Assessing Information Gap in Industrial Performance Analysis for Sustainable Development: Insights from Case Study of Paper Industry in India

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Abstract

Energy and water conservation are the two key sustainability parameters for the industrial sector with respect to natural resource use. Energy intensity, energy productivity and water footprint are frequently mentioned as sustainability indicators in the relevant literature. The construction of these indicators is however, contingent upon availability of relevant database. The current paper attempts to employ the industrial input use related data published in the Annual Survey of Industries (ASI) to construct these indicators for the pulp and paper industry in India. It also explores how these indicators can be interpreted to analyse the sustainability performance of this industry with respect to natural resource use. While constructing these sustainability indicators, it is however, observed that although energy related indicators can be constructed on the basis of the data available in ASI, water footprint assessment cannot be made on the basis of the same due to inadequate reporting on water usage. The energy use indicators, constructed with this database, reveal important insights regarding energy use behavior of the industry. Since water use data were found to be inadequate in ASI, an attempt was made to collect primary data necessary for water footprint calculation through face to face interaction with a paper manufacturing unit as a case study. It is found that companies publish the data on water consumed (in cubic meters) for industrial processes in their corporate sustainability reports. These reports, however, do not publish adequate data in a manner to make results comparable across manufacturing units or to come up with a water use indicator for the industry as a whole. But our efforts show that it is possible to make companies report relevant data for arriving at right kind of water footprint estimates. The study emphasizes the importance of a consistent database to construct sustainability indicators which can be analysed to come up with significant inputs in policy formulation.

1. Introduction

1.1 Performance evaluation criteria to achieve the goals of sustainable development have evolved over the years. Prior to 1960s, under the paradigm of economic growth, investment leading to physical capital accumulation dominated the performance evaluation indicators of any economic actors. Gradually the roles of education, knowledge and skill formation through investment in social and human capital building were acknowledged to

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make the performance indicators more complete. From the decades of 1970s, the role of natural capital (water, air, forest, mineral, fossil fuel etc.) to support economic activities and its contribution in economic development started receiving increasing attention (Peskin and Angeles, 2002). With the emergence of oil crisis in seventies energy resource used by the industries became a pertinent performance indicator. Today all three types of capital – physical, social and natural- are recognized as three important drivers in the manifestation of sustainable development indicators (Dasgupta, 2007). Today while assessing the performance of industries, it is not only their contribution to GDP that is accounted for, but their contribution to formation of human capital through corporate social responsibility and the level of efficiency with which they use the natural resources are also considered to be of significant importance. In Indian context, the policy domain has also emerged to address the resource use efficiency (especially energy and water) and its environmental impacts (Energy Conservation Act 2001, National Environmental Policy 2006, National Action Plan on Climate Change 2008).

1.2 Construction of any sustainability indicator is, however, contingent upon availability of reliable and consistent database. The current paper makes an attempt to explore the scope of Annual Survey of Industries (ASI) data as published by the Central Statistical Organization (CSO) to construct and analyse the energy and water related sustainability indicators with the example of the pulp and paper industry. The paper focuses on energy and water use efficiency as they are the two most important components of the natural resource portfolio for the industrial sector.

1.3 In this backdrop, remainder of the paper is structured in the following manner. In Section 2, energy related indicators are constructed and analyzed on the basis of data available in various volumes of ASI. In Section 3 an attempt is made to collect and analyse primary data necessary for water footprint calculation through interaction with a paper manufacturing unit, as water footprint assessment cannot be made on the basis of ASI data due to inadequate reporting. Finally, Section 4 summarizes the findings of the paper.

2. Analysing evolving pattern of energy use behaviour of the pulp and paper industry in India using long run published database

2.0 New technologies enabling production of increased level of output with unaltered level of input through enhanced input efficiency plays an important role in a resource constrained world. As one of the most energy intensive industries in India, several technological up-gradations have already taken place in past few decades in Indian pulp and paper industry. However, methodologically it remained always challenging to quantify the technological progress, its implications towards energy use and its contribution to the output growth. Availability of ASI data enables us to construct several indicators reflecting the energy use behavior of the industrial sector in the country during the period 1973-74 to 2010-11. The analysis of these indicators reveals important policy implications in this context.

