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PAPER RECYCLING: FACTORS OF INFLUENCE

In an environment of climate change economy, paper recycling is an example of sustainable production in the context of policies adopted and the solutions sought in this area. This raises the current question of the factors that determine and influence the process and our interest in research. The following groups of factors have been identified and systematized in the study: environmental; operational and economic; legal and regulatory. The impact they have on the recycling of waste paper (WP) has been identified in order to facilitate and improve the quality of the products obtained.

Keywords: recycling, waste paper, factors.

Маринова В., Стойкова Т. Рециклирование бумаги: факторы влияния. *В условиях экономики, которая должна учитывать изменения климата, рециклирование бумаги является примером устойчивого производства в контексте принятой политики, а также современных исследований в этой области. Поэтому актуальным является вопрос о факторах, его определяющих, и о влиянии, которое они оказывают на этот процесс. В ходе исследования установлены и систематизированы следующие группы факторов: экологические; эксплуатационные и экономические; нормативно-правовые. Изучено влияние, которое они оказывают на переработку макулатуры, с целью улучшения качества получаемой из нее продукции.*

Ключевые слова: рециклирование, макулатура, факторы.

Background. Waste management is part of EU policies encouraging the development of an economy based on sustainable development. The focus in the waste hierarchy shifts from disposal to recycling. Due to its characteristics, paper is one of the most effectively recyclable waste.

Recycling is considered as one of the most rational methods of utilizing valuable waste components, reducing energy consumption, raw materials, and final disposal [27, p. 214] Encouraging strategies for resource efficiency, recycling and reuse are an important element in achieving social and economic development in conditions of limited access to resources and strong dependence on imports, as well as ecological balance in accordance with the raw materials industry needs [23].

The continuously growing demand for paper and paper products, combined with the shortage of wood fiber resources, determines the necessity to look for supply alternatives of fiber raw materials. Among the various alternatives, recycling is an applicable solution for providing a suitable substitute for primary wood fibers. In a climate-driven economy, paper recycling is an example of sustainable production in the context of policies adopted and the solutions sought in this area. This raises the current question of the factors that determine and influence the process and our interest in research.

The analysis of recent research and publications. Globally, various authors are examining the change in properties that determine the quality of different types of fibrous materials as a result of recycling. [17, pp. 314, 327; 35, p. 1625]. The focus in discussing paper recycling issues is on the impact of basic raw materials and technological operations on the fiber recovery process and the opportunities to improve its negative effects, related to the quality of the products obtained. [25, p. 57; 33; 8, p. 17–19]. There is interest in the broader analysis, revealing the preconditions and limitations for recycling waste paper, identifying the factors that influence it, which is the reason for targeted research on the problem.

The aim of the article is to present and systematize the factors that influence the recycling of waste paper (WP) to facilitate and improve the quality of the products obtained.

Materials and methods. In the study the descriptive – analytical approach, the methods of comparison, analysis and synthesis have been used.

Results. The recycling process is linked to a number of legal, economic, operational and environmental aspects that determine its direction and limitations. Although almost any paper is recyclable, about 19 % of paper consumed is non-recoverable due to technical reasons [3, p. 463]. Ristola [22] states that, nevertheless, globally, about one third of the volume of used paper that could potentially be used for recycling is simply thrown away.

Essentially, all papers can be produced based on WP. Kirova – Blazheva [11, p. 22–23] explains that different types have their own possibilities for final usage and their quantities vary. Switching to a lower quality category is possible, but into higher is difficult. This means that the highest quality WP can be used in the production of lower grade paper.

According to various authors, the potential limitations of using WP for recycling are related to the availability of sources from which the used

paper products can be recovered, with their location and their collecting improved. [8, p. 19, 36]. There is also an influence from the development of the demand and supply of WP and the reflection of global trends on raw materials on the delivery and prices of WP [4; 30; 34], the costs of alternative waste processes [7; 12, p. 1–18; 14, p. 1391–1398]. In addition, the deliberate attitude and raise of population culture on recycling issues [28, p. 271–273; 26, p. 97; 29, p. 72], as well as the clarification of environmental policy terminology [15, p. 431–449; 31, p. 46] is important. This will affect the quality of the recycled paper used, which is a major factor in the quality of the finished product.

