TECHNOLOGICAL CHANGE AND ENERGY EFFICIENCY: UNDERSTANDING THE LINKAGES IN INDIA'S PULP AND PAPER INDUSTRY

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Abstract: The increase in industrial energy efficiency reduces the operating cost and increase asset value. It also benefits by conserving resources and reducing greenhouse gas emission, marshalling sustainable development. The improvement in energy efficiency at the sectoral level in turn translates into national macroeconomic gains including increase in GDP, ensuring energy security, and moderating international energy prices. This study examines the energy demand of energy-intensive pulp and paper (P&P) manufacturing in India. Using Annual Survey of Industries Commodity Classification on ASI data this study, perhaps for the first time, classify the P&P industry into different raw material based sectors, viz, wood-based P&P sector, agro-based P&P sector, and recycled paper-based P&P sector. It applies Log Mean Divisia Index to examine the contribution of the activity effect, structural effect and energy intensity effect on the changes in energy demand. The result shows that increase in the activity effect raises energy consumption in the industry during 2000-2010. Although the structural effect raises its energy use, its contribution is insignificant. The negative energy intensity effect stimulated by technological progress in the production process, however, reduces the total energy use change in the P&P industry in India. The policy evaluation and field survey based evidences reveals that technological changes in the production process of the P&P industry in India is induced by various public policies on industrial energy efficiency, environmental pollution and sustainable raw material consumption. Summing up, the study suggests policy measures that would further improve the use of energy.

Keywords: Pulp and paper industry, Government policies, Technological change, Energy intensity, and Decomposition of energy use change.

JEL Classification: C33, C43, L73 and Q41.

"It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change".

-Charles Darwin[1]

1: Introduction

Globally, the industry accounts for one-third of final energy used and for almost 40 percent of worldwide carbon dioxide (CO_2) emissions.[2] In 2007, total final energy use in industry amounted to 3019 million tonnes oil equivalent (Mtoe) (Trudeau, Tam, Graczyk, and Taylor, 2011).[3] Between 2000 and 2010, the total industrial final energy use increased by 31 percent, from 103 Exajoule (EJ) to 135 EJ (Table 1). The observed growth in energy consumption has been mainly driven by increasing demand and production of industrial output in major countries like China and India. The shares of the Organization for Economic Co-operation and Development (OECD) regions' industrial energy consumption, however, declined from over 50 percent in 2000 to 36 percent in 2010, reflecting a major downturn in industrial economic activity.

Table 1: Global Industrial Energy Consumption by Region (in %)

Region	2000 (103 EJ)	2010 (135 EJ)
China	14	28
India	5	6
Latin America	6	5
Africa and Middle East	7	8
Other Developing Asia	6	8
Other Non-OECD	11	9
OECD	51	36
All	100	100

Source: International Energy Agency (IEA), 2013

[1] As cited in The World Bank (2002).

[2] The industrial emissions are classified into two broad categories: direct emissions and indirect emissions. The direct emissions include fuel combustion and process-related CO_2 emission from within the industry. The direct emissions of CO_2 from the industry is 7.6 Gigatonnes of CO_2 (Gt CO_2). Indirect emissions are from the power generation sector due to electricity use in the industry. The indirect emission from the industry is 3.9 Gt CO_2 (Trudeau et al., 2011).

[3] The total industrial final energy includes energy used as a feedstock in the chemicals and petrochemicals sectors, as well as energy used in coke ovens and blast furnaces.

India is fourth largest energy user with 6 percent share of global industrial total energy use.[4] Up to 150 Mtoe of final energy was used for industrial purposes in 2007, accounting for 38 percent of the country's total energy used.[5] India's industrial energy use mix comprises coal, oil, natural gas, electricity, and biomass and waste (Table 2).[6] The biomass and waste constitutes a substantial portion of total industrial energy demand in India. The share of biomass and waste in total industrial energy demand in India is 19 percent compared to 6 percent of the world's mix of energy demand. Since the combustion of biomass is considered as carbon-neutral the large share of regenerative biomass use as a fuel makes the industry in India one of the least CO_2 intensive compared to the industry worldwide. As for total electricity consumed about 30 percent of the electricity used by industry is generated by captive power plants which indicates the industry is becoming inventive, self-reliant, and less polluting.

Table 2: Industrial Energy Mix (in Percentage)

Energy Type	India	Global
Coal	33	27
Oil	23	23
Natural Gas	10	20
Electricity	15	20
Biomass and Waste	19	06
Other	-	04
Total	100	100

Source: Trudeau, Tam, Graczyk and Taylor, 2011

Globally, the energy consumption of five energy-intensive industries (iron and steel; chemical and petrochemical; non-ferrous metal; non-metallic minerals including cement; and paper, pulp and print) increased relative to the other industrial sectors between 2000 and 2010. These five sectors together accounted for more than 67 percent of the total final industrial energy use in 2010, compared with 58 percent in 1990 (IEA, 2013). In India, these

[4] For understanding the role of energy intensity in CO_2 emissions from Indian manufacturing industries, see Sahu and Narayanan (2013).

[5] Energy demand in the industry in India is projected to increase, so as to account for more than 50 percent of the country's total energy consumption by 2040 (IEA, 2015).

[6] About 30 percent of the electricity used by industry is generated by captive power plants (Trudeau et al. 2011).

five sectors accounted for about 56 percent of total industrial energy consumption in 2007 (Trudeau et al., 2011).

Among these energy-intensive sectors, the pulp and paper (P&P) industry was the fourth largest industrial energy user in the world in 2007, consuming 164 Mtoe of energy, which amounted to 5 percent of the total global industrial energy consumption (ibid). According to the Bureau of Energy Efficiency 'BEE' (2011), the P&P industry in India ranked seventh among the high energy-consuming manufacturing sectors in 2007, using about 1.4 Mtoe of energy**.** The energy consumption in the P&P industry in India, however, has been falling over the years. The percentage share of energy use in the P&P industry in organized manufacturing industries in India declined from 4.20 percent in 1961-62 to 2.95 percent in 2011-12. The declining energy use in the P&P industry is also reflected in the falling share of energy in total input of the sector. It declined from 14.36 percent in 1961-62 to 13.75 percent in 1971-72. This proportion, however, increased to 19.88 percent in 1981-82, and to 20.61 percent in 1991-92. The share of energy consumption in total inputs declined again in 2001-02 to 18.28 percent, and in 2011-12, it further declined to 12.68 per cent. The decline in energy consumption does not necessarily imply a direct increase in energy efficiency. Other factors such as structural change or activity change could affect the change in total energy consumption. To that end, the purpose of the present paper is to examine the factor that induces the change in energy use in India's P&P industry.

The reminder of the paper is organized as follows. Section 2 discusses the existing literature and identifies the research gaps. The data and methodology applied in the study are described in section 3. Section 4 analyses the change in energy demand using the complete decomposition method, and explains the major findings. The final section 5 concludes the study.

2: Review of Literature and Research Gaps

We follow a rich literature studying the decomposition energy demand. We divide the studies that have analyzed the change in energy demand using the decomposition method at the international level and for India. Though most of the international studies on decomposition of change in energy use are carried out for the industry there are a few studies like Alam and Butt (2001), Gales, Kander, Malanima, and Rubio (2007), Metcalf (2008), Cantore and Fokeer (2011), and Nasab, Alami, Dahr, and Sadeghzadeh (2012) have investigated the change in energy use for different national economies. The changes in industrial energy demand for a group of countries have been studied by Unander (2007), Mulder, de Groot, and Pfeiffer (2013), and Zhang (2013). The change in industrial energy demand in different individual counties has been analyzed by Boyd, McDonald, Ross, and Hanson (1987), Howarth, Schipper, Duerr, and Strom (1991), Liu, Ang, and Ong (1992), Choi, Ang, and Ro (1995), Ang, Zhang, and Choi (1998), Boyd and Roop (2004), Zhao, Ma, and Hong (2010), and Hasanbeigi, Can and Sathaye (2012). The decomposition analysis for the change in energy use in Indian economy has been studied by Mukhopadhyay and Chakraborty (1999) and Bhattacharya and Paul (2001). A similar exercise for the Indian manufacturing industry was done by Ray and Reddy (2007), Sahu and Narayanan (2010), Jena (2011), and Chakraborty and Dasgupta (2014).

Most of the existing literature on the P&P industry in India highlighted the issues either relating to the Total Factor Productivity Growth (TFPG) or environmental pollution. Goldar (1986), Ahluwalia (1991), Mongia and Sathaye (1998), Schumacher and Sathaye (1999), Roy, Sathaye, Sanstad, Mongia and Schumacher (1999), Ramaswamy (1999), Pradhan and Barik (1998, 1999a), Kathuria (2002), Goldar and Kumari (2002), Unel (2003), Balakrishnan et al. (2006), Milner, Vencappa and Wright (2007), Pattnayak and Thangavelu (2010), Veermani and Hashim (2011), Ray (2012) Kathuria, Raj and Sen (2013) Chakraborty and Dasgupta (2014), Ray (2014) and others have examined the TFPG of India's P&P industry. The researchers like Dasgupta and Murty (1985), Pradhan and Barik (1999b), Pandey (2005), Schneider, Hoffmann, Gurjar (2009), Powers, Blackman, Lyon and Narain (2011), Sahu and Narayanan (2013) have analyzed the different aspects of environmental pollution of the P&P industry in India. Recently, the change in energy use in the manufacturing sub-sectors in India has been examined by Ray and Reddy (2008), and Reddy and Ray (2010). They used firm-level data of PROWESS given by Centre for Monitoring Indian Economy (CMIE) and decomposed the change in energy use of a group of manufacturing sectors in India including the P&P industry.