2.1 Targeting energy intensity reduction for the energy intensive industries in India

2.1.1 Enhanced energy efficiency is considered to be one of the most important parameters of industrial sustainability (UNIDO, 2011, Roy et al 2013). In the National Mission on

Enhanced Energy Efficiency (NMEEE 2008), seven energy intensive industries are identified to primarily act upon with respect to their energy use behaviour. A more rigorous energy intensity decline is targeted through creation of a market based policy like Perform Achieve and Trade (PAT). These industries are subject to energy intensity targets to achieve within the stipulated period of 2011-12 to 2013-14 followed by a trade between over-achievers and under-achievers. Energy efficiency in India in-fact contributed significantly to bring down the total energy consumption but the historical trend of such intensity reduction in many cases remained less than what is needed to touch the world best within coming years (Roy et al 2013). Since there are other factors apart from energy intensity that influence the total energy demand of an industry, decomposition of energy demand is a useful tool to understand retrospectively the relative contribution of different drivers of change of energy demand including energy efficiency (Ang & Lee, 1996). Prior to considering the example to the pulp and paper industries, total energy demand of the energy intensive manufacturing sector in the country is decomposed using the above mentioned ASI data. The framework of analysis is as follows:

Let,

E_t = total industrial energy consumption

$E_{i,t}$ = energy consumption in industrial sector *i*

Y_t= total industrial production

$Y_{i,t}$ = production of sector *i*

$S_{i,t} = Y_{i,t}/Y_t$ = production share of sector *i*

$I_t = E_t/Y_t$ = aggregate energy intensity

$I_{i,t} = E_{i,t}/Y_{i,t}$ = energy intensity for sector *i*

The subscript *'t'* denotes the time period

Thus, total energy consumption at period 't' could be expressed as:

$$\boldsymbol{E_t = \sum_i E_{i,t} = \sum_i Y_t \frac{Y_{i,t}}{Y_t}\frac{E_{i,t}}{Y_{i,t}} = \sum_i Y_t S_{i,t} I_{i,t}} \quad \text{.....(1)}$$

It shows that at any point of time energy demand could be explained in terms of three drivers (level of output Y, sectoral/structural composition of the industrial sector represented by relative output shares of energy intensive and non-energy intensive industries i.e. values of S_i and energy intensity of different sectors I_i). Using these three drivers as explanatory effects, the change in energy consumption can be theoretically decomposed using additive and/or multiplicative methods as represented below:

In additive form change in energy demand could be expressed as

$$E_T - E_0 = \Delta E_{TOT} = \Delta E_{OE} + \Delta E_{SE} + \Delta E_{IE}$$

2.1.2 Based on Divisia Index, a Log-Mean Divisia Index (LMDI) method is adopted (Ang & Choi, 1997) here to decompose the total energy use of energy intensive industries in India into activity effect, structural effect and energy intensity effect for the period 1973-74 to 2010-11. This gives perfect decomposition as it satisfies the factor reversal test and results do not contain any residual term and is consistent in aggregation. Given LMDI the decomposition of energy consumption change is identified as follows:

$$\Delta E_{OE} = \sum_i w_i ln\left(\frac{Y_T}{Y_0}\right) \quad .....(2)$$

$$\Delta E_{SE} = \sum_i w_i ln\left(\frac{S_{iT}}{S_{i0}}\right) \quad .....(3)$$

$$\Delta E_{IE} = \sum_i w_i ln\left(\frac{I_{iT}}{I_{i0}}\right) \quad .....(4)$$

Where $w_i = \frac{E_{i,T}-E_{i,0}}{\ln E_{i,T}-\ln E_{i,0}}$

2.1.3 A decomposition analysis of total energy use of energy intensive industries in India, using ASI data (which includes pulp and paper industry) is represented in Figure 1. This helps to understand the contribution of technological and behavioral drivers in energy use. Results show that energy intensity in the industrial sector, especially in energy intensive manufacturing sector has decreased over the past decades and helped neutralizing a part of energy use growth emerging out of output/activity growth.

2.1.4 In Indian context, while activity growth without technological and behavior change could have led to 147% increase in the energy use by seven energy intensive manufacturing industries in India energy efficiency gain has pulled it down by 50% (Figure 1). This implies that in a developing country where the activity growth will continue as a development imperative, reduction in energy use intensity can help the industries to stay on a sustainable energy use pathway.

2.2 An Analysis of Input Productivity in Pulp and Paper industries

2.2.1 The nature of efficiency achieved in energy use is contingent upon efficient management of other inputs and their relation to energy input. This paper employs the growth accounting method[2] to explore the overall input productivity of the pulp and paper industry in India. Availability of ASI data allows us to undertake the study for almost past four decades (1973-74 to 2010-11). To get a better understanding the study period is divided into three sub periods: 1973-74 to 1985-86, 1986-87 to 1999-00 and 2000-01 to 2010-11. The choice of the sub periods are contingent upon the land mark policy changes brought in the context of industry sector, especially in the pulp and paper industry. The first sub period is the pre-liberalization era for the Indian industrial sector. In the 1970s excise concessions were given to small agro based paper mills, which resulted in a rapid increase of small mills and capacity of the pulp and paper industry in the county. The second sub period records a number of significant changes in both economic and industrial policies in the country. The second sub period starts with the initiation of the official process of liberalization during mid 1980s which culminated in 1991 (Roy et al 1999). During late 80's, i.e. at the beginning of the second sub-period the paper industry was in a severe oversupply situation with capacity utilization rates being around 60% (CPPRI

[2] For detailed methodology please refer to Roy, J., Sathaye, J., Sanstad, A., Mongia, P., & Schumacher, K. (1999). Productivity Trends in India's Energy Intensive Industries. *The Energy Journal, 20* (3), 33-61.

