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# The Management of Municipal Waste through Circular Economy in the Context of Smart Cities Development

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**ABSTRACT** The paper focus on the topic of circular economy in the context of sustainable development, as one major objective of today's societies. Circular economy is mostly characterized by the need to improve the use of resources, by reducing waste and recycling. Under the sustainable development broader circumstances, circular economy becomes one of the important part of providing resources for the future generations, based on intra and intergenerational solidarity, having as starting points the 3 R (reuse, recirculation, recycling) and extending the lifecycle of products. Also, a circular economy is an important factor to develop the smart cities. The smart city can be understood as a sustainable city, a city well performing in economy, governance, but also in environment and living. The paper aims to identify a set of major actions recommended at the European Union level in order to promote this vision. It aims as well to highlight some of the economic and institutional barriers that might be faced at all economic levels. The EU recommendations associated with the trends of increasing the prices of raw materials and also with the need to reduce the import dependency such as better ensure the energetic security and sustainability by respecting the imperatives of environment protection, require a focus on efforts towards these directions. Starting from these approaches, we analyzed the progress achieved by Romania in the last ten years and the extent to which the country is prepared to implement an efficient management of municipal waste in order to promote the circular economy vision. Based on the progresses obtained in the last decade, we appreciate that Romanian decision makers had understood the importance of circular economy and had taken some specific action dedicated to the focus on this direction. Although some of the indicators referring to recycling show an improvement in Romania, it still has to improve performance in this field. We consider that one of the main challenges for the future in terms of circular economy refers to the further development of the sectors associated with the circularity of resource and with the emergence of employment opportunities, based both on an active involvement of public and private sectors.

**INDEX TERMS** Circular economy, municipal waste, linear economy, sustainable development, recycling, smart cities.

## I. INTRODUCTION

In the context of a smart, sustainable and inclusive development, as important prerequisites of Europe 2020 strategy there is an increasingly role played by the technological progress designed to facilitate an efficient and effective use of resources, in order to reduce waste and to allow the application of more and better procedures. By these means we

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consider that the natural reconstruction of resources will not be substantially improved and thus we will not be able to ensure enough quantities of resources for the future generations (for applying the intergenerational justice principles). As illustrated within the literature, an economy based on these principles can be considered to function like a circular economy. It concerns also a production and consumption model based on the reuse and recycling of materials such as to contribute to the extension of the products lifecycle. This is consider to be a traditional vision.

In reality, based on a broader vision of the circular economy we have to take into account not only the consumption and production of goods and services, but also a better and more efficient and effective use of renewable energy, as well as the transformation of waste in materials dedicated to new production flows. This broader vision requires a cross-disciplinary systemic and holistic approach of the functioning of the economy as an integrated system, in which each element influences the functionality of the whole system. Many nations are promoting more and more this vision mostly considering the environmental and population growth challenges.

In the context of the smart cities, it is necessary to combine competitiveness and sustainable urban development simultaneously. Fundamental components of a smart city are technology factors (digital and information city), institutional factors (smart growth) and human factors (knowledge, learning city). Cities have to improve quality of life by creating efficiency and by a better use of resources. So, a smart city is based on a circular economy, which means both an increase in the economic and social value (by increase in the value of products and by improvement in working conditions), but also an increase in the environment value (by the resilience of natural resources).

This paper focus on the analyze of the state of the transition process towards a circular economy in Romania, in the context of the current recommendations and requirements for a better development of this type of economy at the EU level. Our paper starts with a conceptual analysis of the term of circular economy, that despite it had been widely debated in recent years, has no an unanimously accepted definition. Then we analyze the state of the circular economy in Romania, considered under the larger umbrella of the European Union context, highlighting the main strengths and weaknesses of the transition process toward a circular economy.

The paper is addressed to the researchers and decision-makers from Romania, because it targets a quite insufficiently developed topic, focusing both on the challenges and opportunities that decision makers have to be able to identify, in order to adopt the proper policies, strategies and ways of action in the future.

## II. CIRCULAR ECONOMY. LITERATURE REVIEW

Despite the fact that the term of circular economy had been widely debated over the last years, we consider that it is not yet sufficiently developed, mostly considering its purpose and the complex relationships with other concepts.

European Union, but also many other nations such as China and Japan consider circular economy as a key solution for food and water security and for a long-term sustainable socio and economic development. Korthonen *et al.* [1] consider that the domain of ecological economics is one of the most appropriate inspirational sources of the circular economy, mostly considering the general functional background and its policies and practices. Michelini *et al.* [2] show that the current linear socio-economic system with discard products

at the end of their life cycle is the main cause of natural depletion.

They consider the most important goal of the circular economy as one of the new economics model in which the restoration and circularity of the product components will be the appropriate response to the inefficient resource management.

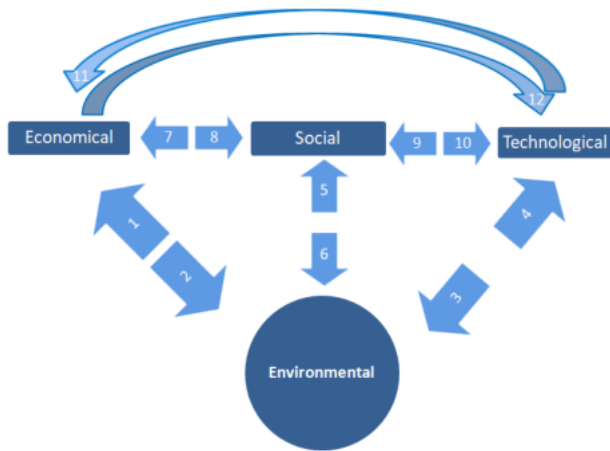
Unlike the linear economy, based on an extensive use of resources, which has negative impacts on environment due to the waste generation, the circular economy involves the reutilization of the materials such as the waste from the manufacturing process to become a potential materials source for another process [3].

