

Paper recycling as an element of sustainable development

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Abstract: *Paper recycling as an element of sustainable development.* In the contemporary era of environmental consciousness, sustainable development has become an integral part of global policies. This article delves into the role of paper recycling within this paradigm, highlighting its significance, and benefits, but also the challenges faced in the recycling process. It underscores the environmental, economic, and societal implications of paper recycling and the necessity of integrating it into global sustainable development goals. The paper also touches upon the concept of a circular economy, emphasizing the need for holistic strategies that integrate paper recycling as a key component of sustainable development.

Keywords: recycling, sustainable development, circular economy, wastepaper

SUSTAINABLE DEVELOPMENT: BALANCING GROWTH WITH CONSERVATION FOR A SECURE FUTURE

The modern era is characterized by an exponential growth in consumerism. The demand for single-use products, fast fashion, and mass production techniques has placed enormous stress on our natural resources. These practices have led to environmental degradation, from deforestation to plastic pollution in our oceans. This overconsumption, coupled with an often wasteful approach to using resources, highlights the pressing need for sustainable solutions.

Sustainable development, as a concept, is a response to the accelerating challenges that our world faces due to rapid industrialization, increased consumption, and neglectful environmental practices. The idea of sustainable development revolves around a form of growth and progress that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. Concern for sustainable development took a concrete form in the second half of the 20th century, focusing on three key pillars that underpin the approach to development that is balanced and equitable:

- **Economic Sustainability:** This involves fostering economic growth and productivity in ways that are socially inclusive and beneficial for all, without depleting the resources that future economies will depend upon.
- **Social Sustainability:** This considers the social aspects of development. It emphasizes the importance of creating an inclusive society where everyone has access to basic services, human rights are respected, and social cohesion is nurtured.
- **Environmental Sustainability:** This refers to managing and conserving the natural resource base. The main goal here is to prevent the degradation of the Earth's ecosystems, reduce environmental risks, and ensure that the planet's natural resources will be available for future generations.

The concept of sustainable development suggests that these three pillars must be considered and balanced together. Ignoring one in favor of the others could lead to adverse

outcomes. For instance, unchecked economic growth might result in environmental degradation, which in turn might harm future economic prospects and social well-being.

The United Nations' adoption of "The 2030 Agenda for Sustainable Development" [2] in 2015 was a landmark step towards global recognition of the challenges ahead. This agenda offers a comprehensive roadmap, marked by specific targets and objectives aimed at transforming our world. It includes the objectives that are necessary to protect the planet, end poverty, respect human rights and provide high quality of life for everyone. The priorities by 2030 are fair transformation to low-carbon economy, circular economy and resource-efficient economy. Another missions are sustainable production and consumption of food, long-term modernization of infrastructure, encouragement to doing business sustainably as well as decent jobs, improvement of quality of water, combatting climate change, promoting peace, justice, and strong institutions [3]. The 2030 Agenda for Sustainable Development is therefore a visionary blueprint, reflecting a global consensus on the direction of humanity's future. Achieving the SDGs (Sustainable Development Goals) will require sustained efforts, collaboration, and innovative solutions. Mainly, solutions like fostering innovations in sustainable technologies, and integrating circular principles in industries have to be taken [4].

THE CIRCULAR ECONOMY: A PARADIGM SHIFT FOR SUSTAINABLE DEVELOPMENT

Traditionally, the global economy has largely followed a linear model of "take-make-dispose". However, the burgeoning global population, coupled with mounting consumption rates, poses critical challenges to resource availability and waste management. With growing concerns over depleting natural resources, environmental degradation, and climate change, there is a rising emphasis on the circular economy (CE) as an alternative model. The Circular Economy emerges as a potential solution, focusing on the longevity, renewability, and recuperation of resources. At its core, the CE promotes a restorative and regenerative approach to production and consumption based on three fundamental principles:

