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THE EXAMPLES OF MODERN SOLUTIONS IN THE FIELD OF WASTE MANAGEMENT IN CIRCULAR ECONOMY MODEL TRANSFORMATION

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Abstract

The work examines the role of innovative solutions in order to make more efficient use of waste and the reduction of their storage. Such solutions are necessary in the transformation process of linear economy to circular model. In the new model, the role of waste is being changed. Waste has not yet been treated as a by-product of economic activity but as a valuable resource that can be reused in the production process.

There were also analysed how extent is the development of innovativeness in Poland in comparison to other European Union Member Countries. There is also analysed the direction of changes in the waste management field, especially in the structure of municipal waste. Another aim is to examine the examples of the Polish enterprises acting in waste management sector and the kind of innovative methods they use. In the article there were also presented supportive tools for implementing innovations in enterprises, with a focus on the waste management. They include among others: National Smart Specialisations and Regional Smart Specialisations.

Key words: municipal waste, National Smart Specialisations, innovative methods in waste management field

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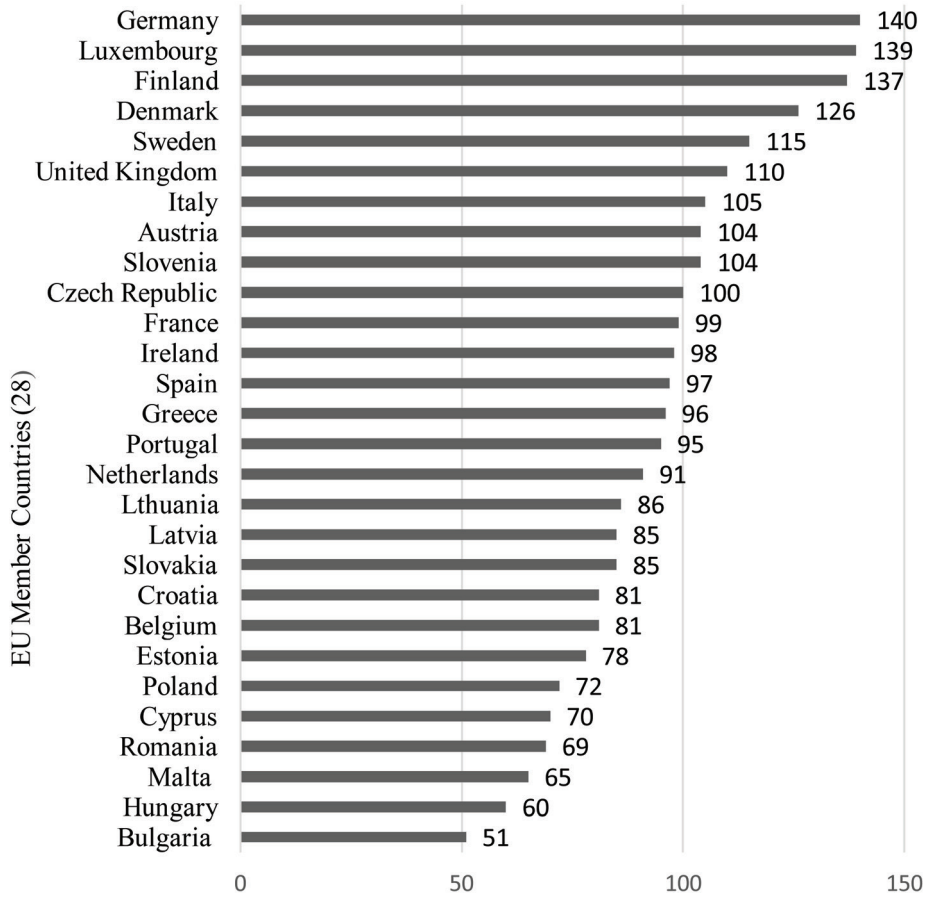
INTRODUCTION

