

## INDICATORS FOR SUSTAINABILITY IN INDUSTRIAL SYSTEMS CASE STUDY: PAPER MANUFACTURING<sup>♦</sup>

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**Abstract:** The paper describes a framework for promoting sustainability by using indicators for sustainable production. The concept of sustainable production is described as it is viewed by various organisms actions involved in the analysis of the sustainable industrial systems. The measure of sustainability is approached considering indicators of sustainable production, addressing both their dimensions and qualitative and quantitative features.

The proposed framework refines the sustainability dimension for a case study which envisages sustainability in paper manufacturing. The analysis takes into account the life cycle analysis for the considered process since the environmental impact is seen as an essential sustainability indicator. Paper recycling and reuse is associated environmental and social costs, as a preferred alternative in waste minimization hierarchy in the manufacturing of non-trees eco-friendly paper.

Proactive initiatives to improve the environmental performances of production process are considered as powerful tools for improving the paper manufacturing environmental footprint.

**Keywords:** *environmental, life cycle, pollution, paper products, recycling*

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## INTRODUCTION

Today, the industrial system is responsible both for the quality of life around the world and for the serious threaten the environment faces at a global level. Now, it is largely accepted that industrial manufacturing system influences in a major way the quality of the environment. Moreover the world community faces serious problems where the demand for natural resources is increasing and emissions and waste accumulate, as these affect the quality of life. The unsustainable production and consumption is considered to be the main cause of environmental damage [1]. Particularly, pulp and paper manufacturing has many positive and negative environmental and social impacts, owing to specific features of production, consumption and wasting.

The pulp and paper industry is considered among the world's largest generators of air and water pollutants, waste products, and the gases that cause climate change [2, 3]. Besides, it is one of the largest users of natural resources, including fresh water, energy, and forest products. Sometimes, forests that are essential for the air and water, wildlife habitat, climate protection, are being logged for fiber, industrial manufacturing. In many places, forests are being cleared for replacement by plantations that have reduced ecological value and employ toxic chemical herbicides and fertilizers [4, 5].

Solving these problems requires industry to adopt principles of sustainable development. Both industry and communities should adopt and support the sustainable industries performances indicators framework. For example paper buyers should be encouraged to share this responsibility by using less paper, choosing recycling whenever possible, encouraging a shift to non-wood fibers products and avoiding buying from or investing in companies with poor social records. At least, this framework should be used to establish baselines, set targets continuously progress toward sustainable industrial production.

Today, sustainability has become an essential part of manufacturing and business strategies in the paper industry, which is active in the three interdependent pillars of sustainability: environmental, economic and social [6].

Sustainable development in industrial system goes beyond environmental preservation. Economic prosperity and solidarity is required by the society. But the aim is to protect the environment and its resources while satisfying human needs and boosting progress [7, 8]. The implications of these actions must be considered to ensure that future generations are able to satisfy their needs.

Substantial and continual efforts over the last decades in the paper industry have significantly reduced its impact on the environment, as much as achieving sustainable development requires changes in industrial flowsheets, the type and quality of resources involved in the manufacturing process waste treatment and management, emissions control, the quality of products.

The objective of this research is to develop an integrated analysis, which targets the sustainability of the pulp and paper industrial system in particular, paper manufacturing, based also on some sustainability indicators.

## **SUSTAINABILITY IN PAPER MANUFACTURING**

In order to develop optimal strategies for sustainability in paper manufacturing it is crucial to establish comprehensive, generic approaches concerning economics, reliability and product quality along with maximizing the use of already available process internal resources [1, 9, 10].

A set of necessary conditions that paper industry must fulfill in order to be sustainable includes [11, 12]:

- reducing the use of materials and energy in products and their production,
- closing of material loop systems, to conserve resources and prevent waste,
- minimization or avoidance of waste,
- reuse and recycling products,
- disposing of non-recyclable products or production waste in an environmentally acceptable way,
- planning of products which are easy to repair, adaptable, durable and with longer lifetime,
- minimization of transportation needs,
- cleaner production technologies and procedures throughout the product life cycle,
- improving a process technology,
- research and development in environmentally sound technologies,
- consideration of the social role played.