- **Design out Waste and Pollution:** the concept of designing products and processes that minimize waste and pollution from the onset. This involves innovative design techniques, use of non-toxic and biodegradable materials, and considerations for end-of-life product management.
- **Keep Products and Materials in Use:** this principle emphasizes extending the life cycle of products and materials as long as possible. It includes practices such as repair, refurbishment, and recycling. By ensuring a continuous circulation of products and components in the economy, it is possible to reduce the demand for raw material extraction and mitigate the associated environmental impact.
- **Regenerate Natural Systems:** this principle acknowledges that certain natural resources are finite and aims to rejuvenate depleted resources and restore damaged ecosystems. It therefore includes practices that restore natural capital.

The Circular Economy, though a relatively recent concept in the spectrum of sustainable development, offers profound economic, environmental, and social benefits. It stimulates growth by introducing new business models and fostering innovation. This innovation can open up new market segments and revenue streams. Transitioning to a more circular economy has the potential to generate jobs, particularly in sectors like recycling, refurbishment, and remanufacturing. What is important, CE practices often reduce dependency on raw materials, leading to significant cost savings. Efficient resource utilization means companies can achieve more with less. In terms of the environment, CE reduces waste generation, leading to decreased landfill usage and associated environmental hazards. CE significantly also reduces the need for resource extraction, thereby conserving natural reserves. Resource optimization and sustainable practices contribute to a decrease in energy-

intensive processes, subsequently reducing greenhouse gas emissions. In a social context, CE encourages local employment. The shift towards CE demands a skilled workforce in areas like sustainable design, repair, and refurbishment, leading to enhanced skill development and training opportunities. This economic model fosters a culture of responsible consumption, wherein consumers are more informed and conscientious about their purchasing decisions, supporting businesses that prioritize sustainability. It also can contribute to a healthier living environment by reducing the amount of pollution and waste. This directly impacts public health and overall well-being.

While the CE offers promising solutions, it also presents challenges. Transitioning from a linear to a circular model requires significant behavioral shifts among producers, consumers, and policymakers, and also often demands advancements in technology for effective resource recovery and sustainable production. There might be initial economic setbacks as industries tied to the linear model might face obsolescence. Initial costs of transitioning can be high, and some industries may face resistance due to perceived threats to their existing business models. The absence of supportive policies or the presence of regulations that unintentionally promote the linear model doesn't make things easier.

To summarize, the circular economy is not just an economic model; it represents a paradigm shift in how we perceive growth, resource use, and waste management. By reorienting the economy towards sustainability and regeneration, the CE presents a viable pathway to address pressing global challenges while ensuring continued economic prosperity. While challenges exist, with collaborative effort, innovative thinking, and supportive policies, a circular future is attainable.

PAPER RECYCLING: A PATH TO ECOLOGICAL RESPONSIBILITY

Amid the broader spectrum of sustainable development and circular economy lies the critical aspect of resource management. With the paper industry being one of the most resource-intensive sectors, paper recycling plays a pivotal role in promoting sustainable resource management and mitigating environmental degradation. Paper recycling offers a multitude of environmental, economic, and societal advantages. One of the primary advantages of recycling paper is the conservation of natural resources. Reduced demand for virgin pulp leads to fewer trees being cut down. This preserves forests, which are crucial for biodiversity and carbon sequestration. In addition to resource conservation, the production of recycled paper significantly reduces energy consumption compared to manufacturing paper from raw materials. For every tonne of paper approximately 4000 kWh of electricity is saved. This energy efficiency contributes to decreased greenhouse gas emissions, carbon dioxide emissions are 20-50% lower than in the production of new paper, further promoting environmental health. Notably, the water consumption in the paper recycling process is also markedly less by at least 30 000 liters per ton of paper than in traditional paper production [5]. Another pivotal environmental advantage is the reduction in landfill waste. As paper is recycled, its volume in landfills diminishes, which in turn minimizes the use of landfill space and cuts down on methane emissions. Recycled paper usually does not need to be re-bleached with chlorine so emission of dioxins also decreases. From an economic perspective, paper recycling, over time, can be more cost-effective than producing new paper, attributing this to savings in energy and raw material expenses. Furthermore, the paper recycling industry often demands more labor-intensive processes than conventional paper production. This creates numerous job opportunities in collection, processing, and the sale of recycled paper. With a global market progressively leaning towards sustainable products, businesses dedicated to producing and marketing recycled paper items can exploit this burgeoning segment and promote green innovation. On the societal front, paper recycling is instrumental in endorsing sustainable practices. Conscious paper recycling cultivates a culture of responsibility, and