The central idea is to retain resources in the production processes based on their reutilization, by producing more value added for a longer period of time, in a production system as closed as possible. The adoption of the circular economy concept refers mostly to two distinct directions: customer interface (by proposing value to customers) and suppliers networks by reconciliation of the producer's own internal activity [4]. No matter the direction, it is generally considered that the circular economy is a combination of three main concepts: *Reducing resources consumption*, *Reusing waste* and *Recycling activities*. All the three concepts result finally in economic and environmental prosperity by providing social equity both for actual and future generations, according to the intergenerational justice principle [5], [6].

Some authors [7] highlighted the connection between the two concepts, conditioning sustainability by the existence of circular economy. The similarities between the two concepts refer to the integration of non-economic aspects in the development equation, considering cross disciplinary holistic approaches. These highlight the increasing of both costs and risks, associated with the need for more incentives, regulations and for a better cooperation between the stakeholders from different economic levels.

The key issue in assuring a sustainable development is the flow of transferring materials and energy between nature and human. The pressure on environment is higher, due also to the global population growing, and thus to an increasing population consumption. All these challenges and transformations ask for rethinking the sustainable development based on the principles of circular economy, by using cyclical materials flows, renewable energy sources and cascading type energy flows [1].

The concept of sustainable development had evolved in time and is based on the long-term vision of development that takes into account more and more the need to assure the equity between countries and generations and the inter-connections between the economic, social and environmental dimensions of sustainable development. The current technological evolutions make it necessary to take into account the technological sector mostly in the context of the amplified importance of the knowledge and innovative based economy. Under these broader cross disciplinary approaches we consider it is important to illustrate the complex and dynamic



**FIGURE 1.** Major interactions between economic, social, technological and environmental dimensions of sustainability. Source: Designed by the authors.

interactions between the economic, social, technological and environmental dimensions of development as a central pillar for sustainability effectiveness and circular economy (Figure 1).

As illustrated in figure no. 1 the most important relationships between the economic, social, technological and environmental dimensions of sustainability are:

1. environment considered as a natural input, representing the main resources provider;
2. economic pressure on environment and public implication for assuring a healthy environment and for an efficient recycling process;
3. the care for preserving heavily renewable resources and for increasing the use of renewable resources;
4. the constraint of creating and using new technologies which use smaller quantities of resources, to reuse resources and recycle them;
5. the human and environment health;
6. the pressure on the environment and the increasing need of preserving and protecting the environment;
7. the characteristics of human resources (e.g. the consumption patterns, the quality of human capital);
8. a more equitable distribution of revenues among societies members according to micro and macroeconomic objectives;
9. influencing the occupational structure in accordance with the requirements of implementing the new technological way of productions;
10. the constant need to develop new technologies for improving the future community's socio-economic existence;
11. providing technologies in accordance with new requirements of recycling and circular economy;
12. investments for new eco-technologies.

Banaite and Tamasiuniene [8] appreciate that, in order to assure a better functionality of the circular economy there have to be taken into account three perspectives that are also highly correlated. These perspectives refer to the

environmental impact, economic benefits and to the resources scarcity that should request a more intensive collaboration between nations, both public and local administrations and the whole society.

Goals and targets have to be set at the microeconomic, mezzo and macroeconomic levels, starting from firms, industries levels and moving towards local municipalities and finally towards the whole country and to the EU level. They refer to: stock optimization, eco-efficiency and eco-effectiveness, waste reduction [9].

The concept of the circular economy had become better known at the end of the '70s, when the initial idea of functioning of living systems was extended to the industrial processes and economic systems. More studies attribute the introduction of the circular economy concept to Pearce and Turner [10]. These authors showed that the economy was developed by using the natural resources for production and consumption, without taking into account the recycling of waste.

These types of approaches were also influenced by Boulding's work [11], which describes the earth as a circular system, which has a limited capacity of waste assimilation, requiring a better cooperation between economy and environment [7].

Nowadays, the term of circular economy has become more complex, by incorporating many concepts used in fields that focus on sustainability, such as: industrial ecology, eco-efficiency, waste management, renewable energy, recycling, smart cities. Bocken *et al.* [12] define circular economy as a business model which is "slowing, closing, and narrowing resource loops", Bonciu [13] considers circular economy "a new frame of mind, a new perspective", Xiao and Huang [14] "a new path of industrialization" and Preston [15] "a paradigm shift in the way things are made". Many authors [16]–[19] appreciate circular economy as a system which replaces the concepts such as 'end-of-life' with reuse of wastes and their reduction through a better quality design of products, materials and systems.

Reike *et al.* [20] and Blomsma and Brennan [21] divided the evolution of circular economy concept into three periods: the period dealing with waste (1970-1990); the second period Connecting Input and Output in Strategies dedicated to Eco-Efficiency (1990-2010) and the third phase since 2010 until today, focusing on the maximizing Value Retention in the Age of Resource Depletion.

The first period in which the awareness of resources exhaustion appears, the wastes management has become more and more problematic, stands out by the publication of the Club of Rome (1972) [20], marking the passage to the next period. The second period is characterized by the increase of ecological movements and by measures, focused especially on the reduction of pollution. It had focused on regulating the wastes management in landfills and their cremation. In this period it is considered that there are the most important roots of circular economy, focusing on recycling and on concepts such as cleaner production and industrial ecology [22].

The third period is marked by an increase in the awareness of resources exhaustion, as a consequence of their excessive exploitation, having to face also an increase of population in many regions of the world.