The succinct review of literature related to change in energy demand revealed that the most of the studies were conducted at the economic group level, national economy level and aggregate industry level. However, there is no study that analyzes the change in energy use exclusively at the sub-sectoral level. The present study, however, uses Annual Survey of Industries (ASI) data at the 5-digit level and classifies the P&P industry in India into three different raw materials based sectors: wood-based P&P industry, agro-based P&P industry and recycled paper (RCP)-based P&P industry, and tries to measure the contribution of different factors on the total energy use change.

3: Data and Methodology

The objective of the study is examined by applying the Log Mean Divisia Index (LMDI) approach. The data on total output and energy use in the P&P industry in India is drawn from Annual Survey of Industries (ASI) factory level unit data published by Central Statistical Office, Ministry of Statistics and Programme Implementation, Government of India. We apply ASI Commodity Classification (ASICC) 2009 on ASI data to generate unit level database for different raw material based P&P sectors, namely, wood-based P&P industry, agro-based P&P industry and recycled paper-based P&P industry.[7] The study divides the industry into its raw material use based sectors because the P&P industry in India is highly fragmented and diversified in terms of the number of mills using different types of raw material and in terms of the scale of operation. Table 3 demonstrates that this industry majorly uses wood-based, agro-based and RCP-based raw materials for producing paper and paper products. There are 85 large scale wood-based P&P mills (about 11.20 percent of the total mills) in the country which produce around 36 percent of the total paper and paper products in 2011-12. These large sizes integrated P&P mills are owned by big business conglomerates and corporate groups. They have better financial capacity to carry out large expansion and modernization. These mills have also undergone significant modernization by installing input efficient technology in the production process and pollution controlling systems. These mills produce good quality high-grade paper and paper products. They are domestically competitive and also have a presence in the overseas

[7] On how different raw material based P&P industry database is created see Appendix- 1.1.

market through exports [Jaakko Poyry Consulting (JPC), 2002, Central Pulp and Paper Research Institute (CPPRI), 2004; National Productivity Council (NPC), 2006]. The medium-sized agro-based P&P mills form 21.08 percent of the total factories and account for around 29 percent of the total production. The significant portion of the P&P factories in the industry (about 67.72 percent of the total mills) in the country is dominated by small-sized RCP-based mills, which account for 35 percent of the total production. Most of these small and medium-sized mills are owned and managed by local business groups or independent village producers running only one mill targeting their respective local markets (JPC, 2002; CPPRI, 2004). The industry, however, is dominated by medium sized agro-based and small sized RCP-based P&P mills. They constitute about 88.80 percent of total number of the P&P mills in the country, contributing 64 percent of the total production in 2011-12.

Table 3: The Scale of Operation of Different Raw-material based P&P Mills

Type of Raw-material for Paper Industry	Scale of Operation (TPD)	Number of Mills			Production Share (%)		
	2011-12	1991	2000	2011-12	1991	2000	2011-12
Large Integrated Wood-based	100-1100	28 (8.62)	28 (7.37)	85 (11.20)	41	38	36
Medium Agro-based	50-100	87 (26.77)	111 (29.21)	160 (21.08)	32	36	29
Small Waste Paper-based	5-50	210 (64.62)	241 (63.42)	514 (67.72)	27	26	35
Medium Agro-based + Small Waste Paper-based	-	297 (91.38)	352 (92.63)	674 (88.80)	59	62	64
Total	-	325 (100.00)	380 (100.00)	759 (100.00)	100	100	100

Notes:
(1) TPD: Tonnes Per Day.
(2) Figure in parenthesis refers to the percentage share in different raw material based sectors in total number of mills in the industry.
Sources:
1991: Indian Pulp and Paper Technical Association, 1992
2000: Central Pulp and Paper Research Institute, 2000a
2011-12: Department of Industrial Policy and Promotion (DIPP) Annual Reports, 2010-11, 2011-12.

Although the unit level database has been generated for different raw material based P&P sectors, due to insufficient observations for panel data analysis, the factory level unit data has been aggregated to 5-digit industry level data for the study.[8] The wholesale price indices (WPIs) are obtained from Indiastat.com. The data set used in this study runs from 1999 to 2010. Moreover, the energy use in the P&P industry in India has been examined through the field research conducted in two phases (pilot survey during January-March 2012 and field survey during January-March 2013). The field research contains focus group discussions with various key actors and institutions in the P&P industry in India such as the Central Pulp and Paper Research Institute (CPPRI) Saharanpur, Uttar Pradesh; Central Pollution Control Board (CPCB), New Delhi; State Pollution Control Board (SPCB) Odisha Bhubaneswar; Indian Paper Manufacturers Association (IMPA) New Delhi; and Indian Agro and Recycled Paper Mills Association (IARPMA) New Delhi. The factory visit was conducted in different raw material based P&P mills producing different varieties of paper and paper products. The large scale wood-based P&P mills such as J.K. Paper Mill Limited, Rayagada, and Ballarpur Paper Mill Limited in Koraput of Odisha state have been covered in the field survey. The large scale RCP-based Emami Paper Mill operating in Balasore of Odisha state was also taken for the study. The data and information gathered from the field research has been applied in this study to substantiate the findings of the secondary data based analysis.

4: Estimation of Change in Energy Consumption

The changing energy consumption in India's P&P industry is analyzed using the complete decomposition method. This section has two sub-sections. The first part discusses the framework of decomposition analysis while the second part presents the computation results.

[8] The NIC-2008 based 5-digit industry level harmonised classification of P&P industry is given in Appendix-1.2.

4.1: Industrial Energy Demand Decomposition: A Methodological Framework

The decomposition analysis is conducted at the national level by dividing the economy into two groups- low energy intensive sectors and high energy intensive sectors. The analysis is also done at the sectoral level. The input-output analysis and index decomposition analysis (IDA) are the two important tools used for analyzing change in energy use. In the decomposition analysis, three general approaches have been used to decompose the change in energy use. The 'energy consumption approach' analyzes the decomposition of the total energy consumption changes in the industry, while the 'energy intensity approach' decomposes the aggregate energy consumption to output. In both approaches, specific decomposition methods can be formulated using additive or multiplicative form. In multiplicative decomposition, a change in an aggregate given as ratio is decomposed. The additive decomposition, an absolute change of an aggregate (differential quantity), is decomposed. The third approach called the 'energy coefficient' approach. It is an extension of the energy consumption approach that has been built on the concept of energy coefficient and elasticity. To study the evolution of historical energy demand, the energy consumption approach and energy intensity approach have been applied in the literature. The energy coefficient approach is used to understand the energy demand projection, particularly in identifying the underlying the demand trends (Ang, 1995; Ang and Lee, 1996).[9]

The popular decomposition methods used in the literature can be divided into two groups: the Laspeyres index and the Divisia index. Laspeyres index estimation often yields large residuals, and fails in both the factor-reversal test and the time-reversal test, which are addressed in Log Mean Divisia Index (LMDI). Ang, Zhang and Choi (1998) proposed the additive decomposition method while Ang and Liu (2001) proposed the multiplicative approach of LMDI Method-I (LMDI-I), which can be used to factorize a change in the physical quantity of an energy or environmental indicator. Both the versions are based on the Divisia index and use a logarithmic mean weight function, which yields perfect decomposition and consistency in aggregation, and also handles the problems associated with zero values in the data set. Although several variants of the decomposition approach

[9] See for detail understanding on advantages and disadvantages of different decomposition approaches.

have been developed, Ang (2004) recommended LMDI-I as the most preferred method for its theoretical foundation, adaptability, simpler formulae, ease of application and result interpretation, and other desirable properties in the decomposition analysis.[10] Therefore, we apply LMDI-I to understand the contribution of different pre-defined factors in the changes in the energy use in India's P&P industry during 2000-2010.

The decomposition analysis in the energy decomposition proceeds as follows. First, we present the general IDA in additive form and then discuss the general formulae of LMDI. Finally, we present time-series decomposition of change in energy demand.[11]

Index Decomposition Analysis

To decompose the changes in energy consumption in India's P&P industry we follow the decomposition analysis guided in Ang (2005). Let V be an energy-related aggregate. Assume that there are n factors $\left(x_{1,}x_{2,\dots\dots\dots,}x_n\right)$ contributing to changes in V overtime and each is associated with a quantifiable variable. At the sub-category level the relationship $V_i = x_{1,i}, x_{2,i}, \dots\dots\dots x_{n,i}$ holds, where subscript i is sub-category of the aggregate. The general IDA identity is given by,

$$\mathrm{V} = \sum_{\mathrm{i}} \mathrm{V_i} = \sum_{\mathrm{i}} \mathrm{x_{1,i} x_{2,i} \dots \dots x_{n,i}} \qquad (1)$$

Further, assume that aggregate changes from $V^0 = \sum_i x_{1,i}^0 x_{2,i}^0 \dots \dots x_{n,i}^0$ in period 0 to $V^T = \sum_i x_{1,i}^T x_{2,i}^T \dots \dots x_{n,i}^T$ in period T. The objective is to derive the contributions of the n factors to the change in the aggregate which can be expressed using additive decomposition form as,

$$\Delta \mathrm{V_{tot}} = \mathrm{V^T} - \mathrm{V^0} = \Delta \mathrm{V_{x_1}} + \Delta \mathrm{V_{x_2}} + \cdots \dots + \Delta \mathrm{V_{x_n}} \qquad (2)$$

The subscript tot represents the total or overall change and the terms on the right hand side refer to the effects associated with the respective factors in equation (1).

[10] For an understanding of the methodological development of decomposition analysis, see Ang and Zhang (2000), Ang, Liu, and Chew (2003), Ang, Liu and Chung (2004).

[11] For advantages and disadvantage of period-wise versus time series decomposition analysis, see Ang and Lee (1994), Ang (1995), and Ma and Stern (2008).