encourages communities to be conscious consumers, motivating them to embrace other eco-friendly habits. These initiatives help individuals grasp the broader implications of waste management and environmental conservation.

Despite its evident benefits, the recycling process for paper contends with a range of challenges that impede its efficiency and overall effectiveness. Low quality of paper waste is one of the primary challenges in paper recycling. Achieving an increase in the paper recycling rate necessitates utilizing recycled fibers sourced from premium-quality paper. This importance arises due to the fact that with each recycling cycle, the mechanical and printing characteristics of the material degrade due to the limited number of recycling rounds [6-10]. Fibers lose quality and get shorter with each recycling process, accompanied by a deterioration in their swelling and flexibility attributes. After several cycles, the fibers become too short to produce new valuable paper. According to the literature, the maximum number of possible recycling cycles for wood fibers ranges between 4 and 7 [11,12]. The fiber primarily undergoes changes in the first two to four recycling cycles in terms of water retention capacity and strength potential, while further changes are marginal.

Contamination of paper waste is also one of the primary challenges in paper recycling. Recycling paper as a raw material involves a multi-stage treatment, including the separation and removal of contaminants to produce recycled pulp. Mixed materials, such as plastics, food residues, metal, and other waste products, can reduce the quality of recycled paper, disrupt the recycling process, and increase processing costs. Certain paper types, such as coated, laminated paper, or with glue content, present intricate technological challenges in the recycling process. Substances used in the manufacture of such products are referred to as stickies. Stickies is a general term for all tacky components in the recovered paper pulp and are categorized according to their origins as primary, resulting from recovered paper and secondary, originating from recycling process. These sticky particles can be referred to as macrostickies, microstickies, or potential secondary stickies based on their size and their behaviour. The ability to remove adhesive applications, which create sticky particles during the paper recycling process, is a very important quality aspect related to the product. Stickies do not dissolve in water, so during recycled paper production, while heat and pressure act, particles from the adhesive can block equipment and lower the quality of the produced paper. So, for effective recycling, the paper needs to be easily repulpable, and any adhesives should be detachable. This is crucial for every kind of paper product. For all white grades paper must be also deinkable. Deinkability refers to the capability of a printed product to undergo a deinking procedure, effectively removing most of the ink or toner. This shall restore, as well as possible the optical properties of unprinted product [13]. However, some inks are difficult to remove, and the chemicals used in this process can be highly harmful to the environment. Additionally, substandard recycled fibers elevate the presence of harmful substances within the paper composition [14-16]. Subpar wastepaper quality therefore not only diminishes the paper production capability of pulp but also leads to heightened usage of chemical additives and fillers, resulting in the generation of substantial by-products and thereby presenting significant environmental and economic challenges [17].

Undoubtedly, a significant problem in the social context is the lack of awareness among consumers about the importance of proper paper recycling. Many people are unaware of the correct methods to segregate and dispose of paper, leading to reduced efficiency in collection and recycling. Moreover, not all institutions, whether public or private, prioritize or promote paper recycling, which reduces the overall volumes being recycled. Implementing effective public awareness campaigns can help educate consumers about proper paper recycling practices, including the importance of contamination-free recycling and proper sorting. Moreover, given that recycled paper isn't solely processed in its country of origin, it's

crucial to establish concepts like eco-design and eco-collection concepts on an international scale to enhance the sustainability of the paper cycle.