As a result of the studies, we suggest that the factors that influence the paper recycling process can be systematized, as shown in the following *table.*

Factors influencing the recycling process of WP

Factors for the paper recycling process		
1. Environmental friendliness of production	2. Operational and economic	3. Legal and regulatory
environmental awareness	recycling costs	definition and classification of paper for recycling
the effectiveness of waste management systems	capacity of recycling plants (factories)	prohibitions and licensing requirements
resource (green) economy policies	price of primary raw materials	waste legislation
ecodesign of paper and cardboard products	alternatives to waste management	quotas for trade
availability of sources and raw materials for recovery	market conditions for recyclable materials	defining "best practices" for waste management
climate change reporting	quality of paper for recycling	voluntary agreements

Environmental friendliness of production is a leading factor in the recycling of WP. ***Environmental awareness*** is still a major factor affecting paper recovery in European countries, especially for countries with low collection rates. Studies show that the better informed people are about recycling, the more likely they are to engage in recycling and to remain pleased with their actions. Raising of the awareness could be carried out with different campaigns depending on the target group, with the main efforts being made by the state institutions (communities, etc.). [15, p. 431–449]. Research results [10, p. 195–220] confirm that recycling behavior is consistent with the principles of the Schwartz altruism model, according to which it is influenced by social norms, personal norms and awareness of the consequences. Empirical studies [32, p. 1717–1737] show that demographic and economic conditions have a significant impact on recycling rates. Open economies, those which are actively involved in recyclable materials trade, generally generate higher rates of utilization and recovery of secondary raw materials. Authors [5, p. 434–442] summarize that people with access to

structured recycling programs have much higher recycling rates than those with no such program. Moreover, individual attitudes to the environment affect recycling behavior only in the community, with easy access to a structured recycling program.

The effectiveness of waste management systems is a key factor in the recycling of WP. Improving the collection rate of WP requires a conscious attitude and enhancement of the population culture about the recycling issues. This, combined with the use of more efficient collection systems requiring pre-sorting of discarded waste, is a prerequisite for improving the recyclability of the waste mass by shortening the re-sorting process in paper processing [30]. Recycling is one of the waste management system capabilities and should be considered in the context of a common waste management strategy. Furthermore, the implementation of recycling utilization and recovery must be supported by systematic plans of action and the private initiative should be complemented by the public participation [4].

Recycling policies include various projects, programs and actions that facilitate the organization and implementation of recycling processes for WP**.** Recycling programs reduce pollution, generate energy savings, decrease global climate change and pressures on biodiversity [21, p. 38–57]. Recycling is a comprehensive method for environmental protection, targeting to limit raw material consumption and reduce quantity of waste [24, p. 322]. Recycling policies for secondary fibrous materials are supported by a number of initiatives such as: sustainable consumption and production, the thematic strategy for the sustainable use of natural resources; European Union proposals on industrial pollution, etc.

The potential limitations of using WP for recycling are related to the ***availability of sources*** from which the used paper products can be recovered, with their location, and with their collection improved. There is also an influence from the development of the demand and supply of WP and the reflection of global trends on raw materials on the delivery and prices of WP. The method of collecting paper depends on the collection area (city, village), its characteristics (population, housing structure, type of industry), and the customers for the paper collected. Sources of waste paper can be industry (business), households and separate individuals, using different collection systems: containers of different colors, shopping centers, recycling centers, special landfills for packaging waste [30].

The eco-design of products from paper and cardboard according to the authors [16, p. 429] is a key issue for the production of high quality recycled mass and therefore for increasing the use of secondary fibrous materials as a raw material in the paper industry, and the reason for its absence are the high prices, legislation and regulations.

The Climate changes are used in understanding of the so-called eco-efficiency and are reflected in the developing documents that provide guidance and recommendations on the process of recycling with minimizing carbon footprint.

The operational and economic aspects of recycling are interrelated factors that include basic quantifiable indicators such as: reducing the cost of the product manufactured; saving resources, energy, chemicals; improving control of the WP trading markets. They should be considered in a mutual relationship.

The focus in the waste hierarchy shifts from their disposal to their recycling. Due to its characteristics, paper is one of the most effectively recyclable waste. The level of recycling of paper and cardboard packaging waste in our country has increased in recent years compared to the general level in Europe. Data from audit reports and statistics from the pulp and paper industry [6, p. 3–16; 18, p. 17] show the ***wide capacity abilities*** of paper and cardboard recycling by processing plants in the country and the importance of this resource for securing production within the requirements of the "circular economy". The costs of ***alternative waste management options*** such as incineration with energy utilization or landfill are also important. The high cost of alternatives clearly helps the recycling process [4]. Some authors, during evaluating of recycling processes [14, p. 1391–1398], conclude that paper recycling, in terms of environmental lifecycle, is equal to or better than its incineration with energy recovery only when recycling technology is with the highest level of environmental performance.