2002). In early 1990s the government reversed the policy to make large units more competitive (e.g. by removing excise concessions from agro based mills) (Narayana and Sahu 2010). In 1997 this sector was fully de-licensed followed by large inflow of funds. Hence the second sub period captures the impact of initiation of the process of liberalization. The third sub-period accounts for adoption of a series of unique policies guided towards efficient energy use and mitigation of emission of global pollutants. The Energy Conservation Act was adopted in 2001 to provide for efficient use of energy and its conservation and the Bureau of Energy Efficiency was established. In 2006, the National Environmental Policy was adopted which identified interdependencies among, and transboundary character of, several environmental problems and encouraged the industries to participate in the Clean Development Mechanism (CDM) through capacity building. It also emphasized on industrial energy efficiency; producing more industrial output using less energy recourse. Following this, the National Action Plan on Climate Change was adopted in 2008 under which National Mission on Enhanced Energy Efficiency provided a legal mandate for the implementation of the energy efficiency measures through the institutional mechanisms of the Bureau of Energy Efficiency (BEE) in the Central Government and designated agencies in each state. As mentioned in the Action Plan, PAT was introduced in the year of 2012. So, the third sub-period carries the impact of a number of emerging climate change mitigation related policies with special focus on energy efficiency along with the residual impact of liberalization.

2.2.2 Growth accounting exercise and estimates of Total Factor Productivity Growth (TFPG) using the ASI data reveals that during 1973-74 – 2010-11, in the pulp and paper industry in the country, on an average there was not much improvement of input productivity (Table 5). During the first sub-period, there was a negative growth of input productivity implying that had there been no change in input level, output would have declined. While it remained so during the second sub period as well, an improvement was observed during the third sub period. During 2000-01 to 2010-11, a 7.85% growth in output was associated with 1.6% growth in input productivity. This implies that approximately 20% of output growth in the pulp and paper industry could have happen without any increase in quantity of inputs but due to increase in the efficiency of inputs. In output growth, however, on an average, contribution of input growth remained much higher than input efficiency growth. If the goal is to make steadily increasing technological progress supplementary to autonomous historical trend observed here thorough strategic intervention is needed. This is even more necessary to avoid the lock in effects if technological progress that had been observed in Indian pulp and paper industry (Roy et al 2013).

2.2.3 It is evident that Indian paper industry has started experiencing improvement in autonomous technological progress and during 2000-01 to 2010-11 reflected in input productivity growth. However, from the perspective of energy use, the major question remains, 'how energy saving has this autonomous technological advancement been so far?' The parametric estimation of translog cost/production function using ASI data shows that although for the study period as a whole the industry exhibited an energy using bias, during post 1986-87 it started becoming significantly energy saving in nature. This implies that the share of energy cost since the second sub period declined as a proportion of total cost along with autonomous technological advancement. It is also evident from the trend of cost shares for this industry over the study period (Figure 2). This is interesting because it captures the behavioural change among the producers who are paying greater attention to the reduction of energy cost share in total cost of production to remain competitive during post-liberalization era. During the first sub-period the low productivity was caused largely by the protection afforded by high tariffs on imported paper products and other policies, which allowed inefficient, small plants to enter the market and flourish (CPPRI 2002). There was a growing competition during the second sub period, especially towards the end, given the fact that the large production units were encouraged. It also compelled the manufacturing units to reduce their energy cost as for the paper industry it constituted quite high a proportion of the total cost (Figure 2). Also during the last decade, there was a significant policy drive to encourage reduction in energy consumption in the energy intensive industries in India with a focus to the agenda of sustainable development (NEP 2006, NAPCC 2008). The reason behind the pulp and paper industry exhibiting energy using technological change during pre 1986-87 may be technology lock-in which is not tested and reported here.

