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Abstract

We develop and analyze physical energy intensity indicators for Indian manufacturing sector. Energy consumption in five industrial sub-sectors, viz., iron and steel, aluminium, textiles, paper and cement is examined for the period 1990–2005. It is feasible to develop specific energy consumption indicators that reflect the physical reality more accurately than monetary energy intensities. These indicators allow us to analyze the effect of change in product mix over time. The use of physical energy intensity indicators improves comparability between countries, offers valuable input for policy-makers regarding intra-sectoral structural changes, and provides detailed explanation for observed changes in energy intensity. Hence, the results of the study point out the need to use physical indicators for policy making.

Key words: Energy intensity, manufacturing/industry sector, product mix, energy indicators

JEL Codes: P28, Q42, Q43

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1. INTRODUCTION

India ranks sixth in the world in total energy consumption and needs to accelerate developments in energy sector to meet its growing needs. The country is rich in coal and other renewable energy resources (like solar, wind, hydro and bio-energy) but has very small hydrocarbon reserves (0.4 percentage of the world's reserve) and hence is forced to import over 25 percent of its primary energy needs as crude oil and natural gas. Industrial sector consumes nearly 50% of the total commercial energy. Hence, it is essential to improve the efficiency levels; for this, one has to understand past trends in energy use and assess the factors that contribute to changes in energy consumption and measure the performance of energy-related policies. The three main factors that determine the level of energy consumption in an economy are: overall activity or production levels, structure of the economy, and the output or activity per unit of energy use. This last component is referred to as energy intensity[1], and reduction in it occurs when the level of service/activity/output are enhanced for a given amount of energy inputs. Since it is relatively easy to understand the relationship between the amounts of energy needed to produce one physical unit of some good, changes in physical indicators are likely to provide reliable estimates of changes in energy efficiency (Phylipsen *et al*. 1996, 1997; CIEEDAC 1996; Farla *et al.* 1997). Energy intensity is inversely related to efficiency; less the energy required to produce a unit of output or service, the greater is the efficiency. A logical conclusion, then, is that declining energy intensities over time may be indicators of improvements in energy efficiencies. A more useful indicator of energy intensity may be the ratio of sectoral/sub-sectoral energy use to the output or activity of the sector/ sub-sector.

In the past few decades, indicators that reflect changes in energy intensity have been used to monitor efficiency changes and cross-country comparisons are made. Prior to mid─80s, however, policy-makers were primarily concerned with the effect of shifting energy consumption on economic growth. As a result, energy policies were often coupled with economic policies that were typically implemented to boost a nation's economic performance. In the current debate, global warming and climate change shifted the focus, in part with the efficiency of energy

[1] Energy intensity refers to the energy used per unit of output or activity. Total energy consumed in a sector, for example, is a product of energy intensity per unit of output and the total amount of output provided. When output is measured in physical units, an estimate of physical energy intensity is obtained (e.g., TJ/tone). Economic energy intensity, on the other hand, is calculated using dollar value output measures (e.g., TJ/Gross Domestic Product in rupees).

use. This is because fossil fuels such as coal and oil create energy directly related to the level of carbon dioxide emissions in the atmosphere. The more fossil fuels are burned, the greater is the level of CO_2 emissions. Although increasing economic growth is still a priority for many governments, the focus has shifted to capitalizing the environmental benefits associated with efficient use of resources rather than just the economic benefits of conservation. The amount of energy consumed by a country and the efficiency of that energy use are the two major factors determining a country's overall performance of economic as well as of environment. In other words, policy-makers are increasingly concerned with physical along with that of economic implications of energy use. The changes in energy intensity can provide policy-makers with the information needed to design appropriate greenhouse gas mitigation strategies. As a result, energy intensity indicators (particularly cross-country comparisons of them) are increasingly being touted as a very useful and necessary instrument for climate change negotiations and policy-making

In the present study, manufacturing energy use is disaggregated into five sub-sectors. They includes; iron and steel, paper and pulp, aluminium, cement and textiles. We examine the energy intensity, measured as delivered or final energy per unit of output for each of these sub-sectors. We measure the impacts of changes in sub-sectoral energy-intensity on manufacturing energy use and compare changes over time. In order to assure international comparability, disaggregation is limited to two or three digit sectors. Data are taken from industrial statistics and national energy studies (CMIE and Prowess). In addition to extending the analyses over three periods (1990─95, 1995─2000 and 2000─2005) and reorganizing the sectors somewhat we have also corrected and updated the previous data using new information wherever available. Lack of data, particularly prior to 1990, makes it difficult to study intensity changes on a more disaggregated level.

2. ENERGY USE IN INDUSTRY

It is important to note that industrial energy consumption differs significantly from that of other sectors, particularly residential and commercial.

(i)E*lectricity:* The industrial sector is relatively less dependent on purchased electricity than the commercial and residential sectors since it produces a significant fraction of its own power through direct fuel inputs and some industries, through cogeneration. A form of cogeneration is combined heat and power (CHP), which produces thermal and electric energy from a single fuel source.

(ii)Petroleum products: Petroleum products represent a larger fraction of industrial energy inputs than those of the commercial and residential sectors. However, a large fraction of consumption is not for fuel use, but rather as raw material for petroleum refining and chemical manufacturing.

(iii)Natural gas: In the industrial sector, natural gas represents a significant fraction of total energy consumption than for other sectors. In addition to fuel use, natural gas is also an important raw material in industries such as chemical manufacturing and petroleum refining.

(iv)Coal: Despite being an important fuel source for some industries, the use of coal by the industrial sector has declined steadily since 1950 (when it was the largest fraction of industrial fuel inputs) to a relatively small fraction of industrial fuel inputs today. Over the same period, use of coal in electric power generation has grown rapidly (currently supplying more than 60 percent of energy inputs for electric power generation), and thus represents an important, though indirect, source of energy for all three end–use categories except in transportation, particularly commercial and residential sectors.

(v)Renewable: The industrial sector is a significant user of renewable fuels, in part due to the extensive use of biomass fuels in paper and pulp products industry.

As shown in Table 1, between 1990 and 2005, the shares of coal consumption decreased from 89 to 69% whereas the share of petroleum products rose from 3.4 to 14.6%. The share of electricity has not increased significantly due interrupted supply. Due to this concern, industries used to generate electricity at their captive units and hence then increase in the share of petroleum products. Hence, there is an increase in the shares of internal energy generation with respect to total energy (generation + purchased electricity) in almost all sectors except iron and steel industry—aluminum (16%-24%), cement (16%-43%), paper (42-54%), and textiles (14-44%) .

Table 1: Energy consumption across industries

	Energy Consumption (Peta Joules)									
Years	1990					2005				
Industries	Coal	Elect.	Gas	Petro.	Total	Coal	Elect.	Gas	Petro.	Total
Iron and Steel	495.6	17.4	0.1	17.2	530	640.4	45.3	2.3	40.2	728
Aluminum	113.1	8.8	0	3.6	126	224.3	38	0	46.5	309
Textiles	18.5	11.6	0.3	7	37	20.2	169.8	4.6	178.7	373
Cement	224.1	18.9	6.9	4.2	254	392.1	52.2	4.5	22.3	471
Paper	42.8	9.3	0.2	1.7	54	100.6	10.8	1.8	3.4	117
Total	894.1	66.1	7.6	33.7	1002	1377.6	316.1	13.3	291	1998
Share (%)	89.3	6.6	0.8	3.4	100.0	68.9	15.8	0.7	14.6	100.0

To investigate the changes in energy use and production, we compare the data of 2005 with that of 1990 (correcting for changes in the structure of manufacturing). Not surprisingly, there is a major decline in the growth rate of energy use in steel, cement and paper implying that these industries have achieved energy efficiency in a big way. A significant share of this decline may be due to overall reduction in energy intensity, and the rest by reduced share of oil in manufacturing energy use. The energy use continues to be higher in case of aluminium, and textiles (Table 2).