The performance and efficiency of this approach can be evaluated using quantitative and qualitative indicators of sustainable development, as dynamic instruments for targeting environmental, social and economic objectives for sustainability. This framework is entailed to establish baselines, set targets and continuously progress toward sustainable industrial production [13]. The sustainable industry performance indicators compress large amounts of information from different sources into a format easier to understand, compare and manipulate.

These targets help the decision-maker visualize what actions will need to be emphasized in future [14].

## **ENVIRONMENTAL IMPACT OF PAPER MANUFACTURING PROCESS**

### **Relevant aspects of life cycle for paper products**

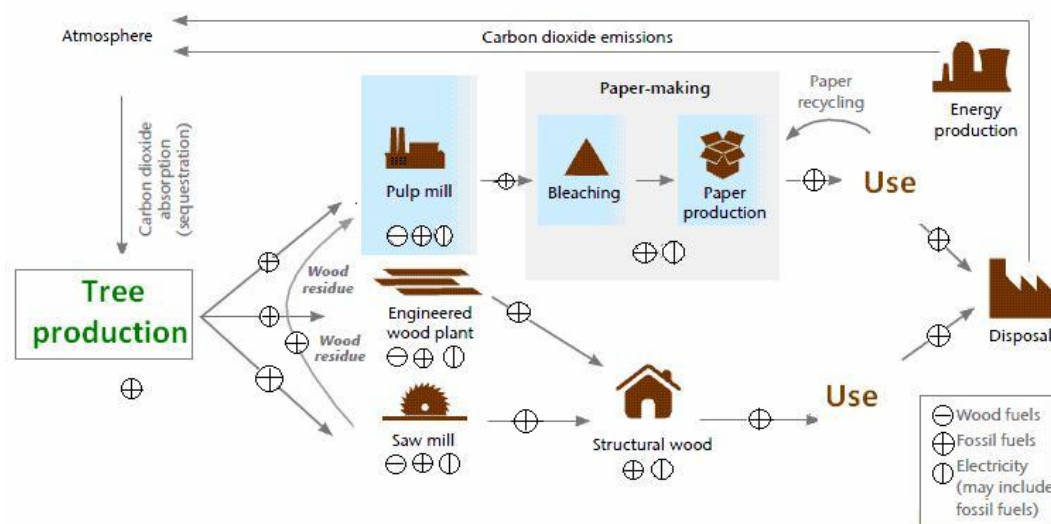
The environmental impacts of pulp and paper industry's impacts on the environment are notable not only for their magnitude but also for their effects, ranging from damage to forests, pollution of air and water, generation of solid waste and emissions of greenhouse gases. These impacts occur at all phases of the paper lifecycle, from fiber acquisition to manufacturing, and till to disposal. The life cycle of paper has additional characteristics from which different options for end of life are most important.

The life cycle analysis for paper industry is important as to provide a comprehensive understanding of the environmental impacts of its activity and to assist the decision making process concerning new instruments for ensuring sustainability [15, 16].

Several publications are already available on the analysis of the environmental impacts of pulp and paper production as well as from the treatment of the wastewater and waste resulting in different processes [2, 4, 8, 17, 18].

In 1998, the US Environmental Protection Agency [18], promulgated guidelines and emissions standards, collectively known as the „Cluster Rule” intended to reduce the discharge of toxic pollutants in waste-waters and emissions of hazardous air pollutants for the forest products industry [19]. In this context, life cycle assessment could be a valuable tool to identify the best solutions.

The life cycle of the paper products is characterized by a number stages, such as (Fig. 1): generation of energy in wood pulping, forestry services and waste management systems, services distribution (refers to the transport of printing and writing paper from the paper mill to the place of consumption), final disposal (it consists of land filling, incineration and recycling) [20].