2.2.4 Similar to the trend of other industries in India, the capital input has grown to substitute labour throughout the study period. The only exception that demands attention is the complementary relation between labour and capital during the second sub period. A likely explanation is as follows. There was a steady fall in employment during this sub period. Although there was a secular decline in the wage-rental ratio, almost 15% of the workers in the organized manufacturing sector in the country lost their jobs between 1995-96 and 2000-01 (Nagaraj, 2004). Simultaneously, there was severe shortage of capital formation in the sector during the initial half of this period. Although the process of liberalization started, the prolonged financial shortages of the sector continued till the end of the sub period. It was only towards the second half of 1990s when financial agencies like The Industrial Development Bank of India (IDBI), Industrial Credit and Investment Corporation of India (ICICI), and Indian Renewable Energy Development Agency (IREDA) etc. became willing to advance the long term soft loans to modernize the industry (Kujur 2012, Narayana and Sahu 2010; Mathur, Thapliyal and Singh, 2009). This simultaneous downfall of capital and labour could have resulted in such a complementary relationship.

2.2.5 The industry has evolved over time to significantly substitute energy inputs either by capital or material (Table 3) showing technological changes that are finding substitute for energy. The relationship between energy and material is of special importance. In one hand they are evolving as substitutes and on the other hand the technological bias is exhibiting an increasing share of material input. So the nature of technological progress in both ways is raising the cost share and the use of material input in the paper production process in India. If the goal is finally to make the whole production process less recourse intensive then in strategic management these features can be accommodated.

2.3 How Does Price Induced Changes Matter in Input Use Behavior?

2.3.1 Empirical estimates of negative own price elasticity especially for energy input have far reaching positive implications as far as energy consumption and resultant CO_2 emissions are concerned (Roy *et al.*, 2006). In the pulp and paper industry along with the fact that the cost share of energy has come down since 1985-86 along with the technological progress, negative own price elasticity of energy is also in place (Table 4). The long run own price elasticity is however, estimated to be lower as compared to the short run elasticity values estimated for the sub-periods with gradual increase in the absolute value of the elasticity.

2.3.2 This implies that industries do take decision to reduce their energy consumption. In balance there is reduction in energy use. Estimates also suggest that such behavioural response is actually increasing in the recent years. . The possible reason could be the fact that in recent years the industry in modernizing with new technologies to become more energy efficient in the face of the emerging policy domain and rising fuel cost. For the final sub period of 2000-01 to 2010- 11, the absolute value of elasticity is greater than unity suggesting that 1% increase in fuel price will induce this industry to reduce its energy use by more than 1%. The price elasticity also reflects the behavior of average productivity of the factors. For example, during 1973-74 -2010-11 the own price elasticity -0.22 for energy in the paper industry implies that a 1% increase in the price of energy would increase energy productivity by 0.22%. Now given that energy and material are substitutable (Table 3), an increase in the price of energy would on the one hand improve energy productivity (reduce energy intensity) because of the negative own price elasticity but on the other hand it would additionally reduce material productivity and hence will make the production process more material intensive.

2.3.3 One of the important drivers to enhance the input efficiency is definitely availability, diffusion and adoption of new technology. In India, the potential of energy efficient technology adoption is very high as there are significant interplant variations in energy use per unit of output produced within an industry (Goldar, 2010). Perform Achieve and Trade[1] scheme adopted under NAPCC (NAPCC 2008, para 4.2), the energy intensity targeting and sale of energy saving certificates by the over achiever to the under achiever is indeed a strategic technological progress management strategy with target of energy saving bias. The study shows that unless supplemented by well designed energy certificate price policy the outcome cannot be anticipated given the behaviourial responsiveness of industries (Roy, 2010; Dasgupta *et al.*, 2011).

3. Water use efficiency: Case Study of a Paper Production Unit

3.0.1 Water accounting is increasingly becoming an integral part of corporate resource use accounting (Chakraborty & Roy, 2012). The Water Footprint of a business or "corporate water footprint" or "organizational footprint" can be defined as the total volume of fresh water that is used directly and indirectly to run and support the business. Or, it can be defined as the total volume of freshwater that is used directly and indirectly, to produce the products and services of that unit expressed in terms of the volume of freshwater use per year. For quantifying this amount "corporate water footprint" or "organizational footprint" or the volume of freshwater use at the place where the actual production and water use takes place is measured (Hoekstra & Chapagain, 2007; 2008). The water footprint is expressed as green, blue and grey water footprints. The green water footprint refers to

[3] http://www.beeindia.in/ accessed on 30th May 2012.

the consumption of rainwater stored in the soil as soil moisture. The blue water footprint refers to the surface and ground water (consumed and evaporated). The grey water footprint refers to volume of freshwater required to assimilate the load of pollutants. In developing countries like India, water footprint can be used as indicator for sustainable water management, especially for industries in the face of competing demand for water. Accounting for corporate water use through the application of water footprint concept can identify the water related risks of businesses. This can influence business strategies as well as help in formulating water policy relevant for business sector. There is dearth of studies on water footprint for Indian industries. We could not get much secondary source of information, which could provide us with dependable estimate of water footprint of industries. Current statistics of water use related to different industries (Annual Survey of Industries, various issues) in India is given in terms of money spent for purchase of water. Water provides input service for productive activity, which might consist of ground/ surface water extraction service, municipal water supply service, wastewater-recycling service etc. These statistics do not provide any scope to estimate the WF of an industrial production unit. So we approached a number of individual industrial units and finally got one paper production unit who was willing to share time and effort to support the proposed research objective through providing access to information. Data was collected through primary survey, using a pre set questionnaire (can be seen upon request from authors).