Table 2. Production and primary energy consumption by sub sector

Sub sector	Production			Growth rate (%)	Energy Use (PJ)		Growth rate (%)
	Unit	1990	2005		1990	2005	
Iron and Steel	Mt	38.4	61.1	3.1	530	728	2.1
Aluminum	Mt.	2.3	4.6	4.7	125	308	6.2
Textiles1[2]	M. Sq. meter.	1613	11767	14.2	33	317	16.4
Textiles2	Mt.	0.4	3.3	16.1	4.4	56.4	18.5
Cement	Mt.	32.5	116.9	8.9	254	471	4.2
Pulp and paper	Mt.	1.3	4.4	8.6	54	116	5.3

3. ENERGY INTENSITIES ACROSS INDUSTRIES

Energy use is usually measured at the point of consumption, i.e., the factory or establishment. "Own energy" (including internal use of hydropower, biofuels, or internal waste heat) should be combined with purchased energy at useful heating values. It is also possible to measure total energy consumption, internal and external, for any final product by using input and output tables to measure the energy embodied in materials and intermediate products. This is much more data- intensive as the input and output tables are complex. There are different approaches for measuring output in manufacturing sector. Physical output would be preferred for most homogenous products across a firm. However, using energy consumption data is not accessible from many countries since aggregate physical output can not be easily defined in many sectors in which case the earlier method of estimating energy intensity can be applied. As the homogeneity across the product increases, we would be able to approach better indicator for energy intensity and similar way can define the emission/CO_2 intensity.

3.1 Iron and Steel Industry

The Indian steel industry is categorized into two groups: (i) Major producers (integrated steel mills), and (ii) other producers (electric arc furnace). Major producers use blast furnace to produce molten iron from iron ore, coal, coke, and fluxing agents. A basic oxygen furnace (BOF) is used to convert molten iron, along with up to 30 percent steel scrap and alloys, into refined steel. Electric arc furnace (EAF) steel mills utilize steel scrap and up to 30 percent of other iron-bearing materials to produce steel. EAF steel plants primarily produce carbon steels as well as alloy and specialty steels. Some processors produce small quantities of steel (flat/long products) from

[2] ***Textile1****: Cloth and Gray Cloth;* ***Textile2****: Cotton yarn, Fabric, Jute goods, Polyester chips, Yarn*
OE=output effect on energy consumption.

materials procured from the market or through their own backward integration. India produces 71% of steel from blast furnace (pig iron) and the rest through DRI (sponge iron) produced by electric arc furnace, induction furnace and Corex routes. Scrap is the main input for producing steel through electric arc furnace (EAF) or induction furnace (IF) routes. The EAF route is an efficient one for manufacturing steel in moderate-size plants and in regions where scrap supply is abundant and power is cheaply available (Table 3)

Table 3: Iron Production (mt) - Process wise (India and the world)

Region	Product	Avg. (mt/annum)		
		1991-95	1996-2000	2001-2005
India	Pig Iron (BOF)	15.63	20.62	24.8
	Sponge Iron (DRI)	2.10	5.16	7.64
	Total	17.73	25.78	32.44
	Share of DRI (%)	12.62	25.04	30.68
World	Pig Iron (BOF)	479.28	538.34	665.92
	Sponge Iron (DRI)	226.32	235.46	295.26
	Crude Steel	705.58	773.8	961.18
	Share of DRI (%)	47.55	43.7	44.48
	Indian Steel as % of World	2.53	3.34	3.4

Table 4: Physical energy intensity in iron and steel industry (1990-2005) (GJ/Tonnes)

Product	Energy intensity (GJ/ton)			Reduction (%)	Avg. annual change (%)	World best
	1991-1995	1996-2000	2000-2005			
Alloy steel	7.2	6.2	6.5	9.72	0.65	
Castings	5.8	5.1	5.5	5.17	0.34	0.1
Cold rolled strips	1.2	1.8	1.9	-58.33	-3.89	0.4
Ferro alloys	45	27.2	14.5	67.78	4.52	
Forged products	7	6.9	6.3	10	0.67	
Hot rolled coils	4.2	3.8	3.4	19.05	1.27	2.1
M.S. ingots	4.9	4.3	4.2	14.29	0.95	
MS rolled	3.4	3.5	2.8	17.65	1.18	
Pig Iron	24.1	16.6	17.3	28.22	1.88	14
Rolled products	3.7	3.8	3.1	16.22	1.08	
Sponge iron	26.9	27.3	29.2	-8.55	-0.57	
Steel	42.6	41.5	37.1	12.91	0.86	14.2
Steel billets	2.7	2.7	2.8	-3.7	-0.25	1.6

The iron and steel industry is the largest consumer of energy in the Indian industrial sector consuming about 10% of electricity and 27% of coal, which constitute nearly 35% of production cost. The primary sources of energy are coking and non-coking coal, liquid hydrocarbons and electricity of which coking coal accounts for about 75%. The process of making iron in blast furnaces accounts for nearly 70% of the total energy consumption. Indian industries consume nearly 7.2 - 8.2 million Kcal to produce one tone of steel, while units in the developed countries use around 5 million kcal. As shown in Table 4, every product, except cold-rolled strips, has achieved significant reduction in energy intensity during 1990─2005 ranging from 5.17% for alloy steel to almost 60% for ferro alloys. Although a few products experienced some increase, the general trend has been slower rates of decline. In the case of MS-rolled products, the intensity increased somewhat during 1996─2000, before it fell by 2005, resulting in almost 17% energy savings over the 15-year period during 1990─2005.

3.2 Pulp and Paper Industry

Paper is an energy-intensive product depending primarily upon forest-based raw materials (wood, bamboo and other non-conventional materials). The industry is divided into three categories: forest and agro-based, and other (waste paper, secondary fiber, bat fiber and market pulp). Presently, there are about 515 units (large and small-scale) engaged in the manufacture of paper and paperboards and newsprint. Any unit with a capacity of over 24,000 tones per annum is classified as large-scale plant. The output includes: writing paper, newsprint, magazine stock, paperboard, cardboard, sanitary tissue and other decorative products from cellulose fiber (wood). There are five steps in paper production: (i) Wood preparation, (ii) Pulping, (iii) Bleaching, (iv) Chemical recovery, and (v) Paper making. The pulping process accounts for 26% of the energy used, whereas bleaching accounts for about 7% and the rest for chemical recovery process. Two-thirds of the final energy needed to remove water is used in the drying section of a paper machine to remove the final 1% of water. Energy bill accounts nearly 25% of the manufacturing cost in paper industries. The energy intensity in Indian paper industry is higher than that of developed countries as reported in Table 5. The figures for electrical and thermal energy are: 1092 kWh/ton and 4.32 MKcal/ton, whereas the international values are around 650 kWh/ton and 2.9 Mkcal/ton, respectively.

