“Opportunities and barriers of the Ukrainian industry transition to the circular economy”

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OPPORTUNITIES AND BARRIERS OF THE UKRAINIAN INDUSTRY TRANSITION TO THE CIRCULAR ECONOMY

Abstract

The paper aims to highlight the status of the circular economy implementation in the EU and Ukraine, as well as to determine the advantages, challenges, opportunities and barriers to transition to circular supply chains. The main problems of waste management in Ukraine are explored, including faulty legislation, underinvestment, state policies and enlightenment regarding the circular economy, formal approach to the implementation of programs and strategies that should improve economic conditions, dominance of most waste-generative – extractive – industries in the economic structure of Ukraine. It is found out that the legislative framework for circular- and bio-economics in Ukraine does not meet the global challenges and requirements of the Association Agreement between Ukraine and the EU and needs urgent improvement measures. Studying the EU experience allowed describing the advantages and challenges of a circular economy that emerge in Ukraine. The article presents a mathematical model aimed at describing the peculiarities of a circular economy in the countries with low and high levels of industrial ecologization as well as understanding conditions for resource conservation during production processes. An econometrical model of the correlation between the solid waste generation, GDP and capital investment into environmental protection in Ukraine is used to demonstrate the absence of the latter's influence on the waste generation at the current technological level of the national industries. The research results allow developing recommendations for state policy for the industrial sector and environmental protection that may be implemented at the current stage to achieve Sustainable Development Goals 2030.

Keywords circular economy, industrial development, waste treatment and management, environment protection, public policy, European Union, Ukraine

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INTRODUCTION

Understanding that industrial development is one of the key factors for achieving prosperity and welfare has become universal relatively lately. And although there is no country in the world that has achieved a high level of economic and social development without industrial transformations, such transformations have kept pace with negative ecological repercussions and increased social inequality. Therefore, the UNIDO Lima Declaration dated December 2, 2013, entrenched the term of inclusive sustainable industrial development (ISID) and stressed the importance of taking all advantage of the industrial potential for the long-term and sustainable development of the humankind.

Modernizing the industrial sector in such a way that it allows shifting to a circular economy can be considered one of the main modern challenges, as it requires new business models, new economic ties and value chains. Industrial enterprises should leave the traditional model of an "effective use of resources" and aspire for increasing the longevity and reusability of materials, products and assets (Deineko & Tsyplitska, 2018).

The concept of a "circular economy" appeared as a response to increased consumption and the resulting accumulation of waste that is either environmentally harmful or hard to recycle in a reasonable time span. Circular economy represents such an economic model that associates itself with the "green development" and ensures the transition from the mass consumption to the responsible consumption. A closed cycle of resource (product) consumption lies in its foundations, decreased pressure on the environment. The circular mechanism also includes technical and biological cycles. Consumption occurs only in biological cycles, where food products and biological materials are adapted to returning to the system through natural processes. These cycles regenerate living systems that, in turn, provide renewable resources for economy. Technical cycles, on the other hand, renew and recreate products, components and materials through their repeated exploitation, repairs, regeneration or (in the worst-case scenario) recirculation (Valko, 2018). Reintroduction of materials and resources into the cycle is usually considered to be more energy-effective and, as per Ghisellini, Cialani, and Ulgiati (2016), results in less greenhouse gases than waste incineration. Aside from its ecological effect, a circular economy has an economic impact, that is, it creates new workplaces, spares resources and creates alternative energy sources.

The European Commission has already developed and adopted the Circular Economy Package – a bundle of legal initiatives, providing target values for waste recycling (Bourguignon, 2018). Some of the EU businesses are implementing successful projects on recycling and using solid waste in manufacturing.

Achieving the Sustainable Development Goals 8 "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all", 9 "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", and 12 "Ensure sustainable consumption and production patterns" calls for enacting the principles of circular economy into the state's business system.

1. LITERATURE REVIEW

The modern concept of circular economy is a synthesis of a number of scientific approaches and schools, including the sustainable development concept described in the Rio Declaration on Environment and Development (UNESCO, 1992), the functional economy concept of Stahel (1997), Frosch's (1992) concept of industrial ecology, Pauli's (2010) concept of blue economy, etc.

The history of circular economy, as well as a review of strategic documents, which set the priority of circular economy in the national development as well as the global status, were explored in "The road to circularity: Why a circular economy is becoming the new normal" (Justenhoven et al., 2019). Authors disclosed the perspectives for business sector and the steps to implement in public policy to achieve circular economy goals, in particular, prioritizing renewable inputs, increased duration of product utility, recovering by-products and waste.

OECD (2019) has analyzed circular economy in big cities and regions of several countries of the world and developed recommendations on future cities' and regional strategic priorities of circular economy development. Survey results from 34 European cities and regions showed high involvement (15 cities) in circular economy initiatives. The priority sectors of circular economy programs are waste (76% of cities), building (61%), land use (52%), food (52%), manufacturing industry (45%), water (42%), digitalization (54%) and sharing economy (50%). The authors also discussed indicators and tools for implementing a circular economy.

