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CASE STUDY

Ecological footprint of paperboard and paper production unit in India

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Abstract It is important to evaluate the performance of industries in a growing economy like India through responsible resource use assessments. The article estimates ecological footprint (EF) to communicate the environmental effects of a paperboard and paper production unit in India based on information collected through face-to-face interview method. EF has been calculated by adopting component or bottom-up approach taking into consideration all the components of EF (land, energy, freight and employees transport, water, materials and wastes). Results show that the total EF for production and allied activities of the case study unit varies between 5,62,845 and 2,15,564 ha and EF per tonne of production varying between 23.61 and 9.03 ha. This is based on the production of 23,828 Mt of output of specialty and tissues paper, and the variation occurs due to higher and lower conversion factor for materials and water. The hotspots of EF are energy, materials and wastes.

Keywords Ecological footprint · Paper production · India

1 Introduction

How to manage rapid industrialization and economic growth without environmental degradation is major challenge today towards sustainable development. Ecological

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Footprint is one of the measures suggested in the literature (Weidmann and Barrett 2010) to assess environmental performance. The ecological footprint (EF) measures the use of available bio-productive space and is measured in hectares (ha). The EF of an economic output is a measure of how much productive land and water an economic agent requires using prevailing technology to produce the consumption level and to absorb all the waste generated. It acts as a resource accounting tool to keep in track the effect of humanity's consumption of natural resources and generation of wastes. A large number of studies have estimated ecological footprint to measure the dependence of a given population on the natural environment and assess ecological deficits (Wackernagel and Rees 1996; Wackernagel et al. 1999b). This approach has been used in the calculation of the ecological footprint and bio-capacity for more than 200 countries—Australia (Lenzen et al. 2001); New Zealand (McDonald et al. 2004); Austria, Philippines and South Korea (Wackernagel et al. 2004); China (Chen et al. 2007) to name a few along with other nations and the world (Ewing et al. 2010); at the local and regional level (Simmons and Chambers 1998; Simmons et al. 2000; BFF 2002) and Stockholm Environment Institute (SEI) (Barrett et al. 2002); for University campus (Li et al. 2008); for businesses (Barret and Scott 2001; Lenzen 2003; Mc Loone et al. 2008); life-cycle assessment of products (Huijbregts et al. 2008); ecological footprint of products and the influence of nutrients and non-CO_2 greenhouse gas emissions (Hanafiah et al. 2010); biodiversity footprint of products compared to ecological footprint of product (Hanafiah et al. 2012). Applications of the footprint method to assess industrial systems are not too many. EF estimation for paper pulp production has been analysed with the help of this method of component-based approach by Kissinger et al. 2007.

In India, ecological footprint analysis has been used for estimating the impact of tourism on the sustainability of different states (Cole and Sinclaier 2002; Sonak 2004); the expansion of city limits over natural landscapes (Arabindo 2006; Burte and Krishnankutty 2006); and for a University campus (Thattai et al. 2007); transport for the city (Munshi 2007). The industry sector plays an important role with 17.64 % GDP share (in 2012–2013) in the fast economic growth of India (http://www.rbi.org.in/Scripts/PublicationsView.aspx?id=15123).

It is important to know the impact on ecological resources and non-renewable energy consumed by the industries in their production process. Literature survey in the Indian context reveals that considerable gap in knowledge exists in the performance evaluation of the industries through resource use assessments.

This paper makes an attempt towards estimation of ecological footprint for one paperboard and paper production unit in India. At present in India, there are 759 pulp and paper mills with an installed capacity of 12.7 million tons producing around 10.11 million tons/annum of paper/paper board and newsprint out of the total world production of around 402 million tons. The Indian paper industry structure consists of small-, medium- and large-sized paper mills having production capacities ranging from 10 to 1,150 tons per day. The industry employs wood, agro residues and recycled/waste paper as the major raw material for manufacturing different varieties of paper, paper board and newsprint. Paper mills in India continue to face challenges with forest (wood)-based raw materials. The projected demand for paper by 2025 is 24 million tonnes leading to an estimated shortfall of 12 million tones of wood (Kulkarni 2013). This is due to the reasons that agro-based industries are closing down because of pollution-related problems and waste paper quality and price putting pressure on the paper industry (Kulkarni 2013). In 2000, the share in production of paper from wood-based raw materials, agro residues and recycled/waste paper had been 39, 31 and 30 %, respectively (Kulkarni 2013). The case study unit chosen for the present study is a good representation of an important segment of Indian paper manufacturing units and belongs to a company which is forerunner in terms of modernization and follower of sustainable development goals.