Out of 100 units of energy consumed in pulp and paper industry, 75─80percentage is consumed in process heating and the rest as electric power. In order to produce one tone of dried pulp, 0.215 MKcal of power and 6.5 tones of steam are used in Kraft with black liquor recovery process, while 1.45 tones of steam and around 3.5 MKcal power are used in acid sulphite process–mills. In developed countries, steam used varies from 6─9 t/t and power from 1550─1250 kWh/t.

Table 5: Physical energy intensity in pulp and paper industry (GJ/ton)

Product	Energy Intensity GJ/ton			Reduction (%)	Avg. annual change (%)	World's best
	1991-1995	1996-2005	2000-2005			
Writing and printing paper	36.4	34.1	34.3	5.77	0.38	7.6
Paper and paperboards	22.9	24.2	21.8	4.80	0.32	9.6
Paper	34.1	32	30.6	10.26	0.68	7.3
Newsprint	35.8	31.9	29	18.99	1.27	7.2
Kraft paper	19.7	17.8	10.7	45.69	3.05	7.8
Average	29.82	28.06	25.35	14.99	0.99	

During 1991─95 and 2000─2005, energy intensity declined in every product of pulp and paper industry ranging from 10─46 percent across product range. In particular, significant reductions were achieved in real energy intensity in newsprint (46%). The real energy intensity in the paper industry declined by 15 per cent during1 990─2005 at an annual average rate of 0.99% (Table 5). The reduced energy intensity was largely caused by reductions in oil use after the jump in crude price in 1979. This was especially apparent in paper and pulp that have access to cheap occasional (interruptible) power and biomass.

3.3 Textile Industry

Electricity is the main energy consumption in textile industry, which is used for machinery, cooling, temperature control, lighting, office equipment, etc. Fuel oil, liquefied petroleum gas, coal and city gas are used in boilers to generate steam to drive the motor and compressor. Various end uses of steam are: dying and finishing, fiber production, spinning, weaving and clothing, manufacturing and lighting (Table 6).

Table 6: Overall Physical energy Intensity in textile industry (GJ/Ton or MJ/meter)

Product	Unit	Energy Intensity			Reduction (%)	Avg. annual change (%)
		1991-1995	1996-2000	2001-2005		
Cloth	MJ/meter	21.5	22.5	26.1	-21.40	-1.43
Cotton yarn	GJ/tonne	12.7	13.6	15.1	-18.90	-1.26
Fabric	GJ/tonne	46.3	43	32.4	30.02	2.00
Grey cloth	MJ/meter	10.6	16.2	15.9	-50.00	-3.33
Jute goods	GJ/tonne	4.5	3.6	3.2	28.89	1.93
Polyester chips	GJ/tonne	15.5	17.1	13.5	12.90	0.86
Yarn	GJ/tonne	19.3	20.9	21.2	-9.84	-0.66

In the textile industry, energy intensity rose for many products, although production fell during the same period. Most of the decline in energy intensity occurred in two products: fabric, jute goods and to a smaller extent to polyester chips.

3.4 Aluminum Industry

Aluminum is used in cans, scooters, construction, for making specialized alloys, automobiles and aerospace parts. The per capita consumption of aluminum in India is low at less than one kg per annum as against 25─30 kg in US and Europe, and 15 in Japan. The key industries in India that use aluminum are power, transportation, consumer durables, packaging and construction. Of these, power is the biggest consumer (about 44%) followed by infrastructure (17%) and transportation (10─12%). However, internationally, the pattern of consumption is in favor of transportation, primarily due to large-scale aluminum consumption by the aviation industry. Growing demand for consumer goods and automobiles in India is likely to give a huge boost to consumption of recycled aluminum, the demand for which is bound to shoot up as it is much cheaper than the primary metal and is environment-friendly too.

The primary aluminum production process consists of three-stages─ (i) mining of bauxite, (ii) refining of bauxite to alumina, and (iii) smelting of alumina to get aluminum. India has the fifth largest bauxite reserves with deposits of about 3 billion tones or 5% of world deposits. The production of one ton of aluminum requires two tones of alumina and that alumina requires 2─3 tons of bauxite. The aluminum production process can be categorized into two categories: upstream and downstream activities. The upstream process involves mining and refining while the downstream process involves smelting and casting and fabricating. Downstream-fabricated products consist of rods, sheets, extrusions and foils.

Aluminum production is very highly energy intensive process, and hence power is amongst the largest cost component in manufacturing of aluminum. Energy intensities seem to decline for most products, except for aluminium extrusion. For ingots and metal products, during 1996─2000, the intensity decreased somewhat, before it rose in 2005, resulting in almost about 6─8% energy savings over the 15-year (1990─2005).

Table 7: Overall Physical energy Intensity Aluminum Industry

Product	Average intensity (GJ/tonne)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2000	2000-2005		
Aluminium extrusion	14.55	15.99	17.45	-19.93	-1.33
Aluminium foil	10.43	11.57	11.95	-14.57	-0.97
Aluminium ingots	19.96	19.77	18.23	8.67	0.58
Aluminium metal	90.95	90.22	85.19	6.33	0.42

3.5 Cement Industry

Cement production is one of the most energy-intensive industries, with energy representing 30- 40% of the total production cost. Cement manufacturing requires very large amounts of energy and manufacturers use a variety of energy inputs. Among the most common types of fuels used are fuel oils, coal, petroleum, coke and natural gas. It is also one of the major industrial emitters of greenhouse gases, particularly CO2. Because of this, many companies have invested in energy efficiency measures, such as converting wet kilns to dry kilns, or to adding pre-calciners and pre-dryers. This gives energy efficiency improvement an important role in reducing production costs. Historically, energy intensity has declined and more recently seems to have stabilized. Energy intensity of cement production decreased due to increased capacity of the more energy efficient dry process for clinker making, energy efficiency improvements and reduced clinker production per ton of cement produced. The still relatively high share of wet-process plants in India suggests the existence of a considerable potential for energy efficiency improvement, when compared to industrialized countries.

Table 8: Specific physical energy Intensities in cement industry

Fuel	Average intensity (GJ/ton)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2000	2001-2005		
Coal	5.4	4.2	3.4	37.04	2.47
Elect.	0.6	0.5	0.5	16.67	1.11
Gas	0.2	0.1	0.1	50.00	3.33
Petro.	0.1	0.2	0.2	-100.00	-6.67
Total	6.3	4.9	4.2	33.33	2.22
Range	2.7 - 10.8	2.3 - 9.1	2.2 - 7.9		
Production	42.8	74.9	116.9		

Primary energy intensity in the cement industry decreased during 1990–2005, at an average rate of 2.2% per year. During the same period, it fell from 6.3 GJ/ton in 1990 to 4.2 GJ/ton in 2005 (Table 8). Table 7 also shows the developments in specific fuel and electricity consumption. It indicates a slow decrease in specific electricity consumption, which is due to increased penetration of the modern dry process (pre-heater/pre-calciner technology), but is very small in comparison to fossil fuel consumption. Specific fuel consumption decreases strongly during the same period. Between 1970 and 1999, primary physical energy intensity for cement production dropped 1%/year from 8.5 to 6.2 GJ/ton.