In the LMDI approach, the general formulae for the effect of the k^{th} factor on the right hand side of equation (2) is,

$$\Delta V_{x_k} = \sum_i L(V_i^T, V_i^0) \ln\left(\frac{x_{k,i}^T}{x_{k,i}^0}\right)$$

$$= \sum_i \frac{V_i^T - V_i^0}{\ln V_i^T - \ln V_i^0} \, ln\left(\frac{x_{k,i}^T}{x_{k,i}^0}\right) \qquad (3)$$

Where $L(a,b) = (a-b)/(\ln a - \ln b)$ is the logarithmic mean of two positive numbers a and b, and $L(a,a) = a$.

Decomposition of Energy Consumption Change

Decomposition analysis separates the effect of key components on the energy end-use trends overtime. Three main components usually considered in the literature on decomposition analysis are: (i) Scale of aggregate activity (activity effect), (ii) Sectoral activity mix (structural effect), and (iii) Sectoral energy intensity/technological change (intensity effect).

(i) Activity effect: The change in the aggregate associated with a change in the overall level of the activity.

(ii) Structural effect: The change in the aggregate associated with a change in the mix of activity by sub-category.

(iii) Energy intensity: The change in the aggregate associated with changes in the sub-category energy intensities.

The IDA identity in equation (1) is performed for the aggregate energy decomposition of India's P&P industry as,

$$E = \sum_i E_i = \sum_i Q \frac{Q_i}{Q} \frac{E_i}{Q_i} = \sum_i Q \, S_i \, I_i \qquad (4)$$

Where,

$$Q = \sum_{i} Q_i : \text{Overall Activity Level or Total Output (All sectors)}$$

$$E = \sum_{i} E_i : \text{Total Energy Consumption (All sectors)}$$

$$S_i = \left(\frac{Q_i}{Q}\right) : \text{Activity Share of Sector } i$$

$$I_i = \left(\frac{E_i}{Q_i}\right) : \text{Energy Intensity of Sector } i$$

We assume the industrial energy demand and industrial production data are given for a total of n industrial sectors. Defined ΔE_{tot} is the change in total industrial energy demand from year 0 to year T, and is given by $E_T - E_0$. Here, we decompose ΔE_{tot} into three effects associated with the following factors: the change in industrial production in the industry [activity effect (subscript 'act') ΔE_{act}], the change in production structure of sub-sectors [structural effect (subscript 'str') ΔE_{str}] and the change in sectoral energy intensity [intensity effect (subscript 'int') ΔE_{int}]. From equation (2), the additive form of decomposition is given as,

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int} \qquad (5)$$

Where

$$\Delta E_{act} = \sum_{i} w_i \ln\left(\frac{Q^T}{Q^0}\right)$$

$$\Delta E_{str} = \sum_{i} w_i \ln\left(\frac{S_i^T}{S_i^0}\right)$$

$$\Delta E_{int} = \sum_{i} w_i \ln\left(\frac{I_i^T}{I_i^0}\right)$$

$$w_i = \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

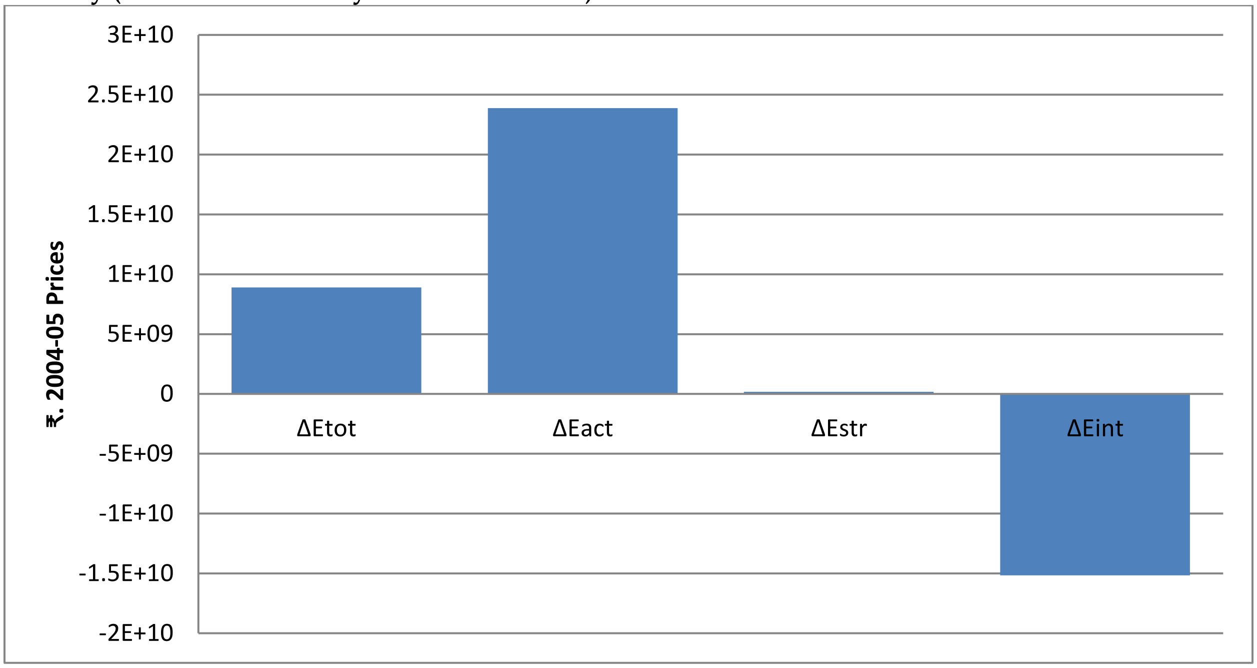
4.2: Complete Decomposition Model: Results and Discussion

We apply LMDI-I and examine the contribution of various effects to the total energy use change in the different raw material-based sectors of the P&P industry in India: wood-based P&P sector, agro-based P&P sector, and RCP-based P&P sector. Figure 1 presents the accumulated yearly sum (from 2000 through 2010) of complete decomposition of change in total energy consumption. Table 4 shows the decomposition results and their estimated effect as a percentage of change in the total energy demand. The results show that the change in total energy consumption in the P&P industry in India during 2000-2010 has been largely contributed by the change in the activity effect and intensity effect. The activity effect (or rise in output) increases the energy consumption as expected.[12] The accumulated (period-wise) activity effect during 2000-2010 accounts for 268.27 percent of the accumulated total energy consumption change in absolute value.[13] Although the structural effect is positive, its contribution to the changes in total energy consumption is insignificant. The yearly sum structural effect contributed about 1.90 percent of the accumulated total energy use.

[12] The link between energy consumption and economic growth in India using time series econometric is demonstrated by Mallick (2009), Tiwari (2012), and Shahbaz, Mallick, Mahalik, and Sadorsky (2016).

[13] Like Ang et al (2003), and Ma and Stern (2008) we calculate change in effects of $\Delta E_{act,} \Delta E_{str} and \ \Delta_{int}$ as a percentage of ΔE_{tot}.

Figure 1: Presentation of Additive Decomposition of Change in Energy Consumption for India's P&P Industry (Accumulated Yearly Sum of 2000-2010)



Notes:
(1)ΔE_{tot} is the change in total industrial energy demand from year 0 to year T.
ΔE_{act}, ΔE_{str} and ΔE_{int} are activity effect, structural effect and intensity effect, respectively.
(2) A positive number indicates an effect that increases the total energy demand.
(3) A negative number indicates an effect that decreases the total energy demand.
Source: Author's Calculation based on ASI data.

However, the negative EI effect neutralized part of increasing energy use emerging out of the activity effect and structural effect. The accumulated EI effect reduces the total energy consumption, accounting for -170.17 percent of the accumulated total energy use. In other words, the decline in EI (or increasing energy efficiency through technological changes) pulled total energy use down by -170.17 percent during 2000-2010. Actual energy consumption would have been higher without energy efficiency improvements.

Table 4: Results of Additive Decomposition of Change in Energy Consumption for India's P&P Industry (2000-2010)				
Year	ΔE_{act}	ΔE_{str}	ΔE_{int}	ΔE_{tot}
2000-2001	10236101346 (253.89)	129302257.5 (3.21)	-6333670197 (-157.10)	4031733407
2001-2002	-944816707.6 (34.84)	-129437918.5 (4.77)	-1637431534 (60.38)	-2711686160
2002-2003	4000241304 (195.57)	29198063.54 (1.43)	-1984029730 (-97.00)	2045409637
2003-2004	2802113298 (-2309.76)	-294662025.2 (242.89)	-2628767577 (2166.87)	-121316304.9
2004-2005	-127097261.8 (13.63)	189754560.3 (-20.34)	-995455241.7 (106.72)	-932797943.2
2005-2006	838980355.3 (-32.04)	-250018407.5 (9.55)	-3207883170 (122.49)	-2618921222
2006-2007	2496735054 (122.27)	39056729.01 (1.91)	-493837088 (-24.18)	2041954695
2007-2008	2281574326 (104.40)	163138666.4 (7.46)	-259229746 (-11.86)	2185483247
2008-2009	1076636479 (82.68)	-49513794.76 (-3.80)	275037122.6 (21.12)	1302159807
2009-2010	1224990486 (33.27)	342453360.1 (9.30)	2114162405 (57.43)	3681606251
2000-2010	23885458679 (268.27)	169271490.9 (1.90)	-15151104757 (-170.17)	8903625413

Notes:
(1)ΔE_{tot} is the change in total industrial energy demand from year 0 to year T.
ΔE_{act}, ΔE_{str} and ΔE_{int} are activity effect, structural effect and intensity effect, respectively.
(2) Figures in parenthesis give the estimated effect as a percentage of ΔE_{tot}. Thus, in this case it is given by, for instance, in 2000-01 (₹. 2004-05 prices), ΔE_{act} = 10236101346 and ΔE_{tot} = 4031733407, So, ((10236101346)/(4031733407)*100) = 253.89 per cent.
(3) A positive number indicates an effect that increases the total energy demand.
(4) A negative number indicates an effect that decreases the total energy demand.
Source: Author's Calculation based on ASI data.

