826	0.38749	1.0901
	Total Intensity ('000 mtoe/Rs crores)	0.8616	0.7849	1.1961	1.1779	1.2013	0.9331	1.0044	1.2419	1.410	**1.090**
Aluminium	Coal Intensity ('000 mtoe/Rs crores)	0.1522	0.1377	0.154	0.1706	0.1139	0.1416	0.0529	0.0677	0.1005	0.1212
	Electricity Intensity ('000 mtoe/Rs crores)	0.3915	0.1837	0.2124	0.1434	0.1408	0.167	0.1852	0.1335	0.2355	0.1992
	Petroleum Intensity ('000 mtoe/Rs crores)	0.26413	0.16768	0.08606	0.05539	0.09604	0.12873	0.1298	0.16158	0.16861	0.1398
	Total Intensity ('000 mtoe/Rs	0.80783	0.48908	0.45246	0.36939	0.35074	0.43733	0.3679	0.36278	0.50461	**0.4602**

	crores)										
Paper	Coal Intensity ('000 mtoe/Rs crores)	1.20129	0.89006	0.98717	0.99980	1.07200	1.15195	1.22390	1.46147	1.09060	1.1198
	Electricity Intensity ('000 mtoe/Rs crores)	0.09592	0.08575	0.08534	0.07214	0.06866	0.06435	0.07315	0.07251	0.07499	0.0769
	Petroleum Intensity('000 mtoe/Rs crores)	0.10640	0.26588	0.25044	0.31710	0.38180	0.34705	0.40085	0.4559	0.43943	0.3294
	Total Intensity('000 mtoe/Rs crores)	1.4036	1.24169	1.32295	1.38904	1.52246	1.56335	1.69790	1.98988	1.60502	**1.5262**
Fertilizer	Coal Intensity('000 mtoe/Rs crores)	0.48403	0.42044	0.55369	0.55577	0.51135	0.59221	0.49925	0.66869	0.64162	0.5475
	Electricity Intensity ('000 mtoe/Rs crores)	0.09282	0.07430	0.06434	0.05526	0.04718	0.04396	0.02920	0.03759	0.03124	0.0529
	Petroleum Intensity('000 mtoe/Rs crores)	0.36791	0.26315	0.19273	0.26515	0.46727	0.17157	0.16738	0.37982	0.32025	0.2884
	Total Intensity ('000 mtoe/Rs crores)	0.94476	0.75789	0.81076	0.87618	1.0258	0.80774	0.69583	1.0861	0.99311	**0.8887**

Source: Own estimate

Table-3: Energy intensity in selected manufacturing sectors in India (Cont.)

Industry/ Years	Energy intensity	1996-'97	1997-'98	1998-'99	1999-'00	2000-'01	2001-'02	2002-'03	2003-'04	2004-'05	Average of entire time periods
Glass	Coal Intensity ('000 mtoe/Rs crores)	0.33567	0.21179	0.27764	0.25839	0.18245	0.12904	0.11656	0.15728	0.17549	0.20492
	Electricity Intensity ('000 mtoe/Rs crores)	0.07336	0.07269	0.07081	0.06681	0.05856	0.04841	0.06506	0.06467	0.07498	0.06615
	Petroleum Intensity('000 mtoe/Rs crores)	0.37191	0.59046	0.46234	0.69446	1.11062	0.77407	1.18428	1.26632	1.12479	0.84214
	Total Intensity('000 mtoe/Rs crores)	0.78094	0.87494	0.81079	1.01966	1.35163	0.95152	1.3659	1.48827	1.37526	**1.1132**

Chemical	Coal Intensity('000 mtoe/Rs crores)	0.13262	0.13606	0.20908	0.07409	0.10470	0.10327	0.25340	0.14201	0.12149	0.1419
	Electricity Intensity ('000 mtoe/Rs crores)	0.06136	0.06373	0.04958	0.03915	0.03289	0.04235	0.06059	0.04083	0.04674	0.04858
	Petroleum Intensity('000 mtoe/Rs crores)	0.31229	0.24538	0.23302	0.22780	0.45030	0.29220	0.46018	0.32520	0.45714	0.3337
	Total Intensity('000 mtoe/Rs crores)	0.50627	0.44517	0.49168	0.49168	0.58789	0.43782	0.77417	0.50804	0.62537	**0.5242**
Aggregate manufac-turing	Coal Intensity('000 mtoe/Rs crores)	0.1415	0.1396	0.1475	0.1522	0.174	0.1607	0.1648	0.1553	0.1399	0.1528
	Electricity Intensity ('000 mtoe/Rs crores)	0.03013	0.03006	0.03069	0.03013	0.0302	0.0329	0.0288	0.0258	0.0223	0.0290
	Petroleum Intensity('000 mtoe/Rs crores)	0.1241	0.2954	0.3617	0.1353	0.1929	0.1878	0.1411	0.1418	0.1305	0.2045
	Total Intensity('000 mtoe/Rs crores)	0.2957	0.4650	0.5389	0.3176	0.3971	0.3814	0.3347	0.3229	0.2927	**0.3863**