Wijkman and Skånberg (2016) explored Polish and Czech practices of implementing the circular economy principles in the national economic systems. They pointed at the progress in energy efficiency and resource efficiency of both economies, which was achieved thanks to the implementation of governmental policies that stimulate business to select sources and technology more effectively. That policy includes taxes, fiscal privileges, resource-efficient economy development programs, funding programs and programs aimed at supporting innovations in the field of energy and protection of the environment. Scientists also point

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out the positive influence a circular economy has on the employment, but they note that new skills and knowledge are necessary (Ministry of the Environment of Finland, 2019). At the same time, Wijkman and Skånberg (2016) note that modern governments are working on the "one problem at a time" principle instead of a system approach, thus focusing only on particular industries or economic sectors during a limited time period. Another side of policies fragmentation in the sphere of circular economy was explored by Preston, Lehne, and Wellesley (2019). The authors stood up for integrated implementation of the circular economy in each country. They considered the separate strategies or action plans on circular economy as ineffective, and that achievement of full economic inclusion into resource circulation required implementation of the whole ideology of circular economy in all spheres of life activity. They have pondered a number of global initiatives that must be implemented for a comprehensive adoption of circular economy by the developed industrial countries.

Annually, the World Economic Forum develops and substantiates measures of state economic policies and corporate governance to accelerate the circular economy development. Among the prepared reports and documents, the following should be mentioned: "Building circularity into economies through sustainable procurement" by UNEP (2018), "The circularity gap 2019" by Circle Economy (2019), "Circular Value Creation: Lessons from the Capital Equipment Coalition" by PACE (2019), etc.

The report of Finnish Environment Institute (Berg et al., 2018) discussed the necessity of chemical information accompanying the product during its lifecycle, the link between poverty reduction and circular economy, and the importance of relevant government actions in both developing and developed countries. They argue that to achieve the Sustainable Development Goals, the resources circulation must be provided.

Hedberg et al. (2019) consider possible measures to implement digital solutions for developing a circular economy. To date, a significant array of applications has been created to measure a company's own ecological footprint, to transfer surplus foodstuffs to restaurants and cafes for charity purposes, to monitor the environment during transportation, etc. However, the spread of sustainable thinking faces a number of obstacles, including the lack of information on waste and the possibilities for its recycling, acquisition and use, lack of incentives for industrial companies to use recycled materials, illegal incineration of waste, etc. To create an effective roadmap for the digital circular economy, the authors have developed four key recommendations for EU institutions that may be of use to Ukraine as well:

- to define a vision and take coherent actions;
- to use governance, policies and regulation to provide a framework for action;
- to use economic instruments to incentivize and enable the transition;
- to strengthen partnerships and empower citizens for better results.

Thus, modern sources on circular economy mainly consider its conceptual provisions, methodological aspects of indicators monitoring and successful practices of foreign countries. However, little work is devoted to the study of the possibilities of implementing these practices in individual countries, as well as the role of the state in these processes.

In Ukraine, as in the rest of the world, introducing circular economy begins with the methodological basis for monitoring its processes. In this context, Zvarych (2017) examines the existing indicator systems proposed by foreign scholars for the economy as a whole and its various sectors; Galushkina et al. (2017) stress the need for statistical reform in implementing the appropriate indicators to reflect the progress towards sustainable development goals and green economy modernization.

Ukraine has already started to implement the strategic priorities of the green economy, including the circular economy. The key drivers of this process were the signing of the Association Agreement with the EU in 2014, the approval of the global Agenda 2030, the implementation of

the 17 SDG at the national level, the ratification of the Paris Climate Agreement 2015, and the accession to the Green Industry Platform UNIDO. The provisions of these documents were implemented by the Cabinet of Ministers of Ukraine (2017) in the National Strategy on Waste Management in Ukraine until 2030 and the National Plan on Waste Management until 2030 (Cabinet of Ministers of Ukraine, 2019). However, the issue of circular economy is reflected in strategic documents rather superficially. They envisage general measures for developing waste management infrastructure; creating an information system that includes data on the volume of waste generation and waste management operations; developing regional waste management plans; creating conditions for the transition to a new waste classification in accordance with the European one; adopting laws and by-laws establishing requirements, procedures and rules, and a central executive authority for waste management, technical regulations and standards.

In 2019, Ukraine has not yet adopted the relevant laws on waste management (a framework law), on small batteries, batteries and accumulators, on the waste of electrical and electronic equipment, on the waste of oil products, on burial of waste, on mining waste management, on decommissioned vehicles etc., which are expected to comply with EU directives. Also, the existing regional environmental programs provide for the construction of new landfills, contrary to the principles of the circular economy (it is clear that these measures are not sufficient for fundamental changes in the economy).