The positive influence of the activity effect that raised the total energy consumption during 2000-2010 is because of expansion of production which grew at a Compound Annual Growth Rate (CAGR) of 10.96 percent during this period. The growth in the production has been backed by addition in the production capacity to the industry by the establishment of new factories. As the total number of P&P mills increased from 380 in 2000-01 to 708 in 2009-10 with a CAGR of 7.94 percent, the total installed capacity of the industry also increased from 5100 thousand metric tonnes (MT) in 2000-01 to 11500 thousand MT in 2009-10, growing at a CAGR of 9.75 percent.

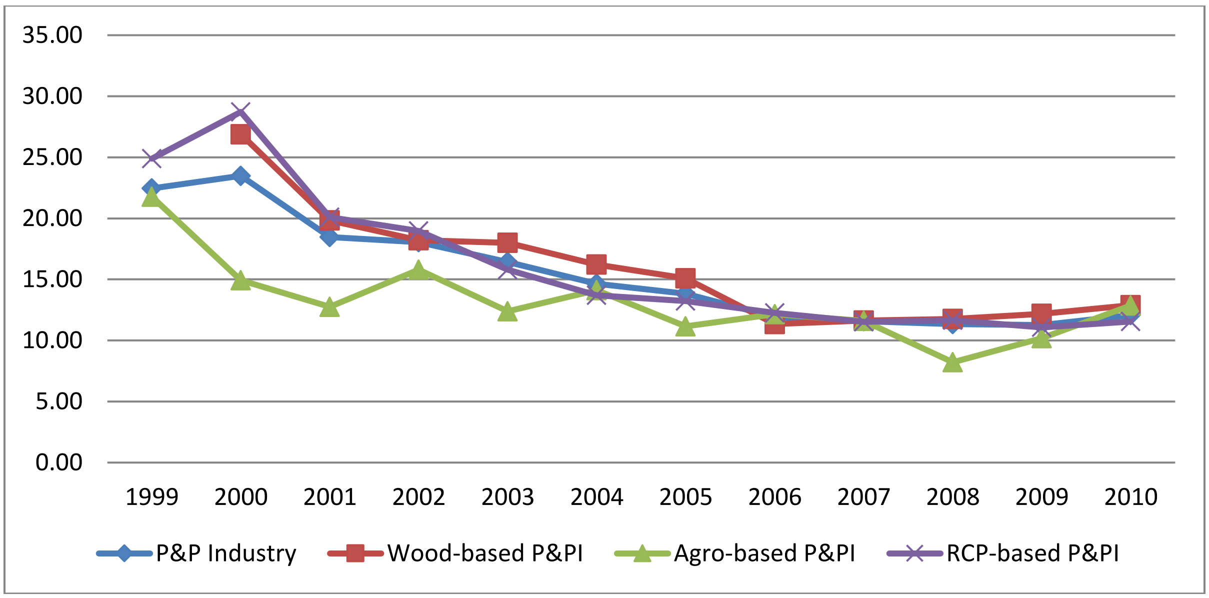
The structural change effect is observed to be negligible in the total energy consumption change as the P&P industry in India has witnessed an increase in the number of RCP-based P&P mills in the total number P&P mills in India (Table 3). This significant change in the structure of the industry is also reflected in the increasing use of RCP-based raw material in the total raw-material consumption use in the P&P industry in India (Table 5). However, the rising number of RCP-based factories using waste paper as a raw material in the industry, which evidently consumes lesser quantity of energy to produce one unit of output (Table 6) brings down the total energy use in the industry.

The negative energy intensity (EI) reduces total energy consumption in the industry. The improvement of energy efficiency provides benefits at multiple levels. At the sectoral level, the benefits include high productivity and competitiveness, better energy service by the energy provider, and infrastructure benefits that reduce the operating cost and increase asset value. The high energy efficiency at the sectoral level in turn, provides gains at the national level by offering new employment opportunities, reducing energy-related public expenditures, and ensuring energy security. There are also positive macroeconomic impacts, including increase in GDP. The effort for energy efficiency also provides benefits at the international level by reducing greenhouse gas emission, moderating international energy prices, and natural resource management for sustainable development (Ryan and Campbell, 2012).

The EI of this industry has been declining, more so after 1990. The EI is calculated as the ratio of value of total fuels consumed to the value of total output. The real value of 'fuels consumed' is estimated by deflating it by the composite 'energy price index' for India at 2004-05 prices. The energy price index is constructed using weights obtained from the Input-Output Transaction Table of India for 1993-94, 1998-99, 2003-04, 2006-07, and 2007-08 published by the Central Statistical Organisation (CSO). Appropriate Wholesale Price Indices (WPI) (electricity, mineral oils, and coal and lignite) are collected from the Index Number of Wholesale Prices in India, base 2004-05=100, from Indiastat.com. The value of 'total output' is deflated by the Wholesale Price Index (WPI) of paper and paper products in

India at 2004-05 prices to get its real value. The EI of India's P&P industry fell from 22.46 percent in 1999 to 12.08 percent in 2010. Looking at the EI of its three major raw material-based P&P sectors during the last one decade from 1999 to 2010 we find that it has declined in all categories (Figure 2). In the wood-based P&P sector, EI reduced from 26.89 percent in 2000 to 12.88 percent in 2010. The agro-based P&P sector witnessed a fall in EI, from around 21.77 percent in 1990 to 12.86 percent in 2010 while during the same period in RCP-based P&P sector, it declined from 24.90 percent to 11.56 percent.

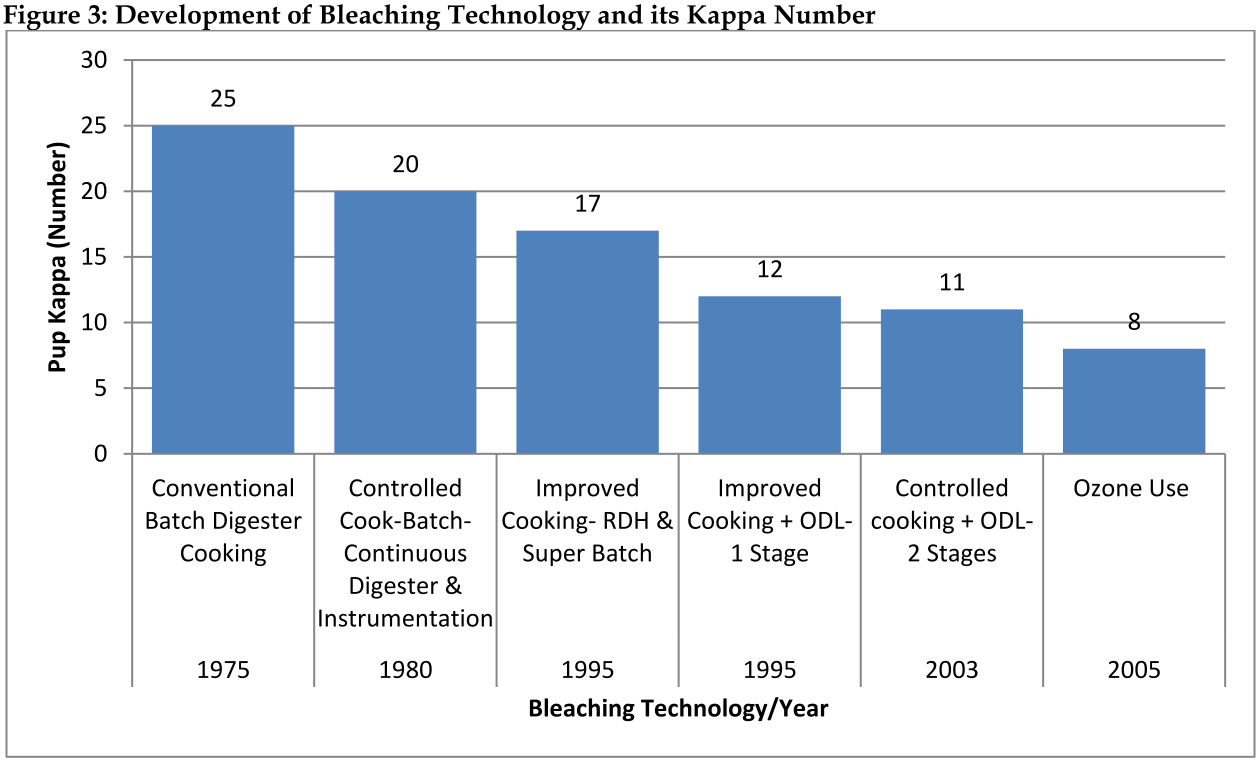
Figure 2: Energy Intensity of India's Pulp and Paper Industry (in %)



Source: Author's Calculation based on ASI data.

The decline in EI is resulted due to technological changes in the production of the P&P industry in India. The technological improvements in the P&P industry in India is reflected in the increasing total factor productivity growth, shown in the studies by Virmani and Hashim (2011), Kathuria, Raj, and Sen (2013b), Chakraborty and Dasgupta (2014). The increasing adoption of energy-saving modern technology in the major production process (raw material preparation, pulping, pulp washing and bleaching, stock preparation, and paper making) of different raw material based P&P sectors over the years have increased the energy efficiency of the P&P industry in India (CPPRI, 2000a, 2000b, 2004; Panda, 2005, 2007).[14] For instance, the increasing consciousness for environmental pollution and consumer preference of good quality products (white paper) pressures the P&P industry to use sophisticated bleaching sequences.[15] Over the years, there has been a substantial improvement in the bleaching technology from conventional batch digester to Ozone bleaching, which reduced the pulp Kappa number from about 25 in 1975 to 8 in 2005 (Figure 3). The modern technology reduces the capital costs and operation costs, making bleaching sequences more economical. With improvements in the bleaching technology the Kappa number has also declined, which indicates the reduction in the use of energy, water and chemicals in the bleaching sequences and thereby corresponding decline in waste water effluent parameter such as Adsorable Organic Halide (AOX).