3.6 Carbon emissions and emission-intensities across industries

Since manufacturing accounts for about 80 percent of industrial energy consumption, energy-related carbon emissions in industry also account for the same level. The carbon intensity of energy use is the amount of carbon emitted per unit of product manufactured. Both the mix of energy sources used and the uses of energy affect carbon intensity. For electricity that manufacturers purchase, the carbon emissions occur where the electricity is generated, rather than at the manufacturing establishment. These emissions are assigned here to the ultimate product (Table 9).

Table 9: Carbon emissions through the use of various energy carriers

Industry category	Carbon emissions (Million tones)									
	1990					2005				
	Coal	Elect	Gas	Petro	Total	Coal	Elect.	Gas	Petro	Total
Iron and Steel	55.0	5.5	0.0	1.3	61.8	71.1	14.3	0.2	3.1	88.7
Paper	4.8	2.9	0.0	0.1	7.8	11.2	3.4	0.1	0.3	15.0
Aluminum	12.6	2.8	0.0	0.3	15.6	24.9	12.0	0.0	3.6	40.5
Textiles	2.1	3.7	0.0	0.5	6.3	2.2	53.7	0.3	13.8	70.0
Cement	24.9	6.0	0.5	0.3	31.6	43.5	16.5	0.3	1.7	62.0
Total	99.2	20.9	0.5	2.6	123.2	152.9	99.9	0.9	22.4	276.1
Share (%)	80.5	16.9	0.4	2.1	100.0	55.4	36.2	0.3	8.1	100.0

Table 10 presents an in-depth analysis of carbon intensities in Iron and steel industry. Here we discuss trends and make comparisons for this industry at the aggregate level, which include alloy steel, castings, cold rolled strips, ferro alloys, etc. Between 1990 and 2005, the carbon emissions increased from 60 to 89 million tonnes with annual growth rate of 3.3% in iron and steel industry during 1990─2005. Forged product and steel billets contribute around 80% to total emissions. The emission intensity decreases (less polluting than earlier) in almost all types of product except cold-rolled strips and sponge iron during 1990─2005.

Table 10: Emission Intensity of different products in Iron and Steel Industry

Product	Emission Intensity (T CO_2/ton)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2000	2000-2005		
Alloy steel	0.84	0.72	0.78	7.14	0.48
Castings	0.68	0.59	0.66	2.94	0.20
Cold rolled strips	0.14	0.21	0.22	-57.14	-3.81
Ferro alloys	5.29	3.19	1.75	66.92	4.46
Forged products	0.82	0.80	0.76	7.32	0.49
Hot rolled coils	0.49	0.44	0.41	16.33	1.09
M.S. ingots	0.57	0.50	0.50	12.28	0.82
MS rolled	0.39	0.41	0.33	15.38	1.03
Pig Iron	2.83	1.94	2.09	26.15	1.74
Rolled products	0.43	0.44	0.37	13.95	0.93
Sponge iron	3.16	3.20	3.53	-11.71	-0.78
Steel	5.00	4.87	4.48	10.40	0.69
Steel billets	0.31	0.31	0.33	-6.45	-0.43
Overall	1.61	1.27	1.22	23.78	1.58

Physical energy intensity of alloy steel production, defined as primary energy use per metric ton of product, dropped 7.4%, from 0.84 to 0.78 T CO_2/t between 1991 and 2005. The highest reduction achieved for ferro alloys was 66% with an annual change of 4.46%, whereas for cold- rolled strips, the energy intensity has increased from 0.14 to 0.22 T CO_2/ton of product.

The carbon emissions from pulp and paper industry amounted to 16 million tonnes in 2005 indicating an increase of 11.5 million tonnes since 1995 (a 2.5─fold increase). Nearly 73% of these emissions came from paper, writing, and printing paper. During 1991─95 and 2000─2005, carbon intensity declined in every product ranging from 16-52% across the product ranges with an average of around 27%. In particular, significant reductions were achieved in newsprint with reduction of around 19%. The real energy intensity in the paper industry declined by 27 percent over the period 1990─2005 with annual average rate of 1.79%. The reduced energy intensity was largely due to improvement in energy efficiency and inter-fuel substitution (Table 11)

Table 11: Emission Intensity of different products in Pulp and Paper

Product	Emission Intensity (tCO_2/tones)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2005	2000-2005		
Writing & printing paper	5.30	4.59	4.41	16.79	1.12
Paper & paperboards	3.33	3.26	2.80	15.92	1.06
Paper	4.96	4.31	3.93	20.77	1.38
Newsprint	5.21	4.29	3.73	28.41	1.89
Kraft paper	2.86	2.39	1.37	52.10	3.47

Between 1990 and 2005, carbon intensity in textile industry decreased for gray cloth, jutes goods and polyester chips by 1.90, 2.07 and 0.72 percent respectively. On the other hand, cotton yarn have the highest increase in emission intensity with 7.37%, which means that the production of cotton is continued to be produced inefficiently (Table 12).

Table 12: Emission Intensity of different products in Textile industry

Type of product	Unit	Emission Intensity (t CO_2/ton)			Reduction (%)	Avg.annual change (%)
		1991-1995	1996-2005	2000-2005		
Cloth	Kg/met.	3.97	4.38	4.83	-21.75	-1.45
Cotton yarn	Kg/met.	1.64	3.27	3.46	-110.51	-7.37
Fabric	(t CO_2/ton).	2.38	2.71	2.84	-19.42	-1.29
Grey cloth	(t CO_2/ton)	7.81	8.58	5.59	28.43	1.90
Jute goods	(t CO_2/ton)	0.78	0.73	0.54	31.11	2.07
Polyester chips	(t CO_2/ton)	2.78	3.38	2.48	10.82	0.72
Yarn	(t CO_2/ton)	3.47	4.15	3.97	-14.46	-0.96

During 1990─2005, the total carbon emissions from aluminum industry increased to 40.5 million tones from 24.9 million tones (annual growth rate is 4.2%). There is a decrease in carbon intensity in two products─Aluminum ingot and aluminum metals while the reverse is true for aluminum extrusion and aluminum foil (Table 13). Overall, the change in energy intensity (t CO_2/ton) is not significant.

Table 13: Emission Intensity of different products in Aluminum Industry

Product	Emission Intensity (t CO_2/ton)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2000	2000-2005		
Aluminum extrusion	2.00	2.21	2.34	-17.00	-1.13
Aluminum foil	1.43	1.60	1.60	-11.89	-0.79
Aluminum ingots	2.74	2.73	2.45	10.58	0.71
Aluminum metal	12.5	12.4	11.4	8.80	0.59

In cement industry, carbon emissions are around 100 million tones of which about half is from the energy consumption while the rest is from process emissions. During 1990─2005, the emissions from energy source increased from 25 to 49 million tones (6% annual growth rate). Emission- intensity decreased due to increased capacity of production and improvement in energy intensity and substitution effects. The emission intensity decreased across all types of fuel consumption except for petroleum products. When compared to industrialized countries, the intensity is still high among wet-process plants suggesting a considerable potential for energy and carbon saving and energy efficiency and emission intensity improvement (Table 14).

