# MUNICIPAL SOLID WASTE AND NON-HAZARDOUS WASTE PROCESSING FOR SUSTAINABLE CIRCULAR ECONOMY THROUGH BLOCKCHAIN

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## ABSTRACT

*The circular economy is a tool to achieve the criteria for sustainable development in the solid waste processing. In addition to the advantages, many disadvantages have been identified in the application of this measure. With regard to the recycling of raw materials, the main one is the lack of traceability of the product over several production life cycles. The assessment of the advantages and disadvantages should be done after a thorough analysis of the processing data. Therefore, according to the regulatory framework, a method for tracking material flows based on blockchain has been proposed. The object of the research is a plant for solid household waste in Sofia. The plant's raw materials are classified into four streams: landfill, sale products, combustion products as refuse-derived fuel (RDF), and recycling. Conceptual models based on Distributed Ledger Technology (DLT) have been proposed to track the main material flows from the plant. The choice of a specific application as a Blockchain platform will depend on the parameters of the communication scheme. The data stored in the blocks will be the starting point for the analysis and tracking of the full processing cycle.*

*Keywords: distributed ledger technology, blockchain, solid waste, recycling, circular economy.*

## INTRODUCTION

The existence of legal prerequisites for the creation of „environmental standards, regulation of human health and employment, safe industrial and commercial activities" are basic, but insufficient to achieve sustainability in modern society" [1]. Sustainability is consumption with care for future generations and progress in one area should not lead to regress in another [2]. That is why it is necessary for the contractors in the face of politicians, businessmen, non-governmental organizations, and manufacturers not only to create a regulatory framework but also to introduce new technologies and monitor their effects.

### Defining the problem

Social, technical, economic, environmental, and human resources are the main pillars of sustainability, and they are overlapped to varying degrees in modern industries. Often the implementation of measures in one area leads to improvement in another. For example, the introduction of digital technologies in agriculture is an economic and technical measure leading to a reduction in energy consumption, but at the same time bettering the ecology of the environment and the living conditions on the farm [3]. Introducing leisure activities, motivation of staff, Got It practices, etc. through the new technologies leads to improvement of working conditions [4, 5] and the result is a significant social and economic effect. In the last two years, due to the COVID crisis, working settings have deteriorated and in response, management and HR companies rely on qualified and stimulating online communication to help future workers and available staff adapts [6]. All these examples show that digitalization is leading to improvements in all areas of the economy.

Often, when environmentally meliorated conditions are required, the circular economy is used as a means to achieve sustainability, but there is no clear line between the two concepts. The reasons are different definitions of the term or names such as green growth, circular growth, and others. The result is many questions about the advantages and disadvantages of its application. To put it more clearly, the term refers to measures for the transfer of raw materials from the consumer, through recycling, back to the consumer in order to reduce costs, increase revenue and manage risk [7]. The result must be economic growth and increased resource efficiency [8]. In short, the measures can be classified into the following areas (scenarios) [9]:

- Preservation of the function of products or services;
- Preservation of the product itself or increase of its life of service through increased durability, reuse, recovery, renewal, and recovery;
- Preservation of the components of the product through reuse, restoration, and redirection of parts;
- Preservation of materials through recycling and downcycling;
- Saving embodied energy by recovering energy from incineration facilities and landfills;
- Measuring the linear economy as a reference scenario assessing the level of implementation of the circular economy, including reduced waste generation [9].

From the above-listed measures, it can be concluded that they are mainly related to the reduction of waste, as they have a negative impact on the environment. The type of measures applied depends on the type of waste. The most hazardous wastes are classified as emitted by the mining and pharmaceutical industries [10], and household waste, as the latter is a result of a diverse number of hazardous raw materials being used in everyday life [11].

Unfortunately, in practice, the pursuit of a circular economy as a means of achieving sustainable development by reducing waste and the consumption of natural raw materials does not always lead to a positive result. According to critics, green growth has „scattered boundaries, insufficiently clear theoretical grounds“ [7], and structural barriers to implementation must be linked to the question „Which is better?“ [12]. First of all, we must mention the impossibility of assessing the cycles of hazardous raw materials, which, when recycled, re-enter people‘s daily lives. Another example is the impossibility of producing clean green energy because the cultivation of biofuel from palm oil is associated with habitat disturbances of orangutans and leopards in Borneo. As well as the placement of photovoltaics on areas used to produce food for poor countries in violation of the principles of sustainable development [13].