Another systemic shortcoming is the lack of a focus on the formation of the institute of environmental reputation of enterprises and environmental assessment of the regulatory impact of regional regulatory acts.

It can be stated that Ukraine is moving rather slowly towards a resource-efficient economy. Therefore, the purpose of this study is to identify opportunities and obstacles to the implementation of the circular economy principles in Ukraine and to develop recommendations for the governmental environmental and economic policies to facilitate its development.

2. HYPOTHESIS

The hypothesis of the research is that the technological level of environmental protection is not sufficiently advanced in Ukraine to substantially impact the circular economy development and that the role of the state in the introduction of the circular economy principles into the economic practices is really crucial.

3. RESEARCH METHODOLOGY

The study will analyze the state of waste management in the EU and Ukraine using statistical and graphical methods and present comparative characteristics of waste management methods.

Druzhynin (2009) developed a balance equation of resources, production volumes and waste, defining the conditions under which the balance would meet the principles of circular economy.

To display the opportunities and obstacles for the introduction of circular economy and the peculiarities of environmental and economic processes in the Ukrainian economy, the econometric modeling method will be used, which will help to identify the relationships and dependencies between environmental and economic indicators. Reuse or recycling of solid waste is one of the issues that circular economy solves, so it is important to study its dynamics and relationship with the rate of production.

Druzhynin (2009) considered resource saving impact modeling using a combined environmental-economic approach. Following their logic, the main condition for the introduction of a circular economy in the field of solid waste is the introduction of new technologies, changes in production and business model of an enterprise, part of the input materials and/or energy resources of which are replaced by solid waste and products of its processing. Capital investment is a key indicator of technological change that includes equipment, technological infrastructure and environmental construction costs. This includes the costs of construction of new facilities, expansion, reconstruction, restoration, technical re-equipment of existing enterprises and facilities, overhaul and purchase of environmental equipment for long-term use.

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Using the abovementioned approach, it is assumed that there is a non-linear relationship between the volumes of solid waste (SW), the gross domestic product (GDP) that contributes to the production of this waste, and the capital investments in solid waste management (CI). This allows estimating compensation elasticity. To transform and represent it in a linear form of the model, the study will use the growth rates of each variable (Δ), whereby the following model is obtained:

$$\Delta SW(t) = A(t) + \alpha \cdot \Delta GDP(t) - \\ -\beta \cdot \Delta CI(t) + \varepsilon(t), \quad (1)$$

where A, α, β are constants, $\alpha \geq 0, \beta \geq 0$, ε is the residual, and t is a time period (year).

At the same time, α and β are the elasticity coefficients. Constant A represents the extent of ecological progress. The dependency of ΔSW on ΔGDP is direct, and the dependency of ΔSW on ΔCI is the inverse, as modern technological progress provides less industrial pollution and waste.

The model will show the effectiveness of capital investment in solid waste management and the impact of production growth on waste generation.

The annual data of The World Bank and the State Statistics Service of Ukraine for 2006–2018 are used to build the model. GDP is taken in constant prices in US dollars. Solid waste (SW) is presented in thousands of tons and includes both industrial and consumer waste. Capital investment in solid waste management has been brought to constant prices by adjusting the price index of industrial producers. According to the 2006–2018 data, the growth rate of each indicator was calculated and included in model (1). As time series derivatives were used, it was reduced to 12 years (2007–2018).

Based on the results of the modeling and analysis of statistical data and EU experience, the development vectors of the state economic policy and the directions for creating a new corporate culture will be identified. This will contribute to the targeted and consistent implementation of the circular economy principles.

4. RESULTS AND DISCUSSIONS

4.1. Waste management status in Ukraine

Ukrainian economy functions largely within the framework of a linear economic model. Only a small part of the waste is reused, recycled or disposed of. The vast majority of waste, including valuable and limited resources, are disposed of in landfills or incinerated. According to the State Statistics Service of Ukraine (2019), in 2018, waste disposal sites accumulated 12.9 billion tons of waste, which is 22.5 thousand tons per 1 square meter of the country's territory or 306.9 tons per person, which is 6.1% higher than in 2010.

Statistics show that the extractive industry is the largest pollutant (Figure 1).

The dynamics of the extractive industry and general waste indicators in Figure 1 point to a wave-like nature of waste generation, but not fully associated with changes in production in the country. Waste generation growth has been observed in 2004–2007, 2010–2013 and 2017.