3.0.2 In this section, water footprint for the paper production unit manufacturing "newsprint" and "printing & writing paper" has been estimated, so that challenges in the process can be understood. In addition, the goal is to assess what information gap needs to be bridged at official statistics level, if water footprint estimates are to be generated for Indian industries. The component-based method or bottom – up approach (Leenes and Hoekstra, 2008) has been adopted in this study. This is found to be the most appropriate after reviewing all other methods applied in various studies.

Let,

WF = Water Footprint

BWF_O = Operational Water Footprint

BWF_s = Supply - Chain Water Footprint

$WF_{bus, oper, input}$ = Operational WF for production inputs

$WF_{bus, oper, overhead}$ = Operational WF for overheads

$WF_{bus, sup, input}$ = Supply - chain WF for production inputs

$WF_{bus, sup, overhead}$ = Supply - chain WF for overheads

BWF_{green} = Green WF

BWF_{blue} = Blue WF

BWF_{grey} = Grey WF

3.0.3 The case study production unit is waste paper based unit, so green water footprint is not relevant. Because of that reason only blue and grey water footprints are estimated. WF is calculated by adding the Operational WF (direct *water use)* and Supply Chain WF (indirect *water use).* Both Operational and Supply - Chain WF consist of two parts: the water footprint directly associated with the production of the product in the business unit and an overhead water footprint. The following relations explain the methods of estimation.

$$WF = BWF_O + BWF_s \quad \text{.........(5)}$$

$$WF_{bus,\ oper} = WF_{bus,\ oper,\ input} + WF_{bus,\ oper,\ overhead} \quad \text{.........(6)}$$

$$WF_{bus,\ sup} = WF_{bus,\ sup,\ input} + WF_{bus,\ sup,\ overhead} \quad \text{.........(7)}$$

Both in case of operational and supply - chain water footprint distinction is to be made between green, blue and grey water footprint by presenting the results with the help of the following formulae.

$$BWF_{bus,oper,\ input} = BWF_{o.\ green} + BWF_{o.blue} + BWF_{o.grey} \quad \text{.........(8)}$$

$$BWF_{bus,oper,\ overhead} = BWF_{o.\ green} + BWF_{o.blue} + BWF_{o.grey} \quad \text{.........(9)}$$

$$WF_{bus,\ sup,\ input} = BWF_{s.\ green} + BWF_{s.blue} + BWF_{s.grey.} \quad \text{.........(10)}$$

$$WF_{bus,\ sup,\ overhead} = BWF_{s.\ green} + BWF_{s.blue} + BWF_{s.grey.} \quad \text{.........(11)}$$

Finally, the total footprint of the business unit (BWF) is given by the sum of its operational (BWF_O) and supply - chain water footprint (BWF_S).

3.0.4 In this case study both production and overhead WF have blue and grey WF components because green component will be of zero value. It is important to understand each of the components well to be able to compile relevant data.

3.1 *Operational Water Footprint*

Operational WF consists of Operational WF directly associated with the production of the product in the business unit and an Overhead WF. Operational blue water footprints of the products [see Equ.8] include the sources from which water is used by the mill, water is incorporated in the products as ingredient, and water consumed during the production process along with effluent water discharged (operational grey WF) [see Equ. 8] and an overhead WF related to for example water consumed by employee's mainly drinking water, in kitchen, toilets, cleaning, gardening or washing working clothes (overhead blue WF) [refer to Equ. 9]. With this definition, working with the paper unit's environmental department detailed breakup of water use had to be collected. It was not readily available so the department had to work meticulously to come up with reliable numbers.

3.1.1 Operational WF based on Freshwater Consumption

Out of the total freshwater consumption of 2,48,000 m^3 / year, 70% (1,72,500 m^3 / year) is treated and discharged into the river Ganges and is thus returned to the hydrological system from which it is withdrawn (thereby not forming a part of WF). Because this is withdrawn and returned to the freshwater system this does not form WF of the production unit. The balance 30% (75,900 m^3 / year) is the freshwater consumed by the unit in its production process. This 30% includes18% (31,740 m^3 / year) lost in evaporation during production process of paper making. This evaporation is happening at the boiler. Rest at paper making, in wastes paper pulping, for sealing and cooling, in wastewater treatment plant and for domestic use. 30% also includes freshwater consumption of 10,350 m^3 / year for domestic purpose. This is the overhead operational water footprint [please refer to Equ. 6][4].