Transformation of the linear economy to the circular model requires multifaceted changes in waste management. Waste is the key in the new economic model, in which great attention is payed to the maximum use of waste with minimal consumption of resources. The path of change of the European society to „recycling society" and the new economic value of waste are announced by EU regulations and deadlines in this area, obligatory for the members of the European Union. In achieving the new and higher levels of recycling set by the European Union, the prevention of waste disposal will be at the same time particularly important. According to the European Commission's 'Closing the loop: new circular economy package' of December 2015, the level of municipal waste preparation for reuse and recycling in 2030 should be 65% (including 75% of packaging waste). It is also planned to reduce the municipal solid waste storage to 10% (Closing the loop – An EU action plan for the circular economy, online). In Poland, in the year 2020 the level of recycling is to reach 50%. In pursuit of the goals, it is necessary the legal and administrative instruments implementation to protect the environment, but also the use of innovative solutions in waste management. These changes will concern waste enterprises and waste processing companies. In particular, companies operating as recovery organizations and as regional municipal waste treatment facilities will be of particular importance. Taking into account the future development of circular economy, special attention is paid to the possibility of using waste energy while keeping the protection of environmental components and saving fossil fuel consumption.

THE DEVELOPMENT OF THE ECO – INNOVATIONS IN THE EUROPEAN UNION AND POLAND

Innovation is a concept originating in Latin as innovatio, which means the renewal, change. This is the introduction of something new, or the newly introduced (Słownik języka polskiego PWN, online). In the waste management particular important are eco-innovations. Eco-innovation is defined as an innovation that reduces the negative humans' impact on the natural environment, increases the efficiency of the use of natural resources, or reduces the dependence on the supply of raw materials. Innovation works in three dimensions: ecological, economic and security. The essence of innovation itself is the implementation of a new or radically improved product, process or service (Szpor and Śniegocki 2012). Eco-Innovation can be divided into three types of initiatives: reducing the negative impact on the environment, solving environmental problems, developing eco – friendly products / services (Dąbrowska 2010).



Source: Based on Eco-Innovation Action Plan

Figure 1. Eco-Innovation Index in 2016 for EU Member Countries (28)

The classification of technical and technological eco-innovation includes business technologies, inter alia driven technologies – production systems increasing quality, production efficiency, increase efficiency, more cost – effective or reduce costs. Another groups in this classification are: clean technologies improving environmental results; appropriate technologies (simple production systems also improving environmental results but implemented for economic purposes); low-fruit technologies – fairly simple production systems that modify existing ones to improve environmental performance (Barbiroli and Raggi 2003)

The Eco-Innovation Observatory is the research and information platform for eco-innovations in Europe, was created in the European Union. The Eco-Innovation Scoreboard (Eco – IS) and the Eco-Innovation Index, which

shows how well individual Member States perform in different dimensions of eco-innovation compared to the EU average, and presents their strengths and weaknesses (Eco-Innovation Action Plan, online). Eco-Innovation Index of the year 2016 is presented for 28 UE Member Countries (Fig.1). According to the data of Eco-Innovation Index for Poland in comparison to other European Union Member Countries (28) we can see that the position of Poland is relatively low. Situation in Poland with the rest of the EU just says that Poland is, according to Eco-Innovation Index 2016, the sixth country out 28 from the end. And this position has got an economic origin. Poland has occupied with an index value of 72. Compared to Germany that has taken first place with the 140 score, the result of Poland is almost twice lower.

In previous years the position of Poland according to Eco-Innovation Index was also very poor. The Polish green technology market is in the early phase of development. The significant problems of developing the eco-innovativeness in Poland have an economic origin. The most important problem is the high cost of implementation. Another problem is the uncertain return on such investments, difficult access to capital, and the imperfect fiscal system – the lack of incentives for enterprises to implement innovations. These barriers can explain the slow development and implementation of innovations in Poland.