Figure 3: Development of Bleaching Technology and its Kappa Number



Source: Panda, 2007

[14] For in-depth discussion on the emerging energy-efficiency and greenhouse gas mitigation technologies for the P&P industry, see Kong, Hasanbeigi and Price (2012).

[15] Bleaching sequences are used to deliginify the pulp in the early stages and employ chemical agent to destroy the residual colour in later stages. The entire bleaching process is carried out in such a manner that strength characteristics and other papermaking properties are preserved, and environmental pollution is curbed (CPPRI, 2004).

The increase in technological capabilities of the industry also improved its in-house utilization of waste water and organic solid wastes generated out of the production system. It enabled the conversion of different types of waste into productive inputs to generate in-house energy in CHP.[16] For instance, the organic solid waste in the form of dust generated in the raw-material preparation section earlier treated as waste disposal is now used as input in the boiler of CHP for steam generation. The black liquor generated in the washing, screening and cleaning section and oxygen delignification section drained out to water bodies earlier, is now used for generating power in CHP after treatment in a chemical recovery plant and lime re-burning plant.[17] The solid wastes generated in different stages of the production process such as bleaching, and paper making which were previously disposed off in open spaces is now used for power generation in CHP after treatment in an effluent treatment plant (ETP). Unlike earlier, the effluent discharged in CHP is reused for power generation after treatment in ETP. The evolution of production process in different sectors of the P&P industry in India during the 1980s and 2010s, which made it energy efficient and less polluting, is presented [(Wood-based P&P sector: Figures 4a & 4b), Agro-based P&P sector: Figures 5a & 5b), & (RCP-based P&P sector: Figures 6a & 6b)]. Different types of recycled waste are now used in the in-house CHP, which has reduced the demand for power from external sources such as the state power grid. It has also reduced the intermediary input costs and lowered the industry's energy-use related CO_2 emission and water pollution.[18]

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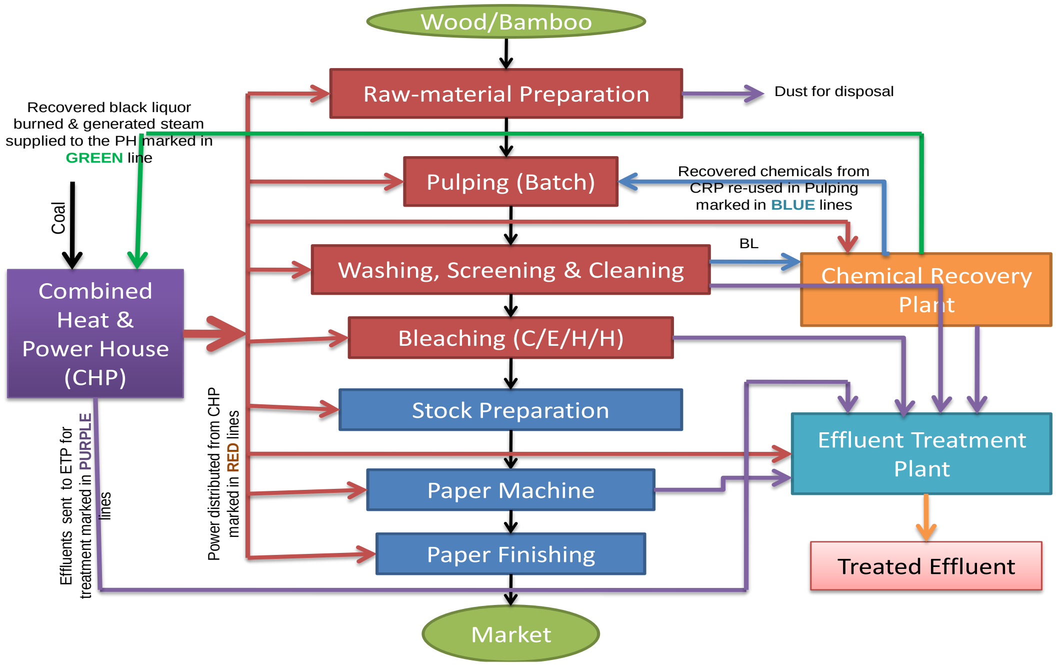
[16] The main fuels used in the boiler for co-generation are coal, lignite, rice husk, saw dust, agro-residues and other organic wastes (black liquor) generated in the factory (CPPRI, 2004).

[17] For understanding the role of black liquor in energy efficiency and CO_2 emission in the P&P industry, see Joelsson and Gustavsson (2008).

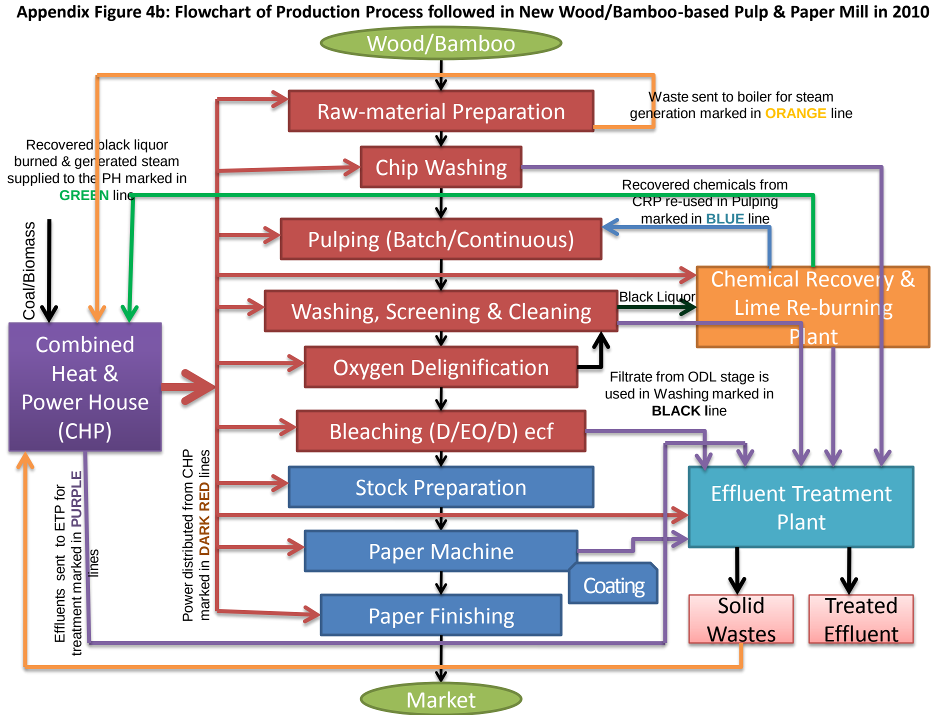
[18] Paul and Bhattacharya (2004) analyzed energy-use related CO_2 emission in the Indian economy during1980-1996. They applied the complete decomposition method and found that improvement in energy efficiency reduces CO_2 emission in the industrial sector due to fuel switching and application of fuel cleaning techniques in the production process.

Appendix Figure 4a: Flowchart of Production Process followed in Old Wood/Bamboo-based Pulp & Paper Mill in 1980



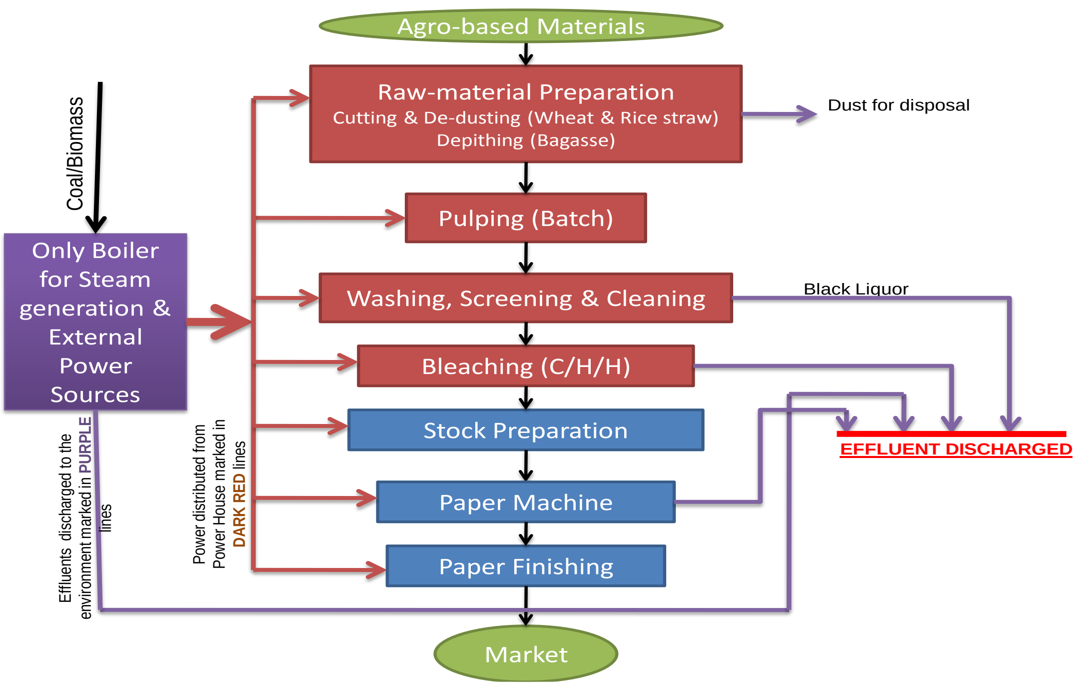
Source: Author's Compilation based on Field Survey, 2013

Appendix Figure 4b: Flowchart of Production Process followed in New Wood/Bamboo-based Pulp & Paper Mill in 2010