As highlighted by some authors, under the auspices of circular economy it is possible to obtain and keep economic growth, based on using fewer resources, improving the production technologies, using recycled raw materials and using renewable energy [20], [23]. The study of Vut *et al.* [24] shows the existence of a direct connection between the measures adopted to increase the productivity of resources, associated to circular economy and the increase the GDP. The authors consider also that in order to obtain a sustainable economic growth we have to focus on the recycling of waste, which lead also to a decrease in the costs of production. According to the approaches identified within the literature, the concept of circular economy is tackled differently, as there are many definitions between which we can see there are more or less interferences. For instance Kirchherr *et al.* [5] emphasize, based on the analysis of 114 definitions, that there might be a risk that based on such a high number of approaches, the concept might collapse, due to a relatively constant conceptual contention, that might affect not only the research, but also the practice.

### III. CIRCULAR ECONOMY AT THE EUROPEAN UNION LEVEL

European Union defines circular economy as “an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized”. This is the basis for the development of smart cities, that also means *the use of information and communication technologies for better resource use and less emissions* [25].

Many European Union countries have implemented special initiatives dedicated to the development of the circular economy, based on policies and pilot programmes, especially in Germany, United Kingdom, Denmark, Norway and the Netherlands. These countries have stood out by the speed with which they implemented measures of supporting circular economy both at the governmental and company levels.

At the EU level the efforts for developing circular economy have amplified lately, by adopting special designed packages of measures and strategies stimulating the transition towards a circular economy. They aim at some strategic targets, such as:

- recycling all plastic packaging until 2030;
- introducing some compulsory recycling rates for different categories of wastes;
- increasing the use of raw materials resulted from recycling;
- reducing by 50% the food wastes, until 2030;
- increasing the recycling rate of municipal wastes by 65%, until 2030.

At the EU level, environmental policy became legally binding by the Single European Act (1986). In 1973, after the UN Conference in Stockholm (1972), the first

Action Programme for the Environment for the medium term (1973-1977) for the EU had been developed. So far many special designed programs have been developed with this purpose. These programs had been recalibrated shifting from a focus on the qualitative approach (the need to protect water and air), towards more quantitative approach that focus on pollutant emission and integrating the concept of sustainable development within the EU strategies dedicated to the environmental protection.

In order to monitor the progress obtained in the process of transition towards the circular economy, at the EU level, experts analyse indicators covering the areas of production, consumption, waste management, creation of new jobs generated by the development of the circular economy.

As there is not only one aggregate indicator which measures the circular economy, the monitoring reports of implementation of circular economy at the EU level are based on a group of 10 indicators, which are divided into 4 categories.

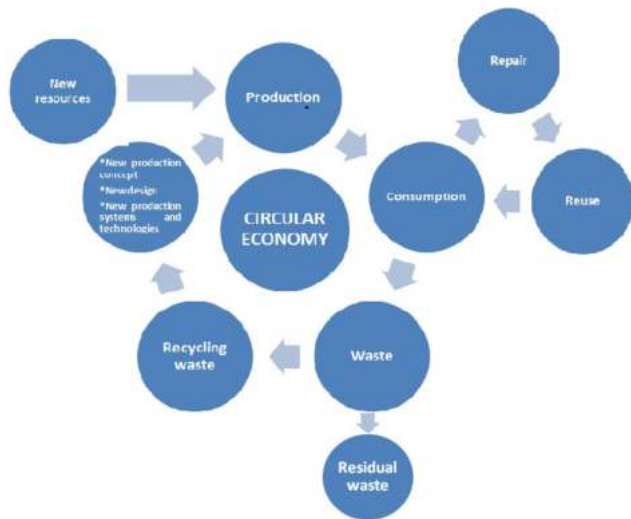
These categories are: (1) production and consumption, (2) waste management, (3) secondary raw materials and (4) competitiveness and innovation. According to the last report [26], out of 8 billion tons of materials processed every year in the EU, which turn into products or energy, only 0.6 billion tons come from recycling. Thus, out of 2.2 billion tons of wastes, 0.6 (27%) re-enter in the system under the form of recycled materials.

The benefits of transition towards a circular economy are the reduction of pressure on environment, energy saving, reduction of CO<sup>2</sup> emissions, reduced waste management costs, improvement of supply with raw materials, stimulating innovation and the creation of new jobs. As a result, the demand for raw materials decreases as many materials are preserved or waste is returned into the production process. This implies decreasing import dependency and reducing the vulnerability of industries in front of the price fluctuation or the insecurity of supply caused by resource depletion, scarcity or other geo-political complex factors [27].

There are barriers to implement circular economy on the European Union level. Kirchherr *et al.* [28] refer to cultural barriers expressed by the lack of consumer interest and the hesitant company culture driven by market barriers, induced by some inconsistent governmental intervention designed to accelerate the speed of transition process towards circular economy. Even if circular economy might be attractive for companies, Ritzen and Olundh [29] show that there are many financial, structural, operational and technological barriers. These barriers had been analyzed in correlation with innovation management. These authors highlighted that a radical change is needed in order to assure a quite strong connection between sustainability and the business development model. As many other transition processes, passing towards circular economy, might imply an uneven distribution of results between workers, costumers, companies, industrial sectors, regions, considering that some groups might benefit while other might lose [30]. European Union [31] experts consider that circular economy implies some challenges related to

sharing, leasing, reusing, repairing, recycling process. The first major challenge faced during the implementation of circular economy process is the finance one, both for public and private sectors. It includes new costs for asset investment, research and development, but also public expenditure focusing on subsidy and investments in the waste management. The second important challenge refers to the lack of an institutional framework properly designed to stimulate and encourage an efficient resources reuse and recycling. The third challenge of transition towards circular economy is the quality of the human capital, unprepared yet for the new technical skills required by the new concept. This third challenge implies also financial costs for companies in order to invest in special dedicated training programs for the existing workforce or for offering increased wages to attract highly skilled workers. Finally, an important challenge of switching from a linear towards a circular economy is the one generated by the complexity of consumers' behavior which needs changes and improvements. Surpassing all these boundaries ask for the implementation of a set of actions designed in a distinctive way according to different levels and policy areas.