The company's Paperboards and Specialty Papers Division is one of the India's largest, technologically advanced and most eco-friendly paper and paperboards business. The unit under consideration is a pioneer in the manufacture of a wide range of specialty papers in India. Specialty papers manufactured in the unit involves precise control of technical properties which are remarkably different from the specifications and precision levels required for other commodity paper grades. These products need to cater to the specific requirements of individual customers. The unit has developed significant capabilities in product development and other research covering specialty papers through one of the best-equipped paper laboratories in the country. It operates with three paper machines having a capacity of 30,000 tonnes per annum (TPA), namely PM1-7000 TPA, PM3-16000 TPA and PM4-7000 TPA and specializes in fine papers and tissues. The product range from this unit comprises opaque papers for fine printing such as the Bible, dictionaries, cigarette tissues, medical grade papers, anti-rust papers, electrical insulation papers, decor surface, printing and barrier papers. The unit is ISO 9001, ISO 14001 and OHSAS 18001 certified. The study site covers a total area 26.31 acres (1 acre = 43,560 square feet). The built-up area of the mill is 5,48,296 square feet, road area is 1,11,788 sq. ft., and parking area is 32,503 sq. ft. The unit produced 23,828 MT of output of specialty and tissues paper in the year under consideration, i.e., 2008–2009.

This article also demonstrates the ways in which ecological footprint can be estimated using unit level data collected through face-to-face interview method. Final choice of the study unit has been mainly determined by willingness of the unit to cooperate in data sharing and time commitment for face-to-face interview.

The remaining part of the paper is structured as follows. Section 2 provides a detailed description of the research methodology adopted; Sect. 3 presents results and analysis. The paper concludes with Sect. 4 where limitations of the study as well as some possible policy interventions for reducing EF for paperboard and paper production unit are suggested.

2 Methodology for estimating ecological footprint

In this paper, we have used the EcoIndex™ Methodology developed by Best Foot Forward (Chambers et al. 2000) utilizing a 'component' or bottom-up approach to perform ecological footprint analysis. The reason behind selecting this methodology is that it considers various components of resource use and waste production by an entity. Also this methodology is suitable for calculating the EF values of certain activities using data appropriate to the region under consideration (Simmons et al. 2000). Another advantage of this adopted methodology is that it is easier to communicate and is informative. The breakup of each individual activity and its resultant impacts has a well-defined beneficial appeal to those concerned with policy making and education. However, the methodology is not free from disadvantages. The availability of reliable and detailed data poses a serious challenge to make comparative studies at national and international level. Being a very data intensive methodology, small assumptions made in the absence of required data can lead to different results. Thus, careful consideration of each component of the life cycle of a product or process in detail is a genuine barrier to the widespread adoption of this methodology. It is true that the method is not currently used by ISO standards and there are alternative methods also suggested in the literature (Weidmann and Barrett 2010), still estimating this one single index provides interesting information to identify relative resource behaviour of a production unit as well as to identify hotspots.

For calculating the ecological footprint of the industrial unit, following equation is used (Lyndhurst 2003):

$$\begin{aligned} \mathrm{EF_{BUS}} = {} & \mathrm{EF}_{L\,(\mathrm{km}^2)} \times \mathrm{CF} + \mathrm{EF_{EN\,(GWh)}} \times \mathrm{CF} + \mathrm{EF_{FT\,(ton\,km)}} \times \mathrm{CF} + \mathrm{EF_{ET\,(passenger\,km)}} \times \mathrm{CF} \\ & + \mathrm{EF}_{\mathrm{WT}\,(\mathrm{m}^3)} \times \mathrm{CF} + \mathrm{EF}_{M\,(\mathrm{tonnes})} \times \mathrm{CF} + \mathrm{EF}_{W(tonnes)} \times \mathrm{CF} \end{aligned} \tag{1}$$