LEGISLATION – STANDARDS IN THE RECOVERY AND RECYCLING OF PAPER AND CARDBOARD

One of the key documents in waste management is The Waste Framework Directive (2008/98/EC) [18] presents an avenue for specific waste streams, after undergoing a recovery process and meeting certain standards known as the End-of-waste criteria, to no longer be classified as waste. These standards mandate that the waste aligns with several conditions, such as having specific common uses, a market demand, adherence to technical stipulations for their applications, compliance with existing product legislation and standards they replace; and the absence of any overall adverse environmental or human health impacts [19].

For waste paper to be reclassified from waste, upon its transfer from its originator to another party or before its usage at a paper production facility, it needs to meet the following conditions:

- It should be categorized per European specification "EN-643- Paper and board - European list of standard grades of recovered paper and board".
- The content of non-paper components must be equal to or less than 1.5% of its air-dried weight.
- The waste paper, inclusive of its elements such as ink and dyes, must not possess any hazardous traits as outlined in Annex III of Directive 2008/98/EC.
- Visual inspections shouldn't detect absorbed substances like oil, solvents, paint, or any food remnants in the waste paper.
- Once acquired by its producer or importer, waste paper streams, when used as an input, should always be stored separately from any other waste, including different grades of waste paper.
- All treatments needed to prepare the waste paper for direct input to pulping in the manufacture of paper products, such as sorting, separating, cleaning, or grading, and except de-baling, should have been carried out.

In terms of collecting, sorting, recycling, and trading paper and cardboard for recycling, every country has its unique set of regulations, laws, and legal documents. It's vital to ensure that these regulations don't adversely affect the market for separately collected paper materials. Collection initiatives, both obligatory and voluntary, have most likely had the most significant and lasting influence on paper salvage and the provision of recycled fiber.

As part of the circular economy package, Directive 2008/98/EC is amended by Directive (EU) 2018/851 [20]. The replacing directive sets out the minimum operational requirements for extended producer responsibility systems. These can also encompass organizational responsibility and responsibility for contributing to waste prevention and enhancing the reusability and recyclability of products. The directive also tightens regulations on waste prevention. The directive also specifies new waste recycling levels and provides examples of measures to promote the waste management hierarchy.

Currently, thanks to the introduction of the Directive of the European Parliament and Council EU 2018/851, the amount of recovered waste paper has increased. This significantly expands the raw material base of the paper industry in Poland. However, the quality of the recovered waste paper still leaves much to be desired. For paper and cardboard to undergo the recycling process, they must be of the right quality, which is directly affected by the collection method, among other things. The EN 643 [21] standard is appropriate for assessing quality. An extremely important aspect of preparing the right quality of waste paper is sorting out papers and cardboards that are unsuitable for processing in the paper industry. Therefore, the PN-EN 643 standard [22] introduces definitions, among which attention should be paid to

those concerning prohibited and unwanted materials (wastes). If waste containing paper and cardboard is prepared in such a way that it meets the criteria specified in this provision and the recipient can use it directly in further production processes, it should be considered that they do not have the characteristics of waste. Such material is then called standardized waste paper.

To ensure the proper quality of the raw material, plants often apply their own requirements for the supplied material. Recovered paper and cardboard that do not meet these are returned to the supplier. Among the criteria related to this type of raw material are: types and varieties of raw material, sizes, weights, and the way bales are packaged, moisture content, identification and delivery date, as well as the method and conditions of acceptance. Other criteria include paper and non-paper contaminants and sanitary conditions, such as biological contamination, etc. Such contaminants cause technological problems, especially in defibering and sorting, and also generate waste disposal costs. One of the most important aspects of ensuring the right quality of waste paper is, therefore, sorting out papers and cardboards that are unsuitable for processing in the paper industry.