3. 1.2 Operational WF and Wastewater

It needs mention that the production unit uses recycled water on a continuous scale. So at any point of time freshwater use measured at inlet point of the unit can be less than the measure of water at the outlet point showing discharge of wastewater going to water treatment plant. This is evident from Table 5. The wastewater treated in treatment plant is 5,62,350m^3/ year which is greater than the freshwater use. However, treated wastewater is not considered for WF estimation. But an account of wastewater consumption by the case study unit is interesting to note to get an overall water usage and good practices by the production unit. Of the treated wastewater (5,62,350 m^3 / year), 5,36,475 m^3 / year (95.3%) is used for waste paper pulping and the rest 25,875 m^3 / year is used for gardening, in the kitchen and toilet of the production unit. Out of the total treated wastewater of 3,86, 500 m^3 / year, a part amounting to 8,625 m^3 / year (4.46%) is disposed off in polluted form along with the sludge. The sludge mixed polluted water is dispatched to the board mill for making 'Sundry paper'. The water content in the sludge helps to reduce fresh water requirement during board making.

3.1.3 Operational WF based on Colour Component

Therefore the grand total water requirement of 8,10,750m^3 in the year 2011 - 12 consists of 1,72,500 m^3 / year m^3 is returned to the hydrological system and 5,62,350 m^3 is total treated wastewater. Therefore, 75,900 m^3 of freshwater is actually used in the production process (operational and overhead blue WF) and 8,625 m^3 of polluted water that has been disposed off along with the sludge (operational grey WF) by the unit in the year 2011 - 12.

To sum up by returning to Equ. (8) we can provide the following numbers for the case study unit:

$$
\begin{aligned}
BWF_{bus,oper,input} &= BWF_{o.\ green} + BWF_{o.blue} + BWF_{o.grey} \\
&= 0 + 65{,}550 m^3/\ year + 8{,}625\ m^3/\ year \\
&= 74{,}175\ m^3/\ year
\end{aligned}
$$

Using Equ. (9) the overhead operational WF can be shown as

$$
\begin{aligned}
BWF_{bus,oper,\ overhead} &= BWF_{o.\ green} + BWF_{o.blue} + BWF_{o.grey} \\
&= 0 + 10{,}350\ m^3/\ year + 0
\end{aligned}
$$

So, total Operational Water Footprint (inputs + overhead) of the unit (as per Equ. 6)

$$
\begin{aligned}
WF_{bus,\ oper} &= WF_{bus,\ oper,\ input} + WF_{bus,\ oper,\ overhead} \\
&= 74{,}175 m^3 /\ year\ + 10{,}350\ m^3 /\ year \\
&= 84{,}525\ m^3 /\ year
\end{aligned}
$$

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[4] Total freshwater - freshwater discharged to hydrological system (2,48,000 m^3) - (1,72,500 m^3) = 75,900 m^3 (as in Equ. 2) ·
$WF_{bus,\ oper} = WF_{bus,\ oper,\ input} + WF_{bus,\ oper,\ overhead} = 74{,}175\ m^3 + 10{,}350\ m^3$

3.2 *Supply - Chain Water Footprint*

3.2.1 If we consider Equation (5), (7), (10) & (11) we see WF_S(the supply - chain WF) to be estimated. The supply chain water footprint calculates the water use in the supply - chain per business unit (per year). When the product originates from a supplier outside the own business, the value of product water footprint has to be obtained from supplier or estimated using indirect data known about the production characteristics of the supplier.

3.2.2 In the scope of this study, supply - chain related to the product inputs consists of the following components eg. the ingredients bought by the company (purchased pulp, fillers and white pigments, coloured pigments and chemicals) and other items or inputs bought by the company for processing their product and used in production e.g. labeling products, packaging materials. The final products of the paper unit are manufactured from waste paper that are either purchased from domestic markets or imported from international markets. However, wastepaper itself does not contain any water except the negligible amount of water that is sprinkled on them at the time of packing before sending it off to different locations. The pulp is then made from the wastepaper in the factory of the unit and not purchased from external sources. The water footprint of chemicals that have been purchased by the unit from different suppliers can be ignored as there is no reliable data.

3.2.3 The overhead supply - chain WF consists of all goods and services used in the factory that are not directly used in the production process e.g. water footprint of infrastructure (construction materials like steel, and concrete etc.); water footprint of materials and energy for general use (office materials, cars and trucks, fuel, natural gas, electricity etc.). These data are also not within the purview of the unit. So, for the case study unit the WF estimation reduces to BWF = BWF_o= 84,525 m^3 for the year 2011 - 12.