Let $\mathrm{EF_{BUS}}$ = total ecological footprint of business unit, EF_L = ecological footprint of land use in km^2 sq km, $\mathrm{EF_{EN}}$ = ecological footprint of energy use in GWh, $\mathrm{EF_{FT}}$ = ecological footprint of freight transportation in tonne-km, $\mathrm{EF_{ET}}$ = ecological footprint of employee transportation in passenger-km, $\mathrm{EF_{WT}}$ = ecological footprint of water consumption in m^3 cubic metres, EF_M = ecological footprint of material use in tones, EF_W = ecological footprint of waste in tones, CF = conversion factors in ha/year (hectare/year).

2.1 Process description

Ecological footprint analysis of the selected paperboard and paper production unit has been studied on the basis of the primary data collected from a factory located in the state of West Bengal of India. A brief description of the technological process, major equipments and facilities of the production unit is given:

2.1.1 Technological Process

The technological process includes basic principles as given underneath:

1. Slushing of pulp board with water.
2. Refining/beating and mixing of pulp with sizing and loading chemical such as rosin, alum, chalk, talcum, China clay.
3. Paper is manufactured on Fourdrinier machines using the blend prepared in the way as mentioned in step 2 above.
4. Conversion of paper rolls into small reels and bobbins.
5. The reels and bobbins are packed and dispatched.

2.1.2 Major Equipment and Facilities Used

- PREPARATION OF STOCK
- To prepare stock, pulp is slushed with water in hydra-pulper, then it is mixed with fillers, sizing chemicals, dyes and pigments and other wet end chemicals in different proportions. Fine-tuning of stock quality is made on secondary refining stages, and the stock passes through centri-cleaners and pressure screens to remove grits and fibre lumps.
- PAPER MACHINE
- Paper is made in the form of flat and relatively thin mat consisting of fibres deposited at various angles but essentially in the plane of sheet. In the paper-making process, the water is removed through wire drainage, suction boxes, couch rolls, presses and ultimately through dryers to about 5 % moisture levels. Watermark on paper is

imparted by dandy rolls at the wet end, and the paper gets reeled on big roll of two to five tones. It is tested in the laboratory for its quality and goes for finishing operation.

- FINISHING:

From the parent roll, the paper is cut to small size reels and packed. The packed paper goes to customers or converters.

In addition to this, the unit has two coal-fired boilers with two turbines and well-equipped ETP plant.

2.2 Study boundary and data collection

For calculating ecological footprint of this case study production unit under consideration, the consumption resulting from the activities relating to the production of finished goods has been included. Data have been gathered from the production unit using a preset questionnaire (enclosed as Annexure 1). To be able to implement Eq. (1), the study collects data that includes:

- Land use
- Energy use
- Freight transport inbound and outbound (raw materials, products, wastes and output)
- Employee travel to and from work
- Water use
- Forest land use (Material Use)
- Waste disposed and sold off

In this analysis, *Built-up land* constitutes the built-up area, total parking area and road length of the production unit. *Grid electricity* includes the electricity purchased from state grid and also electricity consumed for treating wastewater plants. Data on freight transport movement include both inbound and outbound transport (for raw materials, products, wastes and output as a whole and not in segregation). For calculating the footprint from freight transport in case of air and road, conversion factor prescribed by Chambers et al. (2000) was used, whereas the conversion factor given by Barrett et al. (2002) is used in the case of transportation service used for freight movement via ship and railways and also for the transportation service by bikes used for employees movement.