Table 14: Specific carbon emission intensity in cement industry

Fuel	Average intensity (tco2/ton)			Reduction (%)	Avg. annual change (%)
	1991-1995	1996-2000	2001-2005		
Coal	0.60	0.47	0.38	37.04	2.47
Elect.	0.19	0.16	0.16	16.67	1.11
Gas	0.01	0.01	0.01	50.00	3.33
Petro. Prod.	0.01	0.02	0.02	-100.00	-6.67
Total	0.81	0.65	0.56	31.19	2.08
Range	0.38 - 1.47	0.26 - 1.35	0.36 - 1.14		
Production	42.8	74.9	116.9		

4. ENERGY AND CARBON INTENSITY DECOMPOSITION ANALYSIS

Energy efficiency is negatively related to energy intensity, i.e. higher the intensity, lower is the energy efficiency. However, this does not hold good for the entire sector since it is influenced by the entire production structure. This means that energy intensity itself is not a good indicator of efficiency. If we wish to single out the efficiency effect, decomposition analysis has to be conducted. Here energy efficiency indicators decompose the changes in energy consumption due to production, structural and efficiency effects.

There are two types of physical efficiency indicators. The simple specific energy (SEC) consumption is as ratio of total energy consumption (GJ) to total production (tones).

$$SEC\ simple = E/P \quad (1)$$

For the present study, we use the following equation to express the changes in energy use in the manufacturing sector from 1990 (t = 0) to 2005 (t=n):

$$PPI = \sum_{i=1}^{n} P_i * SEC_i \qquad \textbf{(2)}$$

P_i = i[th] product

SEC_i = Specific energy contribution product i (shares of energy consumption by particular product in total energy consumption by that industry)

Adjusted SEC can be written as

$$SEC_{adjusted} = E/PPI \qquad (3)$$

Change in the energy consumption can be decomposed w.r.t production, structure and EE effect by the use of Decompositions of total energy consumption is given as:

$$E_t = \sum_{i=1}^{m} E_{it}$$

$$E_t = \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} E_{ijt}}{P_{it}} \cdot \frac{P_{it}}{\sum_{i=1}^{m} P_{it}} \sum_{i=1}^{m} P_{it} \qquad (4)$$

$$E_t = \sum_{i=1}^{m} e_{it} . \alpha_{it} . P_t$$

where

E_{it} = Energy cosumption or Carbon emission by ith industry at time t

P_{it} = Total value of output in ith industry at time t

P_t = Total value of output at time t

e_{it} = Energy intensity or Carbon intensity of ith industries at time t

α_{it} = Shares of value of output for ith industries at times t

J denotes the types of energy

The total decomposition in different factors can be given as

$$\Delta E_t = \Delta O_{effect} + \Delta e_{effect} + \Delta ST_{effect}$$

$$\Delta e_{effect,t} = \sum_{i=1}^{m} \Delta e_{it}((P_t.\alpha_{it}) + 1/2(\Delta P_t.\alpha_{it} + P_t.\Delta\alpha_{it}) + 1/3(\Delta P_t.\Delta\alpha_{it}))$$

$$\Delta O_{effect,t} = \sum_{i=1}^{m} \Delta P_t((e_{it}.\alpha_{it}) + 1/2(\Delta e_{it}.\alpha_{it} + e_{it}.\Delta\alpha_{it}) + 1/3(\Delta e_{it}.\Delta\alpha_{it}))$$

$$\Delta ST_{effect,t} = \sum_{i=1}^{m} \Delta\alpha_{it}((P_t.e_{it}) + 1/2(\Delta P_t.e_{it} + P_t.\Delta e_{it}) + 1/3(\Delta P_t.\Delta e_{it}))$$

where

$\Delta O_{effect,t}$ Change in energy consumption or Carbon emission due to output effect

$\Delta e_{effect,t}$ Change in energy consumption or Carbon emission due to energy intensity effect

$\Delta ST_{effect,t}$ Change in energy consumption or Carbon emission due to structural effect

ΔE_t Change in total consumption

Decomposition of energy intensity:

$$e_t = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{E_{ijt}}{P_t}$$

$$e_t = \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} E_{ijt}}{P_{it}} . \frac{P_{it}}{\sum_{i=1}^{m} P_{it}} = \sum_{i=1}^{m} e_{it}.\alpha_{it} \qquad (5)$$

The manufacturing sector energy intensity and product mix effect are taken as major components for decomposition of the manufacturing sector change in energy intensity.

Taking total differentiation of previous intensity equation w.r.t time

$$\Delta e^{t}_{total} = \Delta e^{t}_{TMPeffect} + \Delta e^{t}_{STeffect}$$

$$\Delta e^{t}_{TMPeffect} = \sum_{i=1}^{m} \Delta e_{it} (\alpha_{it} + 1/2(\Delta \alpha_{it}))$$

$$\Delta e^{t}_{STeffect} = \sum_{i=1}^{m} \Delta \alpha_{it} (e_{it} + 1/2(\Delta e_{it}))$$

where

$\Delta e^{t}_{TMPeffect}$ Change due to technology management and practice effect at time t

$\Delta e^{t}_{STeffect}$ Change due to structural effect at time t

Δe^{t}_{total} Change in total energy intensity at time t

4.1 Energy efficiency improvements in manufacturing industries

Using the above methodology, physical energy indicators of various industrial categories are assessed. The results of the analysis are shown here.

Table 15: Specific energy consumption (by product-wise) in iron and steel industry (1990-2005)

		Production		
Product	Unit	1990 (A)	2005 (B)	(B-A)/A (%)
Alloy steel	Mt.	0.33	0.56	69.70
Castings	Mt.	0.1	0.17	62.46
Cold rolled strips	Mt.	0.45	2.26	402.09
Ferro alloys	Mt.	0.13	0.3	123.82
Forged products	Mt.	11.04	21.31	91.56
Hot rolled coils	Mt.	1.25	5.5	336.52
M.S. ingots	Mt.	7.07	8.13	14.11
MS rolled	Mt.	5.39	3.16	-41.79
Pig Iron	Mt.	1.44	2.45	69.12
Rolled products	Mt.	0.73	1.2	64.17
Sponge iron	Mt.	0.24	1.17	381.36
Steel	Mt.	7.49	12.29	62.88
Steel billets	Mt.	0.65	2.58	296.32
Total	Mt.	36.29	61.07	59.05
PPI	Mt.	7687	12235	66.34
Energy consumption	PJ	529.8	727.9	39.37
SEC simple	GJ/tones	13.6	11.92	-13.70
SEC adjusted	GJ/tones	72.23	59.5	-19.70

In iron and steel industry, production increased for almost all types of products, except MS– rolled product. Production of various steel products grew from 36.29 Mt in 1990 to 61.07 in 2005, an increase of 68% (Table 1), but the energy consumption grew by only 37% from 52.89 to 729.8 PJ indicating a lower rate of growth of energy over growth rate. This means that overall SEC decreased by 13.7%. This change may be due to less energy–intensive products such as hot–rolled coils, cold–rolled strips and steel billets with respect to others products. During the same period, PPI increased by 59%, which is less than that for steel production, while the adjusted SEC decreased by 19.7%. The overall physical product index increased by 67% compared to 1990 because overall production and energy consumption both increased in almost all types of products, expect MS rolled.