The circular economy generates complex relations between production, consumption, waste and recycling, as shown in figure 2.



**FIGURE 2.** Complex relations that arise within the circular economy. Source: Designed by the authors.

Circular economy involves the reduction of consumption of raw materials, the design of products to make it easier to use and the extension of lifecycle of the products by maintenance and repairs. When the products get in the waste stage, it has to aim at their recycling and their next reintroduction within the production process.

**IV. CIRCULAR ECONOMY IN ROMANIA IN EUROPEAN UNION CONTEXT**

There are many reasons that justify why Romania needs to develop circular economy. Some of these reasons refer to the

need of resources for assuring the national security and environmental protection, increasing welfare under the conditions of the limitation of resources, adding value by minimizing costs of raw material, solving the problem of waste. Also, the climate change affects the availability of natural resources and through the development of a circular economy some resources can be recovered and reused.

We consider that Romania is at the beginning of its transition towards a circular economy, as it can be noticed from the comparing analysis of specific indicators with European Union as a whole (table 1).

**TABLE 1.** Comparative analysis of the circular economy indicators, 2000-2017, Romania and EU-28.

Indicators	2000		2017	
	RO	EU	RO	EU
Resource productivity (EUR per kg)	0.4811	1.4695	0.3294	2.04
Resource Productivity (Index)	100%	100%	68%	138.8%
Domestic material consumption per capita (tones per capita)	7,7	15.59	25,09	13.57
Water productivity (EUR per m <sup>3</sup> )	10,4	-	22	-
Greenhouse gas emissions per capita (Tones of CO <sub>2</sub> per capita)	6.3	10.8	5,8	8.7
Generation of waste (all waste generated in a country per inhabitant and year, excluding major mineral wastes, dredging spoils and contaminated soils) (mil tones)	-	-	2.535.100	177.557

Source: Eurostat, 2018, EU policy Indicators, Circular Economy, [33]

Considering the efficiency of resources use, measured by the economic value of GDP generated by each kilogram of resources used from natural environment, we can notice that Romania obtained only 0.32 Euro, in 2017, for each kilogram of resources, a decreasing value compared to 2000 and at large distance from EU average of 2.04 euro (6 times higher). In 2017, this indicator represented 68% compared to the level recorded in 2000 in Romania and 138.8% compared to EU, the same period.

In terms of the domestic consumption of resources, measured in tons/capita, we found that Romania recorded an increase between 2000 and 2017 from 7.7 tons to 25.09 tons, by 225%, while the indicator decreases in EU. Even if Romania recorded economic growth in the analysed period, we also have to mention that the growth rate of consumption of resources exceeds the growth rate of GDP. This shows that Romania uses more and more natural resources, but produces low economic value, as a result of the fact that, in general, it exports mostly raw material, and not especially finished products as it is recommended for a long-run sustainable development.

The economic value which Romania produces with every m<sup>3</sup> of water extracted from the natural environment is 22 Euro, which shows a lower productivity compared to other European Union countries. The highest productivity level of water is recorded in Luxembourg (1017) and Denmark (339).

The lower level of greenhouse gas emissions per capita recorded by Romania, compared to the EU average illustrates the lack of an active industry [33].

The generation of waste in Romania represents 7% of EU waste generation. Analyzing waste generation in tones per inhabitant, can be noticed that, in 2016, 5 tones was generated in EU and 9 tones in Romania. Romania exceeds the EU average, being on the 6th place at waste generated per inhabitant in 2016, after Finland (22 tones), Estonia (18 tones), Luxembourg (17 tones), Bulgaria (16 tones) and Sweden (14 tones). One explanation might be that, in Romania the economic growth is mostly based on consumption and there has not yet been developed a mentality that promotes also the environmental concerns.

At the EU average level, in 2016, 37,8% of waste was recycled and only 4% in Romania. In Romania, most of the waste generated is landfill. The highest recycling rates are recorded in Belgium, Latvia, Italy and Slovenia [34].

European Union developed an aggregate indicator that expresses the circularity of materials within the consumption-production flow. The circular material use rate measures the share of material recovered and fed back into the economy in overall material use [32]. At European Union level, 11.7% of total material represents secondary materials, thus saving extraction and using the primary raw materials. Countries like Netherlands, Belgium and France have the highest circular material use rate, around or above 20%. This indicates that secondary materials substitute for primary raw materials at a level that indicates a better understanding of the importance and the conceptualization of the circular economy concept which implies reusing the materials into the production flows. The levels recorded by Ireland, Romania and Greece, below 2%, indicate the need for progress and special designed policies adopted within this sector, together with an increasing public awareness of the importance of reducing environmental impact by using secondary materials (Figure 3).

Circular material use rate is influenced by the level of economic development of EU countries. The statistical data show the existence of a direct correlation between the level of economic convergence, expressed by GDP as percent of EU average and circular material rate. The two aspects, circular economy and economic growth, are supporting each other at the European Union level (Figure 4).

As the economies and societies continue to develop, they move towards a higher level of human needs and, as a consequence, a higher attention is paid to some aspects which surpass the economic area, so that they understand and get a higher level of awareness of the importance of security in order to better assure resources for the medium and long term.