In Ukraine, waste management mainly includes recycling, incineration and disposal to designated sites or facilities. According to the statistical data, 1/7 of the whole territory of the country is covered with garbage, and only 4% of garbage is recycled; most of it is disposed into specially designated places (about 70%), a significant part of it is recycled (about 30%) and a small part (< 0.3%) is burned. As of 2017, Ukraine accumulated 12.4 billion tons of waste, including 0.37 billion tons in 2017. And in the structure of waste in 2017, the largest share is still occupied by coal preparation waste and waste generated during demolition works for the construction of mines, open-pit mines, coal mining, sludge and tailings of iron ore preparation, waste of iron ore mining, nickel and limestone mining, scrap (State Statistics Service of Ukraine, 2019). Regarding the partial disposal of this waste, there has been an increase in the reuse of blast furnaces, steelmaking and ferroalloy slags, but the problem remains acute (Gahovych, 2012).

Source: State Statistics Service of Ukraine (2019).

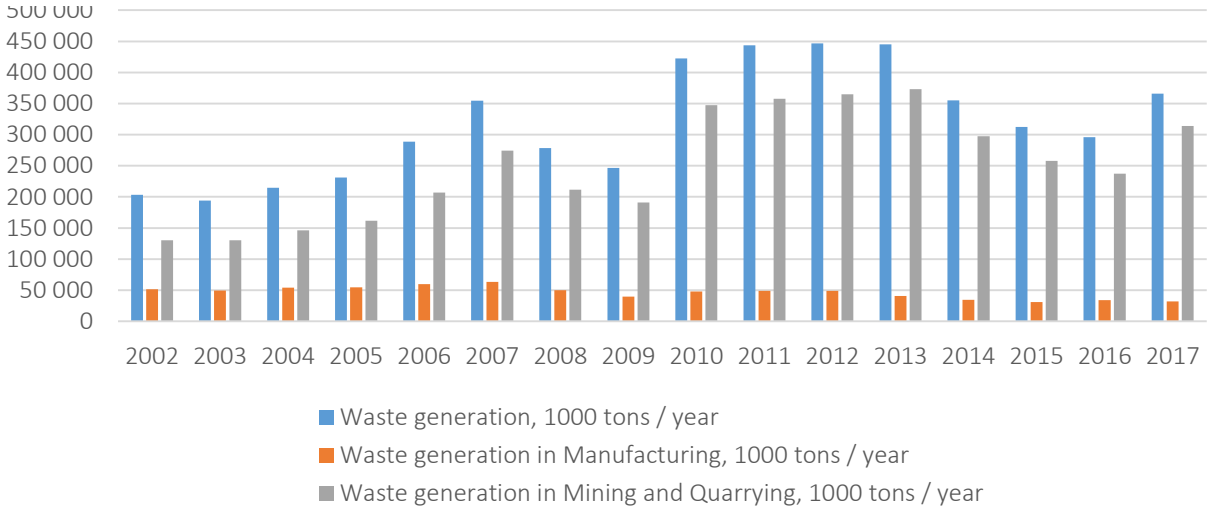

Figure 1. The waste generation in the Ukrainian economy, 2002–2017

At the time of the research, the only waste processing plant in the country has ceased to operate, as had the four incineration plants, of which only the Kyiv-based Energy plant operated until August of 2018. It has been processing up to 25% of the municipal solid waste in Kyiv, all the while creating heat energy for dwellings. During 2017–2018, a number of foreign investors expressed their desire to build new waste processing plants in Ukrainian cities. However, the stumbling block is the Ukrainian legislation that has many gaps, in particular, as Mischenko, Omelianenko, and Makovetska (2013) note, in terms of setting tariffs that determine the profitability of production and the rate of return on investment. Despite the adoption of the Law of Ukraine "On Waste" in 1998, which started a new stage of formation of the waste management system and took into account modern global developments, it was a subject to annual changes and additions, and as of 2018, several new alternative draft laws were registered.

However, national legislation is still unable to fully stimulate the reduction of waste generation, as well as household waste sorting, which is one of the most important factors in ensuring the functioning of waste processing plants, not to mention its inability to stimulate the modernization of equipment to reduce the harmful impact on the environment, etc.

4.2. Balancing the circular economy: conditions for different economies

Modeling the balance of resources and production results allows establishing the basic conditions for waste management in the context of the circular economy.

Circular economy sets new conditions for the balance of resources and production. One can assume that the model of material flows in a region's or country's eco-industrial system provides a balance between the resources used directly for production and consumption and the products and by-products of production that include industrial pollution, as well as waste from consumption.

$$R_n = Q + W_{nr} - W_r, \quad (2)$$

$$W_r = w_c - w_u, \quad (3)$$

$$\text{thus, } R_n + w_c = Q + W_{nr} + w_u, \quad (4)$$

where R_n denotes natural resources used in production or directly consumed (as recreational resources, for household livelihoods, etc.); Q is the product output; W_{nr} – waste non-recyclable – production and consumption waste, with this level of technology not recycled and reused; W_r – waste recyclable – production and consumption waste that,

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with the current level of technology, can be recycled and reused; w_c – waste circulated – waste that is already circulating through the value chain as a substitute for input R_n, and w_u – waste uncirculated – potentially reusable waste (with or without industrial recycling), that is, at the level of available technology, production processes and costs, is not included into the value chains.