Table 16: Specific energy consumption in pulp and paper industry

		Production		
Production	Unit	1990 (A)	2005 (B)	(B-A)/A (%)
Kraft paper	'000 tones	7.6	259.7	3311.5
Newsprint	'000 tones	189.9	662.9	249.0
Paper	'000 tones	649.6	1870.2	187.9
Paper & paperboards	'000 tones	205.3	675.3	229.0
Writing & printing paper	'000 tones	214.9	911.2	324.1
Total	'000 tones	1267.3	4379.4	245.6
PPI	'000 tones	121.7	89.5	-26.5
Energy consumption	Peta Joules	53.7	115.9	115.7
SEC_{simple}	GJ/tonnes	42.6	26.5	-37.9
$SEC_{adjusted}$	GJ/tonnes	121.7	89.5	-26.5

In paper and pulp industry, production of various products increased from 1.27 to .4.38 million tones (an overall increase of 245%) whereas energy consumption grew by 116% only during same period (1990–2005). This means that the pulp and paper industry has done significant work to reduce energy intensity or increase energy efficiency. Overall decrease in energy intensity emanates from two factors: structural shift (change in product mix) and other is the pure energy intensity change across different products. We have discussed these issues later. The industry recorded energy–efficiency improvements of 26.5% in 15 years.

Between 1990 and 2005, the production of cloth in textile industry increased from 1,613 to 11,767 million meters (an increase of 634%) and various forms of yarn and chips increased by 842% whereas energy use rose by 908%. This shows that the textile industry has shifted to more mechanization than earlier and hence energy intensity increased during same period. The simple as well as adjusted SEC show increase in energy intensity.

Table 17: Specific energy consumption in textile industry

Product	Product		Production		
Product	Product	Unit	1990 (A)	2005 (B)	(B-A)/A (%)
Cloth	Cloth	Million meter	1599.6	11151.1	597.1
Grey cloth	Grey cloth	Million meter	13.2	616.3	4582.8
Cotton yarn	Cotton yarn	'000 tonnes	60.9	532.4	773.6
Fabric	Fabric	'000 tonnes	1.6	96.1	5890.4
Jute goods	Jute goods	'000 tonnes	120.5	558.6	363.6
Polyester chips	Polyester chips	'000 tonnes	14.8	326.9	2104.7
Yarn	Yarn	'000 tonnes	151.1	1774.8	1074.7
Textile1	PPI		1591	10702	572.7
	Energy consumption	PJ	32.6	316.8	872.3
	SEC $_{simple}$	MJ/sq meter	20.2	26.9	33.3
	SEC $_{adjusted}$	MJ/sq meter	20.5	29.6	44.4
Textile2	PPI		125.7	1365.9	986.8
	Energy consumption	PJ	4.434574	56.4	1171.3
	SEC $_{simple}$	GJ/tonnes	12.7	17.1	34.9
	SEC $_{adjusted}$	GJ/tonnes	35.3	41.3	17.0

The production of aluminium products grew by 66.5% during period 1990–2005 (Table 18). There is an adjusted energy efficiency improvement by 16.3%.The specific energy intensity increase in Aluminum extrusion and Aluminum foil where as decrease for Aluminum ingots and Aluminum metal product.

Table 18: Specific energy consumption in Aluminum Industry

Product types	Unit	Production 1990 (A)	2005 (B)	(B-A)/A (%)
Aluminum extrusion	'000 tonnes	116.3	392.7	237.6
Aluminum foil	'000 tonnes	93.5	258.1	176.1
Aluminum ingots	'000 tonnes	977.6	575.2	-41.2
Aluminum metal	'000 tonnes	1137.9	3406.4	199.4
Total	'000 tonnes	2325	4632	66.5
PPI		1621	3209	98
Energy consumption	PJ	128.1	308.1	140
SEC simple	GJ/tones	53.8	66.5	23.6
SEC adjusted	GJ/tones	114.8	96.0	-16.3

Table 19: Specific energy consumption in cement industry

Product types	Unit	Production 1990 (A)	2005 (B)	(B-A)/A (%)
Cement	Mt.	32.5	116.9	260
Coal	PJ	220.9	393.6	78.2
Elect.	PJ	22.7	49.7	119.0
Gas	PJ	6.5	5.0	-23.0
Petroleum product	PJ	4.1	23.1	467.3
Energy consumption	PJ	254.2	471.4	85.5
SEC $_{simple}$	GJ/ton	7.82	4.03	-48.5

Between 1990 and 2005, cement production grew by about 260% whereas energy use rose by only 85.5%. This is due to shift from wet process to dry process resulting in efficiency improvement of 48.5%.

5.2 Energy Consumption and Intensity Decomposition Result

The decomposition analysis shows the factors that play a role in increase/decrease in energy consumption and energy intensity among different products. The decomposition is done at product level for each type of energy–intensive industry. The energy consumption has been decomposed into three factors─output effect, intensity effect and structural effect (as shown in equation (4)) whereas energy intensity has been decomposed into two factors─intensity effect and structural effect (as given in equation 5)). Energy consumption across industries and products is discussed here.

In iron and steel industry, the increase in energy consumption is mostly due to increase in production levels and there is no effect of structural or intensity changes. If there had been no change in energy intensity since 1990, to support increments in output levels the energy requirement for iron steel industry would be higher by 323 PJ over the present use and would have generated 109mt more CO_2. However, due to improvements in energy efficiency (decrease in energy intensity effect) and unfavorable changes in product mix, the industry required only 198 PJ more energy, with emission levels of 27million tones of CO_2. The improvement in energy utilization by intensity effect (-125 PJ) is higher than unfavorable movement in structural change (12.5 PJ), and hence the overall energy savings are positive (125 PJ). Similarly, the intensity effect has higher impact (-82 mt CO_2) on reducing emissions than increase due to structural effect (59 mt CO_2) and therefore there is an overall decrease (-23 mt CO_2) in emissions due to output level effect. The impact technology and management practice (intensity effect) is higher than structural effect on energy savings and hence the overall energy intensity decreased by 1.7GJ/tonnes during 1990─2005.

In the case of pulp and paper industry, if there were to be no changes in intensity and product mix, the energy consumption and emission levels would have increased by 87.5 PJ and 9.5 mt $CO_{2,}$ respectively, due to increase in output levels during 1990─2005. However, due to improvements in energy efficiency and favorable change in product mix, the overall increase in energy consumption and carbon emissions was limited to 62.5 PJ and 7.0 mt$CO_{2,}$ respectively. For some of the products, the structural effect is positive, i.e. the impact on energy savings is negative while the overall intensity effect is higher than the structural effect. This means that, as a whole, the effect is positive on energy savings. Technology and management practice effect (intensity effect) and structural effect have contributed 88 and 12%, respectively, in reducing the energy intensity by 12.9 GJ/ton. Intensity and structural effects have reduced the carbon intensity by 1.4 t/t CO_2 and 0.2t/t CO_2 and hence the overall emission intensity decreased by 1.6t/t CO_2 during 1990─2005. This means that intensity effect has higher impact on energy savings and efficiency than structural (product mix) effect.