Recycling costs are a combination of the following costs: for the collection of recyclable materials, for pre-treatment (logistic) operations and for the recycling process itself. Economic profitability[1] is a major motivator for recycling initiatives. The cost of collecting and sorting waste is the most important factor determining the overall profitability of recycling. ***Improving the market conditions for recyclable materials*** as a result of increased demand for recycled goods will also contribute for reducing the net cost of recovering materials. Studies [34] confirm that removal of waste collection and waste disposal costs are leading factors for the effectiveness of recycling and composting programs. When decommissioning costs remain low, the collection and treatment of recyclable materials alone cannot be profitable. As landfill costs increase, the cost of disposal will increase the cost of recycling. Other authors [7] conclude that paper producers could reduce the cost of raw materials by mixing secondary fibers with primary fibers and reusing their residues and clippings, rather than disposing of them at solid waste landfills. In support of this, the results [2, p. 489-497] of a funded project by the German Federal Ministry of Economics and Technology lead to a technological concept that allows high quality white paper products to be produced cost-effectively from recycled fibers. The replacement of fibrous raw materials in the processing of pulp from recycled fibers in the production of paper packaging has two main objectives: reducing production costs from one hand, and modifying the weights of the

[1] The economic profit from recycling is due to a reduction in the necessity of buying raw materials, a decrease in environmental and waste disposal costs, or a direct profit from the sale of recycled or recyclable materials.

top layers while ensuring cost reductions and product requirements, on the other. The research assuming for standard paper factory resulted in cost savings of € 6.6 million per year. In this regard, price controls on WP are essential as its use is considered as one of the most important ways to preserve cellulose fibers during the depletion of natural resources. Enhanced recycling provides low material costs and the use of WP should be considered not only as economic development but also as a part of industrial policy [12, p. 1–18].

The cost of primary raw materials, which can be considered from the recycling point of view as perfect substitutes for secondary raw materials, is another important factor for the economic attractiveness of recycling. As such, this price is generally highly dependent on world trade and on world commodity prices. World commodity prices tend to hesitate. The higher the prices of primary materials, the more attractive the secondary materials become [30]. A price comparison should be made between cellulose (primary fibers) and WP (secondary fibers). The prices of fiber materials vary depending on the type and ***market conditions***. Inevitably, prices are linked to a balance between demand and supply – when supply is higher than demand, prices are low. WP prices are influenced by other factors, including prices controlled by WP traders [34]. The value of WP is determined by the following considerations: the cost of losses from WP and other solid wastes; its performance in the paper machine; the type of fibers present and the cost of the primary fibers and the displacement of the secondary fibers; the impact of used recycled fibers on the selling price of the product; the costs associated with the disposal of waste [13]. The prices of WP are largely determined by the price of the obtained paper and cardboard products. Unlike other materials such as metal and plastic, WP does not suffer from large price increases [34]. However, these other materials are part of products that typically have much higher value added, while recovered paper is almost entirely used for the production of paper and cardboard mainly in low value added products.

The components of the cost of collecting and delivering the raw WP include: collection fees: transportation (fuel, vehicles, labor), fees for the purchase of waste paper, rental of containers, costs and means of delivery and others; production costs: sorting, baling, administrative cost; prices of buildings and equipment; on waste disposal; transportation to the enterprise, etc. [13]. Recycling requires companies to collect, export and reprocess recyclable materials, as well as companies to produce recycled materials. In order to clarify the environmental benefits of how useful recycling is, analyzes of transport distances from collection point to paper mills are made. Recycling reduces the need for imported pulp – for countries without their own sources of wood pulp, this is a major economic benefit of recycling [1, p .49; 20, p. 455–460].

Globally, WP collection and consumption must be combined, balanced, with regional imbalances and gaps being filled by international trade. Worldwide use of WP cannot exceed global collection, therefore there is

a direct link between regional paper and cardboard collection activities and net waste paper trade [11, p. 22–23].

Other elements that affect the prices of OX are: *availability* – depends on the collection scheme as well as consumption models; *quality* – depends on the collection scheme and the separation technology; *international demand* for paper products; *international demand for waste paper, transportation costs; timber price; costs of alternative outputs /markets/ recycling* [34]. Factors limiting recycling may be: other applications of WP for which there are no statistics; the capacity of recycling plants [19, p. 125–160]. Also relevant here are: ***the quality of the WP used***; the perceived quality of the new paper; the allowable and acceptable wastes from the treatment of WP. According to the authors [16, p. 429; 30], quality is the main prerequisite for expanding the use of recycled paper as a raw material, the main drawback being the supply of insufficient quality of WP. The quality of waste paper and paperboard depends on many parameters, and rapid and comprehensive monitoring of secondary fiber material forcing manufacturers to require certificates containing quality indicators: moisture content and content of unusable materials (including non-paper components and injurious to production paper and cardboard). It is necessary to qualify the type of paper and the possible variety of paper inclusions in the composition. The determination of ash content, volatile compounds, lignin content, ink, chemicals (according to REACH legislation), adhesives, additives is additionally required and also relevant.