EXAMPLES OF NATIONAL AND REGIONAL SUPPORT FOR INNOVATION IN WASTE MANAGEMENT

Stimulating innovation is introduced through legal instruments. The Act of 4 November 2016 amending some acts specifying the conditions of conducting innovative activity, so – called "Small innovation law". The purpose of the Act (2016) is to facilitate innovation. Changes concern, inter alia: The Personal Income Tax Act, the Corporate Income Tax Act, the Tax Ordinance, and the Law on Higher Education. Enterprises will benefit from greater reliefs for research and development, and researchers from the commercialization of their inventions. One of the examples of the actions leading to changes in the direction of the changes to circular economy is supporting for research, development and innovation (R & D & I) in the new financial perspective for 2014 – 2020.

The goal of National Smart Specialisations, in addition to the competitiveness of the economy and increasing its added value, is also transforming it into a resource efficient economy, including natural resources. National Smart Specification List, published by the Ministry of Development – status of July 2016, presents a wide range of solutions for waste utilization and reducing material consumption. The whole document is based on many examples of areas where it is possible to reduce the generation of waste. A continuous update of the description of the specialization is planned, which will provide the basis for

financial support. Noteworthy is chapter 11 in the list of NSS that is dedicated to minimizing waste production, including waste unsuitable for reprocessing and material or energy use of waste. Examples of actions in this area are listed as: waste-free or low-waste innovative production technologies. In addition, the list includes series of examples of innovative actions in the area of recovery, including recycling (Krajowe Inteligentne Specjalizacje).

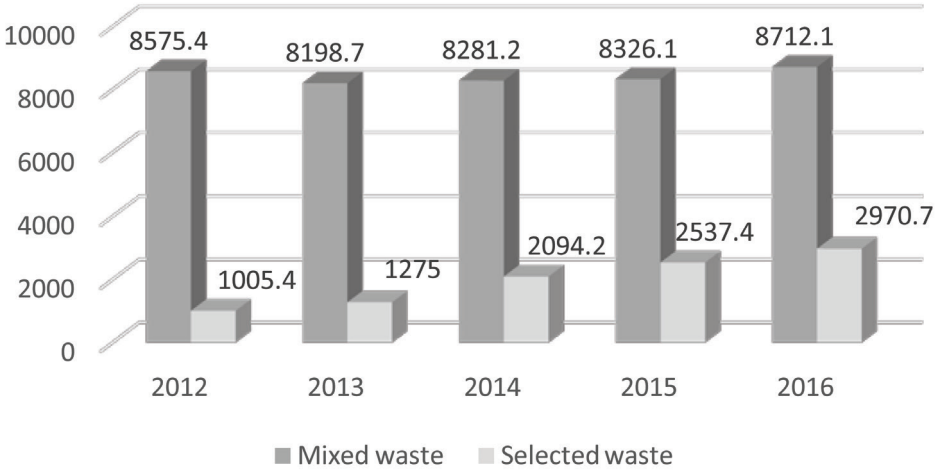
Regional support for innovation in waste management is based on Regional Operational Programs matched to individual voivodships, including Regional Smart Specialisations (RSS). These are grants covering Research and Development (R&D). Each voivodship has slightly different development directions due to its differential economic, competitive and innovative potential. In addition, there are different areas of implementation, patenting, and different scientific and technological specializations.

The sample list in the "Intelligent Specializations of the Malopolska Region" document, shows detailed description of the areas indicated in the Regional Innovation Strategy for Malopolskie Voivodship 2014-2020. From the extensive list of the various directions of application of smart specialization in the analysed region, see subsection 4.6. „Waste management". It includes inter alia: minimization of waste generation by methods, tools, processes and technologies; waste-free or low-waste innovative production technologies; analytical methods to reduce reagent consumption, waste production in industrial and environmental monitoring processes; innovative technologies to multiply materials; reuse the amount of industrial waste by selective acquisition of waste during production process; minimize the production of packaging waste by introducing innovative materials (Regulamin konkursu 2015). All of these examples of innovative initiatives, given in Reginal Innovation Strategy are agree with the National Smart Specialisations, but they are more accurate and suitable for regional needs.