Footprint area per unit of *water consumption* includes water consumed in process, cooling and water supplied for domestic use. However, the same footprint conversion rate has been applied for water used for process and cooling. The footprint area per unit of *material use* (*purchased pulp* in case of this study) has been calculated by making an estimate of the wood required (in m^3) for making a 1 tonne of pulp and not paper. Reason is that wood requirement and the weight of pulp are related. One such rough estimate shows that 4.73 m^3 of green wood (assumed that the purchased pulp is derived from greenwood in this case) is required to make a tonne of pulp (http://www.ruraltech.org/projects/conversions/briggs_conversions/briggs_ch08.chapter08_combined.pdf). The wood required to make the purchased pulp (in m^3) is converted into tonnes of wood [1 tonne of wood = 1.4 m^3 of wood (http://bioenergy.ornl.gov/paper/misc/energy_conv.html)], and the wood required (in tonnes) is converted into hectares by using conversion factor of timber (Chambers et al. 2000). Calculation of EF of materials is based only on the quantity of pulp used in the production process and ignoring other auxiliary materials because of the non-availability of conversion factors.

The study unit treats the generated wastes in two ways. Primarily, a major portion of the waste is sold off for recycling outside production unit's boundary and used in the making of board, boxes, bricks and construction of roads and the remaining ones are disposed off. It has been assumed that the disposed off wastes are thereafter used as landfill wastes. However, detailed data segregating each individual type of sold off and disposed off wastes with their corresponding amount being available, each type of data on wastes is multiplied by their corresponding conversion factor. For calculating the footprint of the wastes sold off, the conversion factors for the recycled wastes have also been used depending on the nature and amount of such sold off wastes. The details of the nature and amount of wastes sold off are obtained from the environmental report of the paper plant. Table 1 shows the data set collected from the production unit, their corresponding conversion factors and the sources from which such factors have been adopted for the purpose of calculation. Data for calculation of footprints have been gathered on the basis of personal face-to-face interview within the framework of the questionnaire. Ecological footprint of the case study unit is calculated on 330 working days basis (after providing for 10 % of the total number of days as days of maintenance).

3 Results and discussions

The conversion factors of various items of footprint (Table 1.) reveal that for water and materials (pulp), there are two types of conversion factors, one being the lower end conversion factors and the other being the higher end conversion factors. This variability in the footprint conversion factors occurs in case of raw materials because lower end conversion factor is used when pulp is derived from softwood and higher end ones in cases when pulp is derived from hardwood. Since the unit under study uses imported pulp only it is difficult to know what kind of wood has gone into it. So both the factors have been used to arrive at the range of values. For water, the variations in the conversion factors occur as conversion values for water depend on things such as efficiency of treatment and distribution. The results of the final ecological footprint figure have been calculated by taking into consideration both these conversion factors thereby giving a range of values.

Figure 1 shows the final ecological footprint for the case study paperboard and paper unit taking the lower end conversion factors for water and materials, and Fig. 2 presents the final results by considering the higher end conversion factors for water and materials.

The total ecological footprint for the production and allied activities of the case study paperboard and paper production unit is found to vary in between 5,62,845 and 2,15,564 ha, and ecological footprint per tonne of production varies between 23.61 and 9.03 ha for the year 2008–2009. This is based on 23,828 MT of production, and the variation occurs due to higher and lower conversion factors for materials and water. The component with the greatest contribution to the total ecological footprint is the ecological footprint of materials 4,19,303 ha (74.49 %) when higher end conversion factor for material and water is considered. The second and third largest contributor to the unit's ecological footprint is that of waste (17 %) followed by energy (7.28 %). The footprint of water comes fourth (0.80 %) and that for transportation service of freight (0.43 %) occupies the fifth position in this ranking for contribution in the total ecological footprint, whereas the impact of built-up land (0.05 %) and transportation service of employees movement (0.00002 %) has been the least.

However, when lower end conversion factor for material and water is considered, the waste component has the highest percentage (44.33 %) in the total ecological footprint of