These examples show that despite the current regulatory framework in support of the introduction of the Circular Economy as a tool for sustainability [14], further research is needed for the creation of conceptual models for the integrated effect not only on the environment as well also on the social, the technical and economic spheres, employment and others [7, 8]. The models for introducing circular production must clarify the impact of the main negatives, classified as the lack of:

- adequate assessment of the economic impact;
- possibilities for the application of new products or the disposal of hazardous waste during the conversion of the substance while it is being treated [7];
- real assessment of the life cycle of raw materials in circulation: consumer-processor-consumer;
- lack of adequate assessment of the impact of circular economy measures on sustainable development.

Despite all the criticism, it has been found that the introduction of the circular economy in many cases leads to a positive economic result - increasing GDP, reducing the harmful effects of processed material flows, abandoning long-term non-degradable products, replacing them with rapidly degradable [8], minimizing resource use and prevention of maximum waste through recycling and reuse [9, 15]. To achieve resilience in all spheres of society, scientists and businessmen are faced with the problem of developing successful models for using green growth. The aim is to restore and regenerate the environment by reducing the amount of waste and landfills, increasing the share of processed, while respecting the long-term value of products and materials, i.e. to be recycled repeatedly.

To counteract criticism of the limited conceptual framework and the lack of coherence of circular economy measures leading to sustainable development, the EU regulatory framework is constantly evolving. For example, the change from „Sustainable Growth: Supporting a greener and more competitive, resource-efficient economy" to the „Europe 2020 Strategy". To find the intersection of the circular economy with sustainable development, researchers propose solutions [12] based on the measures set out in the Europe 2020 Strategy and the OECD Green Growth Strategy [17]. One of the new proposals is the introduction of digital technologies for monitoring material flows to increase efficiency and assess the impact of recycling, which is the purpose of this article [12].

An example of the implementation of these priorities is the construction of waste recycling plants, but with opportunities for automated management and monitoring of the necessary indicators, the analysis of which will improve their efficiency. That is why the topic of the research is the development of a conceptual model to increase the traceability of the products from the plant for the processing of solid household waste. The analysis of the data would lead to the possibility to determine the economic, environmental, and social components of assessing the pace of processing [18]. The economic aspect embodies the green and circular economy through the percentage of investments in fixed assets to protect the environment from pollution with industrial and consumer waste. In order to comply with the principles of production without waste, an environmental component has been introduced, measured by percentages of generated waste from production and consumption. Compliance with the principles of responsible consumption is expressed through the social components, measured by the degree of utilization and disposal of waste [18]. All these components are measured through stages of assessment, diagnosis, and forecasting of changes in the integrated indicator, which allows for determining the system as stable or unstable. The implementation of this system requires a rigorous statistical report, without loss of data, which must be provided to the relevant regulatory or legal authorities in a timely and consistent manner. Data collection, sharing, evaluation, analysis, and forecasting, and their indicators clearly suggest the use of digital data-sharing technologies, such as the Blockchain platform as one of the Distributed ledger technology (DLT) platforms.

The aim of this study is the development of conceptual models for tracking recycled and deposited products from a solid waste processing plant to customers and government agencies through DLT.

**Research Methodology**

The object for the development of a conceptual model for tracking flows is an installation for solid waste recycling. Conceptual models for tracking material flows based on Blockchain technologies have been developed in accordance with the requirement for digitization of the regulatory framework to prove the applicability of the circular economy. As no platform is selected, the term DLT is summarized in the article. The choice of a specific platform, such as Blockchain or Hyperledger Fabric, will depend on the requirements of the communication scheme.

The authors believe that by implementing the data collection and sharing system among the responsible institutions there will be clear, accurate, unchanged data on the quantities of recycled, sold, deposited and recovered materials. The analysis of the recorded data will help to assess the efficiency of the plant, the logistics to customers, and the opportunities for introducing new technologies in changing the quality of the input product. This is necessary because the capacity of newly built recycling plants are growing more slowly than the amount and type of waste disposed of requiring increased recycling efficiency [19] and a change of the technological line. Another fact supporting the need for such a study is the observed "export" of second-hand products from Western to Eastern Europe. This places an additional burden on recycling companies and thus not only reduces their efficiency against various criteria of sustainable development [20] but sometimes the established technological lines are incompatible with the products received for processing.