**Figure 1.** The life cycle stages of printing and writing paper (adapted upon [20])

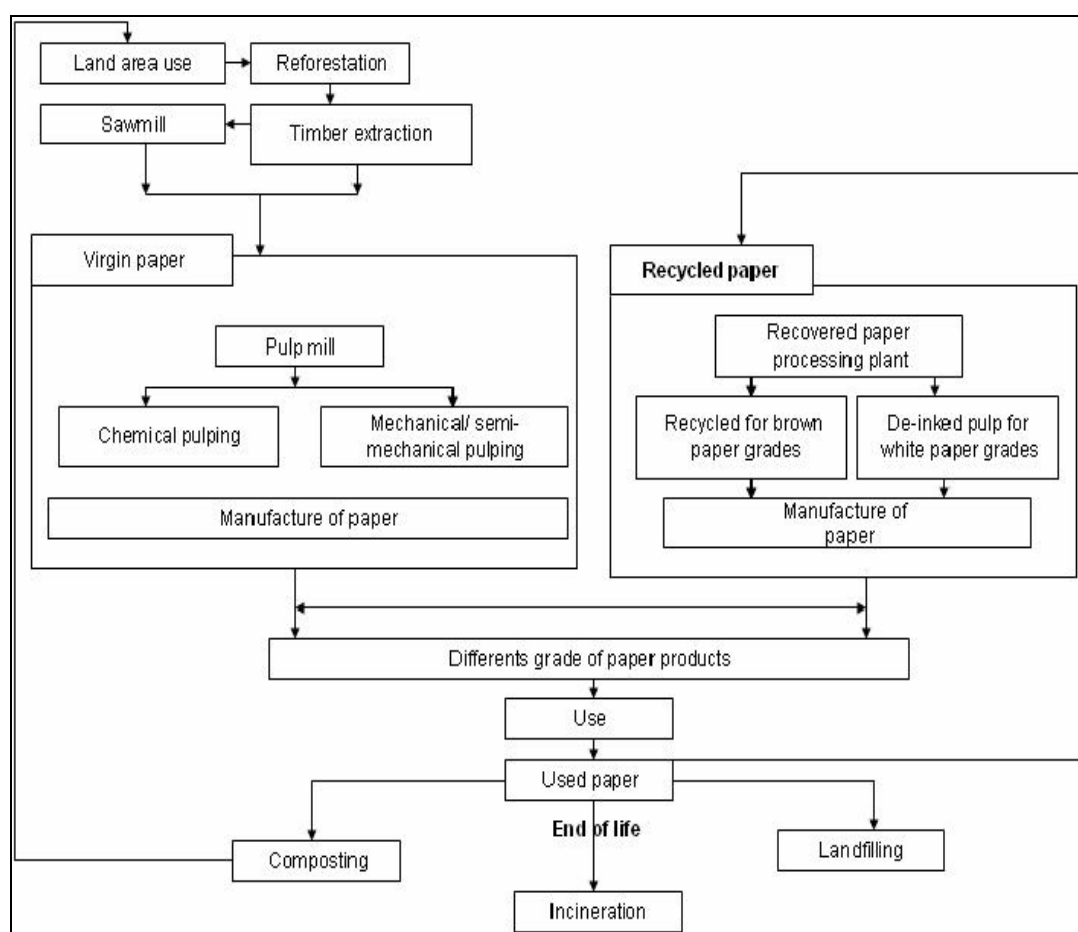
The life cycle of paper shows specific features from which different options for end of life are most important. Recycling of recovered paper and board is considered to reduce environmental impact of paper and board manufacture processes. Moreover benefit of paper recycling is generally assumed to be advantageous in many countries considering that, in waste management hierarchy, reuse and recycling are most preferable to energy recovery, which is superior to landfill. The recycling of already recycled paper depends on the fiber quality, this being a key research issue in paper recycling [5].