Based on equations (3) and (4), minimization of residual waste can be achieved under two main conditions:

1) $(W_{nr} - W_r) \to \min$, so $W_{nr} \to \min$ or $W_r \to \max$, then $(w_c - w_u) \to \max$, and $w_c \to \max$ or $w_u \to \min$;

2) $(R_n - Q) \to \min$, then $R_n \to \min$ or $Q \to \max$.

The first condition describes the situation of countries with insignificant level of production ecologization, including Ukraine. Under the second condition, the achieved production capacity increases only if the same level of resource consumption is maintained, or the same production volumes are achieved for less resource consumption. This situation is typical for the developed countries that introduce new technologies and pursue the policy of "greening" the economy. In other words, the eco-industrial system in the circular economy should be based on optimizing the use of natural resources, as well as on the self-recovering and self-regulating functions of the ecosystem.

4.3. The European Union experience: advantages and challenges of circular economy

In the European Union, circular economy has been declared one of the priorities of the industrial development strategy. For this purpose, Eurostat (2019) introduced a number of indicators to monitor the volume of recycled materials, whose share increased from an average of 9.3% to 11.7% in the EU from 2007 to 2016. The leaders in the reuse of resources are the Netherlands (29%), France (19.5%), Belgium (18.9%), the UK (17.2%), and Italy (17.1%). On the other hand, Luxembourg and Finland show a significant reduction in the reuse of materials in line with 24.1% (2010) to 6.5% (2016) and from 13.5% (2010) to 5.3% (2016), respectively. Metals (25.2%), non-metallic minerals (15.2%), biomass (9.1%) and fossil energy materials (2.5%) are the materials that have traditionally the highest proportion of reuse.

The EU is already actively implementing the ten principles of the 10R circular economy defined in 2018 by the World Economic Forum: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover.

Some European companies have already been able to successfully "embed" these principles in the modernization of industrial production, while ensuring a level of profitability guarantees a timely return on investment and further growth of the business. They partially refuse to use products made of materials that are difficult to process, or apply the trade-in system – the exchange of goods that have already been in use for new ones. Nguyen, Stuchtey, and Zils (2014) analyzed the activities of a global apparel retailer, H&M, who abandoned the use of plastic packaging for consumers and launched a program to collect old customer clothes in exchange for discounts on new clothes. The resulting clothes are sent through a partner company for further processing and use in the form of a "cascade" process until it is completely worn out as a material. The Renault factory in Choisy-le-Roi is reconstructing car engines, transmissions, pumps and other components for resale. The plant's regeneration operations use 80% and 90% less energy and water respectively than the new production facilities, with an operating profit higher than the corporation as a whole.

Sweden uses waste-to-energy technology, 99% of garbage in the country is used as fuel for power plants or as raw material for production. At the same time, the country imports garbage from Norway, Great Britain, Germany, who pay it to make use of their waste. Austria has turned the waste incineration plant into a thermal power plant for the production of thermal energy and disposes 265 thousand tons of waste per year in such a way. Belgium has introduced the Ecolizer innovation, which allows estimating the volume of waste from production, its impact on the environment and the cost of transportation and disposal. More than 100 waste processing plants have been built in Poland. Waste is used to produce

Source: Eurostat (2019), State Statistics Service of Ukraine (2019).