In aluminum industry, there is an improvement in energy intensity but it is due to shift from low- to high-energy intensive products and hence the overall energy intensity increased over time. If there was no change in intensity and product mix, then the energy consumption and emission levels might have increased by 120 PJ and 17.4 mtCO_2, respectively, due to increase in output levels during 1990─2005. However, due to improvement in energy efficiency and unfavorable change in product mix, the overall increase in energy consumption and emission levels was only 116 PJ and 15 mt CO_2, respectively. For some of the products, the structural effect is negative, i.e. the impact on energy savings is positive while the overall intensity effect is less than the structural effect. This means that the overall effect is negative on energy savings. The technology and management practice effect (intensity effect) have 33 and 60% impact on reducing energy and emission intensity, respectively, whereas structural effects have 130 and 160% impact on increase on energy and emission intensity.

Table 20: Result of Decomposition Analysis (1990-2005)

Actual	Energy Consumption and intensity						
	Consumption Decomposition			Intensity Decomposition			
	OE	IE	ST	Total	TMP	ST	Total
Iron and Steel	310.8	-125.4	12.5	197.9	-1.8	0.2	-1.7
Pulp and Paper	87.5	-22.0	-2.9	62.5	11.3	1.5	-12.9
Aluminum	120.1	-21.1	84.1	183.2	-4.2	16.8	12.6
Textile 1	234.1	51.0	-2.1	283.0	6.9	-0.3	6.6
Textile 2	44.7	1.4	6.8	52.9	-1.1	-5.0	-6.1
	Carbon emission and Intensity						
	OE	IE	ST	Total	TMP	ST	Total
Iron and Steel	50.1	-82.2	59.0	26.9	-1.3	1	-0.3
Pulp and Paper	9.5	-2.1	-0.3	7.0	-1.4	-0.2	-1.6
Aluminum	17.4	-4.6	12.2	25.0	-0.9	2.4	1.5
Textile 1	45.7	8.5	-0.3	53.8	1.1	0	1
Textile 2	8.6	0.5	1.0	10.0	0.2	0.5	0.7

Notes [3]

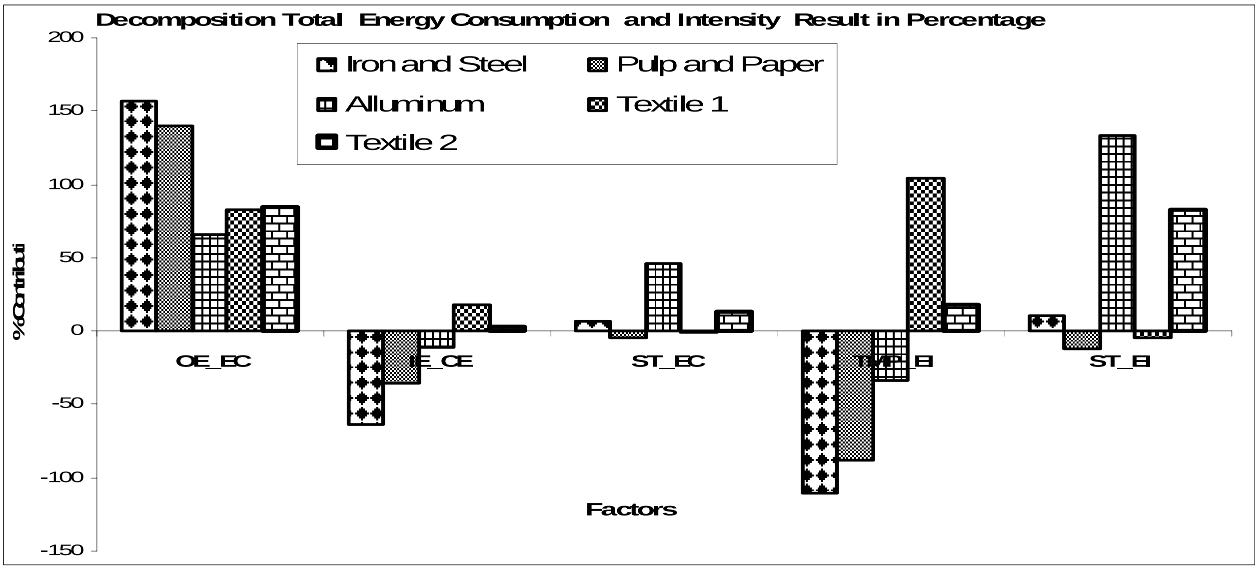
Based on the output, the textile industry is categorized into two—Textile1 and Textile 2, with production units designated in million square meters and tones, respectively. The units for energy intensity are given as MJ/square meter (Textile1) and GJ/tones (Textile2), respectively, while for emission intensity the respective units are given as kg CO_2 emission per sq meter of production (Textile1) and t CO_2 emission per tones of production (Textiles 2).

[3] *IE= Intensity Effect on energy consumption or carbon emission, ST =Structural effect on energy consumption or carbon emission, TMPE_EI=Technologies and Management Practice effect on energy intensity or emission intensity, ST_EI =Structural effect on energy intensity or emission intensity*

If there were no changes in intensity and product mix, then the energy consumption increases by 279 PJ is due to increase in output. However, due to shift from less to more mechanized methods of production and unfavorable change in product mix, the overall increase in energy consumption is higher 336 PJ during 1990–2005.

Figures 1 and 2 are summarizing the results of factors affecting energy consumption, energy use and intensities using decomposition technique. The output effect has a positive impact always on the increase in energy consumption and carbon emissions across all industries. The impact of energy and carbon intensities (efficiency) on energy consumption is negative for iron and steel, pulp and paper and aluminum industries, and is positive for textile industry. The structural effect has positive impact on energy consumption and carbon emission levels for iron and steel, aluminum and textile industries and is negative for pulp and paper, and Textile1. The intensity (Technology and management practice) effect is negative on energy and carbon intensities for iron and steel, pulp and paper and aluminum industries whereas it is positive for textile industry as a whole. The structural or product mix effect is negative for pulp and paper and Textile1 but is positive for iron and steel, aluminum and Textile2 on energy and emission intensities

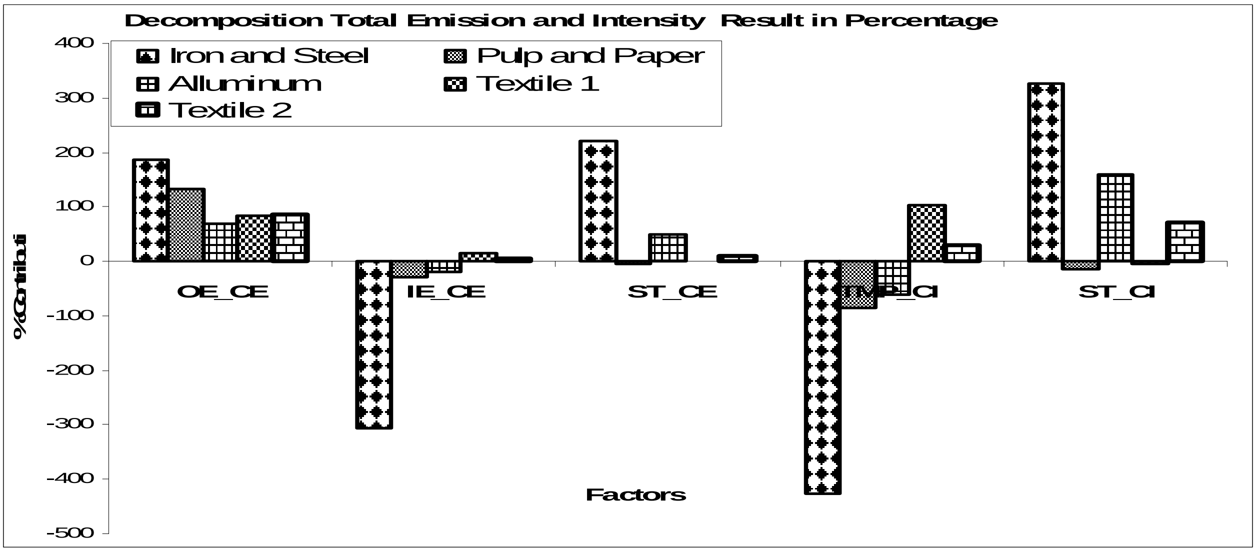
Figure1: Factors in increase/decrease Energy consumption and Intensity