Source: Own estimate

Table-4: Measurement of Energy intensity by Energy-Input ratio (%)

Year	Cement Industry	Aluminium Industry	Glass Industry	Fertilizer Industry	Paper Industry	Iron&Steel Industry	Chemical Industry	Aggregate manufacturing
1979-	28.37	23.24	21.71	14.40	12.59	16.73	10.13	6.47
80-81	27.68	24.27	20.97	14.29	15.34	16.05	9.45	6.93
81-82	28.64	24.56	24.08	15.01	15.92	13.57	10.44	7.12
82-83	27.42	23.66	24.91	14.75	16.53	13.48	10.54	7.54
83-84	29.19	29.52	22.2	14.89	16.56	15.37	11.78	8.39
84-85	27.26	30.36	21.69	15.19	16.54	13	11.29	8.70
85-86	28.86	27.26	22.99	14.91	14.66	13.39	10.85	9.15
86-87	30.85	28.73	22.5	14.65	15.69	12.37	11.69	9.06
87-88	31.65	30.12	22.27	18.12	15.01	12.32	11.83	9.30
88-89	26.83	28.63	22.33	16.31	15.22	11.47	10.27	7.69
89-90	30.53	29.39	22.58	20.27	14.30	10.43	11.35	7.76
90-91	32.41	25.44	18.53	16.27	13.76	11.35	11.08	7.72

91-92	30.93	29.99	21.69	15.25	14.53	10.88	10.18	8.04
92-93	30.80	25.03	19.57	14.82	14.28	10.44	10.32	8.43
93-94	32.34	20.61	18.84	14.24	13.36	10	9.66	7.92
94-95	31.37	24.35	18.12	14.17	14.45	10.93	10.25	7.80
95-96	32.60	25.87	19.05	13.36	14.29	11.47	10.23	7.23
96-97	27.67	24.21	16.82	14.18	13.12	12.12	10.18	7.87
97-98	26.97	15.83	15.17	12.52	11.8	10.36	9.68	7.12
98-99	26.28	18.4	15.48	10.35	10.98	10.68	7.25	5.90
99-00	24.64	18.9	16.08	10.58	11.22	9.99	7.85	6.15
00-01	19.81	18.87	15.89	11.84	9.28	9.19	8.26	6.36
01-02	25.28	21.17	12	10.93	8.76	8.55	8.14	6.21
02-03	20.67	21.19	16.02	10.42	9.12	9.79	8.89	5.89
03-04	21.57	17.57	15.68	12.46	8.68	10.33	8.31	5.73
average	**28.04**	**24.29**	**19.49**	**14.17**	**13.44**	**11.77**	**9 .97**	**7.46**

Source: Own estimate from ASI (several issues)

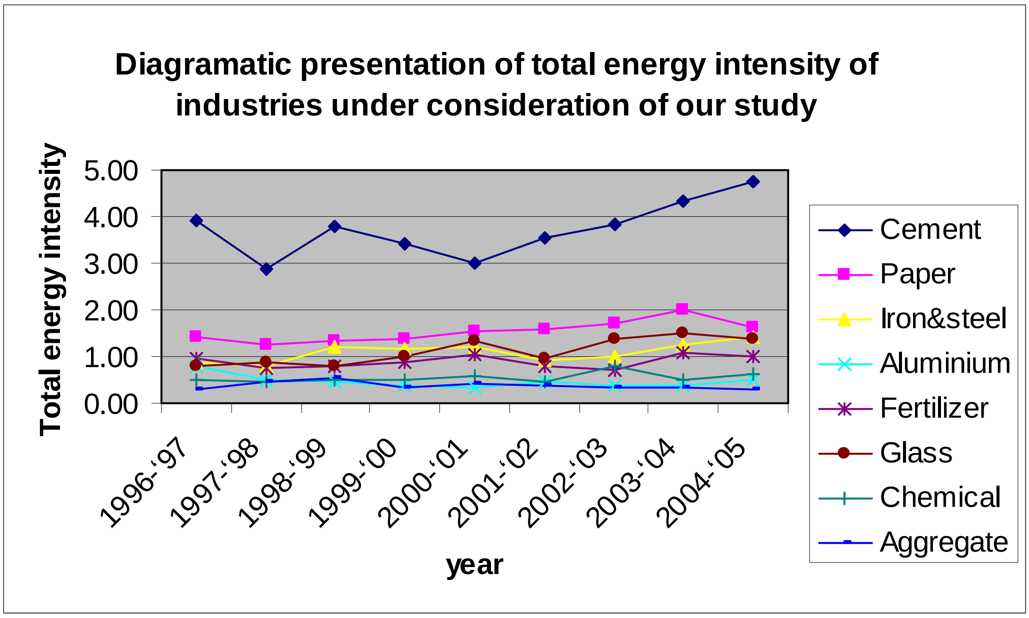

Figure:1