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Procedia
Social and Behavioral Sciences
ELSEVIER
Procedia - Social and Behavioral Sciences 124 (2014) 344 – 350

SIM 2013

# Research on the possibility to apply Ecological Footprint as environmental performance indicator for the textile industry

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**Abstract**

There is growing interest in ecological footprint analysis in aiding our understanding of societal demands on the biosphere. Moreover, attention is focused on new potential applications of the technique. Recently, its application to enterprises has been proposed. In the present study, an apparel plant was analysed. The overall purpose of this study was to develop a tool useful for evaluating the environmental impact evolution due to the performance of the plant, as well as for comparing the environmental performance of different manufacturing processes. Data collected were divided in three main categories: energy, resources and waste. The main contributor to the ecological footprint is the resources category, meaning that the changes in fashion will probably affect in the future the results of the indicator. A smaller contribution was the energy used in the manufacturing process, the selection of renewable energy sources being another possibility to reduce the footprint. In the category of wastes, the main contribution was that of urban wastes, which unfortunately cannot be recycled at the moment.


Selection and peer-review under responsibility of SIM 2013 / 12th International Symposium in Management.

*Keywords:* ecological footprint; textile industry; sustainable development; indicators.

## 1. Introduction

Despite the importance of sustainability, there is no common accepted methodology in the scientific community to evaluate it. In several assessment methods, sustainability measurements have undergone an evolution going from qualitative to quantitative analysis to synthesis. The notion of Ecological Footprint (EF) was introduced in 1996 by Rees and Wackernagel when this indicator was defined as the area of land and water hypothetically required to provide the resources and to absorb the waste generated by a human population. The EF is a quantitative tool that uses material and energy flows to estimate the biophysical 'load' that human populations or industrial processes impose on ecosystems around the world (Reese & Wackernagel, 1996). Initially this indicator was calculated in order to assess the environmental sustainability of households, cities, regions, or even nations. It was recently suggested its application to companies, taking into consideration that they also represent organisations that consume goods and services and generate waste. Today it is considered one of

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1877-0428 
Selection and peer-review under responsibility of SIM 2013 / 12th International Symposium in Management.
doi:10.1016/j.sbspro.2014.02.495

the most relevant indicators for the assessment of impacts on the environment, which can also be used in conjunction with other indicators, such as the carbon footprint and water footprint (Galli et al., 2007).

## 2. Ecological footprint estimation

This paper presents a method of EF estimation that can be used for the textile sector, presenting a study case for a textile firm in the apparel industry.

The data used in this study were divided into three large categories: energy, resources and waste that are detailed in the table 1.

It is important to specify that the electricity, not being a direct source of energy that can be procured from the nature had to be divided accordingly to the sources of the supplying company.

We have to mention also that in this case we have analysed only the confection process which is studied within the production process and the distribution channel. Thereby, the material inputs in the company's activity contain products already manufactured, while the output is made of pieces of clothing prepared to be sent to the finishing process or to the stores.

In order to calculate the indicator, we have used the data regarding the activity of the apparel company in the year 2012, synthesised in the table 2.

Table 1. Categories included in the estimation of the ecological footprint

| Category | Unit |
|---|---|
| **Energy** | |
| Coal | kWh |
| Oil | kWh |
| Natural Gas | kWh |
| Nuclear | kWh |
| Hydroelectric | kWh |
| Wind | kWh |
| Solar | kWh |
| Biomass | t |
| **Resources** | |
| Plastic | t |
| Paper and cardboard | t |
| Cotton | t |
| Fire sintetice | t |
| Wool | t |
| | t |
| Metal | t |
| Water | $m^3$ |
| **Waste** | |
| Paper and cardboard | t |
| | t |
| Plastic | t |
| Textile | t |
| Urban | |

### 2.1. Energy footprint

The energy consumed in the manufacturing process comprises the electricity, the natural gas for the heating station and the gasoline for the transportation and also for the heating station.

We have calculated the electricity consumption in the manufacturing process. To express this data in energy consumption units, we have used the data from the National Agency for Energy Regulation for the electricity mix in Romania, shown in table 4 (The National Agency for Regulation in Energy, www.anre.ro, 2012). Renewable energies have very high energy productivity (EP), and it is assumed that their energy footprint is irrelevant as compared to the energy footprint from fossil fuels and nuclear energy, as it can be seen in table 3. Then it has to be take into consideration the EP of fuels and the efficiency factor for electricity production. For these calculations, up-to-date equivalence factors (*e*) must be considered for the project, to turn the results in hectares into global hectares (gha). These equivalence factors are shown in table 5.