Figure 2 presents schematically the flow chart for inventory analysis in performing life cycle studies of the paper products.

### Environmental indicators

Responding to the need for a metric in assessing the sustainability of a certain system, some sustainability indicators or indexes are applied. One of the first metrics developed

for measuring sustainability is the ecological footprint, developed over 15 years ago [7, 21].



**Figure 2.** The flow chart for inventory analysis in performing life cycle studies of the paper (adapted upon [5])

It is well-known that the footprint of the industrial system has expanded several times in the last five decades, supporting an improved quality of life for an ever increasing population [22, 23]. Today, the industrial footprint exceeds the globally available biocapacity.

Apart of this indicator of sustainability, industry and community are encouraged and supported to adopt performance indicators frameworks to measure sustainability [13]. Environmental space is a tool for exploring sustainable development benchmarks on a sound scientific basis, and it is helpful to derive indicators of sustainable development for various applications.

In fact, these indicators provide one of the most relevant tools of performance and need sometimes to be supplemented by other qualitative and scientific information.

In this context paper industry is one of important economic activities that are adopting the concept of sustainable development. This trend is shown by several improvements and investments that have been undertaken by the sector in order to improve its environmental performance:

- minimize paper consumption,
- clean production,
- responsible fiber sourcing,
- maximize recycled content.

More than many other industrial sectors, this industry plays an important role in sustainable development, mainly because its raw materials - wood fibers - are renewable, recyclable and biodegradable.

Indicators are used for compressing, manipulating and understanding large amounts of information [24]. According to Greiner (2001) [3], an indicator has three main purposes: to raise awareness and understanding of the issues it indicates, to help in decision-making, and to measure the achievement of established goals. A good indicator is described as understandable, reliable, and accessible by Sustainable Measures (2010) [25].

Table 1 describes some sustainability indicators applied in paper manufacturing according to the analyzed goals and according to their benefits. These indicators could allow to measure progress toward four the goals, illustrated in the first column of Table 1.

**Table 1. Environmental indicators for paper industry [26, 27]**

Objectives	Environmental indicators	Benefits
Minimizing paper consumption:	<ul style="list-style-type: none"> <li>• global paper and paperboard consumption, by country or region</li> <li>• per capital paper and paperboard consumption</li> <li>• per country paper and paperboard consumption</li> <li>• paper printing paper and writing paper consumption</li> </ul>	<ul style="list-style-type: none"> <li>• it reduces demand for wood and the environmental impacts of commercial forestry</li> <li>• less energy, water and chemicals are consumed and lowers emissions to the air and water</li> <li>• fewer pollutants are released during manufacturing and less paper is sent to landfills or incinerators</li> </ul>
Maximizing recycled content	<ul style="list-style-type: none"> <li>• percent of pulp made from recovered fiber</li> <li>• percentage of recycled content in papers and paper products, by sector and grades within sector</li> <li>• consistent minimum content recycled fiber specifications and standards</li> <li>• range of recycled paper choices available in each grade</li> <li>• volume of paper in the municipal solid waste stream</li> <li>• recovery rates by grade of paper</li> <li>• recovery rate for office papers</li> <li>• percentage of recovered high grade papers directed to "highest and best use" such as printing and writing paper</li> </ul>	<ul style="list-style-type: none"> <li>• it reduces the demand for wood, thus also reducing the pressure to harvest forests and to convert natural forests and ecologically sensitive areas into tree plantations.</li> <li>• is generally a cleaner and more efficient manufacturing process than making paper from trees, since much of the work of extracting and bleaching the fibers has already been done.</li> <li>• cuts both solid waste and greenhouse gas emissions created by disposing of paper in landfills</li> <li>• paper requires less total energy to manufacture than virgin paper, even when factoring in energy required to collect and transport</li> </ul>