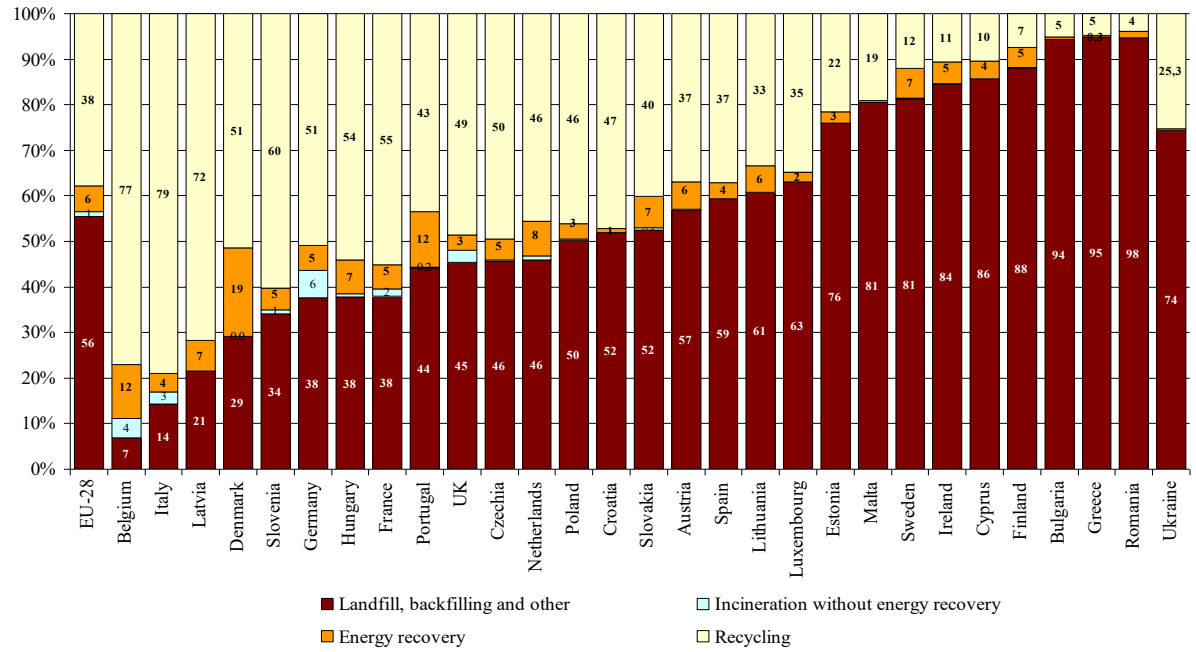

Figure 2. Waste treatment in EU-28 and in Ukraine, 2016

alternative fuels and recycled raw materials (plastic, metal, aluminum). In the Netherlands, the introduction of the circular economy principles has become the leading strategy for sustainable development: 7 billion Euros are saved annually and about 54,000 jobs are being created (Kocheshkova & Trushkina, 2017).

The situation in waste management in the EU-28 in 2016 shows that most countries, especially those with higher GDP per capita, are expanding recycling programs and projects, but the share of landfill and dumping remains high (Figure 2). In comparison, Ukraine was included in the analysis, where 74% of waste is used unproductively (dumped or buried).

The experience of the EU countries has clearly demonstrated both the positive effects of the circular economy and its challenges (Figure 3).

Source: Authors.

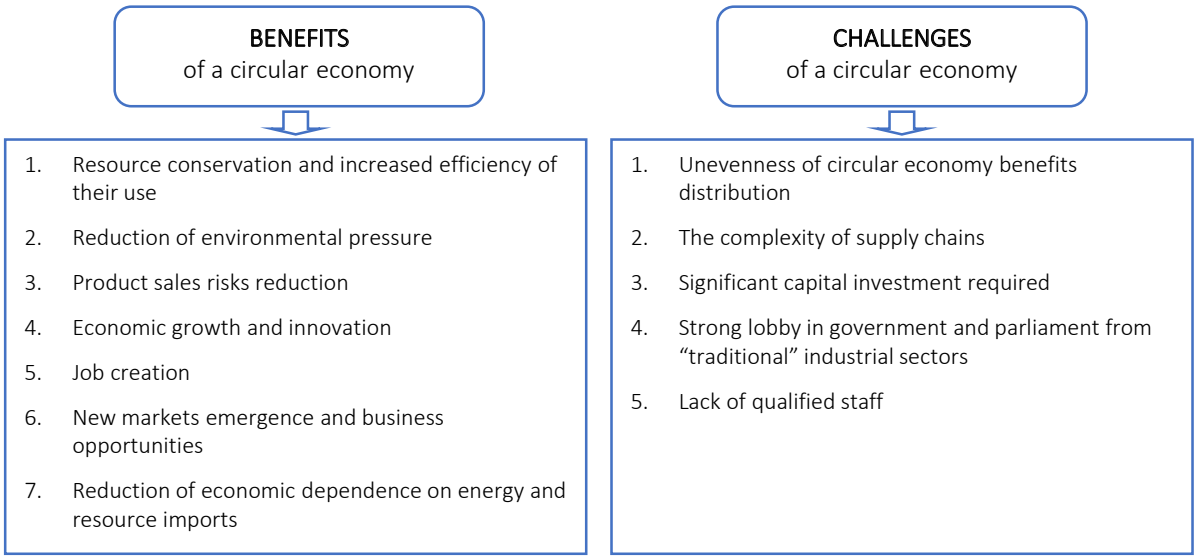

Figure 3. Benefits and challenges of circular economy for Ukraine

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This is convincing evidence in favor of:

1. Resource advantages: improved security of resource potential and reduced dependence on imports. Innovative resource efficiency technologies across all value chains can reduce the use of processed and raw materials in the EU by 24% by 2030, with annual primary resource savings estimated at EUR 600 million for the EU-27 (excluding Croatia);

2. Environmental benefits: activities related to the implementation of efficient waste management policies will have a positive impact on the reduction of greenhouse gas emissions by 424-627 million tones of CO2 equivalent over the period 2015–2035;

3. Economic benefits related to economic growth and innovation opportunities. Circular economy can become a platform for innovative approaches, such as technologies and business models that create greater economic value with less use of natural resources. Significant cost reductions will be achieved in several sectors of the economy – production of complex durable goods (estimated at EUR 340-640 billion annually in the EU alone), food, beverages, textiles and packaging (estimated at USD 700 billion per year, which represents 20% of the material costs in these sectors every year) (European Environment Agency, 2016).