The summary of operational and economic aspects of WP recycling includes consideration of: total costs, production cost per mass of recycled paper, production cost range for primary fibers, determination of the economic limit for recycling, WP and cardboard prices, amortization of equipment, operating expenses and the use of WP itself [9, p. 17].

The perception of WP as waste, rather than a valuable raw material for paper production, can be an obstacle to recycling processes. To overcome this misperception of WP, the Confederation of European Paper Industry (CEPI) has been lobbying hard for legislators to promote separate collection of WP, explaining that recovered paper is not a "waste" product but should be treated as a "valuable raw material". This is also supported in the proposal to amend Directive 2008/98/EC on waste, where it is a key aspect of increasing resource efficiency and within a circular economy means "closing the circle". **Legal and regulatory factors** include, as a starting point in the development of recycling policies, the view of recovered paper (cardboard) as a special raw material, rather than waste, and the determination of the various quality indicators to be met. Authors [4] summarize the obstacles that may arise in the recycling process, such as the ***definition of WP*** – inconsistent definitions such as waste or recyclables, hazardous or not, is a factor that creates many difficulties and confusion in statistics. The definition of ***"best practices"*** for waste management should be defined taking into account the entire life cycle of waste and should be updated in connection with scientific and technical progress.

Trading in waste material is an important point, revealing the basis of various contractual agreements, ***trading quotas*** adopted. The price of WP and the trade itself should be determined according to its classification under the accepted standard list of recycling paper – *EN 643:2014 European list of standard grades of paper and board for recycling*. Proper classification is a major factor in the effective application of WP and enables the production of products with optimum quality characteristics according to functional purpose. In addition, clearly regulated trade ensures facilitated ***contractual relationships*** and process efficiency. For recycling purposes, a complete characteristic of the paper used is required – classification and determination of its composite composition in order to improve its recyclability and to obtain a quality paper product. In the recycling process, recycling papers are divided into different groups and grades, as they are subject to different recycling processes and their standardization improves their recycling processes and guarantees a quality finished product. Paper manufacturers need high and consistent quality of WP in large volumes. Increased demand leads to an increase in claims as well as a higher demand for controlled quality WP gardes [30].

Waste legislation are proving to be an important factor in realization of recycling – high energy prices and subsidies such as the possible increase in paper inceneration and the use of WP for energy production; the slower further growth of WP collection in some countries, which is already high could also be a limiting factor. Recycling waste management options are not always clear either. Re-use slows or avoids the accumulation of various products in the waste recovery and disposal systems, thus avoiding the cost of activities with them [21, p. 38–57]. ***Legislative restrictions*** need to be addressed - administrative burdens for reducing pollution, paper production requirements. The European institutions support strategies that promote resource efficiency in realtion with environmental trends in industrial production. However, there must be coherence across the spectrum of different legal documents so that the role of secondary fibrous raw materials in the circular economy and modern manufacturing thinking is clear. A number of specific provisions governing recycling focus rather on individual, isolated aspects of waste collection and recycling and do not take into account the market forces that operate in systems and processes. Precise regulation and monitoring of recycling targets is required. According to authors [4], the appropriate framework for building a European recycling strategy should include: the creation of operational definitions and statistics; clear coordination with research funding and development of the decision-making process; identifying „best practices" at local and European level; creation and maintenance of databases; a strategy for integration with other policies.

Conclusion. In summary, it can be said that in the context of environmental appeals, recycling is the ecological production of paper using resource-saving raw material. The recycling process generates a number of direct and indirect benefits, such as: conserving resources and energy,

stimulating the growth of green industries and green technologies, reducing the need for landfills and incinerators, reducing the dependence on new materials. The clear identification of the factors that influence the WP recycling processes enables measures to be taken to properly account for the effect they have on the final product formation and its quality. Such systematic major groups of factors are – environmental, operational and economic, legal and regulatory. At the same time, a number of factors have an impact on the recycling process and questions remain to be resolved, mainly related to the used WP (its availability, collection, quality), as well as to the economic, environmental and social point of view of the process. This draws attention to the use of WP, which is a key factor in the quality and effictiveness of the products obtained from it.

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Marinova V., Stoykova T. Paper recycling: factors of influence.

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Conclusion. In summary, it can be said that in the context of environmental appeals, recycling is the ecological production of paper using resource-saving raw material. The clear identification of the factors that influence the WP recycling processes enables measures to be taken to properly account for the effect they have on the final product formation and its quality. Such systematic major groups of factors are – environmental, operational and economic, legal and regulatory. At the same time, a number of factors have an impact on the recycling process and questions remain to be resolved, mainly related to the used WP (its availability, collection, quality), as well as to the economic, environmental and social point of view of the process. This draws attention to the use of WP, which is a key factor in the quality and effictiveness of the products obtained from it.

Keywords: recycling, waste paper, factors.