## INDICATORS FOR SUSTAINABILITY IN PAPER MANUFACTURING

	<ul style="list-style-type: none"> <li>percentage of mixed paper in recovered paper collections vs. sorted papers</li> <li>exports of recovered paper as a percentage of total recovered volume</li> <li>recycling capacity</li> </ul>	<p>recovered paper compared to energy used to harvest and transport timber.</p>
Responsible fiber sourcing	<ul style="list-style-type: none"> <li>monitoring endangered forests</li> <li>stakeholder engagement and agreements</li> <li>certified paper products</li> <li>rate of conversion of forests to plantations</li> <li>number of corporate commitments to avoid conversion of forests</li> <li>use of herbicides on tree plantations</li> <li>use of synthetic fertilizers on tree plantations</li> <li>outdoor field trials of genetically engineered trees</li> <li>availability of non-wood plant fiber for pulp and paper</li> <li>leading non-wood fibers in papermaking</li> <li>pulping capacity for non-wood plant fibers</li> </ul>	<ul style="list-style-type: none"> <li>end the use of wood fiber that threatens endangered forests and other high conservation value ecosystems.</li> <li>end the clearing of natural ecosystems and their conversion into plantations for paper fiber.</li> <li>source any remaining virgin wood fibers for paper from independent, third-party certified forestry operations that employ the most environmentally and socially responsible forest management and restoration practices.</li> <li>eliminate widespread use of pesticides, herbicides and fertilizers in plantations and fiber production.</li> <li>use alternative crops for paper if comprehensive and credible analysis indicates that they are environmentally and socially preferable to other virgin fiber sources</li> </ul>
Clean production	<ul style="list-style-type: none"> <li>wood, water and energy use</li> <li>calcium carbonate use</li> <li>greenhouse gases</li> <li>sulfur dioxide</li> <li>nitrogen oxides</li> <li>particulate matter</li> <li>hazardous air pollutants</li> <li>volatile organic compounds</li> <li>total reduced sulfur</li> <li>mercury</li> <li>biochemical oxygen demand</li> <li>chemical oxygen demand</li> <li>total suspended solids</li> <li>adsorbable organic halogens</li> <li>dioxins and dioxin-like compounds</li> <li>total nitrogen and total phosphorus</li> </ul>	<ul style="list-style-type: none"> <li>minimize the combined impacts of water, wood and chemical usage, as well as air, water, solid waste, and thermal pollution across the entire paper productions system including: fiber production/sourcing, pulping, production, transportation, use disposal</li> <li>eliminate harmful pulp and paper mill discharges and the use of chlorine compounds for bleaching</li> </ul>

In order to comply with European regulation and ensure sustainable values of performance indicators the paper industry should use the best available technology to minimize the use of water, energy, chemicals and other raw materials, as well as

minimize emissions to air and water, solid waste and thermal pollution, to eliminate toxic waste and mill discharges, reduce brightness of products to reduce levels of bleaching and eliminate the use of chlorine and chlorine compounds for bleaching.

Any new pulp mill developers must demonstrate environmentally and socially sustainable sources of fiber.

The most effective way to reduce the negative impacts of the paper industry is to use it more efficiently, thus helping to reduce the demands for non – renewable resources and at the same time reducing waste and saving money. Explore paperless alternatives such as electronic communication and encourage innovation to cut packaging could be sustainable alternatives.

Paper buyers should seek to use as high a level of recycled content wherever possible, because this is the best way to avoid negative social impacts, particularly in forests. It is important for buyers to be able to track and analyze where the paper they use comes from and be satisfied that the paper source is sustainable.

Where virgin fiber is necessary, seek to ensure that negative social impacts are minimized by sourcing [28 - 30].

## CONCLUSIONS

The environmental performance evaluation by using suitable indicators could provide definite information, connected with the knowledge of all bottlenecks both from the range of the environmental protection and also from the range of the technical and organizational aspects of paper industry.

This information may help paper industry to better understand the actual impact or potential impact of its environmental aspects and thus assist in the planning and implementation of environment protection indicators.

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