Table 2. The inventory data that have been processed

| | 2012 |
|---|---|
| **Input** | |
| **Raw materials** | |
| Cotton fabric (kg) | 55000 |
| Wool fabric (kg) | 25000 |
| Synthetic fabric (kg) | 3000 |
| Paper and cardboard (kg) | 1800 |
| Plastic (kg) | 950 |
| | 320 |
| Zippers (kg) | 630 |
| | 125 |
| **Energy** | |
| Electricity (kWh) | 750000 |
| Natural gas ($m^3$) | 135000 |
| Diesel fuel (t) | 2.7 |
| **Water** ($m^3$) | 22500 |
| **Output** | |
| **Production** | 7230000 |
| **Air emisions** | |
| $SO_2$ (kg) | - |
| $NO_x$ (kg) | 738 |
| $CO_2$ (kg) | 24282 |
| CO(kg) | 195.6 |
| **Waste** | |
| Textile (kg) | 2800 |
| Paper and cardboard (kg) | 1300 |
| Plastic (kg) | 180 |
| Urban waste ($m^3$) | 155 |
| Hazardous waste | |
| Bateries (kg) | 2 |
| Fluorescent lamps (kg) | 5 |
| Oil filters (kg) | 4 |
| Mineral oils (kg) | 40 |

Table 3. Conversion factors for energy (Wackernagel & Reese, 1996, Doménech, 2006)

| Primary source of energy | Embodied energy | | Natural productivity | Energy productivity | | Land category |
|---|---|---|---|---|---|---|
| Carbon | 0.012 | GJ/kWh | | 55 | GJ/ha/yr | Fossil land |
| Liquid fuel | 0.012 | GJ/kWh | | 71 | GJ/ha/yr | Fossil land |
| Gas fuel | 0.012 | GJ/kWh | | 93 | GJ/ha/yr | Fossil land |
| Nuclear[b] | 0.0036 | GJ/kWh | | 71 | GJ/ha/yr | Fossil land |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hydro power | 0.0036 | GJ/kWh | | | 15 000 | GJ/ha/yr | Pasture land |
| Wind power | 0.0036 | GJ/kWh | | | 60 000 | GJ/ha/yr | Pasture land |
| Solar energy | 0.0036 | GJ/t | | | 40 000 | GJ/ha/yr | Arable land |
| Biomass | | | 5.49 | t/ha/yr | | | Arable land |

Once the fuel consumption is defined in units of volume (litres), the footprint of fuel consumption can be expressed as:

$$EF_f = \frac{F}{EP} * e_f \qquad (1)$$

where $EF_f$ is the ecological footprint of fuel consumption (gha/year), *F* is the Fuel consumption (GJ), EP is the Energy productivity of fuel (GJ/ha/year). The result of the calculation is 74.535 gha.

The consumption is calculated from the primary energy consumption *i* and the energy productivity, applied to each of the sources.

Table 4. Power supplier electricity mix (The National Agency for Regulation in Energy, www.anre.ro, 2012)

| **Primary source of energy** | **Percentage** |
|---|---|
| Fuel-oil and gas-oil | 0.60 |
| Coal | 37.60 |
| Natural gas | 14.30 |
| Hydro power | 22.20 |
| Nuclear | 19.60 |
| Wind power | 44.00 |
| Other renewable resources | 0.40 |

The formula used is:

$$EF_{we} = \sum \frac{P_i}{EP_i} * e_f \qquad (2)$$

where $EF_{we}$ is the weighted ecological footprint of electricity consumption (gha/year), $P_i$ is the Primary energy consumption (GJ), $EP_i$ is the Energy productivity (GJ/ha/year). The ecological footprint of the electricity consumed in the manufacturing process of the textile company is 42.209 gha.

Table 5. Equivalence factors (WWF, 2006)

| **Land category** | **Factor (gha/ha)** |
|---|---|
| Fossil land[a] | 1.4 |
| Arable land | 2.1 |
| Pasture land | 0.5 |
| Forest | 1.4 |

[a] Area for the absorption of $CO_2$ emissions derived from the use of fossil sources of energy.

### *2.2. Resources footprint*

Table 6. Conversion factors for materials (Wackernagel & Reese, 1996, Doménech, 2006)

| Material | Embodied energy | | Natural productivity | | Energy productivity[a] | | Land category |
|---|---|---|---|---|---|---|---|
| Plastic | 43.75 | GJ/t | | | 71 | GJ/ha/yr | Fossil land |
| Paper & cardboard | 30 | GJ/t | 1 | t/ha/yr | 71 | GJ/ha/yr | Forest/Fossil land |
| Cotton fabric | 10 | GJ/t | 1 | t/ha/yr | 71 | GJ/ha/yr | Arable land/Fossil land |
| Wool fabric | 10 | GJ/t | 0.02 | t/ha/yr | 71 | GJ/ha/yr | Pasture land/Fossil land |
| Synthetic fabric | 43.75 | GJ/t | | | 71 | GJ/ha/yr | Fossil land |
| Metal accessories | 100 | GJ/t | | | 71 | GJ/ha/yr | Fossil land |
| Water | | | 1500 | $m^3$/ha/yr | | | Forest |

[a] The use of fossil energy is supposed in all cases for the manufacture of goods.