Table 1 Data, sources and conversion factors for estimating ecological footprint

Information needed	Source and units of measurement	Unit and conversion factor	Reference
Land use			
(1) Built-up area of the unit	Paperboard and paper unit Sq. ft	ha-years 2.51	Chambers et al. (2000, p. 73)
(2) Parking area			
(3) Road length of the mill unit			
Direct energy use			
Grid electricity	Paperboard and paper unit KWh/year	ha-years/GWh 150	Barrett et al. (2002, p. 47)
Coal	Paperboard and paper unit MT/year	ha-years/GWh 103	Barrett et al. (2002, p. 47)
Transportation service use for freight movement *(raw materials, products, wastes and output)*			
Air	Paperboard and paper unit ton—kms/year	ha-years/1,000 t-km 0.32	Chambers et al. (2000, p. 87)
Road	Paperboard and paper unit ton—kms/year	ha-years/1,000 t-km 0.07	Chambers et al. 2000, p 87
Sea	Paperboard and paper unit ton—kms/year	ha-years/tonne 0.01	Barrett et al. (2002, p. 42)
Rail	Paperboard and paper unit ton—kms/year	ha-years/tonne 0.01	Barrett et al. (2002, p. 42)
Transportation service use for employee movement			
Bike	kms/year	ha/pass km 0.000037	Barrett et al. (2002 p. 52)
Water consumption			
Mains (process)	Paperboard and paper unit m^3/day	m^2 years/100 l ha/m^3 Low—0.0002 High—0.0009	Chambers et al. (2000, p .155)
(Cooling)	Paperboard and paper unit m^3/day	ha/m^3 Low—0.0002 High—0.0009	Chambers et al. (2000, p .155)
(Domestic)	Paperboard and paper unit m^3/day	ha/m^3 0.00197	Chambers et al. (2000, p. 138)

Table 1 continued

Information needed	Source and units of measurement	Unit and conversion factor	Reference
Materials use			
Purchased pulp	Paperboard and paper unit MT/year	ha-years/tonne (4.73 m^3 of wood is required to make for 1 tonne of pulp and global average yield kg/ha for wood pulp {t} in RWE is 198)** 1.0–5.7 (Timber–lower end for softwood and higher end for hardwood)	Chambers et al. (2000, p. 138)
Chemicals pigments (white and coloured)	Paperboard and paper unit MT/year	Not available	Not available
Wastes			
Waste—sold off and assumed to have been recycled and used for the making of bricks, road, board and boxes)	Paperboard and paper unit MT/year	ha-years/tonne Brick—0.08 Paper and card board—2.04	Chambers et al. (2000, p. 138)
Waste—disposed off (assumed to be have been used as landfill wastes)	Paperboard and paper unit MT/year	ha-years/tonne	
Paper	Paperboard and paper unit MT/year	ha-years/tonne 3	Chambers et al. (2000, p 95)
Plastic	Paperboard and paper unit MT/year	ha-years/tonne 2.38	Barrett et al. (2002 p. 71)
Metal/scrap	Paperboard and paper unit MT/year	ha-years/tonne 7.76	Barrett et al. (2002 p. 42)
Scrap wood	Paperboard and paper unit MT/year	ha-years/tonne 0.299	Barrett et al. (2002 p. 42)

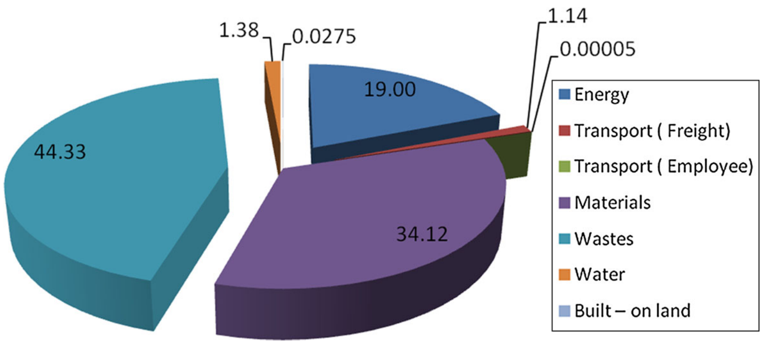

Fig. 1 Diagram showing the ecological footprint of the paperboard and paper production unit (*lower end conversion factor*)