We consider that the first stage of the circular economy development is the creation of new employment opportunities

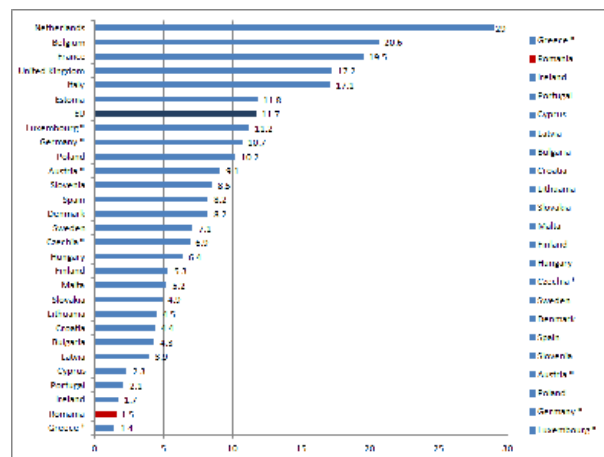


FIGURE 3. Circular material rate use (% of total material use), EU, 2016, \* Refers to 2015, [32].

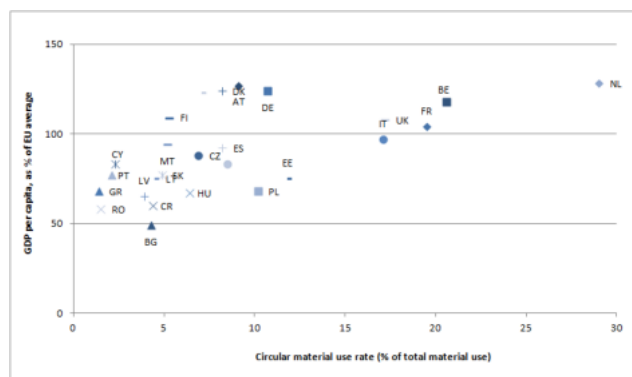
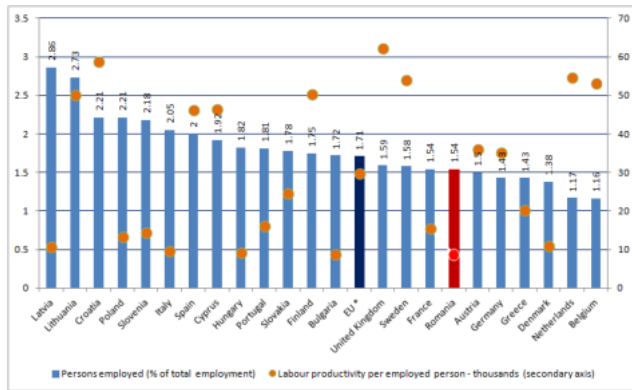


FIGURE 4. Correlation between circular material rate and GDP, 2016. Source: Computation based on Eurostat Statistics [32].

within this sector. This involves, on one hand, the existence of a technological basis for the operationalization of this process and, on the other hand, the existence of skilled workforce in this field. For less EU developed countries, both directions can be limited by the lack of resources (the technical-material base and the human capital), situation that involves the allocation of important financial resources. At the European Union level, share of the employment in circular economy sector refers to employment in recycling, repair, reuse, rental and leasing sector [32]. Because at an economy level it is important not only the level of employment, but also its quality reflected in the results obtained, we have calculated the work productivity per employed person in the circular economy at the EU level. The results showed that countries with a relatively high weight of workers within circular economy compared to EU average have a low labour productivity. This shows that this sector needs supplementary investments and measures that stimulate the private investments in a field being just at the beginning of its existence, even if the effects of using secondary materials as substitute for primary raw materials are not necessarily evaluated in short term. Lower labour productivity per employed person compared to share

of employment in the field recorded countries from Central and Eastern Europe (Hungary, Poland, Slovenia, Romania, Bulgaria) because they are making effort to comply with the EU requirements with a background of an insufficiently qualified labour force (Figure 5).



**FIGURE 5. Employment in circular economy sector and labour productivity per employed person, EU, 2015, \* - refers to 2014; Source: Eurostat Statistics [32].**

Despite these aspects, we consider that there are also progresses that had been made in terms of recycling different type of waste within the European Union. This is a remarkable progress designed to ensure the consumption of future generations. But it is also a great challenge. Romania has made progress in terms of recycling packaging waste, increasing from a rate of 30.6% in 2007 to 55.9% in 2017. It was a fast convergence process with the EU average of 67% recycling rate in 2017. Also, progresses were made in Romania and EU in terms of recycling municipal waste and bio-waste. For Romania, steps should be passed further in order to ensure a closer level to European Union and, as a consequence, an efficient waste management waste policy.

Circular economy is characterized by more adapted production processes to the development of sustainable goods, aiming to increase the possibility of a fast and efficient recovery of recyclable materials from products at the end of use period. It is also characterized by the existence of more rational and better educated consumers who care more for the exhaustible resources of the planet and for assuring the prerequisite for the consumption of future generations and who understand the importance of exploitation at the highest level the resources already included into the production processes.

According to Courvoisier, Sennes, Ricard, Ribeyre (2014) and Caeiro (2012), sustainable consumption is mainly driven by education; these authors highlight the role of education in the formation of a more responsible consumption behaviour [35], [36]. Also, Varela-Candamio, Novo-Corti and Garcia-Alvarez show that environmental education reveals as a powerful tool in order to generate “green” behaviour among citizens, through an econometrical study on Spain [37]. The investment in consumer education, both on the formal and informal levels, allows the creation of a core set of skills that contribute to the improvement of the lifestyle of the

consumers, to ensuring and maintaining the environmental health, which is considered as a mid and long-term personal, social and economic advantage.

Considering Romania’s efforts focus into this respect, we can mention campaigns specially designed to better promote recycling, implementation of programs and projects at Romanian public universities and companies. The study of Novo-Corti et al. [38] shows that the economic higher education system in Romania has started with small steps designed to adapt to environmental requirements. Romanian educational system is interested in organizing special dedicated programs, projects and debates focusing on sustainable developmental issues and in introducing such courses [38].