Notes[4]

[4]*OE_EC =output effect for Energy consumption, IE_EC = Intensity Effect for Energy consumption, ST_EC=Structural effect for energy consumption, TMPE_EI=Technologies and Management Practice effect for Energy intensity, ST_EI =Structural effect for energy intensity*

Figure2: Factors in increase/decrease Co2 emission and Emission Intensity



Notes [5]

Changes in energy intensities and specific energy consumption (Table 19) show substantial improvements in energy use in textiles (cloth and grey cloth) and pulp and paper industries (shown by negative sign of structural effect). On the other hand aluminum industry has shown a positive sign indicating increase in energy intensity.

5. IMPACT OF CHANGING ENERGY INTENSITIES

Saving energy and reducing environmental impacts should be important goals for any country. As shown earlier, industrial sector has achieved significant reductions in aggregate manufacturing energy intensity between 1990 and 2005, from a 20% reduction in iron and steel industry to almost 33% in cement industry. After a temporary increase, the intensities steadily declined for most products. Although some sectors experienced continuous improvement of intensities, the general trend has been slow rates of decline. The tables clearly show significant decreases in energy intensity over the time in the production of cement, textiles and paper and pulp. Some of these savings may not be due to increased energy efficiency on a useful energy level, but might have been caused by reductions in oil use after the jump in crude prices in 1979. This is especially apparent in paper and pulp that have access to cheap occasional (interruptible) power and biomass. The reduced oil use in this sector was compensated by increased use of electricity and biomass, but still an 11% reduction of energy intensity was achieved in this sector over the years.

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[5] OE_CE =output effect on carbon emission, IE_CE = Intensity Effect on carbon emission, ST_CE=Structural effect on carbon emission, TMPE_CEI=Technologies and management practice effect on carbon intensity, ST_CI =Structural effect on carbon intensity

The savings in 1990–2000 were achieved despite lower oil prices during that period. The high economic growth resulted in upturn for production of raw materials and some savings might be a result of better capacity utilization. The decline in energy intensity in paper and pulp is partly owing to hike in energy use in 1980s caused by increased use of biomass and oil with lower thermal efficiency than electricity it substituted. Reduced intensity in 1990s is caused by reductions in energy use per output in production of paper and pulp. In 1990–95, small changes occurred in textiles, paper/pulp, while unreliable disaggregated energy data make it difficult to judge the development in other raw material areas. The differences in energy savings among different sectors are presumably due to differences in energy prices and in the relative importance of oil in the manufacturing industries.

It is interesting to know that energy intensities of most manufacturing sub–sectors have increased although significant efficiency improvements, in physical terms, have taken place. This means that the rate of growth of energy use is faster than production. As energy consumption increases with energy service demand (production effect), and decreases with improving energy efficiency (efficiency effect) and production structure (structure effect), the energy increase in energy use during 1990–2000 was the result of higher production effect than combined efficiency and structural effects. In general, the demand for energy services grows faster than energy efficiency. Energy conservation polices alone cannot cope with growing energy demand. There is a need for restructuring in energy–intensive industries.

6. DISCUSSION

Energy–intensity indicators allow gain insights into energy efficiency levels in various sectors of the economy, and better understand the way each structure in each sector affects energy use. The methods are relatively easy to apply, and typically need data that is readily available. They are also fairly inexpensive policy tools; give a lot of information with relatively little trouble. However, this information (depending, of course, on the breadth and depth of the particular analysis) tends to be very general. Given the complexities associated with mitigating global emissions and the enormity of potential costs associated with implementing resource conservation programs, information is largely insufficient. Most importantly, these indicators do not address costs associated with energy conservation or CO2 mitigation measures. Suggesting technological changes or inducing structural changes is unlikely to result in a successful reduction in resource use. For a successful programme information about costs of implementing the measures and short– as well as long–term social costs they generate. Comparing marginal costs of different mitigation measures with marginal costs accorded by those measures is a very necessary part of deciding on the strategies that will truly succeed. Bottom-up, empirical estimations of marginal costs of abatement options, like those typically provided by policy simulation models, are much better suited to judging the genuine effectiveness of potential mitigation options since they take into account costs, feedback mechanisms, price and non-price effects, as well as technological and structural changes.

It is not known for certain whether ambiguity or the extents of energy intensity indicators truly reflect improvements in energy efficiency. Since at face value, they suggest that no real improvements in energy efficiency have occurred over the years; this, however, is generally not the case over an extended period. In such a scenario, how to find indicators and/or data that reflect even small changes in energy efficiency is the issue. Increased reliance on physical intensity indicators might better quantify the link between physical energy consumption and energy efficiency. In fact, this is truly, what is of interest to most climate change policy-makers who are concerned with the physical (environmental) effects of climate change is the relationship between the amounts of energy consumed to make one physical unit of some product. However, economic intensity indicators, which track the amount of energy, needed to produce one rupee of output will still be critical in terms of the information they can provide to policy-makers.

7. CONCLUSIONS

The study shows that India still has a high-energy intensity in manufacturing. This does not necessarily mean that manufacturing has the lowest energy efficiency, but rather that there are structural differences that could not be isolated at desegregation level. Low energy prices and high-energy intensities in all sub-sectors lead us to believe that there is a significant potential for energy savings in Indian manufacturing industries. In a longer time perspective, the electricity intensive industries may have to face high market prices. With prices of fossil fuel on rampage, electricity and renewable energy may stand out as an attractive alternative.

The present study on physical intensity indicators is sure to provide answers for policy–makers. The increased use of physical intensity indicators instead of economic intensity indicators may also give policy-makers more information, since a gain in energy productivity (which might be shown by an economic intensity indicator) does not necessarily equal a resource gain. Climate change policy-makers are likely to be more concerned with the latter. Such indicators offer insight into how industrial activity is affecting energy use (and therefore CO2 emissions). Comparisons across sectors of energy intensity are useful for providing analysts of how well/poorly countries are doing with respect to energy efficiency. Very often, the conclusions from such studies suggest that a particular country must implement more measures to improve energy efficiency. It also shows that how the country is consuming comparatively larger quantity of fossil fuels per ton of output making it harder to achieve emission targets. Hence, energy intensity indicators are beneficial in looking at macro components that drive changes in energy use providing energy analysts with a broad sense of how energy efficiency is changing in the economy. They are also critical of specific industry agencies that may want to track energy changes in certain sub-sectors and industries. Since the demand for energy services grows faster than energy efficiency improvements, energy conservation polices alone cannot cope with growing energy demand. There is a need for restructuring in energy–intensive industries. In the context of climate change, energy intensity indicators can indicate where future research should be concentrated upon.

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