The weakness of the study is the inability to assess the life cycle of products and opportunities to change technology because they are not included in the analysis. They will be the subject of further research based on the data obtained nowadays.

## EXPERIMENTAL

Experimental work on this problem is a long process, including data collection, development of a use case, prototype, and subsequent actual implementation on a particular DLT platform. To achieve the set goals, a conceptual model of communication based on the plant's technology is first presented.

**Technological scheme**

In the waste treatment plant under discussion - Sofia Waste Treatment Plant (OPTSTPO), domestic and industrial unharmful waste products are collected and after them, by-products, compost, and electricity are produced or they are landfilled. In the working areas of the Sofia waste treatment plant, there was built and put into operation a reception area, a landfill for non-hazardous waste depot „Sadinata“ and a Wastewater treatment plant (WWTP) on 21.12.2012. In January 2014, the Biological Treatment Plant at the “Khan Bogrov” site was put into operation. In September 2015 - the Plant for the mechanical-biological treatment with a production of RDF fuel started work. In the following comments and figures, the OPTSTPO will be briefly called Sadina, in the area where it is located.

The technological scheme is developed according to the requirements of the standard [21] and it includes the collection of biowaste delivered to the plant entrance by various companies and organizations with several stages of processing. At the production site, they are processed mechanically - cleaning and shredding, followed by anaerobic digestion and homogenization of the shredded materials in a buffer tank. The resulting substrate is sanitized by heating at a temperature of 70°C, and the resulting product is transported to a storage tank. The product of anaerobic digestion is biogas, which produces heat and electricity in a gas engineering system, combined heat and power unit (CHPU). The system for the production of electricity from biogas, as well as the processing of material flows, are discussed in detail by the authors in other publications [22].

**Output flows**

As a result of the activity of the OPTSTPO, material flows are created, which do not include the produced electricity, divided according to the type and purpose. According to the purpose, they are separated for landfills, products for sale, combustion products (RDF), and recycling, and they are visualized in Fig. 1.

According to the type, such as paper, plastic, metal, glass, etc., the materials are included in material flows with a positive price and they are sold cheaply or used for recycling. The others are the materials with a negative cost, which are not sought by the companies (polyethylene - clean bags, stretch film). Sofia Municipality pays for its utilization. The last part of the unusable products is deposited and these quantities are reported to the Ministry of Environment and Water (MoEW) and Sofia Municipality.

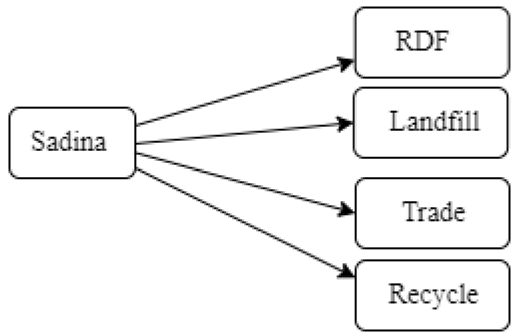


Fig. 1. Output flow scheme.

**Building a communication system**

For unmodifiable and secure tracking and sharing among the participants of the type and quantities of material flows, the construction of a Blockchain is suggested. All these flows for different types of materials cannot be shared through a single Blockchain channel, so structures must be created for each channel. Meanwhile, materials are separated, one part of which goes for disposal and the other for combustion depending on its characteristics. For now, it is impossible to trace the life cycle from the entrance of the plant to its exit of each type of material, because at the entrance the waste is mixed and in the process of processing the components are separated - paper, cardboard, glass, plastics, aluminum, ferrous metals, leather, and others.

The suggested scheme allows not only reporting on the activities of the plant, but also of all participants at the exit of the plant. In this case, they are the companies that buy compost or recycled materials. By implementing the proposed communication, trust will be achieved among the partners - traders, plant, and regulatory authorities.

In this case, the implementation of DLT is recommended because it provides visibility to all network participants’ communication in real-time synchronized, decentralized, and replicated with the ability to share and store identical data in all nodes using cryptographic algorithms [23]. Network participants record, modify and validate data through a private key and consensus mechanism [24]. Their read-only or read-write rights are negotiated through a smart contract that governs the behavior of the confidential channel.