**V. THE MANAGEMENT OF MUNICIPAL WASTE IN ROMANIA AS ONE OF THE KEY PILLARS OF THE TRANSITION TOWARDS THE CIRCULAR ECONOMY**

At the EU level, the 6th Environment Action Programme, called *Our choice, our future* (2001-2010) [39] had drawn for the first time the attention on waste management, regarding the objective of increasing the degree of recycling and preventing their creation.

The first distinct approach of the problem of waste and recycling (prevention and recycling of waste) was launched in 2005 as a thematic strategy for *The 6th Environment Action Plan*. It aims at improving waste management by recycling in order to reduce the negative impact on the environment. This concern was also used within the plan called *Living well, within the limits of our planet* [40], implemented in 2014 which pays a particular attention to the transformation of waste into a resource, by emphasizing the importance of some preventive measures, reuse and recycling, and phasing out wasteful and damaging practices like land filling. A special consideration had been given to the management of hazardous waste so as to minimize the effects on environment and human health [41].

The new concern of the European Union regarding waste management was included in a *Circular Economy Package* that aims at a greater recycling and reuse during the products lifecycles in order to bring benefits for both the environment and the economy [42]–[44]. The most important benefit for the economy refer to the savings resulted from the recycling and reuse of scarce resources and to the positive effects of new job creation and investments dedicated to a sustainable growth and development.

Romania, as one member of the European Union, is committed to observe and adopt the Community legislation. For the environmental policy, the principle of subsidiarity (*Single European Act*) was applied for the first time. This principle was subsequently recognized by *the Maastricht Treaty* as a fundamental operating principle of the EU. This implies the Union intervention when an issue cannot be resolved satisfactorily at one of the Member State level because of its scale or effects. The sectors covered by the common environmental policy are: waste management, water pollution, air pollution, bio-diversity and soil protection. In Romania,

in the field of waste management the first *National Waste Management Strategy* was developed in 2002. Until now, other strategies have been developed in order to better achieve the recycling targets.

In order to analyze the recycling process we paid a particular attention to municipal waste in smart cities. It is important to consider it because in recent years it has had an upward trend due to the population growth, urbanization, and due to the increasing living conditions and economic growth. Some researchers show that household waste generation is also influenced by family size, education level and by the monthly family income evolution [45]. However, in order to support the recycling of this kind of waste, government authorities and NGOs have to be more and better involved by supporting policies designed to encourage recycling, such as infrastructure development in the field or providing tax incentives. The success of an efficient management of recycling depends on the technological solutions as well as on the links between environmental, economic, legislative and institutional matters supporting this system [46].

Omran and Schiopu (2015) demonstrated, using an quantitative analysis based on a questionnaire, that actions of households and their perceptions about recycling have an important role in ensuring the success of any sustainable policy for waste management at the local, regional or national levels [47].

In Romania, the generation of municipal waste per capita (kg per capita) has decreased in 2016, compared to 2000 (table 2).

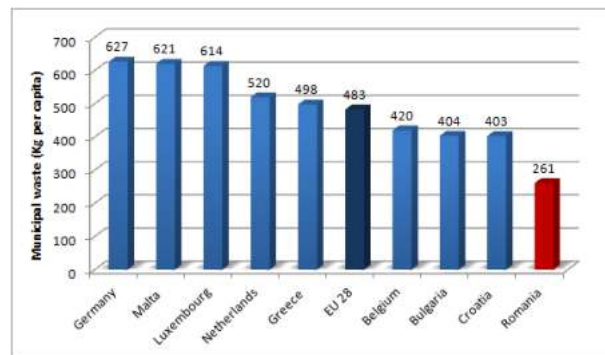
**TABLE 2. Evolution of the generation and recycling of municipal waste in Romania and EU, 2000/2016.**

Year	2000		2016	
Indicators	RO		EU	
Generation of municipal waste per capita (kg per capita)	355	521	261	483
Recycling rate of municipal waste (%)	0%	38%	13,3%	45,3%

Source: Eurostat, 2018, EU policy Indicators, Circular Economy, [33]

The recycling rate is among the most reduced of EU, only 13.3%, compared to 45,3% at the EU average. A large part of municipal wastes is eliminated by storage or by incineration, which shows that Romania is far from the target of 65%, the recycling rate of municipal wastes, which had been established as a target that has to be reached until 2030. Some waste materials, such as food waste and green waste generating from households, can be used in agriculture as a high quality natural fertilizer [48] (Figure 6).

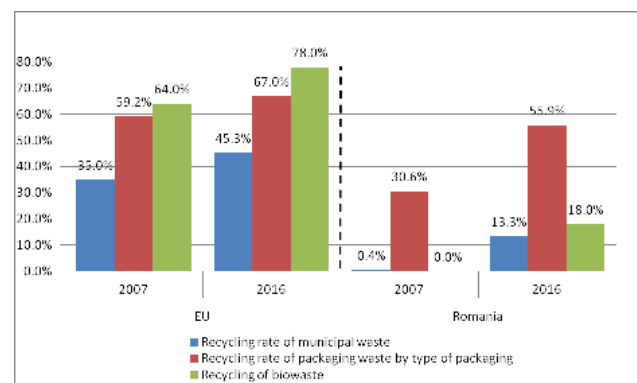
As concerning the recycling of waste from plastic packaging, we estimate that there will be a significant progress, considering the proposal for reforming the contributions to EU budget since 2020. This proposal takes into account a new source of income: a national contribution depending on the quantity of plastic packaging wastes which are not recycled. This will encourage the transition of EU towards a circular



**FIGURE 6. Municipal Waste generated in 2016, kg per capita [34].**

economy, by stimulating the member states to reduce the quantity and intensity of such kind of waste [49].