CHANGES IN THE STRUCTURE AND AMOUNT OF MUNICIPAL WASTE IN POLAND

In the environmental policy and environmental management regulations, not only the protection of the environmental components from the negative impact of waste is crucial. It is also evident, that one of the efforts is to increase the participation of waste in recycling and recovery processes. The European Commission proposes in the year 2025 to prohibit the disposal of waste that could be recycled. One of the ways to reduce waste is a more efficient selective collection. It is significant for transforming the economy into a circular model. In Poland the municipal waste management system was changed in the period 2012-16. Now, the voivodship self-governments responsibility includes the adoption of Voivodship Waste Management Plans, according to the new division into waste man-

agement regions. A new hierarchy of waste management was also implemented. It includes: waste prevention, preparation for re-use, recycling, other recovery processes and disposal. Municipal waste management should take place within the region. Waste should be processed or disposed of, as close as possible to the place of production, in accordance with the principle of closeness. The property owners' duties include paying for waste management and, most importantly, correct waste segregation "at source". From 2013, when the amendment to the Act of 13 September 1996 on maintaining cleanliness and order in communes came into force in Poland, the structure and the amount of municipal waste has been changed.



Source: Own work based on data of CSO (2016)

Figure 2. Municipal waste (mixed and selected) in the period 2012-2016 in thousands of tonnes

As the figure 2 shows, the decrease in waste mixed in 2013 compared to 2012 was noted by 4.4%. In 2014-2015, the amount of mixed waste received was at a similar level. In 2016, there was an increase in mixed waste compared to 2015, by 4.6%. The implementation of the Act on maintaining cleanliness and order in communes changed the approach to selecting waste. In the analyzed period 2012-2016, there was an increase in the amount of municipal waste collected selectively in Poland. The year 2014 was the first full year of the amendment to the act on maintaining cleanliness and order in communes. That is why the largest increase in the amount of waste collected selectively was recorded in 2014 compared to 2013 – up to 60%. In 2015, compared to 2014, the growth of separately collected waste was 23%, and in 2016, compared to 2015, it reached 17%. The direction of change in this field seems to be beneficial.

Data of the year 2016 shows that more than 50% of mixed waste goes to storage (mixed waste goes to landfills after previous processing) and only 4% of separately collected waste. 16% of mixed waste and 5% of separately collected waste were thermally transformed. Only 15% of mixed waste is recycled, and 63% selectively collected waste. 13% of mixed waste is targeted for biological transformation and 28% waste collected selectively (CSO 2016).The tendency of growing the amount of municipal waste and the obligations proceedings toward them caused the significant role of selected and non-selected waste in waste management.

Due to National waste management plan, the forecast of municipal waste production in Poland – glass, metals and plastics, the amount of municipal waste will increase in years: 2020 and 2022.

Table 1. Forecast of municipal waste generation divided into fraction (years: 2020, 2022)

Specification	Forecast of municipal waste generation divided into fractions [in thousands of Mg]	
	2020	**2022**
Paper and cardboard	1889.4	1949.2
Glass	1412.7	1454.5
Metals	288.5	286.5
Plastics	1885.7	1973.3
Total	**5476.3**	**5663.5**

Source: Based on NWMP (2014)

From 1st July 2017 in Poland, new rules for segregation of municipal waste were applied. Now to four fractions (of paper, metal, plastics and glass) is added another one – biodegradable waste. Paper will be stored in blue containers, glass in green containers or bags (with the possibility of separation into clear glass – a white container will be used for it and a green container will be used for coloured glass). The yellow container is intended for metal and plastic waste, while the brown container will store biodegradable waste (Regulation 2017).

A key solution to the changes in waste management, especially in terms of management and reduction of the amount of waste stored is innovation. Thanks to innovative methods implemented in companies operating as recovery organizations as well as in companies producing waste, it is possible to reduce and reuse of waste and change it into another form and save resources. Processed waste can continue to be used as materials in the manufacturing process or energy recovery at the site of production, or used in other companies. Innovative

methods are very helpful for large-scale waste management for the local governments (connected especially with management of municipal waste).