STATISTICS ON PAPER AND CARDBOARD RECYCLING

The amount of recovered paper produced worldwide in 2021 surpassed 244 million metric tons. This represented an increase of nearly seven percent in comparison to the previous year, and a 70 percent growth when compared to 2000 levels [23] (Fig. 1). Producing such a huge amount of recovered paper would not be possible without conscious recycling of paper waste.

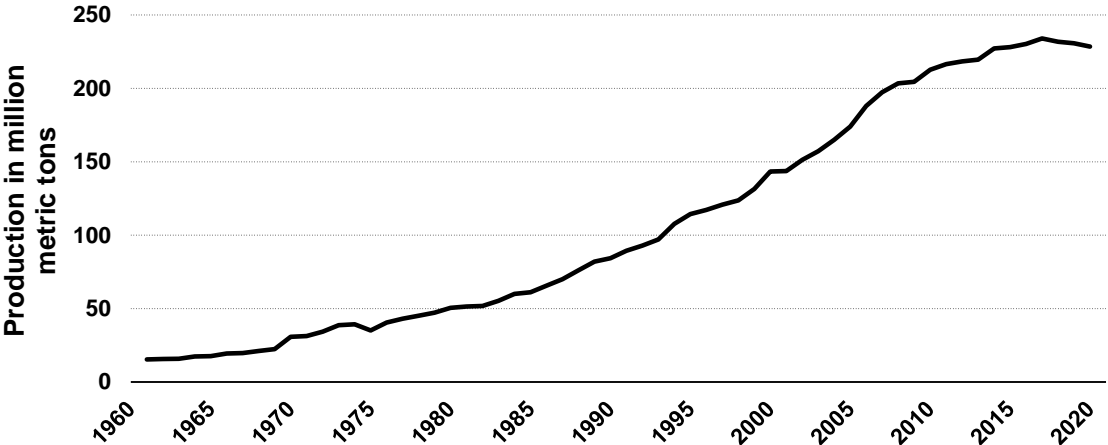


Figure 1. Production volume of recovered paper worldwide from 1961 to 2021 (in million metric tons)

The global paper recycling rate stands at around 58% [24-27]. In some more developed countries, the paper recycling rate even reaches 70–75% of the total amount of paper waste generated nationally [28]. Europe, in particular, boasts the highest paper recycling rate in the world, followed by North America, while Asia, Latin America, and Africa have the lowest recycling rates [29].

According to a declaration adopted in 2021 by the European Paper Recycling Council (EPRC) [30], the recycling rate for this material in Europe should reach 76% by 2030. An EPRC report [31] indicates that in the previous year (2022) both paper and cardboard consumption and paper collection for recycling in Europe decreased by 1.8% and 5%, respectively, while the 2021 recycling rate was 72.8%. In 2022, it reached 70.5% (exactly 54.9 million tons). The paper industry thus saw a decline in the use of paper for recycling (PfR) by 6.2%, amounting to 49.1 million tons. This decline was caused by the war in

Ukraine and the energy crisis. High electricity and gas prices affected the pulp and paper sector that uses recycled fibers, as they rely more on gas supplies than mills using primary fibers. The decline in consumption in 2022 affected all paper types except sanitary paper and cardboard; these recorded increases of 3.5% and 6.5% [32]. Despite these recent downward trends, it's worth noting that over the last 30 years, there has been a significant qualitative change in paper recycling – the rate increased from just about 40% in the early 1990s (which is also high compared to other developed countries, e.g., the USA's rate of about 65%). There's a significant variance among different types of paper, which is derived from the desired properties of the end product (e.g., high-quality graphic papers have technically limited possibilities of using waste paper due to their characteristics). Packaging papers lead the way, with a total recycling rate of around 75%. Recycling rate of paper and cardboard packaging waste in the European Union by country is presented in Figure 2. In contrast, the aforementioned graphic paper segment lags behind with a rate of just under 30%. Other papers, including sanitary papers, use around 40% of recycled material [33].