The EU Waste Statistics [34], places Romania on the last position in the European Union in terms of recycling of municipal waste. Romania has a recycling rate of just 13,3%, much lower compared to the EU average of 45,3%. Romania is far behind the highly developed countries, where recycling values had reached 50-70% (Figure 7).



**FIGURE 7. The evolution of the recycling rate of municipal waste, of packaging waste and of bio-waste in EU and Romania, between 2007 and 2016, [32].**

The trend of municipal waste recycling rate had increased during the period 2007-2017, but there are major differences between these indicators registered in Romania and the European Union (Figure 8).

If we look at the sectors that produce waste in Romania compared with those from EU, we can observe that, in 2016, the largest share in terms of waste generation, 87%, is held by the mining sector and quarrying industry, which shows an industry that is still not yet adapted to the principles of sustainable development. At the EU level, the values of this indicator are divided across industries (25%), the construction sector having the largest share of 36,4% (Figure 9).

The total waste generated by economic activities and households can be expressed in correlation to population size. In 2016, the average amount of waste generated reached 5 tons per capita in the EU. From this point of view, Romania

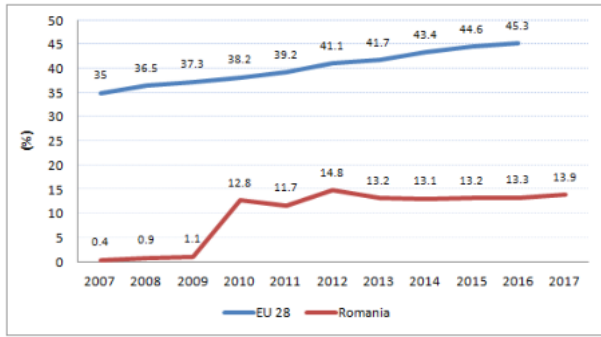


FIGURE 8. Dynamic of recycled rate of municipal waste, 2007-2017, Romania and EU (Source:Eurostat, [32]).

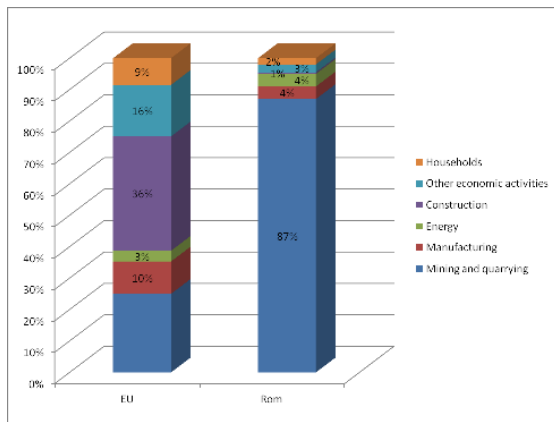


FIGURE 9. Waste generation by economic activities and households (% in total) Romania and EU 28, 2016, [32].

registered about 9 tons per capita, an increase compared to the previous period. Much of the waste generated in the EU was mineral waste. The evolution of this type of waste shows a connection with the structure of an economy. The states with higher mineral waste, such as Romania, Bulgaria, Estonia, have conducted significant mining industry [34]. It is important to know the type of waste generated, but it is very important to know to what extent it can be reused or recycled. It is also important the recycling technology. Some studies analyze the impact of such methods on municipal waste and the environment. One of the method was proposed by Sahinkaya [50]. This uses acid and ultrasonic pretreatment on the disintegration of municipal waste.

The authors Trentea, Bodea and Marcus analyze Romania’s situation regarding recycling by categories of products (materials) [51]. According to the study of these authors, the rate of recovery and recycling has increased in Romania for the following products: glass, paper, plastic, metal, wood, end of life vehicles and packaging waste. These increases, though not spectacular, are favourable for environmental protection and were based on measures to encourage reuse and recycling such as “Rabla” Programme for end of life vehicles. Nevertheless, much of the waste generated in Romania is not recovered or recycled, but destroyed [34].

For a better waste management it is highly recommended to join the efforts of municipality, public sector, corporations and individuals. This process of recycling involves the collaboration between all those economic actors interested in environment protection, ensuring a healthy economic growth and development. It also requires a marketing strategy designed to support waste management, which does not exist in Romania yet, but which could help the improvement of the recycling process [52].

Although some European Union countries had made a significant progress comparing to the others in terms of recycling management efficiency, we have to accept that there is no ideal solution, adaptable to any economy.

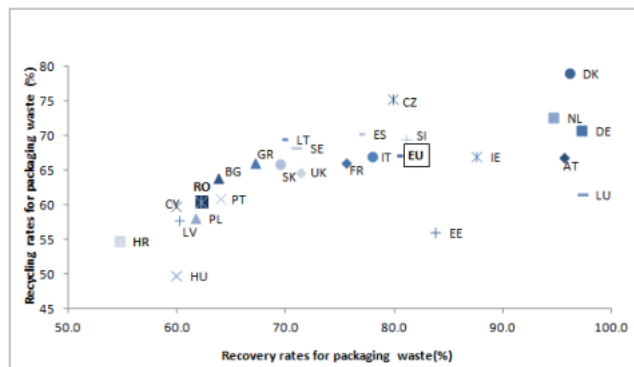
The development of waste management systems requires time and covers different stages. Therefore, countries that have not yet developed enough such systems, like Romania, might benefit from the experience of highly developed countries, but they cannot achieve a great leap in a very short time [53].

Some basic principles should be taken into consideration in order to contribute to a better, more efficient and effective waste management and they might help step by step the development of this system as well:

- *the precautionary principle*: anticipating problems that may arise and reduce waste production,
- *the accountability principle*: the polluter has to pay pollution costs,
- *the proximity principle*: waste should be disposed or processed closer to the area where they were produced [54].