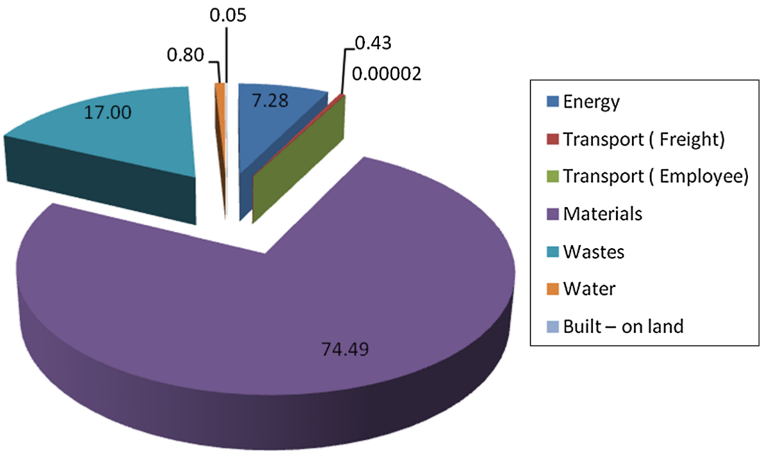

Fig. 2 Diagram showing the ecological footprint of the paperboard and paper production unit (*higher end conversion factor*)

the unit, followed by the ecological footprint of materials (34.12 %) and that of energy (19 %). The lower conversion factor for materials indicates that the pulp purchased from international markets has been derived from softwood timber. In this case, ecological footprint of water has the fourth highest percentage (1.38 %) and transport for freight movement the fifth highest percentage (1.14 %) in the total ecological footprint. Built-up land (0.275 %) and transport for employees movement (0.0005 %) take the last two positions, respectively, in the total footprint contribution.

Another interesting point is that when the higher end conversion factor for water has been taken along with that of materials (Fig. 2), the percentage contribution of water in the total ecological footprint is less, only 0.80 % (Fig. 2) as compared to the scenario when lower conversion factor for water is taken along with that of materials. In the latter case, percentage contribution of water in the total ecological footprint is 1.38 % (Fig. 1). This is because of the difference in the total footprint ranging between 2,15,564 and 5,62,845 ha for the year 2008–2009.

Pulp constitutes the largest portion (60.55 %) of the raw material purchased by the company, followed by chemicals (22.34 %), whereas fillers, white and coloured pigments together comes third in this ranking (17.09 %). The majority of these raw materials are imported from countries such as Austria, Germany, USA., Canada, Malaysia, Thailand, Brazil as the raw materials required for the manufacturing of specialty papers are not available locally. This is one of the main reasons for which material use constitutes the largest share of the ecological footprint.

Out of the total waste (57,597.51 tonnes) generated by the unit, a large portion of it 56,573.21 tonnes (98 %) is sold off and recycled outside the boundary of the production unit for making of bricks, board, boxes and in road construction in the nearby locality. The rest of the portion of wastes 1,024.30 tonnes (2 %) is disposed off and has been assumed to be used as landfill wastes. The ecological footprint of sold off wastes amounts to 92,266 ha (96.35 %) and that of the disposed off wastes is 3,493 ha (3.65 %) out of the total footprint for wastes (95,579 ha).

Direct energy consumed by the company is from grid electricity and coal used in the captive plant for the generation of electricity through steam turbine. Ecological footprint of direct energy from two of the above sources taken together amounted to be 40,996 ha for the year 2008–2009. The generation of electricity through steam turbine in the captive plant of the production unit has resulted in higher ecological footprint of energy. The ecological footprint resulting from electricity generation at the captive plant alone amounts to 30,488 ha, i.e., accounting for (74.36 %) of the total ecological footprint from direct energy, whereas EF of energy resulting from electricity purchased from grid amounted to 10,508 ha accounting for only (25.64 %) of the total EF of direct energy consumed.

Water used in the process, as well as for cooling and domestic use, has been taken into account here for footprint calculation. Two conversion factors, high and low, have been used for the calculation. Taking the higher conversion factor, the ecological footprint of water is found to be 4,517 ha and taking the lower end one the observed result is 2,977 ha. However, exclusion of water supplied for domestic use would cut down the ecological footprint of water by 2,538 ha. The ecological footprint numbers help in identifying the hotspots or factors affecting the size of the unit's footprint. The hotspots are namely: energy (generation of electricity in captive plant through coal-fired steam turbine), imported materials (i.e., pulp and chemicals required for the manufacturing of specialty papers) and wastes (due to non-segregation and absence of proper recycling of wastes within the unit).