Depending on the access and the rights of the participants, DLT can be public, private, or hybrid [25]. A private network applies to a number of participants who share confidential or non-interesting for others data with the rest of the network participants. In this case, neither confidential data nor company-specific data is shared, as it is in the municipal public reports, so the network may be public. In the event of a change in regulatory conditions or the appearance of a participant who must retain the data, the channel may be turned as private with limited access rights. Then the network will be transformed into a hybrid one. It is suggested that the materials be divided into flows according to their purpose.

## RESULTS AND DISCUSSION

### Materials for sale

In this group, there is an example with produced compost. The Biological Treatment Plant at the Khan Bogrov has produced a certain amount of compost, which has been distributed to citizens at the exit of the plant or sold through a transport company that has signed a contract with "Sadina". The produced and sold quantities of compost (as well as other materials) are also registered at the output of the plant and the data is shared as reports to the Municipality, a trading company, the National Revenue Agency (NRA), the Executive Environment Agency (EEA). The compost is sold to various companies through the transport company. At the exit of the plant, according to an order of the mayor of Sofia, every citizen who has paid his taxes is entitled to 10 kg free compost - Decision № 202 of the Sofia Municipal Council and Protocol No 80 of 23.04.2015. The mayor of Sofia Municipality has set an order with a definite day to distribute standard compost free of charge. These quantities are also recorded as a report.

In practice, the compost is used for fertilization, and the one the plant produced is divided into fractions up to 10 mm and 10 - 40 mm. The companies that buy it, usually after the purchase, report this deal as expenses to the NRA, and to the EAE at the MoEW.

All the quantities of compost and other materials produced are recorded. The diagram shows the flow of one compost fraction in two channels - sales and reports. Through a program interface (API) on the code implemented in the smart contract, the rights of the participants are determined - reading and answering or just reading. The quantities of material are measured by a digital device and recorded in the DLT core by an operator. The operator must be identified. The data entered in this way is verified and validated by a digital key. These are already real reports. The transport company communicates through application for data. To comply with the obligations of GDPR [26], the correct DLT (Blockchain, Hyperledger Fabric, Waltonchain, Iota, Ripple, Ethereum, and other) application must be selected, because there is a possibility of data leakage due to the use of a digital certificate by the operator [11].

Due to the development of the legislation, a scheme has been suggested in which traders have a communication node and can confirm the quantities received (they have the right to read and write data). Often these are companies that buy materials for recycling. According to the interface of the smart contract, only commercial companies can respond to the reports received with the plant, which confirm the type (in this case compost) and the amount of material received, leading to facilitated communication and trust among partners.

Through an interface (RO) and appropriate application for data to the regulatory authorities and the municipality node (according to the smart contract with read-only capabilities), reports about sold and produced quantities of compost from the enterprise are sent (Fig. 2). For other materials, it is contacted through other channels. These are ferrous and non-ferrous metals, paper and cardboard, hard plastics, soft plastics, tetra pack packaging, leather, glass, rubber, nylon, and more.

The processing plant also reports the sale of the quantities of other extracted materials in which companies are interested - plastic, metal, compost, paper, aluminum, iron, and glass to the Sofia Municipality, the EEA, and the NRA. In the process of operation of the plant over the years the interest in the types of materials changes. For example, recently we have witnessed an interest in tetra pack packaging and its collection and sale have begun. The same scheme can be applied to each of the listed or new materials.

An example design is illustrated in Fig. 3. The main interfaces are IReadOnly, which should be implemented by all classes needed for reading operations. Write interface should be implemented by all classes used for writing operations. A combined ReadWrite behavior

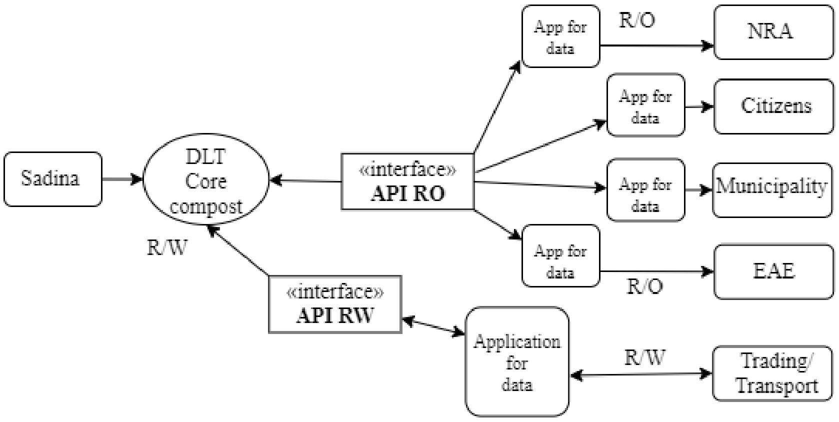


Fig. 2. Communication scheme for tracking sales materials.