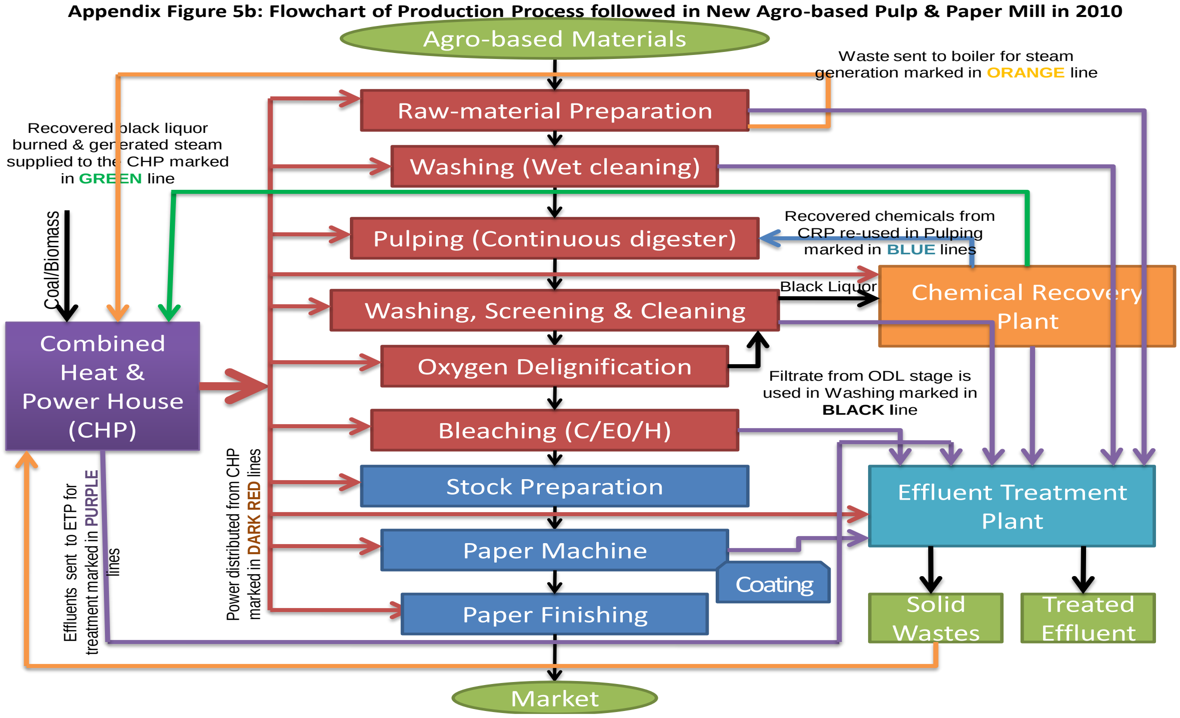
Source: Author's Compilation based on Field Survey, 2013

Appendix Figure 5a: Flowchart of Production Process followed in Old Agro-based Pulp & Paper Mill in 1980



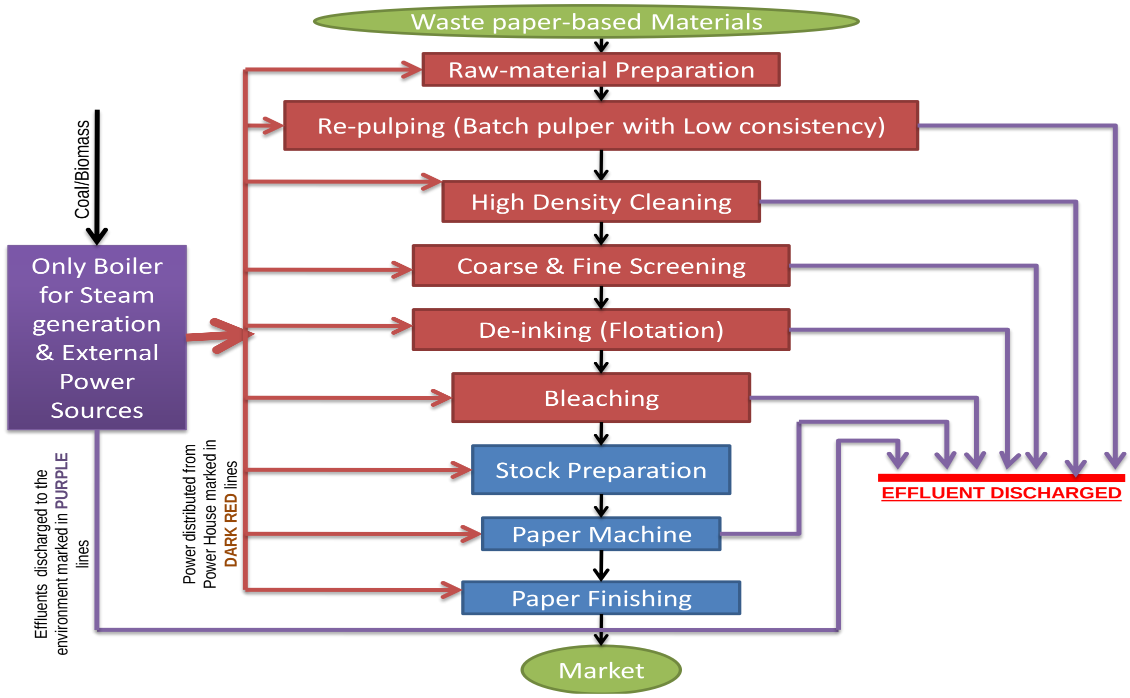
Source: Author's Compilation based on Field Survey, 2013

Appendix Figure 5b: Flowchart of Production Process followed in New Agro-based Pulp & Paper Mill in 2010



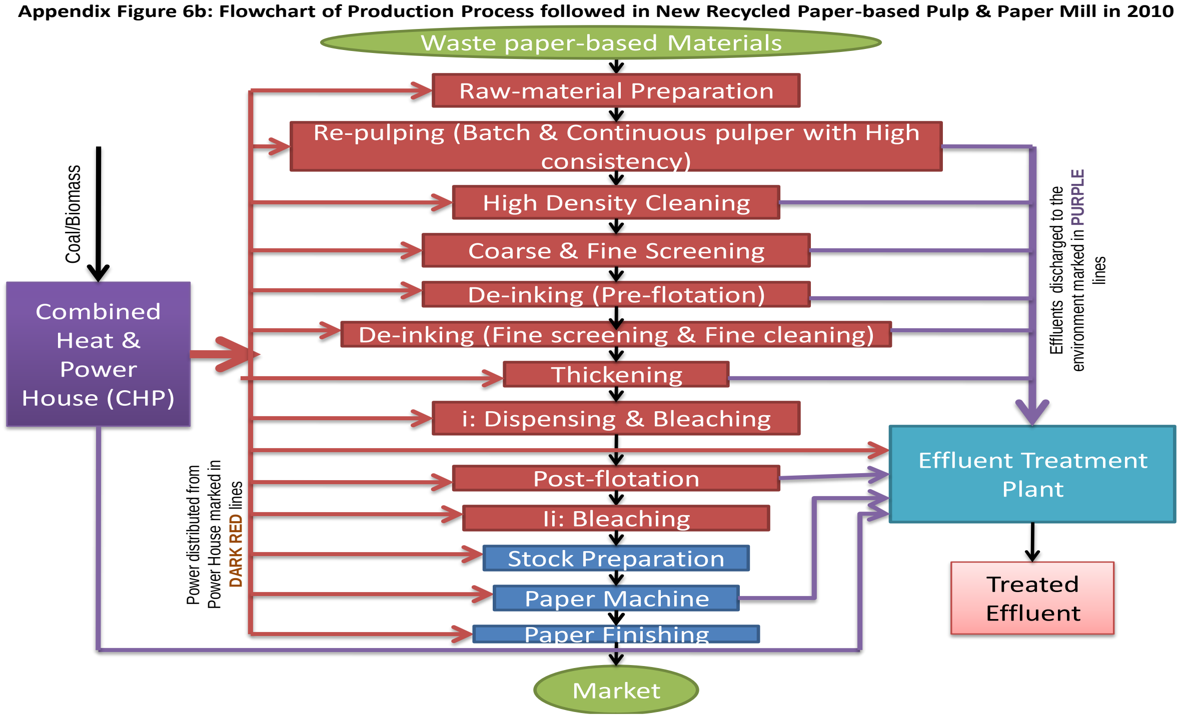
Source: Author's Compilation based on Field Survey, 2013

Appendix Figure 6a: Flowchart of Production Process followed in Old Recycled Paper-based Pulp & Paper Mill in 1980