4. The social benefits of stable consumer behavior and increased jobs. Social innovation relates to the sharing economy, eco-design, reuse and recycling, and other developments resulting in more predictable consumer behavior and better health and safety. The European Environment Agency (European Commission, 2016) estimates that improved waste legislation and simplification, better monitoring and implementation of best practices to ensure increased recycling and reduced waste disposal will lead to an increase in new jobs to 178,000 by 2030.

5. Future benefits. Receiving revenue from a particular asset after it has been repaired or rebuilt triggers new business models and deepens customer relationships.

At the same time, the benefits from the introduction of circular economy will not be evenly distributed among all of the economy sectors. There will be businesses, regions or social groups that will incur losses, while others will make profits. Examples include jobs in the extractive industries, which will decrease, and enterprise that produce cheap consumer goods. Effective accrual of benefits from the circular economy is also dependent on how fast may the skills and education required for may be achieved, as well as on their quality, as it is important to ensure the supply of skilled workers to the modernized industries. In addition, modernization of production facilities requires changes in business processes, establishment of new relations and possibly breaking old ones.

4.4. Constructing a regression model: Are capital investments sufficient to protect environment in Ukraine?

European practices show a link between increased production, waste and efforts, including investment, to reduce waste. It is essential to consider the situation in Ukraine and analyze this relationship by building a regression model.

The data used for the econometric modeling to reveal the relationship among the volumes of solid waste generation, GDP and capital investment in environment protection in Ukraine is presented in Table 1.

Table 1. Data for the regression analysis

Source: Own calculations based on the State Statistics Service of Ukraine (2019) and the World Bank (2019) data.

Year	Growth rates of solid waste, %	GDP growth rates, %	Growth rates of investment in environmental protection, %
2007	22.84	7.59	–4.28
2008	–21.55	2.30	–19.64
2009	–11.45	–14.76	–11.19
2010	71.50	3.83	–1.66
2011	5.03	5.47	109.19
2012	0.66	0.24	–40.49
2013	–0.33	–0.03	–2.19
2014	–20.27	–6.55	–6.22
2015	–12.04	–9.77	–30.83
2016	–5.25	2.44	148.53
2017	23.72	2.47	–11.49
2018	–3.75	3.34	–59.25

Table 2. Descriptive statistics and regression results

Source: Own calculations.

Variables	Value	S.D.	*t*-statistics	*P*-value	Significance (α = 0.05)
Intercept	4.951	7.179	0.690	0.508	Insignificant
ΔGDP(t)	1.958	1.160	1.687	0.126	Insignificant
ΔCI(t)	–0.051	0.127	–0.399	0.700	Insignificant

Indicators	Value
Multiple R	0.4904
R^2	0.2405
Observations	12
F (α=0.05)	1.425
Significance F	0.29

Table 1 shows that changes in presented indicators are highly volatile in their nature that can a negative impact on the model quality. Applying the data to the econometric equation (1), the following results can be obtained (see Table 2).

Therefore, the model can be presented and described as follows:

$$\Delta \hat{SW}(t) = 4.951 + 1.958 \cdot \Delta GDP(t) - \\ -0.051 \cdot \Delta CI(t). \quad (5)$$

The resulting model demonstrated the inadequacy at the 5%-level and, at the same time, the insignificance of coefficients. However, the independent variables explain 24% of variation of growth rates of solid waste. The coefficient signs really justify the direct and inverse relationships of the two variables. The elasticity of solid waste volumes stipulates the growth in *SW* by 1.958% in response to a 1% change in *GDP*. But the elasticity effect of capital investment in solid waste management is quite weak, namely, the 1% growth in capital investment causes only 0.051% decrease in volumes of solid waste. Therefore, to compensate for the negative impact of production growth, the amount of capital investment must be huge, which is impossible in view of their unproductive nature.

Thus, the model output justifies the hypothesis that the technological level of environmental protection in Ukraine is not advanced enough to have a significant impact on the circular economy development. Also, one can assume that factor elasticity tends to decrease over time: modernized technologies have lesser impact in comparison with previous ones. The replacement of recycling systems with more advanced systems results in fewer effects than their first installation; the restrictions on environmental impacts become more severe but changes are getting smaller.

4.5. Policy recommendations

To take advantage of the benefits of the circular economy and achieve results in waste management, Ukraine should accelerate the implementation of solutions that are already successfully implemented in the flagship countries. Particularly, they can be used in the context of the following areas:

1. The government's structural policies aimed at reducing the extractive industry and increasing the services sector will enable the circular economy to become an important source of economic growth. According to the UNEP study (2015), economies with a growing share of services importing industrial goods can increase their material productivity based on domestic consumption of materials due to changes in their economic structure. According to the World Bank (2019), the share of industry in Ukraine's GDP decreased by 31.2% from 1991 to 2018, reaching 23.3%; and the share of services in GDP increased from 28.8% to 51.3%, i.e. by 22.5% over the same period. Thus, Ukraine can take advantage of the circular economy to accelerate economic growth.