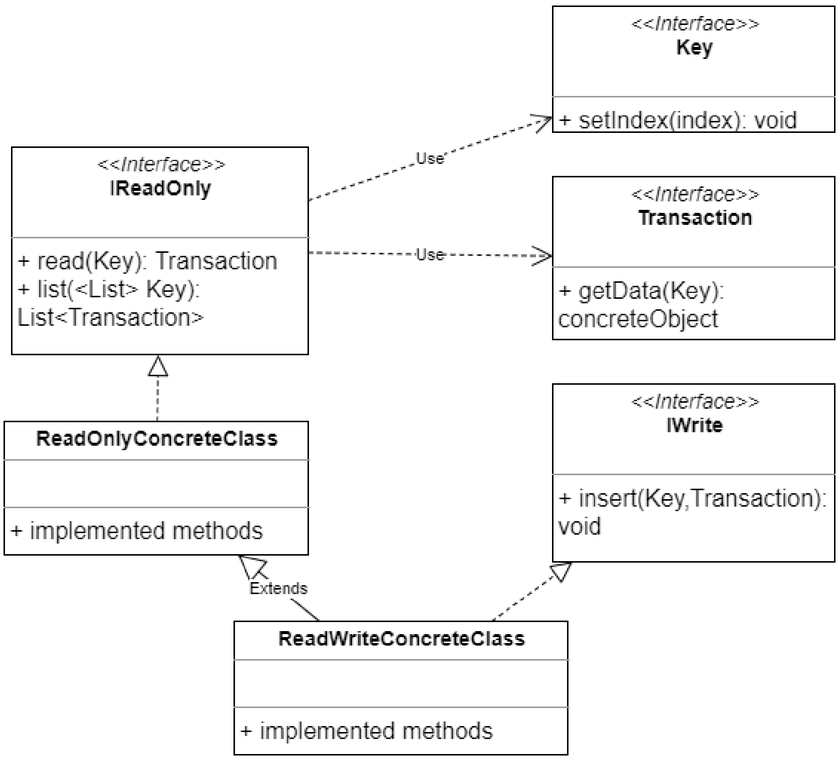


Fig. 3. Scheme of Interface communications.

is introduced by RearWriteConcreteClass extending ReadOnlyConcreteClass and implementing the IWrite interface.

**Materials for disposal**

These are materials that are not subject to recycling and recovery. The quantities and types of the deposited are reported to the MoEW and Sofia Municipality. There is a separate channel for each type of deposited material. These are large impurities separated from the total waste at the inlet, some components of ferrous metals, and PVC (no recycling plant).

The diagram visualizes the tracking of quantities of ferrous metals (Fig. 4). Another part of them is for sale. The processing plant records the data in its own node, which is replicated to the DLT nodes of the MoEW and the Municipality. According to the agreed smart contract under the obligations of the regulation, they have read-only rights. Reports are submitted with the quantities reported and measured by electronic scales. The operator enters, verifies, and validates the data in the DLT core after his identification with a digital signature. These actual reports are shared with the listed authorities.

**Combustion materials**

These are materials with a negative commercial cost. They are processed to refuse-derived fuel (RDF - waste fuel), which is part of the process of the production of electricity and heat according to the principles of sustainable development. It includes the diversion of ‚residual' waste from the landfill to its thermal recovery together with the emitted carbon emissions that together are used to generate electricity. In this case, along with municipal solid waste, large amounts of methane released from available municipal waste are also recovered [27]. This is an example of achieving a unified model in the circular economy and sustainable development according to the recommendations of achieving better levels of recycling [28].

The quantities of each type of combustion material go to RDF, which is part of the heat and electricity generation process and is internal to the plant, i.e. data is not shared with external companies and bodies and there is no need to make a scheme for the exit.