Source: Author's Compilation based on Field Survey, 2013

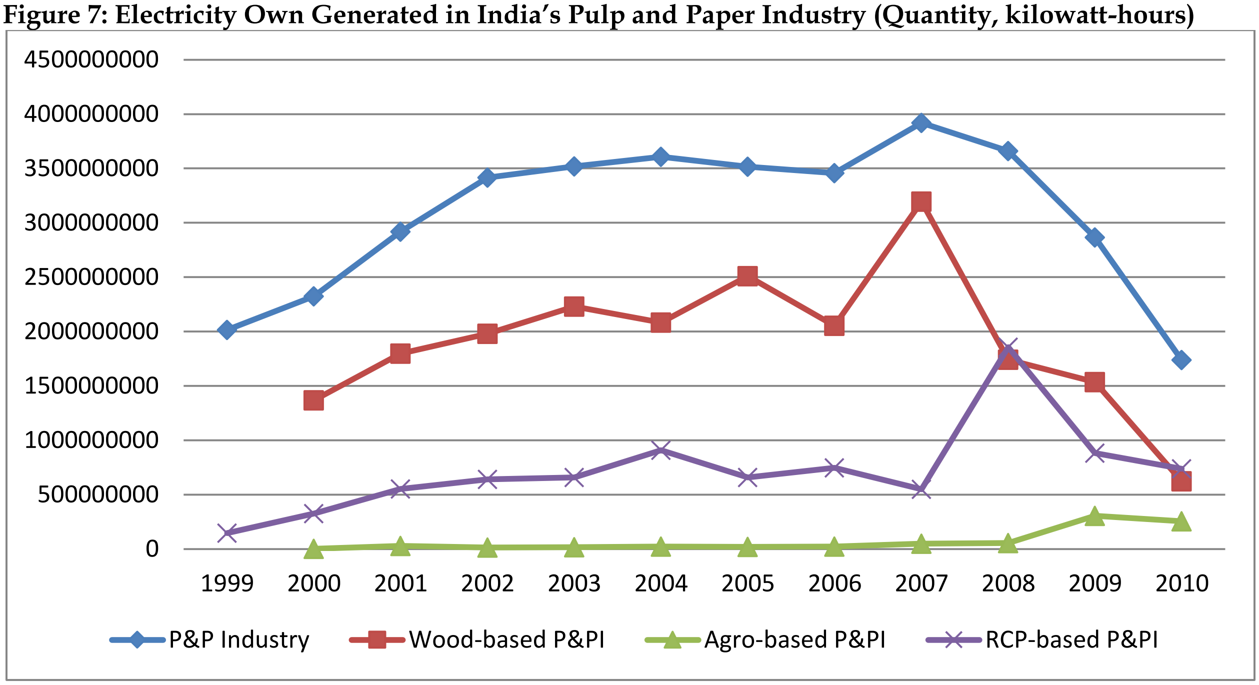
Appendix Figure 6b: Flowchart of Production Process followed in New Recycled Paper-based Pulp & Paper Mill in 2010



Source: Author's Compilation based on Field Survey, 2013

Owing to technological changes in the production process, the quantity of 'electricity own generated' through CHP by different sectors of the P&P industry had been growing, until its recent fall which could be due to the decline in economic activity because of financial crisis. In India's P&P industry, the highest amount of electricity is cogenerated by the large-sized technologically efficient wood-based P&P sector, followed by RCP-based P&P and agro-based P&P sectors (Figure 7). In-house electricity generation in the agro-based and RCP-based sector is low because of the lack of chemical recovery plants and CHP plants for co-generation (CPPRI, 2004; NPC, 2006; Field Survey, 2013).

Figure 7: Electricity Own Generated in India's Pulp and Paper Industry (Quantity, kilowatt-hours)



Source: Author's calculation based on ASI data.

The decline in EI in India's P&P industry could be attributed to three major reasons occurring simultaneously, such as, change in industrial energy efficiency policy, change in policy for reducing environmental pollution and change in raw material use. These are discussed below.

Change in Policy for Increasing Energy Efficiency: The first of these is the systematic policy initiatives by the government to make the sector energy efficient. Yang (2006) collated the various industrial energy policies modulated by different government agencies to achieve higher energy efficiency. This includes the policies of 1980s which gave high priority to energy efficiency and related environmental improvement. The government set up the National Energy Efficiency Program to promote indigenous capabilities for design and manufacture of energy efficient equipment. It made energy and environment management mandatory. In 1989, the government introduced the disclosure of company-level energy use information, and established the Energy Management Centre under the Ministry of Energy to promote and support the energy efficiency program. In 1991, the government introduced several reforms in energy prices and liberalized the regulatory regime. Further reforms were undertaken in energy pricing for the development of market-based-prices to guide energy efficiency initiatives and promote international competitiveness in 1993. Import of low quality coal was allowed in 1994. The accelerated depreciation of energy efficiency and pollution control equipment was allowed in 1995. The BEE under Ministry of Power was set up under the provisions of the Energy Conservation Act, 2001 which made mandatory provisions of energy consumption norms and energy audit, and establishing energy efficiency standards and labelling. The Electricity Act, 2003 pays specific attention to energy conservation and captive Combined Heat and Power (CHP) cogeneration.[19] The Integrated Energy Policy 2008, the first comprehensive energy policy by the Indian government, deals with energy security, access and availability, affordability and pricing. It also addresses multifaceted energy efficiency and environmental concerns by emphasising on the application of energy efficient technologies and demand side management and conservation (Ahn and Graczyk, 2012). The National Mission for Enhanced Energy Efficiency was set up in 2010 under the Ministry of Power and BEE with the mission to usher in four new initiatives to significantly scale up the implementation of energy efficiency in India. The flagship of the Mission is the Perform, Achieve and Trade (PAT) mechanism, which is a market-based mechanism to make

[19] Captive stations are units set up by industrial plants for their exclusive supply. It burn fuel inputs to generate electricity.

improvements in energy efficiency in energy-intensive large industries and facilities more cost-effective by certification of energy savings that could be traded. The PAT mechanism is designed to allow designated consumers to not only achieve their legal obligations under the Energy Conservation Act, 2001, but to also provide them with necessary market-based incentives to overachieve the targets set for them. In March 2007, the Ministry of Power notified units consuming energy more than the threshold in nine industrial sectors, namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron and Steel, Aluminium, and Railways as energy intensive industries' designated consumers. The designated consumers are required to submit the annual energy consumption report to the designated authority of the state as well to BEE, comply with the energy conservation norms and standards prescribed, purchase energy saving certificates for compliance, allow monitoring and verification of compliance by designated energy auditors. It incentivises the excess achievement of the target set by issuing energy saving certificates. It also has provision of penalty for non-compliance (BEE, 2011). These institutional monitoring might have instigated the industry to improve energy efficiency through the use of energy-saving technologies in production processes.

Change in Policy for Reducing Environmental Pollution: The Ministry of Environment and Forest, Government of India, identified the P&P industry as one of the 17 'red category' high polluting industries in India [Ali and Srikrishnan, 2001; Tewari, Batra and Balakrishnan, 2009; Central Pollution Control Board (CPCB), 2016].[20] In addition to the major production process, the P&P industry requires investment in the installation of oxygen delignification plants, chemical recovery plants, lime re-burning plants and effluent treatment plants to meet pollution control standards (CPPRI, 2004).[21] The pollution controlling plants handle waste water and solid wastes generated in various sections of the

[20] For India's water and air prevention and pollution control Acts, environment protection Act., see CPCB (2010). It also outlined rules and notifications pertaining to pollution control.
[21] For an understanding of the corporate responses to Clean Development Mechanism (CDM) in India's P&P industry, see Schneider, Hoffmann, and Gurjar (2011).
For an understanding of effective environment management tools and its implications on the P&P industry in India, see Powers, Blackman, Lyon, and Narain (2011).

production process and convert them into re-usable materials, thus reducing pollution load. Owing to stipulation of installation of chemical recovery plants and pollution control systems to reduce the pollution level, many of the factories using agro-residues as their raw material switched to the use of recycled fibre, which is less polluting by nature (CPPRI, n.d). RCP-based material is environmentally less polluting compared to wood-based and agro-based raw materials, attracting manufacturers to the use of RCP-based raw material (Table 6).

Switch to Energy Efficient Raw Material: The third important reason for the decline in total energy use in the P&P industry in India could be shift in the usage of raw material. The industry moved away from using energy-intensive conventional wood-based raw material to energy efficient and environmentally friendly unconventional RCP-based material. The share of RCP in total raw material use in the P&P industry in India increased significantly from around 35 percent in 2000 to 47 percent in 2011 (Table 5).

Table 5: Percentage Share of Different types of Raw Material in Total Raw Material Use in India's Pulp and Paper Industry

Segment	1970	1995	2000	2002	2005	2009	2011
Wood-based (%)	84	39.18	29	36.8	35	39	31
Agro-based (%)	09	32.36	36	32.4	30	31	22
Recycled fibre based (%)	07	28.46	35	30.8	35	30	47
Grand Total	100	100	100	100	100	100	100

Source: Kulkarni, 2013

As can be seen in above table, the share of forest-based raw material in the total raw material consumed by the P&P industry India has declined drastically from 84 percent in 1970 to 31 percent in 2011. The decline in the use of wood-based material is due to high wood prices caused by shortages in the supply. The insufficient availability of wood-based material due to the supply ban on forest-based wood to the industry opened new avenues for the use of alternative unconventional raw materials such as agro-based raw material and RCP-based raw material. The use of agro-based raw material and RCP-based raw material in the small- and medium-scale P&P mills were encouraged by the government through the provision of facilities such as tax holiday, excise duty remission and liberalized import of machine and tools during 1970s and 1980s. The establishment of a vast number of small- and medium-sized agro-based and RCP-based P&P mills was promoted to meet the burgeoning domestic paper demand, especially in offices and in the education sector, and to realise self-sufficiency in the paper and paper products. These two raw material based sectors were also incentivised because of their small gestation period and potential for improving the employment and income, especially in the rural India. All this increased the usage of unconventional raw materials in the industry. The share of agro-based material in the total raw material use increased from 9 percent in 1970 to 22 percent in 2011. Similarly, the share of RCP-based raw material increased from 7 percent in 1970 to 47 percent in 2011.

Although there is a copious supply of agro-based raw material, its share in total raw material consumption has started falling from 36 percent in 2000 to 22 percent in 2011. The share of agro-based material declined due to various reasons. First, its seasonal availability led to the need for extensive storage space at the mill site and the scattered nature of production led to high costs of assembling and transportation. Second, the poor strength and drainage properties and high silica content of straw pulp resulted in low quality of paper products such as Kraft paper and paperboards. Low fibre quality also resulted in generation of huge pollution load. Third, lack of chemical recovery plant, pollution control system, and cogeneration of power plant, increased the cost of production and pollution load of these units. Besides this, the industry also faces competition in the use of agro-residues which are consumed as raw material in various other sectors. For instance, wheat straw is traditionally used as cattle feed and for hut roofing in rural India. The bagasse is applied as fuel material in cogeneration of captive power plants of sugar mills, and so on (CPPRI, n.d; 2000a, 2004; JPC 2002; Datt and Mahajan, 2012).