The ecological footprint of water is calculated by the procedure which considers the forest as a water producer, whereby the consumption of this resource is included in that of forest land. In order to calculate forest productivity ($m^3$/ha/year), the hypothesis that a forest of wetlands can produce 1500 $m^3$ of fresh water per hectare per year is assumed (Solis-Guzman, Marrero, & Ramirez de Arellano, 2013). Therefore, the formula employed for the calculation of the EF of water consumption is:

$$EF_{ww} = \frac{W}{FP} * e_f \tag{3}$$

where $EF_{ww}$ is the weighted ecological footprint of water consumption (gha/year), *W* is the Water consumption ($m^3$) and FP is the forest productivity ($m^3$/ha/year). The result of the calculation process is 21 gha.

The ecological footprint of other resources is calculated by the formula:

$$EF_i = \sum \frac{V_i}{NP_i} * F_j + \sum \frac{EV_i}{EP_i} * F_j \tag{4}$$

Two columns may be considered for the subsequent operations: the one with the original values of each category ($V_i$) and the one with these values expressed in energy units ($EV_i$). The former is divided by the natural productivity ($NP_i$), while the latter is divided by the energy productivity ($EP_i$) in order to express them in space units. Thus, a last step in the estimate must be performed: the outcome of the previous division has to be multiplied by an equivalence factor ($F_j$) which will normalize and homogenize the different kinds of land (*j*) in relation to their productivity(Herva, Alvarez & Roca, 2012).

The overall ecological footprint of the resources input in the manufacturing process of the textile factory is 768.65 gha.

*2.3. Wastes footprint*

The determination of the EF of waste is based on the methodology of Wackernagel (Wackernagel et al., 1999), which states that the footprint associated with waste disposal and emissions is calculated in the same way as for materials: with the same energy intensity but subtracting the percentage of energy that can be recovered for recycling.

It should be borne in mind that in the methodology used here, all consumption is allocated to the fossil footprint, except in the case of paper where consumption also affects the forest footprint.

The procedure uses conversion rates already incorporated into previous research (Herva et al., 2008). These conversion rates can refer to various types of waste from very different origins (hazardous, non-hazardous, paper, etc.). For our case study, non-hazardous waste and paper waste are of interest.

For non-hazardous waste, the procedure is based on the energy intensity (EI) of the production of the material from which the waste is made, with a deduction of the percentage of energy that can be recovered by recycling. Some of these types of non-hazardous waste are organic, excavated earth, or mixed CDW. The conversion rate is calculated by using the formula:

$$CR_x = \frac{EI_x}{EP} * \left(1 - \frac{\%R_x}{100} * \frac{\%SE_x}{100} * e_f\right) \tag{5}$$

where each of these terms is: $CR_x$: Weighted Conversion Rate of non-hazardous waste (gha/year/t), $EI_x$: Energy Intensity of the production of the material from which the waste is made. For these values, the energy intensities of the materials to be recycled must be known.

The ecological footprint of the wastes is calculated with the formula:

$$EF = \sum CR_i * G_i \tag{6}$$

where $G_i$ is the waste generation.

The recycled waste are paper and plastic. The urban waste in Romania is recycled only 10%. The total ecological footprint of the waste resulted from the manufacturing activity of the textile company is 20.41gha.

*2.4. Emissions footprint*

The factory air emissions affect two environmental problems: global warming and acidification. The Ecological Footprint accounts for the carbon dioxide emissions, principal responsible for the global warming. An attempt to incorporate the acidification category ( $NO_x$ and $SO_2$ ) to the total footprint area has been done, considering a critical load of $20 \times 10^{-3}$ eqv. $H^+/m^2$ year for Europe. The emissions of the studied manufacturing activity have an ecological footprint of 9.34 gha.

## 3. Conclusions

As part of CSR reports, simple indicators of sustainable development, easy to understand, are preferable to a multitude of complex indicators. In this paper it was analyzed only the impact of the manufacturing activity, because we have considered that the Ecological Footprint is the concept that best fits this goal, being that the inputs that already have passed through a manufacturing process can be incorporated directly in the analysis, without studying their own production process.

The study shows that the global value of the footprint was mainly influenced by the category of resources, especially by the type of fabrics used in the manufacturing process. This shows us that this indicator is proper to effectively asses the environmental performance of different production and management options that can be considered in an industrial process.

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