**Recyclable materials**

These are the quantities of materials sold for recycling. Their quantities and type are reported to the authorities similar to the scheme in Fig. 2. The difference is that it does not concern quantities to be provided free of charge to citizens.

## CONCLUSIONS

It has been established that the work of OPSTSTPO is in accordance with the criteria for the circular economy as a tool for achieving sustainable development. Therefore, the technology applied in the Sofia waste treatment plant-Sadina is an example of achieving a circular economy in line with the criteria for sustainable development. It has been proved that in order to achieve a better level of recovery and recycling of solid non-hazardous municipal waste, logistics of input and output

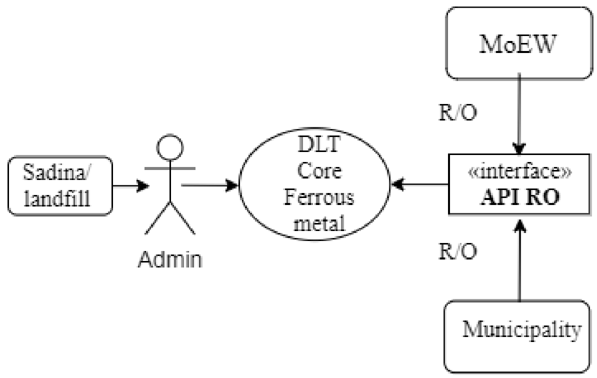


Fig. 4. Communication scheme for tracking materials for disposal.

flows, digitalization, and recording of data with the possibility of subsequent analysis are necessary. For this purpose, the output flows from the plant were studied.

Conceptual models for communication and data sharing based on DLT for the sold quantities and type of materials and compost, quantities and type of recyclable materials, for the quantities of deposited materials and RDF are suggested. The data shared through the proposed schemes can be used by the responsible authorities to analyze the pace and quality of processing in order to increase efficiency. In addition, the developed scheme for communication leads to trust, security among the partners, and long-term collection of non-modifiable, immutability, and traceability data. This is a real prerequisite for the possibility of long-term analysis.

The purpose of future work is to make a connection between the input and output quantities of materials in the plant and to offer a model for data sharing via some of the platforms of DLT as Blockchain, which must comply with the requirements of the GDPR. At the moment this is impossible because a large part of the waste arrives at the plant mixed, and its separation by types of solid waste takes place at different stages of the technological process. It is envisaged that in the future the materials will be divided at the entrance of the plant, which will be a prerequisite for the implementation of a complete scheme for reporting, monitoring, and analysis to achieve an efficient circular economy according to the criteria for sustainable development. Based on the acquired data, it will be possible to make an analysis for the introduction of additional technological lines for the processing of newly created materials, which is a trend in our time.