EXAMPLES OF INNOVATIVE METHODS APPLIED IN ENTERPRISES OPERATING IN WASTE INDUSTRY

European Union's aim is limiting the quantity of waste, recycling of waste giving important and solid source of raw materials, energy recovery from non-recyclable materials and practical elimination of landfill waste. So, the waste recycling system should be designed in such a way that it does not store waste, as the guidelines for transformation into a circular economy (Komunikat Komisji 2014).

More and more enterprises dealing in waste industry are guided by the path of such waste management, which enables the sustainable use of rare natural resources. In traditional waste management (especially for municipal waste) the most popular is mechanical and biological system. However, this system does not meet all the expectations of waste management. Waste segregation is the first stage in waste management. It prepares the waste to composting. The natural composting is cheaper method, but the time of processing is longer. Composting process depends on putting the enriched organic matter on heaps of 1-2 meters, water sprinkling and holding for 3 months. Accelerated composting eliminates the disadvantages associated with time outside temperature and is more expensive. Composting technologies are considered as complementary to natural composting (Grzymała et al. 2011).

Innovative solutions are visible at the mechanical sorting stage of the waste. Modern optical separators are used for such operations. These devices select glass, plastic and other materials with a distinction of their individual colours of waste mass. This material is ready for recycling. Important in new system of waste management are waste-to energy installations. One of the opportunities of reuse of waste is the acquisition of alternative fuels – Refuse Derived Fuel (RDF). Alternative fuels are substitutes for conventional fossil fuels. The alternative fuels are fuels produced from high calorific waste, generated by households or industry. Due to their high calorific value, after appropriate transformation, it is possible to use them in thermal processes. The raw materials used for the production of alternative fuels are: plastics, wood, fabrics, paper, mineral fractions or composite materials. But fuel of this type is difficult to combine with other sources of fuels such as coal or biomass because of variable combustion temperatures or different volatile substances. It is important to improve the percolate fraction. It involves purifying and separating metals from it, removing metals and nonmetals from it precisely, clean, adequately disintegrate, as well as investigate and determine its parameters and fuel properties. The recipients of

the RDF fraction are mainly cement plants. Below there are a few examples of companies using innovative solutions and operate in waste industry.

One example of companies operating in the waste industry and using innovative methods is MIKI RECYKLING Ltd., based in Krakow. From 31 March, 2014, the company main status is regional municipal waste treatment facilities. The company deals with the processing of municipal and other waste for their purification and the production of alternative fuels. Since 2011 has been launched a specialized line for manual and mechanical sorting of waste within the R12 waste recovery process, processing mixed and selectively collected waste into alternative fuels. Fuel is received by the largest cement plants in Poland. The high calorific value (above 19 $MJ \cdot kg^{-1}$) and the low chlorine and sulfur content guarantee a continuous supply of valuable energy by the company (MIKI RECYKLING, online).

Another example of environmental investment in waste management has been implemented in Bioelektra Group Inc., a municipal waste processing company. It develops technologies for the full recovery of raw materials from waste and their reuse. The plant operating in Różanki in the Municipality of Susz processes 50 thousand tons of waste annually. Roto Steril Technology does not require separate waste collection, i.e. segregation at source. Waste is segregated by machines. Effective processing and recovery of municipal waste using the mentioned technology takes place through 5 stages: reception of waste (pre-fragmentation, transfer to feeder); sterilization in autoclaves – Roto STERIL BEG7000 (the process is carried out in autoclave, the empty autoclave chamber is filled with waste, followed by heat treatment, and afterwards sterilized waste is removed from the autoclave). The technology sets the standards of modern waste management and sustainable development; discharge of waste charge (stabilization of waste, equalization of temperature with ambient temperature and evaporation of moisture); separator work (the waste is directed to mechanical sorting, than the individual fractions are separated); transfer of fractions.