The share of recovered paper in the total raw material use has been continuously increasing. This was because of establishment of large numbers of small-sized RCP-based P&P mills during the same time as when agro-based P&P mills were set up. The shortages in the wood-based material supply in the country encouraged firms to use RCP-based raw material. Further, the stipulation that chemical recovery plants and pollution control systems be installed to reduce the pollution level forced many of these factories using agro-residues as their raw material to switch to the use of recycled fibre (CPPRI, n.d). The use of recycled fibre has gained popularity also because of its energy efficient and environmentally sustainable nature (Table 6 & 7).

Table 6: Energy Consumption among India's Pulp and Paper Mills (Per tonne of paper)

Mills	Heat (gigajoules)	Power (kilowatt hours)
Forest-based	25	1,800
Agro-based	15	1,000
Waste paper-based	6	850

Source: Jaakko Pyory Consulting, 2002

Table 7: Effluents Generated by India's Pulp and Paper Mills

Mills	Effluent flow (l/kg. paper)	TSS*	COD*	BOD*	AOX*
Forest-based	175	11	37	3.7	0.4
Agro-based	120	40	47	10	n/a
Waste paper-based	32	2.6	8.7	1.3	n/a

Notes:
(1) *: Indicates the parameters of mill effluent pollution load measured in kg/tonne of paper.
(2) TSS: Total Suspended Solids; COD: Chemical Oxygen Demand; BOD: Biochemical Oxygen Demand; and AOX: Adsorbable Organically bound Halogens.
Source: Jaakko Pyory Consulting, 2002

5: Summary and Conclusion

In the manufacturing industry, especially in energy intensive sectors like P&P, the efficient use of energy is the key to minimizing costs of production and reducing environmental impacts. This study tries to fill the gaps in the literature at the sub-sectoral industry level study. Using ASI data for 1999 to 2010, we analyzed the factors that contribute to the change in energy use in the P&P industry in India. We applied the LMDI approach, a complete decomposition method to understand the contribution of various pre-defined factors on change in energy demand during 2000-2010. The analysis shows that increase in activity raises the total energy demand. The increase in the activity effect could be attributed to addition of production capacities in the industry by the establishment of new factories. Although the structural effect is positive, its contribution to the changes in total energy consumption is insignificant. The negligible structural effect on total energy use change is because of increasing number of RCP-based P&P factories using waste paper as a raw material, which uses lesser quantity of energy to produce one unit of output. The decline in the energy intensity effect, however, is main driving force for the decline in total energy demand in India's P&P industry. The observed trend of declining energy intensity could be due to systematic policy initiatives by the government emphasizing increasing energy efficiency through the adoption of energy-efficient carbon neutral technology in the production process. It could also be due to the shift in raw material use from conventional energy-consuming wood-based material to unconventional energy-efficient RCP-based material. Considering the contribution of declining energy intensity on total energy consumption in the P&P industry in India, and scope the scope for further improvements in energy efficiency compared to international standards the study calls for enhanced attention for higher energy efficiency in the industry. The differential energy efficiency exhibited by different raw material-based P&P sectors in the industry urges for specific policy attention for different raw material based P&P sectors in order to improve the overall energy efficiency of the P&P industry in India, which will in turn increase its sustainability.

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Appendix- 1.1

Identification of Different Inputs Consumed by the P&P Industry in India

To identify different types of inputs consumed by NIC-2008 based (17011-17099) Manufacture of Paper and Paper Products factory in India mentioned in Block-H (Indigenous Input Items) and Block-I (Imported Input Items) in the unit level data of ASI given for 1998-99 to 2009-10,we follow below mention steps using Stata/S.E. 11.2.

Step 1: To find out the maximum amount of a particular input consumed by the factory, we used the 5-digit input code given by ASI Commodity Classification (ASICC)-2009. We measured the input coefficient of all ten major basic indigenous items reported in Block H and all five major basic imported items reported in Block I of ASI data separately. Input coefficients are measured as follows:

Input coefficient 1 = Purchase Value of input 1 / Total basic items

Input coefficient 2 = Purchase Value of input 2 / Total basic items

Input coefficient 10 = Purchase Value of input 10 / Total basic items

We used the same technique to find out the input coefficients of Block I, which has the five major basic imported inputs consumed by the unit.

Since purchase value (in ₹.) has been used to measure material and energy consumption in the ASI Tabulation Plan, we considered purchase value to estimate the input coefficient. Lack of data due to under-reporting on quantity consumption for all inputs is another important reason for considering purchase value.

Step 2: In the same file, we traced the ASICC codes of these basic inputs of Block H and Block I separately. The steps followed for this are:

First, we identified the ASICC codes of input cases of Block H and Block I using the ASICC code Manuals for different years given by the ASI.

Secondly, we clubbed some of the related ASICC codes to identify the broader classification of raw material-based industries. For example, the wood-based P&P factory uses wood and bamboo as its primary inputs; therefore, we clubbed wood, forestry and logging products, and bamboo to form a wood-based input. Appendix Table 1.1 shows how we identified the ASICC coded inputs.

Step 3: We dropped the input coefficient if its value was less than the other coefficients in all ten cases of Block H and all five cases of Block I. Thus, the maximum value of the input coefficient and its respective ASICC codes are retained while others are deleted. In this way, we kept only the maximum value of input coefficients and its respective ASICC codes in all cases.

Step 4: Knowing the maximum value of input coefficients and its ASICC codes, we dropped all other ASICC if it does not belong to the specified ASICC code in all cases. Hence, we created a database where only the above-mentioned ASICC codes and their input coefficients in all ten cases in Block H and all five cases in Block I are retained.

Step 5: Finally, we clubbed some of the predetermined ASICC codes (given in Appendix Table 4.4) to generate data on different raw material-based P&P sectors. For instance, we clubbed item 1, 2 and 3 to trace the wood-based P&P factories.

Step 6: We estimated the total quantity of consumption and total purchase value of different inputs combining those from indigenous as well imported sources.

Appendix Table 1.1: Harmonization of ASICC				
S.No.	**ASICC-2009 Code**	**Item Descriptions**	**Harmonised item code for the study**	**Harmonised Item for the study**
1	51101 –54129	Wood, corck and thermocol	1	1 + 2 + 3 = Wood-based inputs = 1
2	14401 –14489	Forestry and logging products	2	
3	12935	Bamboo	3	
4	11101 – 4389	Animal, vegetable, horticulture, forestry products, beverages	4	4 + 5 +6 = Agro-based inputs = 2
5	14501 –15619	Produce or sericulture and beverages, tobacco and pan masala	5	
6	16301 –17299	Misc. Non-edible substances of animal/vegetable origin n.e.c. and Services and processes relating agricultural activities and animal husbandry	6	
7	54108	Waste paper	7	7 + 8 = Recycled paper-based inputs = 3
8	55101 – 7339	Paper and paperboard	8	
9	16101 – 16129:	Natural water & ice for industrial use	9	Water consumption = 9
10	21101 –29899	Ores, minerals, minerals fuels, lubricants, gas, electricity	10	Ores, minerals & fuels = 10
11	31102 – 39089	Chemicals & allied products	11	Chemicals = 11
12	54107	Sludge, ETP	12	Sludge = 12
13	41101 – 49899	Rubber, plastic, leather and products thereof	13	Rubber, plastic and leather products = 13
14	61101 – 69189:	Textile and textile articles	14	Textile materials =14
15	71101 – 79589	Base materials, products thereof and machinery and equipments, and parts thereof, excluding transport equipments	15	Machinery & equipments = 15
16	81101 – 85299	Railways, airway, ships and road transport equipment and related equipments and parts	16	Transport equipments = 16
17	91101 – 99221:	Other manufactured articles & services	17	Other manufactured articles = 17
18	97101 – 97989	Service related items	17	Services = 17
19	.	Other inputs	18	Other inputs = 18
Source: Author's Compilations				

Appendix- 1.2

Harmonised Classification of NIC 5-digit Manufacture Paper and Paper Products Industry in India

Appendix Table 1.2: Classification of 5-digit Manufacture of Paper and Paper Products Industry in India					
S.No.	**NIC 2008**	**5-digit Industry**	**NIC 1998 & 2004**	**NIC 2008**	**Harmonisation of NIC 1998, 2004, & 2008**
1	17011	Manufacture of pulp	21011	17011	17011
2	17012	Manufacture of newsprint	21013	17012	17012
3	17014	Manufacture of packing paper	21014	17014	17014
4	17015	Manufacture of special purpose paper/paper products for computers	21017	17015 + 17091	17015
5	17016	Manufacture of paperboard, strawboard	21015	17016	17016
6	17017	Manufacture of hardboard including false board & chipboard	21016	17017	17017
7	17019	Manufacture of other primary paper material including composite paper & paperboard, n.e.c.	21019	17019	17019
8	17022	Manufacture of corrugated paper , paperboard & containers	21023	17021 + 17022	17022
9	17023	Manufacture of cardboard boxes	21022	17023	17023
10	17024	Manufacture of sacks & bags of paper	21021	17024	17024
11	17029	Manufacture of other containers of paper & paperboard n.e.c	21029	17029	17029
12	17092	Manufacture of paper cups, saucers, plates, hoops, cones & other similar products	21091 + 21092	17092	17092
13	17093	Manufacture of paper, including printing, writing & photocopying ready for use	21012	17013 + 17093	17093
14	17094	Manufacture of paper pulp articles other than containers (such as egg trays, dolls, mache articles, wall paper)	21093 + 21094 + 21095 + 21096	17094 + 17096	17094
15	17095	Manufacture of file cover/file board & similar articles	21097	17095	17095
16	17097	Manufacture of carbon paper & stationary items	21098	17097	17097
17	17099	Manufacture of other pulp & paper products n.e.c.	21099	17099	17099
Source: Author's Compilations					