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## REFERENCES

1. J. Dernbach, J. Mintz, Environmental Laws and Sustainability: An Introduction, Sustainability, 3, 2011, 531-540, doi:10.3390/su3030531.
2. G. Brundtland, Report of the World Commission on Environment and Development: Our Common Future, WCED, 1987, p. 300.
3. N. Mihailov, B. Evstatiev, I. Stoyanov, Utilization of the animal heat production for reducing the energy expenses, International scientific student's conference Slovakia, Slovak University of Agriculture in Nitra, 2006, 208-214.
4. B. Galabova, B. Trifonova, Innovative practices in the management of a mining company, J. Min. and Geo. Sci., 61, 2018, 25-29.
5. V. Petrova, D. Kostova, V. Velev, Corporative social responsibility – factor for sustainable development, Annual of the University of Mining and Geology ,'St. Ivan Rilski", 55, 4, 2012, 21-27.
6. B. Galabova, B. Trifonova, V. Petrova, E. Dimov, Strategies for adapting human resource management policies in raw material enterprises in the covid-19 contex: theoretic and applied aspects, Annual of the University of Mining and Geology ,'St. Ivan Rilski", 64, 4, 2021, 1312-1820.
7. H. Corvellec, A. Stowell, N. Johansson, Critiques of the circular economy, J. Ind. Ecol., 2021, 1-12, doi:10.1111/jiec.13187.
8. E. Hysa, A. Kruja, N. Rehman, R. Laurenti, Circular Economy Innovation and Environmental Sustainability Impact on Economic Growth: An Integrated Model for Sustainable Development, Sustainability, 12, 2020, doi:10.3390/su12124831.
9. G. Moraga, S. Huysveld, F. Mathieux, G. Blengini, L. Alaerts, K. Acker, S. Meester, J. Dewulf, Circular economy indicators: What do they measure? Resources Conservation and Recycling, 146, 2019, 452-461, doi:10.1016/j.resconrec.2019.03.045.
10. A. Boteva, M. Parashkevova, B. Vladkova, Waste utilization by sulphide non-ferrous ores processing plants, Proceedings of the XII Balkan Mineral Processing Congress, Delphi, Greece, 2007, 599-603.
11. T. Hristova, N. Savov, S. Vambol, V. Vambol, DLT for sustainable material flows management in the processing of municipal solid waste and nonhazardous waste: example of Sofia (Bulgaria) municipality, Proceedings of the II International scientific-practical conference "Ecology. Environment. Energy-saving", Ukraine, 2021, 30-34.
12. A. Velenturf, P. Purnell, Principles for a Sustainable Circular Economy, Sustainable Production and Consumption, 27, 2021, 1437-1457, doi:10.1016/j.spc.2021.02.018.
13. A. Murray, K. Skene, K. Haynes, The circular economy: an interdisciplinary exploration of the concept and application in a global context, J. Bus. Ethics, 140, 2017, 369–380, doi:10.1007/s10551-015-2693-2.
14. European Commission, Closing the loop - An EU action plan for the Circular Economy COM/2015/0614 final, European Commission, Brussels, Belgium, 2015, p. 21.
15. W. Steffen, K. Richardson, J. Rockström, S. Cornell, I. Fetzer, E. Bennett, R. Biggs, S. Carpenter, W. Vries, C. Wit, C. Folke, D. Gerten, J. Heinke, G. Mace, L. Persson, V. Ramanathan, B. Reyers, S. Sörlin, P. Boundaries, Guiding Human Development on a Changing Planet, Science, 347, 2015, doi:10.1126/science.1259855.
16. European Commission, Europe 2020 Strategy, European Commission, 2020, p. 37.
17. OECD, OECD Annual Report, OECD Publishing, 2009, p. 130.
18. T. Khudyakova, E. Lyaskovskaya, Improving the Sustainability of Regional Development in the Context of Waste Management, Sustainability, 13, 4, 2021, doi: 10.3390/su13041755.
19. Z. Zhou, Y. Tang, J. Dong, Y. Chi, Ni M, Li N, Y. Zhang, Environmental performance evolution of municipal solid waste management by life cycle assessment in Hangzhou, China. J. Environ. Manag, 227, 2018, 23–33, doi: 10.1016/j.jenvman.2018.08.083.
20. B. Horvath, E. Mallinguh, C. Fogarassy, Designing Business Solutions for Plastic Waste Management to Enhance Circular Transitions in Kenya, Sustainability,

10, 5, 2018, doi: 10.3390/su10051664.

21. N. Mihailov, D. Antonova, I. Evstatiev, I. Stoyanov, N. Evstatieva, K. Martev, A. Manukova, D. Pavlov, O. Dinolov, E. Kumanova, S. Kadirova, R. Ivanov, Ts. Georgiev, Renewable energy sources and technologies, Ruse, Primax, 2012.
22. T. Hristova, N. Savov and P. Hristov, Investigation of the possibilities for application of DLT in the production of electricity from biogas, Proceedings of the 12th Electrical Engineering Faculty Conference (BulEF), Varna, Bulgaria, 2020, 1-5, doi: 10.1109/BulEF51036.2020.9326027.
23. H. Natarajan, S. Krause, H. Gradstein, Distributed Ledger Technology (DLT) and Blockchain, FinTech, 1, 2017.
24. S. Seibold, G. Samman, Consensus - immutable agreement for the internet of value, KPMG, 2016, p. 28.
25. European Commission, Procedure completed 2017/2772 (RSP), European Commission, 2017.
26. P. Hristov, W. Dimitrov, The blockchain as a backbone of GDPR compliant frameworks, 8th International Multidisciplinary Symposium Simpro, 20, 1, 2018, 305-310.
27. J. Powel, T. Townsend, J. Zimmerman, Estimates of solid waste disposal rates and reduction targets for landfill gas emissions, Nat. Clim. Chang., 6, 2016, 162–165.
28. European Commission, The role of waste-to-energy in the circular economy, Brussels, COM(2017) 34 final, 26.1.2017.