It is worth considering the technology used in separator work. Thanks to magnetic separators it is possible to separate ferrous and non-ferrous metals from the waste. In the mechanical-pneumatic screening system and eddy current pre-RDF fraction (Refused Derived Fuel) is separated. RDF fraction is also called the fuel or surplus fraction, which functions as an alternative fuel. It is important that the fuel has a proper calorific value so that it can be used energetically. The most technically demanding separation stage is the work of optical sorters and separation of plastic elements (with the isolation of PET and PP fractions) and very high quality glass in the form of pure cullet. The key element of technology is the separation of the biodegradable organic fraction, which is sterile, free of pollutants by other fractions and has high energy values. Bioelektra Recycling deals with the processing and recycling of plastics. The company's offer is petal and granules obtained by plastics processing. Plastics Recycling Plant in Nidzica

has a technological line with a capacity of 3 500 Mg per year. The company also purchases plastic PET (Bioelektra Group, online).

Another example of modern municipal waste management is NOVAGO Ltd. The mission and purpose of NOVAGO's activities is to be an effective and ecological solution to the problem of ever –increasing waste and to provide alternative sources of energy from renewable resources. The company is also the important producer of refuse derived fuel (RDF) from municipal waste. The production capacity of NOVAGO's plants is 300 thousand tons of RDF per year. Advanced and innovative installations operating in the company's 6 plants have allowed processing of 1 000 000 tons of waste in 2016 (NOVAGO, online).

One of the example of innovative methods in waste management is the Chemical Method called "KAMITEC". This method was invented in The KMITEC Ltd. It can be very useful for multi-material waste. It involved heating multilayer packaging waste or their sections in an organic solvent in which polyethylene dissolves, which results easy separation of aluminum and cardboard. After evaporation of the solvent, they are suitable for reprocessing in specialized plants for full-value products. The plastics are processed into fuels or primary material. Thanks to the development of a unique technology of rinsing polyethylene gluing the individual layers of packaging, it is possible to easily isolate the remaining components. Organic liquids used as solvents, unlike acetic acid or water have a very low heat of evaporation and specific heat. The consumption of heat and electricity is disproportionately low compared to other methods used. As a result of this method, it is possible to recover all the raw materials included in the multi-material waste – especially package, with high efficiency of about 99.9%. The remaining 0.1% are contaminants included in the recovered aluminum (KAMITEC, online).

Another method used to recover aluminum and other metals, when mechanical separation of their multi-material parts is difficult, is called RECLEN – Renewable Clean Energy. This technology is used, for example, by: Ezo Recycling, Recycling and Energy Inc. This technology is directed to municipal waste. The ultimate goal of it is to process waste for electricity and heat in high-efficiency cogeneration. The recycling process takes place without the release of pollutants into the environmental components. Sorting of municipal waste not use mechanical but chemical methods. Thanks to this method the raw materials of very high purity are recovered (RECLEN, online).

CONCLUSIONS

Enterprises operating in waste industry face many challenges that will require the implementation of eco-innovative solutions. Comparing Poland and other UE member countries, the level of eco-innovation is low. In 2016 Poland

has occupied the sixth place from the end with an index value of 72 – as the data of Eco-Innovation Index shown. Innovative solutions have been stimulated by the support from European Union. Examples of National Smart Specializations show the directions of innovation development, also for the waste industry. The Regional Smart Specializations show the advantageous solutions for each region. Waste management has been changed at the level of voivodships and communes due to new regulation implemented last years. Especially the structure of municipal waste is being changed in the period 2012-2016. The voivodship self-governments are responsible for the implementation of Voivodship Waste Management Plans, according to the new division into waste management regions. The very significant challenge for the enterprises working in waste management sector will be implementing the innovative methods due to EU requirements. These methods should allow to reduce energy consumption, saving the raw materials and reduces the emission of CO2 to the atmosphere. Examples of innovative methods are the "KAMITEC" or "RECLEN" discussed in the text.

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