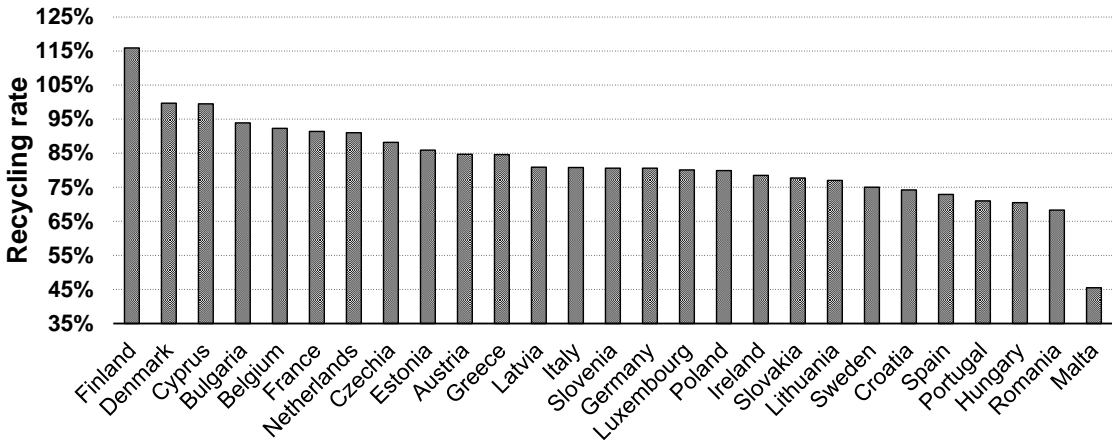


Figure 2. Recycling rate of paper and cardboard packaging waste in the European Union in 2019, by country [34]

Despite the decline recorded in 2022, Europe continues to be a global leader in paper recycling. The global average for fiber reuse was 2.5 times, while in Europe it was 3.5 times [35]. The EPRC report even terms paper recycling as an industry "made in Europe", characteristic of our region, generating economic value-add and setting standards for the rest. Hence, achieving the targeted 76% recycling rate by 2030 is still deemed attainable by the industry.

It's also worth mentioning that the pulp and paper industry is very strong in export markets, with an export rate of 21% for paper and cardboard production. Currently, the main export destinations for European PfR are India, Indonesia, Turkey, and Vietnam. Other countries, such as Malaysia and Thailand, have also increased their import of European PfR. Overall, total exports outside of Europe increased by 8.0% compared to 2021 [36].

SUMMARY

Paper recycling, an essential facet of sustainable development, presents both opportunities and challenges. Addressing these challenges necessitates a multi-pronged approach that includes technological advancements, economic incentives, effective policies, and heightened public awareness. With the paper industry playing such a vital role in modern society, it becomes crucial to advance recycling efforts to ensure both consumer satisfaction, environmental conservation, and economic viability. A united effort in championing and

adopting paper recycling practices can set a path to a sustainable, economically robust, and socially conscious future.

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Streszczenie: *Recykling papieru jako element zrównoważonego rozwoju.* We współczesnej dobie świadomości ekologicznej zrównoważony rozwój stał się integralną częścią polityk na szczeblu globalnym. Niniejszy artykuł zgłębia rolę recyklingu papieru w tym paradygmacie, podkreślając jego znaczenie i korzyści, ale także wyzwania związane z procesem recyklingu odpadów papierowych. Podkreśla również środowiskowe, gospodarcze i społeczne konsekwencje recyklingu papieru oraz konieczność włączenia go do globalnych celów zrównoważonego rozwoju. W artykule poruszono także koncepcję gospodarki o obiegu zamkniętym, podkreślając potrzebę holistycznych strategii integrujących recykling papieru jako kluczowy element zrównoważonego rozwoju.

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