Considering consumers, they might contribute to an increase in the efficiency and effectiveness of waste management process by purchasing organic products with smaller packaging, reusing packaging and their separate collection for recycling. From this point of view, in Romania there have been registered some progress, but there are still problems that need to be solved both concerning the separate collection of waste and the purchase of organic products, which involve higher costs for the consumer. They have to do all in order to get the highest benefits from a healthier life and a cleaner environment, in return bearing a higher purchase price of the product. As illustrated in Figure no. 10 there is a direct correlation between the recycling rate for packaging waste and the recovery rates for packaging. This means that those countries who have high recycling rates have also high recovery rates for waste. The most performing countries in recycling and recovery are: Denmark, Germany and the Netherlands. On the other hand, the least performing are: Croatia, Hungary and Latvia. According to the official date of European Commission, Romania converge to the European Union average, both for recycling and recovery rates, recording a quite important increases from 30.6% in 2007 to 60.4% in 2017, in the case of the first rate, and, from 36.6% in 2007 to 62.3% in 2016 in the case of the second (Figure 10).

At the company level, the support can be achieved through the production of environmentally friendly goods, using



**FIGURE 10.** Recovery and recycle rate for packaging waste in European Union, 2016, [34].

green technologies and by limiting energy wastage and excessive use of packaging. Corabieru, Corabieru and Vasilescu draw attention to the importance of the design of the products steps, because even in this stage, it has to be taken into account their degree of recycling and thus to encourage the development of recycling [55]. At this level, it has been registered a relatively little progress in Romania. The analysis of *the Green Business Index (GBI)* indicator for Romania shows the recycling situation at the level of companies in Romania and allow decision makers to understand what the main trends in the field are. This indicator examines the environmental responsibility of the companies [56].

According to the GBI, in 2013, only 31% of companies in Romania had declared they had adopted a sustainable development strategy, and in 2017, 89.3% of these had an environmental policy or strategy. 88.5 % of companies use environmental management systems, being concerned about energy saving, waste reduction, and employee training campaigns. But, with respect to the waste recycling, progress was poor, the number of companies that have accumulated unused waste stocks at the end of the year was increasing [56].

To reduce the gap to the highly developed countries, concerning the reuse and recycling of waste, Romanian authorities have to provide the necessary resources to implement effective waste management policies. Decision makers from different level (micro, mezzo, macro) have also to provide the necessary infrastructure for collecting and recycling waste, by creating partnerships with business, in order to better collect and recycle these resources. Romania is lagging behind in terms of implementing these policies due to limited financial resources, especially due to a low interest manifested by decision makers for these kind of projects.

Specialized studies emphasize the importance of the social issues for increasing the efficiency and effectiveness of waste management systems, because the public participation in the planning and implementation of these systems are as important as technical and economic issues concerning waste management [57].

Therefore, the increase of the performance of expected results might be achieved through joint efforts of

individuals, local communities, organizations, companies and government.

## VI. CONCLUSION

The transition towards the circular economy is very important for Romania, which has to keep up with the transformations existing at the European level. Circular economy means more than recycling waste; it is a complex way of organizing, which involves changes in both production and consumption, such as to reduce resource consumption and to minimize waste. At the same time, the shift to the circular economy must be correlated with the development of smart cities. The debate and the practice of circular economy are essential for this transition, which is considered to be just on an early stage in Romania.

We consider that efforts made by Romanian decision makers on different levels have to be amplified because, as highlighted by our paper, Romanian potential to develop the circular economy, as a premise for the development of smart cities, is far behind as compared to the EU most developed countries.

Currently, the efficiency and effectiveness of resources use in Romania is low; the recycling rate is among the lowest in the EU, most of the waste is deposited or incinerated, and it is not yet developed a life cycle of waste management. We consider that Romania is far from reaching and being convergent with the strategic European targets of circular economy. For example, the circular material use rate, which measures the share of material recovered and fed back to the economy in total material use, is only 1.5% in Romania, compared to the EU average (11.7%).

Although some of the indicators on recycling (recycling rates of municipal waste, recycling bio-waste) show an improvement for Romania, because they have increased in 2017, compared to 2007, Romania still has to make progress. Recycling rate of packaging waste grew from 30.6% to 55.9% in the analyzed period, getting close to the EU average (67%).

We consider that in order to develop the circular economy in Romania, the efforts has to be cumulated, both in terms of public and private sectors involvement and concerning also consumers.

In the future, it would be very important for Romanian companies how they use their resources such as sustainability to become a driver of innovation and competitiveness, by improving the way to apply circular economy principles.

Even if the involvement of private companies and public organizations in joint environmental projects is low, decision-makers from different levels might be more involved through fiscal, financial and legislative instruments to support companies investing in the development of the circular economy. In this respect, public and local authorities have to develop joint programs with educational institutions, private companies and non-governmental organizations.

There is a need for applying modern technologies for the operationalization of this process and to assure the existence

of a skilled workforce in the field. An important role is played by investments, both in physical and human capital by educating also consumers, who have to be more aware of their role within this process. Educated consumers will better understand the need to prove rationality in consumption, to reduce waste, but also the role of recycling, adapting consumer behavior to the requirements of the circular economy. In order to achieve efficient and effective results, the state and companies have to provide the necessary infrastructure for the collection and recycling of waste, which is from our point of view quiet poorly developed now in Romania.

Companies, citizens and authorities have to work together and cooperate to make the systematic changes work within the system based on circular economy. Also, a challenge for the future trend in circular economy in Romania is the further development of sectors associated with circularity of resource and the creation of new employment opportunities within this sectors based on both public and private involvement and on public-private partnerships.

Our research is a stage in the analysis of smart cities development from the point of view of the circularity. Although the paper focuses on the study of the circular economy, this is an important topic for the transition to smart cities, both at the Romanian and European Union level. In the future, we will extend the research to study the development of smart cities in Romania in the context of the European Union.

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