Footprint estimates are useful guide for adopting environmentally responsible actions. Previous study of EF estimation of twenty small–medium-sized enterprises (SMEs) situated within the Mid-West region of Ireland helped in identifying the 'hotspots' of each of the SMEs activities and the footprint reduction potential of such activities (Loone et al. 2008). EF has been considered as a powerful tool identifying the over consumption of resources by humanity and communicating the potential sources of un-sustainability to the general public and corporate decision makers (Weidmann and Barrett 2010). We tried to assess scope for interventions to help reduce the EF for the production unit under study. Alternative scenarios are identified, and based on our interaction with the unit, we could identify the barriers towards implementation of solutions for reducing EF under alternative scenarios. Also we recommend intervention points for breaking the barriers. These possible policy interventions for reducing EF for paperboard and paper production unit are presented in Table 2.

Table 2 Possible policy interventions to reduce ecological footprint for paperboard and paper production unit

Ecological footprint				
Factors affecting company's footprint	Possible alternative scenarios	Likelihood of changing them by company's efforts in short and medium term	Barriers for change	Solutions/breaking the barriers
1. Generating electricity in captive plant through steam turbine	Increasing use of grid electricity Reduction in energy component of ecological footprint can reduce total carbon footprint (CO_2 eq in kg) by 51 %	Low	1. Increasing unreliability in grid power supply 2. Purchase of total electricity requirement from the regional/national power grid will increase the monetary cost 3. Steam is an integral part of paper manufacturing process, and this steam is obtained from generating electricity through steam turbine	1. Centralized low carbon generation capacity enhancement and power contracts to provide reliable power supply 2. National Policy correcting coal price by making it sensitive to carbon content 3. Policy incentives to fuel switch from coal to low carbon fossil fuel gas or low carbon alternative fuel
2. Imported raw material (pulp)	1. By increasing the use of import substitutes for raw materials to reduce material component of ecological footprint	Low	1. Currently, no import substitute exists or even if available, it is in very small quantity	1. Policy incentives for the development of cost competitive import substitutes, new industries, infrastructure and supply chain to make the required pulp available locally
3. Wastes not segregated and recycled	1. Segregation and recycling scheme for sold off wastes particularly metal/scrap, paper and plastic 2. If 100 % of the generated fly ash is used in the making of bricks and clay (instead of 50 % under the present situation), then together it can decrease the waste footprint by 91 %	High Medium	1. Hidden costs are not observable to the management. Management decision to be taken in this matter	1. Innovations for waste recovery/regulations for waste disposal

4 Conclusion

Ecological footprint of a paperboard and paper production unit in India is estimated and analysed. The dominating components are on site coal-based power production, use of imported materials and offsite waste disposal. The current study shows that industrial units in India do maintain data though in a scattered way but for preparation of various official reporting purpose to State-Level Pollution Control Board. However, the dialogue with unit managers revealed that they found ecological footprint a new concept although they are familiar with water and carbon footprint concepts. Full implementation of the methodology was not possible due to missing conversion factors for some of the auxiliary raw materials. It was realized that they can be developed, but need more targeted research.

Despite data gaps, the derived footprint numbers can be used by the company and by policy makers as well. The company can now see how it can adopt socially responsible sustainable development steps and take strategies for dissemination of the information to shareholders. It can also enhance image of the company to earn goodwill in market place. First action may be to switch over to more cleaner fuel for power generation, and second may be to create demand for locally produced raw materials and waste recycling within system boundary. For national level policy maker, it can provide a clear idea of wherein lies the new investment opportunity through expansion of new production processes and scope for using renewable sources of energy. Also it can provide an insight to what might be the new incentive designs to encourage up-taking of cleaner power production by industrial units. However, these numbers by themselves cannot be expected to drive investment decisions as there may be other barriers towards technology choice. However, these numbers are useful indicators of intervention for making possible efficient use of a nation's resources. Existing method of data compilation by the production unit is found to be considerably satisfactory to arrive at total estimate of ecological footprint of a manufacturing unit. However, for longer run, the company can reorganize their data management system and official data collection process. They also can standardize the format for data reporting that can help in getting such indices to induce better environmental management practice.

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