3.2.4 Table 5 presents the results of the total Water Footprint and Figure 3 represents the colour component of the water footprint of the unit.

3.2.5 The operational water footprint of the paper producing unit for the year 2011 - 12 is 84,525 m^3 (Table 5)and footprint per unit of production is 4.79 m^3/ tonne of product output. Blue water footprint constitutes 75,900 m^3 (90%) and grey water footprint 8,625 m^3 (10%) of the total (operational) water footprint for the year 2011 - 12 as shown in Table 5. It has already been mentioned green water footprint of the unit is zero as it is waste paper based paper production unit. This shows that pulp type and production location affect the total water footprint of the product and the ratios of green/ blue/ grey significantly. It also shows that including spatial dimension in water footprint assessment is important. The blue water component is high due to the fact that there is no green water footprint in this case study unit and also because freshwater withdrawn from the river Ganges is not used for irrigational purposes by the unit. However, a major portion of water withdrawn from the river Ganges is returned to the system from which it is withdrawn thereby reducing the operational blue WF. Contribution of grey WF in the total water footprint of the unit is only 10%, as because out of the total treated wastewater only a part (8,625 m^3 / year) gets polluted during the pulp and paper making. The performance of the study unit in the matter of freshwater consumption is below the proposed benchmark (of 19 m^3 / tonne) and far below the relaxed standard of water consumption (of 49 m^3 / tonne) as prescribed by the National Productivity Council (in its Development Guidelines for water conservation in Pulp and Paper Sector in 2006). The polluted water discharged by the production unit along with sludge amounted to around 0.48 m^3 / tonne of paper for the year 2011 - 12, much below the National Productivity Council's prescribed benchmark and relaxed standard. All these means that the case study unit is a best practice unit so far WF as performance indicator is concerned.

4. Conclusion

4.1 The current study explores how far the ASI data, in its existing form, provide scope to construct environmental performance indicators like intensity, energy productivity and water footprint for the paper industry in India. Our analysis shows while energy use related indicators could be constructed quite comprehensively using ASI data, they are inadequate to construct WF indicators which are much discussed in the context of sustainable water use. The analysis of indicators constructed on the basis of ASI data in the context of energy use brings out significant behavioural responses of this industry which could be used as important inputs in policy choice. The productivity growth of inputs, its nature with respect to energy use, the response of industries to an increase in the price of energy and other inputs – all could be estimated using the official ASI data. The situation is however, different in case of water use related data. Since water use data were found to be inadequate in ASI, an attempt was made to collect primary data necessary for water footprint calculation through face to face interaction with a paper manufacturing unit as a case study. It is found that companies publish the data on water consumed (in cubic meters) for industrial processes in their corporate sustainability reports. These reports, however, do not publish adequate data in a manner to make results comparable across manufacturing units or to come up with a water use indicator for the industry as a whole. But our efforts show that it is possible to make companies report relevant data for arriving at right kind of water footprint estimates. While estimating WF of the paper production unit we took into consideration operational footprint only due to the lack of availability of data relating to overhead supply – chain WF. So it would be important to see, how results would have changed if we could calculate the total (operational and supply – chain) WF. However estimation of WF of the case study unit helped us to assess what needs to be done if water footprint estimates are to be generated for Indian industries. The study revealed that detailed data of freshwater consumption and water wastewater discharge by industries (along their production and supply chain) is required for estimating industrial WF. The critical WF components contributing towards global water footprint of humanity was also identified by comparing the WF of the concerned industrial unit with that of an existing global or reasonable benchmark. Our unit level study effort shows it is possible to get data from industrial units on quantity of fresh water use, waste water generation, discharge and treatment, within ASI framework and can thereby help in bridging the gap in official statistics. The work that has being initiated in this study can be carried forward to larger scope and development of appropriate database and management tool.

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Table 1: Growth Accounting (in %) for pulp and paper industry in India

Period	Output	Capital	Labour	Material	Energy	Total input	Input Productivity
1974-75 - 2010-11	6.33%	1.10%	0.30%	4.20%	0.74%	6.33%	0.00%
1974-75 - 1985-86	6.71%	1.27%	0.61%	4.61%	1.28%	7.76%	-1.04%
1986-87 - 1999-00	4.78%	1.47%	0.18%	2.70%	0.79%	5.14%	-0.36%
2000-01 - 2010-11	7.89%	0.45%	0.11%	5.65%	0.08%	6.29%	1.60%

Author's estimation on the basis of ASI data

Table 2: Bias in Technological Progress of pulp and paper industries (1973-2010)

Input	1973-74 to 2010-11	1973-74 to 1985-86	1986-87 to 1999-00	2000-01 to 2010-11
Capital	Saving*	Saving*	Saving	Saving*
Labour	Saving*	Saving	Saving*	Saving*
Energy	Using	Using*	Saving*	Saving*
Material	Using*	Using	Using*	Using*