2. Public procurement is a tool that will create new prerequisites for the formation of a closed-loop economy. Thus, in the EU countries public procurement accounts for 14% of GDP, in OECD countries 20% of GDP, and in Ukraine it amounts to about 13% of GDP. Consumers of goods within the framework of

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public procurement can make a choice in favor of eco-commodities or goods that use recycled materials. There are many models for this: buy-sell back, buy-resell and service instead of purchase (when the use of goods is executed in a leasing transaction). The introduction of such procurement requires the creation of a new business model of public-private relations, as well as the development of sharing economy. It is desirable to establish a recommendation percentage of such purchases in the legislation. The implementation of such a project will contribute to the achievement of the 2030 Sustainable Development Goals, in particular Goal 12 – Responsible consumption and production.

3. Encouragement of capital domestic and foreign business investment and public investment in innovative developments related to new technological solutions for the circular economy.

4. Propaganda of culture of circular economy, which should create a new outlook on consumption and production for people of any age: starting from reduction of quantity of materials used at product delivery to the consumer (less packaging, its manufacture from materials that can be processed, etc.), finishing designing of products whose life cycle is much longer and which are easier to maintain, repair, etc.

5. Implementation of the relevant employment policies, based on the training of specialists with new competences in the field of circular economy, namely, knowledge on the environmental impact of products on the environment and people, technologies of their processing, skills of finding the best solutions in the organization of production, sale and consumption of products to reduce waste, etc.

6. Implementation of the "from waste to resources" ideology by the government, which provides for the development of markets for secondary raw materials and the reuse of water, in particular, the promotion of construction of waste treatment and disposal facilities, the introduction of stricter requirements for businesses to purify water and air from harmful substances, etc.

7. At the state level, adoption and implementation of a system of indicators from the circular economy in official statistics to monitor the relevant processes of production and consumption of products.

8. To impose appropriate restrictions on the import of products made of materials that cannot be disposed of or that are long and expensive to dispose of.

9. Development of infrastructure for the circular economy, from the means for sorting household waste to manufacturers of composting machines, construction of sorting stations and plants, recycling factories, etc.

10. Establishment of a mandatory assessment of the environmental impact of regulatory and legislative acts at the regional level, which will allow identifying systemic distortions in regional economic policies that prevent the circular economy introduction.

CONCLUSION

Nowadays, Ukraine faces serious barriers to its transition to a circular economy. These are classical reasons for the slowdown in the country's innovative development, such as the domination of raw material in exports, high levels of corruption, decrease in investment, etc. Also, these are additional socio-cultural and economic obstacles, such as state support for the extractive sector, low confidence in the government, poor awareness of the environmental degradation consequences, as well as inability to negotiate and work together for a long period of time. Among the microeconomic reasons one can emphasize the business' desire to attain quick profits without a thought about long-term negative effects and investment in circular economy projects with low profitability.

European experience in introducing circular economy sets new trends for the design of strategic priorities for national development. The practice of European countries allows assessing potential changes in the economies where the development of circular economy becomes one of the priority tasks, i.e.:

1. the state as the main driver of "green" development should change the structure of public procurement and be guided by ecologically expedient types of production;

2. legislative and executive authorities should develop regulatory support for the circular economy operation, using the experience of European countries with similar legal and institutional systems;

3. business entities should envisage changes in market conditions and global trends, modernizing their production and investing in processing;

4. the formation of new business models will take place, from simple, related to the replacement of some components by others, raw materials and materials, to complex, providing for the formation of new links in the production process within the enterprise and the full or partial change of the technological process;

5. the structure of demand for labor will need new specialists in production design; and

6. financial and credit institutions should be established and/or programs should be developed to finance projects on recycling or other types of waste disposal.

The introduction of circular economy should be based on basic market laws – in the absence of demand for recycled waste and products, it loses its economic viability. Therefore, to justify investment, it is necessary to stimulate market demand and create new value chains within the country. This will inevitably lead to the extinction of certain activities and enterprises that shift from old to new or start businesses. As a result, the system of economic relations within and outside the country will change, and the design of the country's economy will change.

The transition to a circular economy involves not only adjusting value chains to reduce impacts on ecosystems, but also a system shift towards long-term sustainability at all levels of the management mechanism to create new economic opportunities and ensure environmental and social benefits. Therefore, the concept of circular economy is a promising model for Ukraine to ensure sustainable development and achieve SDG 2030 by incorporating sustainable use of resources into the basis of industry growth.

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