**statistically significant at 5% level*
Authors' estimation on the basis of ASI data

Table 3: Inter-factor substitutability of inputs in pulp and paper industry (1973-74 to 2010-11)

Factors	1973-74 to 2010-11	1973-74 to 1985-86	1986-87 to 1999-00	2000-01 to 2010-11
Capital- Labour	Complement	Substitute*	Complement*	Substitute*
Capital - Material	Substitute*	Substitute	Substitute*	Complement
Capital-Energy	Substitute*	Substitute*	Complement	Substitute*
Labour- Material	Substitute*	Substitute	Substitute*	Substitute*
Labour- Energy	Substitute	Substitute	Substitute	Substitute
Material- Energy	Substitute	Substitute	Substitute*	Substitute*

**statistically significant at 5% level*
Authors' estimation on the basis of ASI data

Table 4: Own price elasticity of inputs in Indian pulp and paper Industries

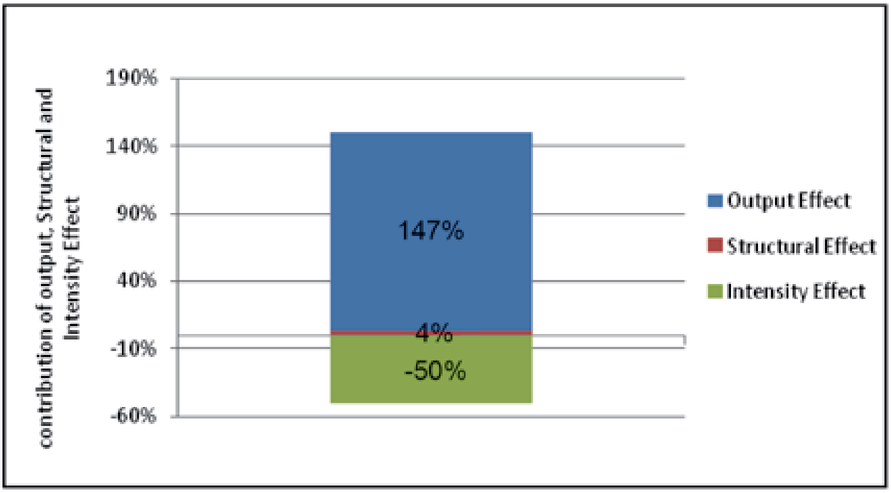
1973-74 to 2010-11	1973-74 to 1985-86	1986-87 to 1999-00	2000-01 to 2010-11
-0.22	-0.60	-0.74	-1.22

Authors' estimation on the basis of ASI data

Table 5: Water Footprint of Paper Production Unit for the year 2011- 12

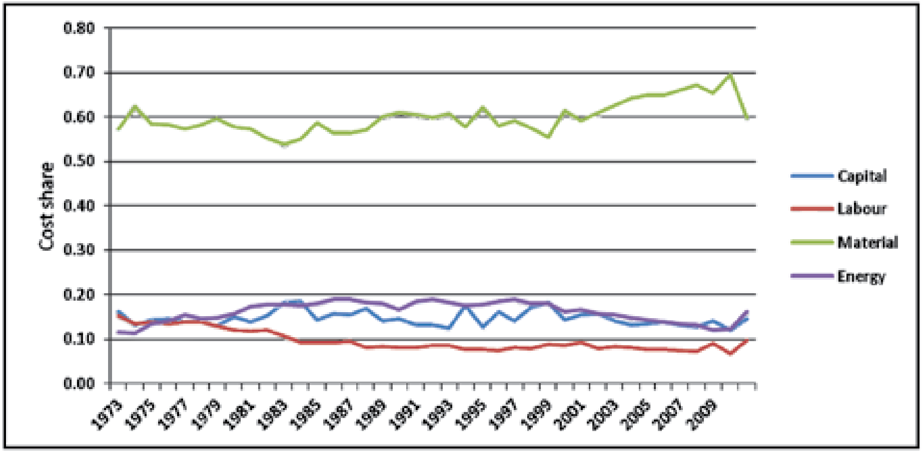
Information needed	Water Footprint (m^3 / year)			
	Green	Blue	Grey	Total
Operational Water Footprint	0	75, 900	8,625	84, 525

Figure 1: Decomposition of increase in energy use in energy intensive manufacturing industries in India



Source of data: Annual Survey of Industries, various volumes

Figure 2: Cost share of inputs in pulp and paper industry in India (1973-74 to 2010-11)



Authors' estimation on the basis of ASI data

Figure 3: Colour Components of the Water Footprint of the Paper Production Unit (2011 – 12)